REPORT

Greater Wellington Regional Council

Wairarapa Water Use Project
Prefeasibility Phase - Engineering Report

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Greater Wellington Regional Council

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Sect 6- 8	27/3/15	Ver 5	Draft for peer review of water availability, water demand and hydrology aspects.	DMK/DCL
Sect 1-9	4/5/15	Ver 6	Draft for peer review of engineering arrangements of storages, headworks and distribution.	DMK/DAF/DAB
Sect 10-13	7/5/15	Ver 7	Draft for peer review of engineering arrangements of storages, headworks and distribution.	DMK/DAF/DAB
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Glossary

Abbreviations

BBO	Bloxam, Burnett and Olliver Limited
BCM	Bond Construction Management Limited
CAPEX	Capital expenditures, incurred when money is spent either to buy fixed assets or add to the value of an existing fixed asset with a useful life extending beyond the taxable year, typically physical assets such as property, buildings or equipment.
CFRD	Concrete Faced Rockfill Dam, a dam type
DEM	Digital Elevation Model
FCD	Fixed Cone Discharge, a type of valve used for free discharge energy dissipating applications to perform regulating or control functions under full pressure, high flow conditions. Designed to provide controlled discharge of water while protecting the downstream environment. The valve breaks up the water into a large, hollow, expanding spray. Often, a stationary hood is used to concentrate the discharge spray into a more controlled flow stream.
FRP	Fibre Reinforced Plastic, refer also GRP below.
GG	Governance Group for the Wairarapa Water Use Project
GIS	Geographic Information System
GNS	Institute of Geological and Nuclear Sciences Limited
GRP	Glass-fibre Reinforced Plastic, a material sometimes used in production of pipes
GWRC	Greater Wellington Regional Council
IAF	Ministry for Primary Industries, which manages the Irrigation Acceleration Fund, a fund set aside to support investigation into regional rural water harvesting, storage and distribution infrastructure.
K	Cretaceous-aged soils and rocks
l/s	Litres per second (rate of discharge)
LiDAR	Light Detection And Ranging, a method for collecting topographical data points
LG	Leadership Group for the Wairarapa Water Use Project
m^3/s	Cubic metres per second (rate of discharge)
MALF	Mean Annual Low Flow
MCA	Multi-criteria Analysis, a basis for ranking and comparing schemes
MCE	Maximum Credible Earthquake, the largest earthquake that can be reasonably expected to occur along a recognised fault or within a geographically defined tectonic province
MCM	Million Cubic Metres
MDF	Maximum Design Flood, the largest flood which a dam is designed to endure without an uncontrolled release of water

Mi	Miocene-aged soils and rocks
NB	Nominal Bore
NIWA	National Institute of Water and Atmospheric Research
OBF	Operational Basis Flood, the design flood for which the dam and appurtenant structures must remain operational, with any damage being negligible and readily repairable following the event
OPEX	Operational expenditures required for day-to-day functioning i.e. the ongoing cost for running a product, business or system, typically covering items like wages, utilities, maintenance and repairs. OPEX is incurred in the course of ordinary business as opposed to CAPEX (refer preceding), which creates future benefits beyond the tax year.
P&G	Preliminary and General costs are those expenses incurred before and after the work producing the project deliverables, together with those costs that are non-specific to a particular scheduled deliverable. P&G includes such costs as mobilisation, site establishment, site disestablishment, and site offices
PAW	Profile Available Water reflects the soil's capacity to hold water assessed for the soil profile to a depth of 0.9 metres or to the potential rooting depth (whichever is the lesser)
PCL	Pickens Consulting Ltd
PE	Polyethylene, a material frequently used in production of pipes
PIC	Potential Impact Classification, a system of classifying dams according to the incremental consequences of hypothetical dam failure, so that appropriate dam safety criteria can be applied
PMF	Probable Maximum Flood, the theoretical largest flood resulting from a combination of the most severe meteorological and hydrologic conditions that could conceivably occur in a given area
PN	Pression Nominale (French: Nominal Pressure), which indicates the approximate maximum operational pressure that a pipe can support with water at 20°C in bars i.e. the maximum pressure for a PN6 pipe is 6 bar
PRV	Pressure Reducing Valve
PwC	PricewaterhouseCoopers
QEII	Queen Elizabeth II National Trust open space covenants. A National Trust open space covenant is a legally binding protection agreement, which is registered on the title of the land. It is voluntary but once in place binds the current and all subsequent landowners. Each covenant is unique. It can apply to the whole property or just part of the property. There can be different management areas within a covenant with varying applicable conditions. Conditions can be stringent where rare or vulnerable natural features or habitats are being protected.
RCC	Roller Compacted Concrete
RFP	Regional Freshwater Plan for the Wellington Region, December 1999 (GWRC)
RMA	Resource Management Act
RPS	Regional Policy Statement for the Wellington Region, April 2013 (GWRC)

SAG	Stakeholder Advisory Group for the Wairarapa Water Use Project
SCS	U.S. Department of Agriculture, Soil Conservation Service, now known as the Natural Resources Conservation Service.
SMEC	Snowy Mountains Engineering Corporation
SPASMO	Soil Plant Atmosphere System Model, a physically-based dynamic generic plant growth and nutrient leaching model, used to estimate irrigation requirements and leaching from paddocks
T&T	Tonkin & Taylor Limited
VFD	Variable Frequency Drive, a type of motor controller that drives an electric motor by varying the frequency and voltage supplied to the electric motor
WG	Working Group for the Wairarapa Water Use Project
WRENZ	Water Resources Explorer New Zealand (http://wrenz.niwa.co.nz)
WRIT	Wairarapa Regional Irrigation Trust
WWUP	Wairarapa Water Use Project

Terminology

90th percentile	The value, derived from a statistical analysis, below which 90% of observations may be found e.g. the value that has a 1 in 10 chance of being exceeded
Borrow materials	Materials, usually soil, sand, silt, gravel, rock, or a combination thereof, excavated for use as fill - typically to construct a dam or canal embankment within the context of the current project
Category A groundwater	Groundwater directly connected to surface water and subject to the same allocation limits and minimum flow restrictions as surface water takes
Category B groundwater	Groundwater that has not been classified as either Category A or Category C
Category C groundwater	Groundwater not directly connected to surface water
Command area	The gross area that could be supplied with water by a WWUP scheme
Core allocation	The total amount of water in a catchment that has been authorised for abstraction at any time flow is above the minimum flow but below the 'supplementary flow' threshold (see definition below)
Dead storage	For the purpose of this study, dead storage has been interpreted as the portion of reservoir volume set aside for environmental flushing flows and sedimentation over the operational life of the scheme. In addition to the dead storage allowance for environmental flushing flows, the supply-demand modelling and resulting storage sizes implicitly provide for augmentation to maintain minimum environmental flows in the river during natural low flow periods when the river would otherwise fall

	below the minimum flows set out in the Draft Natural Resources Plan (GWRC September 2014).
Distribution system/network	Conveyance structures located downstream of the reservoir, comprising existing rivers, canals, races and pipework that transfer flow from the reservoirs to the command areas
Evapotranspiration	The sum of the evaporation and plant transpiration to the atmosphere
Flood routing	A technique to predict the changes in rate of discharge as water moves through a reservoir accounting for the reduction in the peak rate of discharge due to temporary storage in the reservoir
Flushing flows	High river flows, usually associated with rainfall, which flush out the river system
Full Supply Level	Water level corresponding to gross storage volume in the reservoir. Water levels will be temporarily higher than Full Supply Level during floods that occur when the reservoir is already full.
Gross storage	Sum of dead and live storage
Harvesting	Transferring water to a storage from a nearby stream/river located in a different catchment. This definition is different from the Regional Policy Statement, which uses harvesting to refer to on-river storage also.
Headworks	Storage reservoir, dam structures required to impound the reservoir, and any intakes, conveyances and pump stations (if required) to 'harvest' water to fill the reservoir
Left/Right (true)	Refers to side of valley or waterway when looking downstream.
Live storage	For the purpose of the current study, live storage has been interpreted as the portion of reservoir volume available for supply to WWUP scheme water users (excludes dead storage)
Net supplied area	The portion of the command area expected to actually be supplied, after accounting for buildings, tracks, hedges etc
Off-river storage	Storage filled primarily by 'harvesting' i.e. transferring water from a nearby stream/river located in a different catchment
On-river storage	Storage filled primarily by 'own catchment infill' i.e. by storing flow from the local catchment of the stream on which the storage is situated
Own catchment infill	Flow available from the local catchment of a stream on which a dam is situated
Refill reliability	Refers to the reliability or frequency with which a reservoir is completely filled. Refill reliability can be expressed as an Average Recurrence Interval or Annual Exceedance Probability of a failure to fill to Full Supply Level. Refill reliability may or may not impact on supply reliability.

Reservoir	A natural or artificial pond or lake used for the storage and regulation of water, used interchangeably with 'storage' within the current report in some contexts
Run-of-river take	Abstraction occurring directly from a river or stream and that has no significant storage component
Scheme	Headworks and associated distribution network to transfer water from storages to a command area
Supplementary allocation	The total amount of water in a catchment (in addition to core allocation) that has been authorised for abstraction at times when flow exceeds the 'supplementary flow' threshold
Supply reliability	Refers to the ability of a scheme to supply water to meet the expected demand. A shortfall could be expressed either in terms of units of discharge or in terms of volume to be supplied over a given period of time, or more complex criteria. Supply reliability can be expressed as an Average Recurrence Interval or Annual Exceedance Probability of a shortfall event.
Uptake	The commitment of water users to use (buy) water from the scheme

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Executive summary

Introduction

The Wairarapa Water Use Project (WWUP) has been established to support planning for regionally integrated multi-purpose water use based on harvesting, storage and distribution of water in the Wairarapa Valley. The WWUP aims to maximise the productive capacity of the Wairarapa Valley through water storage and distribution infrastructure for irrigation and also to meet a range of other environmental and community needs, such as power generation, municipal water supply, recreational, and cultural purposes.

Greater Wellington Regional Council (GWRC) and the Ministry for Primary Industries (IAF) have allocated funding to advance the WWUP. The intention is to progress through a series of Phases as follows:

1 Options Identification and Analysis (complete);

2 Options Refinement (complete);

3 Prefeasibility (current); and

4 Feasibility.

The Options Identification and Analysis Report was completed in April 2013 and the Options Refinement Report in August 2013. Tonkin & Taylor (T&T) has been engaged to complete the engineering investigations for the Prefeasibility Phase, which are presented in the current report. The initiation of any subsequent phases has been dependent on the outcome of each preceding phase. No commitment has yet been made by GWRC to proceed beyond the Prefeasibility Phase. Advancement beyond Feasibility to Consent Application, Design and Construction will depend on a range of factors including cost-benefit, potential scheme uptake by water users, stakeholder input, and funding. During Options Refinement, both single-storage schemes and variants of a multi-storage scheme, which provided coverage of medium and high priority areas across the Wairarapa Valley, were considered. Subsequently, Prefeasibility has concentrated on comparing single-storage schemes on their own merit as independent options. Six possible single-storage schemes have been analysed and compared to Prefeasibility level. The work to date has drawn on information and experience derived from previous investigations and similar studies elsewhere in New Zealand.

The regionally integrated approach remains relevant, but providing coverage of priority areas across the Wairarapa Valley by integrating some of the lower-ranking single-storage schemes, or potentially adjusting some of the higher-ranking single-storage schemes (likely adding cost), has been deferred during Prefeasibility until investigations have indicated that one or more of the single-storage schemes appear financially favourable or not financially favourable, recognising that *viability* is not expected to be proven until full Feasibility. The single-storage arrangements developed during Prefeasibility may not represent the most cost-effective arrangements to suit any possible longer term plan comprising multiple storages.

The overarching objective of the Prefeasibility Phase is to provide information that will be used to decide what schemes should be studied during full Feasibility. The findings from the engineering assessment will feed into a broader multi-criteria analysis, led by the WWUP Project Team with inputs from a range of specialists on environmental, social, cultural and financial aspects, as well as from T&T. The information and recommendations presented in this report form one part of the information that the WWUP Project Team and the community will consider in determining whether to proceed with further investigations, and if the decision is made to proceed, determining the scope of further investigations.

Water Use and the Need for Storage in Wairarapa

GWRC has undertaken extensive investigations of the surface and groundwater resources of the Wairarapa Valley and considers that a carefully conceived and executed water scheme could help restore the balance of the Wairarapa's stressed water resources. This conclusion is reflected in GWRC's over-arching environmental policy directive, the Regional Policy Statement, which requires regional plans to promote efficient use of water and promote 'water harvesting'; i.e. taking and storing water when the availability is high and using it when needed, for instance for agricultural production when there is a soil moisture deficit. Through the current Regional Plan review process, GWRC is looking at appropriate ways in which to allocate water and set minimum flows to protect instream ecosystems, while also managing potential land use impacts in an environmentally and economically sustainable way.

The current resource consents to take surface water account for nearly all of the available 'core allocation' from the rivers of the Wairarapa Valley; i.e. the existing run-of-river takes are approaching full allocation of the 'core allocation' in most zones identified in the operative Regional Freshwater Plan. Likewise, there is limited additional groundwater available, especially now that investigations have confirmed that there is strong interconnection between surface water and groundwater in the Wairarapa. Therefore, GWRC has determined that to reliably meet increased water demand in a sustainable manner, water will have to be supplied from storage. As a result, the scheme options presented in this report all incorporate storage, in some cases involving infrastructure to harvest water from an adjacent catchment, in addition to water distribution infrastructure.

Previous Phases of Investigation

A range of organisations has previously undertaken investigations into potential water storage schemes in the Wairarapa prior to GWRC's involvement. These earlier investigations have primarily been driven by water demand in specific areas. GWRC's involvement changed the focus to a broader, valley-wide, holistic and integrated approach. To date, the GWRC funded investigations have included an initial Scoping Study, an Options Identification and Analysis Phase, and an Options Refinement Phase, which considered and built on the previous studies by other organisations.

Key constraints and exclusions were agreed at the beginning of the Options Identification and Analysis Phase, and have been retained for both the Options Refinement Phase and current Prefeasibility Phase. In particular, dam sites in the Tararua Forest Park and on the main stems of the Ruamahanga River, Tauherenikau River, Waiohine River and Waingawa River are excluded from consideration for recreational and environmental reasons principally.

Options Identification and Analysis Phase

During the Options Identification and Analysis Phase, 243 storage options were identified for consideration based on an initial sweep accounting for all possible sites with suitable topography for creating storage greater than 3 MCM[1] and complying with the key exclusions described in the paragraph above. The large number of storage options was progressively and systematically refined to a short-list of nine storage options based on a preliminary understanding of environmental impacts and risks, cost-effectiveness, geology and active faults, impacts on infrastructure and towns, water availability, land tenure constraints, and a range of social, cultural, environmental, financial and opportunity/risk factors.

[1] Million Cubic Metres

Nine scheme options were developed to a concept level suitable for comparison, each comprising one of the short-listed storages and an associated indicative command area. The nine 'single-storage' schemes were assessed on their merit as independent, alternative options. As such, the indicative command area was selected for each scheme on the basis of the area that could be supplied most cost-effectively from the relevant storage site. As the locations of the storages are not evenly distributed around the Wairarapa Valley, the associated indicative command areas tended to overlap, and significant areas of the Valley were not covered.

Options Refinement Phase

The decision to undertake an Options Refinement Phase emerged from the recommendations set out in the Scheme Options Identification and Analysis Report, feedback on that report from GWRC's peer reviewers, Stakeholder Advisory Group (SAG), Leadership Group (LG) and Working Group (WG), and the key findings presented at meetings with the SAG and LG during March 2013.

During the Options Refinement Phase, T&T was tasked with developing a concept for an integrated valley scheme that comprised multiple storages supplying an indicative command area providing coverage of the high and medium priority areas in the Wairarapa Valley study area i.e. a 'multi-storage' scheme rather than 'single-storage' schemes. In addition, two additional storage options in the Tauweru Valley catchment and a smaller version of the Black Creek storage were developed as three independent 'single-storage' schemes to a concept level suitable for comparison with the nine 'single-storage' schemes developed during the previous Options Identification and Analysis Phase. Two of the original nine 'single-storage' scheme options were eliminated as unrealistically expensive compared with the other sites under consideration, resulting in a 'top ten' list of possible storage sites.

The 'top ten' single-storage schemes were compared through a multi-criteria analysis (MCA) accounting for environmental, financial, social, cultural and opportunity/risk criteria. There was relatively little difference in the overall MCA scores between the top ten schemes, especially if only the top nine schemes were considered.

In order to ensure coverage of the medium and high priority areas in the Wairarapa Valley, the study area was divided into zones, and a priority storage and back-up storage was identified for each zone. The priority storages recommended for further investigation were:

- Tividale (Site 10)
- White Rock Road (Site 135)
- Te Mara (Site 197)
- Black Creek (Site 210), including a smaller variant option identified as Wakamoekau (Site 206)
- Mangatarere (Site 215).

In addition, there was considered to be substantial room for considering alternative arrangements and cost savings for the multi-storage scheme. Understanding how multiple storages could fit together in a cost-effective arrangement to provide coverage of the medium and high priority areas was considered important for ensuring a long-term cost-effective strategy for water management in the study area. Therefore, further development of the distribution aspects of the multi-storage scheme was recommended for investigation along with further work on the specific storage sites.

These recommendations were endorsed at meetings with the SAG and LG during September 2013.

Prefeasibility (Current Phase)

The scope and direction of the current Prefeasibility Phase has been developed progressively in an adaptive and collaborative manner. At the completion of each stage, the scope of the remainder of Prefeasibility has been reviewed with the WWUP Project Team and either endorsed or revised as appropriate. Other specialists, peer reviewers, and representatives of the IAF have also provided input at key points, such as at review points during the Value-engineering phase.

A collaborative scoping process with the WWUP Project Team was undertaken from October 2013 to January 2014, also informed by a workshop between IAF and GWRC, several collaborative meetings with SAG, and input from the local community during site meetings and community 'drop-in' days. The process culminated in an Offer of Service in February 2014. The objective of investigations was narrowed to focus on 'what information is required to decide what schemes should be studied during full Feasibility', with the expectation that any investigations not necessary to answer this question would be deferred until the full Feasibility Phase. In addition, early assessment of any possible 'fatal flaws' that could be used to eliminate schemes and avoid unnecessary work was favoured. For instance, the assessment of the use of the Makara River, Huangarua River and Tauweru River for conveyance was brought forward, since the findings could have a significant effect on whether Site 10 Tividale and Site 135 White Rock Road are suitable/favourable for further investigation.

The programme was divided into six Workstreams, undertaken by the wider team in addition to T&T:

- Workstream 1: Revise command area and assess use of rivers for conveyance;
- Workstream 2: Geotechnical assessment of storages focussing on six shortlisted storage sites including site visits, digger pits, and a 'fatal flaws' assessment;
- Workstream 3: Supply-demand matching, design, geotechnical assessment, and cost estimates for the distribution aspects of a multi-storage scheme to confirm selected storage sites are appropriate for a cost-effective, long-term strategy;
- Workstream 4: Non-engineering studies, including arranging access for site visits, stakeholder and community engagement activities, and coordination of hydrometric data collection for possible schemes;
- Workstream 5: Additional studies for possible inclusion, expected to be more fully scoped following review points part way through the programme; and
- Workstream 6: Overall management, coordination and reporting on Prefeasibility investigations.

Workstreams were interspersed with Review Points to enable due consideration of issues by the WWUP Working Group, Governance Group as well as Stakeholders, and assessment of any possible 'fatal flaws' that might eliminate schemes early in the process.

The scope presented in the February 2014 Offer of Service focussed on six storage sites[2] (Site 10 Tividale, Site 135 White Rock Road, Site 197 Te Mara, Site 206 Wakamoekau, Site 210 Black Creek,

[2] At the close of Options Refinement, the preferred storage options were referred to as a 'shortlist of five sites and a variant or subset of one of the five sites'. This is because the storage and to a lesser extent the command area of Site 206 Wakamoekau is essentially encompassed within the extents and infrastructure required for Site 210 Black Creek. However, for the purposes of the current report, the preferred storage options have been referred to as a 'shortlist of six sites' since:

- Site 206 Wakamoekau has proven more promising with further investigation.
- Site 206 Wakamoekau is fundamentally different in that it does not involve a dam on Black Creek.
- Because Site 206 Wakamoekau does not involve a dam on Black Creek, referring to the scheme as a 'Black Creek variant/subset' is confusing.

and Site 215 Mangatarere) shortlisted from the Options Refinement phase of work. Distribution arrangements were to be assessed in the context of a multi-storage scheme i.e. an integrated command area supplied by various combinations of the six storage sites.

In line with a progressive, adaptive approach to the scope of the Prefeasibility study, changes to the scope of Prefeasibility were proposed following the Task 3A Engineering Assumptions Teleconference at the start of Workstream 3. In particular, the WWUP Project Team elected to shift from development of distribution arrangements for a multi-storage scheme to development of independent single-storage schemes, each comprising a single storage and associated distribution network. The primary driver for this shift was the desire to determine the most cost-effective scheme layout that could be associated with each storage, and fairly compare individual schemes.

It was accepted that the shift to single-storage schemes would likely result in overlap of the indicative command areas for each scheme and leave significant areas of the Wairarapa Valley not covered, similar to the arrangements developed during the previous Options Identification and Analysis Phase. However, this was considered appropriate to meet the objective, advised by the WWUP Project Team, of identifying the most cost-effective scheme layout that could be associated with each storage.

In addition to the shift from a multi-storage scheme to single-storage schemes, the scope was also adjusted to expedite an improved understanding of the financial favourability of possible schemes:

- Updating arrangements and cost estimates for storages and associated reporting was brought forward from Workstream 5 to Workstream 3, including supporting tasks required as an input to updating storage arrangements; and
- A Value-engineering workshop was added into the programme, which focussed on improving the understanding of the financial favourability of possible WWUP schemes, particularly with respect to the construction and operational cost of schemes, identifying opportunities to modify the schemes or design criteria of the schemes to reduce costs; and obtaining input from independent experts to explore alternative engineering approaches and review work undertaken to date.

The Value-engineering Workshop was held over two days from the 15 to 16 September 2014 at T&T's Auckland Offices. It was attended by a facilitator N Brown, SMEC as independent engineers, T&T, representatives and specialist advisors of IAF, cost peer reviewer Bond Construction Management Ltd (BCM), engineering peer reviewer Pickens Consulting Ltd (PCL) and members of the WWUP Working Group.

Some of the key outcomes emerging from the workshop and review exercises were as follows:

i Various design criteria and assumptions have a significant impact on construction costs. The sensitivity of production on-farm and whole-of-scheme costs (incorporating on-farm costs) to changes in key criteria and assumptions should be assessed to improve scheme financial favourability. Initial indications were that there are a number of design criteria and assumptions that could be modified resulting in significant cost savings but only relatively minor reductions in farm productivity.

ii Possible changes to scheme layouts were identified that could potentially result in significant changes to cost estimates, though in most cases further work would be required to determine whether the changes are technically viable and to determine the magnitude of saving.

iii The BCM review of cost estimates included the following conclusion:

'Given the stage of design and the current state of knowledge regarding the anticipated location of borrows and sources of imported fill etc. we concluded that the rates used by T&T were, in general, within the range we would normally expect' (BCM 21 September 2014).

In light of overall findings from the Value-engineering Workshop, the scope of the remainder of Prefeasibility was revised as follows:

- Delivery of final reporting was deferred until further work could be undertaken during Workstream 5 to test and revise design criteria and to assess the opportunities for savings identified during the Value-engineering Workshop.
- An 'Interim Update on Value-engineering Workshop' Report (T&T September 2014) was added into the programme which would be considered at the Governance Group meeting on 2 October 2014.
- Following the Value-engineering Workshop and subsequent discussions with the WWUP Project Team, a preference emerged to adopt design criteria and assumptions that are less conservative to target 'mid-range'/'most likely' cost estimates to provide a preliminary indication of financial favourability rather than 'safe' cost estimates for budgeting purposes. Additional tasks were undertaken to challenge design criteria and test the sensitivity of production on-farm to changes in design criteria. In parallel, tasks were undertaken to confirm the sensitivity of construction costs to changes in design criteria.

  This included:

  – Dry matter modelling by Aqualinc Research Ltd (Aqualinc) to assess the sensitivity of on-farm production to service delivery assumptions, including peak scheme water supply rate. The assessment considered a pilot area in the vicinity of Carterton area as a test case, which is common to the indicative command areas for several of the schemes. (Aqualinc memos 6 November 2014, 17 November 2014, 21 November 2014, and 10 December 2014).
  – Extrapolation of dry matter modelling findings to schemes beyond the pilot area using correlations with soil PAW (Profile Available Water), average irrigation season rainfall, and average irrigation season evapotranspiration. (Aqualinc 5 February 2015).
  – Assessment of sensitivity of distribution costs to peak scheme water supply rate and design velocities in a pilot area in the vicinity of Carterton test area, common to several of the shortlisted schemes: 'Specimen distribution scheme cost sensitivity to select design parameters' (T&T 23 October 2014).
  – Assessment of sensitivity of scheme costs to water allocation assumptions. (T&T 13 November 2014)
  – Derivation of flood hydrographs at storage sites, which was required as an input to the assessment of cost savings through reducing diversion culvert and spillway sizes by accounting for attenuation of flood peaks via reservoir storage effects.
  – Assessment of alternative options for harvesting including gravity supply. (Opus September 2014, SMEC December 2014, Pickens Consulting Ltd 28 September 2014).
- The scope of Workstream 5 was expanded to include updating supply-demand matching and storage and distribution arrangements for revised design criteria as informed by the tasks listed above and incorporating the opportunities for savings identified during the Value-engineering workshop, such as:

  – Supply reliability was based on matching live storage size to the 1 in 5 year drawdown volume rather than 1 in 10 year drawdown volume as derived from frequency analysis. This criterion, used to select the storage size, controls the frequency with which the storage empties[3], restricting water supply to WWUP scheme water users. Water supply restrictions due to the storage emptying were predicted in 5-7 years of the 30 years modelled based on the revised approach, rather than occurring in 3 years generally based on the original approach.

- A seasonal volume cap was incorporated based on the 1 in 10 year water demand. This criterion imposes a restriction on the maximum cumulative volume of water supplied in any one irrigation season even if the storage[4] is not empty. The maximum cumulative volume cap was based on the unrestricted supply volume required in a 1 in 10 dry year.
- Water allocation rules were revised. Residual flows released below dams were set to the first step down threshold[5] to avoid impacting on existing core allocation consents. Water allocation rules governing harvesting of water to fill storages were revised to assume some limited availability of core allocation.
- Scheme-specific peak supply rates / system capacities were established.
- Scheme-specific allowances for distribution losses were established based on whether the distribution network is fully piped or dependent on conveyance by river or canal.
- Design velocities in the distribution network (resulting in smaller pipe sizes) were increased where excess head is available and where the risk of transient pressures can be managed cost-effectively.
- Overpressure arrangements in the distribution network were revised.
- The appropriateness and cost-effectiveness of GRP was considered as an alternative to the spiral-welded steel and PE pipes previously assumed.
- The opportunity to incorporate bellmouth spillways at Tividale and Mangatarere storages was considered.
- ‘Hydraulic jump’ dissipators at the toe of spillways at Te Mara and Black Creek (southern dam) were replaced with ‘flip buckets’.
- The size of spillways and construction diversion arrangements was reduced by accounting for attenuation of flood flows through reservoir storage effects (flood routing[6]).
- Filter and drainage zone arrangements in dam embankments were revised.
- Intermediate overflow channels and reinforced rockfill (that allows for some overtopping without unravelling) were incorporated as part of the construction diversion arrangement at dams where appropriate.

Assumptions and Limitations

The work undertaken in the Prefeasibility Phase is based on several assumptions and performance criteria regarding water demand estimates, water availability, scheme service parameters (reliability, water pressure etc.), and engineering design criteria, which may potentially change

[3] Except for the dead storage set aside for sedimentation and environmental flushing flows.
[4] Meaning ‘live storage’ excluding dead storage set aside for sedimentation and environmental flushing flows.
[5] The first step down threshold is the value at which consented takes must reduce to help prevent rivers falling below minimum environmental flows as defined in the Draft Natural Resources Plan for the Wellington region (GWRC September 2014).
[6] Flood routing is a technique to predict the changes in rate of discharge as water moves through a reservoir accounting for the reduction in the peak rate of discharge due to storage in the reservoir.

during later phases of work and more detailed investigations. In addition, GWRC is currently reviewing policies around water allocation and minimum flows as part of its Regional Plan review process. The work undertaken on the WWUP to date has made assumptions on water allocation scenarios that may change, particularly as the Regional Plan review process evolves.

Furthermore, the assessment of likely costs of potential schemes is preliminary due to the number of uncertainties at this early stage of investigation. The scheme layouts have been developed to a Prefeasibility level, and modifications to arrangements can be expected during later investigation, consultation and design stages.

Scheme Assessments

Six single-storage schemes have been advanced through the full Prefeasibility programme of evaluation in this phase of work. The key attributes of these six schemes are presented in Table ES-1 following. Reservoir storage capacity of each of the schemes ranges from 18 to 46 MCM (live storage).

Figure ES-1 shows the location of the six reservoir storage sites and the indicative command area associated with each storage. Although six single-storage schemes are shown together on one figure (Figure ES- 1), it is not expected that all six options would be developed in combination as they currently stand. If more than one option is developed in conjunction, some rearrangement of the indicative command area associated with each command area would potentially be required to remove overlaps.

The key attributes summarised in Table ES-1 cover:

1. Scheme number and name;
2. Description of general location and the river/stream/valley in which it is located;
3. The source of water for each scheme, either from the stream's own local catchment, or harvested from an additional source;
4. Dam arrangement, describing dam type, full supply water level, dam height, and spillway arrangement;
5. Approximate reservoir volume (live storage);
6. Average volume supplied on-farm per annum, after allowing for conveyance losses;
7. Maximum annual volume supplied on-farm in the 30 years of modelling, after allowing for conveyance losses;
8. The approximate number of hectares that could be serviced by each scheme (net area supplied), and the flow requirement to service it;
9. Description of distribution pumping requirements;
10. What existing infrastructure could potentially be affected by each scheme, focusing on public roads;
11. Assessment of the 'riskiness' associated with each scheme in relation to financial and engineering elements on a comparative basis;
12. Assessment of the 'opportunities' associated with each scheme in relation to financial and engineering elements on a comparative basis;
13. Assessment of the relative financial favourability of each scheme based on construction cost compared with net area supplied ($/ha);
14. Assessment of the relative financial favourability of each scheme based on construction cost compared with maximum annual volume supplied on-farm in a drought year ($/m^3).

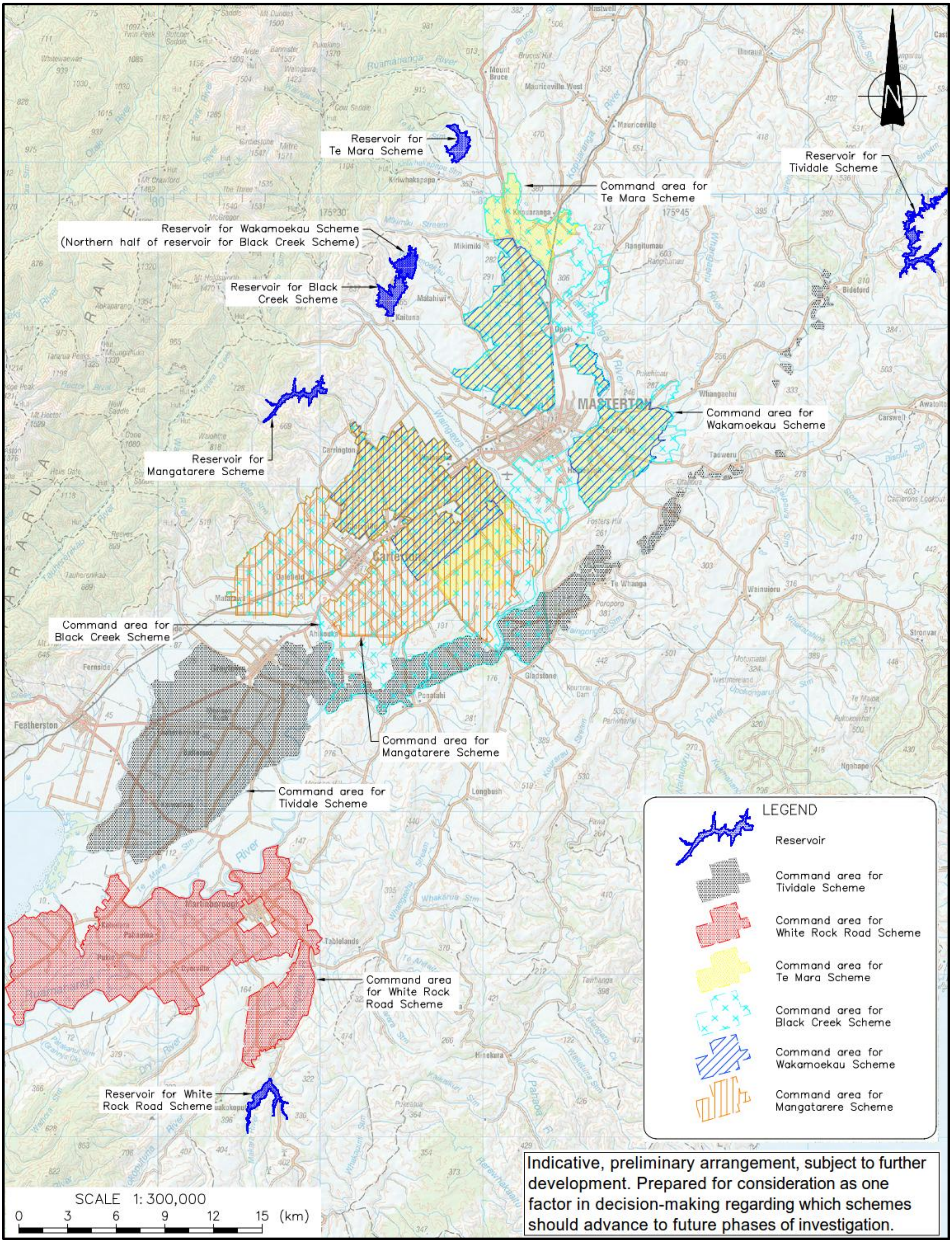

Figure ES- 1 Location of six short-listed reservoirs and indicative command areas assumed for Prefeasibility evaluation as independent, alternative scheme options

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Table ES- 1: Key engineering attributes of six schemes

Scheme name and number	Location of storage (reservoir)	Water source	Dam arrangement	Reservoir volume (live storage)	Average volume supplied on-farm per annum	Maximum annual volume supplied on farm in dry year Note	Indicative net area supplied and flow requirements	Distribution pumping	Effect on existing public infrastructure	Engineering Opportunities	Engineering Risks	Financial favourability based on $/ha (net area supplied)	Financial favourability based on $/m³ supplied in dry year
Tividale (Scheme 10)	24 km northeast of Masterton One dam on the Tauweru River, downstream of the confluence with Mangapurupuru Stream	Local catchments: Tauweru River & Mangapurupuru Stream	• Zoned earthfill • Full supply level 179.1 mRL • 44 m high • Single spillway	29.2 MCM	22.9 MCM	30.2 MCM	9,800 ha south of Greytown and east of the Tauherenikau River, also alongside the Tauweru River and Ruamahanga River; 3,900 l/s	Significant pumping required for distribution	Mangapurupuru Road and Coopers Road to be realigned to maintain access to properties	MCA Score 2.8 Moderately favourable	MCA Score 1.0 Least favourable	MCA Score 4.1 Favourable	MCA Score 1.0 Least favourable
White Rock Road (Scheme 135)	10 km south of Martinborough, at White Rock Road. One dam on the Makara River, downstream of the confluence with Mangapari Stream.	Local catchments: Makara River & Mangapari Streams	• Zoned earthfill • Full supply level 129.9 mRL • 46 m high • Primary spillway (bellmouth) & auxiliary spillway	23.2 MCM	20.2 MCM	27.4 MCM	7,600 ha encircling Martinborough and extending to the south and west as well as up the Huangarua River valley; 3,100 l/s	Significant pumping required for distribution	White Rock Road to be realigned; private roads assumed to be abandoned; possible realignment of high voltage power line	MCA Score 1.0 Least favourable	MCA Score 1.5 Least to less favourable	MCA Score 1.0 Least favourable)	MCA Score 1.1 Close to least favourable
Te Mara (Scheme 197)	17 km northwest of Masterton, west of State Highway 2. One dam on the Te Mara Stream and a minor saddle dam	Local catchment: Te Mara Stream Also, harvesting from Ruamahanga River at a peak rate of 1.4 m³/s	• Zoned rockfill • Full supply level 300.2 mRL • 44 m high • Primary spillway & auxiliary spillway	23.3 MCM	24.1 MCM	34.0 MCM	9,700 ha, north, east & southwest of Masterton; 3,700 l/s	No pumping required for distribution	None, apart from paper road	MCA Score 5.0 Most favourable	MCA Score 5.0 Most favourable	MCA Score 3.3 Moderately favourable	MCA Score 2.7 Moderately favourable
Wakamoekau (Scheme 206)	12 km northwest of Masterton, at the end of Falloon Settlement Road. One dam on Wakamoekau Creek.	Local catchment: Wakamoekau Creek Also, harvesting from Waingawa River at a peak rate of 1.2 m³/s	• Zoned rockfill • Full supply level 269.8 mRL • 43 m high • Primary & auxiliary spillway	18.8 MCM	20.4 MCM	28.9 MCM	8,100 ha north, east & southwest of Masterton; 3,100 l/s	Some pumping required for distribution	Assume abandonment of roads within reservoir footprint	MCA Score 3.1 Moderately favourable	MCA Score 4.8 Close to most favourable	MCA Score 5.0 Most favourable	MCA Score 5.0 Most favourable
Black Creek (Scheme 210)	12 km northwest of Masterton, at Falloon Settlement Road. One dam on Black Creek and a second dam on Wakamoekau Creek.	Local catchments: Black Creek and Wakamoekau Creek Also, harvesting from Waingawa River at a peak rate of 5.6 m³/s	• Zoned rockfill • Full supply level 272.1 mRL • 43 m high (Black Creek) & 45 m high (Wakamoekau Creek) • Primary spillway & auxiliary spillway (both dams)	46.2 MCM	46.2 MCM	67.0 MCM	19,700 ha north, east & south of Masterton, extending close to the Waiohine River; 7,600 l/s	Some pumping required for distribution	Assume abandonment of roads within reservoir footprint	MCA Score 3.8 Favourable	MCA Score 2.4 Less favourable to moderately favourable	MCA Score 4.5 Favourable to most favourable	MCA Score 3.5 Moderately favourable to favourable
Mangatarere (Scheme 215)	13 km west of Masterton, at Mangatarere Valley Road. One dam on Mangatarere Stream.	Local catchment: Mangatarere Stream	• Zoned rockfill • Full supply level 237.9 mRL • 63 m high • Single spillway	29.3 MCM	22.8 MCM	33.6 MCM	9,700 ha north, east & west of Carterton; 3,900 l/s	Some pumping required for distribution	Several kilometres of Mangatarere Valley Road to be realigned to maintain access to properties and Tararua Forest Park	MCA Score 3.4 Moderately favourable to favourable	MCA Score 4.7 Close to most favourable	MCA Score 4.1 Favourable	MCA Score 3.4 Moderately favourable to favourable

Notes : MCM = million cubic metres. MCA = Multi-criteria Analysis. mRL = metres Reduced Level, relative to Wellington Vertical Datum 1953. 'Maximum annual volume supplied in a dry year' is the maximum annual volume assumed to be supplied in the 30 year period modelled based on historical rainfall patterns.

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Comparison of Schemes

The six single-storage schemes as developed during the Prefeasibility Phase will be compared through a multi-criteria analysis (MCA) accounting for environmental, financial, social and cultural criteria as well as risks and opportunities. The findings from the MCA will provide an important input into decisions on what schemes should be studied during full Feasibility.

The MCA is being led by the WWUP Project Team, which is coordinating inputs from a range of specialists including T&T, which has been tasked with providing MCA scores in relation to engineering elements. A financial score, risk score and opportunity score has been prepared for each scheme in relation to engineering elements. The financial score is based on the current assumed layout of headworks and distribution given the current level of investigation, while the risk and opportunity scores reflect areas of uncertainty and areas for further investigation. Further background on the nature of these scores is provided in the following paragraphs.

T&T has provided an estimate of initial construction cost and significant operational costs to PricewaterhouseCoopers (PwC) based on our current understanding of engineering aspects. PwC has combined these costs into a Net Present Cost for each scheme that accounts for the time-value-of-money. The Net Present Cost has been normalised with respect to the benefit provided, where benefit is measured as the net area supplied for each scheme ($/hectare), or as the volume of water supplied in a drought year ($\$/m^3$).

A 1 to 5 scale has been used. This scale is comparative, rather than absolute; i.e. a scheme scoring a 1 is least favourable compared with other schemes under consideration but is not necessarily unfavourable in a wider context. Likewise, a score of 5 does not necessarily mean a scheme is favourable in an absolute sense. The comparative scale is described as follows:

1 Least favourable
2 Less favourable
3 Moderately favourable
4 Favourable
5 Most favourable.

The results of the MCA ranking for engineering elements only are presented in the last four columns of Table ES-1. The details that have contributed to the MCA scores are presented in the tables for each theme and scheme in Appendix C and Appendix D.

Conclusions

In terms of command area locations, the following is noted:

- Scheme 135 White Rock Road and Scheme 10 Tividale supply water to essentially independent command areas, except for some minor overlap of Scheme 10 Tividale and Scheme 210 Black Creek.
- Scheme 197 Te Mara, Scheme 206 Wakamoekau, Scheme 210 Black Creek and Scheme 215 Mangatarere supply water to command areas that overlap substantially.

In terms of the Prefeasibility cost estimates, the following is noted:

- A wide range for cost estimates for each scheme is considered realistic for the current level of design development. There is substantial overlap of the cost estimates for the six schemes when the expected range of -15%/+30% is considered.

- When financial favourability is considered in terms of \$/ha (net supplied) or \$/m^3 supplied in a drought year, Scheme 206 Wakamoekau appears the most promising. Scheme 210 Black Creek and Scheme 215 Mangatarere are the next most promising and are similarly favourable. Scheme 197 Te Mara is moderately favourable. Scheme 135 White Rock Road appears to be the least promising of the six schemes. Scheme 10 Tividale appears similarly favourable as Scheme 210 Black Creek and Scheme 215 Mangatarere if considered on the basis of \$/ha (net supplied), but appears the least favourable if considered on the basis of \$/m^3 supplied to farm gate in a drought year[7].
- The lowest ranked scheme is 24% more expensive than the highest ranked scheme in terms of \$/ha and 22% more expensive in terms of \$/m^3 supplied in a dry year. This is a relatively small difference when considered against the uncertainty range in the cost estimates. This indicates that all six schemes are in a similar range in terms of overall affordability.

The assessment of financial favourability has been based on comparing single-storage schemes as independent alternative options that would not be developed in conjunction without modifications to arrangements. The single-storage arrangements developed during Prefeasibility may not represent the most cost-effective arrangements to suit any possible longer term plan comprising multiple storages.

In terms of the assessment of opportunities for cost savings and risks for cost increases and technical issues, the following is noted:

- There is unavoidable uncertainty across many areas given the Prefeasibility stage of investigation. The many factors tend to balance each other out in combination. Nevertheless, there is still the potential for a 'fatal flaw' to arise with respect to one of these factors.
- In terms of opportunities for cost savings, Scheme 197 Te Mara is clearly the most favourable, followed by Scheme 210 Black Creek, and then Scheme 215 Mangatarere. Scheme 10 Tividale and Scheme 206 Wakamoekau are similarly moderately favourable. Scheme 135 White Rock Road is clearly the least favourable of the six schemes.
- In terms of risks of cost increases and technical constraints, Scheme 197 Te Mara is again clearly the most favourable, very closely followed by Scheme 206 Wakamoekau and Scheme 215 Mangatarere. Scheme 210 Black Creek is less favourable to moderately favourable in terms of risk. Scheme 10 Tividale is the least favourable of the six schemes, though Scheme 135 White Rock Road only slightly more favourable than Scheme 10 Tividale.

Recommendations and Next Steps

The MCA scores for financial favourability, opportunities for savings and risks for cost increases and technical issues produced in this report comprise one component of the wider MCA process being coordinated by the WWUP Project Team. Inputs from other specialists, addressing environmental, financial, social and cultural themes, will be integrated with T&T's scores in the MCA. The resulting comparison of schemes (ranking) will provide an important input into decisions on what schemes should be studied during full Feasibility.

T&T has compared the six schemes by considering the financial, risk and opportunity scores presented in this report. The three sets of scores have been considered separately rather than numerically combining the scores into an overall ranking. Based on this comparison considering

[7] This is because the annual water demand (m^3/ha) in a drought year is expected to be notably lower for the Tividale scheme than the other five schemes.

engineering aspects and cost, the following interim recommendations are provided, which will need to be reviewed in the wider MCA context integrating inputs from other specialists:

- Scheme 206 Wakamoekau appears to be the most promising scheme in terms of potentially advancing to full Feasibility.
- Scheme 215 Mangatarere and Scheme 210 Black Creek are the next most promising. Scheme 210 Black Creek is marginally more promising in terms of the financial and opportunities scores, but has a notably less favourable risk score than Scheme 215 Mangatarere.
- A staged programme of development could be considered with Scheme 206 Wakamoekau comprising Stage 1, and either the southern half of Scheme 210 Black Creek or Scheme 215 Mangatarere considered as Stage 2.
- Scheme 197 Te Mara is only moderately favourable in terms of financial scores, but has the most favourable risk and opportunity scores of any of the schemes and is only 10% more expensive than the highest ranked scheme in terms of $/ha and 13% more expensive in terms of $/m^3 supplied in a dry year. Potentially, a smaller scheme size could be considered that minimises the scheme's dependence on water harvesting from the Ruamahanga River and minimises overlap with the command areas of the schemes above.
- Scheme 10 Tividale and Scheme 135 White Rock Road appear to be the least promising of the schemes, though Scheme 10 Tividale is relatively favourable on a $/ha (net area supplied) basis[8]. However, these schemes cover independent command areas that for the most part do not overlap with the schemes above, and also have cost estimates within 6% (Tividale) and 24% (White Rock Road) of the highest ranked scheme in terms of $/ha or 22% (Tividale) and 22% (White Rock Road) in terms of $/m^3 supplied.
- Potentially, an alternative dam site for Scheme 135 White Rock Road could be considered 5 km upstream[9] of the current location that would avoid the need and cost of realigning White Rock Road and the associated bridge. No further investigation of the alternative dam site has been undertaken during Prefeasibility, but preliminary indications from earlier WWUP phases suggest that the site may be relatively cost-effective in terms of dam embankment earthworks. The alternative site would involve a smaller scheme due to reduced water availability.
- Scheme 197 Te Mara, Scheme 10 Tividale and Scheme 135 White Rock Road could provide an essential component of the long-term plan for maximising the capacity of the Wairarapa Valley.

Areas requiring further investigation have been identified throughout this report. These identified areas will need to be rationalised and prioritised into a scope of work for any schemes progressing to full Feasibility. Priority could be given to investigating any areas that could represent 'fatal flaws' to eliminate unfeasible schemes early in the full Feasibility programme. Priority could also be given to commencing collection of any data that requires a long period of record, for instance hydrometric data.

It is emphasised that even if GWRC (as client) decides to proceed to the next phase of investigations, this level of assessment is still an early stage of any project development and does not imply any commitment to seek resource consents or proceed through to construction.

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[8] Scheme 10 Tividale is least favourable on the basis of $/m^3 supplied in a dry year. This is because the annual water demand (m^3/ha) in a drought year is expected to be notably lower for the Tividale scheme than the other five schemes.
[9] This site was identified in previous reports as Site 142 Makara and described as a potential alternative for Site 135 White Rock Road that could potentially be free of limestone, though this would need to be confirmed by site inspection.

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