.

Figure 17: Headwall damage and erosion at the base

Following the storm events, the area was inspected, and the following repair was contemplated:

1. Replacement of the brick bulkhead with an enhanced reinforced concrete with brick veneer after the erosion mitigation;
2. Addition of 6" thick shotcrete lining to the last 6' long culvert to encase (5) steel rod/end-plates to tie-back the displaced stone retaining wall.

Before this plan was approved by National Park Service, owner of the historic stone wall, the subsequent storm hit the area on July 8, 2019, escalating the situation to a potential higher consequence failure of the retaining wall, along with the 15' brick culvert including a 9' diameter inlet and outlet pipe. More critically, Reservoir Road, which functions as a dirt berm enclosing the flooding plain, was at risk.

Upon additional entry inspection of the 15' culvert behind the bulkhead, it was evident the brick culvert wall was pulled apart longitudinally in same direction of the 2"+ outward displacement of the stone retaining wall bearing on the brick arch end of the 15' culvert. It also revealed that the 8 French-drain ports cut above spring lines of the 9' inlet pipe to facilitate drainage in front of the stone retaining wall were blocked.

Figure 18: Culvert head wall failure causing failed earth/stone berm

Following the July 2019 rain, the repair plan was revised to include replacement of the bulkhead with heavy-duty reinforced concrete. As the bulkhead was replaced, and a manway access added, an agreement was reached with NPS to rehabilitate the entire 15' culvert along with the bulkhead. The NPS granted DC Water and expedited approval for construction and was willing to evaluate the historic stone retaining wall for a proposed mortar pointing stabilization.

Figure 19: Rebuiding headwall with soil anchorage in mind

Following the repairs implemented, DC Water Engineering believes that the road's stability is contingent upon the integrity of the stone wall. After the structural upgrade of the bulkhead and culvert, the wall becomes the weakest link. The old-fashioned stacked stone wall, which is on the historic register in Washington DC, must be retrofitted with mortared joint to survive the impact of displacement evident in differential settlement, tilting and missing of stone blocks. NPS also agreed to address the blocked French-drain ports as part of its flood plain study.

LESSONS LEARNED FROM MITIGATION PROJECTS

As the rain events of 2018 and 2019 have shown, the resiliency of DC Water's buried sewer infrastructure depends greatly on resistance to erosion in unexpected ways:

- A perfect storm always supersedes the designed storm, presenting an ultimate resiliency test – infrastructure design is only as good as design assumptions;
- Pipeline resiliency is defined exclusively at the weakest link(s) in the system, this should be a major focus of pipeline integrity management;

- A risk-sensitive set of engineering principles demand ―outside-of-the-pipe" thinking which goes well beyond the material selection and takes nothing for granted. This should include all aspects including pipe bedding, support from surrounding soil mass, and all consequential input, such as impact of failure to surrounding area, etc.

DigIndy Tunnel System Collection Consolidation Sewer Construction Update

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ABSTRACT

Citizens Energy Group (Citizens) is implementing a long-term control plan to address combined sewer overflows (CSOs) in Indianapolis, Indiana. The "DigIndy" plan includes provisions for a series of CSO diversion structures, consolidation sewers, screen and gate structures, approach channels, drop shafts, and a tunnel for storage and conveyance. There are multiple tunnel segments and corresponding near surface projects planned over a span of 10–15 years. The paper discusses the overall tunnel system and highlights the recent near surface sewer projects. The projects are near surface sewer projects under construction in 2018–2020 including multiple cast in place concrete structures to divert flow from a CSO to the Dig Indy tunnel through large diameter collection and consolidation sewers. Sewer installation includes trenchless technology and open cut excavations in multiple locations. The challenges of construction in an urban environment around numerous existing utilities while coordinating with other municipal projects will be discussed.

PROJECT DESCRIPTION

Each year there are 60-80 combined sewer overflow (CSO) events that contribute an average of 8 billion gallons of untreated wastewater into the waterways of Indianapolis, Indiana. In accordance with a Federal Consent Decree, Citizens Energy Group, owner of the wastewater system is implementing a Long-Term Control Plan to address CSOs on behalf of the City. Included in the "DigIndy" control plan are provisions for a series of CSO diversion structures, consolidation sewers, drop shafts, and a 28-mile long network of six 18-foot diameter tunnels. Beginning near the Indiana State Fairgrounds on the north, and ending on the south side of Indianapolis, DigIndy is the largest public works project in the city's history.

The plan includes using existing system capacity, expanding and upgrading the existing treatment facilities and a new storage and conveyance system. The storage and conveyance system is known as the DigIndy Tunnel System and will capture up to 95 percent of CSOs along six Indianapolis waterways, reducing overflows as required by the US Environmental Protection Agency (EPA).

With a volume of more than 290 million gallons, the tunnel system will extend along Fall Creek, White River, Eagle Creek, Pogues Run, Pleasant Run, and Bean Creek to create an underground storage and transport facility for combined sewer overflows. Approximately 20 miles of the tunnel network has been completed to date with the Fall Creek portions of the tunnel underway in Winter 2019. All CSOs captured, stored, and transported in the tunnel system will be treated at one of the City's advanced wastewater treatment plants. The tunnel system consists of the following tunnel segments as shown in Figure 1:

Deep Rock Tunnel Connector (DRTC)

- 7.6 miles of 18-foot finished diameter tunnel with 3 drop shafts

- Discharges to pump station at Southport AWTP

Eagle Creek Tunnel (ECT)

- 1.7 miles of 18-foot finished diameter tunnel with 1 drop shaft
- 2,800 feet of consolidation sewer

White River Tunnel (WRT)

- 5.8 miles of 18-foot finished diameter tunnel with 7 drop shafts
- 4,800 feet of 24-inch to 108-inch diameter consolidation sewer

Fall Creek Tunnel (FCT)

- 3.8 miles of 18-foot finished diameter tunnel with 13 drop shafts
- 4,400 feet of 24-inch to 108-inch diameter consolidation sewer

Lower Pogues Run Tunnel (LPT)

- 1.8 miles of 18-foot finished diameter tunnel with 2 drop shafts
- 1,400 feet of 72-inch to 144-inch diameter sewer

Pleasant Run Deep Tunnel (PRDT)

- 7.3 miles of 18-foot finished diameter tunnel with 10 drop shafts
- 19,600 feet of 24-inch to 72-inch diameter consolidation sewers

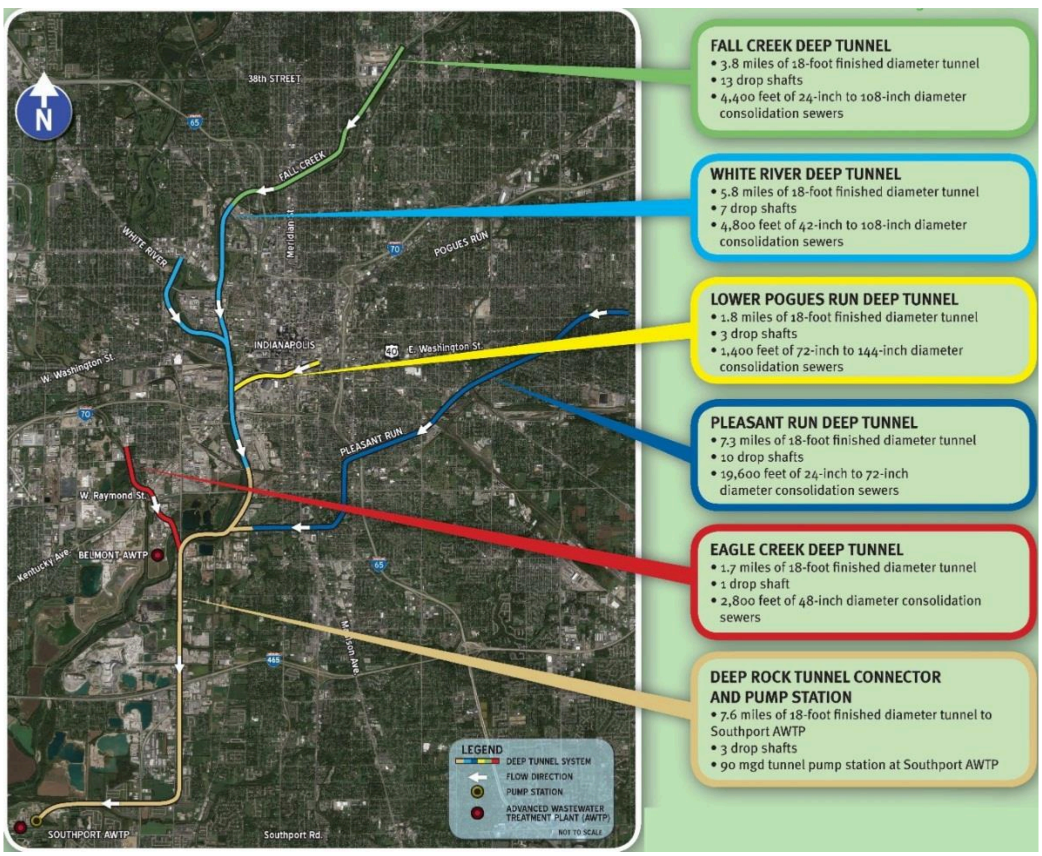

Figure 1. DigIndy Tunnel System Program Overview.

Under the Federal Consent Decree, a timeline to achieve full operation of CSO compliance was established with the requirement that all work in the plan be complete at the end of 2025. The DRTC was placed online at the end of 2017, which includes the deep tunnel pump station, and included the ECT. Prior to December 31, 2021 LPT and WRT must be complete and functional in the system. Finally, by the end of 2025 FCT and PRDT must also be online in the system.

The tunnel system major civil components consist of diversion structures, collection consolidation sewers (CCS), screen and gate structures, deaeration chambers, approach channels, drop shafts, vents shafts, connection tunnels (adits), and the main tunnel.

Diversion structures are cast-in-place concrete structures that are installed along each CSO sewer to divert flow from the CSO outfall to the consolidation sewers. The structures are also equipped with a combination baffle wall and hinged bar screen to prevent solids and floatables from entering the waterway during an overflow event. A typical diversion structure is shown in Figure 2.

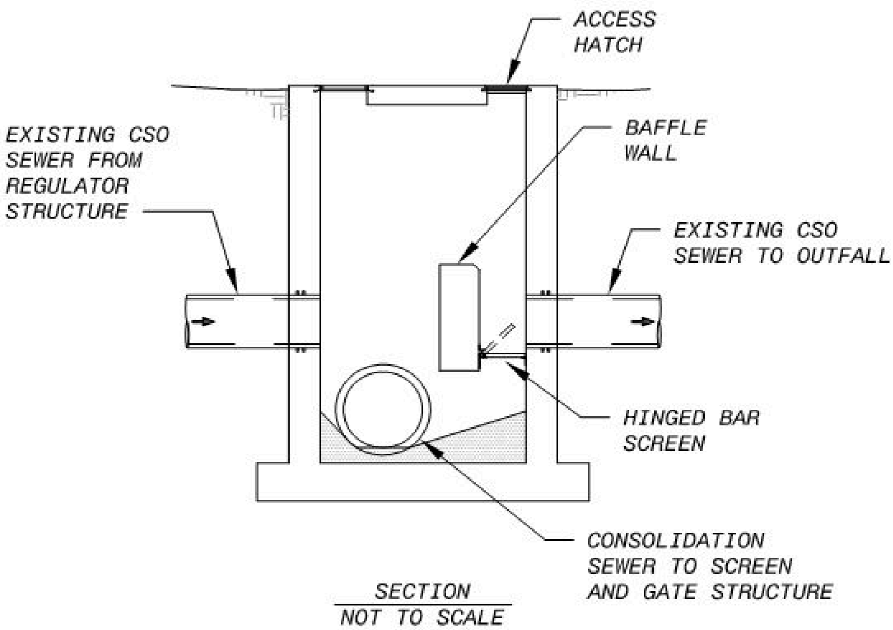

Figure 2. Typical Diversion Structure.

The DigIndy Tunnel System is a massive undertaking. Not only have the tunnel segments been divided into different construction packages, the near surface work has also been divided into multiple construction packages for several reasons including coordination of timing with other City projects and to even out capital spending for the projects over the 15-year construction timeline. Project descriptions follow for the three projects discussed in this paper.

The Lower Pogues Run CCS Phase construction package has a construction cost of $24 million. The project includes four cast in place diversion structures to divert flow from CSOs to the DigIndy tunnel through collection and consolidation sewers ranging in size from 60-inch to 120-inch in diameter and are in downtown Indianapolis in an urban neighborhood and adjacent a large public stadium. The project additionally includes two screen and gate structures and approach channels that connects to the LP-01 and LP-02 drop and vent shafts which direct flow to the tunnel.

The Lower Pogues (LP) Run CCS Phase project includes near surface conveyance infrastructure components associated with the project as follows:

- For LP-01, a cast-in-place diversion structure is installed to capture combined sewer overflow (CSO 128) along Lower Pogues Run. The CSO 128 sewer is 102-inch diameter, while the diversion structure is 30 feet deep.
- For LP-01, approximately 190 feet of 84-inch diameter collection consolidation sewer is installed to divert flow from the CSO to the screen and gate structure.
- For LP-01, a screen and gate structure and approach channel is installed to direct flow to the tunnel. Both structures are nominally 35-feet deep. The screen is 9-feet high by 14-feet wide with 6-inch spacing and protects the approach channel transition structure which allows the flow to narrow and lengthen to attach to the walls of the drop shaft and spin downward to the tunnel which is nominally 200 feet below the approach channel.
- For LP-02, a cast-in-place diversion structure is installed to capture combined sewer overflows (CSO 136 & 152) along Lower Pogues Run. The CSOs 136 & 152 are combined in a single box conduit that is 12-feet high by 16-feet wide, while the diversion structure is 25 feet deep.
- From the diversion structure, approximately 470 feet of 96-inch diameter collection consolidation sewer is installed to divert flow from the CSO to a second diversion structure.
- A second diversion structure is installed to capture combined sewer overflows from CSO 133 and accept flows from two other diversion structures. The CS0 133 is a 60-inch diameter sewer while the second diversion structure is 38 feet deep.
- The second diversion structure conveys flow from CSO 133 and two other diversions structures to the Screen and Gate Structure through approximately 55 feet of 120-inch diameter collection consolidation sewer.
- A third cast-in-place diversion structure is installed to capture combined sewer overflow (CSO 138A). The CSO 138A is a 66-inch diameter sewer, while the diversion structure is 20 feet deep.
- From the third diversion structure, approximately 380 feet of 60-inch diameter collection consolidation sewer is installed to divert flow from the CSO.
- For LP-02, a screen and gate structure and approach channel is installed to direct flow to the tunnel. Both structures are nominally 38 feet deep. The screen is 14-feet high by 16-feet wide with 6-inch spacing and protects the approach channel transition structure which allows the flow to narrow and lengthen to attach to the walls of the drop shaft and spin downward to the tunnel which is nominally 200 feet below the approach channel.

The Madison Avenue Sewer Extension construction package has a construction cost of $3 million. The project includes upsizing of existing dry weather flow sewers to divert flow from CSOs to the existing sewer collection system. The new sewers range in size from 18-inch to 24-inch diameter and are in downtown Indianapolis in an urban neighborhood and adjacent an entertainment district and several office buildings. The project additionally includes weir modifications on existing CSOs to divert flow into the existing sewer collection system. The Madison Avenue Sewer Extension project resulted from a value engineering exercise which found that a drop shaft site formerly planned on Lower Pogues Run could be eliminated if these upgrades were instead made in the collections system. This resulted in significant cost savings to the overall project by eliminating the typical near surface infrastructure and deep shaft construction typically required for a drop shaft site.

The Madison Avenue Sewer Extension project includes near surface conveyance infrastructure components associated with the project as follows:

- Approximately 950-feet of 24-inch sewer is connected to an existing regulator manhole on CSO 125 which contains a diversion weir for the existing 64-inch diameter combined sewer overflow. The new sewer upsizes an existing one and the sends flow south along Madison Avenue to a 54-inch diameter existing sanitary interceptor for eventual treatment at the plant. Additionally, a weir raise modification was made within the regulator manhole on CSO 125 to direct flow to the new 24-inch diameter sewer.
- Approximately 40-feet of 18-inch diameter sewer is connected to an existing sewer on CSO 153 which contains a diversion weir for the existing 24-inch diameter combined sewer overflow. The new sewer upsizes an existing one and then sends flow southeast within Illinois Street to a 64-inch diameter existing sanitary interceptor for eventual treatment at the plant. Additionally, a weir raise modification was made within the new regulator manhole on CSO 153 to direct flow to the new 18-inch diameter sewer.

The Fall Creek CCS Phase IV construction package has a construction cost of $4 million. The project includes a single cast in place diversion structure to divert flow from a CSO to the DigIndy tunnel through a 96-inch collection and consolidation sewer and is in Indianapolis in an urban neighborhood adjacent and within the Indiana State Fairgrounds. The project will eventually connect to a screen and gate structure and approach channel that connects to the FC12 drop and vent shaft which direct flow to the tunnel.

The Fall Creek CCS Phase IV project includes near surface conveyance infrastructure components associated with the project as follows:

- A cast-in-place diversion structure to capture combined sewer overflow (CSO 141) along Fall Creek. The CSO 140 sewer is 102-inch diameter, while the diversion structure FC12-DV-1 is 35 feet deep.
- Approximately 700 feet of 96-inch diameter collection consolidation sewer to a future screen and gate structure.

DESIGN

Efficient use of labor and office resources is necessary to produce design deliverables on-time and within budget for a project such as DigIndy. Although this paper focuses on only a portion of necessary infrastructure for three drop shafts, the overall system includes 32 drop shafts and all necessary near surface construction for each. To ensure efficiency on the design of these near surface sites, standard protocols were developed for several actions and requests. Client contact was established through a single point of contact with the Engineer, combining similar requests to streamline responses and keep the team on schedule. Utility coordination and permitting were centralized as well for all collection consolidation sewer projects to streamline responses and maintain schedule. The assignment of design team effort to specific tasks was closely tracked and managed, as were all production requests. Another challenge of managing the design of multiple construction packages is maintaining consistent design between contracts. Consistent design incorporating lessons learned as construction contracts are completed is critical to ensure uniform operation across the system. Similarly, detailed review of contractor submittals during construction is necessary to confirm consistent products are installed throughout the system. With seven previous drop shafts nearing completion of construction, value engineering options have been presented by Contractors and incorporated into subsequent designs. One example is that constructability reviews have simplified the reinforcing steel design within cast in place structures to allow more efficient and properly consolidated wall pours around existing sewers. These and other lessons learned allowed for a successful design and construction Lower Pogues Run CCS Phase, Madison Avenue Sewer Extension, and the Fall Creek CCS Phase IV projects.

Community and stakeholder coordination during the planning phase is critical to successfully managing project risks and schedule. Conflicts must be identified early in the design to be adequately addressed within the planned schedule. Coordination with permitting agencies and land owners is also important, as any delay could severely impact project implementation. Coordination must begin early to understand land owner preferences and concerns, allowing sufficient time for negotiation and design modification. Permit preparation begins at 60 percent design to ensure timely approval. A pre-submittal meeting is conducted between the design team and permitting agencies to confirm all requirements and expectations will be met upon submittal.

CONSTRUCTION

The projects were solicited for contractor pricing proposals in Spring 2017 and Spring 2019. As a private entity, Citizens Energy Group does not have to choose a contractor based strictly on a low bid resulting from a public tender and instead pre-selects qualified contractors and then solicits proposals and negotiates the award with a contractor.

Utility coordination was undertaken with the private utilities prior to beginning each construction contract. Utility relocations were required for gas and water which are owned by Citizens Energy Group. Gas and water relocations were necessary to install structure which required a temporary earth retention system. Also prior to construction, shotcrete or CIPP lining was undertaken by another contractor on the existing CSO sewers to be diverted along the alignment of the new collection consolidation sewer. Lining material was selected for the sewers after video inspection indicated that replacement would not be required.

Although multiple pipe materials are acceptable to the Owner and were options in the project specifications, the Contractor elected to use centrifugally cast fiberglass reinforced polymer mortar (CCFRPM) pipe for all consolidation sewers over 24-inch diameter. Both piles and lagging earth retention systems and a slide-rail trench protection system were used for the construction of the diversion structures. Trenchless sewer installation methods were required for some sewers on both the Lower Pogues CCS Project and the Madison Avenue Sewer Extension.

CONCLUSION/CURRENT STATUS

Design and management of a large program has involved many moving parts and adaptability to change has been a key component to its success thus far. The implementation of a staggered construction schedule for the various similar projects in the DigIndy plan has allowed both the owner and design teams to learn along the way.

Efficient use of labor and office resources is necessary to produce design deliverables on-time and within budget. To ensure efficiency, standard protocols were developed for several actions and requests including client correspondence and response tracking of common issues throughout the different near surface drop shaft designs. Utility coordination and permitting were centralized as well for all collection consolidation sewer projects to streamline responses and maintain schedule. Maintaining consistent design between contracts was critical to ensure uniform operation across the system and detailed review of contractor submittals during construction is necessary to confirm consistent products are installed throughout the system over the 10-15 year construction timeline of the different near surface drop shaft projects.

These projects had specific challenges with coordination between ongoing construction projects within and around the project limits. Specific challenges included planning road shutdowns to occur at specific intervals based upon numerous City events including sporting events, marathons, and other planned annual events as well as coordination with business owners to permit access to business throughout construction.

The Madison Avenue Sewer Extension project will be put into service upon completion in 2020. The LP CCS and FC CCS projects will not be put into service until the DigIndy Tunnel system has been completed. Once the segment of deep tunnel is in place and ready to accept flows, the near surface infrastructure will be connected and put into service. The Lower Pogues Run Tunnel has a completion date of 2021 and the Fall Creek Tunnel in 2025, but it was essential that this near surface infrastructure be completed now in conjunction with other area projects and developments.