SENIOR DESIGN PROJECT

Pump station and pipeline design for SW Stillwater

Abstract

Enclosed are documents showing our design process addressing the pressure issues in the southwest zone of Stillwater, OK

MDAWGL ENGINEERING CO.

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Executive Summary

Introduction

The City of Stillwater has requested that the water pressure in the Southwest Region of Stillwater be reanalyzed to provide adequate pressure to the homes and businesses until the year 2040. In order to do this, MDAWGL will make a population projection and design a booster pump station between Country Road and the water tower at Range Road and 19th Street via Highway 51 and Range Road. The pump-house site will be at the Southeast corner of Highway 51 and Range Road. In addition to the booster pump station, MDAWGL will also be installing a new pipeline along and boring underneath Highway 51, underneath Range Road and along Range Road below driveways. At the booster pump station, an underground storage basin will be constructed to ensure that the runoff water is collected and that there is not an increase in runoff to the land acquired.

Outline

Hydraulic/ Design Basis

Pipeline

Booster Station

Site Layout

Foundation Design

Hydrology

Construction Management

Cost Estimates

Problem Statement

The Southwest Region of Stillwater, Oklahoma needs to provide adequate water pressure to the area until the year 2040. Currently the area at the Range Water Tower provides less than the state regulated 25 psi. This area of Stillwater is likely to experience the rapid rate of growth in the next coming years. These trends can be seen by looking at where development has occurred in the past couple of years.

Design Decisions

This design calls for three major design items:

(1) Booster Pump Station

(2)Detention Basin

(3) Water Pipeline

The booster pump station will be a 62 x 42 foot building. It will be a CMU with brick veneer structure with a truss system and metal roof. The foundation of the building will be a strip footing with a 6 inch slab floor. A crane will be installed in the building to provide easy movement of motors, pumps, and other difficult to move items. Three pumps, 1190 rpm 14.35 inch impeller, will be used to handle a flow of 1450 gallons per minute each. The booster pump station will be able to be controlled remotely from the water distribution center as well as manual control at the station. Two release valves and a check valve will be used for each pump.

A detention reinforced concrete detention basin of size 11 x 12 x 10.5 foot was chosen to handle the runoff created by the structure. A 3 inch pipe will be used to carry the water to the storm water system.

The water pipeline system will consist of a 24 inch pipeline 5280 feet long. There will be three borings made, once under Highway 51 and twice under Range Road. A 6x6 foot trench will be used to lay the pipe down with a 3.5 foot cover. Air release valves will be installed along the pipeline to release air pockets that collect at each high point of a pressured line.

Hydraulic/Design Basis

Primary Factors

Resulting Design

We can support up to 1425 gpm with one pump at full speed. This means we will need to turn on the second pump in 16 years.

Pipeline

Booster Station

Site Location

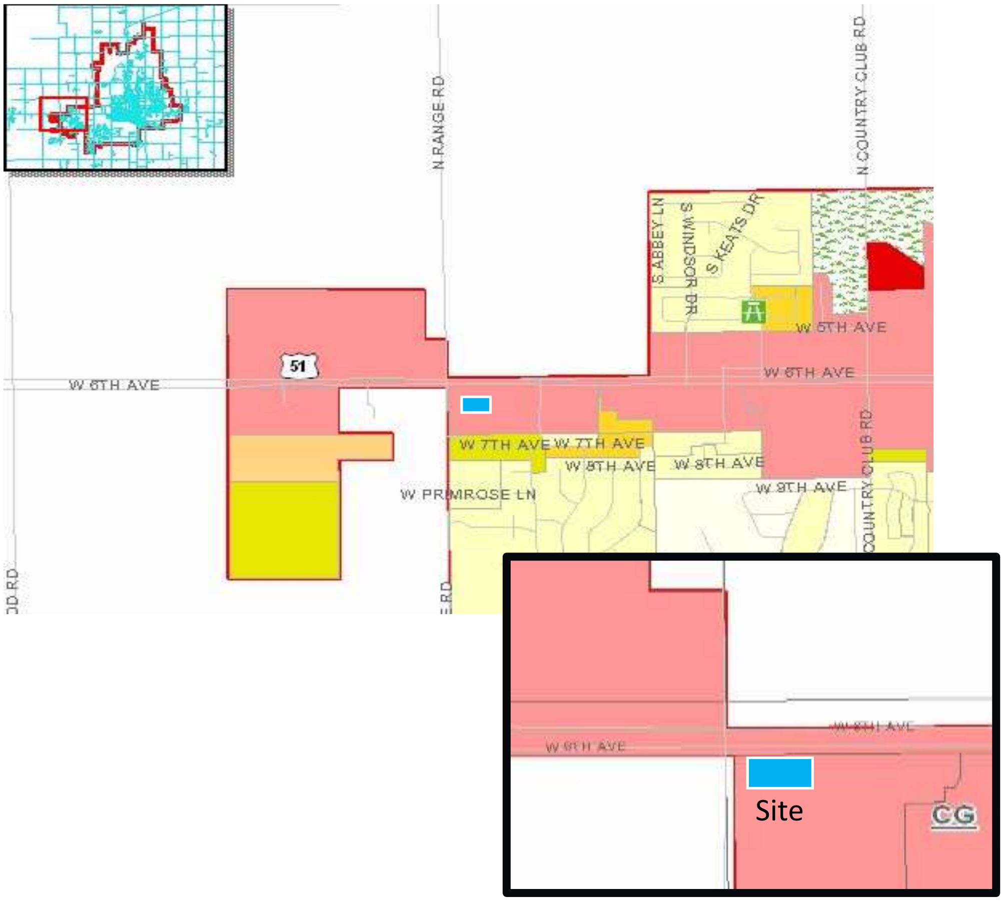


Figure 1-Pump Station Location

The proposed site is on the south east corner of 6th and Range. We chose this location based on the cheaper price of land and the simpler hydraulic model. The site will consist of a 62ft x 42ft building to house the pumps and computer controls.

Site Layout

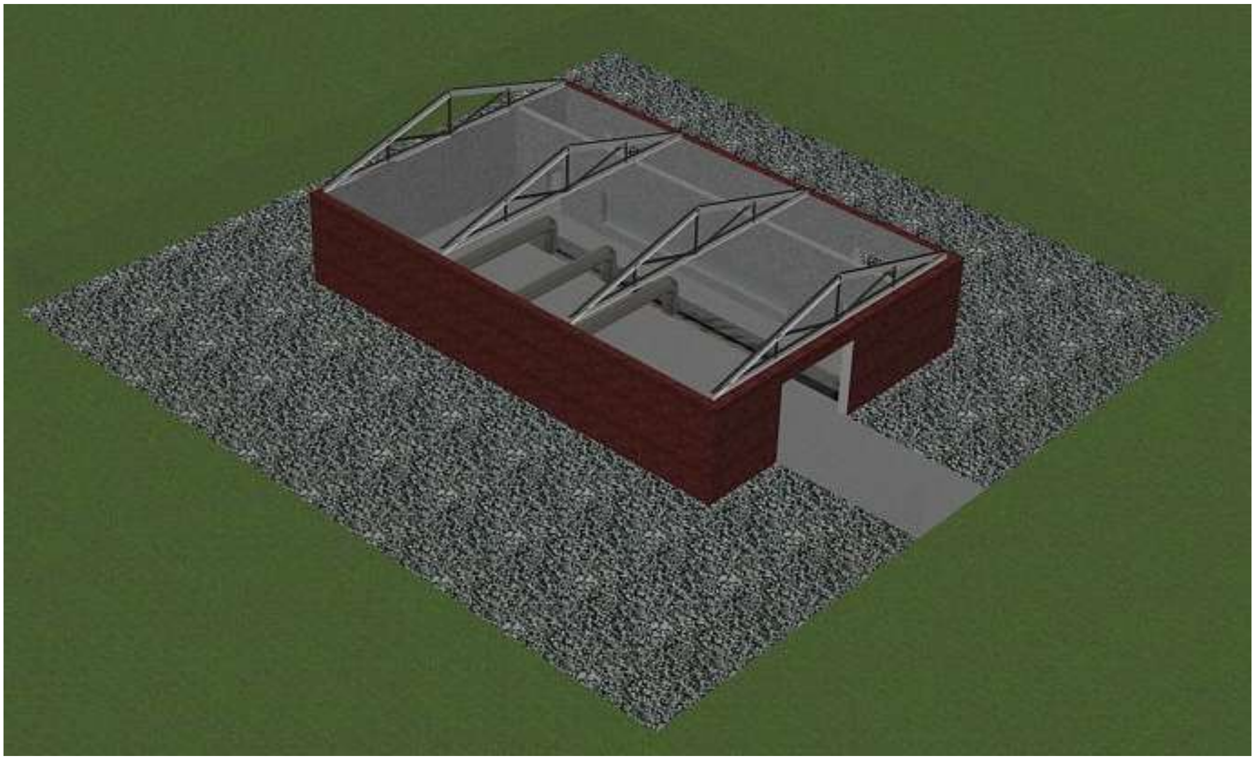


Figure 2-Pump Station Schematic

Figure 3-Pump Station Plan View

The pump station shown in figure 2 will house three 40Hp pumps, three variable frequency drives in the control room, and a two-ton crane required for pump maintenance. The building will be consist of:

- 24” concrete slab
- 12”x8”x16” CMUs
- Brick veneer in order to match OSU campus aesthetics
- Metal single leaf doors
- Galvanized 22 gauge metal roofing
- 10’ x 10’ steel 24 gauge garage door
- W10x22 and LL2.5x2.5x4x0 truss members
- Strip footing foundation
- VFD control scheme
- Underground storage tank
- PLC control panel

- Pressure transmitters
- Telemetry

Roof Design

The roof is a Pratt A design truss. The design consists of four trusses spaced 20 ft. apart each across the 60 ft. length of the building. Wind loads and dead loads were calculated for the two middle trusses which would be holding an effective area of 800 sq. ft. each. The design called for a 20 psf load for dead loading in the roof. The calculations below show the resulting vertical wind load pressures.

Basic Wind Speed	V	90	mph
Importance Factor	I	1	
Exposure Category	C		
Adjustment Factor	Lambda	1.21	

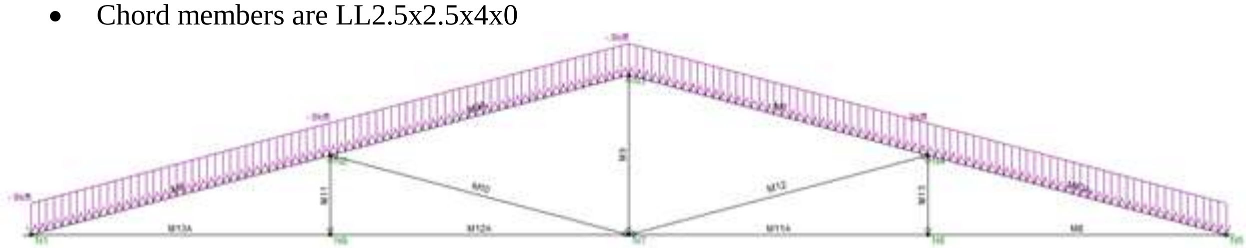
	Horizontal Pressures				Vertical Pressures			
	A	B	C	D	E	F	G	H
	12.8	-6.7	8.5	-4	-15.4	-8.8	-10.7	-6.8
Net Pressure (ps)	15.488	-8.107	10.285	-4.84	-18.634	-10.648	-12.947	-8.228

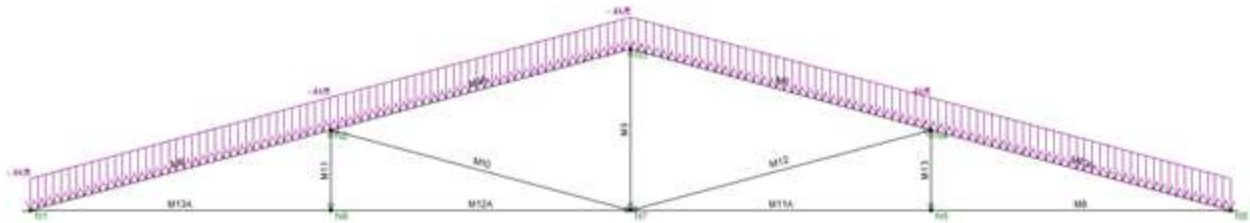
Design Pressures	
Vertical	Horizontal
-18.634	15.488

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
	5.9	5.9	5.9	14.6	14.6
	-14.6	-24.4	-36.8	-15.8	-19.5
Net Pressure (ps)	-17.666	-29.524	-44.528	-19.118	-23.595

These loads resulted in the following truss design:

- Outer members are W10x22
- Chord members are LL2.5x2.5x4x0





L...	Joint Label	X [k]	Y [k]	Z [k]	MX [k-ft]	MY [k-ft]	MZ [k-ft]
1	N1	38.915	19.463	0	0	0	34.513
1	N5	-38.915	19.463	0	0	0	-34.513
1	Totals:	0	38.927	0			
1	COG (ft):	X: 20	Y: 2.68	Z: 0			

L...	Joint Label	X [in]	Y [in]	Z [in]	X Rotat...	Y Rotat...	Z Rotat...
1	N1	0	0	0	0	0	0
1	N2	.018	-.172	0	0	0	-1.074e-3
1	N3	0	-.189	0	0	0	0
1	N4	-.018	-.172	0	0	0	1.074e-3
1	N5	0	0	0	0	0	0
1	N6	0	-.171	0	0	0	1.18e-3
1	N7	0	-.194	0	0	0	0
1	N8	0	-.171	0	0	0	-1.18e-3

Overview of Control Scheme

The booster station will house three pumps, each with its own variable frequency drive (VFD). A VFD is a type of motor controller that drives the electricity of a motor by varying the frequency and voltage supplied to the electric motor. The pumps will each require a VFD due to the conservation of energy it will result in. Each pump is designed for the maximum daily demand but that will not always be the case. The VFD will be able to adjust the power supplied to the motor to achieve a lower RPM when flow demand decreases.

Foundation Design

To ensure a safe structure, a proper foundation of has been designed. The foundation will consist of a reinforced strip foundation supporting a 24” slab and all building components. A concrete strength of 4 ksi and a steel yield strength of 60 ksi has been chosen for all reinforced components. The depth of the strip footing will be set at 3 feet below grown level. The footing will contain a wall of 12 inches and a base of 3 feet wide. It has been design to carry a distributed load of 7.4 kips per linear foot, a moment of 2.91 kip-ft, and a shear force of 3.88 kips. The strip foundation will be reinforced with #3 bars spaced at 12 inch centers. In addition, three #3 bars spaced accordingly along the strip to ensure adequate shrinkage and temperature. Capacity check of the foundation resulted in a more than adequate design. The current design carries a nominal moment capacity of 4.17 kip-ft and a shear capacity of 14.5 kips, both of which are greater than the required 2.91 kip-ft and 7.4 kips.

The Primary slab was also designed according to ACI 318 specifications. The slab will be simply supported and have a span of 40 feet. The slab will need to contain a moment capacity of 93.3 kip-ft as well as a shear capacity of 9.3 kips. To ensure a proper design, a required thickness of 24” was necessary. The slab will be designed for flexure reinforced with #9 bar spaced at 12 inch centers. To ensure the proper protection shrinkage and temperature control, #4 bars will be used, each on 6 in centers. Tables 2 indicates a summary of the design loads, required size, and reinforcement configuration for each section for the strip footing and the primary slab.

Table 2. Summary of Strip foundation and Primary slab

	Strip Footing	**Primary Slab**
W [lb/ft]	7.40	0.42
V [kips]	3.88	9.3
M [k-ft]	2.91	93.3
Df	3 ft	N/A
Base	3 ft	N/A
Wall thickness	12"	N/A
Thickness	1.5 ft	24"
Flexure Design	Use #3 bars on 12" centers	Use #9 bars on 12" centers
Shrinkage and Temp. control	Use #3 bars on 12" centers	Use #4 bars on 6" centers

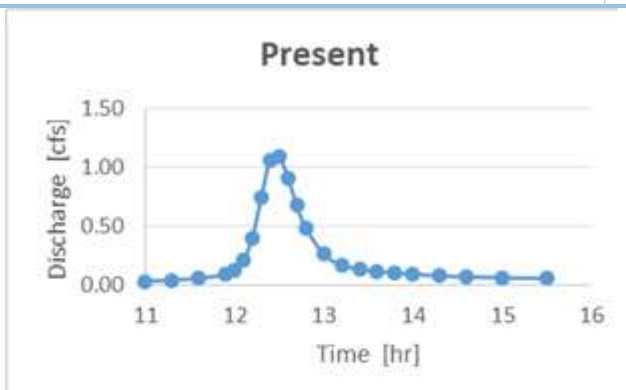
Hydrology

To design for a 100 year flood, the present and developed water sheds were analyzed to determine a required volume size for a retention basin. The hydrology analysis was performed with the guidance of the TR-55 for urban hydrology for small watersheds. In its present state, the land consists of type D soil which is primarily associated with short prairie grass. This type of surface is related to a manning roughness coefficient of 0.15. Given a desired drainage area of 100 ft. by 100 ft., a flow length of 100 ft was examined. Using a two-year 24-hour rain fall event of 3.75, a slope of 0.04 ft. /ft., a roughness coefficient of 0.15, and the flow length, we were able to compute a total travel time of 0.076 hr. for the undeveloped land. After development, the surface will consist primarily of concrete. With a roughness coefficient of .011, the developed area will result in a total travel time of .056 hr.

Using watershed data presented to us by the TR-55, we were able to tabulate the discharge differences between the present and developed stage. A difference of 1.19 cubic feet per seconds was observed. This difference in flow demanded a necessary retention basin of 11 ft. by 12 ft. by 10.5 ft capable of holding 1042 cubic feet of water. Table 3 demonstrates the design constraints. Figure 1 shows a hydrograph for the present state of the land. Figure two show a hydrograph for the developed land.

Table 3. Present and develop design constraints

Subarea Name	Time of Concentration Tc [hr]	Travel time summation ΣTt [hr]	Ia/P	AmQ [mi^2-in]
Present	0.20	0.30	0.10	0.001869
Developed	0.10	0.10	0.10	0.001869



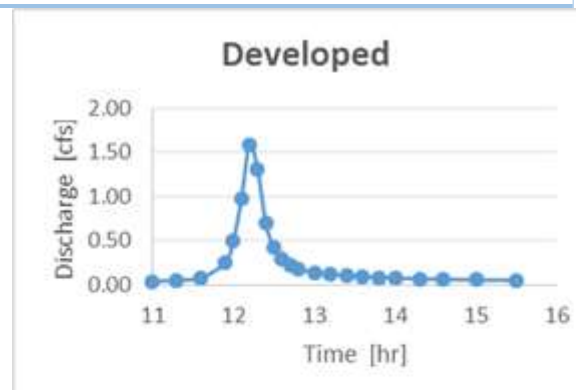


Figure 1. Hydrograph for present condition conditions

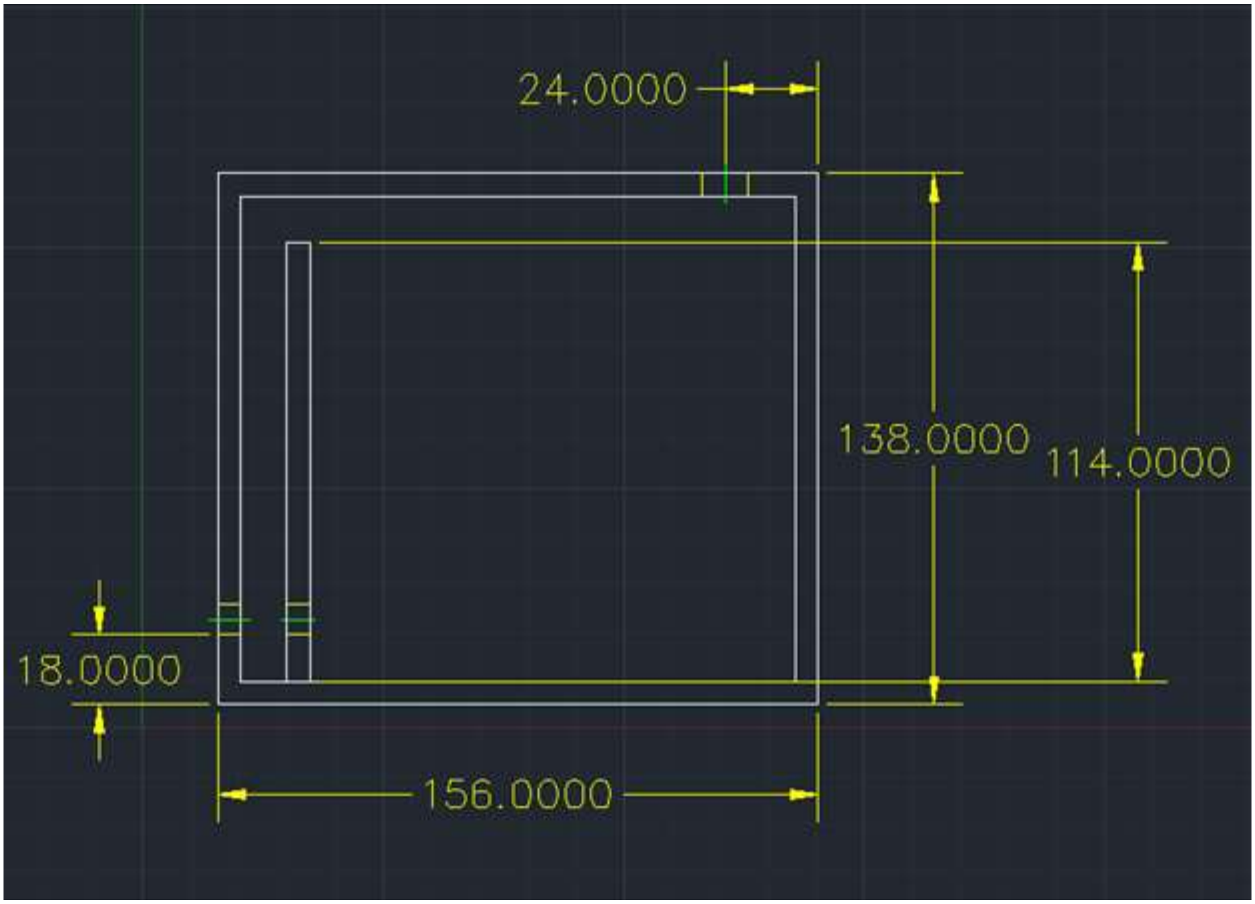
Figure 2. Hydrograph for developed

Retention Basin

The hydrology analysis resulted in a necessary retention basin with a capacity of 1142 cubic feet. The retention basin will contain a 3 in pipe that will release water at flow rate of 10 ft^3/sec. The retention basin will be placed underground, made of reinforced concrete, and have design dimensions of 11 ft x 12 ft x 10.5 ft. The side walls will be designed to support a 17.9 k-ft moment and a shear of 2.7 kips imposed on the structure from the resultant load of 10.3 kips coming from the saturated soil and the pore water pressure. The bottom slab of the retention basin will be built to support an 18.6 k-ft moment and a shear force of 6.2 kips created from the load of the 1142 cubic feet of water being held. The top slab will only be designed support light loads primarily coming from its own weight. Tables 1 indicate the design loads, required size, and reinforcement configuration for each section. Each section was design according to ACI-318 regulations. A concrete strength (fc') of 4ksi and steel yield strength (fy) of 60 ksi were used for all calculations. Please see appendix for calculations.

Table 1. Design summary of retention basin

	Side Walls	**Bottom Slab**	**Top Slab**
W [lb/ft]	10.30	1.3	0.1
V [kips]	2.70	6.2	0.6
M [k-ft]	17.89	18.6	1.8
Thickness	12"	12"	6"
Flexure Design	Use #5 bars on 6" centers	Use #5 bars on 6" centers	Use #4 bars on 12" centers
Shrinkage and Temp. control	Use #4 bars on 6" centers	Use #4 bars on 6" centers	Use #4 bars on 12" centers



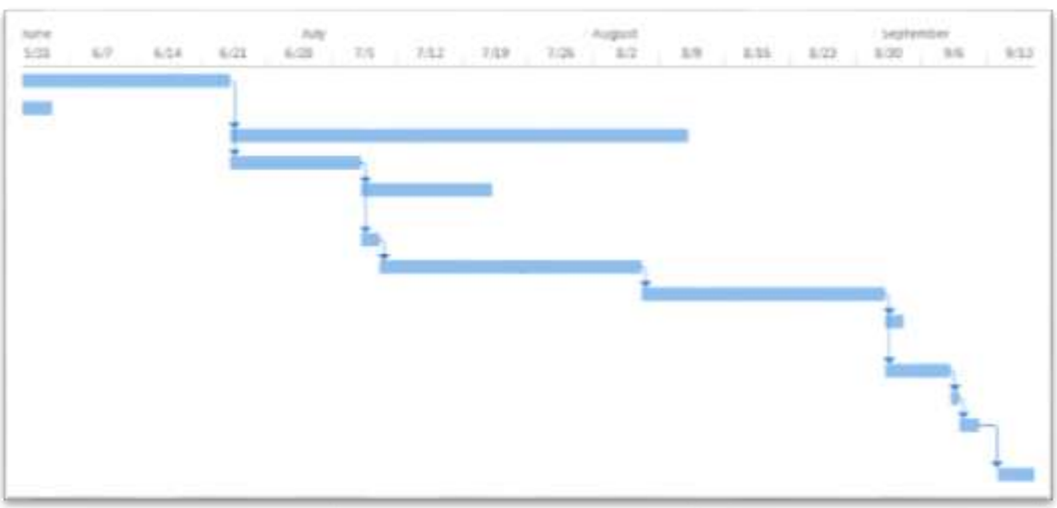
Necessary Utilities

Construction Management

Construction Schedule

Trenching	17 days	Mon 6/1/15	Tue 6/23/15	
Boring	4 days	Mon 6/1/15	Thu 6/4/15	
Piping	35 days	Wed 6/24/1!	Tue 8/11/15	1
Cut/Fill	10 days	Wed 6/24/1!	Tue 7/7/15	1
Underground Storage Tank	10 days	Wed 7/8/15	Tue 7/21/15	4
Slab/Foundation	2 days	Wed 7/8/15	Thu 7/9/15	4
Walls	20 days	Fri 7/10/15	Thu 8/6/15	6
Brick Veneer	18 days	Fri 8/7/15	Tue 9/1/15	7
Overhead Crane	2 days	Wed 9/2/15	Thu 9/3/15	8
Truss	5 days	Wed 9/2/15	Tue 9/8/15	8
Roof	1 day	Wed 9/9/15	Wed 9/9/15	10
Doors/windows/trer grate	2 days	Thu 9/10/15	Fri 9/11/15	11
Pump/VFD/Controls	5 days	Mon 9/14/1!	Fri 9/18/15	12

Figure 4-Task List



T Figure 5-Gantt Chart for Project Construction

To determine the construction schedule RSMeans was used to calculate the labor hours per unit of work. Once the total labor hours were calculated we divided that by a reasonable amount of workers to get an accurate time in days. Certain tasks cannot be performed until their preceding task is completed, while other tasks can start independently of others. A start date of June 1, 2015 was picked to give time after the bidding process. The project duration is around 3 months, so the new pump station can be implemented as soon as possible in order to provide sufficient water pressure.

Cost Estimates

	Cost Estimates						
Pipelines		Quantity	Units	Materials	Labor	Equipment	Total
	24" PVC	13950	Feet	29.5	12.5		$ 585,900.00
	Trenching	13950	Cubic yards		20.5	11.7	$ 449,190.00
	Air Release Valves (Only check valve in Rsmeans)	4	Each	16100	225	80	$ 65,620.00
	45 (no straight fittings in Rsmeans, used 45 to be conservative)	88	Each	600	60		$ 58,080.00
	90	20	Each	850	60		$ 18,200.00
	Boring	150	Feet		23	12.5	$ 5,325.00
							$ -
					Pipelines Total=		$ 1,182,315.00
Pumphouse		Quantity	Units	Materials	Labor	Equipment	Total
	6 Inch Concrete Slab	2400	Square Feet	1.96	0.82	0.29	$ 7,368.00
	Strip Footing	200	Linear Feet	24	28		$ 10,400.00
	Walls (CMU)	3240	Each Block	2.27			$ 7,354.80
	Brick Veneer	2496	Square Feet	3.61	6.9		$ 26,232.96
	Doors (metal single leaf, self-framing, incl. butts, lockset and fra	4	Each Door	560	155		$ 2,860.00
	Roof (galvanized 22 guage 2" deep)	2604	Square Feet	1.78	0.44	0.03	$ 5,859.00
	Garage Door (steel 24 guage 10'x10')	1	Each	1025	385		$ 1,410.00
	Trusses(W10x22)	81.41	Linear Feet	27	4.42	2.7	$ 2,777.71
	Overhead Crane (2 ton)	1	Each	2500			$ 2,500.00
	Underground Storage Tank	1	Each	12500			$ 12,500.00
	Gravel (crushed 3/4", 3" deep)	844.5	Square Yard	3.71	0.32	0.66	$ 3,960.71
							$ -
							$ -
							$ -
							$ -
					Pumphouse Total		$ 83,223.17
Pumps		Quantity	Units	Materials	Labor	Equipment	Total
	1170 RPM 14.3" Impeller 40 Hp	3	Each Pump	16000			$ 48,000.00
	Variable Frequency Drive	3	Each Pump	7500			$ 22,500.00
	PLC conrol panel	1	Each	60000			$ 60,000.00
	Pressure Transmitters	3	Each	1000			$ 3,000.00
	Telemetry	1	Each	20000			$ 20,000.00
					Pump Total		$ 153,500.00
		City Index (OKC)	Time Index	Capital			Total
Total Cost							
		0.818	1.09950924	1			$ 1,276,280.89

Figure 6-Cost Estimates Spreadsheet

To get an accurate cost estimate RSMeans heavy construction data from 2011 was used to gather the materials, labor and equipment cost information for each item. The cost was given per unit so in order to obtain the total cost we multiplied by the appropriate units. To get the most realistic estimate we used a time and city index. Oklahoma City was the closest similar city to Stillwater and found it to be less expensive than the national average values provided in RSMeans. The RSMeans book is also given in 2011 dollars, making it necessary to convert to 2015 dollars. Not all of our items were located in RSMeans. This forced us to interpolate values of similar materials.

Communication and Coordination with City

Team leader, Dylan Adame, will act as coordinator with the city. Should any problems occur on the construction site, a change in design plans, or other criteria that should be discussed, Mr. Adame will be the person to speak with. As engineers, we are required to hold the safety of the public paramount and let the client know problems with the design and construction.

Team Qualifications

Our team has gained a broad knowledge of Civil Engineering disciplines through our education at Oklahoma State University. We believe that our courses have adequately prepared us for the challenges faced in both problem solving and design. Attached (Figure 1) is the course list for the Civil Engineering Degree plan at OSU, we believe the courses; Geotechnical Engineering, Transportation Engineering, Applied Hydraulics, Hydrology, Environmental Engineering, Surveying and Construction Management have given us the necessary tools to implement the new waterline and pump station in southwest Stillwater.

Many of these courses, in particular Applied Hydraulics, have given our team real world experience in which we designed a water distribution, storm and sewer system for the artificial town of Keystone Heights, Ok.

Our team strives to create quality work, meeting the scope, budget and schedule of the client. Our engineers are always on hand to answer any questions or concerns that may develop throughout the design and construction process.

Project Experience

Throughout MDAWGL's studies in engineering school, a wide variety of topics have been covered through the core curriculum offered at Oklahoma State. The following projects and homework assignments recognize key components of the job requested, and the examples will highlight LDAWG's ability to complete the tasks required

Keystone Heights Project, Oklahoma

Members of MDAWGL Engineering Co. have crucial expertise and skill in creating detailed technical reports involving both hydraulics and hydrology. In Hydraulics, each individual student creates a water distribution system, a sewerage system, and a stormwater control system for the town of Keystone

Heights, Oklahoma. Each student and member of MDAWGL is either currently working on this project, or has completed this project in previous semesters.

The Keystone Heights Project includes the following:

- Calculations for Sizing Distribution Pipelines and Water Towers
- Calculations for Sizing Distribution Pumps w/ Pump Curves
- Designing Layout for Sewerage System
- Calculations for Sizing Sewerage System Pipelines and Lift Stations
- Calculations for Sizing Sewerage System Pumps w/ Pump Curves
- Simple and Logical Controls for all Pump Stations
- Calculations for Stormwater Runoff for a 400 Acre Walmart Lot
- All Calculations in Accordance with Oklahoma DEQ Standards

IDF Curves

In Hydrology, one of the fundamental concepts in the course is reading and calculating Intensity-Duration Frequency Curves (IDF). Homework problems consistently called for reading IDF curves and determining the amount of rainfall in 100 year return periods and calculating the volume of rain. With this knowledge, MDAWGL Engineering can ensure any construction meet with required local regulations with the empirical data to support the request.

Computer Software Experience

Along with required hand calculations and chart readings, the engineering students in MDAWGL Engineering have experience with using WaterCAD, SewerCAD, and StormCAD produced by Bentley Systems. This increases our efficiency and productivity to deliver on schedule as proposed. Additionally, members are proficiently trained in AutoCAD, with some members having Bentley MicroStation and AutoCAD Civil 3D exposure. This will allow for high quality products by our firm and MDAWGL Engineering will use the tools appropriate to complete this project professionally.

Sub consultant Experience

(Hydraulics Expert) Dee Ann Sanders, Ph.D., P.E.

- Ph.D. - Civil Engineering, University of Texas, 1977
- M.S. - Environmental and Planning Engineering, University of Missouri-Rolla, 1974
- M.S. - Bioenvironmental Engineering, Oklahoma State University, 1972

- B.S. - Civil Engineering, University of Missouri-Rolla, 1971

(Geotechnical Expert) Xiaoming Yang, Ph.D., P.E.

- Ph.D. - Civil Engineering, University of Kansas, 2010
- M.S. - Geo-Engineering, Tongji University, China, 2006
- B.S. - Geo-Engineering, Tongji University, China, 2003

Project Team

MDAWGL Engineering Co. has all five members of the firm dedicated to this project because efficiency and focus is extremely important to us. Our team members have a professional working relationship, and we hope to grow our recognition and reliability with each of our staff representing our capabilities to the best of our abilities.

Appendices/Calculations