A Pump-Test Method for Rope-Pump Wells to Forecast Seasonal Changes in Yields

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Introduction

Nearly half of the population of Nicaragua resides in rural communities where access to water is limited to ground water wells, or in many cases of people living in extreme poverty use surficial water sources. Due to the low population density in rural areas, a single well may serve small groups of families. Therefore ground water extraction in a watershed is characterized by numerous wells with a maximum depth of 200 ft.[1]. Reliance on groundwater in rural Nicaragua has increased considerably since the introduction of rope-pump wells in the 1980s[2]. Since 1985 almost all perforated and dug wells have been equipped with rope pumps due to its simple design, low cost, reliability, and ease in repairing[3]. The success of these wells has helped improve the livelihoods of rural farming families, thus leading to the installation of thousands of rope pump wells in Nicaragua since this period.

Although the use of groundwater is important in rural zones of Nicaragua, little information about aquifers and well behavior exists. The situation is complicated for many reasons, including: lack of economic resources to perform hydrogeologic investigations, complex fractured bedrock aquifers, difficulties in accessing wells, and lack of a characterization method appropriate for use in the types of wells used in many areas. Like many countries in the developing world, ground water resources are utilized with little understanding of aquifer characteristics, leading to unmanaged use[4]. This type of activity frequently causes unsatisfactory well performance: significant drops in water table levels, well interference, and changes in water quality. In Nicaragua it is common that the winter rains do not adequately recharge hard rock aquifers and well users frequently suffer the debilitating effects of dry wells towards the end of summer.

A method to approximate the quantity of available water during the dry season, and the abstraction rate appropriate to ensure its continued use during that period, would aid rural farmers whose wells consistently become dry in the summer. I propose a method adapted from Herbert et al. (1992), which requires a series of pump tests in the well performed over the course of a week just after the seasonal rains have ceased. The results from these tests will be used to project the behavior of the well as the phreatic level changes over the course of the dry season. From these estimates, yield predictions can be made to ensure continual use of the well throughout the summer. This method appears to be simple and easily adaptable to rope pump wells. The results can greatly improve individual well owners' abilities to regulate well use without expensive aquifer characterization.

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[1] Meza, L., 2006, personal communication
[2] Análisis Sectorial Agua Potable y Saneamiento de Nicaragua, 2004, p. 95
[3] Análisis Sectorial Agua Potable y Saneamiento de Nicaragua, 2004, p. 95
[4] Moench, 2004

Previous Work

Given that groundwater exploration and exploitation is more expensive than using surficial water sources, and that large groundwater reserves are commonly used in the developed world, a majority of the research on groundwater behavior is concentrated in first world countries by universities and institutions with big spending power. As a result, studies conducted to understand complete hydrogeological systems rely on high-tech, expensive testing methods and models, using precipitation-, evaporation-, and climate-databases that date back decades, well monitoring databases spanning nearly that same time, and comprehensive drilling logs. Furthermore, researchers are able to take advantage of data sharing between institutions.

On the other end of the spectrum, while groundwater is being more and more used to meet people's needs the developing world, little work is being done to tailor hydrological sustainability studies for shallow residential wells using low-tech extraction methods. Commonly, in the developing world well testing is primitive, models are non-existent, little or no climatic information exists, there is no well monitoring, and only sparse, incomplete drilling logs are available. What information does exist is typically tied up in a centralized government institution and cannot be accessed by anyone but authorized personnel. Due to the nature of working in the developing world, where governmental institutions are strapped economically and most foreign aid is slated for building infrastructure, virtually no economic resources are allocated for improving knowledge of regional groundwater resources or assessing well performance. Studies of these types are normally costly and time consuming, and with a common "meet immediate needs" mentality, little emphasis is placed on planning and actions to ensure sustainability.

One study, completed by Herbert et al, (1992), has been performed to predict long-term (6 months) behavior for low-tech hand dug wells in hard rock aquifers in the developing world. The study was performed in a collector well with adits located in Malawi. At the end of the rainy season, the well was tested by pumping two hours a day (4 l/s) three times a day for an eight day period. The depth to water table was measured before and after each pumping period. They found that the total drawdown could be divided up into two different parts – the constant daily change from start to end of each pumping day and background level drawdown. They noted a gradual fall in background drawdown which was used to predict background drawdown that would occur after the entire dry season. Because of a roughly proportional relationship between drawdown and discharge, and the head available in the well, it was possible to calculate a safe discharge rate that could be maintained over the course of the dry season.

Objectives

The outcome of this study will (1) determine if an adapted form of Herbert et al.'s (1992) pump test method applied to rope pump wells in fractured bedrock aquifers can be used as a predictive tool for phreatic level changes over the course of the dry season, (2) provide well users estimates of sustainable abstraction rates that will most likely ensure continued use of the well during the entire summer, and (3) equip rope-pump wells with a simple and economic system that can be used to monitor phreatic level and well production. This last objective will aid agencies currently in the process of inventorying water resources for improved watershed management plans.

Methodology

I propose adapting a pump-test method based on the long-term field test used to predict safe yield in collector wells with horizontal adits described in Herbert et al. (1992). Three rope pump wells within the same watershed will be chosen (see Site Selection) for intensive testing and monitoring. Fieldwork will begin just before the seasonal rains have stopped (around September), and includes:

> **Well-user interviews –** Interviews will be used to determine which wells in the watershed are commonly used and suitable for study, and to estimate abstraction rates for the dry season. At this time, all efforts will be made to choose families with interest, who will be asked to participate by recording daily abstraction rates over the course of the summer.
>
> **10 day pump tests** - Wells will pumped continuously for a predetermined period of time three times each day for about 10 days. (After ensuring discharge rate will not cause well to dry up before end of test.)
>
> **Phreatic level measured –**Measurements taken before and after each pumping period in all three wells.
>
> **Monthly depth to water table measurements taken –** Starting one month after 10 day pump test and continuing until end of summer. Three observation wells (unused wells) in the watershed will be monitored as well to gather data on water table seasonal variations.
>
> **Monthly well-user interviews –** Regular interviews will be used to monitor daily abstraction records from well users.

After the 10 day pump test and initial interviews are completed, the observed time-drawdown trends for each well will be used to discern the behavior of the "background" (not including daily changes due to pump test periods) drawdown as a result of regular abstraction during the pump test. Values will be corrected for given abstraction rate estimates determined in the well-user interviews, and then trend will be extrapolated over a period of up to six months to predict background drawdown that would occur during an entire dry season. Finally, a safe discharge rate for each well will be calculated.

To aid in explaining the methodology, test data from Herbert et al. (1992) is used:

Pumping regime: Daily 06:00-08:00; 11:00-13:00; 16:00-18:00

Pumping rate: 4 l/s

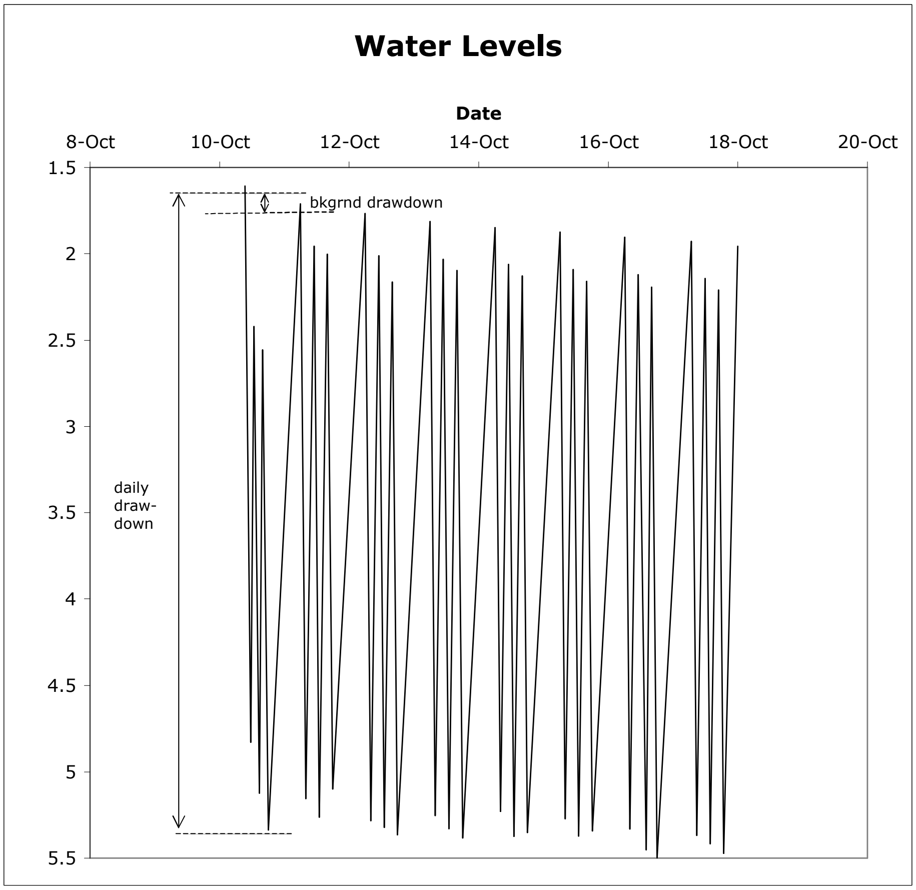

Figure 1: Observed drawdown in a hand-dug, large-diameter, bedrock well (adapted from Herbert et al. 1992)

Figure 1 shows drawdown versus time for the pump test. Drawdown is broken up into two parts - the drawdown background, and the daily change in drawdown from the start to the end of each pumping day.

Figure 2 shows background drawdown versus time for pump test regime and background drawdown values corrected for estimated abstraction rates (as gathered from interviews).

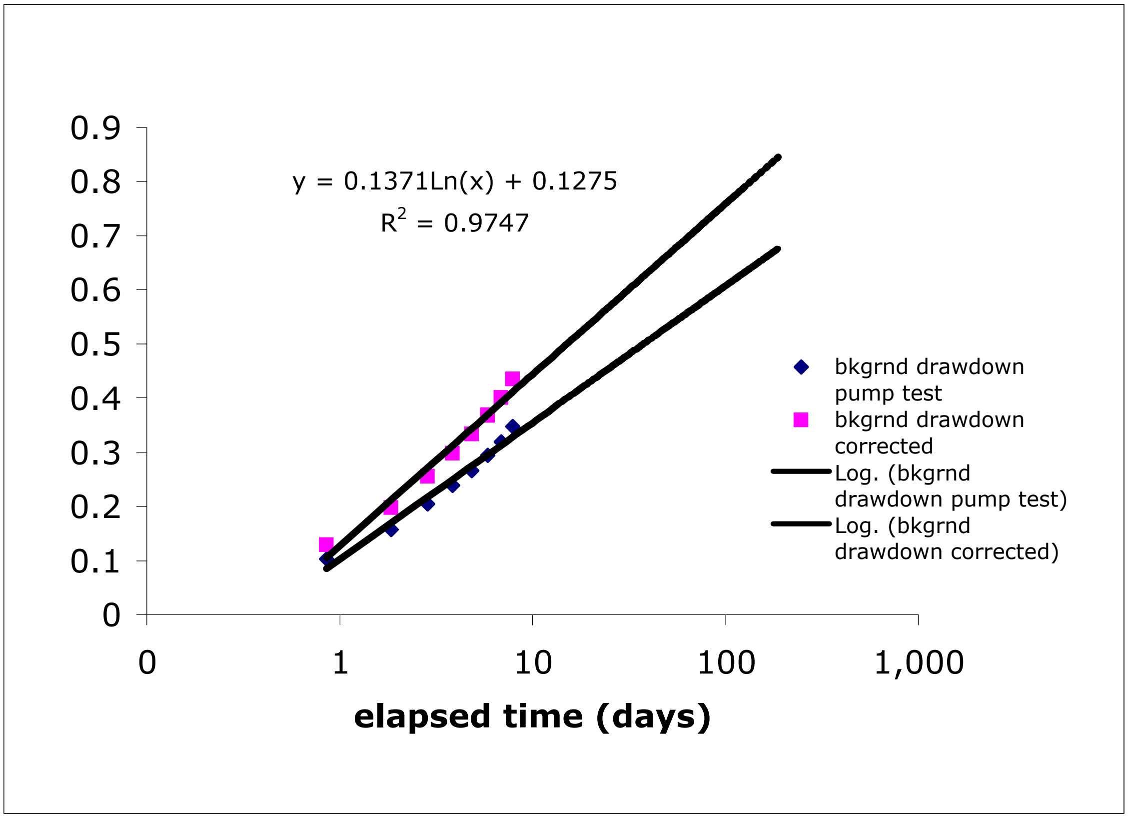

Figure 2: Plot of drawdown versus time, extrapolated to 180 days.

The extrapolated background drawdown values for next 180 days are listed in Table 1.

Table 1: Projected background drawdown during summer.

Month	Projected drawdown (m)
Nov	0.59
Dec	0.69
Jan	0.74
Feb	0.78
Mar	0.81
Apr	0.84

Monthly measurements will then be taken over the course of the summer to determine the validity of the projected water table levels. Throughout the summer, well users will be tracking abstraction values, which will be used to verify estimates given at initial stages of pump test.

Finally, the data will be used to determine the safe discharge of each well that will ensure its use over one dry season. Though it will not be a tested value, it will give the well users an idea of a sustainable discharge rate.

Site selection

The study will be performed in the watershed (Figure 1) of Apompuá, located near Juigalpa, Chontales, tentatively beginning September 2006 and ending May 2007.

The watershed of Apompuá is a part of the municipality of Juigalpa (3 km east of the city of Juigalpa), and is located by geographic coordinates 12º 02' 30" North, 85º 14' 58" West. The watershed is 52.9 km^2. Its principal communities are: Apompuá, Santa Rita, and San Antonio.

The selection of the watershed of Ampopuá was based on several advantages it presents.

- A topographic map (1:50,000), and geologic and hydrogeological maps (1: 250 000) of the area are available.

- During March 2006, a water resource inventory was completed of the watershed – a collaborative effort of locals and the watershed subcommittee of Juigalpa. This inventory includes location and dry-season flow of surficial water sources, and location and general description (owners, age, state of well, etc.) of hand excavated and perforated wells.

- According to ENACAL-DAR Engineer Luis Meza, the institution has installed 14 rope-pump wells within the watershed, and according to the ENACAL-DAR well registry database, 10 of these wells have been described by ENACAL-DAR at the time of installation (2000-present).

- The zone offers topographic variation; low regions (communities of San Antonio) corresponding to areas less than 200 masl, intermediate regions (Santa Rita) between 200 and 400 masl, and the high region (Apompuá) above 400 masl.

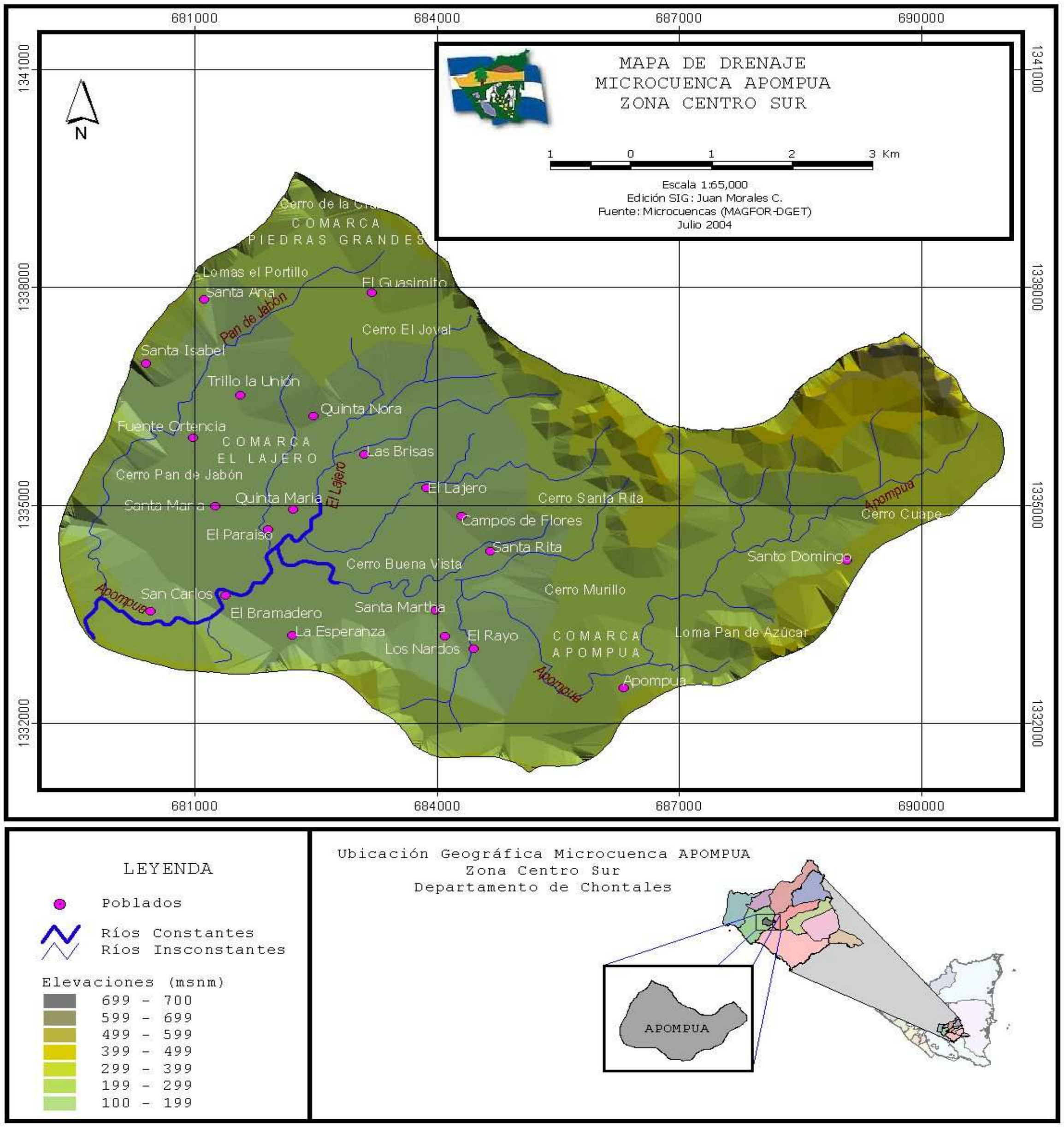

Figure 3: Map of Apompuá watershed, Chontales, Nicaragua (from INTA Centro Sur).

Wells will be selected for performance testing based on the following considerations:

- Wells will be the sole source of water for the household.
- All three will be close enough to test and monitor in one day.
- At least one well will have a history of drying up at end of summer.
- Wells depth and depth of the pumping mechanism must be known.
- Well users appear to be responsible and interested in cooperating with study, willing and able to record daily water use.

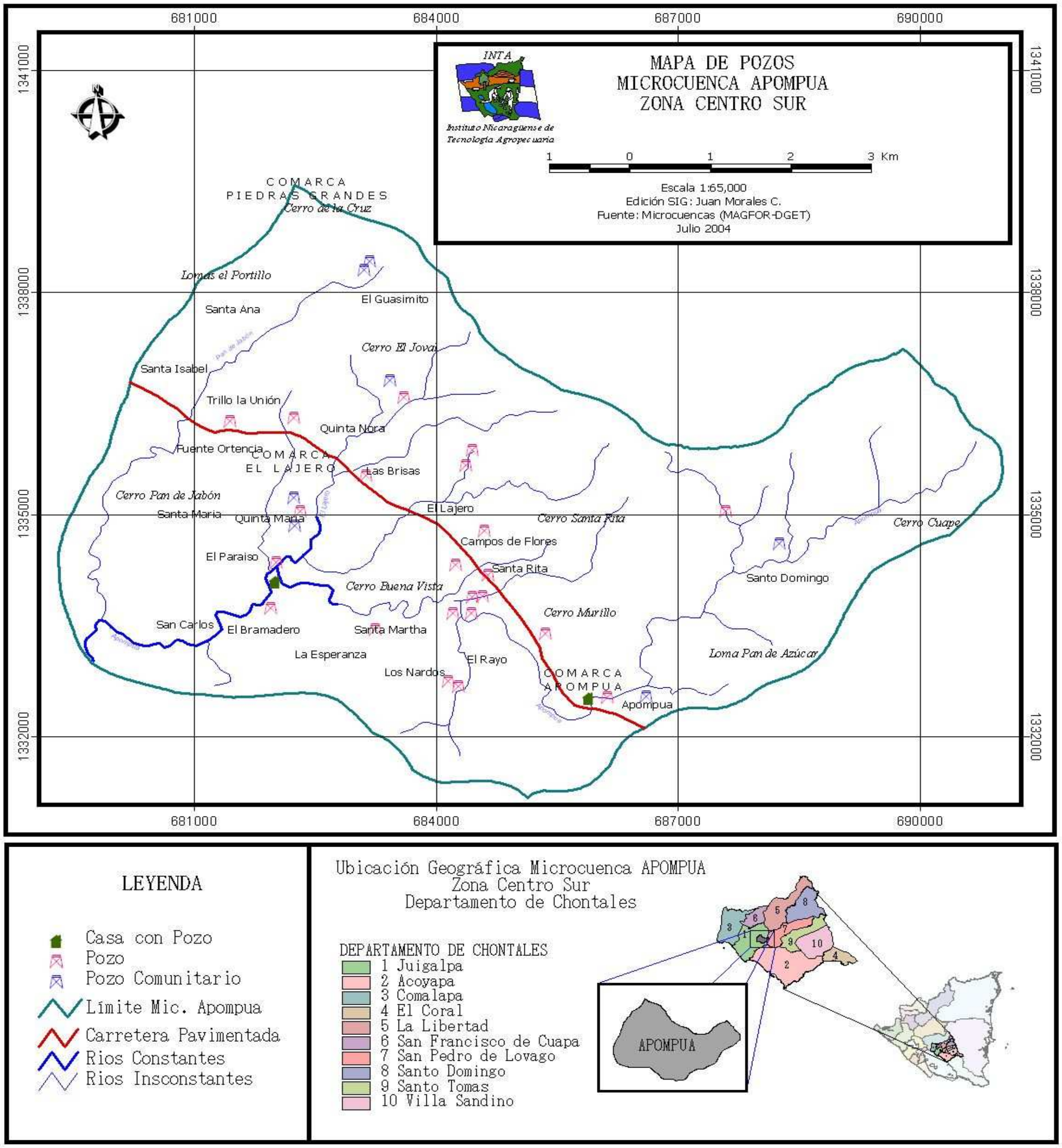

Figure 4: Map of Apompuá watershed wells, Chontales, Nicaragua (from INTA Centro Sur).

Timeline

The study dates may shift due to uncertainties in actual transition from the rainy to the dry season. The approximate timeline is listed in Table 2.

Time period	*Activities*	*Date*
Oct-Nov 2006	Work plan presentation, coordination with organizations	Week of Oct 9
	Well user interviews	Week of Oct 23
	Well selection and signing of work agreements with well committees	Week of Nov 6
	Installation of Rotoplast tank and PVC pipe	Week of Nov 13
	Well sitting to gauge actual well use	Week of Nov 13
	Hire field hand; logistic arrangements	Week of Nov 13
	Preliminary pumping tests (2 consecutive days)	Week of Nov 27
Dec 2006	Pumping tests	Dec 1-10
	Data processing; projection	Dec 10-13
Jan-Jul 2007	Presentation of work-to-date	Jan 20
	Monthly well monitoring	First week each month
	Estimated well use surveys (monthly)	First week each month
Agu-Nov 2007	Write up results	
	Present results in Nicaragua	
	Publish results	

Anticipated Benefits

Approximating the quantity of water available and abstraction rate to ensure the continual use of a well over the course of the dry season would be useful to well users in the following ways:

- Improve efforts to better manage ground water resources to ensure reliability throughout the dry season.
- Provide a quantitative estimate of well capacity and estimated safe yield abstraction rate during the dry season.
- Offer a way to define and regulate equal use of extracted well water in order to avoid conflicts among well users.

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