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Design of an Appropriate Water Supply System for Dolores Water District, Abra

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Abstract

Water is an essential resource for all living organisms, yet water systems often face challenges in supply, energy consumption, and sustainability. The Dolores Water District (DWD) in Abra, Philippines, currently relies on high-powered electric pumps to distribute water to its service areas, resulting in high operational costs and vulnerability during power outages caused by typhoons and other calamities. This study proposes the integration of a gravity-fed upland spring water system with the existing pump-based distribution—a conjunctive use approach—to improve energy efficiency and water reliability. The objectives of the study are to assess the current condition of DWD in terms of energy consumption and water performance, and to evaluate how the proposed system design affects these parameters. Using a combination of system analysis, hydrological assessment, and energy evaluation, the study anticipates that the inclusion of a gravity-fed water supply will reduce electric energy usage, lower operational costs, and maintain continuous water service even during power interruptions. The findings aim to provide a sustainable water management strategy that enhances service delivery while promoting energy efficiency in local water districts.

Chapter 1

1.0 Background of the Study

Water is everywhere. It is very essential to every living and as well as non-living organism on earth. It also considered as source of life and in fact no one can live without it. Because of its importance, many big companies get interested in business and because of these businesses, the water resources were in trend. Indeed, World Health Organization[WHO] and, UNICEF (2005) expounded that human life, like all animal and plant life on the planet, is dependent upon water. Not only water is needed to grow food, generate power and run industries, but it is needed as a basic part of daily lives – human bodies need to ingest water every day to continue functioning. Communities and individuals can exist without many things if they have to – they can be deprived of comfort, of shelter, even of food for a period, but they cannot be deprived of water and survive for more than a few days. (p. 26)

From the Water Systems (n.d.), it was revealed that there is the same amount of water on Earth today as there was 3 billion years ago. About 70 percent of the earth's surface is covered in water, and 97 percent of that is salty or undrinkable. Three percent of the water on Earth is freshwater, but 2.997 percent of that is locked up in icebergs and glaciers. Only 0.003 percent of the world's water is available to us for all our needs and uses. Of the total world's freshwater supply, over two thirds are found underground. There is a limited supply of fresh water in the world and about 25 percent of this fresh water is in the lakes and rivers of Canada. Water is our precious resource.

It was also in the same article that it was pointed out that toilets (while consuming nearly one quarter of our municipal water supply) use over 40 percent more water than needed. Many homes lose more water from leaky taps than they need for cooking and drinking. A single lawn sprinkler spraying 19 litres per minute uses 50 percent more water in just one hour than a combination of ten toilet flushes, two 5 minute showers, two dishwasher loads, and a full load of clothes. One litre of oil can contaminate up to 2 million litres of water. Landfills, leaking gasoline storage tanks, leaking septic tanks, accidental spills and farm land treated with pesticides and fertilizers are a few examples of how we are treating our precious groundwater (para. 1).

One source of water supply is the gravity fed water from mountain springs. TeachEngineering (2013), cited that water and hydrological engineers play a large role in addressing water poverty through the creation of appropriate technologies to provide water to developing communities. One common solution, given available topographic relief, is the implementation of gravity-fed water systems that pipe water without pumping or requiring costly energy. Typical gravity-fed system designs include a dam or spring catchment to collect the water and the water is piped via gravity through a number of treatment processes (sedimentation, filtration, chlorination). When the water reaches the community, it is clean and in ample supply. To correctly design gravity-fed water systems requires engineers to have a good understanding of civil engineering, physics and fluid mechanics (para. 1).

Because water is very important, many big industries got interested in managing this resource. Hence, they made systems so that management of this aquatic supply is to be maintained. According to dictionary, water system is a group of independent but interrelated elements comprising a unified whole; "a vast system of production and distribution and consumption keeping the country going". But a simpler definition was given that where it was stated that it is a system for supplying water to a community.

An example of a water system is the Public Water Systems. This is a water system of the United States of America where The United States is fortunate to have one of the safest public drinking water supplies in the world. According to the United States Environmental Protection Agency (EPA), public drinking water systems consist of community and non-community systems. A community water system (CWS) supplies water to the same population year-round. It serves at least 25 people at their primary residences or at least 15 residences that are primary residences (for example, municipalities, mobile home park, sub-divisions). Non-community water systems are composed of transient and non-transient water systems.

Transient non-community water systems (TNCWS) provide water to 25 or more people for at least 60 days/year, but not to the same people and not on a regular basis (for example, gas stations, campgrounds). Non-transient non-community water systems (NTNCWS) regularly supply water to at least 25 of the same people at least six month per year, but not year-round (for example, schools, factories, office buildings, and hospitals which have their own water systems). (Centers for Disease Control and Prevention, 2014, p. 1)

Moreover, according to the same article, of the approximately 155,693 public water systems in the United States, 52,110 (33.5%) are community systems and 103,583 (66.5%) are noncommunity systems, including 84,744 transient systems and 18,839 nontransient systems. Over 286 million Americans get their tap water from a community water system. Eight (8) percent of U.S. community water systems provide water to 82 percent of the U.S. population through large municipal water systems. Although the majority of community water systems (78%) are supplied by ground water, more people (68%) are supplied year-round by community water systems that use surface water. (Centers for Disease Control and Prevention, 2014, p. 1)In the Philippine setting, Water Environment Partnership in Asia (n.d.), revealed that the country is endowed with rich natural resources, including water, which are essential for the country's economic development and in meeting its Millennium Development Goals (MDGs). Water resources of the Philippines include inland freshwater (rivers, lakes, and groundwater), and marine (bay, coastal, and oceanic waters). Overall, there is sufficient water but not enough in highly populated areas, especially during dry season. Access to clean and adequate water remains an acute seasonal problem in urban and coastal areas in the Philippines. The National Capital Region (Metro Manila), Central Luzon, Southern Tagalog, and Central Visayas are the four urban critical regions in terms of water quality and quantity. The Government's monitoring data indicates: Just over a third or 36 percent of the country's river systems are classified as sources of public water supply: Up to 58 percent of groundwater sampled is contaminated with coliform and needs treatment; Approximately 31 percent of illness monitored for a five-year period were caused by water-borne sources; and many areas are experiencing a shortage of water supply during the dry season. (para. 6)

In the research of Mac Maquito and Max Maquito (2006) in their Ünderstanding Water Districts in the Philippines, they pointed out that the Philippines is said to be rich in water resources (The Integrated Water Resources Management Plan Framework 2006). It has 421 principal river basins, of which 20 are major river basins. The average annual rainfall is about 2,400 mm, of which 1,000 mm to 2,000 mm are collected as run-off by a natural topography of river basins, natural lakes, and numerous small streams. 16 major lakes each covering 400 hectares and above. In addition to surface water, the Philippines also draw from groundwater sources, which Contribute 14 percent of total water resources of the Philippines. Region I (Ilocos Region) and Region VII (Central Visayas – Cebu, Bohol, Negros Oriental) are the highest potential source of groundwater. About 86% of piped-water supply systems use groundwater as a source. (Water Environment Partnership in Asia, State of water environmental issues – Philippines).

On the other hand, Water Supply and Sanitation in the Philippines (2015) spelled out that data from the UNICEF-WHO Joint Monitoring Programme indicate that the Philippines is on track to meet its Millennium Development Goal targets for water supply and sanitation. However, with a population of more than 94 million in 2011, there are still some 7.5 million Filipinos without access to improved water supply facilities and 24 million without access to improved sanitation. Roughly 8.3 million people still defecate in the open and just 3 percent are connected to centralized sewerage systems. (p.IV)

At present, Abra has its water system. One among the functional system is the Bangued Water District. On its "Executive Summary",(n.d), indicated that the Bangued Water District was formally created on December 29, 1975 by virtue of resolution Number 293 passed by the Sanguniang Bayan of Bangued, Abra. Subsequently, the Local Water Ulities Administration (LWUA), which is the regulatory body of local water districts, issued its Conditional Certificate of Conformance numbered 028 on August 24, 1976. With the expansion of its service to the services to the neighboring towns of Peňarubia, Tayum, Pidigan, the Bangued Water District changed its name to Metro Bangued Water District (MBWD). (para. 1)

Additional information about MBWD is that the system draws water from the Lusuac Spring, about 8 km southeast of Bangued. It is located at Bgy. Lusuac in Peñarrubia at an elevation of about l94 meters above msl. Source facilities include a spring impoundment and intake box. The spring is enclosed by an artificial impounding structure made of cyclopean masonry lined with concrete. It is protected from falling leaves, twigs and other objects by a fine net cover and is enclosed by wire mesh and barbed wire. Water from the spring is conveyed to a nearby concrete intake box. The discharge of the spring as measured in 1989 was 208 lps. The WD is only utilizing 42 lps at present. The majority overflows into several irrigation channels. (Metro Bangued Water District, n.d. para. 1)

The municipality of Dolores has also its own water system run by Local Water Utility Administratoin (LWUA).
From Department of Internal Local Government Information, Dolores is situated in the central western part of the province of Abra. It is approximately within 120°50' east longitude and between 17°35" and 17°40" latitude. It is bounded on the north by the municipality of San Juan, on the east and southeast by the municipality of Lagangilang, on the west by the municipality of La Paz and on the southwest by the municipality of Tayum and the Abra River. (See map at Appendices)
Dolores has 15 barangays and a municipal land area of 4,050.03 hectares representing 1.02 percent of the total provincial land area. Among the municipality's barangays, Kimmalaba has the largest land area with 663.03 has. while Cabaroan is the smallest with an area of 93.53 has. The land use pattern is as follows: built-up area - 99.05 hectares or 2.45 percent of total municipal land area, forest land - 252.72 hectares or 6.24 percent, agricultural - 2,411.72 hectares or 59 percent, bamboo land - 461.30 hectares or 11.39 percent, stony land - 373.84 hectares or 9.20 percent, rivers/creeks - 407.07 hectares or 10.05 percent and roads - 44.96 hectares or 1.11 percent
Compared to other municipalities, Dolores is not so hilly and mountainous, though it has several hills. Among its hills are Immitlog, Namilagan, Cabuloan and Apaz. Valleys are mostly located along the banks of the Abra and the Malanas-Tineg Rivers.
Due to its rather flat terrain, the municipality has a relatively warm and moderate climate. Evenings are moderately warm and dawns are humid during the months of June to October, very warm during the months from March to May and cool during the months of November and December. Season is wet and dry with the driest months occuring from January to February. The months of July and August are "heavy downpour months" when typhoons usually occur. During these months, rivers and creeks overflow flooding practically all barangays destroying properties. (Dolores Quick Facts, n.d. para. 1, 2, 3).
At present, the system is using pump to supply water to the six zones covering the three (3) barangays of Dolores, Abra namely Poblacion, Bayaan and Pacac. It has two (2) water reservoirs. This water pump is supplying about eight hundred (800) household members. There is another existing system supplying Barangay Taping which water is direct from the spring where it is plenty of water even the time of dry season and is not covered by the two (2) reservoirs. It also supplies around eighty (80) households. The former six (6) zones are paying the minimum amount at around Php 300.00 equivalent to ten (10) cubic meter of water aside from the volume of water they consumed in a month, while the latter barangay is not paying the minimum but instead, they pay per cubic meter of water consumed amounting to a more or less Twenty pesos (php20.00) per cubic meter.
Based from the story of Hilario Guzman, a pump operator of Dolores Water District, at first, the municipality of Dolores has gravity fed upland spring water supply where the source is at Barangay Supiil in the municipality of San Juan. But when LWUA took over the management, they pulled out the pipes connected to the spring source and they drilled a well (next to river) near the area of the consumers to change water system to direct pumping (electric). This is for the reason that water from gravity fed from upland spring is not able to supply the water need of the growing number of water users. On the operation of water pumping the water district pay an electric bill of more or less 60,000php a month. He (Hilario Guzman) also added that when the strong typhoons Lando (2015) and Lawin(2016) destroyed the electric posts of Abra, where the maintenance group of the ABRECO took more or less two (2) months to repair the damages, resulting that the whole water district did not operate.

One of the reasons why the researcher wanted to propose for the design of the water system is that the current water system is using a high powered water pump to supply water to the consumers. This water pump consumes a big amount of electric energy that costs the management to pay high electric bills.
Therefore the administration wanted to look for a solution that will reduce the high costs of electric bills and at the same time can provide plenty of quality water to the community. An alternative way that the administration is thinking is through solar – generated water pump. Furthermore Abra is prone to calamities like typhoons where electric current disruption may come naturally. Hence the management would like to have an alternative source of electricity in the form of diesel generator to mobilize the pump. Since the water pump is run through electric power, supply of water to the community will naturally stop.
Likewise, on the part of the consumers, the high costs of electricity burdens them and at the same time a high cost of water bill that they will shoulder since the water system also uses electricity for it to function.
The spring water supply was discontinued primarily because of old pipes being used in the system. The pipes connected to the spring are made up of galvanized iron and at present they are already rusting. Some are already breaking because of rusts and some are already leaking. In some other instances, a reason why these pipes were destroyed was because of the people in the community, specifically farmers where they urged to wreck the main line intended to their plants and animals where the large portion of the main line is installed across the farm fields. Appendix S show some images of old pipe of the existing gravity fed water by spring.
In running some water systems, electric energy is needed. Today, energy saving is sounds in our community, some groups and organization are made research, guidelines and articles on how to save energy. On the side of technology, more inventions that produced need a less energy but have same performance.
In the article "Guide for Conducting Energy Efficiency Potential Studies" defined Energy efficiency as that using less energy to provide the same or an improved level of service to the energy consumer in an economically efficient way. Sometimes "conservation" is used as a synonym, but that term is usually taken to mean using less of a resource even if this results in a lower service level. The Action Plan recognizes that energy efficiency. Includes using less energy at any time, including at times of peak demand through demand response and peak shaving efforts. (National Action Plan for Energy Efficiency, 2007, p. 2-1),
The role of energy in the water industry was discussed in "Electricity Use and Management in the Municipal Water Supply and Wastewater Industries that Electricity is used to power equipment such as pumps, fans and blowers, mixers, centrifuges, ozone generators, and ultraviolet (UV) disinfection equipment. The equipment usually operates around-the-clock, but peak demands occur during the peak hours. The use of electricity for water has grown during years and will continue grows. Market growth (in terms of use of electricity) is accompanied by increased demand. The challenge, therefore, becomes (1) how to accommodate the requirements for increased electric service and (2) how to institute measures to promote better energy management and improved efficiency. Improved energy efficiency can be brought about by better management of operations and the incorporation of technological changes. (Electric Power Research Institute, Water Research Foundation, 2013, p. 1-2)
In this study, the researcher will attach the new gravity fed water supply design to the existing water system of the Dolores Water District, Dolores, Abra (See Appendix B) known as the conjunctive use of

water (water pumping and Gravity fed upland spring water supply combination) as a key to energy efficiency.

According to the Sustainable Sanitation and Water Management (n.d) it defines conjunctive use of water as related to the combined use of ground and surface water. Due to the augmented water source, higher water reliability can be achieved. Conjunctive use therefore functions as a buffer for periods of water scarcity. The idea of this management approach is to use surface water when the water table is high and change to groundwater when the water table is low. This technique might be especially important as a buffer function for mitigating impacts of climate change, such as increased heat and drought (FOSTER et al. 2010). (para. 1)

The connection of new gravity fed upland spring water to existing water supply of the Dolores Water District (DWD) is hopeful to be the best solution to save energy. As Gravity Water Systems in Eastern Ghats, India (2011) defines energy efficiency "by the geography of hilly terrain offers a tremendous advantage of supplying the water from the spring source to the point of use at the least or no distribution cost at all. This is by far the strongest factor which makes Gravity Fed Water System the supply system of choice". (p. 7). By the continuous flow of water from spring water, pump work will be reduced the time to fill the storage tank, and the researcher assumed that water services continue even the absence of water pump

1.1 Objectives

This study aims achieve the following objectives

1) What is the present condition of Dolores Water District in terms of
   a) Energy consumption
   b) Water performance
2) How is the proposed water supply design for DWD affect the current condition of the water system in terms of?
   a) Energy consumption
   b) Water performance

1.2 Conceptual Framework

The whole story of the proposed project will be revolving on the operational paradigm of the study which will be making use of the input, process, and the output

PRESENT SITUATION

- **High Energy consumption**
- **Water Performance**
- **Poor Design Of Gravity Fed Water Supply**

1.3 Significance of the Study

This project study would be very essential since it will give insights to the management of the Dolores Water District, since this proposal is one of the options on how they will solve the existing problem. Hence, the significance of this study is not only to the resident members of LWUA, but also beneficial to the following:

Provincial Government of Abra is reach in springs, therefore the materialization of this project would be important to the government officials in making resolutions to make use of the God given nature productively by converting these resources into usable ways. The adaptation of this technology to the other municipalities who are not making use of this advantage will be reached out.

The Municipal Government of Dolores, the result of this project will be profitable because of the lesser current is to be incurred in the flow of water because of the energy derived from the integration of Gravity fed water to the current existing LWUA water system. The service of the water system is likewise to be improved.

The DWD administration is to be advantageous to the implementation of the project for the following reason; the amount to be paid to the electric cooperative would be reduced because of the less consumption of energy that is for the brought about by the increase water source.

The researcher himself is also to be benefited from the outcome of this proposal. This is not only for the fact that the researcher is of the locality but for his professional development. That somehow, in some little ways he can share his knowledge and skills through the insights he derived from his academic endeavor to the development of the water system from which his waters will be coming from. The application of his field is really realized.

The ultimate beneficiaries of the project are the resident-consumer members of the LWUA Dolores. Since, there is decrease of the bills to the electric cooperative, and then it follows that the water bills of the consumed will also be lessen. The services also of the LWUA Dolores are to be more enjoyed by the consumer hoping that it is also to be improved.

To the future researcher, this study would also be useful to them because it will guide them on how they will be going to do about their work. It will help them formulate a new study by extending the result and as well as the coverage area of the project.

It will serve as an eye opener to them or as a bird's eye view so that they can maximize the use of these natural resources. They can formulate ordinances on how to protect and conserve water, and as well as to safeguard the different element of the water system

1.4 Scope and Delimitation

The focus of the study is to design the appropriate components of gravity fed water supply suited to DWD, Dolores, Abra in terms of energy consumption, and water performance services. The design of the detailed and most storage tank with built in sedimentation plus chlorinator and piping is to be considered. Water treatment system are not include to the design

To get the proper blueprint of the design, the use of Water System Design and Standards and EPANET Simulation Software must be considered where the water system layout in terms of the water source, pipe lines, fittings, hydraulic grade line, coefficient of friction of pipes, water pumps etc.

The design is limited to the Dolores Water District covering six zones encompassing the three barangays of Dolores such as Poblacion, Bayaan, and Pacac. The system to the barangay Taping in not considered in this design.

Chapter 2

2.0 Literature of Water Supply System

Water Supply system is an infrastructure for the collection, transmission, treatment, storage, and distribution of water for homes, commercial establishments, industry, and irrigation, as well as for such public needs as firefighting and street flushing. Of all municipal services, provision of potable water is perhaps the most vital. People depend on water for drinking, cooking, washing, carrying away wastes, and other domestic needs. Water supply systems must also meet requirements for public, commercial, and industrial activities. In all cases, the water must fulfill both quality and quantity requirements. (https://www.britannica.com/technology/water-supply-system). Water supply system basic components are water source, water transmission system, and water treatment plant and water distribution system. See Figure 1

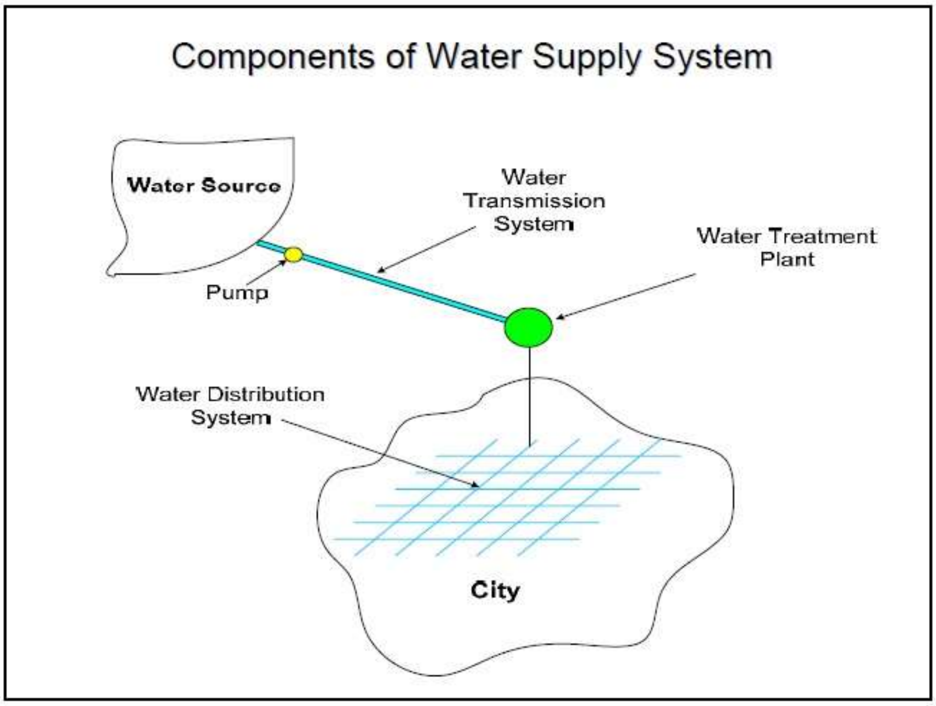

Figure 1. Components of Water Supply system (image by Google)

2.1 Water Supply System Basic Components

2.1.1 Source of Water Supply

Sources of water supply are classified as Surface water sources and Ground water sources.

Surface Water Source originates mostly from rainfall and is a mixture of surface run-off and ground water. It includes large rivers, ponds and lakes, and the small upland streams which may originate from springs and collect the run-off from the watersheds.

A ground water source is that portion of the atmospheric precipitation, mostly rainfall, which has percolated into the earth to form underground deposits called aquifers (water-bearing formations). These will usually be jetted, dug, driven, or bored wells.

2.1.2 Water treatment

The alteration of a water source in order to achieve a quality that meets specified goals. The treatment of public drinking water to remove pathogenic, or disease-causing, microorganisms began about that time.

Treatment methods included sand filtration as well as the use of chlorine for disinfection. The virtual elimination of diseases such as cholera and typhoid in developed countries proved the success of this water-treatment technology. In developing countries, waterborne disease is still the principal water quality concern.

2.1.3 Water transmission

The water needs to be transported from the source to the treatment plant, if there is one, and onward to the area of distribution.

2.1.4 Water distribution systems

Convey water drawn from the water source or treatment facility, to the point where it is delivered to the users. These systems deal with water demand that varies considerably in the course of a day.(Nemanja Trifunovic, n.d., p. 466)

2.1.4.1 Types of distribution systems

Branched configuration - networks are predominantly used for small-capacity community supplies delivering the water mostly through public standpipes and having few house connections. The direction of the water flow and the flow rates can readily be determined for all pipes. See Figure 2.

A looped network usually has a skeleton of secondary mains that can also be in a form of branch, one loop, or a number of loops. The network in large (urban) distribution systems will be much more complex essentially a combination of loops and branches with lots of interconnected pipes that requires many valves and special parts.

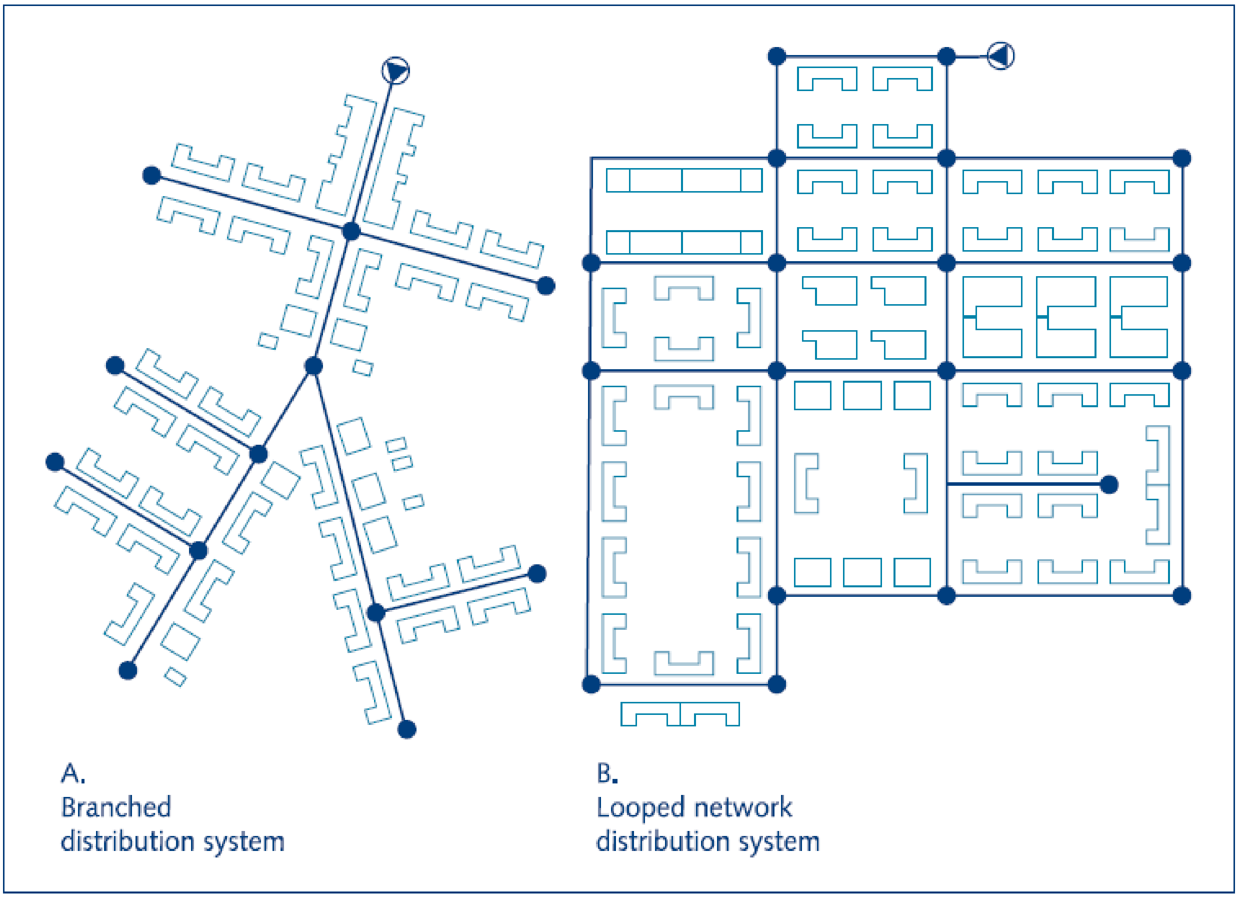

Figure 2. Types of distribution systems (Nemanja Trifunovic)

Chapter 3

3.0 Design and Methods

In order to make a good design of appropriate water supply system of Dolores Water District (DWD), the following data may consider. Table 1 shows the activities in accomplishing the objectives of the study and the number of hours that allotted for each activity.

CHRONOGRAM OF ACTIVITIES

Table 1. Activity Plan Gannt Chart

Activity	Month						
	January	9-February	10-March	10-April	10-May	15-June	27-July
A. Finalization of proposal project title		x					
B. Preparation of Project proposal			x				
1. Literature review		x	x				
2. writing introduction (with problem, objectives, research question, significance of the study)		x	x				
3. Writing methods section (with identified research design, methods and data gathering techniques etc.)		x	x				
C. Surveying							
surveying area for header tank, and pipe lines		x	x				
D. Project Designing					x	x	
E. Project Final Defense							x

3.1 Pipeline Route Survey

Surveying is needed for collecting data to help in the design of the transmission main. The type of survey needed for planning the pipeline depends on the route topography. Unlike other topographical survey which uses instruments like abney levels, transit, and others, the researcher made used of a Global Positioning System (GPS) locator and Google Earth Pro application.(Water Partnership Program, 2012, p. 12.11) A handheld GPS where located to some target points, excluding road points of the proposed pipe route and the existing pipe route, and collected coordinate points of GPS are plotted to Google Earth Pro, which shows satellite view and the elevation profile of the points. A summary of the GPS coordinates taken at each point, is shown in Figure A

Figure A.GPS Coordinates plotted on GooglePro. (image by Google Earth Pro)

On the other hand the researcher will change the pipe route not just the reasons discuss above, but it is for Hydraulic Grade line (HGL) purposes. For a single pipe size, the HGL should always lie above the profile. If it does not, then the water may still flow but at sections where the profile lies above the gradient there is a negative pressure which can cause air or pollution to enter the pipeline. (Scott Faiia, 1982, p. 14)

Figure B illustrates those sections of the pipeline where negative pressures occur should be redesigned to eliminate them.

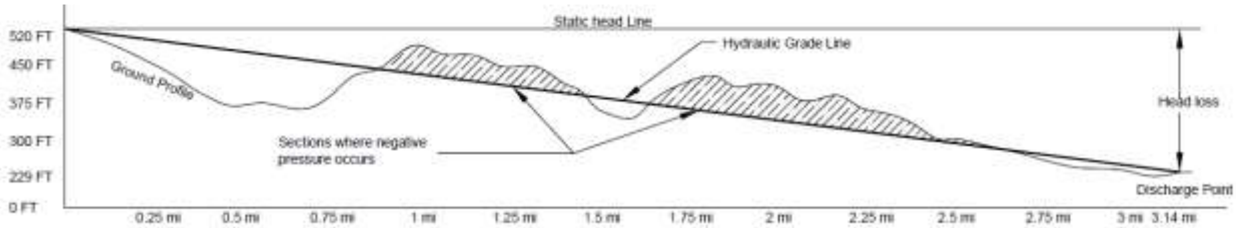

Figure B. The sections which show negative pressure occurs

By the help of Google Earth Pro, the researcher find a good elevation profile and good pipe route, which is from the source down to the Baug – Supiil road then turning to bottom part of the hillside of Lam – ag, San Juan until it reaches the main road going to Dolores, Abra. After which, he visited the locations to prove that it is possible to become a good pipe routes. (See Figure C and Figure D).

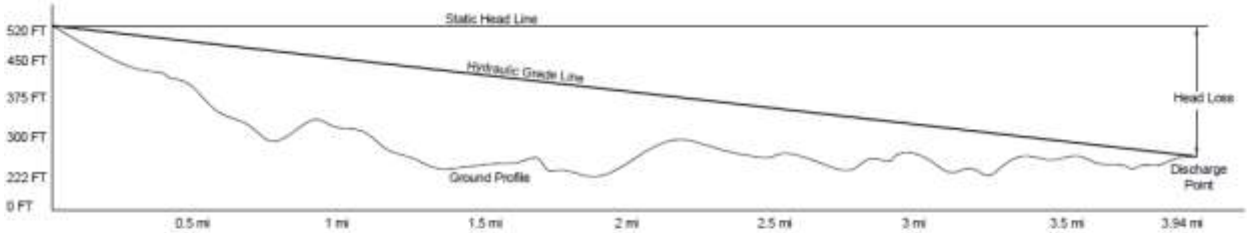

Figure C. The HGL above the ground profile of the proposed pipe route

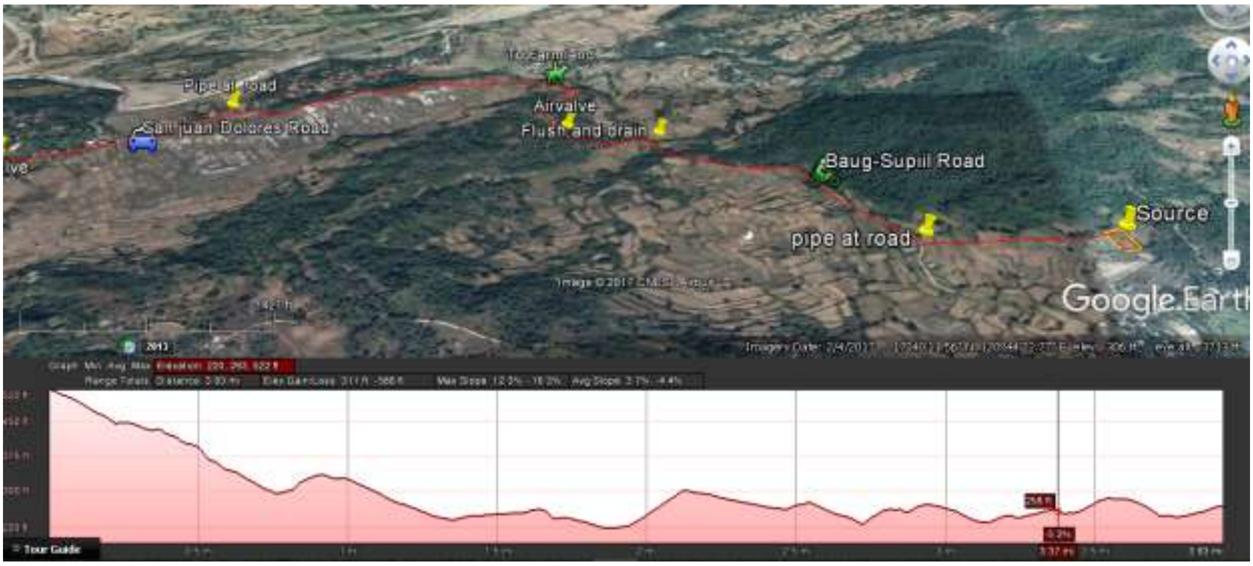

Figure D. New pipe route (red) and elevation profile (pink) (by Google Earth Pro)

3.2 Quantity of Source Water

Accurate measurement of quantity would require frequent monitoring over a period of several years and should preferably include a drier than average year. However, this information is generally not obtainable and estimation must be made from point measurements. As many point measurements as possible should be taken and they should be during the driest part of the year. Experience and judgments are critical. Note should be taken of the condition of the catchment area, vegetation, land use etc. Comments of longtime local residents regarding reliability and change over time are also useful. These however, must be weighed carefully because people always tend to overestimate flows during dry periods and will sometimes falsely report that a source never dries up for fear of losing the project. It is best to be conservative when estimating the minimum flow of water from a spring. (Scott Faiia, 1982, p. 3)

The researcher decided to design a large storage of water which directly connects water tables to overcome the water demand of the consumers, satisfy design period factor, population growth and considering for expansion purposes. (See Appendix R for computation) As a great evidence for large storage design like this is possible since the area have a lot of potential spring sources which was visited last April 14, 2017. From the north east corner, south west corner and the center of the lot area owned by DWD have springs (water source), and there are a lot more springs below the lot area of DWD. See Figure E, and Figure F.

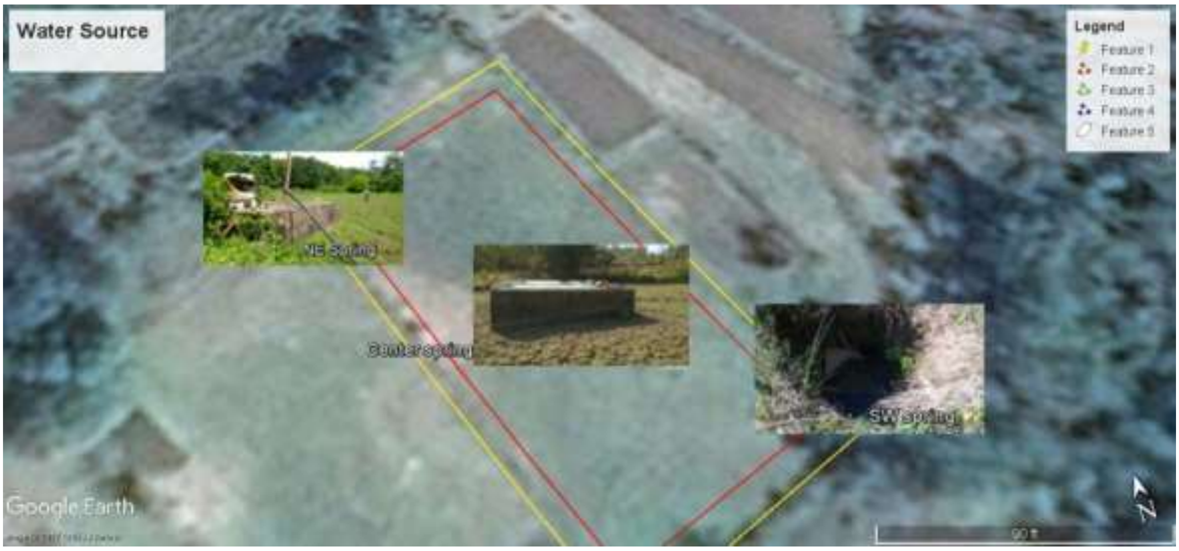

Figure E. Images of potential water spring in some parts of Lot owned by DWD.

Figure F. Images of water below the Lot owned by DWD.

3.3 Quality of Water Source

Quality generally fluctuates much less than quantity but it would also require monitoring over a long period to establish an accurate estimation. Point measurements should include periods of both high and low flows. In general, the greater the fluctuations, the greater the amount of data that must be collected. The main considerations in assessing quality are bacterial quality, consumer acceptability and chemical quality. (Scott Faiia, 1982, p. 4)

The water bacteriologic examination result of Supi-il Water spring base from Ilocos Training and Regional Training Center (ITRTC), Department of Laboratories are 0 Heterotopic Plate Count (HPC), <1.1 MPN/100 mL total coliforms and <1.1 MPN/100 mL Fecal coliforms which remarks PASSED. See Appendix C.

3.4 Water demand

Water demand is the quantity of water that the treatment plant must produce in order to meet all water needs in the community. Water demand includes water delivered to the system to meet the needs of consumers, water supply for firefighting and system flushing, and water required to properly operate the treatment facilities. The objective of this section is to determine the current water demand characteristics and to project future demand requirements that will establish system component adequacy and sizing needs. Water demands are classified as, Average Annual Demand (AAD), Average Daily Demand (ADD), Maximum Month Demand (MMD), Peak Weekly Demand (PWD), Maximum Day Demand (MDD), and Peak Hourly Demand (PHD), which is the maximum volume of water delivered to the system in the said times. (Civil West Engineering Services, Inc, n.d., p.1).

Base from the record in the month of April, the members consumed 11,146 cubic meters (MMD) where it was computed an average of 373 cubic meters a day (ADD). Peak hour demands consumes water about 17 percent of the daily water demands (See figure G) which water supply need to provide a 17.545 liter per second to overcome the demand in peak hours (Steven Buchbergera, Toritseju Omaghomib, Timothy Wolfec, Jason Hewittd, Daniel Colee, 2015, p. 14)

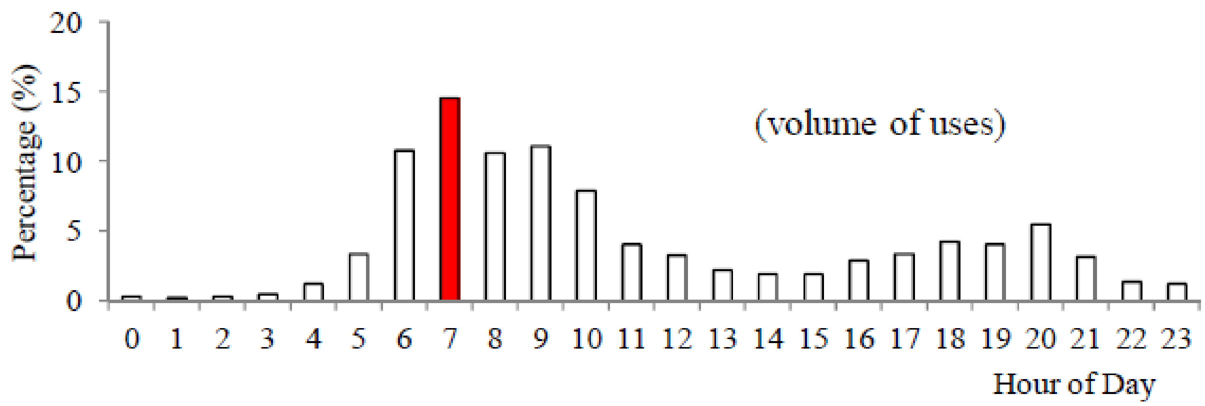

Figure G. Percentage of water use in every hour in one day, (Steven butchberger et, al, 2015)

3.5 Demand Allocation

In water distribution network modeling, the topology of the network is commonly mapped as a (directed) graph consisting of nodes and links (Walski et al., 2001). Pipe sections with constant parameters are modeled as links. Intersections, water inlets, points of water withdrawal and locations of pipe parameter changes are modelled as nodes. Coordinates related to the nodes define the spatial location. To calculate the hydraulic system state (pressures and flows) the water demand of the consumers is assigned to the relevant nodes as the driving parameter (demand driven simulation). Figure H schematically shows the abstraction of a water distribution network.(Nicolai Guth and Philipp Klingel, 2012, p. 283).

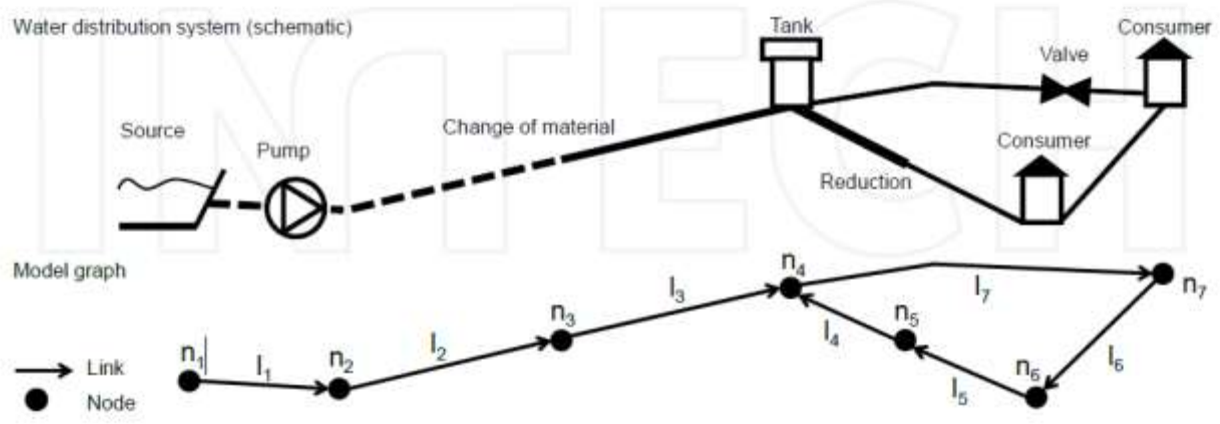

Figure H . Illustration of a water distribution system and the corresponding model graph (Nicolai Guth and Philipp Klingel, 2012)

In reducing the nodal demand model the researcher will collect each members that connects in each link of the distribution line and consider as one node, (See Appendix O)

In addition to this activity, since the Dolores water District DWD has no any documents to the details of the water distribution line, the researcher used Google Earth Pro to measure the approximate length, topographical elevation of each link of the distribution line which is important in running to the Hydraulic analysis using the EPANET. The measurements from the Google earth Pro have a negligible variance as compared to the actual measurements as he tested it himself. Figure I shows approximate measurements of the buried pipe along the streets.

Figure I. Measuring approximate length of distribution pipe along the street

Chapter 4

4.0 Proposed Engineering Design and Hydraulic analysis

The recommended design solution is redesigning the gravity-fed water supply that would provide potable water to every user from a clean water source. The following engineering design was developed taking into consideration the feasibility, sustainability, ease of maintenance, and potential environmental impacts to the locality caused by diversion of the spring water.

Furthermore, in designing the gravity fed water supply, the researcher will consider to meet the following, the demand of the consumers particularly on peak hours, the quantity of the source of water, design period factors, population growth, and water treatment.

To capture water, a 10,320 m^3 of earth excavated general spring box was constructed by masonry having structures and a galvanized roofing sheet designed which includes an overflow pipe, cleaning drain and a valve to halt flow for maintenance operations on the proposed pipeline to follow. To reduce the environmental impacts, the diversion of water from the overflow pipe should be placed to allow the flow of water to continue where the stream occurs naturally. After the spring box, a chlorinator is to be installed to make sure that some microorganisms are to be lessened before water will travel in a 14'' nominal diameter (ND) polyethylene (PE) pipeline and finally, to the consumer. From the source, a PE pipeline will be buried into the farm land until it will reach the road of Barangay Supi-il, See Appendix U for details. Water drain discharges and flushes out are to be located at the stream of Supi-il, approximately 1,200 meters below the water source. At the stream where a bridge is located, the Polyethylene pipeline material will be changed to ductile iron material pipe in order to cross the bridge. From the bridge of Barangay Supi-il, the pipe will be changed again to a PE pipe then continually to be buried beside the Baug – Supi-il road, an air valve is to be installed to the pipeline 241meters after the bridge of Barangay Supi-il where air lock may form at that point. Pipeline will be continually to be buried until it reaches again a stream of Barangay Baug, at that point the pipeline will not be crossing the bridge of barangay Baug anymore, but it will turn left that crosses a little part of the farmlands until it reaches the hillside of barangay Lam-ag, San Juan. The pipeline is not to be installed beside the stream going to hillside of Barangay Lam – ag for erosion purposes. Pipeline will be continually buried from the hillside going to the San Juan – Dolores road. As the pipeline is continually running to San Juan – Dolores road, another flush out will be installed to the pipeline before it reaches the Municipality boundary. Another air valve is to be installed into the Boundary of the two municipalities. As the pipeline steps down to Barangay Pacac, where the end of the existing distribution line of DWD occurs, the researcher will connect the proposed pipeline by means of a reducer Tee (See Appendices for Branch drawing) and a control valve. Upon reaching the town of Dolores, the pipe line traverses and branches to some points of existing distribution line of Poblacion Dolores, See Figure J.

In addition, the PE pipe that penetrates to the distribution lines of Poblacion are intented not to reduce the pipe size just because of expansion purposes that someday when the demand grows where storage tanks may built to any point of the town.

After all components design are completed, the existing and proposed design will undergo hydraulic analysis to determine how the hydraulic behavior of the pipe network should be analyzed.

Figure J. Proposed Pipeline (red) branches to existing Distribution line (yellow green) (By Google Earth Pro)

4.1 Spring box

The Proposed Spring box of Dolores consist of the following features, water deposit portion having a volume of 7403.5 m^3 (if full), gabion-2630 m^3, 4m x 4m x 1m water sedimentation and water drainage canal. The first stage of the construction of the proposed project is the excavation of 10320 m^3 of earth, to be followed with construction of 48 isolated footings for the foundation of the structure; all of the footings have dimensions of 0.3m x 1.0m x1.0m. The erection of columns comes next, 48 posts with dimensions of 0.3m x 0.3m x 8m, together with the making of 0.2m x 0.35m rectangular tie beams one meter high from the top of the footing to the upper edge of the beam that is intended to resist bending of long column. After 7-day curing period, all forms will be removed and the building of gabion will take place, the gabion will be used as a permanent fortification material to the excavated side of the soil and it will be the one responsible in filtrating the water content of the saturated soil, allowing it to flow into the water deposit portion of the pond.

The highest part of the gabion is enclosed of steel cladding that will protect the pond from foreign materials that will possibly contaminate the water deposit. At the longitudinal center of the pond there will be a flat form that is 1.5m in width that will be used as a passage material at the middle of the structure. Then the upper portion is closed with corrugated and translucent roofing that will protect the pond from rain and leaves that could be carried by wind. Appendix D - O shows detailed drawing of spring box.

4.2 Transmission main pipe

Mains which are used for transporting water from the source of supply (master meters), to elevated storage tanks, and then, water from the elevated storage tanks throughout the service area along major streets/roads. Customers can be connected to these mains for their water supply needs (typically 10-inch and larger). (Consolidated Water District #1, 2013, p.11)

The recommended design of transmission main (excluding the pipe crossing the bridge and the pipes adapter to the water source) by the researcher is having a nominal diameter (ND) of 14", actual outside diameter (O.D) of 15.30" and an average internal diameter (ID) of 10.857" Ductile iron pipe size (DIPS) Polyethylene (PE) pipe, having a pressure rating of 254 psi. (DR7.3) as per AWWA C901 for Polyethylene tubing (Charlotte Water, 2016, p.10) and use butt fusion weld for jointing. See Figure K. `

Figure K. Polyethylene (PE) pipe butt fusion weld. (images by ISCO industries)

Except from the pipeline from source down to the road of barangay Supi-il, the pipe is typically buried 0.6 meters above the pipe crown, to the roads, and even in the farmland of Lam –ag, San Juan, which is considered as the vehicular loading. See Table 2 (Mr. Paul Dale, 2011, p. 17) and the protection of pipe from farming activities. Ductile iron pipes will use as adapter from the storage to PE transmission main, and for lay outing on the top of the bridge of Barangay Supi-il. See details in Appendix S-U.

Table 2. Minimum cover of PE pipe (Mr Paul Dale, 2011, p. 17)

MINIMUM COVER OVER PIPE

Loading condition	Minimum cover m
Not subject to vehicular loading	0.30
Subject to vehicular loading— (a) no carriageways; (b) sealed carriageways; (c) unsealed carriageways	 0.45 0.60 0.75
Pipes in embankments or subject to construction equipment loads	0.75

4.3 Hydraulic Analysis during Peak hours using EPANET

Among the current software available in the internet and from proprietary sources, the EPANET is highly recommended. EPANET is public domain software developed by the US Environmental Protection Agency that can be downloaded free on the internetThe software tracks the flow of water in each pipe, the pressure at each node, and the height of water in each tank.(Water Partnership Program, 2012, p.12.4)

In this part the existing water system and proposed water system will run to the EPANET to test if the distribution of water will overcome the peak hour demand using same demand parameters of the consumers.

4.3.1 Existing Water System on EPANET Simulation

The existing water system having a 15 hp electric pump and two reservoirs (Poblacion Tank having 441 cubic meter and Bayaan and Pacac tank 50 cubic meter) will not meet the peak hour demand, as a result on EPANET simulation. This was evidenced by the negative pressure that occurs on some junctions having demands which is now the actual happening in some area of DWD, particular at Zone 2, 3,and 4 See Figure L and Appendix P.

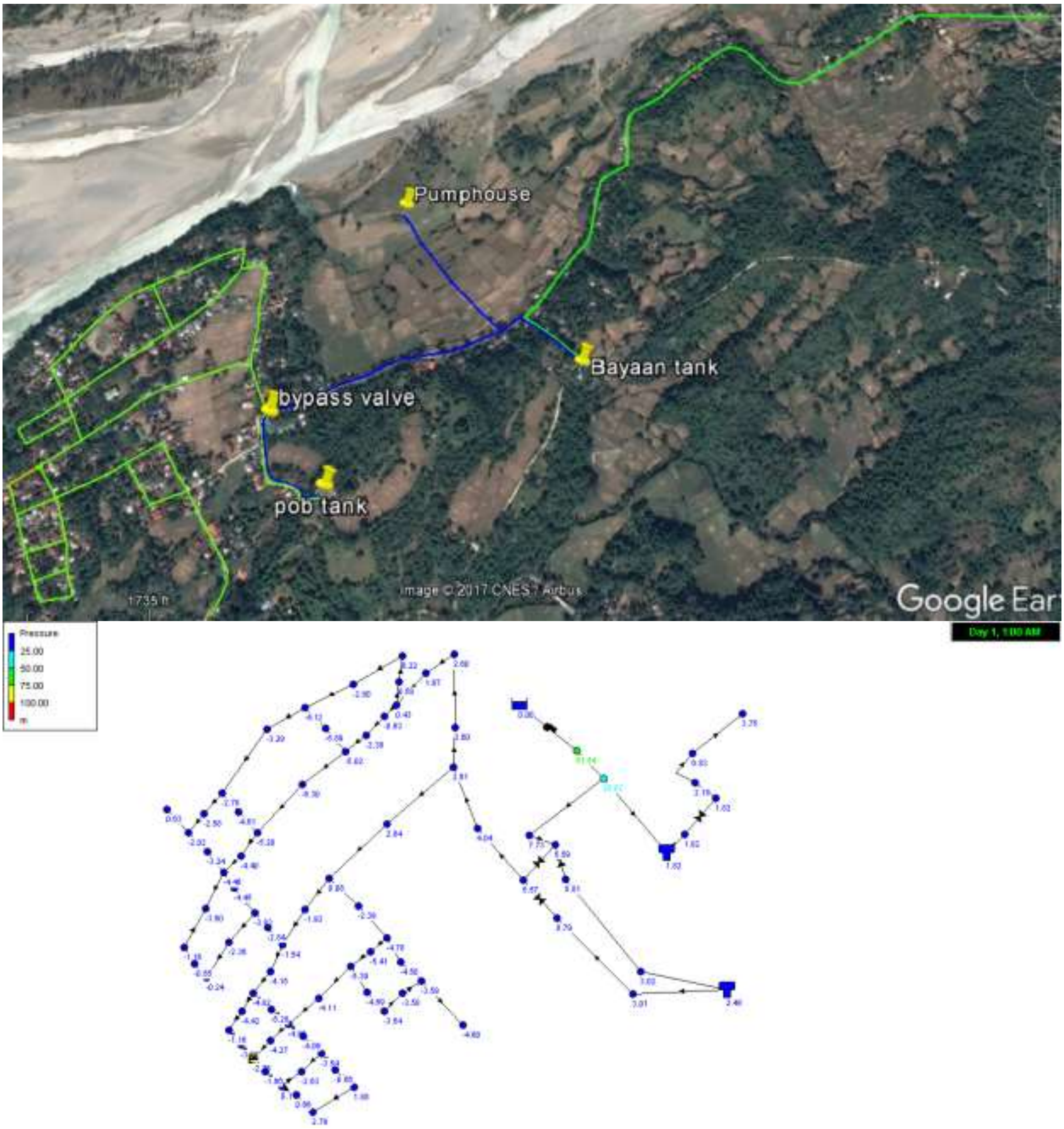

Figure L. image (by Google Earth Pro) and EPANET result in peak hours. Where negative pressure exist to corresponding demand node. Blue colors shows low pressure

4.3.2 Proposed Water System on EPANET Simulation

By the connection of a 14" (ND) transmission main pipe from high elevation spring to the different points of existing distribution line, and water pump are shut off, the result of calculation of EPANET is "Successful" where no negative pressures to corresponding nodes occur. See Figure M and Appendix Q

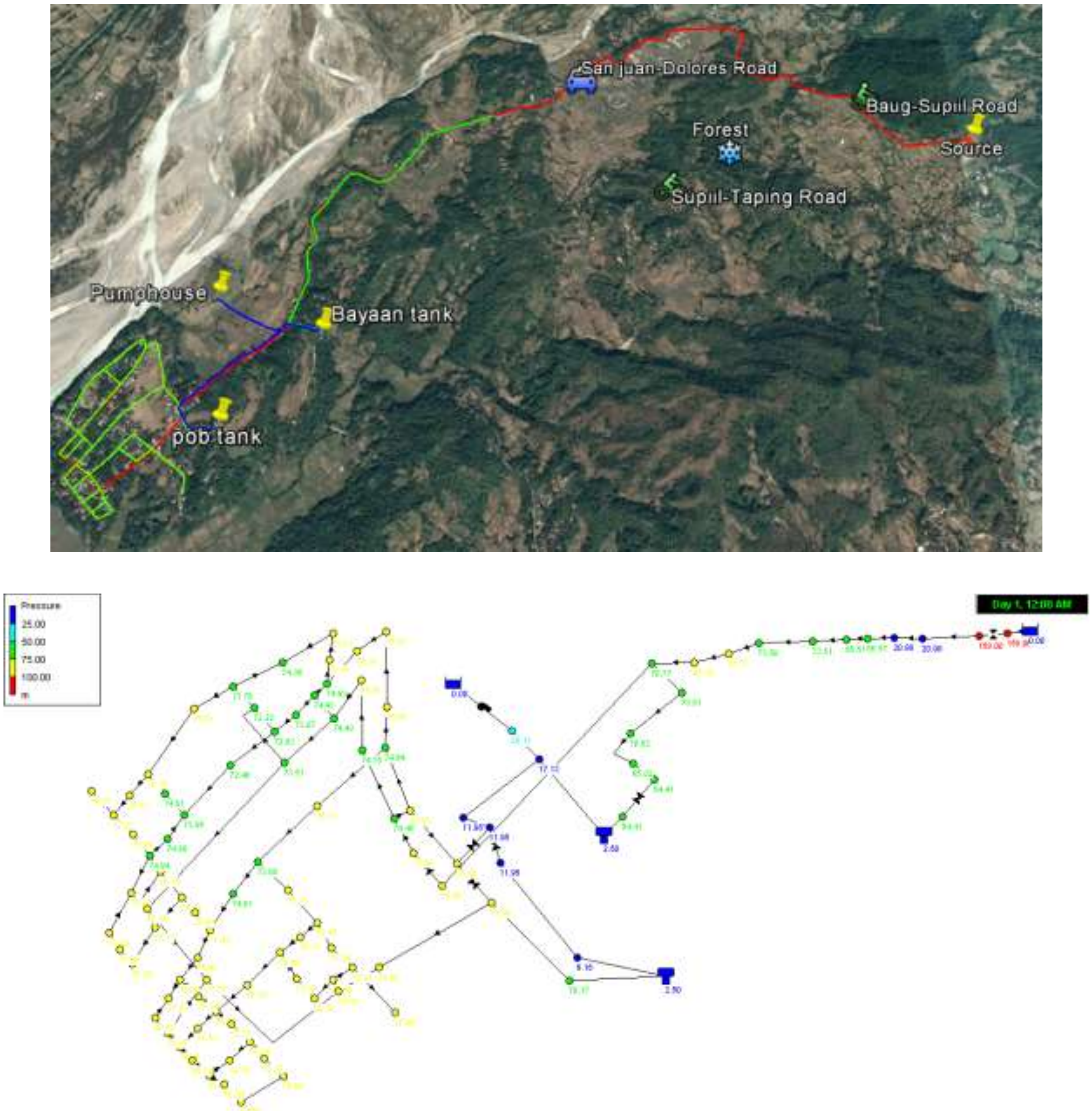

Figure L. Image (by Google Earth Pro) and EPANET result in peak hours. Where good pressure exist to corresponding demand node.

Chapter 5

5.0 Summary, Findings, Conclusions and Recommendations

This chapter presents the over-all summary and the findings of the study about the Designing Appropriate Water System for DOLORES WATER DISTRICT, Finally, Conculsions and recommendatare also presented.

5.1 Summary

The proposed water system design for the DOLORES WATER DISTRICT, particularly the integration of spring and well water supply started during the first quarter of the calendar year 2017. The study determined the present condition of Dolores water district in term of its energy consumption, and water performance. The EPANET was used to run the present design of the system and the proposed designed. The researcher has developed an appropriate water system design recommendation to lessen the current problem encountered by the DWD, which is the high energy consumption, water performances like peak hour water demand shortage, power interruptions made by different cases. And also it will serve as a best proposal compared to solar and diesel powered pump.

At the beginning of the study, the researcher was immerged to the DWD for 500 hours to complete the data and information needed to the design. While in the water district, an assessment was done on the water needs of the people, the condition of distribution line, storage tanks, water pumps and the energy consumed by the management. From analysis of the collected data and through further research, the researcher prepared a design and recommendations for the DWD to implement the most sustainable solution to their water problems.

The final design was the addition of a new gravity fed water supply design to the existing water system of DWD. It was found that the water supply by the water pump and distribution line of the system will no longer response to water peak hour demands and other water problem interruptions, that is why a 14" pipe from spring water will branched to points of distribution line to give more water supply with good pressures. Also included are the detailed hydrological calculations, detailed design components, as well as in-line chlorinator design to ensure proper disinfection within the system.

Sustainability is one of the principal considerations for this proposal. Each element is designed to achieve the maximum performance at the lowest possible cost. Likewise, the system components are designed for easy maintenance by the technical group.

5.2 Findings

The most common operation of the pump is working from 4 am to 10 pm. aside that the DWD using power to get water; the one that affect the high energy consumption is the direct pumping. Due to their distribution line which were not well designed, pumps are used to work just to push water to the consumers by means of bypassing the storage tank particularly at the Poblacion which is only nearby consumers were able to use the water contained by the storage. Storage tanks are capable to reach the water demands but because of smaller distribution mains potential energy of the storage tanks are not enough to push water to the consumers.

Since the distribution mains are small and not well designed, it also affects the water performance during peak hour demands. Another problem of the DWD is the growing number of members, proven that water produced by the water pump is lesser than the peak hour water demands of the consumers as the district is obviously using a direct pumping for water needs, resulting to the other members to wait (particular to remote area) until others get water, causing delay to their activities.

5.3 Conclusion

Above the problems that exist in the Dolores Water District, the energy conservation, water performances problems; the best solution for this is to adopt and implement the proposal. In terms of energy consumption, the only bill of DWD if this proposal is to be implemented is on the minimum to

ABRECO (50php/month) where the pump becomes an advantage of the water district because it serves as a backup when there is maintenance operation on transmission mains and the spring water source.
By this new water system design, the DWD now is not subject to long time waterless during great calamities by which power automatically shut down because ABRECO facilities were damaged.
Water demand are clearly not a problem in this proposal due to a large volume of water coming from large distribution mains and as it run through the EPANET simulation software and it meets the standard pressures of the distribution lines.
This design is too much better to those proposed alternative to the management. On solar powered pump, the district will be free of energy charged in time of summers, but as the Philippines has dry and wet season where solar power are inefficient without the presence of the sun.
As discussed above that the water pump cannot supply the peak hour demand, diesel generator proposal must be turned down. On the other side, fuel engine generator is more costly compared to using electric energy which is the problem absorber is the consumers.
Finally, as one vision of the district; to extend the water services, the proposed design is also capable for water service expansion, the spring water source can supply water the succeeding barangays like Talogtog, Mudiit, Bulala, Kimmalaba, and even some Barangays of Lagangilang. See Appendix X the topographic profile between the source and the target places.

5.4 Recommendations

If the proposal is planned well and to be implemented, the management will seek for some consultancies like Structural design, hydrologist, and others that some information are not beyond on researcher's knowledge.
In addition to safety water, the DWD must provide complete water treatment facilities to ensure the health of the consumers as water is directly delivered from water source to the consumers.
Since the proposed design of the DWD water when ran through the EPANET simulation software overcome the peak hour demand of each node, then the management may use this design and allot budget for its operation.
The design of DWD water is implemented, there will be a strong pressure of water to the distribution lines which may overcome the existing distribution line, and then the management will use pressure reducing valves to some points of the existing distribution lines.
Expansion of the system is also to be recommended in the nearby barangays of Dolores Abra where a number of user-consumers as large as the existing members are located.
Likewise, the creation of manual of operation is also recommended to be made by the management so that the system is to be maintained, to be improved and to be used properly by the community.
Lastly, as an outgrowth of this study, a parallel study is to be recommended to the other water districts, not only in the municipality of Dolores but to the whole province of Abra, much more than the Cordillera region and even to the whole country.

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