Konbit Sante
CAP-HAITIEN HEALTH PARTNERSHIP

WATER AND WASTEWATER IMPROVEMENTS AT JUSTINIAN HOSPITAL

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1. INTRODUCTION

1.1 INADEQUATE WATER AND SANITATION ADVERSELY AFFECT MEDICAL CARE AT JUSTINIAN HOSPITAL

The Justinian Hospital (HUJ) in Cap Haitien, Haiti lacks the water and sanitation infrastructure essential to medical care. The hospital has struggled with an inadequate supply since the municipal system broke down. Hand laundry consumes most of the flow, leaving little or no water for doctors to wash between patients. The well water is so hard (nearly brackish) that it fouls the autoclaves used to sterilize surgical equipment. Little water is available for patients and their families, who have to buy drinking water from street vendors and often have none for personal hygiene.

Sanitation at the hospital is as limited as the water supply. Most of the families and patients depend on pit latrines so dirty that many people turn to discrete corners and bushes. Some of the patients and staff have access to toilets that are flushed using water from a bucket. Sanitary wastewater from restrooms and bucket showers flows to cesspools on the hospital grounds. These provide limited treatment but no disinfection. The partly treated wastes discharge underground, leading to contamination of the groundwater supply and the in-ground reservoirs of water located on the hospital grounds.

1.2 MULTIPHASE APPROACH TO IMPROVING THE WATER AND WASTEWATER SYSTEMS

In 2003, Konbit Sante began multiphase project to address immediate water and wastewater needs and develop sustainable solutions for the long-term. The goal was to provide a reliable and sufficient water supply to the HUJ for cleaning, personal hygiene, sanitation, and to a limited degree, consumption.

Phase 1 focused on evaluating the hospital utilities, identifying water priorities, assessing the impact of supporting utilities (e.g., electrical power), and developing short and long term options for improvements. Section 2 summarizes key findings of this analysis.

During Phase 2, volunteers and hospital staff implemented several short term solutions to increase the water supply, eliminate sources of contamination, and reduce leaks in the water distribution system. Section 0 summarizes the work and progress-to-date. The improvements were made possible with the generous support of private donors, Global Giving, Rotary Foundation, and volunteers. Much of Phase 2 was completed by March 2009; however, poor quality water from a new well has required a change in plans, as discussed later in this report.


42,500-Gallon Elevated Storage Tank

In Phase 3, Konbit Sante and staff at HUJ will develop long term solutions for the hospital's water and wastewater systems, with consideration of improvements to the local and municipal systems.

2. WATER AND WASTEWATER SYSTEMS AT HUJ

illustrates a simplified diagram of the HUJ water system at the start of the project. The hospital relied on a single 320-foot deep bedrock well since the municipal water supply ended years ago. The water was pumped to a 42,500-gallon elevated concrete storage tank through a galvanized steel pipe, which passed through a medical waste pile. Water from the storage tank flowed by gravity through a distribution system to in-ground concrete reservoirs (+/- 2,000 gallon storage) located adjacent to many of the buildings. Many of the reservoirs also received rainwater from the building roof.

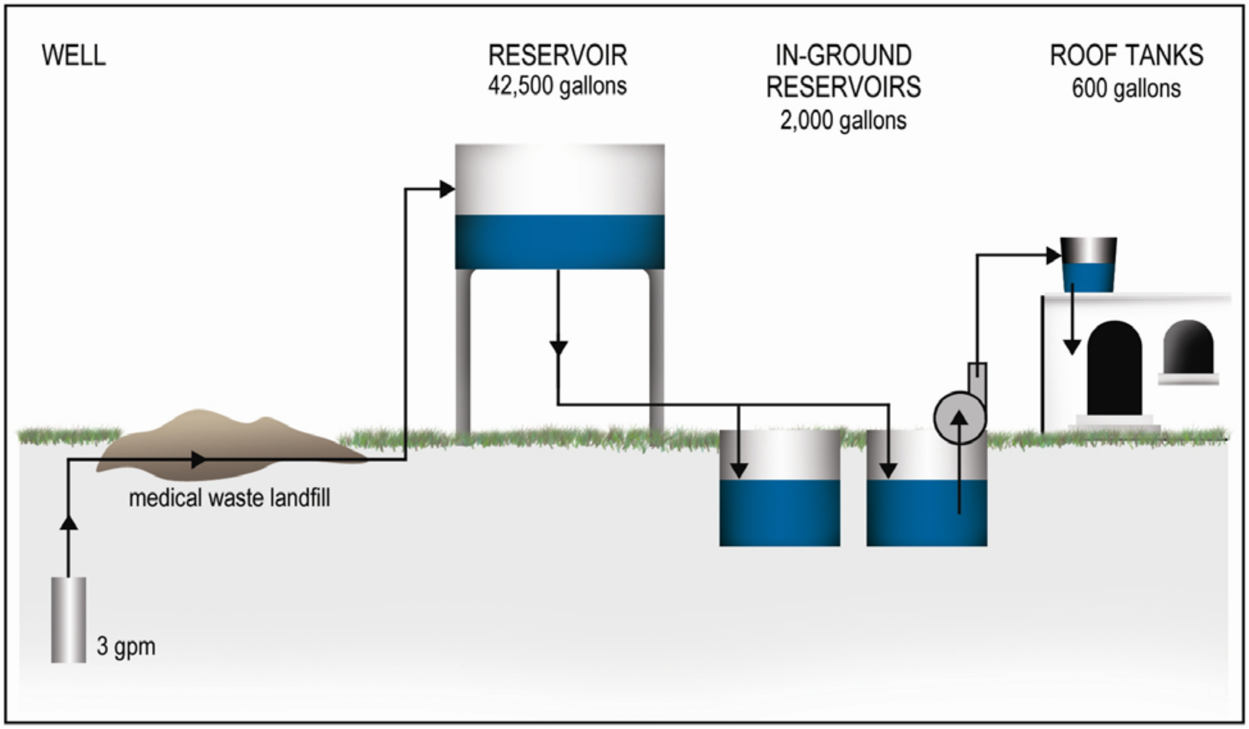


Figure 1 Justinian Hospital Water Distribution System

Several of the reservoirs were equipped with jet pumps that delivered water to 600-gallon black polyethylene tanks mounted on building roofs. Water flowed from the roof tanks to the building plumbing system. These tanks supplied minimal pressure, far less than needed by washing machines, water softeners, sterilizers and other equipment.

During power outages and for buildings or areas that are not served by a rooftop tank, hospital workers draw water by hand from the in-ground reservoirs and fill drums located at the points-of-use. The hospital staff notified the water system operator when they needed water and he delivered it. The reservoirs were otherwise locked to prevent unauthorized access.

Drawing water from in-ground reservoir

2.1 WATER QUANTITY WAS INADEQUATE FOR HOSPITAL

The 320-foot deep bedrock well supplied up to 6,000 gallons per day (gpd) of water to HUJ when there was adequate power. More typically, the hospital lived with less than 2,500 gpd due to frequent power outages.

It has been difficult to define the amount of water needed by HUJ. Most of the staff have operated with so little water for so long that they were unable to define the amount they would need if water were readily available. Similar facilities in less industrialized countries would typically need 18,000 to 24,000 gpd. On the other extreme are typical volumes used by hospitals in the United States, which range from 130 to 260 gallons/bed-day, or 32,500 to 65,000 gallons per day for a hospital the size of HUJ. This volume would be impractical without a viable municipal supply.

The staff and patients used the available well water for laundry, sanitation, and other demands, but not typically for drinking due to the extreme hardness (over 450 ppm). Most people purchased drinking water in packages or bottles from vendors. Even the oral rehydration center, which cared for children suffering from life-threatening dehydration, could not rely on the hospital's water supply.

The hospital administration identified and prioritized its water demands based on its limited supply (Table 1). They did not include several demands listed in the table because the existing supply was insufficient to meet them.

Many but not all water demands needed to meet the drinking water standards. Exceptions included water for sanitation (e.g., flushing toilets), general cleaning, and fire protection, which did not need to be drinking water quality. Some uses (identified in the table) had special water quality requirements beyond drinking water standards.

Table 1 Priority Water Demands at the Justinian Hospital

Rank	Department	Special Quality Requirements	Typical Water Demands						
			Laundry	Hygiene	Toilet Flushing	Drinking	Medical	Sterilizer	Other
1	Laundry	Softened, Hot	√	√					
2	Pharmacy			√		√	√		
3	Maternity	Softened*		√	√	√	√	√	√
4	Surgery	Softened*		√		√	√	√	
5	Dentistry	Softened*		√		√	√	√	
-	Eyes, Ears, Nose & Throat			√		√	√		
-	Family Practice			√	√	√	√		
-	Women's & Men's Ward			√	√	√			
-	Resident Housing			√	√	√			
-	Nursing School			√	√	√			
-	Administration			√	√	√			
-	General Public Use			√	√	√			
-	Fire Protection - general								√

* Softened water is needed for autoclaves and other equipment that heats water.

2.2 WATER SUPPLY CONTAMINATED WITH COLIFORM BACTERIA

The original well supplied a small flow of very hard water. Table 2 summarizes the well water quality based on a grab sample taken at the wellhead in 2003. The water meets the U.S. Drinking Water standards for inorganic compounds but it is too hard for many uses. Hardness, primarily a measure of calcium and magnesium, is a concern because of the operational problems it poses in the distribution system, laundry and sterilizers. Scale in the distribution piping has reduced the effective diameter and carrying capacity of pipes (e.g., reducing a 3-inch diameter pipe to less than 2 inches) near the well and water storage tank. In the laundry, hard water has required more soap and water due to the formation of scum. In equipment with heating elements (e.g., water heaters and sterilizers), hard water has deposited scale, which has shortened the lives of the elements.

Tests Show Hospital Water is Contaminated with Coliform Bacteria (Yellow Jars)

Bacterial analyses found the well water was free of contamination, but all of the water in the distribution was contaminated, including the storage reservoir. Fecal contamination was found in many samples collected from sinks in the hospital. One of the sources of contamination was thought to be the galvanized pipe that passed through the medical waste pile. At a loss of power, the water drained back into the well, creating a vacuum that could suck contaminated groundwater into leaking pipe joints. This could explain how the well water tested clean and the tank water contaminated.

Table 2 Hospital Well Water Quality

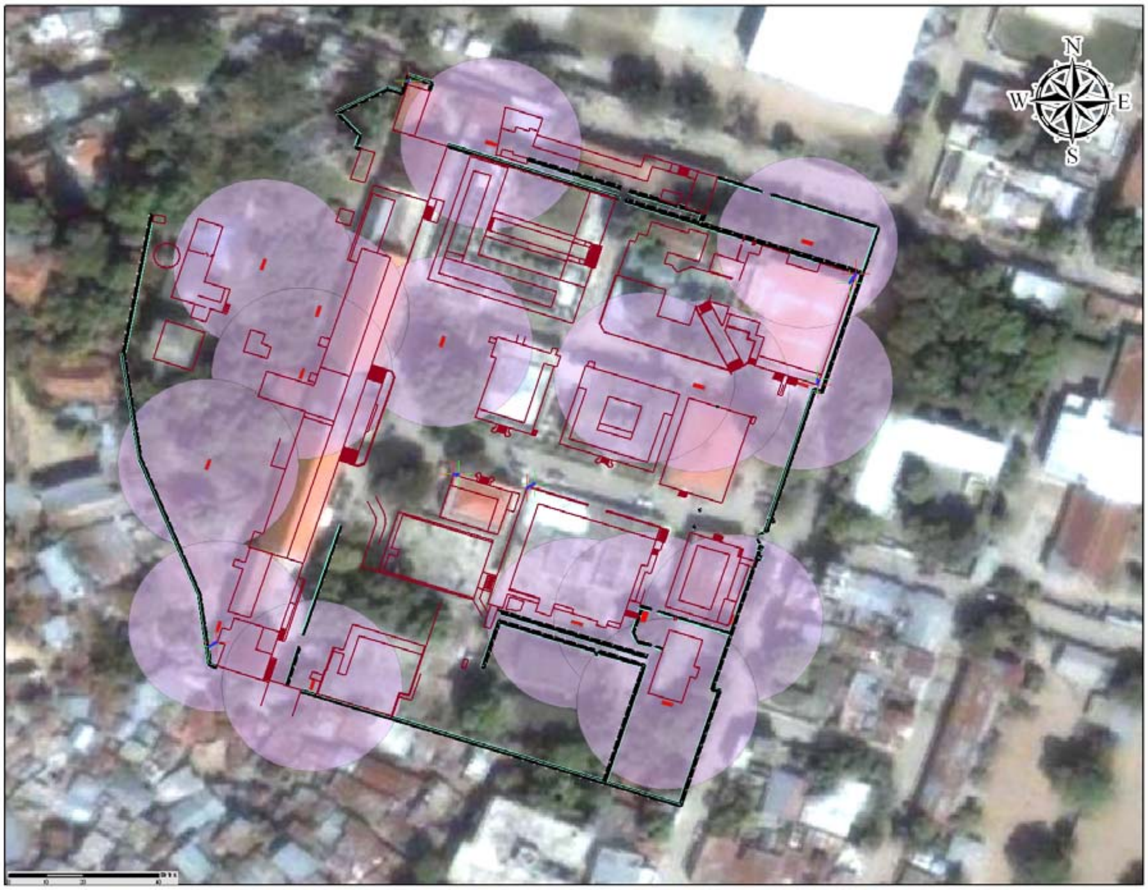
Parameter	Units	Analytical Results	U.S. Drinking Water Standard (MCL)
Conductivity	ppm	625	
pH	SU	7.0	8.5
Hardness	ppm as $CaCO_3$	460	500
Calcium	ppm	104	500
Magnesium	ppm	49	50
Chloride	ppm	93	250
Copper	ppm	<0.01	1.3
Iron	ppm	<0.025	0.3
Manganese	ppm	<0.001	0.05
Sodium	ppm	75	100
Lead	ppm	0.001	0.015
Arsenic	ppm	<0.001	0.01
Fluoride	ppm	0.21	4.0
Uranium	ppb	0.5	30
Color	units	<5	15
Turbidity	NTU	0.2	1

2.3 Wastewater Treatment Threatened Water Supply

Since the start of the project the hospital has used latrines and flush toilets for sanitary waste disposal. Most of the flush toilets required the user to fill them with a bucket. Much of the gray water from showers and laundry discharged to the storm sewer system.

The flush toilets and some other wastewater sources discharged to cesspools located throughout the grounds. These were three-compartment tanks that discharged to the ground without benefit of a leach field or disinfection. Wastes underwent anaerobic digestion in the first chamber, solids settled in the second chamber, and the wastewater was "filtered" in the last chamber through sand before entering the ground. The hospital plumber explained that there was no pumping service in Cap-Haitian to pump out the tanks, so there has been minimal maintenance performed over the years.

Disposal of partly treated wastewater risks contaminating the groundwater and hospital water supply. In the U.S., wells are typically kept 25 meters from wastewater leach fields. Figure 2 illustrates the hospital property with magenta-colored circles extending 25 meters from each latrine and cesspool. The building outlines are in red. There is limited space on the hospital property that is open (i.e., no building), accessible, and outside the zone of possible contamination.



Aerial photograph from Google Earth

Figure 2 25-Meter Zones around Cesspools and Latrines Limit Viable Areas for New Wells

2.4 OPTIONS FOR IMPROVING WATER SYSTEM AT HUJ

The analysis of Phase 1 concluded that HUJ had an inadequate quantity of water due partly to the limitations of the existing well and poor electrical supply. Most of the water was contaminated through infiltration of groundwater into the distribution piping and from rainwater entering the underground tanks adjacent to the buildings. The project team identified a number of improvements to address these problems, estimated their costs and feasibility. The options selected for implementation in Phase 2 were expected to best meet the project goal project goal – developing a reliable water supply that facilitated medical care at the hospital – in the short term (Table 3).

Table 3 Selected Improvements for the HUJ Water System in Phase 2

Task	Description	Comment
1	Renovate the existing well and its power supply	The well needed a more consistent power supply to maximize its output. This included: (1) replacing the electrical service; (2) providing a backup power supply; (3) installing a variable frequency drive to allow the pump to run when 1-phase or 3-phase power was available; and (4) improving the security at the well house.
2	Improve the water distribution system to eliminate leaks and contamination	The replacement of the water main through the waste pile would eliminate an important source of contamination. Other sections were also expected to need repairs once the pipe was pressurized.
3	Provide a new well and associated equipment	A new well would increase the flow, but it might not provide enough water to meet all the hospital's needs [a]. The new well required: (1) providing an electrical service and a backup power supply; (2) constructing a well house; (3) connecting to the distribution system; and (4) installing a chlorine disinfection system.
4	Water conservation	Though opportunities for reducing water use were limited, the installation of spring-loaded faucets was expected to minimize waste once the supply was increased. These faucets would also improve hygiene because medical staff could operate them using foot or knee pedals.

(a) In the mid-1990s, the U.S. Army Corps of Engineers evaluated the water resources in Haiti and reported that in the vicinity of the Justinian Hospital, "unsuitable to small quantities of fresh water are available from Cretaceous to Quaternary igneous and metamorphic rocks," at depths greater than 320 feet.

The selected options focused on increasing the water quantity with less emphasis on water quality. The public health community continues to debate the relative importance of quantity versus quality on reducing water-related morbidity and mortality. In 1993, the United States Agency for International Development (USAID) reported that hygiene and sanitation were more important than water quality in reducing diarrhea, water-borne diseases, and skin infections (Sobsey, 2007). Other researchers subsequently found that improvements in water quality could produce significant (i.e., greater than five percent) reductions in diarrheal and other enteric diseases and should be addressed in water system improvements (Sobsey, 2007). The Disease Control Priorities Project (Cairncross, 2007) recently concluded,

> While availability of clean, uncontaminated drinking water is critical in preventing diarrheas, dysenteries, and typhoid (fecal-oral diseases), increasing water *quantity* and convenience reduce the water-related disease burden the most. Most water-related disease, including skin and eye infections, and diarrhea, is transmitted person-to-person because of a lack of water for personal hygiene. The more water available and the more convenient it is to collect, the more people will use for hand-washing and other hygienic practices.

Some important options, not selected due to limited resources, should be considered in future when there are means. These include, among others:

- Municipal Water Supply: Improving the municipal water supply would greatly benefit the community. The local water company (Société Nationale d'Eau Publique, SNEP) has been working with various non-governmental organizations (NGOs) to reconstruct the municipal water supply. In 2007, engineers have estimated it would cost US$60 million to renovate most, but not all, of the water system. The proposed improvements did not include the hospital.

- Centralized Wastewater Treatment: This could be implemented at the hospital and better for the community. The urban setting, poor quality electricity, and lack of infrastructure to handle residuals complicate any solution.

3. PHASE 2 – IMPLEMENTATION OF WATER SYSTEM IMPROVEMENTS

Volunteers with Konbit Sante have coordinated support from Global Giving, the United Nations, and Rotary Foundation to implement the Phase 2 improvements to the water system. The first construction project focused on eliminating a major source of contamination, a deteriorated pipe from the well to the storage tank that passed through a waste pile. In 2006, a team of local workers installed a seamless plastic pipe, encased in concrete. The type of pipe was not readily available in Haiti, so Konbit Sante shipped it along with medical supplies in a container.

Work in the summer of 2008 focused on maximizing the output of the existing well. Volunteers and hospital staff installed a new electrical service for the existing well. The improvements included a backup power supply and equipment that allowed the pump to run on generator and the municipal power supply. Hospital staff were very pleased with the improved supply, but the volume was still inadequate for all the various needs.

New Electrical Service

Installing New Door on Pump House to Protect Control System

In September 2008, a new well was installed. Konbit Sante worked with the United Nations to locate the well and the UN covered the costs for drilling the well and installing the pump. This saved money for additional improvements to the distribution system.


Drilling the New Well at Hospital

We contracted with a Haitien builder to construct a masonry pump house, which provided a secure and weather-tight enclosure for the backup power supply, pump controls and disinfection system.

Konbit Sante volunteers returned in January and March of 2009 to connect power to the pump and connect the pump to the water distribution system. Electricians installed a new electrical service, connected an inverter with backup battery power supply, and installed a level sensor to monitor and help control the pump. Plumbers installed a chlorine disinfection system and replaced critical valves and leaking sections of pipe in the distribution system. The hospital administration asked that the pipe from the well be installed along a different route than originally planned, which required some additional valves, but avoided disruptive construction through a key building.

The well began delivering approximately 18 gpm of water in March 2009, increasing the hospital's supply by over six times. The relative abundance appeared to have solved HUJ's problem of an inadequate supply.

Subsequent laboratory tests at the State of Maine found elevated concentrations of nitrate (43 mg/l). The Safe Drinking Water Act regulates nitrates to less than 10 mg/l because higher concentrations can harm or kill infants and fetuses. The nitrates were probably from the wastewater cesspools located throughout the hospital grounds. The geology of the area would be expected to have fractures or cracks in the bedrock which could allow partly treated wastewater to reach the well, even though the closest cesspool was over 25 meters away.

The hospital stopped operating the well, concerned that some parents might unknowingly harm their children by giving them a glass of water. A sample collected after the well had been offline for six weeks contained 24 mg/l nitrates. It is possible the nitrates are being flushed from the groundwater, but their concentration is still too high for consumption by infants.

4. PATH FORWARD

Elevated nitrates in the most abundant well have required a reexamination of the next steps toward improving the water system at HUJ. Of the following four options, Option 4 – separate distribution systems for utility and potable water – seems most suitable for HUJ.

- Option 1: Water Treatment – Water treatment systems (e.g., ion exchange) can remove nitrates, but such systems are expensive and impractical in Haiti, which lacks the infrastructure (e.g. companies who can regenerate and replace the ion exchange resin) to maintain them.
- Option 2: New well – A new well could be installed, but with all of the cesspools located around the hospital, it would likely be contaminated unless it was very deep.
- Option 3: Centralized Wastewater Treatment – The hospital could install a centralized wastewater treatment system and remove the cesspools. This would address an important need at the hospital, removing the likely source of nitrate contamination. It would probably take several years for the nitrates to be flushed from the groundwater, so this solution would not provide immediate benefits.
- Option 4: Separate Water Distribution Systems – Two water distribution systems could be installed at the hospital. The new and highest yielding well would connect to the existing elevated storage tank and flow by gravity to each building. It would supply utility water for cleaning, personal hygiene, toilets, and other demands that did not require potable water. These uses comprise the greatest demands in all water systems. The older and lower yielding well would supply drinking water to a few select buildings or faucets. Konbit Sante would work with the hospital to identify the preferred locations. This potable water could be softened to make it more palatable and disinfected to prevent contamination in the distribution system.

The fourth option represents a viable alternative to help the hospital meet its water needs in the short term. It is consistent with the original project goal and could be paid for with the funds saved by having the UN drill the new well and by finding an alternate route for connecting the well to the storage tank.

If implementation of Option 4 does not use all of the remaining funds, the extra money could be used to install water conservation fixtures in key settings and to install gravity sewers for the future wastewater treatment system.