Report

Dudley Creek Flood Remediation

Downstream Options Multi Criteria Analysis (MCA)

Prepared for Christchurch City Council

Prepared by Beca Ltd (Beca) and Opus International Consultants Ltd (Opus)

20 July 2015

Revision History

Revision Nº	Prepared By	Description	Date
1	Stephanie Brown	Issued for information in advance of MCA criteria workshop (schedule for 30 April 2015)	22 April 2015
2	Stephanie Brown	Issued following MCA criteria workshop (30 April 2015) with draft criteria added	11 May 2015
3	Stephanie Brown	Criteria updated following review by MCA workshop participants	20 May 2015
4	Alex Jenkins	Updated to include Option C	10 June 2015
5	Stephanie Brown	Update following scoring workshop	20 July 2015

Document Acceptance

Action	Name	Signed	Date
Prepared by	Stephanie Brown and Alex Jenkins	A. Jenkins	17 July 2015
Reviewed by	David Heiler		17 July 2015
Approved by	David Heiler		20 July 2015
on behalf of	Beca Ltd and Opus International Consultants Ltd		

Executive Summary

As part of the Dudley Creek Flood Remediation project (Project), the Christchurch City Council (Council) resolved to undertake further analysis of three options for increasing the flow capacity of Dudley Creek downstream of Warden Street. The options assessed are:

- Option A – Warden Street Bypass and Banks Avenue Channel Works
- Option B – Warden Street Bypass, Marian College, Richmond Park and Residential Red Zone Bypass
- Option C – Stapletons Road Channel Works, Petrie Street, Randall Street and Medway Street Piped Bypass.

This report sets out the steps to run an assessment process in order to evaluate the shortlisted options for the downstream section of the Project. A multi criteria analysis (MCA) process was carried out in order to evaluate the shortlisted options. The process followed is:

1. Establish the decision context – the purpose of the MCA, identify the decision maker(s) and other key players, design the assessment system
2. Identify the options to be assessed to achieve the objectives
3. Identify the criteria
4. Scoring – describe the consequences of the options, score the options on the criteria, check the consistency of the scores on each criteria
5. Weighing – assign weights and scores to each option to reflect their relative importance to the decision
6. Combine the weights and scores for an overall value
7. Examine the results
8. Sensitivity Analysis

At a workshop in April 2015 the criteria were established and consultation with the community on the options followed. Following the close of consultation a scoring and weighting workshop was held on 14 July 2015 to assess the options. Technical experts scored the options against the criteria. The weightings were carried out using 1000Minds software, which adopts a pairwise approach.

As a result of the process, corridor Option C is recommended.

A separate MCA Workshop was held on 15 July 2015 to identify a preferred conveyance method using the same scoring and weighting process, against a subset of the criteria used in the first workshop. The weighting percentages from the original workshop were scaled so that the subset values sum to 100%.

Each of the three corridor options were assessed for pumped and gravity solutions, with the gravity option scoring higher for each corridor. Therefore, gravity conveyance is recommended.

As a result of the process, a gravity conveyance solution along corridor Option C is recommended.

Contents

1 Introduction

1.1 Background

This report sets out the steps to run an assessment process in order to evaluate the shortlisted options for the downstream section of the Dudley Creek Flood Remediation project (Project).

As part of the project, the Council has resolved to undertake further analysis of three options for increasing the flow capacity of Dudley Creek downstream of Warden Street. These options are:

- Option A – Warden Street Bypass and Banks Avenue Channel Works
- Option B – Warden Street Bypass, Marian College, Richmond Park and Residential Red Zone Bypass
- Option C – Stapletons Road Channel Works, Petrie Street, Randall Street and Medway Street Piped Bypass.

The Project scope requires that the options are evaluated using a Multi Criteria Analysis (MCA) framework – a framework belonging to the Multi Criteria Decision Making (MCDM) group of frameworks. MCDM is the umbrella term for "the study of methods and procedures by which concerns about multiple conflicting criteria can be formally incorporated into the management planning process"[1]

1.2 Why use MCA?

MCA is suitable when an intuitive approach is not appropriate, for example because the decision-maker(s) feel the decision is too large and complex to handle intuitively, because it involves a number of conflicting objectives, or involves multiple stakeholders with diverse views. Often there is a desire for a formal procedure so that the decision making process can be made open and transparent, and is seen to be fair.

A MCA model is a software package in which alternatives and criteria are specified, data is entered and MCA method is undertaken to process the decision.

A key feature is its emphasis on the judgement of the decision making team, in establishing objectives and criteria, assessing relative importance weights and, to some extent, in judging the contribution of each option to each performance criteria.

MCA has many advantages as:

- it is open and explicit
- the choice of criteria that any decision making group may make are open to analysis and to change if they are felt to be inappropriate
- scores and weights, when used, are clear and are developed according to a process
- it can provide an important means of communication, within the decision maker and sometimes, later, between that body and the wider community
- it provides an audit trail.

However, it is important to remember MCA is a tool and that people make decisions. The MCA process assists people in making decisions. That assistance can take many different forms including: providing structure to discussions, documenting the process, separating matters of fact from matters of judgement,

[1] MCDC Society, 2006

making value judgements unambiguous, creating shared understanding about the issues, generating a sense of common purpose and often, gaining agreement about the way forward.

1.3 The Assessment Process

All option assessments require a clear documented process in order to understand how the decision was made. The key test of an option evaluation process is that other experts in the field should be able to repeat the process and come to the same decision.

The process is:

1. Establish the decision context – the purpose of the MCA, identify the decision maker(s) and other key players, design the assessment system
2. Identify the options to be assessed to achieve the objectives
3. Identify the criteria
4. Scoring – describe the consequences of the options, score the options on the criteria, check the consistency of the scores on each criteria
5. Weighing – assign weights and scores to each option to reflect their relative importance to the decision
6. Combine the weights and scores for an overall value
7. Examine the results
8. Sensitivity Analysis

2 Decision Context

The purpose of the MCA is to use it to evaluate the three shortlisted options for the downstream section of the Project.

The decision maker(s) are:

- Christchurch City Council

Other parties involved in the Project are:

- Stakeholders – CERA, Marian College, Ministry of Education (Shirley Boys High School), CCC Parks (Richmond Park), Ngai Tahu
- Directly affected parties – landowners whose property would be required
- Landowners adversely impacted by EQ related change to flood risk (those benefitting from the proposed works)
- Community affected by proposed works (but not directly affected by land acquisition)

The key players are anyone who can make a useful and significant contribution to the MCA. Key players are chosen to represent all the important perspectives on the subject of the analysis. The key players are:

- Engineering
- Ecology
- Landscape
- Consenting
- Property
- Community

3 Project Objectives

The objectives of the Project have been proposed by the project team and accepted by CCC following some refinements. The primary project objective is:

> *Return the Flockton Street area to pre-EQ levels of flood risk as measured by the number of consented residential floor levels that are modelled to flood in the 1 in 10 year and 1 in 50 year storm.*

In doing so the Project must achieve:

- Achieve the primary objective of returning flood risk to pre-EQ levels in the Flockton St area
- Meet the timelines imposed on the project. These are:
  - Commence construction by September 2015 for the agreed alignment for the "Upstream" portion
  - Make a recommendation on the preferred option for the" Downstream" portion by August 2015
  - Achieve the primary objective and substantially complete construction by August 2017
- Obtain Resource Management Act (RMA) and building consents to undertake the works
- Maintain compliance with RMA and building consents
- Secure property and access required for the project
- Work within a budget (currently set by CCC at $48M but to be confirmed)
- Solution to meet the requirements of the CCC Waterways, Wetlands and Drainage Guide

There are other what can be called 'nice to haves' that we would also like to do:

- Provide additional flood risk benefits over and above the primary objective
- Enhance CCC's and our own reputation with CCC, the public and stakeholders
- Improve amenity value along waterways
- Provide enhanced ecological habitats along waterways
- Develop solutions which consider the operation of the entire drainage network over the whole of its life

Setting objectives is important because the criteria used when comparing the options are closely linked to the objectives. In addition, if designation under the RMA is sought it is necessary to demonstrate that the option selected will meet the objectives of the project.

4 Options to be Assessed

The options to be assessed are:

- Option A Corridor – Warden Street Bypass and Banks Avenue Channel Works
- Option B Corridor – Warden Street Bypass, Marian College, Richmond Park and Residential Red Zone Bypass
- Option C Corridor – Stapletons Road Channel Works, Petrie Street, Randall Street and Medway Street Piped Bypass

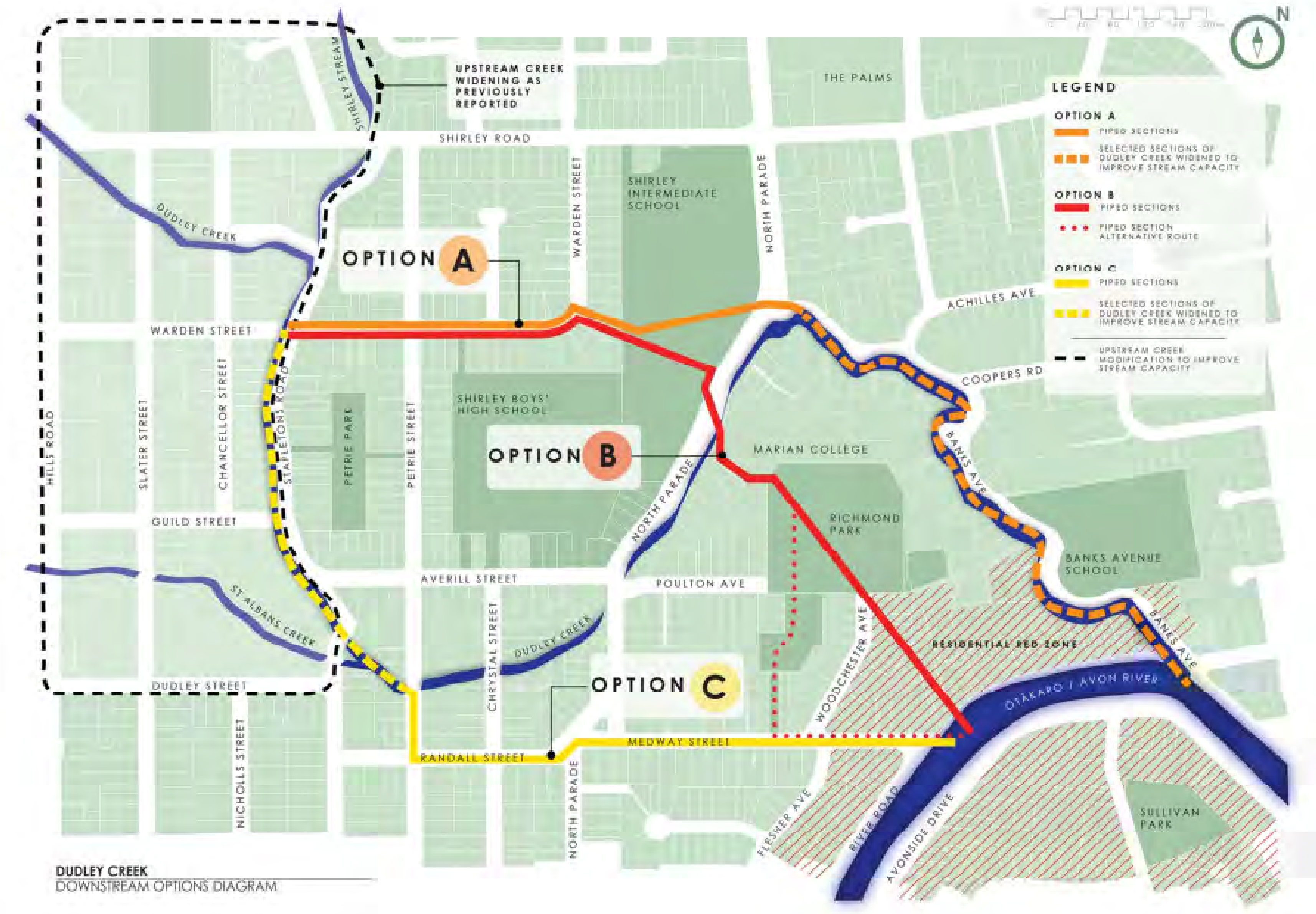
The above are corridor options. Within these options the following sub-options are currently being investigated to assess their viability:

- Option A sub-options:
  - Option A1 – Warden Street Gravity Bypass and widening of Dudley Creek along Banks Avenue
  - Option A2 – Warden Street Pumped Bypass and widening of Dudley Creek along Banks Avenue
- Option B sub-options:
  - Option B1 (short) – Gravity Bypass along Warden Street and through Marian College, Richmond Park and Residential Red Zone Bypass
  - Option B2 (short) – Pumped Bypass along Warden Street and through Marian College, Richmond Park and Residential Red Zone Bypass
  - Option B3 (short) – Gravity Bypass along Warden Street and through Marian College, Richmond Park and along Medway St to Avon River (bypassing RRZ)
  - Option B4 (short) – Pumped Bypass along Warden Street and through Marian College, Richmond Park and along Medway St to Avon River (bypassing RRZ)
- Option C sub-options:
  - Option C1 – widening of Dudley Creek along Stapletons Road, Gravity Bypass along Petrie Street, Randall Street and Medway Street
  - Option C2 – widening of Dudley Creek along Stapletons Road, Pumped Bypass along Petrie Street, Randall Street and Medway Street

Corridors A, B (with RRZ bypass option) and C are presented on the following sketch.

The corridor options were assessed through the MCA process.

The decision to pump or gravitate flows along these corridors was assessed through a separate MCA process that used a subset of the MCA criteria and the relative weightings determined by the MCA process.


N
UPSTREAM CREEK WIDENING AS PREVIOUSLY REPORTED
SHIRLEY STREAM
SHIRLEY ROAD
THE PALMS
LEGEND
OPTION A
PIPED SECTIONS
SELECTED SECTIONS OF DUDLEY CREEK WIDENED TO IMPROVE STREAM CAPACITY
OPTION B
PIPED SECTIONS
PIPED SECTION ALTERNATIVE ROUTE
OPTION C
PIPED SECTIONS
SELECTED SECTIONS OF DUDLEY CREEK WIDENED TO IMPROVE STREAM CAPACITY
UPSTREAM CREEK MODIFICATION TO IMPROVE STREAM CAPACITY
DUDLEY CREEK
OPTION A
WARDEN STREET
SHIRLEY INTERMEDIATE SCHOOL
NORTH PARADE
ACHILLES AVE
COOPERS RD
HILLS ROAD
SLATER STREET
CHANCELLOR STREET
STAPLETONS ROAD
PETRIE PARK
PETRIE STREET
SHIRLEY BOYS' HIGH SCHOOL
OPTION B
MARIAN COLLEGE
BANKS AVE
RICHMOND PARK
GUILD STREET
AVERILL STREET
POULTON AVE
BANKS AVENUE SCHOOL
ST ALBANS CREEK
CHRYSTAL STREET
DUDLEY CREEK
RESIDENTIAL RED ZONE
WOODCHESTER AVE
OPTION C
OTAKARO / AVON RIVER
DUDLEY STREET
MEDWAY STREET
RANDALL STREET
NICHOLLS STREET
FLESHER AVE
RIVER ROAD
AVONSIDE DRIVE
SULLIVAN PARK
DUDLEY CREEK
DOWNSTREAM OPTIONS DIAGRAM

5 Criteria

5.1 Background

The purpose of identifying criteria is to develop the means by which the options will be tested and compared. Each criterion must be measurable, that is, it must be possible to assess, at least in a qualitative sense, how well a particular option is expected to perform in relation to the criterion. This means, for each criteria, answering the question:

> "Is it possible in practice to measure or judge how well an option performs on these criteria?"

This is done by understanding what would distinguish between a 'good' choice and a 'bad' one.

5.1.1 Criteria requirements

Developing criteria requires consideration of:

- Do the criteria capture all the key aspects of the objectives that are the point of the MCA
- Over what timeframe are the criteria assessed
- It must be possible in practice to measure or judge how well an option performs on the criteria
- The ability to distinguish between a good choice and a bad one
- Independent criteria - can you assign preference scores for the options on one criterion without knowing what the options' preference scores are on any other criteria?
- Avoid using two or more criteria that essentially measure the same attribute as this would essentially amount to double counting
- Are there criteria which are unnecessary?

and finally, have we included all the criteria necessary to compare the options' performance?

In essence developing criteria is asking "what do we care about" and being able to "describe the consequence (what does it look like)".

5.2 Development of the Criteria

A workshop was held on 30th April 2015 to discuss potential criteria. The workshop was attended by:

- CCC - Project Managers, Surface Water Technical Consultants, Land Drainage Manager, CCC Land Drainage Unit Manager (in part) and Environment and Heritage Unit Manager (in part)
- Project Team - Consenting Lead, Design Lead - Upstream Section, Design Lead - Downstream Section, Team Leader, Landscape Lead, Ecology Lead.
- CERA – Horizontal Infrastructure team, Legal and Policy representatives.

5.2.1 Key areas to consider

The following list includes the outcomes that those at the workshop consider as key for the project.

The bottom lines

- Needs to meet primary objective, that is flood risk reduction in the Flockton St area
- Needs to have achieved the primary objective by August 2017
- Be acceptable to CERA from a process and issues considered point of view.

Hydraulic Performance

- Flood risk reduction benefits over and above primary objective (of flood risk reduction in the Flockton St area)

Cost

- Capital
- Capital renewals, operation and maintenance
- Whole of life cost (which incorporate the above)

Long Term Sustainability

- Future proofed solution
- Resilience to damage in future natural hazard
- Ability to upgrade to convey higher flows (to provide increased level of service)
- Ability to adapt to climate change (coping with higher downstream water level or more intensive rainfall)

Operation

- Operability and maintainability
- Reliability/vulnerability during high flow event
- Health and safety risks during operation

Property, Consenting and Legal

- Risk of not meeting timetable due to consenting or property
- Risk of legal action – cost, reputation, delays
- Risk of delays due to reliance on CERA approval

Constructability

- Health and safety risks during construction (worker and public)
- Traffic and pedestrian impacts
- Noise and nuisance
- Disruption to public and services
- Risk of damage to other assets

Alignment with CCC's Wetland and Waterways Values (6 values, less drainage)

- Ecology
- Landscape
- Recreation
- Culture
- Heritage

Community

- Social cohesion
- Happy people
- Amenity effects
- The community is left with an asset

5.2.2 Changes to the criteria

Prior to the scoring workshop there was a review of the criteria and wording. This was done to ensure that the criteria remained valid following all the investigation work. There were some changes made. Section 5.3 includes the criteria used for the final assessment.

5.3 The Criteria Used

To ensure that the options were robustly assessed and relevant statutory requirements met, the MCA framework criteria factored in both cost, design and non-cost related outcomes. The non-cost outcomes essentially provide an assessment of the environmental, social and cultural 'effects' of the options, while the cost outcomes essentially focused on the economic component. Together, the non-cost, design and cost related outcomes provide a comprehensive assessment of the option.

Sub-criteria under each project outcome were developed to more clearly inform the assessment. The outcomes and sub-criteria are presented below.

Flood Hazard Reduction

	Outcome	Criteria	Definition	Measurement
FLOOD REDUCTION	The degree to which the project provides mitigation of the flood risk	D1 – Vulnerability	Reliability of the option including any residual flood risk - design	The degree of robustness of the option and consequence of failure during a flood event
		D2 - Hydraulic performance / opportunity	Flood risk reduction over and above the primary objective of flood risk reduction in the Flockton St area	Ability of the option to reduce flood risk in other areas

Note that the project needs to meet the primary objective (flood risk reduction in the Flockton Street area). This means accepting that the options presented can meet the objective, otherwise they would not be assessed.

D1 is about how reliable the on-going 'operation' of the option is.

While there might be minor changes to the design options, it is to be assumed that no further optimisation would occur to the extent that it would change the outcomes.

Cost

	Outcome	Criteria	Definition	Measurement
	The whole of life cost of the project	C1 - Whole of life cost	Whole of life costs including operation, maintenance and renewals	Whole of life cost estimate

The lowest cost option is to be seen as the preferred option under this criteria.

The whole of life cost includes:

- Capital cost, capital renewals, maintenance and operation costs that are a component of the whole of life cost:
  - Capital cost

- Cost to operate
- Maintenance requirements – this captures the ability to maintain as this comes at a cost
- Capital renewals (e.g. replacement of pumps and electrics at say 15 years)
- Earthquake related costs (resilience assessment)
- Implementation of health and safety requirements.

The whole of life assessment includes an assessment of the ability of the option to maintain service following a future earthquake event and an assessment of the estimated costs associated with rebuilding the asset following a future earthquake event.

If there are other aspects of property acquisition that are not necessarily financially compensated for then these are captured elsewhere – e.g. social impacts, disruption during construction.

There is an indirect cost of ongoing flooding to properties if there is a delay in delivering the project due to legal challenge and extended land access negotiations. This will be reported separately from the capital cost of the scheme as it is not a direct cost to CCC. The cost and risk of this is evaluated under the timeframe risk criteria (R2).

Environment

	Outcome	Criteria	Definition	Measurement
ENVIRONMENT	The project integrates well with the environment and any adverse effects on the ecology, landscape, recreation, heritage and culture are minimised	E1- Ecology - instream	The impact on the self-sustaining process and inter-relationships among plants, animals and insects	The degree of change compared to the existing environment (instream and riparian)
		E2 - Landscape	The impact on the special character of sites and places, their aesthetic qualities and their meaning to the community	The degree of change compared to the existing environment
		E3 – Heritage & Culture	The impact on sites and activities of historical and natural significance The impact on Ngai Tahu and the community's perception of a resource and its values, indicated by community involvement in management, celebration of past events and planning for the future – with a focus on the objectives of the Mahaanui Iwi Management Plan	The degree of change compared to the existing environment
	The health and wellbeing of the community has been considered	E4 – Community impact (social)	The option provides for peoples wellbeing and sense of community Note this includes recreation	Qualitative assessment of impact – quality of life, community cohesion, recreation, health & wellbeing. This will be measured through consultation feedback
	Temporary effects from construction are managed	E5 - Construction	Effects of constructing the option including the natural environment, traffic, pedestrians, noise, disruption	The degree of adverse effect from construction activities

	Outcome	Criteria	Definition	Measurement
			to public and services, health and safety risks, damage to other assets, access to private property.	

In setting the criteria we have taken into consideration the CCC's 6 Values (minus drainage). These values are expressed in the Waterways, Wetlands and Drainage Guide: Part A Visions.

The option already includes the appropriate mitigation (ie. we can't do something that has totally unacceptable effects). The timeframe over which the impact is assessed will vary for each of the criteria. When the option assessment is undertaken the timeframe used for each criteria will need to be documented.

Consideration of the criteria excludes cost to implement mitigation and cost of property acquisition.

Long Term Sustainability

	Outcome	Criteria	Definition	Measurement
LONG TERM SUSTAINBILITY	The project is considered sustainable in the long term	S1 - Long term hydraulic sustainability	Ability to future proof the solution for climate change, to meet demands for increased levels of service and to cope with over design events (> 50 yr ARI) flows	Qualitative assessment of the ability of the adapt to meet changing hydraulic needs

While a short term solution might met the current flooding issue it could preclude future opportunities or even the means to address future adverse effects (eg. climate change). This is not about the cost of enabling a future proofed solution, or the cost to fix something if a future natural hazard was to occur, but the ability to come along at a later date and provide additional benefit. By long term we mean 50+ years based on the life of the asset.

The resilience to damage in a future earthquake has been factored into the whole of life analysis (C1). This includes consideration of the cost to repair damage and the current earthquake risk profile for Canterbury.

Risk

	Outcome	Criteria	Definition	Measurement
RISK	Risks have been managed to the extent practical	R1 - Legal Risk	The extent to which there is risk around legal action	The degree of unmanageable risk
		R2 - Timeframes	Not meeting timeframes due to consenting or property access agreements	The degree of unmanageable risk
		R3 – Red Zone land	Red Zone land - ability to acquire or access and use the land	The degree of risk around access to Red Zone land – purchase or easements and ongoing use

No project can be completely risk free but risks can be managed. This is about the degree of risk with each option, i.e. the extent to which there is risk around delays, legal action and CERA approval. It includes risk around residual flood risk. The risks around timing (ie. delivery of the project) are captured here.

6 Scoring

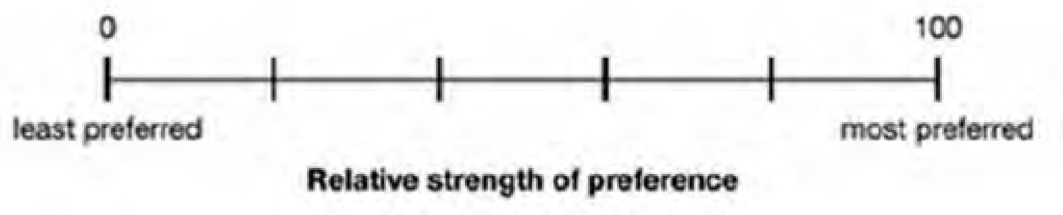
6.1 Background

MCA techniques commonly apply numerical analysis in two stages:

- Scoring
- Weighting

The expected consequences of each option are assigned a numerical score on a strength of preference scale for each option for each criterion.

In this way more preferred options score higher on the scale, and less preferred options score lower. Typically scales extend from 0 to 100, where 0 represents a real or hypothetical least preferred option (worst outcome), and 100 is associated with a real or hypothetical most preferred option (best outcome). All options considered would then fall between 0 and 100.



Once the end points are established for each criterion, there are three ways in which scores may be established for the options.

1. Value: to translate a measure of achievement on the criterion concerned into a value score on the 0 – 100 scale. The value functions are normally linear however, in some cases it may be appropriate to use a non-linear scale eg. noise levels are measured on a decibel scale is that non-linear

2. Direct rating: when a commonly agreed scale of measurement for the criteria in question does not exist, or where it is not possible for undertake the measures (eg. time or resources). Uses the judgement of an expert simply to associate a number in the 0–100 range with the value of each option on that criteria

3. Series of pairwise assessments expressing a judgement of the performance of each option relative to each of the others

Each of the three methods outlined above can also be used to establish the relative weights to be given to criteria.

6.2 Approach to Scoring

Prior to the workshop the technical experts were asked to assess the options and score against the criteria of relevance to their expertise. In general the scoring system adopted a direct rating. The scoring used is:

All scoring of the Corridor Options against the Criteria are to be scored on a 0 to 100 scale.

Where

- 0 = very low or a real or hypothetical least preferred option (worst outcome / completely fails the criteria, strong negative effects)
- 25 = low
- 50 = moderately meets the criteria (adequate, neutral)
- 75= high
- 100 = very high or a real or hypothetical most preferred option (best outcome / completely meets the criteria such that it is an ideal level of performance, strong positive effects).

Scoring was in units of no less than 5.

6.3 Outcomes of Scoring Process

Important Note: The project objectives limit the scope of what can be achieved. In some areas there is a "missed opportunity" the most obvious being environmental enhancement. This is due to the project being a recovery project. In other circumstances the CCC's 6 values approach would be an important component of a project and enable a wider perspective to be taken.

A workshop was held the 14th July 2015 to confirm the scores and weight the criteria. The workshop was attended by:

- CCC - Project Sponsor, Project Manager, Land Drainage Manager, Land Drainage Recovery Programme – Technical Manager, Consultation Leader, Procurement Project Manager
- Project Team - Consenting Lead, Design Lead - Upstream Section, Design Lead - Downstream Section, Team Leader, Landscape Lead, Ecology Lead, Hydraulic Designer.

At the workshop the technical experts presented their assessment of the options against the criteria and the score they had assigned to each option. In some cases amendments were made to the scores as a consequence of discussion.

Each of the technical experts scoring assessments are provided in Appendix 1.

The scores assigned are:

Table 1: **Overall scoring matrix**

Ref	Criteria	Option A	Option B-short	Option B-long	Option C
D1	Vulnerability	80	70	70	80
D2	Hydraulic Performance	50	60	60	80
C1	Whole of life	65	55	45	65
E1	Ecology instream	90	45	45	75
E2	Landscape	85	45	45	75
E3	Heritage & Cultural*	85	40	40	75

Ref	Criteria	Option A	Option B-short	Option B-long	Option C
E4	Community impact	25	70	70	60
E5	Construction	50	40	40	40
S1	Long term hydraulic sustainability	60	50	50	60
R1	Legal risk	40	70	70	60
R2	Timeframe risk	20	50	50	40
R3	Red Zone land risk	50	10	100	100

* Heritage and Culture – The Maori cultural values scoring was undertaken using the objectives of the Mahaanui Iwi Management Plan. See the notes in Appendix 1 for E3.

7 Weighting

MCA decision preferences are expressed through criteria weights. In doing so the importance of each criteria relative to other criteria is expressed.

Weighing assigns weights for each of the criterion to reflect their relative importance to the decision. The process of deriving weights is fundamental to the effectiveness of a MCA.

Weighing techniques include[2]:

- Pairwise comparison – statements made of preference between pairs of criteria
- Swing weights – think about the attractiveness of the swing from worst to best on each criteria
- Ordinal ranking – rank criteria in order of importance
- Fixed point scoring – distribute a set number of points amongst the criteria
- Rating – assigning a score of importance to each criteria.

The weightings were calculated using 1000Minds. The software applied a PAPRIKA method – an acronym for '**P**_otentially_ **A**_ll_ **P**_airwise_ **R**_an_**K**_ings of all possible_ **A**_lternatives_'. It calculates point values (or 'weights') on the criteria. Point values represent the relative importance of the criteria or attributes to decision-makers.

7.1 Weightings used

The weightings, as established using a pairwise assessment are:

Table 2 Weightings established by pairwise process

Ref	Criteria	Weighting (%)
D1	Vulnerability	15.1
D2	Hydraulic Performance	9.4
C1	Whole of life	5.7
E1	Ecology instream	7.5
E2	Landscape	7.5
E3	Heritage & Cultural	3.8
E4	Community impact	5.7
E5	Construction	1.9
S1	Long term hydraulic sustainability	13.2
R1	Legal risk	11.3
R2	Timeframe risk	11.3

[2] Harding reference

Ref	Criteria	Weighting (%)
R3	Red Zone land risk	7.5

8 Analysis

This section provides the analysis of the results. The analysis is presented as a stepped approach as follows:

- Cost
- Cost, performance measures and community feedback – as the key performance measures required by the project objectives
- Cost, performance measures and environmental – recognising that CCC best practice is to use the 6 values
- Cost, performance measures and combined environmental (with environmental factors grouped into a single criteria) – this recognises the key projects objectives and the lesser importance of environmental enhancement to this land drainage recovery project
- Overall – adds in risk – as risk, specifically timeframes, are important

In order to determine the final scores the criteria weightings have simply been 'scaled'. The limitations of this therefore need to be recognised.

8.1 Cost

If cost was the sole consideration in selecting an option, A and C are considered equally good and are cheaper than either of the B options. For the purposes of corridor selection, raw MCA scores relating for gravity conveyance have been used as the separate gravity vs pumped assessment has concluded that gravity conveyance is preferred.

Criteria	OPTION							
	A		B -short		B - long		C	
Capital Cost*	$27.7M	$32.5M	$28.8M	$35.9M	$32.0M	$39.2M	$26.2M	$30.5M
Whole of Life Cost*	$28.6M	$34.0M	$30.6M	$37.4M	$33.8M	$40.7M	$28.1M	$32.0M
C1 - Whole of Life cost raw MCA score*	63.1	46.7	57.0	36.4	47.3	26.4	64.5	52.7
C1 – Adopted Whole of life cost raw MCA score for corridor evaluation	65		55		45		65	

* The costs and raw MCA scores are presented for gravity (left) and pumped (right)

8.2 Cost and Performance

Cost, performance and community feedback have been considered as these are the key principles. Option C rates the highest.

	Option A	Option B-short	Option B-long	Option C
Total Score	60	60	59	69

8.3 Cost, Performance and Environmental

To recognise the importance that would normally be placed on the 6 Values, the environmental criteria are added to the matrix. The total score reflects the technical and environmental aspects of the options but excludes the three risk criteria. Option C is the preferred option but closely followed by Option A.

	Option A	Option B-short	Option B-long	Option C
Total Score	68	55	54	71

8.4 Cost, Performance and Combined Environmental

Environmental factors have been grouped together as a single criterion under this scenario. This recognises the key project objectives and the lesser importance of environmental enhancement to this land drainage recovery project. The total weighting for Environmental criteria (combination of E1, E2, E3) is 7% under this scenario, which is similar to the importance of cost and community impact. Option C is the preferred option.

	Option A	Option B-short	Option B-long	Option C
Total Score	54	54	60	64

8.5 Overall

The overall performance matrix includes all the criteria and weightings as determined at the MCA workshop. The three risk criteria are included recognising that while an option may be technically good the ability to deliver the option is critical. Option C is the preferred option.

Table 3: **Overall performance matrix**

Criteria	Weighting	A		B-short		B-long		C	
		raw	final	raw	final	raw	Final	raw	final
Vulnerability	15.1	80	12.08	70	10.57	70	10.57	80	12.08
Hydraulic Performance	9.4	50	4.7	60	5.64	60	5.64	80	7.52
Whole of life	5.7	65	3.71	55	3.135	45	2.57	65	3.71
Ecology instream	7.5	90	6.75	45	3.375	45	3.38	75	5.63
Landscape	7.5	85	6.38	40	3	40	3	75	5.63
Heritage & Cultural	3.8	85	3.23	40	1.52	40	1.52	75	2.85
Community impact	5.7	25	1.43	70	3.99	70	3.99	60	3.42
Construction	1.9	50	0.95	40	0.76	40	0.76	40	0.76
Long term hydraulic	13.2	60	7.92	50	6.6	50	6.6	60	7.92

		A		B-short		B-long		C	
sustainability									
Legal risk	11.3	40	4.52	70	7.91	70	7.91	60	6.78
Timeframe risk	11.3	20	2.26	50	5.65	50	5.65	40	4.52
Red Zone land risk	7.5	50	3.75	10	0.75	100	7.5	100	7.5
Total			**58**		**53**		**59**		**68**

8.6 Comment on previous investigations

In 2014 an options assessment was undertaken for two options[3]. While there were some differences in the criteria used, some general comments can be made about the 2014 and this process. The criteria and weightings determined in 2014 are presented in Table 4.

Table 4 Criteria and weightings from 2014 assessment

Criteria	Description	Weighting (%)
Timing	Time to design, consent, construct and achieve a significant reduction in flood risk in the catchment	11
Cost – Capital	Cost of design, consenting and construction	8
Cost - Operational	Whole of life costs	5
EQC Collaboration Opportunity	'Increased Flooding Vulnerability (IFV)' properties that are returned to pre-earthquake levels of flood risk	12
Benefits by floor level	The number of houses that no longer experiencing flooding within the house	22
Benefits by Property	The number of properties no longer experiencing regular foundation flooding	14
Residual Hazard Risk	Flood risks that remain in the project area or potentially increase due to changes in the catchment or climate. Residual risk include over design floods, further seismic activity, failure of the Kensington Ave pump station or blockages	5
Social and Environmental Impacts and Opportunity	Impact on landscape, ecology, heritage, cultural, recreational opportunities, social wellbeing. And opportunity to strengthening the local neighbourhood and community	7
Economic Impacts	Impact on local businesses and residential property values	10
Property Impacts	Properties impacted by the construction	6

[3] Jacobs, Dudley Creek Options Optimisation & Selection Report, November 2014, prepared for Christchurch City Council

Caution is required in making comparisons between the 2014 and this criteria and weightings assessment. However, at the broad level cost, environmental and the importance of timing have similar weightings.

8.7 Additional Sensitivity Analysis

Uncertainty is inherent in the MCA process because the decisions makers preferences, expressed as weights, are subjective values. Sensitivity analysis explores the robustness of the result(s) and how sensitive they are in changes to the model. It systematically varies the weights and/or data to see how they affect the results. If a minor variation in one criteria significantly influences the result, that parameter should be subject to further scrutiny.

A number of sensitivity tests were undertaken on the scores and the weightings. Sensitivity testing of changes to the weightings have been presented in sections 8.1 to 8.6 above. The conclusion was that variations to the weighting do not affect the outcome.

Comments are provided on two sensitivity tests relating to scoring, as these were matters that workshop attendees specifically requested be looked at:

- Whole of life cost– costs were adjusted based on a 100 year evaluation period and a further earthquake during the life of the asset included. While this marginally increases the whole of life costs, there is no technical reason to adjust the scores. If cost is given an equal weighting to performance, Option C still has the highest score and a 1 point difference between B-long and A.
- Heritage and Cultural – if this criteria is given the same weighting as the other environmental ones, Option C is still has the highest score.

9 Pumped vs Gravity Assessment

A separate MCA Workshop was held on 15 July 2015 to identify a preferred conveyance method using the same scoring and weighting process as for the corridor MCA, against a subset of the criteria used.

Each of the three corridor options were assessed for pumped and gravity solutions, with the gravity option scoring higher for each corridor. Therefore, gravity conveyance is recommended.

This analysis is presented in the memo included in Appendix 2.

10 Recommendation

The MCA process has identified Option C as the preferred option under evaluation scenarios. A separate review of pumped vs gravity conveyance identified gravity conveyance was preferred for all options.

As a result of the process, a gravity conveyance solution along corridor Option C is recommended.

Appendix 1 - Technical Experts Scoring Assessments

D1 – Vulnerability

Note: the 0 to 100 scale for flood reduction is:
- more reliable outcome = higher score
- less reliable outcome = lower score

General comments: Criteria interpreted as performance in flood event including design event and over-design (large event). This includes robustness and consequence of failure.

Concept designs for all options are for to the same inflows and to achieve the same upstream water levels at Warden Street and therefore the Flockton Street area. Mitigation measures will include inlet design to provide large screen area designed to avoid blcoakage, outlet design to minimise build-up of sediment from river inflows (e.g. flap gate), design to provide access for maintenance, regular maintenance and monitoring.

Option	Pros	Cons	Doubts/risks and opportunities	Score 0 - 100
Route A	▪ Low outlet blockage risk - outlet is an open channel ▪ In open channel, conveyance capacity continues to increase with depth	▪ Inlet blockage risk with debris from upstream	▪ Maintenance of pipe and channel inlets and outlets	80
B – short	▪ N/A	▪ Outlet blockage risk with siltation from Avon ▪ Inlet blockage risk with debris from upstream ▪ Either siphon under river or additional in/out of river – both have increased blockage risk	▪ Maintenance of pipe inlet and outlet and siphon or second inlet/outlet	70
B – long	▪ Same as B - short	▪ Same as B – short	▪ Same as B - short	70
Route C	▪ In open channel, conveyance capacity continues to increase with depth	▪ Outlet blockage risk with siltation from Avon ▪ Inlet blockage risk with debris from upstream – consequence slightly higher than Route A due to constrained channel downstream	▪ Maintenance of pipe and channel inlets and outlets	80

D2 – Performance

General comments: Criteria interpreted as improvement of water levels in other areas apart from Flockton Street area.
Concept designs for all options achieve the same upstream water levels at Warden Street and therefore the Flockton Street area, and don't increase levels above current or pre-earthquake in other areas.

Option	Pros	Cons	Doubts/risks and opportunities	Score 0 - 100
Route A	▪ Improved water levels along Stapletons Road ▪	▪ Water levels are marginal compared to current water levels in upper Banks Ave	▪ Assumes widening can be achieved as designed	50
B – short	▪ Improved water levels along Stapletons Road ▪ Improved water levels along upper Banks Avenue	▪ N/A	▪ Assumes widening can be achieved as designed	60
B – long	▪ Same as B - short	▪ Same as B - short	▪ Assumes widening can be achieved as designed	60
Route C	▪ Significant improvement in water levels along Stapletons Road ▪ Improved water levels along upper Banks Avenue	▪ N/A	▪ Assumes widening can be achieved as designed	80

C1 – Whole of Life Costs

Overview

This memo presents preliminary scoring of the whole of life cost of options for the Downstream Option MCA workshop.

Cost evaluation criteria (taken from the MCA report) are as follows:

	Outcome	Criteria	Definition	Measurement
COST	The capital and ongoing costs of the project	C1 - Whole of Life Cost	Whole of life costs including capital, operation, maintenance and renewals	Whole of life cost estimate

The lowest cost option is deemed to be the preferred option under this criteria.

Whole of Life Cost – includes capital cost, capital renewals, maintenance and operation costs:

- cost to construct
- cost to operate
- maintenance requirements – this captures the ability to maintain as this is a component of the cost
- capital renewals (e.g. replacement of pumps and electrics at say 20 years) over the period of evaluation
- earthquake related costs (from resilience assessment)
- implementation of health and safety requirements.

Capital Renewals, Operating and Maintenance Requirements

A meeting was held with staff from the CCC Land Drainage team and City Care Ltd, who hold the Land Drainage Maintenance Contract, to review maintenance and operational aspects of each of the downstream options.

The key comments from this meeting were as follows:

1. The whole of life analysis should match the method used by SCIRT for evaluating EQ rebuild options. That is a 30 year net present value evaluation period and uses a discount rate of 8%. Whole of life costs for a 100 year evaluation period have also been analysed as this generally matches the asset life of new pipelines and civil structures.

2. The proposed works will not change the amount of creek maintenance required (vegetation maintenance, mowing, weed, debris and silt removal). Therefore creek maintenance costs will be the same for each corridor option regardless of the creek modifications involved.

3. Operating and maintenance requirements for gravity pipelines subject to high tidal backflows (Options B and C):

    a. Inspection and light cleaning of inlet and outlet grates once per month and after every wet weather event. Assume 0.5 days per month for operator with ute = $350/inspection (allow 15 inspections per year, which sums to $5,250/year).

    b. Annual cleaning of grit/silt trap and outlet structure using sucker truck or small excavator. Assume 1 day operation for sucker truck or 5 tonne digger + truck and traffic management = $2,500/clean (once per year)

   c. Five yearly cleanout of silt within pipeline using possibly drag buckets and high pressure jetting. Assume digger and truck, temporary pumping and traffic management for 1 week = $25,000/clean (once every 5 years)

4. Operating and maintenance requirements for gravity pipelines not subject to high tidal backflows (Option A):

   a. Inspection and light cleaning of inlet and outlet grates once per month and after every wet weather event. Assume 0.5 days per month for operator with ute = $350/inspection (allow 15 inspections per year, which sums to $5,250/year)

   b. Annual cleaning of grit/silt trap and outlet structure using sucker truck or small excavator. Assume 0.5 day operation for sucker truck or 5 tonne digger + truck and traffic management = $1,500/clean (once per year)

5. Capital renewals on gravity pipelines subject to tidal backflows (Options B and C):

   a. Replacement of penstock actuator and controls every 20 years at $20,000

   b. The replacement of pipelines and civil structures will fall outside of the evaluation period as they have a design life of 100 years.

6. Capital renewals on gravity pipelines not subject to tidal backflows (Option A):

   a. Nil (the replacement of pipelines and civil structures will fall outside of the evaluation period as they have a design life of 100 years).

7. Operating and maintenance requirements if pumping station and pumped pipelines:

   a. Inspection and light cleaning of inlet and outlet grates once per month and after every wet weather event. Assume 0.5 days per month for operator with ute = $350/inspection (allow 15 inspections per year, which sums to $5,250/year)

   b. Annual inspection and maintenance, including 3 monthly operation of generator - $25,000/year (based on comparison with pump station maintenance costs in SCIRT NPV spreadsheet)

   c. Operating costs – power = $50,000/year (based on 500kW of pumps, operating for 300 hours per year at 65% efficiency and 20c/kWhr + allowance for diesel)

8. Capital renewals on pumping options:

   a. Replacement of pumps every 25 years at $250,000

   b. Replacement of electrical and controls equipment every 20 years at $250,000

   c. Replacement of generator equipment every 20 years at $450,000

Resilience Assessment

Resilience Assessment Methodology

This resilience assessment has focused on the performance of the asset in a future earthquake event. It is an assessment of the ability of the option to maintain service following a future earthquake event and an assessment of the estimated costs associated with rebuilding the asset following a future earthquake event.

Other natural hazards such as flooding, fire and storms also pose a risk to the asset but with appropriate design the risk profile for each option should be the same. This will require electrical equipment to be positioned above flood levels, storm loadings to be factored in the design of above ground structures and fire protection systems provided.

SCIRT developed a methodology for considering the relative resilience of different rebuild options and this method has been used to include a measure of resilience in the whole of life analysis used for evaluating downstream options. This assessment of resilience is consistent with the requirements of the Infrastructure Design Standard (IDS) which requires new infrastructure to be designed to minimise life cycle costs over the life of the asset.

Guidance from GNS and the approach adopted by SCIRT for considering earthquake risk are presented in the below text extracted from Section 4.6 of the Infrastructure Recovery Technical Standards and Guidelines (IRTSG, Current Version 4.3). SCIRT have confirmed that GNS advice on the EQ risk profile for ChCh is still current. For the purposes of analysis, it is assumed that earthquake related costs occur at Year 5 on the timeline.

For a 100 year NPV analysis, a second EQ at Year 20 has been applied to test the sensitivity of increased earthquake risk on option selection. This resulted in a small increase in the whole of life cost of each option but did not change to resulting raw MCA score.

Extract from Section 4.6 of the Infrastructure Recovery Technical Standards and Guidelines (IRTSG, Current Version 4.3)

4.6 RISK

Current advice regarding modelling of the expectation and impacts of earthquakes in the Canterbury region received from GNS (Nov 2012) is summarised in Table 4.7. The scale of the events involved is selected by GNS to be sufficient to cause liquefaction where in-ground infrastructure rebuild activities are centred. There are four principal source areas as indicated by the magnitude range and location radius in the table. The expected number of events is shown for SCIRT use in comparisons of construction resilience and cost that are used in selection of design options.

Table 4.7: Seismic Hazard Probabilities

Earthquake Sufficient to Cause Liquefaction in Christchurch		Expected Number of Events	
Magnitude Range	Radius (km) from Eastern Christchurch	Next 5 years	Next 20 years
5.8-6.5	10 km	0.142	0.25
6.5-7.0	50 km	0.072	0.17
7.0-7.5	100 km	0.033	0.10
>7.5	200 km	0.052	0.20
Cumulative Total (Average Number)	All events	0.30	0.72
Probability	An event	26%	51%
Cumulate Number Range (95% confidence)	All events	None to 2	None to 3

Note: This table is not intended for application to structures controlled by the Building Act.

4.6.1 Variations to Standards

S&S has decided and HIGG confirmed that suggests at this time that the appropriate risk over time to be considered during the rebuild would allow for the potential of one event approximating the June 2011 event within a twenty year period. For the purpose of net present value (NPV) analyses, assume this event occurs at year 5.

Considering Resilience in the Concept Design of Options

The concept design of options has considered how the resilience of options can be improved. Information on this is presented in Section 7.1.12 of the Downstream Options Report, and in more detail in the Concept Geotechnical Report included in Appendix E of the Downstream Options Report.

This analysis has focused on each options' resilience to earthquake related damaged. It is assumed that the risk of damaged from other natural hazards (flooding, fire, storm) is the same for each option following appropriate design.

A summary of issues and mitigation measures incorporated into the concept design are as follows:

1. Gravity pipelines

   All the options involving gravity bypass pipelines may be affected by post construction static settlement, and in significant seismic events they will be affected by joint displacement caused by ground settlement and lateral spreading. There is also a risk of seismically induced floatation. To a degree the seismic risks can be mitigated (but not removed) by geogrid wrapped bedding, geotextile wrapping around the pipe joints and extended footings. There will however be joint displacement and damage in large seismic events and repair will most likely be required.

2. Pressure pipelines and pump stations

   Pressure pipelines are expected to be more resilient, particularly if constructed from end restraining flexible pipe such as polyethylene. The main risk is seismically induced floatation which can be managed through appropriate trench detailing. Pump stations would be at risk of seismic damage (settlement, lateral spreading, floatation, structural damage). However these risks can be reduced through appropriate design. An area of weakness will be the pump station inlet which will be a gravity pipeline.

3. Creek Widening

   The effect of widening Dudley Creek on the seismic performance of the adjacent land and buildings has been assessed. The effect of the widening was assessed to be very minor such that no mitigation work is required, provided the widening is further than 15m from such land or buildings and the creek bed is not lowered (removing competent material). In areas where widening is required within 15m of private land or buildings a site specific assessment needs to be made and some form of mitigation work (such as a retaining wall or mass stabilisation) might be required.

Estimate of Earthquake Related Costs

Earthquake costs are an estimate of the costs associated with responding to a future earthquake event. This includes:

1. First response costs to restore a minimum level of service through cleaning, temporary over pumping, the completion of emergency repairs to restore service, repair works to other affected assets, etc, and

2. Asset repair costs to permanently repair earthquake damage.

The mitigation measures incorporated into the concept design are expected to allow the assets to continue to operate during and following a significant earthquake without the need for immediate emergency repair works (ie Nil first response costs).

Asset repairs works and costs have been estimated as follows:

1. Gravity pipelines

   We have assumed that the pipeline though the RRZ and near waterways will remain serviceable during and following an earthquake event but will require repair to joints which pull apart due to differential settlement or lateral spread. Differential settlement could also result in dips within the gravity pipeline.

   Geotextile wrapping proposed under 3.2.2 above should prevent the migration of fines into the pipeline but the leaky joints could, over the longer term, lead to erosion and ground settlement along the pipeline. Repair could be completed through repairs to individual joints, lining sections of the pipeline where joints are leaking, or replacing sections of the pipeline.

   For the purposes of the assessment, it is been assumed that pipelines within 50m of the waterway and through the RRZ (150m long) will require replacement. This is based on ground damage observations following the 2010/2011 earthquakes where ground cracking with apertures of greater than 50mm were observed up to 50m back from the waterway and through the RRZ (refer section 5 of Concept Geotechnical Assessment Report).

   This results in the following earthquake related costs, which will occur at year 5 on the timeline:

   - Option A: 100m replacement (Warden St + North Parade connections to Dudley Creek) = 100m x $12,300/m = $1.23M
   - Option B: 50m (Warden St only as trenchless crossing of Dudley Creek mitigates this risk) + 150m through RRZ = 200m x $12,300/m = $2.46M
   - Option C: 50m (Petrie St) + 150m through RRZ = 200m x $13,200/m = $2.64M

2. Pressure pipelines and pump stations

   The pressure pipeline is currently assumed to be constructed from solid wall polyethylene (PE). This end restraining flexible pipeline is not expected to sustain damage as a result of an earthquake. It may differentially settle but any dips that result from this are not expected to affect the operation of the line.

   The pump station will be designed to cope with a future earthquake without loss of service or structural damage. An area of weakness is the gravity inlet pipeline to the pump station, which could experience the same damage as other gravity pipelines. The following allowance has been made to repair the gravity inlet pipeline to the pump station:

   - Options A and B: 50m replacement (pump station inlet) = 50m x $12,300/m = $0.62M
   - Option C: 50m replacement (pump station inlet) = 50m x $13,200/m = $0.66M

3. Creek widening

   Some local bank collapse could be expected from an earthquake but the effects will be minor and localized. The effects are also expected to be no worse in a widened waterway than in an unmodified waterway.

   We have therefore made no allowance for first response costs or repair costs associated with widened waterway works.

Whole of Life Cost Estimates

Whole of life estimates have been developed using a net present value (NPV) over a 30 year period with a discount rate of 8%. This aligns with the whole of life analysis process undertaken at SCIRT, which has previously been accepted by CCC.

An assessment has also been completed using a 100 year period, which equates to the design life of pipelines and civil structures. The results for this did not differ from the results for the 30 year evaluation period.

An assessment has also been completed using the discount rate of 5.6%, which is more in line with standard CCC financing costs. This resulted in a shift in whole of life values, but resulting raw MCA scores were very similar.

Summary of Comparative Whole of Life Costs

Corridor A		Corridor B-short (B1/B2)		Corridor B-long (B3/B4)		Corridor C	
A1 Gravity	A2 Pumped	B1 Gravity	B2 Pumped	B3 Gravity	B4 Pumped	C1 Gravity	C2 Pumped
$28.6M	$34.0M	$30.6M	$37.4M	$33.8M	$40.7M	$28.1M	$32.0M

Scoring Whole of Life Cost

Whole of Life costs have been converted into MCA scores using a weighted attributes method from NZTA's Competitive Pricing Procedures (CPP) manual. This has been selected as it is an industry recognised method of converting a cost to a score. The method (from Section 2.7 of CPP) is:

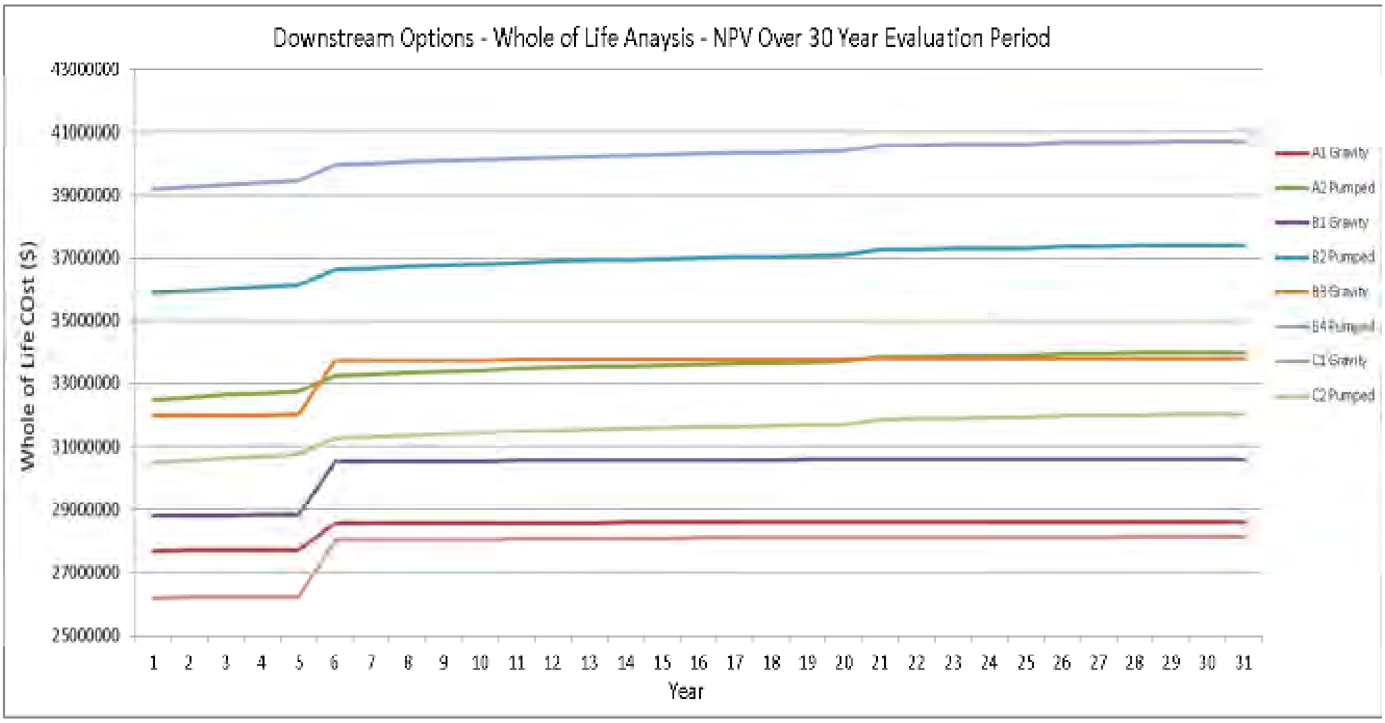
$$\text{Raw MCA Score} = 50 + 100 \times \frac{(\text{Median Whole of Life Cost} - \text{Whole of Life Cost})}{(\text{Median Whole of Life Cost})}$$

Whole of Life (WOL) scores are presented below (30 year evaluation with a discount rate of 8%).

Further detail on the whole of life is included on the whole of life plots.

Summary of MCA Scores for Whole of Life Costs

	Corridor A		Corridor B1/B2 (B-short)		Corridor B3/4 (B-long)		Corridor C	
Option	A1 Gravity	A2 Pumped	B1 Gravity	B2 Pumped	B3 Gravity	B4 Pumped	C1 Gravity	C2 Pumped
Capital Cost	$27.7M	$32.5M	$28.8M	$35.9M	$32M	$39.2M	$26.2M	$30.5M
Whole of Life Cost	$28.6M	$34.0M	$30.6M	$37.4M	$33.8M	$40.7M	$28.1M	$32.0M
Individual WOL Raw MCA Score	63.1	46.7	57.0	36.4	47.3	26.4	64.5	52.7



E1 – Ecology instream

The scoring of the environmental criteria (instream ecology) was based on determining 'the degree of change compared to the existing environment'. The determination is therefore to the direction of change and the magnitude of that change - whether the change is a degradation of the existing environment (i.e., a score less than 50), has no change to the existing state (i.e., a neutral score of 50), or is an ecological improvement of the existing environment (i.e., a score greater than 50). This change is compared to the existing ecological condition of Dudley Creek as determined in the ecology report (McMurtrie, 2015).

The scores are on the basis of a comparison between the four existing routes and their designs as per the Downstream Options Report, and is not compared against any other hypothetical options or additional enhancement opportunities not included within the current route design options. To that end a very high score reflects the greatest level of positive change possible within the current design options, but does not mean that there are not other design options that could improve ecological condition further (such as improving instream habitat condition along the length of Dudley Creek rather than just at those areas that are going to be altered to provide additional flood capacity).

Option A (piped along Warden St, widening along Banks Ave)

SCORE (out of 100)	90	Scoring criteria	» LOW score: Negative change (environmental impact) compared to existing condition » HIGH score: Positive change (enhancement) compared to existing condition

Pros

The instream condition (instream habitat, aquatic invertebrates, fish) along Banks Ave is currently in poor condition (with the exception of a small riffle at Archilles Ave). There is thus great potential (in the MEDIUM – LONG TERM) to vastly improve instream ecology with the right design of the instream and riparian environment. Scoring has therefore been based on the fact that we can achieve the following in those sections undergoing modification for flood mitigation:

- Narrow the low flow channel and create good fish habitat along the newly created channel edge
- Good riparian planting of trees, shrubs and bankside/freshplain cover (native and not so small that it is overtopped with weeds, with good overhang of the water)
- Remove fine (and contaminated) sediment and replace with clean gravels
- Add rocks, and where possible, logs to the low flow channel
- Ensure sufficient use of (suitable) trees to continue to shade the stream (to keep macrophyte growth down) while keeping autumn leaf-litter inputs (from large exotic deciduous trees) to a minimum.

This option provides the best opportunity for ecological improvement to the existing instream ecological state of Dudley Creek. Approximately 400 m of stream will undergo bank/channel works and thus enhancement, which is roughly 60% of the Banks Ave section. This is the greatest distance of enhanced channel for all of the options, and thus provides the greatest LONG-TERM ecological benefit and increased likelihood of ecological success.

Being situated in the lowest section of Dudley Creek, there is greater connectivity of enhanced sections to the Avon River, which will allow for better migration routes for some biota.

There is a greater change of ecological success due to the longer (and semi continuous) section of stream that will be improved.

Cons

Loss of channel shading in the SHORT-TERM until replacement trees become established (especially with the North to East aspect of the channel). This may result in more macrophyte growth in the short-term, although this will hopefully be partly mitigated by more streamside planting providing for some additional (albeit) low shading of the channel.

Doubts/Risks and opportunities

Opportunity

- The significant opportunity to greatly improve instream values (by following the design criteria listed above in 'Pros').
- Will possibly enable the removal of plant pest species (male/female ferns, ivy, *Tradescantia*, old mans beard, etc) – although many of these are on private land and so may not be touched.
- Ability to remove (and not replace with the same species) exotic trees that are environmental weeds (i.e., sycamore, ash and other species) that also contribute large amounts of leaf litter to the stream in autumn.

Risks

The devil is in the detail…..

Not implementing the ecological enhancement options as outlined in the ecology report will greatly diminish the enhancement potential. To get ecological improvement the following would be required:

- Narrow the low flow channel and create good fish habitat along the newly created channel edge (already planned)
- Good riparian planting of trees, shrubs and bankside/freshplain cover (native and not so small that it is overtopped with weeds, with good overhang of the water) (already planned)
- Remove fine (and contaminated) sediment and replace with clean gravels
- Add rocks, and where possible, logs to the low flow channel
- Ensure sufficient use of (suitable) trees to continue to shade the stream (to keep macrophyte growth down).

Choice of replacement trees will impact positively or negatively on instream ecology.

- Negative effects: replacing trees with too many large exotic deciduous trees will add too much leaf-litter to the stream – causing water quality issues and stagnating water
- Positive effects: a greater number of large native trees (instead of exotic deciduous) to provide shading and lower level of leaf-litter input. A far more ecologically sustainable option in the long-term.

Wouldl need to make sure that the riffle at Archilles Ave is protected during the channel and banks works in this area. Key aspect will be to retain the gradient that exists in this section.

Will be greater environmental disturbance during the construction phase (due to the nature of the works) but the long-term benefits far out-weigh the short-term construction risks (especially with adequate measures during construction to mitigate construction effects).

Lack of sediment removal in those sections that aren't being widened (and thus enhanced) that could potentially smother improved sections immediately downstream with migration of sediment particles. This would depend on depth of fine sediment in those sections and near-bed water velocity during flood flow conditions.

All options include a flood bypass structure, thus all options have the same risk that any bypass structure could provide suitable habitat for mosquito breeding if there are areas of isolated ponded water that remain in the structure for prolonged periods after flood flows have receded. This is therefore not accounted for this in the scoring (as it is an equal effect across all route options).

Option B - short (piped through red zone)

SCORE (out of 100)	45	Scoring criteria	» LOW score: Negative change (environmental impact) compared to existing condition » HIGH score: Positive change (enhancement) compared to existing condition

Pros

There are no long-term positive ecological changes for instream ecology of Dudley Creek, as the diversion is fully piped and thus does not interact with the stream itself.

However, there is also no significant negative changes (i.e., this option also doesn't greatly reduce the existing ecological condition of the stream). Thus on the whole this option doesn't improve or greatly degrade the existing condition.

Cons

There is no opportunity for ecological enhancement of Dudley Creek as the works are all piped and thus away from the stream channel (i.e., there is 0 m of channel that can be enhanced). Given the existing poor ecological condition of the stream (especially in relation to instream habitat and aquatic invertebrates), the inability to improve ecological condition is a significant disadvantage for this criteria.

There will be some short-term construction effects on instream ecology due to limited works associated with the stream channel itself (i.e., work limited to the intake/outlet structures and the piping under the stream channel to cross at North Parade) and any discharges that may occur during construction of the pipe. While these will not be as significant as for Route A or C, there also won't be any long-term ecological improvements to mitigate any short-term impacts, which could be seen as a potential disadvantage.

Does not provide any opportunity to at least return the stream to pre-earthquake condition, which would at least require the removal of liquefaction sand (which has been shown to have had a detrimental effect on stream biota).

Doesn't reflect the CCC '6 values' (which includes ecology) approach to waterways, and generally goes against the approach to waterway management as specified in the Waterways, Wetlands, and Drainage Guide.

Doubts/Risks and opportunities

Opportunities

Within the project scope there are no opportunities for instream ecology with this option.

Risks

All options include a flood bypass structure, thus all options have the same risk that any bypass structure could provide suitable habitat for mosquito breeding if there are areas of isolated ponded water that remain in the structure for prolonged periods after flood flows have receded.

The potential for fish to move up into the partially submerged pipe and thus be lost to the fish stock (likely to be limited to eels). Unsure how much of a risk this will be until the detailed design phase (including confirmation of the height of the pipe in relation to water level during low and high tide, what type of structure will be on the pipe outlet etc).

Unsure what risk there is of creating a subterranean mosquito-breeding habitat due to the pipe being permanently fill of water for a portion of its length. This will ultimately depend on

- Access to the wetted pipe habitat from the surface (if no direct access from manholes etc then it may not be an issue)
- Whether the water is continually flowing or is stagnant water (the latter is better for mosquito larvae)
- The amount of organic matter (i.e., leaf-litter) that may sit in the water in the pipe and rot (creating food for larvae)
- Access into the pipe by fish such as eels (that may predate on the mosquito larvae)

Option B - long (piped around red zone)

SCORE (out of 100)	45	Scoring criteria	» LOW score: Negative change (environmental impact) compared to existing condition » HIGH score: Positive change (enhancement) compared to existing condition

There is little difference from this option compared to Route B –Short in terms of instream ecology, as the pipe exists Dudley Creek, crosses under Dudley Creek, and enters the Avon River at the same locations. Thus refer to 'Route B – Short' above for details.

Option C (widening along Stapletons Road, piped down Medway St)

SCORE (out of 100)	75	Scoring criteria	» LOW score: Negative change (environmental impact) compared to existing condition » HIGH score: Positive change (enhancement) compared to existing condition

Pros

The instream condition (instream habitat, aquatic invertebrates, fish) along Banks Ave is currently in poor condition – with the exception of some good adult longfin eel habitat downstream of Stapletons Road. There is thus great potential (in the MEDIUM – LONG TERM) to vastly improve instream ecology with the right design of the instream and riparian environment. Scoring has therefore been based on the fact that we can achieve:

- Narrow the low flow channel and create good fish habitat along the newly created channel edge
- Good riparian planting of trees, shrubs and bankside/freshplain cover (native and not so small that it is overtopped with weeds, with good overhang of the water)
- Remove fine (and contaminated) sediment and replace with clean gravels
- Add rocks, and where possible, logs to the low flow channel
- Ensure sufficient use of (suitable) trees to continue to shade the stream (to keep macrophyte growth down) while keeping autumn leaf-litter inputs (from large exotic deciduous trees) to a minimum.

There are fewer native trees on the public (true-left) side of the channel (compared to Route A), so channel widening will provide an opportunity to introduce more native tree species (which is far better for instream and riparian ecological values).

Approximately 280 m of stream will undergo undergo bank/channel works and thus enhancement, which is roughly 65% of the Stapletons Rd section. This is approximately half the distance of stream that would undergo enhancement under Route A – so provides the second-best long-term ecological improvement.

Cons

Loss of channel shading in the short-term until replacement trees become established – although this may not be that much of an issue given the North to South aspect of the channel (thus the existing trees on the west bank and retained large trees at the top/north end of the channel will retain some shading potential. That, combined with the existing high bank and additional lower overhanging planting may be sufficient shading until the replacement trees become established.

The length of channel that will be reworked for flood remediation (and thus provide the opportunity for ecological improvement of instream habitat) is roughly half that of the Route A option, thus there is less habitat that will be improved and thus less ecological improvement overall.

As this section of stream is several kilometres upstream of the confluence with the Avon River, the level of connectivity of the improved stream sections to the Avon River is less than compared to Route A.

Doubts/Risks and opportunities

Opportunity

Great opportunity to improve instream ecology with the right design of instream and terrestrial environment (by following the design criteria listed above in ‘Pros’).

Will possibly enable the removal of plant pest species (male/female ferns, ivy, *Tradescantia*, old mans beard, etc) – although many of these are on private land and so may not be touched.

Provide the opportunity for greater representation of native plants and trees along the true-left bank (currently the majority of native trees are on private land on the true-right with few native trees on the true-left side).

Risks

The devil is in the detail…..The same risks identified in Route A are relevant here.

E2 – Landscape and Terrestrial Ecology

Route A

Pros

- Enhanced Warden St streetscape values through replacement street tree planting
- Enhanced landscape and terrestrial ecology values along approximately 800LM of Banks Ave including:
  - Improved public accessibility along and to the waters edge from time of project completion
  - Minimal disturbance of private landscape values on true right bank
  - Retention of the majority of trees with long term life expectancy
  - The removal, and replacement, of 50 trees (41% of total tree removals) with short term life expectancy
  - Retention of existing landscape character elements including high canopy trees, maintained lawn, and a diverse range of underplanting
  - Retention of existing native tree clusters as habitat and food source for resident birds/insects
  - Improved riparian and terrestrial ecological values in the medium to long term through native planting
  - Improved habitat values for bird and insect life in the short to medium term
  - Improved bird and insect habitat diversity in the short to medium term
  - Improved native plant and animal diversity in the short to medium term
  - Enhanced landscape character in the medium to long term by improved long term health and sustainability of tree stock through the removal &/or potential removal of trees with short-medium term life expectancy
  - Reduced impact of leaf litter on water health, increased shade, and reduced water temperature in the short to medium term through increased use of native evergreen tree species along Creek edge.

Cons

- Short term negative visual and ecological impacts of the removal of 122 tree and shrub groups along the route – 43% of the 284 surveyed
- Short term loss of some landscape character and habitat values along Banks Ave through tree and shrub removal
- No enhancement or improvements to landscape or terrestrial ecological values along Stapletons Road section of Dudley Creek or along the Creek between Stapletons Rd and North Parade.

Doubts/risks and opportunities

- Risk to overall landscape and ecological values that improvements will only take place in the 7 areas along Banks Ave identified for bank modification, so minimising the potential opportunities for improved accessibility, habitat diversity, habitat connectivity, and the long term sustainability of the existing landscape character along the Banks Ave, Stapletons Road, and Stapletons Rd to North Parade downstream lengths of Dudley Creek.

Score

- 85/100

Route B - short

Pros

- Enhanced Warden St streetscape values through replacement street tree planting

Cons

- Short term negative visual and ecological impacts of the removal of 44 tree and shrub groups along the route – 60% of the 74 trees surveyed to be removed during construction
- Short term loss of some landscape character and habitat values in Shirley Intermediate, Marian College, Richmond Park and the Residential Red Zone through tree and shrub removal
- No proposed bank works and therefore no improvement to landscape or terrestrial ecological values along any section of Dudley Creek

Doubts/risks and opportunities

- Risk to overall landscape and ecological values along the entire length of the downstream area of Dudley Creek because flood mitigation improvements will only take place with piping, so risking opportunities for improved accessibility, habitat diversity, habitat connectivity, and the long term sustainability of the existing river bank character and values. Lack of any significant response to 6-values approach.

Score

- 40/100

Route B - long

Pros

- Enhanced Warden St streetscape values through replacement street tree planting

Cons

- Short term negative visual and ecological impacts of the removal of 44 tree and shrub groups along the route – 60% of the 74 trees surveyed to be removed during construction
- Short term loss of some landscape character and habitat values in Shirley Intermediate, Marian College, Richmond Park and the Residential Red Zone through tree and shrub removal
- No proposed bank works and therefore no improvement to landscape or terrestrial ecological values along any section of Dudley Creek.

Doubts/risks and opportunities

- Risk to overall landscape and ecological values along the entire length of the downstream area of Dudley Creek because flood mitigation improvements will only take place with piping, so risking opportunities for improved accessibility, habitat diversity, habitat connectivity, and the long term sustainability of the existing river bank character and values. Lack of any significant response to 6-values approach.

Score

- 40/100

Route C

Pros

- Enhanced Randall and Me
- dway St streetscape values through replacement street tree planting
- Enhanced landscape and terrestrial ecology values along approximately 500LM of Stapletons Road including:
  - Improved public accessibility along and to the waters edge from time of project completion
  - Minimal disturbance of private landscape values on true right bank
  - Retention of the majority of trees with long term life expectancy
  - The removal, and replacement, of 28 trees (40% of total tree removals) with short term life expectancy
  - Retention of existing landscape character elements including high canopy trees, maintained lawn, and a diverse range of underplanting
  - Improved riparian and terrestrial ecological values in the medium to long term through native planting
  - Improved habitat values for bird and insect life in the medium to long term
  - Improved bird and insect habitat diversity
  - Improved native plant and animal diversity
  - Enhanced landscape character by improved long term health and sustainability of tree stock through the removal &/or potential removal of trees with short- medium term life expectancy
  - Reduced impact of leaf litter on water health, increased shade, and reduced water temperature in the short to medium term through increased use of native evergreen tree species along Creek edge.

Cons

- Short term negative visual and ecological impacts of the removal of 70 tree and shrub groups along the route – 62% of the 112 surveyed
- Short term loss of some landscape character and habitat values along Banks Ave through tree and shrub removal
- No enhancement or improvements to landscape or terrestrial ecological values along Banks Ave section of Dudley Creek or along the Creek between Stapletons Rd and North Parade.

Doubts/risks and opportunities

- Risk to overall landscape and ecological values that improvements will only take place in the 2 areas along Stapletons Road identified for bank modification, so minimising the potential opportunities for improved accessibility, habitat diversity, habitat connectivity, and the long term sustainability of the existing landscape character along the balance of Stapletons Road, Banks Ave and the Stapletons Rd to North Parade downstream lengths of Dudley Creek.

Score

- 75/100

E3 – Culture and Heritage

This assessment is made by the Lead Planner for this project who has a good overview of likely impacts and environmental considerations of the options. As the Lead Planner is neither a heritage nor cultural expert, the following is a high level assessment based on available information including a preliminary Archaeological Scoping Report and the Mahaanui Iwi Management Plan, 2013. It also reflects on outcomes that might be addressed by either criteria including landscape and instream ecology.

Based on the definition of 'Heritage & Culture', the following main elements are assessed:

- Natural Significance / Community Values, which are considered to be closely interlinked
- Historical / Archaeological Significance, to reflect the European heritage
- Cultural / Archaeological Significance, to reflect the Maori heritage
- Ngai Tahu Values.

To assist with the assessment for Ngai Tahu Values, a representative of Tuahiwi Runanga was invited to the MCA workshop but was unable to attend. Therefore, guidance has been taken from the Mahaanui Iwi Management Plan, 2013, consistent with the submission of Mahaanui Kurataiao (MKT). The definition to determine the scoring of the environmental criteria was defined as 'the degree of change compared to the existing environment'. Therefore, the determination is whether there is a change and the extent of the change between the options. It does not determine the degree of change to which the options address MKT values and concerns, nor the change against hypothetical options not included within the project scope.

The overaching key themes of the Mahaanui Iwi Management Plan have been used in consideration of the changes each of the options achieve. The key values relevant to this project are:

- Restoration of indigenous biodiversity (including riparian vegetation)
- Addressing climate change
- Access to Mahinga Kai
- Impacts on water quality
- Re-naturalisation of waterways (modification for flood control)
- Unnatural mixing of water.

Option	Pros	Cons	Doubts/risks and opportunities	Score 0 - 100
Route A	• Enhanced landscape values with works targeting those areas where existing tree health is most compromised. • Improved ecological habitat and health of the waterway by avoiding stagnant water. • Enhanced native riparian vegetation and native ecological values with improved fish habitat and waterway health. • While there would be an immediate impact on existing amenity values from initial tree loss, unhealthy species will be targeted and replanting will improve the overall appearance and amenity value over time. • Improved recreational value of the waterway by providing safe access points and paths where feasible, thereby increasing the potential use of the waterway by the community. • Improved public access to the waterway would potentially increase the value the community places on the resource. • Preliminary assessments of potential archaeological risk show two recorded archaeological sites on the banks of Dudley Creek along Banks Avenue. However, no works are proposed for these sites and therefore, should not be affected.	• A construction period is necessary to achieve the works, creating short term impacts on the community. • During construction, amenity, landscape and ecological values will be low. • There will be limited public access to the waterway during construction. • Upon completion of construction, a period of establishment and growth of the revegetated riparian margin may take several years to be realised, although the opportunities for instream values should be more immediate.	• A midden site is recorded at 409 River Road. Whilst the site has been largely destroyed, it's presence is indicative of a wider pattern of pre-European Maori activity along the banks of Dudley Creek. There, there is potential for nearby unknown archaeological sites which may be disturbed by the works. However, these can be addressed at the very least through an Accidental Discovery Protocol, or if not, an Archaeological Authority.	85

Option	Pros	Cons	Doubts/risks and opportunities	Score 0 - 100
B – short	• There are no recorded archaeological sites at either the inlet/diversion or outlet/discharge points.	• While works within the waterway are limited to the inlet/diversion and outlet/discharge points of the bypass, there will still be short term construction impacts. • There is extremely limited opportunity to provide for any natural, heritage or cultural values along any stretches of Dudley Creek. The change compared to the existing environment is considered to be negative.	• A midden site is recorded at 409 River Road. Whilst the site has been largely destroyed, it's presence is indicative of a wider pattern of pre-European Maori activity along the banks of Dudley Creek. There, there is potential for nearby unknown archaeological sites which may be disturbed by the works. However, these can be addressed at the very least through an Accidental Discovery Protocol, or if not, an Archaeological Authority. • Lost opportunity to provide for cultural values through improved ecological and biodiversity opportunities, and creating additional environmental value for the community.	40
B – long	• Works within the waterway are limited to the inlet/diversion and outlet/discharge points of the bypass. Therefore construction impacts on the waterway and on the community are limited. • There are no recorded archaeological sites at either the inlet/diversion or outlet/discharge points.	• While works within the waterway are limited to the inlet/diversion and outlet/discharge points of the bypass, there will still be short term construction impacts. • There is extremely limited opportunity to provide for any natural, heritage or cultural values along any stretches of Dudley Creek. The change compared to the existing environment is considered to be negative.	• A midden site is recorded at 409 River Road. Whilst the site has been largely destroyed, it's presence is indicative of a wider pattern of pre-European Maori activity along the banks of Dudley Creek. There, there is potential for nearby unknown archaeological sites which may be disturbed by the works. However, these can be addressed at the very least through an Accidental Discovery Protocol, or if not, an Archaeological Authority. • Lost opportunity to provide for cultural values through improved ecological and biodiversity opportunities, and creating additional environmental value for the community.	40

Option	Pros	Cons	Doubts/risks and opportunities	Score 0 - 100
Route C	• Enhanced landscape values with works targeting those areas where existing tree health is most compromised. • Improved ecological habitat and health of the waterway by avoiding stagnant water. • Enhanced native riparian vegetation and native ecological values with improved fish habitat and waterway health. • While there would be an immediate impact on existing amenity values from initial tree loss, unhealthy species will be targeted and replanting will improve the overall appearance and amenity value over time. • Improved recreational value of the waterway by providing safe access points and paths where feasible, thereby increasing the potential use of the waterway by the community. • Improved public access to the waterway would potentially increase the value the community places on the resource. • Preliminary assessments of potential archaeological risk show two recorded archaeological sites on the banks of Dudley Creek along Banks Avenue. However, no works are proposed for these sites and therefore, should not be affected.	• A construction period is necessary to achieve the works, creating short term impacts on the community. • During construction, amenity, landscape and ecological values will be low. • There will be limited public access to the waterway during construction. • Upon completion of construction, a period of establishment and growth of the revegetated riparian margin may take several years to be realised, although the opportunities for instream values should be more immediate.	• A midden site is recorded at 409 River Road. Whilst the site has been largely destroyed, its presence is indicative of a wider pattern of pre-European Maori activity along the banks of Dudley Creek. There, there is potential for nearby unknown archaeological sites which may be disturbed by the works. However, these can be addressed at the very least through an Accidental Discovery Protocol, or if not, an Archaeological Authority.	65

E4 – Community Impacts

Option A

PROS

- Water enters the Avon River upstream of properties
- Makes best use of existing waterway and opportunity for enhancement
- Less risk of damage to manmade structures from lateral spread

CONS

- Disproportionate amount of information in the consultation document led to the perception that Council preferred Option A
- Up until now there has been no direct impact of flooding on these residents
- The stream is in a prominent location for the stream boundary properties (ie at the entrance to residences).
- Mature and existing vegetation (both public and private) contribute to the overall street scape of Banks Avenue that is recognised by the wider community
- Totally opposed to any form of tree removal
- Concerns raised by MOE regarding crossing SBHS land

Option B

PROS

- No impact on residential property
- Pipe under the ground is invisible once the work has taken place
- Submission numbers indicate option B as the most preferred option
- Not putting another community at a risk of flooding
- Seen as less impact on the community
- Seen as the most direct route
- Seen as the "tidiest" option
- Cheaper maintenance than an open drain
- No tree removal

CONS

- Community does not identify that the use of RRZ could be an issue
- Residents closer to the Avon River consider they will become more flood prone because of where the discharge of the water into the Avon will be
- One of the affected landowners supports an alternative option
- No firm support from all affected land owners

Option C

PROS

- Proposed tree removal not a major concern
- Flood risk reduction for stream side properties
- Location of the creek is less prominent for affected properties, typically located in their back yard
- A number of properties either just been rebuilt or just about to be rebuilt so in a position to talk about landscaping/bank work opportunities on private property

- Able to retain existing high value trees
- Recognition that the works will create an enhanced street and stream environment
- Initial support for ongoing negotiations from major landowner
- Ongoing communication with affected residents is crucial
- Considered the most economic
- Positive meetings held with directly affected residents
- Opportunity to enhance the water environment
- Does not need agreement to cross RRZ

CONS

- Private property works, but this may vary depending on the final alignment
- No secured/definite private property agreements
- Considerable concern that at the point where the bypass starts in Petrie Street that this could create an increased flood risk for those immediate residents if modelling data and assumptions are incorrect
- Number of properties at different stages of EQC/Insurance stages
- Submitter numbers are less than Option B (not considerably)

SCORES

Note: the 0 to 100 scale is:
- low degree of impact (more positive effects) = higher score
- high degree of impact (more negative effects) = lower score

Criteria	OPTION			
	A	B -short	B - long	C
E4 – Community Impact	25	70	70	60

E5 – Construction Effects

This has been considered in terms of the impact on residents, road users and stakeholders such as the schools and users of the parks.

Option A:

On road work requiring significant traffic management and disruption: 50m North Parade (busy), 350m Warden Street (quiet)

Channel works requiring some disturbance: 400m

Bridges: 9

Special stakeholders: MOE – submission notes the effect of noise (working periods limited) and need to limit disruption to sports

Summary: Schools work and Banks Ave bridges in particular are disruptive:

Score: 50/100

Option B:

On road requiring significant traffic management and disruption: 100m North Parade (very busy), 350m Warden Street (quiet), 200m Medway Street (quiet)

Through park: 350m

Special stakeholders:

- MOE – submission notes the effect of noise (working periods limited) and need to limit disruption to sports
- Richmond Park – loss of use for a season

Summary: Schools work in particular is disruptive & while there is more road work there is less work on bridges (the latter being quite disruptive to people's daily lives)

Score: 40/100

Option C:

On road requiring major TTM and disruption: 50m North Parade (busy), 700m Petrie, Randall, Medway (quiet)

Channel works requiring some disturbance: 400m

Bridges: 2

Special stakeholders: None

Summary: No direct impact on school, but higher on residents.

Score: 50/100.

S1 –Long term hydraulic sustainability

Note: the 0 to 100 scale for long term adaptability is:

- a greater ability to adapt the option = higher score
- less ability to adapt the option = lower score

General comments: Criteria interpreted as long term hydraulic sustainability including ability of option to respond to upgrades/changes in the upstream catchment/s increasing inflows and climate change (two aspects: increased rainfall and sea level rise). All options are currently designed for the same upstream inflows.

<table>
<tr><th>Option</th><th>Pros</th><th>Cons</th><th>Doubts/risks and opportunities</th><th>Score
0 - 100</th></tr>
<tr><td>Route A</td><td>▪ Could do widening along Stapletons later
▪ With increases in flows, open channel section provides additional conveyance capacity with increased water level</td><td>▪ Difficult to achieve further widening along Banks Ave
▪ Will need downstream pumping to deal with sea level rise</td><td rowspan="4">▪ Asset life of system is 100 years
▪ Need to consider long term system and options for what can be incorporated now and later (to delay capital expenditure)
▪ Timeframe for sea level rise and increased rainfall intensities is uncertain, but guidelines recommend 1m sea level rise and 16% additional rainfall.
▪ Upstream upgrades yet to be decided through LDRP projects and other future decision.</td><td>60</td></tr>
<tr><td>B – short</td><td>▪ Could do widening along Dudley Creek (incl Stapletons Road and Banks Ave) later</td><td>▪ With increases in flows, pipeline provides less additional conveyance capacity with increased water level than open channel
▪ Will need downstream pumping on both pipeline and Dudley Creek to deal with sea level rise
▪ In & out of Dudley Creek option would require two pump stations rather than one</td><td>50</td></tr>
<tr><td>B – long</td><td>▪ Same as B - short</td><td>▪ Same as B - short</td><td>50</td></tr>
<tr><td>Route C</td><td>▪ With increases in flows, open channel section provides additional conveyance capacity with increased water level
▪ Could do widening along Banks Ave later</td><td>▪ Will need downstream pumping on both pipeline and Dudley Creek to deal with sea level rise</td><td>60</td></tr>
</table>

R1 – Legal Risk

R2 – Timeframe Risk

Risk and timeframes are linked, so both are considered together, but scored separately. Risks and timeframes as defined in the MCA document require consideration of agreements required, consultation submissions (ie stakeholders views), and special issues associated with an option. Consenting risk is not considered specifically, on the basis that the risk should be relatively low through the OIC consent process.

Timeframe risk has been considered from a starting point that all options are buildable in the project timeframe, provided the construction start is not delayed. The main risk to achieving the timeframes would therefore be things that might prevent construction starting.

Option A

Property & agreements required:

- HNZ – purchase house on Warden St
- MOE – lay pipe across Shirley Intermediate School
- Owners of nine bridges requiring replacement (multiple owners each bridge)

Submissions:

- HNZ – none received, but understood to be low risk
- MOE – submitted in favour of C – on the basis of least disruption to schooling and no impact on land development potential
- Numerous resident's submissions – in general a strong feeling of opposition
- Community Board – in opposition

Special issues that could give rise to challenge:

- Banks Ave perceived amenity loss in light of there being other options
- Perceived issues with lower Dudley capacity and increased flood risk

R1 Legal Score: 40/100 - based on the apparent organised opposition of the affected community.

R2 Time Score: 20/100 - high risk of starting work without bridge agreements, as bridges are at the lower end of the scheme and agreement to replace is required to deliver scheme benefits. Time taken to reach agreements could easily delay the whole scheme.

Option B

Property / Agreements:

- HNZ – purchase house on Warden St
- MOE – lay pipe across Shirley Intermediate School
- Catholic Diocese – lay pipe across Marian College

Submissions:

- HNZ – none received, but understood to be low risk
- MOE – submitted in favour of C – on the basis of least disruption to schooling and no impact on land development potential

- About 50 resident's submissions – general lack of opposition
- Community Board – neutral

Special issues that could give rise to challenge:

- Perceived effect of discharge on Avon River levels, and general flood risk

R1 Legal Score: Challenge less likely given the low level of apparent opposition. **70/100**

R2 Time Score: Agreements with MOE and the Catholic Diocese remain a risk in term of timeframe. Work could not start without those agreements**. 50/100**

Option C

Property / Agreements:

- Land owners on Stapletons Road – minor effect on land (about 12 owners)
- Anglican Living – owners of Churchill Courts site
- Land owners between Stapletons and Petrie Street – significant effect (2-3 owners)

Submissions:

- About 40 resident's submissions – ranging from general support to concern about specific issues (eg landscape, disruption, migration of flooding to them)
- Anglican Living – support and willingness to discuss work on their land
- Community Board – neutral

Special issues that could give rise to challenge:

- Perceived effect of discharge on Avon River levels, and general flood risk
- Perceived flood migration to Stapletons Road

R1 Legal Score: Challenge would appear unlikely given the low level of apparent opposition. **60/100**

R2 Time Score: Moderate risk associated with property agreements, particularly between Stapletons and Petrie St where the impact of the scheme is higher. This risk is somewhat mitigated by a possible 'fall back' position involving running the bypass pipe along Stapletons rather than Petrie Street (but at an extra cost): **40/100**

R3 – Red Zone Land

Note: the 0 to 100 scale for risk is:

- risk is easily managed = higher score
- the degree of risk is high and hard to manage = lower score

Option	Pros	Cons	Doubts/risks and opportunities	Score 0 - 100
Route A	Benefit to crown as RRZ flooding risk (from Dudley Creek) will be reduced through construction of stopbank on the right bank and through upgrade of the River Rd culvert.	CERA approval required for around 4,000m² of land along the side of Dudley Creek to be acquired for bank widening into RRZ.	Uncertainty over CERA's ability to provide this approval within the timeframes of this project.	50
B – short		This option cuts across RRZ, potentially limiting the Crown's ability to develop this land. Impact on RRZ significantly higher than for Option A.	Uncertainty over CERA's ability to provide this approval within the timeframes of this project.	10
B – long	N/A – no impact on RRZ	N/A – no impact on RRZ		100
Route C	N/A – no impact on RRZ	N/A – no impact on RRZ		100

Appendix 2 – Pumped vs Gravity Assessment

Overview

Appendix 2 presents an evaluation of pumped vs gravity conveyance for downstream options being considered for the Dudley Creek Flood Remediation Project.

Pumped conveyance involves pumping flows along the bypass corridor through a pressure pipeline. Gravity conveyance relies on the hydraulic grade available between the inlet and outlet of the bypass to convey flows by gravity through a larger gravity pipeline.

The evaluation was undertaken using a subset of criteria used for evaluating the downstream corridors. Relevant Criteria are presented in Section 2 of this memo. The evaluation was undertaken at a workshop on 15 July 2015 that involved the following participants:

- CCC Staff - Land Drainage Manager, Senior Surface Water Planner, Land Drainage Recovery Programme Manager – Technical, Dudley Creek Project Manager
- Project Team staff - Downstream Design Manager, Upstream Design Manager, Team Leader, Hydraulic Design, Hydraulic Design Lead

Relevant Criteria

The following criteria from the main corridor selection MCA were considered relevant to the evaluation of pumped vs gravity conveyance:

D1 – Vulnerability

D2 – Hydraulic performance / opportunity

C1 – Whole of life cost

E4 – Community impact (social)

E5 – Construction

S1 – Long term hydraulic sustainability

The following sections provide further detail on these criteria:

Flood Hazard Reduction

	Outcome	Criteria	Definition	Measurement
FLOOD REDUCTION	The degree to which the project provides mitigation of the flood risk	D1 – Vulnerability	Reliability of the option including any residual flood risk - design	The degree of robustness of the option and consequence of failure during a flood event
		D2 – Hydraulic performance / opportunity	Flood risk reduction over and above the primary objective of flood risk reduction in the Flockton St area	Ability of the option to reduce flood risk in other areas

Cost

	Outcome	Criteria	Definition	Measurement
COST	The capital and ongoing costs of the project	C1 – Whole of life cost	Whole of life costs including operation, maintenance and renewals, earthquake related costs and risks	Whole of life cost estimate

Environment

	Outcome	Criteria	Definition	Measurement
ENVIRONMENT	The health and wellbeing of the community has been considered	E4 – Community impact (social)	The option provides for peoples wellbeing and sense of community Note this includes recreation	Qualitative assessment of impact – quality of life, community cohesion, recreations, health & wellbeing. There was no specific question in the MCA over pumped vs gravity. This was assessed based on experience of the Tay St Drain PS and other infrastructure projects in ChCh.
	Temporary effects from construction are managed	E5 – Construction	Effects of constructing the option including the natural environment, traffic, pedestrians, noise, disruption to public and services, health and safety risks, damage to other assets, access to private property.	The degree of adverse effect from construction activities

Long Term Hydraulic Sustainability

	Outcome	Criteria	Definition	Measurement
LONG TERM SUSTAINBILITY	The project is considered sustainable in the long term	S1 - Long term hydraulic sustainability	Ability to future proof the solution for climate change, to meet demands for increased levels of service and to cope with over design event (> 50 yr ARI) flows	Qualitative assessment of the ability of the option to adapt to meet changing hydraulic needs

Scoring

Scoring System

The same scoring system as used for the corridor MCA has been used for evaluating pumped vs gravity.

The scoring system is:
All scoring of the Options against the Criteria are to be scored on a 0 to 100 scale.
Where 0 = very low or a real or hypothetical least preferred option (worst outcome / completely fails the criteria, strong negative effects)
25 = low
50 = moderately meets the criteria (adequate, neutral)
75= high
100 = very high or a real or hypothetical most preferred option (best outcome / completely meets the criteria such that it is an ideal level of performance, strong positive effects)
Scoring should be in units of no less than 5.

Scores

Table A2.1 presents the raw scores agreed on at the workshop. Justification for raw scores is provided.

Table A2.2 presents the analysis of MCA scores using raw MCA scores from the workshop and the relative weightings agreed at the MCA corridor workshop on 14 July 2015. As we are considering a subset of the overall weightings, the weighting percentages have been scaled so that they sum to 100%.

The weightings and raw MCA scores have been used to calculate a final score for each criteria and option. These have been summed to provide a total score for pumped and gravity conveyance for each corridor option.

Recommendation

The MCA process for evaluating pumped vs gravity conveyance has identified that gravity conveyance is preferred for all downstream corridor options. Gravity conveyance is therefore recommended.

Table A2.1 Raw MCA Scores and Justification

	Pumped Conveyance			Gravity Conveyance			Justification
Option	A	B (long)	C	A	B (long)	C	
D1 – Vulnerability							
Outlet	*60*	*60*	*60*	*60*	*50*	*50*	Gravity outlet adequate. Pump outlet marginally better at self flushing.
Inlet	*45*	*45*	*45*	*50*	*50*	*50*	More potential for pumped inlet blockage due to pump start/stop operation
Pipeline	*60*	*60*	*60*	*55*	*50*	*50*	Pumped line less reliant on maintenance. Gravity for A less vulnerable that B or C
Siphon (if any)	-	*35*	-	-	*25*	-	Applies to B only. Pumped siphon less vulnerable than gravity.
Pump Station	*40*	*40*	*40*	-	-	-	Applies to pumped options only. Gravity lines do not rely on pump station.
Agreed overall score	40	40	40	50	45	50	On balance, gravity conveyance has been assessed as being less vulnerable than pumped conveyance due to pumped's reliance on a pump station. Note that the overall score is not a weighted average of the different sores as the importance of different components varies.
D2 – Hydraulic performance	55	55	55	50	50	50	Potential for pump to draw water level down lower in creek during smaller events, resulting in slightly less flood risk during smaller events
C1 – Whole of life cost	45	25	55	65	45	65	Raw MCA scores from Whole of Life Analysis. Refer separate Whole of Life memo (doc ref 10923376)
E4 – Community impact	40	40	40	50	50	50	On-going disruption associated with operating and maintaining pump station and generator in residential environment
E5 – Construction	40	40	40	50	50	50	Pumped and gravity pipeline construction effects considered equal. Greater disruption associated with construction of a pump station
S1 – Long term hydraulic sustainability	50	50	50	55	55	55	Gravity lines cope with greater than design event flows better than pumped lines. Gravity lines can be pumped in the future to meet increased flows whereas pumped lines are limited by flow velocity and headloss within smaller diameter pipelines. The key point is ensuring that gravity pipelines are selected so that they can be used as pressure lines in the future.

Table A2.2 Analysis of MCA Scores

Option	Adjusted Weightings from MCA	Pumped Conveyance						Gravity Conveyance					
		A		B		C		A		B		C	
		Raw	Final	Raw	Final	Raw	Final	Raw	Final	Raw	Final	Raw	Final
D1 – Vulnerability													
Outlet		*60*		*60*		*60*		*60*		*50*		*50*	
Inlet		*45*		*45*		*45*		*50*		*50*		*50*	
Pipeline		*60*		*60*		*60*		*55*		*50*		*50*	
Siphon (if any)		-		*35*		-		-		*25*		-	
Pump Station		*40*		*40*		*40*		-		-		-	
Overall score	30%	40	12	40	12	40	12	50	15	45	13	50	15
D2 – Hydraulic performance	18%	55	10	55	10	55	10	50	9	50	9	50	9
C1 – Whole of life cost	11%	45	5	25	3	55	6	65	7	45	5	65	7
E4 – Community impact	11%	40	4	40	4	40	4	50	6	50	6	50	6
E5 – Construction	4%	40	1	40	1	40	1	50	2	50	2	50	2
S1 – Long term hydraulic sustainability	26%	50	13	50	13	50	14	55	14	55	14	55	14
Total	100%		**46**		**44**		**47**		**53**		**49**		**53**