Appendices

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Appendix A: Project Proposal

Designing a Water Distribution System for Future Growth

A Major Qualifying Project Proposal
submitted to the Faculty of
WORCESTER POLYTECHNIC INSTITUTE
in partial fulfilment of the requirements for the
degree of Bachelor of Science

by
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Adam Carrier
Bryan Sadowski

Date:
14 October 2015

Proposal Submitted to:

Professors Suzanne LePage and Paul Mathisen
Worcester Polytechnic Institute

Capstone Design Statement

Civil Engineering
This project fulfills the capstone design requirement for Civil Engineering. The requirements for capstone design is set by the Accreditation Board for Engineering and Technology (ABET) to give students an engineering design scenario where realistic constraints must be accounted for. The design experience must address constraints including economic, environmental, sustainability, manufacturing, ethical, health and safety, social , and political concerns.

Economic
The final recommendations of the project take into account the cost of construction of each component. Treasure Valley is a trust and is limited in their budget, which was a factor in the project team's decision making process. Each component recommended was determined based on maximizing efficiency, while minimizing the cost of implementation.

Environmental
Treasure Valley provides an opportunity to experience nature. Suggestions to improve the system are intended to have minimal impact on the surrounding ecosystem. All recommendations comply with state and federal regulations involving wetland and watershed protection, as well as drinking water standards for human consumption.

Sustainability
This project attempted to ensure the long term sustainability of Treasure Valley by increasing the number of people the water system can service. The end result is a readily accessible resource that supports the development of young scouts. By getting the resident scouts involved in the design, they can both improve their own water system and gain valuable skills in the process.

Manufacturability
The recommendations created for Treasure Valley are given in short term and long term improvements. The goal being Treasure Valley can make improvements immediately while at the same time take steps in specified time intervals to make long term improvements. It would also be ideal to get the Boy Scouts involved in construction to fit a STEM curriculum or in completion of their Eagle Project.

Ethical
Throughout the project, the project team followed ethical guidelines by presenting all gathered data honestly and provided recommendations that would be in the best interest of the reservation and its trustees. These ethical guidelines are set forth by the American Society of Civil Engineers.

Health and Safety
Since the project involved the distribution of drinking water, health regulation was a primary concern. The camp follows the health code of the Town of Oakham's Board of Health for the regulation of TVSR's facilities. The project followed the state and federal regulation that governs

the quality of public drinking water, regulation such as the Clean Water Drinking Act. All drinking water being distributed was determined safe according to U.S. Environmental Protection Agency standards.

Social

With more access to drinking water in more locations and the efficiency of the system improved, the camp will be able to house more scouts. The increase capacity of the system along with long term recommendations ensures the camp will be able to increase its size year after year.

Political

Treasure Valley spans four different towns each with their own set of regulations. Each addition to the water system follows the code of the town that part of the system lies in.

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1.0 Introduction

The Treasure Valley Scouting Reservation (TVSR) provides a location for the Boy Scouts of America to learn valuable survival skills and enjoy the wilderness. Treasure Valley is under the stewardship of a Trust that relies solely on grants and donations to maintain the facility; financial costs are a major consideration in the development of potential solutions for their water system. This site is able to acquire and distribute its own drinking water to the residents of the camp through a system of wells and pipes. Throughout the years, the camp has grown in size and the number of campers attending its summer program has steadily increased. TVSR has been able to supply potable water throughout its history, but this system has reached the point where the infrastructure needs to improve in order to meet the growth and future needs of all users of the reservation (Mohegan Council, 2015).

Currently, Treasure Valley's water system consists of three operational wells and one inactive well, servicing key areas of the reservation with seasonal and year round water access. The system runs on a temporary piping system and has a mixture of permanent and flexible water delivery techniques. The locations and conditions of the present wells divide the camp into three separate water networks independent of each other and service distinct areas of the camp. These wells are scattered throughout the camp and come with their own set of unique challenges and problems which this project will address.

The existing water system of the camp is inefficient and in most areas, antiquated and outdated. This has resulted in a multitude of issues for Treasure Valley, as their water systems have been strained due to the passage of time and rising demands. A large number of the inefficiencies in Treasure Valley's water system exist due to the lack of a complete inventory and maintenance records of their water system. An inventory would help TVSR determine if the existing winterized water system should be expanded by providing an overview of the costs associated with winterizing. This project would potentially identify locations for new areas of the reservation that could be serviced by new connections. There is also a potential need to develop safety measures for a fire suppression system, and a fail-safe system to redistribute water in the event of a well failure.

In 1988 a Water Distribution Study was prepared by Howland Engineering for Treasure Valley in order to determine and document existing conditions, make recommendations for improvements to the system, and also explore the possibility of implementing a fire suppression system for TVSR. This engineering report will be analyzed to determine the applicability of recommendations that were not completed and what, if anything, has changed since the report was issued. This will be used primarily as a reference point for new measurements collected by the project team in order to determine a change in performance of the system.

Since the 1988 Water Distribution Study, the only substantial modification made has been the removal of a large water storage tank in 2014. There has not been a complete inventory done on the system since 1988, and because of this, maintenance logs and records for TVSR's water system have not been well maintained (McQuaid, 2015). The lack of an inventory makes it difficult to determine what components of Treasure Valley's water distribution system should be upgraded or replaced, or what the cost of upgrading the system would be to the reservation as estimates cannot easily be made. Both of the aforementioned issues have contributed to a haphazardly compiled water system for Treasure Valley which is in need of improvement with regards to design and efficiency.

A full inventory of the connections, pumps, wells, and piping system would help solve long term maintenance issues and identify potential problems before they arise, while also projecting future maintenance costs. This inventory would benefit any future organization that works with the system, as the inventory would provide information on what kind of pipes were used, when the pipes were installed, and the length of pipe that was placed. Developing a more permanent, winterized water system would provide Treasure Valley with the opportunity to service more campers and groups year round. A resilient water distribution system would ensure that Treasure Valley could continue functioning in the event of a partial system failure, while also enabling the creation of a fire suppression system.

Each of TVSR's wells are capable of supplying a portion of the camp with water; how they are managed and updated will play a large role in their serviceability and lifespan. The goal of this project is to design a functioning water system for Treasure Valley that provides opportunities for system growth and expansion. The project team will work with stakeholder to improve system capabilities in order to establish a dynamic representation of the water system. Annual maintenance tasks will be improved to assist in yearly upkeep, while the determination of future water needs will establish a baseline for generating short and long term operational goals. This project has the potential to have greatest effect on Treasure Valley Scout Reservation for the next fifty years.

2.0 Background

2.1 Treasure Valley Scout Reservation

Founded in 1925, Treasure Valley provides a location for camping and experiencing the outdoors to both Boy Scouts and Cub Scouts each summer. After many years and numerous expansions, Treasure Valley serves scouts each summer and operates 24 designated camping areas (Szafarowicz, Aspinwall, Girouard, & Machamer, 2013). The Reservation encompasses 1,600 acres of campground that is accredited by the Boy Scouts of America to provide a wilderness exploration to young scouts in central Massachusetts. Treasure Valley Reservation includes land in Oakham, Paxton, Rutland, and Spencer Massachusetts, shown in Figure 1 below.

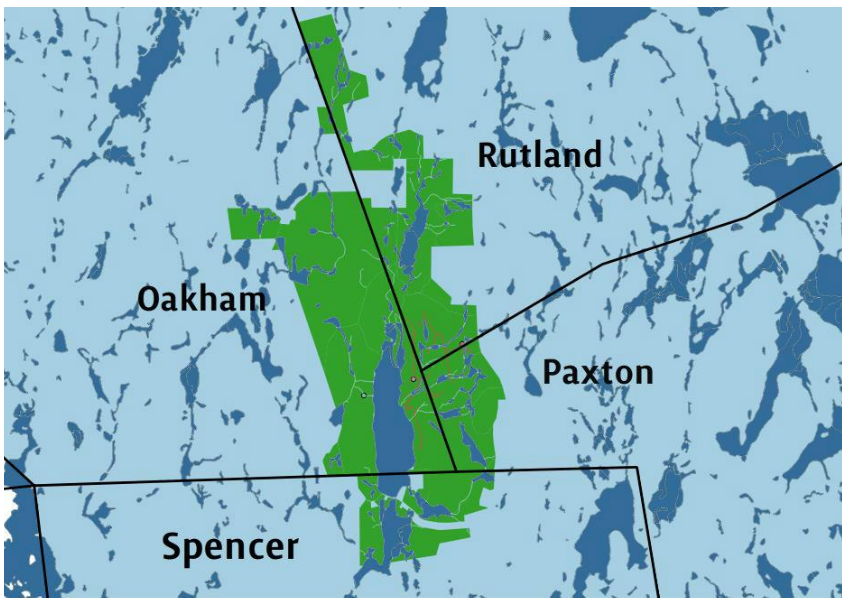

Figure 1: Treasure Valley Scout Reservation, shown on the borders of Oakham, Paxton, Rutland, and Spencer.

The camp is divided into two major areas, Treasure Valley East which is used by the Boy Scouts, and Treasure Valley West, which serves the Cub Scout Program (McQuaid, 2015). The reservation offers many ways to enjoy the landscape including 70 miles of hiking/biking trails, shooting ranges, and encompasses Browning Pond, a 90 acre body of water that provides the scouts with opportunities for aquatic recreation (Mohegan Council, 2015). Treasure Valley is fully operational during the summer for boy scouts and also provides opportunities for year round camping in East Camp. The reservation generates its own drinking water from three wells on site, and provides campers with latrines, showers, and hot water for cooking and cleaning at most campsites (Mohegan Council, 2015).

The Boy Scouts of America operate ten councils in the state of Massachusetts, and the Mohegan Council manages the Boy and Cub Scouts of central Massachusetts. This includes Treasure Valley and three regional districts, Massasoit, Hassanamisco, and Quinsigamond, and spans 30 towns in Massachusetts (Szafarowicz et al., 2013). All of the decisions made at the reservation must pass through the Board of Trustees of Treasure Valley (Mohegan Council, 2015). The board of trustees of Treasure Valley is composed of three members and is responsible for overseeing the annual operation of the reservation.

Recently, the Board of Trustees has decided to pursue future plans for various components of Treasure Valley, such as the expansion and opening of new campgrounds, planning new scouting activities, and future modifications and improvements of their water system. This final objective is the primary focus of our project, as we have been tasked with providing recommendations and suggestions to the Board of Trustees of Treasure Valley for upgrades and expansions of their water delivery system.

2.2 Groundwater Wells

A groundwater well is a commonly used method for providing rural and suburban communities with fresh drinking water. The ideal amount of water for a well to produce for a small-to-medium sized community is between one to five hundred gallons per minute (gpm), but the size of the community is the most important factor when determining water needs (Harter, 2003). Typically, wells are dug vertically down and are designed to tap into healthy aquifers or groundwater sources, from which the water is pumped up and passed through a filtration system and then distributed across the water network. Well pumps have a general lifespan of 10 to 15 years, depending on various factors and water usage (Conway, 2013). This makes it necessary to record installation and maintenance dates on all pumps so that replacements and repairs can be made on a regular basis.

Structurally, groundwater wells should be designed to last 50 years or more free of contamination and capable of withstanding the pressures of the earth (Harter, 2003). A typical well consists of a bottom pump, well screen, and well casing surrounded by a gravel pack. Water flows through the well screen which is designed to keep sand and gravel from the gravel pack out of the well. The gravel pack is constructed to keep sand and fine particles from moving into the well. The pump is housed by the blank well casing which also serves to provide a pathway from the aquifer to surface and keep drinking quality groundwater from interacting with lower quality groundwater in shallower ground (Harter, 2003). From there, the water is then pumped to the surface for use at the surface where the casing is designed to prevent shallow material from caving into the well.

2.2.1 Watershed

Treasure Valley Scout reservation lies in the Chicopee River Watershed of Central Massachusetts, which encompasses approximately 723 square miles (Simcox, 1992). The reservation is located in the south easterly portion of the basin and is shown in Figure 2. The reservation currently has three operational wells and one decommissioned well with access to the aquifer. These wells meet all the present needs of the camp, but there is uncertainty over whether or not these wells will meet the future water demands of the camp. To this end, we hope to compile accurate, updated information on the aquifer and wells of Treasure Valley in order to forecast how future water needs of the camp will be met.

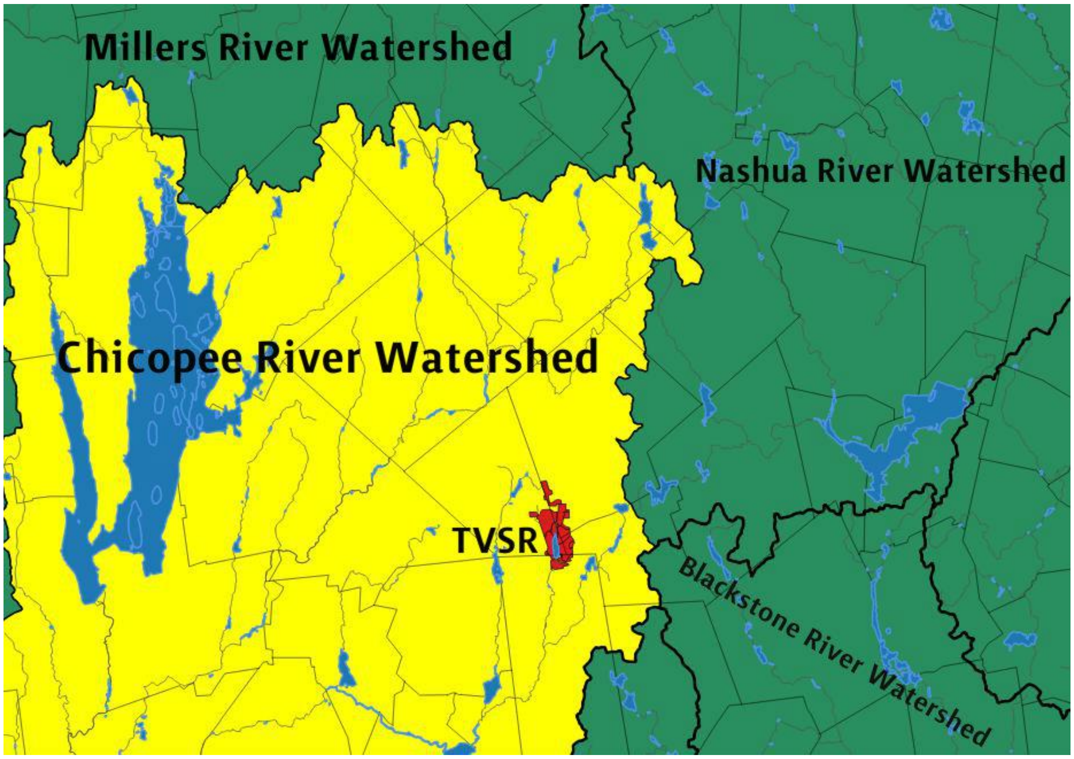

Figure 2: A map of the Chicopee River Basin (Simcox, 1992).

2.3 Water System Classification

A large amount of people in the United States receive drinking water from public water systems. According to the U.S. Environmental Protection Agency, a public water system is classified as a system that provides water for human consumption through pipes or other constructed conveyances to at least 15 service connections or serves an average of at least 25 people for at least 60 days a year. A public water system can be further classified into a Community Water System, a Non-Transient Non-Community Water System, and a Transient Non-Community Water System. TVSR falls into the category of Transient Non-Community Water System because the system provides water to an area that people do not stay in for a long period of time. As of 2010, about 87,000 of these types of public water systems serve 13.1 million people in the United States (United States Environmental Protection Agency, 2012). TVSR is obligated to follow regulation set by the Massachusetts Department of Environmental Protection because of their classification of water systems.

2.4 TVSR Well History

In order to adequately map and propose improvements to the groundwater well system of Treasure Valley, a full understanding of the history behind each well is essential. This section will detail the four wells presently located on the Treasure Valley Reservation.

The first well, known as the Farmhouse Well, has a chlorine bleach drip to treat high bacteria levels. The East Lodge Well has a high iron and manganese count, and the West Lodge well has low water pressure. The Boonesville Well is the fourth well located on the reservation, but it has not been used since the late 1980s and no one knows if there are any problems with the well today. All four wells are circled in blue in Figure 3 below.

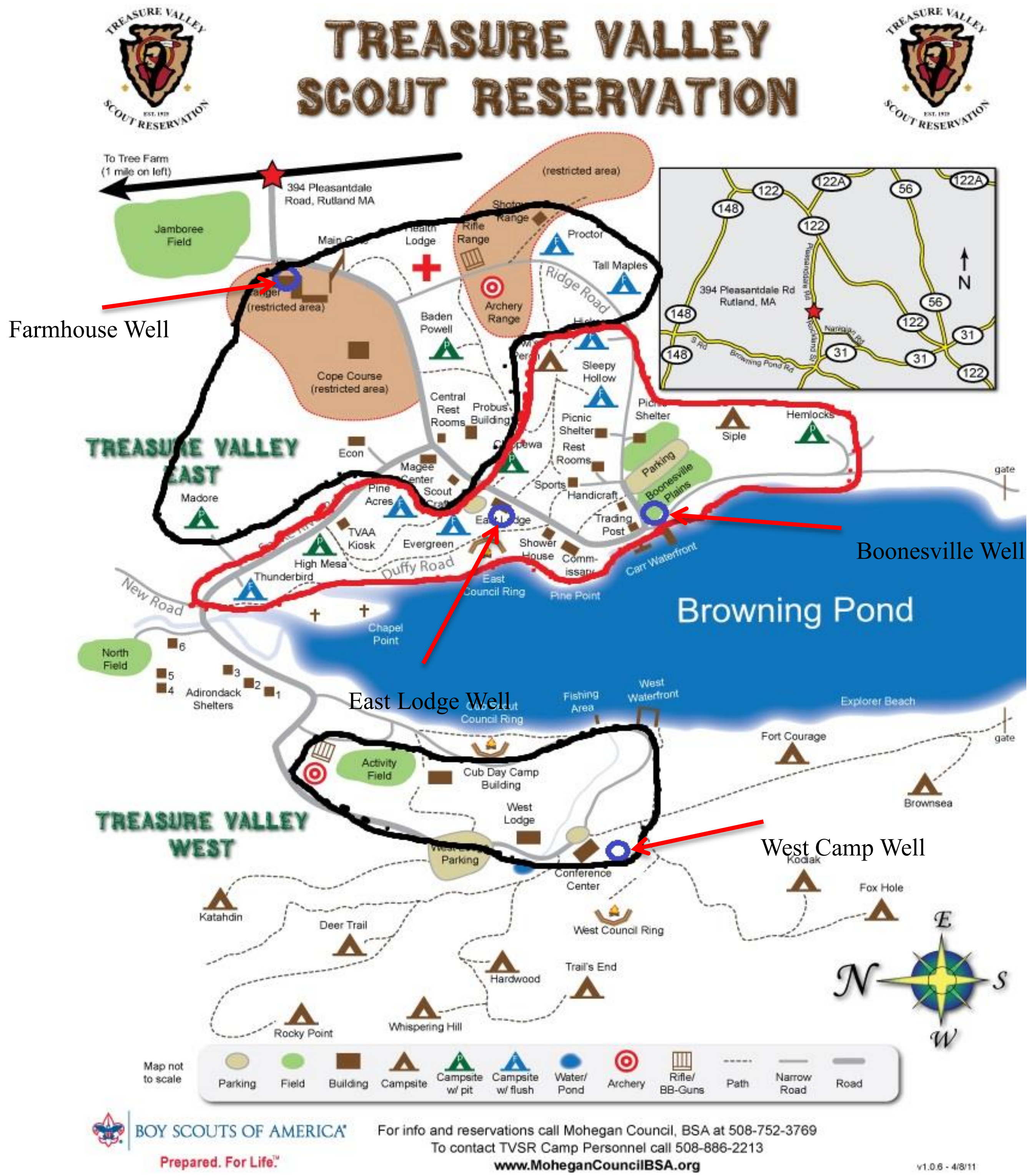

Figure 3: Location of the 4 wells of Treasure Valley and the areas they service (McQuaid, 2015; Mohegan Council, 2011)

2.4.1 Boonesville Well

The Boonesville Well is located on Boonesville Plains near Browning Pond, identified by the black arrow in Figure 4 below. This well supplied the East Lodge water distribution system with groundwater, but was disconnected from the East Lodge system in 1973 due to decreased demand. This well was then used to supply a large fiberglass tank in West Camp via an approximately three inch heavy duty black PVC line that runs underneath and diagonally across Boonesville Plains to a point just north of Carr Waterfront. From there it continues under the bottom of the pond. At the West Waterfront there is a service pit where the heavy duty black PVC line joins a blue pipe that runs up the hill to the fiberglass water tank that supplied the campsites and shower house of West Camp.

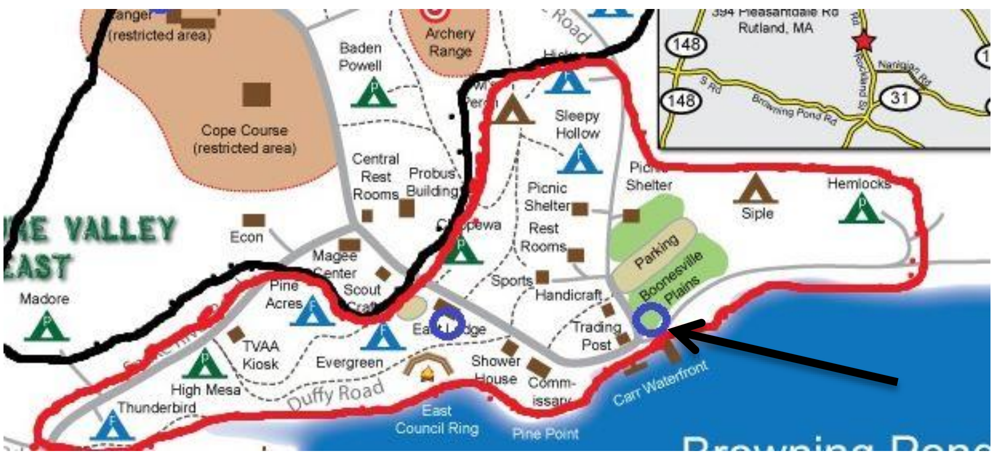

Figure 4: The location of the Boonesville Well (McQuaid, 2015).

The Boonesville Well and associated piping system have been unused since the closing of West Camp as a resident camp in 1979. The pipe manifold outside the Boonesville Pump House has lines leading in and out of it which have the ability to supply the East Lodge water distribution system, but the well produces water at such a high pressure that is blows apart the steel fittings on the manifold. Due to this reason, the well is kept offline and unused by TVSR. There was a large steel pipe that led from the Boonesville well to a large steel tank between Hickory and Tall Maples campsite. Since the well was shut down, there are sections of the line still underground, but the remaining pipe above ground has been largely removed over the summers by Michael McQuaid and Boy Scouts.

2.4.2 East Lodge Well

The East Lodge well is situated in the basement of TVSR's East Lodge, which is the primary dining hall for East Camp. This well supplies water to the red circle in Figure 5. The well also fills the storage tanks in the ground beneath East Lodge kitchen and above ground between Hickory and Tall Maples campsites.

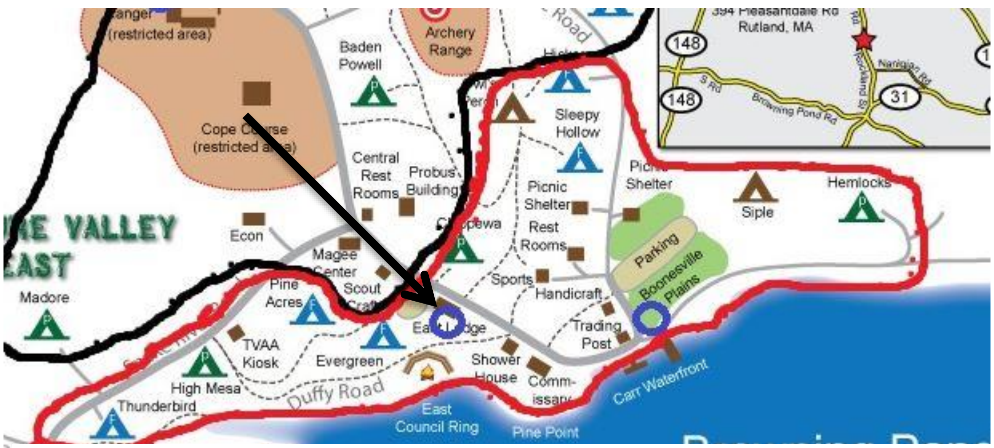

Figure 5: The location of the East Lodge Well (McQuaid, 2015).

Due to the East Lodge well's location, the well is inaccessible for alteration, but has the most advanced pump and monitor system in the camp. The well has a variable pump pressure monitoring system that provides data on the pressure in the well in real time (citation). Any changes or alterations to the well in East Lodge could conflict with existing building regulations, due to the physical location of the well. These regulations, which will be investigated more fully as part of this MQP, could prove prohibitive to any modifications or upgrades to East Lodge or the East Lodge well, as the regulations could require a substantial investment on the behalf of TVSR in order to become compliant.

2.4.3 The Farmhouse Well

Located in the Farmhouse of TVSR, the Farmhouse Well services the area outlined in black in Figure 6 below. The Farmhouse Well supplies the Farmhouse/Training Lodge, King Cottage, Director's Cottage, Ranger Station, Health Lodge, Shooting Sports spigot, Econ spigot, campsites Madore, Baden-Powell, and Tall Maples. This well also fills the water storage tank in the basement of Farmhouse. This well has a chlorine treatment system as identified in the 1988 Water Distribution Study conducted by Howland Engineering (Howland Engineering Inc., 1988).

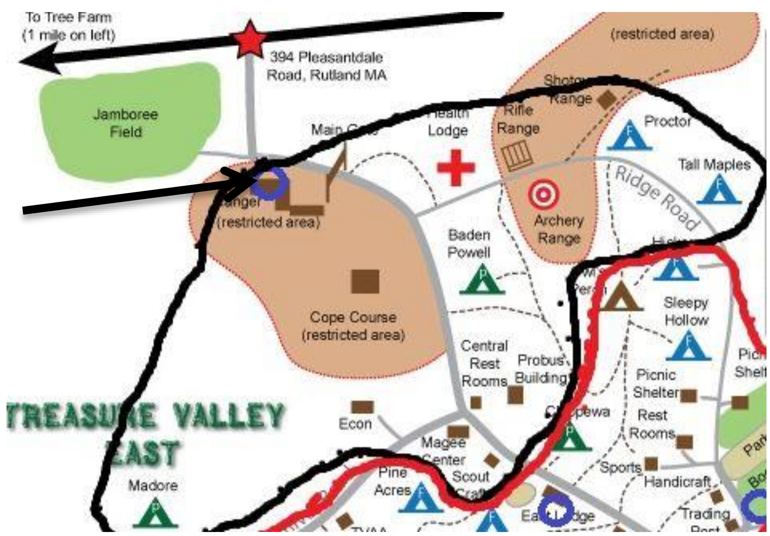

Figure 6: The location of the Farmhouse Well (McQuaid, 2015).

2.4.4 West Camp Well

The West Camp Well services the West Camp, a rarely used part of the camp. Located on the south side of the Conference Center, the well provides drinking water to West Lodge and the Cub Day Camp Building and various activity fields, Figure 7. The well lies on a high topography in relation to the rest of the camp and is enclosed in a cement casing. This well has many problems with it which brings to question the functionality of it. The well has a low pull to begin with, as well as problems with contaminants such as iron and manganese. This well is connected to water storage tanks located underneath the West Lodge (McQuaid, 2015). This system has the capability to connect to the Boonesville system via a long pipe that runs under the pond, but currently remains independent as the water demands for West Camp has fallen over the years.

Figure 7: Location of the West Camp Well (McQuaid, 2015).

2.5 Applicable Regulations

Treasure Valley Boy Scout Reservation is spread over four towns in Massachusetts. Located within the four towns of Oakham, Rutland, Spencer, and Paxton, Treasure Valley must abide by all of the regulatory laws each town enforces. To simplify future regulatory time management, Oakham board of health was elected to represent the other three towns when working with the Reservation.

The most stringent regulations enforced on the Reservation are the water regulations. Some of these rules have limited the functionality of the camp and provide a baseline for improvement.

The Safe Water Drinking Act gives the EPA the authority to create regulations for drinking water of either maximum contaminant levels or maximum contaminant level goals. The Total Coliform Rule regulates coliform bacteria, which are used as "surrogate" organisms to indicate whether or not system contamination is occurring.

Coliform bacteria are considered an "indicator" organism because both the bacteria and other dangerous pathogens come from fecal matter. Having a high coliform bacteria concentration means there is fecal matter present, it's more efficient to just test for coliform bacteria rather than many dangerous pathogens (New York State Department of Health, 2011). The Trihalomethane Rule established a standard for total trihalomethane of 0.10 mg/L. levels at all monitoring locations within the distribution system must comply. The Surface Water Treatment Rule requires a disinfectant residual be maintained at locations in the distribution system. The Lead and Copper Rule requires that lead and copper concentration be below action levels in samples taken at the worst case or highest risk consumer's tap. (king water distribution systems : assessing and reducing risks) (http://www.neiwpcc.org/neiwpcc_docs/campma.pdf)

3.0 Methodology

A complete water system plan will be established for the reservation and will serve as the baseline for the future expansion and development of the camp. By conducting an inventory of the water distribution system as a preliminary way of organizing all available resources, any outstanding gaps in the system will be identified. Investigation into modeling software will establish a mechanism for which scenarios of system failure and system modification can be simulated. Potential improvements based on simulations will be separated into short and long term feasibility with the intention of keeping TVSR camper capacity aligned with actual camper attendance.

The goal of this project is to design a functioning water system for Treasure Valley that provides opportunities for system growth and expansion. To accomplish this goal the following objectives will be achieved:

- Work with stakeholders to improve system capabilities
- Establish a dynamic representation for the water system
- Improve maintenance tasks associated with annual upkeep
- Determine water demands based on future camping needs
- Generate short and long term operational goals of the camp

These objectives will be carried out and explained in the following sections.

3.1 Taking an Inventory of the System

A multi-phase plan is needed in order to accurately take an inventory TVSR's water system, centralize all applicable information, and give useful recommendations on how the camp should be maintained and designed for the future. Taking a full inventory of the water distribution system will be the first step in designing a more efficient and encompassing system.

The next step would be compiling all map data that has already been generated using ESRI's ArcGIS software package (will be referred to as GIS). Another software package that will be used to analyze map data is QGIS 2.10 Pisa, an open source application similar to GIS. The GIS files would need to be updated with missing data to give a better picture of the entire system. Missing information would include well location, well types, pipe size, pipe locations, pump types, water storage tank locations and sizes, and unused pipe locations. All components of the water infrastructure need to be accounted for in GIS in order for the project to succeed.

Any information will need to be stored centrally such that the stakeholders and other camp governing officials have access to material necessary for maintaining the facility. A common form will be designed so all future and existing data is standardized and easily accessible. There are several programs that can create forms to organize the way data is recorded. One such program is Microsoft Access: a service that allows for the easy organization of tables, queries, and data to be altered with standardized forms. This database could be used to document the various components of Treasure Valley's system and allow for logging of water system servicing. Flow rates, well pressures, and item inventories would be documented to establish baseline levels of data for future comparisons. The database would be user friendly and allow Treasure Valley to easily compare conditions of the camp across many years in order to detect fluctuations in performance of wells and the water system.

3.1.1 Initial Data Collection

On Wednesday, October 21, the project team will be collecting data on campsites, wells, and water system components. This data will be collected by the use of a GPS system at the disposal of the WPI Civil and Environmental Engineering Department. Other data will be gathered with the assistance of Michael McQuaid, Properties Manager of TVSR. Michael will provide information on campsites, hot water service locations, and well information that will be compiled and included in the team's model of TVSR's water system.

Regarding campsites, it is necessary to identify which areas are already serviced by water and which areas need to be incorporated into the network. Areas of the camp that currently have hot water and the existing infrastructure capabilities will be identified. In order to complete the map of TVSR's water system, it is necessary to identify all existing piping and specifications, such as diameter, length, and functionality. Information on wells such as depth, lining type, and any contamination history will be gathered. This information, coupled with the specifications for each pump will provide accurate measurements and allow for calculations of the amount of water that is in TVSR's existing network during operation.

To begin the coordinate data gathering the team will start at a pump and continue outward following the network of pipes to campsite locations. Any permanent and auxiliary connections leading from each well will be identified and mapped to establish the flow of water throughout the reservation. This data will then be uploaded into a mapping software and a complete map of the water system will be created. This map will serve as the reference point for all future models of TVSR's water system and will be improved upon and expanded by the project team.

Throughout the data collection process, the project team will take note and identify any deficiencies within the system. These notes will be included in the final report in the form of recommendations for system improvement for delivery to TVSR, with the goal of improving the water distribution system.

3.2 Dynamic Representation

All system information, after being compiled and centralized, will be incorporated into a dynamic representation of the whole system. Different methods of system improvement can be tested remotely without having to spend money on on-site implementation. By modeling this information visually, scenarios can be run to determine the effect partial failure can have on the system as a whole. GIS and a hydraulic system modeling software will be the primary resources used in representing the system. All necessary information such as locations of nodes, length of piping, and topographical data will be put into GIS to get an overview of the system. The water infrastructure data will be transferred into a modeling software where dynamic scenarios of the system will be examined. Each of the possible issues that could occur within the system will be tested and the effects will be recorded.

This design technique will allow for full system functionality in the face of partial system failure. Using system modeling, it is possible to add or subtract components such as nodes, pipes, and storage tanks to adjustment the system with the goal of improved efficiency. An extended period analysis of the distribution system will show possible failure scenarios and general degradation points of the system. Several recommendations of plans for both long term and short term improvements to the network will be generated.

3.3 Evaluation

After design alternatives have been created, the project team will begin evaluation of the different scenarios and recommendations for TVSR. Evaluations will be based on a rubric composed of important and relevant criteria as identified by the project team and TVSR stakeholders. This rubric will be based on categories such as cost, time, feasibility, and desirability of each alternative. Each of these categories will have a varying range of points that can be assigned from specific categories based on the importance of that category to the camp. To determine what solution the project team will formulate their proposed recommendations around, the points will be tallied up and the best solution for TVSR will be chosen based upon the available criteria.

3.4 Project Schedule

The following Gantt Charts, Table 1 and Table 2, outline the expected timeframe the project team anticipates each task of this proposal will require. This illustrates the approximate number of weeks each phase will take and when each phase should be completed.

Table 1: Proposed project schedule for A and B term.

A/B-Term Gantt Chart									
Proposal Writing									
Data Collection									
Compile Data									
Model Data									
Create Scenarios									
Score Scenarios									
Generate recommendations									
Write paper									
	A Term	A/B Break	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7

Table 2: Proposed project schedule for C term.

C-Term Gantt Chart									
Score Scenarios									
Generate Recommendations									
Edit Paper									
Create Poster									
Present to TVSR									
	B Term	B/C Break	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7

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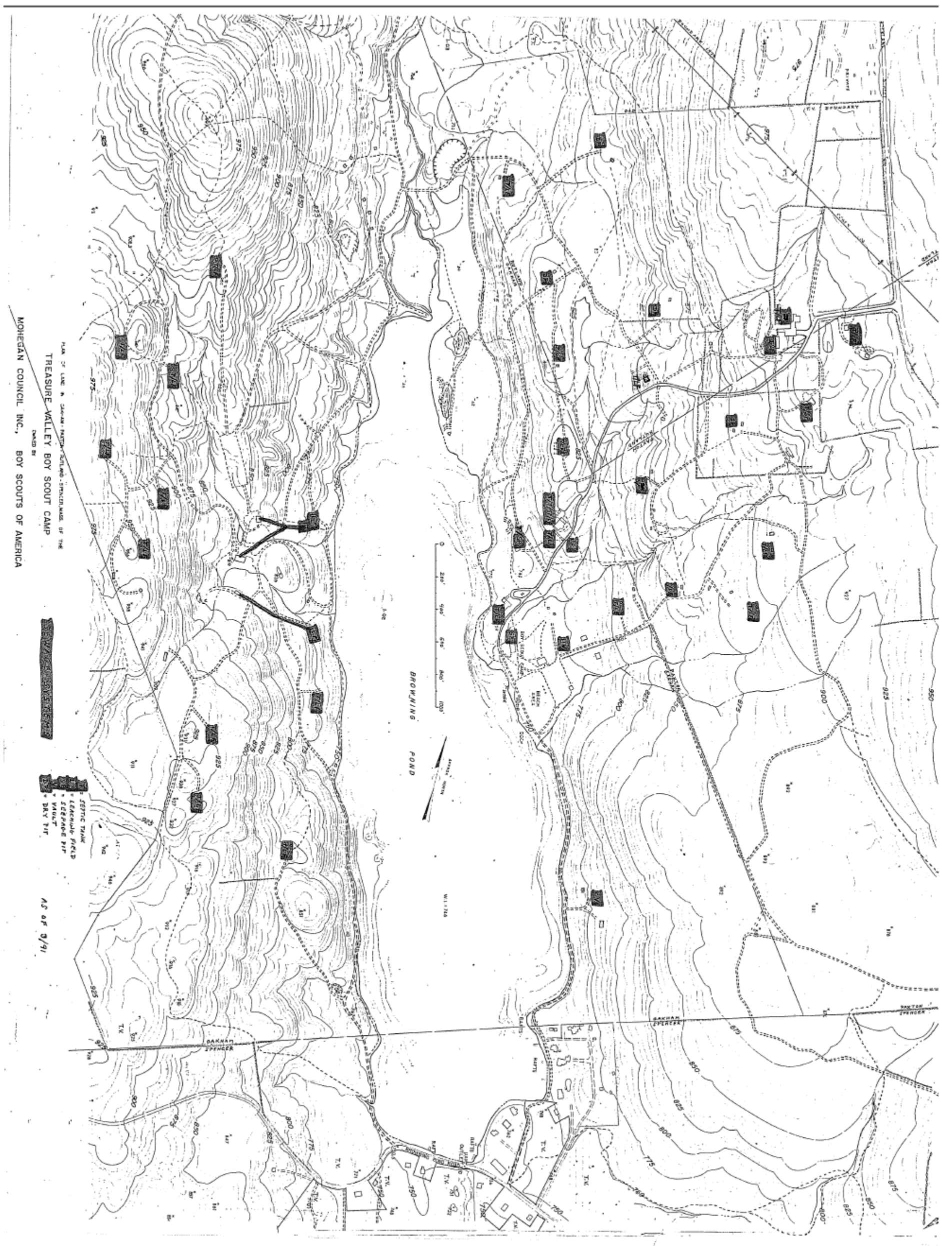
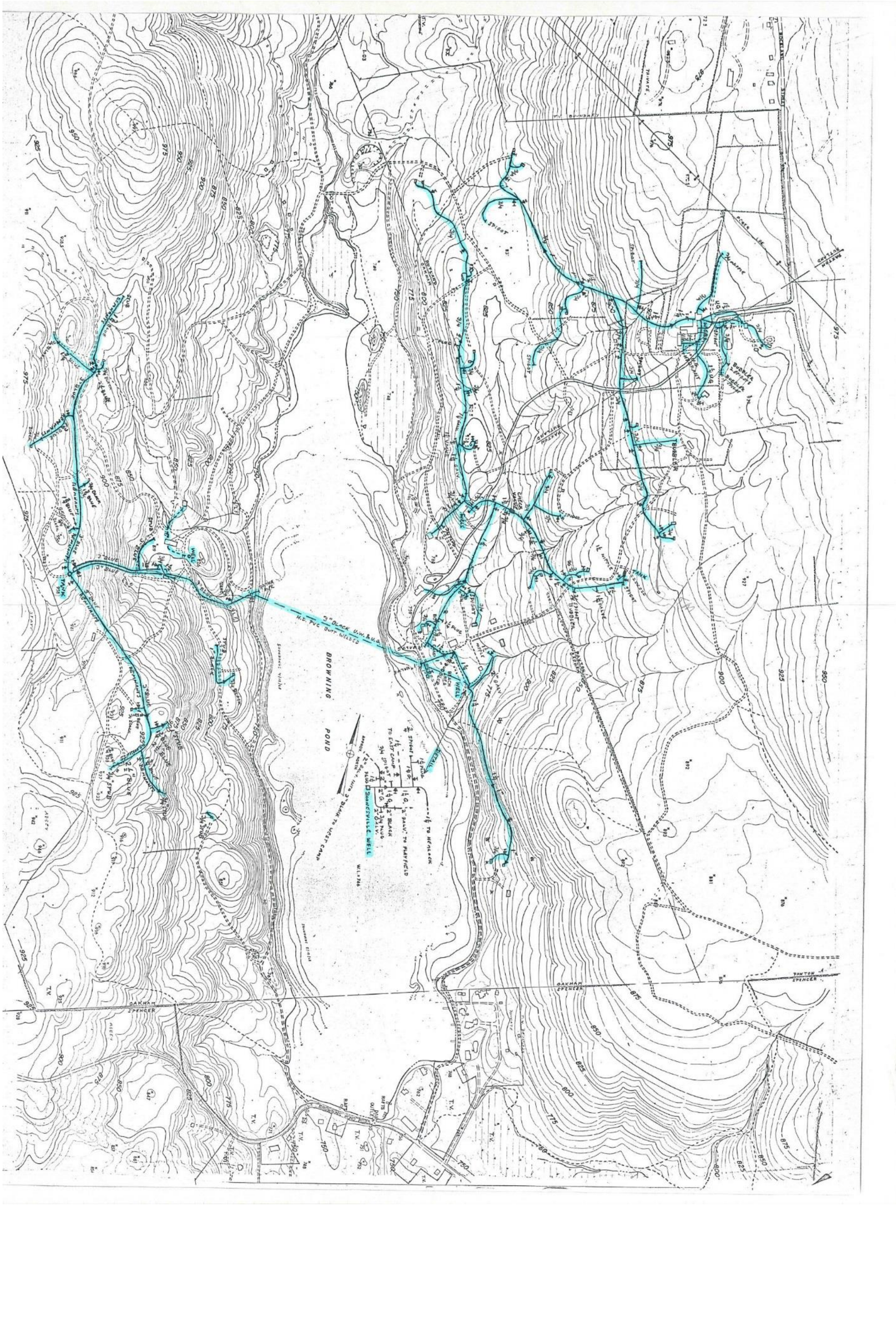
Appendix B: Septic System Map



Appendix C: Water Pipe Map



Appendix D: Survey responses of various TVSR stakeholders

	Ray Griffin	Jay Eager	Michael McQuaid	Jeff Hochkiss	Warren Bock	Tom Chamberland	Sum	Value
Well relocation	1	2	2	4	1	2	12.0	1
Well contamination treatment	1	3	1	1	2	3	11.0	1
Replacing eisting piping	5	4	5	2	3	5	24.0	2
Winerizing pipe system	9	5	3	3	5	4	29.0	2
Moving septic fields	11	8	9	11	4	6	49.0	3
Relocation of East Lodge	11	9	10	11	9	9	59.0	3
Implementation of storage tanks	5	7	8	11	6	11	48.0	3
Do nohing to the existing water system	11	11	7	11	10	10	60.0	3
Fire suppression system	3	10	4	5	8	7	37.0	2
Water system expansion	1	6	6	11	7	1	32.0	2
*10 modifications were listed, with a blank space for a write in suggestion. These were ranked from 1-11, with 1 being the most desired and 11 being the least.								
Values were determined based on the total sum of the modifications. The ranges are as follows: **1:** 1-12 **2:** 13-37 **3:** 38-60								

Appendix E

Cost analysis tables for various piping materials and the labor hours associated with installation

Please note: Cells highlighted in yellow were interpolated by the project team

All cost estimates were found in the 2011 version of RSMeans.

Babbitt, C., Baker, T., Balboni, B., Bastoni, R. A., Chiang, J. H., Christensen, G. W., . . . Waier, P. R. (2011). *RSMeans Plumbing Cost Data* (M. J. Mossman Ed.). Norwell, MA: Reed Construction Data Construction Publishers & Consultants.

Table 1: Total Pipe Material Costs

Material		3/4"	1"	1 1/4"	1 1/2"	2"
Galvanized Steel	**Price/Foot (Home Depot - 1/24/2016)**	**$1.74**	**$2.08**	**$2.90**	**$4.14**	**$4.39**
	COST (AG)	$11,341.29	$1,647.06	$5,229.40	$11,003.81	$680.92
	COST (BG)	$5,143.77	$0.00	$4,535.83	$3,546.41	$3,092.67
PVC	**Price/Foot (Lowe's - 1/24/206)**	**$0.29**	**$0.45**	**$0.74**	**$0.63**	**$0.89**
	COST (AG)	$1,914.17	$355.26	$1,328.07	$1,667.97	$137.49
	COST (BG)	$868.16	$0.00	$1,151.93	$537.57	$624.45
	Price/Foot (RSMEANS - 1/28/206)	**$0.17**	**$0.22**	**$0.34**	**$0.46**	**$0.70**
	COST (AG)	$1,110.61	$174.46	$612.68	$1,221.76	$108.50
	COST (BG)	$503.71	$0.00	$531.42	$393.76	$492.80
Polyethylene	**Price/Foot (Home Depot - 1/25/2016)**	**$0.19**	**$0.33**	**$0.45**	**$0.59**	**$0.81**
	COST (AG)	$1,239.96	$258.60	$809.46	$1,574.48	$125.60
	COST (BG)	$562.38	$0.00	$702.10	$507.44	$570.45
	Price/Foot (RSMEANS - 1/28/206)	**$0.60**	**$0.84**	**$0.97**	**$1.09**	**$1.63**
	COST (AG)	$3,919.80	$666.12	$1,738.93	$2,895.04	$252.65
	COST (BG)	$1,777.80	$0.00	$1,508.30	$933.04	$1,147.52
Chlorinated polyvinylchloride	**Price/Foot (Home Depot-1/27/2016)**	**$2.91**	**$4.25**	**$6.01**	**$7.26**	**$9.71**
	COST (AG)	$18,978.37	$3,370.25	$10,821.01	$19,269.28	$1,505.05
	COST (BG)	$8,607.52	$0.00	$9,385.82	$6,210.28	$6,835.84

Table 2: Labor hours associated with the installation of various piping material

	3/4"	1"	1 1/4"	1 1/2"	2"
Galvanized Steel	**0.131**	**0.151**	**0.18**	**0.2**	**0.25**
ABOVE GROUND	855.823	119.743	324.36	531.2	38.75
BELOW GROUND	388.153	0	281.34	171.2	176
PVC	**0.1**	**0.011**	**0.012**	**0.013**	**0.015**
ABOVE GROUND	653.3	8.723	21.624	34.528	2.325
BELOW GROUND	296.3	0	18.756	11.128	10.56
Polyethylene	**0.019**	**0.021**	**0.0215**	**0.022**	**0.027**
ABOVE GROUND	124.127	16.653	38.743	58.432	4.185
BELOW GROUND	56.297	0	33.6045	18.832	19.008

Table 3: Labor costs of installing various pipe materials

PIPES - Labor Costs	3/4"	1"	1 1/4"	1 1/2"	2"
Galvanized Steel	**$8.60**	**$9.55**	**$10.30**	**$11.20**	**$13.80**
ABOVE GROUND	$56,183.80	$7,573.15	$18,560.60	$29,747.20	$2,139.00
BELOW GROUND	$25,481.80	$0.00	$16,098.90	$9,587.20	$9,715.20
PVC	**$0.54**	**$0.60**	**$0.66**	**$0.72**	**$0.79**
ABOVE GROUND	$3,527.82	$475.80	$1,189.32	$1,912.32	$122.45
BELOW GROUND	$1,600.02	$0.00	$1,031.58	$616.32	$556.16
Polyethylene	**$1.03**	**$1.11**	**$1.16**	**$1.20**	**$1.48**
ABOVE GROUND	$6,728.99	$880.23	$2,081.31	$3,187.20	$229.40
BELOW GROUND	$3,051.89	$0.00	$2,081.31	$1,027.20	$1,041.92

Table 4: Component labor hours for different material components

	3/4"	1"	1 1/4"	1 1/2"	2"
Three-Way Connectors - PVC	**0.132**	**0.152**	**0.1685**	**0.185**	**0.208**
ABOVE GROUND	1.584	0.304	0.8425	1.85	0.416
Connectors - PVC	**0.088**	**0.1**	**0.1125**	**0.125**	**0.139**
ABOVE GROUND	0.352	0	0.225	0.5	0.139

Connectors - Polyethylene	**0.152**	**0.175**	**0.1855**	**0.196**	**0.208**
ABOVE GROUND	0.608	0	0.371	0.784	0.208

Table 5: Component labor costs for different material components

	3/4"	1"	1 1/4"	1 1/2"	2"
Three-Way Connectors - PVC	**$7.10**	**$8.20**	**$9.10**	**$10.00**	**$11.25**
ABOVE GROUND	$85.20	$16.40	$45.50	$100.00	$22.50
Connectors - PVC	**$1.09**	**$4.54**	**$6.05**	**$7.55**	**$14.70**
ABOVE GROUND	$4.36	$0.00	$12.09	$30.20	$14.70
Connectors - Polyethylene	**$8.20**	**$9.45**	**$10.03**	**$10.60**	**$11.25**
ABOVE GROUND	$32.80	$0.00	$20.050	$42.40	$11.25

Table 6: Insulation Costs of Above Ground Piping

		3/4"	1"	1 1/4"	1 1/2"	2"

Foam Insulation	**Price/Foot (Home Depot - 1/25/2016)**	**$0.27**	**$0.33**	**$1.63**	**$1.63**	**$1.58**
	COST (AG)	$1,731.25	$263.01	$2,938.39	$4,330.94	$244.68
Rubber Insulation	**Price/Foot (Home Depot- 1/25/2016)**	**$1.04**	**$1.21**	**$2.74**	**$1.70**	**$2.68**
	COST (AG)	$6,805.21	$958.21	$4,937.98	$4,511.66	$415.92
1/2" wall	**Price/Foot (RS Means)**	**$0.68**	**$0.75**	**$0.87**	**$1.06**	**$1.38**
	COST (AG)	$4,442.44	$594.75	$1,567.74	$2,815.36	$213.90

Table 7: Hours and Costs per foot segments of PVC trenched at a depth of three feet

PVC Diameter (inches)	Hours Required per foot	Total Hours	Cost per foot ($)	Total Cost ($)
0.75	0.08	522.64	3.78	24,694.74
1.0	0.086	68.198	4.05	3,211.65
1.25	0.089	160.378	4.21	7,577.41
1.5	0.092	244.352	4.36	11,580.16
2.0	0.109	16.895	5.15	798.25

Table 8: Component labor costs

3/4"	1"	1 1/4"	1 1/2"	2"
$2.48	$2.13	$3.50	$3.07	$4.09
$2.78	$8.85	$12.45	$16.05	$28.00
$3.28	$5.82	$11.48	$11.48	$11.98
$60.25	$60.25	$83.35	$123.75	$132.45
$7.98	$11.60	$14.92	$20.81	$26.70
$3.74	$4.98	$6.58	$6.78	$8.98
$1.09	$4.54	$6.05	$7.55	$14.70
$0.79	$0.83	$1.45	$2.06	$2.76

Appendix F: Field Reports

Date of visit: October 21, 2015

Location: Treasure Valley Scout Reservation

Purpose: Take photos of water pumps, filters, heaters, and pipes in all areas of the Reservation

Attendees:
WPI: Bryan, Adam, Nick
TVSR: Mike McQuaid

Notes:
We visited the Farmhouse Well, East Lodge, Boonesville Plains, and the West Camp well. We took pictures of every label and picture on all hot water heaters, filters, and pumps in each location.This data was collected so that we could compose an accurate representation of the water systems at TVSR. We identified the locations in TVSR that have year round and seasonal hot water access and discussed how the camp works with Mike. We were introduced to Ranger Matt, who helped provide us with more information about the water system of TVSR. After our discussions, we went up to the TVSR map room with Mike and looked for copies of the water and septic systems of TVSR. We identified multiple maps that we would like to look at when composing our project, and Mike said he would take them home and scan them for us to use.

We attempted to gather GPS data as well, but it began to rain when we were setting up the equipment and we decided to not collect data using the school's equipment in the rain.

Date of visit: October 23, 2015

Location: Treasure Valley Scout Reservation

Purpose: Collect GPS data for campsites and water pipe locations

Attendees:
WPI: Adam, Nick

Notes:
We wanted to use the GPS equipment and therefore had chosen a sunny day with few clouds in the sky in order to take accurate measurements of TVSR campsites and pipe locations. We were able to set up the base of the TOPCOM system and acquire a lock of its location at West Camp, but from there on we could not get the Rover and Base. We resorted to taking a reading from the GPS and recording the Longitude, Latitude, and Elevation that we thought was accurate. We did this for the majority of the campsites and then struggled to come up with a method for recording the location of a water pipe moving through the woods. This led us to downloading an app for iPhone called MapmyHike. This app was able to map the path we took following the water pipe from the Boonesville well to the Hemlocks Campsite. We were not sure how to export this data, however, and so we decided to only take that one measurement and come back at another date when we sure we could access all the data we collected.

Date of visit: October 29, 2015

Location: Treasure Valley Scout Reservation

Purpose: Collect GPS for pipe and wells throughout TVSR

Attendees:
WPI: Adam, Nick, Bryan

Notes:
We returned to TVSR on the 29th armed with a new iPhone application called “Map Plus”. This application allowed us to walk the water pipes of TVSR with the app open, and as we walked the app recorded the GPS coordinates of the phone every 50 feet. The application allowed us to take photos to mark the location of shut off valves and intersections, as well as the start and end of the piping that we were looking at. This app was extremely useful to our team, as we were able to to get accurate coordinates for all of the piping and well location. This was an extremely long day of work for the team, but we were successful in our endeavour.

Date of visit: November 18, 2015

Location: Treasure Valley Scout Reservation

Purpose: Review pipe locations and collect well data

Attendees:
WPI: Adam, Nick, Bryan

Notes:
We arrived at TVSR on this sunny and brisk Fall day. The intention was to gather more data on the pipes and wells. With the use of a depth gauge and the some “creative” methods to remove the well heads, we were able to get the depth to water on <u>all four</u> of the wells. Our results are in the table:

Farmhouse	14.8 ft
West Lodge	12.15 ft
East Lodge	38.4 ft
Boonesville	3.4 ft

As far as flow rate data, we were were able to test the flow rate of Farmhouse well. This is currently the only well online at TVSR. We accessed a bigot connected to the Farmhouse system and measured the time it took to fill four gallons. A borrowed 5 gal bucket served for measuring purposes. Multiple measurements were taken and the results can be seen with this table:

Trial #	Time to fill 4 gal (sec)	Flow Rate (gpm)
Trial #1	48.13	4.99
Trial #2	48.03	5.00
Trial #3	48.15	4.98
Average	48.10	4.99

The final accomplishment of the trip was searching and mapping the remaining pipes for the GIS shapefile. All unaccounted for pipes are confirmed to be underground and will be labeled as such.

Appendix G: How to use QGIS

How to Use QGIS

A Quick Guide for Treasure Valley Scout Reservation (TVSR)

Created by Treasure Valley Triumvirate (TVT)
Worcester Polytechnic Institute
February 2016

Table of Contents

Glossary of Terms

QGIS – a shorthand for Quantum Geographic Information System

Shapefile – a file format compatible with QGIS as well as ArcGIS

CRS – a shorthand for Coordinate Reference System. It is a way for all files on QGIS to line up

Polygon – a type of feature that can be any shape and represents various structures on QGIS

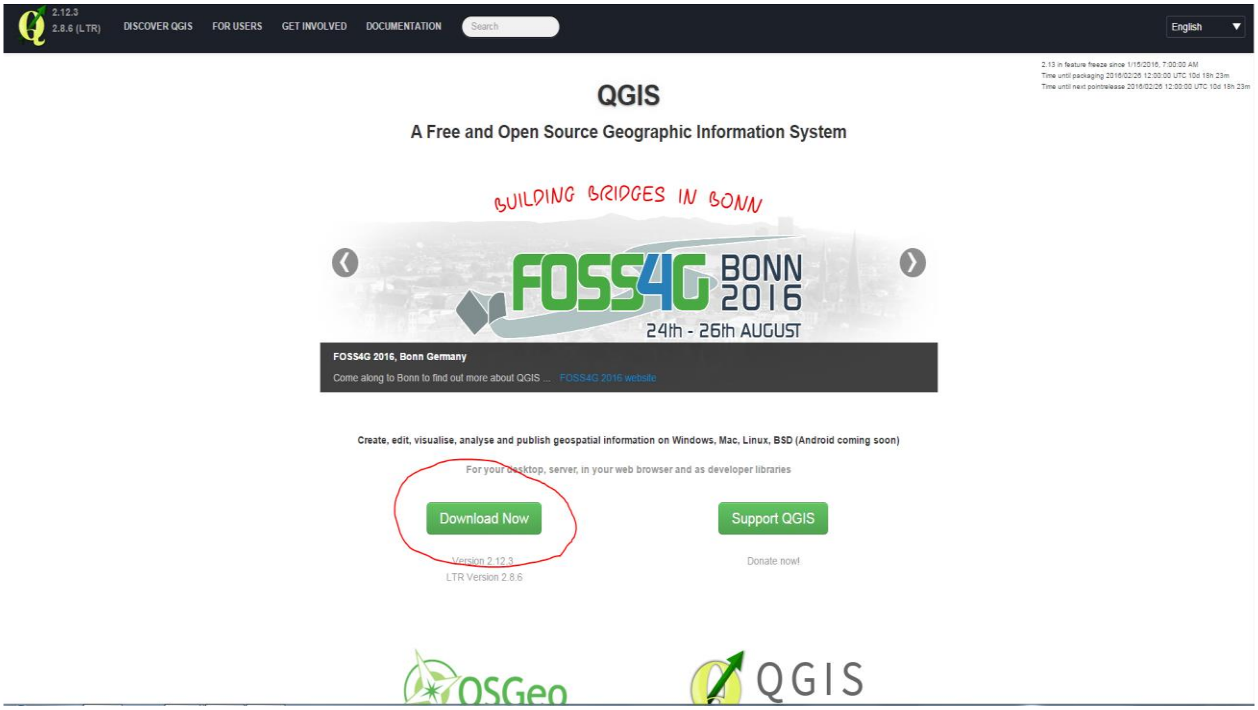
Buffer zone – the zone around a feature; can be used to show the distance away structure have to be built away from other structures

Section 1: Installing QGIS

The first step is downloading the program QGIS. This is an free web application.

Navigate to the website www.qgis.org/en/site.

Click on the "Download Now" button and download the "Latest release" for new users. Open the download link and follow the step-by-step process for installing the program.



When installing, select your desktop as the desired folder for installation. This will create a QGIS icon on your desktop.

Section 2: Setting Up and Navigating QGIS

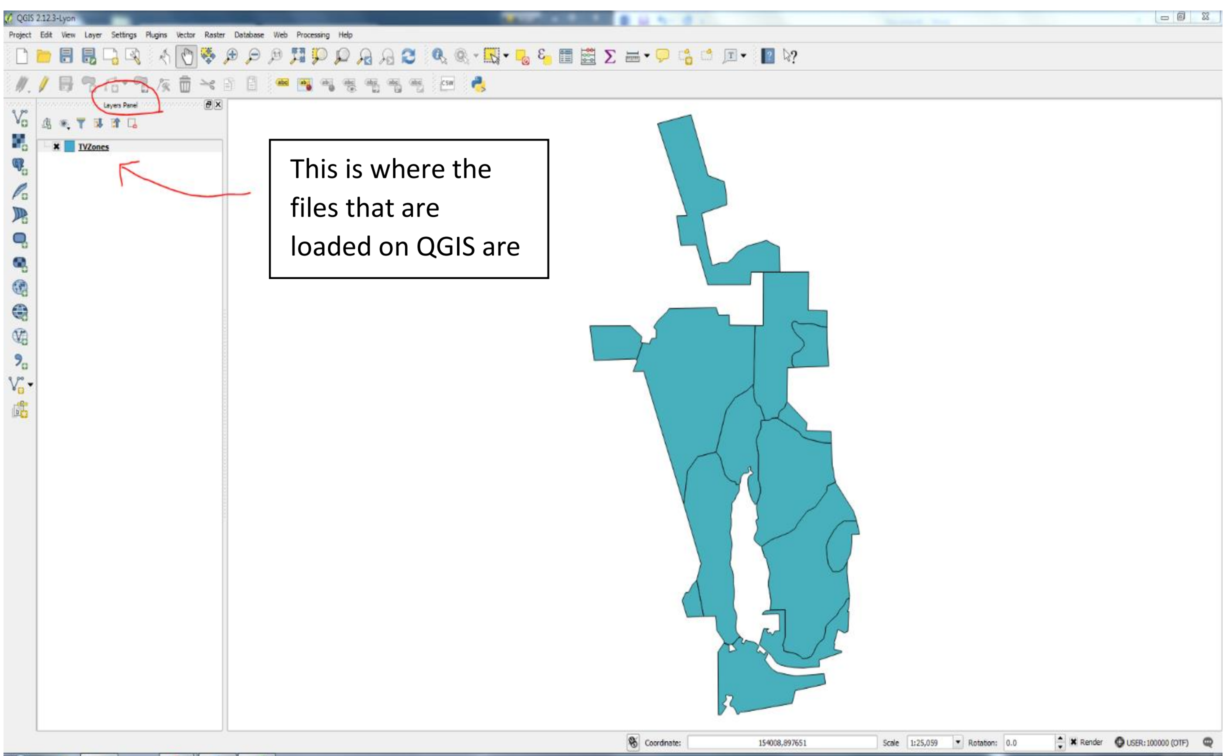
Once QGIS is installed on your computer, locate and open it.

The first thing you are going to see is a blank map. There are going to be many toolbars available for this program, but since the main purpose is to view shapefiles, the only toolbar that you need to make sure is open is the layers panel. This is where added shapefiles will appear, where you can re-order the layers, and where you can turn certain layers off or on.

If the Layer Panel is not visible, go to the “View” dropdown menu and highlight “Panels”. Make sure “Layers Panel” is selected.

Try adding the file “TVZones” to the program. This should always be the first file added to QGIS to serve as a base. To open this file, located where the files you downloaded from the TVSR site are and select “TVZones.shp”. There are going to be many files with the same file, you are only going to need the one that ends in .shp. Drag and drop this file into the QGIS screen and it should appear on your screen as shown.

This process works for any file you decide to add to the map.



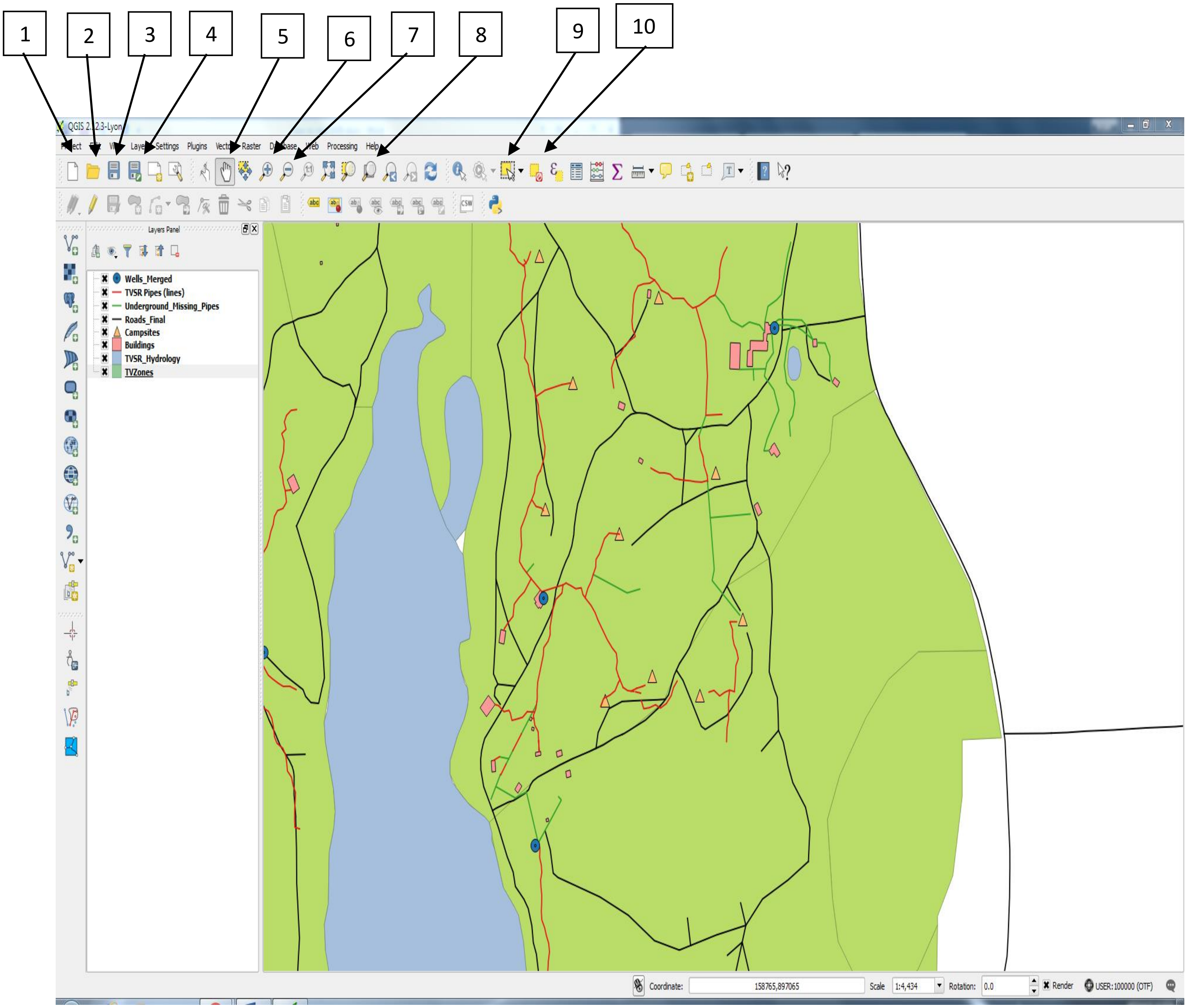
Notice how the file that was dragged over now appears in the Layer Panel on the left side of the screen. There is a little x next to the shapefile name which can allow the visual to appear and disappear. When there are multiple files in the Layer Panel, clicking on the file name and dragging it up or down results in the reordering of these layers. This will allow layers to be placed on top of each other.

To remove a file completely from the Legend, simply right click on the file name and click remove.

Before you begin adding more files to QGIS the Coordinate Reference System (CRS) needs to be set. Locate the "TVSR_Hydrology.shp" file and add it to QGIS. Once you see "TVSR_Hydrology" in the Layers Panel right click on it and select "Select Project CRS from this Layer". The CRS has been set and you can now add any files you would like.

There are some basic functions of QGIS that need to be identified to effectively use it. These tools are for viewing purposes only and every effort should be made to avoid editing the files unless it is intended. Below is a numbered list of functions, the corresponding number is labeled on the following picture. A short description of each function is also included.

1. New – Begins a new project
2. Open – Opens a saved project
3. Save – Saves the current project
4. Save As – Saves the current project as a new project
5. Pan Map – Allows you to click and drag the map to view more
6. Zoom In – Zooms in where you click
7. Zoom Out – Zooms out where you click
8. Zoom to Layer – Zooms in on the layer that is highlighted in the Layers Panel
9. Select Features by Area of Single Click – When a file is highlighted in the Layers Panel, clicking on a feature that is a part of that file will highlight the feature on the file's attribute table
10. Deselect Features from All Layers – Deselects highlighted features


1
2
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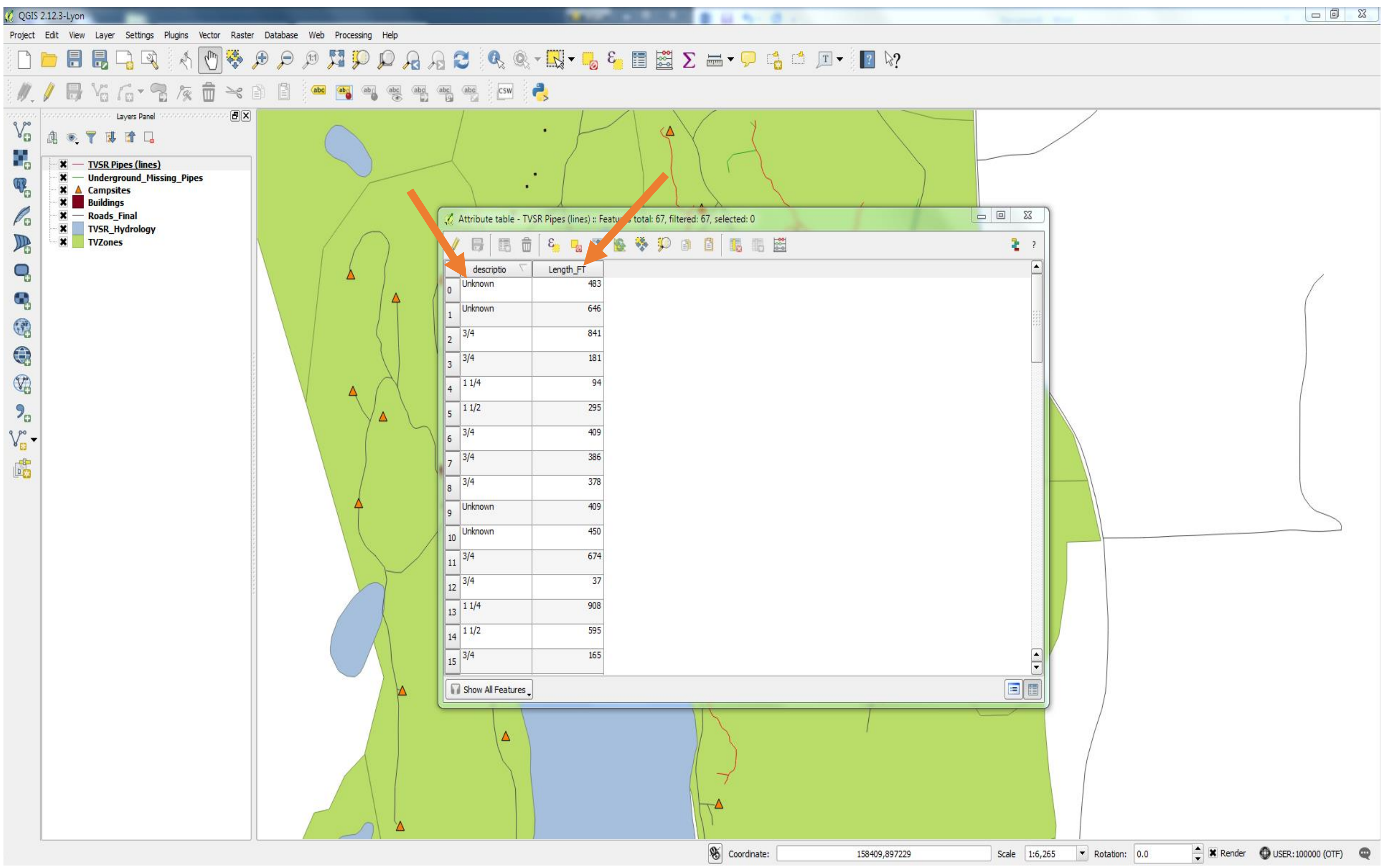
6
7
8
9
10
Settings
Plugins
Raster
Processing
Help
Layers Panel
Wells_Merged
TVSR Pipes (lines)
Underground_Missing_Pipes
Roads_Final
Campsites
Buildings
TVSR_Hydrology
TVZones
Coordinate:
158765,897065
Scale
1:4,434
Rotation:
0.0
Render
USER:100000 (OTF)

Section 3: The Attribute Table

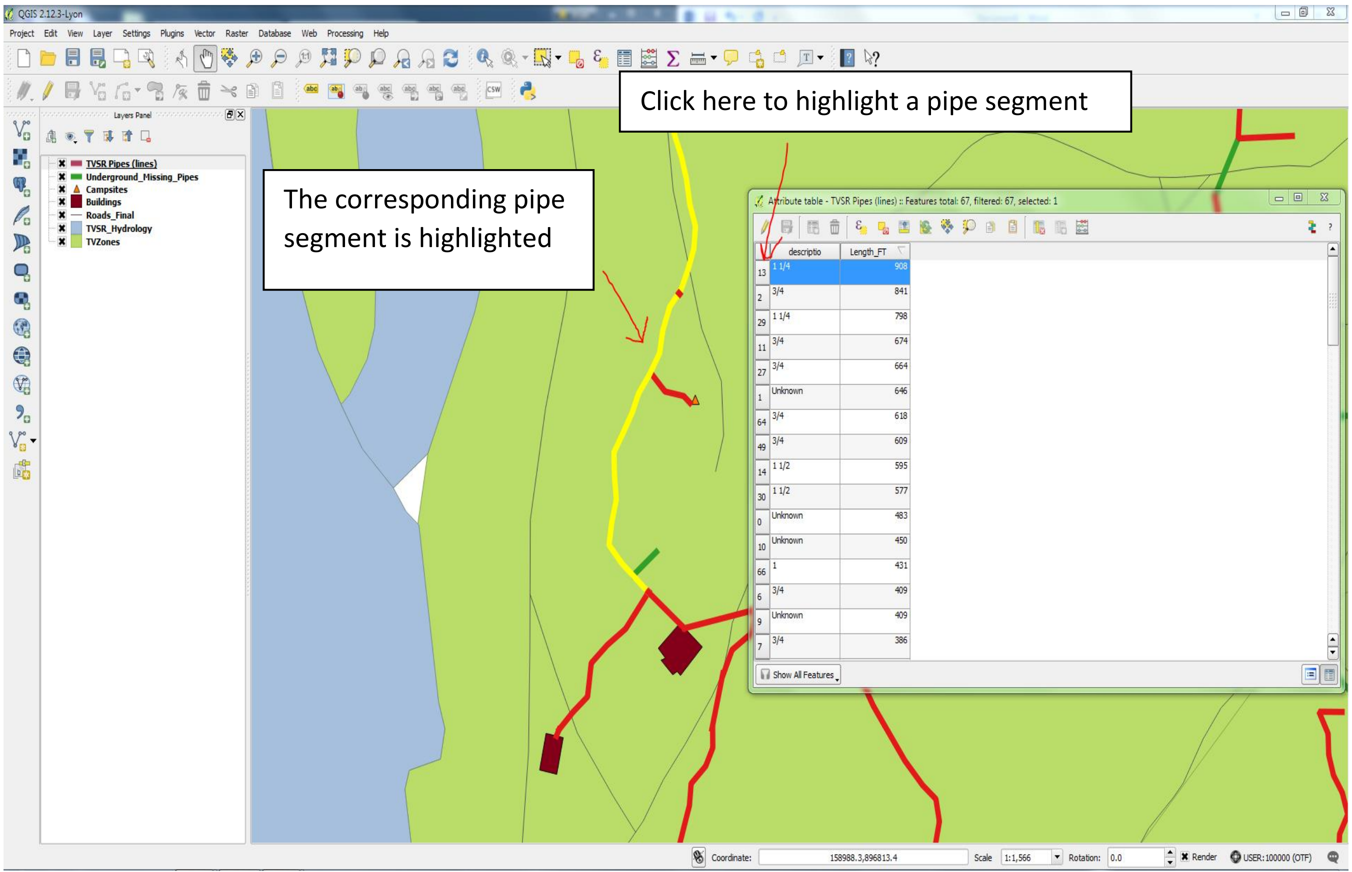
The attribute table is a powerful tool for QGIS. Each shapefile has an attribute table that gives certain information about the shapefile. What the attribute table of each shapefile contains is outlined in Section 6.

To view the attribute table of a certain shapefile, simply right click on the file name and select "Open Attribute Table". This will bring up the attribute table for that file. The example is the attribute table of "TVSR Pipes (lines)" which is the above ground piping network. You will notice the attribute table gives the pipe diameter and length of each segment of pipes.



The attribute table can also be reorganized by to show the files in order from largest to smallest or vice versa. This can be done by clicked the name of the category in the Attribute Dialog box identified above.

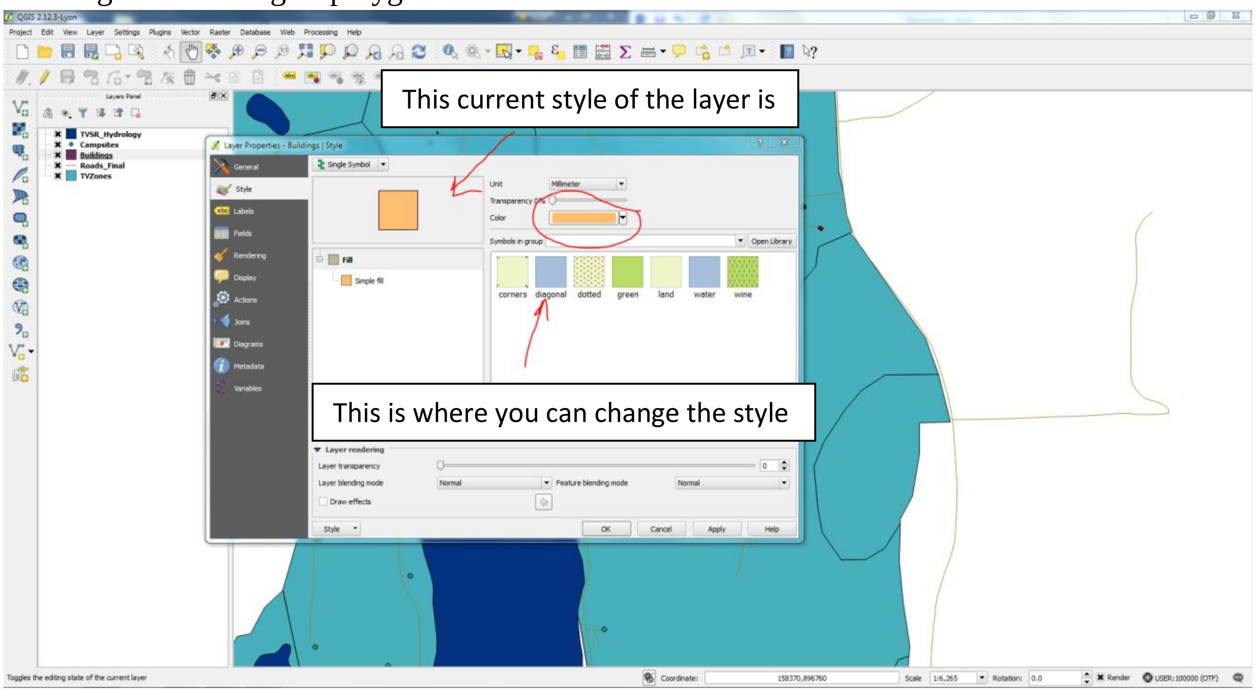
The attribute table also can identify certain segments of pipe on the map. By clicking one of the numbers lining the left side of the Attribute Dialog Box, the corresponding segment of pipe will be highlighted on the map. This is shown in the following photo. This also applies to the attribute table of any shapefile.



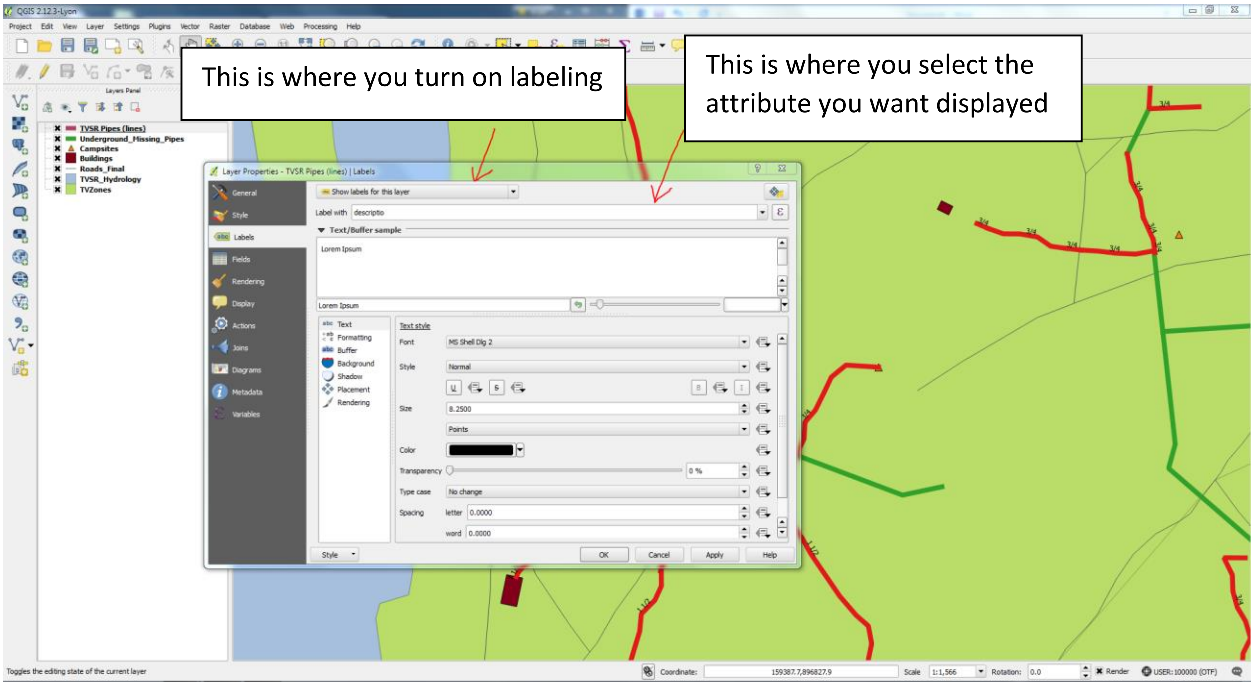
Section 4: Changing the Style and Labeling

When files are added to QGIS the style is set randomly. This may not be helpful to you, so you may want to change how it is displayed.

To do this right click on the file for ehich you wish to change to the style. Then click on “properties,” which will bring up a dialog box called “Layer Properties.” On the sidebar select the “Style” option, this will bring up all the style for that particular layer. Shapefiles can be points, lines, and polygons so the styles will change slightly depending on the file you selected. In this menu you can change the color, line thickness, and other aspects of the shapefile. The dialog box to change a polygon file can be seen below.



Labeling features in QGIS can also be done to show information from the Attribute Table displaying directly on the corresponding feature. This is done by right clicking on the file and clicking on properties. In the Layer Properties dialog box click on the “Labels” tab on the left side of the box. Next, click on the dropdown menu at the top of the dialog box and select the “Show labels for this layer” option. Then click the dropdown menu immediately below to select the attribute you would like labeled for the feature. Select “Ok” when you are finished. To illustrate this, the above ground pipes shapefile was again used.



Notice in the dialog box you are able to change the style, color, and size of the text that displays on each segment.

Section 5: Where to Download Files

The files created by the Treasure Valley Triumvirate team for the purposes of MQP as well as the files the team felt would assist TVSR in future operations are saved on the TVSR website. The files will need to be downloaded from the site to be used on QGIS.

Name of File	Type	Author	Description	Attribute Table
IWPA_POLY_DISSOLVED	Polygon	MassGIS	Shows the IWPA zone radii for all four of TVSR's wells	Has information on the length and area of each of these polygons
ZONE1_POLY_DISSOLVE	Polygon	MassGIS	Shows the Zone 1 radii for all four of TVSR's wells	Has information on the length and area of each of these polygons
ZONE2_POLY_DISSOLVE	Polygon	MassGIS	Shows the Zone 2 radii for all four of TVSR's wells	Has information on the length and area of each of these polygons
TVZones	Polygon	MQP Group 2015	Shows the zones of TVSR	Identifies the name of each zone and the total area
TVSR_Hydrology	Polygon	MQP Group 2015	Shows the major water bodies on TVSR property	Has information on the length and area of each of these polygons
Roads_Final	Line	MQP Group 2016	Shows the roads that run through TVSR property	Contains the length of each segment of road
Buildings	Polygon	MQP Group 2015	Shows the locations of buildings owned by TVSR	Contains the name of each building, how people can stay in it, the use, and whether it has access to hot water
Campsite	Point	MQP Group 2015	Shows the locations of campsites owned by TVSR	Contains the name of each campsite, if/what type of latrine there is, which side of the camp it's on, capacity, and if it has access to hot water
Wells_Merged	Point	MQP Group 2016	Shows the locations of all four groundwater wells	Lists the names of each of the wells
Farmhouse Well Service Zone	Polygon	MQP Group 2016	Shows the area the Farmhouse Well serves	Nothing
West Lodge Well Service Zone	Polygon	MQP Group 2016	Shows the area the West Lodge Well serves	Nothing
East Lodge Well Service Zone	Polygon	MQP Group 2016	Shows the area the East Lodge Well serves	Nothing
Old Storage Tank	Point	MQP Group 2016	Shows the location of the old destroyed storage tank	Nothing
Property_line	Line	MQP Group 2015	Shows the property lines of TVSR	Nothing

TVSR Pipes (lines)	Line	MQP Group 2016	Shows the location of the above ground piping network	Lists the diameter and length of each segment of pipe. Also has information on the flow velocity of water through the pipe segment.
TVSR Pipes (points)	Point	MQP Group 2016	Shows the locations of components of the water system	Lists the type of component is located at the point and the picture name that corresponds to a picture taken of the actual location
Underground_Missing_Pipes	Line	MQP Group 2016	Shows the location of the underground piping network	Lists the diameter and length of each segment of pipe. Also has information on the flow velocity of water through the pipe segment.
Septic System	Polygon	MQP Group 2016	Shows the location of all the septic systems located at TVSR	Identifies what type of septic system each polygon is
Leaching_Fields	Polygon	MQP Group 2016	Shows the location of all Leaching Fields located at TVSR	Nothing
Septic_Tanks	Polygon	MQP Group 2016	Shows the location of all Septic Tanks located at TVSR	Nothing
Septic_System_Buffer_other_septic_100ft	Polygon	MQP Group 2016	Shows the minimum distance away each septic system needs to be away from another septic system	Identifies what type of septic system the feature is buffering
Septic_System_Buffer_property_lines_10ft	Polygon	MQP Group 2016	Shows the minimum distance away each septic system needs to be away from another septic system	Identifies what type of septic system the feature is buffering
Septic_System_Buffer_publc_well_2ft	Polygon	MQP Group 2016	Shows the minimum distance away each septic system needs to be away from a public well	Identifies what type of septic system the feature is buffering
Septic_System_Buffer_surface_waters_25ft	Polygon	MQP Group 2016	Shows the minimum distance away each septic system needs to be away from a surface water body	Identifies what type of septic system the feature is buffering
Septic_System_Buffer_water_supply_line_10ft	Polygon	MQP Group 2016	Shows the minimum distance away each septic system needs to be away from a water supply line	Identifies what type of septic system the feature is buffering
Possible_Well_Sites	Polygon	MQP Group 2016	Shows the areas where a new well can be constructed and where it can't according to MassDEP regulation	Nothing
New Piping Network	Line	MQP Group 2016	Shows the suggested layout of the pipe work recommended by the project team	Lists the length of each segment of pipe
NEW WELLS	Point	MQP Group 2016	Shows several locations the project team recommends a well to be drilled	Nothing

IWPA NEW WELLS	Polygon	MQP Group 2016	Shows the IWPA radius that was estimated for the new well locations	Nothing
Zone1 NEW WELLS	Polygon	MQP Group 2016	Shows the Zone 1 radius that was estimated for the new well locations	Nothing

Contact

If there are any questions regarding the files provided to by the project team or using QGIS please direct them to the project alias. After the May 2016 further questions can be directed to Bryan Sadowski.

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Bryan Sadowski:

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