DAD – an Innovative Dose and Drain Land Dispersal System

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ABSTRACT

The originally designed Queenstown land dispersal area was to be inside river protection works on the Shotover River Delta. This original design required a gravel platform to limit groundwater breakout with an estimated capital cost of $19 million. To reduce cost, a system was investigated on the river-side of the protection works. To meet iwi and other stakeholder's concerns, the new land dispersal system had to drain naturally through the underlying silts, rather than being forced through under pressure. To allow this, high void space plastic stormwater storage cells have been designed into the system instead of a LPED system. A large diameter feeder pipe was designed to allow a large volume dose to be applied to the field with minimal pressure that rapidly fills the voids and then allows the effluent to drain naturally through the underlying silts and sands. This innovative design reduced the estimated capital cost to $4.3 million. To support the operation, a number of piezometers are being installed that will be monitored to confirm groundwater mounding modelling predictions undertaken during consenting. This saving has resulted in the direct discharge of effluent to the Shotover River stopping four years earlier than planned.

Keywords: dose, drain, land dispersal, land disposal, silts, stormwater cells

INTRODUCTION

Queenstown Lakes District Council (QLDC) Shotover Wastewater Treatment Plant (WWTP) receives municipal sewage from Queenstown in addition to the Arrowtown, Lake Hayes, and Arthur's Point communities and recently consisted of a facultative treatment pond system located on the Shotover River Delta. The WWTP has recently been upgraded by the installation of a Modified Ludzack-Ettinger (MLE) system that treats two thirds of the flow, then blends with the pond effluent prior to UV sterilisation.

The original/consented Shotover WWTP upgrade is staged as follows:

- Stage 1: Upgrade the WWTP to provide partial wastewater treatment to meet mean effluent quality of 30:30:20:260 (BOD:TSS:TN:*E.Coli*) to be operational by end of 2016;
- Stage 2: Install Phase 1 of the land dispersal system between 2016 and 2022 and have all dry weather flows discharged into land;
- Stage 3: When nitrogen load triggers are reached (about 2025), implement Stage 3 of the WWTP upgrade so that effluent quality meets mean 10:10:10:10 effluent quality; and
- Continue to expand the land dispersal system in phases as required to meet flows.

The original consent had a reasonably standard LPED dispersal field located inside the Otago Regional Council (ORC) revetment. Groundwater mounding modelling showed that due to the relatively low permeability material on the land side of the revetment, 2.5 m depth would need to be excavated and replaced, resulting in more than 500,000 m^3 of material needed. This is shown in Figure 1.

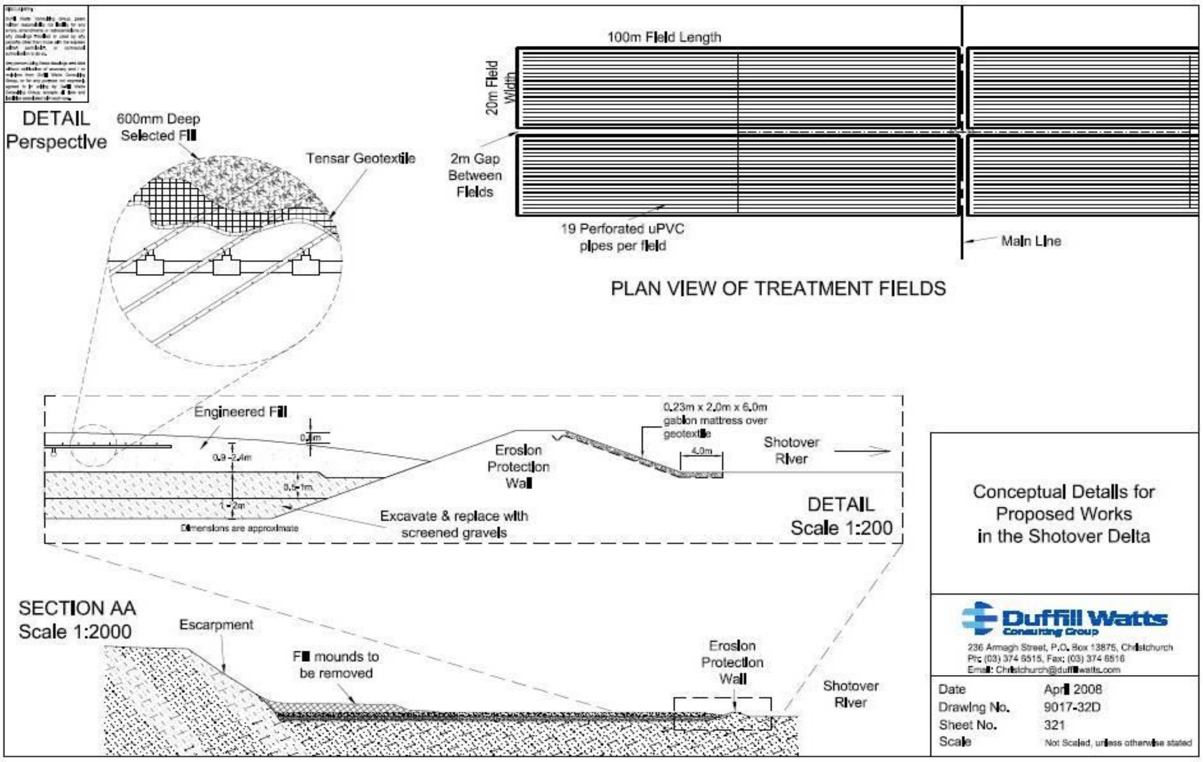

Figure 1: Original LPED Concept inside ORC Revetment

The main reason for the change in location of the dispersal field was the loss of the economic supply of gravel that was to be available for building up the (LPED) platform. The gravel was to be made available at low cost during the removal of the delta islands by ORC as part of the Shotover River training works. However, due to timing, the material from the islands was utilised in the building of the airport RESA (Runway Extension Safety Area) and the revetment and river training wall. As a consequence of this, the cost to import gravel to construct the LPED platform is now estimated to have increased at least 3-fold, resulting in the LPED construction costs going from $7.7 M (2010) to $19 M now.

QLDC engaged Lowe Environmental Impact (LEI) and Fluent Infrastructure Solutions (Fluent) to come up with alternative solutions, consult with stakeholders and to consent a variation to the discharge to land consent.

DOSE AND DRAIN (DAD) CONCEPT DESIGN

Field Investigations

Significant test pitting, infiltration testing, permeameter testing and particle size analysis (PSA) was undertaken throughout the proposed dispersal area and a correlation made with text book values (Domenico and Schwartz, 1998), as shown in Figure 2.

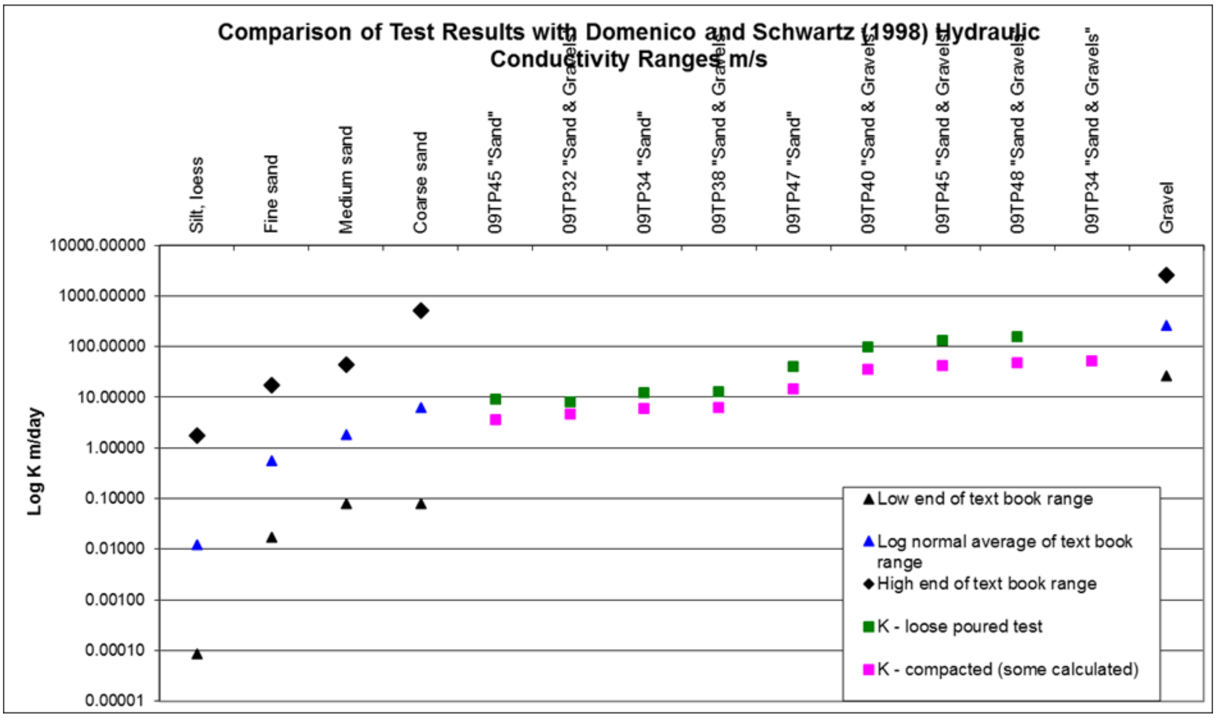

Figure 2: Comparison of the PSA tests results with Domenico and Schwartz (1998)

Based on the results shown in Figure 2, it was concluded that a strong correlation between PSA and K_{sat} existed, thus allowing accurate permeability calculations to size the dispersal field. It was concluded that an average K of 10 m/d would be achievable, with localised areas of up to 60 m/d. Cross sectional profiles were developed to see where the DAD system should be located, as shown in Figure 3.

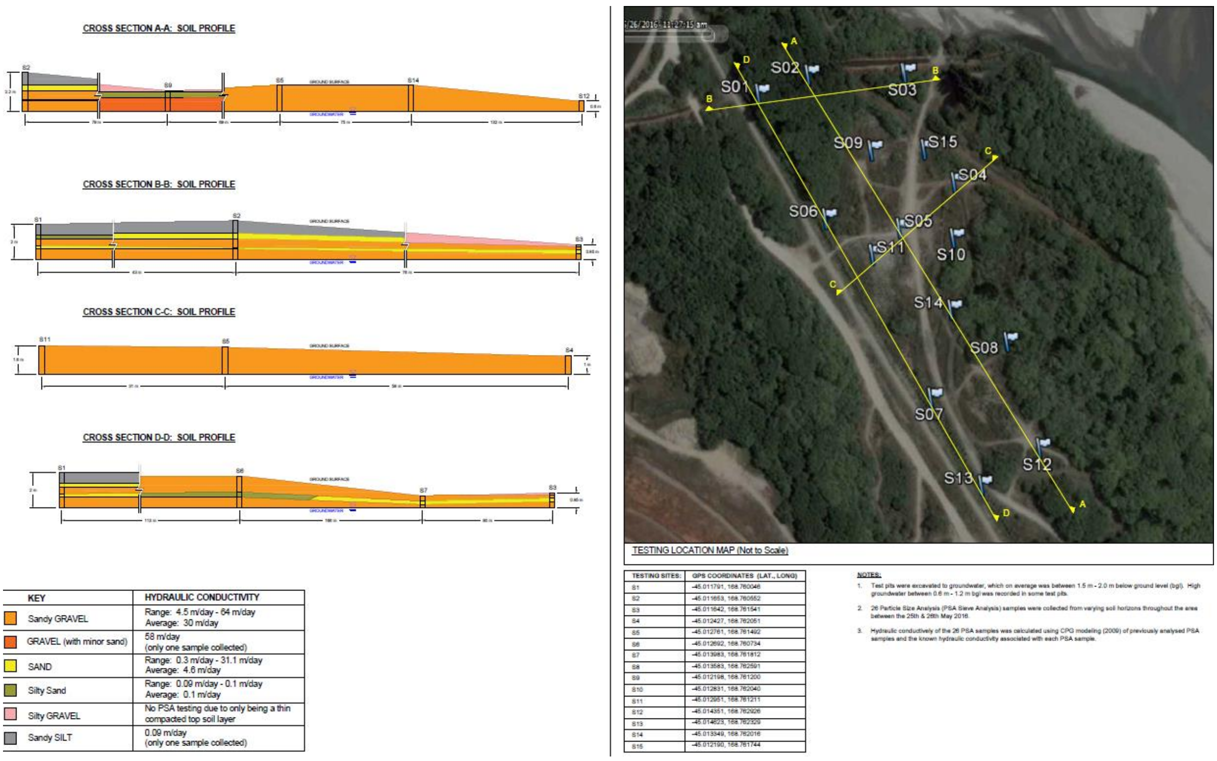

Figure 3: Cross Sections and Material Profiles

Concept Development

The result of consultation with iwi required the new concept had to have the passage of treated effluent through natural material (silts, sands and gravels) and not be forced through at unnatural rates. A gravity dose to subsurface storage, followed by slow release and drainage through underlying natural material was decided on – dose and drain, or DAD. In addition, ORC required that there be no groundwater mounding with breakout on the surface, even though the land dispersal system was never relied on for any improvement in effluent quality, as treatment at the WWTP met recreational bathing water standards. This required the filling of low spots within the dispersal area to eliminate potential for this to occur.

The concept consists of a series of subsurface pipes and subsurface storage conduits (large stormwater water cell storage units (Figure 4) that will accept the dose and slowly release treated effluent. These are buried similar to a LPED but with a lower number of larger pipes and conduits rather than a network of smaller pipes. The DAD system is:

- two outer 400 m long water cell storage conduits in eleven sections;
- twenty two 70 m storage cells connecting to the outer cells; and
- a central 600 mm dia. conveyance conduit, that also provides the dose.

Figure 4: Stormwater Storage Cells Considered in the DAD Concept

The conveyance pipe has a number of electronic actuator valves along it to enable sections to be sequenced through their dosing cycle. Manual valves are also included on each sub-section that can be fully closed off or partially closed off, in order that sections can be rested for maintenance and to control flows to evenly distribute the effluent, particularly to alter flow to sections where natural material is less free draining.

The size of the new discharge field will initially be approximately 2.8 ha and will be installed so that there is a minimum distance to the Shotover River of 50 m.

The DAD system is designed to cope with a peak flow of 430 L/s which corresponds to 37,150 m^3/day per day, which is 12.6 % higher than the 2044-year Peak 20-yr Wet Weather Flow. Current average flow is around 13,000 m^3/d, or 150 L/s.

The adopted average infiltration rate over the site of 10 m/d was reduced by 50 % as a factor of safety to allow for BOD:TSS in the discharge. These are low, at 30:30 at Stage 1 and reducing to 10:10 in Stage 3, thus a factor of safety of 2 is considered conservative. Therefore, the design is:

- rate of 5 m/d on the trench area;

- 1,570 m of 4 m wide trench (assumed to be 6 m of infiltration, i.e. allowing 1 m side wall each side); and
- an effective trench area is 9,420 m^2.

At full flow over a 24-hour period at 430 L/s (this is unlikely to occur even in wet weather flow), 37,150 m^3/d will be applied and result in a loading of 4 m/d over the whole site. Average loading on the effective trench area is 1.2 m/d in Stage 1 and 1.7 m/d in Stage 3.

Based on the test pitting investigation, the groundwater at the location of the dispersal field is considered to be present at an average depth of 1.5 m bgl (min 1.2 m bgl; max 2.0 m bgl), however, low areas will be filled (Figure 5) so that the initial depth to groundwater is a minimum of 1.5 m. Considering a DAD bed 400 m long and 70 m wide with average daily flows, groundwater mounding modelling (Hantush, 1967) for Stage 3, when assessed over a 1-year period gave 1.4 m groundwater rise in the centre of the field. Groundwater mounding will be intensively monitored via numerous piezometers as it is intented to treat this initial dispersal field as a full working trial in order to set design parameters for future expansion, if required.

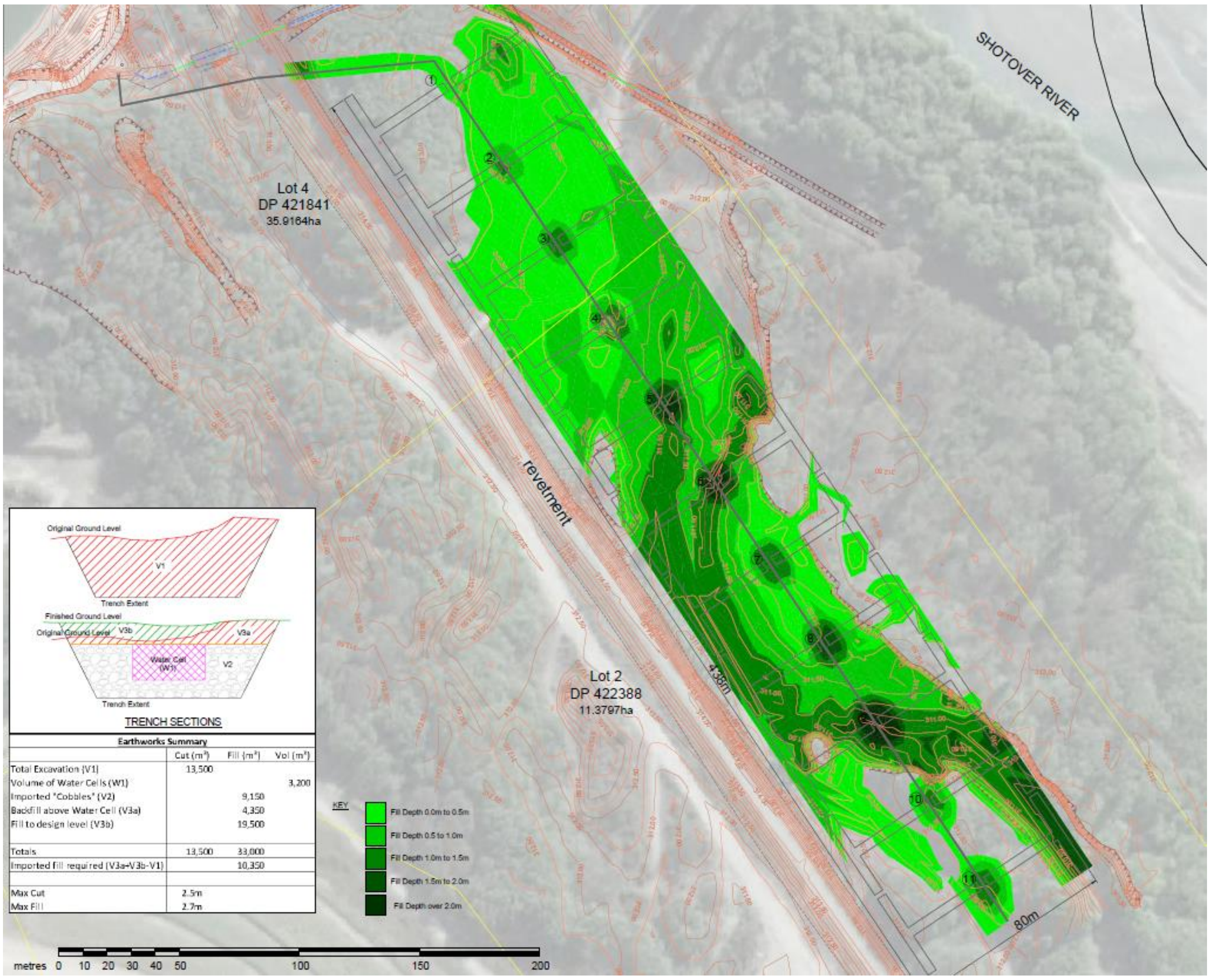

Figure 5: Depth of Fill over DAD Field

Operation

Under normal dry weather flow, 3 - 4 blocks will be operating and these will be spaced out, i.e. Block 1, 4 and 7 will be running. If pressure starts building up in the main dosing pipe, then pressure transducers along the pipe will open further electronically actuated valves, until at full design wet weather flow all 11 blocks will be operating. The blocks will also be on a timer, so that effluent is sequenced through and evenly spread over the entire area to minimise mounding. The operation during dry weather flow and a high rainfall event is shown in Fluent Solution's sketch below (Figure 6).

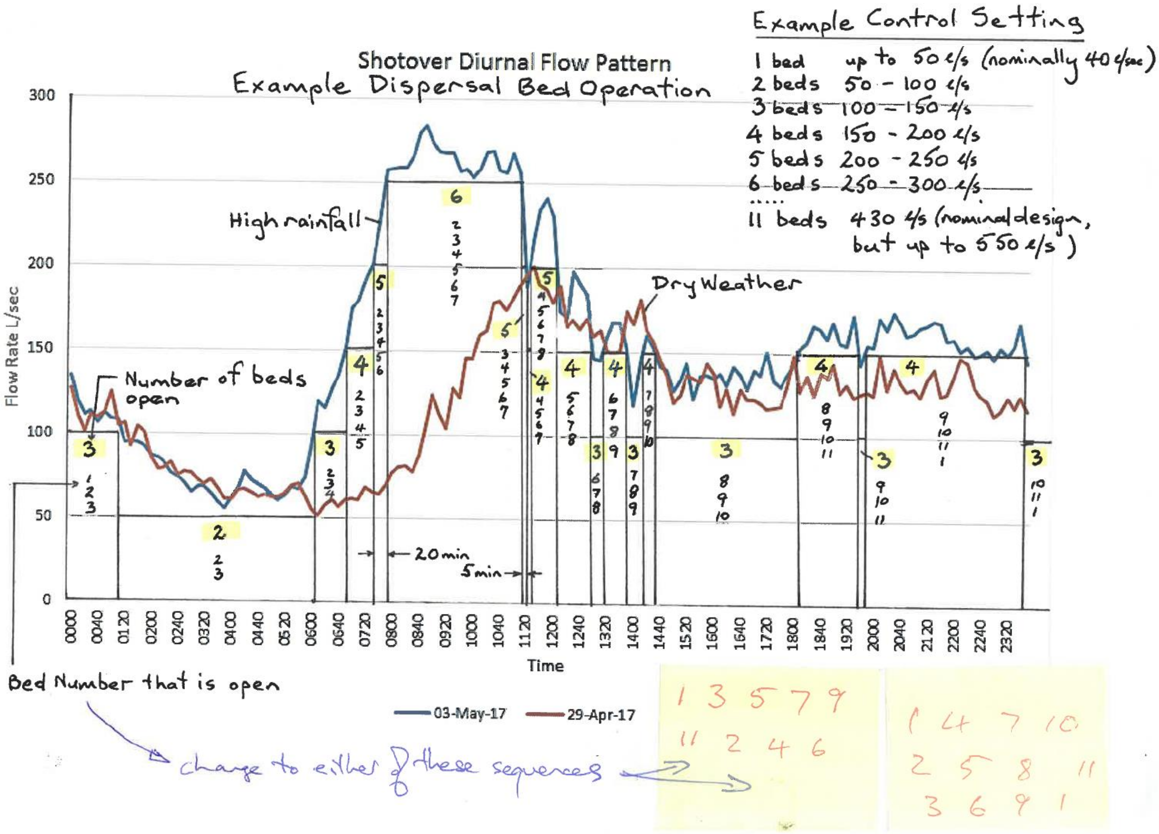

Figure 6: Block Sequencing during Dry and Wet Weather Flow

The original concept had all areas connected but with intermediate shutoff valves. The concept that has been tendered is now split into 11 separate blocks, each one 100 mm stepped down from previous one to minimise earthworks, as shown on Figure 7.

Each block has storage/void space of 440 m^3 and under normal operating conditions, each cell will take nearly 3 hrs to completely fill, ignoring exfiltration. The initial timer setting will be 4-hrs on, then cycle to the next cell. This is over-ridden by the pressure transducer during wet weather flows.

Concept details are shown in Figures' 8 – 11.

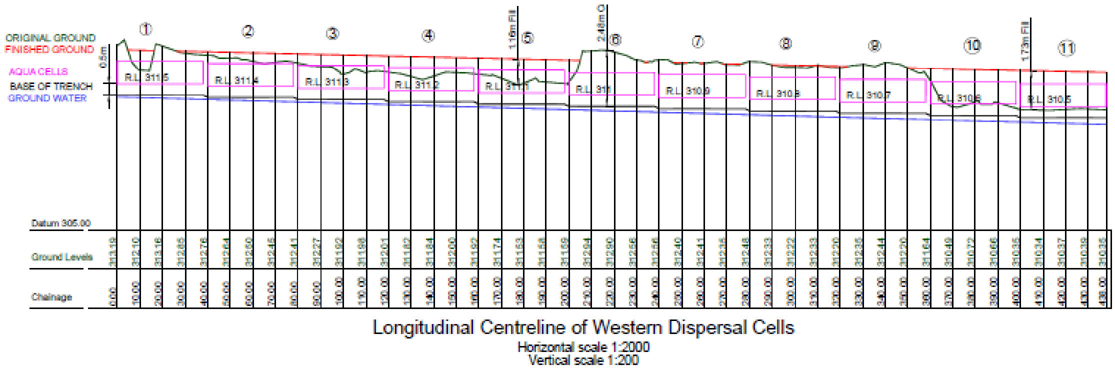

Figure 7: Long Section of DAD, showing stepping down of Blocks

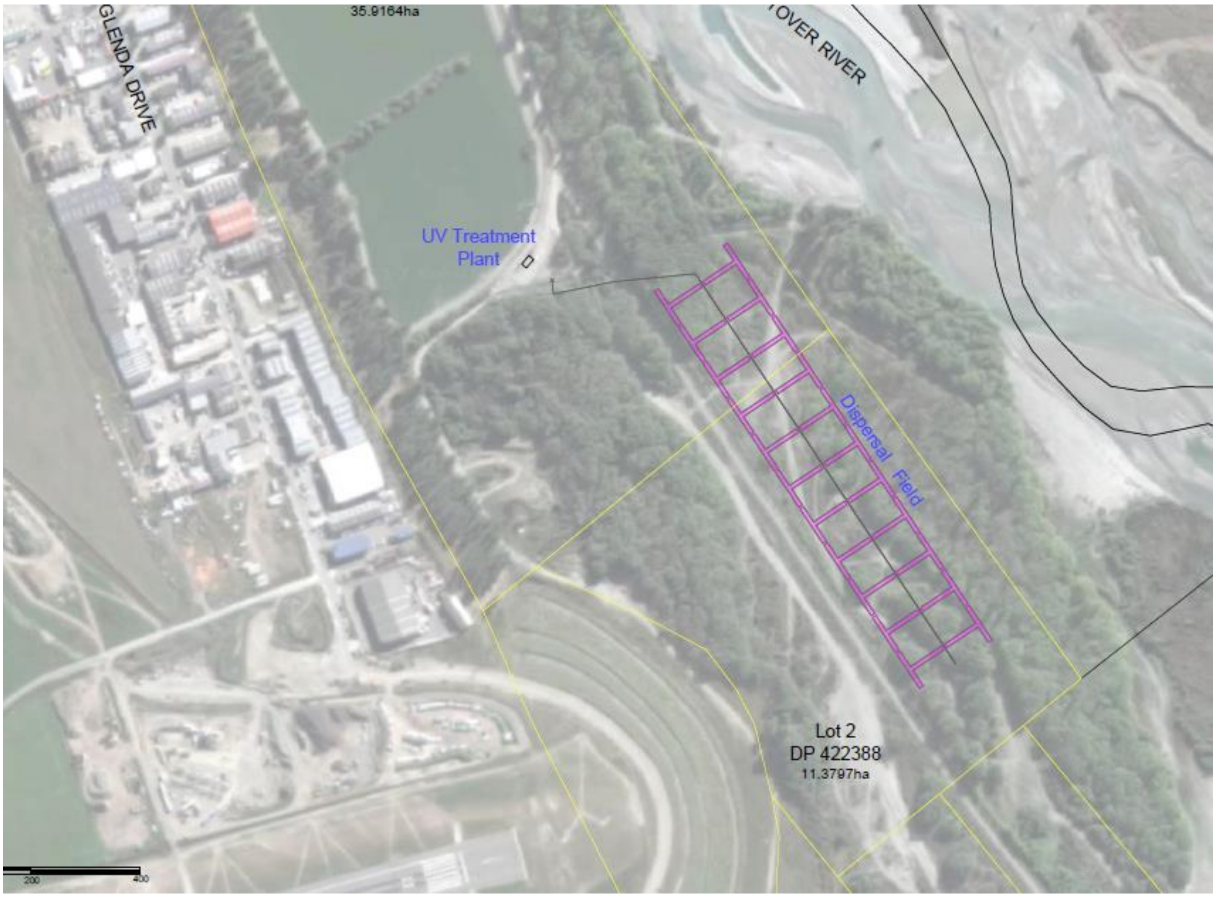

Figure 8: Location of DAD System on Shotover River

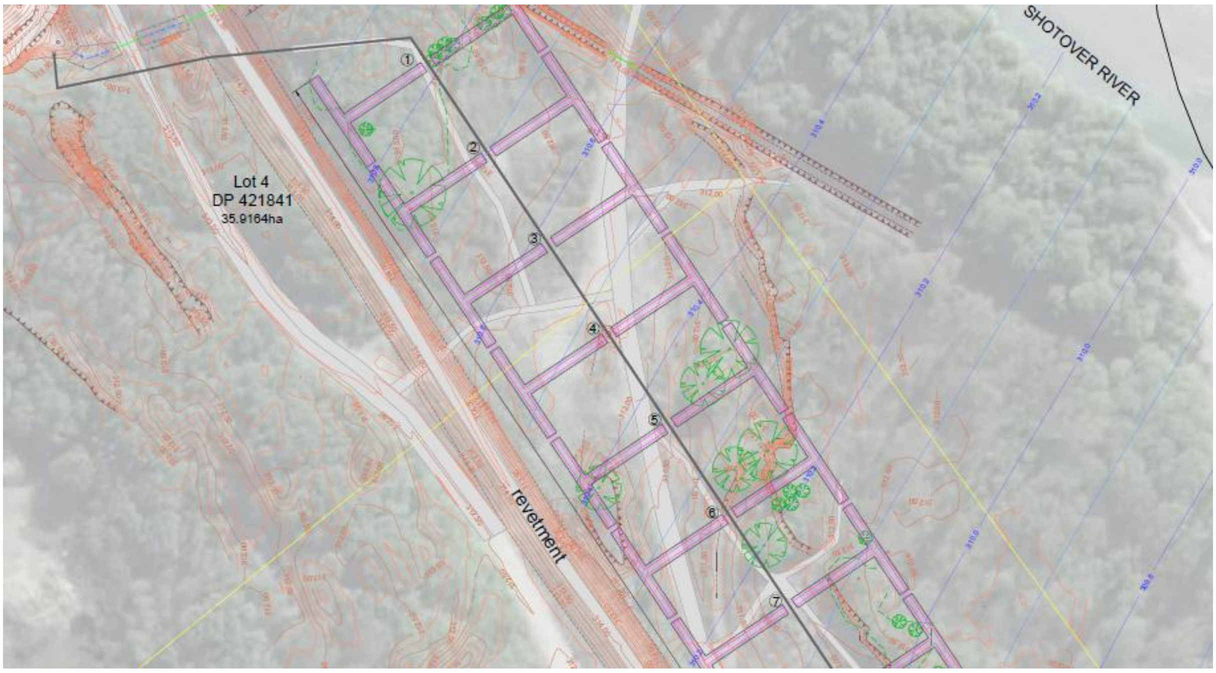

Figure 9: Expanded Detail of DAD System

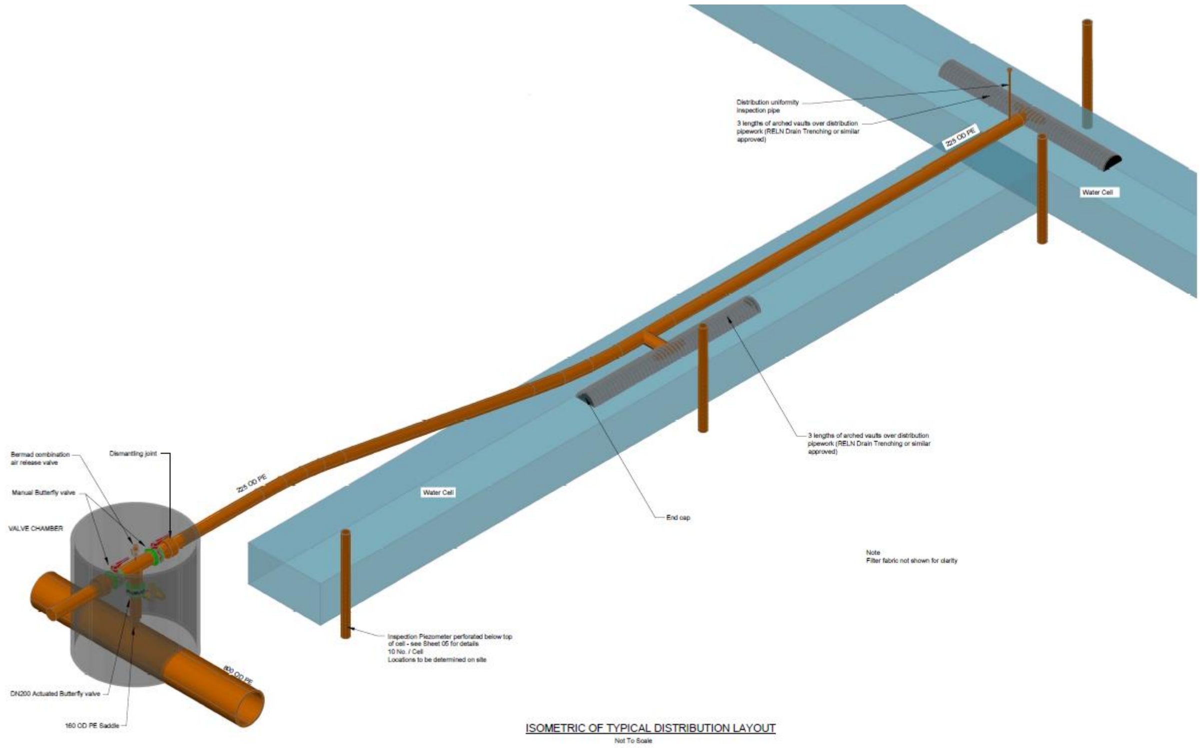

Figure 10: Concept of DAD System

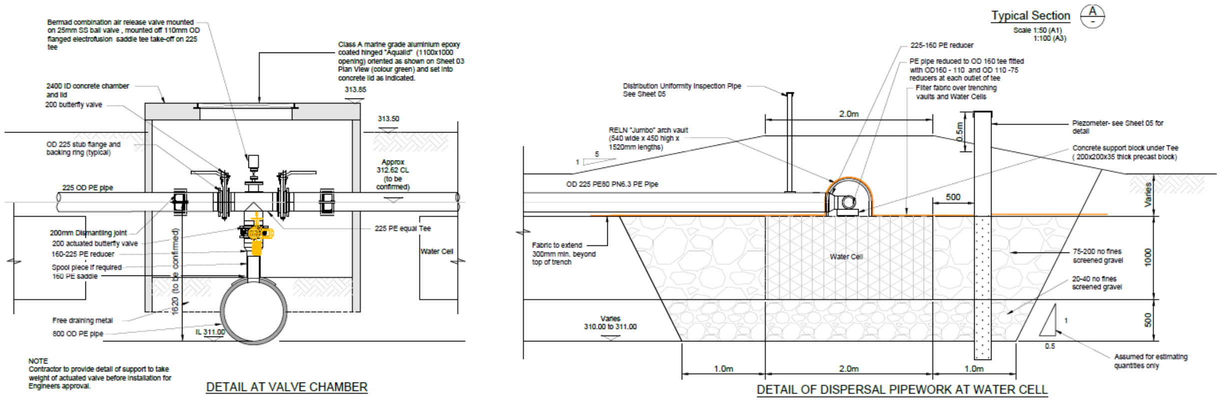

Figure 11: DAD Details showing Valving, Trench and Monitoring Piezometers

WHAT NEXT

Tender and Construction

The supply of the cells and valves, and construction of the DAD system is currently out to tender. Tenders close between the time this paper has to be submitted and the conference. Tender assessment will be occurring the week of the conference and award the following week, with construction planned for April to July 2018.

Monitoring

The DAD field will have 110 piezometers (10 per Block) installed through it. These are for operational purposes, i.e. to adjust valves to ensure lower permeability areas receive less input. In addition, nine piezometers will have pressure transducers and data loggers to monitor groundwater elevation.

CONCLUSIONS

This is a very new concept that has not been used anywhere else as far as the author is aware.

The concept makes use of high volume void space to accept a dose, then allow it to drain under gravity through natural silts, sands and gravels. This is considered acceptable to local iwi.

The concept has resulted in a saving to the community of nearly $15 million, although final tender prices have not yet been received. This saving has resulted in the direct discharge to the Shotover River being ceased four years ahead of schedule – another win to the community.

Monitoring will show how effective the system is and whether it needs to be expanded in future.

AKNOWLEDGEMENTS

The concept is the result of brainstorming by the author, Derrick Railton and Martin O’Malley (both Fluent Solutions) and Lane Vermaas (QLDC).

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