Sustainable Pumping Station Design for Rural Ecuadorian Communities

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Abstract

Simply designed economical pump stations can provide consistent sustaining water service for rural communities. Rural Ecuadorian community water systems in the Andes Mountains often require high pressure pumping. In the past, these high pressure pumping stations frequently failed due to design and pump installation deficiencies. This paper discusses the common problems observed in small rural water pump stations and measures necessary to improve their reliability.

In cases where high-pressure pumping is required, submersible pumps provide high efficiency and reliable service. A simple pump station design using submersible pumps installed in an economical structure is presented. This approach has been used successfully by a large number of rural Ecuadorian communities in Chimborazo Province.

UN Millennium Development Goals (MDG) call for reducing child mortality rates two-thirds by 2015 and cut in half the percentage of those living without a sustaining supply of clean water by 2015. The World Health Organization points out that 884 million people lack an improved water source and 2.6 billion people lack access to improved sanitation. Studies (Solis, 2006) indicate that only 13% of the rural water systems in Ecuador are sustaining. Sustainable water pumping facilities are crucial to attain UN Millennium goals.

Background

Rural Ecuadorian communities generally build and manage their own water system with limited help from government agencies. Most communities are of indigenous background, Quichua being the most predominant. In the 1960's the indigenous people were granted citizen status in Ecuador allowing them to acquire water rights. As a result, many rural community water systems have been built in recent decades with varying levels of success. Although a large percentage of rural water systems are fed by a high elevation water source and operate by gravity, frequently the closest highest quality source requires pumping.

A large number of Ecuadorian communities built pumped water systems during the “UN Decade of Water” of the 1980’s. Many Andean communities in the sierra are located at elevations from 2000 to 4000 meters and require high-pressure pumping in the range of 1 Mpa to 3 Mpa (141 to 423 psi). Only a limited number of these pumped rural water systems built in the 1980’s were sustaining, and the majority either failed or provided limited benefits. In some cases, pumps burned out in a matter of months of operation. Failed centrifugal pumps were sometimes replaced with positive displacement pumps requiring costly maintenance and providing much lower efficiencies. These subsequent measures also prejudiced the long-term sustainability of those rural water systems.

A cursory study of the inoperative water systems and those with operational problems revealed a number of frequent causes;

- Over sized pumps with a pumping capacity exceeding the flow rate provided by the water source.
- Lack of security allowing vandalism or theft of pumping equipment.
- Inadequately secured pumping equipment allowing pump to move.
- Lack of back-up pump.
- Sediment in water source.
- Lack of low water level cut-off protection for pump suction.
- Lack of voltage protection.
- Lack of over current protection.
- Lack of electrical ground.
- Lack of lightning/surge protection
- Inadequate provisions for motor cooling.
- Absence of electrical conduit and other fittings to protect electrical wiring.
- High power consumption or low pump efficiency.
- Substandard materials.

Many of these problematic pumping installations had costly unnecessary water storage at the pumping facility. The expense of the unnecessary structure exceeded the costs which would have been required to improve the pump installation.

Water Source

The water source should be an adequately protected spring or completely sealed well which not only prevent debris from entering the water system but also protect the water from contamination. These measures protect the pumps and provide for consistent water quality. Debris can damage the pumps, valves and cause unnecessary cleaning work.

In cases where the well or spring produce sand or sediment, adequate settling volume should be allowed in the well or pumping structure. In the case of spring water sources, the receiving structure should be designed so that it can be cleaned periodically if and when sediment accumulates. The pump suction should be spaced above the floor of the structure to allow adequate depth for sediment accumulation.

Surface water sources do not normally provide reliable water quality for small rural Ecuadorian communities. Although treatment is intended in some rural water systems, rarely are the funds available to build the water treatment facilities or finance the level of operation required. The periodic sediment and debris experienced in surface water not only deteriorate the water quality but are also a maintenance liability and a hazard to the equipment.

Pump selection, cooling, and sizing

Pumps should be selected to supply the daily peak demand projected in 5 to 20 years. Larger flows of the short-term peak demands can be supplied from storage in water systems with high level storage. Most electric pumps can run 24/7 when necessary to take full advantage of the flow from springs and wells with limited capacity. The pumping rate should not normally exceed the flow provided by the spring or well. This design approach allows the use of smaller pumps which reduces the initial cost of the pumping facilities as well as the maintenance and replacement costs.

Submersible pumps often form the best option for small communities requiring high-pressure pumping. The large number of stages in submersible pumps and the opportunity to select the number of stages needed, make these pumps ideally suited for low flow high-pressure applications.

Conventional centrifugal pumps with air-cooled motors need to be installed above flood level and in well ventilated space of adequate volume for cooling. Air-cooled motors may need periodic cleaning when operating in a dusty environment. Additionally it is important to provide adequate lighting and space for routine maintenance on the pumps. Normally a pump station should be equipped with at least one backup pump so that the facility can provide 100% of the design flow with one pump out of operation.

Pumps should be physically secured to avoid vibration or movement. Conventional centrifugal pumps should be adequately bolted and secured to the floor. Sanitary seals or compression rubber seals should be used where the pipe passes through the floor so that the water is protected from contamination and pipes from vibrating.

Submersible pump installations

Pump submergence should be at an adequate water depth so that the pump does not cavitate or suction air. Some manufacturers recommend a depth of 3 meters. Submersible pumps installed in drilled wells should be located above the well screen so that they receive the upward flow of water to cool the pump motor. The water velocity flowing by the motor should be at least 76 mm per second, to keep the pump motor at a uniform temperature. Pumps installed in large diameter wells or in cisterns should be installed with a flow sleeve to maintain this flow velocity. Nominal 4" submersible pumps can merely be fitted with a 110 mm diameter plastic pipe to serve this purpose.

The 4" flow sleeve can either be fastened to the pump using stainless steel clamps above the pump suction or a 4" sanitary well seal can be clamped to the discharge pipe immediately above the pump. In the latter case, three small machine screws with nuts can be used at 120 degree intervals to hold the flow sleeve centered around the electric motor.

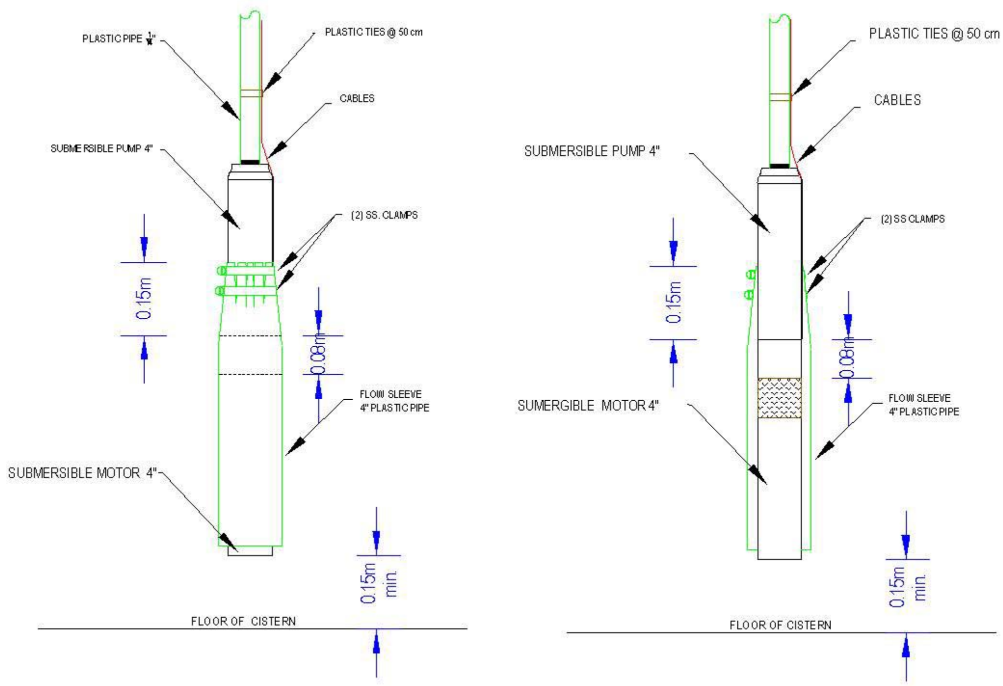

Figure No. 1 Sketches of a cross-section and the exterior of a 4" plastic pipe flow sleeve for a nominal 4"submersible pump.

Reliable check valves should be installed as recommended by the manufacturer to avoid backflow. Leaky check valves not only waste energy, they can be damaging to the pump by allowing reverse flow or allowing the pump to start under low pressure with damaging increased pump thrust on the bearings.

Where 4" submersible pumps are installed with a pump house enclosure above the cistern, it is advisable to allow a plugged 160 mm opening in the roof directly above the pump installation. This allows easier removal and installation of the pump without excessive pipe unions or couplings.

Pumps should be normally equipped with a low-level cutoff switch to shut off the pumps when the water level drops excessively at the pump suction. This prevents pump or motor burn out and hence improves sustainability of the pumping equipment. The importance of adequate suction pressure is accentuated for pumps operating at high altitudes because of decreased atmospheric pressure. Pumps should only be operated within the suction pressure range recommended by the manufacturer to avoid damaging cavitation and low pump efficiency.

Figure No. 2 Photograph showing a duplex submersible pump installation. Note individual control boxes and pump panel on wall.

Figure No. 3 Photograph of the piping for submersible pump installation. Note sanitary seal and the secure conduit for electric power.

Electrical protection and wiring

Grounding of the electrical system is extremely important in the case of submersible pumps, since the pump is submerged in conductive liquid. Lightning and surge protection is important for the same reason, since lightning or power surges follow the easiest route to ground. Lightning/surge protection is best placed adjacent to the breaker panel providing power to the pumps. Some submersible pumps are manufactured with internal lightning (surge) protection.

The voltage of rural power supply often varies widely. It is important to protect the pump motor from excessive extremes which could overheat or damage the motor. Over current protection shuts the motor down due to a locked pump, lack of cooling, or overloading. Smaller submersible motors are commonly furnished with internal thermal protection.

Electrically pumped water systems are only as reliable as the electric installation. Therefore it is important that NEC and/or applicable local electrical codes requirements be implemented. Wiring should be adequately protected by either flexible or rigid conduit. Fittings such as service entrances should be used as necessary to fully protect the wiring.

Pump automation

Automation of water pumps is advisable to keep the water system reservoirs at or close to full. Generally communities without pump automation only provide intermittent water service. High pressure water systems increase the challenge of running a water system manually, since the vertical elevation between the pumps and the highest reservoir is increased.

In rural areas where power outages may last for several days, it is important to keep reservoirs constantly at or close to full so that the users have enough water stored for essential needs during those outages. Rarely do operators have the time or discipline to monitor water levels to the degree necessary to keep the reservoirs full without automatic controls to start and stop the pumps. Pump stations built in the 1980's did not use automatic start/stop controls for pumps because of the lack of maintenance infrastructure in rural areas of Ecuador to maintain that equipment. Improved transportation and increased availability of electric suppliers allow simple pump automation to be a practical improvement worthy of consideration in many communities.

Pumps can be automated using an electrical float switch in the top reservoir to start and stop pumps. A relay located in the pump control panel senses when the circuit opens and closes to activate or stop the pump. A buried cable between the pump house and the top reservoir provides the connection between the electric switch and the relay in the pump panel. Commonly, the buried cable can be one to two kilometers in length.

In certain circumstances, in AC actuated control circuits the effect of the cable capacitance of long control cables can be a problem. It may prevent the disconnection of contactors due to the cable capacitance present. Even if the command contacts are open, the coil current can still flow due to the cable capacitance so that the contactor remains in the ON position if sufficient sealing current is present. Normally, this problem can be solved by using contactors with higher coil sealing power or switching a resistance parallel to the coil such as a small incandescent bulb. Electric float switches need to be checked periodically, since the internal contacts are susceptible to corrosion in a wet environment.

Our experience indicates that it is unwise to use PLC’s in the pump control logic unless adequate resources are available to help the community reprogram or troubleshoot the PLC when necessary. The frequent power outages in rural areas can cause the PLC to lose its programming. PLC’s are not necessary in the pump control logic unless automatic pump alternation is needed. Manual alternation between two pumps can be done on a weekly basis rather than at each cycle, thus eliminating the need for a PLC and reducing cost.

Figure No. 4 Photograph of a simple duplex pump panel with meters for the current draw of each pump and voltage.

Security

The pump house should be provided with a secure locking entrance door and the cistern with a lockable sanitary cover. These measures which protect the equipment from theft, vandalism and unauthorized access are necessary to assure reliable operation of the equipment.

Design & Operational Experience

A common tendency in rural Ecuador is to provide substantial storage at the pumping facility. This storage is costly and unnecessary unless the water system has users at a lower elevation which can be fed by gravity from that storage. It is illogical to provide storage if the electric pumps can operate 24/7 to take full advantage of the spring or water flow.

Only a minimum volume of storage is needed at the pumps normally. When a deep tank is needed for submersible pumps, round concrete pipe of 1 meter diameter or larger can be placed in vertical stacked and sealed sections to economically build the well or water receiving tank where the pumps are installed.

Float switches used at the high level reservoir receiving the pump flow are a common maintenance issue since the contacts can easily become fouled. Often these switches only have a life of two or three years. The float switch is normally installed with a hysteresis of 150 to 450 mm. Thus, when the water level in the top reservoir recedes by that amount, the switch closes sending current to the pump panel relay and starting the pump.

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References

ITT Corp. – Goulds Pumps, Residential Water Systems-Service Manual (June 2010). http://completewatersystems.com/wp-content/uploads/2011/06/GSSERVICE.pdf

Peerless Pump Company. (July 2006). *SUBMERSIBLE MOTORS…RELIABLE PERFORMANCE DEPENDS ON RELIABLE INSTALLATION* – Technical Information Bulletin No. 32. http://www.peerlessxnet.com/documents/tibs/TIB-32_Submersible-Motors-Reliable-Performance-Installation.pdf

Solis, Fernado, et al. (2006) *Estudio de Sostenibilidad de los Sistemas deAgua Potable Rural.* CARE and CAMAREN. Quito, Ecuador. http://www.oas.org/dsd/MinisterialMeeting/CRITERIOS%20Y%20ACCIONES%20EN%20PRO%20CUMPLIMIENTO%20ODM%20AGUA%20Y%20SANEAMIENTO.pdf

Rydbeck, B. & Gillis, H. (January 2010). *A Comparison of Water Supply Methods for Rural Ecuadorian Communities*, EWRI Conference - An International Perspective on Environmental and Water Resources, Chennai, India.

Rydbeck, B. (January 2009). *Achieving Sustainable Water Supply and Sanitation Improvements for Rural Ecuadorian Communities*, EWRI Conference - An International Perspective on Environmental and Water Resources, Bangkok, Thailand.

UN Millennium Development Goals (2005). http://www.unmillenniumproject.org/reports/goals_targets.htm