STORMWATER SYSTEM WITH NO APPARENT RUNOFF

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ABSTRACT

The Christchurch Southern Motorway: Stage Two (CSM2) has just received Resource Management Act permissions from the Board of Inquiry. The 17 km route commences at Halswell Junction Road and travels southwest to Rolleston.

The CSM2 Project provided a range of challenges for dealing with stormwater, groundwater and flow in stockwater races. To a casual observer the nearly flat plains have no obvious water features. Road names such as Marshes, Waterholes and Springs Road however give some indication of historic water features; and the current Canterbury Plains from a water take perspective are over allocated leading to depressed groundwater.

From a water perspective, our areas of interest were:

- The collection and treatment of road runoff and discharge of this treated stormwater to ground as there are no adjacent natural water courses.
- The project crosses the plains and also crosses nine Selwyn District Council stockwater races for which no discharge was permitted.
- There was potential runoff from upstream of the project to be passed beneath the project in a series of inverted siphons. However there is no evidence of recent ponding or runoff within these catchments.
- The Central Plains Water Irrigation Scheme is consented and as part of that scheme, groundwater levels are predicted to rise to an extent where parts of the CSM2 project would be impacted during critical rain events in conjunction with groundwater highs.

This paper sets out the issues, challenges and solutions.

KEYWORDS

Stormwater, Consenting, Assessment, Groundwater, Flooding, Stockwater Race, Mitigation, AEE.

PRESENTER PROFILE

Tony Miller is a Principal Engineer in GHD's Stormwater and Asset Planning Service Group based in Auckland. He holds a BEng form the University of Auckland (1980) and is CPEng accredited. Tony has more than 35 years' experience in the contracting and consulting engineering in NZ, UK, Canada, Australia and the Pacific Islands.

His experience covers a wide range of projects including canals and irrigation, hydro generation and pumping stations, bridges and river works, stream restoration, wetlands, ponds and dams for treatment and attenuation for a range roading projects. Tony has presented evidence before at Council hearings, Environment Court and Board of Inquiry.

1 INTRODUCTION

This paper is about the surface water related impacts, effects and the methods we used to mitigate these effects on the current New Zealand Transport Agency (NZTA) Southern Motorway Project between Christchurch and Rolleston.

1.1 PROJECT DESCRIPTION

This NZTA Christchurch Southern Motorway: Stage Two (CSM2) Project that, in conjunction with Stage 1, are being progressed as part of Christchurch's Southern Corridor Roads of National Significance (RoNS) package. This package aims to provide more efficient and safer access to Lyttelton Port and the Christchurch City Centre for people and freight from south of Christchurch.

The CSM Stage 1 Project has recently opened and connects from Brougham Street, traverses around the eastern edges of Wigram Air Force base and terminates at Halswell Junction Road.

The CSM2 Project commences at Halswell Junction Road with a new green field four lane grade separated 8 km motorway south to Main South Road (adjacent to Robinson Road). The project continues south with widening the existing two lane highway to a four lane limited access expressway of the Main South Road to the Canterbury township of Rolleston. The total project length is 17 km and also involves an additional length of approximately 16 km of local road changes.

Figure 1 overleaf shows the CSM2 Project in Yellow and the Main South Road Four Lane (MSRFL) and local roads in Blue.

The CSM2 project has just received RMA permissions from the Board of Inquiry (BOI). The project has now progressed to the detailed design phase which is due for completion later this year.

The northern end of the project is within Christchurch City Council (CCC) jurisdiction, whereas the balance of the project is within Selwyn District Council (SDC) and all is within the control of Environment Canterbury Regional Council (ECan).

1.2 SURFACE WATER

As part of any roading project and especially in New Zealand, there are a range of interactions with surface water and in this case with groundwater as well.

For our role in this project during the Scheme Assessment Report (SAR), and consenting phases, the project provided a range of challenges for dealing with stormwater, groundwater and stockwater race flows. To a casual observer, the nearly flat plains appear to have no obvious water features. Road names such as Marshes, Waterholes and Springs Road however give some indication of historic water features in the area.

The current Canterbury Plains from a water take perspective are over allocated; with the groundwater table levels now well below historic levels.

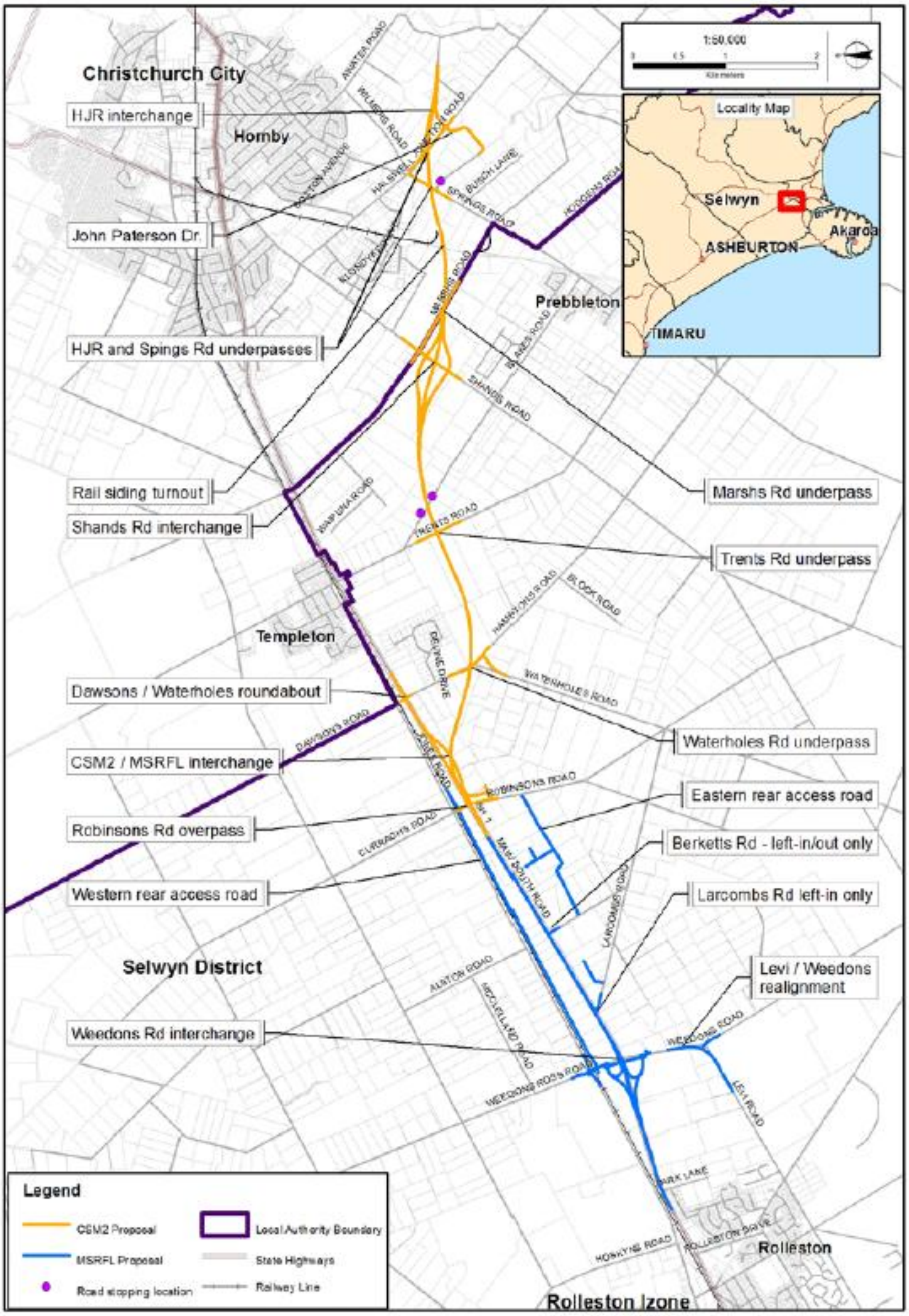

Figure 1 Project Extents

2 ISSUES AND CHALLENGES

From a water perspective there were a range of issues and challenges as set out as follows:

2.1 COLLECTION, TREATMENT AND DISPOSAL OR RUNOFF

The project crosses the plains at an oblique angle to the down gradient slope. The longitudinal alignment of the proposed main alignment is relatively flat. Runoff is well controlled from the pavement by usual application of road geometry.

The project does not cross any natural water courses but does cross nine stockwater races controlled by SDC. No discharge from the roads is permitted to any of the stockwater races. Thus all project runoff has to discharge to ground.

The degree of treatment of stormwater runoff before it is discharged to ground is prescribed in the ECan operative 'Natural Resources Regional Plan' (NRRP). In this document the discharges outside the "Less than 6 m to groundwater zone" could discharge without treatment, whereas within the "6 m zone", all discharge to ground requires treatment.

In zones where discharge to ground is within the "6 m to groundwater zone" the treatment is prescriptive and involves first flush basins and drainage through nominated media.

The proposed ECan 'Land and Water Regional Plan' was notified in 2013; however the plan is not yet operative. Thus the provisions of the plan do carry some weight in planning terms.

The design, adopted for this project, for treatment of surface water also complies with the NZTA Stormwater Treatment Standard for State Highway Infrastructure".

2.2 SELWYN COUNCIL STOCKWATER RACES

SDC has some 2,000 kilometres of existing stockwater races travelling across the plains from various river inlets or 'head works'. The various schemes began in the 1870's and 1880's and have since been added to and, in some places, retired or lost.

The races exist to supply drinking water to stock, animals and, in rare cases to rural households. Their secondary purpose is for emergency fire-fighting use.

In response to large rainfall events, SDC typically close the inlet to the stockwater race network to increase the race network capacity to be available to carry flood flows. This helps to reduce flooding of the race network and highlights the land drainage function of the network. Little information is known of the dry and wet weather flow in the networks, however SDC know that the storm flows greatly exceed the stockwater flows in some parts of the stockwater race network.

During the June 2013 floods the stockwater race network flows at the intake were reduced to 10% of the usual daily flow rate for nine consecutive days. During this time much of the lower race network was overwhelmed whilst large areas of inundation downstream of Springs Road drained away. (Note: Springs Road is a short distance downhill of the project)

The CSM2 Project crosses the plains and also crosses nine SDC stockwater races for which no discharge from the highway is permitted into the races. Notwithstanding this there are flows from the surrounding land which do enter the race network during heavy rain. These flows are transmitted downstream and most end up in Lake Ellesmere, although some races terminate in areas where soakage to ground facilities are possible.

2.3 OVERLAND FLOW

The alignment of the motorway crosses the down gradient slope of the plains at an oblique angle. The high point is near the southern end adjacent to Rolleston with the project generally falling north east towards Christchurch.

As stated above, the project crosses nine stockwater races but also crosses a number of ancient river channels.

There is no recent evidence of these old river channels carrying water within the project area, however there is evidence of these channels and land depressions holding ponded water following larger rainfall events. In the June 2013 floods, this rainfall event had a return period exceeding a 10% AEP event, extensive ponding occurred some limited distance downstream, however more limited ponding was observed at or upstream of the project alignment.

Following the recent March 2014 floods there has been further surface ponding observed. The storm frequency, in this area to the south of Christchurch, was less than a 20% AEP event however the ponding was not significant. We await further information from the CCC officers for aerial photos and rainfall analysis to confirm our assumptions and refine the project risks.

2.4 CENTRAL PLAINS WATER

The Central Plains Water (CPW) Irrigation Scheme has been consented and now forms part of the planning landscape of the area surrounding the CSM2 Project. Although detailed design and construction of the CPW had not commenced at the time of the Board of Inquiry hearing for this project, the predicted effects of the CPW scheme were considered part of the base case.

The work undertaken as part of the SAR and consenting phase for the scheme predicted groundwater level rise of more than 6 m. This rise is due to:

- Irrigation water leaking from the base of the irrigation races and other CPW infrastructure,
- As a result of irrigation, there is potential for irrigation water in excess of the evapotranspiration rate and that used by plants to infiltrate to ground, and
- The aquifer beneath the Canterbury Plains in this area is over allocated from a groundwater take perspective. As a result or the CPW Project, irrigation water will replace a number of the current groundwater takes.

As such there is a predicted rebound in groundwater levels. In so far as the CPW Project impacting on this CSM2 Project, the impacts would be observed as follows:

- At Robinsons Road the predicted effect of the CPW Project on our project was up to a 4 m rise in groundwater, and at Halswell Junction Road the predicted rise was 1-2 m, and
- Within 2 years of CPW Project construction being complete, advice received stated that 90% of the ultimate effects would be felt

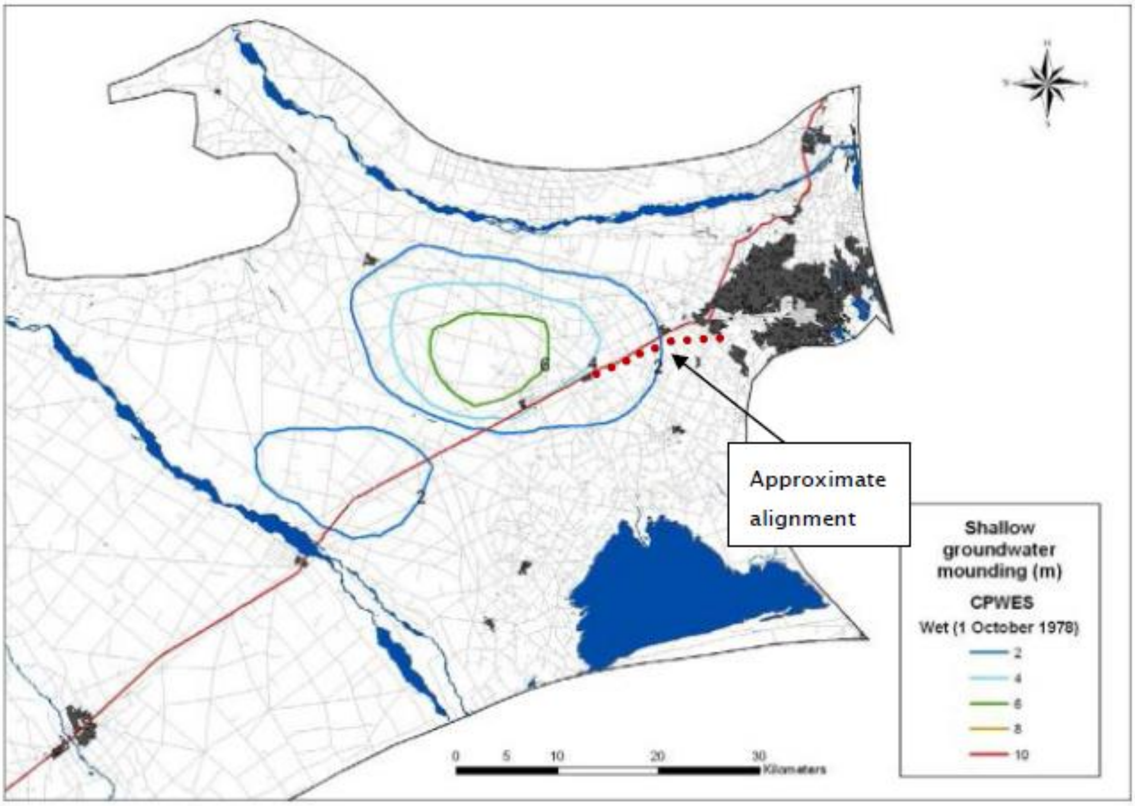

Figure 2 Isometric contours of predicted Groundwater Mounding at the CPW hearing

3 SOLUTIONS TO ISSUES

3.1 PROJECT RUNOFF

Runoff generated on the pavement is dealt with in the design process by application of relevant standards to prevent build-up of surface flow beyond 4 mm in depth. The application of a standard 3% cross fall and of super elevation where appropriate is usually achievable on two lane carriageways. We have achieved NZTA standard design criteria on this project.

Long flat vertical road profiles on this CSM2 Project however provided more of a challenge. We have therefore adopted the following approach:

- Swale drains each side of the carriageway for most of the project length. This allows for collection of pavement runoff to a swale either side of the carriageway. Each swale has a longitudinal fall, albeit near flat in places. Two third height bunds are installed in the swales at notional 100 m centres, the purpose of which is to allow stormwater to pond behind the bund. Flow through a gabion basket has been adopted to remove gross pollutants, ponding will encourage settling out of the sediment load. Downstream of the bund a connection is made to a soak pit for disposal to ground. An example of an existing swale is shown in Figure 3 below,

- Exceptions to swale collection systems occur at over and underpasses and that section of the project adjacent to Halswell Junction Road. In these cases traditional kerb and channel and pipe collection conveyance has been used,

- Where the NRRP requires further treatment, first flush basins and filtration media have been incorporated into the swale and pond designs,

- Local road, overpass and underpass runoff is also collected and treated in swales where practical,

- Adjacent to Halswell Junction Road, a series of ponds has been used for the treatment of runoff prior to discharge to ground,
- Swale performance was analysed. Total annual load of TSS, Zinc, Copper and TPH were analysed and efficiency removal or load reduction factor of 60% to 80% was used. The effect on the receiving environment was deemed less than minor,
- Much of the project relies on swale treatment prior to discharge to ground. Here much of the TSS will become trapped in the ground matrix leading to maintenance issues rather than further downstream effects. For the balance of contaminants, the situation is complex and dependent upon vegetation and the constructed build-up of soil matrix in the base of the swales. Pre-treatment within the swales will reduce particulate and soluble fractions of contaminants, and
- The ultimate receiving environment for most of the project is the surrounding ground and the potential effect on the project on discharges to groundwater was also considered.
- This assessment included;
    - depth from ground level to groundwater,
    - the distance and depth of existing water take bores from the project, and
    - the potential for contaminant reduction between base of swale and groundwater.
- In order to mitigate for effects on users of water takes, shallow bores and those additional bores in close proximity to the project alignment would be closed off and a new bore sunk at a greater distance away.

Figure 3; Example of an existing swale on MSRFL section of SH1

3.2 SELWYN COUNCIL STOCKWATER RACES

A typical stockwater race is shown in Figure 4 below.

Figure 4; Existing Stockwater Race along Marshes Road

The project crosses nine different races and sometimes more than once. As the main vertical alignment of the motorway is generally at grade, the invert of the swales either side of the main alignment are often up to 1.2 m below centreline level. We have chosen to use a duplicate siphon to convey stormwater under the motorway carriageway for a number of reasons including:

- A smaller pipe will convey normal stockwater race flows beneath the motorway in an inverted siphon. The velocity in this pipe will maintain velocity, reduce the chance for sediment deposition, and maintain a similar velocity for fish passage progression up and down the stockwater race network.

- A second larger pipe has been designed to convey storm flows beneath the carriageway. A weir structure will be used upstream and down to prevent debris entering the inverted siphon,

- As part of the safety reviews and in order to avoid human and animal entrapment at intakes during high flows, details are being developed to provide a safe environment for stock and people prior to the flood intake, and

- The duplicate inverted siphon system allows for maintenance to be undertaken on either pipe. Over pumping for maintenance is not an option for an active motorway corridor and as such a level of redundancy is included.

A typical stockwater race duplicate inverted siphon is shown in Figure 5 below,

From Weedons Ross Road the stockwater race flow north alongside the southbound carriageway and within the existing road corridor. As a result of the project widening to four lanes in this area there is insufficient room within the proposed road corridor for both the stockwater race and the swale for treatment of road runoff.

Geometry of the new highway and boundary limitations has required the design to consider pushing the stockwater race underground over a two kilometre section. Maintaining the race alignment within the designation was required for project certainty. As a result of a two kilometre piped section the impact upon fish passage was considered and mitigation measures including light wells and intake screens have formed part of our assessment.

The final solution is being developed in the detailed design phase. Possible changes include moving parts of the two kilometre section out into private property where agreement can be reached. For the balance of the two kilometre section, a piped solution will be required.

During the hearing process with the BOI and their advisors, debate as to the ability of fish to migrate up a long pipe was discussed. Alternative solutions using fish screens to deprive fish from access to the long pipe were proposed by the BOI reviewers but rejected. A solution was reached where no fish screens were to be required on the basis of increased risk of blockage and maintenance requirements. However a compromise was added to include light wells / manholes at 60 m centres for light and fish resting locations.

3.3 OVERLAND FLOW

The project alignment crosses a number of poorly defined overland flow paths.

During the specimen design and consenting phase of the CSM2, we could not define with certainty, each sub-catchment and overland flow path that would arrive at the upstream side of the project alignment as accurate topographical data (including Lidar) was not available and access to private property was also not permitted.

Our analysis was based upon identifying typical catchments and dealing with the mitigation of effects by proposed consent conditions. One of which was to limit the maximum afflux (or increase in upstream flood level) based upon the existence or absence of existing dwellings upstream of the project.

Where no existing dwelling upstream of the project existed, then a maximum afflux of 250 mm was adopted. Where dwellings were identified then a zero afflux was adopted in the passage of the 1% AEP event. These proposed afflux levels were written into proposed consent conditions. These were subsequently adopted by the BOI.

In order to pass potential overland flow, a series of single inverted siphons shall be used to convey theoretical flows beneath the project alignment. Once these flows are passed under the proposed alignment, flow dispersal downstream of the inverted siphon shall be undertaken in a manner that does not impact upon existing dwellings and structures downstream of the project.

As part of the current detailed design phase, Lidar is now available and the catchment boundaries can be defined with an increased level of confidence. Single inverted siphon locations are being confirmed. Of interest to the project team now is whether there is a likelihood of catchment hopping and/or future land use changes (rural to urban) upstream of the project.

Catchment hopping in this context is defined as flows from an identified existing catchment, flowing across to an adjacent catchment and arriving at the project boundary in a larger magnitude than the downstream catchment alone would generate. In order to overcome this potential, catchment areas are being notionally increased in area to allow for this potential.

As for water race siphons, entry to overland flow inverted siphons is also a safety issue and appropriate effort is being applied to have an acceptable screened structures. Downstream discharge locations are being confirmed and the impacts of these potential discharges are being confirmed.

Our design has relied upon CCC Waterways Drainage Guide (WWDG) guidelines for the potential rainfall/runoff rates. As the current plains have highly variable infiltration rates, discussion between the client NZTA and consultant is underway to determine whether larger irrigation trials on the rainfall/runoff model are warranted to establish a more representative infiltration design rate. The purpose is in order to potentially reduce siphon infrastructure. Otherwise WWDG guidelines will be used for the rainfall/runoff model to calculate overland flow rates.

3.4 CENTRAL PLAINS WATER

The CPW Project is now consented and as part of the impacts assessed for their consent, significant increase in groundwater rise was predicted. This was up to 6 m rise in groundwater within 18 months of the CPW scheme being operational.

However since the consent phase for the CPW Project, there has been a change in design philosophy during the CPW Project detailed design phase that include:

- Synthetic lined canals as part of the primary distribution system, and
- Fully piped secondary distribution system to the farm gate.

As a result less CPW irrigation water is predicted to be lost to groundwater. As part of our CSM2 detailed design phase, further groundwater modelling has been undertaken and revised predictions show a lessor extent in the rise of groundwater highs from the CPW Project.

The implications to the CSM2 Project are currently being assessed and although the intervention measures to reduce groundwater impacts on the project are reduced, intervention is still required.

Insofar as this project is concerned this has resulted in benefits as set out below:

3.4.1 ROBINSON ROAD

The consent design involved the CSM2 alignment at grade and a 6 deep excavation to allow Robinson Road to pass beneath CSM2. Groundwater highs predicted during the consent phase had the potential to flood the Robinson Road Carriageway.

As part of detailed design phase the vertical geometry of the main alignment has been raised by 1.5 m. Robinson Road low point (beneath CSM2) alignment has also been raised. This together with the reduction in the predicted groundwater highs result in the peak groundwater highs always being below the carriageway of the raised Robinson Road carriageway.

Note: NZTA terminology describes an underpass or overpass of a minor road in terms of the main alignment. For example:

- *At Robinson Road Overpass. The main alignment passes over Robinsons Road, and*
- *At Halswell Junction Road underpass. The main alignment passes under Halswell Junction Road.*

Stormwater runoff from the Robinson Road depression is collected and stored in a chamber to contain a short duration storm prior to discharge to ground. Primary treatment is limited to gross pollutant and some sediment removal. A low volume pump is also provided and will come into operation when the groundwater is high in order to accelerate drainage of the tank prior to the next rain event. Discharge from the pumped system is to surface soakage.

3.4.2 CSM2 ALIGNMENT, TRENTS TO HALSWELL JUNCTION ROAD

This six kilometre section of new motorway is constructed at grade. The swales either side of the motorway are up to 1.6 m beneath ground level and disposal fields are an additional 1 m beneath this level.

The only method of disposal of surface runoff is to ground over this section of motorway. The consented CPW scheme groundwater highs came within this lower 1 m zone and as such progressive failure of soakage to ground was deemed a risk during the consenting phase of the project.

As part of the detailed design phase and as a result of revised modelling predictions the disposal area remains above groundwater highs and as such, the level of risk of progressive failure of the soakage system has been reduced.

3.4.3 HALSWELL JUNCTION ROAD JUNCTION

This section of the project is the junction with the CSM1 Project. The vertical geometry falls to a low point adjacent to Halswell Junction Road underpass.

In order to achieve an acceptable degree of stormwater treatment at the Halswell Junction Road underpass location, swales were not appropriate because of lack of grade and reduced depth to groundwater highs. Traditional kerb and channel and pipe conveyance system to pass runoff to a traditional stormwater pond.

The receiving ponds adjacent to Halswell Junction Road are named as the 'Maize Maze' and 'Ramp Ponds' which are shown in figure 6 below. The Maize Maze pond includes the following features:

- First flush basin (or forebay). This is to receive first runoff from the catchment including motorway alignment and overpass local roads. This basin has a low permeability liner to encourage treatment and deposition prior to discharge to the second basin,

- Second basin. To store runoff water in excess of the first flush. This basin also has a low permeability liner for similar purposes. Discharge is by a low flow connection to the third basin,

- Third basin. This third basin has no liner and discharge to ground is encouraged.

- Collectively all three basins have sufficient volume to store runoff from the 1% AEP 24 hour event. The last basin also has a manual drain mechanism that is able to be opened subject to consent conditions that involve liaison with CCC & ECan River Managers. Discharge is to be allowed and controlled once the capacity of the downstream Halswell River has receded sufficiently to allow drainage of the ponds without affecting flooding within the river catchment.

- The Halswell River has a critical time of concentration period of up to 60 hours. The design had to allow for flexibility for storage of the 100 year 24 hour runoff and to hold this in storage until the Halswell River has spare capacity. The draining of ponds is set out in the Operational and Maintenance (O&M) manuals and allows for volume in a subsequent storm to be stored.

- The rational for manual drainage of ponds has been based upon analysis of previous storm events that showed a period of at least 2 - 3 days rain free days following each large rain event.

3.4.4 HALSWELL JUNCTION ROAD & MAIZE MAZE POND GROUNDWATER

The groundwater regime at Halswell Junction Road has groundwater highs near the base level of the proposed Maize Maze Ponds. With the CPW rise in groundwater there was a potential for groundwater to rise above pond invert level of the pond and as such flow back into and partially fill the ponds prior to a large rain event. This in turn would decrease the ability of the pond to store the required runoff volume.

In order to reduce the potential impact of rising groundwater, a gravity based, groundwater interception gallery has been developed. This has the ability to intercept groundwater and keep the peak groundwater level at the beginning of the storm to below pond invert level.

The concept relies on discharge of intercepted groundwater in a flat pipeline (1:500) and to gain elevation downstream. This pipe over 750 m in length gains sufficient elevation to allow for a discharge by gravity to Upper Knights Stream. (Note: The Canterbury plains have an average downhill gradient of between 0.7% and 1%).

A plan and section through the Halswell Junction and Maize Maze Ponds is shown in Figure 6 and 7 below.

The Maize Maze Pond and adjacent Ramp Ponds have been consented but the detailed design phase of the project is yet to commence. The stormwater philosophy developed for the consenting phase involved a series of challenges to collect and store runoff past the critical 60 hour period for the Halswell River.

By artificially holding groundwater level rise below pond invert level until at least the commencement of the large rain event, storage volumes can be maintained to the design pond volume. Groundwater lowering by a gravity based system was a key element in the design.

4 SUMMARY

The project team has successfully overcome a number of hurdles in respect of collection, treatment and discharge of stormwater and to mitigate for a number of adverse effects. In summary these include:

- Avoid project runoff discharge to SDC controlled stockwater races,
- Collection, conveyance and treatment of all runoff,
- Discharge of treated runoff to ground,
- Dealing with surface runoff that has the potential to arrive at the upstream project boundary, passing this flow beneath the project and discharging the flow in a manner that does not cause adverse downstream effect,
- Assessment of groundwater to ascertain whether mitigation is required, and
- Providing mitigation in design by a system that intercepts rising groundwater and discharge of this in a manner that does not cause worsening of flooding in the Halswell River downstream.

Further work is underway in the detailed design phase of the project. The project risks have been identified and managed in a manner to deal and to assess the impact and consequence of those risks.

One of the major contributors to the risk reduction is further detailed groundwater modelling that has led to lowered predictions of groundwater highs in comparison to the consented design. This has resulted in reduced levels of mitigation intervention.

5 CONCLUSION AND LESSONS LEARNED

The project has involved a number of problems and solutions to stormwater collection, conveyance, treatment and disposal not usually encountered on larger transport related projects.

As a member of the design team we have appreciated being part of the client interface and overall project team meetings early in the design and consenting process. This has enabled a range of options to be openly discussed with the wider team prior to locking down designation boundaries, and ensuring sufficient land and resources are available for mitigation of adverse effects.

6 REFERENCES

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7 ACKNOWLEDGEMENTS

- Client NZTA' representative, Steve Proud (Senior Project Manager).
- Stormwater Treatment Expert Witness; Earl Shaver - Aqua Terra International Ltd
- Groundwater Expert Witness; Mark Utting – Beca

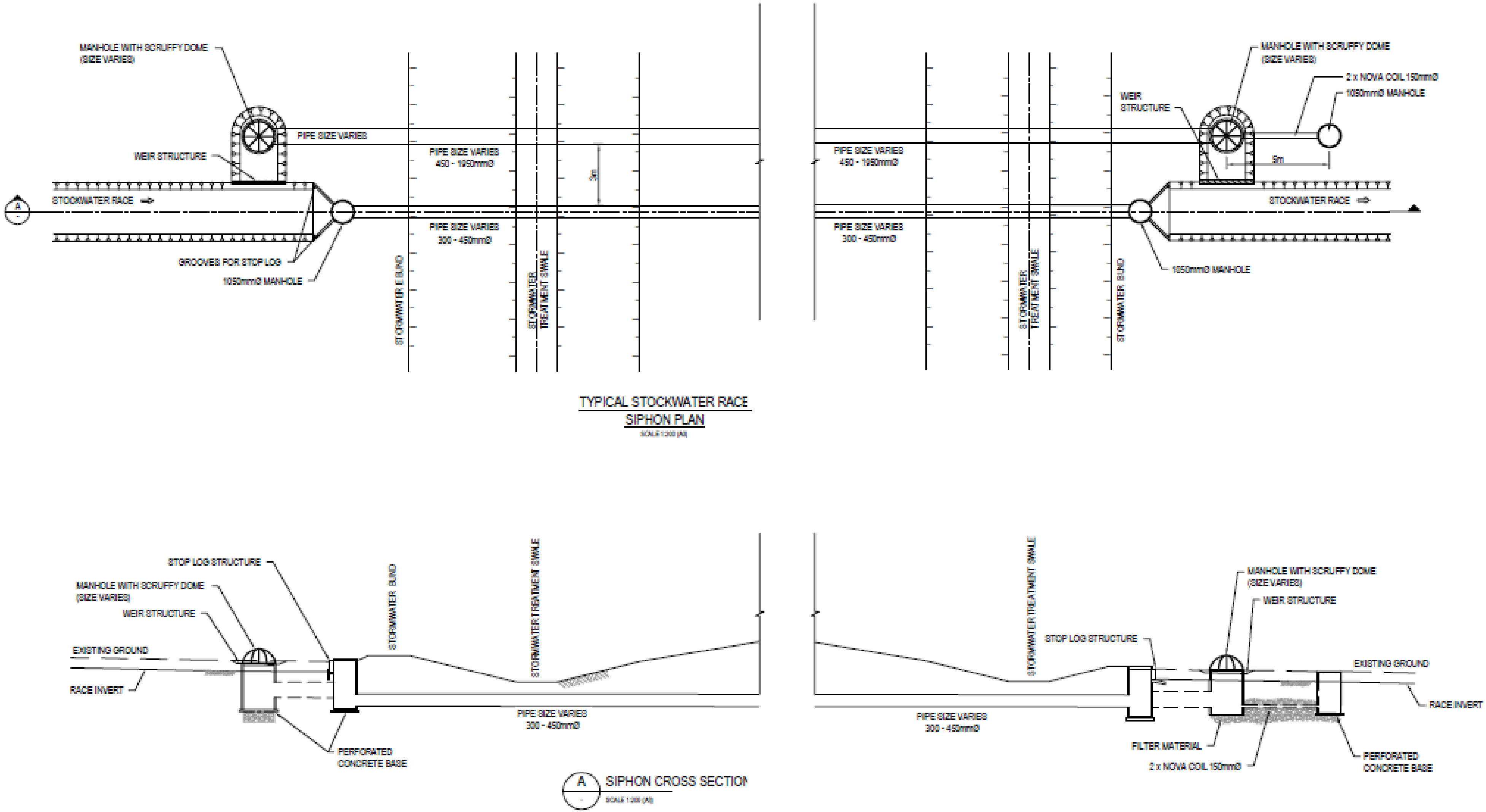

Figure 5 Showing a duplicate inverted Siphon

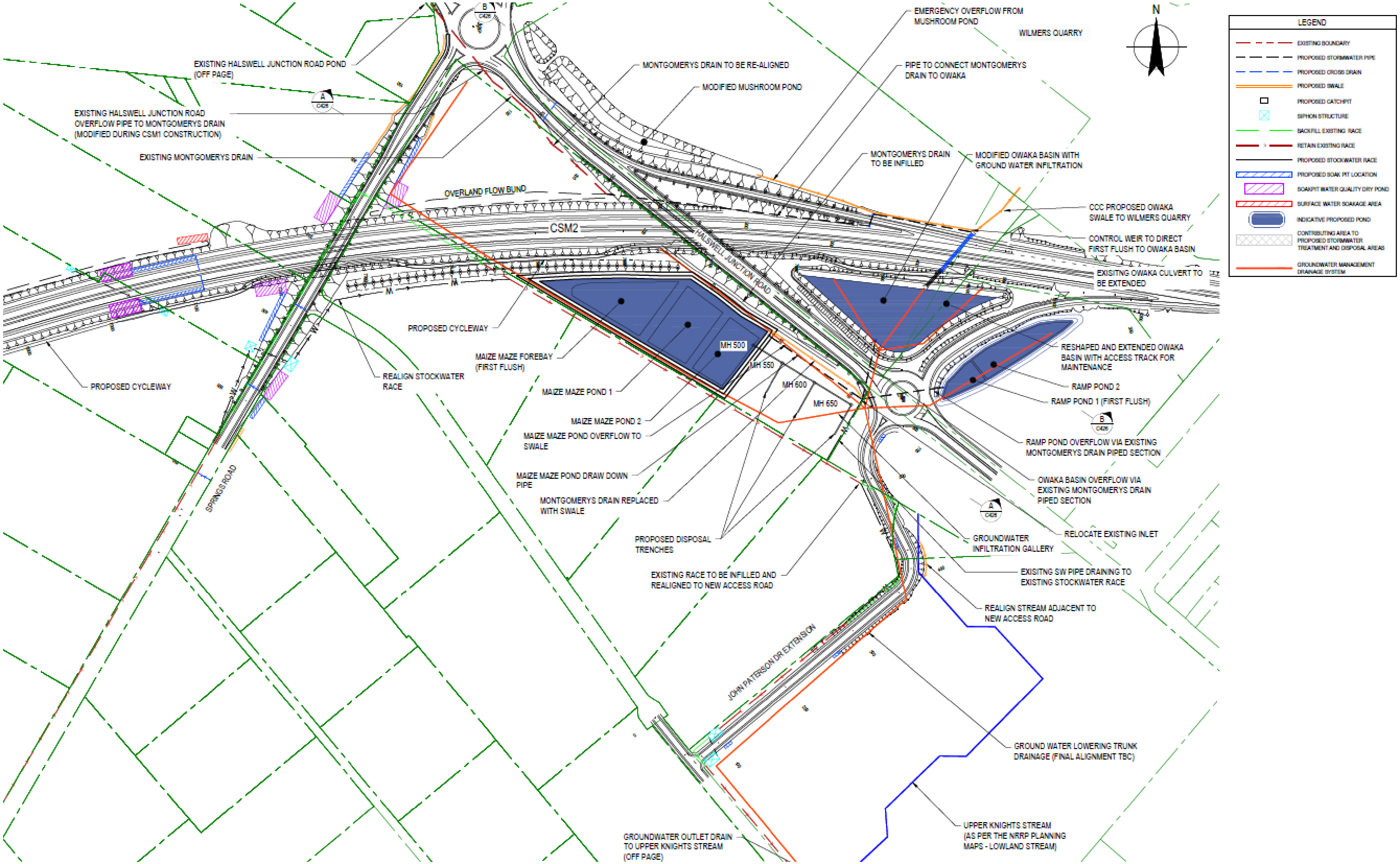

Figure 6 Showing Layout of Halswell Junction Road, Maize Maze Ponds and under drainage system

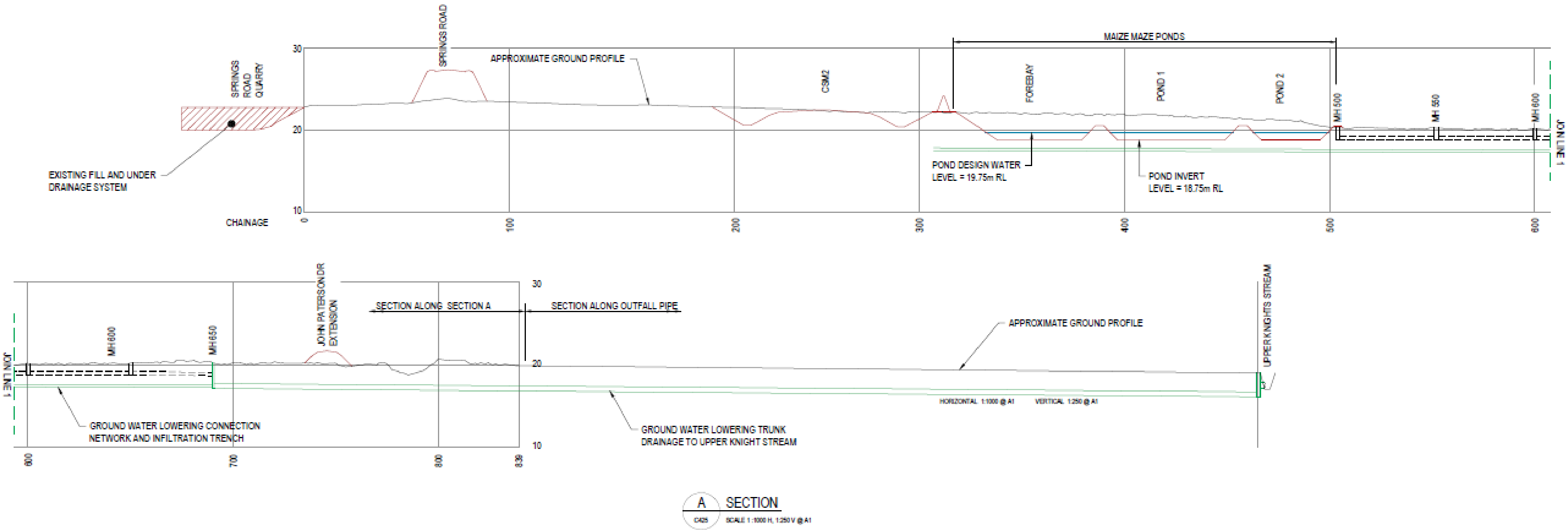

Figure 7 Showing Longitudinal Section through Maize Maze Ponds and showing the under drainage system