# THE EASTERN INTERCEPTOR PROJECT

*O. Smith, R.Rogers (BBR Contech ltd), J. Graham (AECOM NZ Ltd), W. Brown (Watercare Services Ltd)*

## ABSTRACT

The Eastern Interceptor is a critical component of Auckland's wastewater transmission infrastructure. Originally constructed in 1962, this 19km reinforced concrete trunk sewer conveys around 60% of Auckland's wastewater from Okahu Bay to the Mangere WWTP.

Sections of this asset had suffered significant concrete degradation due to hydrogen sulphide attack. Concrete had delaminated and reinforcing steel was exposed and corroded. In order to prolong the asset life and ensure continued reliable operational performance, Watercare decided to rehabilitate two specific sections of degraded concrete and steel.

The rehabilitation was achieved by using high-pressure water-blasters (hydro-demolition) to clear away degraded concrete and contamination, tie in new supplementary reinforcing steel where required, and then apply Sewpercoat HS2000 to repair the sewer wall.

Watercare partnered with Aecom and BBR Contech for delivery of this project. Due to the criticality of the Eastern Interceptor, the work had to be delivered with the asset remaining in service at all times. This project team worked collaboratively to manage this project safely and effectively in what was an extremely hazardous construction site. This included managing confined space risks, odour control, operational flow regimes, and working with sensitive stakeholders.

This paper demonstrates how a complex rehabilitation project can be delivered safely and effectively on a critical infrastructure asset while remaining in operational service.

## KEYWORDS

**Sewer rehabilitation, risk management, asset management, health & safety**

## 1 INTRODUCTION

The term 'Eastern Interceptor' may sound like a fighter jet left over from the days of the Cold War, but for the Eastern Interceptor Rehabilitation Project team the expression has a distinctly different meaning. The Eastern Interceptor is a large-diameter reinforced concrete wastewater pipeline that follows a 19km path across Auckland, from Okahu Bay to the Mangere Wastewater Treatment Plant (WWTP).

The Eastern Interceptor is owned and operated by Watercare Services Ltd. (Watercare) and forms a critical component of Auckland's wastewater transmission infrastructure. The sewer pipeline conveys approximately two-thirds (approximately 7m$^3$/s) of Auckland's wastewater and acts as the main collection point for tributary sewer arterials along its route. The 19km long sewer pipeline was constructed between 1957 and 1962 by a combination of conventional tunnel and cut and cover techniques using predominately cast in-situ reinforced concrete. Due to the critical nature of the Eastern Interceptor, Watercare maintains a rigorous monitoring and maintenance programme.

Detailed investigations into the condition of the pipeline by Watercare established that some sections of the sewer pipeline had been significantly affected by biogenic corrosion. Significant deterioration of the concrete and reinforcing steel was observed in a number of locations along the pipeline length, reaching critical levels and requiring rehabilitation to restore the durability and performance of the sewer in these areas. In order to prolong the life of the asset and ensure continued reliable operational performance, Watercare initiated a rehabilitation project on two specific sections of the Eastern Interceptor.

Watercare partnered with AECOM and BBR Contech for delivery of this project. Due to the criticality of the Eastern Interceptor, the work had to be delivered with the asset remaining in service at all times. The project team worked collaboratively to manage this project safely and effectively in what was an extremely hazardous construction environment. This included managing confined space risks, odour control, operational flow regimes, and working with sensitive stakeholders.

## 1.1 BIOGENIC CORROSION

Biogenic corrosion of concrete is a well-known and documented phenomenon impacting the wastewater industry. Deterioration of concrete by biogenic corrosion is responsible for large numbers of concrete structures worldwide requiring repairs or replacement and the problem represents a significant cost to the wastewater industry.

Often misunderstood, the process of biogenic concrete corrosion is not the direct result of the release of hydrogen sulphide from the wastewater attacking the concrete, but put simply, the result of the release of sulphuric acid as a by-product from the bacterium that are present within the sewerage system (Kurtovich & Graham 2005).

A generalisation of the process of biogenic corrosion of concrete in wastewater pipes such as the Eastern Interceptor is shown in Figure 1.

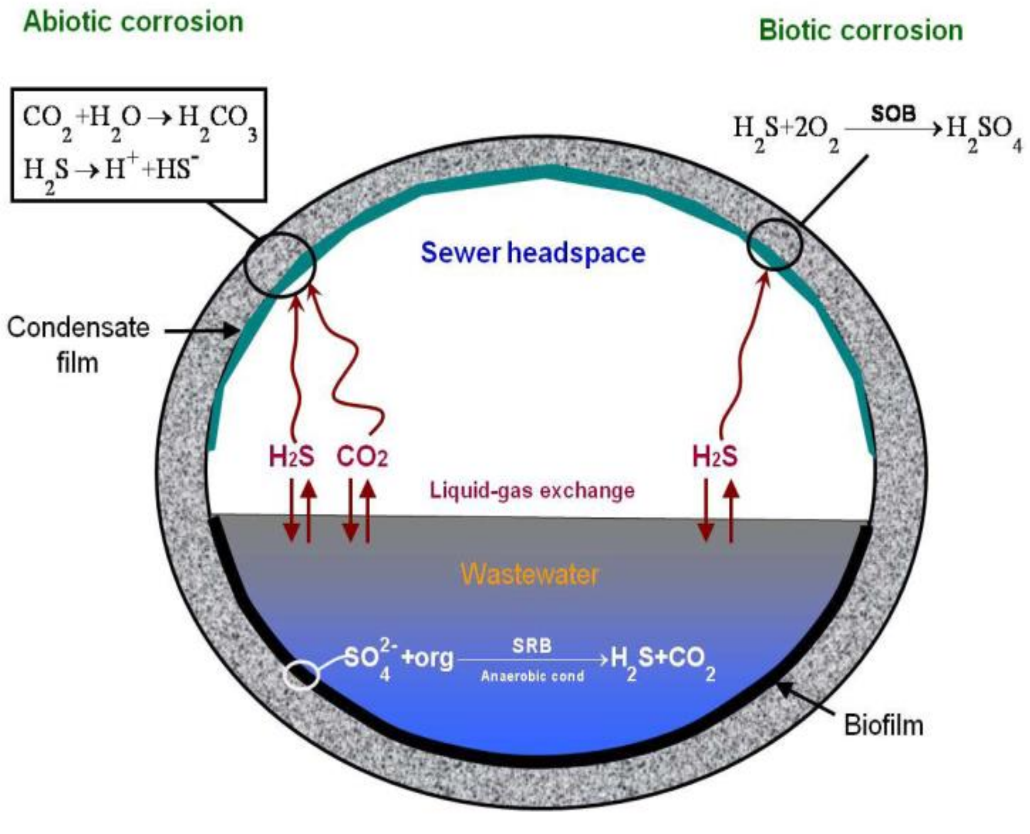


*Figure 1. Simplified biogenic corrosion process diagram reproduced from (Wells et al. 2009)*

Typically, damage to concrete is more pronounced immediately downstream of turbulence caused by flows entering from other pipes or constrictions in the flow. This turbulence provokes the hydrogen sulphide to be released from the flow as a gas into the atmosphere within the pipe. As water is formed as a result of oxidation of the hydrogen, elemental sulphur is left to accumulate on the surfaces above the flow. When conditions are right, the colonies of bacterium thrive in the sulphur rich deposits, multiply in number and produce the sulphuric acid that attacks the concrete.

The chemistry of Ordinary Portland Cement (OPC) lends itself to reaction with acidic compounds like the sulphuric acid ($H_2SO_4$) derived from hydrogen sulphide ($H_2S$). The by-product of this reaction is Gypsum

($CaSO_4$), a weak and soluble solid that provides no protection for the remaining un-reacted cement beneath. Key factors in determining the rate of biogenic corrosion are temperature, sulphate ion concentration in the liquid phase, $H_2S$ concentration in the gas phase, thickness of pipe slime layer, concentration of oxygen ions in the liquid phase and the extent of undisturbed condensation on the pipe wall (Kurtovich & Graham 2005).

# 2 STRUCTURE AND SCOPE OF THE REHABILITATION WORKS

AECOM NZ was engaged by Watercare to provide professional services associated with design, procurement and construction supervision for the Eastern Interceptor Rehabilitation Project. The contract for the physical works was put out for competitive tender and awarded in early 2013 to BBR Contech. Key sub-contractors Tunnel & Civil Ltd and Intergroup Ltd. were engaged by BBR Contech to perform the civil and ultra-high-pressure waterblasting preparation works respectively. The contract split the pipeline remediation works into two separable portions, comprising:

- Separable Portion 1 (SP1): 230m-long section within the WWTP
- Separable Portion 2 (SP2): 450m-long section in Sylvia Park, Mount Wellington

The Sylvia Park section posed some particularly complex challenges for the project team, as it was located within residential areas including a large component within the Sylvia Park Primary School grounds.

The development of the rehabilitation strategy for the Eastern Interceptor was influenced by a number of constraints arising from the requirement to undertake the work while the sewer was still operational. These included:

- The location of the two Separable Portions
- Flow levels in the sewer and that flows could only be controlled to permit a working window of approximately 6 hours in the pipeline per shift
- The repairs were beyond simple localised patches
- An unknown quantity of exposed and damaged reinforcing bars, which would require replacement and reinstatement of cover concrete
- The material product selected would need to be resistant to biogenic corrosion and suitable for use in the wastewater industry
- The repair material had to withstand full flow of the sewer within only one hour of installation.
- Stringent noise and odour control requirements necessary to maintain a positive public image for the client and project while working on with live sewerage in close proximity to the general public

These constraints essentially ruled out epoxy mortars or installed liners for use in this pipeline.

The repair material selected for the Eastern Interceptor rehabilitation project was Kerneos SewperCoat® calcium aluminate concrete, which is composed of both calcium aluminate cement and calcium aluminate aggregates. SewperCoat® was selected after demonstrating excellent resistance to biogenic corrosion, over the last ten years, at other locations along the Interceptor. A key advantage of this material was that it both restored the deteriorated concrete lost to biogenic corrosion and it provided a protective layer to resist future deterioration.

Ultra-high-pressure waterblasting (hydro-demolition) was used to remove the degraded concrete and contamination, and to prepare the surface. Supplementary reinforcing steel was tied in place where required before SewperCoat® was applied to the pipeline walls and invert using a dry spray gunite technique. Figure 2 shows the internal profiles of the Eastern Interceptor pipeline sections remediated during application of SewperCoat®.

*Figure 2. Internal profiles of the Eastern Interceptor and typical equipment for gunite application in the Eastern Interceptor*

The scope of works for both separable portions included:

- Civil enabling works and installation of new access apertures to provide access to the sewer in a number of different locations, with each entry point forming a succinct site compound
- Supply and operate ventilation, flow management, safety apparatus and specialised access equipment to provide a safe working environment and facilitate the sewer pipeline rehabilitation works
- Remove degraded concrete in approximately 680m of live sewer pipeline by means of ultra-high pressure water blasting to provide a clean and sound surface free of any deleterious elements
- Replace corroded steel
- Reinstate concrete with SewperCoat® using the dry spray gunite technique

# 3 PLANNING AND PRGRAMMING OF WORKS

The Eastern Interceptor is the only conduit for delivering wastewater from Auckland's central isthmus and Eastern Suburbs to the Mangere WWTP and the size of the flow makes diversion impractical. Flow rates could only be reduced for short periods of time while wastewater was stored temporarily upstream in the Hobson Bay tunnel. In addition, the flow in the work areas could not be completely shut off because uncontrolled tributaries are located all the way along the length of the pipeline. All in-sewer works needed to be performed during dry weather periods in order to avoid the risk of rapid rises in flow level following high rainfall events in upstream catchments.

The level of flow control that was possible varied significantly following bad weather, and consequently considerable planning was required to minimise disruption to each shift, and to the activities scheduled each week. Flow levels within the sewer also fluctuated on a daily basis, and the working windows were timed to coincide with periods of low flow, resulting in working windows generally between the hours of 3:00am and 9:00am for SP1 (WWTP phase) and 5:30am to 11:30am for SP2 (Sylvia Park phase).

The variables affecting flow levels within the pipeline necessitated constant communication and coordination of works between the rehabilitation project team and Watercare operational staff controlling and monitoring the flows and providing approval for entry to the pipeline. The sewer pipeline rehabilitation was broken into shorter increments to satisfy the seasonal working windows so as to not prepare too great a pipeline length in advance of the SewperCoat® application.

Site works commenced in early 2013 with SP1 at the Mangere WWTP followed by SP2 at Sylvia Park, completed in February 2016. The disruption to the project caused by wet weather events lead to the project temporarily shutting down over the three winter periods from 2013 to 2015.

## 3.1 SEPARABLE PORTION 1 – WASTE WATER TREATMENT PLANT, MANGERE

SP1 consisted of a 230m long section of the Eastern Interceptor located within the Waste Water Treatment Plant (WWTP) and lies between Manhole 2 (MH02) and the confluence chamber, where the sewerage is discharged into the treatment plant. This section of the pipeline is rectangular in section, approximately 2.3m wide and 2.2m high. The site plan for SP1 is shown in Figure 3.

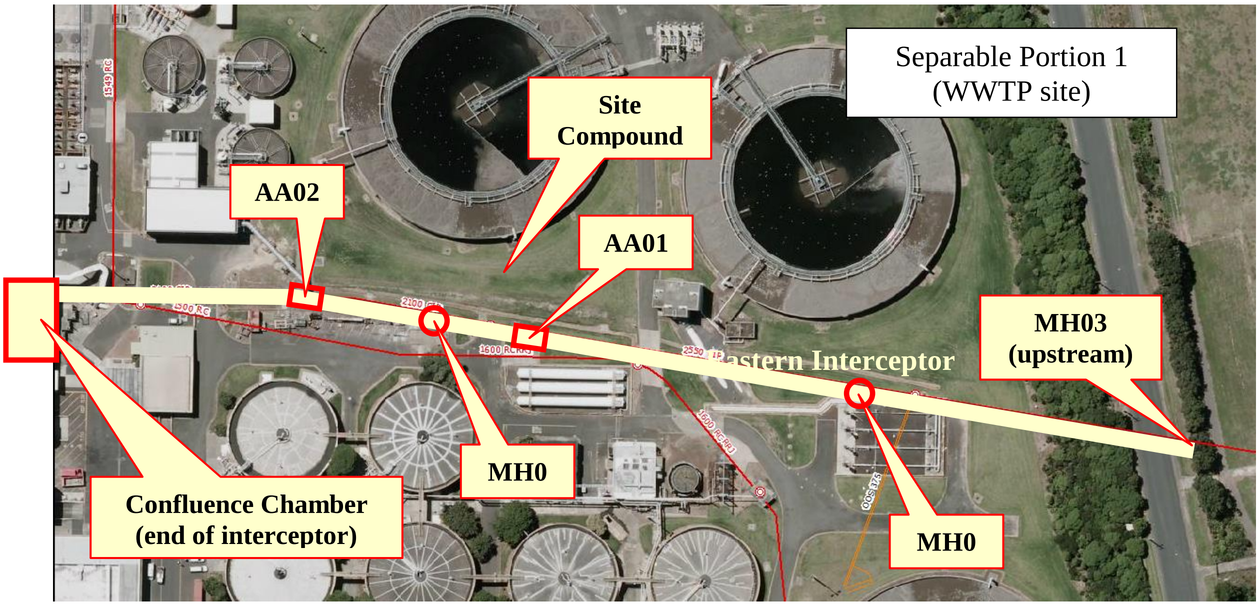


*Figure 3. Site map of Seperable Portion 1 (WWTP Site)*

While the full 230m length of sewer pipeline remediated in SP1 is located within the WWTP, a stand-alone site compound was required at Manhole 3 (MH03) to provide ventilation, located outside the WWTP, approximately 850m upstream of MH02. Two new temporary access apertures (AA01 and AA02) were excavated and formed, and existing access points and manholes in the area used for ventilation purposes. Site establishment within the WWTP included a site compound directly adjacent to the sewer pipeline at AA01.

The ventilation system was comprised of a high powered fan extracting foul air from the sewer at MH03 and a high powered fan blowing fresh air into the sewer at MH02. An additional high powered fan extracted air downstream of the works area near AA02. This ventilation system greatly minimised the quantity of foul air present in the work areas, and provided forced circulation of fresh air and a safe atmosphere for personnel working within the pipeline. In addition to the ventilation system, the environment was constantly monitored for dangerous concentrations of gasses in accordance with requirements for work within a confined space.

### 3.1.1 CONSTRUCTION OF SP1 - WWTP

The two temporary access apertures, each approximately 2.5 x 4m, were excavated and constructed for the plant and personnel access into the wastewater pipeline. The access apertures were also designed to take into account possible extreme flow events considering operational data obtained from Watercare, with reinforced concrete wall risers sized to accommodate the potential high flows. Removable lockable covers were fitted, which were secured back in place over the openings at the end of each shift.

Further temporary penetrations into the sewer were constructed for ventilation and winch driven and cables that controlled the movement of the work barge and cleaning equipment in the pipeline.

Once all enabling works were completed and signed off, the ultra-high-pressure waterblasting commenced to remove all loose delaminated concrete and prepare the surface for SewperCoat® application. An innovative means of cleaning and surface preparation was implemented, employing the use of a remote cleaning machine shown in Figure 4 which was mounted on wheels and fitted with multiple high pressure nozzles. The remote cleaning unit was run continuously, winched backwards and forwards over a number of shifts until the required level of surface preparation was achieved. With the great majority of the ultra-high pressure water blasting preparation work being completed remotely, the project was able to significantly minimise and reduce the high risks associated with operating ultra-high pressure waterblasting equipment by hand within the wastewater pipeline environment.

*Figure 4 Hydro-demolition cleaning trolley (left), and post substrate clean/preparation (right)*

Following the completion of the surface preparation works, application of the SewperCoat® material commenced. A minimum of 25mm SewperCoat® depth was specified and regular depth gauges were installed to monitor the thickness of application. A custom made work barge to fit within the wastewater pipeline was fabricated for the dry spray gunite works, specifically designed to carry equipment and plant for the rehabilitation works. The barge and spraying operation is shown in Figure 5. The barge also served the critical function of providing a means to extract injured personnel should a serious incident have arisen. With working windows in the live sewer restricted to approximately 6 hours per shift, satisfactory completion of each shift's SewperCoat® application was emphasised to minimise rework.

*Figure 5. Application of SewperCoat® at the WWTP (SP1)*

A joint inspection between the consultant and contractor served as a hold point for release of each section after the substrate cleaning and preparation works. As the sewer was always live and flows were increased following the completion of each shift, rigorous daily checks and photographic records were captured. At the commencement of each shift of SewperCoat® application, the section of pipeline identified for spraying was cleaned again by hand using a low pressure water-blaster in order to ensure that any sewerage waste and fat build up was removed. Regular QA testing was performed over the course of the project, including lab testing for compressive strength of the SewperCoat®, in-situ adhesion testing and daily thickness measurement checks to ensure the required thickness was installed (Figure 6).

*Figure 6. Inspection following hydro-demolition and rebar installation in SP2 (left), and SewperCoat® adhesion testing (right)*

An example of unexpected site factors encountered during the project was the early identification of asbestos containing cement board in a section of the Mangere Wastewater Treatment Plant phase of works. The asbestos containing material had been introduced as sacrificial concrete formwork for the construction of a section of the sewer roof. The section affected was isolated from the works to minimise delay and costs to the project, including re-establishing the ventilation system to bypass the area. Works continued while a specialist asbestos removal company was engaged and a safe works methodology was developed by the project team. An existing diversion structure bypassing the affected section was commissioned which involved the design and construction of temporary stop log walls. Once commissioned, the diversion structure enabled the asbestos removal works to proceed while the main sewer flow was diverted around the affected section. Careful coordination was required during the removal works and subsequent sewer rehabilitation, timed to coincide with the summer, autumn seasons, reducing inclement weather risks.

## 3.2 SEPARABLE PORTION 2 – SLYVIA PARK

SP2 consisted of a 450m section of the Easter Interceptor pipeline located between Manhole 33 and Manhole 35 (MH33 and MH35) in the Sylvia Park/Mt Wellington areas. A site plan for SP2 is shown in Figure 7. The upstream 130m section of pipeline to be remediated, and the main site compound and temporary sewer access aperture AA04 were situated within the Sylvia Park School grounds. The remaining 320m of sewer pipeline included in the SP2 scope was primarily located within the Sylvia Park residential area between Sylvia Park School and Aranui Road.

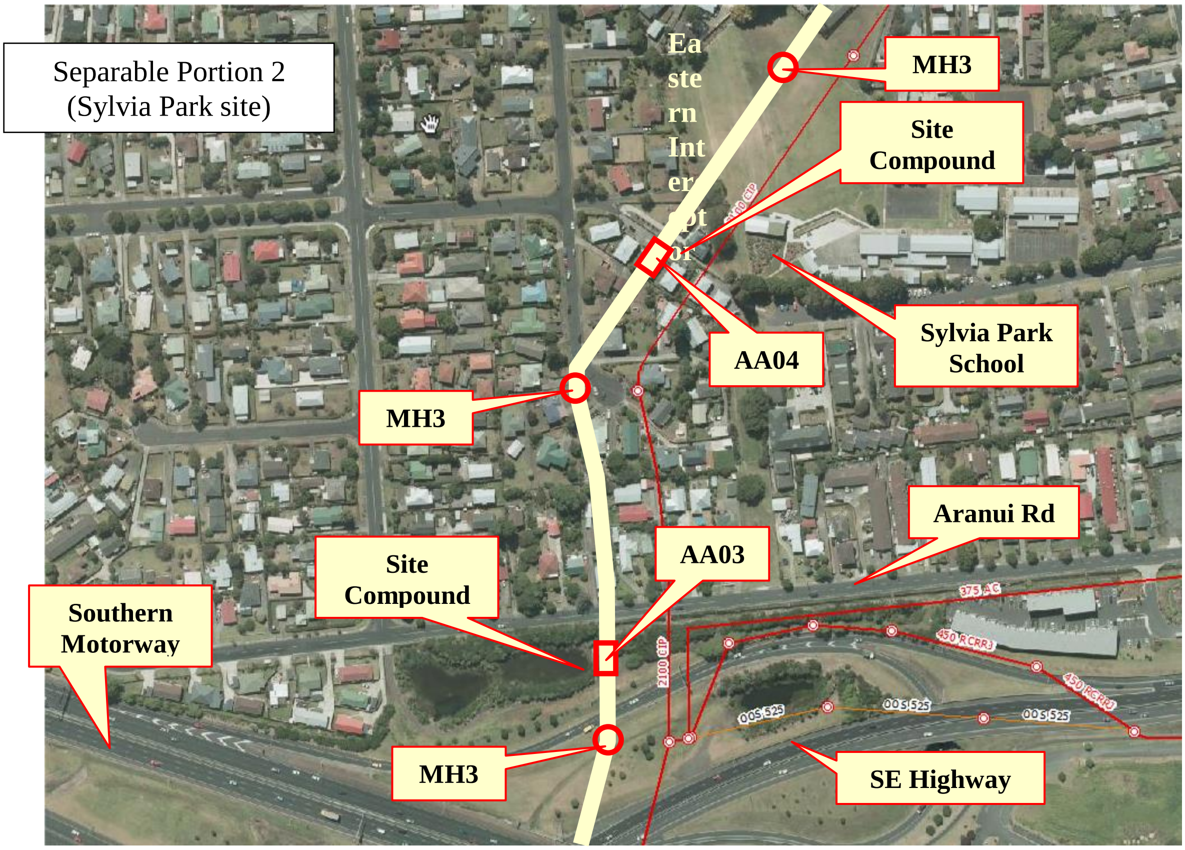


*Figure 7. Site map of Seperable Portion 2 (Sylvia Park site)*

An additional access aperture AA03 was constructed in the reserve area to the south of Aranui Road. The downstream extent of the SP2 rehabilitation works was defined by MH33, located in the grass reserve area enclosed by the South Eastern Highway off-ramp and the Southern Motorway. Site establishment at the two main pipeline access apertures also included ablution blocks with showers, office, lunchroom and storage containers.

Consideration of the physical constraints of the sewer and existing manhole locations combined with the limited number of sites available for construction of temporary access locations, were important factors in the early planning for the establishment works. The section of pipeline running under Aranui Road presented the added complication because the sewer reduced to 1.5m in height, which necessitated modifications to the cleaning method.

The unappealing nature of sewer works and close proximity to the school and the general public, required significant attention during SP2. Letter drops were undertaken communicating key project updates to residents and business owners located in neighbouring areas and including regular consultation with Sylvia Park School, a key stakeholder and neighbour to the works. The regular project messages and consultation, and some flexibility in the methodology to address specific issues raised by stakeholders proved essential to the successful completion of the works in SP2.

### 3.2.1 CONSTRUCTION OF SP2 - SYLVIA PARK

The SP2 section of the Eastern Interceptor included two different cross sections, one semi elliptical section approximately 2.2m high and 2.2m wide, and one adjoining rectangular section with heights varying between 1.5m and 2.2m. The remote cleaning unit was modified to suit the shape of the pipeline and deployed again for the Sylvia Park phase of works, operated by a winching system requiring some careful detailing taking into account the bends in the pipeline encountered during this phase. Some hand cleaning using ultra-high pressure waterblasting was required to reach certain areas requiring additional cleaning, although this was reduced significantly due to the implementation of the remote cleaning unit.

For the SewperCoat® application, a work trolley similar to the barge was designed and fabricated to run on wheels, taking into account the reduced flows encountered in the Sylvia Park pipeline sections (Figure 8).

*Figure 8. Remote cleaning unit modified for the elliptical pipe section (left), and wheeled work trolley with SewperCoat® application in the Sylvia Park section (right)*

The management of technical issues that arose during the project was done by close consultation between the main project team members. An example was the discovery of an unexpected black colouring that formed on the freshly cleaned concrete substrate during the Sylvia Park phase of works (Figure 9). The black colouring became evident following the remote cleaning work. Due to the unknown properties of this condition, the decision was made to temporarily halt the application of the SewperCoat® until more was known about what was causing the black colouring effect. Samples from within the sewer were collected and dispatched to a laboratory for independent analysis immediately following extraction. The testing was unable to confirm the exact source and properties of the colouring although there was evidence to support the theory that it was some type of rapid bacterial/algal growth. The decision was made to remove the black colouring prior to the SewperCoat® application and further testing revealed the use of hydrogen peroxide to be effective in its removal.

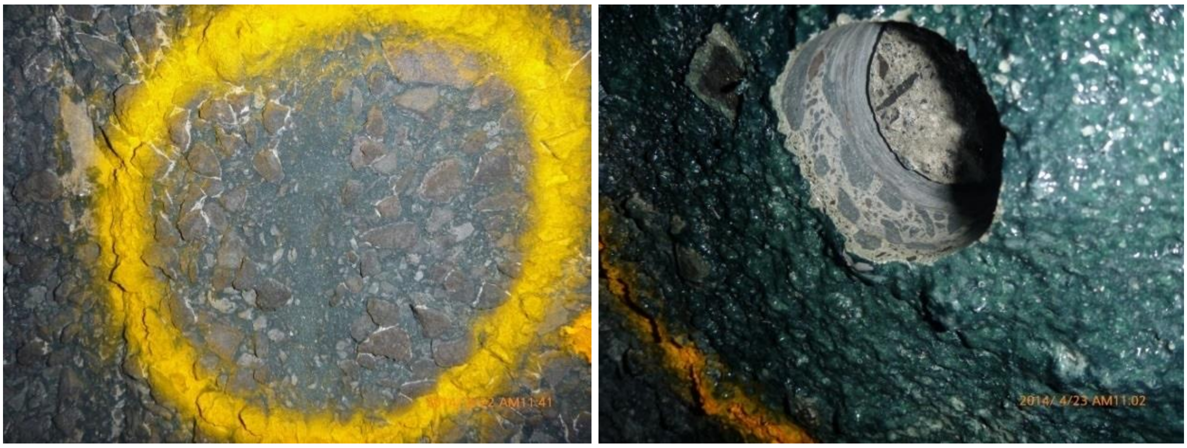


*Figure 9. Black organic staining which appeared on alkaline surfaces of cleaned concrete and applied SewperCoat® in SP2*

The impacts associated with introducing the hydrogen peroxide application at the beginning of each shift of SewperCoat® application were worked through by the project team and the remaining wastewater pipeline rehabilitation at Sylvia Park was structured into smaller segments. This enabled a targeted approach to the black removal, increasing certainty of delivering completed rehabilitated sections of pipeline prior to incurring stand downs associated with the winter inclement weather periods.

### 3.2.2 ENVIRONMENTAL ISSUES SPECIFIC TO SP2

Undertaking sewer rehabilitation work in the Sylvia Park residential areas also required a number of environmental management strategies to deal with the issues presented and to minimise the impact of the project to the neighbouring residents and stakeholders, including the school.

Prior to the Sylvia Park phase of works commencing, likely noise impacts were assessed and noise management strategies developed. This included the implementation and development of a “U” shaped noise enclosure that was located within the main Sylvia Park School compound, shown in Figure 10. The noise enclosure was specifically designed to house the ultra-high pressure waterblasting cleaning unit followed by the Gunite spray equipment once the preparation and cleaning works were completed. The fans used for the ventilation were also fitted with silencers in order to reduce the associated noise impacts. The success of the noise management strategies was critical in maximizing the available working windows in the sewer, particularly when taking into account the 5:30am sewer entries during the Sylvia Park Phase of works. This was verified by noise monitoring undertaken during the works.


*Figure 10. Noise control enclosure in Sylvia Park School (left), ventillation chimney (centre) and activated carbon filter for odour control (right)*

A most significant challenge overcome during the project was the management of odour related issues. The works required temporary access apertures into the sewer pipeline and high powered fan extraction to remove foul air from the work area in the sewer to create a safe atmosphere for the personnel working within the pipeline, odour issues were a critical factor to resolve to ensure impacts to surrounding residents were minimised.

An 8-metre-high chimney was initially established at the extraction ventilation point at MH35 with the aim of dispersing the extracted air in order to reduce the odour impact. When complaints were received regarding odour issues, the project team implemented the introduction of odour control fogging by placing the rings of nozzles around the chimney, injecting odour oxidizing agents into the air flow. When this was found to still not achieve the desired odour neutralisation, to the works were temporarily halted in the Sylvia Park area and relocated to another section of the pipeline at the Wastewater Treatment Plant while the project implemented the design and construction and commissioning of a new activated carbon filter, housed in a 20-foot container, which proved successful in significantly reducing odour related complaints and associated stand-down delays for the remainder of the project (Figure 10). An odour curtain was also developed to restrict foul air flows into the pipeline works area, consisting of a series of heavy rubber mats hung from the sewer ceiling at a location above MH35. The odour curtain was attached to a pulley system so it could be raised above the sewer flow at the end of the day’s shift remotely from outside the wastewater pipeline. To manage the impact of SewperCoat® dust being extracted through the ventilation system during the rehabilitation works, temporary structures with filter cloth were erected at the ends of the extraction fans.

## 4 HEALTH AND SAFETY

Working in a live sewer is a high risk activity. Robust planning and control measures were employed to ensure that the works were carried out safely. Standard industry processes and tools were used, such as job safety analysis and access authority approvals, confined space entry permits and formal evacuation plans. Some of the key health & safety risks and management methods are discussed here:

Confined space entry was an obvious and prominent risk. Personnel were working in a live sewer at times up to 150m from the nearest egress point. This required careful liaison with operational staff to monitor weather and flow upstream. This dialogue continued throughout the shift during the sewer entries, as it was critical that regular flow monitoring of the sewer levels was communicated to the site team. Confined Space Entry Permits were completed for each person entering the wastewater pipelines, and involved continuous atmospheric monitoring for safe atmospheric conditions at all times during the confined space work.

With critical safety items of plant being used, such as generators, winching equipment and fans controlling environmental conditions, daily plant checks were necessary. Redundancy of critical safety systems was also a necessity, with additional ventilation on hand if required.

Due to the critical nature of the work in this contract, all personnel entering or working around the wastewater pipelines were required to wear and maintain high levels of PPE as laid out in the specific job risk assessments and safe work method statements. PPE was inspected before and after each shift with defects reported to site supervisory staff for immediate repair or replacement. Rubber dry suits or waders were sized for each person entering the sewer, providing protection against biological contamination and keeping personnel dry while working in the live sewer pipelines. Respiratory fit testing training was also implemented for staff, taking into account the critical function of respiratory protection when working within a live sewer pipeline and the respective work activities.

A cleaning protocol was established for the sewer entries, which included the development of a three-tiered decontamination process. Separate areas were established where personnel could dress for entry into the sewer gear plus “dirty” areas set for wash down and decontamination purposes including removal of contaminated disposable protective clothing.

For works in the sewer pipeline involving spraying of SewperCoat® and areas where hand held ultra-high pressure water blasting was required, the operatives were equipped with a fixed air supply line feeding breathing helmets. The air supply was made available via an electric compressor fitted with air purifying filters.

*Figure 11. Typical PPE for sewer entry (left) and PPE inspection prior to confined space entry (right)*

Safety grills or screens were fitted daily at the downstream end of the section of sewer pipeline being worked on. These were provided in the extreme event should personnel or equipment have been washed downstream.

An emergency response plan was developed and combined with emergency evacuation drills during the course of the project. Indeed, situations were encountered due to high gas levels or sudden rainfall events being carefully monitored where the organised evacuation of the confined space entry crews was required.

## 5 OUTCOMES AND CONCLUSIONS

The conditions encountered during the course of the project were as demanding as one could imagine. Without question, this project presented significant challenges, considering the difficult site factors and hazards associated with working in a live sewer pipeline, sometimes up to 150 metres from the nearest confined space entry and egress point.

The final success of this project can be attributed to the close working relationships established between the various project team members. Necessary changes to methodologies and risk profiles throughout the project to address unforeseen circumstances were made collaboratively between the client, consultant and contractor. Maintaining positive stakeholder relationships during the course of the project, which spanned three calendar years was assisted immensely by the proactive and collaborative approach led by Watercare in responding to stakeholder concerns.

It is testament to the collaboration, effort and input from all of the project team members that over the course of more than 300 days of working in the wastewater pipelines there were no serious accidents. A great health and safety outcome when considering the issues associated when performing large scale technical remedial works in such a challenging environment.

A number of learnings from the project will inform future sewer rehabilitation works. Of significance is the considerable early planning and collaboration required between project team members to maximise efficiencies of rehabilitation works during limited seasonal working windows while minimising the impacts to stakeholders.

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