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Demonstration and Validation of Polymer Concrete Piping for Corrosive Environments

Final Report on Project F14-AR07

Clint A. Wilson, Jaclyn S. Edwards, Sarah L. Lamkin, Anthony Delgado-Connor, and Paul C. Simonton

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Construction Engineering Research Laboratory

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Clint A. Wilson, Jaclyn S. Edwards

Construction Engineering Research Laboratory
U.S. Army Engineer Research and Development Center
2902 Newmark Drive
Champaign, IL 61822

Sarah L. Lamkin

Truman State University
20 E Normal Street
Kirksville, MO 63501

Anthony Delgado-Connor

University of Illinois at Urbana-Champaign
1206 W Green Street
Urbana, IL 62801

Paul C. Simonton

P.C. Simonton & Associates, Inc.
309 N Main Street
Hindsville, GA 31313

Final report

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Under Project F14-AR07, “Polymer Concrete Piping for Corrosive Environments”

Abstract

Sewer pipes and structures that convey aggressive wastewaters or are exposed to aggressive soil types can rapidly deteriorate, leading to premature leakage and service failure. This problem impacts mission execution on U.S. military installations by creating operational disruptions that require unplanned emergency repairs, increasing operational costs and reducing infrastructure service life. An emerging alternate material, polymer concrete, is made with high-strength resins and aggregates that have excellent resistance to corrosive factors inside and out as compared with standard concrete. Polymer concrete also has relatively high compressive, tensile, shear, and flexural strengths compared to ordinary concrete.

This report documents a field demonstration of a polymer concrete pipe (PCP) structure measuring 24 in. diameter by approximately 200 linear feet, including seven manholes and two junction boxes. Performance was monitored through coupon testing in the wet well and in the laboratory. Results indicate that PCP is significantly more resistant to sulfuric acid than Portland cement concrete. PCP is relatively new to wastewater applications, so extra attention is needed during acquisition because practices recommended by polymer concrete manufacturers may differ from those used in conventional wastewater infrastructure projects. The calculated return on investment for this project is 9.27.

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Preface

This demonstration was performed for the Office of the Secretary of Defense (OSD) under Department of Defense (DoD) Corrosion Prevention and Control Project F14-AR07, "Polymer Concrete for Corrosive Piping." The proponent was the U.S. Army Office of the Assistant Chief of Staff for Installation Management (ACSIM) and the stakeholder was the U.S. Army Installation Management Command (IMCOM). The technical monitors were Richard J. Frey (OUSD(A&S), Materiel Readiness, Corrosion Policy and Oversight), Ismael Melendez (IMPW-E), and Valerie D. Hines (DAIM-ODF).

The work was performed by the Engineering and Materials Branch of the Facilities Division (CEERD-CFM), U.S. Army Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL). Significant portions of this work were performed by P.C. Simonton & Associates, Inc., Hinesville, GA. At the time of publication, Vicki L. Van Blaricum was Chief, CEERD-CFM; Donald K. Hicks was Chief, CEERD-CF; and Michael K. McInerney was the ERDC CPC Program Coordinator. The Deputy Director of ERDC-CERL was Dr. Kirankumar Topudurti and the Director was Dr. Lance D. Hansen.

The Commander of ERDC was COL Ivan P. Beckman and the Director was Dr. David W. Pittman.

Unit Conversion Factors

Multiply	By	To Obtain
degrees Fahrenheit	(F-32)/1.8	degrees Celsius
feet	0.3048	meters
fluid ounce (us liquids)	29.573	milliliters
inches	0.0254	meters
square feet	0.09290304	square meters
pounds per square inch	0.0068948	Megapascals

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1 Introduction

1.1 Problem statement

Sewage and wastewater infrastructure are critical to operations and readiness on all U.S. military installations. Many sewer pipes and structures convey highly corrosive contents and are also exposed to acidic or chloride-infused soils. These conditions can rapidly deteriorate pipes both inside and out, causing premature leakage and service failure. Wastewater system failures negatively impact mission execution by disrupting operations and requiring unplanned emergency repairs. This problem increases operational costs and decreases infrastructure service life.

The cost of sewer and industrial waste line corrosion ranks seventh among the top 25 highest contributors to Department of Defense (DoD) corrosion costs (Herzberg, O'Meara, and Stroh 2014, Table N-1). Installation Status Report (ISR)* program data for fiscal year (FY) 2012 show either a Red or Black condition status for over 1,550 miles of sewer pipe at Army installations in Facility Category Group F83200, Sewage/Waste Collection Lines. (Note that this category excludes storm sewers.) Sanitary system manholes are typically required at a minimum of every 400–800 ft, depending on the terrain and diameter of pipe. Assuming an average of 500 linear feet (lf) of pipe per manhole, approximately 16,400 Army sanitary manholes were failing by FY12 reporting.

In a significant number of repair or replacement cases, corrosivity conditions will warrant the use of pipe materials which are stronger or more corrosion-resistant than the widely specified ductile iron pipe and polyvinyl chloride (PVC). Ductile iron is strong but not corrosion resistant unless lined with a ceramic coating, and PVC is corrosion resistant but not as strong as iron.

Sewer infrastructure at Army installations is likely to require high-strength materials due to the use of heavy vehicles traversing the roads above the infrastructure. Sewer infrastructure also may need to be constructed using

* ISR is an Army decision-support database tool for garrison commanders that is used to assess the condition of installation infrastructure and other areas of responsibility. ISR data are provided on an annual basis.

non-corrosive materials due to exposure to biogenic sulfides which can rapidly deteriorate concrete and iron. When wastewater infrastructure is perforated by corrosion, soil and rocks can enter the pipes and directly obstruct sewage flow, a condition that requires immediate maintenance or repair. Also, having soils present in the waste stream can increase energy use at the treatment plant and damage expensive equipment such as pumps. Deteriorated wastewater structures are especially problematic in areas with a high water table or rainfall amounts because perforations can allow hazardous liquids to leak into the surrounding soil while providing ingress for infiltration or inflow.

The DoD Corrosion Prevention and Control (CPC) Program funded ERDC-CERL to demonstrate and validate the performance of polymer concrete pipe (PCP) in a wastewater system subjected to aggressively corrosive conditions. The research team investigated a PCP product in terms of its strength and corrosion resistance as compared with Portland cement concrete. Polymer concrete contains aggregate materials similar to conventional concrete, but the binder consists of a polymeric matrix instead of Portland cement. Polymer concrete manufacturers claim improved reliability, performance, service life, and substantial cost avoidance.

1.2 Objectives

The objectives of this demonstration/validation project were to do the following:

- Install a corrosion-resistant polymer concrete material in Army installation sewer pipes and manholes affected by aggressive corrosion.
- Document and evaluate the performance of the demonstrated polymer concrete products and compare their performance with conventional concrete products on a life-cycle basis.
- Suggest guide specification revisions to facilitate use of the PCP material where appropriate.

1.3 Approach

Seven manholes and two junction boxes were installed at the influent line of the Hinesville Wastewater Treatment Plant, which serves Fort Stewart. Additionally, coupons of standard Portland cement concrete and polymer concrete were hung in a wet well at the plant with a high concentration of hydrogen sulfide (H_2S) to provide a direct, easily observable comparison of corrosion resistance.

Lab testing was executed by ERDC-CERL and an independent testing laboratory. At CERL, two different methods were used to test sulfuric acid resistance of the test specimens: immersion and cyclic sulfuric acid drip. The latter test allowed for the investigation of a thin film reaction that may better simulate conditions for pipes in service.

Material compressive strength testing was performed by certified third-party testing lab (Maxim Technologies of Houston, TX), which was selected by the PCP supplier.

1.4 Metrics

The performance metrics for the demonstrated polymer concrete consisted of the following:

1. How well the product met the specifications for the selected application, which is an indicator of market-readiness
2. Ease of product installation
3. Product's ability to resist high concentrations of sulfuric acid
4. Product's compressive strength

For this project, conventional Portland cement concrete specifications were adapted for designing PCPs and manholes. The project-specific specifications required shop drawing submittals. The specifications were used to assess the characteristics and quality of the received products in terms of the design requirements.

The ease of installation was determined by the installers and project engineers through comparison with similar projects specified using conventional materials.

The selected benchmark for acid resistance was ASTM C267-01, *Standard Test Method for Chemical Resistance of Mortars, Grouts, and Monolithic Surfacings and Polymer Concretes*. Because of practical limitations, as explained below, both in the field and in the laboratory, the standard was adapted. Coupons were immersed at the wastewater treatment plant, as described under Approach, and inspected over time for surface loss. Samples were also subjected to a laboratory drip test to simulate a thin-film interaction with the pipe substrate, which is more representative than full immersion of what occurs in wastewater system environments. The drip test simulates the typical environment found in sewer pipes that promotes oxidation-reduction reactions. This environment in turn fosters the aerobic production of sulfuric acid that attacks the inside crown of a pipe. Therefore, a drip test is more applicable for this demonstration than the ASTM immersion test methodology. Evaluation of the field test results relied primarily upon visual inspection. Laboratory evaluation also included weighing for sample mass loss, and surface observations were also recorded by using scanning electron microscopy and energy-dispersive x-ray spectroscopy.

Compressive testing by the third-party laboratory used by the vendor was performed in general accordance with ASTM C579 and ASTM C 497. See section 3.3 for discussion and results.

2 Technical Investigation

2.1 Technology overview

PCP is an emerging technology that is becoming more widely used in the United States. This demonstration verified the use and benefits of PCP in a field application at a wastewater treatment plant serving Fort Stewart, GA. At the plant, the piping and structures are exposed to highly corrosive sanitary sewage containing high concentrations of biogenic sulfide in the form of sulfuric acid. The conventional approach to mitigating damage caused by acidic sanitary sewer gases is to specify PVC material or a corrosion-resistant lining system installed in existing Portland cement concrete structures.

For applications that require both internal corrosion resistance and high external load resistance, the conventional choice is typically to specify ceramic-lined ductile iron pipe, which is strong enough to resist most external loading without deflecting or deforming. However, the integrity of the ceramic coating may be compromised during fabrication, handling, or installation, which will leave bare iron exposed to the interior corrosive elements and create a perforation hazard over time.

PVC offers good corrosion resistance but lacks the load capacity needed for some applications. Also, PVC is generally not used in diameters exceeding 24 in. At shallow depths, the trench for PVC pipe is backfilled with gravel or stone for the full trench width and depth to resist pipe deflection. In many areas, stone backfill is not readily available at an affordable price, and substitute backfill materials are not as effective in bearing structural loads. In some cases, full support of subgrade PVC pipe requires concrete encasement.

Portland cement concrete is a very common material choice for sewer system structures (e.g., manholes), and it performs well in applications where it is not exposed to corrosive sewage and gases. One exception, however, is where pressure force mains empty into the gravity sewer system. Between pumping cycles, raw sewage is retained in the force main and becomes septic. When this anaerobic wastewater is dumped into the gravity system, the septic wastewater containing certain bacteria combine with oxygen in a process that ultimately forms sulfuric acid that then attacks the concrete. In such cases, chemical-resistant liners or fiberglass manholes has been incorporated into the structure, either during the factory precasting process or in the field. Using sheets of PVC material to form an internal protective vessel has proven successful on some new construction projects.

Rehabilitation of existing structures or poured-in-place linings require field application of an acid-resistant coating to the inside of the pipe structure. In the past, field-applied coatings have had problems either with pinholing during application or with poor adherence to the concrete. In addition, the most successful systems dominate their market niches without competition, so they tend to be very expensive.

Polymer concrete incorporates several properties that make it a good candidate for use in sewage systems that require high strength and effective corrosion and chemical resistance. It is formulated with high-strength thermosetting resins and aggregates, and it has been adopted overseas as a cost-effective solution for these types of exposures. PCP can be used for new lines or repairs, trenchless installations, or direct burial. Compared with conventional wastewater structure materials, PCP offers several advantages. For example, it has higher compressive, tensile, shear, bonding, and flexural strengths than Portland cement concrete. Also, polymer concrete is inherently resistant to degradation by acids and other corrosive substances, so it does not require a corrosion-resistant liner.

Polymer concrete's corrosion resistance is consistent throughout its entire wall thickness. Its dense mix design and physical properties avoid the connective pore structure in Portland cement concrete that promotes high permeation by liquids. Therefore, corrosive materials do not penetrate the material, which greatly slows the rate of pipe corrosion. Polymer concrete products are corrosion resistant in exposures over the wide pH range of 1.0 to 10.0 (Polymer Pipe Technology [PPT]/Interpipe 2006) It is also resistant to other harsh chemicals. See the corrosion resistance table in Appendix A for more information.

Polymer concrete pipe tests well for strength in comparison to traditional Portland cement concrete pipe. Compressive, flexural, and tensile strength properties are much higher for polymer concrete than traditional concrete pipe, as shown in Table 1 (The Engineering Toolbox 2017; PPT/Interpipe, https://www.polymerpipe.com/aboutus.htm). Polymer concrete also performs well in freeze/thaw cycling. After 16,000 cycles, the PCP experienced no weight loss whereas Portland cement concrete experienced a 25%

weight loss after 750 cycles (ABT Inc. 2017). Differing mix designs and materials will cause variation in performance.

Because of its advantages (Table 1), polymer concrete offers a potentially viable and cost-effective solution to many problems that contribute to the excessive life-cycle costs of many wastewater treatment systems on military installations.

Table 1. Mechanical properties of polymer concrete and Portland cement concrete.

	Polymer Concrete	Portland Cement Concrete
Compressive Strength	8,000-14,000 psi	3,000-6,000 psi
Flexural Strength	3,000-4,000 psi	400-700 psi
Tensile Strength	1,200-1,600 psi	300-700 psi

Because a single field demonstration cannot test the many different corrosive environments that such pipe may encounter on military installations, ERDC-CERL also conducted in-house laboratory evaluations to verify the polymer concrete corrosion-resistance claims. See test results in section 3.2 of this report.

2.2 Field work

To demonstrate PCP in the field as an alternative to traditional large-diameter buried pipelines for sewer, industrial wastewater, or stormwater flow, approximately 200 lf of 24 in. PCP, seven manholes, and two junction boxes were installed at the influent line of the Fort Stewart/Hinesville Wastewater Treatment Plant. The PCP demonstration site is located just upstream of the headworks of the new wastewater treatment plant that was constructed during 2016–2017. Fort Stewart collaborated with the City of Hinesville, GA, to fund construction of a new Sequencing Batch Reactor Treatment Plant.

The project reported here required significant levels of coordination among ERDC-CERL, Fort Stewart, the City of Hinesville's engineering firm (P.C. Simonton & Associates, Inc., Hinesville, GA), the installation project's contractor (Petticoat-Schmitt Civil Contractors, Inc., Jacksonville, FL), and the vendors of the polymer concrete materials (Polymer Pipe Technology/Interpipe, Des Moines, IA).

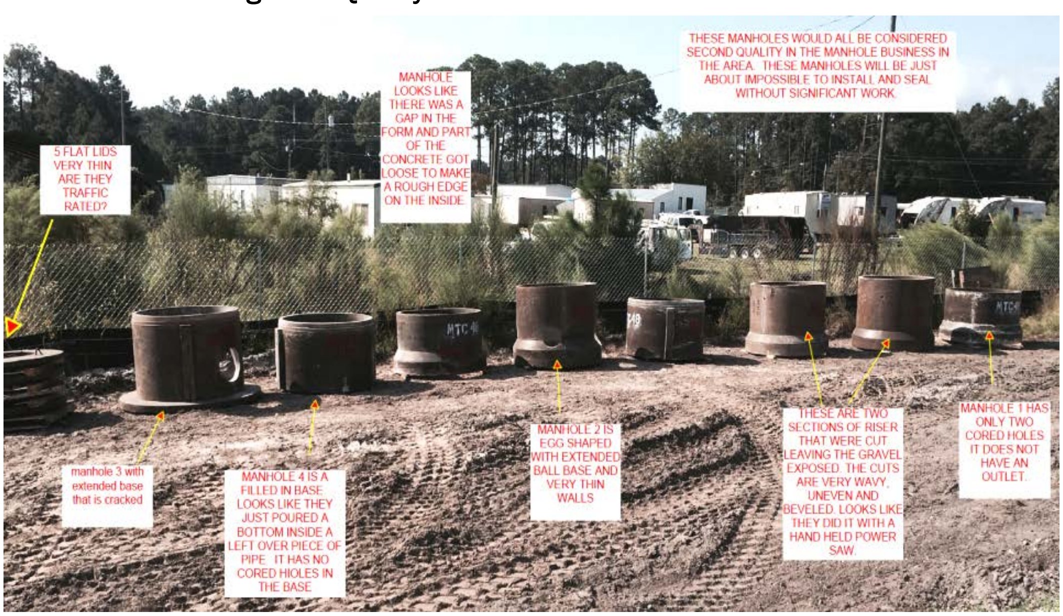
P.C Simonton & Associates managed bidding. The company also developed plans and specifications for purchasing and installing the materials and structures (see Appendix B). The City of Hinesville issued a purchase order on 29 September 2014 to the pipe vendor for its Polymercrete materials for manholes, pipes, and junction boxes. The sales agreement was returned and finalized in mid-December 2014.

2.2.1 Polymer concrete manholes

Shop drawings (shown in Appendix C) were drafted, reviewed, and agreed upon for the purchase of seven polymer concrete manholes. The duration of this process was approximately six months due to delays caused by the materials supplier. During the shop drawing review, it was found that the supplier was not accustomed to supplying structures with the requested cored pipe holes or flexible pipe connectors (boots). In addition, many of the inlet and outlet holes were either incorrectly located or specified at the wrong size.

The materials vendor committed to ship the first load in late May 2015. Several delivery dates were missed, but a shipment of manholes was eventually delivered in September 2015. These manholes, however, were unusable and were rejected with the support of a second opinion from Fort Stewart representatives. The quality was unacceptable, and the manholes were not manufactured in accordance with the specification (documented in Figure 1).

Figure 1. Quality issues with first set of manholes.



The following quality issues were encountered and documented:

- Castings did not match the shop drawings.
- Eccentric cones were specified for the tops, but thin, flat tops were mistakenly supplied.
- The bases were different than the designs.
- Pick-up holes were cored all the way through the walls of the structures, and there were an improper number of cored holes. This element was also out of specification. The configuration provided was unacceptable because it would have created a significant source of inflow and infiltration.
- The wall thickness was inconsistent. Manholes were not circular in section as required—particularly Manhole 2, which was “egg-shaped” in section and had a wall thickness of 1 1/2 in. on one side and 3 1/2 in. on the other.
- The top cut lines wave up and down, as shown in the Figure 2. The tops were also ragged.
- Gaps and cracked bases were observed. A gap is shown in Figure 3.

Figure 2. Uneven cut lines.

Figure 3. Gap in manhole.

To address the quality issues, the involved parties decided the manufacturer would receive another opportunity to supply new manholes and retrieve the out-of-quality manholes from the site. The manufacturer was required to review and resubmit shop drawings in accordance with specifications. The required timeframe to receive the new manholes was two weeks. This deadline had been set to match a competitor's expected delivery date. The shipment was required to be scheduled with by giving 48 hr. notice (during working days) to the construction contractor to arrange for inspection and unloading. The replacement manholes shipment was received two weeks behind schedule (22 October 2015), and quality problems remained. The engineering consultant rejected manhole 6 because one of the pipe inlet holes was at the wrong elevation. The rest were accepted, despite some deviation from shop drawing requirements (because of the dire need to avoid additional schedule delays to construction). The engineer noted that the manholes did not meet the specifications for wall thickness, nor did they meet the shop drawing height. In assessing the overall problem and its causes, the following factors may have contributed:

- Since the strength of the polymer concrete material is so much greater than Portland cement concrete, a thinner wall is often used to construct each structure. It was discovered that in order to use less of the polymer concrete material, the supplier was attempting to use standard concrete manhole forms, with the alteration of placing baffles in the forms to reduce wall thickness. The baffles were not fabricated or placed very precisely, which resulted in an inconsistent wall thickness. The inconsistent wall thickness is detrimental to placement of pipe boots in the walls of the structures.
- The structure fabricator reportedly had a difficult time setting up the form to properly construct the manholes because of an inability to interpret the elevations shown on the shop drawings.
- During the casting of the manholes, the product supplier contacted Trelleborg, the supplier of "Kor-N-Seal boots,"* to obtain the minimum wall thickness required for the boot installation. The minimum thickness reportedly given to the supplier was 2 ½ in.; however, it was later discovered that Trelleborg had noted that the minimum thickness of 2 ½ in. was for a straight wall. The 2 ½ in. minimum was too thin, and that measurement should not have been applied to a curved wall structure, as was the case in these manholes. This problem led to leaks in the manholes after they were installed by using normal installation practices for typical concrete, then backfilled, and then observed to determine if they were sealed properly against the groundwater entry. The leaks were present at the joints and around the boot installation. A

* http://www.trelleborg.com/en/pipe-seals/products--and--solutions/connector--sealing--systems/pipe-to-manhole/kor--n-seal--i--106_406--series--pipe-to-manhole--connector

thickness of 3 in. is needed on a curved surface. The minimum thickness is important because it must provide enough contact surface for the boot installation band, which is critical to providing a watertight seal.

Due to the supplier quality issues described above, the following corrective actions had to be taken by the construction contractor:

- Because each structure was approximately 2 in. shorter in height than specified, the contractor had to build up the manhole or use a taller casting to make the manhole usable. A budget of $1,000 per manhole was allotted to complete the modifications.
- Additionally, the manholes were supplied with pick-up inserts that did not fit the industry standard pick-up key, so the contractor was required to purchase suitable pick-up keys.
- In order to properly install the manhole boots, the site contractor had to thicken the walls around all pipe openings. The contractor excavated each structure, built forms around all openings, and used Sika epoxy grout to thicken the walls enough to achieve proper installation of the boots. Once the grout materials were set and cured, the boots were reinstalled and observed for 24 hours. The thickening process provided sufficient contact area for the boots and the leaks were no longer present.
- Some structures arrived with sections assembled and others arrived separated. To achieve a consistent product sample, it was requested that the supplier send enough polymer concrete mixable product to assemble the unassembled units. The polymer product that was sent was very thin and runny, and it did little to seal the horizontal joint when mixed in accordance with the instructions. After much work by the onsite contractor, the structures were made watertight by mixing the material at a different ratio than the instructions provided. The remaining manholes were assembled using RAM-NEK® bitumastic material* to seal horizontal joints. This type of installation was much easier and formed a watertight joint. Total cost experienced by the contractor to correct all flaws in the manholes delivered was $27,561.32.
- The 2 in. height deficit on each manhole was resolved in several different ways. Some were extended by ordering a taller iron casting for the

* https://us.henry.com/performance-additives/concrete-joint-sealants/rn101-ram-nek-preformed-flexible-gasket-strips, accessed 27 December 2018.

manhole or by using a PVC/Portland cement concrete extension. Each manhole was delivered with a 24 in. circular opening in the top for access. To avoid direct contact between the sulfuric acid and the Portland cement concrete extension, a 24 in. PVC pipe was used to extend the 24 in. opening, then a larger pipe was used to form a 6 in. thick neck around the 24 in. PVC pipe. A concrete grout was used to fill in the gap and secure the PVC pipe extension. This modification resulted in an acid-resistant PVC extension secured with a 6 in. thick Portland cylinder poured around it. After these numerous mitigation efforts were complete, the manholes were installed and working. Figure 4 shows a polymer concrete manhole during installation.

Figure 4. Polymer concrete manhole during installation.

2.2.2 Polymer concrete pipe

The process of acquiring the PCP was similar to the manhole structures. The specification described the design of the pipe, and shop drawings were developed for approval. (Engineering specifications can be found in Appendix B and shop drawings are shown in Appendix C). Sections of the new pipelines included PVC sections to allow comparison of the two products in the future. Shop drawings were received seven months after the initial request, and multiple deadlines were missed by the manufacturer. It was agreed to receive the pipe in two shipments. The first shipment contained the first two of the 10 ft. lengths of pipe. The delivery deadline for the first shipment was not met; instead, casting began at the factory on the original shipment day. The first shipment arrived on 4 April 2016. The second shipment arrived on 30 April 2016 and contained the remaining 180 ft of pipe, along with stainless steel couplings. No special equipment was required to unload the pipe.

Problems were encountered while preparing the pipe for installation. The first two joints of pipe were installed in the entry of the treatment plant headwork's structure in two separate alignments, so no joining of the pipe was required. However after the remaining pipe was delivered, the installation contractor attempted to join two sections of pipe together but found that the coupling "racked" (Figure 5) and would not form a watertight seal when pressure was placed on the joint. In talking with the pipe supplier, it was found that a gasket is normally supplied for the pipe that the coupling rests against to control its alignment, but that was not originally done in this case. This usual gasket is normally referred to as a "dirt shield" because it keeps dirt from pushing the coupling out of place in a boring (trenchless) application. A secondary benefit of this gasket, not fully recognized in the past, is that it keeps the coupling aligned during a trenched installation. After several months, dirt shields were received and installed.

Another issue arose with the inflatable plugs, which are typically used during pipe installation for preventing entry of groundwater and for testing upon completion. There were interior seams in the pipe (Figure 6), apparently a result of the poor-quality forms. The seams caused the inserted plugs to leak. The supplier traveled to the site and corrected the seams near the pipe ends by grinding the seams smooth. The pipe wall was smooth at the ends, but it still had some ridges along the barrel of the pipe. In sanitary sewer use, if the pipes were smaller diameter, these seams could collect rags and debris that could clog the pipe and cause a backup. However, due to the larger size and flow of this project, it was not a concern. The installation contractor stated that in their experience working with other pipe materials such as PVC, reinforced concrete pipe, high density polyethylene (HDPE), and ductile iron pipe, grinding and homing is rarely a concern. A tighter quality assurance and quality control program during manufacturing of the product could be expected to facilitate a reliable, routine installation procedure for this product.

Figure 5. Misalignment of the couplings upon homing.

Figure 6. Interior seam in the PCP.

The PCPs were successfully installed after correcting the aforementioned issues. Images of the PCP during installation are shown in Figure 7 and Figure 8.

Figure 7. View during installation of PCP.

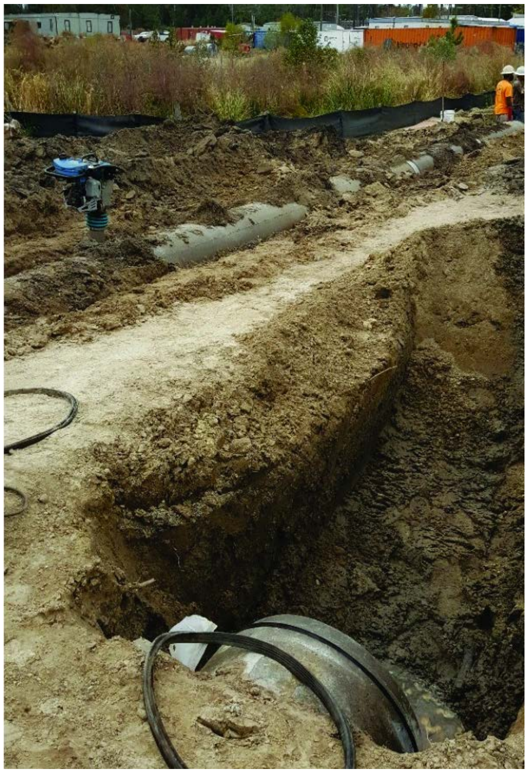


Figure 8. PCP (right) installed alongside PVC pipe (blue-green).

2.2.3 Polymer concrete junction boxes

The last polymer concrete structures received were the two influent boxes, which were placed at the headworks of the old plant to divert flow to the new plant. The plant has two influent lines—one from Fort Stewart and the other from the City of Hinesville. The Hinesville influent box receives flow from a five mile long, 24 in. force main. The discharge from this force main is very high in H_2S, with peaks of in excess of 350 ppm of H_2S. The Fort Stewart influent line is fed by one gravity line and one force main. Peak H_2S levels from the Fort Stewart influent line have measured at times in excess of 400 ppm.

Placement of these influent structures was performed under a bypass operation, because minimal downtime for the installation was critical. In addition, it was important that these structures be very resistant to sulfuric acid attack. Installation of a lined concrete structure would have required multiple bypass operations to complete the lining of the concrete structure; the first bypass would be to install the structure and then, at least one more by pass to weld the PVC or other liner at the pipe entry and the liner joints. The pipe arrived on site with all the correct openings and boots on the Fort Stewart structure; however, the Hinesville structure had an entry hole that did not match shop drawings. The inlet hole was required to have a 30 in. diameter, with a boot capable of fitting over the existing 24 in. C-905 PVC pipe. Instead, the influent box arrived with a 28 in. hole and a boot of the incorrect size. The correctly sized boot was shipped loose with the structure, so the onsite contractor had the hole re-cored and inserted to correct the error. The cost of this correction was $1,359.80.

While it was difficult to obtain a box delivered that met shop drawing requirements and could accept all existing pipe entries, the final installation was simple and without delay. The influent flow diversion box installation, in the Hinesville city engineer's opinion, was the perfect fit for the polymer concrete product. The highly resistant material needed no coating that would have delayed installation, and the extra work required for preparation was offset by the quick and easy installation.

All PCP and related structures were installed by December 2016. On 15 December 2016, flow was diverted into the first of two pipelines, and all flow to the new plant was diverted on 28 December 2016.

2.3 Commissioning and monitoring

2.3.1 Field/construction verification of properly installed technology

Primary commissioning tests for sewer pipe and structures included an infiltration/exfiltration test, low-pressure air test, and visual inspection. All structures were eventually installed to the line and grades shown in shop drawings, inverts were built in the structures, and some structures were raised to meet grade by using PVC-lined concrete extensions. Due to the coupling problem, the pipe was somewhat more cumbersome to install in making the connection between pipe joints. All pipe was installed, inspected, and videoed for compliance with shop drawings and specifications (specifications shown in Appendix B, and shop drawings reproduced in Appendix C).

2.3.2 Field performance monitoring and testing

2.3.2.1 Monitoring of wet well coupons

Polymer concrete and Portland cement concrete sample coupons were prepared and hung inside the first-stage recirculation pump station wet well at the wastewater treatment plant; this was done as a means of acid-resistance performance testing. The H_2S levels in the wet well were measured consistently in the 400–600 ppm range, and the air space was an enclosed environment. Initially, the sample coupons were measured monthly, but because the deterioration was gradual on all surfaces and the attack of sulfuric acid on the concrete caused swelling of the concrete coupon, the measurements did not allow any conclusive proof that one sample was surviving better than the other. Visual comparison, however, gave clear indications and therefore, it was used as the evaluation technique (see results in Chapter 3. The original coupons are shown in Figure 9 and Figure 10; side-by-side visual comparison photos are shown in Table 2, Chapter 3.

2.3.2.2 Multiple materials installed for comparison

To allow for direct comparison of performance, new sections of 24 in. PVC pipe were also placed in-line with the new 24 in. PCP in the treatment plant.

Figure 9. Original polymer concrete sample, approximately 52 x 203 x 203 mm.

Figure 10. Original Portland cement concrete sample, approximately 92 x 203 x 203 mm.

2.3.3 Laboratory performance testing

Two in-house laboratory experiments were performed at ERDC-CERL to validate the manufacturer's claim that polymer concrete is resistant to sulfuric acid.

The first experiment was an immersion acid-resistance test using two manufacturer-supplied polymer concrete samples. One sample of Portland cement concrete, mixed by a local commercial concrete company and sampled directly from the mixer truck, was formed at ERDC-CERL and was also included in the test. The four samples were placed in a glass dish with a solution of approximately 5% sulfuric acid (66.3 ml of water and 3.7 ml of ~96.5% sulfuric acid). Note that this is an accelerated test, as sulfuric acid found in a deteriorating wastewater system is likely to be in the range of 1.0 percent concentration (Attiogbe and Rizkalla 1988). The samples remained immersed in the sulfuric acid solution for several weeks. Results for this experiment were determined by observation and comparison (see section 3.1 and section 3.2).

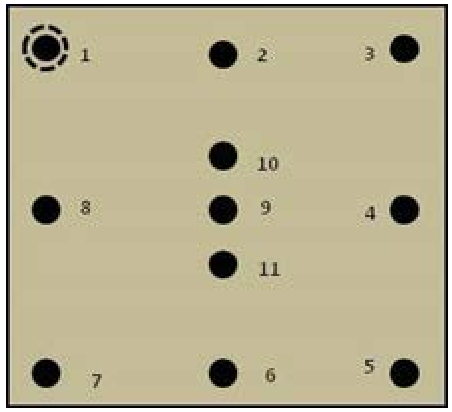
Additionally, sulfuric acid resistance was also tested via a thin film mechanism that ERDC-CERL researchers created in the lab to more closely represent actual field conditions prevalent in a sewer pipe. The major components (Parafilm; ¾ in. diameter, clear PVC schedule 40 pipe; and Masterflex C-Flex Ultra tubing, size 17) in the system used for the test were first tested via immersion in 5% sulfuric acid to ensure each component's integrity. After being immersed for approximately one month, the samples showed no sign of degradation. Therefore, these components were used to build the experimental setup shown in Figure 11.

Figure 11. Experimental setup for exposure test to thin film of sulfuric acid.

This system was designed for sulfuric acid flow in a closed circuit from the beaker, through the pump into the PVC pipe, onto the samples, and back to the beaker. Three funnels held the samples and provided acid recycling assistance. Each funnel was connected to a drain tube that flowed back to the beaker of the stock solution, which was approximately 5%–10% sulfuric acid. The beaker was covered to prevent evaporation and to anchor the tubes in place.

Prior to acid exposure, the mass and thicknesses of two samples of polymer concrete and one sample of regular concrete were measured. The masses were measured using a digital balance, and the thicknesses were measured using a 0–1 in. deep throat micrometer at 11 different locations on the sample (Figure 12). It was necessary to measure at several locations because the samples were not uniform in thickness. The black dots in Figure 12 indicate the 11 points of measurement, to provide an approximate pattern; dot numbers mark the order in which measurements were taken. Dot #9 was placed directly on the reinforcing bar that penetrated the polymer concrete samples. The dotted line around dot #1 ensured a consistent starting point for measurements. Dots #10 and #11 were moveable: they were located relatively to be above and below the rebar.

Figure 12. Diagram of approximate thickness of measurement points on samples.



A sulfuric acid solution was prepared using 600 mL of tap water and 68 mL of concentrated sulfuric acid. Solution pH was measured and recorded using a pH meter; however, there were problems with the accuracy of the meter. The acid was so concentrated that it was difficult for the meter to quickly determine the pH. Therefore, pH strips were used as a confirmation that the solution was highly acidic. Samples were placed in funnels at a slight angle to allow the acid to drain off. Two mechanical timers were used to regulate the solution pump. The first timer was used to run the pump—in time intervals of 5 minutes on and 12 minutes off, then 30 seconds on and 12.5 minutes off—over the course of each 30-minute time period. The second timer ran the experiment for nine hours/day. The intent was to simulate a thin film of acid on the samples.

The experiment ran under these circumstances weekly, Monday–Friday, for four continuous weeks. At the conclusion of each week, the samples were rinsed with deionized water, brushed with a wire brush, and left to dry for the weekend. Pictures were taken of each sample before and after rinsing. The masses and thicknesses of each sample were measured on the following Monday. At the beginning of weeks three and four, a new acid solution was prepared because of large losses in volume due to corrosion debris that caused clogs in the funnels and resulted in acid overflow out of the funnels. The main pump's supply tube was also replaced during week three due to wear.

As was the case with measuring the thickness of the large coupons in the wastewater treatment plant wet well, accurate thickness measurements were difficult to achieve in this experiment. There was measurement variation in micrometer use, and the materials did not deteriorate uniformly.

Thus, two additional techniques were used to observe changes: scanning electron microscopy (SEM) and energy-dispersive x-ray spectroscopy (EDS). These two characterization methods were used to observe surface changes due to the acidic environment. Following the acid tests, the samples were placed in an oven for 11 days at 200 °F to reduce moisture in the samples prior to the SEM and EDS observations.

3 Discussion

3.1 Field coupon testing

Polymer concrete field coupons performed excellently. Table 2 shows a visual comparison of before and after the samples were hung in the wet well. The Portland cement concrete samples show a loss in the binder, exposed aggregates, and a general weakening of the material. The polymer concrete appears to remain intact.

Table 2. Pictures showing specimens before and after wet well exposure show visual comparisons between polymer concrete and Portland cement concrete.

Material	Before	After
Polymer Concrete		
Portland Cement Concrete		

3.2 CERL laboratory test results

3.2.1 Thickness comparisons

As noted in section 2.3.3, accurate thickness measurements were difficult to achieve before acid immersion because the unexposed specimens were not of uniform thickness, which created measurement difficulties using the micrometer. Compounding the problems with thickness measurements, the specimens did not deteriorate uniformly during exposure. Consequently, results gathered from the sulfuric acid immersion test were based on visual inspection only.

3.2.2 Visual inspections

Figure 13 shows visual comparisons between one Portland cement concrete specimen and polymer concrete specimens after acid exposure. Visual inspections verified that the polymer concrete samples resisted attack much better than the Portland cement concrete. The rebar in the polymer concrete samples did not visibly degrade much, probably because it had formed a protective oxide layer.

Figure 13. Visual comparison of one Portland cement concrete sample (far left) and three polymer concrete samples after immersion (to the right of the Portland sample).

As stated above for the thin film sulfuric acid experiment, thicknesses were measured but not incorporated into the final results because, despite repeated attempts, micrometer measurements were inconclusive. Visual inspection and mass loss provided more reliable results.

3.2.3 Mass loss comparisons

Table 3 shows mass loss for each sample over the course of the experiment. The results show insignificant mass loss in the polymer concrete samples; however, the Portland cement concrete specimen lost roughly 20% of its mass. Thus, the acid had a much greater detrimental impact on the Portland cement concrete.

Table 3. Mass loss of samples throughout experiment.

	Initial (g)	Week 1 (g)	Week 2 (g)	Week 3 (g)	Week 4 (g)	Total Change (g)
Polymer Concrete A	79.04	79.02	79.03	78.91	79.02	0.02
Polymer Concrete B	80.21	80.21	80.21	80.14	80.20	0.01
Portland Concrete	123.01	120.19	111.41	104.91	99.65	23.36

Additionally, visual inspections were performed. Deterioration to the Portland cement concrete was obvious to the naked eye (see Figure 14 for an example). Further evidence of deterioration is the collection of debris at the bottom of the funnel, which occurred multiple times and led to system failure. Notice the surface is also no longer smooth. However, it was difficult to see any changes in the polymer concrete. The rebar formed an oxide layer within a few days, making it appear black. The polymer concrete sample B did appear to show very slight signs of corrosion on its aggregate components.

3.2.4 Scanning electron microscopy (SEM) imaging

SEM images were taken to better characterize the samples. Table 4 shows results of the Portland cement concrete exposed to approximately 5%–10% sulfuric acid when compared to an unexposed sample, via visual inspection and SEM results. There are observable differences between the two states. Table 5 shows a similar comparison, except it compares only the polymer concrete samples. The aggregate in the polymer concrete probably contained different materials. One type of aggregate in the polymer concrete seemed to be more susceptible to attack than other aggregate materials. There is also a black tint to the polymer concrete samples after exposure, but the samples did not appear to be degraded.

Figure 14. Visual evidence of mass loss of the Portland cement concrete, and the resulting clog in funnel is also visible.

Table 4. Visual comparison between an unexposed and exposed sample of Portland cement concrete.

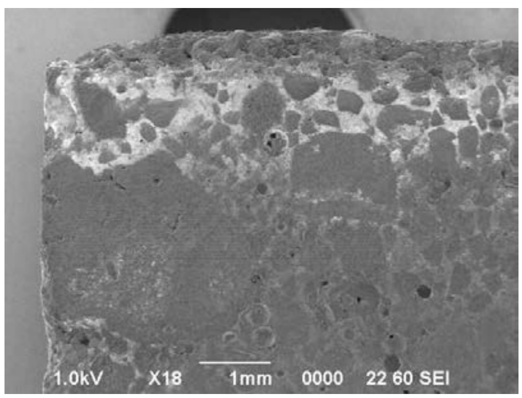
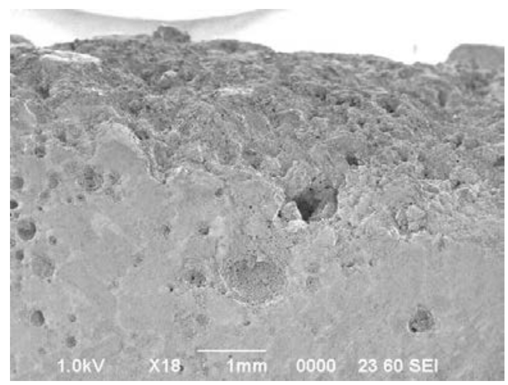
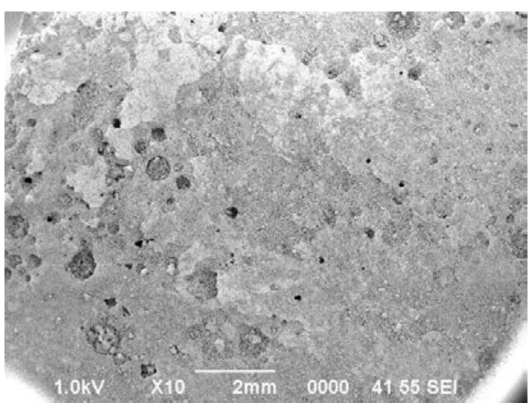
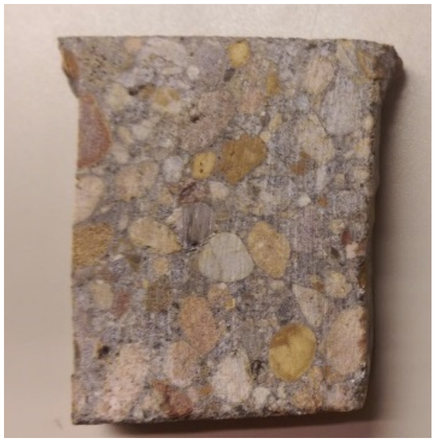
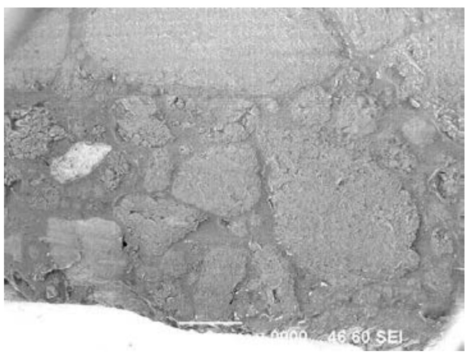
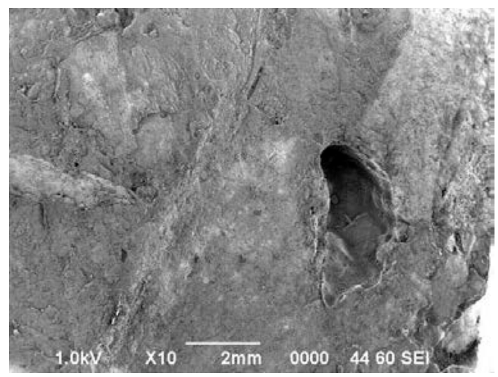
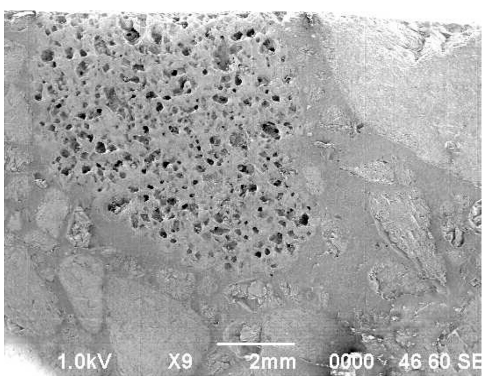
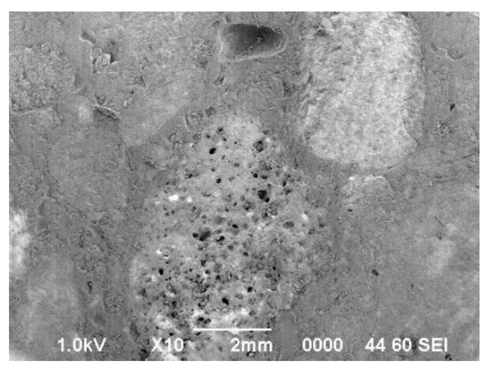
Type of material	Unexposed to Acid	Exposed to Acid
Portland cement concrete visual		
Portland cement concrete – profile SEM view		
Portland cement concrete– alternate SEM view (surface became rougher).		

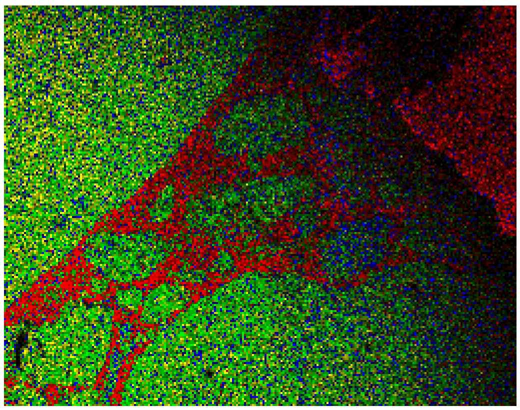
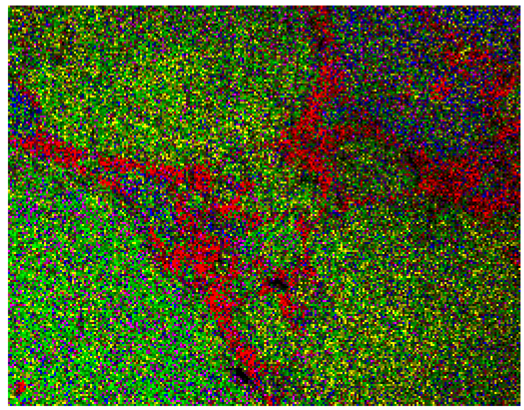
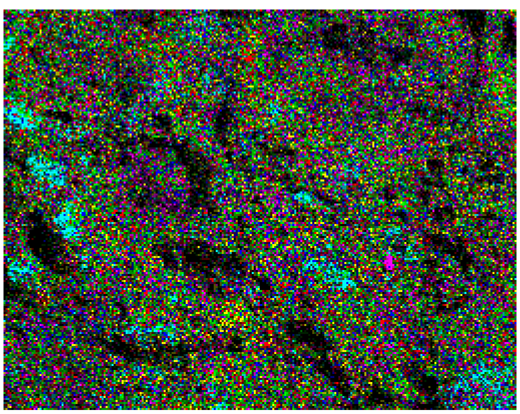
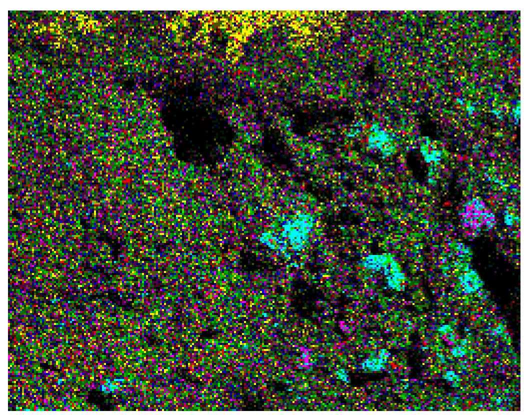
Table 5. Comparison between polymer concrete, unexposed and exposed to acid.

Material	Unexposed to Acid	Exposed to Acid
Polymer concrete		
Polymer concrete – SEM image showing surface defects		
Polymer concrete alternate sample, SEM view (sample with more porous aggregate)		

3.2.5 Energy-dispersive X-ray spectroscopy

EDS was another characterization tool used. This tool was used to gather element composition maps of an unexposed sample and an exposed sample of the polymer concrete and of the Portland. The overlay composition maps are shown in Table 6. Each color corresponds to an element (e.g., royal blue indicates aluminum).

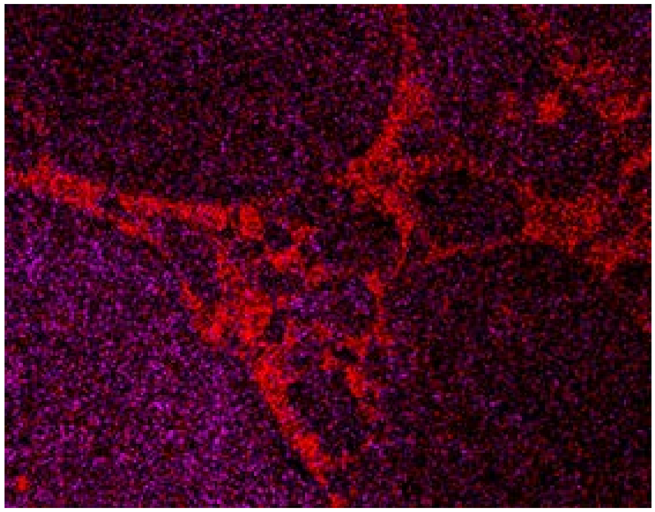
Table 6. Comparison of EDS composition maps for polymer concrete and Portland cement concrete, with each color corresponding to a different element (see notes).

	Unexposed	Exposed
Polymer Concrete*		
Portland Concrete**		

1. Al-royal blue, C-red, O-Green, Si-Yellow | S-purple (only present in exposed sample)
2. Al-purple, Ca-royal blue, C-dark red, F- dark blue, K-dark green, Mg- yellow, O-green, Si-cyan, S-red

The images in Table 6 show that the polymer concrete has a more distinct compositional makeup. The predominately green and yellow areas are silicon and oxygen based, representing the aggregate in the concrete. The primarily red areas represent the polymeric binder (carbon-based). After sulfuric acid exposure, sulfur was quite dispersed but appeared to be more concentrated in aggregate regions, as demonstrated in Table 6 and in Figure 15 (an overlay showing only the carbon and the sulfur). The binder area did not appear to absorb much sulfur.

Figure 15. Overlay of carbon (red) and sulfur (purple) after exposure of polymer concrete to acid.



Additionally, when comparing the two Portland cement concrete images in Table 6, it was observed that before acid exposure, most of the elements were evenly dispersed. However after the exposure, the silicon and magnesium regions were more defined and concentrated. This finding led to the conclusion that there was initially a well mixed variety of materials because of a smooth cement binder layer on this sample. However, after the exposure, many aggregates were clearly visible due to a loss in the binder via sulfuric acid attack.

3.3 Third-party compression tests

Material compressive strength testing was performed by certified third-party testing lab (Maxim Technologies of Houston, TX), which had been selected by the PCP supplier. However, ERDC-CERL could not verify or replicate the test results because the samples sent to the research team were not the appropriate size and shape for standard compression testing. It was later discovered that the testing certification provided by the supplier was out of date, so no compression test data are presented here. For more information about compressive strength, a prospective user should consult the supplier. The PPT/Interpipe design calculation methodology reproduced in Appendix D has related information.

3.4 Lessons learned

1. The biggest problems encountered during the project were missed delivery times by the pipe and structure supplier, and the delivery of

products that were off-specification and flawed by fabrication problems. Any acquisition of this product should carry appropriate penalties for nonperformance to include bid bond, performance bond, and liquidated damages for nonperformance of contract terms. In addition, market research should carefully validate supplier capabilities.

2. Consider having a representative of the pipeline owner inspect the materials prior to shipping from the manufacturer's site.
3. The wastewater industry is not currently the primary market for polymer concrete; the mining industry is. This fact may have led to some of the difficulties in the project. Some PCP and structure manufacturers may not be completely familiar with the requirements of the sanitary wastewater market. However, competition does exist. Also, the company chosen for this project to supply polymer concrete materials was purchased by another company during the project. This change in ownership may have contributed to the difficulties.
4. The pipe and structure installation should have been much the same as the installation of more traditional materials. Installation would have been fairly routine had it not been for the necessary adjustments to the structures provided. The adjustments were required because of off-specification deliverables and fabrication flaws.
5. A patching method is available for polymer concrete, but the water-to-mix ratio may need adjustment. In this project, the manufacturer's recommended mix ratio produced a very wet mix. To be successful, a thicker mix was used by adjusting the water-to-mix ratio. The patch material consists of the same resin blend used for casting the structures, but it has a different aggregate blend (yet with the same corrosion resistance).
6. The use of polymer concrete pipes is recommended only when acid resistance or high strength is required. For example, high strength is needed when soil cover depth is minimal and vehicle traffic is expected over the pipe. If soil cover depth meets system structural design standards, PVC pipe is preferable because of its lower initial cost.
7. Polymer concrete structures, such as manholes, are a good alternative to lined concrete structures if the structures are regularly exposed to hydrogen sulfide or other highly corrosive gases in sewer systems. Polymer concrete structures are resistant to highly corrosive environments without a coating or lining system. The downtime for installation of the polymer concrete structure is shorter than other alternatives because there is no need for an extra lining step. This shortened installation

time may present a savings opportunity greater than the extra cost for procuring polymer concrete materials.

8. Additional cost comparison data between polymer concrete and Portland cement concrete is provided in Appendix E.

4 Economic Analysis

This analysis is performed in accordance with Office of Management and Budget (OMB) Circular No. A-94, *Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs*.

4.1 Costs and assumptions

Table 7. Demonstration project costs.

Cost Description	Funding Source		Totals ($k)
	OSD ($k)	DPW (In-Kind Match*) ($k)	
IN-HOUSE			
Labor (O&M)	20**		20**
Labor (RDT&E)	60		60
Awards	--	--	--
Purchases (O&M)	10	--	10
Travel / Training (O&M)	10	--	10
Travel / Training (RDT&E))	10	--	10
Misc (RDT&E)	15	--	15
OTHER GOVERNMENT AGENCIES			
OGA (RDT&E)	5	--	5
CONTRACT			
Private Industry (O&M)	160	285	445
College / University	--	--	--
FFRDC	--	--	--
Other Non-Profit	--	--	--
TOTAL ($k)	290**	285	575**

* As an in-kind match, Fort Stewart DPW is providing $285k to the rebuild of the Hinesville Waste Water Treatment Plant, which supports Fort Stewart. The PCP being demonstrated was installed as part of this construction, as described herein.

** This includes $5k that will be a separate future funding requirement to complete the ROI Re-assessment Reports that are due two years after the final technical report is published.

4.1.1 Alternative 1 (baseline case)

Per the 2011 RS Means, it is estimated that a conventional 4 ft diameter and 6 ft deep concrete manhole costs $1,550 with frame and cover. Adjusting for inflation from the 2011 RS Means costs by +6% = $1,650. Add in the same amount ($1,650) for excavation, footing, and backfill. An additional $300 is required for gaskets. However, in locations with high H_2S or other corrosive conditions, additional measures are needed, such as a manhole liner. Assume the use of a manhole liner at a cost of approximately $25/sq ft. The liner cost is the area of the inside of the manhole (4 ft x 3.14 x 6 ft) multiplied by $25/sq ft = $1,900 per manhole. The calculated conventional manhole cost with a liner is $1,650 + $1,650 + $300 + $1,900 = $5,500. Sources for cost figures are from RS Means and Concrete Conservation Incorporated (Elkton, FL). The cost summary for this case is shown in Table 8.

Table 8. Cost summary for baseline case.

Baseline Case Costs	Cost ($)
First costs	5,500
Annual operating and maintenance costs[1]	0
Periodic component replacement or refurbishment[2]	N/A

1. It is assumed that both the new and the alternative (polymer concrete structures as demonstrated) will last 30 years with equal maintenance. Thus, the net (difference) maintenance cost is zero dollars.

2. No periodic component replacement or refurbishment is considered necessary within the 30-year analysis. Service life exceeds 30 years.

4.1.2 Alternative 2 (polymer concrete)

It is unlikely the conventional manhole with liner described above would match the quality of a polymer concrete manhole. However, the costs are compared as if the two manholes are of equal quality. The polymer concrete manhole is estimated for similar dimensions to the on described above at a cost of $3,000 with gaskets. However, no liner is needed in this case. The fact that no liner has to be installed in the field can be an advantage when time is sensitive. Freight is the same as for a conventional manhole. Installation is the same as for conventional, if not faster. A cost summary for this alternative is shown in Table 9.

Table 9. Cost summary for demonstrated case.

Demonstrated Case Costs	Cost ($)
First costs	3,000
Annual operating and maintenance costs[1]	0
Periodic component replacement or refurbishment[2]	N/A

*It is assumed that both the new and the alternative (polymer concrete structures as demonstrated) will last beyond 30 years with equal maintenance. Thus, the net maintenance cost is zero dollars over the 30 year analysis.

**No periodic component replacement or refurbishment is considered

4.2 Projected return on investment (ROI)

A 7% discount rate is used for the return on investment (ROI) calculation, consistent with CPC program guidance (OMB Circular A-94). The 7% rate is built into the Table 10 spreadsheet. The projected ROI is 9.27 over 30 years. The calculation is based on a required CPC project investment of $575,000. A summary of the analysis is shown in Table 10.

For the ROI calculation, cost savings only from manholes at Army installations are considered, although polymer concrete sewer system structures offer significant additional benefit. Also, it is acknowledged that PCP use for sewers could offer modest additional savings in certain situations, but those are not included in the calculation.

Installation Status Report (ISR) data for 2012 report over 1,550 miles of sewer pipe in Facility Category Group F83200 (Sewage/Waste Collection Lines) for all installations, counting only those that have a condition of Red or Black. This figure includes combined sewers, but not storm sewers. Sanitary sewer manholes are required every 400–800 ft of pipe, depending on the terrain and the size of pipe. It is assumed that an average of 500 ft of pipe is used with each manhole, although the actual distance is probably shorter. Therefore, the number of Army sanitary manholes in failing condition is roughly 16,400 (1,550 miles x 5,280 ft per mile = 8,184,000 ft / 500 ft ≈ 16,400 manholes).

Considering manholes only (not pipes), if the Army replaces only 5% per year of the 16,400 already-failing manholes, that number is 820 manholes per year (0.05 x 16,400). In some instances, the use of polymer concrete replacement manholes will be justified, as determined on a case-by-case basis. It is further assumed that only 200 of the 820 manholes per year are suitable for polymer concrete. (Note that only those manholes in the worst condition, per the ISR, are considered here). This number will likely include many of the manholes serving in the most corrosive or otherwise harsh environments, and so those types of environments are good candidates for polymer concrete technology. The baseline alternative considered for the ROI calculation is replacing these existing manholes with conventional manholes and manhole liners.

Therefore, per the cost calculations above, the annual baseline cost of conventional manholes with liners is $5,500 x 200 manholes = $1,100,000.

The comparative cost if polymer concrete manholes are used instead is $3,000 x 200 = $600,000. This is the "new system" cost used in Column D of the spreadsheet in Table 10. The ROI calculation accounts for a 5-year phase-in of the new technology.

There is added benefit derived from preventing sanitary sewer pipe leaks (infiltration and inflow)—the installation avoids operation interruptions and unplanned maintenance costs at the treatment plant. These benefits are not accounted for in this calculation, but doing so would improve the ROI.

There is still even more potential cost benefit because many DoD installations can benefit from polymer concrete technology, but only Army sites are factored into this ROI estimate.

Note again that the required investment includes $5k out-year funds that are needed to complete the required CPC program's ROI Reassessment Report that is due two years after the final report is published.

Table 10. ROI calculation.

Return on Investment Calculation

Investment Required			575,000
Return on Investment Ratio	9.27	Percent	927%
Net Present Value of Costs and Benefits/Savings	8,320,630	13,649,570	5,328,940

A Future Year	B Baseline Costs	C Baseline Benefits/Savings	D New System Costs	E New System Benefits/Savings	F Present Value of Costs	G Present Value of Savings	H Total Present Value
1	1,100,000		1,000,000		934,600	1,028,060	93,460
2	1,100,000		900,000		786,060	960,740	174,680
3	1,100,000		800,000		653,040	897,930	244,890
4	1,100,000		700,000		534,030	839,190	305,160
5	1,100,000		600,000		427,800	784,300	356,500
6	1,100,000		600,000		399,780	732,930	333,150
7	1,100,000		600,000		373,620	684,970	311,350
8	1,100,000		600,000		349,200	640,200	291,000
9	1,100,000		600,000		326,340	598,290	271,950
10	1,100,000		600,000		304,980	559,130	254,150
11	1,100,000		600,000		285,060	522,610	237,550
12	1,100,000		600,000		266,400	488,400	222,000
13	1,100,000		600,000		249,000	456,500	207,500
14	1,100,000		600,000		232,680	426,580	193,900
15	1,100,000		600,000		217,440	398,640	181,200
16	1,100,000		600,000		203,220	372,570	169,350
17	1,100,000		600,000		189,960	348,260	158,300
18	1,100,000		600,000		177,540	325,490	147,950
19	1,100,000		600,000		165,900	304,150	138,250
20	1,100,000		600,000		155,040	284,240	129,200
21	1,100,000		600,000		144,900	265,650	120,750
22	1,100,000		600,000		135,420	248,270	112,850
23	1,100,000		600,000		126,540	231,990	105,450
24	1,100,000		600,000		118,260	216,810	98,550
25	1,100,000		600,000		110,520	202,620	92,100
26	1,100,000		600,000		103,320	189,420	86,100
27	1,100,000		600,000		96,540	176,990	80,450
28	1,100,000		600,000		90,240	165,440	75,200
29	1,100,000		600,000		84,360	154,660	70,300
30	1,100,000		600,000		78,840	144,540	65,700

5 Conclusions and Recommendations

5.1 Conclusions

Results of coupon sulfuric acid tests in wet well, immersion, and cyclic exposure indicate that polymer concrete will resist biogenic sulfide corrosion much better than regular Portland cement concrete. The polymer concrete also provides an advantage over Portland cement concrete in strength. Thus, when these properties are needed, it is a suitable replacement material in wastewater systems. Polymer concrete structures should be expected to provide longer service lives than traditional products. However, the polymer concrete market is not currently targeted toward the wastewater industry, so extra attention may be required during the acquisition process for scheduling, communication, and quality assurance.

5.2 Recommendations

5.2.1 Applicability

This technology has far-reaching utility across the DoD. This technology is applicable to most military installations because wastewater infrastructure deterioration is very common.

5.2.2 Implementation

PCP and structures for sewer and wastewater systems are expected to have significantly better corrosion and abrasion resistance than traditional materials now used by military installations. Material costs may be higher but will be offset by improved service life and possibly by reduced installation O&M time.

Unified Facilities Guide Specification (UFGS) 33-30-00, *Sanitary Sewers*, and Unified Facilities Criteria (UFC) 3-240-01, *Waste Water Collection*, dated 1 Nov 2012 were reviewed. Only the UFGS is recommended for update, specifically in "section 2.3.1, Miscellaneous Materials," in the form of a designer's note. The suggested designer's note is as follows:

> Polymer concrete pipes, structures, and manholes are a suitable option for precast materials.

> Polymer concrete pipe may be useful when the structural loads are high and corrosion resistance is essential. Polymer concrete manholes may be useful in lieu of lined concrete structures. Extra attention is needed during acquisition because standard practices among polymer concrete manufacturers may differ from those in the traditional sanitary sewer industry.

This implementation approach has been coordinated with the U.S. Army Corps of Engineers (USACE) technical proponent.

References

ABT, Inc. 2017. PolyDrain® Pre-Engineered Surface Drainage Manual. Online document: https://www.abtdrains.com/wp-content/uploads/2017/01/cat-PolyDrain.pdf. Troutman, NC: ABT, Inc.

ASTM C267-01. 2012. "Standard Test Method for Chemical Resistance of Mortars, Grouts, and Monolithic Surfacings and Polymer Concretes." West Conshohocken, PA: ASTM International.

Attiogbe, Emmanuel K., and Sami H. Rizkalla. 1988. "Response of Concrete to Sulfuric Acid Attack." *ACI Materials Journal* 85(6): 481–488.

The Engineering ToolBox. 2017. "Concrete - Properties." Online resource, webpage accessed 26 April 2017: http://www.engineeringtoolbox.com/concrete-properties-d_1223.html.

Herzberg, Eric F., Norman T. O'Meara, and Rebecca F. Stroh. February 2014. *The Annual Cost of Corrosion for the Facilities and Infrastructure of the Department of Defense*. Report DAC21T4, revision 1. Tysons, VA: LMI Government Consulting.

Office of Management and Budget (OMB). 1994. *Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs*. OMB Circular No. A-94. Washington, DC: Office of Management and Budget.

Polymer Pipe Technology/Interpipe. 2006. *iNTERpipe Product Specification Guide*. Des Moines, IA: The current version of this specification guide is available at https://www.polymerpipe.com/aboutus.htm.

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Appendix A: Chemical Corrosion Resistance of Resin in PCP

Table A1. Corrosion resistance guide (PPT/Interpipe 2006, 62–69).

Corrosion Resistance Guide

Corrosion resistance information has been supplied by resin manufactures. Individual service conditions should be evaluated when selecting the appropriate pipe products. Design engineers should check with PPT to inquire about special operating conditions.

Chemical Environment	%	Standard °F	Option °F
Acetaldehyde	100	NR	NR
Acetic Acid	0-25	170	210
	25-50	150	180
	50-75		140
Acetic Acid, Glacial	100	NR	NR
Acetic Anhydride	100	NR	NR
Acetone	10	NR	180
	100	NR	NR
Acetonitrile	100	NR	NR
Acetophenone	100	NR	NR
Acetyl Chloride	ALL	NR	NR
Acrylic Acid	0-25	NR	100
Acrylic Latex	ALL		120
Acrylonitrile	100	NR	NR
Acrylonitrile Latex	ALL		
Alkyl Benzene Sulfonic Acid	92		120
Alkyl Benzene C_{10} -C_{12}	100		
Allyl Alcohol	100	NR	NR
Allyl Chloride	ALL	NR	NR
Alpha Methyl Styrene	100	NR	NR
Alpha Olefin Sulfates	100		120
Alum	ALL	170	210
Aluminum Chloride	ALL	170	210
Aluminum Chlorohydrate	ALL	150	210
Aluminum Citrate	ALL	170	210
Aluminum Fluoride	ALL	NR	80
Aluminum Hydroxide	ALL		180
Aluminum Nitrate	ALL	140	180
Aluminum Potassium Sulfate	ALL	170	210
Aluminum Sulfate	ALL	170	210
Amino Acids	ALL		100
Ammonia, Liquified	ALL	NR	NR
Ammonia, Aqueous			
Ammonia (Dry Gas)	ALL		100
Ammonium Acetate	65	NR	100
Ammonium Benzoate	ALL		180
Ammonium Bicarbonate	ALL	120	160
Ammonium Bisulfite (Black Liquor)		NR	180
Ammonium Bromate	40		160
Ammonium Bromide	40		160
Ammonium Carbonate	ALL	80	150
Ammonium Chloride	ALL	170	210
Ammonium Citrate	ALL	120	160
Ammonium Fluoride	ALL		150
Ammonium Hydroxide (Aqueous Ammonia)	1	NR	200
	5	NR	180
	10	NR	150
	20	NR	150
	29	NR	100
Ammonium Lauryl Sulfate	30		120
Ammonium Ligno Sulfonate	50		
Ammonium Nitrate	ALL	140	200
Ammonium Persulfate (Mono or Di Base)	ALL	NR	180
Ammonium Phosphate	ALL	140	210
Ammonium Sulfate	ALL	170	210
Ammonium Sulfide (Bisulfide)	ALL	NR	120
Ammonium Sulfite	ALL	NR	150
Ammonium Thiocyanate	20	140	210
	50	80	110
Ammonium Thiosulfate	60	NR	100
Amyl Acetate	ALL	NR	NR
Amyl Alcohol (Vapor)		100	150
Amyl Alcohol	ALL	80	120
Amyl Chloride	ALL	NR	120
Aniline	ALL	NR	NR
Aniline Hydrochloride	ALL		180
Aniline Sulfate	Sat'd	140	210
Aqua Regia (3:1 HCl-HNO3)	ALL	NR	NR
Arsenic Acid	80		110
Arsenious Acid	20	80	180
Barium Acetate	ALL	NR	160
Barium Bromide	ALL		210
Barium Carbonate	ALL	80	210
Barium Chloride	ALL	170	210
Barium Cyanide	ALL		150
Barium Hydroxide	ALL	NR	150
Barium Sulfate	ALL	170	210
Barium Sulfide	ALL	NR	180
Beer		80	
Beet Sugar Liquor	ALL	110	180

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Corrosion Resistance Guide

Chemical Environment	%	Standard °F	Option °F
Benzaldehyde	100	NR	NR
Benzene	100	NR	NR
Benzene, HCl (wet)	ALL	NR	NR
Benzene Sulfonic Acid	30	NR	210
Benzene (Vapor)	ALL	NR	NR
Benzoic Acid	ALL	170	210
Benzoquinones	ALL		150
Benzyl Alcohol	ALL	NR	NR
Benzyl Chloride	ALL	NR	NR
Black Liquor (pulp mill)	ALL	NR	180
Bleach Solutions			
Calcium Hypochlorite	ALL	NR	180
Chlorine Dioxide		NR	160
Chlorine Water	ALL	NR	180
Chlorite	50	NR	100
Hydrosulfite		NR	180
Sodium Hypochlorite	0-15	NR	125
Borax	ALL	170	210
Boric Acid	ALL	170	210
Brake Fluid			110
Brine, Salt	ALL	170	210
Bromine	Liquid	NR	NR
Bromine Water	5		180
Brown Stock (pulp mill)		NR	180
Bunker C Fuel Oil	100	140	210
Butanol	ALL	NR	120
Butanol, Tertiary	ALL		
Butyl Acetate	100	NR	NR
Butyl Acrylate	100	NR	NR
Butyl Amine	ALL	NR	NR
Butyl Benzoate	100	NR	
Butyl Benzyl Phthalate	100		180
Butyl Carbitol	100	NR	100
Butyl Cellosolve	100	NR	100
Butylene Glycol	100	150	160
Butlylene Oxide	100	NR	NR
Butyraldehyde	100	NR	NR
Butyric Acid	50	80	210
	85	NR	80
Cadmium Chloride	ALL	150	180

Chemical Environment	%	Standard °F	Option °F
Calcium Bisulfite	ALL	140	180
Calcium Bromide	ALL		200
Calcium Carbonate	ALL	160	180
Calcium Chlorate	ALL	150	210
Calcium Chloride	Sat'd	170	210
Calcium Hydroxide	ALL	160	180
Calcium Hypochlorite	ALL	NR	180
Calcium Nitrate	ALL	170	210
Calcium Sulfate	ALL	170	210
Calcium Sulfite	ALL		180
Cane Sugar Liquor/Sweet Water	ALL	110	180
Capric Acid	ALL		180
Caprylic Acid (Octanoic Acid)	ALL		180
Carbon Disulfide	100	NR	NR
Carbon Tetrachloride	100	NR	100
Carbowax	100		100
Carbowax Polyethelene Glycols	ALL		150
Carboxyethyl Cellulose	10		150
Carboxymethyl Cellulose	ALL		150
Cashew Nut Oil	ALL		
Castor Oil	ALL		160
Chlorinated Pulp			180
Chlorination Washer Hoods/Ducts			180
Chlorinated Waxes	ALL	150	180
Chlorine (liquid)	100	NR	NR
Chlorine Dioxide		NR	160
Chlorine Gas (wet or dry)			210
Chlorine Water	ALL	NR	180
Chloroacetic Acid	25		
	50	NR	
	80		
	100	NR	NR
Chlorobenzene	100	NR	NR
Chloroform	100	NR	NR
Chloropyridine	100	NR	NR
Chlorosulfonic Acid	ALL	NR	NR
Chlorotoluene	100	NR	NR
Chrome Plating Solution		NR	120
Chromic Acid	5		110
	20	NR	NR

Corrosion Resistance Guide

Chemical Environment	%	Standard °F	Option °F
Chromium Sulfate	ALL		150
Chromous Sulfate	ALL	140	180
Citric Acid	ALL	160	210
Cobalt Chloride	ALL		180
Cobalt Citrate	ALL		180
Coblat Naphthenate	ALL		150
Cobalt Nitrate	15		120
Cobalt Octoate	ALL		150
Coconut Oil	ALL	150	180
Copper Acetate	ALL	170	210
Copper Chloride	ALL	170	210
Copper Cyanide	ALL	130	210
Copper Fluoride	ALL	NR	210
Copper Nitrate	ALL	170	210
Copper Sulfate	ALL	170	210
Corn Oil	ALL		200
Corn Starch	ALL		210
Corn Sugar	ALL		210
Cottonseed Oil	ALL		210
Cresylic Acids	ALL	NR	NR
Crude Oil, Sour or Sweet	100	170	210
Cyclohexane	100	NR	120
Cyclohexenone	100	NR	NR
Decanol	100		120
Dechlorinated Brine Storage	ALL		180
Deionized Water		170	200
Demineralized Water		170	200
Detergents, Organic	100	100	160
Detergents, Sulfonated	ALL	120	200
Diallyphthalate	ALL	110	180
Diammonium Phosphate	65	120	210
Dibromophenol		NR	NR
Dibromopropanol	ALL	NR	NR
Dibutyl Ether	100	NR	100
Dibutylphthalate	100	150	180
Dibutyl Sebecate	ALL		200
Dichlorobenzene	100	NR	NR
Dichloroethane	100	NR	NR
Dichloroethylene	100	NR	NR
Dicloromethane (Methylene Chloride)	100	NR	NR

Chemical Environment	%	Standard °F	Option °F
Dichloraopropane	100	NR	NR
Dicloropropene	100	NR	NR
Dichloropropionic Acid	100	NR	NR
Diesel Fuel	ALL	140	180
Diethanolamine	100	NR	80
Diethyl Amine	100	NR	NR
Diethyl Ether (Ethyl Ether)	100	NR	NR
Diethyl Formamide	100	NR	NR
Diethyl Ketone	100	NR	NR
Diethyl Maleate	100	NR	NR
Di 2-Ethyl Hexyl Phosphate	100		
Diethylenetriamine (DETA)	100	NR	NR
Diethylene Glycol	100	170	200
Diisobutyl Ketone	100	NR	NR
Diisobutyl Phthalate	100		120
Diisobutylene	100	NR	NR
Diisopropanolamine	100		110
Dimethyl Formamide	100	NR	NR
Dimethyl Phthalate	100	NR	150
Dioctyl Phthalate	100	150	180
Dioxane	100	NR	NR
Diphenyl Ether	100	NR	80
Dipiperazine Sulfate Solution	ALL		
Dipropylene Glycol	ALL	170	200
Distilled Water	100	170	200
Divinyl Benzene	100	NR	NR
Embalming Fluid	ALL	NR	110
Epichlorohydrin	100	NR	NR
Epoxidized Soybean Oil	ALL		150
Esters of Fatty Acids	100	150	180
Ethanolamine	100	NR	NR
Ethyl Acetate	100	NR	NR
Ethyl Acrylate	100	NR	NR
Ethyl Alcohol (Ethanol)	10		120
	50		100
	95-100		80
Ethyl Benzene	100	NR	NR
Ethyl Benzene/Benzene Blends	100	NR	NR
Ethyl Bromide	100	NR	NR
Ethyl Chloride	100	NR	NR

...vironment	%	Standard °F	Option °F
...hyl Ether)	100	NR	NR
...le	100	NR	NR
...formate	100	NR	NR
...hydrin	100	NR	100
...e	100	NR	NR
...nide	ALL	NR	NR
...ride	100	NR	NR
	ALL	170	200
...Monobutyl Ether	100	NR	100
...Tetra Acetic Acid	100	NR	100
	100	NR	NR
	100		140
	ALL	170	210
	ALL		180
	ALL	170	210
	ALL	170	210
	ALL	170	210
...e	ALL	170	210
	ALL	170	210
	ALL	170	210
		120	120
...l		120	120
	10	150	210
	15		
... HCl	30:10		
	10	NR	150
	35	NR	100
	Fumes	NR	180
	25-56	NR	150
	10	100	180
	50	NR	100
	100		

Chemical Environment	%
Gluconic Acid	50
Glucose	ALL
Glutaric Acid	50
Glycerine	100
Glycolic Acid	10
	35
	70
Glyoxal	40
Green Liquor (pulp mill)	
Heptane	100
Hexachlorocyclopentadiene	100
Hexamethylenetetramine	65
Hexane	100
Hydraulic Fluid	100
Hydrazine	100
Hydrobromic Acid	18
	48
Hydrochloric Acid	10
	15
	25
	37
Hydrochloric Acid & Organics	
Hydrocyanic Acid	10
Hydrofluoric Acid	1
	10
	20
Hydrofluosilicic Acid	10
	35
Hydrogen Bromide, gas	ALL
Hydrogen Chloride, dry gas	100
Hydrogen Fluoride, gas	ALL
Hydrogen Peroxide, (storage)	5
	30

ronment	%	Standard °F	Option °F
	100		
	100		
	100		
	ALL	80	120
	ALL		100
te	ALL		200
te	ALL		200
	ALL		120
		140	180
	100		180
	100	140	180
	ALL	130	210
	ALL		120
	ALL		210
	100		150
	ALL		
	ALL	110	210
	ALL		200
	ALL	140	210
	ALL		210
	ALL	160	180
	ALL	170	210
	ALL	170	210
e	ALL		
	ALL	170	210
	ALL		210
bonate	ALL	130	180
fite	ALL		180
onate	15	130	180
ide	ALL	140	210
oxide	ALL		210

Chemical Environment	%	Standard °F
Methyl Alcohol (Methanol)	100	
Methyl Ethyl Ketone	ALL	NR
Methyl Isobutyl Ketone	100	NR
Methyl Methacrylate	ALL	NR
Methyl Styrene	100	NR
Methylene Chloride	100	NR
Milk and Milk Products	ALL	100
Mineral Oils	100	170
Molasses and Invert Molasses	ALL	
Molybdenum Disulfide	ALL	
Molybdic Acid	25	
Monochloroacetic Acid	80	NR
Monochlorobenzene	100	NR
Monoethanolamine	100	NR
Monomethylhydrazine	100	NR
Morpholine	100	NR
Motor Oil	100	140
Mustard	ALL	
Myristic Acid	ALL	
Naptha, Aliphatic	100	110
Naptha, Aromatic	100	
Naphthalene	ALL	130
Nickel Chloride	ALL	140
Nickel Nitrate	ALL	140
Nickel Sulfate	ALL	140
Nicotinic Acid (Niacin)	ALL	
Nitric Acid	2	150
	5	150
	15	120
	35	NR
	50	NR

ironment	%	Standard °F	Option °F
ene)	100	170	210
nts, pH<12	ALL	100	160
	100	170	210
water phase)			80
	100	170	210
	100	170	210
oly Phosphate	10	120	210
e	100	NR	100
	10	NR	150
	30	NR	100
cid)	5	NR	NR
	>5	NR	NR
hyde Resin	ALL		100
	80	140	210
por & Condensate		170	210
chloride		NR	NR
	100	170	210
de	100	170	210
olic)	10	NR	
	100	NR	
tant	ALL	NR	
hydrochloride			
Cadmium Cyanide			
, Chrome		NR	120
, Gold			
, Lead			
, Nickel			
, Platinum			
, Silver			
, Tin Fluoborate			
Zinc Fluoborate			
Acid (115%)		140	210

Chemical Environment	%
Potassium Carbonate	10
	50
Potassium Chloride	ALL
Potassium Dichromate	ALL
Potassium Ferricyanide	ALL
Potassium Ferrocyanide	ALL
Potassium Hydroxide	10
	25
Potassium Iodide	ALL
Potassium Nitrate	ALL
Potassium Permangenate	ALL
Potassium Persulfate	ALL
Potassium Pyrophosphate	60
Potassium Sulfate	ALL
Propionic Acid	20
Propionic Acid	50
Propylene Glycol	ALL
i-Propyl Palmitate	ALL
Pyridine	100
Quaternary Ammonium Salts	ALL
Rayon Spin Bath	
Salicylic Acid	ALL
Sea Water	
Sebacic Acid	ALL
Selenious Acid	ALL
Silicic Acid (hydrated silica)	ALL
Silver Cyanide	ALL
Siver Nitrate	ALL
Sodium Acetate	ALL
Sodium Alkyl Aryl Sulfonates	ALL
Sodium Aluminate	ALL
Sodium Benzoate	ALL

ronment	%	Standard °F	Option °F
e (Soda Ash)	35	NR	160
	ALL	NR	210
	ALL	130	210
	10	NR	160
	50	NR	100
	50		210
	5	80	210
	15		
te	ALL	140	210
ate	100	170	210
nzene Sulfonate	ALL		
thate	5		
de	ALL	170	210
ide	ALL	170	210
	ALL	80	180
ate	ALL		120
phosphate	10		150
ide	20		160
	1	NR	150
	5	NR	150
	10	NR	150
	25	NR	150
	50	NR	200
ite	15	NR	125
e	20	170	
lfate	ALL		180
sphate	ALL	170	210
	ALL	170	210
	ALL	170	210
	ALL		180
e	20		
ate	ALL		150

Chemical Environment	%
Sodium Triphosphate	ALL
Sodium Xylene Sulfonate	40
Sorbitol	ALL
Soybean Oil	ALL
Soy Sauce	ALL
Spearmint Oil	ALL
Stannic Chloride	ALL
Stannous Chloride	ALL
Stearic Acid	ALL
Styrene	100
Styrene Acrylic Emulsion	ALL
Styrene Butadiene Latex	ALL
Succinonitrile, Aqueous	ALL
Sucrose	ALL
Sulfamic Acid	10
	25
Sulfanilic Acid	ALL
Sulfite/Sulfate Liquors (pulp mill)	
Sulfonated Animal fats	100
Sulfonyl Chloride, Aromatic	
Sulfur Dichloride	
Sulfur, Molten	
Sulfuric Acid	0-25
	26-50
	51-70
	71-75
	76-93
	Fumes
Sulfuric Acid/Ferrous Sulfate	10/Sat'd
Sulfuric Acid/Phosphoric Acid	10/20
Sulfuryl Chloride	100
Superphosphoric Acid (105% H_3PO_4)	100

ironment	%	Standard °F	Option °F
Tetracetic Acid Salts	ALL		
phosphate	5		
	60	80	125
	10		100
	100	NR	NR
thylamine Sulfonic Acid			210
	100	NR	NR
ate (TDI)	100	NR	NR
	Fumes		80
Acid	ALL		210
	100		210
	100		
hyde	100	NR	NR
cid	50	80	210
	100	NR	
		NR	
romethane	ALL		80
	100	NR	NR
	ALL		
Sulfonate	ALL		210
	ALL	110	
Lauryl Sulfate	ALL		
	ALL		
	100		
hlorobromide		NR	NR
drochloride	ALL	NR	130
te	ALL	NR	
ol	100		
ate	50	120	175
		NR	
on			

Chemical Environment	%
Whiskey	ALL
White Liquor (pulp mill)	ALL
Wine	ALL
Xylene	ALL
Zinc Chlorate	ALL
Zinc Chloride	ALL
Zinc Cyanide	ALL
Zinc Nitrate	ALL
Zinc Sulfate	ALL
Zinc Sulfite	ALL

Appendix B: Contract Specifications*

SECTION 02655 – POLYMER CONCRETE MANHOLES

PART 1 – GENERAL

1.1 SUMMARY

A. This specification shall govern for the furnishing of all work necessary for installation of polymer concrete manholes to be constructed.

1.2 REFERENCES

A. ASTM D 6783 Standard specification for polymer concrete pipe

B. ASTM C 478 Standard specification for precast reinforced concrete manhole sections

C. ASTM C 443 Standard specification for joints for concrete pipe and manholes using rubber gaskets

D. ASTM C 923 Standard specification for resilient connectors between reinforced concrete manholes structures, pipes, and laterals

E. ASTM C 33 Standard specification for concrete aggregates

F. ASTM C 497 Standard test methods for concrete pipe, manhole sections, or tile

1.3 SUBMITTALS

A. Submittals shall be made in accordance with General Conditions and shall be made in sufficient time prior to manhole construction to allow for incorporation of any changes.

B. Submit shop drawings for each manhole. Drawings shall include manhole number, location, rim, and invert elevations, dimensions, reinforcing details, joint details, and component parts.

1.4 TOLERANCES

* Developed by P.C Simonton & Associates, Inc., Hinesville, GA.

A. Departure from and return to true vertical from the established manhole alignment shall not exceed ½ inch per 10 feet, up to 2 inches for the total manhole depth.

B. Manufacturing tolerances shall be per ASTM C 478.

PART 2 – PRODUCTS

2.1 MATERIALS (per ASTM D 6783)

A. Resin: The manufacturer shall use only polyester or vinyl ester resin systems designed for use with this particular application. Resin content shall be a minimum of 7% by weight.

B. Filler: All aggregate, sand, and quartz powder shall meet the requirements of ASTM C 33, where applicable.

C. Additives: Resin additives, such as curing agents, pigments, dyes, fillers, and thixotropic agents, when used, shall not be detrimental to the manhole.

D. Elastomeric Gaskets: Gaskets shall be suitable for the service intended. All gaskets shall meet the requirement of ASTM C 443.

2.2 MANUFACTURING AND PRODUCT CONSTRUCTION

A. Manholes: Manhole components shall be manufactured by the vibratory vertical casting process resulting in a dense, non-porous, corrosion-resistant, homogeneous, composite structure. Manholes shall be steel reinforced per ASTM C 478.

B. Joints: The manhole components shall be connected with an elastomeric sealing gasket as the sole means to maintain joint watertightness. Joints at pipe tie-ins shall use resilient flexible pipe to manhole connectors per ASTM C 923. In cases where ASTM C 923 connectors cannot be used, the pipe shall be grouted into the manhole wall using a corrosion resistant grout and rubber water stop grout ring.

C. Fittings: Cones, reducer slabs, base slabs, and adjusting rings shall be of the same material as adjoining riser sections. Fittings shall be manufactured elastomeric gaskets, epoxy bonding, or fiberglass overlay.

D. Invert Channels: Invert channels may be built in the field after the manhole and pipe have been installed. If Portland cement concrete is used to form the bench and channel it shall have a minimum compressive strength of 3,000 psi. The exposed Portland cement concrete shall then be lined with epoxy. Epoxy shall be Spectrashield 3 part system, or approved equal, and applied per the manufacturer's recommendation.

Physical Property	**Min Value**	**Test Method**
Compression Strength	14,500 psi	ASTM C579
Tensile Strength	1,400 psi	ASTM C307
Flexural Strength	3,900 psi	ASTM C580
Bond Strength to Bricks	750 psi	Pull Blocks
Water Absorption	.15%	ASTM C413

2. Concrete surfaces that have a furan resin mortar placed against them much be coated with the furan resin mortar manufacturer's recommended primer and prepared in accordance with the furan resin mortar manufacturer's recommendations.

3. The bench and channel brick mortar components shall be free of cracks, holes, delaminations, foreign inclusions, blisters, or other defects that result in a variation of inside diameter of more that 1/8 inch from that obtained on the adjacent unaffected portions of the surface or defects that would, due to their nature, degree, or extent, have a deleterious effect on the manhole performance as determined by the ENGINEER.

4. Mortar Manufacturers: Furalac Green Panel Mortar by Henkel, or approved equal.

E. Acceptable manufacturer: Manufacturer of manholes shall employ manufacturing methods and material formulation in use for a minimum of 2 years. Manufacturer of manholes shall have been actively producing manholes under current name for a minimum of 2 years with no more than one year between manhole projects. References demonstrating this requirement shall be submitted for review. Polymer concrete manholes shall be manufactured in accordance with ASTM C 478.

2.3 DESIGN

A. Manholes shall be designed to withstand all live loads and dead loads as described in project plans and specifications. Dead loads shall include overburden load, soil side pressure, and hydrostatic loading conditions.

B. Manholes wall thickness shall be designed to resist hydrostatic pressures with a minimum safety factor of 2.0 for full depth conditions from grade to invert. In no cases shall the wall thickness be less than 3 inches.

C. Manholes shall be designed with sufficient bottom anchorage and side friction to resist buoyancy.

D. The manhole shall be manufactured in one class of load rating. This class shall be H-20 wheel load (minimum 16,000 pounds dynamic wheel load).

2.4 TESTING

A. Manholes: Manholes shall be manufactured in accordance with ASTM C 478

B. Joints: Joints shall meet the requirements of ASTM C 443.

C. Compressive strength: Polymer concrete shall have a minimum unconfined compressive strength of 9,000 psi when measured in accordance with ASTM C 497.

D. Manhole Leakage: Manhole shall be tested in accordance with ASTM C 1244 Standard Test Method for Concrete Sewer Manholes by the Negative Air Pressure (Vacuum) Test.

2.5 CUSTOMER INSPECTION

A. The Owner or other designated representative shall be entitled to inspect manholes prior to receipt.

2.6 HANDLING AND SHIPPING

A. Handling and shipping shall be performed in accordance with the Manufacturer’s instructions.

PART 3 – EXECUTION

3.1 INSTALLATION

A. Installation: The installation of manholes shall be in accordance with the project plans and specifications and the manufacturer’s recommended practices.

B. Handling: Properly rated slings and spreader bar shall be used for lifting. The type of rigging used shall be per the manufacturer’s recommendation.

C. Jointing:

1. Sealing surfaces and joint components shall be inspected for damage and cleaned of all debris.

2. Apply joint lubricant to elastomeric seals. Use only lubricants approved by the manufacturer.

3. Use suitable equipment handle and set manholes.

4. Placement and compaction of surrounding backfill material shall be applied so as to provide sufficient and equal side pressure on the manhole.

D. Field Tests:

1. Infiltration / Exfiltration Test: Maximum allowable leakage shall be per local specification section 02650.

2. Low-Pressure Air Test: Each section may be tested with air pressure (5 psi max). After allowing the pressure to stabilize, the system passes the test if the pressure drop, due to leakage, is equal to or lesser than that specified.

SECTION 02660 – STEEL REINFORCED POLYMER CONCRETE PIPE

PART 1 – GENERAL

1.4 DESCRIPTION

B. Furnish all tools, equipment, materials, and supplies and shall perform all labor required to complete the work as indicated in the Contract Documents.

C. Furnish, install, and test polymer concrete pipe, fittings, and appurtenances of the dimensions and to the lines and grades shown on the Contract Documents.

D. Provide complete and workable piping systems and any miscellaneous fittings and specials required for proper completion of the work shall be considered as having been included under this Section.

E. Provide all jointing materials, other miscellaneous appurtenances, and accessories.

1.5 RELATED SECTIONS

A. Section 02221, Backfill & Compactor.

B. Section 02650, Sanitary Sewer.

1.6 REFERENCES

A. ASTM A276, Standard for Stainless and Heat-Resisting Steel Bars and Shapes.

B. ASTM C33, Standard Specifications for Concrete Aggregates.

C. ASTM C443, Standard Specifications for Joints for Concrete Pipe and Manholes Using Rubber Gaskets.

D. ASTM C579, Standard Test Method for Compressive Strengths of Chemical Resistant Mortars, Grouts, Monolithic Surfacing, and Polymer Concretes.

E. ASTM D4161, Standard Specification for “Fiberglass” (Glass-Fiber-Reinforced-Thermosetting-Resin) Pipe Joints Using Flexible Elastomeric Seals.

F. ASTM D6783, Standard Specification for Polymer Concrete Pipe.

G. ASTM F477, Standard Specification for Elastomeric Seals (Gaskets) for Joining Plastic Pipe.

H. ASTM C-76, Standard Specification for Reinforced Concrete Sewer Pipe.

I. ASTM C-497, Standard Test Methods for Concrete Pipe, Manhole Sections, and Tile.

1.7 QUALITY ASSURANCE

A. Manufacturer's Qualifications:
1. Manufacturer shall be approved by ENGINEER.

B. Component Supply and Compatibility:
1. Obtain all pipe material included in this Section, regardless of the manufacturer, from a single polymer concrete pipe and fittings manufacturer.

1.5 SUBMITTALS

A. Shop Drawings: Submit the following:
1. Detailed drawings of the pipe, gaskets, joints, pipe special sections, access shafts, connections, and test reports on the properties of the gasket material.
2. Manufacturers Certificates of Compliance with this Section and above referenced Standards for each size of pipe and fitting used.
3. Manufactures Certificate of Compliance for resin compound.
4. Manufacturer instructions on storage, handling, transportation, and installation.
5. Certified test reports on materials manufactured for this project.

B. A sample piece of pipe approximately three-foot long of each diameter, if requested by ENGINEER.

1.6 SOURCE QUALITY CONTROL

A. Shop Test:
1. Manufacturer shall maintain a continuous Quality Control Program and shall provide the ENGINEER with certified test reports.
2. Joints of selected pipe shall be given a hydrostatic test prior to delivery.

PART 2- PRODUCTS

2.1 SYSTEM PERFORMANCE

A. Pipe shall be designed for an external live loading, including impact, equal to AASHTO H-20 loading with earth cover as shown.

B. The polymer concrete piping system shall be specifically designed, constructed, and installed for the service in sanitary sewers.

2.2 MATERIALS

A. Resin System: The resin shall have a minimum deflection temperature of 158°F when tested at 264 psi. Pipe shall not contain Portland cement or other corrodible elements other than steel reinforcement.

B. Filler: Aggregate shall conform to a maximum grain size of 5/8 inch. The sand shall have a maximum grain size of 16 mesh. The filler shall be an inert powder. The aggregate, sand, and inert powder shall be cleaned, washed, and dried. All aggregate, sand, and powder shall meet the requirements of ASTM C 33.

C. Additives: Resin additives, such as curing agents, pigments, dyes, fillers, thixotropic agents, etc., when used, shall not detrimentally effect the performance of the product.

D. Elastomeric Gaskets: Gaskets shall meet ASTM C443 and be supplied by approved gasket manufacturers and be suitable for the service intended. Gaskets shall be polyisoprene rubber and suitable for the service intended. Gaskets shall be either affixed to the pipe by means of a suitable adhesive or shall be installed in such a manner so as to prevent the gasket from rolling out of the pipes' pre-cut grooves.

E. Stainless Steel Couplings: Stainless steel joint sleeves and couplings shall meet the requirements of ASTM A276.

2.3.1 DETAILS OF CONSTRUCTION

A. Pipe: The manufacturer shall use only polyester or vinyl ester resin systems with a proven history of performance in this particular application. Manufacture pipe by the vibratory vertical casting process resulting in a dense, non-porous, corrosion-resistant, homogeneous, composite structure. The pipe wall shall consist of a thermosetting resin and aggregate and shall meet the performance requirements of ASTM D6783. Steel reinforcement is acceptable.

B. Joints: Unless otherwise specified, the pipe shall be connected with a 304 stainless steel or fiberglass reinforced sleeve/coupling utilizing and elastomeric sealing gasket as the sole means to maintain joint water-tightness. The joint shall meet the performance requirements of ASTM C443. The joint shall have an outside diameter equal to or slightly lesser than the outside diameter of the pipe. When pipe is assembled, the joints shall be essentially flush with the outside diameter of the pipe. Joints at tie-ins may use couplings that extend beyond the outside diameter of the pipe.

C. Fittings: Flanges, elbows, reducers, tees, wyes, laterals, and other fittings shall be capable of withstanding all operating conditions when installed. Fittings shall be manufactured from mitered sections of pipe and joined by epoxy bonding or fiberglass overlay.

D. Diameter: The actual diameter of the pipes shall be in accordance with ASTM C-76.

E. Lengths: Pipe shall be supplied in nominal lengths of 10 feet. Actual laying length shall be nominal +/-1 inch. At least 90 percent of the total footage of each size and class pipe, excluding special order lengths, shall be furnished in nominal length sections. Special short lengths may be used where surface geography or installation conditions require shorter lengths.

F. Strength Class: Pipe shall be Class III, IV, and V. Quality of materials, process of manufacture, and finished pipe shall be subject to inspection and approval by ENGINEER.

The minimum wall thickness, measured at the narrowest point along the pipe, shall provide sufficient axial compressive strength to withstand anticipated jacking loads. For jacked installation, the wall thickness shall include a minimum factor of safety against jacking forces of 1.5.

G. End Squareness: Pipe ends shall be square to the pipe axis with a maximum tolerance of 1/4 inch.

H. Straightness: Pipes shall be straight to within ¼ inch per linear foot.

I. Marking: Each pipe section shall be marked at both ends inside and on the outside to identify the manufacturer, manufacturer number (identify factory location and date of manufacture), nominal diameter, pipe strength class.

J. Inspection: The OWNER or ENGINEER shall be entitled to inspect pipes or witness the pipe manufacturing. Should the OWNER request to see specific pipes during any phase of the manufacturing process, the Manufacturer must provide the OWNER with adequate advance notice of when and where the production of those pipes will take place.

PART 3- EXECUTION

3.1 ACCEPTANCE OR REJECTION

A. The pipe shall be free of cracks, holes, delamination's, foreign inclusions, blisters, or other defects that result in a variation of inside diameter or more than 1/8-inch from that obtained on adjacent unaffected portions of the surface or defects that would, due to their nature, degree, or extent, have a deleterious effect on the pipe performance as determined by the ENGINEER. Prior to installation, damaged pipe shall be either repaired or field cut to remove the damaged portion as approved by a Manufacturer's representative. Retest within 60 days prior to installation all pipe that is more than 180 days old from the date of manufacture to ensure compliance with the requirements of this Section. Do not install pipe that is more than 2 years old from the date of manufacture.

B. Should the ENGINEER elect not to inspect the manufacturing or testing of finished pipes, it in no way implies approval of products or tests.

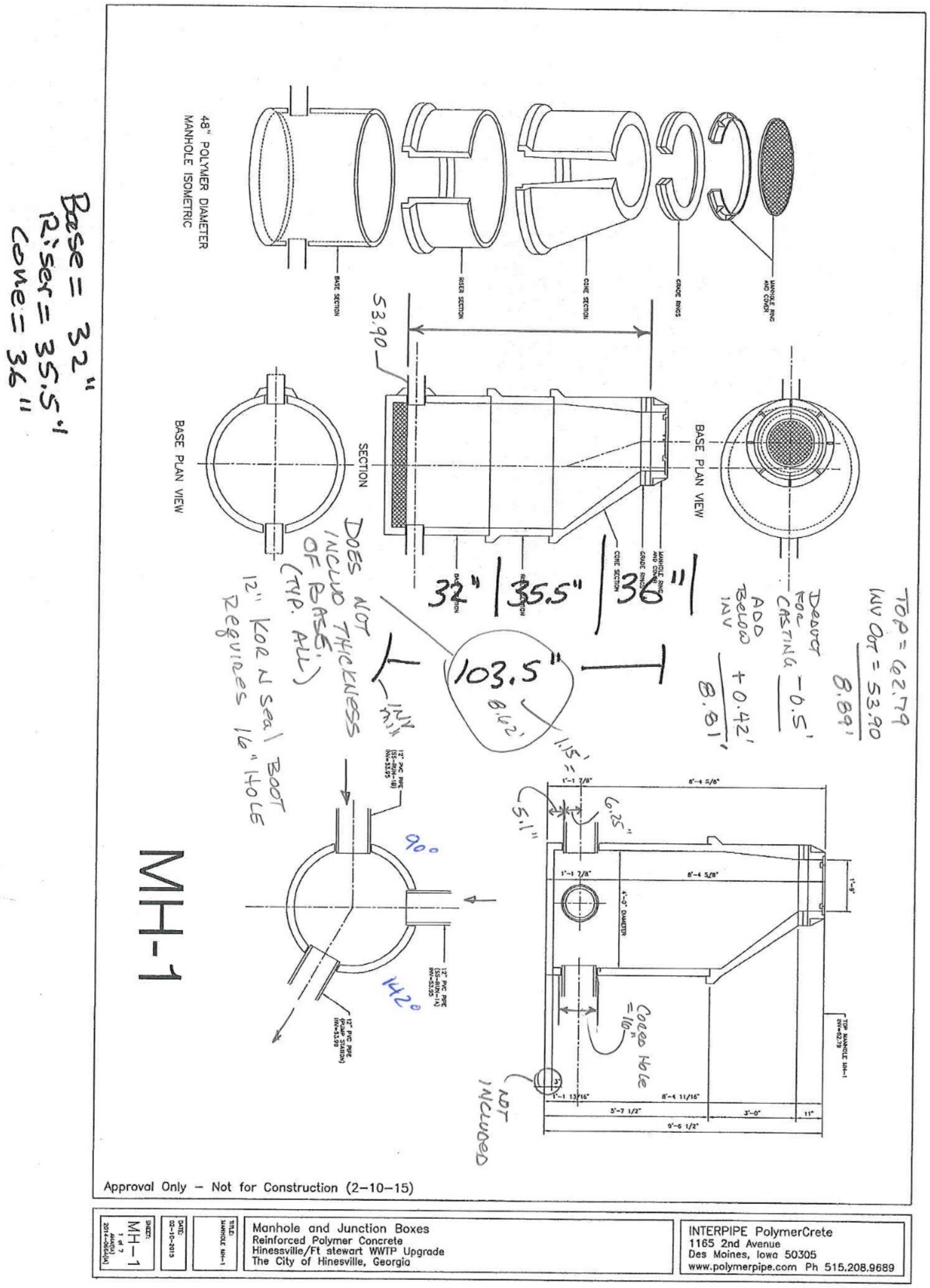
3.2 INSTALLATION

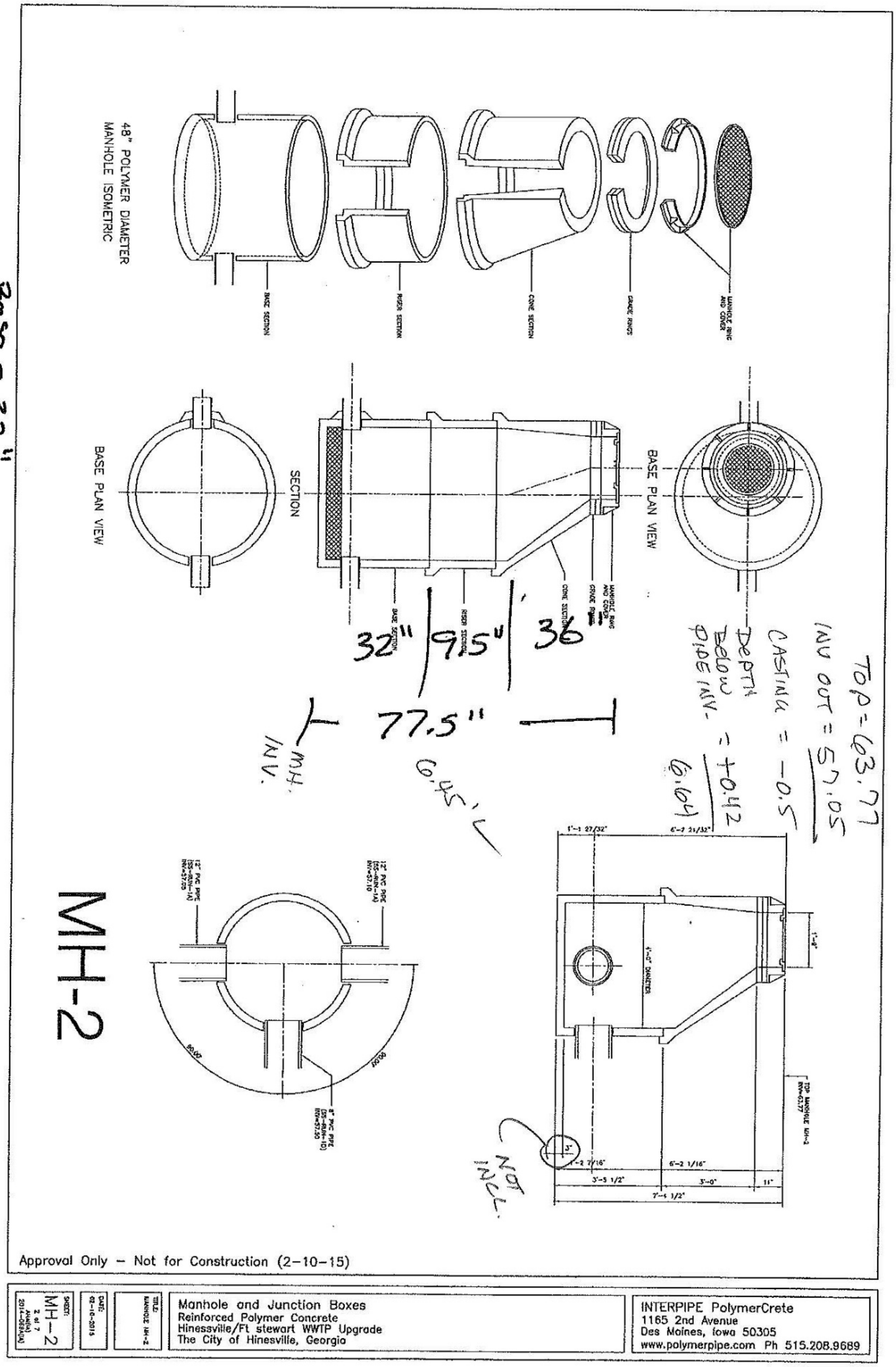
A. Trench excavation, bracing methods, foundation preparation, pipe bedding, trench backfill and related operations shall be in accordance with the requirements of Section 02221 and 02650,

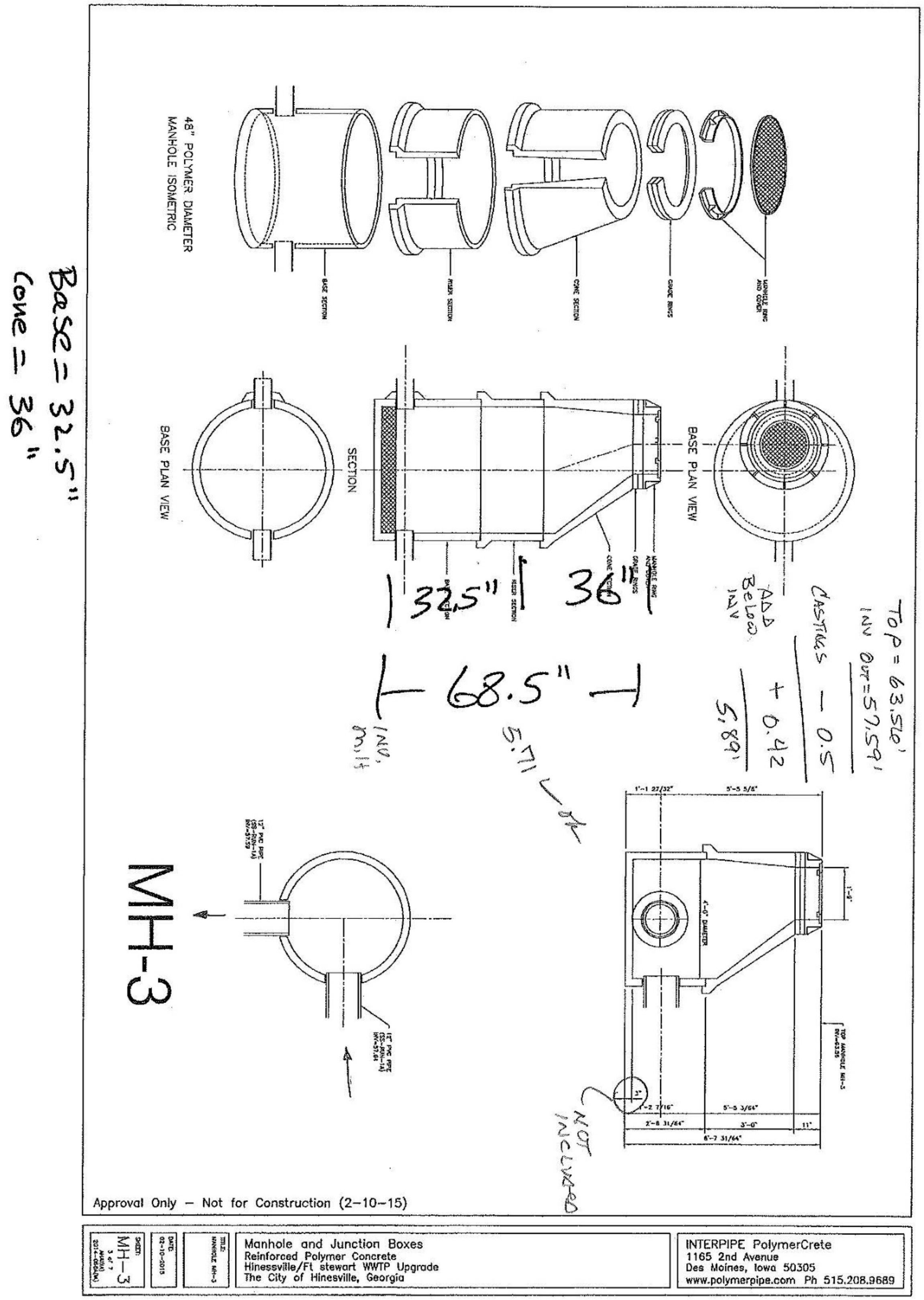
The manufacturer shall furnish a suitable qualified field service representative to be present during the installation of pipe for the first two manhole to manhole segments of each size pipe installed.

Appendix C: Interpipe Shop Drawings

Manhole shop drawings




48" POLYMER DIAMETER MANHOLE ISOMETRIC
BASE SECTION
RISER SECTION
CONE SECTION
GRADE RINGS
MANHOLE RING AND COVER
BASE PLAN VIEW
SECTION
BASE PLAN VIEW
MH-2
Base = 32"
Riser = 9.5"
Cone = 36"
32"
9.5"
36"
77.5"
MH. INV.
6.45'
TOP = 63.77
INV OUT = 57.05
CASTING = -0.5
DEPTH BELOW PIPE INV. = +0.42
6.64
NOT INCL.
Approval Only – Not for Construction (2–10–15)
MH–2
Manhole and Junction Boxes
Reinforced Polymer Concrete
Hinesville/Ft stewart WWTP Upgrade
The City of Hinesville, Georgia
INTERPIPE PolymerCrete
1165 2nd Avenue
Des Moines, Iowa 50305
www.polymerpipe.com Ph 515.208.9689


Base = 32.5"
Cone = 36"
48" POLYMER DIAMETER
MANHOLE ISOMETRIC
BASE SECTION
RISER SECTION
CONE SECTION
GRADE RINGS
MANHOLE RING AND COVER
SECTION
BASE PLAN VIEW
32.5"
36"
68.5"
TOP = 63.56'
INV OUT = 57.59'
CASTINGS − 0.5
ADD Below INV
+ 0.42
5.89'
4'-0" DIAMETER
NOT INCLUDED
MH-3
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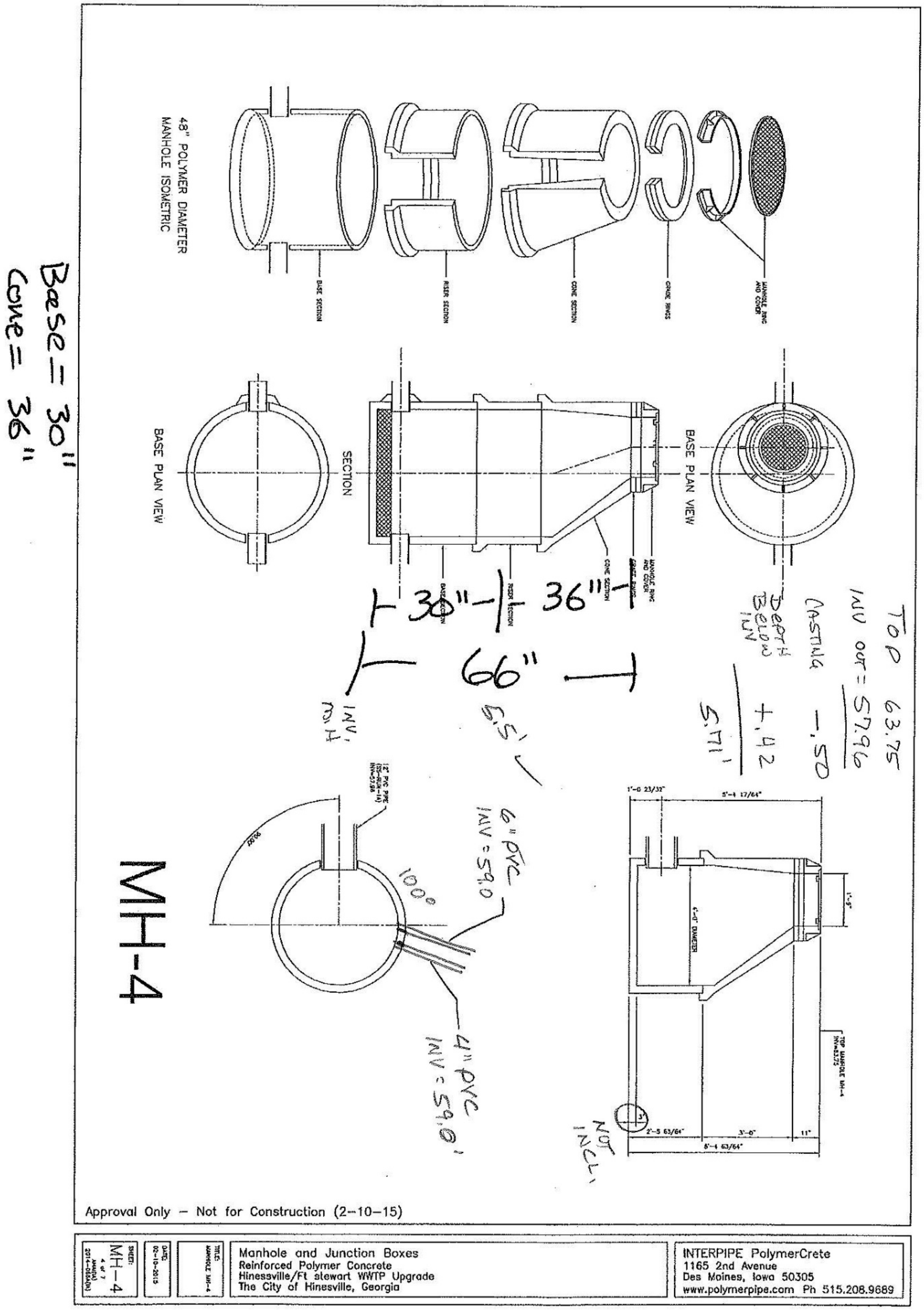
48" POLYMER DIAMETER MANHOLE ISOMETRIC
BASE SECTION
RISER SECTION
CONE SECTION
GRADE RINGS
MANHOLE RING AND COVER
SECTION
BASE PLAN VIEW
BASE PLAN VIEW
Base = 30"
Cone = 36"
30"
36"
66"
5.5'
TOP 63.75
INV OUT = 57.96
CASTING -.50
DEPTH BELOW INV +.42
5.71'
6" PVC INV = 59.0
4" PVC INV = 59.0'
100°
90.00°
MH-4
NOT INCL.
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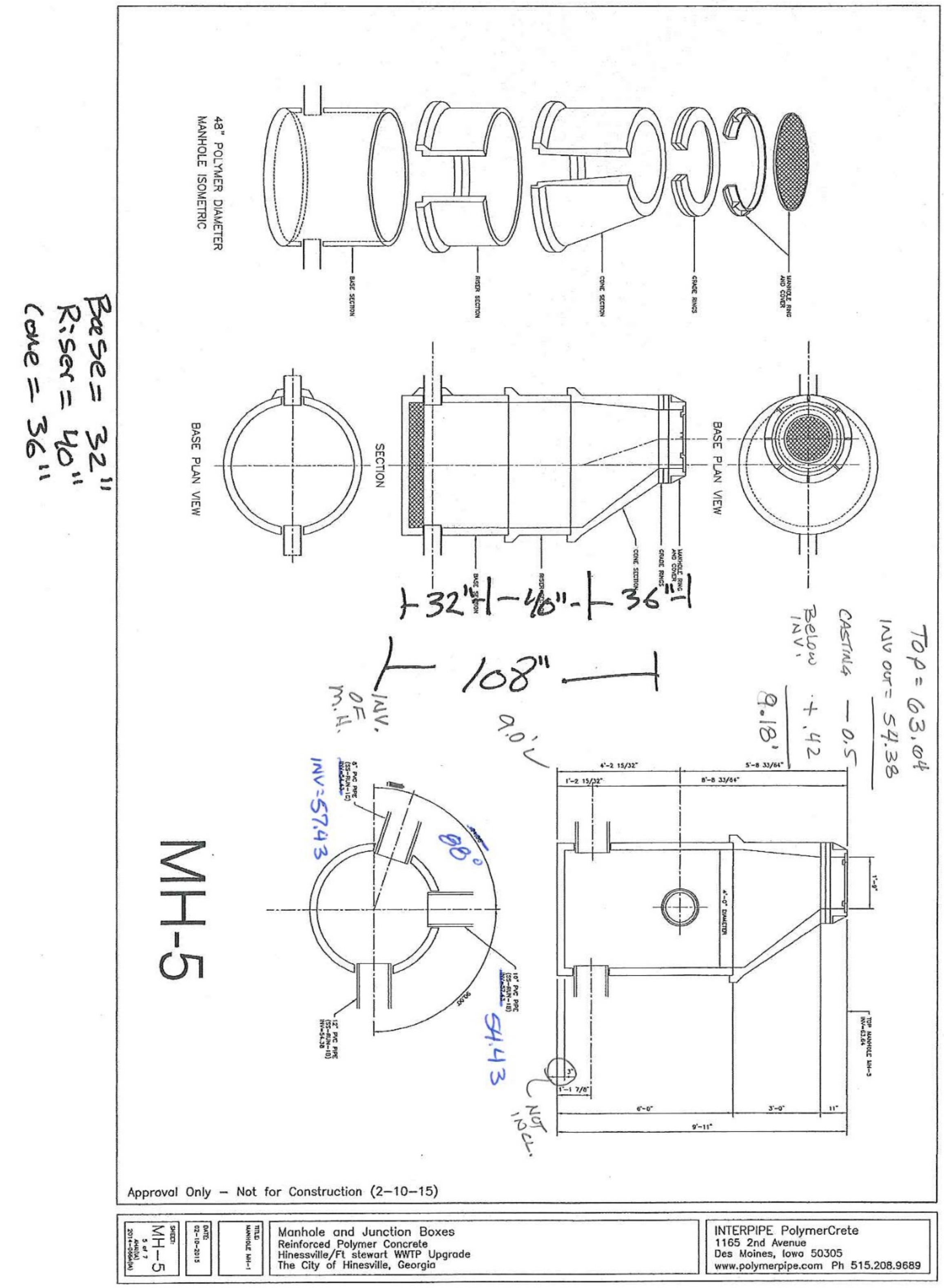

48" POLYMER DIAMETER MANHOLE ISOMETRIC
BASE SECTION
RISER SECTION
CONE SECTION
GRADE RINGS
MANHOLE RING AND COVER
SECTION
BASE PLAN VIEW
Base = 32"
Riser = 40"
Cone = 36"
32"
40"
36"
108"
INV. OF M.H.
9.0'
TOP = 63.04
INV OUT = 54.38
CASTING -0.5
BELOW INV. +.42
9.18'
MH-5
INV=57.43
80°
54.43
NOT INCL.
4'-0" DIAMETER
8" PVC PIPE
10" PVC PIPE
12" PVC PIPE
6'-0"
3'-0"
11"
9'-11"
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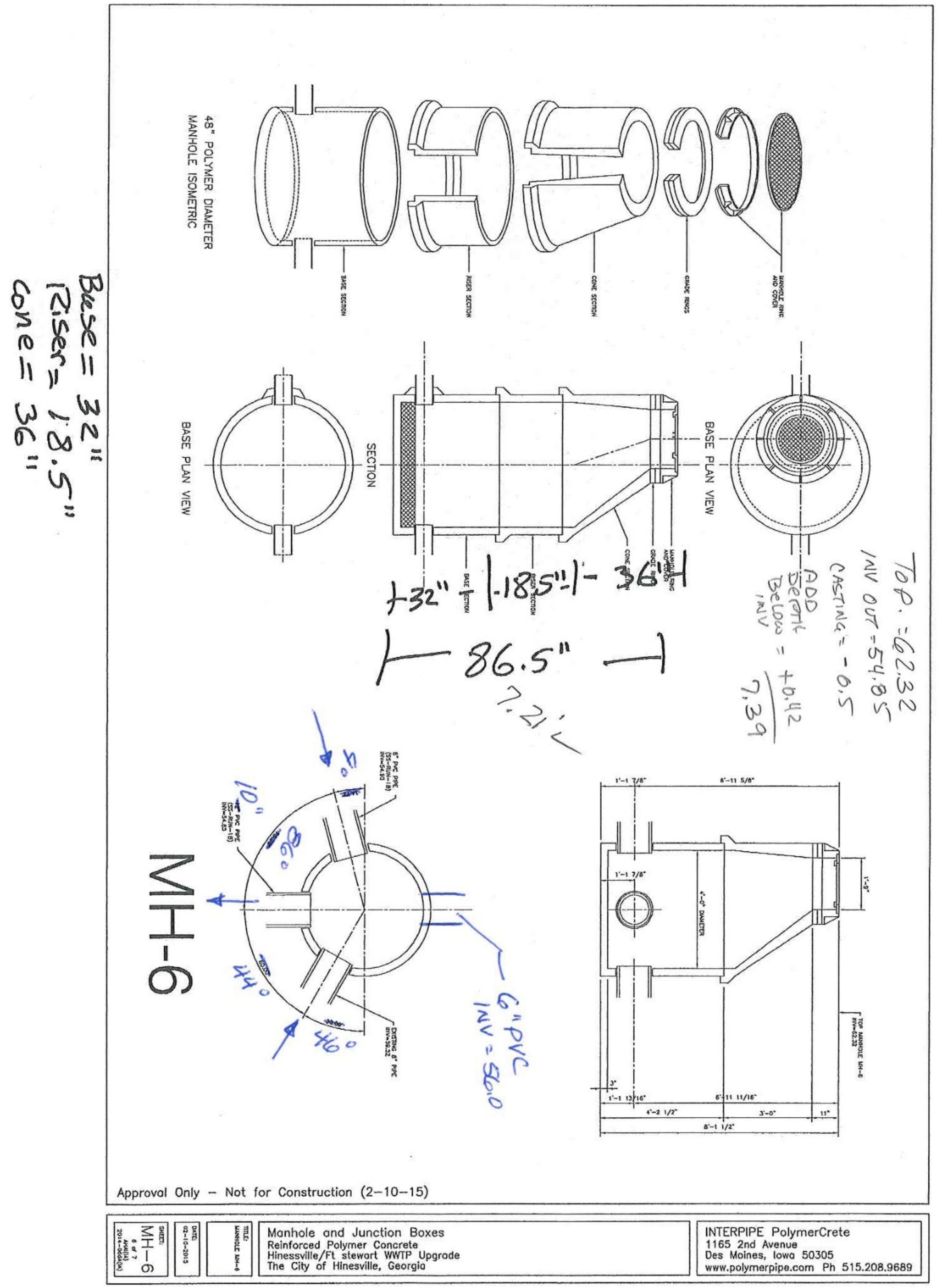
MH-5


48" POLYMER DIAMETER
MANHOLE ISOMETRIC
BASE SECTION
RISER SECTION
CONE SECTION
GRADE RINGS
MANHOLE RING AND COVER
Base = 32"
Riser = 18.5"
Cone = 36"
SECTION
BASE PLAN VIEW
32"
18.5"
36"
86.5"
7.21'
TOP. = 62.32
INV OUT = 54.85
CASTING = -0.5
ADD Depth Below INV = +0.42
7.39
MH-6
10"
86°
144°
46°
6" PVC INV = 56.0
4'-0" DIAMETER
8'-1 1/2"
Approval Only – Not for Construction (2-10-15)
Manhole and Junction Boxes
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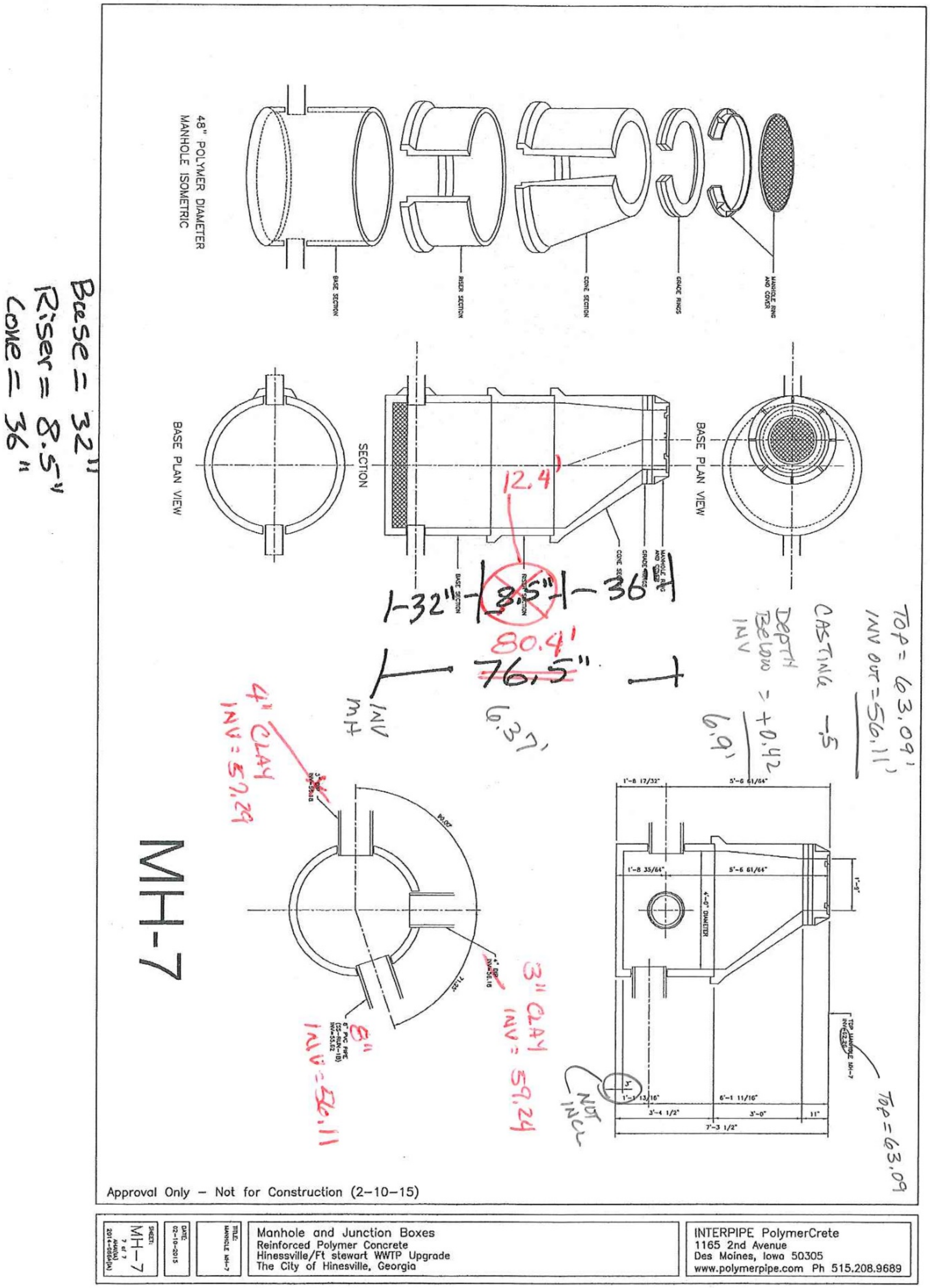
INTERPIPE PolymerCrete
1165 2nd Avenue
Des Moines, Iowa 50305
www.polymerpipe.com Ph 515.208.9689
SHEET: MH-6
DATE: 02-10-2015
TITLE: MANHOLE MH-6


48" POLYMER DIAMETER
MANHOLE ISOMETRIC
Base = 32"
Riser = 8.5"
Cone = 36"
SECTION
BASE PLAN VIEW
BASE PLAN VIEW
12.4'
80.4'
76.5"
TOP = 63.09'
INV OUT = 56.11'
CASTING -.5
DEPTH BELOW INV = +0.42
6.9'
6.37'
4" CLAY
INV = 57.29
3" CLAY
INV = 59.24
8"
INV = 56.11
NOT INCL
TOP = 63.09
MH-7
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Des Moines, Iowa 50305
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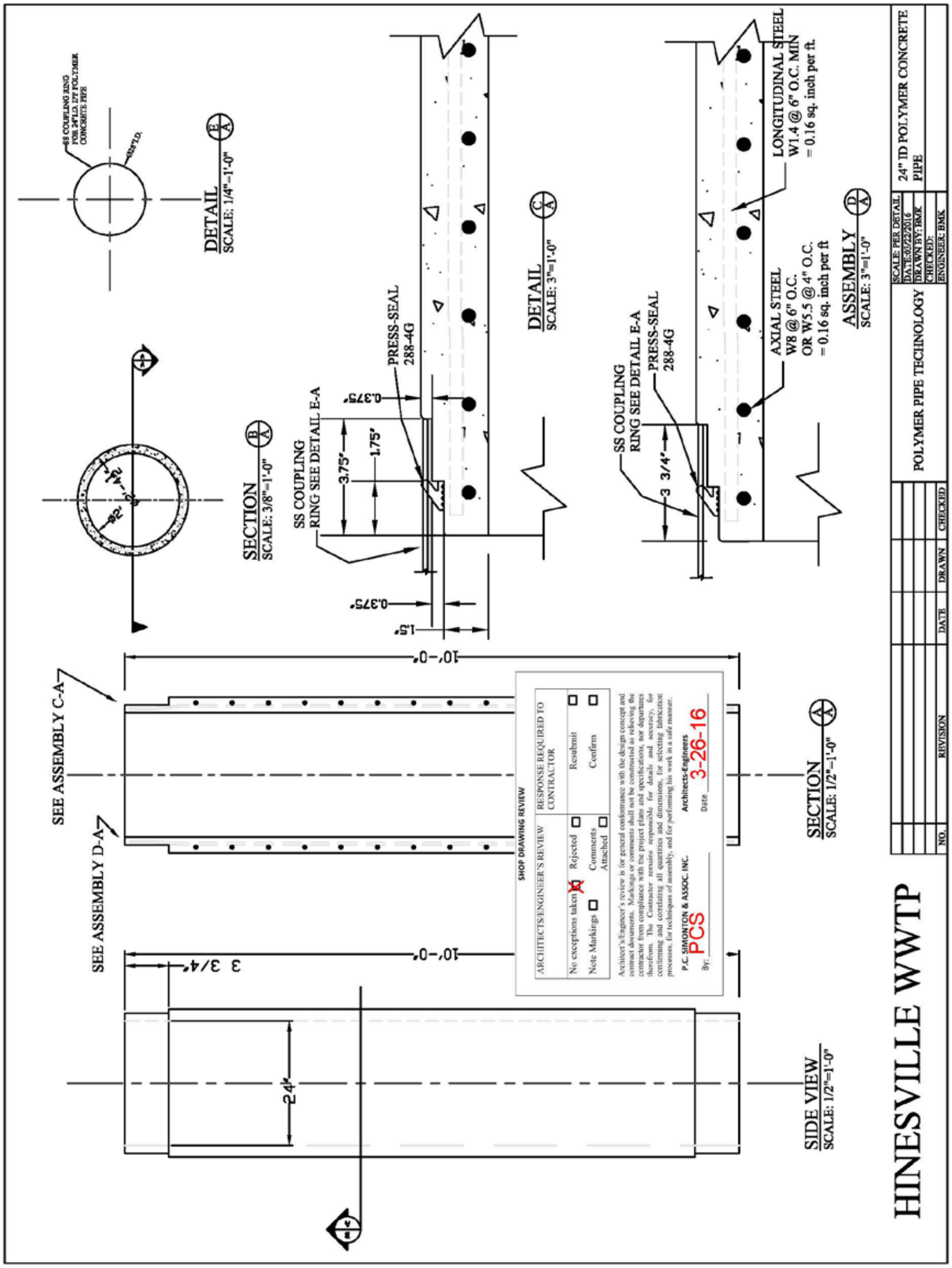
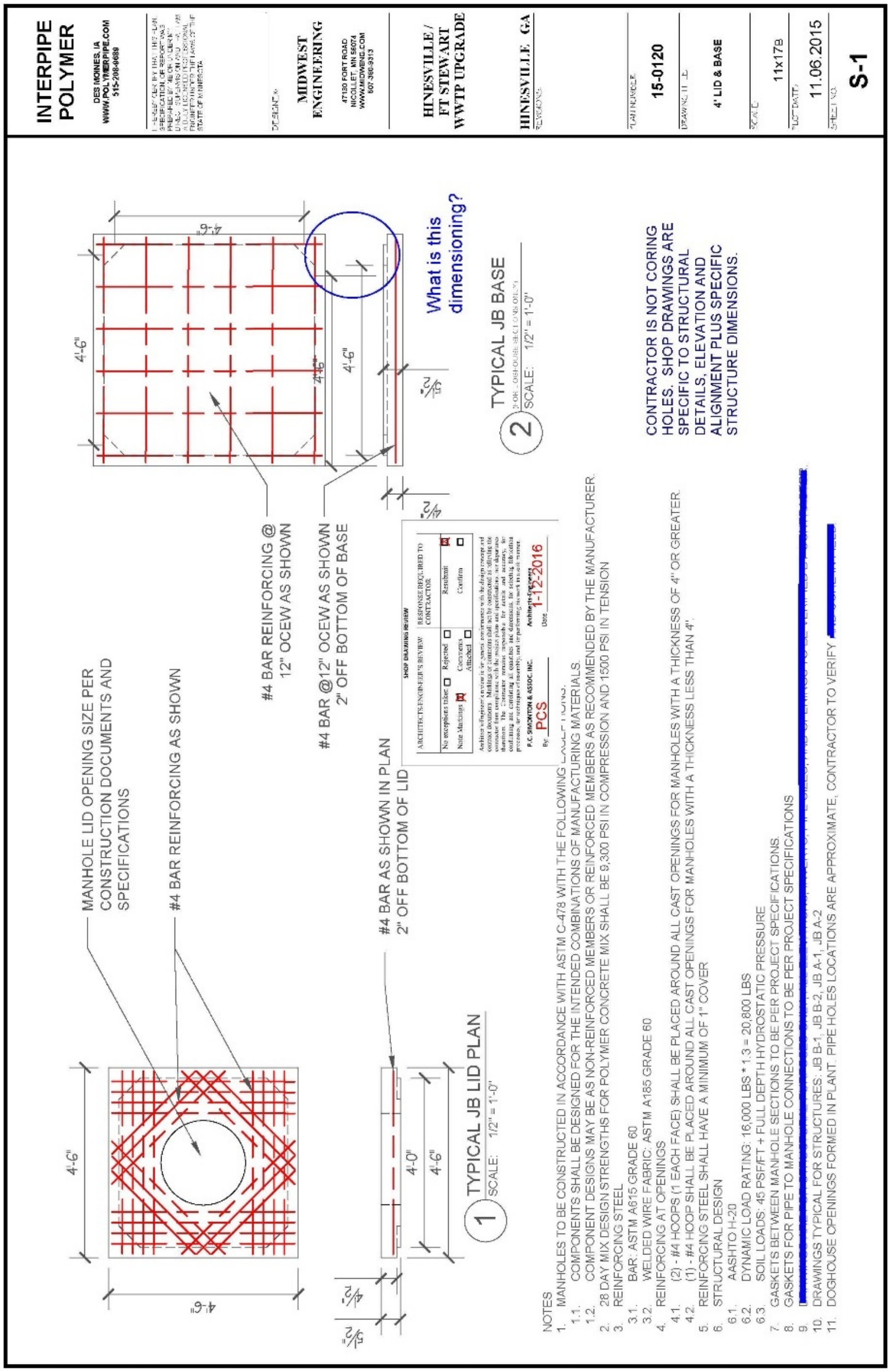
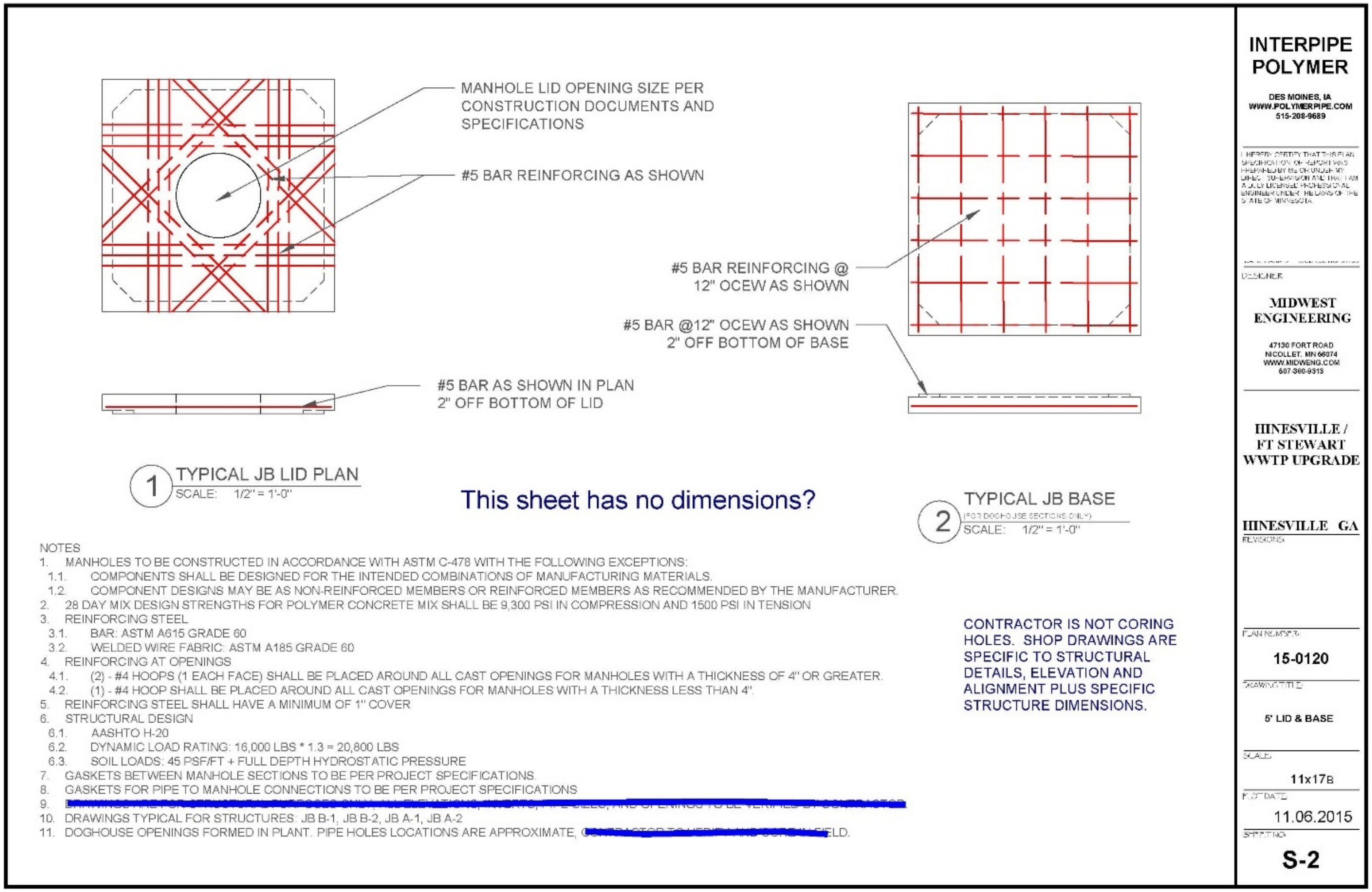
Pipe shop drawings



Junction box shop drawings

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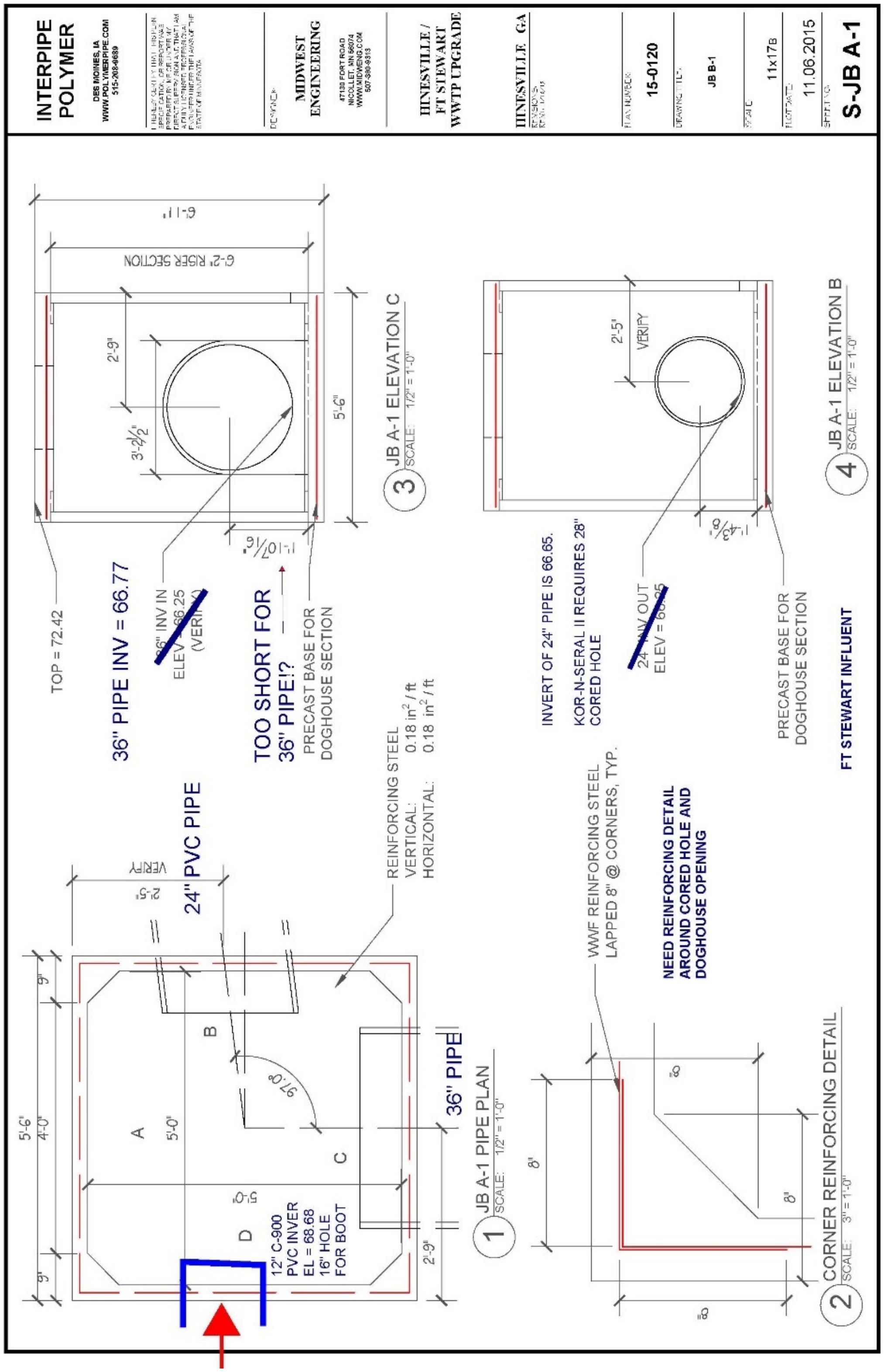
WWW.POLYMERPIPE.COM
515-208-9689
DESIGNER
MIDWEST ENGINEERING
47130 FORT ROAD
NICOLLET, MN 56074
WWW.MIDWENG.COM
507-360-9313
HINESVILLE / FT STEWART WWTP UPGRADE
HINESVILLE GA
15-0120
5' LID & BASE
11x17B
11.06.2015
S-2
MANHOLE LID OPENING SIZE PER CONSTRUCTION DOCUMENTS AND SPECIFICATIONS
#5 BAR REINFORCING AS SHOWN
#5 BAR AS SHOWN IN PLAN 2" OFF BOTTOM OF LID
#5 BAR REINFORCING @ 12" OCEW AS SHOWN
#5 BAR @12" OCEW AS SHOWN 2" OFF BOTTOM OF BASE
1 TYPICAL JB LID PLAN
SCALE: 1/2" = 1'-0"
This sheet has no dimensions?
2 TYPICAL JB BASE
(FOR DOGHOUSE SECTIONS ONLY)
SCALE: 1/2" = 1'-0"
NOTES
1. MANHOLES TO BE CONSTRUCTED IN ACCORDANCE WITH ASTM C-478 WITH THE FOLLOWING EXCEPTIONS:
1.1. COMPONENTS SHALL BE DESIGNED FOR THE INTENDED COMBINATIONS OF MANUFACTURING MATERIALS.
1.2. COMPONENT DESIGNS MAY BE AS NON-REINFORCED MEMBERS OR REINFORCED MEMBERS AS RECOMMENDED BY THE MANUFACTURER.
2. 28 DAY MIX DESIGN STRENGTHS FOR POLYMER CONCRETE MIX SHALL BE 9,300 PSI IN COMPRESSION AND 1500 PSI IN TENSION
3. REINFORCING STEEL
3.1. BAR: ASTM A615 GRADE 60
3.2. WELDED WIRE FABRIC: ASTM A185 GRADE 60
4. REINFORCING AT OPENINGS
4.1. (2) - #4 HOOPS (1 EACH FACE) SHALL BE PLACED AROUND ALL CAST OPENINGS FOR MANHOLES WITH A THICKNESS OF 4" OR GREATER.
4.2. (1) - #4 HOOP SHALL BE PLACED AROUND ALL CAST OPENINGS FOR MANHOLES WITH A THICKNESS LESS THAN 4".
5. REINFORCING STEEL SHALL HAVE A MINIMUM OF 1" COVER
6. STRUCTURAL DESIGN
6.1. AASHTO H-20
6.2. DYNAMIC LOAD RATING: 16,000 LBS * 1.3 = 20,800 LBS
6.3. SOIL LOADS: 45 PSF/FT + FULL DEPTH HYDROSTATIC PRESSURE
7. GASKETS BETWEEN MANHOLE SECTIONS TO BE PER PROJECT SPECIFICATIONS.
8. GASKETS FOR PIPE TO MANHOLE CONNECTIONS TO BE PER PROJECT SPECIFICATIONS
9. [redacted]
10. DRAWINGS TYPICAL FOR STRUCTURES: JB B-1, JB B-2, JB A-1, JB A-2
11. DOGHOUSE OPENINGS FORMED IN PLANT. PIPE HOLES LOCATIONS ARE APPROXIMATE, [redacted]ELD.
CONTRACTOR IS NOT CORING HOLES. SHOP DRAWINGS ARE SPECIFIC TO STRUCTURAL DETAILS, ELEVATION AND ALIGNMENT PLUS SPECIFIC STRUCTURE DIMENSIONS.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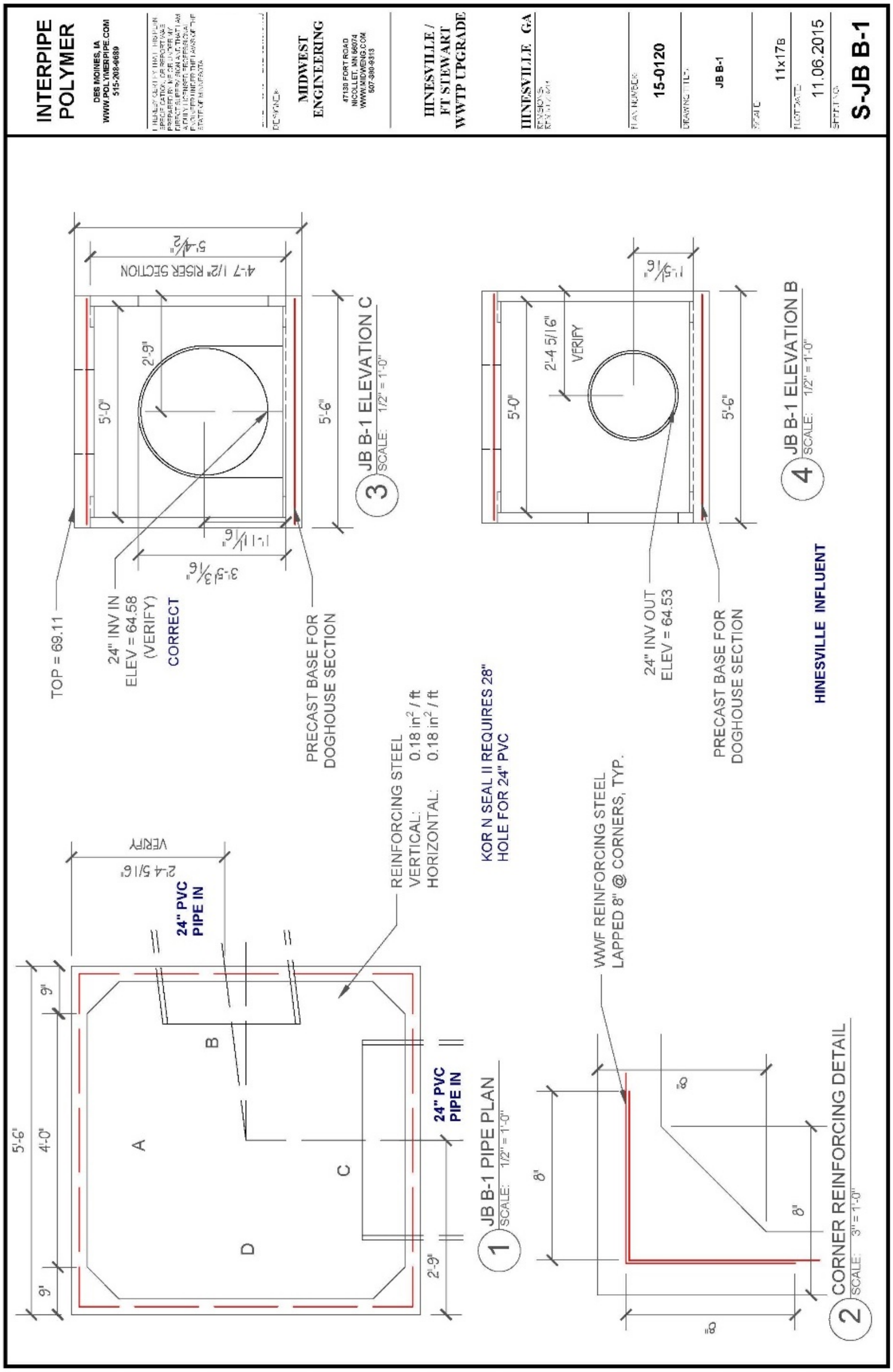
MIDWEST ENGINEERING
47130 FORT ROAD
NICOLLET, MN 56074
WWW.MEWENG.COM
507-990-9313
HINESVILLE / FT STEWART WWTP UPGRADE
HINESVILLE GA
15-0120
JB B-1
11x17B
11.06.2015
S-JB A-1
TOP = 72.42
36" PIPE INV = 66.77
36" INV IN ELEV = ~~66.25~~ (VERIFY)
TOO SHORT FOR 36" PIPE!?
PRECAST BASE FOR DOGHOUSE SECTION
REINFORCING STEEL
VERTICAL: 0.18 in²/ft
HORIZONTAL: 0.18 in²/ft
INVERT OF 24" PIPE IS 66.65.
KOR-N-SERAL II REQUIRES 28" CORED HOLE
24" INV OUT
PRECAST BASE FOR DOGHOUSE SECTION
FT STEWART INFLUENT
WWF REINFORCING STEEL LAPPED 8" @ CORNERS, TYP.
NEED REINFORCING DETAIL AROUND CORED HOLE AND DOGHOUSE OPENING
24" PVC PIPE
36" PIPE
12" C-900 PVC INVER EL = 68.68 16" HOLE FOR BOOT
6'-11"
6'-2" RISER SECTION
2'-9"
3'-2½"
5'-6"
1'-10⁷⁄₁₆"
2'-5"
VERIFY
1'-4⅜"
5'-6"
4'-0"
5'-0"
97.0°
A
B
C
D
1 JB A-1 PIPE PLAN SCALE: 1/2" = 1'-0"
2 CORNER REINFORCING DETAIL SCALE: 3" = 1'-0"
3 JB A-1 ELEVATION C SCALE: 1/2" = 1'-0"
4 JB A-1 ELEVATION B SCALE: 1/2" = 1'-0"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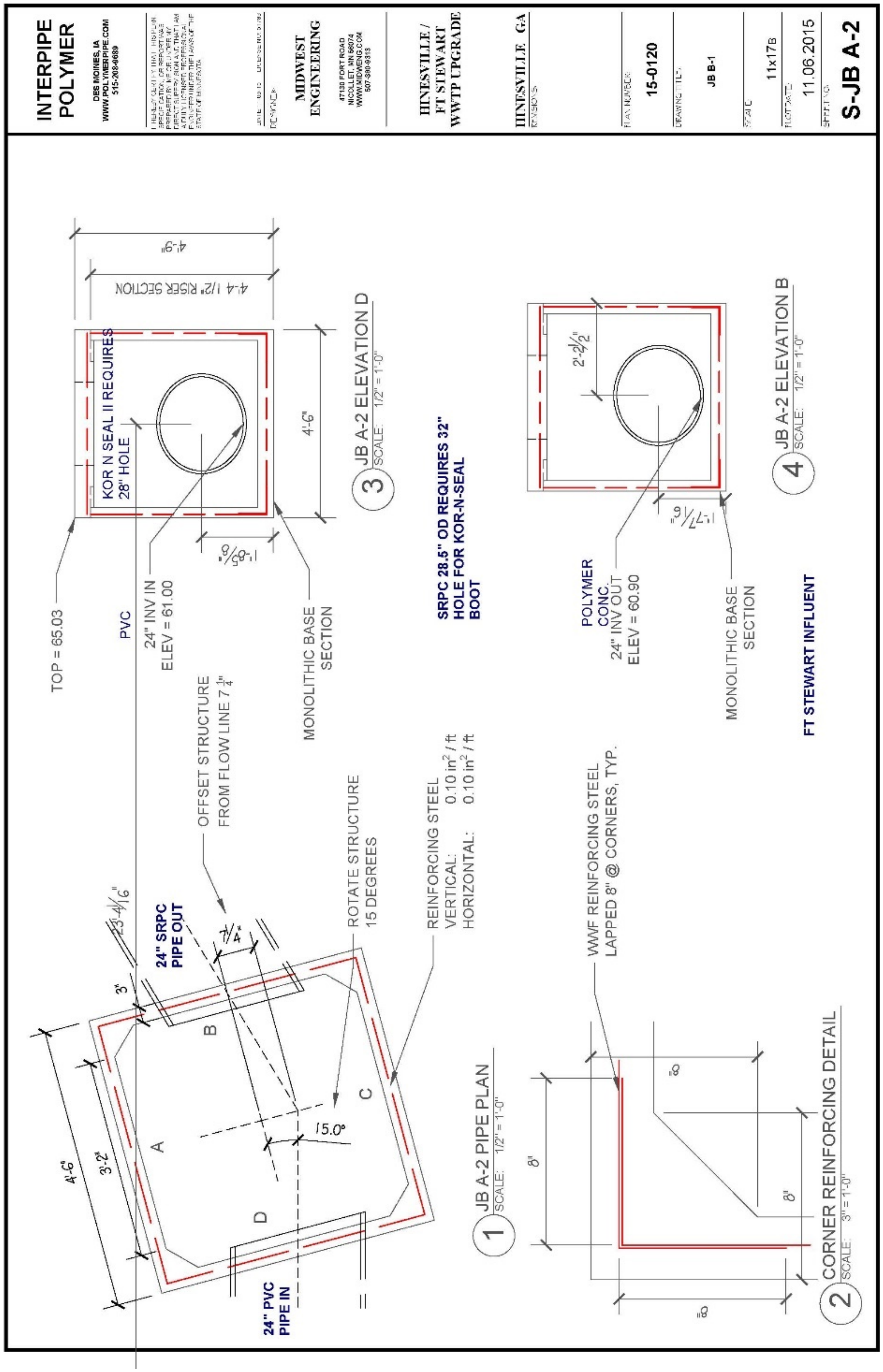
507-380-9313
HINESVILLE / FT STEWART WWTP UPGRADE
HINESVILLE GA
15-0120
JB B-1
11x17B
11.06.2015
S-JB B-1
TOP = 69.11
24" INV IN
ELEV = 64.58
(VERIFY)
CORRECT
PRECAST BASE FOR DOGHOUSE SECTION
4'-7 1/2" RISER SECTION
5'-4 1/2"
2'-9"
5'-0"
5'-6"
1'-11/16"
3'-5 13/16"
3 JB B-1 ELEVATION C
SCALE: 1/2" = 1'-0"
24" INV OUT
ELEV = 64.53
2'-4 5/16"
VERIFY
1'-5/16"
4 JB B-1 ELEVATION B
SCALE: 1/2" = 1'-0"
HINESVILLE INFLUENT
REINFORCING STEEL
VERTICAL: 0.18 in² / ft
HORIZONTAL: 0.18 in² / ft
KOR N SEAL II REQUIRES 28" HOLE FOR 24" PVC
WWF REINFORCING STEEL LAPPED 8" @ CORNERS, TYP.
24" PVC PIPE IN
4'-0"
9"
A
B
C
D
1 JB B-1 PIPE PLAN
SCALE: 1/2" = 1'-0"
8"
2 CORNER REINFORCING DETAIL
SCALE: 3" = 1'-0"



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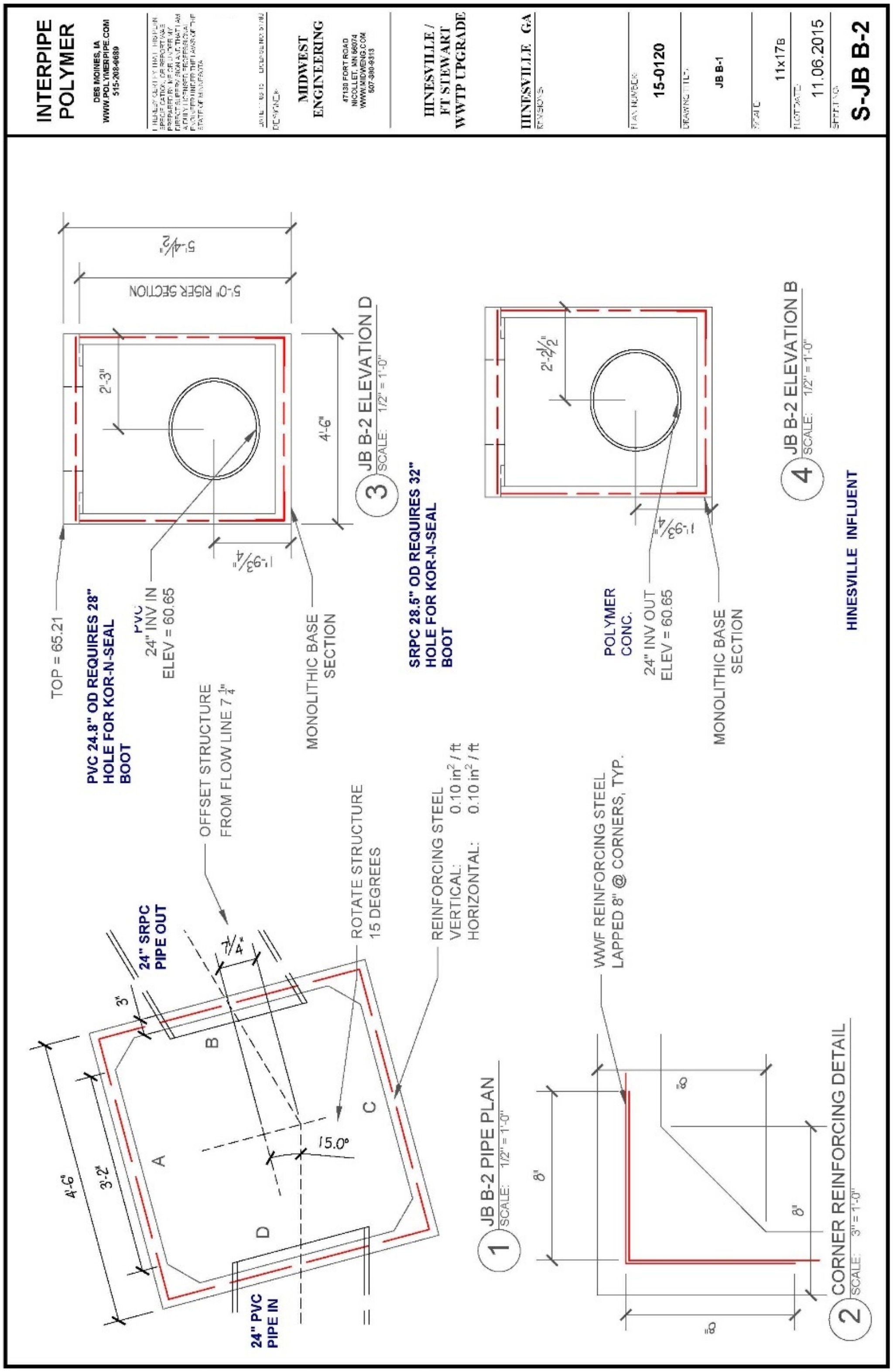
NICOLLET, MN 56074
WWW.MIDWENG.COM
507-380-9318
HINESVILLE / FT STEWART WWTP UPGRADE
HINESVILLE GA
15-0120
JB B-1
11x17B
11.06.2015
S-JB A-2
4'-9"
4'-4 1/2" RISER SECTION
KOR N SEAL II REQUIRES 28" HOLE
4'-6"
1'-8 5/8"
TOP = 65.03
PVC
24" INV IN ELEV = 61.00
MONOLITHIC BASE SECTION
3 JB A-2 ELEVATION D
SCALE: 1/2" = 1'-0"
SRPC 28.5" OD REQUIRES 32" HOLE FOR KOR-N-SEAL BOOT
2'-2 1/2"
1'-7 1/16"
POLYMER CONC.
24" INV OUT ELEV = 60.90
MONOLITHIC BASE SECTION
4 JB A-2 ELEVATION B
SCALE: 1/2" = 1'-0"
FT STEWART INFLUENT
OFFSET STRUCTURE FROM FLOW LINE 7 1/4"
ROTATE STRUCTURE 15 DEGREES
REINFORCING STEEL
VERTICAL: 0.10 in² / ft
HORIZONTAL: 0.10 in² / ft
WWF REINFORCING STEEL LAPPED 8" @ CORNERS, TYP.
24" SRPC PIPE OUT
2'-4 1/16"
3"
7 1/4"
4'-6"
3'-2"
A
B
C
D
15.0°
24" PVC PIPE IN
1 JB A-2 PIPE PLAN
SCALE: 1/2" = 1'-0"
8"
8"
8"
8"
2 CORNER REINFORCING DETAIL
SCALE: 3" = 1'-0"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507-380-9313
HINESVILLE / FT STEWART WWTP UPGRADE
HINESVILLE GA
15-0120
JB B-1
11x17B
11.06.2015
S-JB B-2
5'-4½"
5'-0" RISER SECTION
2'-3"
4'-6"
1'-9¾"
3 JB B-2 ELEVATION D
SCALE: 1/2" = 1'-0"
TOP = 65.21
PVC 24.8" OD REQUIRES 28" HOLE FOR KOR-N-SEAL BOOT
PVC
24" INV IN
ELEV = 60.65
MONOLITHIC BASE SECTION
SRPC 28.5" OD REQUIRES 32" HOLE FOR KOR-N-SEAL BOOT
2'-2½"
1'-9¾"
POLYMER CONC.
24" INV OUT
ELEV = 60.65
MONOLITHIC BASE SECTION
4 JB B-2 ELEVATION B
SCALE: 1/2" = 1'-0"
HINESVILLE INFLUENT
OFFSET STRUCTURE FROM FLOW LINE 7¼"
ROTATE STRUCTURE 15 DEGREES
REINFORCING STEEL
VERTICAL: 0.10 in²/ft
HORIZONTAL: 0.10 in²/ft
WWF REINFORCING STEEL LAPPED 8" @ CORNERS, TYP.
24" SRPC PIPE OUT
3"
7¼"
4'-6"
3'-2"
A
B
C
D
15.0°
24" PVC PIPE IN
1 JB B-2 PIPE PLAN
SCALE: 1/2" = 1'-0"
8"
8"
8"
8"
2 CORNER REINFORCING DETAIL
SCALE: 3" = 1'-0"

Appendix D: PPT/Interpipe Design Calculation Methodology

Design Basis and performance Testing of Polymer Pipe Technology's 24-inch Polymer Concrete Pipe.

Introduction

The purpose of this document is to describe the design basis and subsequent performance testing of Polymer Pipe Technology Inc.'s 24-inch diameter pipe. The design basis is presented first, followed by an evaluation of the D-Load tests conducted by Maxim Technologies, Inc.'s Houston, Texas office and analyzed by their Austin, Texas office.

Design Requirements

The objective of the design was to develop a pipe wall thickness and reinforcement schedule that will meet or exceed the strength requirements of ASTM C-76-95a. *"Standard Specification for Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe"*. The standard is referred to as C-76 throughout the remainder of this document.

Section 7.2 of C-76 defines the requirements for "*modified or Special Designs*". The specific requirements of these alternative designs are provided in Sections 7.2.2 and 7.2.3, these sections are quoted in their entirety below:

> 7.2.2 Such modified or special designs shall be based on rational or empirical evaluations of the ultimate strength and cracking behavior of the pipe and shall fully describe to the owner any deviations from the requirements of 7.1. (Author's note: Section 7.1 is the design tables with wall thicknesses and reinforcing schedules). The descriptions of modified or special designs shall include the wall thickness, the concrete strength, and the area, type, placement, number of layers, and strength of the steel reinforcement.
>
> 7.2.3 The manufacturer shall submit to the owner proof of the adequacy of the proposed modified or special design. Such proof may comprise the submission of certified three-edge-bearing tests already made, which are acceptable to the owner or, if such three-edge-bearing tests are not available or acceptable, the manufacturer may be required to perform proof tests on sizes and classes selected by the owner to demonstrate the adequacy of the design.

The strength requirements under C 76 for 24-inch diameter Class IV pipe are a cracking D-load of 4000 pounds per linear foot, and an ultimate D-load of 6000 pounds per linear foot. The strength requirements under C 76 for 24-inch diameter Class V pipe are a cracking D-load of 6000 pounds per linear foot, and an ultimate D-load of 7500 pounds per linear foot.

Design Basis

Preliminary Design

The initial cross sections were designed using the ultimate strength approach as in conventional reinforced concrete design. Since the purpose was to develop a design that would meet an ultimate load test, no capacity reduction factors or load amplification factors were used in the analysis. However conservative values for the ultimate compressive strength of the polymer concrete (F_c), and the yield stress of the steel (F_y).

Cross sectional bending moments were determined from the following relationship:

Bending Moment at Crown and Invert (Maximum +Moment):

$$M+ = 0.318 * D * R$$

where M+ is the maximum positive moment per foot of length
D is the D-Load per foot of length
R is the pipe radius

Bending Moment at Spring Lines (Maximum –Moment)

$$M- = -0.1817 * D * R$$

where M- is the maximum negative moment, and the other terms are defined as for M+

These expressions are from Advanced Strength of Materials, by Boresi, Sidebottom, Seely, and Smith. Third Edition, John Wiley, 1978. Page 360.

The initial design for the pipe indicated a wall thickness of 2.25 inches, with W20 sire placed on 6-inches on center. This resulted in a circumferential steel area of 0.40 sq. inches per foot of pipe length. The resulting moment capacity was:

$$M= \quad pbd^2f_y(1-0.59(pf_y/f_c))$$

where:

M is the moment capacity
p is the steel ratio (0.40/12x1.125 = 0.0296)
b is the unit width (12–inches)
d is depth to steel (1.125)
f_y is the yield stress of the steel (57,000 psi)
f_c is the ultimate compressive strength of the concrete (8000 psi)

The resulting capacity is 22,400 in-lbs or 1.87 foot-kips. This in turn corresponded to a D-Load of 5,870 lbs./ft. versus the required ultimate D-Load of 6000 lbs/ft. for Class IV pipe. Given the conservative assumptions in the design method this was viewed as a good starting point.

Design Basis

Polymer Pipe Technology utilizes a polymer concrete mix design which produces, in testing, an average compressive strength of 10,800 psi with a standard deviation of 600 psi. This allows the use of a specified compressive strength (f_c) of 9300 psi in accordance with the guidelines of the American Concrete Institute (ACI). The workability of the mix allows for placement around steel as close as 2-inches on center. This allowed for the use of a smaller wire size, with a more uniform distribution of the reinforcement. Since a final wire size and type were selected the yield stress (f_y) was set at 65,000 psi. The design tested therefore had the following properties:

Wall Thickness:	2.25”
Concrete Strength:	9300 psi
Steel Area:	0.42 sq. inches per foot
Steel Type:	ASTM A 82 f_y = 65,000 psi for circumferential steel F_y = 56,000 psi for longitudinal steel
Placement:	Wire Fabric 2 x 8 Mesh, W7 x W3
Layers:	Single Layer to be placed at center (placement error of up to 0.25 inches inside O.K.

The resulting moment capacity is:

$$M = pbd^2 f_y (1 - 0.59(pf_y/f_c))$$

Where:

M is the moment capacity
p is the steel ratio (0.42/12X1.125=0.0311)
b is the unit width (12-inches)
d is depth of steel (1.125-inches)
f_y is the yield stress of the steel (65,000 psi)
f_c is the ultimate compressive strength of the concrete (9300 psi)

The resulting capacity is 26,800 in-lbs or 2.23 foot-kips. This in turn corresponded to an ultimate D-Load of 7,100 lbs./ft. versus the required D-Load of 6000 lbs/ft. for Class IV pipe, and is close to the 7500 lbs/ft. required for Class V pipe.

Test Results

Five 4-foot long sections of 24-inch polymer concrete pipe were provided to Maxim's Houston, Texas Laboratory for testing. The test results are summarized below.

Sample I.D.	Load and Deflection to Produce 0.01-inch crack	Ultimate Load and Deflection
Sample 1*	8,570 lbs/ft 0.270-inches deflection	15,200 lbs/ft 0.900-inches deflection
Sample 2*	5,940 lbs/ft 0.255-inches deflection	9,816 lbs/ft 1.050-inches deflection
Sample 3	7,190 lbs/ft 0.200-inches deflection	10,230 lbs/ft 0.650-inches deflection
Sample 4	6,910 lbs/ft 0.220-inches deflection	12,440 lbs/ft 0.835-inches deflection
Sample 5	6,910 lbs/ft 0.250-inches deflection	11,890 lbs/ft 0.960-inches deflection
Average	7,110 lbs/ft 0.239-inches deflection	11,920 lbs/ft 0.879-inches deflection

*Note Samples 1 and 2 were used to fine-tune the vibration levels. Samples 3, 4, & 5 used the vibration level selected based upon casting Samples 1 & 2.

The test results for each sample are attached.

Summary and Conclusions

The existing 24-inch design is certainly suitable for use as Class V pipe. The performance exceeds the design assumptions due to the following reasons:

1) The predicted moments are based upon elastic theory. Since the polymer concrete and steel allow for significant redistribution of stress at the on set of yielding, more of the structure is able to resist the peak load.

2) The very high tensile stresses that can be carried by the polymer concrete are not accounted for in standard reinforced concrete design applications.

3) The use of minimum strength properties also understates the strength of the pipe. Repeating the calculations using the average strengths of f_c=10,800 psi, and f_y=80,000 psi yields an ultimate moment capacity of:

Test Data prepared by MAXIM Technologies, Inc

Continue from number three of the previous page.

M= $pbd^2f_y(1\text{-}0.59(pf_y/f_c))$

Where:

M is the moment capacity
p is the steel ratio (0.42/12X1.125=0.0311)
b is the unit width (12-inches)
d is depth to steel (1.125-inches)
f_y is the yield stress of the steel (80,000 psi)
f_c is the ultimate compressive strength of the concrete (9300 psi)

The resulting capacity is 32,650 in-lbs or 2.72 foot-kips. This in turn corresponds to an ultimate D-Load of 8,560 lbs/ft. This is approximately midway between the 0.01-inch cracking and ultimate loads measured in the test.

Test Data prepared by MAXIM Technologies, Inc.

POLYMER CONCRETE PIPE
24 – Inch Diameter Jacking Pipe Analysis

Introduction:

These calculations have been prepared by Maxim Technologies, Inc. for Polymer Pipe Technology. The purpose of the calculations is to determine the expected performance of PPT's 24-inch Diameter jacking pipe constructed of polymer concrete. The numbers in parentheses at the end of each section are applicable to the special case of a 25-inch diameter pipe with a wall thickness of 2.25-inches.

Assumptions:

The jacking pipe will have a nominal inside diameter of 24-inches. The wall thickness has been selected as 2.25-inches. Material properties are:

Ultimate Compressive Strength (f_c) = 9300 psi
Maximum Tensile Strength (f_t) = 2000 psi
Modulus of Elasticity = 1,300,000 psi

Safe Jacking Load:

The safe jacking load (assuming a safety factor of 3) can be determined by computing the cross sectional area, moment of inertia, and anticipated maximum eccentricity of the load. The stress in the pipe is given by:

$O = P/A_c + Pcc/j$

Where:

P = Jacking Force
A_c = Cross Sectional Area
$A_c = j\pi \ (R_o^2 - R_i^2)$
R_o = Outer Radius (14.25 – inches)
R_I = Inner Radius (12- inches)
The resulting value for A_c is 185 in.^{2} (192 in.^{2} for 25-inch pipe)
e = eccentricity of jacking force. (1.75")
c = distance to extreme fiber (14.25 – inches) (14.75 in. for 25-inch pipe)
I = Moment of inertia
$I = j\pi \ (R_o^{4-} R_i^4)/4$
The resulting value of I is 16,100 in.^{4} (18,000 in.^{4})

thus:

O = 0.00695 P (P in pounds, o in psi.) (0.00664 for 25-inch pipe) or:
p = 144 o (P = 150 o for 25-inch pipe)

Setting o to 3100 psi, yields P = 446,400 pounds or 223 tons. (yields P = 465,000 pounds or 232 tons for 25-inch pipe.)

Stresses at The Joints During Jacking:

Theoretically the joints should provide nearly the same strength as the pipe wall. The minor reduction in wall thickness is offset by allowing higher local stresses. The higher stresses will be spread throughout the wall thickness within a length equal to one to three pipe wall thicknesses.

Deflection During Joint Testing:

The joints are to be tested using ASTM C 1208. This test calls for the application of a direct shear at the joint. The shear force to be applied is 50 pounds per inch of pipe diameter, or a total force of 1200 lbs. for the 24-inch pipe. The force is applied over a 12-inch length of pipe immediately adjacent to the joint. The ASTM C 1208 method is more challenging than the C 497 method because the pipe is actually under load. The C 497 method places no load on the pipe.

The deflection due to this extremely small load (the pipe self weight is approximately 190 pounds per foot) should be unobservable.

Test Data prepared by MAXIM Technologies, Inc.

Direct Design

Reinforcement

Requirements

Design Parameters:

Concrete Compressive Strength = 9,000 psi
Reinforcing yield strength = 65,000 psi
Reinforcing cover = 1-inch
Installation in accordance with ASTM C 1479
Manufacture in accordance with ASTM C 1417

Diameter	Wall Thickness	Installation Type	Fill Height	A_{SI} (In^2/ft)	A_{SO} (In^2/ft)
24	2.00	2	20	0.100	
24	2.00	2	10	0.216	
24	2.00	2	20	0.322	
30	2.25	1	20	0.265	
30	2.25	2	10	.204	
30	2.25	2	20	.392	
36	2.25	1	20	0.398	
36	2.25	2	10	0.302	
36	2.5	2	20	0.488	
42	2.5	1	20	0.458	
42	2.50	2	10	0.342	
42	2.75	2	20	0.603	
48	2.75	1	20	0.540	
48	2.75	2	10	0.386	
48	3.00	2	20	0.720	
54	3.00	1	20	0.625	
54	3.00	2	10	0.456	0.247
54	3.50	2	20	0.725	0.348
60	3.00	1	20	0.837	
60	3.00	2	10	0.631	0.318
60	3.75	2	20	0.764	0.396
72	4.00	1	20	0.788	0.435
72	4.00	2	10	0.604	0.305
72	5.00	2	20	0.818	0.385

Direct Bury Pipe

Design Thickness (inches)

D-Load strengths correspond to ASTM C-76
(Fc[1] = 8,000 psi, Fy = 56,000 psi)

Wall thickness in inches per pipe class

Nominal Diameter	Class I	Class II	Class III	Class IV	Class V
24	2.00	2.00	2.00	2.25	2.25
27	2.00	2.00	2.25	2.25	2.50
30	2.00	2.25	2.25	2.50	2.75
36	2.50	2.50	2.50	2.50	2.75
42	2.50	2.75	2.75	2.75	2.75
48	3.00	3.00	3.00	3.00	3.00
54	3.50	3.50	3.50	3.50	3.75
60	4.25	4.25	4.25	4.25	4.25
66	5.50	5.50	5.50	5.50	5.50
72	6.00	6.00	6.00	6.00	6.00
84	7.75	7.75	7.75	7.75	7.75
90	8.75	8.75	8.75	8.75	8.75
96	10.00	10.00	10.00	10.00	10.00

For pipe sizes greater than 60 inch diameter PPT has selected a thickness for each size that will allow any of the ASTM strength classes to be obtained by varying the reinforcing.

Test Data prepared by MAXIM Technologies, Inc.

Slipline Pipe

Comparison of **iNTERpipe** and *Fiber-reinforced* slipline pipe

Nomina l Diameter (inches)	Internal Diameter (inches)		Outside Diameter (inches)		Pipe Stiffness (psi)		Safe Jacking Load (tons)	
	PPT	FRP	PPT	FRP	PPT	FRP	PPT	FRP
72	72.0	70.7	75.4	75.4	65	46	590	417
78	78.0	76.6	81.6	81.6	61	46	677	496
82.0	82.0	81.7	87.0	87.0	138	46	995	575
84.0	84.0	83.1	88.6	88.6	100	46	893	601
90.0	90.0	88.6	94.3	94.3	69	46	933	690
96.0	95.5	93.5	99.5	99.5	46	46	920	776

1. Dimensions and properties of FRP pipe are taken from supplier catalog pub. Date 4/00

2. **iNTERpipe** slipline product designed to match FRP pipe outside diameter. Wall thickness selected to provide an internal diameter equal to the nominal diameter or meet requirements for SN 46 classification.

3. **iNTERpipe** Safe Jacking Load set by limiting average compressive strength in the wall to 3000 psi.

Test Data prepared by MAXIM Technologies, Inc.

Flow Rate

Approximate Maximum Flow Rates

The flow rate for a circular pipe flowing full is given by the formula:

$$Q = (D^{8/3} \times S^{1/2}) / (n \times 1.33)$$

Q = Flow in cubic Feet Per Second (CFS)
D = Pipe Diameter In Feet
S = slope in decimal (i.e. 0.01)
N = Manning's Coefficient

A circular pipe actually reaches its peak capacity when the pipe is slightly less than full. The peak capacity is approximately 14% greater than the formula above. Manning's coefficient is dependent on the material and condition of the pipe. Typical design values are provided in the table below.

Kind of Pipe	From	To
Clean Conte Cast Iron	0.012	0.014
Concrete - Rough	0.016	0.017
Concrete Dry Mix	0.015	0.016
Concrete Wet Mix	0.012	0.014
Concrete Smooth	0.011	0.012
Vitrified Clay	0.013	0.015

The approximate range for "n" values for **iNTERpipe** is from 0.012 to 0.014.

Test Data prepared by MAXIM Technologies, Inc.

Test Data

Laboratory Analysis of Polymer Concrete

Report Date: September 24,1998

Test	Results
% Absorption as per ASTM C301	0.7 %
% Acid-soluble matter as per ASTM C301	0.0019 %
Abrasion Resistance as per ASTM C944	
Applied load = 20 lbf @ 3 min.	
Mass loss after 1st run	0.003 %
Mass loss after 2nd run	0.006 %
Mass loss after 3rd run	0.008 %
Total mass loss	0.008 %

Test Data prepared by MAXIM Technologies, Inc.

POLYMER CONCRETE PIPE

36 – Inch Diameter Design Calculations

Introduction:

These calculations have been prepared by Maxim Technologies, Inc. for Polymer Pipe Technology. The purpose of the calculations is to determine the expected performance of PPT's 24-inch Diameter jacking pipe constructed of polymer concrete. The numbers in parentheses at the end of each section are applicable to the special case of a 25-inch diameter pipe with a wall thickness of 2.25-inches.

Assumptions:

The jacking pipe will have a nominal inside diameter of 24-inches. The wall thickness has been selected as 2.25-inches. Material properties are:

Ultimate Compressive Strength (f_c) = 9300 psi
Maximum Tensile Strength (f_t) = 2000 psi
Modulus of Elasticity = 1,300,000 psi
Yield Stress of Wire Reinforcement (f_y) = 65,000 psi

Method:

The flexural strength of the wall sections is estimated using conventional reinforced concrete ultimate strength theory. The moment capacity of the wall is given by:

$M_u = pbd^2f_y(1\text{-}0.59(pf_y/f_c))$

Where:

M is the moment capacity (varies)
P is the steel ratio (varies)
B is the unit width (12 inches for all cases)
D is depth to steel (varies)
f_y is the yield stress of the steel (65,000 psi)
f_c is the ultimate compressive strength of the concrete (9300)

No strength or load factors are used since the intent of the calculations is to develop designs to meet specific destructive test requirements of ASTM C – 76. This analysis has been shown to be conservative on past tests of PCP with these properties.

Applied Loads and Resulting Cross Section Moments:

ASTM C 76 specifies a D-Load for concrete pipe based on the class of service. Services are classified into categories I through V. The majority of pipe used is in classes III and IV. The moments resulting from the applied D-Load may be estimated by:

$M_{(+)}$ = 0.3183 PR and
$M_{(-)}$ = 0.1817 PR
Where:
$M_{(+)}$ = Maximum Positive Moment (at Crown)
$M_{(-)}$ = Maximum Negative Moment (at Spring Line)
P = The applied D-Load (per unit length of pipe)
R = Pipe Radius

The resulting D-Loads, $M_{(+)}$, and $M_{(-)}$ are shown in Table 1.

Class	D-Load (pounds)	$M_{(-)}$ (inch-kips)	$M_{(-)}$ (in-kips)
III	6000	34.4	19.6
IV	9000	51.6	29.4
V	11,250	64.5	36.7

The positive moment is carried by the inner layer of steel and negative moment by the outer layer of steel. A single layer of steel formed into an ellipse may also be used. The latter approach has been selected for this application.

Design of Cross Section and Reinforcement:

Based upon preliminary analysis and manufacturing efficiencies a standard wall thickness of 2.75 – inches has been selected. Allowing for ¾ - inch of clear cover on the inside allows setting a depth of 1.5".

The resulting wire sizes, spacing steel area per foot and resulting moment capacity are shown in Table 2 below. The steel has been sized to resist the

Maximum Positive moment from Table 1. The same steel area will be more than adequate for the negative moments when the cage is formed into an ellipse.

The longitudinal steel shall be W3 on a minimum of 8-inch spacing to assist in the resistance of cracking during handling and to ease in fabrication.

Class	W.S. and spacing	Steel Area (sq. in. per foot)	+Moment Capacity (in-kips)	- Moment Capacity (in-kips)
III	W9 @ 3"	0.36	38.0	32.2
IV	W9 @ 2"	0.54	54.9	46.1
V	W11 @ 2"	0.66	65.3	55.0

Test data prepared by MAXIM Technologies, Inc.

Appendix E: Cost Comparison of Polymer Concrete versus Traditional Materials for Wastewater Pipe, Manholes, and Structures

Further economic analysis is described in this section that compares the cost of PCP products with the current conventional technologies. This comparison was developed by the City of Hinesville Engineer.

Material cost comparisons

As shown in Table E1, the PCP is substantially more expensive per foot than both encased C-905 PVC pipe and lined ductile iron pipe.

Table E1. Costs of PCP, PVC, and ductile iron pipes (P.C. Simonton & Associates, Inc.).

Product	Initial Cost of Material (per ft)	Installation to Meet Loading (per ft)	Total Cost (per ft)
PCP	$216.45	$60.00	$276.45
PVC (C-905)	$42.08	$56.00	$98.00
Ductile iron	$147.00	$60.00	$205.00

The PCP is capable of withstanding extreme compressive loading by direct boring of the pipe. The only material that could be used for comparison to it for strength would be steel casing with carrier pipe inside. An estimated cost comparison for direct bore PCP compared to steel-cased pipe with ductile iron carrier pipe at a depth of approximately 6 in. is shown in Table E2.

Table E2. Polymer concrete vs. steel casing and carrier pipe costs.

Product	Material Cost (per ft)	Installation via Bore (per ft)	Total Cost (per ft)
PCP	$216.45	$200.00	$416.45
36 in. steel casing plus 24 in. carrier pipe	$309.00	$229.00	$538.00

As shown in Table E2, PCP offers a cost advantage over traditional methods for pipeline installation via boring. However, it should be noted that many bore installations, especially under pavement, require casing of the carrier pipe as protection for the area above the pipeline. The PCP application would not meet this requirement. For this reason, the use of PCP pipe for boring would require a unique application that would not require additional cased protection.

Structures

Two cost comparisons for polymer concrete and lined regular concrete manholes are shown in Table E3. The total cost of the PCP structure for either size of pipe is very close to the cost of a manhole for PVC concrete-lined piping. For this project, the demonstrated quality of the concrete-lined PVC structures was much better, but assuming the supplier could improve the quality assurance and quality control process for polymer concrete structures in the future, Table E3 shows that the structures are competitive financially. In addition, the PVC piping's welded joints have failed in some cases. That type of failure would not be an issue in the case of the polymer concrete structures.

Table E3. Costs of polymer concrete structures vs. lined manholes.

Product and Size	Material Cost (each)	Installation Cost (each)	Total Cost (each)
PCP manhole for 24 in. pipe and boots (60 in. dia., 4 ft depth)	$7,528	$5,000	$12,528
PVC, lined manhole for 24 in. pipe (60 in. dia., 4 ft depth)	$7,210	$5,000	$12,210
PCP manhole for 10 in. pipe (48 in. dia., 6 ft depth)	$4,500 plus ring & cover	$2,000	$6,500
PVC, lined manhole for 10 in. pipe (48 in. dia., 6 ft depth)	$3,000 including ring and cover	$2,500	$5,500

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14. ABSTRACT

Sewer pipes and structures that convey aggressive wastewaters or are exposed to aggressive soil types can rapidly deteriorate, leading to premature leakage and service failure. This problem impacts mission execution on U.S. military installations by creating operational disruptions that re-quire unplanned emergency repairs, increasing operational costs and reducing infrastructure service life. An emerging alternate material, polymer concrete, is made with high-strength resins and aggregates that have excellent resistance to corrosive factors inside and out, as compared with standard concrete. Polymer concrete also has relatively high compressive, tensile, shear, and flexural strengths compared to ordinary concrete.

This report documents a field demonstration of a polymer concrete pipe (PCP) structure measuring 24 in. diameter by approximately 200 linear feet, including seven manholes and two junction boxes. Performance was monitored through coupon testing in the wet well and in the laboratory. Results indicate that PCP is significantly more resistant to sulfuric acid than Portland cement concrete. PCP is relatively new to wastewater applications, so extra attention is needed during acquisition because practices recommended by polymer concrete manufacturers may differ from those used in conventional wastewater infrastructure projects. The calculated return on investment for this project is 9.27.

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