2006 APWA PUBLIC WORKS PROJECT OF THE YEAR

Nominated Project: **NORTHWEST SIDE RELIEF SEWER MILWAUKEE, WISCONSIN**
Completion: **NOVEMBER, 2005**
Category: **ENVIRONMENT, MORE THAN $100 MILLION**
Owner: **MILWAUKEE METROPOLITAN SEWERAGE DISTRICT**
Design, Engineering: **BLACK & VEATCH**
Construction: **SHEA-KENNY JOINT VENTURE**

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EXECUTIVE SUMMARY

Like many U.S. cities, Milwaukee faced a serious and growing problem. Population growth and continuing development produced ever-increasing volumes of sewage and stormwater. Aging and undersized infrastructure was woefully inadequate to handle the increase, resulting in sewer overflows and basement backups during wet weather.

In 1998, the Milwaukee Metropolitan Sewerage District formulated a farsighted proposal to accommodate growth, protect water quality and safeguard public health within its 420-square-mile service area. The Northwest Side Relief Sewer was the number-one priority Capital Improvement Project in the District's 2010 Facilities Plan, and its successful completion is a key achievement in realizing the Plan's goals.

The 7.1 mile Northwest Side Relief Sewer tunnel protects seven Northwest Milwaukee communities from sewer overflows and basement backups.

It took over $121 million, more than a year to dig, a machine powerful enough to cut a 22-foot diameter hole through bedrock, and thousands of truckloads of concrete to complete this massive project. More than seven years of planning, design and construction went into the 7.1-mile sewer tunnel, which serves seven northwestern Milwaukee County communities.

The project demonstrates important strategies to confront capital-intensive sewer overflow challenges, where available funding often falls short and pressure to meet regulatory compliance is intense. 130-180 feet below ground, the large scale, multi-functional tunnel both transports and stores wastewater. Its design makes shrewd use of the existing system—not a "band aid" approach to the problem, but a carefully considered design that enables the community to prosper through future growth and development.

The project firmly establishes advanced risk management techniques as critical to success in large-scale underground construction. Through progressive risk management and an intelligent bidding strategy, the team achieved on-schedule, under-budget performance with no significant disputes or delays despite the many risks inherent in construction of a tunnel of this magnitude.

Quietly and out-of-sight, the Northwest Side Relief Sewer is producing notable results for the MMSD and enhancing quality of life in Milwaukee:

- Greatly reduced wet weather overflows and basement flooding.
- Relief to existing interceptor sewers with added system capacity for future growth.
- 88 million gallons of additional storage to accommodate excess flow.
- An energy-saving design that fills by gravity, eliminating the need for an additional pump station.
- Operational simplicity, minimal maintenance and limited operations involvement.
- Designed and constructed for maximum groundwater quality protection.

OVERVIEW

GOOD NEWS AND BAD NEWS

New Growth and Development Versus Old Infrastructure

The Northwest Side Relief Sewer (NWSRS) is the largest sewer project the the MMSD has undertaken since the 1980's construction of the original Deep Tunnel system. In the 1980's, the MMSD built a deep tunnel Inline Storage System (ISS), a series of tunnels that collected and conveyed wastewater to a central treatment plant. One section of the ISS, the Crosstown Tunnel, was constructed westward from the Jones Island Wastewater Treatment Plant, and terminated at the Milwaukee County fairgrounds in the west central section of Milwaukee County.

Before construction of the NWSRS, sewer flows from the northwest section of Milwaukee County were collected and conveyed for treatment by relatively shallow interceptor sewers. Continued growth and development in northwestern Milwaukee County had severely overtaxed the aging and undersized shallow interceptor sewers, and basement flooding and sewer overflows during wet weather became increasingly common.

The main worksite at the south end of the tunnel bordered green spaces and residential areas.

TODAY'S CHALLENGE, TOMORROW'S AMBITION

Underground, an Anchor for Future Growth

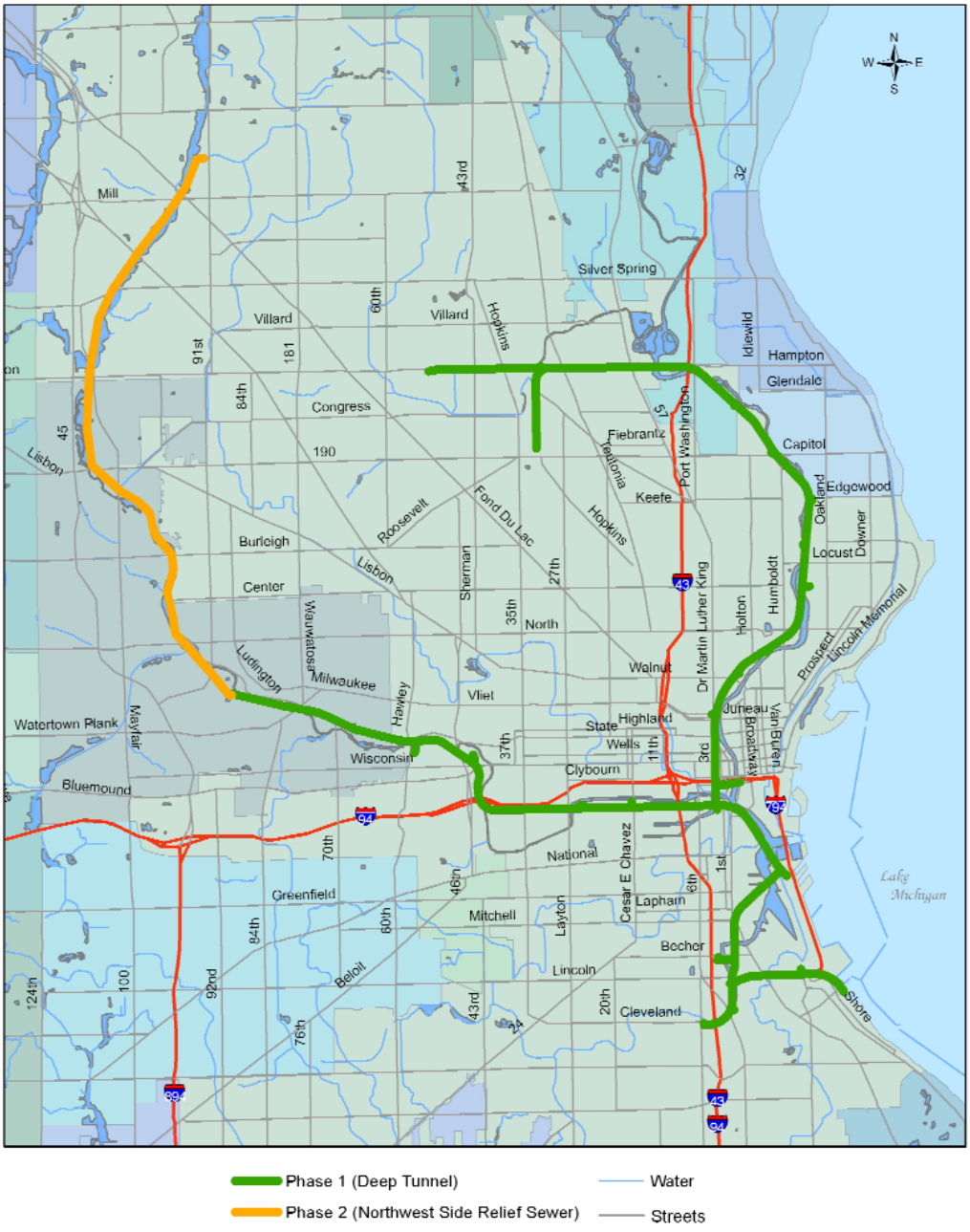
Faced with these difficult realities, the MMSD identified the hydraulic bottlenecks in the shallow interceptor system and proposed construction of an intermediate depth tunnel. Early alternatives included a pumping station at the southern terminus of the proposed tunnel, but detailed analysis of long-term operation and maintenance costs led the MMSD to eliminate the pumping station and extend the tunnel to connect with the Crosstown Tunnel.

After constructive negotiations with the Wisconsin Department of Natural Resources, the MMSD began planning for a design that would provide both conveyance and storage needs for long-term system operations. The end result is an impressive 20% more storage for MMSD's sewage collection system.

From the start, the MMSD approached the project with a cautious eye towards risk. A previous large tunnel project, a segment of the ISS constructed in the 1990s, had experienced negative press and significant construction cost overruns exceeding $100 million. It was a stark reminder to everyone involved that tunneling is, without exception, a risky business. The MMSD was determined that these negative experiences would not be replicated or tolerated on the NWSRS.

THE NORTHWEST SIDE RELIEF SEWER: FAST FACTS

Finished Diameter	20 feet
Tunnel Lining	Cast-in-place concrete, 12 inches thick
Length	37,304 feet (7.1 miles)
Depth	From 130 feet to 180 feet below ground surface
Storage Capacity	88 million gallons
Ancillary Structures	3 inlet structures, 3 access shafts, 1 drain structure
Odor Control	Activated Carbon
Dewatering	0.2 percent slope to ISS



CONSTRUCTION MANAGEMENT

NOT JUST ANOTHER CONSTRUCTION JOB:
The Risky Business of Building Underground

Tunnels and underground works are arguably among the most risk-prone heavy civil construction. Factors such as groundwater and ground stability/behavior are difficult for the owner, engineer and contractor to foresee until the project is in construction–providing a fertile atmosphere for misunderstandings, delays, cost overruns and claims.

This reality drove a top priority in construction management for the Northwest Side Sewer Relief tunnel: a comprehensive risk management strategy that was initiated during the earliest phases of design and carried through to the ends stages of tunnel excavation and installation of concrete lining.

KNOWN AND UNKNOWN RISKS:
Employing a Proactive "Spiral" Strategy

The progressive and proactive "spiral" risk management strategy included identification, communication, and documentation of a range of risks, with mitigation strategies developed and implemented between the MMSD, Black & Veatch and Shea-Kenny for a successful project delivery. The multi-tiered mitigation strategy tackled the challenge with a range of methods and techniques: complete risk evasion, prescriptive construction measures to minimize risk, establishing baselines for sharing risks among stakeholders, and proper and appropriate insurance.

The huge Tunnel Boring Machine used to construct the tunnel measured 430 feet in length and weighed 80 tons.

Some risks could be clearly identified for the NWSRS. The threat of excessive groundwater inflow into the tunnel during excavation was a concern, as was wastewater exfiltration from the tunnel during operation. The potential impacts on local groundwater resources and potable water wells had to be carefully considered. Because construction required blasting, the team had to consider the effect of vibrations on nearby sensitive structures. Safety and environmental issues surrounded the handling of contaminated soil and groundwater.

As daunting as these challenges seemed, at least they were known risks. The team had to remain vigilant and responsive to unknown and unforeseen factors that might not be revealed until construction was well underway.

BEST AND WORST-CASE SCENARIOS:
Tight Contract Documents Confronted the "What Ifs"

For a project with many innovative and dramatic construction strategies, a key to success was a surprisingly unglamorous tool. The contract documents did not sidestep risk issues, and addressed potential adverse conditions up front with specifications for fair and equitable compensation. For example, the risk of excessive groundwater inflow during tunnel excavation was contractually addressed through pre-excavation probing and grouting, continuous monitoring, stand-by pumping capacity and spare water lines. These components were contractually specified to minimize groundwater issues and avoid increased costs and lost time.

A bustle of construction activity at an access shaft within a pristine park setting

A TASK WITH NO ENDPOINT
Risks Monitored, Reassessed and Adjusted, Start to Finish

The project risk strategy was advanced and proactive, and successful results required close collaboration between the MMSD and Black & Veatch. Additional safeguards rounded out the sound contractual plan. An Owner Controlled Insurance Program enabled financial safeguards at a more affordable cost. An auxiliary Design Review Board enabled risks to be reassessed as the project developed.

This top-line risk management approach produced very real, bottom-line results, and significantly contributed to the successful completion of the tunnel on-time, below budget, and without significant disputes or change orders.

PUTTING NUMBERS ON THE UNKNOWN:
Accurate Bids and Schedules despite the Questions

As is common in underground construction, many conditions affecting the contractor's bid would not be known until shaft and tunnel excavation began. When conditions are unclear, contractors typically bid higher to help cover the contingencies, risks and possible obstacles. The NWSRS team took a smarter and more proactive route.

The NWSRS contract documents included a Geotechnical Baseline Report (GBR) prepared by Black & Veatch. The GBR established a contractual statement quantifying a baseline for the geotechnical conditions that were anticipated during construction. Specific conditions addressed included rock properties, groundwater levels, groundwater inflow, ground behavior based on excavation method, and other undetermined factors that might affect cost and schedule. A separate Geotechnical Data Report (GDR) provided the bidders with all data on which both the project design and the GBR were founded.

This basis for risk sharing with the contractor avoided added cost and delay due to disputes. The approach reduced the level of bid contingencies common in traditional models for project contracting, and modified a key clause in the general conditions of the MMSD's standard construction contract. A significant change included the clause for installation of a Disputes Review Board.

AGREEABLE DISAGREEMENT:
Independent Reviewers and Escrowed Bid Documents

Despite the thorough planning, risk management, and contract preparation, disputes might still arise. Again, pre-planning for the possibility was critical. A Disputes Review Board was established and was comprised of three informed and knowledgeable professionals who could provide a nonbinding opinion of disputes between the MMSD and Shea-Kenny. The Board was a low-cost, attractive alternative to mediation, arbitration or litigation.

Not just an inactive "shadow" group, The Disputes Review Board was kept informed throughout the project via quarterly meetings and progress reports so that any decisions on disputes could be rendered quickly. The Board members were mutually selected by the MMSD and Shea-Kenny and, importantly, had no conflict of interest.

In addition, the MMSD required escrowed copies of the bidder's bid documents. This requirement is based on the concept that cost sharing on disputes could be settled more fairly if the contractor's prebid understanding, evaluation, and actual bid tabulation were available. Specific information on the tunnel boring machine (TBM), such as expected average advance rates and expected average TBM penetration rates, was required to be included in the escrow documents for potential use in resolving disputes.

TRIED AND TRUE CONSTRUCTION MANAGEMENT:
Employing the Proven Techniques of the Trade

Careful attention to risk management did not replace traditional, proven techniques to manage and control the construction of the NWSRS. The team employed a range of sound strategies for successful implementation, including:

Rail cars transported workers in and out of the tunnel, a ride that took up to 45 minutes each way.

- Full-time resident engineering and field inspection staff to verify the progress, quantity, and quality of the construction work.
- An overall construction schedule prepared by Shea-Kenny which utilized the Critical Path Method to verify construction progress. Should Shea-Kenny have fallen behind the schedule, they were responsible for development of a recovery plan.
- Bi-weekly project coordination and progress review meetings to discuss and resolve issues that arose during the course of the construction and to coordinate the schedule and upcoming work.
- Progress payments tied to the work completed for each bid item.
- Specified contract completion times with provisions for liquidated damages.

SAFETY PERFORMANCE

LEARNING FROM THE PAST
Difficult Precedents Drive Better Approaches

The MMSD approached construction of the Northwest Side Relief Sewer with a heightened awareness of safety issues, and with good reason. In assessing their loss experience during the $2.7 Billion Water Pollution Abatement Program, from 1978 to 1994, it was apparent that the program was successful from a cost and schedule standpoint, but was marred by 5 tunnel-related deaths. MMSD was determined that measures would be taken to ensure this did not happen in the future.

MMSD knew a different philosophy and approach to safety on construction projects was required, particularly for tunnel projects.

START-TO-FINISH SAFETY FOCUS
Specialists Provide Consistent, Continual Program Execution

Safety specialists ensured that the program was thoroughly coordinated with all parties involved in the project.

The MMSD, through their broker, hired two full-time safety representatives whose duties were to oversee the program and work in cooperation with the individual contractors' safety directors and safety engineers, the State of Wisconsin's safety representative, and insurance carriers' Loss Control Specialists. This plan has been very successful for all projects, especially the NWSRS.

By supplementing a strong safety program, the MMSD was able to positively influence the overall safety experience on the project. But, the most welcome result is what did not occur: there were no deaths or disabling injuries associated with the project.

BETTER SAFETY COORDINATION THOROUGH CONSOLIDATION
Owner Controlled Insurance Program Created a Single Safety Umbrella

In 1999 the MMSD entered into an Owner Controlled Insurance Program (OCIP) for its capital improvement program. Under the OCIP, the MMSD, the prime contractor and all of their sub-contractors at any tier would join into a partnership to enhance and promote safety through the OCIP.

Under the OCIP, the MMSD purchased Workers Comprehensive, General Liability, Builders Risk, and Umbrella Liability coverage which applied to all contractors and subcontractors at any tier while they were on the site. All contractors were required to remove the cost of this coverage from their bids. Safety was the prime driving factor, but there were additional advantages with this program:

- Removed the cost of the insurance from the individual contractors' bids and allowed the MMSD to purchase coverage on behalf of the contractors and obtain volume discounts;
- Reduced the probability of loss through the implementation of consistent, quality safety programs for all contractors;
- Mitigated loss costs by enhancing the coordination of claim administration activities.

Contractors that bid on any project under the OCIP program receive a copy of the Project Safety Guidelines Manual. Any successful bidder agrees to work in accordance with these minimum guidelines. Included in these guidelines is the MMSD's policy on Substance Abuse. The intention of this policy is to establish a drug and alcohol free workplace at all MMSD worksites, helping to assure safe and productive working conditions. The contractor is required to administer a number of unannounced, random drug tests equal to or exceeding 50% of the average number of employees on the construction site. Any employee who is involved in an accident is subject to a drug test if there is reasonable cause.

READY RESPONSE, 24/7

A Trained Tunnel Rescue Team on Stand-by

OSHA standards require that underground construction contractors provide a Rescue Team or make advance arrangements with locally available rescue services. The MMSD contracted with the West Allis Fire Department for these services, and enhanced the Rescue Team's effectiveness with increased coordination. The OCIP Safety Director provided monthly updates to the Tunnel Rescue Team on crucial issues such as underground gas monitoring and ventilation requirements. The 5-person Tunnel Rescue Team was required to comply with OSHA Rescue Team requirements and be available 24 hours a day, 7 days a week.

PROJECT SAFETY: FAST FACTS

Total Project Man Hours	768,174
Number of Incidents	57
Lost Time Injuries per 1000 Man Hours	.0742
Loss Ratio	33%
Experience Modification Rating (EMR)	.44

ENVIRONMENTAL CONSIDERATIONS

A STRONGER COMMUNITY AND ENVIRONMENT:
The Purpose, the Goal, the Impetus

The primary goal of the the Northwest Side Relief Sewer was to accommodate growth and environmental quality in northwest Milwaukee and nearby suburbs. The MMSD's commitment to protecting the environment was rooted in the NWSRS project itself, and was further demonstrated by the proactive and aggressive steps taken to address specific environmental concerns during the course of the project.

A BOLD AND VISIONARY PROJECT:
A Key Link to Improve and Protect Water Quality

Extraordinary environmental sensitivity was required for construction activities within urban park spaces.

Minimizing sewer overflows and protecting water quality are the top priorities at the MMSD. The NWSRS is part of an aggressive overflow reduction plan that the MMSD is working hard to complete. The NWSRS provides relief to the existing 72-inch and 96-inch interceptor sewers serving northwest Milwaukee County by diverting excess wet weather flows above the effective capacity of the interceptor sewers into the NWSRS, where the wastewater will be stored until treatment capacity is available.

This allows continued free discharge of local sewer connections to the interceptor sewers, and minimizes the risk of sanitary sewer overflows in the tributary area. This is key to protecting the quality of area waterways, including the Menomonee River and Lake Michigan.

ELABORATE SYSTEMS TO TREAT TUNNEL DISCHARGE
Confronting a Chief Construction Challenge

High on the team's mind was how to ensure the protection of water quality during construction despite discharge of water from the tunnel excavation. High volumes of groundwater infiltrated into the tunnel during construction, picking up sediments, oils and grease from the mining operation.

Shea-Kenny installed an elaborate system to remove suspended solids from the tunnel water before discharging the effluent to the Menomonee River. The treatment system included settling basins, lamella plate clarifiers, and belt filter presses to reduce the concentration of total suspended solids to meet the MMSD's stringent effluent limits of 30 parts per million, remove oils and grease to less than 15 parts per million and maintain Ph between 6 and 9.

Keeping groundwater out and wastewater in required multiple strategies and techniques.

CONSTRUCTION LEAKAGE AND SEEPAGE:
Ensuring the Protection of Groundwater

The risk of impacting groundwater quality by potential exfiltration of pollutant-laden water from the Northwest Side Relief Sewer was a major environmental concern that required special considerations. The NWSRS tunnel is constructed at a depth 130 to 180 feet below ground surface and below regional groundwater levels. There is a constant inward gradient for groundwater infiltration into the tunnel.

However, when the tunnel is in operation and the tunnel fill line rises above the hydrostatic groundwater head in the surrounding formation, the potential exists for exfiltration of wastewater from the tunnel into the surrounding aquifer.

The construction team kept a close eye on leakage and seepage from beginning to end. Continuous groundwater monitoring acted as a proactive "sentry" to assure the integrity of the groundwater and nearby wells.

The NWSRS was designed with multiple defenses to greatly reduce exfiltration of wastewater into the surrounding bedrock. The first layer was a high-quality cast-in-place concrete lining that was installed on the tunnel circumference. The second layer of defense was an intensive program of grouting any void spaces between the concrete lining and the tunnel circumference (contact grouting). The third layer of defense consisted of grouting permeable bedrock outside of the concrete tunnel lining. The fourth scheme involved proactively managing the pressure of the wastewater within the tunnel to reduce the potential for exfiltration.

Excavated rock was removed with a conveyor belt system along the top of the Tunnel Boring Machine.

EASILY OUTPERFORMING STANDARDS:
57% Lower Than Typical Maximum Limits

The test of success in protecting groundwater levels came after tunnel lining and grouting was completed. Significant groundwater level recovery was observed in existing piezometers which is indicative of the tunnel tightness. In addition, the large reduction in inflow into the tunnel demonstrates that most communication between the tunnel and the surrounding formation has been effectively shut off. The total inflow into the 20-foot diameter, 37,304-feet long tunnel has been reduced from a steady state inflow of approximately 2,300 gpm after mining, to less than 100 gpm following completion of consolidation grouting.

This inflow converts to 85 gallons per day per inch diameter per mile of sewer, which is 57% lower than the typical maximum allowable infiltration/exfiltration limit for sanitary sewers of 200 gallons per day per inch diameter per mile of sewer. Thus, the construction methods have effectively minimized actual infiltration and potential exfiltration, thereby protecting the groundwater resource.

GUARDING GROUNDWATER QUALITY:
Monitoring Acts as a Vigilant "Sentry"

Despite the many precautions and defenses, no system is 100% perfect. MMSD and Black & Veatch developed comprehensive Groundwater Monitoring Plans to keep watch over groundwater quality and water levels in the bedrock aquifer both during both construction and operation of the NWSRS tunnel. This was a vital measure to protect groundwater users in the immediate vicinity: two community water supply wells providing potable water to a subdivision, and three high-capacity irrigation wells owned by a nearby golf course.

The community water supply wells draw water from the same aquifer in which the NWSRS is constructed, and are located just 1,000 feet and 2,340 feet from the tunnel alignment. Two of the high-capacity irrigation wells also draw water from the same aquifer, and the third well extends to a deeper aquifer that is used as a source for potable water. Monitoring assures that a problem can be spotted and mediated quickly—before serious compromises to water quality.

The groundwater monitoring plan identified and characterized the risk of potential groundwater impacts, presented a monitoring program to identify potential releases of wastewater pollutants from the tunnel into the surrounding Silurian dolomite aquifer, presented proposed monitoring well locations and installation details, and identified preventative and remedial measures to mitigate potential adverse affects on groundwater resources in the unlikely case of a pollutant release. Monitoring wells were strategically placed between the tunnel and known groundwater users, as well as in an area where a significant water bearing feature was encountered during tunnel excavation. Groundwater monitoring is a key safeguard to protect the integrity of the groundwater and nearby water supply wells.

An opportunity for reuse: piles of excavated rock sit on the surface before being loaded onto trucks and hauled away.

RESOURCE-FRIENDLY OPERATION
Minimal Energy Requirements by Design

Using the least possible energy for operation is a boon not only to the MMSD and its ratepayers, but the environment as well. The Northwest Side Relief Sewer was designed with efficient use of resources in mind. Rather than using a traditional approach which utilizes pumps to move water, the NWSRS features a "natural" design that relies on gravity to move water. The lack of pumping equates to energy savings as well as increased simplicity in operation.

TONS OF REUSE OPPORTUNITY:
Excavated Rock Recycled Within the Community

During construction, more than 840,000 cubic yards of rock were mined by the tunnel boring machine, transported through the tunnel by train, lifted up to the surface by a conveyor belt system, loaded and hauled away—an average of 180 truckloads of rock rubble per day.

The MMSD recognized that this rubble could be a needed resource elsewhere. The excavated limestone rock was recycled for beneficial use as a high quality crushed aggregate on other construction projects that would benefit the community, including Kohl Park and General Mitchell International Airport.

AT REST, WITH RESPECT:
A Potter's Field Remains at Peace

Milwaukee County was believed to have buried at least 6,000 people on the Milwaukee County Grounds between the late 1800s and mid-1970s. A pre-construction archaeological survey revealed that the surface structures at the south end of the tunnel were in an area where extensive indigent (pauper) burial sites had been recorded.

To avoid impacts to the paupers' grave sites, the MMSD conducted further reviews to confirm that the proposed construction did not extend into areas where graves had been reported. In addition, earth-moving activities for construction of surface structures on the Milwaukee County Grounds were monitored by a qualified archeologist certified by the Director of the State Historical Society of Wisconsin to ensure that human remains would not be disturbed.

THE SNAKE IN THE GRASS:
A Threatened Species Gets Careful Handling

The project location was an area of significant conservation value for a rare snake, the Butler's Gartersnake (*Thamnophis butleri*), which is listed as a threatened species under state law. The MMSD worked closely with the state Department of Natural Resources Bureau of Endangered Resources (DNR) to develop a conservation strategy to secure the long-term protection of the Butler's Gartersnake and its habitat.

The Butler's Gartersnake is a gentle, non-aggressive species that is protected under Wisconsin state law.

The MMSD hired a specialist to survey the work sites for Butler's Gartersnakes and developed a Conservation Plan with avoidance and minimization measures. This included snake removals from work sites prior to construction, snake exclusion fencing to prevent snakes from moving into the construction area from adjacent habitats, and post-construction habitat restoration and monitoring. DNR staff concluded that these conservation measures would minimize impacts to the snake and avoid negative impact to its preservation and recovery.

APPROACH WITH CAUTION:
Constructing Through a Superfund Site

The northern third of the NWSRS alignment presented an unwelcome challenge to the construction team: contaminated river sediment and floodplain soils from a U.S. EPA Superfund site. This portion of the alignment follows the Little Menomonee River floodplain, impacted by and considered part of the Moss-American Superfund site. Excavations for surface structures in this stretch of the alignment required special handling and disposal procedures because of the contamination.

As part of a Phase II Environmental Site Assessment, soil, sediment and shallow groundwater sampling evaluated the nature and extent of contamination. The contaminants of most concern were carcinogenic polycyclic aromatic hydrocarbons. Mitigation measures included minimizing the number of structures in this stretch of the alignment and contractual provisions for the management, handling and disposal of potentially contaminated soils and groundwater. Shea-Kenny prepared a separate work plan for handling of contaminated materials.

COMMUNITY RELATIONS

MAJOR CONSTRUCTION, MINIMAL DISRUPTION:
Quieting the Community's Concerns

Although construction was taking place underground and for the most part, out of sight a project of this magnitude still produces many effects and consequences for the communities above it. The MMSD actively addressed the unique challenges in dealing with the surrounding residents and communities.

Despite the magnitude of the project, disruptions for the surrounding communities were minimal.

The Northwest Side Relief Sewer project generated more than 840,000 cubic yards of excavated rock that needed to be removed from the site. This meant an average of 180 trucks traveling through a residential area 5 days a week for 390 days.

The project also required the use of explosives while excavating the eight shafts. Elected representatives from Milwaukee County and the City of Wauwatosa, as well as administrators from the nearby Milwaukee Regional Medical Complex, were concerned about the possible effects. They also made it clear that they would not stand for empty promises.

DIFFICULT QUESTIONS ANSWERED:
Specific Agreements Create Trust and Cooperation

The MMSD dealt with these issues by entering into Intergovernmental Cooperation Agreements (ICA) with Milwaukee County and the City of Wauwatosa that addressed the concerns. Included in the agreements were such things as alternate haul routes, permissible hours of hauling and blasting, requirements for street sweeping, and methods for determining damage and schedules for the replacement of damaged streets, utilities and trees.

This careful planning yielded very positive results. Through four years of construction the MMSD received a minimal number of complaints from elected officials. The small number of complaints that were received were handled quickly and to the complete satisfaction of the elected officials and constituents.

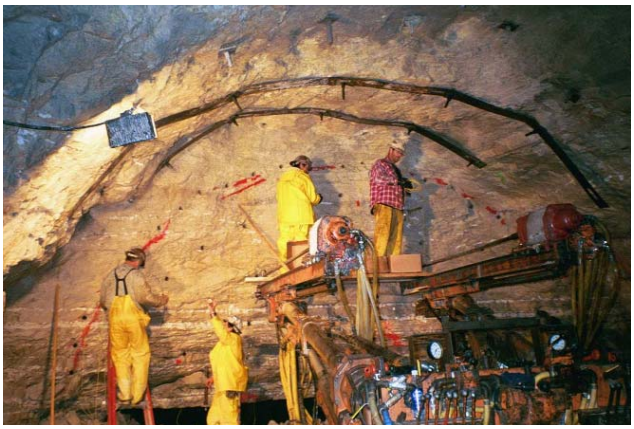
A GOOD NEIGHBOR
Reducing the Nuisance of Major Construction

It's never easy to live or work close to heavy construction, but the project team worked hard to reduce construction inconveniences to a minimum level. Some of the construction impacts that were carefully managed include noise levels, dust, vibrations and odors.

Tunneling operations are not as noisy as other forms of heavy construction, but ventilation fans with high-frequency pitches can be very irritating to nearby residents. The contractor enclosed fans in soundproof enclosures and, in some cases, installed the fans underground to reduce the noise.

Dust is generated when stockpiling, loading and hauling tunnel spoil from the shaft sinks. The contractor controlled dust by wetting the haul roads with water and dust palliatives and by installing covers over the haul rocks to prevent dust from being blown out of the truck beds.

During some phases of construction, Shea-Kenny used drill and blast excavation. The contractor employed best available blasting techniques such as limiting the pounds of explosives on each delay. The contractor also published a schedule so that nearby residents knew, on a daily basis, when to expect a blast. The contractor notified residents in advance if the tunnel boring machine would be in close proximity, preventing alarm over minor vibrations that might be felt from the machine's operation.



Workers prepare for explosive charges to blast bedrock out of an access shaft.

Odor control was a pressing issue both during construction and in the long-term for tunnel operations. This impact was mitigated by the installation of passive activated carbon media in all tunnel vent locations.

PRESERVING THE LANDSCAPE:
Creating Incentives to Save Trees

The Intergovernmental Cooperation Agreement with Milwaukee County used a unique approach to quiet the concerns of Parks Department personnel. They were worried that the contractor would damage or destroy trees that weren't in the way of construction. The ICA required that the District perform a tree survey prior to construction. This survey placed a value on each tree based on the diameter and the species. The contractor would need to pay the County this cost for any damaged trees. The result of this was that the contractor went out of his way to preserve any tree in the area.

BLASTING PAST A SURGICAL CENTER:
Careful Study Alleviates Anxiety over Health Care

The Medical Center had additional concerns related to the blasting. The nearby regional eye center regularly performed surgery during the day. Could vibrations from the blasting affect sensitive instruments and delicate surgeries?

The medical community needed direct, reliable assurances. Shea-Kenny brought in an expert blaster to help with the sensitive negotiations. Besides designing the blast patterns and charges to be used, the blasting expert used seismographs to prove to the Medical Center that the blast vibrations were no more harmful than existing vibrations that were occurring. Using a reliable, scientific approach to deal with the Medical Center was the key to successful communications. Shea-Kenny's expert, a reputable authority with a PhD, was able to communicate extremely effectively with medical professionals and health care representatives.

OBSTACLES, CHALLENGES AND INNOVATION

DIGGING DEEP FOR SOLUTIONS:
Dozens of Challenges, Confronted and Conquered

Underground engineering and construction takes vision, expertise, experience and perhaps most of all, fortitude. These works are among the riskiest undertakings in heavy civil construction, and the Northwest Side Relief Sewer overcame a variety of challenges in design and construction, including:

- Constructing a tunnel liner with exfiltration standards that were approximately five times more stringent than industry standards
- Extremely strict discharge criteria for water that infiltrated into the tunnel during the construction process
- Potential for migration of existing environmental contaminants in the soil above the tunnel into the tunnel or into groundwater wells
- Depletion of groundwater wells along the tunnel alignment in the construction phase
- Minimizing noise, dust, extraneous light and odor in densely populated urban areas and pristine park green spaces
- Constructing the work with minimal vibrations to prevent impacts to the adjacent Eye Surgery Center and the local community
- Preparing geotechnical investigations that discovered and defined, as much as possible, the geotechnical challenges that the contractor might experience
- Constructing a tunnel in a region that had been plagued by significant differing site conditions (DSC) claims on previous tunnel projects
- Geologic challenges including:
  - Solution cavities and shear zones in the bedrock with associated high groundwater inflows and unstable ground
  - Bedrock valley delineation for vertical alignment selection
  - Potential for presence of soils that would compress when dewatering
  - Presence of boulders and cobbles in the soil sections that complicated shaft sinking

Lamella plate clarifiers were used to treat dewatering discharge from construction.

WASTE NOT, WANT NOT:
Stringent Treatment for Dewatering Discharge

Wisconsin Department of Natural Resources (WDNR) considers water generated during tunnel construction an activity regulated under the general Wisconsin Pollution Discharge Elimination System permits. The total suspended solids limitation is 30 parts per million. WDNR's approach for large tunneling projects was to require best available technology for treatment of this type of discharge. A settling basin followed by lamella plate clarifiers and belt filter presses for solids dewatering was incorporated to treat the tunnel construction dewatering discharge.

SAILING AROUND THE DSC
Methods that Avoided Disputes and Cost Overruns

Despite today's advanced technology, designers and constructors still cannot definitively see what lies below the surface of the ground. Surprises are generally the rule rather than the exception in underground construction. If the conditions encountered during construction differ significantly from what the Owner/Engineer predicted in the bid documents (DSC, or Differing Site Condition) the contractor is entitled to additional compensation.

In the not too distant past, owners and engineers, when faced with the myriad of challenges, obstacles and risks associated with such a project, would have taken an "ostrich" approach, staying far removed from the issues. Commonly, responsibility would be shifted to the construction contractor with the hope that potential problems would be solved with minimal impacts to cost or budget.

Wishful thinking like this is, of course, a recipe for disaster on tunneling projects. Construction case law in North America and around the world has firmly established the concept that owners "own the ground" and must pay fair and equitable compensation for civil works constructed underground.

The Northwest Side Relief Sewer is proof positive that large underground projects can be brought to fruition efficiently, cost-effectively and without major disputes among the stakeholders. Given the dozens of cities across the United States confronting similar expensive challenges with aging and inadequate infrastructure, it is a timely and relevant achievement.

The cast-in-place concrete liner is a key design feature that makes the NWSRS one of the tightest tunnels in the county.

ONE TIGHT TUNNEL:
Outstanding Numbers Prove Top Performance

The construction of the NWSRS used appropriate, best available technologies to produce one of the tightest tunnels in the country. The total inflow into the 20-foot diameter, 7.1-mile long tunnel has been reduced from a steady state inflow of approximately 2,300 gpm after mining, to less than 100 gpm following completion of lining and contact and cut-off grouting in mid-June 2005. This is more than five times lower than the already-stringent maximum allowable inflow criterion of 500 gpm specified for the tunnel.

Field measurements and construction records confirm that the actual total groundwater inflow for the entirety of the tunnel has been reduced to less than 100 gpm. This inflow equates to less than half of the typical maximum allowable infiltration/exfiltration limit for sanitary sewers. Groundwater levels are also impressive, having recovered to near pre-construction levels across the entire length of the tunnel.

THE INVISIBLE INVESTMENT:
A Rock-Solid Base for Community Growth

Hydraulic modeling conducted by the MMSD estimated the peak water levels and volume in the NWSRS for a series of storm events. The modeling demonstrated that even with a 25-year storm at ultimate build-out conditions, the tunnel would only be approximately three-quarters full. This is a significant accomplishment that allows the communities served by the NWSRS to grow and prosper with minimal risk of basement backups and local sewer overflows.

BUDGET, COST & SCHEDULE

MILESTONES

Preliminary Engineering Completed	January, 2000
Completed Detailed Design	September, 2001
Construction Notice to Proceed	April, 2002
Completed Tunnel Boring Machine Excavation	April, 2004 (14 months)
Completed Tunnel Lining	May, 2005 (12 months)
Contracted Project Completion	November, 2005
Actual Project Completion	November, 2005

BY THE NUMBERS

Final Constructed Project Cost	$111,994,000
Budgeted Constructed Project Cost	$120,000.000
Engineering	$5,054,000
Construction Management	$4,120,000

A large shaft is constructed to connect with existing interceptor sewers on the Milwaukee County Grounds.

STATE DIRECTIVE SPARKS A BIGGER VISION

A Short-term Setback becomes a Long-Term Opportunity

In the hydraulic modeling process, the original NWSRS design required a 12 foot inside-diameter tunnel to store and convey the peak flow. Subsequent discussions and negotiations between the MMSD and the Wisconsin Department of Natural Resources (WDNR) resulted in requirements for adding more storage to the sewerage system. The MMSD turned this into an opportunity to address longer-range storage requirements by increasing the diameter of the tunnel to 20 feet.

Significant design changes were required when the tunnel diameter increased from 12 to 20 feet. The subsequent increase in engineering fees was approximately $1,127,000 from the originally budgeted amount of $3,927,000. Despite this, the total engineering cost of approximately $5,054,000 was about 4.5 percent of the construction cost, much lower than industry standards which vary from 6 to 10 percent.

CONFIDENT BIDDERS, FEW SURPRISES

Reaping the Rewards of Expert Preparation

The bid opening was a high point for the MMSD. The four lowest bids were extremely close, with the low bid at $116,768,829 and the fourth bid at $120,390,133. It was no accident: feedback from bidders indicated high confidence in the quality of the bidding documents and risk sharing processes that assured the contractor fair and equitable treatment if differing site conditions were encountered.

Allowing for some contingencies, the MMSD set the target budget at $120,000.000. Through proactive construction management and excellent execution, the final constructed cost for the project was $111,994,000.

Likewise, the construction management cost on the project was under budget. The original construction management budget was $5,999,000 and the actual expended cost was $4,120,000.

Through collective efforts between the design engineer, construction manager and construction contractor, the total project was completed 7 percent under budget, saving the MMSD and the public over $8 million.

Ending as it began, the project demonstrated a strong finish. The Northwest Side Relief Sewer began serving Milwaukee's citizens on schedule in November 2005, one year ahead of the Wisconsin Department of Natural Resource's stipulation that the project be completed by the end of 2006.

Northwest Side Relief Sewer Photo 1

The project added 88 million gallons to the Metropolitain Milwaukee Sewerage District's storage systems, a 20% increase.

Digital files or prints available upon request.

Northwest Side Relief Sewer Photo 2

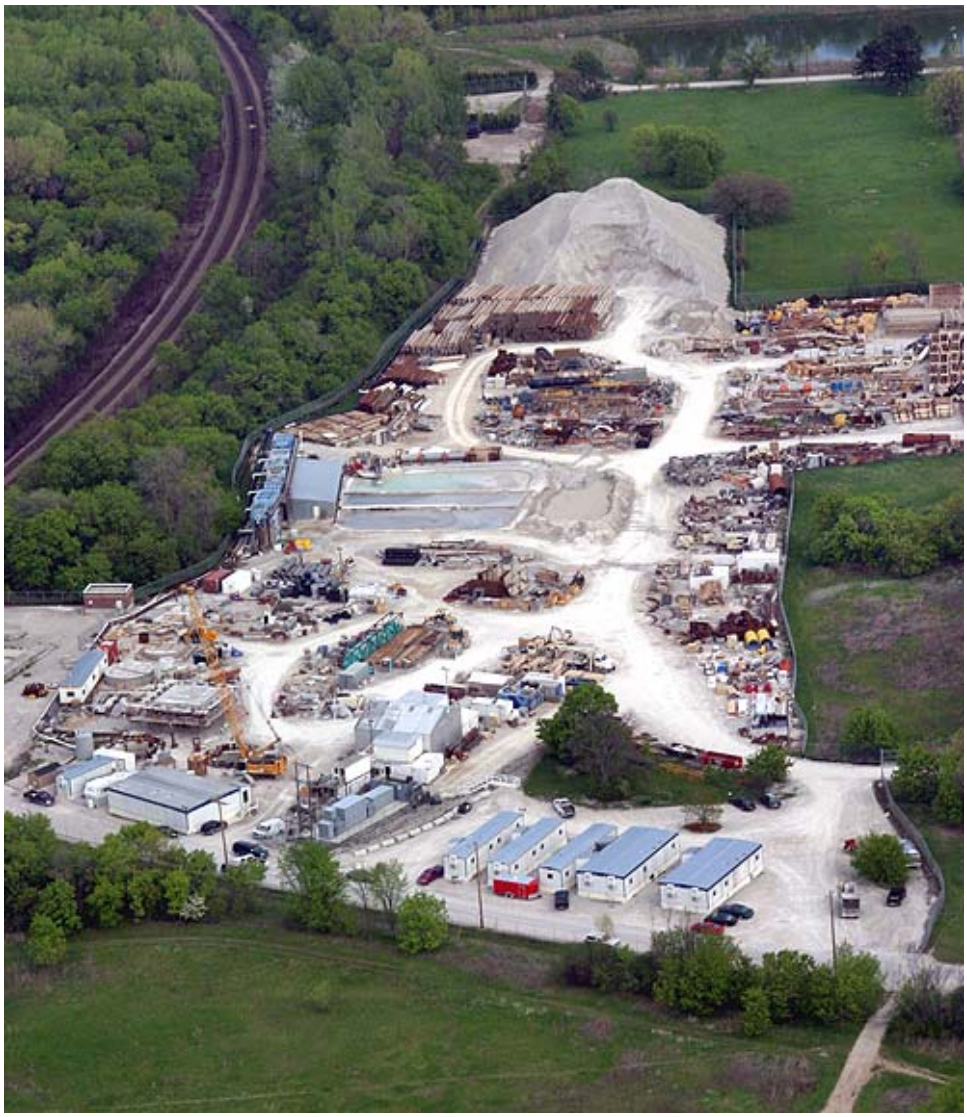
Trains transported people, equipment, excavated material and supplies along the 7.1 mile tunnel during construction.

Digital files or prints available upon request.

Northwest Side Relief Sewer Photo 3

Mutiple defenses were used to control infiltration of groundwater and exfiltration of wastewater during construction.

Digital files or prints available upon request.



Northwest Side Relief Sewer Photo 4

Extra precautions were taken to minimize disruption and inconvenience for communities surrounding the site.

Digital files or prints available upon request.

Northwest Side Relief Sewer Photo 5

A large shaft is constructed to connect with existing interceptor sewers on the Milwaukee County Grounds.

Digital files or prints available upon request.