GUDI Wells: A Challenge in Developing Safe Drinking Water Supply, Republic of Tobago

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ABSTRACT
The Government of the Republic of Trinidad and Tobago has launched a major initiative to transform the nation into developed country status by the year 2020. Fundamental to the government's vision is a major investment in infrastructure and the environment for a reliable water supply and wastewater treatment facilities. This hydrogeological study undertaken in Tobago as part of the Master Plan found that most of the production wells in Tobago correspond to alluvial valleys. Due to the proximity of the wells to surface water bodies, these wells were flagged as potentially under the direct influence of surface water (GUDI), and were recommended for additional treatment to ensure safe drinking water. However, this option has the potential to negate the use of groundwater as a source of practical, cost effective, sustainable water supply.

RÉSUMÉ
Le Gouvernement de la République de Trinité et Tobago a lancé une grande initiative pour transformer la nation dans le statut de pays en voie de développement par l'an 2020. Le principe de base à la vision du gouvernement est un investissement majeur dans l'infrastructure et l'environnement pour une provision d'eau fiables et les facilités de traitement d'eaux usées. Cette étude de hydrogeological entreprise dans Tobago comme la partie du Projet Professionnel trouvé que la plupart de la production bien dans Tobago correspond aux vallées alluviales. En raison de la proximité du bien apparaître des corps d'eau, ces ont été bien fléchi comme potentiellement sous l'influence directe d'eau de surface (GUDI), et ont été recommandé pour le traitement supplémentaire pour garantir boire l'eau sûre. Cependant, cette option a le potentiel pour annuler l'usage d'eau souterraine comme une source de provision d'eau pratique, du rapport coût-efficacité et viable.

1 INTRODUCTION

Groundwater is a precious, cost effective resource, which if used through proper understanding and planning can serve as an economic source for sustainable water supply to communities. As part of the understanding of the availability of this resource and its sustainable development, scientific understanding of the origin, occurrence and flowpaths, as well as the ecosystem features it supports is needed.

Based on sound scientific understanding, source water protection plans can be prepared at a groundwater basin scale for sustainable development and protection of the resource. Proper planning to protect source areas can also help to reduce treatment costs and ascertain long-term cost effective solutions.

With this principle in mind, a scientific understanding of the existing groundwater resources in Tobago was obtained through site visits and review of available reports as part of the existing conditions assessment of the Water Supply Master Plan.

As part of the well condition assessment, site visits were conducted to each production well in Tobago. The purpose of the site visits was to assess the physical condition of the well and associated infrastructure, potential contaminant sources around the wellhead, and the preliminary GUDI status of the well.

As part of the contaminant risk assessment, a preliminary investigation on the GUDI status of the well was conducted. GUDI is defined as groundwater wells under the direct influence of surface water. A GUDI well is one which pumps surface water and as such, the water from the wells needs to be treated equivalent to surface water. As such, GUDI designation of a well has major implications in cost in designing safe drinking water supply. As part of the GUDI assessment, well construction details were examined to determine the potential relationships between the well, the aquifer and nearby surface water features.

2 BACKGROUND

2.1 Physical Setting

The twin island Republic of Trinidad and Tobago is the southern most Caribbean nation, located off the northeast coast of Venezuela. Tobago is located between 11° 09′ and 11° 20′ North Latitude and 60° 30′ and 60° 50′ West Longitude (Figure 1). It has a total area of about 300 square kilometers and extends 18 kilometers east-west and 41 kilometers north-south. Tobago is located approximately 32 kilometers northeast of Trinidad, and is separated from Trinidad by a channel.

The climate in Tobago is tropical, with two major seasons. Generally the dry season is during the months of January to May and wet season is during the months of June to December. The average annual temperature is 26.8°C with diurnal variations of about 6°C (DHV Consultants BV, 1999). The average annual rainfall in

Tobago ranges from 3800 mm on the Main Ridge to less than 1250 mm in the southern lowlands (Maharaj, 2004).

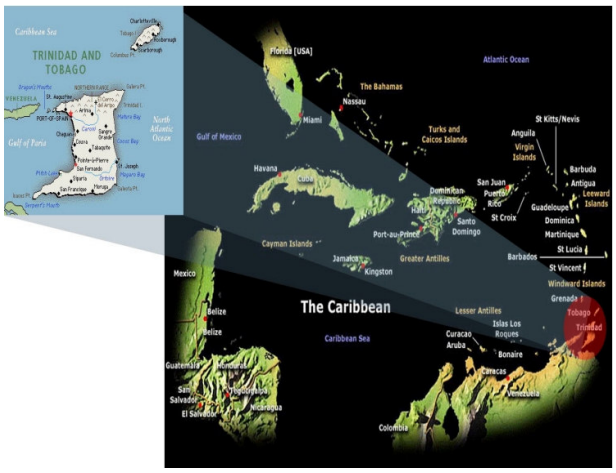

Figure 1. Location of Trinidad and Tobago.

There are two main physiographic features in Tobago: The Main Ridge and Coastal Plain. The Main Ridge runs from the southwest to the northeast and is the dominant relief feature of Tobago. It is a metamorphic and volcanic mountain with a peak elevation of 550 meters above mean sea level. The Main Ridge is about 18 km long and 5 km wide, and occupies the northern third of the island. The southwestern end of the island is occupied by a flat coral limestone platform and is fringed by offshore coral reefs.

2.2 Geology and Hydrogeology

The Water Resources Agency (WRA), a division of the Water and Sewage Authority (WASA) of the Republic of Trinidad and Tobago is responsible for the nation's water resources management. In order to carry out its mandate, the Agency has divided Tobago into five hydrometric areas, which are major hydrologic units that correspond with surface water divides or watersheds. These hydrometric areas, or watersheds, have been further subdivided into fifteen subwatersheds. The well condition assessment, a part of this groundwater study, has been carried out based on these hydrometric areas.

The geology of Tobago is mainly composed of igneous and metamorphic rocks from the Mesozoic period. These rocks that form approximately east-west-striking belt that transect the island, have been divided into 4 main groups: 1) North Coast Schist; 2) amphibolite facies aureole; 3) the ultramafic to plutonic complex; and 4) the Tobago Volcanic Group. There are a number of major and minor faults of all scales occurring as fractures within the island. In the southwestern part of Tobago, Pleistocene coralline limestone is underlain by Tertiary sedimentary deposits that consist of clay, silts, sandstone and gravels (Rockly Bay Formation) (Maharaj, 2004).

3 METHODS

3.1 Review of Existing Information

Available reports reviewed as part of this study, including Metcalf & Eddy (1970), DHV Consultant BV (1999), Water Resources Agency (2001) and Maharaj (2004), indicate that the abstraction of groundwater in Tobago occurs from two types of aquifers, commonly referred to as traditional aquifers and megawatersheds.

Groundwater abstraction occurs traditionally from the quaternary coral limestone, the clastic sedimentary deposits and the alluvial material. The coral limestone in the southwestern part of the island is approximately 12 m thick and highly fractured. According to Metcalf & Eddy (1970) and DHV Consultant BV (1999), groundwater potential exists in this aquifer, but the yield was estimated to be less than 0.083×10^6 m^3/year. Wells drilled into the limestone platform have encountered brackish water and are at present being used for observation purposes (Water Resources Agency, 2001). Abstraction of fresh groundwater occurs from clastic sedimentary deposits in the southwestern part of Tobago (around Rockly Bay), an area with especially high demand for potable water. The alluvial material to the north (Bloody Bay) and central parts of the island are also areas with fresh water bearing potential. According to DHV Consultant BV (1999), estimated yield of groundwater from the traditional aquifers in 1995 was 0.15×10^6 m^3/year. A hydrogeological map of Tobago is provided in Figure 2.

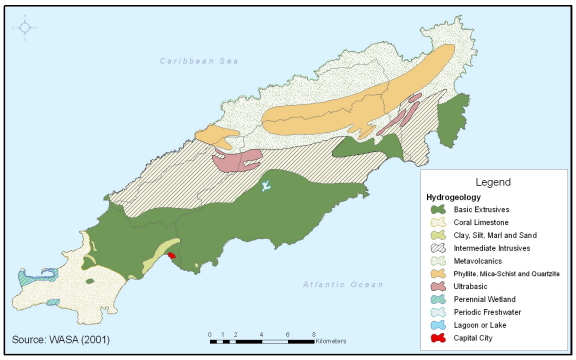

Figure 2. Hydrogeological map of Tobago.

In 2000, the concept of megawatershed was introduced by Lennox Petroleum – Earthwater Technology International (2000). According to this concept, the existence of deep-seated, fracture fed, bedrock aquifers in the island were identified. The term Megawatershed was used to refer to deep-seated sub-surface groundwater systems that may consist of gravel, fracture-hosted (fed) bedrock or sedimentary structures, which are integrated in terms of recharge, discharge, storage, circulation and containment. According to Lennox Petroleum Earthwater Technology International (2000), due to their regional extent, these megawatersheds may not coincide with surface

topographic divides, and may receive recharge from areas of several surface watersheds. In fact, the Megawatersheds have been categorized as large sub-regional, subsurface basins that receive groundwater from several surface catchments in the region. They end where there are no more aquifer quality rocks, or the flow is restricted (Water Resources Agency 2004). The Lennox/ETI (2000) study indicates that a total of 66×10^6 m^3/year of water is available for safe withdrawal from the Megawatersheds. This study proposed sixteen broad areas called favourable zones, which are recharged by the Megawatersheds, where 3.95 $\times10^6$ m^3/year has already been developed.

4 RESULTS AND DISCUSSION

For the purposes of this paper, the information has been organized based on hydrometric areas. A map showing the hydrometric areas and the Tobago water supply wells are provided in Figure 3.

Figure 3. Hydrometric Area Boundaries and Well Locations.

4.1 Well Condition Assessments

GENIVAR's field team performed well condition assessments on all production wells, as well as the majority of observation and abandoned wells, in Tobago. A Water and Sewerage Authority operator escorted the GENIVAR field team and answered questions relating to the wells. Major issues identified during the well condition assessment were related to the proximity of the wells to surface water bodies, access to the wellheads, and quality of the wellheads, well casings and surface seals.

Many of the production wells are located adjacent to surface water bodies, or in their floodplains. This is a concern as these wells may be under the direct influence of surface water (GUDI - Groundwater Under the Direct Influence of Surface Water), and therefore may require additional treatment to ensure safe drinking water quality. In addition, compromised surface seals around the wells, such as cracked or absent concrete pads, damaged well caps, or holes in casings, increase the potential for entry of contaminants into the aquifer. This potential is increased further in locations where site security was found to be a concern, especially in areas where fencing and gates were either not present or significantly damaged, allowing access of unauthorized persons. A more detailed account of the conditions of the various wells can be found in the Review of Groundwater Resources Part II: Tobago (GENIVAR, 2007).

4.1.1 Potential Water Quality Threats Assessment

During the site visits to evaluate the existing condition of the wells, potential threats to water quality were assessed through observation of land uses and site conditions around the wellhead. A preliminary evaluation of potential contaminant sources can be inferred as follows:

- Residential areas - potential for vandalism;
- Rural residential areas - potential for contamination by septic systems;
- Commercial and Industrial areas - potential for commercial and industrial pollution (i.e. solvents, hydrocarbons);
- Agricultural areas - potential for contamination by pesticides, herbicides, fertilizers;
- Livestock areas - potential for contamination by animal feces;
- Oil producing areas - potential for contamination by hydrocarbons and deep brines;
- Other areas, including power stations, transformers, gas stations - potential for contamination by hydrocarbons and fuel tanks;
- Other wells on site - provide preferential conduits for contamination; and
- Surface water - Wells in close proximity to surface water are generally considered to be under the influence of surface water until proven otherwise (termed "GUDI" in Ontario). This is a major issue as under GUDI conditions, groundwater is treated as equivalent to surface water to safeguard the potable water supply.

A summary of the potential contaminant sources is provided in Table 1.

Table 1. Number of wells identified by contaminant potential.

Potential Contaminant Issue	Number of Wells
Residential Areas	1
Rural Residential Areas	4
Commercial Areas	0
Industrial Areas	0
Agricultural Areas	10
Livestock Areas	3
Oil Producing Areas	0
Other Areas	1
Sites with Additional Wells	11
Near Surface Water	18

4.2 Groundwater Quality

Groundwater quality information was provided for twenty-one groundwater samples of different production and observation wells in Tobago. The available data covered the period of 1982 to 2001 (database provided by Water Resources Agency). This data set was used to assess and characterize the geochemistry of the groundwater resources. In this respect, the major anions and cations including Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, SO^{2-} and HCO_3^{-} were plotted on Piper diagram. In order to reduce the potential for compromised samples, a charge balance analysis was conducted on samples that had a complete set of major anions and cations. In situations where the charge balance error exceeded 5%, the water quality information was omitted from the assessment. As a result about 86% of water quality samples were omitted either because they did not satisfy the error criteria or did not have a complete set of major anions and cations. Therefore, only three samples were used for the assessment.

Of these samples one was from Courland 1A, which is screened in the Courland Gravel, and two samples were from Bloody Bay 1, which is screened in the Bloody Bay Gravel. All the samples were graphically represented on piper diagram. The groundwater signature in Courland 1A is calcium chloride (Ca-Cl) type. The chloride concentration and TDS in this well are 3090 mg/L and 5855 mg/L respectively. The source of the salinity raises the issue of either seawater intrusion or the mobilization of deep seated brines and should be further investigated in order to determine the sustainable development of groundwater at this location.

The groundwater signature in Bloody Bay 1 is magnesium bicarbonate (Mg-HCO_3) type with the TDS and chloride concentration of 199 and 21 mg/L respectively. These findings suggest that the source of chloride should be investigated further. No long-term monitoring data was available to conduct trend analysis in order to understand the source. There was insufficient data available to carry out the trend analysis and to evaluate the anthropogenic impacts on the groundwater quality in Tobago.

4.2.1 Groundwater Quality Issues

According to Water Resources Agency (2001), the most serious threats to groundwater in Tobago come from nitrate and bacterial contamination arising from agro-chemical use and sewage effluents from pit latrine soakaways and septic tanks. Saltwater intrusion as a result of over abstraction in coastal aquifers is another concern.

This study also identified the potential for mobilization of deep seated brines in fractured rock aquifers. To address the salinity of groundwater in high TDS areas, an isotopic investigation is recommended to understand the origin and source of the salinity to develop the aquifers as sources for a sustainable water supply.

5 CONCLUSIONS

The following conclusions were made from this study:

- Most of the wells in Tobago are GUDI wells. To develop potable water supply, water from these wells needs to be treated equivalent to surface water.
- The existing water quality data suggests areas of high chloride content. To address the salinity in high TDS areas, an isotopic investigation is recommended.

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