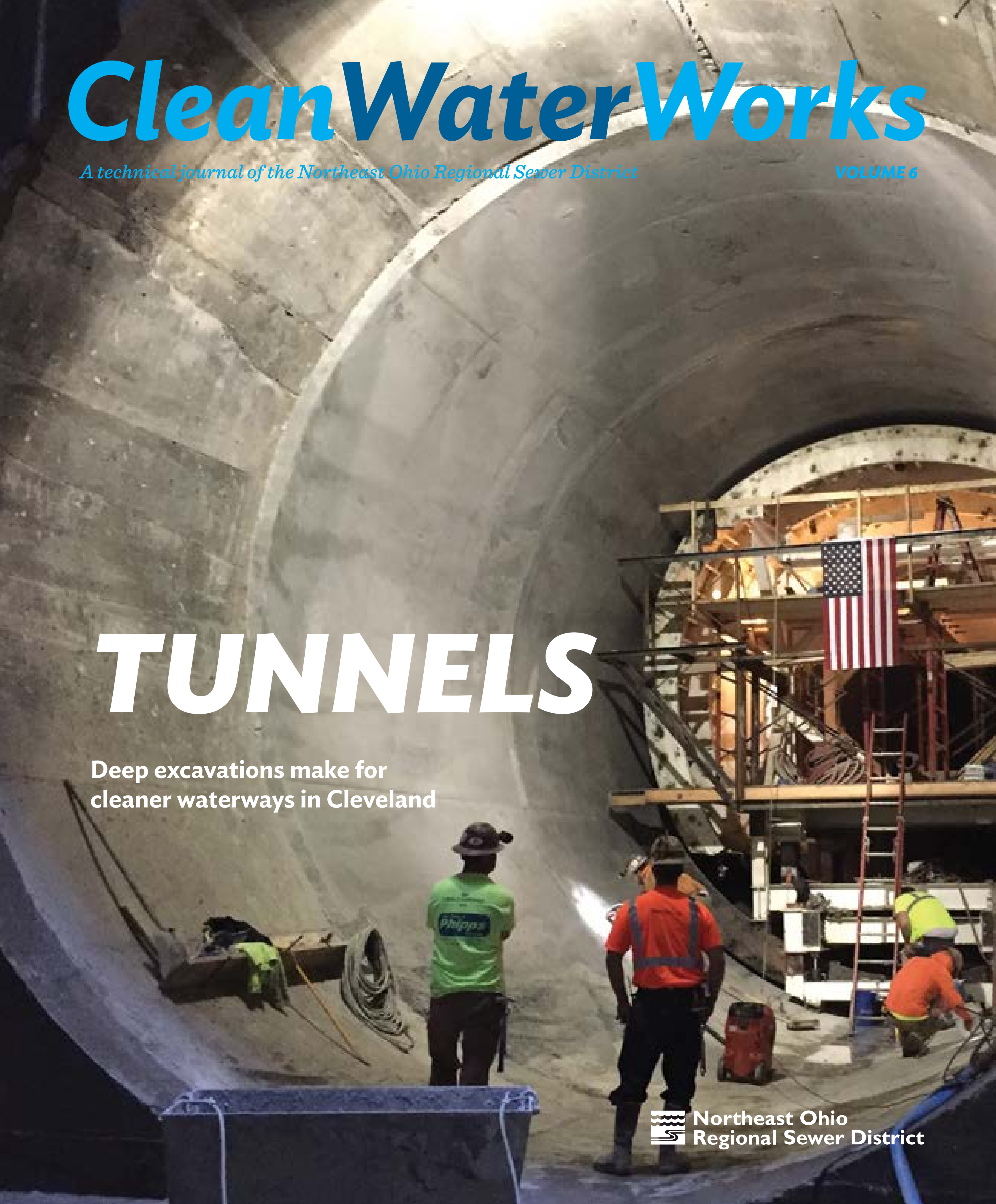


CleanWaterWorks

A technical journal of the Northeast Ohio Regional Sewer District

VOLUME 6

TUNNELS

Deep excavations make for cleaner waterways in Cleveland

Northeast Ohio Regional Sewer District

From the Deputy Director of Engineering & Construction

ERIC MULL

GABRIEL

Dear Reader,

In 2019, the Sewer District made steady and significant progress in its large-tunnel construction projects, providing an excellent opportunity to devote an edition of ***Clean Water Works*** to the topic of tunneling.

As explained on the following pages, combined sewer overflow, or "CSO," is a legacy problem in older cities, posing serious challenges to our clean-water resources. The main component of the District's long-term plan to control CSO is the construction of storage tunnels towards reducing annual CSO by 4.5 billion gallons by 2035.

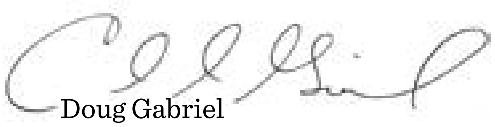
We are well on our way to realizing this goal. Construction of the Euclid Creek Tunnel commenced in 2011, and since then we've completed excavation of three of seven planned storage tunnels, in addition to a variety of associated near-surface projects.

Currently, 62 Sewer District projects have been completed or are active, with $1.24 billion spent or awarded, and *one billion gallons* in annual CSO reduction achieved. This magazine highlights a few of these digs, notably the Doan Valley Tunnel, which runs directly underneath one of the city's cultural and economic hubs, University Circle, and will be completed in 2021.

Other major tunnel projects featured in this *Clean Water Works* are the completed Dugway Storage Tunnel and the Westerly Storage Tunnel, the excavation of which is underway near Edgewater Park.

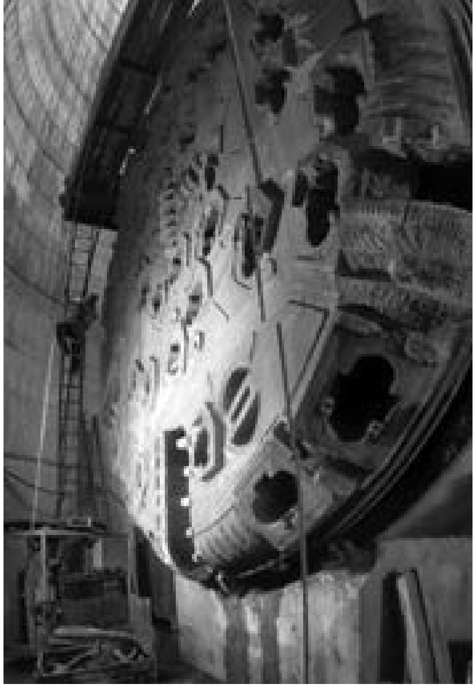
Cleveland is one of many cities throughout the country—including Fort Wayne, Washington D.C., and Akron—working to meet federal requirements to reduce CSO pollution. The benefits to our communities include cleaner beaches and waterways, and the Sewer District is proud of the work competed thus far towards this goal.

I hope you enjoy learning more about these magnificent projects!



Doug Gabriel

Doug Gabriel joined the Northeast Ohio Regional Sewer District in 2010 and has served as Deputy Director of Engineering & Construction since 2017.



Tunnel Boring Machine

Contents

4 The problem
Older sewer systems were designed to discharge

6 Wholly shipped
A tunnel boring machine arrives in Cleveland

8 Dig it!
A crash course in tunnel construction

24 Small but mighty
Microtunneling

28 Deep dive
A new Introduction to Construction course

30 Q&A
Interview with Construction Manager Robert Auber

DATA PAGES:

5 Project Clean Lake storage tunnels

14 Tunnel Boring Machine (TBM) schematic

19 Near-surface structures

22 Tunnel shaft construction methods

25 TBM vs. MTBM

Tunnels

In addition to maintaining over 330 miles of sewers, the Sewer District is responsible for building large storage tunnels to reduce pollution entering Lake Erie and other waterways.

Cover story page 8

ON THE COVER: *The finished, concrete-lined starter tunnel for the Sewer District's Dugway Storage Tunnel, July 2019. Photo by Richard Depew.*

Our Mission is to provide progressive management of sewage and stormwater through fiscal responsibility, innovation, and community partnerships.

Our Vision is to be the environmental leader in enhancing quality of life in the region and protecting its water resources.

This annual magazine gives subject-matter experts the opportunity to explain in greater detail our work and that of our partner agencies.

WRITER & EDITOR
Michael Uva

ART ASSISTANCE
Yolanda Kelly

PHOTOGRAPHY
John Gonzalez
Eric Mull
Michael Uva
NEORSD Archives

CHIEF EXECUTIVE OFFICER
Kyle Dreyfuss-Wells

Normal "dry-weather" flow travels to the wastewater treatment plant

When it rains, a mix of stormwater and wastewater spills over the weir and discharges into the environment untreated.

The problem

Older sewer systems were designed to discharge

In older cities like Cleveland, sewage from homes and businesses flows in the same pipe as the rainwater that runs off streets and rooftops. These "combined sewers" were built over 100 years ago, and originally carried waste away from the public and directly into nearby waterways.

"Combined sewers are pervasive across the Midwest, East Coast, and Upper Northwest, the oldest urban industrial centers," said Sewer District Director of Watersheds Frank Greenland.

Between the 1950s and 1970s, a new generation of pipes called "interceptors" were built to capture the combined wastewater flows and prevent them from discharging directly into waterways. The interceptors conveyed the majority of the combined wastewater to centrally-located wastewater treatment plants.

However, to prevent sewer backups and flooding, the pipes were designed to allow some of the untreated rainwater and sewage to overflow into the environment. This is called combined sewer overflow, or "CSO."

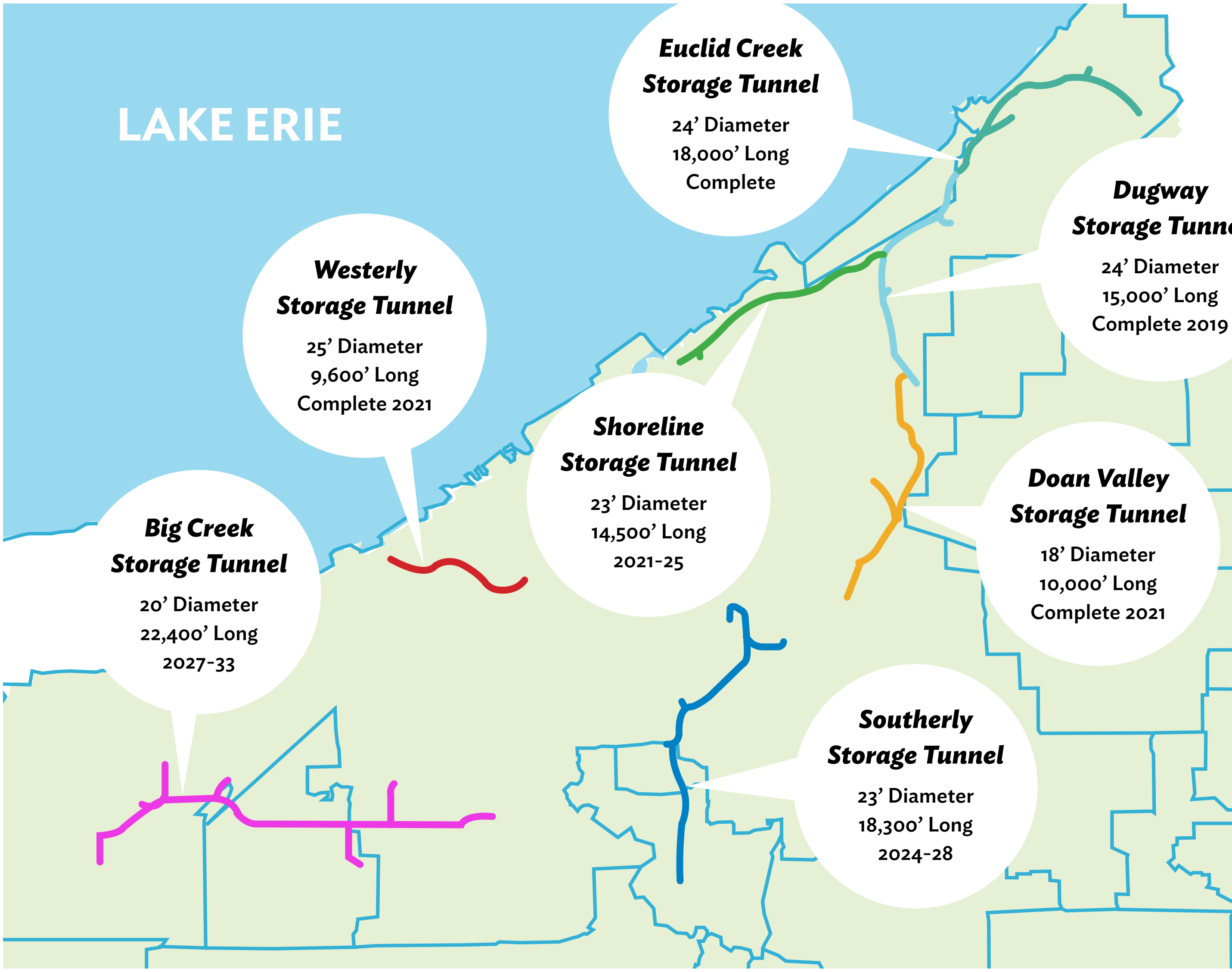
In combined sewers, rain and untreated wastewater flow in a trough. In heavy rains, the combined water overflows a weir and drops into a second, lower tunnel. It then passes through an outfall and into the environment.

The release of sanitary sewage into the environment due to CSOs and other sources can seriously compromise the quality of the receiving body of water. "The primary impact is harmful *E. coli* bacteria," said Greenland. "When it rains, *E. coli* levels elevate in the streams and lake." Following rain events, beachgoers are often advised not to go swimming in Lake Erie.

"I don't think combined sewers are that bad, when you look at the stuff on the streets—oils, greases, junk, litter," said Greenland. "Stormwater in the urban environment has a lot of pollutants that combined sewers capture, and that's a good thing. But the overflows are problematic, and you need to tackle that."

In 1994, the U.S. EPA adopted a policy requiring

Project Clean Lake Storage Tunnels



As spelled out in its consent decree with the U.S. and Ohio EPAs, the Sewer District is constructing seven large CSO storage tunnels.

wastewater agencies to develop long-term plans to further reduce CSO. Cleveland and hundreds of cities around the country have negotiated plans with the EPA to address these overflows.

Project Clean Lake is the Sewer District's federally-mandated, $3 billion plan to reduce CSO volume in Cleveland from 4.5 billion gallons to under 500 million gallons annually. The result will be an estimated 98% capture and treatment of wet-weather flows in Cleveland's combined-sewer system by 2035.

At the heart of Project Clean Lake are seven storage tunnels that will hold combined wastewater and stormwater that otherwise would discharge to the environment. Once a rain event ends, the CSO is pumped up to the surface and to a wastewater treatment plant.

Sewer District tunnels have proven very effective. The Mill Creek Storage Tunnel, completed in 2012, can store up to 72 million gallons of CSO from the Mill Creek Interceptor, which serves Cleveland and 11 other communities. Annual CSO in the Mill Creek watershed has been reduced by 97%. The Euclid Creek Tunnel, completed in 2015, can hold an additional 60 million gallons of sewage and stormwater, reducing pollution entering Lake Erie.

"When you've got a very stringent federal CSO-reduction target, tunnels prove to be fairly cost effective on a dollar-per-gallon capture basis," said Greenland. CWW

JENN ELTING

Wholly shipped

A tunnel boring machine arrives in Cleveland

When the *BBC Plata* docked at the Port of Cleveland in September, she was bringing with her a cleaner Lake Erie.

Cleveland welcomed the *Plata* from Dalian, China. It held the pieces of a tunnel boring machine (TBM) that would begin mining the Sewer District's Westerly Storage Tunnel (WST) in late 2019.

After the *Plata* docked, four of the TBM's largest pieces—a 29'-wide cutter head and three large shields that would encase it when fully assembled—were loaded onto a barge and shipped up the Cuyahoga River to the WST-3 shaft site *(see map, next page)*, where the TBM's underground journey would begin. It was a sight to behold as the massive plastic-wrapped components meandered their way along the crooked river towards WST-3.

Along with the barge, an additional 40 truckloads of equipment were hauled to the same site to accommodate the TBM's underground, eight-week re-assembly, by which it would become the 265-foot long, two-million-pound behemoth capable of excavating the WST.

When completed in 2021, the $135 million tunnel will be nearly 10,000' long and 25' in diameter, and capable of storing more than 360 million gallons of CSO each year, keeping it from discharging into the environment at two existing outfalls *(blue dots on map, right)*.

The TBM will complete its journey at tunnel shaft WST-1, near the Sewer District's Westerly Wastewater Treatment Plant.

The WST is the first Project Clean Lake tunnel constructed on Cleveland's west side, but the fourth constructed as part of District's 25-year, $3 billion investment in our region's sewer infrastructure.

The cutter head is 29 feet tall and weighs 300,000 pounds. It was lowered by crane 200 feet to the bottom of the launch shaft, where it was attached to the TBM being assembled underground.

The tunnel boring machine began its journey at WST-3 and will exit the ground at WST-1 near the Westerly treatment plant.

These tunnels are designed to reduce pollution, and the projects are also job creators. The prime contractor for WST, Jay Dee-Obayashi JV, has committed nearly $21 million to our local subcontracting community, not to mention hundreds of construction workers from right here in Northeast Ohio. *—John Gonzalez* *by Michael Uva*

Dig it!

A crash course in tunnel construction

"WHAT ARE THEY BUILDING THERE, anyway?" is a question motorists might ask upon seeing cranes and other machinery looming behind construction fencing by Interstate 90 and Cleveland's Memorial Shoreway. Even when the job is completed, and the equipment, dust, and safety-vested crews are gone, what remains of the work won't yield an obvious answer, as it's mostly taking place underground.

What they're building are massive storage tunnels—colossal projects that involve tried-and-true excavation techniques, modern technology, and dedicated teams of top-tier engineers, specialists, and laborers.

Seven storage tunnels are being built to fulfill the Northeast Ohio Regional Sewer District's Project Clean Lake goal of all but eliminating sewage overflows into the Cuyahoga River, area streams, and Lake Erie by 2035.

During rainstorms that otherwise overload the capacity of our aging combined-sewer system, these new storage tunnels capture and hold millions of gallons of combined wastewater and stormwater *(see story, page 4)* and keep it from discharging to the environment.

A subterranean tour of the eastside Doan Valley Tunnel and a walkthrough of near-surface projects adjacent to the in-progress Westerly Storage Tunnel comprise a crash course in what's involved in imagining, designing, and building these infrastructure marvels.

A question I am often asked is whether it is possible to go down into the tunnels. People are curious about these massive structures, and want to experience what it's like to be inside of one.

For various reasons, among them safety and liability, it's rare for the general public to tour a tunnel project. For this article, I was given access to the Doan Valley Tunnel (DVT), an 18'-diameter, two-mile-long storage tunnel that will keep 365 millions of gallons of CSO from polluting local waterways each year.

The main construction staging site for this dig sits

A metal staircase provides access into the shaft that leads to the Doan Valley Tunnel.

at the edge of MLK Boulevard near University Circle. There, a 50'-diameter vertical shaft provides access to the mouth of the tunnel 120 feet underground.

On the day of my visit, the overcast sky matches the gray mountain of shale that has been excavated and lifted from the hole, one railcar at a time, by a brightly-painted yellow crane that sits in contrast to its dull surroundings. Nearby, workers assemble short lengths of railroad tracks that are being lowered into the shaft to accommodate the train that moves in and out of the tunnel, all day and night. The longer the tunnel gets, the more rail is needed. “Everything comes in and out via crane,” says Construction Supervisor Karrie Buxton.

Buxton has been with the District for seven years, having started out with a small design firm working on slope-stabilization projects before moving into construction management. “I did a lot of structural work for bridges, big spans, and deep foundation work,” she said. “It lent itself to tunneling, because it’s all soil and rock mechanics, just deeper in the ground.” Before joining the District, she gained municipal experience as Construction Manager for the City of Shaker Heights. “I wanted to get back into a civil environment, where you’re challenged and feel like you’re giving something back,” she said.

From the “crow’s nest,” a metal platform near the lip of the shaft, we watch the third-shift workers exit the ground to head home. Karrie explains the “lock-out tag-out” procedure, by which the crews keep track of who is in the tunnel. Each worker signs out a pair of numbered brass tags, keeping one on his or her person and the other on a pegboard mounted next to the tunnel shaft. That second tag is moved from the “In” column to “Out” every


Senior Engineer Martino Scialpi, engineering intern Michael Wenning, laborer Nick Morganti, and Construction Supervisor Karrie Buxton

time the worker leaves the tunnel.

We prepare to descend the metal staircase leading to the tunnel. “When you’re 200 feet below, you still get a little excited,” Buxton says. “Even when you’ve done a lot of heavy industrial projects, once in a while you catch yourself and say, ‘Yeah, this is really cool’.”

The crane unloads another railcar, also referred to as a “muck box.” These carry the spoils that come straight from the cutter head that is excavating the other end of the tunnel. Circular blades mounted on the cutter head spin and scrape away at the rock face. The cutter head spins and advances about five feet per hour.

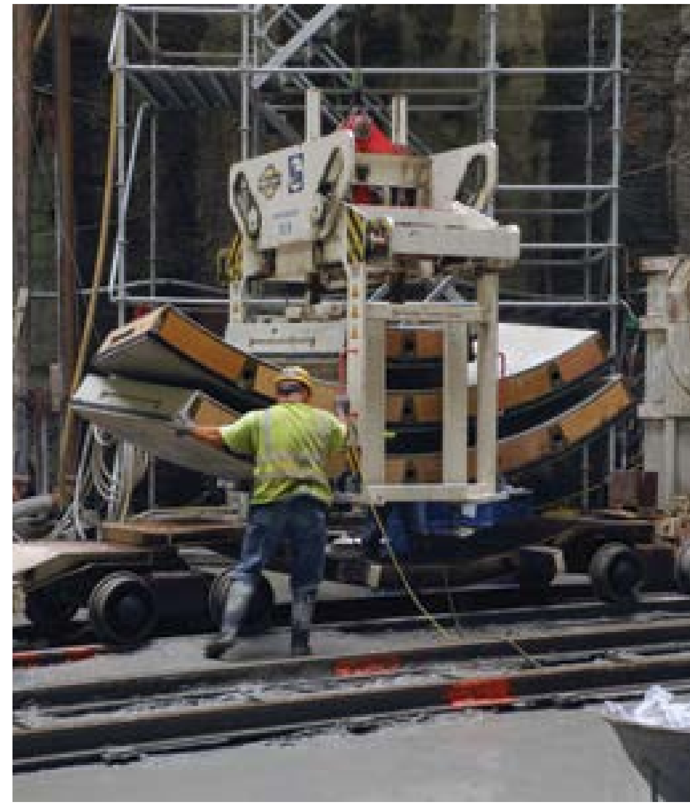
Some tunnel projects use a conveyor-belt system to transport the freshly-dug rock, but the DVT operation relies on a locomotive running in and out of the tunnel. “Every five feet of mining fills up eight muck cars,” says Buxton. “We have two trains running 24/7, and we’re pulling out about 1,900 cubic yards of shale every day.”

Most of the ground material in Cleveland is called Chagrin shale. “It’s a weak rock, easy to get through and not very abrasive, compared to granite, which contains quartz and is very abrasive and can wear down the equipment,” explains Mike Piepenburg, a project geologist with Mott MacDonald, the design firm for several recent Sewer District tunnel projects. “Although shale is easier on the machine, the parting surfaces are horizontal, making for different dynamics of how ground relaxes and behaves, and requiring a somewhat different approach to traditional excavation.” (One incidental advantage of mining through shale is its re-use possibilities, such as backfill for roadways.)

The crane hoists a muck car out of the shaft, empties the shale on the ground, and returns it underground. The “bottom lander,” a crew member down in the shaft, hooks up chains to the next car, and communicates by walkie talkie to the “top lander” and the crane operator to make sure the cars and other materials descend and ascend safely.

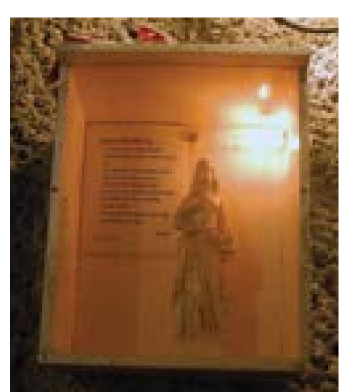
Along with the muck cars are “segment cars,” onto which the crane lowers the segments that will be pieced together to form the rings that make up the tunnel lining. Each ring consists of six segments, made of steel fiber reinforced concrete, which are manufactured in Macedonia, Ohio. “We’re fortunate to have a manufacturer so close to our project locations,” said Buxton. On average, the work proceeds at a rate of 14 rings per day—about 70 feet.

A crane unloads a muck box full of excavated shale.



Pieces of tunnel lining are placed on the segment car.

While the muck cars unload, Karrie and I speak with Martino Scialpi, Senior Engineer for the tunneling contractor McNally/Kiewit DVT Joint Venture. Scialpi has been in the business for about 13 years, but his interest in tunneling dates back to his childhood in Italy. "Tunneling was my thing since I was a kid," he said. "I really wanted to be in this industry, and I feel lucky, because that doesn't always happen. I actually got to do what I wanted to."



The DVT's St. Barbara

Scialpi studied mining engineering in college, and his first tunnel job was with an Italian contractor, in Ethiopia. He has worked on projects in Hong Kong, Austria, Turkey, Italy, Australia, China, and now Cleveland. "We're making great progress here. It's a fairly young group of people. I am so proud to be part of this."

He points out a small, glass-faced box mounted on the wall of the shaft. It contains a statue of St. Barbara, the patron saint of miners. "It's more of a European tradition, but it's growing here, too," said Scialpi. "Being from Italy, I had to bring a St. Barbara!"

The muck cars now empty, we climb aboard the locomotive, and begin our two-mile journey to where the tunnel boring machine, or "TBM," is steadily scraping its way ahead. A ride that I anticipate taking five minutes turns into 10, then 15, then 20, the walls of the 9,000-plus feet of finished, concrete-lined tunnel a shadowy blur. The train engine gives off a lot of heat.

Running the length of the tunnel are several conduits: a ventilation system—a flexible "bag" that extends like an accordion bellows as the tunnel gets longer—as well as utility pipes carrying water, electricity, and the grout mixture that is used to cement the concrete segments into place as the TBM advances. The "A" and "B" components of this mixture are housed in tanks in an aboveground grouting station and, after being fed down the tunnel to the front of the TBM, are injected behind each segment, where they combine, activate, and set in under 15 seconds.

We finally arrive at the rear end of the TBM, which is steadily digging through shale and installing the final


Overhead view of the front of the TBM. The conveyor belt (bottom center) carries excavated shale from the cutter head to the muck cars.

600' of concrete segments to complete the tunnel.

This tunnel is a "one-pass" excavation, which means that the ground is dug and concrete lining installed at the same time. Dating back more than 30 years, one-pass is the most significant tunneling innovation in recent history, and in many cases preferred over the older "two-pass" method, in which the hole is completely excavated before the tunnel lining is installed.

The excavation method is determined both by the ground material and the diameter of the tunnel being constructed. "It's difficult to do single-pass in an eight-foot tunnel, since you don't have a lot of room to carry the segments and things of that nature," said Buxton. "Sometimes large is easier than going small."

Until recently, single-pass had been used primarily in soft-ground tunnel; it hadn't really been done that often in rock tunneling. "But if something works, and it's cost effective, and a contractor increases their production because of it, it becomes commonplace," said Rick Vincent, a design manager in the Sewer District's Engineering & Construction department. "Some of those contractor evolutions happen relatively quickly."

The Sewer District has been an innovator in the single-pass method, specifically in the design of the concrete segments that line the tunnel. "We have a good handle on single-pass now," says Construction Manager Bob Auber, a 26-year District veteran currently managing several large tunnel projects on the east side of Cleveland, including the Euclid Creek Tunnel *(see Q&A, page 30)*.

Buxton, Scialpi, and I dismount from the railcar and walk along the platform that runs alongside the TBM, making sure our ear protection and dust masks are in place. Buxton points out tiny red glowing dots overhead, which indicate the targeting system that helps the TBM operator guide the TBM with great precision. (Typically, the machine will arrive within three inches of its projected destination point.)

We walk up to a box that resembles a highway tollbooth. Inside is John Chesser, one of the TBM operators. He is standing in front of several computer screens displaying graphic interfaces by which he maneuvers and monitors the TBM.

Chesser has been in this business for two decades. Initially, his work involved a lot of traveling. "I decided I wanted to stay in town, and lo and behold, there is plenty

Checking TBM progress from the Operators Cabin

of tunneling in Cleveland for me to do, so here I am," he said. "It has been a pleasure being on this machine. It's clean, there's proper lighting, and after a while you can sometimes forget you're underground."

From the rear of the TBM, an overhead track system with a vacuum apparatus lifts one of the concrete segments from the locomotive and smoothly guides it into position. The rings are built from the bottom up, and a smaller keystone piece completes the ring. Once the ring is grouted into place, the TBM uses horizontal hydraulic jacks to push itself forward several feet, where it will proceed onto the next ring assembly.

Even though we're steps away from the cutter head, there is very little noise, only a mild vibration and a high-pitched hum. A conveyor belt carries a gray slurry of excavated shale, or "muck," away from the cutter head and into one of the train cars that sits at the rear of the TBM. A sprayer positioned above the car wets the shale to keep dust from filling the air.

Once the cars are full, the driver will bring the haul back to the shaft and the cars will be hauled up into daylight. In less than a week from today's visit, the tunnel will be fully excavated and lined.

Saint Barbara Fleeing from her Father (c.1620), by Flemish artist Peter Paul Rubens

About Saint Barbara

SAINT BARBARA IS THE PATRON SAINT OF tunnelers and miners, as well as artillerymen, military engineers, gunsmiths, and others who work with explosives, due to her association with lightning in various legends.

Barbara lived in the 3rd century near present-day Lebanon, and was the only daughter of Dioscuros, a high-ranking and wealthy man who sought to protect Barbara from the outside world by confining her in a sumptuously furnished tower.

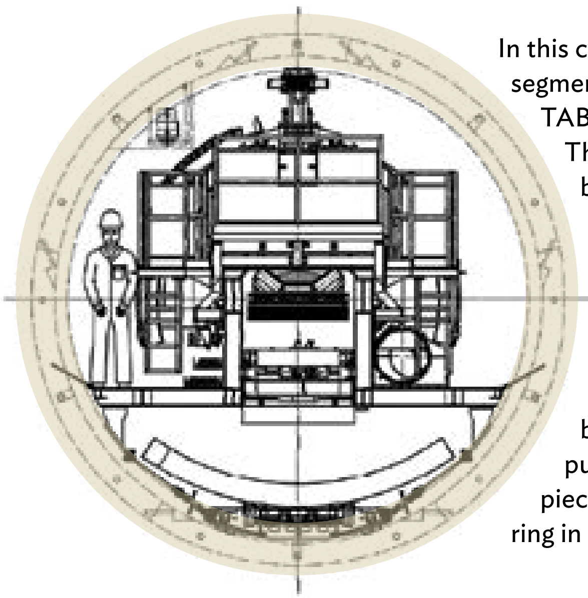
Without her father's knowledge, Barbara converted to Christianity, which at the time was a capital crime. She finally told Dioscuros, and he threatened to kill her, but she miraculously escaped from the tower and took refuge in a nearby mine. Barbara eventually was captured and tortured, and then killed by Dioscuros, who was struck dead by a bolt of lightning as punishment.

As a long-standing tradition, one of the first tasks for each new tunneling projects is to establish a small shrine to St. Barbara at the tunnel portal or at the underground junction into long tunnel headings. This is often followed with a dedication and an invocation to St. Barbara for protection of all who work on the project during the construction period.

SOURCE:
"Saint Barbara," Wikipedia, *last modified November 22, 2019, https://en.wikipedia.org/wiki/Saint_Barbara*

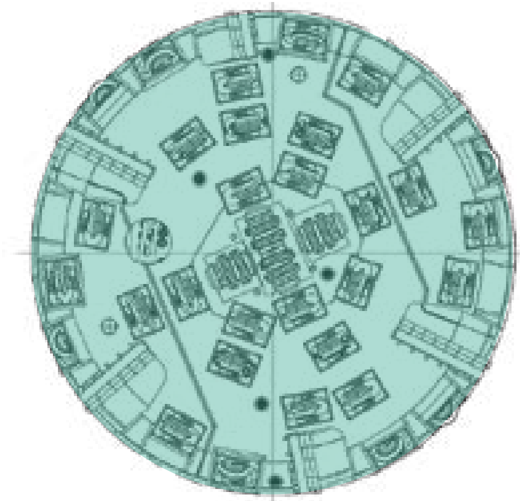
Tunnel Boring Machine

A schematic of the TBM used on the Doan Valley Tunnel. Graphics courtesy of Kiewit Infrastructure Co.



In this cross section, a tunnel segment sits on the SEGMENT TABLE awaiting placement. The segments are placed by the ERECTOR to make a complete ring (gray). Several of each segment can be stacked on tables. Working from the bottom, the erector builds up both sides and puts the small keystone piece on top, setting the ring in place.

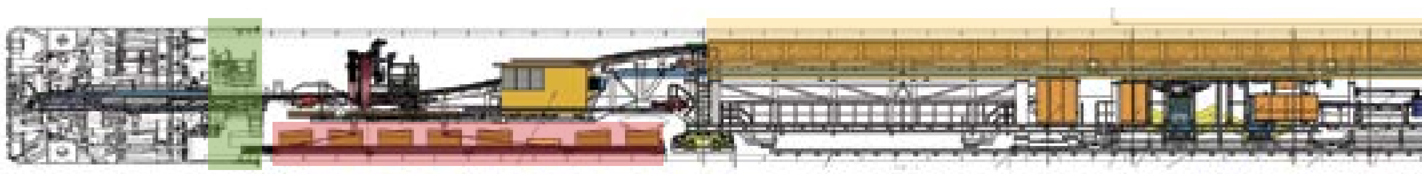
CUTTER HEAD (FRONT)

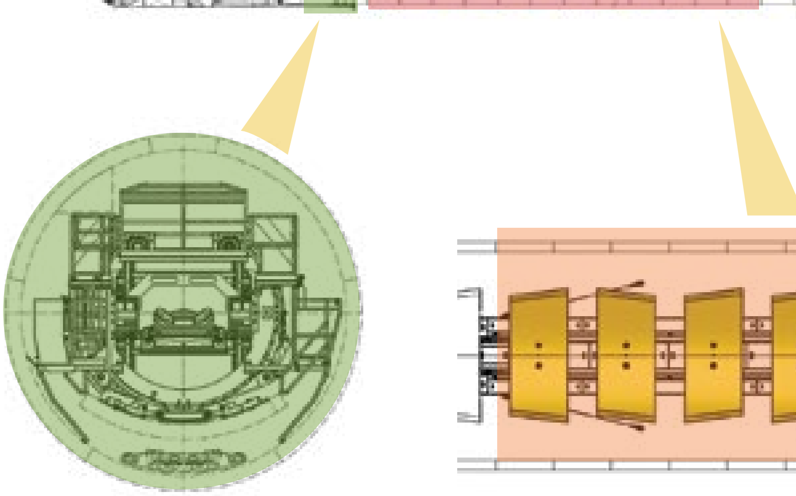


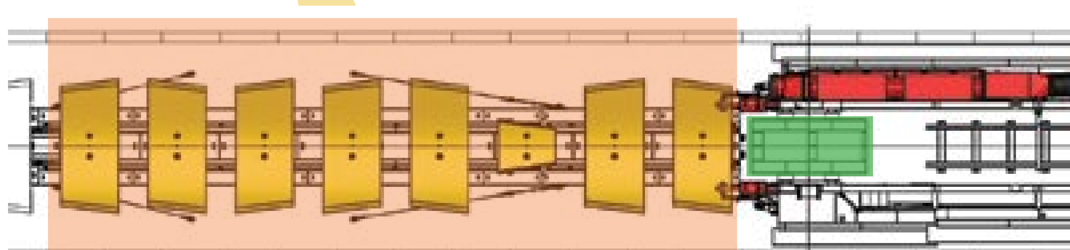
→ →

Mounted on the cutter head are discs of heavy-duty tungsten carbide steel that pulverize the shale. Each disc weighs over 250 pounds.

A conveyor belt system (yellow) carries the excavated shale to the conveyor discharge (blue) at the rear of the TBM. → →







The ERECTOR can rotate a full 360 degrees to place the tunnel-lining segments, and it can also telescope towards and away from the cutter head.

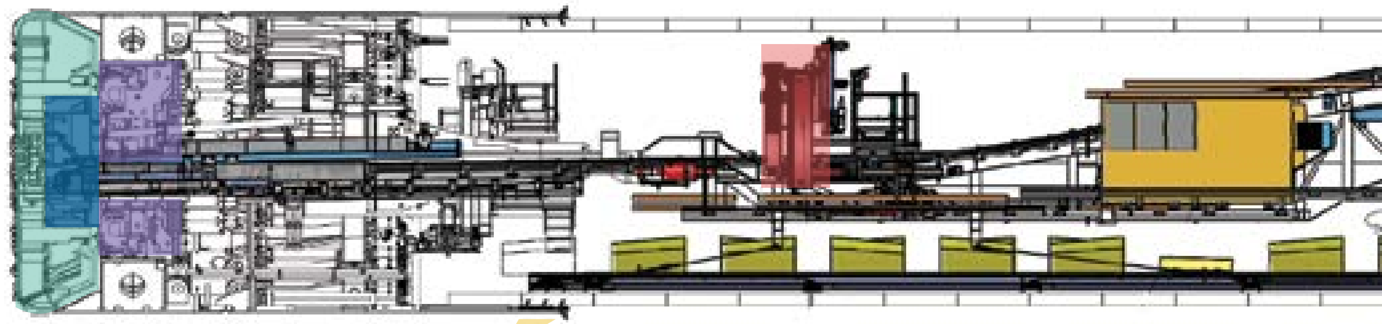
The CONVEYOR STATION (top view) consists of tables onto which the tunnel segments are offloaded from the locomotive. The segment crane (green) picks up an individual segment from the rail car, moves it forward, rotates it, and sets it on one of the tables. Five segments plus one smaller keystone equals a complete tunnel ring.

The MAIN BEARING (dark blue) sits within the cutter head and rotates it. The THRUST (purple) pushes the machine forward using hydraulic jacks.

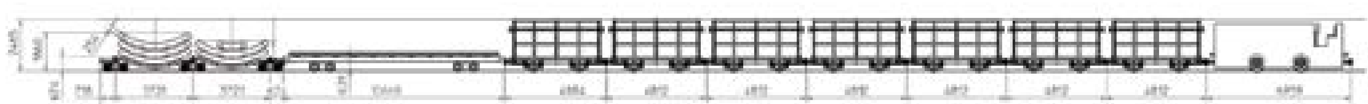
At the tail shield GROUT PORTS, an accelerator is added to the grout mix (sand, water, and cement), cementing the segment in place within 13 seconds.

In the OPERATORS CABIN (yellow) a Human-Machine Interface displays the TBM's guidance systems and performance.

→ →



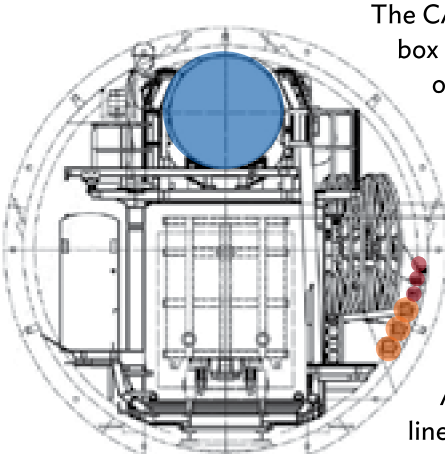
GROUT PORTS



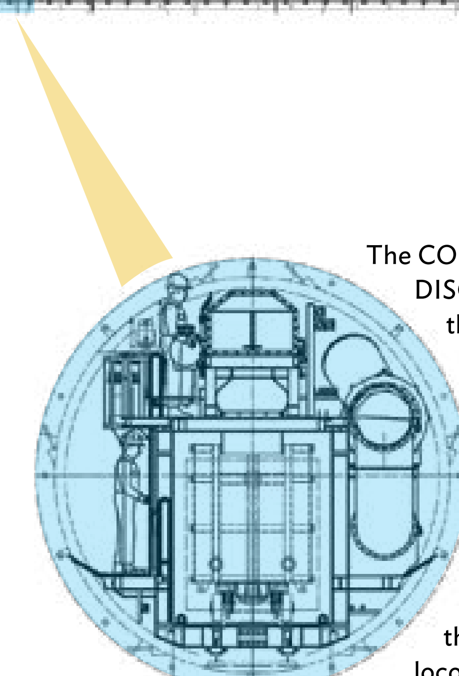
← ← The locomotive brings muck cars, tunnel segments, and other supplies in and out of the tunnel. → →

VENTILATION

ELECTRICAL CABINETS

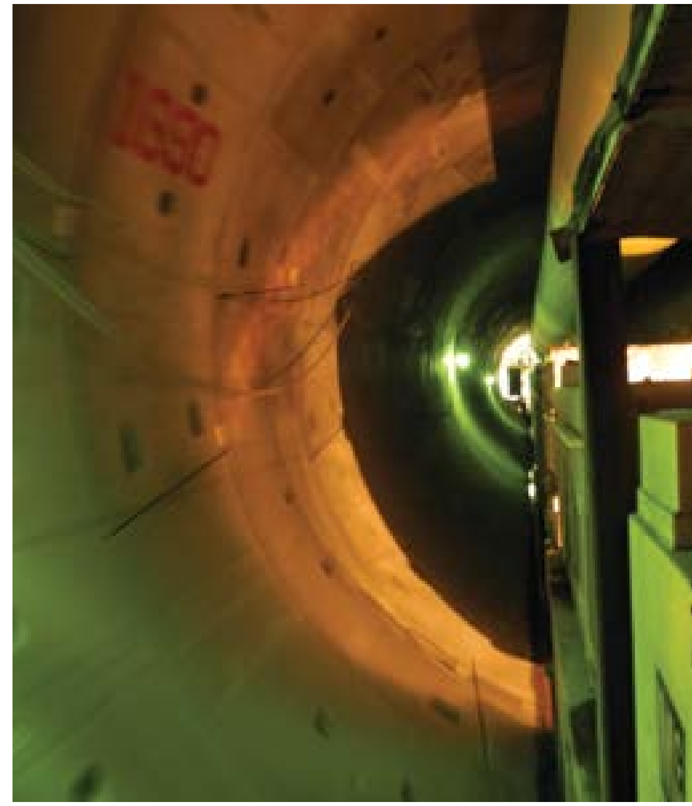


The CASSETTE (blue) is a box containing a flexible line of ventilation bag that reaches the length of the tunnel, up the shaft, and out to the surface. The cassette slowly feeds out the compressed bag as the TBM moves forward, providing air. Also pictured are water lines (orange) leading into and out of the tunnel alongside the A and B components of the grout mixture (red).



The CONVEYOR DISCHARGE is where the excavated shale from the cutter head empties from the overhead conveyor belt and into the muck cars to be carried out of the tunnel by the locomotive. ▫

The TBM pushes itself forward on hydraulic jacks.



The tunnel's finished concrete lining.

RICK VINCENT HAS OVER 26 YEARS OF TUNNEL design experience. "I originally wanted to do bridges," he says. "I was a structural engineer at a firm that had a tunneling discipline that I got drawn into and really liked. It's always interesting work, because ground conditions are different everywhere, even within the same city."

Vincent says that in tunneling, you really have to understand construction methods to do the design. He contrasts their complexity to the relatively straightforward bridge projects he worked on early in his career. "I literally took a homework assignment from college and designed a bridge, and they went out and built it," he says. "There wasn't any consideration of the contractor. It's just a structure and it's going to hold so much weight, it's safe and it works, and there you go."

Ideally, the tunnel construction team is brought in during the design phase to identify constructability problems. "Designers can make anything work on paper, but we never have that perfect blank sheet out in the field," Karrie Buxton says. "We have other utilities to think about, and the public impact to consider when you actually put the design into practice. We can bring aspects to a designer's attention things that we have experienced in the field that a designer might not understand."

"There are some givens—where we have to pick up the flows, where the sewers are, how much flow we have to divert and capture to control CSO," says Vincent. "That all guides us to where the tunnel is going to be, and we look for the optimum alignment to do all of this with the shortest amount of tunnel."

A design project manager at the Sewer District will outline the general parameters of the project, including tunnel capacity, as required by the EPA's mandate to reduce CSO. Then, tunnel design firms respond to the District's request for proposal (RFP). The winning design engineering firm works with District engineers, looking at flow-monitoring data to determine the best options for meeting that mandate and the needs of the end users—the wastewater treatment plant staff.

One factor unique to tunneling is what Vincent calls "the eggshell concept," where the tunnel lining is designed to become one with the ground. "The lining isn't there to hold back the ground, it's there to work with the ground in a controlled way," he explained. "You want the ground to collapse or relax a little bit."

The locomotive and its muck cars full of excavated shale return to the shaft.

Designers design to what is known. Construction teams respond to what is unknown.

—Karrie Buxton

Related to this is the judgement involved in being able to measure "stand-up time," or how long the ground is able to stand on its own, without any support, after it is dug into. This is different for rock, soil, clay, or sand, and the time needed to install the lining is dependent upon how much load it is going to take.

Designers also consider groundwater pressure and many other factors that have some measure of uncertainty. "There's a lot of data collection, analysis, and interpretations of ground conditions to predict how the ground is going to behave," said Vincent. "Once you figure out those things, you and the contractors get to be creative with how to actually get that tunnel built."

The length of the tunnel will influence how many "near-surface structures" will be built. "Where we pick up flows from the existing sewer systems dictates where we need a gate control, or a shaft, or a diversion structure that controls where we'll channel that water from the surface down into the deep tunnel," says Buxton.

I visit another tunnel construction site on Cleveland's west side, not far from the Gordon Square Arts District. Street sweepers spray down the pavement to keep down dust from work being done on a string of structures linking an existing brick sewer to the new Westerly Storage Tunnel (WST), scheduled to be completed in 2021.

The 25'-diameter WST is the largest of the District's storage tunnels thus far, but it is the near-surface structures, which redirect the flow from the existing sewer system into the storage tunnel during rain events, that present the biggest technical challenges. "We're working in a 200-year-old urban environment with many underground utilities," says Mike Piepenburg as we walk through construction near the West 45th Street onramp to the Shoreway. "We examine old records of what was built to prepare the contractor for what they will face. We also sit down with local water and power


Chagrin Shale is easy to mine and not very abrasive, which saves wear on the TBM.


This old brick sewer has been cut so that it can tie into the new diversion structure for WST (see next page). Until then, a temporary steel pipe maintains flow to the Westerly treatment plant.

utilities to discuss what structures can be relocated."

Sometimes, a utility can be moved, but more often, especially with older utilities, the designer will have to figure out a workaround. "On the Doan Valley Tunnel, rather late in the design phase, we moved the entire tunnel over one city block to avoid water mains," says Sewer District Construction Program Manager Doug Gabriel. "Sometimes, what appears in records is different from what's actually there."

Piepenburg leads me to a rectangular excavation across which a 100-year-old, 81"-diameter sewer juts, its brick casing exposed. Despite its age, the sewer is in remarkable condition. "The old masons really knew their trade," he says, noting the three layers, or "courses," of brick. The workers have cut out a segment of this brick sewer so that it can be tied into the diversion structure they're building.

During heavy rain events, this diversion structure takes flow from the brick sewer and directs it into the new WST *(see graphic, next page)*. After the cranes and machinery are taken from the site, access doors in the pavement and two gooseneck ventilation pipes are all the public will see of the work that has occurred here.

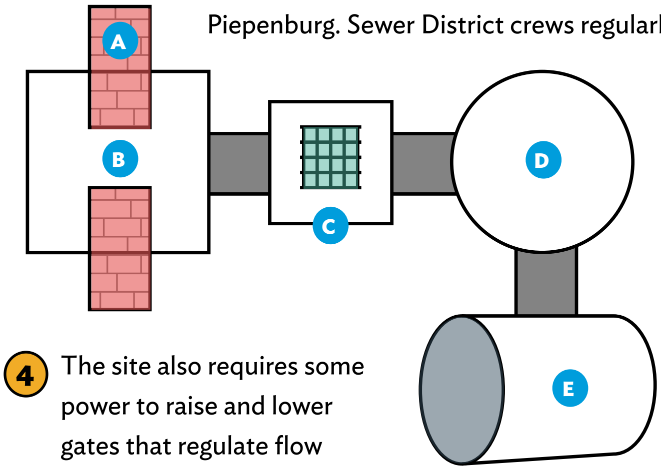
Piepenburg's role is to make sure the design is implemented correctly, and handle any problems. He started his career as an engineering geologist, studying the ground material for open-cut and drill-and-blast tunneling projects in D.C. and Los Angeles. "That work naturally led to seeing how these things were built, learning construction and then inspection and construction management," he says. He has supervised tunnel projects in New York, Atlanta, and Puerto Rico, but since 2011 primarily has worked on Sewer District projects. "It has been nice to be home in Cleveland for the last eight years."

"It's a travel business, you go where the work is," says Doug Gabriel, who currently oversees 35 Sewer District construction projects. "I've always had an interest in construction. My dad was a contractor. In college, I worked for a mechanical contractor, doing piping and HVAC, working in a fabrication shop. I spent a summer at Bethlehem Steel, then went to work for a national mechanical contractor in Southern California." Gabriel's work with the Kiewit company gave him addi-

How CSO gets into the Westerly Storage Tunnel

1 THE EXISTING BRICK sewer pipe (A) conveys wastewater to the treatment plant. A diversion structure (B) is constructed around the pipe, and a segment of the pipe is removed. When it rains and the level of combined sewer and storm flow rises to the height of a weir, it passes into a trough leading to a gate structure (C).

2 The gate structure houses a set of angled screens that capture big debris, such as tires and tree trunks. "It's easier to remove debris at a depth of 20 feet rather than hundreds of feet down," says Mike Piepenburg. Sewer District crews regularly clean these screens.



3 The flow then passes into a deep baffle drop structure (D), falling onto horizontal "steps" the entire shaft depth of 270 feet. The baffles dissipate the energy of the falling water, and also mitigate odors that would be released if flow were to fall unimpeded down the shaft. The flow moves through a small pipe leading to the WST (E).

4 The site also requires some power to raise and lower gates that regulate flow into the WST, although most of the work here is accomplished by gravity.

---

tional experience in mechanical, electrical, and instrumentation projects at treatment plants, and ultimately brought him to Cleveland.

Gabriel says the transition from being a consultant to working as the "owner" of these projects has been interesting. "I've always been a hands-on individual, and outspoken, and at the District I can be both," he says. "I enjoy looking at projects and picking them apart, figuring out what the risks are, and then trying to mitigate those risks in our documents before we put them out to bid."

At each step of the tunnel design phase—the 30%, 60%, and 90% stages—there are opportunities to guide it and make changes. "By the time you get to 90 percent, you pretty much know what you're going to build, and you ask, 'What do I need to put in here to make it buildable?'" says Gabriel. He points to a foot-tall stack of paper, the bid documents for the Doan Valley Tunnel. "Six books for DVT," he says. "Reference info, geotechnical info—you give the contractors as much as you can to get a good quality bid."

Once the tunnel is designed, it goes out to bid. Contractors review not only the drawings and specs, but also the Geotechnical Baseline Report, in which Sewer District engineers spell out the known ground conditions, based on data collected from ground borings.

Since tunneling is riskier than above-grade construction, the cost of any unforeseen ground conditions is covered by the District. Having all parties understand and agree upon the risk documents results in good bids from the contractors. "We try to flush out the 'known unknowns,' and we apply a budget to those so it doesn't become something a contractor has to cover with his own money, so that everybody bids equally," says Gabriel.

"There's an art to writing risk documents," adds Vincent. "You can write a 100-page report that no contractor is ever going to read because it's too long, or you can write a really short one and not say much, and they'll add more contingency to their bid to cover those unknowns. I always like trying to figure out where that balance is."

The best reports are written as realistically as possible so there are fewer surprises for everybody. "We've been very fortunate in getting good high-quality contractors who don't have to apply a lot of risk money to their bids," says Gabriel.

As you might guess, the challenges increase after construction begins. "Then it really gets fun," says Gabriel. "No matter what you did during design, things can change quickly, and when those changes happen, you have to be able to jump on them. Geotechnical risk in these jobs is huge. We do a pretty good job of figuring it out, but when you open up the ground, it can be different. It can cost you millions."

Karrie Buxton gives an example of this happening on the Doan Valley Tunnel project, which lies in a flood zone. "We had a flood and lost our consolidation tunnel, which delayed us," she says. "But it's nothing that you can't overcome or work through, it just takes time. It's all part of understanding the process of what you need to accomplish. There are going to be challenges, but nothing is going to be so big that you can't find a solution, because you have yourself and a fantastic team with a tremendous amount of support that aid in making decisions. You always feel empowered to make the right call."

"We've been able to work through all our issues pretty expeditiously and fairly," says Gabriel. "We've had no litigation, and no unresolved claims." Members of an impartial Dispute Review Board are chosen by the contractors and the Sewer District and meet on a quarterly basis to talk about the project and handle any conflicts.

BIG TUNNEL PROJECTS LIKE THESE DIRECTLY impact Sewer District ratepayers, and need to be managed and delivered effectively and efficiently. "That's why we set key performance indicators [KPIs] and report our progress each month to our Board of Trustees," says Devona Marshall, Director of Engineering & Construction. The KPIs revolve around schedule, budget, and meeting the requirements of the District's consent decree with the EPA.

"Our capital program has drastically increased with Project Clean Lake, both in the number of projects we have to deliver and the money that we have to spend," Marshall says. To ensure sound financial planning, the District improved its design and construction standard operating procedures, and ultimately its project delivery. Marshall's department has largely eliminated paper use, having established Sharepoint as its system for document control and workflow approvals. "We've made everything more efficient," Marshall says.

We've been able to hire and train people who really want to deliver a good product.

—Doug Gabriel

To date, the District has invested $1.42 billion on over 60 CSO-control projects that have reduced annual CSO by one billion gallons, and has realized $426 million in savings through value engineering and effective project management.

Keeping the public informed about the tunnel projects is also critical. "You want to make sure that information gets out to not only the neighbors who are in direct proximity of the work, but also those who are just commuting through," Buxton says. Doan Valley Tunnel construction runs throughout University Circle, a heavily commuter-based route. "That means setting up construction signage, sending out traffic notices, and notifying the police and fire departments and nearby hospitals to make them aware that you'll be blocking or restricting traffic flow."

The number of people working on any one tunnel project is about 100, including a labor force of at least 75, plus the contractor's engineers and managers, Sewer District support staff, and about five to eight supplemental inspectors observing the work.

Doug Gabriel points to his staff as the key to the Sewer District's success on these tunnels, which consistently are completed ahead of schedule and under budget. "We probably have the best collection of construction staff of any agency in this country," he says. "That brings in good contractors and good bids. And if we feel like our designers are not giving us what we need, we call them out on the carpet, too. We've been able to hire and train people who have a good attitude and an aptitude for learning, and really want to deliver a good product." **CWW**

Michael Uva is Senior Communications Specialist at the Northeast Ohio Regional Sewer District.

The DVT's 21-foot tunnel boring machine pushes through the wall of the destination shaft, completing its journey in September 2019.

Tunnel shaft construction methods

Hydromill used to excavate the WST slurry wall

Rebar cage used to make the slurry wall lining

NEXT TO CLEVELAND'S MEMORIAL SHOREWAY, on the site of an abandoned boat-building facility-turned-marshland, is WST-1, the exit shaft for the Westerly Storage Tunnel excavation. When the tunnel boring machine completes its dig, it will be lifted to the surface by crane through this 46'-diameter, concrete-lined shaft.

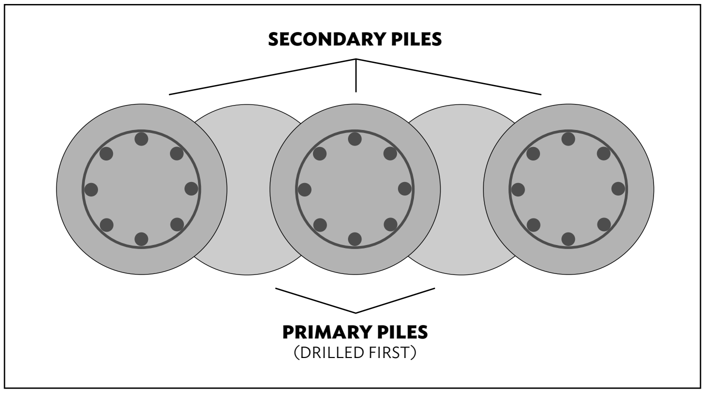
Along with access for construction and maintenance of the tunnels, shafts can serve other functions. At WST-1, a submersible pump station will be built within the shaft, to lift the tunnel's collected CSO back to the surface and then to the Westerly Wastewater Treatment Plant. Other shafts serve as "flow drops" where CSO is directed down into a storage tunnel *(see graphic, page 19)*.

There are many methods for excavating shafts, depending on ground conditions and function. The WST-1 shaft was built using the *slurry wall* or *diaphragm wall* method. Tall concrete panels are installed through the soil down to rock before the soil is excavated. The slurry wall method is especially useful for deep shaft excavations with high groundwater because they are rigid and semi-impermeable. "Keeping water out is one of the big issues when you dig deep," said Vincent.

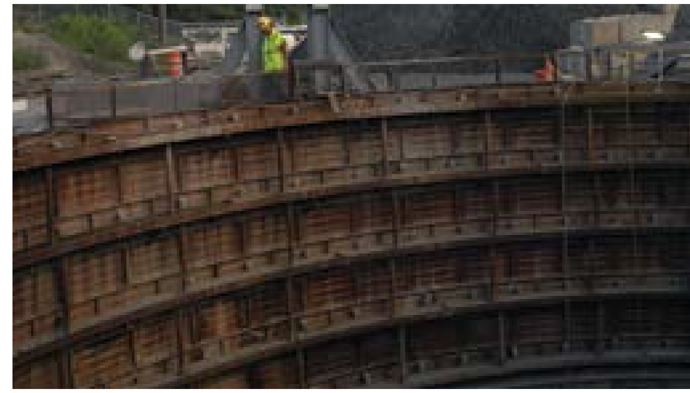
In the slurry method, the ground is scooped out with a clamshell excavator or a sharp-toothed hydromill, and a slurry (a fluid heavier than water, in WST-1's case containing a clay called bentonite) is added to keep the ground from caving in. Flat cages made from rebar are lowered into the bentonite slurry, which is then displaced and pumped out of the hole as concrete is poured in, embedding the rebar. The resulting 9' wide by 3.5' thick flat panels sit next to each other, end to end, forming a circular pattern for the shaft. Once the concrete sets, the shaft is excavated from within that concrete lining.

Another common method is *secant pile wall* construction, which uses concrete cylinders, or "piles," similar to the slurry wall panels, but smaller. Primary piles are installed first to form the circumference of the shaft. Then, steel-reinforced secondary piles are drilled in between the primary piles, intersecting them and cutting away the edges of the two adjacent piles. This creates a wall made of overlapping circles, forming a sealed concrete ring the entire depth of the shaft.

Although it creates a rigid, semi-impermeable shaft, the secant pile wall method is limited to depths of 80 to 110 feet, as beyond that, the piles may veer off course, creating



Secant pile method



Steel liner plate shaft for the Doan Valley Tunnel

Secant pile wall shaft

Formwork for a Sewer District caisson ("shaft sinking") project

windows through which water can infiltrate. For deeper shafts, the slurry wall method is preferred.

Also common in Cleveland is the versatile *steel liner plate* method. Steel plates are bolted to each other and braced with curved steel beams, and the ground within is excavated. Then the next round, or "lift," of liner is placed. The result is a less-rigid lining than concrete. Although the actual excavation can be slower than other rigid semi-impermeable methods, because supports need to be installed as you dig, the overall shaft install time is comparable to that of the slurry or secant pile wall methods. "Since the bottom is open and exposed to soil and water coming in, you have to handle more groundwater than with other methods," said Vincent.

The *caisson shaft* method is less common, used most recently on the District's KRCR microtunnel project *(see page 25)*. It utilizes a form—imagine a giant cookie cutter—that has a pointed "shoe" along its lower edge. The form is filled with concrete, and its weight sinks the form into the soil as an excavator loosens and removes the ground below and within it. "The caisson shimmies its way down a few feet at a time," said Vincent. "Shaft sinking is a fast method, and you're left with a nice thick structure."

Another less-common method for creating a rigid, impermeable shaft in soft soils that contain water is the *ground-freezing* method. Small (4") borings are drilled in a circular pattern. The interconnected borings are filled with a brine, the temperature of which is lowered to freezing, forming a ring of frozen, rigid ground that serves as support. The ground within the frozen ring is excavated, and the inner wall is sprayed with foam insulation to maintain the freeze while the rest of the shaft is dug. A concrete lining is usually applied after excavation.

Rock excavations require a different approach from soil. Explosives can be a cost-effective alternative to labor-intensive scraping away at the rock. The *drill and blast* method uses controlled explosives placed in a pattern: the inner ring of detonations is timed milliseconds before the outer ring, so that the second blast explodes inward to achieve the desired shape. The blasts loosen up to a 10' depth of rock, which is then excavated. The hole is then lined with welded wire fabric sheets, rock dowels, and shocrete (sprayed concrete).

by Michael Uva

Small but mighty

Microtunneling

In addition to its massive CSO storage-tunnel projects, the Sewer District constructs many smaller near-surface lines. One effective method for this is *microtunneling*.

The District's microtunneling projects fall generally in the 48" to 72" finished-diameter range, and the digs are relatively quick projects. On the Dugway West CSO project alone, there were 17 separate microtunnel runs, and a single microtunnel boring machine (MTBM) completed 50 feet of finished tunnel each day, on average.

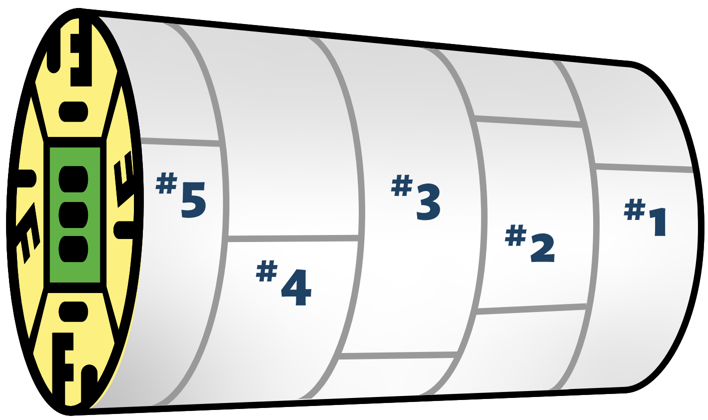
The MTBM is operated via remote control from above ground. It utilizes a one-pass approach, similar to that used by larger TBMs, but microtunneling differs in its installation of the final lining pipe as it progresses.

Large-diameter tunnels on District projects are often comprised of segmental, pre-cast concrete linings, in which lengths of pipe, or "rings," are assembled in place by the TBM as it advances. The TBM places and grouts the first segmental ring and then pushes itself forward from that ring. At the end of the tunnel run, the final ring is installed directly behind the TBM cutter head as it bores through the destination shaft's wall. "But in microtunneling, the first pipe dropped in is pushed forward the entire length of the dig, and ends up at the end of the tunnel," explained Construction Supervisor Brian Daugherty.

Since the entire tunnel lining is being pushed through the ground, the amount of friction increases with each pipe added. To keep things moving smoothly, a slurry lubricant is cycled through a closed system. The amount of lubrication can vary, depending on the ground type (for example, clay versus sand).

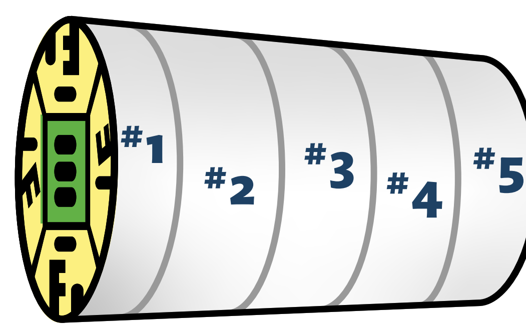
As the cutter head pulverizes the rock and soil, the excavated material is mixed into the slurry and is fed through a hose up to the surface to a building called a separation plant. There the solids are removed and the

TBM vs. MTBM



The TBM used on a project like the Doan Valley Tunnel places and grouts curved concrete segments to complete a ring (#1). Then the TBM pushes itself forward from that first ring and installs the next one, and so on.

In mictrotunneling, one-piece rings (generally concrete, fiberglass, or steel pipe) are inserted and pushed forward as the MTBM excavates the tunnel ahead. The first pipe dropped into the shaft will end up all the way at the far end of the tunnel, right behind the cutter head as it completes its journey.



---

slurry is returned underground and recycled.

One-pass microtunneling can be advantageous in "difficult ground," for example, ground that is saturated with groundwater. In open-cut surface digging, water can flow into the trench and cause complications for the work crew. "With our current technology, the MTBM is designed to equalize the pressure and counteract any water coming in," said Construction Manager Aaron Smith.

Although microtunneling has been around for a while, *curved microtunneling* is relatively new in this country, and the Sewer District has been a leader in advancing this method. It allows for bends in the tunnel that circumvent obstacles such as boulders, underground structures, and poor soil conditions. Curved microtunneling also can allow for fewer tunnel shafts along a sewer run, reducing the impacts on residential neighborhoods and nearby projects, and saving construction time.

In the Summer of 2015, the Dugway West Interceptor Relief Sewer (DWIRS) became the Midwest's first curved microtunnel. Located in Cleveland's Glenville neighborhood, DWIRS ties local sewers into the new Dugway Storage Tunnel system to reduce sewer overflows into the environment.

"Curved microtunneling was groundbreaking for us," said Aaron Smith. "It's always easier to tunnel in a straight line. Once you make a turn, the surveying becomes significantly more complicated." To help maintain control in a curved tunnel run, sophisticated surveying equipment and a laser guidance system is used to continually update and display the position of the MBTM.

Another recent curved microtunneling success for the Sewer District was the Kingsbury Run Culvert Repair (KRCR). This new storm sewer replaced a deteriorated and partially-collapsed brick sewer dating from the early 1900s. Two sections of curved tunnel were includ-

Construction of the DWIRS curved microtunnel.

Concrete pipe awaits descent to line the microtunnel.

The separation plant is where the excavated rock and soil is removed from the lubricant slurry.

The MTBM cutter head breaks through the destination shaft wall, completing the DWIRS excavation.

ed in the design to avoid a brick culvert and a scrapyard containing PCB-contaminated soil.

Open-cut options for the project were considered, but environmental concerns, proximity to railroad tracks, and unknown culvert conditions made the trenchless method more appealing.

Upon its completion in 2017, the KRCR became the longest 60” S-curve microtunnel in North America, as well as the first combined horizontal S-curve and double vertical curve project in the country. The KRCR project also was notable for being at the heart of the Sewer District’s Woodland Central Green Infrastructure project, which uses detention basins to offload stormwater before it can enter the combined sewer system. CWW


We're sewers . . .
and much more!
Clean Water Works
A day at the Beaches
Clean Water Works
An introduction to PLANT OPERATIONS
Clean Water Works
Water Quality & Industrial Surveillance
Clean Water Works
MAINTENANCE SERVICES
Clean Water Works
A NEW DAY FOR THE CUYAHOGA
Visit **neorsd.org/CWW** or get your FREE copies of back issues of Clean Water Works: call **216.881.6600 x6891** or email **askus@neorsd.org**
Northeast Ohio Regional Sewer District

Deep dive

A new Introduction to Construction course

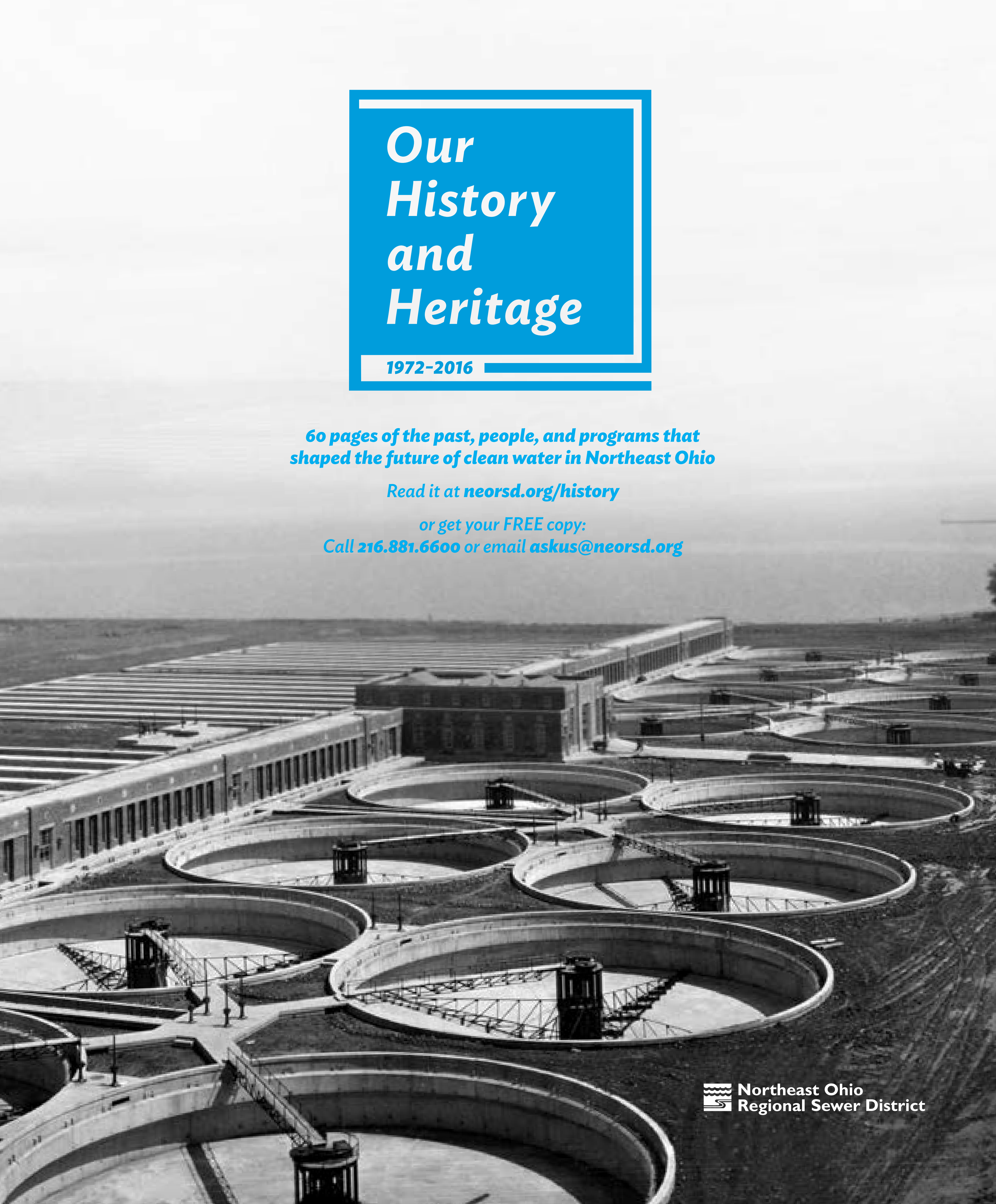
In the Summer of 2019, the Sewer District launched a collaboration with the Urban League of Greater Cleveland: an Introduction to Construction course focused on wastewater and collections systems and aimed at promoting construction careers. The new eight-week course is part of the District's ongoing efforts to increase diversity on its construction projects.

The pilot program's 14 participants made visits to the Southerly Wastewater Treatment Plant and the Nine Mile construction site in Bratenahl, where two of the District's large CSO-control storage tunnels converge. These full-day sessions served as introductions to plant and collection-system construction.

Working closely with his construction managers, Deputy Director of Engineering & Construction Doug Gabriel took the lead on developing the program, and engaged some of our contractors to participate. "The contractors talked about job opportunities and explained what it's like to work in construction," said Devona Marshall, Director of Engineering & Construction. "At the end of the day, they have more jobs than the District, and can give deeper insights into the trade, because while we manage the projects, they actually do it."

The course also benefited from union participation, sponsored by the Construction Employer's Association, as well as from banking, budgeting, and construction safety modules, and "keys to job success," such as resume writing and proper dress for interviews. CWW

John Gonzalez is Communications Manager at the Northeast Ohio Regional Sewer District.


Our History and Heritage
1972–2016
60 pages of the past, people, and programs that shaped the future of clean water in Northeast Ohio
Read it at neorsd.org/history
or get your FREE copy:
Call 216.881.6600 or email askus@neorsd.org
Northeast Ohio Regional Sewer District

Q&A

An interview with Robert Auber, Construction Manager

MICHAEL UVA

How did you get into tunneling?

I've been doing tunnels in Cleveland since the early '80s. I fell in love with it by accident, like most things happen in life. I was replacing an inspector on a job at an engineering firm I worked at. He was gone for vacation. It was only for two weeks, but I was there long enough to ascertain a love and appreciation for this type of work.

Do you think working underground attracts a certain type of person?

It's very interesting. You don't come across many people that do this type of work. They are very dedicated and hardworking. Sometimes they're the second generation doing tunneling and mining. I really wanted to be in that world.

There is a perception of mining that it's dangerous work. Is it?

Because you're working underground, you have to have a high level of understanding of what you're doing, knowing that you have to do it right the first time. Otherwise you could have health and safety issues, and problems on the job.

Here in Cleveland we do a lot of our mining in shale. It's all sedimentary rock. Working in a confined space, you have the propensity to have methane gas, and you have to worry about breathing in the silica dust that gets extracted from the shale when it gets mined. And of course there are fall hazards.

Is there a busy season for tunneling?

We work all year round. We're not affected by the weather, except for high winds and lightning, because of our cranes. Other than that, we're working!

What's one project you're working on?

Our Nine Mile site, just south of I-90, is a critical component to our Project Clean Lake. It's where the Euclid Creek Tunnel, a 24'-diameter storage tunnel, meets the Dugway Storage Tunnel. Also at this site is a deep tunnel pump station that we use to remove all of the combined sewer overflow [CSO] that we amass during wet weather conditions, and pump it into the Easterly Interceptor and to our Easterly treatment plant. That's what it's all about: collecting the CSO going out into the environment so that we can treat it.

What's your approach to managing these big, costly projects?

I have five projects going on right now—almost half a billion dollars worth of work. I have great construction supervisors assigned to those jobs. I don't micromanage. I let them run their projects and have ownership of what they do, and I'm there for big-picture stuff, to make sure things run smoothly, or if they need assistance, to keep the job going. But I'm very blessed because I have a great staff who are very dedicated in what they do. CWW

Robert Auber is a Construction Manager at the Northeast Ohio Regional Sewer District, where he has worked for 26 years.

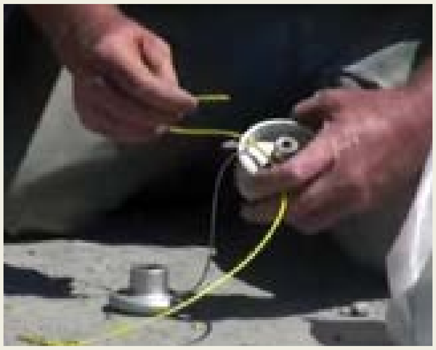
CleanWaterWorks

video extras:

Deep tunnel construction

Tour a 100-year-old brick sewer

Tunnel shaft blasting



Watch the videos at youtube.com/neorsdccr

Watch our CleanWaterWorks program on TV20 Cleveland:

neorsd.org/cwwTV

CleanWaterWorks

Northeast Ohio Regional Sewer District
3900 Euclid Avenue
Cleveland, Ohio 44115-2506

WEB RESOURCES:

neorsd.org
@neorsd

PITCH THOSE PILLS!

Flushing pills down the toilet is harmful to our water supply and the environment. Wastewater treatment plants are unable to remove pharmaceuticals, so they end up in our waterways threatening the environment and public health.

The best way to dispose of unwanted or expired medicine is at a local drug collection site. To find a location near you, dial 211 or visit RxDrugDropBox.org.