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Pipeline Project
12" Natural Gas Transmission Line Replacement

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ENGR 491 – Senior Design



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ABSTRACT

The purpose of this project was to design a gas transmission pipeline that met all federal and local requirements in the most efficient and cost-effective method available. For this project, played the role of a client by providing information regarding the existing conditions of the pipeline, the desired specifications of the new pipeline, the rules and regulations that must be met, and survey data for the selected travel route. University of Southern Indiana students played the role of an independent design firm as well as an independent contractor. The students created a geometric design for the pipeline, a construction plan, and a construction estimate.

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12” GAS TRANSMISSION PIPELINE

INTRODUCTION

The scope of this project includes a summarization of all facets associated with gas transmission pipeline design. The first step in design was to examine the existing conditions and select a travel path for the new pipeline. After the travel path was selected the next step was to research and determine what laws and regulations applied to this project. Once appropriate rules and regulations had been obtained the pipeline was created in Civil 3D. Following the creation of the pipeline in Civil 3D the next step was to create a construction plan by evaluating the constructability of the project. The final step of the project was to construct a detailed and accurate estimate for the overall cost of the project, both the cost incurred by the contractor and cost to the client.

1.1 NATURAL GAS NEED

The need for natural gas is used for many reasons such as heating and electricity. In 2021, natural gas was used about 30.66 trillion cubic feet of natural gas which makes up to around 32% of the United States total energy consumption. Here in the United States, there are 5 different sectors that natural gas is used in: electric power, residential, transportation, industrial, and commercial.

1.1.1 Electric Power

The electric power sector uses natural gas to generate electricity and produces thermal output. In 2021, the electric power sector was around 37% of the total natural gas consumption in the United States. While much of the electric power that is produced is also used in many of the other sectors that use natural gas.

1.1.2 Residential

The residential use of natural gas is used for many of the common needs of the United States population. These are used to heat buildings, heat water, cook, and dry clothes. Approximately about half of the homes in the United States used natural gas to heat spacing and to heat water.

1.1.3 Transportation

The transportation sector uses natural gas as fuel for many compressors throughout pipeline systems. In vehicle transportation, natural gas is either in the form of compressed gas or liquefied

gas. Nearly all the natural gas that is used is used in private vehicle fleets or is in the government.

1.1.4 Industrial

In industrial sector uses natural gas for many different purposes. Mostly for the process of heating (combined heating and power systems), produce chemicals, fertilizer, and hydrogen, and lease and plant fuel.

1.1.5 Commercial

The commercial sector is very similar to the residential sector for uses such as heating, lighting, cooking, and outdoor lighting. Another use for natural gas in the commercial sector is refrigeration and other cooling equipment.

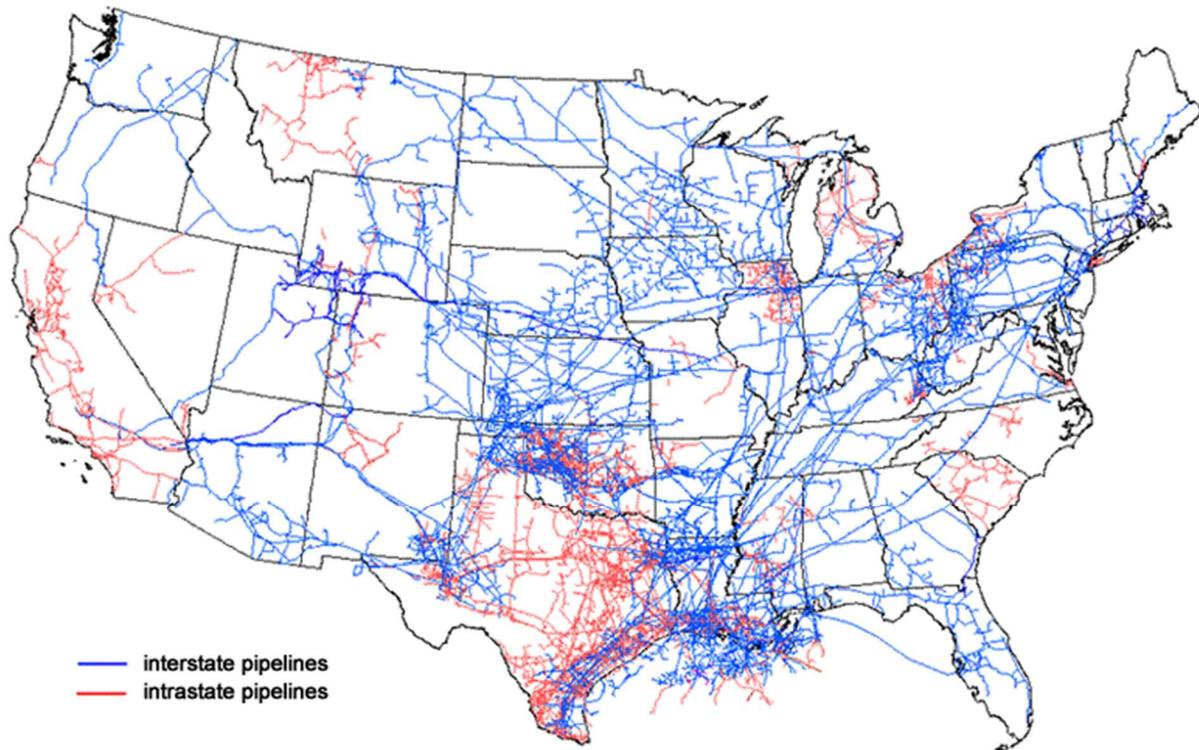
1.2 HISTORY OF PIPELINE OF GAS

The use of natural gas was used much earlier than most people realized. The first recorded use of natural gas was recorded back in approximately 1000 B.C. was used in Greece and 500 B.C. the Chinese started using bamboo pipelines that would transport gas that would seep through to the surface where they would boil sea water to be drinkable. Around the late 1700s, the British would use natural gas. This was produced from coal to light houses and streets. This was later used in Baltimore around 1816 to light streets with natural gas. In 1836, Philadelphia created the first natural gas distribution company, and today is one of the largest and longest operating public natural gas pipeline systems in the United States.

1.3 TODAY'S NATURAL GAS PIPELINE NETWORK

Today natural gas pipeline is used throughout all the United States. Approximately 99% of the natural gas used in the United States comes from North America. It is playing a crucial role in attaining cleaner environmental goals. Natural gas supplies over half the energy that is consumed by residential and commercial customers. Across the United States there is approximately 210 natural gas transmission pipelines that total more than 305,000 miles of interstate and intrastate pipelines. Among the states, Texas is the biggest user with around 58,588 miles of pipeline running throughout the state.

Map of U.S. interstate and intrastate natural gas pipelines



Source: U.S. Energy Information Administration, *About U.S. Natural Gas Pipelines*

Figure 1: United States Natural Gas Transmission Network

1.4 REGULATION

Natural gas regulations have always been regulated by the state and local governments. In 1938, the United States were concerned with the rising power of the natural gas market and would soon pass the Natural Gas Act. This act would regulate the market to make sure that companies would not charge higher competitive prices. The US DOT Office of Pipeline Safety (OPS) are the administrators. They are the administrators of the national regulatory program that ensures the safety and environmental transportation of all forms of natural gas. The Federal Energy Regulatory Commission oversees reviewing and authorizing operations of natural gas pipelines which are usually interstate. Intrastate pipelines, which are pipelines that run from one state to another, are regulated by the state government.

1.5 SAFETY

There have been many fatal accidents that have occurred with natural gas explosions. Due to this natural gas has a strict set of laws that must be followed so that it keeps the public and environment out of dangerous situations. It is always a top consideration when designing, constructing, and use of natural gas transmission lines.

2 PROJECT BACKGROUND

The background of this project is mainly centered around the replacement of aging infrastructure. Gas transmission lines serve a vital purpose to maintaining any cities infrastructure, the pipeline selected for this project plays an especially vital role for the city of Evansville because it moves gas from storage fields on the west side of Evansville to the east side of Evansville. The Pipeline being replaced was installed in the 1950s and needs to be replaced for several reasons such corrosion, flow demand, and outdated techniques used to construct the pipeline. The largest concern about the old pipeline is safety, since the pipe normally operates at pressures more than 500 psi. As part of Modernization program this pipeline needed to be replaces as soon as feasible. There are also time constraints associated with this project because of the increased natural gas usage during the winter, this project must be completed in a timely manager.

2.1 EXISTING CONDITIONS

As previously stated, the purpose of this project is to replace an existing pipeline. The existing pipeline runs across the city of Evansville from the Oliver gas storage field on the west side of Evansville to a gas purchasing point on eastside of Evansville. The existing pipeline is one of the main feeds of natural gas for the city of Evansville and during the summer months it is used to flow gas to the storage fields where it is stored until it is needed during the winter months. The existing pipeline's location runs through multiple geographic settings. These include urban settings, farm fields, utility easements, and road easements. The pipeline that is currently in service is classified as a class 3 gas transmission line and conforms/meets all appropriate regulations as such. The existing pipeline is a part of aging gas transmission infrastructure.



Figure 2: A pipeline ruptured along longitudinal weld.

The pipe was installed around 1954 using construction practices and materials that are now outdated. The existing pipeline consists of pipe manufactured using Electric Resistance Welding (ERW). Although this technique is used today in pipe manufacturing, in the past the method produced pipes prone to deteriorating with age. The line being replaced has several highly corroded areas that were of concern but the driving factor that warranted the replacement of the pipeline was from crack-like defects that were discovered. These defects are thought to be from incorrect manufacturing. These defects can lead to rupture failures and require immediate depressurization of the pipeline. The parts of the pipeline with the most concerning defects were prioritized for replacement first. They went under construction and were finished in 2022. This project is the replacement of the existing pipeline not replaced last year and the project construction will begin in March of 2023.

3 PIPELINE DESIGN PROCESS

3.1 TRAVEL WAY SELECTION

The first step in the pipeline design process is travel way selection. This process decides where the pipeline runs and is controlled by several key factors. Safety is obviously the first concern of any project and pipeline design is no different. The very first step was to draw a line between the two points the pipeline needed to connect. After this straight line had been created, obvious adjustments were made to prevent the pipeline from running into buildings, paved parking lots, and any other obvious obstructions that would inhibit the installation of pipeline. This process was greatly simplified thanks to the existence of the old pipeline, and it was decided to place the old pipeline in the same horizontal alignment of the old pipeline whenever feasible. Top priorities for the travel way selection are listed below.

Safety: Safety is always the paramount consideration when designing a pipeline and selecting a travel way. It is obvious that a pipeline location is one of the largest factors that would determine the effects of an explosion or other related disaster. When selecting the pipeline travel way, every effort was made to avoid areas with much housing. In addition to this, many other factors were considered when selecting the travel way. Structures such as churches, hospitals, and event centers are of special concern because of the impact that a disaster would have on these, and the number of people involved.

Serviceability: Although the pipeline is built to last a minimum of 80 years it is quite likely that at some point the pipeline will need to be serviced. The selection of the travel way keeps the pipeline in the most accessible locations possible. Road right of ways are generally avoided whenever possible due to the issues that arise with working near or on roads but are still quite frequently used in the interest of cost mitigation.

Cost Mitigation: As with any engineering project, cost mitigation is a very important aspect of design. When designing a travel way for the pipeline pre-owned easement and undeveloped land are always the most preferred setting. If these are unattainable, then public easement along roads is considered.

Ease of Construction: A large consideration in the pipeline design is creating a travel way and design for efficient construction. The construction of a pipeline involves lots of large machines that must be transported, moved around, and stored at the project site. Because of these, things

such as the number of road crossings, ditch crossings, and railroad crossings are minimized as much as possible. All these situations add complexity and additional cost to the project.

3.2 PIPELINE CLASSIFICATION

To begin planning the pipeline it was necessary to classify the pipeline per [redacted] lists four separate pipe classifications with the following Criteria.



Figure 3: Pipeline Classification Criteria

Based off these criteria the proposed new pipeline would vary between classes 1,2, and 3. However, according to [redacted] policy any new pipeline be classified as at least a class 3 unless special conditions dictate otherwise. Given the largely suburban setting of the pipeline and in the interest of a conservative and safe design it was determined that the pipeline should be classified as a class 3 for its entire travel way. After the pipelines classification was determined all the appropriate specifications for the pipeline were determined and the design process was started

3.3 PROPOSED PIPELINE LOCATION

When starting the design, the first step consisted of locating the start and end point and looking at the existing pipeline that needs to be replaced. Shown below in *Figure 4*, is the proposed pipeline travel way. The travel way considered the factors that were mentioned in section 3.1.

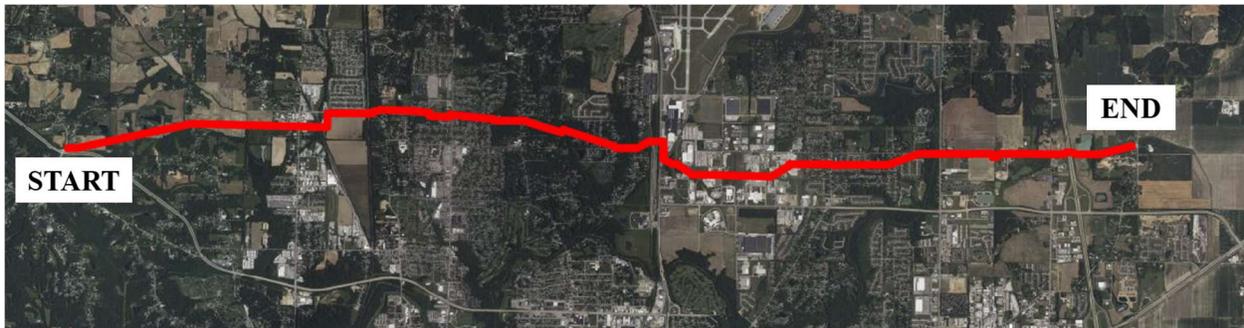


Figure 4: Gas Transmission Pipeline Travel way

In *Figure 4*, the selected travel way is shown. This travel way was selected due to its existing site conditions along the selected alignment. Things such as the number railroad crossings, roadway crossings, and creek crossings were all minimized selecting this route. Railroad crossings, roadway crossings, and creek crossings, typically require trenchless installation of pipe which slows productivity and increases cost. Another reason to avoid these obstructions is to minimize the disturbance with the nearby communities. Another factor that is considered when deciding the pipeline travel way, is the site settings. The preferred site setting is the rural area and minimizes the suburban disturbance which could slow down productivity. The selected site was the most optimal option and that is why it was chosen.

3.4 CIVIL 3D DESIGN

AutoCAD Civil 3D was used to design the gas transmission pipeline. We were given survey data that had been recorded by our client of the existing conditions. In Civil 3D the contour elevations can be developed to give 5' and 10' contours of the existing conditions which can create a surface of the survey data. These surfaces can approximate the conditions that are connected to each survey elevation. From the survey data we were given, it was split up into 4 different surfaces because certain sections of the gas transmission pipeline did not have to be replaced. The new pipeline would just tie into the existing pipeline in place. There are valves that will be installed so that the contractor will know the location of but is out of an alignment feature in Civil 3D is a tool that can be used to create profiles and cross sections. In the plan set that is attached, we were able to create surface profiles for all 4 surface areas. These surfaces represent the existing conditions. The cross sections were taken every 100' but could be taken at any point along the alignment. In our cross sections we displayed 3 different types of cutting methods: open cut, GrundoRam, and Horizontal Directional Drilling. In our cross sections, the following

are annotated: existing surface, 12” gas transmission line, 48” cut” and 60” cuts. Attached is the design plan set found in the appendix.

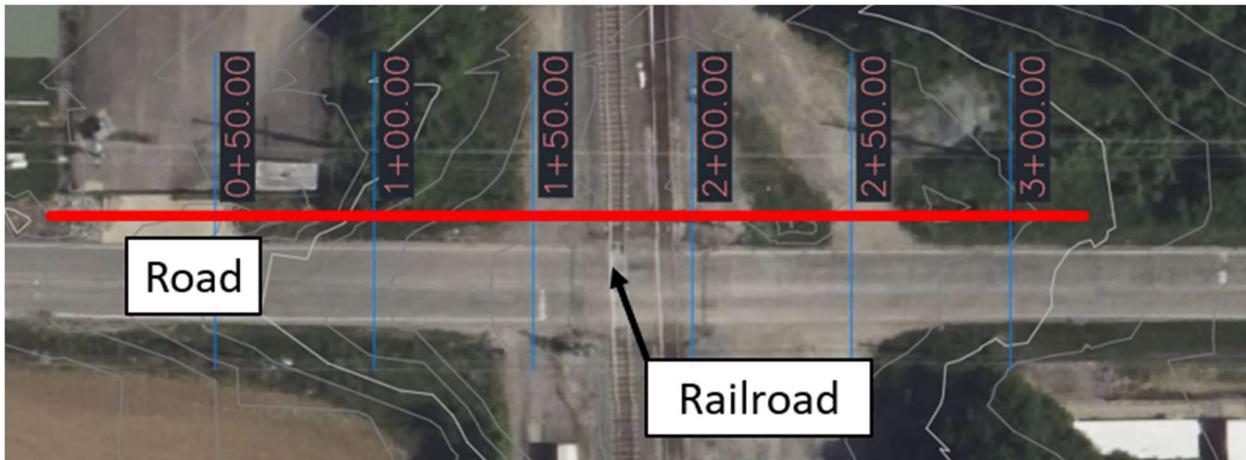


Figure 5: Alignment in Civil 3D

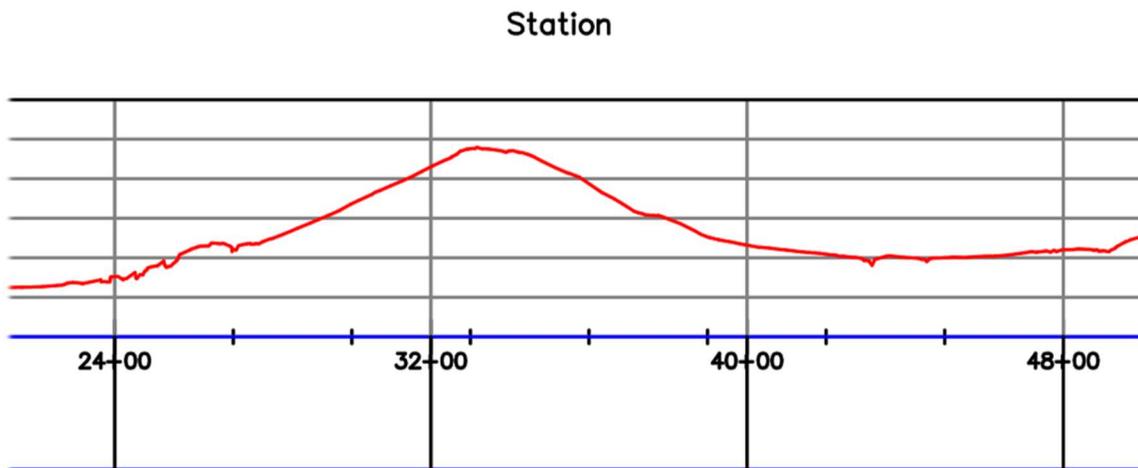


Figure 6: Surface Profile in Civil 3D

3.5 PIPELINE LENGTH

The total pipeline length is 34,853 feet that spans across all four surface areas. In our project there are two different pipeline types that will be used. The first one is just a regular 12” gas transmission pipeline that will be used for open cuts. The total length of pipeline that is used in open cuts is 29,867 feet. The second type of pipeline is used for other types of drilling excluding open cutting. This second type of pipeline is thicker and will have extra protection for the other types of drilling methods, so the pipeline will not break. The length of the second type of pipeline is 4,986 feet.

3.6 ROAD CROSSINGS

In the design of road crossings, we tried to keep them at a minimum to cut the process of other drilling methods while also keeping the costs down too. In the project there are 2 road crossings. These road crossings will use one other underground drilling method of installation. Dealing with the Indiana Department of Transportation, it was necessary to meet their specifications when it comes to road crossings because the pipeline does deal with roadways and other infrastructures. The legal depth requirement is 36” but our client has required that it be 60” in depth. (Indiana Department of Transportation, 2022), (



Figure 7: Road Crossing Example HWY 41



Figure 8: Aerial View of HWY 41

3.7 RAILROAD CROSSINGS

Our client still requires a minimum of at least 60” depth requirement for any drilling method used, but the Railroad company may have specifications that need to be met. Typically, the Railroad company will just require that the pipeline meet the existing pipeline depth for these crossings.



Figure 9: Railroad Crossings Example

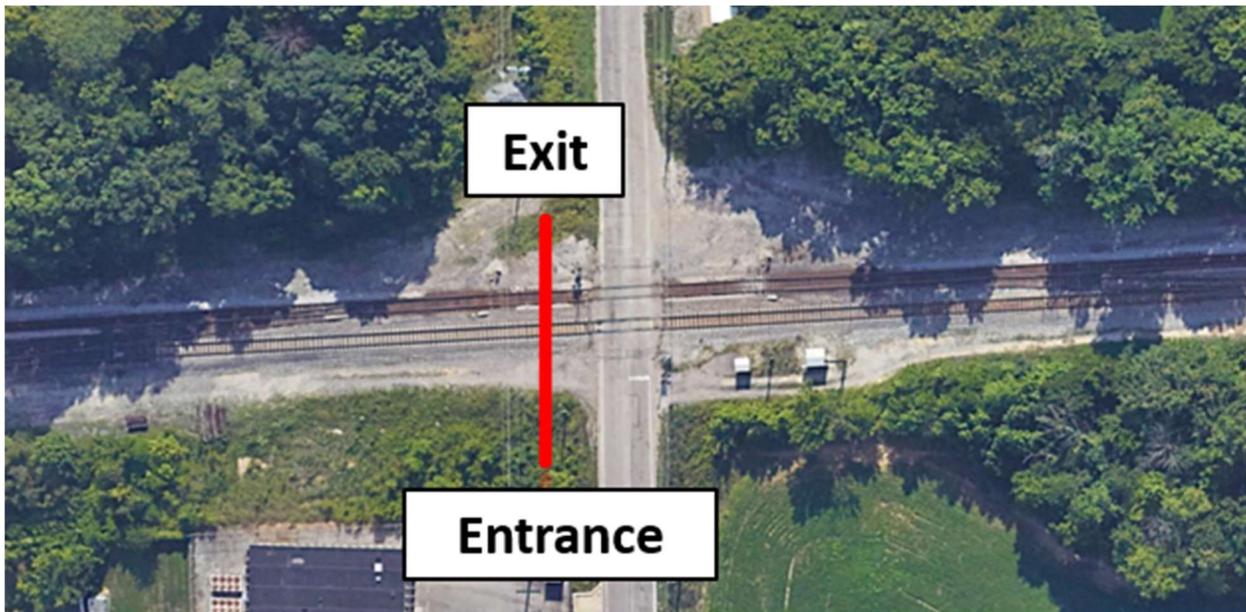


Figure 10: Aerial View Railroad Crossing

3.8 CREEK CROSSINGS

When going under a creek, we would have to meet with the city of Evansville to meet the requirements of the depth. Our client would still like 60” of cover from the bottom of the creek. The method of installation will be one of drilling methods depending on the location and method chosen. The requirement is that the creek will still need to be navigable waterway before and after installation of the gas transmission pipeline.

3.9 TIE IN STATION LOCATIONS

There will be tie in stations locations that will be used to monitor the flow of natural gas. Show in figure below shows the locations of the tie in stations. Looking at figure 11, shows the 4 tie in stations that are in the travel way selection.



Figure 11: Tie in Stations Locations

4 CONSTRUCTION ESTIMATE

A large portion of this project, beyond the project design, was to create a detailed and accurate construction estimate. Construction estimating is a very important aspect of any project because it helps the entity performing a project to be able to forecast and plan for the economic impacts of the project. A typical construction estimate can be broken into 3 separate sections: Materials, Labor, and Equipment. In the sections below each component of the estimate for this project will be discussed and the methods of estimating explained.

4.1 MATERIALS

The first step in creating the cost estimate for the project was to determine the necessary materials. This was easily accomplished by speaking with Engineers who provided all necessary information on what kind of materials would be associated with a gas pipeline. In addition to the information provided, projects constructed in the past were evaluated to provide more information on what kind of materials would be required. Once the necessary materials

were determined, the next step was to decide quantities. This was accomplished by examining the horizontal alignment for the pipeline that was determined from the project's final plan set in Civil 3D. Once the length of the alignment had been determined, the next step in determining the necessary materials was to investigate the methods of pipe installation throughout the alignment. When pipe is installed using trenchless methods the pipe's wall are unavoidably exposed to excess stress and strain than if installed using open cut methods. As a result of this, pipe that is to be installed with trenchless methods must have thicker side wall than pipe to be installed with



Figure 12: Shown above are lengths of gas transmission pipe to be installed using open cut.

open cut. In addition to this, trenchless methods also damage the pipe's protective coating and to mitigate this pipe that is to be installed with trenchless methods must be coated with extra thick and heavy-duty coating to mitigate the threat of corrosion on the pipeline. Because of these reasons, before the bill of materials could be determined it was necessary to evaluate the horizontal alignment and determine what length of pipe is to be installed with trenchless methods to determine to quantify the necessary amount of special pipe. The distance of the horizontal alignment was determined to be approximately 34,853 ft which consisted of 29,867 ft of open cut installation and 4,986 ft of trenchless installation.



Figure 13: Inductions Bends

In addition to the regular sections of pipe, the other materials required included induction bends and valves. Induction bends are required on a pipeline in any areas that require the pipe to turn in a radius that exceeds the natural flexibility of the pipe. The number and type of induction bends required on the pipeline was determined by reviewing the created plan set with a Engineer. Using the information provided by the engineer it was determined that twenty-one 90 degree or smaller bends would be required and eight larger than 90-degree bends would be required.



Figure 14: 12” ball valves to be used.

It was also determined that for a pipeline the length of the given project at least 2 valves would need to be installed. The exact location of the valves would require thorough research into the existing pipe network and thus was deemed beyond the scope of this project. For the pricing of all materials provided the most recent projects’ bid information that included details and cost for all materials. These prices were updated to account for inflation and then directly

used. Shown below is the final bill of materials for the project. The bill of materials for this project is simplified beyond a typical bill of materials for a similar project and this is because there are factors and materials typically included for things such as nearby stations or separate projects. These were deemed outside the scope of this project and thus they were ignored. See Appendix A for an example of a far more complicated bill of materials.

Material Details					
Quantity	Unit	Item	Unit Cost	Total Cost	Description
29867	FT	Pipe	\$ 35.14	\$ 1,049,526.38	12",0.250, X60, ERW, DRL, 14-16 mils FBE
4986	FT	Pipe	\$ 67.37	\$ 335,906.82	12",0.312, X52, ERW, DRL, 14-16 mils FBE/30 mils Powerecrete
-	FT	Pipe	\$ -	\$ -	N/A
-	FT	Pipe	\$ -	\$ -	N/A
-	FT	Pipe	\$ -	\$ -	N/A
2	EA	Valves	\$ 17,358.83	\$ 34,717.66	Typically WeldxFlange
-	EA	Valves	\$ -		
-	EA	Valves	\$ -		
8	EA	Bends < 90 deg	\$ 1,970.00	\$ 15,760.00	-
21	EA	Bends > 90 deg	\$ 2,740.00	\$ 57,540.00	-
-	N/A	Misc.			
-	N/A	Misc.			
Total Material Cost			\$ 1,493,450.86		

Table 1: Materials Details

4.2 CREW

The next key component to creating the construction estimate was to determine the necessary crew required to complete the work. This was done by viewing historical records from similar jobs completed in the past and investigating the crews required for these past projects. In addition to this, Engineers and contractors were consulted and provided valuable information for crew make up. The determination of the crew was split up into labor and equipment. The sections below discuss the composition of both.

4.2.1 Labor

To determine the appropriate labor that would be required for this project, crew information was supplied from a similar pipeline project that was completed in 2021. This past project provided much valuable information but did require updating to wages to account for inflation. In addition to being required to be updated due to inflation some editing for the given crew was required because the scope of the project being used to collect information from was smaller than the

project being estimated. The required changes consisted of adding several additional laborers per Engineers recommendation.



Figure 15: Welding on Gas Transmission Pipeline

A pipeline construction laborer makeup typically consists of a relatively typical crew of any other construction project. General laborers, equipment operators, and drivers make up most of the crew. However, there are several types of laborers that are specialized in gas pipeline construction. These areas of specialty include pipeline welders, pipeline welders' helpers and hydro testing technicians. Pipeline welders work similarly to other types of construction welders however they are specifically trained and adapt at working in the field in many different conditions. They are highly skilled laborers and are often the most expensive laborers on a job site. In addition to the cost each welder as a laborer, each welder will have his own welding rig and for each unit the welder charges for the project, he will also charge an additional rig fee. More details on the welding rig can be found in the equipment section below. Welder helpers are assistance to the welder, they help prepare the pipe for welding as well as help the welder set up inspect welds and coating over the welds after the welding is completed. The hydro test technicians are individuals who specialize in completing hydro tests on pipelines to ensure their integrity they are typically only on a job site for one day to complete a 12-hour pressure test typically a hydrotest crew consists of a single hydrotest Forman who instructs laborers what to do during the hydro test. The rates for each kind of laborer were provided from the past project, except for being adjusted for inflation where directly used. The figure below displays the

expected title of all laborers present for this project, the number of each type of labor, their hourly rate. The original crew that was modified for this project can be found in Appendix B.

Crew Details					
Title	Unit	#	Cost per Unit	% of Project Duration	Total Cost
Labor Foreman	hr	3	\$ 36.91	100%	\$ 149,198.55
Laborer	hr	8	\$ 29.36	100%	\$ 316,479.32
Welder	hr	3	\$ 80.69	65%	\$ 212,008.67
Welder Helper	hr	3	\$ 29.56	65%	\$ 77,667.32
Superintendent	hr	1	\$ 152.95	100%	\$ 206,086.14
Operator	hr	4	\$ 52.11	100%	\$ 280,853.84
Testing Foreman	hr	1	\$ 67.25	Only needed for 12 hours	\$ 807.00
Truck Drivers	hr	2	\$ 51.09	20%	\$ 27,535.64

Table 2: Crew Details

4.2.2 Equipment

The process of determining what kind of equipment would be necessary to complete this project was done to find the necessary labor. Information provided to determine labor also included information about equipment typically used on a project of this scope. As with the labor information costs were updated to reflect current fuel prices as well as inflation. A few additional pieces of machinery were also added to reflect the large scale of this project. All divisional equipment was added to the estimate at the recommendation of industry professionals.



Figure 1616: Side Boom

For the most part this project utilizes standard machinery for any construction site such as excavators, heavy duty trucks, skid steers, pickup trucks, etc. Some specialty equipment was required for this project, and this included the use of side booms, Welding rigs, and hydro test equipment. A side boom is a specialized piece of equipment used specifically for stringing and lowering pipelines into an open trench. A side boom is created from a modified bulldozer where the blade is removed from a large bulldozer and a can't delivering sidearm is attached. No specific information was available for the operational cost of a side boom and so operational costs of a typical bulldozer were used in the estimate with a small amount of additional cost to reflect this specialization of the equipment.



Figure 1717: On site Truck

Welding rigs are specialized pickup trucks used by pipeline welders who do well text the pipe together. They consist of a regular one-ton light duty truck outfitted with a specialized bed that contains the welding machine as well as any other additional materials and supplies required by the welder. They are billed at an hourly cost. cost information for the welding rigs was directly provided in the information attained from previous projects and after being modified for inflation or directly used.



Figure 1818: Hydrotest Equipment

The hydrotest equipment consisted of a hydro test pump and trailer. This equipment is used to pressure the pipeline up with water after it has been built and verified its safety. Cost information regarding the hydro test equipment was also modified for inflation and directly used. The figure below displays the expected type of equipment present for this project, the number of each type of equipment, and their cost rate. An example crew can be viewed in Appendix B, this crew was heavily modified for this project.

Equipment Details					
Title	Unit	#	Cost per Unit	% of Project Duration	Total Cost
Excavator	Week	2	\$ 5,123.98	100%	\$ 209,214.99
Bulldozer/Side Boom	Week	2	\$ 5,632.79	95%	\$ 218,490.48
Skid Steer	Week	2	\$ 3,675.32	100%	\$ 150,065.38
Welding Rigs	Hourly	3	\$ 44.30	70%	\$ 1,899.23
Pick-up Truck	Hourly	4	\$ 29.60	100%	\$ 2,417.17
HD Truck and Trailer	Hourly	2	\$ 79.63	5%	\$ 162.57
Hydro Test Equip.	Daily	1	\$ 356.20	Only needed for 1 day	\$ 356.20

Table 3: Equipment Details

4.3 PRODUCTIVITY PREDICTION

A major component of cost estimating is determining expected productivities for all tasks associated with the project. It is vital that productivity be accurately estimated to create an accurate estimate. Productivity prediction plays the largest part in predicting the overall cost of the project because the project's duration will be based off the expected productivity for each task. This duration will be the basis the entire estimate is built off. The typical approach to creating a

construction estimated for each project is to break the project up into all the tasks associated with the project and project productivities and durations for each individual task. Once this has been completed the productivity and duration for each specific task is then predicted and the crew created and assigned for this task. From this information the complete cost for that specific task is created. This process is very effective and is commonly used on many projects that consist of many different tasks such as a construction project of a bridge or building where many separate tasks exist and there is little overlap in the tasks. Given the background of this project this typical method of estimation was not used because the tasks associated with gas pipeline construction are repetitive and predictable. It was indicated to the students building the estimate that the industry standard for creating cost estimates for a pipeline installation would be based off evaluations of similar projects completed in the past. From these evaluations it is typical to create one productivity for all the work and tasks associated with the project. This method of “lump sum” productivity was utilized for the construction estimate. To accomplish these 8 individual projects that help already been completed sorry valuated. Of these eight projects only five were found to have direct overlap with the current project sharing similar scope and work. For each of these five projects the details of the entire project were analyzed and investigated, and these details were correlated to the overall duration and thus the productivity of the project. Many details were investigated about each project, some of these included the percentage of work being completed in general or suburban areas as well as the amount of pipe being installed via open cut methods or trenchless installation. In addition to these other aspects such as the time review the project was completed the number of row crossings railroad crossings and Creek crossings the amount of station work involved within the project were all recorded and correlated do the duration and productivity determined for the project. Information was provided from that an ideal productivity for a pipeline construction project would be 350 feet per day and that reduction factors would be applied to this to find the expected productivity of a given project. The figure below contains all the project details for predicting duration.

Project Construction Details				
Item	unit	Options	Inputs	Productivity Factors
Location:	%	Suburban	45	0.9375
		Rural	65	
Installation Method	%	Open Cut	84	0.9635
		Horizontal directional Drill	13	
		GrundoRam	3	
		Jack and Bore	0	
Station Work	#	Provide #	0	1
Road Crossings	#	Provide #	2	x 1 day
Creek Crossings	#	Provide #	1	x 2 days
RR Crossings	#	Provide #	2	x 1 day
Pipe Diameter	in	-	12	1 for 12"
Pipe Class	-	Class 1,2,3 or4	class 3	1
Weather Factor	-	0.65-1.0	May-Sep.	0.9
Project Specific Details	-	-	-	-
Six days should be added to schedule and Final Productivity Factor = 0.813				

Table 4: Project Construction Details

Once the details of the project had been thoroughly analyzed it was determined that there would be a reducing factor of 0.833 to the project productivity and given the number of Creek and road crossings there would be an additional six days added to account for mobilization around objects. Using the reduction factor of 0.833 it was determined that expected productivity would be **285 ft per day**. This productivity, with the addition of the 6 additional workdays required for crossings produced an expected duration of **122 workdays** or **20.4 weeks**. The calculated productivity is very reasonable when compared to other projects calculated productivity. The figure below shows this project's productivity, shown in red, compared to the other project's productivity, shown in blue.

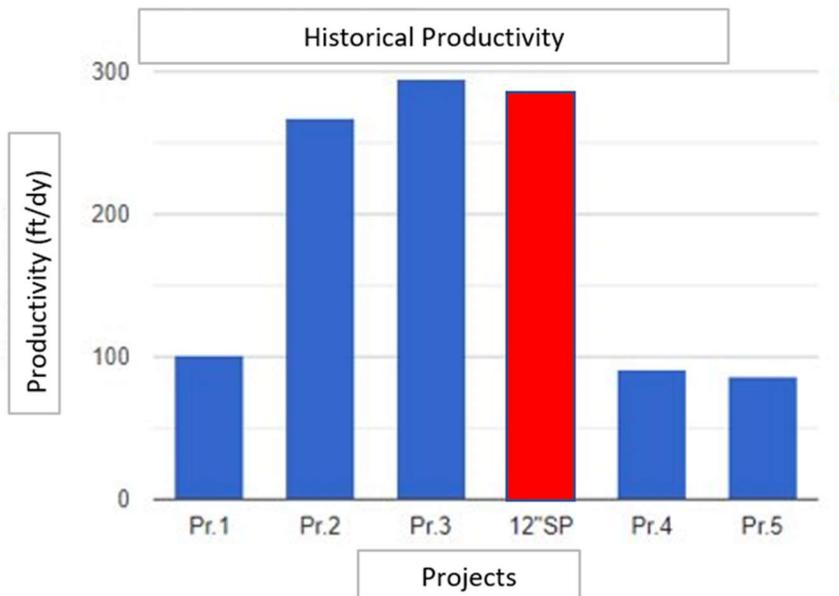


Table 5: Historical Productivity

It can be noticed that two of the projects have significantly larger productivity than the other three. The reason for this is that smaller projects are less efficient than larger projects because a larger percentage of the projects overall duration is spent on mobilization and project setup. Of the 5 projects analyzed, 2 were larger projects (over 25,000 ft) and 3 were smaller (projects under 10,000 ft) and this explains the large difference in productivity. The calculated productivity of this project falls between the productivities of the larger projects. This indicates the calculated productivity is reasonable.

4.4 OVERHEAD, PROFIT, AND CONTINGENCY

Once all the direct cost items such as labor equipment immaterial had been determined the next step in creating the estimate was to determine the correct percentages to be marked up to account for profit overhead and contingency. The first item investigated was overhead which was split up into job office overhead and home Office overhead. In order to determine both job office overhead head and home Office overhead engineers were consulted, and they provided information about an acceptable range for overhead as a total. They instructed that the typical overhead range would be between 5 and 10% further discussion indicated that 8.5% would be a reasonable number for overheads. This total of 8.5% was split up into job office overhead and home Office overhead. Job office overhead covers all costs to the contractor associated with maintaining a job office as well as infield staff. Since pipeline construction has a heavy job office presence most of the overhead was placed under job office overhead. Job office overhead was determined to be 4.5%. Home Office overhead is used to cover all costs associated with a contractor's home office costs that include building maintenance building staff and office supplies and materials. Pipeline construction contractors typically do not have a large home office presence and so only 4% of overhead was placed under home Office overhead. The next step was to determine the necessary profit that would need to be earned with this project. This was accomplished using a spreadsheet developed by the government that considers many different aspects of a project. Considerations of this spreadsheet include degree of risk difficulty of work size of job and so on.

Profit	JOOH	HOOH	Contingency	Total
7.18%	4.50%	4.00%	5.00%	20.68%

Table 6: Overhead Percentage

After careful consideration inputs for each factor were used and the final percentage markup for profit was determined to be 7.18%. When [redacted] engineers were asked about this figure, they instructed that it seemed reasonable. The last estimate markup to be considered was contingency. Contingency is a way for a contractor to mitigate their risk when placing a bid and its purpose is to cover costs that are unforeseen or unexpected. Things such as miscalculated productivities or unpredictable setbacks can have a heavy impact on a contractor if not accounted for and contingency seeks to mitigate this risk. [redacted] engineers were once again consulted for advice on what contingency percentage would be typical for a pipeline construction project. They instructed that it could vary widely depending on the size of the job with larger jobs having smaller contingencies. Based off the information provided it was determined that a reasonable contingency would be 5% and this is what was used for the construction estimate.

Final Cost and Estimate

Once the overhead, profit, and contingency have been calculated the final step in the estimate was to calculate the total direct cost to the contractor performing the work. The table below displays the costs associated with each category of direct cost to the contractor performing the project's construction.

Contractor Cost Summations	
Material	\$ 1,862,000
Labor	\$ 1,271,000.00
Equip.	\$ 583,000.00
Total	\$ 3,716,000.00

Table 7: Contractor Cost Summations

Once the direct cost of the project was known, the necessary adjustments for profit, overhead, and contingency were added. Shown below are percentage and dollar amount mark-ups applied for each of these.

Profit, Overhead, and Contingency		
Title	Percent	\$
Profit	7.18%	\$ 321,747.31
JOOH	4.50%	\$ 201,792.74
HOOH	4.00%	\$ 179,371.32
Contingency	5.00%	\$ 224,214.15
Total	20.68%	\$ 927,000

Table 8: Profit, Overhead, and Contingency

By adding these markups to the constructors, the complete cost estimate can be completed. The final cost for the project is shown below.

Final Cost for Project Bid:
Complete Construction Estimate = 3,716,000+927,000 = \$4,484,000
Cost per Foot = \$128.65

Table 9: Final Cost

As shown above, the total amount that would be billed to the client for this project is **\$4,484,000**. This corresponds to a cost of **\$128.65 per foot**, the cost per footage is what would be used on the construction contract to mitigate any issues with miscalculated pipeline length. It is also industry standard to use a cost per foot in contracts in case additional work is needed it can be simply added using the pre-negotiated price. The cost of \$128.65 per foot appears to be reasonable and within the range of typical cost for a project of this type.

5 CONSTRUCTION DESIGN

A vital part of any construction project is to have a plan for how the actual work will be completed. Many projects can have complicated tasks that must be completed but horizontal construction lends itself toward more repetitive construction processes. During the construction design process all construction design was completed in accordance with

The existing conditions and background of this project add some degree of complexity because of the many settings the pipeline runs through. However, there are only 4 main methods used for pipeline installation. Each of these techniques will be evaluated below.

5.1 OPEN CUT

Open cut is typically the most used method for pipe installation. The reason for its widespread use is because it is typically the fastest and cheapest method for installing pipelines. This is because multiple operators can be running excavators and creating trench for the pipe. While this is happening, it is typical for the rest of the pipeline crew to string the pipe out alongside where the trench is and where it is going to be and weld the pipe and get it completely ready to go into the ground. Once the trench is complete the pipe is then lowered using special equipped bulldozers called side booms. Whenever possible, open cut technique will be used because of its economic and speed. In addition, open cut is highly advantageous in the area of corrosion prevention since the pipe is simply being lowered in there is less chance for there to be nicks in the protective coating put on pipelines and all welds are coded in special protective epoxy. After the pipeline is laid inside the trench the next step in the process is to backfill and then restore the ground surface. Typically backfill is completed using an attachment called a Harley rake on the front of a skid steer and is completed very quickly needing only one machine and one operator. Once the back of the trench has been completely backfilled it is then compacted, and the last step is to come back and seed the pipeline to ensure erosion control. Some of the limitations for open cut are that it is only a viable option in areas with unobstructed ground surfaces making it not a good choice for many suburban applications or in areas with high environmental consequences. In areas where open cut is not a viable option the method that must be used is one of the trenchless installation options. These will be discussed in further detail in the following section period. For most of this project open cut will be used. **Approximately 84% (29,277 ft) of the pipeline will be installed using open cut.**



Figure 1919: Open Cut Method

5.2 HORIZONTAL DIRECTIONAL DRILLING

The horizontal directional drill is the primary method used for trenchless installation of pipes. The process of horizontal drilling begins with the boring of a pilot hole this is drilled by a horizontal drilling machine that essentially a drilling rig that can drill horizontally and is completely directional meaning that it can be controlled with precision to take a selected path.

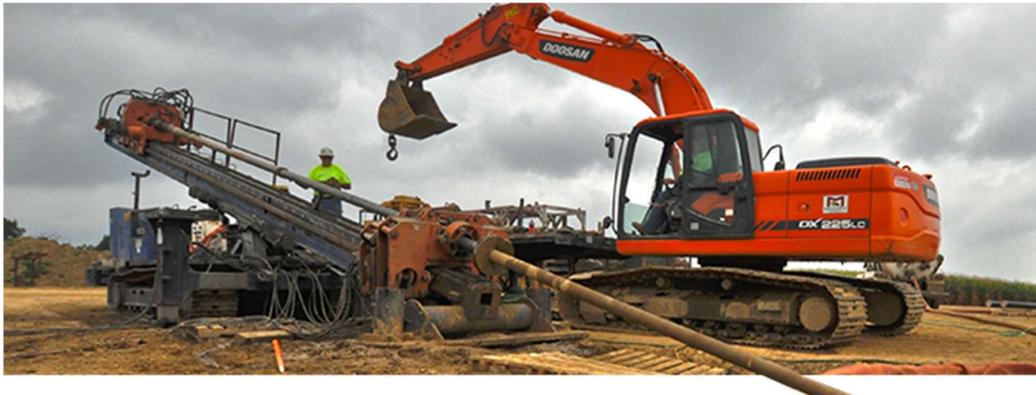


Figure 2020: Horizontal Direction Drilling Method

Once the pilot hole has been drilled for horizontal drill the next step is to complete a process known as reaming. During the reaming process the pilot hole initially being only a few inches in diameter is then widened and expanded to the appropriate diameter for the pipe in the case of this project 12 inches.

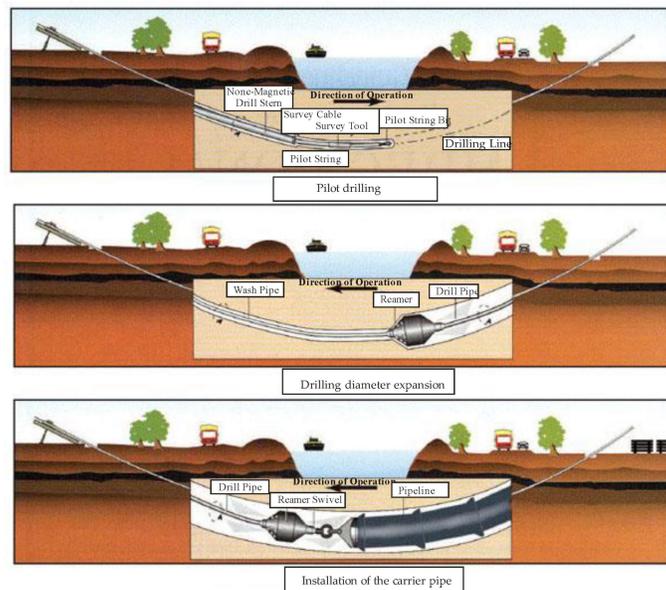


Figure 2121: Horizontal Direction Drilling Process

Once the pipe hole has been reamed out to the appropriate diameter the next step is to complete what is known as the pullback during the pullback the pipe that is to be installed as welded to a cap and pulled through the hole via a cable. horizontal drilling is one of the cheapest methods per foot to complete for pipeline installation because it is completely directional and controllable. It is the best option for large installations of trenchless pipe. one of the limits some of the limitations for horizontal directional drills include spatial requirements and environmental consideration for a horizontal drill to work correctly it must get down to the appropriate depth before going completely horizontal this can present problems in areas with tight spatial restraints because the pipe when it is installed has restraints on the diameter of bin that it can withstand and before the pipes material integrity is compromised. In addition to this when drilling a constant circulation of drilling mud is maintained through the borehole to carry the cuttings that are in the drill out during in some soil settings this can result in what is known as a frack out in which the drilling mud erodes through the soil to the surface not recirculating back to the original drill point. Despite these issues the horizontal directional drill is by far the most common method of trenchless installation and is used in numerous places throughout this project shown below are some of the crossings we will horizontally drill and the cross sections for such. Because of its versatility and cost effectiveness, most trenchless installations for this project will be completed with horizontal directional drilling. Approximately 13% (4531 ft) of the entire pipeline is to be installed using horizontal directional drilling. **Horizontal directional drilling makes up over 80% of the trenchless installation for this project.**

5.3 JACK AND BORE

The next type of trenchless installation pipeline is known as Jack and Bore. The Jack and Bore technique is a trenchless method of installation that consists of horizontal auger mounted on a track that bore a horizontal hole for the pipe to travel through. The auger is placed in the pipe that is being installed and the forward pressure is applied to the auger and pipe. As the auger turns inside the pipe, the boring cuttings are removed through the pipe. The figures below illustrate the jack and bore process. Jack and Bore is typically used in areas where a horizontal



Figure 2222: Jack and Bore Method

directional drill cannot be used to do spatial constraints or to do due to economic consideration. As previously mentioned, horizontal directional drills are usually the preferred method of trenchless installation however in certain settings it is not feasible to complete a drill either due to spatial requirements or in some cases economical requirements. Jack and bore has no kind of directional control and so it can only be used in applications where directional control is not needed. Typical examples of this would include railroad crossings or road crossings or any surface obstruction that is less than approximately 50 feet across. Jack and bore can also be very cost effective when compared to horizontal directional drills because Jack and Bore requires less specialized pipe. During trenchless installation specially coated pipe with thicker side walls must be used to mitigate the stress and strain placed on the pipe during construction. This special kind of pipe costs much more than typical pipe and since a horizontal drill requires more length to get down to the necessary depth, Jack and Bore can be much more cost effective in certain circumstances. Although very useful in some applications, **jack and bore will not be used in the construction of this project.** There were several areas where jack and bore were heavily

considered to be used, however, since the new pipeline is replacing an existing pipeline, it was determined that a Grundo Ram would be a better option.

5.4 GRUNDORAM

Grundo ram is the final method of trenchless installation that we will consider for this project. This is relatively new technology and works off the basic principles of a horizontal jackhammer. The way the method works is by new pipe into the existing hole used by the old pipe. The GrundoRam itself is a pneumatic air hammer that operates off compressed air. The process in the new technique, like a jack and bore, requires two pits to be dug on either side of the crossing. Then the new pipe is welded to the back of the existing pipe and then the Grundo Ram hammers out the old pipe and installs the new pipe all at the same time. Grundo Ram is the preferred method for installing applications where existing pipe is being replaced with new pipe because it is faster to install pipe via Grundo Ram than to bore a new hole for the pipe. Because it only excels in replacing existing pipelines the use of a Grundo Ram is relatively limited. However, since this project is replacing an existing pipeline, it was determined that Grundo Ram would be a good choice to use at several road and railroad crossings. **Approximately, 3% (1046 ft) of the entire pipeline is to be replaced using Grundo Ram.** The method of Grundo Ram makes up just over 18% of the trenchless installations of the project.

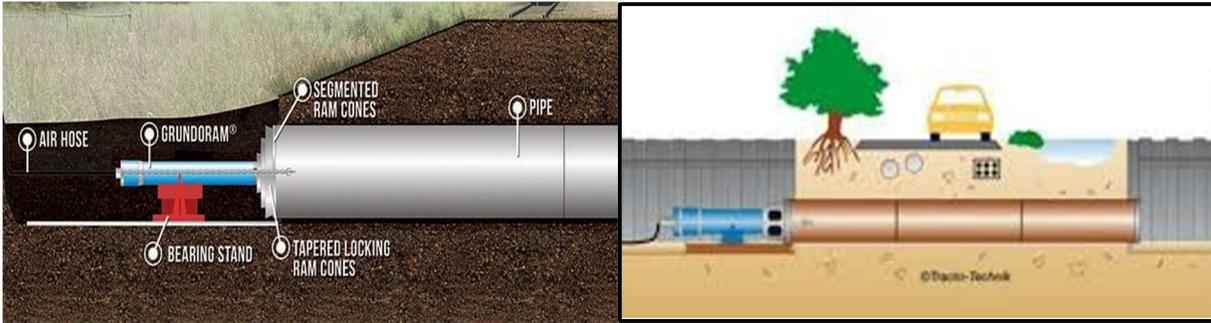


Figure 2323: Grundo Ram Method

6 DESIGN CONSIDERATIONS

6.1 PUBLIC HEALTH, SAFETY, AND WELFARE

The health, safety, and welfare of the public are of top consideration for this project. It will come as no surprise that a gas transmission line can be highly dangerous when gas leaks or pipe failure occurs. The largest threat to the public from the project would be a gas leak leading to an explosion. Given the suburban setting for parts of the pipelines travel way, an explosion in a heavily populated area would have catastrophic affects. To mitigate all health and safety concerns every effort was made to create a design with a high factor of safety. Per

policy and in the interest of creating a conservative design the pipeline was classified as Class 3, and thus subjected to the strictest and most comprehensive rules and regulations. Every precaution was taken to avoid any possible threat of failure. When selecting the pipeline’s travel way, great efforts were made to avoid as much suburbia as possible. When assessing the necessary procurement, all materials were required to be of top quality and meet or exceed all

specifications. All these actions ensure a safe design that will not present any danger to the public.

6.2 GLOBAL

The global impact of any project should always be considered and evaluated by an engineer. The scope and purpose of this project are mainly centered around local and regional needs; however, a failure of the construction could have a global impact environmentally. To learn more about the environmental aspects of the project that could have a global impact see 6.5 Environmental.

6.3 CULTURAL

Cultural Impact of the project was investigated and analyzed. After a thorough analysis it was determined that there would be little to no cultural impact and so mitigation of cultural damage was not evaluated.

6.4 SOCIAL

Social Impact of the project was investigated and analyzed. After a thorough analysis it was determined that there would be little to no social impact and so mitigation to social damage was not evaluated.

6.5 ENVIRONMENTAL

The environmental impact of the project was investigated and analyzed. After a thorough analysis it was determined that there is environmental impact that is involved. The construction of the pipeline would disturb the environment due to the site being across many different sites: pastures, suburban, creeks, and railroads. There are certain legal requirements that must be met when crossing creeks or rivers, so that it will not disturb the natural environment setting.

Personal Reflection

This project was a very positive experience for both team members. Both students have an interest in energy infrastructure for careers, so this project was of special interest to both. This project was valuable experience for all involved regarding the planning and designing process of a construction project. Joseph Bohlen has accepted a position with constructing pipelines similar to the ones in this project. Teamwork was critical for completing this project and many valuable lessons were learned by both students on working together. This

project did present all team members with challenges, but by using critical and creative thinking all obstacles were overcome.

7 CONCLUSION

In conclusion, the purpose of this project was to create a design for a 12-inch gas transmission pipeline. In addition to creating a design, the constructability of the project was to be investigated and a detailed construction estimate determined for the project. The design for the project was completed in Civil 3D and the complete plan set for the entire alignment was completed. The four following methods of pipeline installation were investigated and researched: Open cut, horizontal directional drilling, Jack and bore, and Grundo Ram. Of these four methods investigated, only three were selected to be used in the given pipeline construction. These three include open, cut, horizontal directional, drill, and Grundo Ram. A Detailed construction estimate was created from information provided directly from _____ and a thorough analysis of similar projects completed in the past. After a parametric estimate was built that considered all the factors and details of the project. The final expected cost of the project was determined to be \$4,484,000, which corresponds to a cost of \$128.65 per foot.

REFERENCES

APPENDIX

Appendix A: Bill of Materials for Complex Project

Appendix B: Crew Information

Appendix C: Productivity Prediction

The information below is from one of the projects evaluated while creating the parametric estimate and depicts the evaluation process.

Project Details

Item	unit	Options	Inputs
Location:	%	Suburban	85
		Rural	15
Installation Method	%	Open Cut	78
		Horizontal directional Drill	22
		GrundoRam	0
		Jack and Bore	0
Station Work	#	yes, (if yes provide #)	
		No	X
Road Crossings	#	If yes, provide #	3
Creek Crossings	#	If yes, provide #	1
RR Crossings	#	If yes, provide #	None
Pipe Diameter	in	-	12
Pipe Class	-	Class 1,2,3 or4	class 3
Year Completed	-	2020-2022	2022
Months of Year	-	Jan-Dec	Sep-Nov.

Material Details

Quantity	Unit	Item	Notes
3065	FT	Pipe	Pipe for Open Cut (40 ft lengths)
590	FT	Pipe	Pipe for Trenchless Installation (40 ft lengths)
0	EA	Valves	Typically WeldxFlange
3	EA	Bends < 90 deg	-
8	EA	Bends > 90 deg	-

Crew/Equipment Details

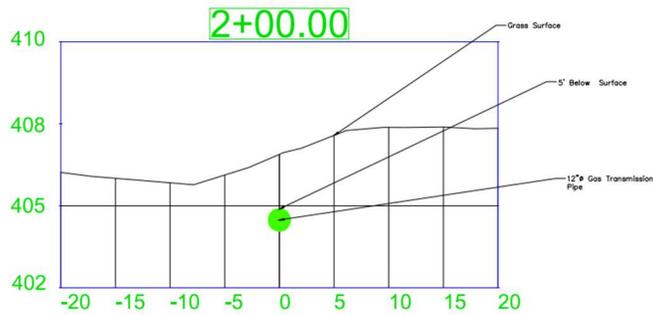
Title	Unit	#	Cost per Unit	% of Project Duration	Total Cost
Labor Foreman	hr	2	36.91	100%	\$ 33,219.00
Laborer	hr	5	29.36	100%	\$ 66,060.00
Welder	hr	2	80.69	65%	\$ 47,203.65
Welder Helper	hr	2	29.56	65%	\$ 17,292.60
Superinrendent	hr	1	152.95	100%	\$ 68,827.50
Operator	hr	3	52.11	100%	\$ 70,348.50
Testing Foreman	hr	1	67.25	Only needed for 1 day	\$ 672.50
Truck Drivers	hr	2	51.09	20%	\$ 45,981.00
Excavator	Week	1	5123.98	100%	\$ 37,148.86
Bulldozer/Side Boom	Week	0	5632.79	95%	\$ -
Skid Steer	Week	2	3675.32	100%	\$ 53,292.14
Welding Rigs	Hourly	2	44.3	70%	\$ 449.65
Pick-up Truck	Hourly	2	29.6	100%	\$ 429.20
HD Truck and Trailer	Hourly	2	79.63	5%	\$ 57.73
Hydro Test Equip.	Daily	1	356.2	Only needed for 1 day	\$ 356.20

Pipe Total	3655
Productivity	81.22222222
OC %	0.838577291
Drill %	0.161422709

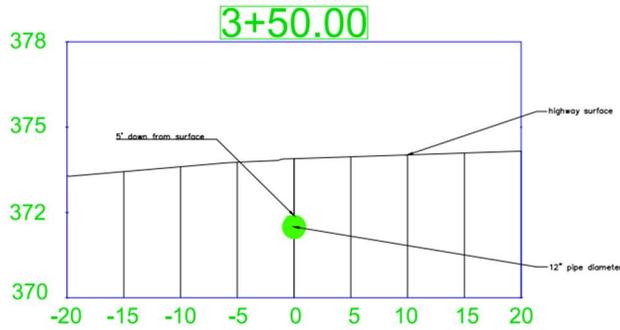
Project Duration (days)	58
Cost	\$ 441,338.52
Weeks	7.25
Work days	45
Hours per day	10

Appendix D: Design Details

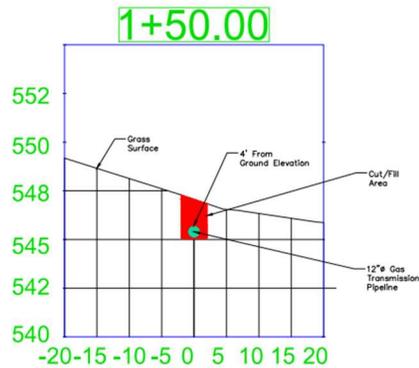
Horizontal Direction Method



Grundo-Ram Method



Open-cut Method



Notes

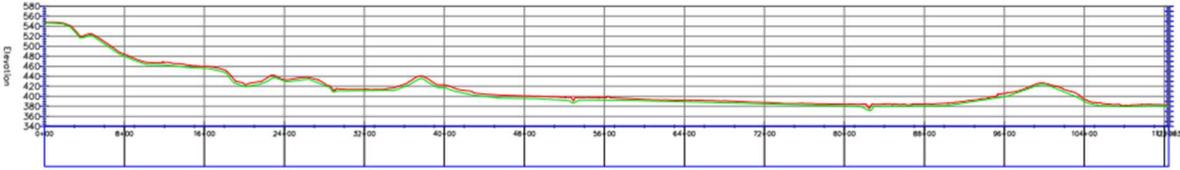
- Any grass/pasture surface out of the way of the public will be an open cut.
- The Cut/Fill area will use the same material. The area must be cut before placing pipeline, and then fill in the area with the previous soil.
- The 12" diameter pipeline will be 4' from the existing surface.

Appendix D: Design Details (continued)

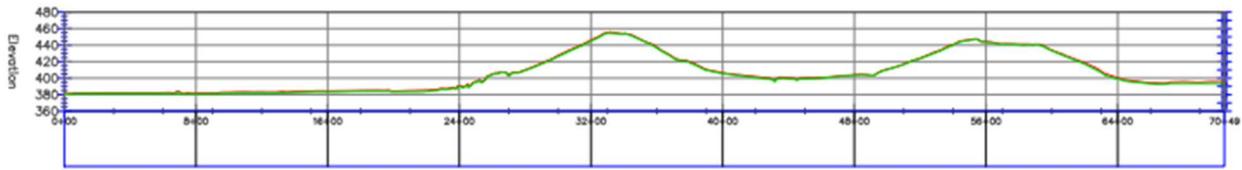
Notes

All Pipe will be 48" below surface.
Easements will vary based on conditions.
Pipe will be deeper when crossing roads and ditches.

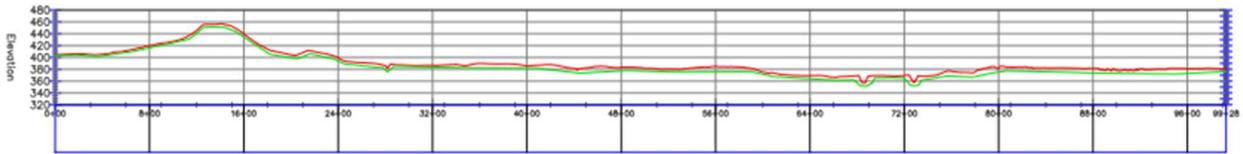
Alignment 1 PROFILE
Station



Alignment 2 PROFILE
Station



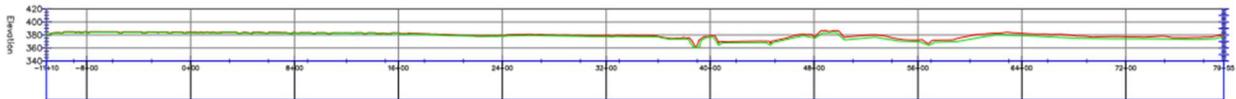
Alignment 3 PROFILE
Station



Notes

All Pipe will be 48" below surface.
Easements will vary based on conditions.
Pipe will be deeper when crossing roads and ditches.

Alignment 4 PROFILE
Station



Appendix D: Design Details (continued)

