AUCKLAND'S CENTRAL INTERCEPTOR: INNOVATIONS FROM PLANNING THROUGH DETAILED DESIGN

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ABSTRACT

The Central Interceptor is a new wastewater tunnel proposed to run between Western Springs and the Mangere wastewater treatment plant (WWTP). The project is needed to ensure there is sufficient capacity in the network to meet planned population growth and development in Auckland, provide a more resilient wastewater system, and provide an initial remedy to historic wet weather discharges in central Auckland.

The main tunnel will be approximately 13 kilometres long and will lie between 15 and 110 metres below the ground surface, and will cross under the Manukau Harbour approximately 15 metres below the seabed. The main tunnel is anticipated to be excavated by Earth Pressure Balance TBM. It will have an internal diameter of 4.5m. Two separate Link Sewer tunnels, 3.2 and 1.1 kilometres in length and constructed by pipe jack methods, will connect into the main tunnel. Drive lengths range from 300 to 960 metres between shafts.

Ground conditions for the tunnels are anticipated to range from alluvial soils to weathered and unweathered bedrock consisting primarily of sandstones and laminated mudstones. Basalt flows are also anticipated at isolated locations. The planning and design addressed several challenges including limiting impacts on groundwater extraction and surface settlement, construction of deep shafts with limited work areas in an urban environment, and corrosive conditions in the sewer system.

Innovative solutions include reducing the number of drop shafts with the implementation of cascade-type drops, providing for non-manned entry construction methods for shafts exceeding 60 metre depth to comply with new health and safety regulations, and design of a durable precast concrete segmental tunnel lining.

KEYWORDS

Central Interceptor, sewer, tunnel, drop shaft, pipe-jacking, hydraulic analysis

PRESENTER PROFILE

Stephen has been working in the water industry in a range of roles (planning, design, operations and construction) for 30 years at Watercare and Metrowater. He is currently the Watercare Design Manager for this project.

Nigel is a Senior Principal with Jacobs New Zealand, as well as being the Central Interceptor Project Manager leading the consultant team of Jacobs NZ, AECOM and McMillen Jacobs. Nigel has over 30 years' experience working on infrastructure projects including the Sydney Desalination Plant and a number of upgrades of the Rosedale Wastewater Treatment Plant.

Victor is a Principal for McMillen Jacobs Associates (NZ), with 25 years of experience in the design and construction of tunnels and deep shafts for water, wastewater and transportation projects. Victor leads the McMillen Jacobs Associates team in New Zealand.

1 INTRODUCTION

Watercare Services supplies water and wastewater services to approximately 1.4 million people living in Auckland, New Zealand. Over the next 30 years this population is expected to exceed 2 million. Our challenge is to meet the demands of growth without compromising on our mission to deliver reliable, safe and efficient water and wastewater services.

Over the next 20 years Watercare will invest almost $6 billion on expanding and upgrading the wastewater network. Part of this investment is the construction of the Central Interceptor, a deep tunnel sewer scheme for conveyance and storage of wastewater from the combined sewer network in central Auckland.

Older parts of Auckland's wastewater system were designed as a combined wastewater/stormwater system collecting both flows in a common pipe. The system includes around 110 overflow structures that discharge diluted wastewater to the harbour and urban streams during heavy rainfall; half of which discharge more than 50 times per year. The Central Interceptor tunnel will divert these overflows to the treatment works resulting in significant environmental improvement. Watercare has obtained resource consents from the regulator to build the scheme which must be operational by 2030.

A further benefit of the tunnel is to reinforce an ageing network which includes a marine crossing that is spigot and socket pipe laid in a shallow trench on the harbour floor. The tunnel will traverse the harbour at depth on a different alignment, which will allow the existing pipe to be inspected and potentially rehabilitated.

The Central Interceptor is being provided to enable growth in the central areas of Auckland, but has wider regional benefits as it provides an alternative flow path to the Mangere WWTP.

After ten years of planning, the project is now moving into the procurement phase. Watercare will appoint a contractor in late 2018, with construction expected to take seven years through to 2025.

The wider scheme has three companion projects:

- CSO Collector Sewers – up to 15km of smaller collector sewers to intercept approximately 100 combined sewer overflows scattered around the western isthmus of Auckland Central; other options include storage tanks or separation

- Waterfront Interceptor – an extension of the Central Interceptor tunnel into the central suburbs: Westmere, Grey Lynn, Ponsonby, Herne Bay and St Mary's Bay

- Wet weather treatment plant – an advanced treatment system at the Mangere WWTP which can handle the combined sewage at a high flow; alternatives are being considered including ballasted flocculation and chemical dosing.

These projects are being reviewed through joint planning between Watercare and Auckland Council's Healthy Waters (council's department that manages stormwater infrastructure) to develop an optimised programme of capital investment.

Figure 1 Graphic showing the geographical location of the Central Interceptor in Auckland

2 PLANNING STAGE

2.1 CONCEPT AND PRELIMINARY DESIGN PHASES

2.1.1 CONCEPT DESIGN

The Central Interceptor project emerged from Watercare's Three Waters Strategy as the preferred solution and Best Practical Option (BPO) for resolving combined sewer overflows from older parts of Auckland's central suburbs. It will also provide for growth in Auckland central suburbs and reduce the risk of premature failure of key network assets in the deeper sections of the Western Interceptor and under the Manukau Harbour.

The Concept Design was completed in 2010 and was submitted as part of the Assessment of Environmental Effects (AEE) for resource consents which were granted in 2012.

Further development of the design was undertaken from 2014 once appeals had been resolved.

2.1.2 PRELIMINARY DESIGN

This phase of the project involved creating new tools and gathering additional data to ensure that the best available information was used to test the Concept Design layout and further optimise the design.

Data gathering included:

- An extensive campaign of geotechnical investigations including 190 rotary boreholes up to 110m deep, including 24 boreholes from a barge in the harbour. Every land based borehole was hydro-excavated to approximately 1.5m depth to check for underground services prior to drilling. In addition in situ tests and geophysical investigations were undertaken.

- Three campaigns of sewage sampling, characterisation and modelling (over summer – winter – summer periods to account for seasonal variation)

- Survey of existing network assets and facilities to confirm tie-ins and site layouts.

As part of the geotechnical investigation Watercare made the cores available to Auckland University geologists for their research in volcanology. Additionally the entire borehole dataset has been uploaded into the New Zealand Geotechnical Database. The cores have all been stored for later examination by tenderers.

Watercare's design team used a number of key tools in developing the design:

- Infoworks CS hydraulic model to assess all incoming flows from the existing network, the effects of different storms and the need for real time control of control gates in the connection points between the tunnel and the network

- Illinois Transient Model (ITM) to assess the effect of surge on tunnel size and performance

- Physical models of drop shaft and pump station wet well

- A number of spreadsheet models for sulphide modelling and pneumatics modelling

- Calpuff atmospheric modelling for assessment of odour dispersion

- A Vulcan 3D geological model of the subsurface ground conditions

- A Navisworks model to federate other models (Autoplant, Prostructures, etc) for the Mangere pump station

The Infoworks CS model is the backbone of the project with the bulk of the hydraulic analysis being done with this model. The model has a long pedigree with over a decade of evolution with refinements being made as updated asset data becomes available. Prior to commencement of the Preliminary and Detailed Design phases the model was reviewed and checked for accuracy, and where found to be deficient, new data was collected and added.

A key feature of the model was integrating hydrological and population information to be consistent with Auckland's growth strategy. The use of an intermediate level growth projection, Unitary Plan development controls and a maximum probable development for impervious surfaces future-proofs the project. Additionally sensitivity tests were undertaken and adjustments were made based on climate change predictions allowing for sea level rise and increased storm intensity.

Although 12 synthetic storms were checked, the Design Storm guiding most of the design was a 10 year ARI with climate change and a safety factor for an increased impervious area.

Checks were made for the governing storm in the pneumatic analysis, and if another storm had a greater effect then the system for handling the venting was adjusted.

Hydrographs from the Infoworks model were used as inputs to the ITM model. Three storms were considered in the surge analysis and each one was evaluated for its effect on the tunnel.

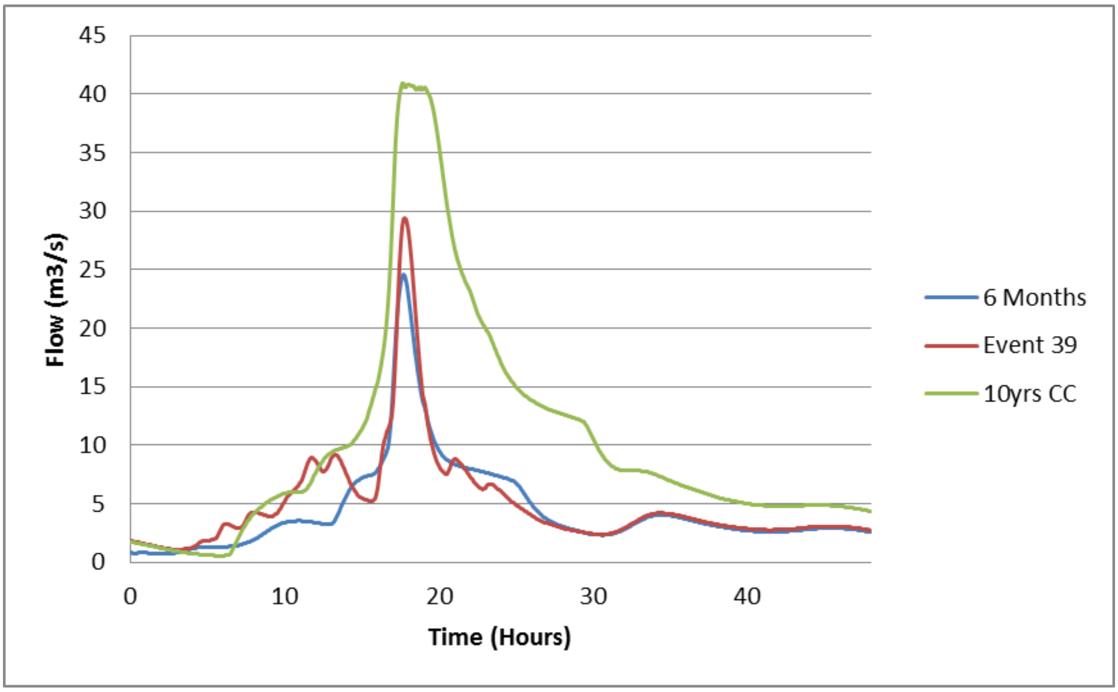

Figure 2 Hydrograph comparing the different storms used to assess the Central Interceptor's performance for managing surge

Surge was found to be the governing factor for sizing the tunnel hydraulically (as opposed to constructability concerns). The selection of the 10 year storm was seen as appropriately conservative given that the other storms did not include the effects of climate change.

The 10 year storm has a larger total volume than other storms, but the ability to store and pass forward flow to the Mangere Wastewater Treatment Plant had to be factored in as well. Using a hydraulic model to evaluate this situation was indispensable.

2.2 DETAILED DESIGN

2.2.1 MAIN TUNNEL DESIGN

Auckland's geology is strongly influenced by volcanic activity with over 50 scoria cones and basaltic lava flows overlying weak sandstones. The East Coast Bays sandstone formation that constitutes the bedrock in Auckland is the preferred tunnelling medium over the harder basalt flows and mixed alluvium layers.

The tunnel corridor is consented in terms of vertical and horizontal position. The shafts are fixed by designations and proximity to the overflows that they will intercept. The tunnel profile has been set at a level that ensures adequate cover under the Manukau Harbour sea bed, and provides appropriate depth at the upstream end for future connections. Avoidance of paleovalleys (where mixed face conditions could lead to high water inflows) and SH16 bridge piles have also been factored into the elevation and alignment.

The new tunnel will be driven at 1 in 1000 grade. This grade was checked to ensure that the flow in the tunnel would be self-cleansing, based on flow inputs at each connection point.

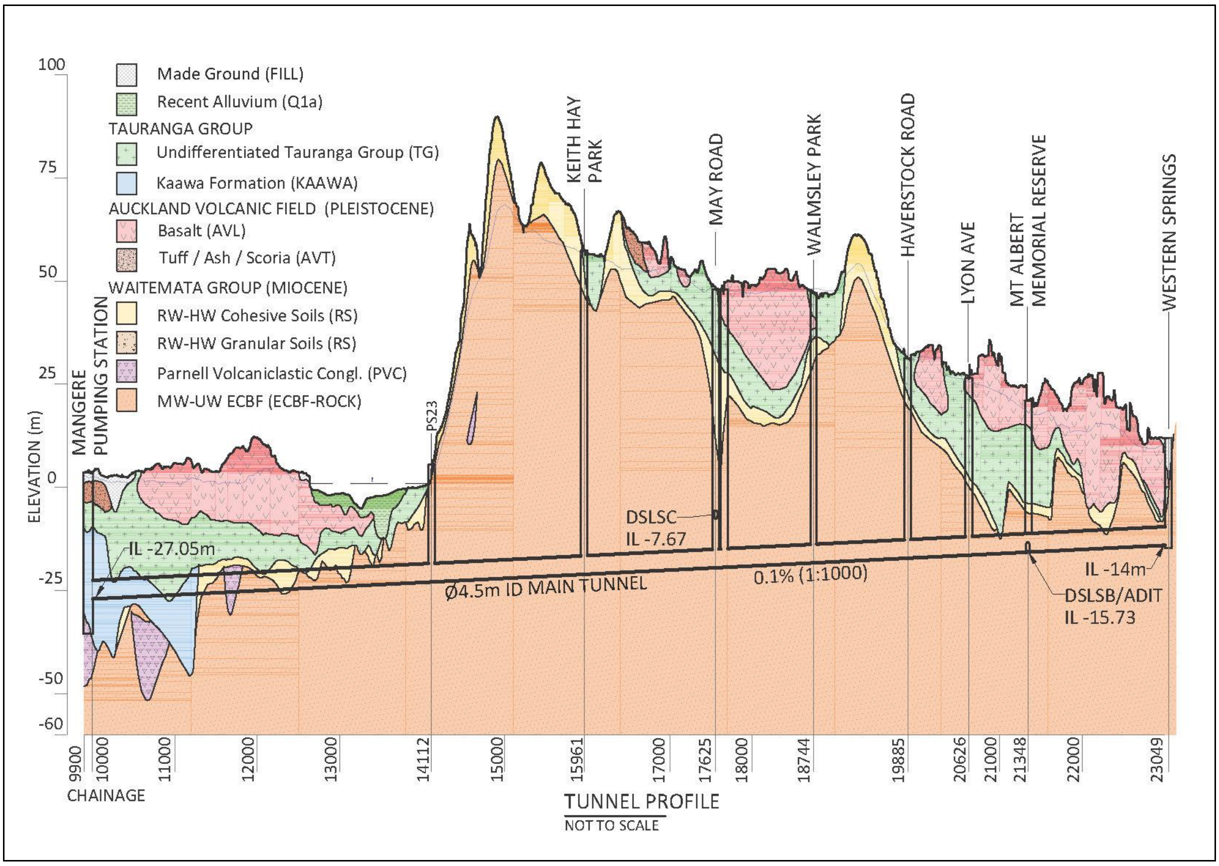

Figure 3 Geological Long Section of the Central Interceptor Main Tunnel

The tunnel traverses central Auckland which is a moderately intensively developed suburban environment. Although there are pockets of commercial and multi-storey apartments it is generally under low rise residential development. The tunnel and associated link sewers will pass at depth under two motorways and three rail crossings and many of the shaft sites are alongside urban streams prone to flooding.

The tunnel depth also means that it will encounter fewer manmade obstacles and the surface effects of tunnelling will be minimised (such as noise, vibration and settlement).

Shafts are located along the consented corridor in a number of parks and a few properties owned or leased by Watercare. Even where Watercare has purchased property the shaft sites are very restrictive and managing construction traffic and disruption will present some challenges to the contractor.

2.2.2 SULPHIDE CORROSION

As part of the tunnel design Watercare has investigated the sewage characteristics within the existing network and found that it is moderately to highly corrosive. Structures installed at the Mangere WWTP in the last 30 years have been found to be heavily corroded. Inflow management through a trade waste compliance team has also helped to reduce the rate of deterioration, but for a deep sewer tunnel with limited access Watercare has put extra effort in to understanding and countering the anticipated effects of the in-sewer environment.

To address these concerns Watercare undertook three campaigns of sewage characterisation, sulphide modelling and considered the need for permanent forced ventilation. It was concluded that even with ventilation and air treatment that the material selection would play an important part in achieving the 100 year design life with limited maintenance. The decision was made to invest in a programme of proving advanced materials that would be used for tunnel and shaft lining.

Investigation of a range of corrosion-resistant materials and sacrificial lining solutions concluded that an acid resistant concrete was the preferred solution. Watercare has been testing a range of materials that profess to have superior acid resistance including geopolymer concrete, anti-microbial additives, calcium aluminates and Ordinary Portland Cement blends with silica fume and pulverised fly ash.

Many of these products have been around for decades, but there is limited information available about their use on sewer assets and precast tunnel linings. Local aggregates have also been tested with these mixes rather than rely on international studies using aggregates that are unavailable in New Zealand. Laboratory testing has included physical properties for pre-casting and in-situ applications; as well as acid bath and biogenic incubation tests.

2.2.3 LINK SEWER DESIGN

There are 4.3km of link sewers ranging between 2m to 2.4m internal diameter at depths ranging from 10m to 65m. The two link sewers serve distinct purposes. Link Sewer C duplicates the Western Interceptor and replaces the vulnerable Hillsborough tunnel and Manukau Siphon sections (under the Hillsborough ridge and Manukau Harbour respectively). Link Sewer B intercepts a number of overflows as well as diverting flow off the Branch 8 sewer and Orakei Main Sewer; thereby creating more headspace for growth in the downstream catchments.

The link sewers service different areas have different sizes and will handle different concentrations of wastewater. Link sewer C will be subject to more corrosive conditions. The construction contractor will have the freedom to select the pipe material best suited to the installation methods, soil and groundwater pressures, and corrosion requirements but it is anticipated that Link Sewer C may be GRP pipe and Link Sewer B concrete pipe. Both Link Sewers are expected to pipe jacked, as the underlying geology, groundwater and distance between shafts permit this technique as described in Table 1.

Table 1 :Link Sewer Drive Lengths

Link Sewer	From/to Shaft Name	Sewer diameter	Drive length	Maximum Hydrostatic head
Link B	Rawalpindi Reserve to Norgrove Ave	2.4m	308m	12m
Link B	Norgrove Ave to MAWM	2.4m	797m	20m
Link C	PS25 to Miranda Ave	2.1m	332m	10m
Link C	Miranda Ave to Whitney Ave	2.1m	612m	22m
Link C	Whitney Ave to Dundale Ave	2.1m	583m	29m
Link C	Dundale Ave to Haycock Ave	2.1m	722m	33m
Link C	Haycock Ave to May Rd	2.1m	966m	56m

The Concept Design had two more link sewers (A and D) which crossed Western Springs Park and Mangere Bridge respectively. Both link sewers had problems with complicated geology (basalt flows) so alternatives were developed to eliminate these sewers.

In order to delete Link Sewer A, flows were diverted to the Rawalpindi Reserve by extending and re-grading a future CSO Collector Sewer (beyond the scope of this project). This decision has thereby eliminated two 22m deep shafts and 970m of DN2100 pipe. The change also adds a motorway crossing under State Highway 16.

For Link Sewer D it was decided to keep the small flows from Mangere Bridge in the Western Interceptor rather than build a technically challenging, unpopular shaft and air treatment facility (ATF) on the Manukau foreshore. This decision thereby eliminated a 28m deep shaft, activated carbon ATF and 590m of 450 pipe trenched in basalt rock; but added periodic flushing of the Western Interceptor through to the WWTP.

2.2.4 DROP SHAFT DESIGN

The tunnel will intercept numerous points in the existing network. Because it is at considerable depth the flow must be dropped into the tunnel in a way that reduces the potential energy that could be imparted to the structures. In the Concept Design it was envisaged that vortex drop shafts would be used, however these require a de-aeration adit and shaft. An alternative design is the cascade drop shaft which is illustrated in Figure 4 below.

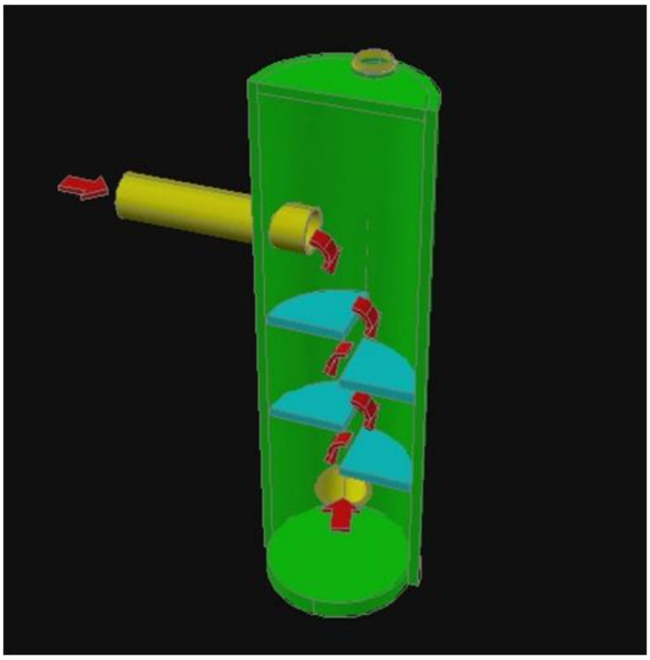

Figure 4 Cascade drop shaft graphic and physical model

Watercare has examples of large drop shafts in its current network. The Rosedale WWTP outfall tunnel has a large cascade drop shaft, whilst the Hobson tunnel has two vortex drops.

A cascade drop was chosen for most of the drop shafts because it is an economic and lower footprint option. This type of drop shaft has been proven internationally and permits man entry for inspection and maintenance. The cascade style of shaft has a dry side and a wet side. The wet side includes baffles or steps (quadrant shaped) at approximate 2-3 meter spacing. This means that the flow never drops more than this height. The deepest shaft is 78m from top to bottom, so the cascade drop shaft provides a means of dropping the flow without damaging the shaft structure. The dry side allows for inspection by CCTV camera or man cage (dimensions of 1500mm by 900mm) lowered by mobile crane into the shaft.

Other benefits of cascade shaft include:

- No special inlet structure required, so surface structures are more compact
- Reduces the level of air entrainment so a deaeration chamber and vent are not required
- Allows for refinement of shafts to suit a wide range of influent flow rates
- Allows for multiple sewer entry points using one drop shaft
- Is largely self cleaning
- The wet side allows for ability to reduce surge effects

The cascade drop shafts were modelled at Auckland University's fluids lab in Newmarket (refer Figure 4) at 1:10 scale for a range of scenarios, including with the tunnel at various stages of filling and different flow rates entering above the main tunnel. Other considerations checked with the physical model included an offset "centre" wall and the shaft mounted directly over the tunnel to reduce the need for an expensive horizontal adit tunnel. These alternatives had been previously modelled without being built, or built without being modelled; so the checks were a necessary part of proving the design. Air flow was also checked by smoke testing. The physical modelling confirmed that the shafts performed well under all scenarios.

Table 2 Shaft characteristics on Main Tunnel

Name	Hydraulic Internal Diameter	Invert Depth	Drop Type	Notes
Western Springs	10.8m	26m	Vortex	Work shaft
Mt Albert War Memorial	4.5m	37m	Cascade	Off-line drop
Lyon Avenue	7.5m	44m	Cascade	
Haverstock Road	7.5m	49m	Cascade	
Walmsley Park	3m	66m	Cascade	Drilled shaft, FRP cascade structure
May Road	7.5m	69m	Cascade	
May Road Work Shaft	10.8m	69m	Vortex	Work shaft
Keith Hay Park	3m	78m	Cascade	Drilled shaft, FRP cascade structure
PS23	4.5m	27m	Cascade	
Mangere Pump Station	13.3m & 16.2m	31m	n.a.	Dual cell D-wall shaft, work shaft

Table 3 Shaft characteristics for Link Sewers

Name	Hydraulic ID	Invert Depth	Notes
Rawalpindi Reserve	5.75m	26m	Link B
Norgrove Ave	4.5m	28m	Link B
PS25	4.5m	12m	Link C
Miranda Ave	4.5m	12m	Link C
Whitney Ave	n.a.	33m	Link C work shaft, backfilled

Dundale Ave	n.a.	25m	Link C work shaft, future access shaft
Haycock Ave	5.75m	31m	Link C

At two work shaft locations vortex drops were chosen since there are large construction shafts sized for the TBM insertion/removal so they can easily accommodate the drop structure and provide the necessary venting facilities. Other minor structures include smaller cascades and plunge drops in approximately 50 ancillary surface structures that connect the sewer network to the drop shaft.

Another innovation was to consider whether the two deepest shafts could be built at the minimum hydraulic diameter to avoid some of the Mining Regulation requirements for safe entry to a deep shaft over 60m deep. To meet this requirement the minimum shaft size would be 4.5m diameter, since winding gear and safe access stairways (or lifts) are required for shafts at this depth. In reality conventional excavation would make the shaft much larger.

Contractors advise that they can blind-drill a 4.5m shaft to 50m but this is about the limit of current technology available in New Zealand. In Australia contractors are building 9m shafts to 45m so the challenge of a 3m shaft to 78m seems feasible.

The proposed solution is to blind-drill to full depth with slurry support of the excavation. Then precast fibre reinforced plastic (FRP) sections of the cascade shaft are inserted and bandage joints are made at the surface before lowering the assembly into the excavation. The slurry is pumped out and the annulus grouted. This technique is not new as it has been previously done on another Watercare project (the Orewa West pump station) to a depth of 25m. The tricky part is connecting the shaft to the precast tunnel lining, but again the Rosedale outfall tunnel has provided some learnings on how to do this safely.

Shaft internal diameters were usually determined to accommodate hydraulics needs, corrosion protection, shaft sinking techniques, and tunnelling operations. Internal diameters were standardised where possible. The shaft excavated diameter is based on temporary support and permanent lining thickness requirements, which assumed construction tolerances for the proposed excavation support systems.

There are nine shafts along the main tunnel alignment, seven shafts along the link sewer alignments, and one large 'dual-cell' shaft for the Mangere Pumping Station. This latter shaft will be slurry wall construction due to the variable ground conditions in Mangere which comprise layers of peat interbedded with marine sediments. The dual shaft consists of two interlinking shafts of 12m and 26m diameter with a common wall (see figure 5).

The dual cell shaft for the Mangere pump station has a number of benefits in terms of providing a back-shunt for launching the TBM and providing a generous sized work area to assemble the TBM at depth. Once the TBM has been launched the tunnelling activity and pump station build can continue concurrently saving time on the critical path. Once tunnelling has been completed the smaller of the shafts is used to connect the air treatment facilities and the emergency pressure relief to the tunnel.

All of the works will fall under the Mining Operations and Quarrying Operations Regulations 2016 which imposes requirements for risk planning and certified officers to oversee the project. Principal Hazard Management Plans and Principal Control Plans are required and the design team has prepared draft documents as part of the Safety in Design processes employed on this project.

2.2.5 MANGERE PUMP STATION (MPS)

The flow coming from the tunnel into the pump station flows through an inlet chamber into the wet well. From there suction pipework draws the sewage through to the dry well submersible pumps which lift the water some 30m to the rising mains that run through the WWTP to the plant's head-works. There are six variable speed pumps (5 duty plus 1 standby) capable of pumping a total of up to 6 cubic metres per second. The pumping rate will be controlled so that the total inflows into the WWTP do not exceed the plant capacity.

The pump station will typically operate on level control with radar sensors located in the wet well. During storms the pumps will switch to flow control using twin magflos located on the rising mains. A failsafe level sensor in the WWTP head-works will trip the pumps if the inflow to the plant exceeds a set point.

The twin rising mains are 1400 OD PE100 (PN12.5) pipes and will run 873m from the north end of the plant into the most congested area of this busy complex. Given their size and the other facilities in the way, this will be a challenge. But the connection point into the WWTP head-works, known as the confluence chamber, is arguably the most critical part of the WWTP as it receives all of the incoming flow which can be up to 9 cubic metres per second. Building the connection point will require bypassing some of this flow, so the temporary works for over-pumping will be substantial.

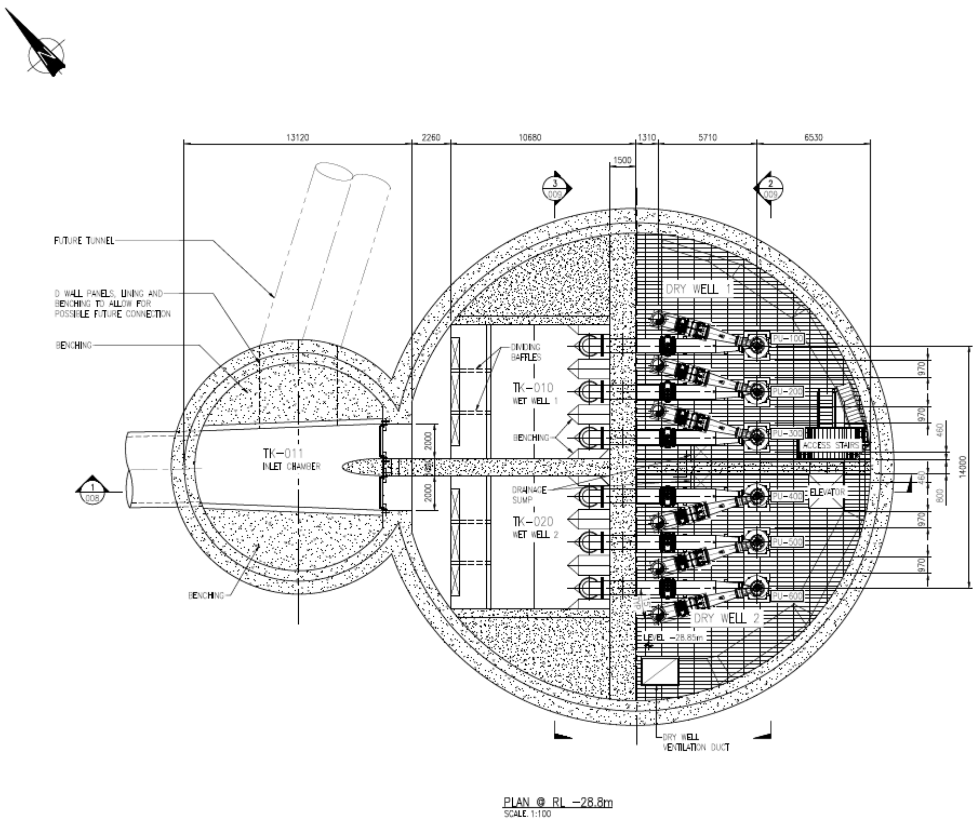

Figure 5 Mangere Pump station in plan view

A further example of resilience of the Central Interceptor scheme is the consent requirement for standby generation at the Mangere Pump Station. Although the pump station has an 11kV ring main supplying it with power from the local Vector substation Watercare will be installing 5MW of diesel generation as a dedicated, in-situ alternative power supply. This will ensure that the pump station should not fail due to a lack of power. The twin wet/dry wells and dual rising mains provide additional resilience.

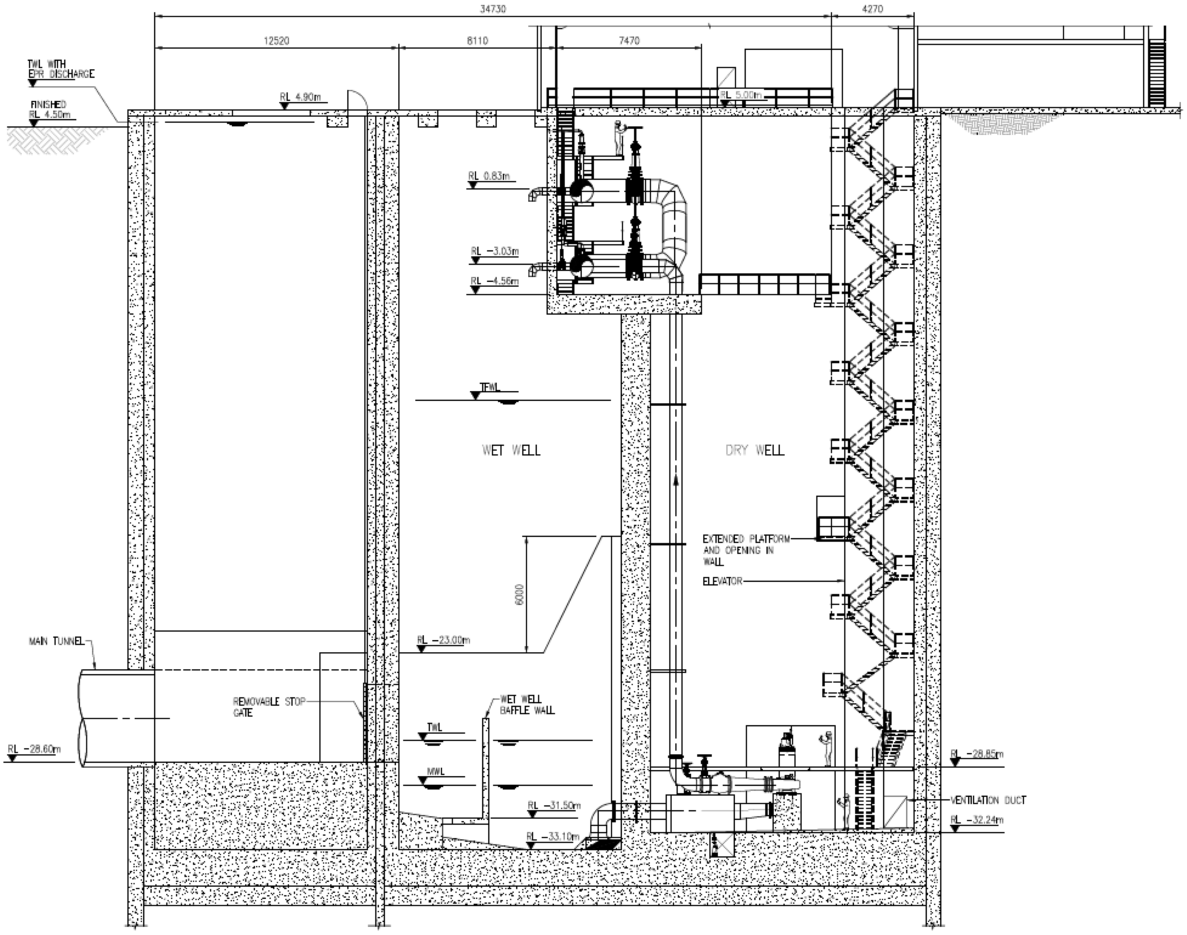

Figure 6 Section through the Mangere Pump Station

2.3 PNEUMATICS AND ODOUR CONTROL

Large diameter sewers have capacity to store large flows but at any time the tunnel is full of water, air or an air-water mix. When the tunnel fills with water the air must be exhausted and as it drains air must be let in to maintain equilibrium. In turbulent, high flow scenarios when the tunnel fills rapidly the potential exists for an air-water mix to be created. As the tunnel becomes full at the downstream end, a surge wave can be created that can travel at speeds in excess of 200 metres per second. If this occurs the water level becomes unstable resulting in the potential for geysering.

The control and balancing of air flow in the tunnel is achieved by weighted dampers. The entire 13km main tunnel and Link Sewer B will operate under negative pressure with forced ventilation operating from the MPS at 12.5 m3/sec. Link Sewer C will be separately ventilated by the fans at the May Road shaft site at 3.5 m3/sec.

This approach to forced ventilation ensures that odours are controlled and the corrosion potential of the sewer environment is reduced. It also makes the tunnel safer should man entry be required.

At the MPS and May Road sites air treatment facilities will be provided:

- At MPS a large open biofilter will be built, similar to others at the Mangere WWTP
- At May Road a closed (covered) biofilter will be required, based on achieving outcomes defined in a performance specification

In the event of a surge incident requiring the rapid evacuation of air from the tunnel, each shaft has an emergency air vent that is also controlled by weighted dampers.

These vents will act as a safety fuse on the rare occasion when a transient wave occurs in the tunnel during intense storm events. In these rare events the tunnel will be full of dilute storm sewage and the risk of odour issues will be minimal.

2.4 REAL TIME CONTROL (RTC)

In order to prevent the instability that occurs when the tunnel overfills, real time control gates are to be installed at the critical connection points to the tunnel shafts. The gates are required at twelve locations and range in size from 0.675 to 2.4m diameter. They will be hydraulically actuated with accumulators sized for two full open-close sequences in the event of power outage.

Additionally the gates are designed for double isolation (an RTC gate and a "guard" gate) so they can be maintained safely. By actuating the critical guard gates and connecting them to Watercare's SCADA network there is a backup gate should the primary RTC gate fail or get jammed. This further demonstrates how the system has been designed for resilience.

The gates are categorized as Priority 1 or Priority 2 depending on the sequence of operation with the objective being to minimise both the frequency and number of locations of wet weather overflow to local streams. Priority 1 gates are positioned on the larger connection points. Hydraulic modelling of tunnel operation during a 5 year time series indicates that Priority 1 gates may close about six times per year; whilst Priority 2 gates may operate about twice per year.

The RTC gate settings ensure that priority is given to sanitary sewage flows from the Western Interceptor (over the combined sewer flows, which are diluted by stormwater). This ensures that not only are the first flush flows from the combined network captured before the gates close, but the more concentrated sanitary flows are contained as a priority. In the event that the tunnel is filled, it is the most dilute storm sewage that is released to the environment.

The hydraulic analysis with RTC controls showed that so long as the MPS was still functional the tunnel only filled in the 10 year ARI Design Storm (with the allowances for climate change and 25% increase on the Maximum Probable Development levels of impervious surfaces). Full model runs showed that annual % capture of overflow volume exceeds the 80% consent requirement.

2.5 SOLIDS MANAGEMENT

The management of grit, sediment and floatables is not unique to Watercare's network. However the point of difference is the depth and accessibility of the Central Interceptor. The ability to maintain the tunnel and link sewers will be limited due to these constraints so it is essential that the sewers are designed with low maintenance and infrequent access requirements top of mind.

The philosophy adopted has been to restrict the entry of solids into the deep tunnel by using side weirs, or "bifurcations". These weirs permit the dry weather flow to continue flowing in the existing (relatively) shallow system where there are facilities like grit traps to manage the accumulation of solids. In some locations full diversion of flow has been allowed, but with a mind to maintain self cleansing velocities in the 4.5m diameter tunnel.

In two locations where access is very restricted there are raked screens to prevent the entry of larger debris, such as plastic bottles and floating logs. This is a "belt & braces" approach since the debris must first pass over the side weir, which are typically set at the peak dry weather flow level, with the ability to raise the weir with timber boards.

In some locations provision has been made to retrofit rock traps and grit traps if deemed necessary at a later time. This space proofing was not possible in all locations due to the amount of available land and upstream network configuration.

The design of the MPS wet well has taken into account the potential for grit and fat to accumulate; though the latter issue tends to be quite localised in the network due to a robust trade wastes regime. Large hatches and pump operation “snore” cycles will assist to manage this issue at the MPS, and most of the debris will pass through the pumps.

The emergency pressure relief at the Mangere Pump Station also has raked bar screens to prevent large solids being discharged to the harbour in extreme storm events.

3 THE TUNNEL BORING MACHINE (TBM)

The work-horse for the project will be the TBM that will be used for the Main Tunnel. At over 5m diameter it won’t be the largest machine used in New Zealand, but it will rank as one of the largest used on a local wastewater project.

The machine has been specified as an Earth Pressure Balanced (EPB) machine which acts like a submarine below the water table. The use of EPB machines in New Zealand is not new as Watercare has completed two projects in the last decade using this technology: the Hobson Bay tunnel and the Rosedale WWTP outfall. Lessons learnt from these two projects have been factored into the design of the Central Interceptor. However the risks to be encountered with this project include the submarine section under the Manukau Harbour and a number of mixed face reaches which have confirmed the need for an EPB machine. The EPB machine will be operated in closed mode through these reaches. The specification of an EPB machine also mitigates the risk of excessive settlement occurring in sections with more sensitive geology.

Other features of the specified machine include:

- The ability to tunnel through short sections of basalt rock (most of the alignment is the weaker East Coast Bays Formation (ECBF) sandstone)
- Reversible twin screw conveyors
- Ability to perform probe drilling in advance of the cutterhead
- Backloaded cutter tools
- Reversible, variable-speed cutterhead drive system
- Real-time data monitoring system
- Laser guided GPS system

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4 CONCLUSIONS

The Central Interceptor project has provided the opportunity for some "out of the box" approaches to design. Some of these solutions are:

- The design has modified some of the shafts from concrete to GRP so that they can be prefabricated and blind-drilled from the surface which avoids man entry into the deepest shafts. This modification to the concept design takes account of regulatory changes, but recognises that the hydraulic requirement can be met without building over-sized shafts to meet man access requirements if suitable technology can be employed. It should also result in a shorter construction period and less disruption to stakeholders.

- In modern engineering the cascade drop shaft has been used for over 100 years (and back into antiquity), but the features employed on this project which depart from the standard design include the off-line centre wall and the shaft over the tunnel

- The study into acid resistant materials is expected to demonstrate alternate materials that will be more durable than Ordinary Portland Cement and ensure that the 100 year design life can be achieved.

- The dual cell shaft for the Mangere pump station has a number of benefits in terms of the tunnelling activity and pump station construction. It saves time on the critical path, and once construction is finished the smaller shaft connects the air treatment facilities and the emergency pressure relief to the tunnel.

The Central Interceptor project has been a decade in the planning phase, and has taken three years in design. A robust process of challenge and review has helped to evolve the design so that it meets its objectives to be a resilient and durable solution. The next phase is expected to take a further seven years through to completion in 2025. The Central Interceptor is one of the largest infrastructure projects in New Zealand and the largest undertaken by Watercare Services.

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David Ward has led the Watercare team through the consenting and detailed design phases. Nigel Kay has led the consultant's project team which includes staff from Jacobs NZ Ltd, AECOM NZ Ltd and McMillen Jacobs Associates. Tony Margevicius of AECOM led the initial design work in this phase of the project, assisted by Duncan Kingsbury, Victor Romero, Martin Evans, Andrew Campbell, Ali Mirza, Damien King, Neil Jacka and Ross Roberts.

REFERENCES

Watercare reports by Jacobs-AECOM-McMillen Jacobs:

"Central Interceptor Main Project Works Detailed Design, Flow Management Report – Detailed Design Updates" (2017)

"Central Interceptor Main Project Works Preliminary Design, Report" (2016)

APPENDIX A: CENTRAL INTERCEPTOR OVERALL LAYOUT PLAN

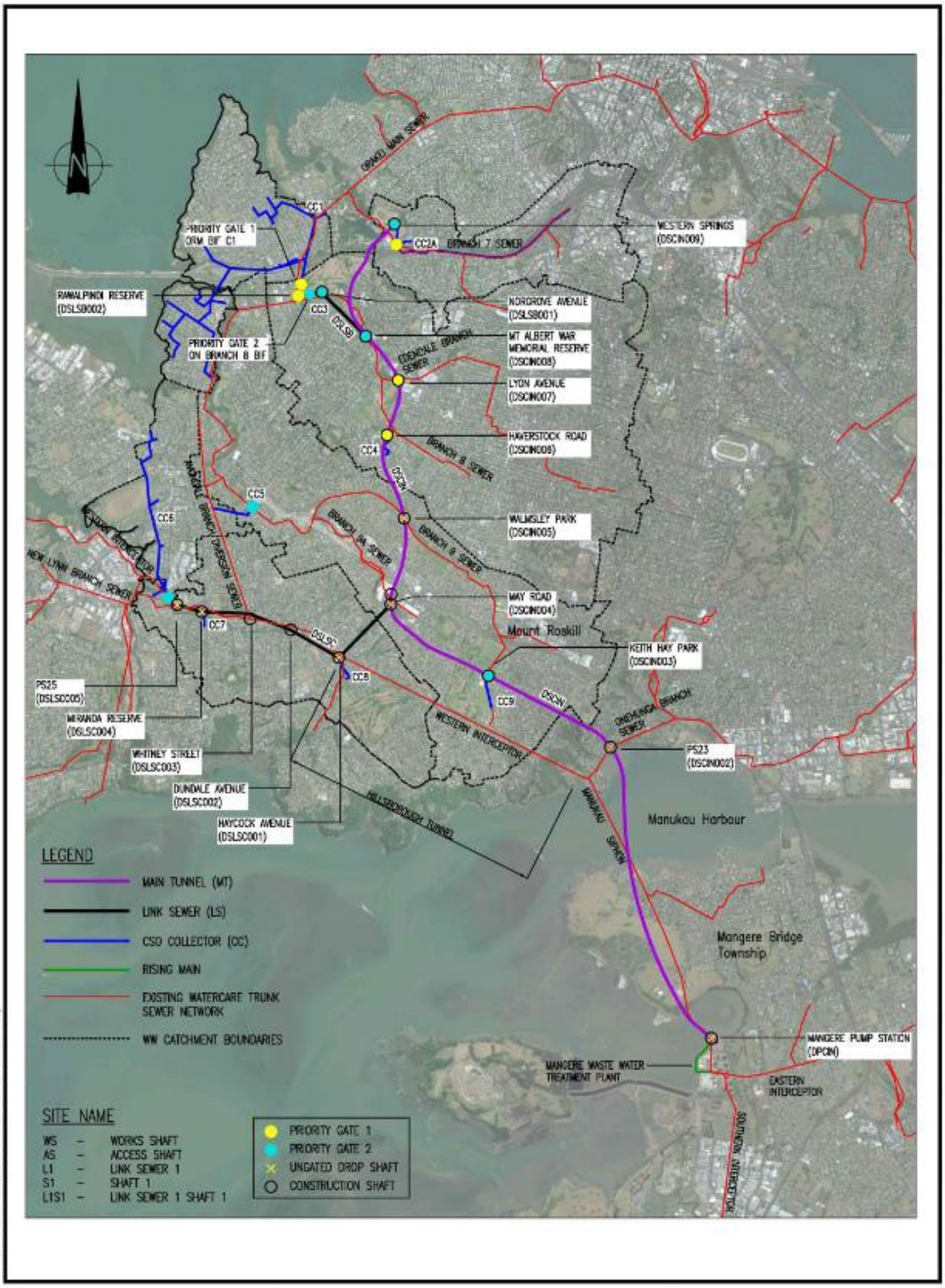

FIGURE 1.2
CI – Overall Layout