CRUMBLE MANHOLE PIE MEETS ITS MATCH

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ABSTRACT

You might say “restoring corroded manholes is easy: just re-line the manhole with a good inert material!” However, there are further considerations if the manhole is to be restored for the longer term.

Expanding a sewerage system to keep up with urban development sometimes has detrimental consequences on existing concrete sewer manholes. Additional hydrogen sulphide (H_2S septicity) can be generated in the original sewers when the newer outlying sewers deliver older sewage from further afield.

In higher concentrations, the presence of H_2S gas in sewers can result in hazardous work environments, odour complaints and accelerated corrosion of assets such as sewers, pump station wells, discharge manholes and treatment plants. These problems generally occur after the infrastructure has been extended. Therefore, operators are typically the front line when the manholes begin to corrode, and H_2S gas is detected.

Western Bay of Plenty District Council and Pattle Delamore Partners Ltd have just completed a two year field trial of four alternative manhole restoration options. The trial aimed to identify the options with the best value for money and the best projected long-term performance in a highly corrosive environment (89 ppm H_2S). We discovered from the trial that retrofit manhole corrosion restorations require a careful design-install approach (compared to new installations).

This paper discusses the very high concentrations of H_2S gas and manhole corrosion faced by Western Bay of Plenty District Council in one of its trunk mains, and how the best restoration solutions were identified and chosen. It also briefly addresses the possible causes of the high H_2S gas levels in the particular delivery main.

KEYWORDS

Manholes, Corroded, Restore, Best Solutions.

1 INTRODUCTION

Western Bay of Plenty District Council (WBOPDC) owns and operates five wastewater sewerage schemes servicing 20,000 persons at:

1. Waihi Beach/Athenree/Bowentown/Pio Shores,
2. Katikati,
3. Omokoroa,
4. Te Puke, and
5. Maketu.

These schemes contain more than 3,800 wastewater manholes, and approximately 5% of them are at risk of corrosion from old or septic wastewater from remote low flow connections.

The wastewater industry research bodies (eg Water & Environment Re-Use Foundation - WERF in USA) typically advise engineers that raw sewage begins to turn “old” or “septic” after several hours of biological breakdown. Laboratory tests show that sewage turns fully septic between 10 to 12 hours old, depending upon the temperature and constituents in the sewage, and the time it has travelled from its source (duration of chemical breakdown).

As septic sewage breaks down it generates a gas (H_2S) which forms sulphuric acid when it combines with moisture in the concrete/steel manholes and is corrosive to concrete and steel wastewater infrastructure.

WBOPDC recognised in 2011 that Omokoroa’s urban growth had not progressed as anticipated when its wastewater system was designed and constructed in 2007. This resulted in lower daily sewage flows and longer delivery times in the rising main and which feeds into the Tauranga City Council wastewater system. WBOPDC subsequently inspected the manholes and discovered high concentrations of H_2S gas, and extensive corrosion in the 23 manholes along its gravity trunk delivery main.

In 2014, Pattle Delamore Partners Ltd (PDP) was engaged to review the assessments and develop a solution to this problem. A product search and a field trial of several corrosion repair products was chosen as the most pragmatic and effective way to identify the best long term corrosion repair solution/s.

2 THE H_2S GAS PROBLEM

Figure 1: Map of Delivery System from Omokoroa to Tauranga.

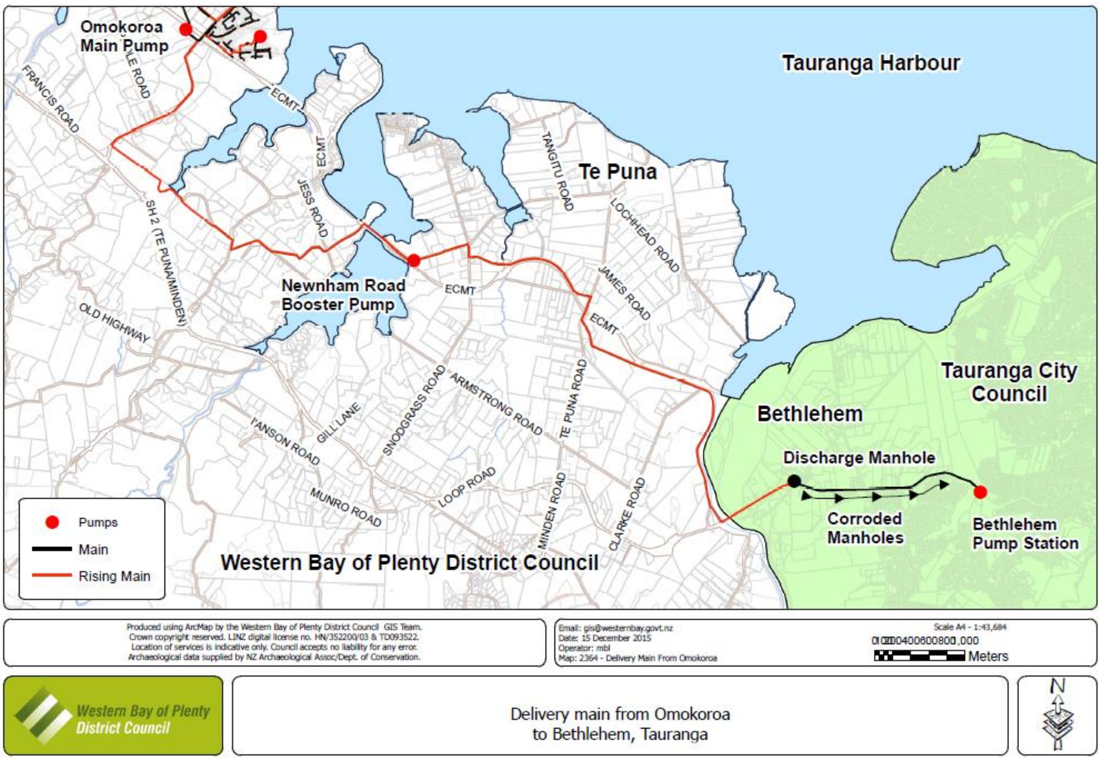

Figure 2: H_2S Levels Logged in Worst Receiving Manhole 0217.

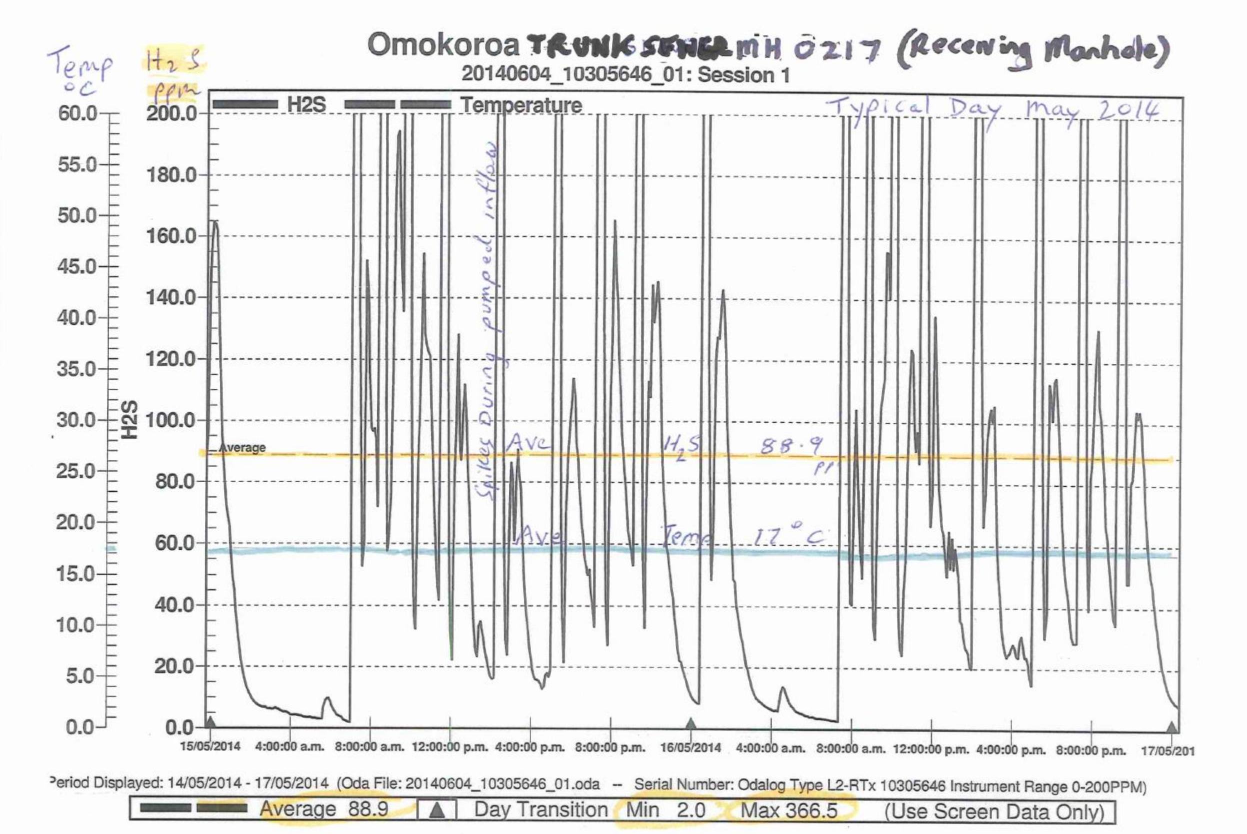

Figure 2 shows daily H_2S gas variations in the worst affected receiving manhole SSMH 0217 during May 2014. The H_2S gas concentrations peaked at 366.5 ppm each time the incoming rising main discharged for 20 minutes or so. Taking into account the lower concentrations between incoming pumping, the average H_2S gas concentration in this manhole is 88.9 ppm. The incoming rising main operates on average 11 times per day and discharges 43 hour old septic sewage into the gravity trunk sewer.

Figure 3: H_2S Profile Along the Trunk Main 2014 & 2015.

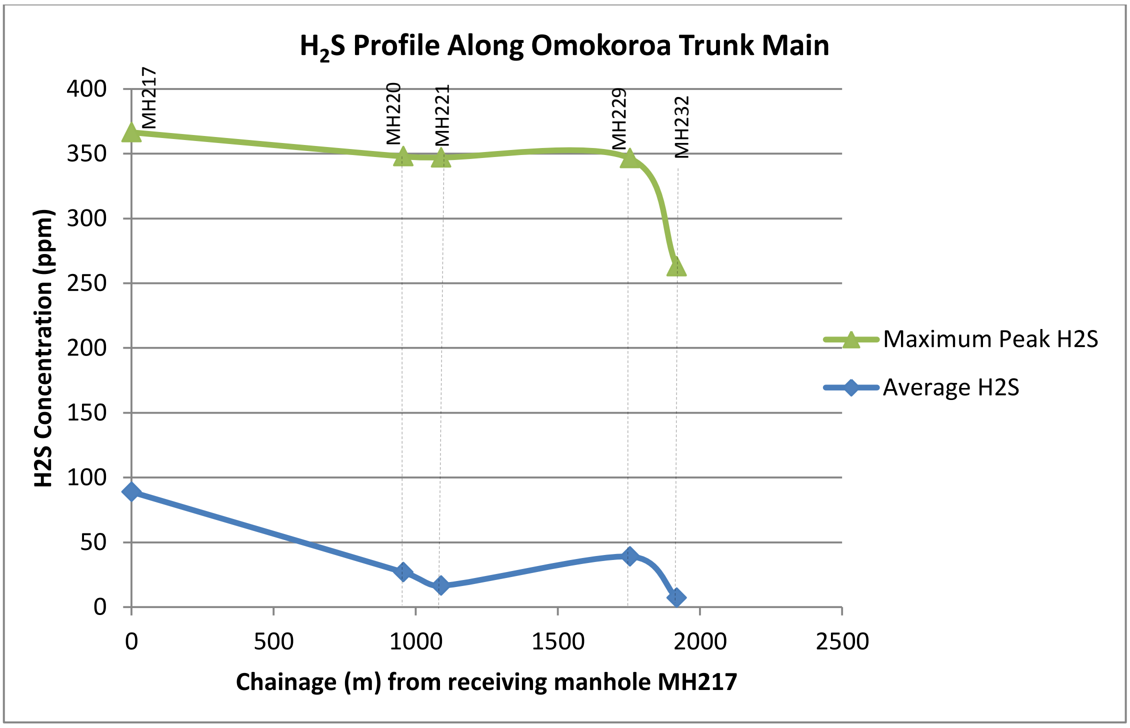

Figure 3 shows the average H_2S gas concentration profile along the 23 manholes, taking into account the lower concentrations between incoming pumping. These levels were logged continuously for a month at a time between 2014 and 2015 using two data loggers that were transferred between 5 of the 23 manholes. The upper line results show peak H_2S concentrations of 370 to 250ppm along the entire length of the trunk main as the incoming rising main discharges its 43 hour old sewage. The lower line shows the average H_2S concentrations drop to 89 ppm in the first few manholes and then go lower to approximately 25 ppm in the manholes further downstream.

These average H_2S gas concentrations are some 18 times higher in the first few manholes and 5 times higher in the remaining manholes than the 5ppm normally allowed in the standard epoxy protection for standard manholes.

3 THE MANHOLE CORROSION PROBLEM

WERF and other industry research bodies advise that H_2S gas generates in sewage that has become septic (oxygen-deficient) after a period of natural biological breakdown. When the sewage is detained in a reticulation system or rising main for more than 10 to 12 hours, anaerobic micro-organisms take over from the aerobic mico-organisms in the break down process. These anaerobic micro-organisms digest the sulphates in the sewage to produce the by-product H_2S gas. This gas is then released out of solution when the sewage reaches a free atmosphere where it combines with the moisture on the concrete and steel surfaces to form sulphuric acid H_2SO_4. This acid then corrodes the concrete and steel surfaces in layers.

The New Zealand wastewater industry recognises that H_2S gas levels above 5 ppm create sufficient acid to cause corrosion of standard epoxy-protected manholes and concrete pipelines. When higher H_2S levels are foreseen at design stage, higher grade epoxies are specified, or the manholes are manufactured with inert materials (HDPE plastic) that can withstand higher H_2S gas concentrations up to 400 ppm.

At the initial inspection of the trunk main manholes by PDP in 2014, the standard (painted on) epoxy liner on the worst affected manholes had lost its adhesion to the parent concrete and hung in sheets around the manhole walls. Corrosion then continued into the parent concrete to form a soft white concrete paste material. Cores drilled through the white paste and manhole walls showed a 33% loss of the original 65mm wall thickness over the 8 years since commissioning in 2007. This is equivalent to an annual wall thickness loss 2mm/year. The level of corrosion to the underside of the concrete manhole lids was relatively minor.

The urban growth in Omokoroa has been much lower than anticipated at the time of design and construction in 2007. Therefore, the sewage flows have been much lower than anticipated, and the detention time in the sewer system much higher than expected.

Council's pumping records in 2016 show that one (1) day's sewage from Omokoroa takes 20 cycles (pumping/stop & filling) @ 2.16 hours each to be completely passed along the 12 km rising main to the trunk sewer in Bethlehem. This amounts to 43 hours detention in the rising main which is much longer than the 10 to 12 hours anticipated at design. This excessive detention is considered to be the main cause of the extremely high generation of H_2S levels and the high corrosion rate in the manholes along the receiving gravity trunk main.

Although this detention time will decrease with increasing sewer connections in Omokoroa, the manhole corrosion has already occurred and it is too extensive and potentially unsafe to ignore.

Photo 1 : Epoxy Coating (sheet) dislodged after 8 years at Manhole 0221

Photo 2: Continued Corrosion of Concrete & Steel Manhole 0226 & 0229.

4 THE MANHOLE ACCESS PROBLEM

Photo 3: Difficult Access to Trunk Main Manholes in SH2 Bethlehem.

Five (5) manholes are positioned under the carriageway of SH2 in Tauranga, and the other 18 are under the edge of the carriageway. Structural failure of one of these manholes would result in a safety hazard to traffic, and/or a contaminated sewage discharge to the groundwater that flows to the grassed channels and into the wetlands around Tauranga Harbour.

SH2 carries busy regional traffic to and from the city of Tauranga. Therefore, any maintenance or restoration work on or under the highway should (wherever possible) be designed to minimise disruption to this traffic. For this reason, extensive excavation and re-compaction of earthworks is not a preferred option in the highways if there is an alternative.

Retrofit repairs to the manholes (without earthworks) are therefore the most practical (and cost effective) option in this situation.

5 RESTORATION OPTIONS

The objective of the trial was to identify the likely costs, risks, and long term performance of each product/method.

The trial demonstrated that a manhole can be fully retrofitted and repaired in less than 8 hours. It also clearly demonstrated that no two manholes are the same when it comes to retrofitting with new materials.

Photo 4: Every Manhole is Unique in its Surfaces, Depth and Shape.

Some manholes are deep with moist walls, others are shallow and somewhat drier, and every manhole has its unique crevices and construction flaws which must be recognised when choosing and fitting repair products. With this variability in mind, PDP and WBOPDC decided to trial four promising products to retrofit and repair the corroded manholes.

5.1 OPTION NO 1

Photo 5: PE Plastic Manhole Inserted into the Existing Corroded Concrete Manhole.

The principle of this method is to replace the corroded concrete manhole with a smaller diameter PE plastic manhole that is inserted and grouted into the old manhole. This type of retrofit repair has been on the market for many years with apparent good results, and it was easy to find willing participants. There was an unexpected surprise though.

Overall, this method took approximately 8 hours to install, and 50% of the work involved confined spaces entry to remove the benching which was in good condition anyway.

The critical flaw of the PE manhole insert design is its floor. It incorporates a PE floor and channelling which requires the concrete benching and channelling to be removed from the parent manhole – the presumption being that the concrete channel and benching is corroded and easily removed. It took 4 hours to remove the concrete channelling in a confined space, and the concrete was in good condition anyway. We discovered that, although the manhole walls corrode, the channels and benching do not. The other flaw with having a PE channel and benching incorporated in the new manhole unit is the need to have it perfectly aligned in 3 dimensions with the incoming and outgoing sewer pipes. This trial has shown this to be very time consuming because onsite modifications to the manhole inverts are usually required. During the trial the manhole inverts were not accurately measured and a 2nd fabricated manhole insert was needed. This is an unacceptable cost and time constraint, and it introduces a risk of creating mismatched inverts that compromise the sewers hydraulics. Therefore, PDP and WBOPDC will (in future) reject PE manhole inserts that offer pre-fabricated PE channels and benching.

However, there is a solution that avoids this extra work and risk. Pre-fabricated PE manhole inserts do not need channels and benching because corrosion does not appear in the channel/benching of manholes. If PE manhole inserts are fabricated with an open bottom which sits on the existing manhole concrete benching the corrosion on the manhole walls will be prevented, and the original channel and benching will not require any risky modifications.

Performance checks (cores drilled through the walls) 9 months following installation showed that the PE plastic manholes were unaffected by the high concentrations of H_2S gas. The grout-backfill had successfully sealed and strengthened the old corroded concrete manhole walls.

5.2 OPTION NO 2

Photo 6: UPVC Plastic Pipe Insert across the Existing Concrete Manhole.

This method was developed by WBOPDC and PDP based upon its apparent simplicity and low cost. The principle of this method was to isolate the H_2S gas within the sewer and therefore stop corrosion of the manhole. Rodding access is maintained through the capped riser shown.

We expected this option to be simple and quick to install. However, as we discovered (as with Option 1) that the variations in the manhole floor and channel configurations present time consuming and expensive installation issues. Overall, it took some 7 hours to fit and seal the fitting into the barrel of the sewer. The corroded walls still need to be repaired if they are structurally compromised.

Performance checks over the months following the installation did, however, reveal that the seal was successful.

Notwithstanding the success of the rubber seals, PDP and WBOPDC will not consider this pipe insert any further because we realised it is susceptible to H_2S gas leakage as the rubber seals and metal brackets age – this can only be tested in the long term. We did realise at the end of the trial that this option could be modified to a much cheaper and longer-lasting solution by using a 600mm high x 800mm circular PE chamber (with a rodding access riser). This chamber could be placed on the manhole benching to allow the original manhole channel to continue under. The whole chamber (up to the rodding riser cap) could then be covered and sealed against H_2S gas leakage with grout backfill.

5.3 OPTION NO 3

Photo 7: Apply a High Grade Epoxy Coating to the existing Concrete Manhole

The principle of this repair method is to seal off the corroded concrete surfaces with a 2 mm layer of the highest grade of epoxy (to resist H_2S gas concentrations of 90 ppm average).

Overall, it took 8 hours to clean, prime, and apply the high grade coating. More than 90% of the work required contractors to be in the confined space of the manhole with special ventilation and gas detection equipment.

The long term performance of the epoxy was assessed from several core samples drilled through the epoxy and parent manhole concrete in two diagonally opposite locations 1m above invert. The 1st set was taken when the epoxy cured at application, and the 2nd set was taken 9 months later after exposure to the high H_2S levels. Each 2nd follow up core was taken immediately adjacent to the previous 1st core to ensure an accurate assessment of changes in coating thickness and adhesion.

The epoxy showed no signs of degradation after 9 months. The epoxy was well bonded to the parent concrete in one area. However, in the diagonally opposite area the epoxy easily sheared off the wall with the drilling. This demonstrates a variable adhesion of the epoxy around the corroded concrete surfaces. The entire epoxy coating principle relies upon consistent adhesion to the surface being protected.

Based upon this observation, epoxies should be subjected to quality control monitoring several years beyond application – particularly for retrofit applications such corroded sewers which typically have humid conditions and difficult-to-clean cracks and crevices.

5.4 OPTION NO 4

Photo 8: Apply a Mortar Type Coating to the Existing Concrete Manhole.

The principle behind this repair method is to seal off the corroded concrete wall and benching with a 15mm layer of mortar sprayed on in 1mm layers.

This method, although similar in principle to the epoxy coating, restores at least part of the wall thickness and strength of the manhole structure by having a 15mm coating thickness. Its automated rotary clean and spray operation controlled from above ground avoids extended periods of confined spaces entry for installation contractors. The manhole is firstly cleaned using a rotary cleaning spray (1^{st} photo above), debris is trapped and removed from the manhole by hand, and the 15mm mortar coating is sprayed in 17 passes down and up the manhole (2^{nd} photo above).

Overall, this method took approximately 5 hours to clean, collect debris, monitor, and spray the mortar to a 15mm thickness.

In terms of long term performance, several drilled cores taken through the mortar and manhole walls using the same method as used for the epoxy coating monitoring. The bond between the mortar and the corroded concrete was very strong in all cores both at application/curing and then 9 months later– the manufacturer of the mortar product attributes this bond to the water absorption qualities of the patented material.

6 CONCLUSION

The specific costs/benefits/risks/performances of each of the four products trialled in the manholes along the Omokoroa Trunk Main are summarised in the Performance Evaluation Matrix in the Appendix.

The costs were relatively similar at around $8,000 + GST to retrofit a typical 4m deep manhole, and the benefits/risks/performances varied.

7 RECOMMENDATION FOR RETROFITTING CRUMBLED MANHOLES.

Based upon the “stand out” benefits of restoring the structural strength, relative ease and quality of installation, and projected long term corrosion prevention performance, the best competitors for corroded “crumble pie” manholes are:

1. Insert a new smaller diameter PE Plastic Manhole (note: do not replace the existing manhole benching and channel).

2. Apply a 15mm mortar coating to the manhole surfaces (*note: research the chosen mortar to validate that it does have a strong long term adhesion to all moist concrete*).

ACKNOWLEDGEMENTS

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REFERENCES

- Water & Environment Re-Use Foundation USA,

- Hunter Water Corporation Water & Sewer Design Manual –Section 4 Sewage Pump Stations & Rising Mains July 2008

APPENDIX A

Table A: Performance Evaluation Matrix : Corrosion Restoration Options

Corrosion Repair Option	Indicative Costs $/m depth of manhole	Installation or Safety Issues	Corrosion Resistance against H_2S	Benefits/Risks	Overall Performance
Option 1. 800mm dia P.E Manhole inserted into the 1050mm corroded parent manhole.	$1,900/m	The MH insert had a design flaw with its PE base which didn't fit with the incoming & outgoing sewers	**Excellent** because PE is inert to H_2S corrosion.	Quick to install in the confined space environment in the manhole. Restores manhole wall strength Inert to corrosion in the short & long term.	**Excellent** if the PE manhole is redesigned to sit over the existing manhole channel and benching – thus removing the need to replace the manhole channel and match inverts to the existing sewer pipes.
Option 2. uPVC Pipe inserted across manhole to join the incoming & outgoing sewer pipes. Seal corroded manhole with mortar spray or epoxy.	$1,900/m	Difficult to insert and seal the uPVC pipe because every manhole channel and invert has a different configuration.	**Uncertain** because the uPVC pipe mechanical insert into the sewer is reliant upon a good seal.	Time consuming to install in the confined space environment in the manhole. High Risk of H_2S gas leakage from rubber seals and metal brackets. Does not restore manhole wall strength.	**Unacceptable – but can become acceptable** if the sealing risk can be eliminated by grouting over a PE pipe insert. Still need to repair the manhole corrosion which limits its competitiveness against the other options.
Option 3. Apply 2 mm thick High Grade Epoxy to the corroded manhole surfaces.	$2,200/m	Time consuming to hand spray the epoxy in the confined space of the manhole. Variable adhesion integrity to the moist corroded manhole surfaces. Does not restore manhole wall thickness.	**Excellent** corrosion resistance of the epoxy, but **unacceptable** adhesion variability to the moist corroded manhole surfaces.	Time consuming to install in the confined space environment in the manhole. Medium Risk of H_2S gas breaching the variable adhesion to the parent concrete. Does not restore manhole wall strength.	**Unacceptable** because 2 mm thick coating does not restore the structural strength of the corroded manhole walls. It is also susceptible to poor adhesion to the moist parent concrete, and the installers have extended exposure to sewage gases.
Option 4. Apply 15 mm mortar layer to corroded manholes.	$2,300/m	Good because it is 80% automated with remotely operated rotary jets and sprays, and therefore requires limited human entry into confined spaces.	Excellent because it showed no corrosion and its bond was very strong to the moist concrete	Quick to apply in the confined space environment in the manhole. Low risk of H_2S attack because it bonded strongly and consistently to the moist concrete. No corrosion observed over 6 months.	**Good** - provided the bond between the new mortar and the old concrete surfaces is regularly monitored (using drill core samples). The 15 mm coating restores the structural strength of the manhole walls.