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## The City of Sergeant Bluff, IA Chooses Pilot Tube Microtunneling over Open Trench Construction

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**ABSTRACT:** The city of Sergeant Bluff IA is located in Western Iowa next to the Missouri River. The First Street Lift Station Elimination and Sewer project was planned to eliminate an aging, costly lift station by installing a gravity trunk line sanitary sewer. The city critically evaluated installation methods and estimated costs for conventional open trench and trenchless options.

Estimated costs for both options were presented to the city in February of 2009. The analysis of costs showed open trench construction at \$225,000 less than the trenchless option. However, the city selected the trenchless method of Pilot Tube Microtunneling for the following reasons:

- 1) potential cost overruns of open trench construction,
- 2) open trench would require entire street replacement,
- 3) the project corridor was critical for school traffic,
- 4) existing utilities would be better protected using trenchless technology, and
- 5) dewatering requirements at each shaft versus along the entire trench would better limit risk.

This project consists of the installation of 15-inch and 21-inch gravity sanitary sewer installed at depths up to 23 ft. The contractor selected 16 ft. diameter shafts and a 3-step installation process utilizing both powered reaming and cutter heads. The soil conditions encountered included silty clays, lean clays and poorly graded sands with blow counts ranging from 2 to 21.

The Pilot Tube Microtunneling process, at the design slopes required for this project, is not a common technology used in the State of Iowa. The Iowa DNR required the city to file a construction permit variance to allow the technology to be used for the project.

### 1. INTRODUCTION

The City of Sergeant Bluff, located along the Missouri River in Northwest Iowa, is a community of 4,227 people. In 2009, the City moved forward with a project to eliminate an existing lift station and install a new gravity sanitary sewer system. The project, a part of the comprehensive planning process since 1998, was made a top priority for the capital improvements program as the aging and undersized First Street Lift Station experienced multiple failures. The City analyzed the cost to install a new gravity sewer by conventional open cut or trenchless methods. Despite an estimated cost that was approximately 20% higher, the City of Sergeant Bluff elected to construct the project using the Pilot Tube Microtunneling installation method.

The City's analysis of the project options included five main issues. The City selected the trenchless method of Pilot Tube Microtunneling (PTMT) due to:

- 1) open trench construction could produce potential cost overruns for impacts of soil conditions,
- 2) open trench would require entire street replacement,
- 3) the project corridor was critical for school traffic,
- 4) existing utilities would be better protected using trenchless technology, and
- 5) dewatering requirements along the entire trench versus at each shaft, which better limits risk.

These issues, discussed in more detail in the design section, ultimately showed that the value of traffic flow for the schools and limited risk of dewatering and underground utilities outweighed the estimated cost differential for PTMT construction.

The project, awarded to Minger Construction, Inc. of Chanhassen, MN, faced a number of obstacles along the way that further validated the selection of PTMT technology as the best method for this project. The design slopes for the sewer were such that conventional standards for trenchless methods could not be met. The Iowa Department of Natural Resources (IDNR) had no trenchless standard in place to accommodate slopes only accepted when using open cut methods. Minger Construction Inc. and Akkerman Inc. provided data that supported the PTMT process and was accepted by the IDNR through a construction variance. A second project obstacle was the record breaking 2011 flooding along the Missouri River that raised the groundwater table above normal levels. The PTMT process allowed for isolated dewatering wells at jacking and receiving pits, which reduced the overall risk of installing the gravity sewer. A third project hurdle was multiple emergency pipe collapses of the existing gravity sewer located near to but upstream of the project. The success of the original project made asking Minger Construction, Inc. to extend the scope of the PTMT work the logical solution. As a result, Minger replaced the failed trunk line with a parallel line.

The original project consisted of 800 LF of 21-inch Vitrified Clay Jacking Pipe (VCP-J) and 3,200 LF of 15-inch VCP-J both supplied by Mission Clay Products LLC, 14 sanitary sewer manholes, and 6 PTMT jacking pits. Construction began in March 2012. The project extension including the nearby gravity trunk line collapse added an additional 1,325 LF of 15-inch VCP-J, four sanitary sewer manholes, and two PTMT jacking pits. The sanitary sewer construction was substantially complete in November 2012. Total construction costs were \$2.6 million.

## **2. DESIGN**

In 2002, the City reconstructed its main lift station, Interstate Lift Station, to provide the depth needed for a gravity sewer to be installed, eliminating the First Street Lift Station. The design for this sewer project employed the minimum slopes allowed for elimination of a lift station. Flows included the existing First Street Lift Station service area at the upstream end of the project. Project design included running 3,200 lineal feet of 15-inch piping from the existing lift station to an existing gravity sewer and force main connection located at Warrior Road and D Street. This piping connection provides the point where the majority of the City's sanitary sewer is collected. The design from D Street west to Sergeant Square Drive required the existing main to be replaced with 800 lineal feet of 21-inch diameter pipe.

The route of the project, as shown in the project location map, included the main east-west commuter traffic corridor (First Street), the main north-south school traffic route (D Street), and the main sanitary sewer corridor (Warrior Road). Due to the traffic constraints and the condition of the existing pavement, the City chose to pursue the option of trenchless technology for construction. The City also desired for the main trunk sewer to be constructed of vitrified clay pipe. The City and their Engineer, Veenstra & Kimm, Inc., worked closely with Mission Clay Products LLC and the National Clay Pipe Institute to analyze the option of PTMT using the specialized NO-DIG clay jacking pipe in the design concept process.

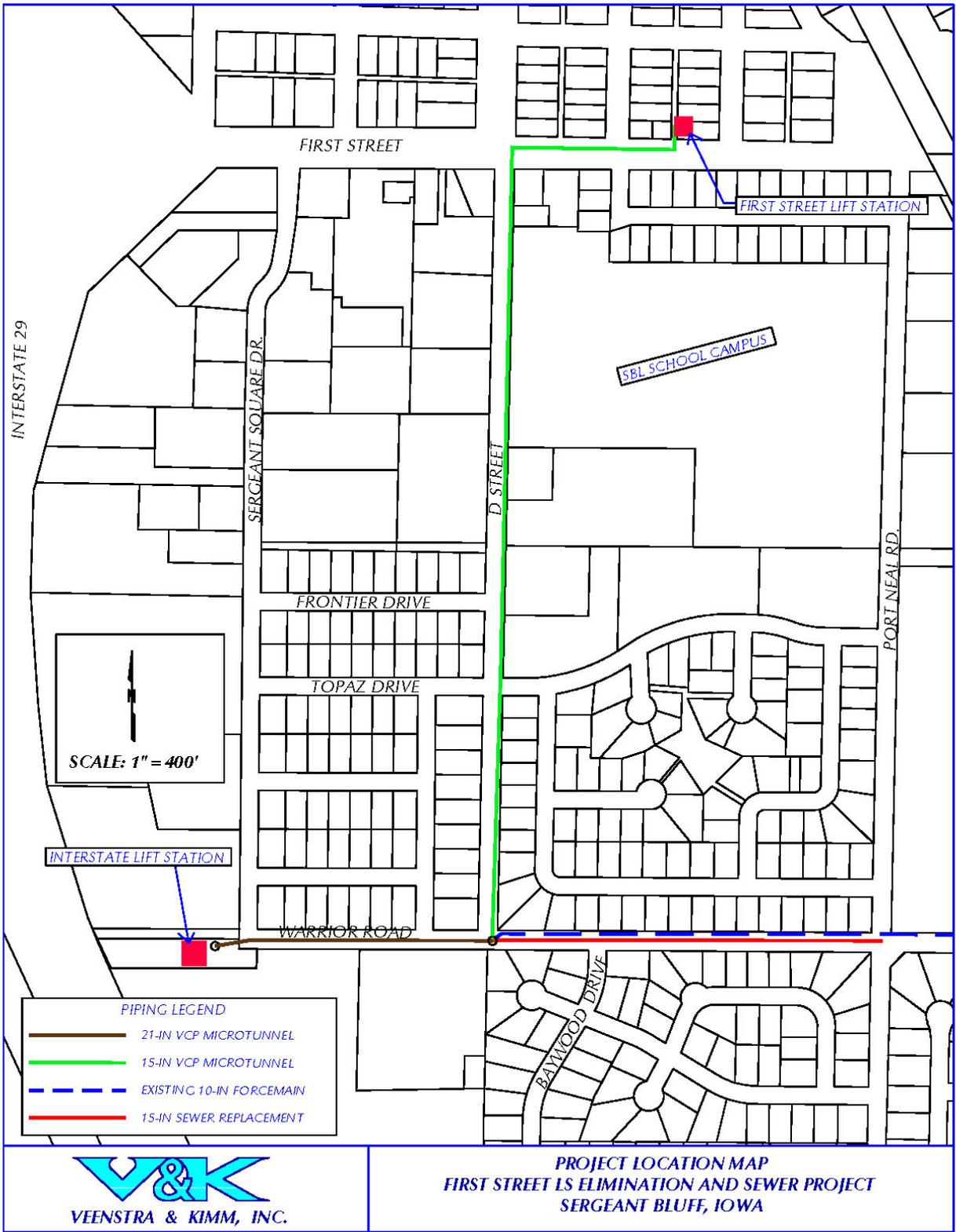


Figure 1. First Street Lift Station Elimination project map

In 2009, two design options for the project were presented to the City of Sergeant Bluff. One option was for open cut methods, which included 8,300 SY of pavement replacement, open cut pipe with CLSM and over 5,000 CY of unsuitable soil replacement for an estimated cost of \$1.125 million. The second option was trenchless technology (PTMT), which greatly reduced the need for replacement of pavement and unsuitable soils. However the total

estimated cost for the trenchless technology was \$1.35 million or \$225,000 more than open cut. The City chose to evaluate the design options by including considerations for impacts of disturbance to traffic, condition of existing pavements, groundwater dewatering and conflicts with existing utilities, as a part of the total estimated cost.

The City considered its traffic system when determining the project design. First Street, with an annual average traffic count of 7,100 vehicles per day, provides the main east-west traffic corridor for the City. Secondly, the Sergeant Bluff School District, which has its Pre-kindergarten through fifth grade buildings adjacent to the project, serves approximately 650 students and uses the D Street corridor for student pick up and drop off traffic.

The pavement conditions for First Street, D Street and Warrior Road were such that did not require replacement. Trenchless technology reduced potential detours and road closures and reduced the amount of pavement to remove and replace for construction.

The groundwater in the project area was at USGS elevation 1075.0. The proposed grades of the sanitary sewer ranged from invert elevation 1071.75 to 1078.00. Therefore, groundwater was going to be an issue for over half of the project. Soils in the City historically have been variable and consist of anywhere between sands, fat clays, lean clays and silty clays. The variation in soils created a potential for additional costs related to wet/unstable soils replacement, construction trench safety, and the number of dewatering wells for the length of construction. PTMT technology reduced the risks associated with dewatering by only requiring dewatering wells at the jacking and receiving pits. Trenchless technology eliminated the need for soils replacement outside of the manhole construction areas.

First Street, D Street and Warrior Road are major utility corridors and have a limited space for deep sewer construction. Open trench construction, along with the unsuitable soils and groundwater, elevated the risk to adjacent utilities. Trenchless technology provided limited disturbance to the existing utilities and reduced the potential for change orders associated with utility adjustments.

Once the City elected to pursue PTMT for the project, a preliminary route was established and a soils report was authorized to explore existing conditions for design. The soils report provided fourteen (14) bore locations at approximately 300 feet apart. The report was used to determine the soil type, blow count, moisture content, and groundwater elevation. The chart below in Table 1 shows the findings of the material based on proposed pipe design elevations and locations.

Table 1: Soils encountered in the pipe zone

<b>Location</b>	<b>Pipe Design Elevation</b>	<b>Groundwater Elevation</b>	<b>Soils Type(s)</b>	<b>Moisture (%)</b>	<b>Blow Count</b>
Warrior Road	1072.0-1073.0	1075.7	Poorly Graded Sands	33-36	2-12
D Street – Warrior to Topaz	1073.0-1074.0	1075.5	Lean Clay	35-38	2-3
D Street – Topaz to First St	1074.0-1077.0	1075.3	Silty Sands/Lean Clay	26-39	3-6
First Street	1077.0-1079.0	1075.2	Lean Clay/Fat Clay	31-39	4-7

Based on the results of the soils report the manholes were designed for a maximum jacking distance of 300 feet. Jacking pits were sized at 10’x28’ requiring a tight shaft system with sealed ends to handle the groundwater. A total of 6 jacking pits were designed so that a line could be tunneled in each direction (upstream and downstream) to a receiving pit. A new manhole was placed at each receiving and jacking pit location. The typical design sections for the jacking pits and open cut piping are shown in Figure 2.

The total elevation difference in the system was such that little room for error existed in the design slopes. The pipe size design for the project was determined based on the IDNR accommodation for minimum slopes by eliminating a lift station. Chapter 12, paragraph 12.5.3 of the Iowa Sewer Design Standards sets design standards for the minimum slope of gravity sewers at 2 fps velocity and states, “Velocities down to 1.5 feet per second may be accepted only when a lift station can be eliminated.” The 15-inch sewer was designed for a slope of 0.140%, which at design flow is 1.97 fps. The 21-inch sewer was designed for a slope of 0.093%, which at design flow is 1.98fps.

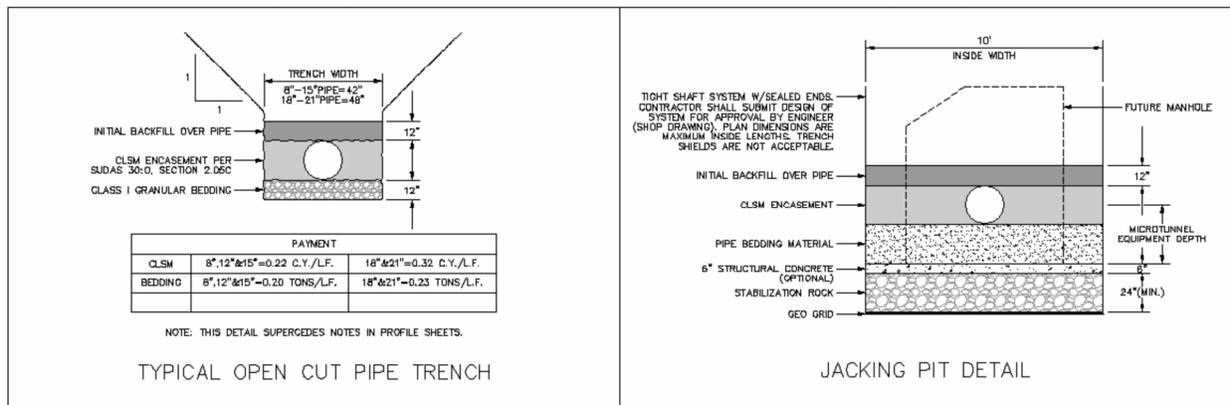


Figure 2: Typical design sections for open trench and jacking pits

The IDNR design manual did not have established standards to accept construction tolerances displayed by PTMT methods. The construction permit review only allowed open cut methods for the pipe slopes and overall project tolerances designed. The City worked with Veenstra & Kimm, Inc., Mission Clay Products LLC and Akkerman, Inc. to submit a design variance request to IDNR. The accuracy documented by Akkerman for the PTMT guided bore machine would provide a vertical tolerance of 0.25 inch per 300 feet of tunneling. Table 2 below shows the statewide standard for typical trenchless construction tolerances compared to the documented guided bore machine tolerances. The typical trenchless tolerances would not have allowed the project to be installed correctly. IDNR accepted the revised tolerances based on the manufacturer's guarantee of accuracy.

Table 2: Line and Grade Tolerances- Iowa SUDAS Standard Specification vs. PTMT

Trenchless Technology	Horizontal Tolerance	Vertical Tolerance
Iowa SUDAS - Standard Bore and Case	± 1.0 foot per 100 feet (3 feet per 300 feet)	± 0.2 feet up to 100 feet; an additional ± 0.1 foot per 100 feet thereafter (0.4 feet per 300 feet)
Guided Bore Machine (PTMT)	< 1 inch per 300 feet	< 1 inch per 300 feet

During final design and in preparation for advertisement of bids the area endured record flooding on the Missouri River. The flooding had an adverse affect on the groundwater table. In May of 2011, the City installed three monitoring wells along the project route. The peak of the flow on the River occurred in July 2011 during the bid process. The groundwater monitoring allowed the Contractors to understand the relative level of the water table based on the River elevation. The start of the project was delayed until February 2012 to allow the receding water table to stabilize to pre-flood elevations. The monitoring wells were used throughout the project to show the effects of dewatering on groundwater.

Minger Construction, Inc. elected to take soil borings during the bid process to verify the spacing of the jacking and receiving pits. The results of their testing allowed the opportunity to extend the manhole separation from 300 feet to 400 feet apart. This value-engineering item allowed the City to reduce the number of jacking pits and manholes required for construction.

### 3. CONSTRUCTION

#### The PTMT Process Used

The tunnel pipe installation began with the excavation and construction of jacking and receiving shafts. All tunnel shafts were excavated with either a Komatsu 200- or 400-track hoe with conventional bucket attachment. These shafts were lined with either a 16 ft. diameter steel caisson (see Figure 3) or a 12 by 18 ft. conventional trench box. The contractor fabricated the caissons, which utilized bolted connections and doors for pipe entrance and exiting, in their shop. Depending on soil conditions and volume, the annular space between the excavated ground and the shoring was filled with either Controlled Low Strength Material (flowable fill or CLSM) or crushed stone. The bottom of each shaft was lined with a base stabilization Geogrid fabric beneath a minimum of 18-inches of crushed stone to stabilize the jacking frame and prevent uplift. This stabilized base was left in place beneath the permanent manhole structure to serve as a foundation upon completion of the tunnel drives.



Figure 3. 16-ft diameter PTMT Jacking Shaft

An Akkerman 4812 guided boring machine was utilized to perform all steps of the pilot tube microtunnel process. This unit has a jacking capacity of 200 Tons, 100 Tons of pullback capacity, and 20,000 ft-lbs of rotational torque. This frame accepted the 4-inch diameter by 30-inch long dual walled pilot tubes, 16-inch by 5-ft length auger casings, both the 24.5-inch OD powered cutter and 20-inch OD powered reaming heads, and final carrier pipe supplied 2 meter drive lengths.

Once the shaft construction was complete, the jacking frame was set to the desired height, grade and line from control points established using conventional surveying techniques. As in all pilot tube installations, the guidance system consisted of a digital theodolite with an integrated camera (mounted independent of the jacking frame), a battery powered LED illuminated target housed in the slant faced steering head, and a computer monitor screen. This guidance system provides the operator with a “real time” view of the position and orientation of the pilot tubes during installation.

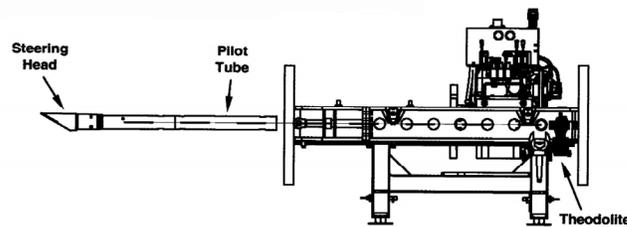


Figure 4. PTMT Step 1 - Installation of the pilot tubes

The **First Step** (see Figure 4) for the installation was to install the 100-mm (4-in) pilot tubes on line and grade [6-mm ( $\frac{1}{4}$ -in) or better accuracy was achieved in the 300-ft drive lengths]. During installation of the pilot tube, the ground was displaced by the slant-faced steering head and no spoil was removed. The pilot tube was then directed on line and grade by rotation during advancement. The hollow stem of the pilot tube provided an optical path for the camera to view the LED target displaying the head position and steering orientation. This step established the centerline of the new sewer installation; all remaining steps followed the path of the pilot tube. Once the pilot tubes reached the reception shaft, the theodolite, video camera, and monitor guidance system were no longer needed in the remaining steps and were removed from the jacking pit.

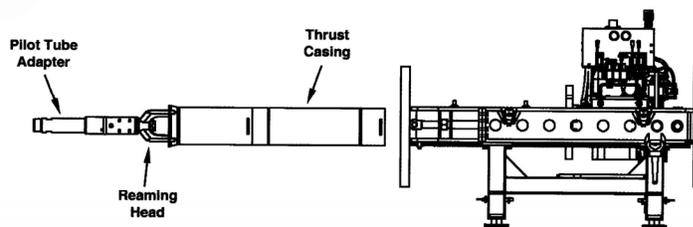


Figure 5. PTMT Step 2 – Installation of 16-inch OD auger (thrust) casings

The **Second Step** (see Figure 5) was to follow the path of the pilot tube with a 16-inch OD reaming head. The front of the reaming head fastened to the last pilot tube in the same manner in which the pilot tubes fasten to each other. Advancing the pilot tubes and reaming head was 16-inch OD thrust (auger) casings, which transported the spoil (displaced ground around the pilot tubes) to the jacking shaft for removal. The contractor removed the spoil with a vacuum method and transported it off site. During the installation of the 16-inch casings, the previously installed pilots were advanced forward into the reception shaft and were disassembled as the casings were installed. This step was complete when the reamer and auger casings reached the reception shaft and all spoil was removed from the bore.

The **Third Step on the 21-inch diameter product pipe** installation was to install a powered cutter head (PCH) behind the auger casings; both advanced by the product pipe (see Figure 6). The powered cutter head increased the bore to match the 24.5-inch product pipe outside diameter. The remaining soil around the previously installed 16-inch OD auger casings (step 2) was taken into the PCH and discharged via the reception shaft by reversing the auger flight direction. The final product pipe was then installed directly behind the PCH. As each section of auger casing was removed from the reception shaft, a section of product pipe was installed in the launch shaft until the process was completed. This step was complete when the PCH entered the reception shaft and the 21-inch pipe lined the bore.

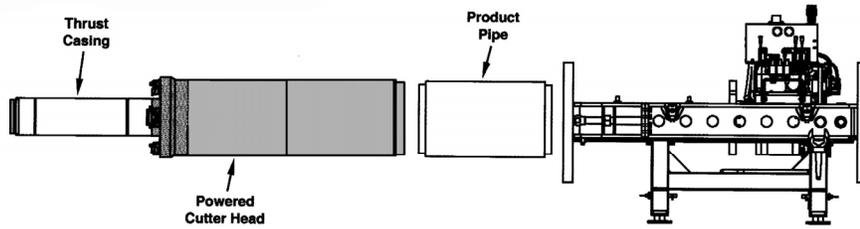


Figure 6. PTMT Step 3 – Installation of product pipe with powered cutter head

The outside diameter of the PCH was 24.5-inches to match the OD of the 21-inch ID vitrified clay jacking pipe. There were two hydraulic motors housed in the PCH used; the first to drive the auger flights and the second to drive the rotating cutter face. Three jetting ports are housed inside the cutter face, connected by a single hose for water distribution keeping the face clean and easing spoil transport. Lubrication ports to keep jacking pressures down were located in the rear of the machine connected by a single hose. Seven hoses (4 total hydraulic, 1 lubrication, 1 jetting, and 1 for a hydraulic pump check valve) ran from the jacking frame through the product pipe to the PCH unit. Staging the pipe at the surface with the hoses installed before the start of this step was crucial to production efficiency.

The **Third Step on the 15-inch diameter product pipe** installation was to install a powered reaming head (PRH) behind the auger casings; both advanced by the product pipe. A PRH works in the same manner as a PCH but



Figure 7. PTMT Jacking Shaft- 20-inch reaming head

without the rotatable cutter face. This powered reaming head (PRH) increased the bore to match the 15-inch product pipe outside diameter of 20-inches. The remaining soil around the previously installed 16-inch OD auger casings (step 2) was taken into the PRH and discharged via the reception shaft by reversing the auger flight direction. As in the 21-inch (PCH) installation, the final 15-inch product pipe was then installed directly behind the PRH providing the axial force required for advancement.

Differing from all other PRH installations to date, the hydraulic motor used to drive the auger flights was not included inside the unit itself (see figure 7). The Minger Construction fabrication shop built a frame, which housed the hydraulic motor used to reverse the direction of the auger flights installed in the second step of the process. This 'powered frame' was installed in the receiving shaft and connected to the auger flights eliminating the need for staging the product pipe with hydraulic hoses to power the motor (See figure 8). This unique modification to the typical PRH method was designed by Patrick Minger and significantly decreased the production time required for the 15-inch pipe installation.



Figure 8. Power supplied from reception shaft to drive the auger flights installed in step 2

#### 4. CONCLUSION

Short-term budget constraints frequently dictate the choices municipalities must make, but the First Street Lift Station Elimination and Sewer project was an exception. It presented the opportunity for the City of Sergeant Bluff, Iowa to do what was best for the short- and long-term interests of their community. While the increased cost of the PTMT approach to this project represented a 20% premium, the additional expense was evaluated and authorized to avoid disruption of major traffic patterns, protect existing utilities, eliminate the need to replace pavement that was in good shape, limit possible cost overruns and greatly reduce dewatering requirements.

The challenges that frequently occur during construction only served to validate the selection of the PTMT installation method.

- Dewatering for an open-trench installation following a record-breaking flood would have created cost overruns.
- The requirement of a construction variance from IDNR could have created an obstacle, but the analytical teamwork of the contractor, the design engineer, the product manufacturer, the equipment manufacturer, the city and IDNR insured a well-reasoned design and installation.
- The collapse of nearby sections of a pipeline created the opportunity to efficiently replace an aging section of the system

In addition to addressing the kinds of challenges that are common on any project of this size, the creation of a new piece of equipment made the installation of pipe even more efficient and helped to make this a remarkable project.

## **5. REFERENCES**

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