DC Water Rapid Repair of Waste Water Treatment Plant Piping System

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ABSTRACT

The Blue Plains Advanced Wastewater Treatment Plant owned by District of Columbia Water and Sewer Authority (DC Water) is one of the largest wastewater treatment plants in the world. One particularly critical pipe within the facility is the Nitrification RAS Line, which transports sludge and is located in underground galleries. Through inspection it was identified that eight elbow sections of the 84-inch steel pipeline had significant thinning and were in need of repair during the scheduled 2013 pipeline shutdowns. Four 90-degree elbows and four 45-degree elbows required a structural upgrade and CFRP was selected as the appropriate structural lining system based on DC Water's previous successful history with this material. The EPA regulates the amount of time this facility can be shut down and dictates that only half the piping can be shut down at one time, so the cleaning, inspection, weld repairs, CFRP and topcoat installation, along with full cure of the repair system had to take place over the course of two 5-day shutdown windows. This paper will provide details and owner feedback on the design and construction process undertaken for this unique project.

1. BACKGROUND ON DC WATER

DC Water's Blue Plains Advanced Wastewater Treatment Plant serves more than two million Washington, D.C, metropolitan area customers from area jurisdictions including Montgomery and Prince George's counties in Maryland, and Fairfax and Loudoun counties in Virginia. With a capacity to treat more than 370 million gallons of sewage per day and a peak capacity of over 1 billion gallons per day, this facility is one of the largest wastewater treatment plants in the world (DC Water). Figure 1 shows a site plan of the Blue Plains Advanced Wastewater Treatment Plant and the project site location.

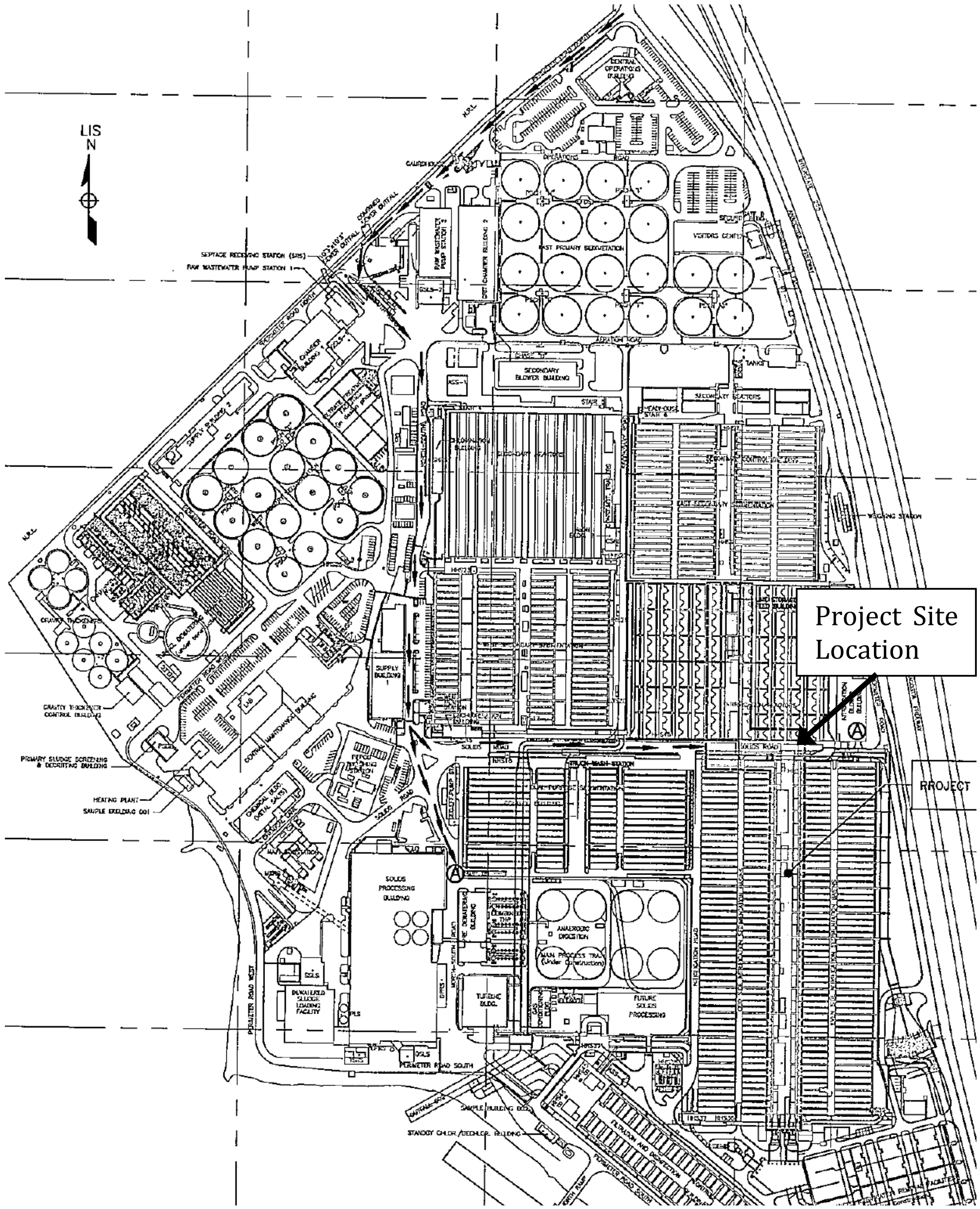

Figure 1. Project site plan

2. BACKGROUND ON NITRIFICATION RAS PIPELINE

Once sewage arrives at the Blue Plains Advanced Wastewater Treatment Plant, it undergoes an extensive treatment process as shown in Figure 2. The nitrification/denitrification process is one of the final steps prior to discharge of treated wat er i nto t he Pot omac R iver and t akes pl ace pri marily i n t he Ni trification Return Activated Sludge (Nit RAS) Building.

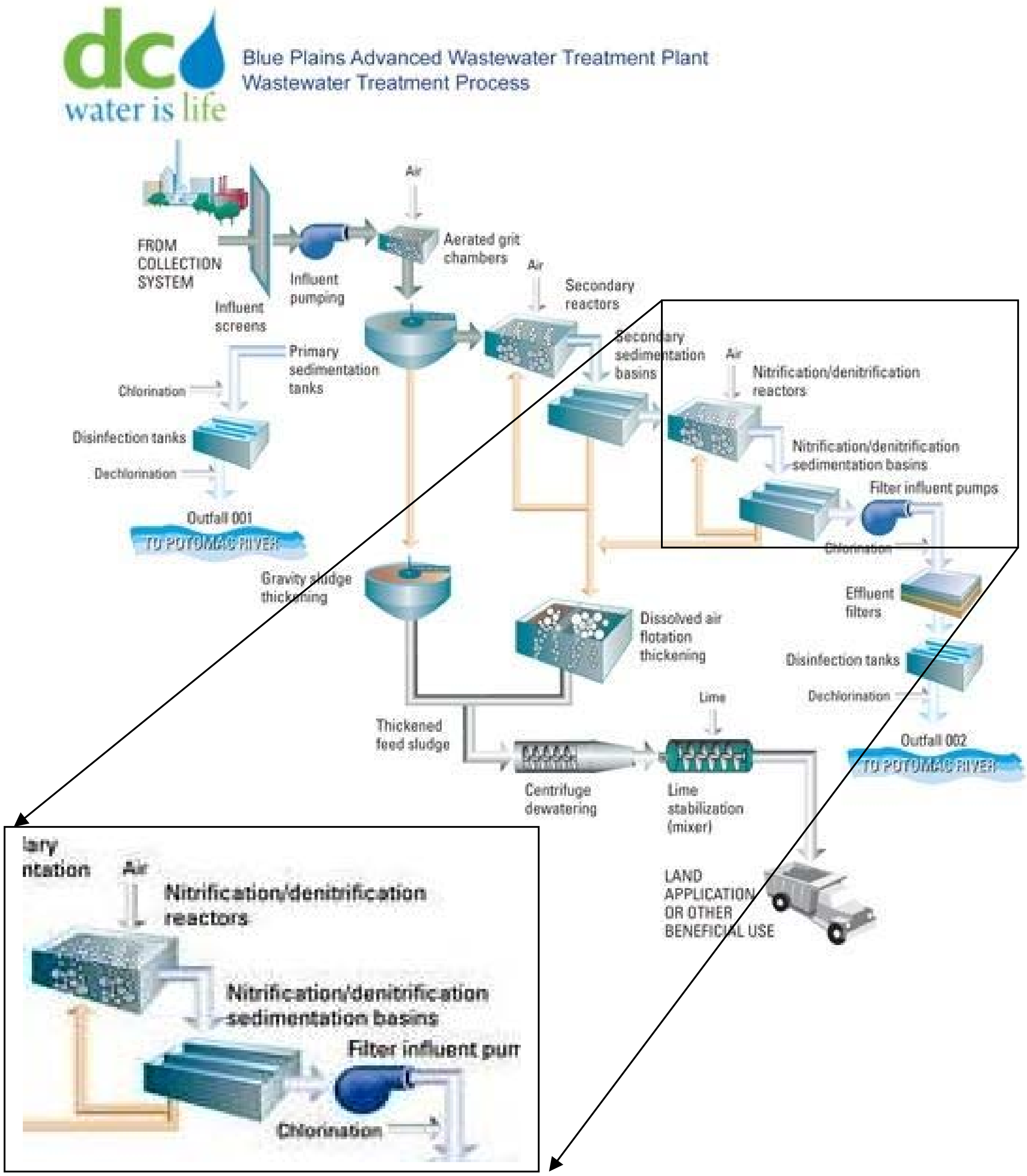

Figure 2. Wastewater treatment process at DC Water's Blue Plains Advanced Wastewater Treatment Plant (DC Water)

Within the Nit RAS B uilding there is a to tal of approx imately 3,500 LF of ste el pipeline that varies in diameter from 20-inch to 84-inch and is located in underground galleries. This Nit RAS pipeline connects the nitrification reactor gallery, the waste sludge gallery, and the nitrification sedimentation gallery as shown in Figure 3.

During a plant upgrade project completed several years ago, deterioration of the Nit RAS pipeline was observed. This was due to abrasion and corrosion, and it was most prominent at the horizontal and vertical bend locations which are shown as regions M-9 and M-10 of Figure 3. Except a few required upsizing of this piping system, no major repairs had been scheduled or executed on these pipe lines since they were put in service more than 20 years ago. As a result of the abrasion and corrosion, leaks had developed in several locations along the length of the pipeline.

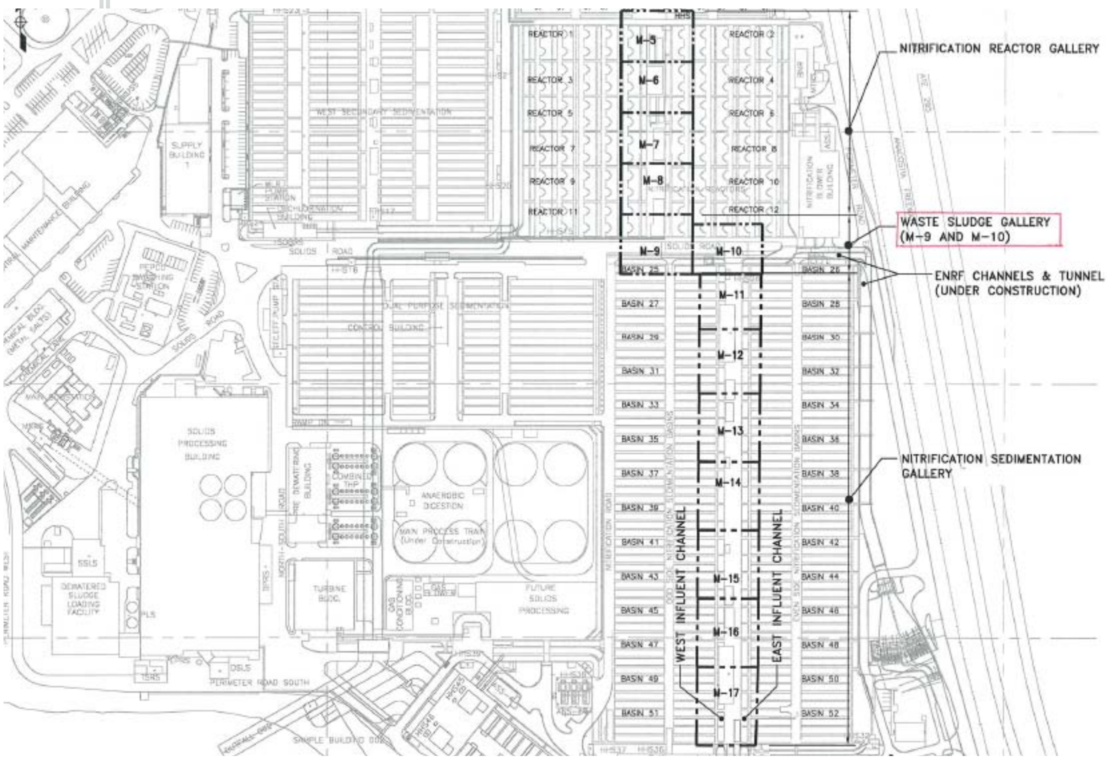

Figure 3. Plan view of Nit RAS Pipeline

The Nit RAS pipeline is divided into two halves: a West or Odd Side and an East or Even side, which allows for operation of the facility to continue at a reduced capacity while one of the pipelines is taken out of service. However, EPA and plant operational requirements severely restricted the timeframe in which either Nit RAS pipeline could be out of service. All work within each pipeline was required to take place within a 5 day shutdown period. Additionally, if a significant precipitation event was forecasted to occur during the shutdown, the pipeline would need to be reinstated within 24 hours of the notification to meet anticipated peak demands. In addition, a minimum of four (4) weeks was required to elapse between completion of work on the first side and start of work on the second side so that the nitrification processes could re-stabilize.

DC Water originally intended to rehabilitate the entire length of Nit RAS pipeline, however the construction schedule requirements did not allow for continuous upgrades during the current outage constraints. Instead, DC Water opted to implement a long-term structural upgrade at the horizontal and vertical bend regions within the pipe line. The bend regions had been identified as areas with more prevalent degradation. In addition, the DC Water decided to inspect the entire length of pipeline while the pipeline was shut down and perform localized temporary repairs in the deteriorated areas identified during the inspection. This approach allowed for the areas with known degradation to be addressed with long term repair solutions and while the inspection and other temporary repairs also allowed for improved planning for future repairs to the pipeline.

3. OPTIONS EVALUATED FOR REPAIR OF NIT RAS PIPELINE BENDS

The designated pipeline regions requiring structural repair consisted of two 84-inch 45° vertical bends and two 84-inch 90° horizontal bends on both the West and East side pipelines, for a total of eight regions. The pipeline segments in need of repair were located approximately 25 feet below grade, within the waste sludge gallery, with part of the scope several feet above the gallery floor and part of the scope suspended from the gallery ceiling as shown in Figure 4. Access for materials and personnel into the pipeline was through existing 20-inch and 30-inch man ways in the pipeline, some of which were only accessible by specially built 20 ft platforms which had to be erected prior to the plant shutdown.

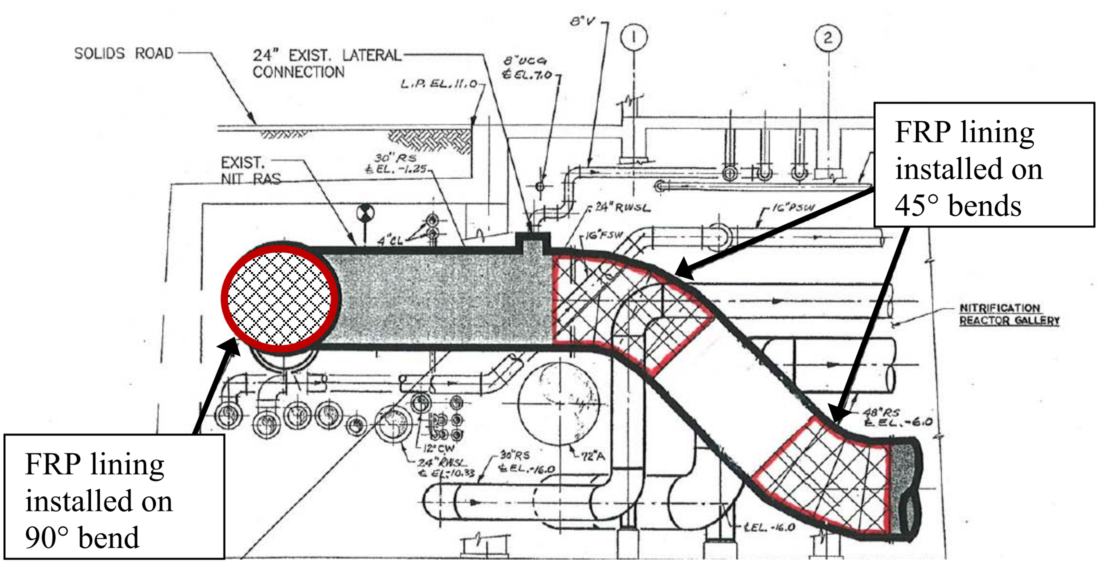

Figure 4. Location of repair

During planning phases for this project, multiple options were evaluated for rehabilitation of the horizontal and vertical bend regions of the pipeline including:

1. Specialty coatings
2. Cured in place pipe (CIPP)
3. Slip-lining
4. Replacement
5. Externally applied carbon fiber reinforced polymer composite (CFRP)
6. Internally applied CFRP system

The selected rehabilitation system, or replacement, needed to take the internal pressure acting on the Nit RAS pipeline without reliance on the host pipe. In addition, it needed to maintain the existing hydraulic conditions within the pipeline without significant change to the internal diameter. Due to the extent of deterioration observed during the previous inspection of the pipeline and the pressure requirements of the Nit RAS pipeline, a more structurally robust repair beyond application of a specialty coating system was determined by DC Water to be necessary at critical bends. The extremely limited access into the waste sludge gallery and Nit RAS pipeline along with the limited construction window ruled out CIPP, slip-lining, and pipeline replacement as potential options.

The two remaining options considered for structural repairs were externally applied CFRP system and an internally applied CFRP system. DC Water had previous history with successfully implemented internally and externally applied CFRP systems for structural upgrades of their pipelines (Bian et al, 2013).

While an externally applied CFRP system would have been ideal from a scheduling standpoint, allowing repairs to take place while the Nit RAS pipeline was still in service, the project logistics rendered this option infeasible. Surrounding utilities and other equipment within the sludge waste gallery made for difficult access conditions to the extent that most of the outside of pipeline was not visible or directly accessible. In addition, this pipeline was experiencing primarily internal deterioration, whereas the previous externally applied CFRP project implemented by DC Water involved a pipeline which was experiencing primarily external deterioration. The source of deterioration for a pipeline is important to take into account because use of an externally applied CFRP system on a pipeline which is degrading primarily on the inside poses a significant challenge regarding termination of the CFRP system onto competent pipe to avoid leakage at the termination locations.

After consideration of costs, risks, schedule constraints and available rehabilitation options, an internally applied CFRP system was selected by DC Water as the method for addressing the designated regions of the Nit RAS pipeline. The implemented system provided a structural internal lining that had a nominal thickness of approximately ¼ inch, which was considered to have negligible impact hydraulically on the system.

4. IMPLEMENTATION OF THE CFRP REHABILITATION SYSTEM

In order to make sure that a qualified CFRP design and installation team was selected, design drawings and a full implementation plan with detailed construction schedule was required as part of the bid submission. The CFRP design involved multiple longitudinal and circumferential layers of unidirectional carbon fiber fabric, electrically isolated from the steel substrate by an initial layer of glass fabric. Both the glass and carbon fiber fabrics were saturated with a two-part 100% solids epoxy using a mechanical saturator staged in the pipe gallery. Figure 5 shows the site location as well as the staging areas available for implementing the repairs.

Figure 5. Outside view of vertical bend regions of Nit RAS pipeline repaired internally with CFRP

Due to the limited time window and criticality of this pipeline, extensive preplanning was performed for this project including multiple walk downs of the jobsite prior to mobilization. In order to meet the construction schedule, the general contractor, the FRP installer and DC water all had personnel on site performing work 24 hours a day during the shutdown. During the same time that FRP installations were occurring, valves were being replaced on the work areas immediately next to the access manholes. In addition, other work was being performed being performed downstream, requiring airflow to be controlled so that dust and contamination would be isolated to a given region of the pipe. Flexible ducting connected to a large environmental control unit staged above grade was utilized to accomplish this effort.

Prior to implementation of the CFRP system, the entire pipeline was pressure washed to remove sludge buildup from the walls of the pipe. The substrate was then prepared using sponge blasting to achieve a near white metal blast SP 10 substrate finish. The use of sponge blast media was selected over conventional grit blast media in order to minimize the dust created in the Nit RAS pipeline and reactor galleries. After surface preparation was completed the entire isolated pipeline region was cleaned and dried to ensure a contaminant free work environment.

The surface preparation was verified through an adhesion test performed per ASTM D4541 on adjacent substrate. Minimum requirement for the adhesion test value was 300 psi, however values achieved were significantly higher as shown on Figure 6.

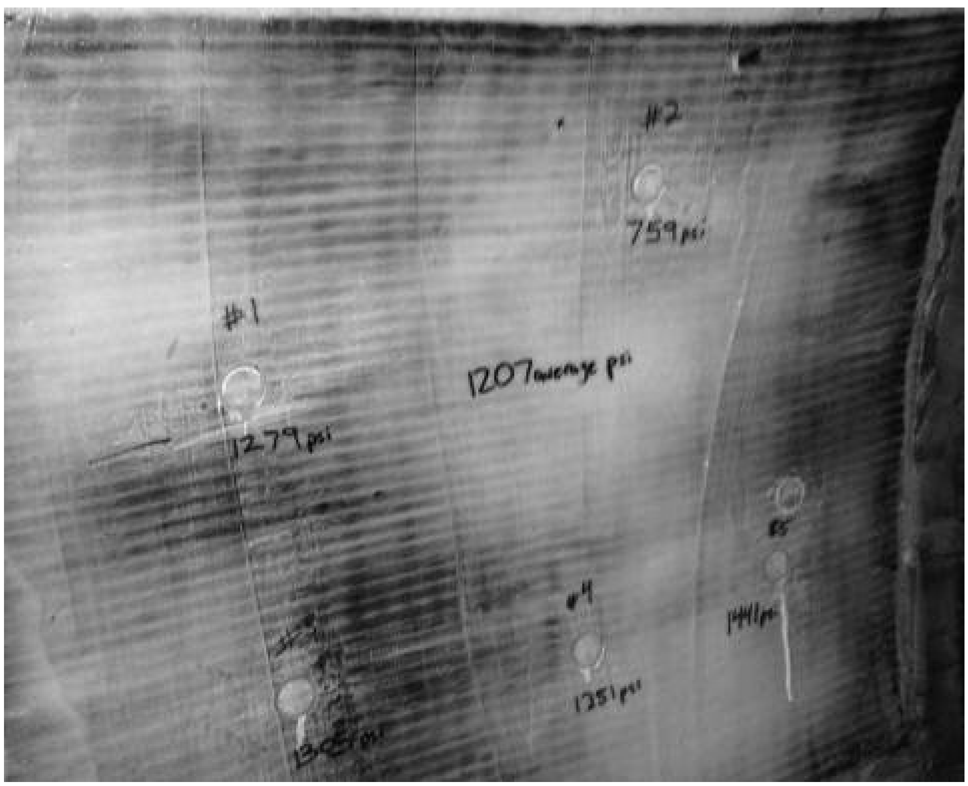

Figure 6. Adhesion test panel with adhesion test results written on the panel

In order to ensure complete access to the work scope on the inside of the pipeline, specialty scaffolding was developed so the FRP could be installed without walking on the repair scope and so that the hoop direction reinforcement could be installed in a continuous piece. Figure 7 shows the access scaffolding installed in the pipeline. All scaffold pieces were designed to in order to fit through the existing manholes and then be assembled on the inside of the pipeline to span the full length required.

Figure 7. Access planking system to allow for full circumferential access to the work scope

In addition to the 45° vertical bends and the 90° horizontal bends, one of the 90° bends intersected with a 42in lateral and specialized detailing was developed to accommodate this connection as shown in Figure 8.

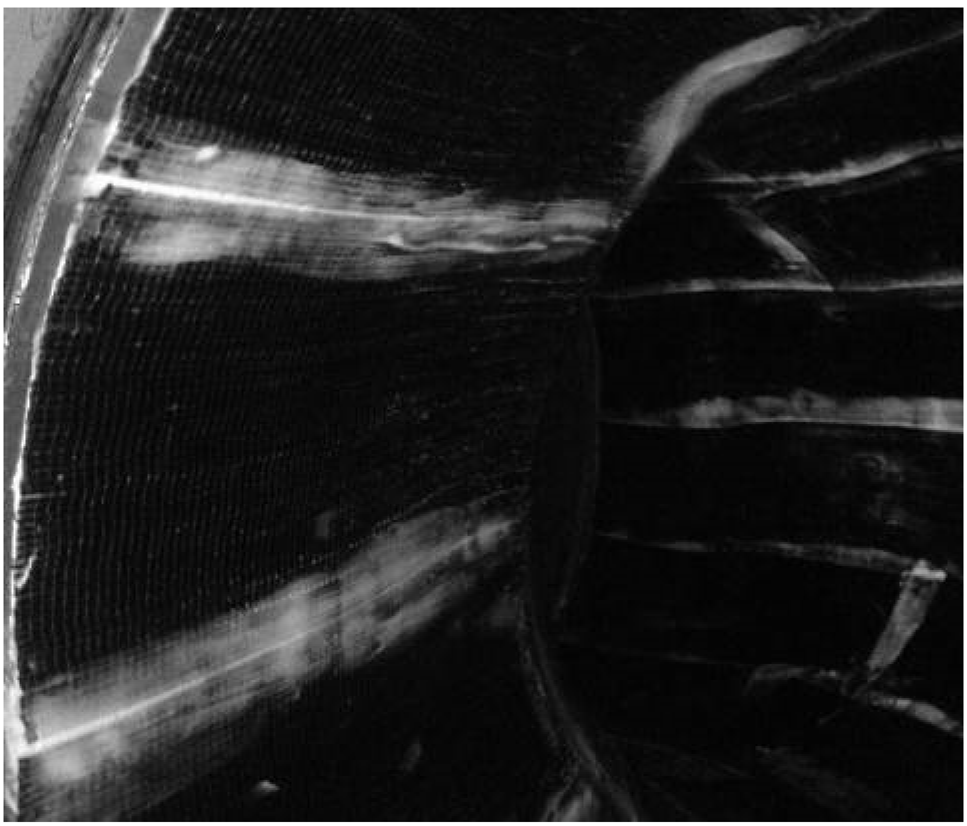

Figure 8. Lateral connection repaired with CFRP

Throughout the installation process, DC Water's third-party inspector and Structural's quality assurance representative documented each stage of the process to ensure conformance with the project drawings and specification. This included observation and documentation of the following:

1. Calibration of the mechanical saturator
2. Alignment of the reinforcing fabric
3. Temperature and humidity in the mixing and pipeline areas
4. Verification of the adhesion test

To facilitate accelerated cure of both the carbon fiber lining system and the chemical-resistant topcoat, the temperature in the pipeline was elevated using in-line heaters attached to the environmental control unit for the project.

An additional chemical resistant topcoat was applied over the FRP system to provide chemical resistance to the nitrification return activated sludge. The completed CFRP lining system with topcoat installed is shown in Figure 9.

Figure 9. Completed CFRP lining

5. CONCLUSIONS

The use of CFRP as a targeted structural system allowed for DC Water to improve reliability on the critical NitRAS pipeline while performing the work within the required 5 day shutdown window. The schedule, site logistics and access requirements on this project created one of the most challenging CFRP pipeline rehabilitation projects to date. Extensive pre-planning for this project and experienced personnel helped to make this project successful.

REFERENCES

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