Document 525
PRE-IMPLEMENTATION REPORT

CHAPTER: Purdue University
COUNTRY: Bolivia
COMMUNITY: Papachacra, Tarija
PROJECT: Improvement of Potable Water Supply
TRAVEL DATES: July 1,2012—July 14, 2012

PREPARED BY
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Mark Shebeck

April 15, 2012

ENGINEERS WITHOUT BORDERS-USA
www.ewb-usa.org

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Pre-Implementation Report Part 1 – Administrative Information

1.0 Contact Information

Administrative Position	Name	Email	Phone Number	Chapter
Project Leads	Witcha Danaisuphachok	wdanaisu@purdue.edu,	(317) 702-3424	

	Tyler Anselm Sara McMullen Mark Shebeck Robert Sedivy	tanselm@purdue.edu ssmcmull@purdue.edu mshebeck@purdue.edu rsedivy@purdue.edu	(317) 410-1764 (317) 833-0859 (317) 908-2292 (708) 856-2816	Purdue University
President, Vice President	Carlos Blanco Kim Reppa	carlosblanco2718@gmail .com, kreppa@purdue.edu	(954) 319-5284 (219) 775-6323	Purdue University
Mentor 1	Chris Breinling	chris.breinling@urs.com	(317) 532-5458	Indianapolis Professional
Mentor 2	Rod Beadle	rbeadle@eraconsultants.c om	(630) 918-7716	Chicagoland Professional
Mentor 3	Jackie Dohrenwend	jdohrenwend@rwa.com	(317) 780-7161	Indianapolis Professional
Faculty Advisor	Ernest Blatchley	blatch@purdue.edu	(765) 494-0316	Purdue University
Assistant Health and Safety Officer	Michael Frank	frank7@purdue.edu	(708) 250-6460	Purdue University
NGO/ Community Contact	Ruben Mamani-Paco	ruben775@yahoo.com	(918) 858-0927	Engineers in Action
Administrative Position	**Name**	**Email**	**Phone Number**	**Chapter**

2.0 Travel History

Dates of Travel	Assessment or Implementation	Description of Trip
October 2009	Assessment	Team of 5 students and 1 professional mentor went to assess the existing conditions of the potable water supply and to assess new supply sources.

3.0 Travel Team

#	Name	E-mail	Phone	Chapter	Student or Professional
1	Rod Beadle	rbeadle@eraconsultants.com	630-918-7716	EWB - Chicago	Professional
2	Drew Sharp	drmsharp@iupui.edu		EWB - Indiapolis	Professional
3	Witcha Danaisuphachok	witchad@purdue.edu	317-702-3424	EWB - Purdue	Student
4	Tyler Anselm	tanselm@purdue.edu	317-410-1764	EWB - Purdue	Student
5	Sara McMullen	ssmcmull@purdue.edu	317-833-0859	EWB - Purdue	Student
6	Pete Rodgers	prodgers@purdue.edu	614-545-8467	EWB - Purdue	Student
7	Dalan Talsma	dtalsma@purdue.edu	260-435-0425	EWB - Purdue	Student
8	Rod Beadle	rbeadle@eraconsultants.com	630-918-7716	EWB - Purdue	Professional

4.0 Health and Safety

4.1 Travel Safety

4.1.1 Department of State Travel Warning/Alert and International SOS Travel Risk Ratings

There are currently no State Department travel warnings for Bolivia, however there is currently a moderate travel risk according to International SOS global security information.

4.1.2 Point to point travel detail

The team will depart Miami International Airport to El Alto International Airport in La Paz, Bolivia with a domestic connection flight to Capitan Oriel Lea Plaza Airport in Tarija, Bolivia. The team will meet with a representative from the partner non-governmental organization Engineers In Action (EIA) in Tarija. Team members and EIA representatives will travel by car for approximately 1 hour to the village of Papachacra.

4.1.3 On-the-ground phone number and email for travel team

Two-way radios will be the primary means of communication between team members at the worksite. Communication between the team members and EIA will be facilitated by phones in Papachacra and Iscayachi. Internet is only available in Tarija for e-mailing U.S. the emergency U.S. contact for the project, Mary Schweitzer.

4.2 Site Safety - Health and Safety Plan

We plan to follow the guidelines in EWB document 600—Health and Safety plan. This is a separate document.

5.0 Budget

5.1 Project Budget

Expense	Total Cost
Airfare	$10,500
Ground Transportation	$850
Food and Lodging	$1,057
Materials and Transportation	$11,917
Labor	$1,460
Other	$1,192
Total	$26,976

5.2 Donors and Funding

Donor Name	Type (company, foundation, private, in-kind)	Account Kept at EWB-USA?	Amount
Boeing	Company	No	$10,000
Schlumberger	Company	No	$2,000
Purdue	Fundraising	No	$3,000
Total Amount Raised:			$15,000

6.0 Project Discipline(s): Check the specific project discipline(s) addressed in this report. Check all that apply.

Water Supply
__X__ Source Development
__X__ Water Storage
__X__ Water Distribution
__X__ Water Treatment
__X__ Water Pump

Sanitation
____ Latrine
____ Gray Water System
____ Black Water System

Structures
____ Bridge
____ Building

Civil Works
____ Roads
____ Drainage
____ Dams

Energy
____ Fuel
____ Electricity

Agriculture
____ Irrigation Pump
____ Irrigation Line
____ Water Storage
____ Soil Improvement
____ Fish Farm
____ Crop Processing Equipment

Information Systems
____ Computer Service

7.0 Project Location

Longitude: 64°57'23.97"W
Latitude: 21°31'14.60"S

8.0 Project Impact

Number of persons directly affected: 550 (Approximate Village Population)
Number of persons indirectly affected: NA

9.0 Professional Mentor/Technical Lead Resume

URS

Chris Breinling, PE

Project Manager/Senior Water Resources Engineer

Overview

Mr. Breinling has over seven years of experience in the field of municipal public works project feasibility, design, and construction. His experience includes the planning and development of a 24 million gallon per day wastewater reclamation facility and a 45 million gallon per day water treatment plant along with the associated pipeline infrastructure interconnects.

His experience also includes stormwater management and drainage design with expertise in water quality detention design, flood routing and existing drainage system analysis. He has worked closely with private neighborhood associations and state water management agencies to provide designs for existing drainage problems and proposed drainage systems.

Areas of Expertise

Municipal Engineering
Water Distribution/Wastewater Collection
Erosion and Sediment Control and Storm Water Pollution Prevention
Hydrology and Hydraulics Modeling
Geospatial Information Systems

Years of Experience

With URS: >1 Year
With Other Firms: 6 Years

Education

BS/2004/Civil Engineering/Valparaiso University

Registration/Certification

2009/Professional Engineer/
Indiana/No. PE10911224

Project Specific Experience

Municipal Engineering

Civil Engineer, State Revolving Fund Water Main Construction Inspections, Indiana American Water – Wabash Valley District, Indiana: Provided construction inspection and contract reporting services for State Revolving Fund (SRF) projects for the Wabash Valley District of Indiana-American Water Company. Projects consisted of obsolete water main replacements, relocations, asbestos cement pipe mitigation, and trenchless distribution system extension projects within Terre Haute, Farmersburg and Sullivan, Indiana.

Civil Engineer, Carmel Water/Sewer Utilities, Carmel, Indiana: Prepared engineering drawings for the proposed addition of 14,000 lineal feet of 36-inch and 30-inch ductile iron water main for the proposed separation of potable water supply from the Indianapolis Water system. The proposed project includes the completion of two roadway jack and bore segments in addition to an existing creek crossing. Coordinated proposed watermain construction with proposed road improvements along 116th Street and 111th Street.

Civil Engineer, Lilly Technology Center and National Starch Biosolids Capture Study, Carmel, Indiana: Prepared engineering study and technical feasibility report for the a proposed exclusive soluble BOD collection system for the Lilly Technology Center and National Starch & Chemical facilities on the near southwest side of Indianapolis. Prepared preliminary sewer alignments and maps for collection of process enhancement flow for the Belmont AWT.

URS

Civil Engineer, Indianapolis Department of Waterworks Capital Project Oversight, Indianapolis, Indiana: Completed multiple treatment plant inspections and construction project walkthroughs on behalf of the Indianapolis Department of Waterworks. Chris oversaw treatment plant equipment improvements and distribution system main replacements constructed under the Veolia Water operations contract.

Site Engineering

Civil Engineer, Chesterton High School Football Field Improvements, Chesterton, Indiana: Prepared engineering drawings and specifications for the proposed synthetic turf replacement project at the Chesterton High School Athletic Complex for a short-schedule football field improvements project within the Duneland School Corporation. Completed erosion and sediment control permits for the proposed project and coordinated site activities with state and local agencies.

Civil Engineer, Martinsville High School Athletic Complex Improvements, Martinsville, Indiana: Prepared engineering drawings and specifications for the proposed synthetic turf replacement project at the Martinsville High School. Prepared engineering calculations and hydrology models for the existing and proposed conditions based on engineering studies of synthetic turfs. Prepared erosion and sediment control plans and coordinated site permitting with state and local agencies.

Civil Engineer, Morgan County Jail Expansion and Work Release, Martinsville, Indiana: Prepared engineering drawings and specifications for the proposed expansion of the existing Morgan County Jail. The proposed project included the design of an expanded storm water drainage system, potable water distribution network, and a sanitary sewer extension to serve the proposed facility. Prepared erosion and sediment control plans and coordinated site permitting with local and state agencies.

Hydraulic Modeling

Civil Engineer, FEMA Floodplain Modeling – Upper Cumberland River Watershed, Kentucky Division of Water: Utilized HEC-GeoRAS to develop hydraulic models for proximate floodplain studies for the Federal Emergency Management Agency in association with the Kentucky Division of Water within the Upper Cumberland River watershed in southeastern Kentucky.

Civil Engineer, Interstate 69 Stream Crossings, Monroe and Greene Counties, Indiana: Prepared hydraulic models for the stream crossings over two separate tributaries of Clear Creek in Monroe County southwest of Bloomington, Indiana and Black Ankle Creek in Greene County as part of Interstate 69 Section 4. Utilized HEC-RAS models to generate natural and proposed bridge floodplain impacts for INDOT permitting purposes.

URS

Civil Engineer, State Road 56 Floodway Impacts Modeling, Orange County, Indiana: US-150/State Road 56 Roadway Improvements – provided engineering support by developing HEC-RAS models for proposed roadway improvements for US-150 northeast of West Baden Springs. Used HEC-RAS models to generate pre- and post-construction floodplain impacts for INDOT and IDNR permitting.

Civil Engineer, Falcon Creek Flood Control Improvements Project, Indianapolis, Indiana: Prepared conceptual flood impoundment levee layout for the proposed flood control project within the Lafayette Square Community Revitalization Enhancement District in the vicinity of 38th Street and Lafayette Road. Prepared hydraulic models and post-construction floodplain impact improvements map demonstrating a reduction in downstream flooding within the Eagledale community along Falcon Creek south of 38th Street.

Civil Engineer, Petersburg Municipal Drainage Improvements, Petersburg, Indiana: Coordinated survey collection and prepared hydraulic models for the analysis of an existing municipal drainageway prone to flooding. Generated hydraulic models of proposed improvements including channel re-grading and sizing of proposed drainage structures to improve runoff conveyance within the project area along 6th Street and Meridian Road near Prides Creek.

Civil Engineer, Pierson Drain Flood Control Analysis, Fort Wayne, Indiana: Prepared hydraulic models and coordinated additional survey for flood control model of residential areas between State Boulevard and Reed Road. Prepared scope of work for proposed flood control improvements along Pierson Drain within the City of Fort Wayne, Indiana.

Civil Engineer, Wayne County Bridge #173 and #303, Wayne County, Indiana: Prepared HEC-RAS model for hydraulic analysis of existing historic bridge and floodplain impacts generated by the proposed structure and realignment of Mineral Springs Road over Greens Fork near Greens Fork, Indiana.

Civil Engineer, Robbins Ditch Flood Improvements, Portage, Indiana: Prepared HEC-RAS model for hydraulic analysis of existing culverts and proposed drainage improvements along the Robbins Ditch corridor in the flood-prone area upstream of Central Avenue in Portage, Indiana

Civil Engineer, Camp Atterbury Bridges #84 and #20, Edinburgh, Indiana: Prepared HEC-RAS model for hydraulic analysis of existing conditions and proposed improvements to the existing bridge located within Camp Atterbury National Guard Base near Edinburgh, Indiana

URS

Hydrology

Civil Engineer, CSO Basin 130 Green Infrastructure, Louisville, Kentucky: Completed infiltration system design for joint Louisville Metropolitan Sewer District/EPA NIRMRL cooperative project to reduce storm water runoff entering the existing combined sewer basin and to monitor the effects on water quality being discharged from the existing CSO basin within the Butchertown neighborhood of Louisville.

Civil Engineer, Rolling Ridge Watershed Characterization Study, Indianapolis, Indiana: Prepared hydrologic models, Geographic Information System (GIS) maps, and HEC-RAS hydraulic models for a culvert analysis at the existing Saint Matthew Parish Church & School site at 56th Street and Binford Boulevard.

Civil Engineer, Glenroy Village Storm Water Drainage Improvements Project, Indianapolis, Indiana: Developed design plans and specifications for a neighborhood-wide storm water collection/ infiltration system for a flood-prone subdivision within the City of Indianapolis as part of the RebuildIndy Storm Water Program.

Civil Engineer, Ingerman Drain Improvements, Hamilton County, Indiana: Designed proposed drain alignment and prepared engineering plans and contract documents for project construction. Coordinated additional survey and utility locates for an existing petroleum pipeline conflict within the project area.

Storm Water Capital Planning/Utilities

Civil Engineer, City of Greensburg Storm Water Capital Improvement Project Plan, Greensburg, Indiana: Prepared planning documents, initial priority ratings, mapping, and cost estimate exhibits for $2.5M worth of storm water drainage and water quality improvement projects within the City of Greensburg Municipal Separate Storm Sewer System.

Professional Societies/Affiliates

American Society of Civil Engineers

American Council of Engineering Companies

National Society of Professional Engineers

Engineers Without Borders

Specialized Training

Confined Space Entry Training – 2011

Chronology

7/2011 – Current: URS Corporation, Indianapolis, Indiana

4/2008 -- 7/2011: DLZ Indiana, Indianapolis, Indiana

2/2005 – 8/2007: WilsonMiller, Inc., Naples, Florida

Rodney A. Beadle, PE, CFM
2519 Lincoln Avenue, Long Grove, Illinois 60047
(630)918-7716
rbeadle@eraconsultants.com

EDUCATION

University of Wisconsin, Milwaukee

Bachelor of Science, Civil Engineering — *1984*

PROFESSIONAL REGISTRATION

Registered Professional Engineer, State of Illinois	*062-045076*
Registered Professional Engineer, State of Wisconsin	*E25883*
Certified Floodplain Manger, ASFPM	*IL-06-00228*

PROFESSIONAL EXPERIENCE

Engineering Resource Associates, Inc., Warrenville, Illinois

Founder/President – Managed the steady growth of a 30 person civil engineering, structural engineering, environmental science and surveying firm with offices in Warrenville, Champaign and Chicago, Illinois. — *1990 to Present*

RJN Environmental Associates, Inc., Wheaton, Illinois — *1987 to 1990*

Project Manager – Directed transportation engineering services for state, county and municipal roadway improvements.

Christian-Roge and Associates, Inc., Chicago, Illinois — *1986 to 1987*

Project Engineer – Transportation and water resource design for federal, state and county highway projects.

US Army Corps of Engineers, Peoria and Chicago, Illinos — *1984 to 1986*

Project Engineer – General design and construction oversight for sanitary treatment plants and water resource projects.

INTERNATIONAL DEVELOPMENT AND DISASTER RESPONSE EXPERIENCE

Engineering Ministries International

Disaster Response –Engineering Consultant providing service to non-governmental organizations to establish clear water, sanitation and hygiene facilities.

- Horn of Africa Famine/Drought, Christian Reformed World Relief Committee, Turkana and Pokot, Kenya — *August/September, 2011*
- Cholera Response, Samaritan's Purse, Port au Prince and Cabaret, Haiti — *December, 2010*
- Indus River Flooding, Food for the Hungry, KPK and Punjab Provinces, Pakistan — *August/September, 2010*
- Post Earthquake Response, Samaritan's Purse, Leogane, Haiti — *February/March, 2010*

International Development – Civil engineer for projects serving ministries throughout the developing world.

- Haiti Arise School and Church, Grand Goave, Haiti — *June, 2011*
- El Shaddai Baptist Church and School, Port au Prince, Haiti — *June, 2010*

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INTERNATIONAL DEVELOPMENT AND DISASTER RESPONSE EXPERIENCE (Continued)

- Hope for Children Clinic and Orphanage, Malakal, Sudan — *May, 2009*
- Centre for Peace and Reconciliation, Kigali, Rwanda — *February, 2008*
- Tien Shan International School, Almaty, Kazahkstan — *June, 2007*
- Youth Camp and Ministry Center, Lubango, Angola — *March, 2007*
- Royal Poultry Microenterprise, Ndola, Zambia — *October, 2006*

Engineers Without Borders, Chicagoland Professional Chapter
Project Lead and Mentor for developing world projects involving flood relief and clean water projects

- Flood Relief Channel, Las Cruces, Guatemala — *2009-2012*
- Water Source Development, Papachacra, Bolivia — *2009-2012*

AWARDS AND RECOGNITION

International Service Award, American Public Works Association, Chicago Metropolitan Chapter — *2011*
President's Volunteer Service Award — *2011 and 2010*
Citizen Engineer of the Year, American Society of Civil Engineers, Illinois Section — *2007*

PAPERS AND PRESENTATIONS

"*Water Quality Testing Workshop*", Engineers Without Borders, Chicagoland Professional Chapter, Chicago, Illinois — *March, 2012*
"*eMi's Response to the Horn of Africa Famine*", Association of Christian Design Professionals, 2011 Annual Conference, Seattle, Washington — *October, 2011*
"*Water Testing During Disaster Response Operations*", Association of Christian Design Professionals, 2011 Annual Conference, Seattle, Washington — *October, 2011*
"*Installation of Clean Water Treatment Systems Following the Haiti Earthquake and Cholera Emergencies*", American Public Works Association, Chicago Metropolitan Chapter, 2011 Annual Conference, Chicago, Illinois — *May, 2011*
"*Lessons Learned from the 2010 Haiti and Pakistan Mega-Disasters*", Association of Christian Design Professionals, 2010 Annual Conference, Ashville, North Carolina — *October, 2010*
"*Engineers as Ambassadors*", American Society of Civil Engineers, Illinois Section Newsletter — *November, 2009*
"*Engineering Challenges and Opportunities in the Developing World*", American Society of Civil Engineers, Illinois Section, Geotechnical Group Meeting, — *December, 2008*

MEMBERSHIPS

Engineers Without Borders
American Public Works Association
National Society of Professional Engineers
Illinois Society of Professional Engineers
American Society of Civil Engineers
Association of Christian Design Professionals
Association of State Floodplain Managers
American Council of Engineering Companies
Illinois Association for Floodplain and Stormwater Management

Drew M. Sharp
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Indianapolis, IN 46202
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Objective

Requirement for EWB Purdue University Chapter Mentor

Education

IUPUI – Indianapolis, IN
Purdue School of Engineering and Technology

Work Experience

RenCon Services, Inc. Indianapolis, IN - 2010-2012
Pyramid Masonry, Inc. Brownsburg, IN – 2005-2010

Skills

Superintendent for RenCon
Journeyman Bricklayer
Administrative Experience
Construction Management

Software

Oracle Pimavera
AutoCad – Civil 3D
Microsoft Excel
Adobe Acrobat

Active Member

Engineers Without Borders – Indianapolis Professionals
Society of Student Constructors – IUPUI
NASTT – IUPUI Chapter

References

Roger Ward, P.E. BCEE – HNTB, Indianapolis, IN
Jackie Dohrenwed, E.I. – R.W. Armstrong, Indianapolis, IN
Chris Breinling, P.E. – URS, Indianapolis
Tom Iseley, Ph.D., P.E. – CEMT Program Director – IUPUI

Experience

As a member of the EWB Indianapolis professionals chapter I was the construction and materials lead for the Kenya Well Project implementation trip earlier this year. My duties included take off, materials selection, layout, and construction methods. My role in the project was determined by my field experience and expertise in masonry. This experience has prepared me and gives me full confidence in my ability to fulfill my duties as a mentor for the EWB Purdue University Chapter.

Pre-Implementation Report Part 2 – Technical Information

1.0 INTRODUCTION

The village of Papachacra is experiencing a shortage of potable water due to the increasing demand from population growth and inadequate existing system. The EWB-Purdue chapter with assistance from Engineers in Action has planned to develop a sustainable solution for the community. The EWB-Purdue chapter is responsible for the design and construction of the system improvement project.

The purpose of this report is to discuss the details of preliminary design regarding the potable water project in Papachacra, Bolivia. The report provides a summary of project background, calculations and details of design components, implementation schedule, associated cost estimates, ownership, and system operation and maintenance procedures

2.0 PROGRAM BACKGROUND

The village of Papachacra is located in mountainous region of Southern Bolivia. The economy is agriculturally based; however, the residents can hardly produce enough yield from their harvests to support themselves. Since the community is continuing to expand, the demand for water is increasing as well. Around 50% of the village's population leaves during the dry season to find work and water elsewhere. Currently, a water system constructed by an organization called CARE, which was later augmented by the National Fund for Productive and Social Investment, can supply enough water for about fifty families. However, the population is now at around 134 families and growing. The government of Bolivia is giving funding to small villages, including Papachacra, to improve their standard-of-living. This means eventually plumbing will be installed in the houses and buildings, further increasing the demand for water.

In October 2009, five students from Purdue University and one professional engineer traveled to the site to do an assessment. They talked to villagers, teachers, and health professionals in the area. The current water source and possible additional sources were tested for traces of nitrates and nitrites, hardness, pH, total chlorine, and free chlorine. The sources such as the Tree Spring and Spring #3 were found to be safe and clean for use and consumption. Despite the available clean water source, they learned that several villagers consume contaminated water from irrigation ditches when there is not enough water from the existing facility. Because of this, villagers are prone to pathogens and illness. Providing the village with a clean water supply has the potential to improve the lives of the current residents as well as the lives of future generations. In addition to the assessment trip, in summer 2010, a topographic survey was also done for the existing system from the spring boxes to the school. The information from the survey was used to define the elevation profile and geographical features of the surrounding area.

3.0 FACILITY DESIGN

3.1 Description of the Proposed Facilities

The goal of the "Improvement of Potable Water Supply" project is to increase the water supply for the community by system modification and addition of the water sources as outlined in Appendix E. Therefore, EWB-Purdue Chapter plans to increase the overflow height of the existing spring box. Additionally, EWB-Purdue Chapter plans to construct a new spring box and pumping system at the Tree Spring in order to increase the overall water supply. From the average of five different measurements of flow rate at the Tree Spring flow channel, the spring can supply approximately at least 17,000 L/day. The total available supply after the completion of the first phase will be approximately 43,000 liters per day. The new spring box will be equipped with a submersible pump with a power supply from solar panels and a battery array. The water will be pumped up to polyethylene storage tanks at the elevation 50 feet greater than the spring. The additional supply will predominantly serve the two upper zones of the village.

The existing facilities in Papachacra, detailed in Appendices H and E, include a water system fed by two springs located in the mountainous region south of the village. The flow rate measurements of the springs were from the average of five individual measurements at the inlets of spring boxes. The first spring, the CARE spring has a flow rate of 16,200 L/day and the second spring, the FPS spring, has a flow rate of 10,000 L/day. The flow from the springs then travels down separate pipelines to the village. The pipelines travel across a gorge, up a small hill, and then down the mountain where they combine in the two tanks above the village. Because the pipe has to travel up the hill before coming down the mountain the flow experiences some undesired head loss on its way to the two water storage tanks, labeled as point 4 in Appendix E. This causes less water to flow out of the spring boxes and down the mountain.

3.2 Description of Design and Design Calculations

<u>Determination of Demand:</u>

The demand calculation of this project is based upon information provided by the community leader. There are 134 families within the community with a current demand of 66 liters per person per day. The average number of persons per household is assumed to be four, thus yielding a demand of approximately 264 liters per family per day. Therefore, the projected total demand is at 35,376 liters per day.

The system is sub-divided into four zones. Two are located in the lower half and the other two are located in the upper half of the community. Currently, the population is roughly evenly split between the upper and lower zones, thus the total demand of the upper and lower area are considered equivalent. The existing system will supply 26,000 L/day and the Tree Spring will supply the new system with at least 17,000 L/day. The existing water system will primarily supply the upper zones. A valve will be added to the current pipe network in order to regulate the amount of flow from the existing system to the lower zones. The valve can be adjusted to allow an equivalent supply to reach the upper and lower zone. The valve allows the water supply to be proportionally divided in the case of expansion. The lower zones will be the sole recipients of the new water supply. The new water supply is located below the upper two zones and would require pumping to raise the water to their level.

The aforementioned estimates of demand were based on calculations presented below. Estimates for future flow rate demand are also calculated below. The estimates for future flow demands were based on the estimate that if each family were to install a flush toilet in their homes it would increase the demanded flow by 40 L/day with the assumption of 4 L/flush. With the current rate of growth from the community census, the village has the potential to reach 180 families in the next 5 to 10 years. Based on the calculations below, it can be seen that the demanded flow could increase five times in the next few years. In order to accommodate this growth, we will examine additional phases in the future that continue to expand and improve the water supply and other aspects of the community.

Determination of Storage Tank Size and Location:

The storage tank was designed to have the capacity to store approximately the amount of water the Tree spring can produce daily (~17,000 L) to ensure that it can sufficiently store water from both the Tree Spring and the existing system. Therefore, we chose to use three polyethylene tanks of 5,000 L capacity each. Each circular tank will have dimensions of 1.85 meters in diameter and 2.25 meters in height. The tanks will be located between the Tree spring and existing treatment tanks with approximate differential elevation of 20 meters. The elevation difference is determined to ensure the water pressure within the pipe of around 40 psi. The tank will be located on the roadside where the road splits off into two routes. See Appendix D., Figure D1.

Determination of Water Quality and Purification Method

From the water testing data collected from the assessment trip, the existing water sources and the Tree spring are very clean and safe for consumption. (See Appendix M) For the existing system, the community water committee uses chlorination for the water treatment and there has been never been an issue regarding water quality. Therefore, the additional water source from the Tree Spring will also be chlorinated by the person in charge from the community water committee.

Required water quality of the new water entering the system as well as the quality of the full system's water after the project is implemented will be compared with the water quality standards for Bolivia outlined in the document in Appendix N below. I will be a requirement of this project that the quality of the water meet these standards for Bolivia especially the standards for Ecoli, Chlorine residuals, Turbidity, Arsenic, and Flouride. Measurements will be taken by the Papachacra water committee as need or as requested by EWB-Purdue to insure that the system remains within the standards outlined in Appendix N.

Determination of Spring Box:

The spring box will be a reinforced concrete structure consisting of #3 or #4 grade 60 reinforcing bars and wall thickness of 8 inches to provide sufficient coverage for the rebar and stirrups. The design and construction method were based on the ACI 318-11 Code. The overall height of the structure will be 6 feet and with width and the length of 7 by 7 feet. The structure will be 6 feet below grade. Medium size aggregates will fill the constricted area to filter water flowing into the spring box. The spring box consists of one chamber with inlets on the wall adjacent to the catchment area at 20 centimeters from the spring box's interior top surface. See Appendix B for additional details. See Appendix B section 2.0 for calculations.

Determination of Pump Specification and Power Requirement:

To determine dimensions of the spring collection box as well as to size and dimension the pump system and solar panels the calculations seen in Appendix A were done. These calculations we done based on a Lorentz PS1200 HR-14 No.1255-X Helical rotor submersible pump, which is a pump that is easily available in La Paz. From the calculations and the use of the curve for this pump it was determined that the pump will need to be run at a flow rate of 15,000 L/day thus providing a pressure head of 30 meters. Running the pump at this rate at increments as the collection box fills will provide the required overall flow rate to ensure that the tanks are consistently filled with fresh water from the tree springs. In running the pump at these rates it will need at up to 500 watts per day. This power will be provided by two 250 watt solar panels and stored in three 12 volt car batteries

FPS Spring Overflow Pipe Extension

The citizens of Papachacra are currently losing a significant amount of water due to the overflow pipe in the spring box. The pipe extends well short of the top of the tank and begins to divert water when the tank has only reached 75% of its capacity. The overflow water is diverted to cattle, but the cattle are receiving more water than necessary while the citizens are not receiving enough water. In order to decrease the quantity of water lost through the overflow pipe we plan to extend the current one inch diameter PVC overflow pipe. This will allow the stored water of the tank to reach a greater height and volume.

The overflow pipe will be raised by attaching an additional segment of a one inch diameter PVC pipe. The segment will be attached using a female-to-female pipe joint. Sealant will be applied to the inside of the joint to create a tight connection. Teflon tape will be applied to the outside of the connection to strengthen connection and reinforce the seal. The added pipe segment will ideally extend the pipe one inch below the sediment chamber wall. The one inch of clearance will prevent the stored water from mixing with the water in the sediment chamber. The water storage capacity of the main holding tank will be increased, subsequently increasing the water directed towards the village.

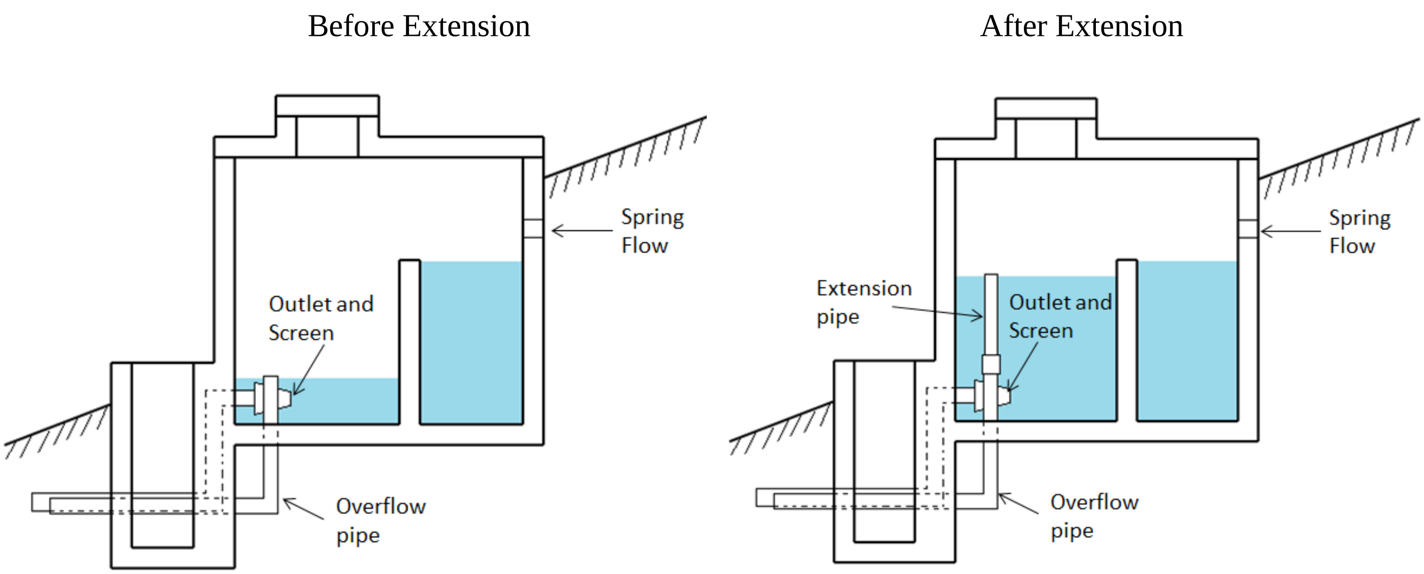


Figure 3.2.1 overflow extension pipe diagram

3.3 Drawings

Drawings included in 525 – EWB-Purdue Drawing Package.

Appendix A – Pump and Electrical System

Appendix B – Spring Box System

Appendix C –Tank and Valve System

Appendix D – Pipe System

4.0 PROJECT OWNERSHIP

The village of Papachacra currently has a water committee in place to monitor and maintain their current water system. The water committee will additionally oversee the new water system. EWB-Purdue will provide the village's water committee with all necessary information regarding the new system including; system installation, maintenance, and repair. A manual containing the information will also be provided. EWB-Purdue has been granted permission to make use of the public water and land on which the water system will be constructed. The water committee will collect fees from the villagers to generate revenue for maintenance and repair.

5.0 CONSTRUCTION PLAN

5.1 Construction Plan

The construction will be done by EWB members, EIA members, community members, a mason, and a local engineer. EWB members will be participating in most of the construction activities except for pipeline excavation and installation, which will be done by the villagers. The excavation and preparation of the pipeline, storage tank and spring box will start before the team arrives in Papachacra and the completion of many components of the project, such as pipe and storage tank installation can be done after the team's departure. The layout of the overall pipeline and excavation site will be sent to EIA and villagers beforehand in order to prepare for the project construction.

EWB-Purdue Chapter will also hire a local mason and engineer to oversee the construction of spring box, solar panels and overall electrical system. EWB members and villagers will also participate in the construction of these components. There will also be at least one mentor or EIA member overseeing the overall construction of each site to ensure that the system is being implemented as designed.

Day 1

- Meet and Greet with the Village
- Assess site and other preparation done by the villagers
- Assess pipeline excavation done by the villagers
- Check the delivered materials

Day 2

- Finish the site and other preparation at the Tree Spring area
- Pick an exact location for the storage tanks, spring box, pump house and solar panels
- Finalized pipe layout at the spring box and storage tanks
- Assess the sites for additional preparation
- Inspect formworks

Day 3

- Continue pipeline excavation
- Site preparation at the storage tank location
- Foundation slab concrete pouring for spring box, pump house and solar stands

Day 4

- Foundation work for storage tanks
- Overflow pipe extension at the existing spring box
- Spring box concrete pouring (except the top slab)
- CMU laying for pump house

Day 5

- Finish pipeline excavation
- Install solar stands and solar panels
- Install pump and batteries
- Rest

Day 6

- Pump + Spring Box system integration
- Wiring of Pump + Batteries + Solar Panels
- Pump and spring box system integration
- Pump, batteries and solar panels wiring

Day 7

- Continue pipe installation
- Pipe integration at tanks
- Top slab concrete pouring for spring box
- Lid concrete casting for spring box
- Install roof structure and doors for pump house

Day 8

- Securing the solar panel and pump house with fences
- Install roof structure and door for pump house
- Finish pipe installation

Day 9

- Pump system Testing
- Valve system Testing
- Trial Run of the system
- Troubleshooting for any problems

Day 10

- Final system check
- Touch up on details

- Room for delays

Note: There can be multiple teams (up to 3) working on any day, depending on the nature of work tasks. Brief construction plan overview will be conducted at the beginning of each day. End of day meetings will also be concluded on daily basis. See Appendix F for construction flow chart.

5.2 Construction Safety Plan

A safety review will be conducted at the start of each day with respect to the scheduled tasks. The safety measures for construction include gloves and work boots for protection from cement burn and physical injuries. The wiring process will be done without any electrical current in the system and overseen by a local engineer specializing in electrical systems. More information about the Construction Safety Plan can be found in the Heath and Safety Plan (form 600).

6.0 SUSTAINABILITY

6.1 Background

The potable water system has been designed to incorporate materials and technology available near Papachacra. The local acquisition of materials will ensure easy and sustainable access to replacements and repairs.

Durability was also considered during the material selection process. The PVC piping will be buried underground and degradation will be minimal. A lifespan of at least 50 years will be expected. The polyethylene tanks have a typical lifespan of 15-20 years. The solar panels have an effective lifespan of 20-25 years. The community leaders and water committee will be provided a manual containing information on all system components and their lifespans.

The solar panels will provide sustainable electricity for the pumps in the system. The village's water committee will be instructed on how to recharge the batteries using an automobile as a generator or by connecting the system to a grid in the event that the solar panels fail to keep the batteries charged.

The chapter's Community Outreach Committee is in the process of designing an educational program to inform the villagers about the new water system, sustainable agriculture, waste management, and proper sanitary and hygienic practices. In order to maintain a sustainable water system the team will educate the community on the importance of water conservation. The vulnerability of the area surrounding the spring will be analyzed and brought to the village's attention in a report outlining possible threats.

Additionally, the chapter will work with the operators of the current water supply system to advance their understanding of the new system as well the chapter's understanding of current water systems in Bolivia. These operators will be asked to monitor key portions of the installation that may require repair or replacement in the future. These operators will be responsible for system maintenance and operation. Furthermore, a community-elected water committee will also aid in sustaining the system.

No environmental impacts or issues were discovered after communicating with the village leaders and examining the area thoroughly during the site assessment. The water depleted from the tree spring will have a very minor effect on the watershed and the change in storage will be negligible after recharge.

6.2 Operation and Maintenance

From Skype conference calls with EIA and interview transcripts from the 2009 assessment trip, it is clear that the community's water committee will take responsibility of all of the operation procedures, maintenance, and repairs for the system. Papachacra's water committee currently operates and maintains their water system effectively and has stated that they are willing to learn and implement the operation procedures for the addition to the system to insure that it will continue to run smoothly.

In order to assist the water committee in operation and maintenance of the new water system, EWB Purdue will provide training during our implementation trip. This training will include ensuring a full understanding of the Operation and Maintenance (O&M) Manual that EWB Purdue will provide after the Pre-Implementation Report (EWB 525) and before the implementation trip. It will be insured that the Papachacra water committee understands periodic maintenance procedures, advised repair protocols, and are provided information such as parts lists, local vendors, and information on who to contact if specialty repairs are needed (e.g. pump, solar panel, or electrical system failures). This O&M manual will also include daily O&M sheets to be completed by the Papachcra water committee and submitted to EWB Purdue on a monthly basis for review and suggestions. This will be continued for the first year following implementation to insure that the community becomes gradually accustomed to the system and can rely on EWB Purdue for helping to monitor the system's health.

Routine maintenance on the system is expected to be minimal and to be only a small addition to the water committee's current maintenance procedures. The components of the system that will require the most maintenance are those in the solar panel, centrifugal pump, and electrical systems. Simple training and the use of parts and a pump that is available in the surrounding area make this maintenance much easier on the community. EIA will also be available to assist the water committee with these components if repairs are needed. Maintenance on other parts of the system will include periodic cleaning of the water tanks, checking for leaks, and insuring that all valves are in working order, none of which will require much technical expertise. It will also be requested that as part of their O&M procedures that the water committee take monthly post-treatment water samples to be analyzed by EIA to insure that the addition to the system has not altered the community's water quality.

The increase in O&M is estimated to be minimal, and the community has stated that they will increase the monthly water fee per family by a small amount to offset these additional costs. If maintenance or repairs prove to be too costly for the community, improvements will be made for Phase II of the implementation. More information about operation and maintenance procedures can be found in Appendix L.

6.3 Education

To address the long-term sustainability of the project for the community, the traveling team will be implementing several education initiatives regarding water conservation, recycling, and basic education on the new additions to the system. Prior to the implementation, educational deliverables will be produced regarding conservation areas identified by EIA. After initial Skype calls, educational target subjects include recycling, water conservation, and composting. Deliverables will include written material in the form of brochures, flyers, signs and optional small 'informational sessions' conducted by the traveling team if time allows. Prior to the team departure, all deliverables will be reviewed by EIA and translated for the community.

The team will also spend time educating the community on the benefits of the project. This will happen by first confirming details with the village leaders and then using their assistance in spreading the word to the community. The emphasis on describing the project to the community is having the community understand the springs only increase water supply and do not produce 'infinite' water use. The team realizes the maximum benefit to the community is achieved when water use does not change significantly from the assessment statistics. To help accomplish this, educational deliverables will focus on water conservation and water reduction methods. One possibility for increased community involvement is to help start a community 'water watch' program where community members can keep track of their water use. An award for participation in the program could be sponsored by the village leadership once approval is gained from the village leadership. It is hoped that this will help community members to feel a sense of pride in conserving water supplies and doing what is best for the community as a whole.

From data provided in the assessments, one of the main consequences of limited water in the dry season is an increase in the possibility of diseases due to poor hygiene habits. The team intends on helping to resolve this issues with educational deliverables addressing hygiene habits and identification of safe water. From interviews with the community, a common occurrence during the dry season is to find community members drinking from open water ponds of untreated water. The team hopes to curtail this practice with educational materials on identification of safe water and on basic water purification practices. Because of the bulk of information available on this subject and others, the team anticipates that more deliverables might be necessary on the second implementation trip.

7.0 MONITORING

7.1 Monitoring plan for current project

As a means of monitoring the project after its completion the EWB-Purdue team will rely on system information and data from the water committee in Papachacra. The water committee will be advised to follow procedures outlined in the O&M which will detail processes for reporting issues with the system and explain how to take periodic measurements. The main pieces of data that will be used to monitor the project will be water quality samples, data on frequency of minor repairs required, and data on success of maintenance procedures. If any of these main categories are not meeting expectations, a solution will be able to be developed quickly and effectively with the help of EIA. Because data will be reported by the community through EIA to EWB-Purdue, problems in the system can be addressed in an efficient manner.

Also a direct means of monitoring that will be conducted by the EWB-Purdue team will be a return trip to the community in the summer of 2013. This trip will be as a means of evaluating the effectiveness of the system, making any needed repairs, and doing an assessment for following phases on the project.

8.0 COMMUNITY AGREEMENT/CONTRACT

See the Memorandum of Understanding in Appendix J.

9.0 COST ESTIMATE

The Costs (in U.S. dollars) associated with this project were estimated using prices given to use from EIA. These costs include the prices of the solar panels, pump and pump circuit, spring box, piping and required valves, storage tanks and all required tools, equipment, and material transportation costs for the proposed project. Labor costs including skilled and unskilled labor have been tabulated at zero dollars because all labor will be provided by the community and volunteers. The conversion rate and prices were provided by EIA and is assumed to be roughly 7 Bolivianos to 1 U.S. dollar. A general overview of the estimated costs for each Component group can be seen below along with a 10 % contingency.

Table 9.0.1: Summary of Estimated Costs for Phase I Installation

Component	Cost (U.S. Dollars)
Photovoltaic Panels (solar)	$1,000
Lorentz helical rotor submersible pump	$2,000
Pump/Solar panel circuit	$535
Spring box	$888
Piping and Valves	$855
5000 L HDPE I Tanks	$3,000
Tools, Equipment, Fasteners and Material Transportation	$2,300
Unskilled Labor	$200
Skilled Labor	$1,260
Subtotal	$12,038
10% Contingency	$1,204
Total Phase I Project Cost	**$13,242**

10.0 SITE ASSESSMENT ACTIVITIES

The first day at the site will consist on only site assessment activities. This will include first walking the site and discussing and taking note of on unanticipated obstacles, terrain, or soil types that may lead to required adaptions in the construction process. Also measurements of each site will be taken and verified with the designs to help plan for needed changes early on. This will all be done along with leading members of the community to insure that they understand how the construction will be carried out and what will be done on which days. This is also when we will divide up the tasks and construction responsibilities of community. We will also do a walk through with the hired mason to insure that he thoroughly understands the design.

A very important site in this project that will need to be assessed accurately early on is the spring box site. Since the spring box design may need to be adapted depending on the depth of the impenetrable layer and exact locations of surrounding tree and root structures the assessment will need to be done very effectively. Because of the sensitivity of this portion of the project we are bring a mentor how has had previous experience installing spring boxes in developing areas.

11.0 PROFESSIONAL MENTOR/TECHNICAL LEAD ASSESSMENT

11.1 Chris Breinling

11.2 Professional Mentor/Technical Lead Assessment

The Purdue University chapter of Engineers Without Borders originally travelled to Papachacra, Bolivia in October 2009 in order to assess the condition of an existing water supply system. Since that time, the Purdue University students have been preparing design documents, project system analysis and prepared the cost estimates associated with the proposed improvements. The existing chapter membership consists of a group of students that are motivated to complete an initial implementation project that melds the disciplines of civil, mechanical and electrical engineering. Tyler Anselm, one of the project leads, used his mechanical engineering experience to develop the spring box and pump station design. Witcha Danaisuphachok (civil engineering student) and Sara McMullen (agricultural engineering student) developed the water distribution system and storage layout that will be programmed into later phases of the project. Mark Shebeck, a civil engineering student who will not be travelling on the 2012 project trip, was instrumental in the development of the modifications required to increase water collection efficiency at the most remote water collection springbox. The students, under professional guidance, were able to make critical decisions with regard to project scope, costs, schedule and constructability issues associated with the delivery of a public water supply system that can be constructed within a ten day period on-site in Papachacra, Bolivia. A carefully developed schedule, along with on-site coordination of personnel in cooperation with Engineers In Action (EIA) will provide for an intense on-site learning and enrichment activity for both students and community members while establishing a technology transfer and system development plan for the community to implement in future years. Traveling mentors from the Chicago and Indianapolis Professional Chapters will include Drew Sharp and Rod Beadle, two engineers who both have been very successful EWB Student Chapter mentors for many years having constructed several water distribution and structural projects each.

11.3 Indianapolis Professional Chapter

Appendix A

1.0 Pump and Electrical System Design and Drawings

The pump seen below in Figure A2 is a Lorentz PS1200 HR-14 No. 1255-X Helical rotor submersible pump that has a built on motor which runs on 72-96v DC and has an efficiency of 65%. It has an outlet pipe diameter 1-1/4" and is specifically designed for solar operation. The specs for this pump are ideal for what we will need in this system. As seen in the pump specifications in Figure A1, the pump will be run at a flow rate of 15,000 L/day which will give a pressure head of 30 m as show by the red line. This flow rate and head will work well for this system as shown by the calculations in Appendix A2 below.

solar generator	vertical lift		5 m 16 ft		10 m 33 ft		15 m 50 ft		20 m 65 ft		30 m 100 ft		40 m 133 ft		50 m 165 ft		60 m 200 ft		70 m 230 ft	
	array mounting		fixed	tracked	fixed	tracked	fixed	tracked	fixed	tracked	fixed	tracked	fixed	tracked	fixed	tracked	fixed	tracked	fixed	tracked
			flow rate [m³/day]																	
480 Wp	irradiation kWh/m²/day	7.5	66	95	34	49	30	43	22	30	18	26	14	20	11	14	8.7	13	6.1	8.7
		6.0	56	80	28	38	24	32	19	27	15	19	10	14	8.5	12	7.0	10	5.5	7.4
		4.5	44	60	22	28	18	24	15	21	12	16	7.0	9.5	5.5	7.5	5.0	6.5	4.5	6.0
	pump type		C-SJ8-5		C-SJ5-8				HR-14						HR-07					
	peak flow rate [l/min]		145		80		75		42		36		28		20		19		17	
	wire size/max. length		4mm² / 60m #12 / 150ft												4mm² / 80m #12 / 200ft					

Figure A1. Pump Specifications

Figure A.2 Lorentz PS1200 HR-14 No. 1255-X Helical rotor submersible pump

Technical Data, Dimensions and Weights

	dimensions					shipping dimensions			
	L	A	B	D	S	packaging	shipping volume	net weight	gross weight
	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[m³]	[kg]	[kg]
Pump Unit (PU) (motor + pump end)									
HR-03, HR-03H, HR-04, HR-04 H	780	595	185	96	G 1 1/4"	850×160×150	0.0204	11.2	12.0
HR-07, HR-10, HR-14, HR-20	771	586	185	96	G 1 1/4"	850×160×150	0.0204	11.5	12.3
Controller									
PS1200						450×250×240	0.0270	4.5	5.3

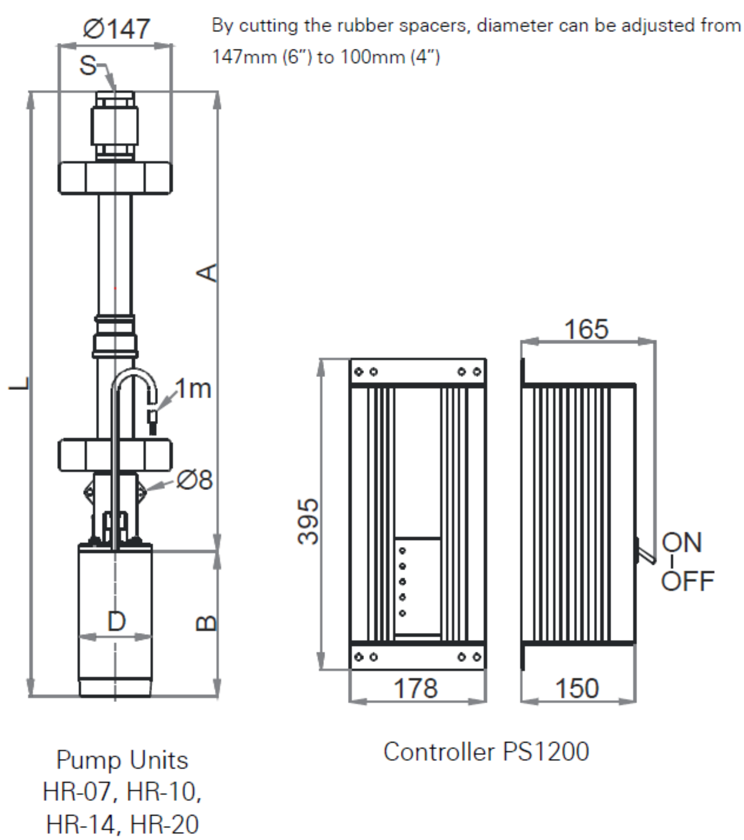


Figure A3. HR-14 pump and controller dimensions

Float Switches to Control Pumping increments

A float switch at the top (1000 L mark) will activate as seen in Figure A4 below when the water has reached the 1000 L level. The pump will then drain the entire 1000 L until the water level reaches the bottom and the 0 L switch is activated shutting off the pump. This cycle will then be repeated throughout the day as water is pumped.

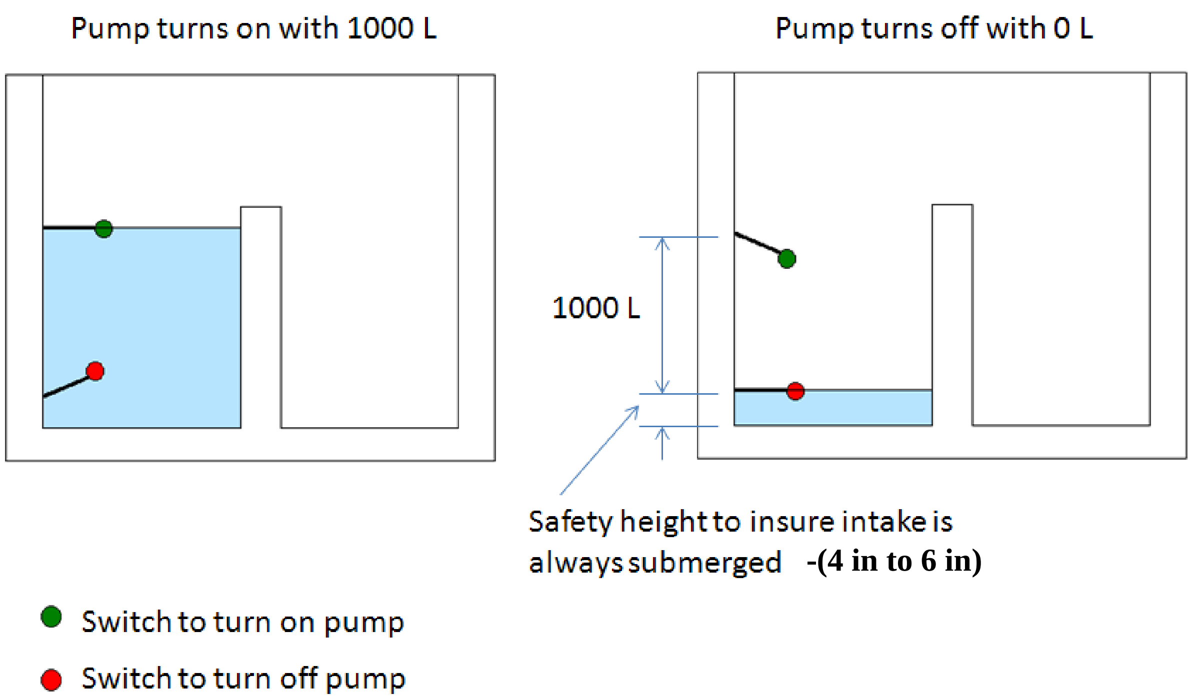


Figure A4. Float switch layout

Pump House

The pump components will be stored in a concrete block pump house with all of the electrical components including the battery array, the motor controller, and wiring. The structure will be well ventilated with screened slots on all sides of the house. The roof will be angled to allow for rainfall to run off. The house will be placed on a concrete slab foundation raised above ground level to prevent rain water from collecting around the area. The house will be constructed as seen below in Figure A5.

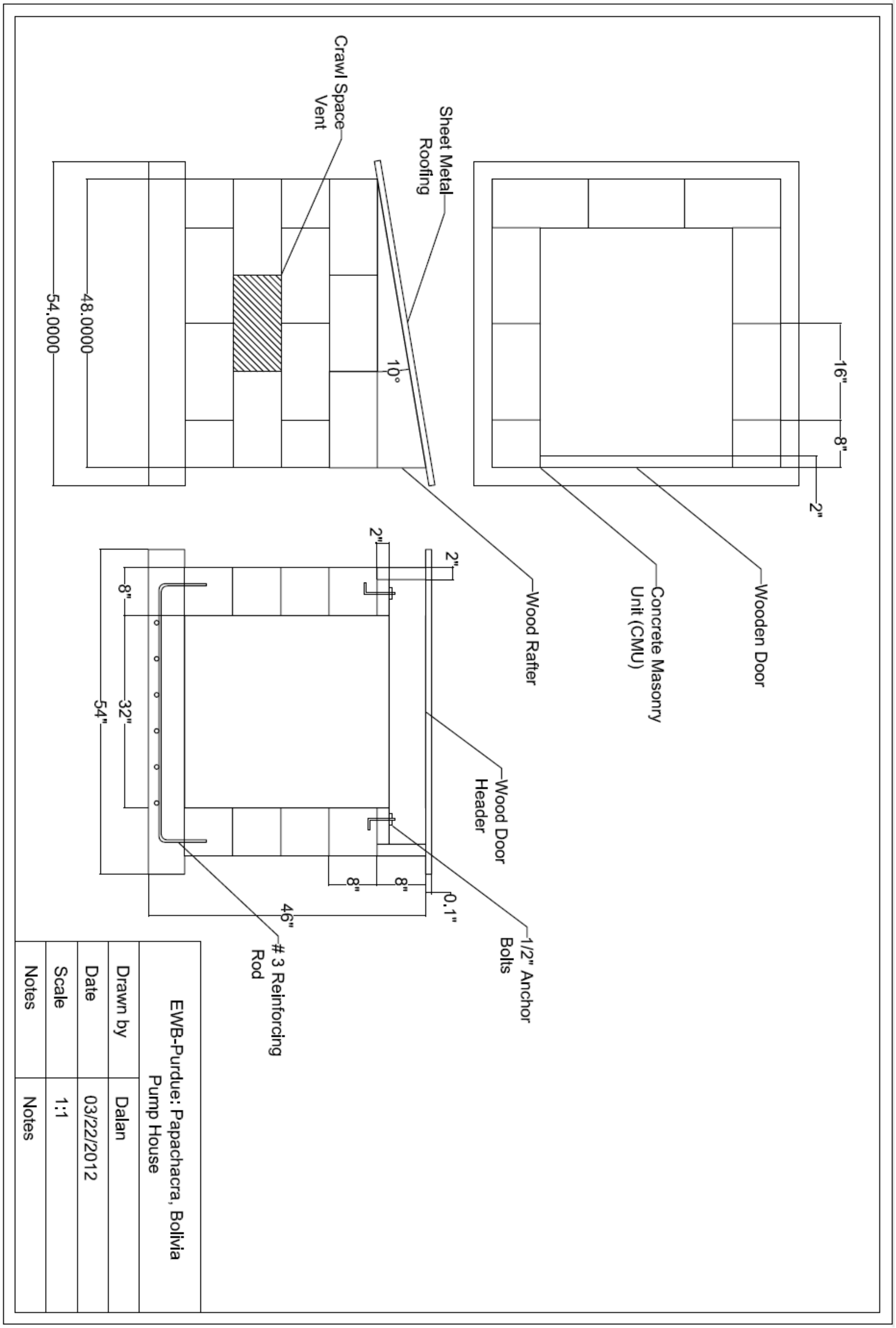


Figure A5. Pump house for controller and batteries

<u>Solar Panels</u>

Two 250 watt solar panels will be used to power the pump system. They will be mounted to solar panel stand as seen below in Figure A6. which will be purchased in Bolivia.

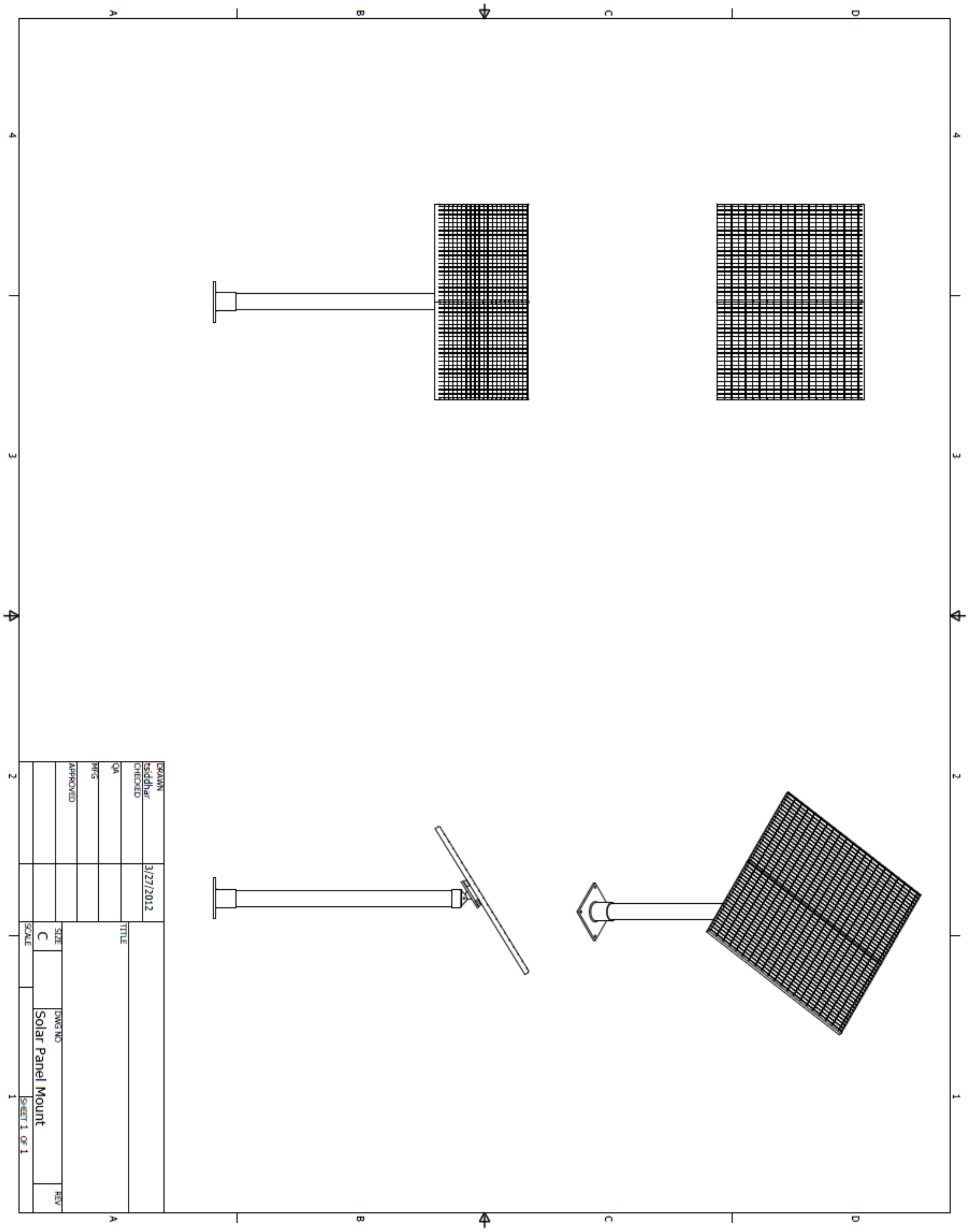


Figure A6. Solar panels and purchased stand

Solar Panel Circuit

To control the pump system a float switch will be used to tell the motor when the tank is full and when it is empty, a pump controller will be used to adjust the motor speed and control the pump, 12 VDC 75Ah, 1.75V per cell batteries, as well as a fuse to protect the system from surges. The components will be connected as seen in the circuit diagram below in Figures A7 and A8.

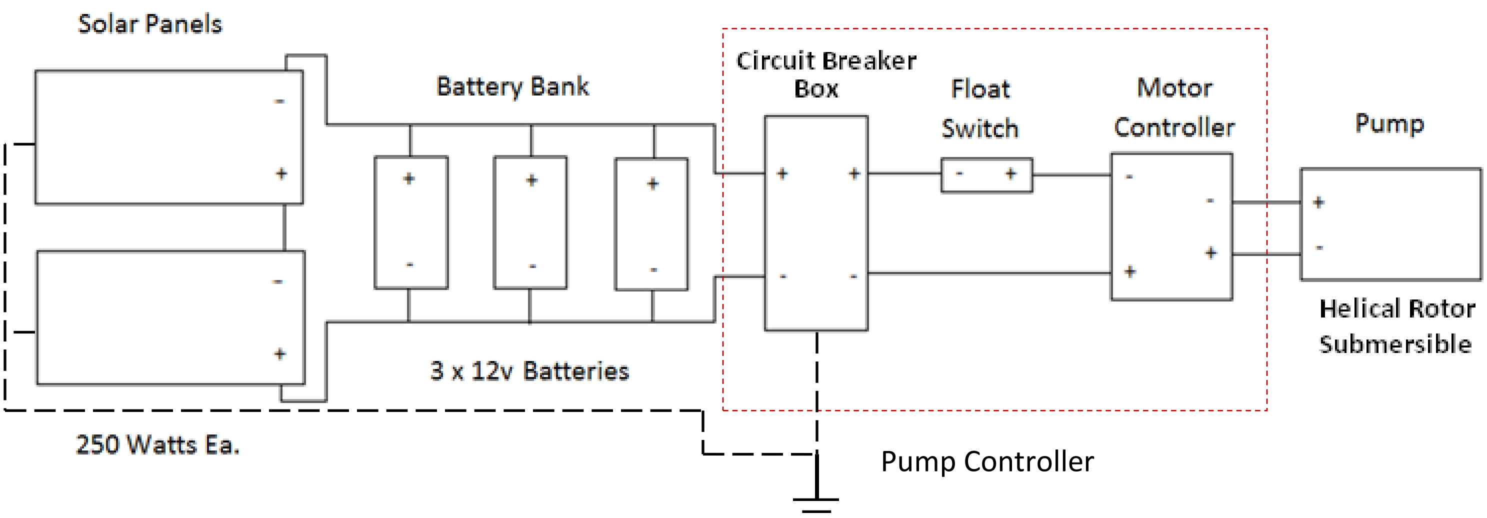


Figure A7. Solar Panel circuit block diagram

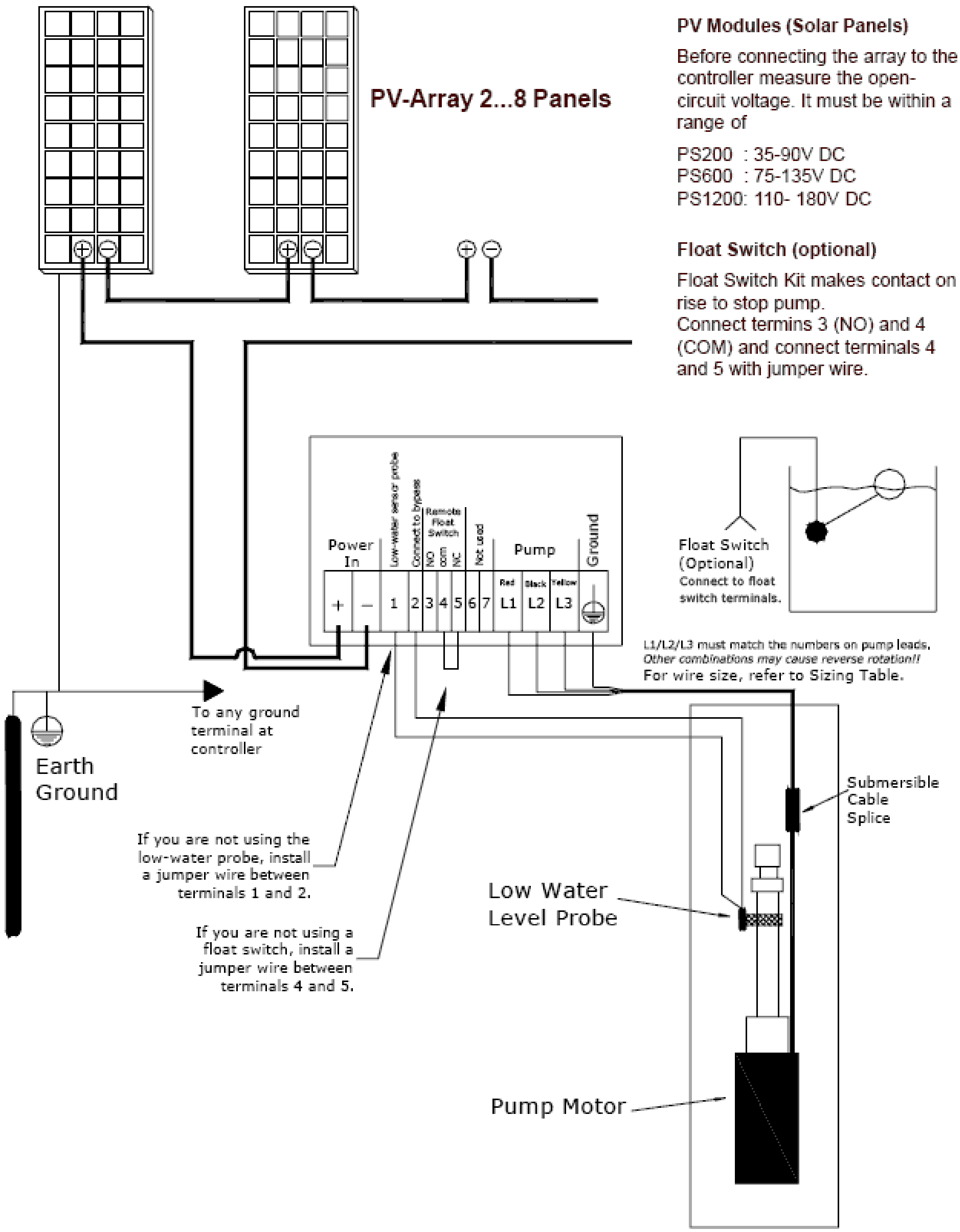


Figure A8. Solar pump wiring circuit diagram

2.0 Pump and Electrical System Calculations

The calculations below outline the determination of the spring box capacities, pump requirements, and power options. Figure A9 below shows the crucial dimension of the interior of the spring box used in the flow calculations

March 26, 2012

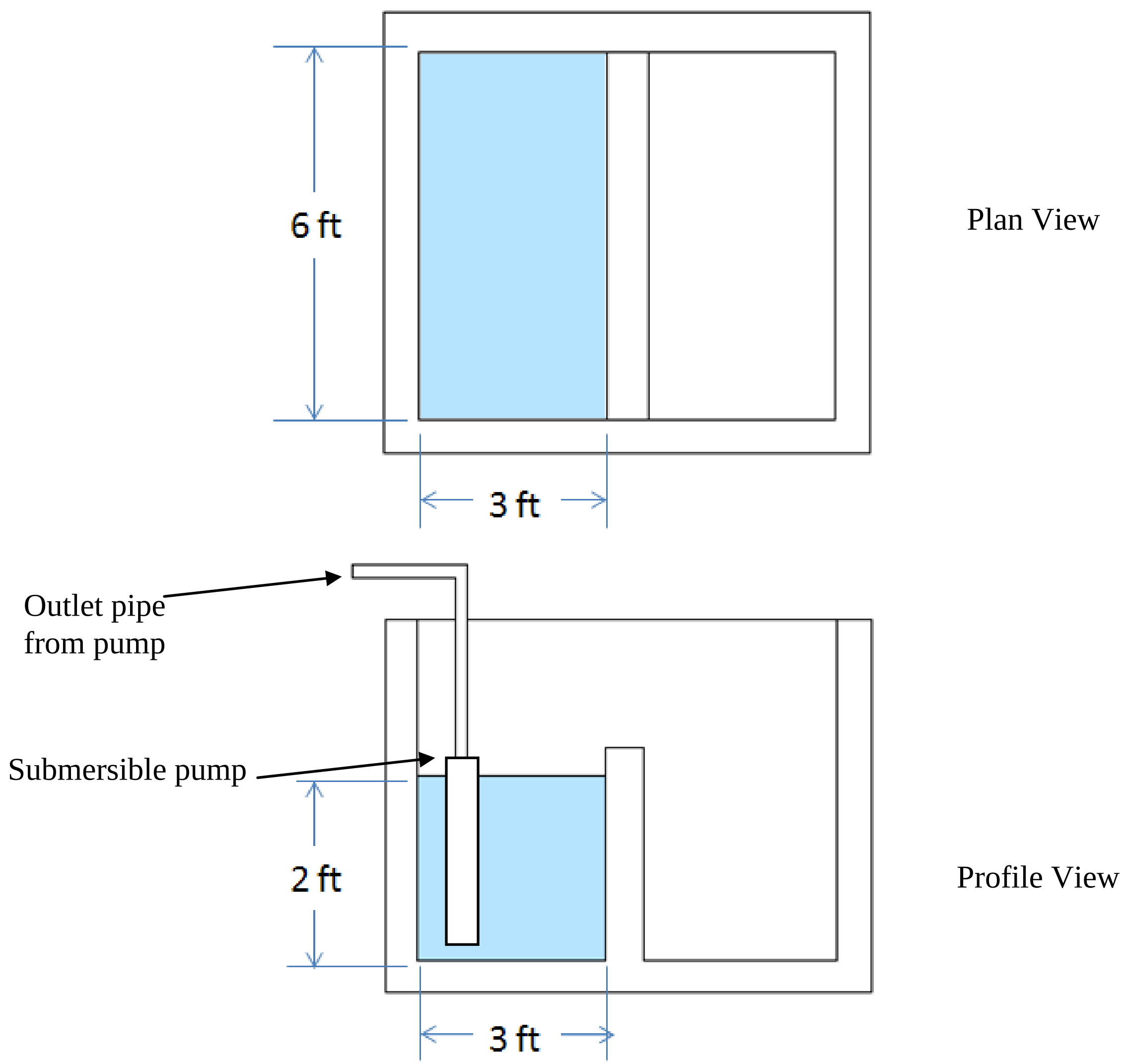


Figure A9. Spring box dimensions (not to scale)

<u>Spring Box Dimensions</u>

$$V = \left(6ft * \frac{12in}{1ft}\right)\left(3ft * \frac{12in}{1ft}\right)\left(2ft * \frac{12in}{1ft}\right)\left(\frac{1\ gal}{231\ in^3}\right)$$

$$V = 269.29\ gal\ \approx \mathbf{1000\ L}$$

At $Q_{spring} = 17{,}000 \frac{L}{day}$ it will take

$t_{fill} = 1000\ L * \frac{1\ day}{17{,}000\ L} * \frac{24\ hrs}{1\ day} = 1.41\ hrs \approx \mathbf{1\ hr\ 30\ min}$ to fill.

<u>Pump Time</u>

We will use a submersible pump as seen in the description below and run it at a flow and pressure drop values of $Q_{pump} = 15{,}000\ L/day$ and $H_{pump} = 30\ m\ (head)$ we can run the pump for

$$t_{pump} = 1000\ L * \frac{24\ hrs/day * 60\ min}{15{,}000\ L/day} = \mathbf{96\ min} = \mathbf{1\ hr\ 36\ min}$$

because $t_{pump} > t_{fill}$ the pump will not run dry. Excess water will overflow to irrigation.

*To account for varying flow rates a safety float switch will need to be added to insure that the pump shuts of long before the flow runs dry. A top float switch will be used to turn on the pump when the tank is filled to the 1000 L mark.

<u>Pump Power and Required Solar Panels</u>

The system will be run off of two 250 Watt solar panels providing 500 W of power. This amount of power is sufficient for running the HR-14 pump seen in the Figure A1. above. According to the NREL Bolivia has 2,292 hours of sunlight per year with an average of 6.3 hours per day with the shortest average of 4.8 hours in March and the longest being 8 hours per day in June offering a radiation of between 1,460 and 2,190 kWh/m^2 per year. These statistics for Bolivia as a whole are consistent with the numbers for Papachacra as seen in the solar map in Figure A10. below and were used in sizing the chosen pump.

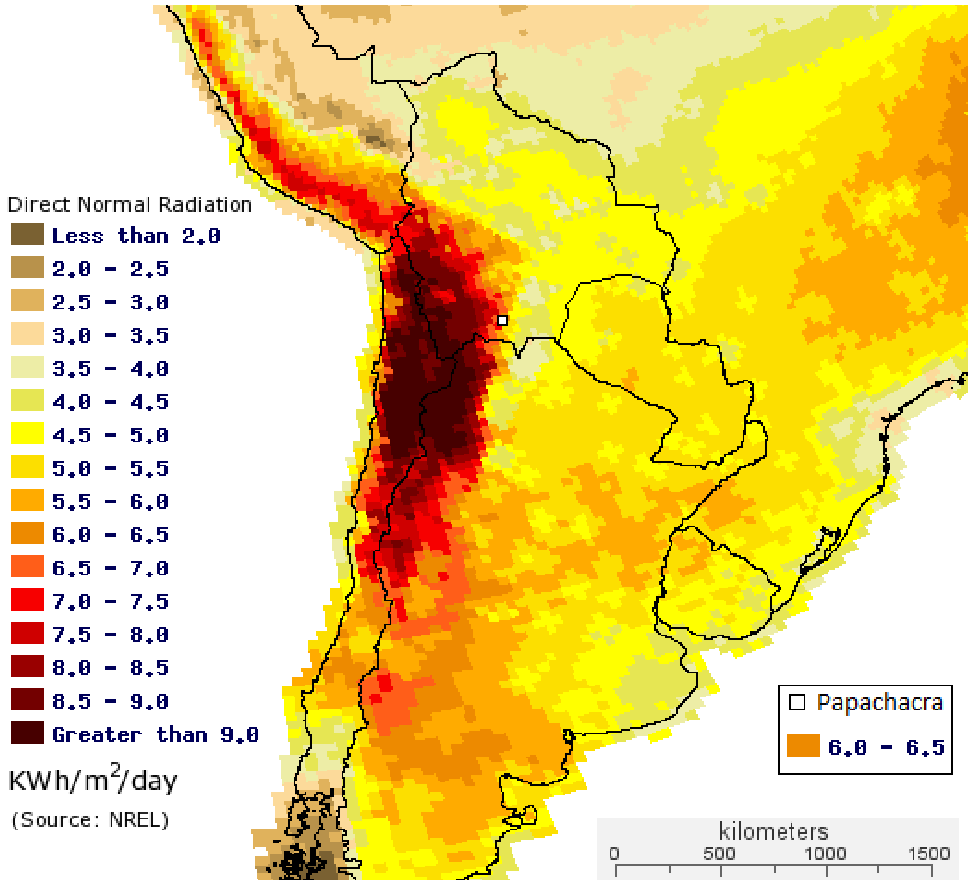


Figure A10. Solar map showing Papachacra, Bolivia

As can be seen below in Figure A1 with an irradiation of 7.5 kWh/m^2/day , as is provided in the months of May, June, and July, the pump will be able to provide a higher flow rate.

Appendix B

1.0 Spring Box System Design and Drawings

Background

The spring source is located in an elevated and wooded area southeast of the village center. Water quality at the collection point has been tested and it has been confirmed to be a safe source of potable water. Water quality data is located in Appendix L. EWB-Purdue will be constructing a spring box at the source of the emerging water. The spring box will protect the source from contaminants and allow the clean spring water to be supplied to the community.

Site Preparation

The spring area will be excavated until flow is evidently concentrated from a single vein augmenting the spring, also known as the eye of the spring. Collecting solely from the eye will reduce or eliminate the amount of water lost to the surrounded area. For the sake of finding the eye of the spring, a temporary drainage ditch will also be dug to keep the excavated area free of water. As one digs, certain veins will weaken until a concentrated vein is established. This final concentrated vein is the eye of the spring. With the assumption that the friction angle of the soil is 35 degree, the vertical slope of excavation of the construction area should not exceed 62.5 degree from the horizontal axis.

Once the eye is located and isolated, the site will be excavated down to the impermeable layer of clay or rock. The depth of the impermeable layer may vary. If the layer is not reached within 1.5 meters of excavation, an artificial impermeable layer will be created by pouring a concrete floor. This bottom impervious layer will act as a waterproof foundation, preventing water from draining under the spring box. After the impervious layer has been reached or created, the walls of the primary filter and capture chamber will be put into place by building wooden forms and placing the tied rebar into the form. Once the rebar is in place, the concrete will be poured into the supported wooden forms. A local mason will be hired to perform all concrete work. The capture area will be backfilled with cleaned rocks purchased in Tarija. The floor and walls of the storage chamber will be formed in a similar fashion using wooden forms and rebar.

Design & Principles of Spring Box Mechanism

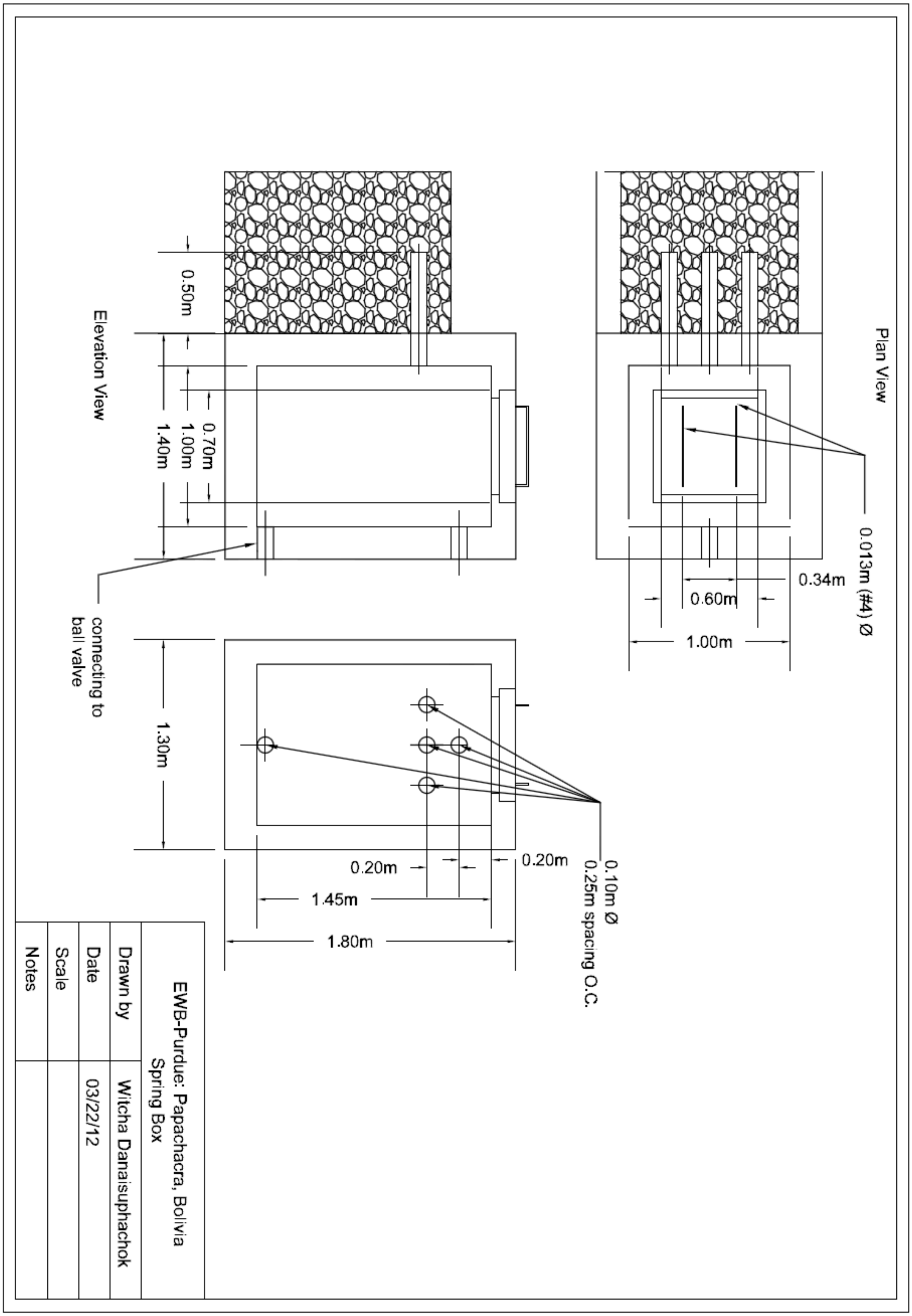
Since the spring box is located directly at the source of groundwater, the need for intensive filtration will not be necessary. The spring box in Figure B1 contains the proposed dimensions. The actual sizing of the box and excavated area will be determined by local conditions and may vary. This is necessary due to the variability of spring size and eye location. An effort will be made to meet the proposed dimensions.

Once the spring box is in place, the water will filter through the aggregate in the primary filtration and capture area and then enter the storage chamber through perforated tile drain piping. The tile drain piping will be equipped with PVC ball valves on the storage chamber side. This allows flow into the storage chamber to be paused in the case of pump and chamber maintenance. The gravel in the filtration and capture chamber is locally available and will be purchased to meet proper size distribution. The gravel should not exceed 1" in diameter. Water will be pumped from the storage chamber and added to the village's water supply. The storage chamber will house an overflow pipe that will allow excess water to drain. The overflow pipe will include a mesh screen to prevent insects or animals from entering the spring box. It will also drain onto a concrete pad to prevent erosion of the spring box site. An additional pipe and valve will be located at the bottom of the spring box. This valve can be opened while the three collection pipes are closed to drain the storage chamber and allow for maintenance. All collection, overflow pipes, and drainage pipes will be PVC. A permanent diversion ditch will be constructed approximately 10 feet above the spring box. This is in place to protect the spring box site from storm water and any potentially carried contaminates.

Design & Principle of Spring Box Structure

The design and construction method of the spring box is according to the ACI 318-11 code. The moment acting against the wall of the spring box is determined from the earth lateral pressure and the end supports of the wall. The soil surrounding the site is assumed to be well-graded dense sand with specific weight of 116 lb/ft^3 and friction angle of 35 degrees. In order to maximize the effective horizontal stress of the soil, the groundwater table is assumed to be below the bottom slab. The loading from the earth is also considered to be dead load for the LRFD factoring equation.

The clear cover of the entire spring box except for the top slab is required to be at least 3 inches since the structure is permanently exposed to earth. The reinforcing bar size #3 will be used for the structure. The bearing capacity of the spring box site was calculated to be able to support the structure sufficiently, therefore the bottom slab will be continuously and laterally supported, and will be constructed as plain concrete structure with 2 layers of #3 rebar mesh to prevent cracking. See the design details and drawing in Figure B1.


Elevation View
0.50m
0.70m
1.00m
1.40m
connecting to
ball valve
Plan View
0.013m (#4) Ø
0.34m
0.60m
1.00m
1.30m
0.20m
0.20m
1.45m
1.80m
0.10m Ø
0.25m spacing O.C.
EWB-Purdue: Papachacra, Bolivia
Spring Box
Drawn by
Witcha Danaisuphachok
Date
03/22/12
Scale
Notes

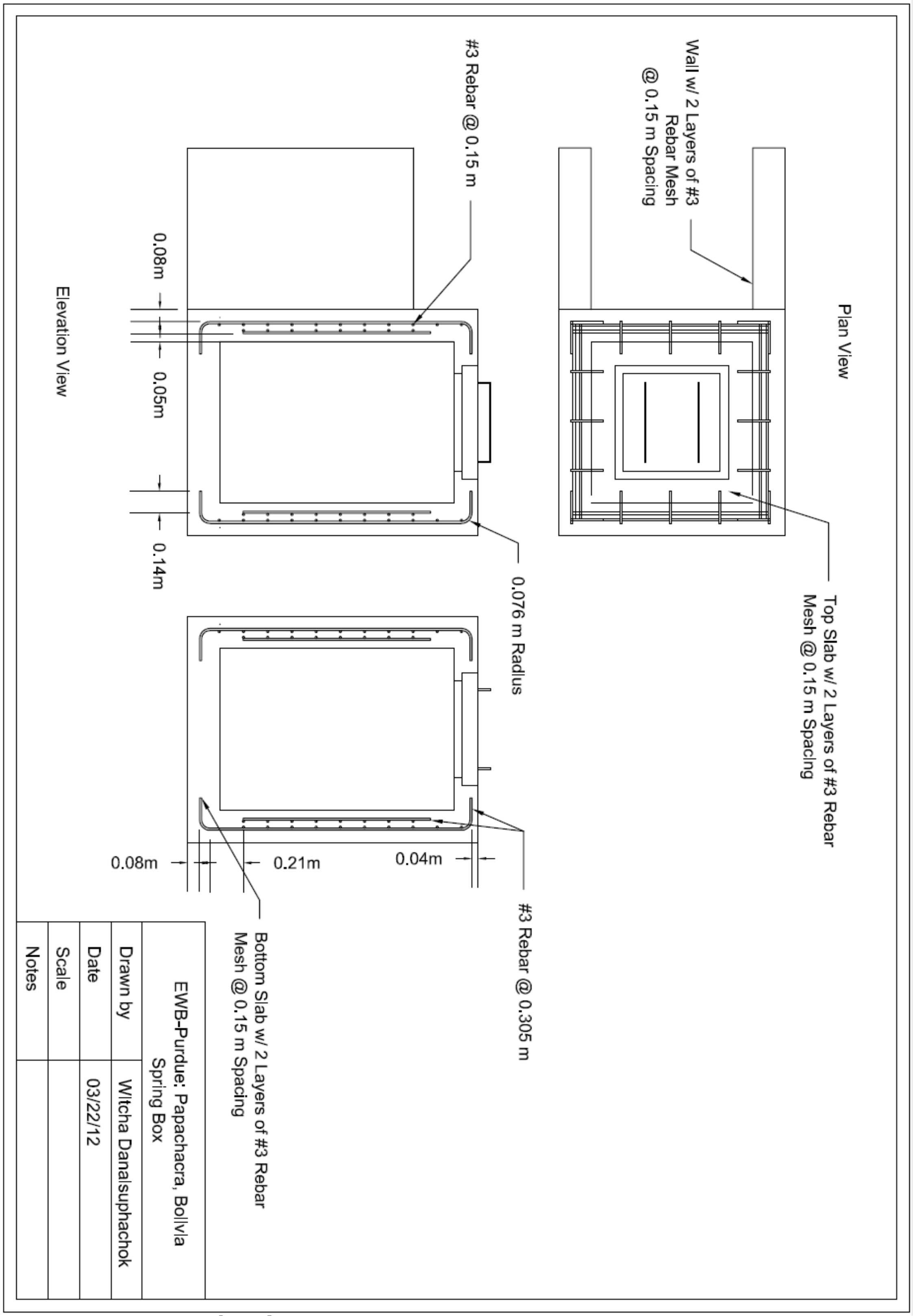


Figure B1. Spring box drawing

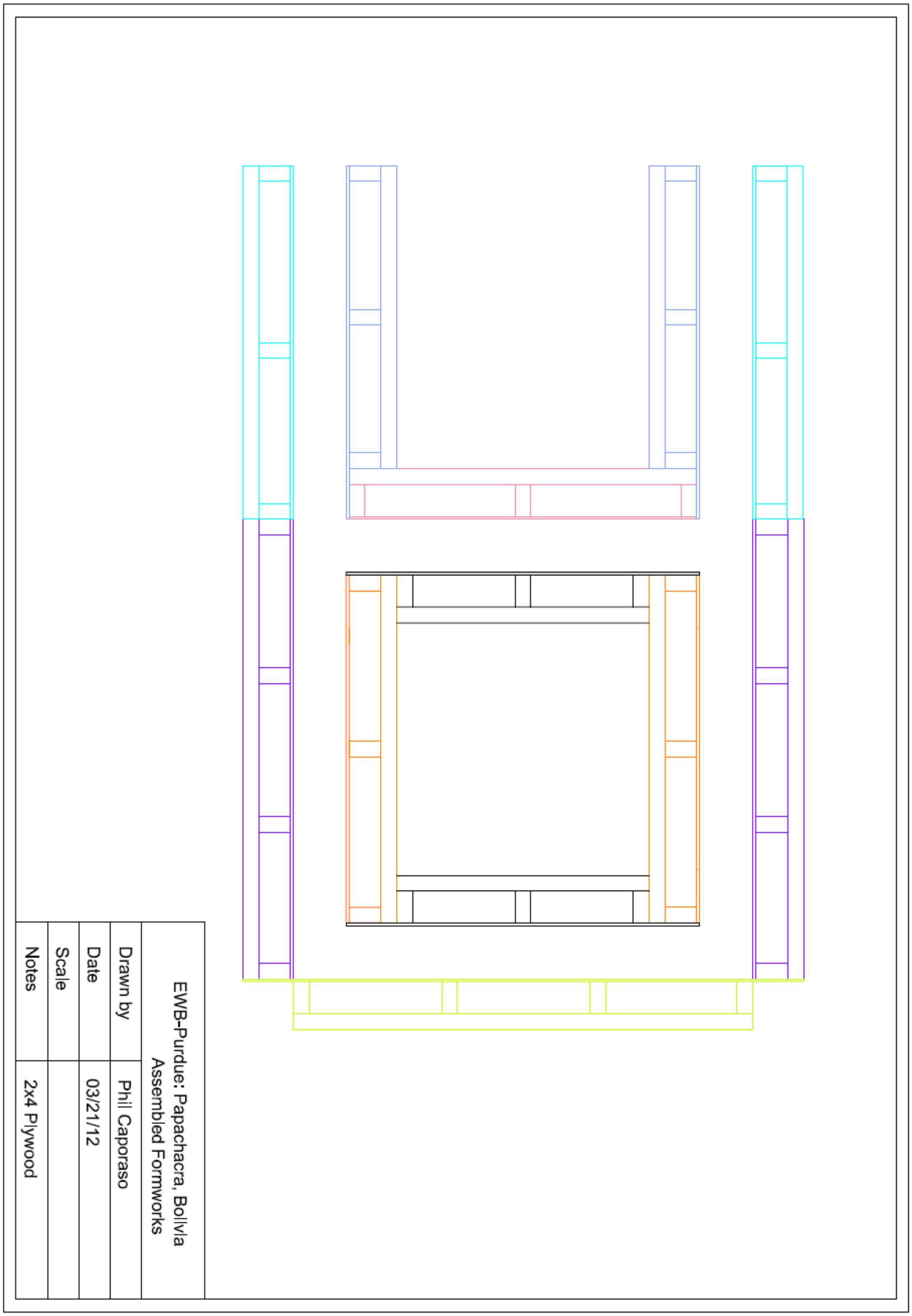


Figure B2. Formwork for spring box

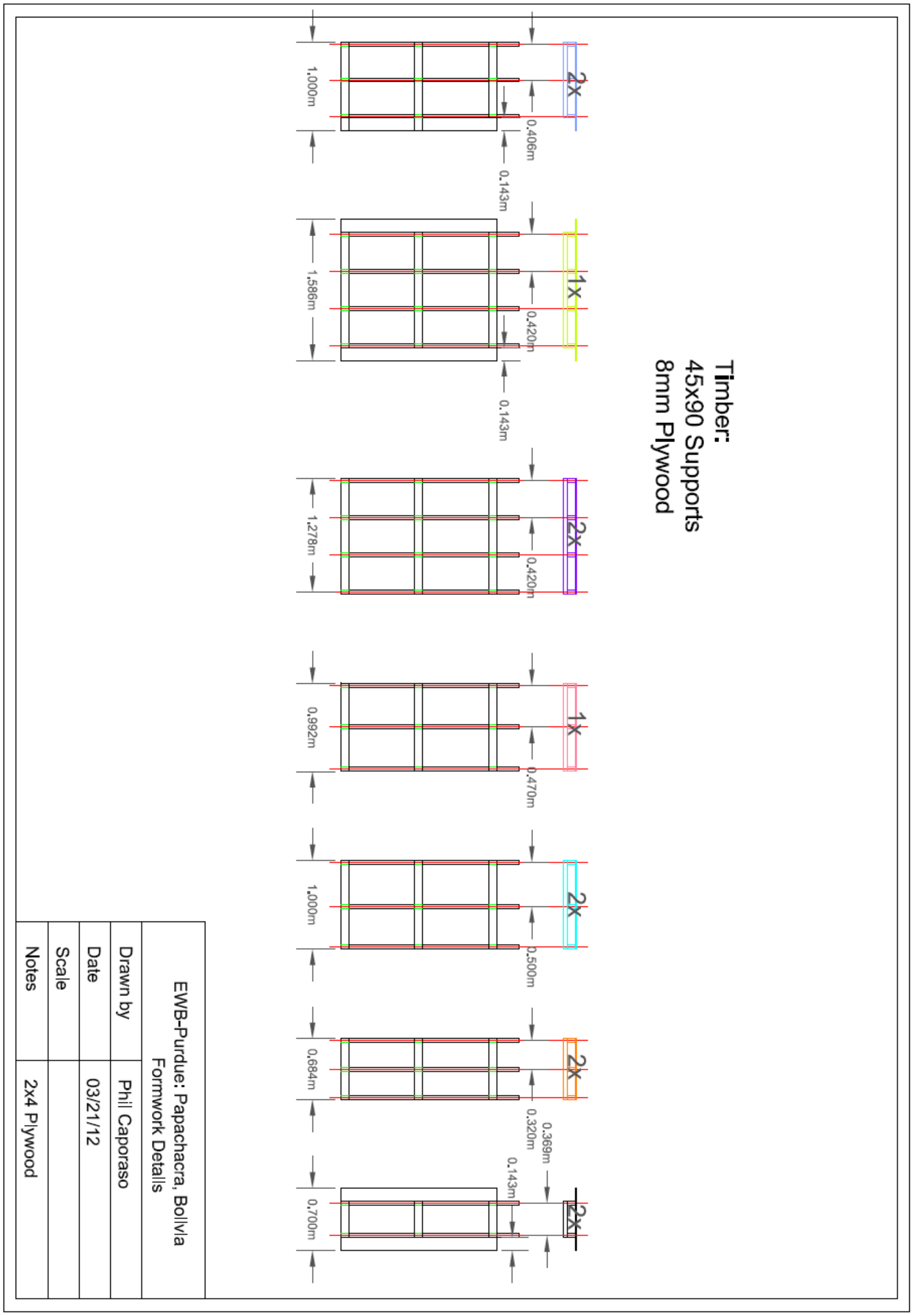


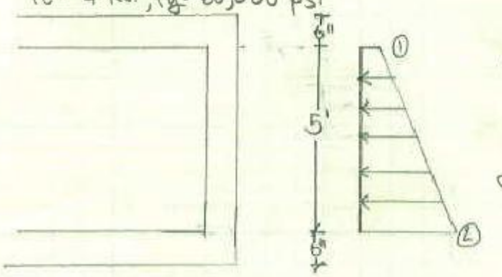
Figure B3. Formwork for spring box detailed

2.0 Spring Box System Calculations

* See fill calculations in section 2 of Appendix A

Spring Wall Calculation — Ref. ACI 318-11

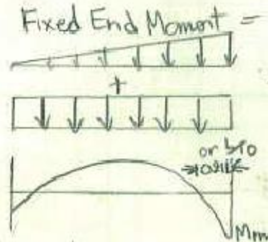
Assume: $\gamma_{Earth} = 120\ lb/ft^3$, Weight of Earth is dead load.
Worst Case ⇒ No water.
Calculation per ft, Effective depth = 5ft
Maximum Moment At bottom and top
Exterior wall thickness = 6 in — Geotech Data. Info
Soil friction angle = 35°
Ground water table > 6ft
$f'_c = 4\ ksi$, $f_y = 60{,}000\ psi$



$K_0 = 1 - \sin\phi = 1 - \sin 35 = 0.426$
$\sigma'_{①} = \sigma - \mu$
$= \gamma_{soil} h - 0$
$= (120\ lb/ft^3)(0.5ft) = 60\ psf$

$\sigma'_{②} = \sigma - \mu$
$= \gamma_{soil} H - 0$
$= (120\ lb/ft^3)(5.5ft) = 660\ psf$

Fixed End Moment = Max moment



$= \frac{wL^2}{20} + \frac{wL^2}{12} = \frac{(660\ lb/ft)(5ft)^2}{20} + \frac{(60\ lb/ft)(5ft)^2}{12}$

$Moment_{max} = 825\ lb\cdot ft + 125\ lb\cdot ft = 950\ lb\cdot ft = 0.95\ k\cdot ft$
At lower corner
LRFD: $M_u = 1.2(D) + 1.6(L) = 1.2(0.95) = \underline{1.14\ k\cdot ft}$

Fixed End Shear = Max Shear
At lower corner $= \frac{qL}{2} + \frac{7qL}{20} = \frac{(60\ lb/ft)(5ft)}{2} + \frac{7(660\ lb/ft)(5ft)}{20} = 1305\ lb$

LRFD: $V_u = 1.2(D) + 1.6(L) = 1.2(1305\ lb) = 1566\ lbs = \underline{1.566\ k}$

Flexure: Assume both positive and negative moment are equal
Treated as one-way slab: min $h = l/20$ — CH 9.5.2.2
Min thickness $= \frac{(5ft)(12in)}{20} = 3\ in$ ⇒ choose 8 in for earth exposure
$d = 8" - 3" = 5"$ ⇒ choose 4.75 in for earth exposure
$\phi M_n \geq M_u$
$\phi M_n = \phi \rho f_y b d^2 (1 - 0.59 \rho \frac{f_y}{f'_c})$

$(1.14)(12)\ k\cdot in = 0.9\rho(60\ ksi)(12)(4.75)^2(1 - 0.59\rho\frac{60}{4})$
$13.68 = 14620.5\rho - 129391.4\rho^2$
$\rho = 1.129$ or $\underline{\rho = 0.00094}$

$A_s = 0.00094(12")(4.75") = 0.0536\ in^2/ft$
Try #3 @ 12" ⇒ $A_s = 0.11\ in^2/ft$
$A_{s,min} = 0.0018(12")(8") = 0.1728\ in^2/ft$ — CH 7.12.2.1 (b)
$0.11\ in^2/ft < 0.17\ in^2/ft$ N.G.
Use #4 @ 12" ($A_s = 0.20\ in^2/ft$)(#10 in metric) or #3 @ 6" ($A_s = 0.22\ in^2/ft$)

Review: $T = C$
$(0.20)(60\ ksi) = 0.85(4\ ksi)(12a)$
$a = 0.294$

Spring Wall Calculation — Ref: ACI 318-11

Review Cont: $M_n = 0.20(60 ksi)(4.75 - \frac{0.294}{2})$
$= 55.236 k\cdot in = 4.603 k\cdot ft$

$c = \frac{a}{\beta_1} = \frac{0.294}{0.85} = 0.346$

$\varepsilon_t = \frac{0.003}{0.346}(5-0.346) = 0.0404 > 0.005 \Rightarrow \phi = 0.9$

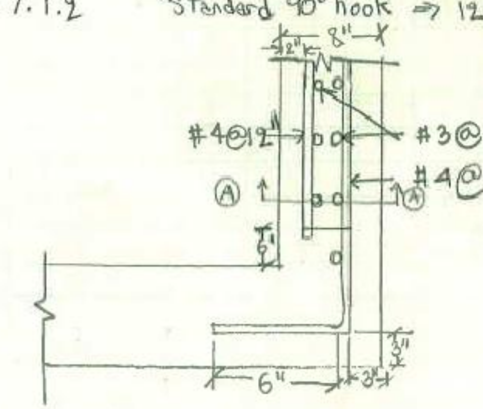
$\phi M_n = 0.9(4.603) = 4.143 k\cdot ft > 1.14 k\cdot ft$ O.K.

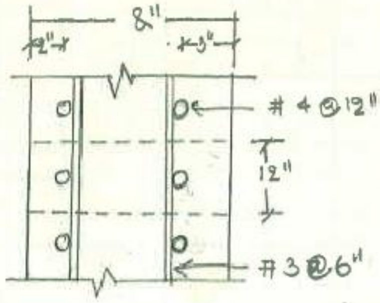
Shrinkage & Temperature Steel:
$A_s = 0.0018(12")(8") = 0.1728 in^2/ft$
Use #3 @ 6 ⇒ $0.11/(10/12) = 0.22 in^2/ft$

Shear: $\phi V_n \geq V_u$, $V_n = V_c + V_s$
$V_c = 2\lambda\sqrt{f'_c}\, b_w d$ CH 11.2.1.1
$= 2(1.0)\sqrt{4000}(8")(12")$
$= 12143\ lb = 12.143 k > 1.566k/0.75 k$
∴ V_s not required since concrete can take shear load
No min A_v requirement CH 11.4.6.1
#3 Stirrup $V_s = \frac{A_v f_{yt} d}{s} = \frac{2(0.11 in^2)(60 ksi)(4.75")}{2 in} = 31.35 k$
$\phi V_n = 0.75(31.35 + 12.14 k) = 32.62 k > 1.566 k$ O.K.

Development Length: straight: $l_d = \left[\frac{f_y \psi_t \psi_e}{25\lambda\sqrt{f'_c}}\right] d_b = \left[\frac{(60000)(1.0)(1.0)}{25(1.0)\sqrt{4000}}\right] 0.5" = 19 in$
5 ft > 19 in O.K.
Hook: $l_{dh} = \left[\frac{0.02\psi_e f_y}{\lambda\sqrt{f'_c}}\right] d_b = \left[\frac{(0.02)(1)(60000)}{(1)\sqrt{4000}}\right] 0.5 \cdot 0.8 = 7.6 in$
5 ft > 7.6 in O.K.

Rebar + Stirrup Concrete details: bar bend diameter: $6d_b = 3 in$. CH 7.2
Stirrup bend diameter: $4d_b = 2 in$ (inside)
Table 4.3.1 ⇒ $F_0, S_0, P_0, C_1 \Rightarrow f'_c = 2500 psi$
CH 7.6.2 Min clear space between layer $= 8" - 2" - 3" - 2(0.5") = 2" > 1"$ O.K.
CH 7.6.5 Max rebar spacing $= 18" > 12"$ O.K.
CH 7.7.1 Clear Cover = 3" (exposed to earth)
CH 7.1.2 Standard 90° hook ⇒ $12 d_b = 12(0.5) = 6 in$





A-A

Bearing Capacity Calculations

Spring Box Bearing Capacity: Terzaghi method

$$q_{ult} = 1.3\, c N_c + q N_q + 0.4\, \gamma B N_\gamma \quad \text{(square footing)}$$

Assume: $\phi = 35^\circ$, $\gamma_{soil} = 116\ lb/ft^3$, $\gamma_{soil,sat} = 135\ lb/ft^3$ (Dense and well graded)

Ground water table at 1 ft below surface

$c = 0$ (non-clay soil), $FS = 3$

Parameters: width = 5 ft, depth = 6 ft

$N_q = 41.44$, $N_\gamma = 45.41$

$$q = \sigma - u = (116\ lb/ft^3)(1\ ft) + (135\ lb/ft^3)(5\ ft) - (62.4\ lb/ft^3)(5\ ft) = 479\ psf$$

$$q_{ult} = 0 + (479)(41.44) + 0.4(135 - 62.4)(5)(45.41) = 19849.76 + 6593.53 = 26{,}443.29\ psf$$

$$q_{allow} = \frac{q_{ult}}{FS} = \frac{26443.29\ psf}{3} = 8{,}814.4\ psf$$

Appendix C

1.0 Tank and Valve System and Drawings

Tank System Description

A Y-joint will connect the existing pipeline with a pipe to the new storage tanks. A 1.5 inch-diameter ball valve will be installed immediately following the joint. The original pipeline will be completely closed off with the valve and divert the flow into the tanks. A 1.5 inch-diameter globe valve will regulate the flow from the pipeline to decrease or eliminate the amount of water being shared between other zones and Zone 3. There will be 3 tanks connected to the inlet pipes from the existing storage tanks and the Tree Spring. The water from both the Tree Spring and the original system will enter at the top of the tanks. Then, an outlet from each tank will exit at the bottom and combine into one pipe. There will also be a ball valve in this pipe to stop the flow from the tanks in case that water from the Tree Spring is contaminated. Then, the pipe will rejoin with the existing pipeline via a Y-joint toward Zone 3 carrying all of the water from the Tree Spring and some or none of the water from the existing system.

Tank Foundation Design

The assumptions of soil type, friction angle, foundation depth and width, and groundwater table were made for the foundation design. The soil is assumed to be well-graded dense sand with specific weight of 116 lb/ft^3 and friction angle of 35 degrees. The depth and width of the foundation is assumed to be 2 ft and 7 ft. The groundwater table around the site is considered to be far below the surface since the area is of high altitude and mainly consists of gravel and sand from weathered bedrock. With the factor of safety of 3, the bearing capacity of the foundation is determined to be far exceeding the service load and more than sufficient for the three tanks.

The soil surrounding the tank site has very high bearing capacity with no apparent threat of settlement issue. Therefore, the ground can support the structure without any reinforced concrete footing. Instead of concrete, sand will be used for footing of tanks to reduce cost and construction time. The excavation of the foundation will be approximately 1-2 feet deep and will be backfilled with sand to the height of 6 inches above the surface. The sand will be leveled and local stones will be used to construct a retaining structure for the above ground footing.

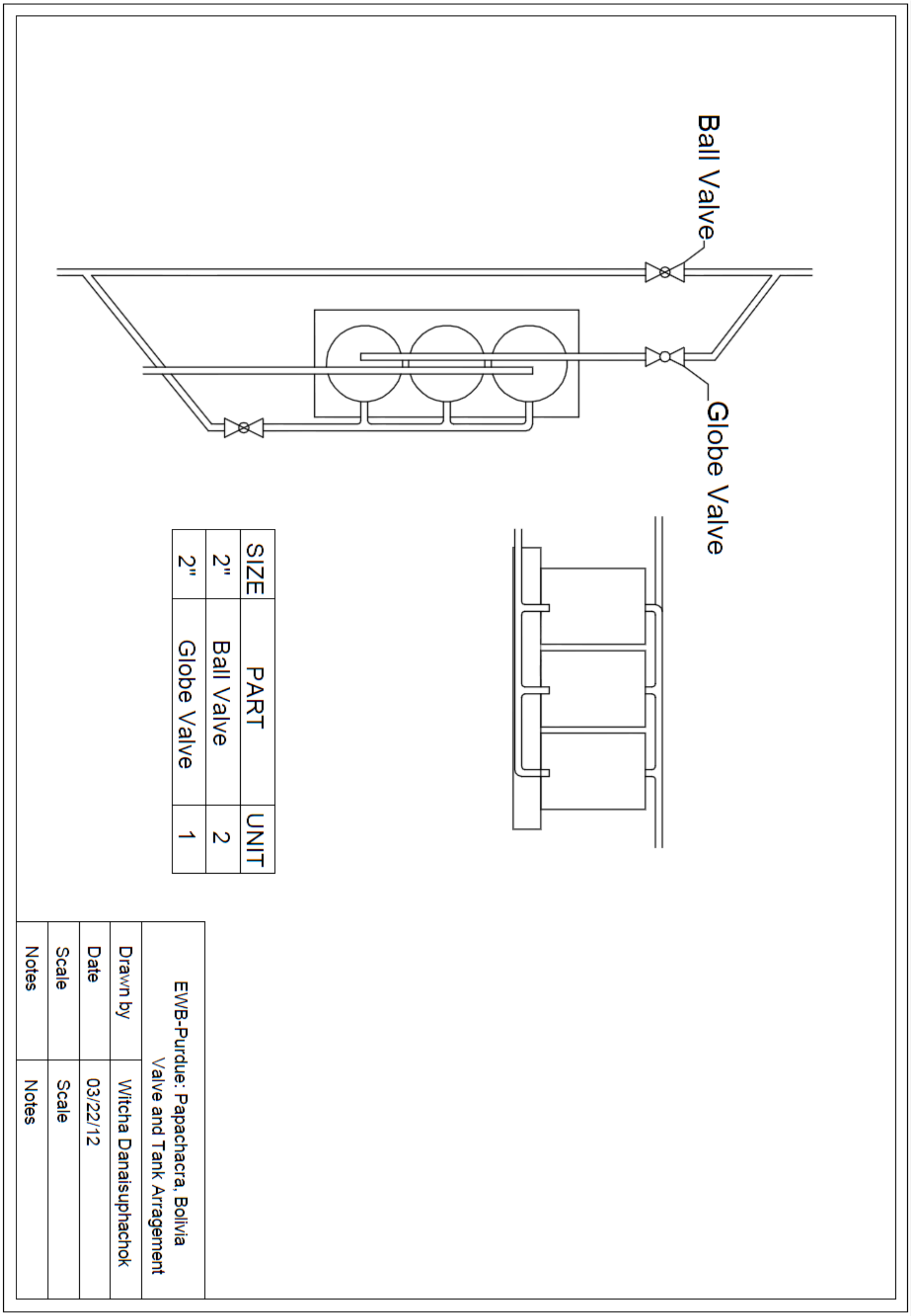


Figure C1. Tank battery schematic

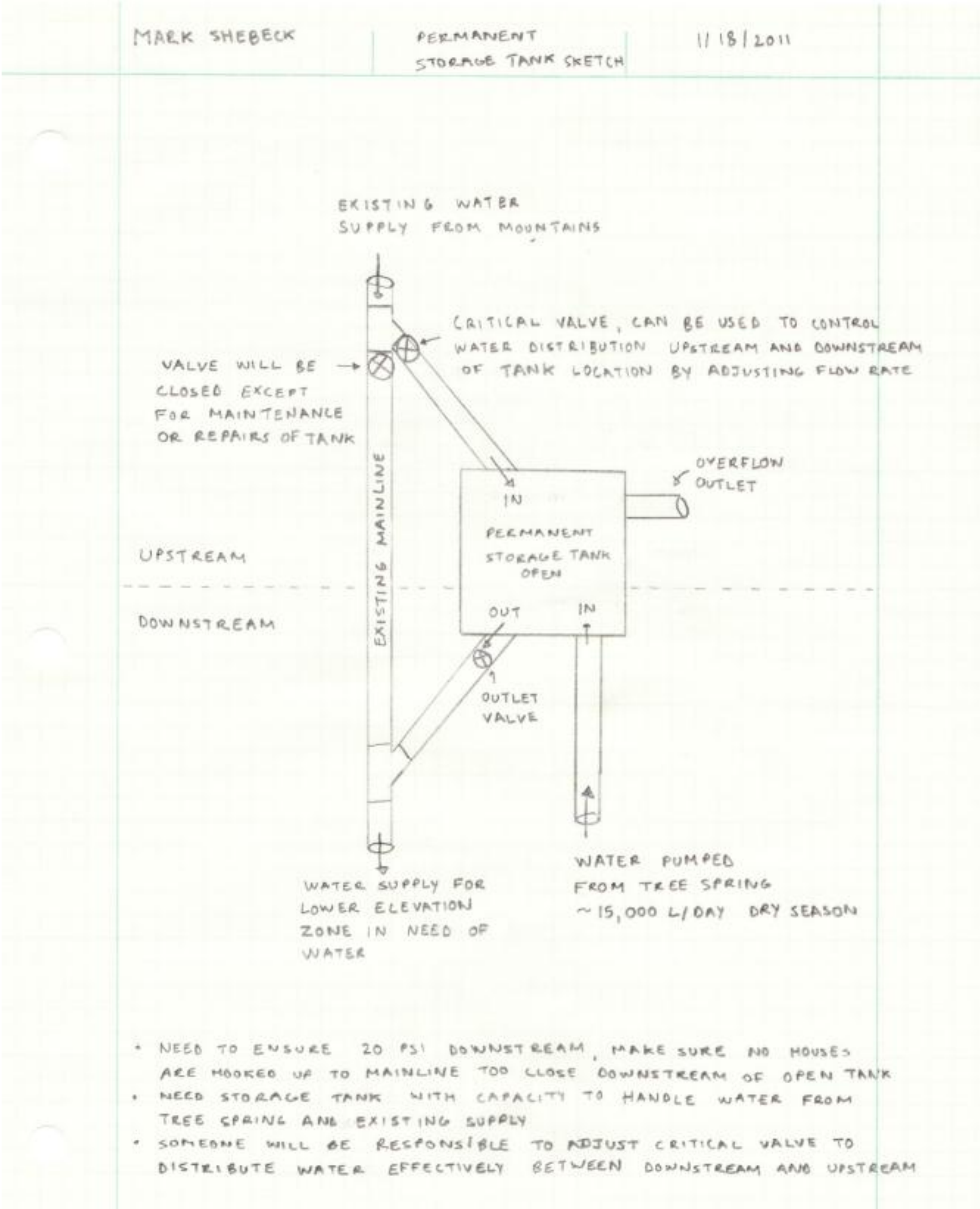


Figure C2. Tank function drawing

Figure C3. Tank to be used for storage system

2.0 Tank and Valve System Calculations

Valve Calculation

$$Q = C_v\sqrt{\Delta P/G}$$

$$Q = 26{,}500\frac{Liter}{Day} = 7000\frac{Gal}{Day} = 4.86\ \frac{Gal}{Min}$$

$$\Delta P = h_s - 0; Valve\ is\ completely\ closed$$

$$h_s = 397\ ft$$

$$\Delta P = 397ft * \ 62.37\ \frac{lb}{ft^3} = 397.3\ psf = 2.76\ psi, G = 1;\ Water\ at\ 60°F$$

$$C_v = \frac{Q}{\sqrt{G/\Delta P}} = \frac{4.86\frac{Gal}{Min}}{\sqrt{1/2.76\ psi}} = \ 8.07$$

FLOW CHARAC-TERISTIC	VALVE SIZE		MAXI-MUM TRAVEL	PORT DIA.	DESIGNS ED AND ET (FLOW DOWN)					DESIGN ES (FLOW UP)				
					Valve Opening, Percent of Total Travel									
					10	30	70	100	100	10	30	70	100	100
	DIN	Inches	mm	mm	C_v				F_L	C_v				F_L
Equal Percentage	DN 25	1, 1-1/4	19	33.3	.783	2.20	7.83	17.2	.88	.783	1.86	9.54	17.4	.95
	DN 40	1-1/2	19	47.6	1.52	3.87	17.4	35.8	.84	1.54	3.57	17.2	33.4	.94
	DN 50	2	29	58.7	1.66	4.66	25.4	59.7	.85	1.74	4.72	25.0	56.2	.92
	DN 65	2-1/2	38	73.0	3.43	10.8	49.2	99.4	.84	4.05	10.6	45.5	82.7	.93
	DN 80	3	38	87.3	4.32	10.9	66.0	136	.82	4.05	10.0	59.0	121	.89
	DN 100	4	51	111.1	5.85	18.3	125	224	.82	6.56	17.3	103	203	.91
	DN 150	6	51	177.8	12.9	43.3	239	394	.85	13.2	41.1	223	357	.86
	DN 200	8	76	203.2	27.0	105	605	818	.96	25.9	97.8	618	808	.85
					X_T				- - -	X_T				- - -
	DN 25	1, 1-1/4	19	33.3	.766	.587	.743	.667	- - -	.754	.763	.630	.721	- - -
	DN 40	1-1/2	19	47.6	.780	.716	.690	.679	- - -	.674	.694	.698	.793	- - -
	DN 50	2	29	58.7	.827	.774	.702	.687	- - -	.863	.849	.792	.848	- - -
	DN 65	2-1/2	38	73.0	.778	.678	.661	.660	- - -	.747	.745	.783	.878	- - -
	DN 80	3	38	87.3	.774	.682	.663	.675	- - -	.768	.761	.754	.757	- - -
	DN 100	4	51	111.1	.731	.643	.672	.716	- - -	.722	.739	.718	.822	- - -
	DN 150	6	51	177.8	.688	.682	.736	.778	- - -	.723	.767	.808	.816	- - -
	DN 200	8	76	203.2	.644	.636	.725	.807	- - -	.825	.681	.735	.827	

Figure C4. Valve sizing chart

Head Loss Calculations

Head loss calculations were done to determine the losses as the water leaves the tank array and rejoins the existing system.

First the velocity of the flow out of the tanks was calculated using Bernouli's Equation as seen below.

$$\frac{v_1^2}{2} + gz_1 + \frac{P_1}{\rho_1} = \frac{v_2^2}{2} + gz_2 + \frac{P_2}{\rho_2}$$

$$v_1 = 0 \qquad z_1 = datum = 0 \qquad P_2 = \rho_1 g z_1$$

$$v_2^2 = \frac{2P_1}{\rho_1}$$

$$z_1 = 1000\ Kg/m^3 \qquad P_2 = 101.3\ kPa$$

$$v_2 = 0.45\ m/s$$

Minor head loses caused by bends and divisions in the system.

$$h_{minor} = K(\frac{v^2}{2g})$$

$$K = \left(\frac{L_e}{D}\right) * f_T$$

Component	Qty.	fitting	L_e/D	f_T	K
1	1	90˚ Elbow	30	0.019	0.57
2	1	45˚ Elbow Tee	20	0.019	0.38
3	2	Standard Tee	20	0.019	0.38
4	1	Ball Valve	150	0.019	2.85
5	3	Tank Exit (Inward Projected)	NA	0.019	1

Minor head loses for each of the component in the pipeline

$$h_{L1} = 1(0.57)\left(\frac{\left(0.45\frac{m}{s}\right)^2}{2\left(9.81\frac{m}{s^2}\right)}\right) \qquad h_{L1} = 0.00645\ m$$

$$h_{L2} = 1(0.38)\left(\frac{\left(0.45\frac{m}{s}\right)^2}{2\left(9.81\frac{m}{s^2}\right)}\right) \qquad h_{L2} = 0.0039\ m$$

$$h_{L3} = 2(0.38)\left(\frac{\left(0.45\frac{m}{s}\right)^2}{2\left(9.81\frac{m}{s^2}\right)}\right) \qquad h_{L3} = 0.0078\ m$$

$$h_{L4} = 1(2.85)\left(\frac{\left(0.45\frac{m}{s}\right)^2}{2\left(9.81\frac{m}{s^2}\right)}\right) \qquad h_{L4} = 0.0295\ m$$

$$h_{L5} = 3(1)\left(\frac{\left(0.45\frac{m}{s}\right)^2}{2\left(9.81\frac{m}{s^2}\right)}\right) \qquad h_{L5} = 0.031\ m$$

Total head lost as flow exits the tank array.

$$h_T = h_{L1} + h_{L2} + h_{L3} + h_{L4} + h_{L5} \qquad \boldsymbol{h_T = 0.079\ m}$$

Tank Area Bearing Capacity: Terzaghi Method

Tank Area Bearing Capacity: Terzaghi Method.

Filled with sand for 2 ft

parameters: width = 7 ft, depth = 2 ft, $N_q = 41.44$, $N_\gamma = 45.41$

w/same assumptions but ground water table far below surface.

$$q = \sigma - u = (116\ lb/ft^3)(2\ ft) = 232\ psf$$

$$q_{ult} = cN_c + qN_q + \tfrac{1}{2}\gamma B N_\gamma$$

$$= 0 + (232)(41.44) + \tfrac{1}{2}(116)(7)(45.41)$$

$$= 9{,}614.08 + 18{,}436.46$$

$$= 28050.54\ psf$$

$$q_{allow} = \frac{q_{ult}}{FS} = \frac{28050.54\ psf}{3} = 9{,}350.18\ psf$$

Appendix D

1.0 Pipe System Design and Drawings

The layout of the pipeline can be seen below in the plan view in Figure D1. The pipe will be laid out from the spring box location along the tree line, up the creek bed, and along the road to the tanks located at about 20 meters above the Tree Spring. The overall pipe length will be 280 meters.

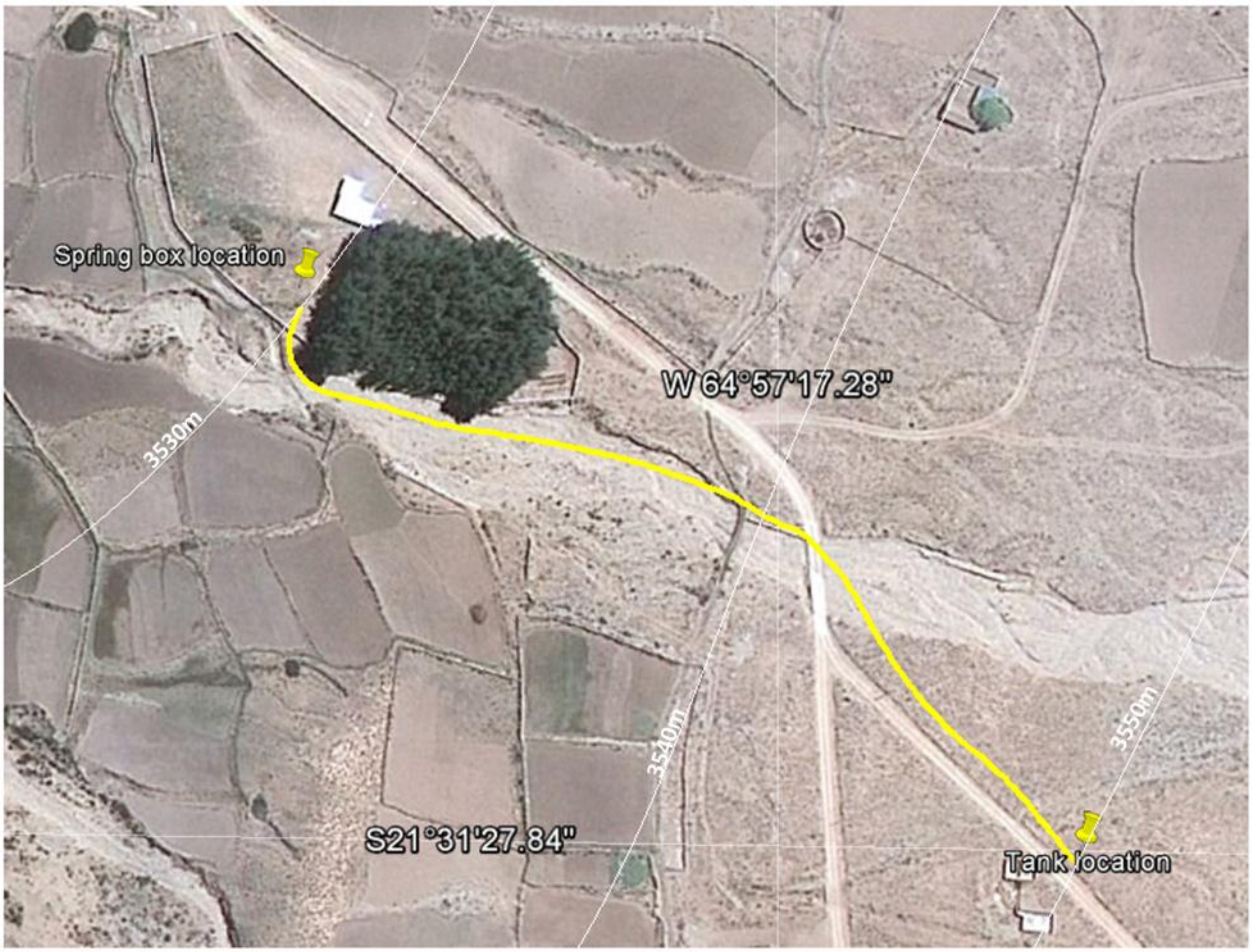


Figure D1. Pipeline Plan View

The profile view of the pipeline can be seen below in Figure D2. The path will have an almost constant slope with an average grade of about 7%.

Elevation Change: 20 meters
Length of Pipeline: 280 meters

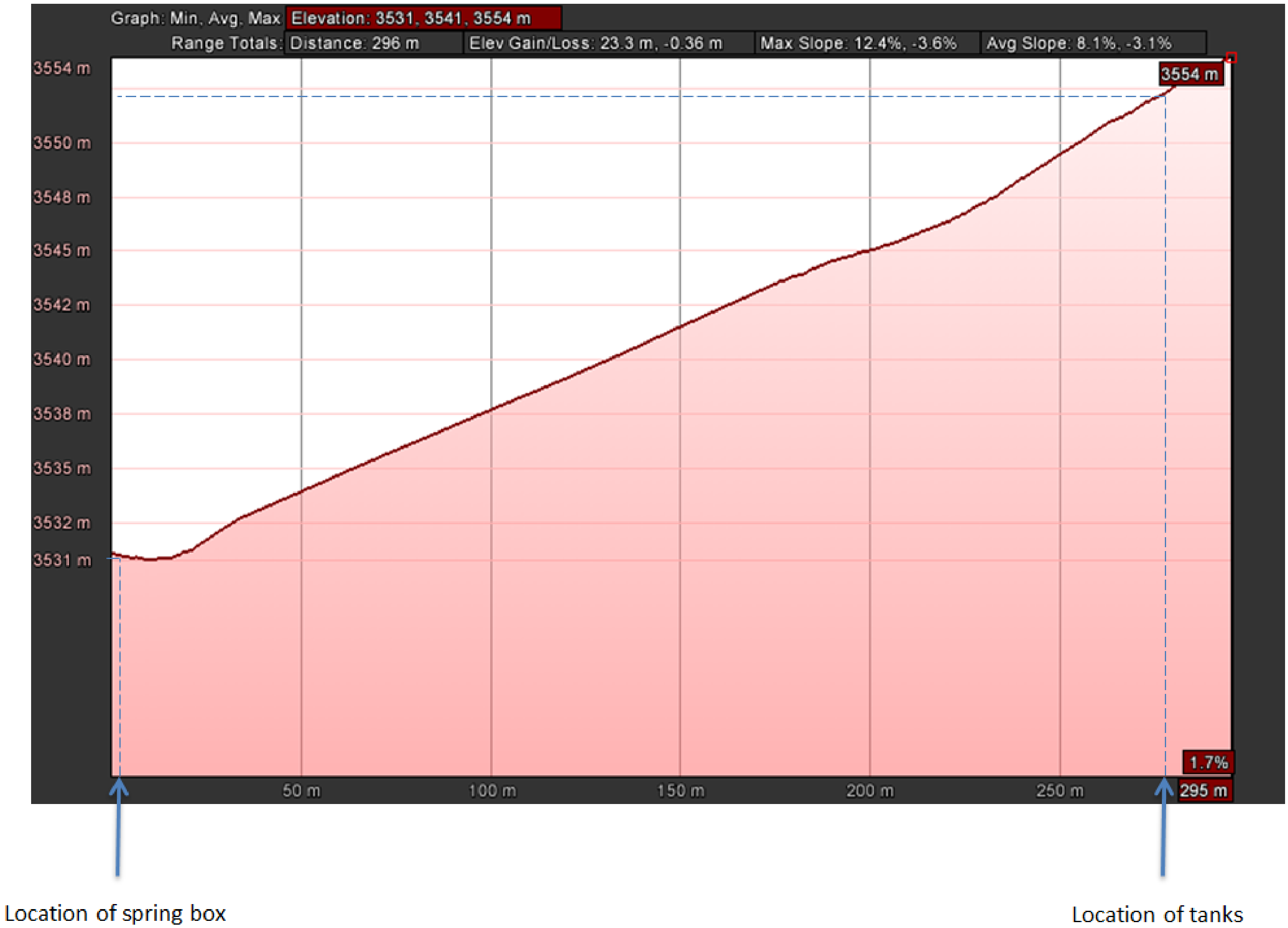
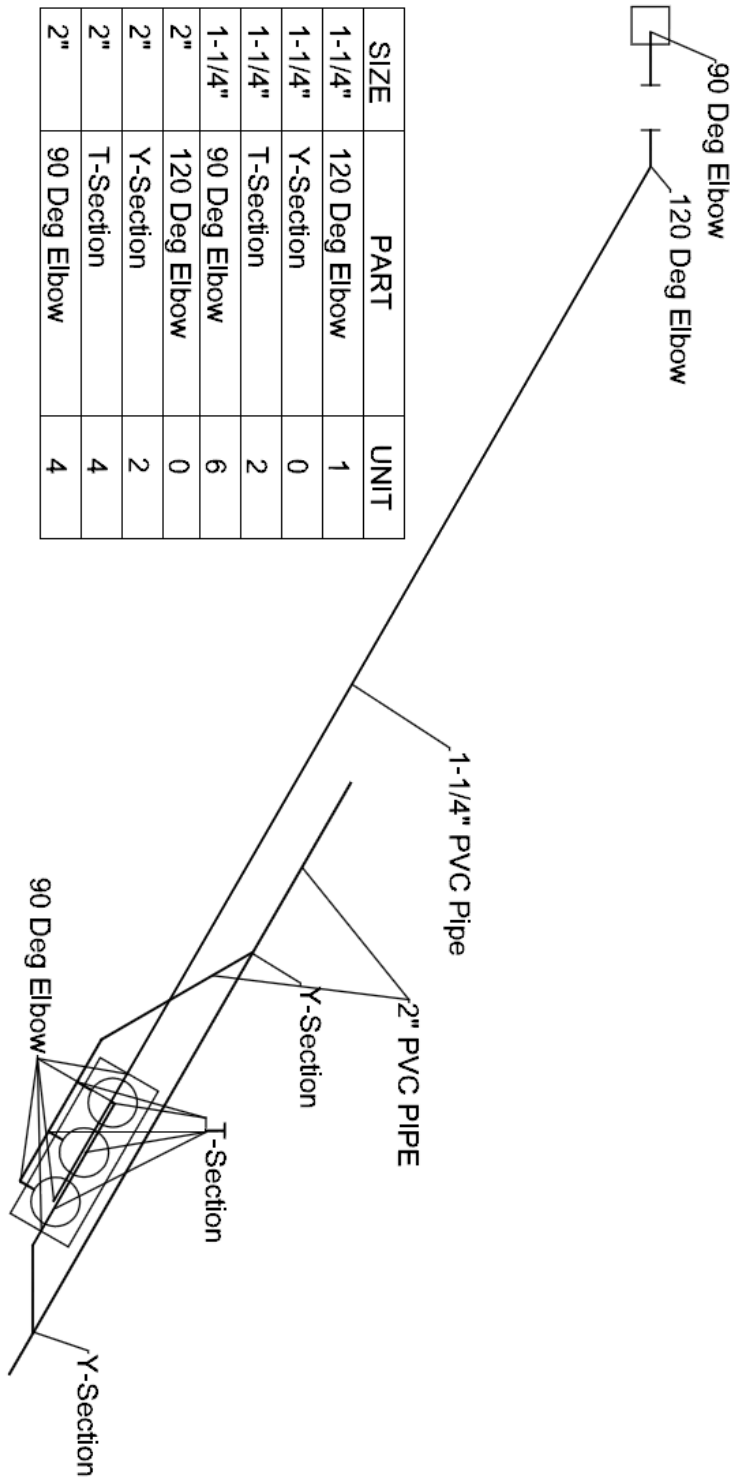


Figure D2. Pipeline Profile View



SIZE	PART	UNIT
1-1/4"	120 Deg Elbow	1
1-1/4"	Y-Section	0
1-1/4"	T-Section	2
1-1/4"	90 Deg Elbow	6
2"	120 Deg Elbow	0
2"	Y-Section	2
2"	T-Section	4
2"	90 Deg Elbow	4

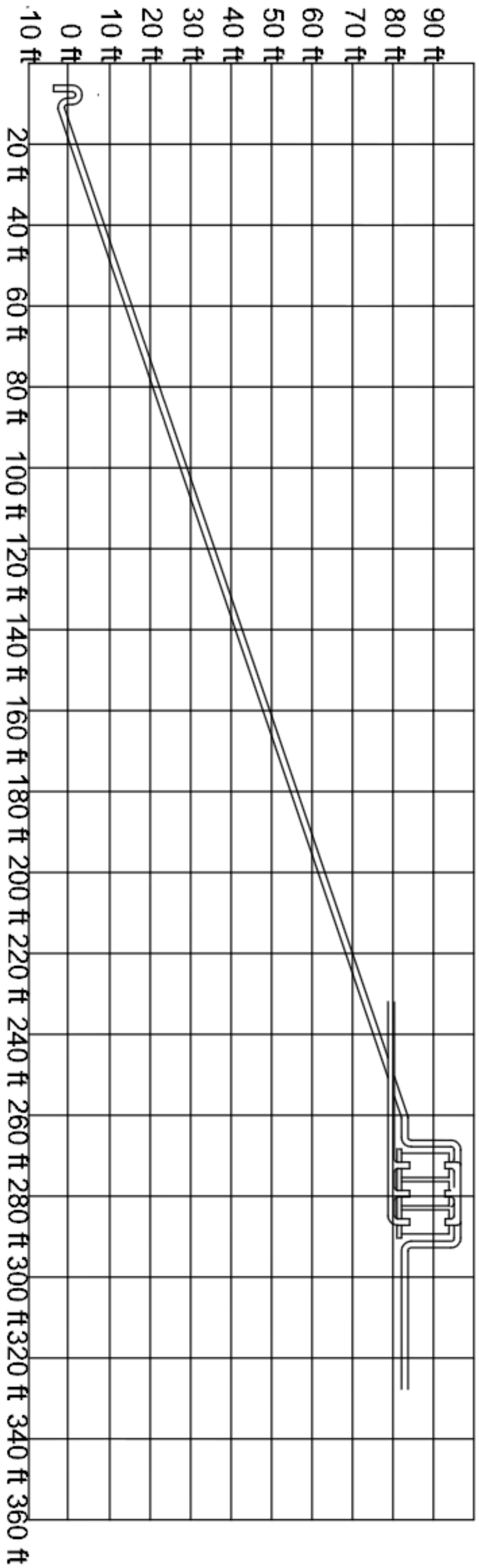


Figure D3. Pipeline layout with fitting positions

2.0 Pipe System Calculations

Head Loss Calculations

Head losses were estimated using the chart provided with the pump manual seen in Figure D3 below. A box is drawn around the value to be used in the calculation. This is chosen because the outlet of the pipe we will use is 1-1/4" and the flow rate is 10.42 L/min thus 0.2 m/100m of pipe is a conservative estimate.

Major head loses incurred due to friction between the water and the inner pipe wall found using Figure D3 below.

$$h_{major} = 0.2 \frac{m}{100\ m\ of\ pipe} * 280\ m\ of\ pipe = 0.56\ m$$

Minor head loses caused by bends and divisions in the system.

$$h_{minor} = K(\frac{v^2}{2g})$$

$$K = \left(\frac{L_e}{D}\right) * f_T$$

Component	Qty.	fitting	L_e/D	f_T	K
1	4	90˚ Elbow	30	0.22	0.66
2	2	45˚ Elbow	16	0.22	0.352
3	2	Standard Tee	20	0.22	0.44

Flow rate and velocity of water in pipe

$Q = 1.736\ x\ 10^{-4}\ m^3/s$ $\qquad D = 1.25\ in = 0.03175\ m$

$A = \frac{\pi}{4}(0.03175\ m)^2$ $\qquad A = 7.917\ x\ 10^{-4}\ m^2$

$v = \frac{Q}{A}$ $\qquad v = 0.219\ m/s$

Minor head loses for each of the component in the pipeline

$$h_{L1} = 4(0.66)\left(\frac{\left(0.219\frac{m}{s}\right)^2}{2\left(9.81\frac{m}{s^2}\right)}\right) \qquad h_{L1} = 0.00645\ m$$

$$h_{L1} = 2(0.352)\left(\frac{\left(0.219\frac{m}{s}\right)^2}{2\left(9.81\frac{m}{s^2}\right)}\right) \qquad h_{L2} = 0.00172\ m$$

$$h_{L1} = 4(0.44)\left(\frac{\left(0.219\frac{m}{s}\right)^2}{2\left(9.81\frac{m}{s^2}\right)}\right) \qquad h_{L3} = 0.00108\ m$$

$$h_{minor} = h_{L1} + h_{L2} + h_{L3} \qquad h_{minor} = 0.0093\ m$$

Total head lost for the pipeline from outlet of pump to inlet of tank array.

$$h_T = h_{major} + h_{minor} \qquad \boldsymbol{h_T = 0.5693}$$

Friction Loss in Plastic Pipe with Standard Inside Diameter (SIDR)

Head Loss from friction in vertical m/ft per 100 m/ft of pipe

FLOWRATE		**PIPE DIAMETER** (inches; nominal, actual)										
		1/2*	**3/4**	**1**	**1 1/4**	**1 1/2**	**2**	**2 1/2**	**3**	**4**	**5**	**6**
US GPM	LPM	0,662	0,82	1,05	1,38	1,61	2,07	2,47	3,07	4,03	5,05	6,06
1	**3,8**	1	0,4	0,1	0,02							
2	**7,6**	3	1,2	0,4	0,10	0,05						
3	**11,4**	6	2,3	0,7	0,20	0,10						
4	**15**	10	4	1,2	0,32	0,15	0,05					
5	**19**	16	6	1,8	0,48	0,23	0,07					
6	**23**	22	8	2,5	0,67	0,32	0,10	0,04				
7	**27**		11	3,2	0,89	0,43	0,13	0,06				
8	**30**		13	3,9	1,07	0,51	0,16	0,07				
9	**34**		16	4,9	1,3	0,6	0,19	0,08				
10	**38**		19	5,9	1,6	0,8	0,24	0,10	0,04			
11	**42**		23	7,0	1,9	0,9	0,28	0,12	0,04			
12	**45**		26	8,0	2,2	1,0	0,3	0,14	0,05			
14	**53**			11	2,9	1,4	0,4	0,18	0,06			
16	**61**			14	3,7	1,8	0,5	0,23	0,08			
18	**68**			16	4,5	2,2	0,7	0,28	0,10			
20	**76**			20	5,4	2,6	0,8	0,34	0,12	0,03		
22	**83**			23	6,4	3,1	0,9	0,40	0,14	0,04		
24	**91**			28	7,5	3,6	1,1	0,47	0,17	0,05		
26	**99**				9	4,2	1,3	0,54	0,19	0,05		
28	**106**				10	4,7	1,4	0,6	0,22	0,06		
30	**114**				11	5,3	1,6	0,7	0,25	0,07		
35	**133**				15	7	2,1	0,9	0,3	0,09		
40	**152**				19	9	2,7	1,2	0,4	0,11	0,04	
45	**171**				23	11	3,3	1,4	0,5	0,14	0,05	
50	**190**				28	13	4,0	1,7	0,6	0,17	0,06	
55	**208**					16	4,7	2,0	0,7	0,19	0,07	
60	**227**					18	5,5	2,4	0,8	0,23	0,08	0,03
65	**246**					21	6,3	2,7	1,0	0,26	0,09	0,04
70	**265**					24	7,2	3,1	1,1	0,30	0,10	0,04
75	**284**						8	3,5	1,2	0,34	0,12	0,05
80	**303**						9	3,9	1,4	0,38	0,13	0,05
85	**322**						10	4,4	1,6	0,42	0,14	0,06
90	**341**						11	4,8	1,7	0,47	0,16	0,07
95	**360**						12	5,3	1,9	0,51	0,18	0,07
100	**379**						14	5,8	2,1	0,56	0,19	0,08
150	**569**						28	12	4,3	1,2	0,39	0,17
200	**758**							20	7,1	1,9	0,66	0,27

*)1/2 data applies to polyethylene pipe only. PVC has smaller ID of 0.612"

SHADED VALUES are velocities over 5 ft per second and should be selected with caution

PEAK FLOW RATE for pipe sizing

Type	LPM	GPM	Type	LPM	GPM
HR-03H	8	2,2	HR-14	42	11
HR-04 / H	13	3,5	HR-20	58	15
HR-07	20	5	C-BF-04	122	32
HR-10	32	8	C-DF-03	167	44

Figure D4. Head loss chart

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Appendix E

Overview of Current system and Phase I changes

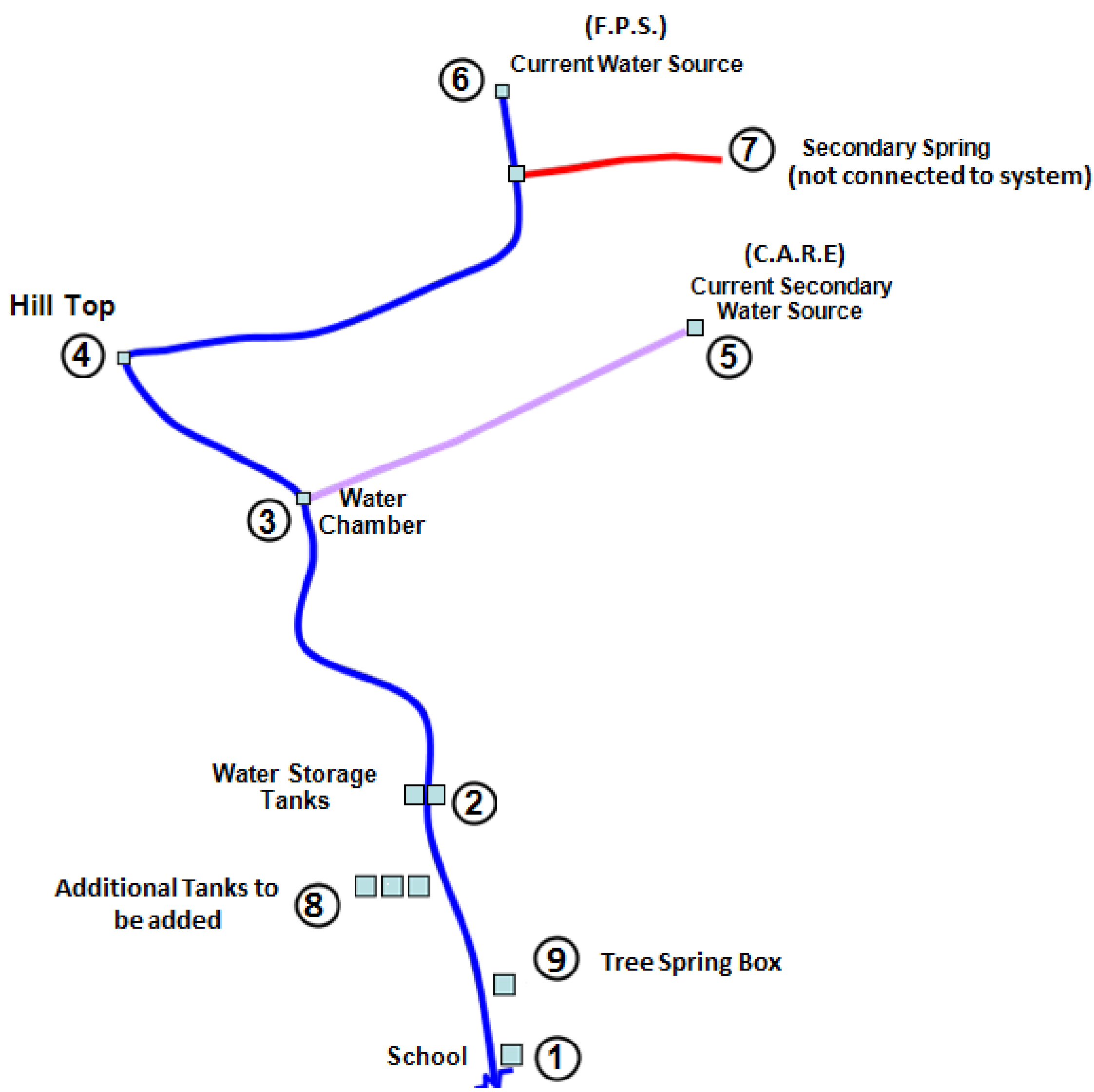


Figure E1. Schematic of Phase I system

<u>Basic Phase I Plan of Action</u>

1. Increase capacity of F.P.S spring box ⑥ by raising the overflow pipe to allow the box to hold more water.

2. Construct spring box at tree spring ⑨ with overflow and valves to allow flow to be used for irrigation in rainy season.

3. Add additional storage ⑧ downstream of the system's current storage tanks ②

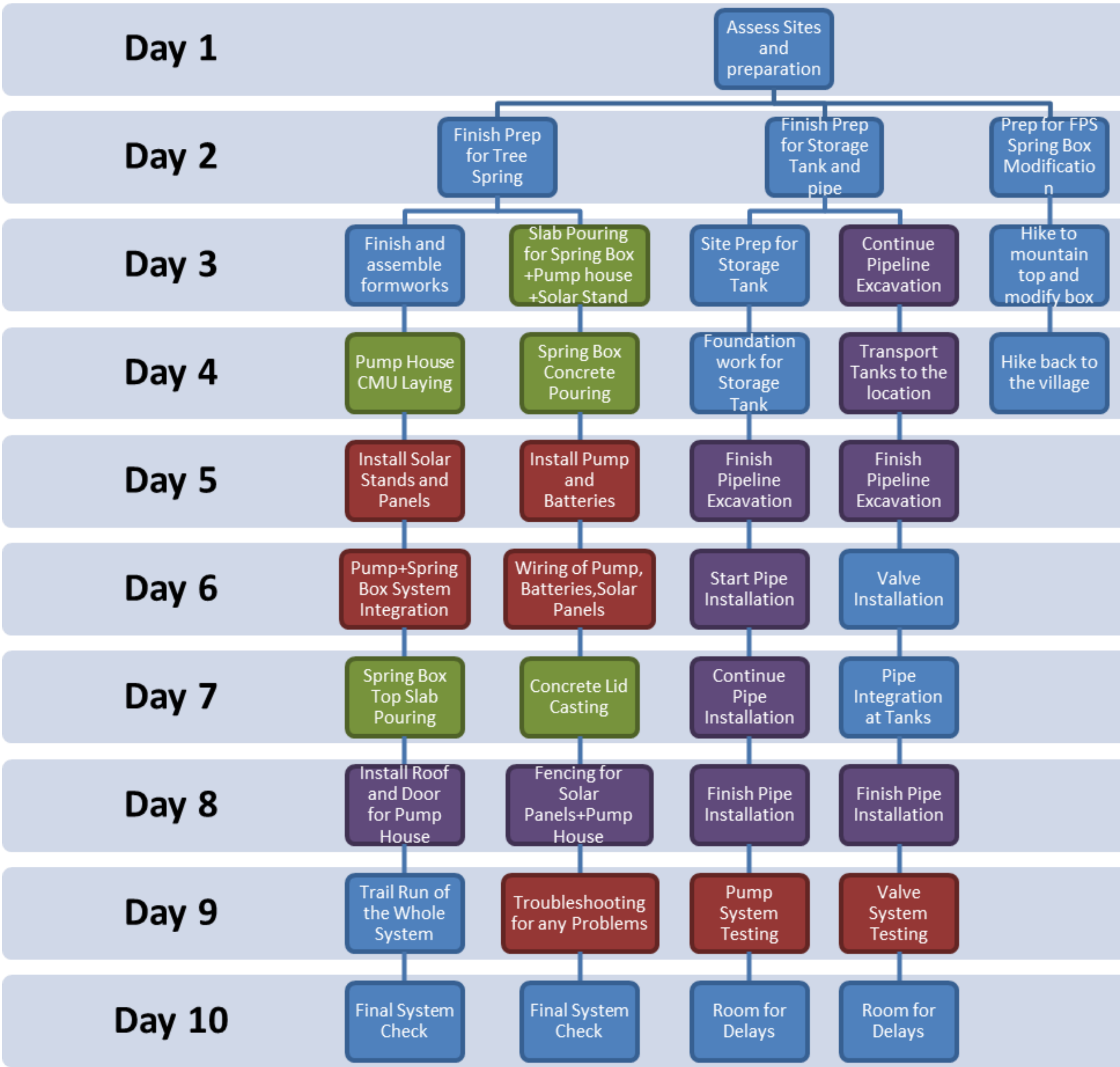
4. Add submersible pump to spring box ⑨

5. Add solar panels to power pump system ⑨

6. Connect piping system between ⑧ and ⑨

Note: These actions are in order of priority. Items not finished during our implementation trip will be finished by the community through the guidance of EIA

Appendix F



EWB + EIA + VILLAGERS
MAJORITY DONE BY HIRED ENGINEER (IVAN DE CASTELLO)
MAJORITY DONE BY HIRED MASON
MAJORITY DONE BY VILLAGERS

Appendix G

<u>Current Flow Demands</u>

$Q = 66\ L/person/day$

$No.of\ Families = 134\ @\ \ 4\ ppl/family$

$$Q_{total} = 66\frac{L}{person} * 134\ families * 4\frac{people}{family} = 35{,}376\ L/day$$

$Q_{supply} = 26{,}000\ L/day$

$Q_{deficit} = Q_{total} - Q_{supply}$

$\boldsymbol{Q_{deficit} = 9{,}376\ L/day}$

*These numbers are based off of the most current information regarding water usage and community size.

<u>Future Flow Demands (in 5 to 10 years)</u>

$Q = 106\ L/person/day$

$No.of\ Families = 180\ @\ \ 4\ ppl/family$

$$Q_{total} = 106\frac{L}{person} * 180\ families * 4\frac{people}{family} = 76{,}320\ L/day$$

$Q_{supply} = 26{,}000\ L/day$

$Q_{deficit} = Q_{total} - Q_{supply}$

$\boldsymbol{Q_{deficit} = 50{,}320\ L/day}$

* These numbers are based off of estimates of future growth as well as the assumption that flush toilets are installed by all members of the community with an additional consumption of 40 L/person/day.

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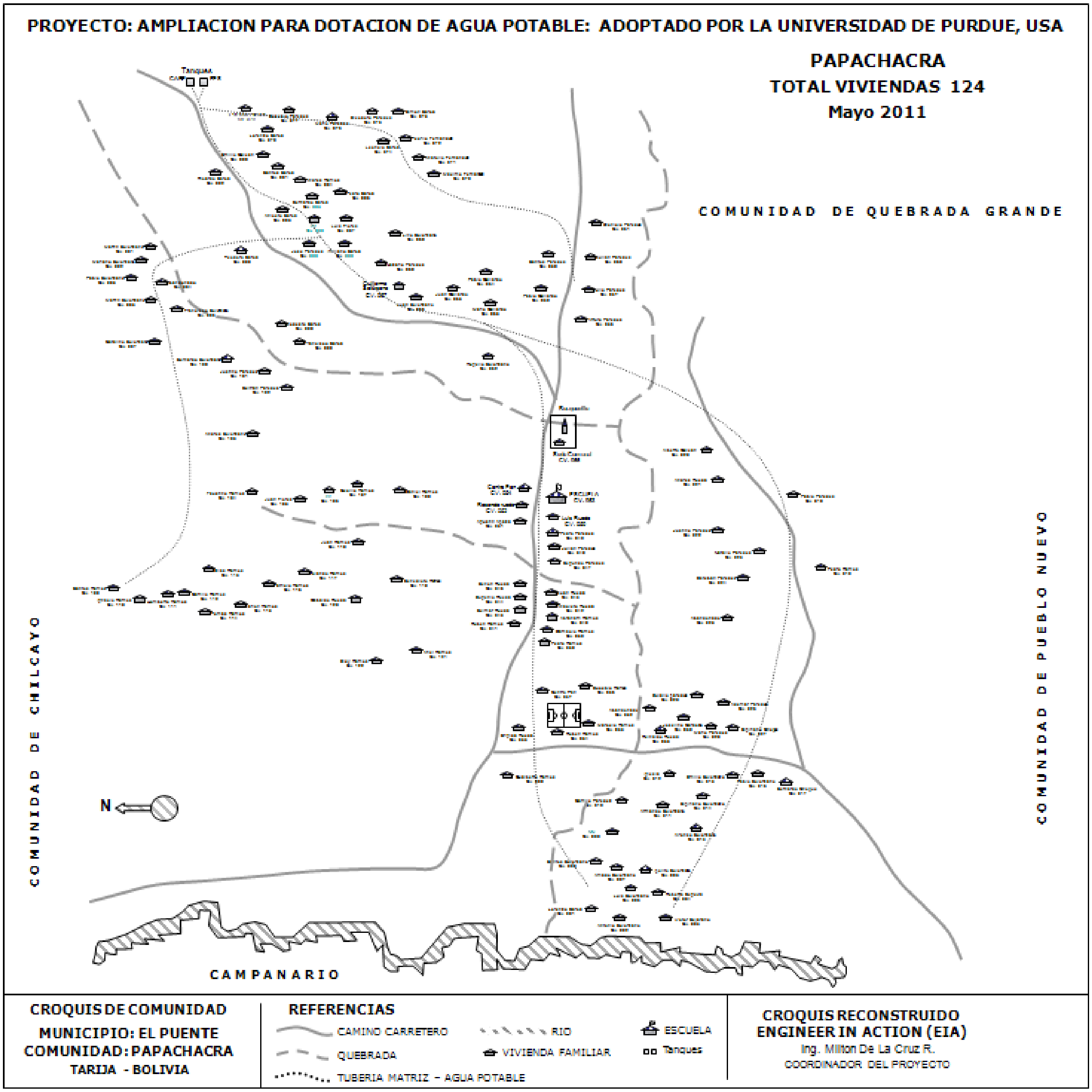
Appendix H

General Map of the Area and the Existing System



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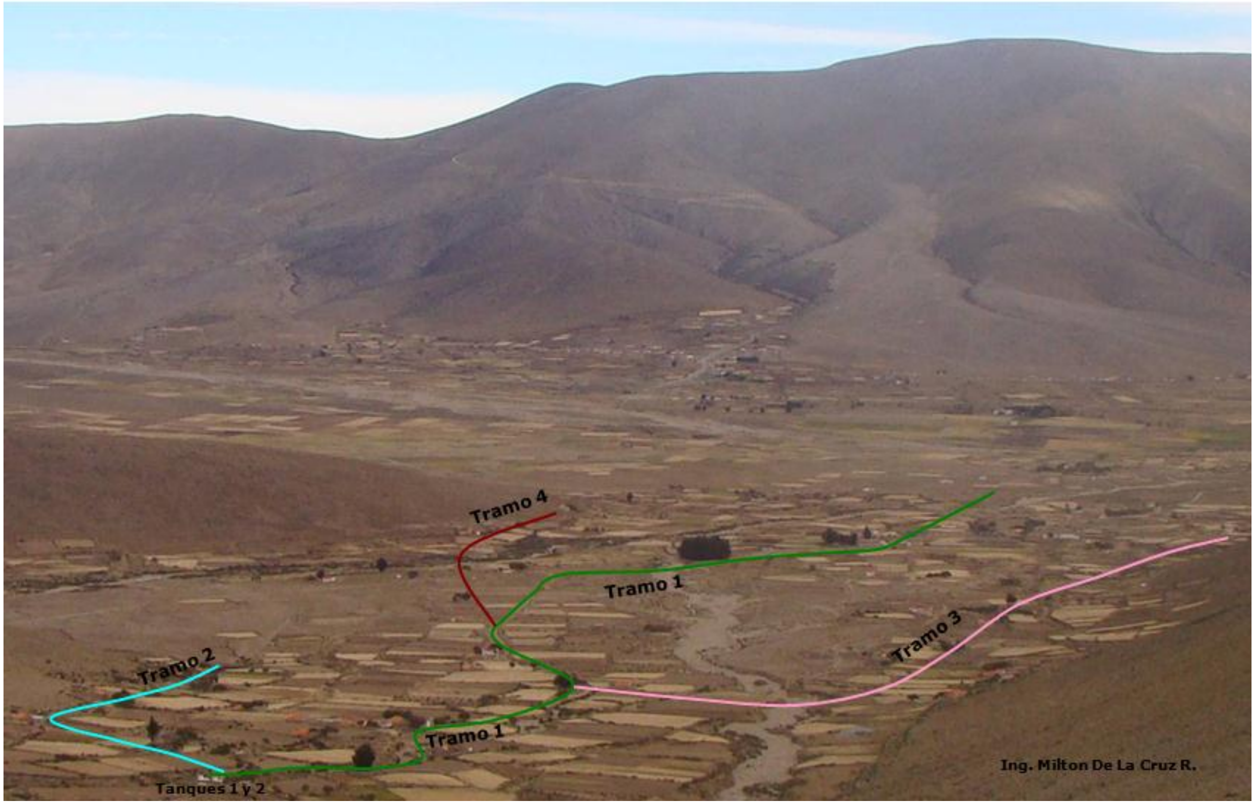
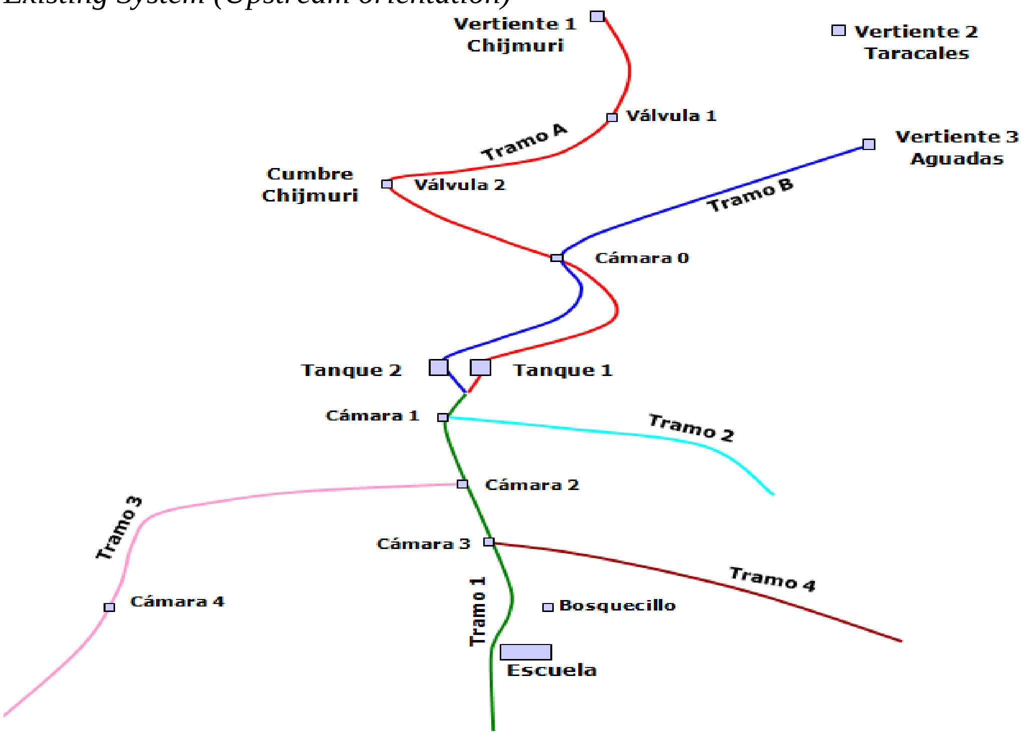
Area Overlook (Downstream orientation)



Existing System (Upstream orientation)



Appendix I

Table G1. EWB-Purdue Cost Estimate

Pump System					
Item	Description	Qty	Units	Unit Price	Total Price
1	Lorentz helical rotor submersible pump	1	EA	$2,000.00	$2,000.00
2	250 Watt Solar panel	2	EA	$500.00	$1,000.00
3	Float Switch	2	EA	$50.00	$100.00
4	Pump Controller	1	EA	$500.00	$500.00
5	Solar Panel Stand	1	EA	$500.00	$500.00
6	12 VDC 75 Ah Batteries	3	EA	$200.00	$600.00
7	Wire (500 M spool)	1	EA	$55.71	$55.71
8	Tools and Equipment	1	LS	$300.00	$300.00
				Total	$4,755.71

Spring Box/Pipe/Tanks/Pump House					
Item	Description	Qty	Units	Unit Price	Total Price
9	Bags of Cement (50 Kg unit weight)	50	EA	$7.90	$395.00
10	Aggregate	8	CM	$17.86	$142.88
11	Sand	3	CM	$5.70	$17.10
12	Forms/Molds	1	LS	$100.00	$100.00
13	1-1/4" PVC Pipe	60	6 m pipe	$13.10	$786.00
14	1-1/4" PVC elbow	5	EA	$0.40	$2.00
15	1-1/4" PVC T-junction	3	EA	$0.40	$1.20
16	2" PVC Pipe	10	6 m pipe	$13.90	$139.00
17	2" PVC elbow	5	EA	$0.60	$3.00
18	2" PVC T-junction	5	EA	$0.60	$3.00
19	2" PVC Y-junction	3	EA	$0.60	$1.80
20	2" PVC Ball valve	4	EA	$24.00	$96.00
21	2" Globe valve	1	EA	$100.00	$100.00
22	5000 L Tanks	3	EA	$1,000.00	$3,000.00
23	Concrete Blocks (standard 8"x 16" blocks)	40	EA	$1.10	$44.00
24	Wood (sheets and boards)	1	LS	$100.00	$100.00
25	Reinforcing Rod	4	12 m length	$10.13	$40.52
26	Drain tile	1	roll	$40.00	$40.00
27	Paint	3	cans	$50.00	$150.00
28	Tools, Equipment,Fasteners and Material Transportation	1	LS	$2,000.00	$2,000.00
				Total	$7,161.50

Total	$11,917.21

Tools listed below are part of Items 8 and 28above

Item	Description	Qty	Units	Unit Price	Total Price
29	Shovel	6	EA	$ 5.00	$30.00
30	Pickaxe	6	EA	$ 5.00	$30.00
31	Trowel	5	EA	$ 5.00	$25.00
32	Rebar Bending Jig	1	EA	$ 10.00	$10.00
33	Wheelbarrow	2	EA	$ 10.00	$20.00

Appendix J

MEMORANDUM OF UNDERSTANDING (MOU)

Between

Purdue Chapter of Engineers Without Borders ("Purdue Chapter")
And
The People of Papachacra, Bolivia

1.1: Purpose & Structure

The purpose of this MOU is to clearly identify the roles and responsibilities of each party as they relate to the development of the water collection and distribution system of Papachacra, Bolivia. It is indispensable for this project's success that both parties agree and understand the following conditions under which this project will be developed. It should be understood by both parties that they both hold integral parts in influencing and shaping the improvement of the water collection and distribution system in Papachacra. Unless Papachacra disagrees with or would like to change any aspect of the project, EWB-Purdue will be proceeding with the work outlined within this MOU. If The People of Papachacra do not fulfill their responsibilities, the project will be subject to termination by EWB-Purdue.

This MOU will be structured in sections describing the distribution of responsibilities associated with several aspects of the Project.

This Project aims to develop and implement an improved water collection and distribution system in the village of Papachacra, Bolivia. The purpose of this project is to collect and distribute water gathered from the Tree Spring located in Papachacra, Bolivia in a responsible and sustainable manner. This is done to improve water availability during months of drought. It is understood that the Project will be completed in a maximum of 10 days.

2. Organization

2.1 Engineers Without Borders-Purdue Chapter

EWB-Purdue Chapter is one of more than 300 chapters of EWB-USA. EWB-USA is dedicated to providing engineering solutions to communities around the world to improve their qualities of living. The projects that the organization are involved with include basic water infrastructure, school, sanitation, energy infrastructure, agricultural infrastructure and other issues that are essential to the quality of life of people. EWB-USA is a non-profit organization created upon the collaboration of professional engineers, engineering students and volunteers. The members

provide engineering solutions to the communities in need through the cooperation between the organization and the communities.
In order to allow EWB-USA and its chapters to successfully carry out each project, the understanding and collaboration between the two parties are required to be addressed. Therefore, it asks that communities provide some sort of support for the requested project. This can take many forms, from providing money or labor during implementation to housing for volunteers or providing materials for the project.

2.2 Papachacra, Bolivia

Papachacra is a community in the Tarija Department of Bolivia. The community is situated in the mountainous, southern region of Bolivia. The economy of the community is mainly agricultural with a population consisting of about 120 families. The community has been experiencing a shortage of water supply for both irrigation and consumption purposes for a period of time. The aging infrastructure and outdated system does not have the capacity to sufficiently supply water to the population at the current level specifically during the dry season. The community's current demand of approximately 37,000 liters per day is being undersupplied by 9,000 liters per day from the current system. Therefore, the EWB-Purdue chapter is aiming to increase the supply by 17,000 liters per day from the new water source in order to fulfill the current and future demand of the community.

3. Project Outline

3.0 EWB-Purdue chapter shall design potable water supply system improvements for the community of Papachacra based on existing system parameters and data.

3.1 EWB-Purdue chapter shall oversee construction of the water system in-person.

3.2 EWB-Purdue chapter shall fundraise for the project, except for maintenance and operations costs that will be provided by the community for sustained system operation.

3.3 EWB-Purdue chapter shall provide the community with a construction schedule, including a specific requested amount of volunteer labor.

3.4 EWB-Purdue chapter shall provide training in operation and maintenance practices for the new facilities constructed during Phase I of the project. This shall include the water storage tanks, collection box, pump and any appurtenances necessary for sustained operation.

3.5 EWB-Purdue chapter shall provide an operation and maintenance manual and training for the installed system.

3.6 EWB-Purdue chapter shall provide hygiene and sanitation education sessions for children and the community.

3.7 EWB-Purdue chapter shall provide an information session regarding water conservation for the community.

3.8 EWB-Purdue chapter will provide guidance in addition to other sources over arising issues associating with the project or when such assistance is needed by the community.

Papachacra:

3.9 The community of Papachacra shall manage and operate the installed system.

3.10 The community of Papachacra shall require that at least one permanent person/committee to oversee the installed system.

3.11 The service provided by the installed improvement system shall have no additional fees for water service unless other conclusions can be reached by the community.

3.12 The community of Papachacra shall secure valuable devices such as the solar panels and the pump from theft and vandalism.

3.13 The community of Papachacra shall oversee the Tree Spring and the immediate area surrounding it to eliminate possible future contamination.

3.14 The community of Papachacra shall conduct maintenance checks and inspection of the installed system and water source on a weekly basis to assure optimal system operation.

3.15 The community of Papachacra shall contact the EWB-Purdue chapter in case of system malfunction and critical technical issues.

3.16 The installed system and the Tree Spring is public property and property entitled to the community of Papachacra.

4. Work Arrangements

4.0 EWB-Purdue chapter will work with the community of Papachacra to dig trenches and lay the pipeline for the water system for a total 416 man-hours each.

4.1 EWB-Purdue chapter will work with the community of Papachacra to prepare the spring box site, place formwork and rebar, and pour concrete for the collection box for a total of 176 man-hours each.

4.2 EWB-Purdue chapter will work with the community of Papachacra to install a centrifugal pump system include the pump and all required connections within a secure pump house for a total of 36 man-hours each.

4.3 EWB-Purdue chapter will work with the community of Papachacra to install the solar panel and required system of mounting devices with a support base for a total of 46 man-hours each.

4.4 EWB-Purdue chapter will work with the community of Papachacra to wire the systems to transfer electrical power from the panels to the batteries and the pump including all required devices for a total of 16 man-hours each.

4.5 EWB-Purdue chapter will work with the community of Papachacra to install the HDPE Phase 1 storage tanks including the foundation as well as the required PVC connections for a total of 96 man-hours each.

4.6 EWB-Purdue chapter will work with the community of Papachacra to make modifications to the existing mountain spring box including but not limited to adjusting the height of the over flow pipe and verifying that the change provided the desired results for a total of 76 man-hours each.

Signatures of EWB Representatives for the Project:

1. ______________________________

2. ______________________________

Signatures of Papachacra Representatives for the Project:

1. ______________________________

2. ______________________________

5.1. La FIEA trabajará con los dirigentes o comité de agua de Papachacra para establecer apoyo continuado para el mantenimiento y reparación del sistema de agua potable cuando sea pedido por EWB-Capítulo de Purdue para Papachacra.

Las Firmas de los Representantes de EWB-Purdue para el Proyecto:

1. ________________________
2. ________________________

Las Firmas de los Representantes de Papachacra para el Proyecto:

1. ________________________
2. ________________________

Las Firmas de los Representantes de FIEA para el Proyecto:

3. [signature] (FIEA)
4. [signature] (FEIA)

FUNDACION INGENIEROS EN ACCION EIA LA PAZ - BOLIVIA ENGINEERS IN ACTION

Se autorisa la Construcción de tres tanque con la toma del Bosquesillo, C arriba de la Escuela y de la tuverio matriz con la Condición de que se Corte a Partir de la Siembra (mes de Junio) desde toma Bosquesillo

Corregimiento de la Com[illegible] PAPACHACA [illegible] Prov. Méndez Tarija-Bolivia

[signature]
Pablo gallardo
Corrigidor de
Papachacra

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Appendix K
Project Labor Hours

Tasks	EWB Effort (MH)	Community Effort (MH)	Day																				Man Hours
			1		2		3		4		5		6		7		8		9		10		
Pipeline[1]			EWB	PAPA	EWB	PAPA	EWB	PAPA	EWB	PAPA	EWB	PAPA	EWB	PAPA	EWB	PAPA	EWB	PAPA	EWB	PAPA	EWB	PAPA	
Stake proposed pipe alignment	8	16	8	16																			24
Dig up proposed line	168	448	24	64	24	64	24	64	24	64	24	64	24	64	24	64							616
Lay PVC pipeline and backfil trench	64	128					8	16	8	16	8	16	8	16	8	16	8	16	8	16	8	16	192
Collection Box[1]																							
Excavate at collection box site	32	64	16	32	16	32																	96
Form foundation slab and set rebar	16	24					16	24															40
Mix cement and place concrete slab	16	24							16	24													40
Form springbox walls and set rebar	16	24									16	24											40
Mix cement and place concrete slab	8	24									8	24											32
Lay aggregate filter													8	16									24
Form concrete top slab and manway	16	24									16	24											40
Connect PVC outlets and inlets	16	24											16	24									40
Pump System[3]																							
Install centrifugal pump	16	16											16	16									32
Install float switch	8	8											8	8									16
Install pump screen	8	16													8	16							24
Solar Station[3]																							
Excavate for mount base	8	16	8	16																			24
Set mount and equipment	4	16			4	16																	20
Mix cement and place concrete footer	4	8			4	8																	12
Prepare and route wiring	4	8					4	8															12
Install (2) 250 Watt Solar panels	8	16							8	16													24
Electrical Box[4]																							
Form covered box[2]	16	16	16	16																			32
Install inverter	0	0																					0
Install potentiometer	0	0																					0
Install car battery	0	0																					0
HDPE Phase I Storage Tanks																							
Clear and level storage tank site	16	16	16	16																			32
Lay and compact sand foundation	32	32			16	16	16	16															64
Transport (4) 5000 L Tanks	16	16					16	16															32
Plumb PVC outlets and inlets[2]	16	24							16	24													40
Connect transmission line to tanks	8	16									8	16											24
Mountain Springbox Modification																							
Prep existing springbox for adjustment	32	48	16	24	16	24																	80
Set overflow modification	16	24					16	24															40
Test/Check improvements	16	16							16	16													32
Total Man Hours	588	1112																					**1524**
Total 8-HR Workdays	73.5	139																					

Assume number of working hours per day is 8

[1] Need an engineer with construction experience with reinforced concrete water tanks and installing pipe

[2] Need someone who is skilled with cement mixing and pouring

[3] Need a mechanical engineer

[4] Need an electrical engineer

Appendix L

Best Operation Practices and Maintenance for Phase I System

The solar pump that will be installed by the EWB team is being installed primarily to provide sufficient water to the community during the arid months of the dry season experienced in Papachacra. Because of this, the pump will be operated exclusively during the dry season when water is scarce. The operation of the pump, as well as regular inspection and maintenance, will be performed by the Water Committee.

The Water Committee is a group of individuals from Papachacra who have received professional training in water systems and have experience with the current water system as well as experience cooperating with the community. Currently this committee has the responsibility of allocating water to individual parts of Papachacra, ensuring that all members have at least some regular access to water. The Water Committee will receive the task of maintaining and operating the solar pump that will be integrated into the existing water system. Before the EWB team leaves Papachacra, members will ensure that the Water Committee has a thorough understanding of the solar pump and its operation.

Additionally, the Water Committee will be given access to a complete copy of the solar pump manual in Spanish so that they have a resource to refresh their understanding of the system and how it operates. In the case that the Water Committee would encounter an extraneous situation outside the scope of their training and not contained within the manual, Ivan Castillo, a professional engineer with abundant experience with water systems, may be contacted. Considering the multiple resources offered to the Water Committee to maintain the pump and its components, we are confident that they will be able to effectively operate the system and implement any necessary reparations.

The Water Committee's operation of the pump will consist of manually turning on and off the pump as required to obtain the desired amount of flow. In order to ensure that the system runs effectively for as long as reasonably possible, regular inspections will be performed. These inspections involve a close inspection of all electrical and mechanical aspects of the pump, so as to ensure that the pump is being operated under optimal conditions. The specific elements of the pump that are necessary to monitor carefully are laid out within the product manual. This portion of the manual provides a description of the parts most liable to be a cause for failure within the system, as well as an explanation as to why these parts require more careful attention. In the case of a failure in the system, the manual provides an extensive troubleshooting algorithm that the Water Committee can readily implement to identify the problem.

Once the problem has been identified, the Water Committee will perform any and all reparations that are required for the system to resume operation. Although the training that the Water Committee has received seems to ensure that they will be capable of performing this responsibility, the community of Papachacra will be able to contact Ivan Castillo, as well as EWB, to receive outside help in repairing the system. We believe that this wide range of resources that we are providing the Water committee will properly equip them to undertake the task of operating the solar pump for the benefit of Papachacra as a whole.

Excerpt from solar pump manual showing the troubleshooting method:

LORENTZ

9 TROUBLE SHOOTING

Please read this section before calling for help.

If you call for help, please refer to the model and serial numbers. (See SYSTEM REPORT, page 3.)

IF THE CONTROLLER MUST BE REMOVED FOR REPAIR OR REPLACEMENT Remove the wires and flexible conduit from the controller and remove the CONTROLLER ONLY.

LEAVE THE JUNCTION BOX IN PLACE.

9.1 If The Pump Doesn't Run

Most problems are caused by wrong connections (in a new installation) or failed connections, especially where a wire is not secure and falls out of a terminal. The *System ON* light will indicate that system is switched on and connected to the controller. It indicates that VOLTAGE is present but (in a solar-direct system) there may not be sufficient power to start the pump. It should attempt to start at intervals of 120 seconds.

Pump attempts to start every 120 seconds but doesn't run

The controller makes a slight noise as it tries to start the pump. The pump will start to turn or just vibrate a little.

1. There may be insufficient power reaching the controller. A solar-direct (non-battery) system should start if there is enough sun to cast a slight shadow. A battery system should start if the supply voltage is greater than 22V (24V system) or 44V (48V system).
2. If the pump was recently connected (or reconnected) to the controller, it may be running in reverse direction due to wiring error. See Section 5.8.
3. If the motor shaft only vibrates and will not turn, it may be getting power on only two of the three motor wires. This will happen if there is a broken connection or if you accidentally exchanged one of the power wires with the ground wire. See Section 9.3, testing the motor circuit and the controller output.
4. The pump or pipe may be packed with mud, clay, sand or debris.
5. Helical rotor models: The rubber stator may be expanded from heat, due to sun exposure or pumping water that is warmer than 72°F (22°C). This may stop the pump temporarily, but will not cause damage. (See Section 12, Temperature Specifications.)
6. Helical rotor models: The pump may have run dry. Remove the pump stator (outer body) from the motor, to reveal the rotor. If there is some rubber stuck to the rotor, the pump end must be replaced.
7. Helical rotor models: The check valve on the pump may be faulty or stuck, allowing downward leakage when the pump is off. This can prevent the pump from starting.

PUMP OVERLOAD (PUMP ON light shows red instead of green) The system has shut off due to an overload. This can happen if the motor or pump is blocked or very difficult to turn and is drawing excessive current (hard to turn). Overload detection requires at least 250 Watt output of the solar array. This can be caused by a high concentration of solids in the pump, high water temperature, excessive pressure due to high lift or a restriction in the pipe, or a combination of these factors. The controller will make 3 start attempts before shutting down the system. The System ON LED will be OFF and the red OVERLOAD LED ON. The system will not reset until the ON / OFF switch is turned OFF and ON again. See Troubleshooting, Section 9.3 "HIGHER CURRENT".

CAUTION DO NOT REMOVE THE CHECK VALVE from the pump. If you want to look for dirt stuck inside the pump, it is preferable to unbolt the pump body and pull it from the pump. IF YOU MUST REMOVE THE CHECK VALVE, use a hardening adhesive sealant on the screw threads when you replace it. Epoxy glue is good. The threads are not tapered. They will leak if a hardening sealant is not used. Teflon tape will make a good seal, but it may not prevent the joint from unscrewing.

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Excerpt from solar pump manual showing maintenance procedures:

LORENTZ

10 MAINTENANCE

10.1 Controller and Pump

Controller and junction box The controller is electronic with no moving or wearing parts. It requires no maintenance. There are rubber gasket seals at the top and bottom, and rubber plugs to seal unused conduit holes. Inspect them to insure that the controller is sealed from moisture, insects, etc. Check that mounting and conduit hardware is tight.

Motor The motor is water-lubricated and requires no maintenance. It is permanently sealed and has no brushes or other frequently wearing parts.

Pump end The pump mechanism (pump end) is lubricated only by water and requires no maintenance. It may wear after some years, especially if there are abrasive solids in the water. If sand accumulates in the storage tank or pipes as a result of normal pumping, it is best to take periodic measurement of the pump's performance. If the flow rate is less than normal, see Section 9.4. A worn pump end can be replaced in the field, after the pump is pulled from the water source.

10.2 Solar Array

Solar array mounting bolts Bolts tend to loosen as the array structure flexes in high winds. Check tightness. All bolts should all have lock washers to keep them tight.

Sun exposure Cut away any vegetation that will grow enough to block solar illumination. Shading even a small corner of the solar array may stop the pump, or greatly reduce its flow.

Solar array cleaning If there is dirt, mineral deposits, bird droppings or other debris stuck to the solar array surface, clean it with water, vinegar or glass cleaner.

Solar Array Tilt Inspect the tilt of the array. The optimum tilt angle varies with the season. Some people adjust the tilt twice per year. Other people set it at a single setting as a permanent compromise. Section 4.5 for details.

Solar Tracker If the system uses a solar tracker, lubricate the bearings, check mounting bolts and mechanism. Refer to tracker manufacturer's instructions.

10.3 Electrical Wiring

Power wiring Inspect wires and connections carefully. Any wires that are hanging loose should be secured to prevent them from swinging in the wind. Exposed wiring must be sunlight resistant and in good condition. In the case of a tracking array, look carefully for any wire damage due to rubbing, bending, or pulling as the tracker swings. If wiring was not performed to professional standards, improve it to prevent faults in the future.

Grounding Inspect the grounding system carefully. All connections must be tight and free of corrosion. Poor grounding can lead to damage from lightning-induced surges. See Section 5.2.

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Appendix M

Water Testing Data

Location	Nitrates ppm	Nitrites ppm	Hardness grain/gal	Ph	Total Chlorine ppm	Free Chlorine ppm
CARE	0	0	0	6.8	0.5	0
FPS	0	0	0	7.0	0	0
NO.3	0	0	0	6.7	0	0
Tree Spring	0	0	50	6.8	0	0

Appendix N

Bolivian Water Quality Standards

IBNORCA **NORMA BOLIVIANA** **NB 512**

Calidad de agua potable para consumo humano – Requisitos

0. INTRODUCCIÓN

La calidad del agua con destino al consumo humano tiene implicaciones importantes sobre los aspectos sociales y económicos que actúan indirectamente sobre el desarrollo de un país. Caracterizar la calidad a través de la definición de los límites permisibles de los parámetros físico-químicos y microbiológicos es fundamental para garantizar la salud pública.

La estructura de la norma toma en consideración la importancia sanitaria de los parámetros a analizar, la calidad y la sensibilidad de las fuentes utilizadas para la producción de agua para consumo humano.

Los objetivos de esta norma son:

a. Garantizar la salud de los consumidores: Los parámetros y sus niveles, que representan un peligro para la salud, son perfectamente conocidos y las exigencias asociadas para la protección del consumidor, están bien definidas. Basados en los conocimientos científicos y epidemiológicos y a los principios de gestión de riesgo, se definen límites permisibles de calidad del agua y se propone una jerarquía en referencia a los riesgos que presentan.
b. Ser factibles en el contexto del país: Las recomendaciones se adecuan lo más posible con la situación existente en los laboratorios y en las empresas prestadoras de servicios de agua y alcantarillado, sin poner en riesgo la salud humana.
c. Ser adaptables: Existen diferencias naturales y socioeconómicas entre los departamentos y las ciudades de Bolivia. Por eso es necesario dar flexibilidad y gradualidad en los requisitos, para permitir una adaptación a las condiciones locales, sin que ello implique poner en riesgo la salud humana.

1. OBJETO

Esta norma establece los valores máximos aceptable de calidad de agua abastecida, con destino al uso y consumo humano y las modalidades de aplicación y control.

2. CAMPO DE APLICACIÓN

Esta norma se aplica a todas las aguas abastecidas con destino al uso y consumo humano, a excepción de las aguas mineros medicinales.

3. REFERENCIAS

Los siguientes documentos normativos contienen disposiciones que al ser citadas en este texto, constituyen disposiciones válidas para esta norma. Como norma está sujeta a revisión, se recomienda, a aquellos que realicen acuerdos en base a ellas, que analicen la conveniencia de usar las ediciones mas recientes de las normas citadas seguidamente.

NB 495 Agua potable – Definiciones y terminología.
NB 496 Agua potable – Toma de muestras.

4. DEFINICIONES

4.1 Agua potable para consumo humano

Es aquella que por sus características organolépticas, físico-químicas y bacteriológicas, se considera apta para el consumo humano y que cumple con lo establecido en la presente norma.

4.2 Características bacteriológicas

Son aquellas que se original por la presencia de bacterias nocivas a la salud humana.

4.3 Características físico-organolépticas

Son aquellas que se detectan sensorialmente o por medio de métodos analíticos de laboratorio.

4.4 Características químicas

Son aquellas debidas a elementos o compuestos químicos orgánicos e inorgánicos, que como resultado de la investigación científica, se ha comprobado que en altas concentraciones, pueden causar efectos nocivos a la salud, perjudicar otros usos o afectar al sistema de abastecimiento.

4.5 Características físico-químicas

Son aquellas que miden las propiedades colectivas, resultantes de la presencia de un número de constituyentes físico-químico.

4.6 Características radioactivas

Son aquellas resultantes de la presencia de elementos radioactivos.

4.7 Plaguicidas

Término genérico que incluye todos los compuestos que forman parte de las siguientes familias de compuestos: insecticidas orgánicos, herbicidas orgánicos; funguicidas orgánicos; acaricidas orgánicos; nematocidas orgánicos; alguicidas orgánicos, los productos derivados y sus metabolitos, productos de degradación y de reacción de los mismos.

4.8 Valor máximo aceptable

Es aquel valor asignado, el cual no debe ser excedido en las condiciones definidas por la presente norma.

5 REQUISITOS

5.1 Requisitos físico-organolépticos

Para efectos de evaluación, el sabor y el olor, se determinan por medio de los sentidos y el color, la turbiedad y los sólidos totales disueltos, por medio de métodos analíticos de laboratorio.

Tabla 1. Requisitos físico-organolépticos

Características	Valor máximo aceptable	Observaciones
Color	15 UCV	UCV = Unidad de color verdadero (y no presentar variaciones anormales – UCV en unidades de platino cobalto)
Sabor y olor	Ninguno	Deben ser aceptables
Turbiedad	5 UNT	UNT = unidades nefelométricas de turbiedad
Sólidos totales disueltos	1000 mg/L (**)	

(**) Valores superiores pueden influir en la apariencia, el sabor, el olor o perjudicar otros usos del agua (veánse guías OPS/OMS).

5.2 Requisitos físico-químicos

Tabla 2. Requisitos físico-químicos

Características		Valor máximo aceptable	Observaciones
Compuestos inorgánicos			
Dureza total		500 mg/L $CaCO_3$	
pH[(1)]		9,0	Límite inferior 6,5
Arsénico	As	0,05 mg/L (*)	Valor mayor tiene efecto sobre la salud
Bario	Ba	0,7 mg/L (*)	Valor mayor tiene efecto sobre la salud
Boro	B	0,3 mg/L (**)	Valor mayor tiene efecto sobre la salud
Cadmio	Cd	0,005 mg/L (*)	Valor mayor tiene efecto sobre la salud
Cianuro	CN^-	0,07 mg/L (*)	Valor mayor tiene efecto sobre la salud
Cloruros [(2)]	Cl^-	250,0 mg/L (*)	Valores mayores originan sabor y corrosión
Cobre	Cu	1,0 mg/L (**)	
Cromo total	Cr	0,05 mg/L (*)	Valor mayor tiene efecto sobre la salud
Fluoruro[(3)]	F^-	1,5 mg/L (**)	Deberá tenerse en cuenta la adaptación climática del lugar
Hierro total	Fe	0,3 mg/L (**)	
Manganeso	Mn	0,1 mg/L (**)	
Mercurio	Hg	0,001 mg/L (*)	Valor mayor tiene efecto sobre la salud
Níquel	Ni	0,05 mg/L (*)	Valor mayor tiene efecto sobre la salud
Aluminio	Al	0,2 mg/L (*)	Valor mayor tiene efecto sobre la salud
Amoniaco NH_4^+		0,5 mg/L (**)	
Antimonio	Sb	0,005 mg/L (*)	Valor mayor tiene efecto sobre la

Características	Valor máximo aceptable	Observaciones
		salud
Nitritos (4) NO_2^-	0,1 mg/L (*)	Valor mayor tiene efecto sobre la salud
Nitratos (4) NO_3^-	45,0 mg/L (*)	Valor mayor tiene efecto sobre la salud
Plomo Pb	0,01 mg/L (*)	Valor mayor tiene efecto sobre la salud
Selenio Se	0,01 mg/L (*)	Valor mayor tiene efecto sobre la salud
Sulfatos $SO_4^=$	400, mg/L (**)	
Zinc (Zn)	5,0 mg/L (**)	
Compuestos orgánicos		
Acrilamida (5)	0,5 μg/L	
Epiclorohidrina (5)	0,4 μg/L	
Benceno	5,0 μg/L	
Benzo[a]pireno	0,2 μg/L	
Cloroformo	200,0 μg/L	
THM (trihalometanos totales)	100,0 μg/L	
Cloruro de vinilo	2,0 μg/L	
Fenol	2,0 μg/L	

(1) Adoptar con respecto al equilibrio calcio-carbónico.
(2) Cuando se utilice un desinfectante como el cloro, el valor admisible de cloro residual libre en cualquier punto de la red de distribución de agua, deberá estar comprendido entre 0,2 y 1,0 mg/l.
(3) Para más información veáse la tabla 7.
(4) La condición según la cual NO_3-/50 + NO_2-/3 <1.
(5) Todos y cada uno de los sistemas de agua deben declarar al estado por escrito, que si usa acrilamida y/o epiclorohidrina para tratar el agua, la combinación (o producto) de dosis y cantidad del monómero, no superará los niveles especificados, a saber: acrilamaida = 0,05%, dosificada a razón de 1 mg/L (o su equivalente); epiclorohidrina = 0,01%, dosificada a razón de 20 mg/L (o su equivalente).

(*) Posible efecto sobre la salud por exposición que supere el valor máximo aceptable (veánse guías OPS/OMS).
(**) Valores superiores pueden influir en la apariencia, el sabor, el olor o perjudicar otros usos del agua (veánse guías OPS/MS).

5.3 Requisitos para plaguicidas

Tabla 3. Requisitos para plaguicidas

Características	Valor máximo aceptable	Observaciones
Plaguicidas	0,1 μg/L	El método de referencia es el establecido en ISO-6468
Plaguicidas totales	0,5 μg/L	

NOTA
- Las concentraciones en plaguicidas, deben ajustarse a los límites definidos en al tabla 3.
- El valor límite "plaguicida", se aplica y se debe comparar a cada compuesto definido como plaguicida, detectado y cuantificado individualmente.
- El valor límite para "plaguicidas totales", se aplica y se debe comparar a la suma aritmética de las concentraciones detectadas y cuantificadas individualmente, de todos los compuestos definidos como plaguicidas.

5.4 Requisitos de radioactividad

Tabla 4. Requisitos de radioactividad en el agua potable

Características	Valor máximo aceptable	Observaciones
Radioactividad alfa global	0,10 Bq/L	Si se sobrepasa el valor límite, es necesario un análisis más detallado de los radionúclidos.
Radioactividad beta global	1,0 Bq/L	

5.5 Requisitos bacteriológicos

Tabla 5. Requisitos bacteriológicos

Características	Valor máximo aceptable	Observaciones
Coniformes totales	0,0 UFC/mL	< 5 NMP/100 mL (*)
Escherichia coli	0,0 UFC/mL	< 5 NMP/100 mL (*)

(*) 95% de las muestras, con la serie de 5 tubos.

5.6 Parámetros de control

Tabla 6. Parámetros de control

Características	Valor máximo aceptable	Observaciones
Conductividad	1500 μmhos/cm (**)	
Alcalinidad total (*)	370 mg/L $CaCO_3$	El mismo está relacionado con el pH.

(*) Índice de Langelier –0,5 a +0,5 para sistemas con tubería metálica.
(**) Valores superiores pueden influir en la apariencia, el sabor o el color del agua (veánse guías OPS/OMS).

5.5 Límites de concentración de fluoruros

Tabla 7. Límites de concentración de fluoruros en el agua potable

Promedio anual de la temperatura máxima diaria del aire (°C)	Concentraciones de fluoruros (mg/L)		
	Bajas	Óptimas	Altas
10,0 – 12,0	0,9	1,2	1,5
12,1 – 14,6	0,8	1,1	1,4
14,7 – 17,7	0,8	1,0	1,3
17,8 – 21,4	0,7	0,9	1,2
21,5 – 26,3	0,7	0,8	1,0
26,4 – 32,5	0,6	0,7	0,8

6. MUESTREO

Se procederá de acuerdo a la Norma Boliviana NB 496

7. MÉTODOS DE ENSAYO

Se procederá de acuerdo a las normas bolivianas correspondientes

8. BIBLIOGRAFÍA

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