USGS

WATER RESOURCES RESEARCH GRANT PROPOSAL

Title: Wellhead Protection Area Management Standards

Focus Category: COV, EDU, GW, HYDROL, M&P, NPP, NU, WQL, WS

Key Words: Aquifer Characteristics, Aquifer Parameters, Groundwater Hydrology, Groundwater Quality, Groundwater Management, Groundwater Quality, Hydrogeology, Planning, Public Health

Duration: March 1, 2000 to February 28, 2001

Fiscal Year 2000 Federal Funds: $25,000

Non-Federal Funds Allocated to Project:

Names of Agencies and of Principal Investigators:

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Congressional District: N/A

Statement of the Critical Problem

The groundwater in the Virgin Islands is highly mineralized, often containing total dissolved solids (TDS) in excess of 1000 parts per million (PPM). Sodium, magnesium and calcium are the primary constituents, rendering continued consumption of untreated groundwater unhealthy for those on a restricted sodium diet.

A large number of homes in the United States Virgin Islands utilize onsite sewage disposal systems because of the unavailability of public sewerage. However, because

local soil conditions (typically a thin layer of topsoil covering a rock substrate) do not lend to appropriate treatment of household sewage, groundwater resources are at risk for contamination by inadequately treated sewage. Additionally, elevated nitrate levels and coliform bacteria have been found in some wells near the main sewer conveyance lines. Compounding this situation is the propensity of the local policy makers to alter use limitations and density requirements on properties (through the rezoning process), thereby creating the potential for increased sewage discharge because of increased density. The absence of protective measures, based on scientific analyses, which would ensure that wells which serve as public drinking water supply are protected could lead to a repeat of the Tutu aquifer contamination.

Wellhead protection is vital to the long-term quality of life in the VI as the population increases. Fresh water is an especially valuable resource in the VI. The meager but important groundwater resources are valuable supplements to the expensive, highly energy-consumptive desalinated water which is so heavily relied upon by much of the population of the VI. Existing untainted groundwater resources must be protected. The resources that have already been subjected to contamination by leaking underground storage tanks (USTs), leaking sewer lines and improper storage and disposal of chemicals, must be managed to protect adjacent uncontaminated sources and restore damaged resources for future use.

Statement of the Results and Benefits

In the Virgin Islands groundwater contributes up to 30% (or about 1 million gallons per day (MGD)) of the Virgin Islands Water and Power Authority's (WAPA) potable water supply on the island of St. Croix (when the well fields are operating at or near capacity). Groundwater resources also comprise a small percentage of WAPA's potable water distribution on the island of St. John. No groundwater is used in the WAPA distribution system on St. Thomas at the present time; however, the Authority has previously investigated the use of groundwater in the Sugar Estate area to augment the current desalinated water supply. Additionally, several independent water suppliers in the Virgin Islands use groundwater as their water source for trucked and bottled water distribution. Utilizing St. Croix as a study area, the project will accomplish the following: 1) address the roles of various territorial, federal and other agencies within the context of the Wellhead Protection Program (WHPP); 2) develop and evaluate the methodology for the delineation of wellhead protection areas (WHPAs); 3) establish the process for inventorying potential contamination sources; 4) identify management mechanisms adequate to protect groundwater supplies; 5) incorporate contingency plans for public water systems; 6) establish requirements for new well development and 7) establish and expand the venue for public participation in the development and management of a WHPP.

The research and results of this project would be applicable to small islands with similar topographic and hydrogeologic conditions that utilize groundwater for public drinking water.

Nature, Scope and Objectives of Research

The proposed project is a practical application of standardized methods of defining wellhead protection areas. It will also incorporate the planning process to ensure proper management of those areas in order to protect the groundwater resources that are utilized by the public. It is intended to be developed and used as a model that can be applied for water quality protection of wells providing public drinking water within the U.S. Virgin Islands and in other small tropical islands with similar hydrogeological and topographical conditions.

The research proposed in this project is intended to:

- Create a systematic methodology for defining the land area around public water supply wells that may impact the quality of the water from those wells;
- Prepare a set of development standards governing the land uses and densities that may be permitted in those critical impact areas;
- Incorporate the delineations (in mapped form) and development standards into a format that can be used as a model for the creation of a Wellhead Protection layer of the draft Virgin Islands Comprehensive Land and Water Use Plan;
- Disseminate the model to other small tropical islands with similar hydrogeological and topographical conditions.

This project will be conducted on St. Croix utilizing public water supply wells that are representative of similarly situated wells throughout the Territory. The protective regions that are developed for areas surrounding the wells will define permissible land uses, based on the potential for contamination of the aquifer supplying the wells and will examine the limitation of densities to ensure appropriate aquifer recharge. Requirements for connection to public sewerage systems or alternative Onsite Sewage Disposal Systems will also be examined as a part of this project.

Methods, Procedures and Facilities

In the Virgin Islands, groundwater is held primarily in three types of aquifers, principally under water table or semi-confined conditions:

a)Carbonate rock system in St. Croix, known as the Kingshill aquifer system. The Kingshill aquifer system is comprised of Miocene-aged limestone rock. It overlies the Jealousy Formation, which is markedly different in color (often called the "blue clay"), but is mineralogically and paleontologically very similar to the Kingshill. Both are thought to have been deposited in deep water, possibly greater than 1000 meters in depth (Gill & Hubbard, 1987). The post-Kingshill carbonates, generally representing reef and shallow-water facies overlie the Kingshill. This formation is less extensive than the Kingshill, but generally more permeable. In areas, this is overlain by Quaternary alluvium derived from the surrounding hillsides - primarily volcanoclastic debris.

b)Fractured bedrock aquifers in the Tutu Valley and Sugar Estate areas of St. Thomas and in the Estate Adrian area on St. John, for example. The Tutu aquifer of St. Thomas has the highest potential yield of any aquifer on the island - estimated to be in the order of 300,000 gallons per day (Jordan and Cosner, 1973). This type of aquifer is comprised of preferentially fractured bedrock overlain by a veneer of unconsolidated alluvial material varying from a few feet to tens of feet thick. As much as six (6) feet of the upper surface of the bedrock is commonly weathered (saprolite) (Geraghty & Miller, 1994), depending upon location. Less weathering is evident on the steep slopes; more in the valley floor. Groundwater is held principally within the fractures in this bedrock with lesser amounts held in the upper weathered saprolite and overlying unconsolidated deposits. The degree of saturation of the upper portions of the aquifer is dependent upon the intensity of pumping in the area and the overall climatic conditions.

c)Bedrock and alluvial deposit aquifers, in the La Grange area of St. Croix, the Long Bay area of St. Thomas and the Coral Bay area of St. John for example, are at the base of watersheds adjacent to the sea on all the islands. The deposited alluvial material was eroded from the surrounding hillsides. The parent rocks are primarily volcanic in origin with the resultant weathered material having high clay content. The groundwater is found in the interstitial spaces within the alluvium and in fractures in the underlying bedrock.

Methodology:

The two criteria for Wellhead Protection Area (WHPA) delineations are: 1) average time required for the groundwater to flow to the well (Time of travel = TOT); and 2) the effects of hydrologic boundaries (e.g., faults, streams and ridge lines). These criteria will allow a technical definition of the WHPA such that the WHPA will represent the actual contributing area (zone of contribution = ZOC) for that well (or well field).
TOT will be used to identify risk zones around the well. It can be expected that various land uses constitute varying risks to the quality of the groundwater received at the well and that the risks to the well diminish as the time of travel and distance from the well increase.

The WHPA will identify zones based on the following:

a) Ownership of the area surrounding the wellhead.
b) A 200-day TOT distance from the well, which will provide a reasonable margin for attenuation of bacteria.
c) A 1-year TOT distance from the well, which will ensure attenuation of most viruses.
d) A 5-year TOT distance, to ensure containment of known contaminant sources within the ZOC.
e) A 10- to 15-year TOT within the ZOC to assure an effective pollution mitigation response to a known pollution source.

All TOT distances from sample wells will be plotted on maps utilizing ArcView® Geographic Information System.

The delineation of the WHPA will be one of three methods, based on the amount and quality of information available: 1) Calculated Fixed Radii Method, 2) Simplified Variable Shapes Method, and 3) Numeric Flow/Transport Models, if time and monies are available.

The Calculated Fixed Radius (CFR) method of WHPA delineation uses a simple volumetric flow equation to calculate a radius around the wellhead for a given TOT. The data required to determine a CFR include the time of travel, well pumping rate, porosity of the aquifer and open screen interval.

The Simplified Variable Shapes (SVS) method requires, in addition to the data specified above, data for hydraulic gradient, hydraulic conductivity, saturated thickness and hydrologic divides. SVS provides more realistic down-gradient and lateral limits to the water source for the well.

The development of Analytical Flow and Transport models (AFT) to more closely represent actual field conditions requires significant site-specific information for calibration. The basic type of information needed is similar to the SVS method, however more data points are required within the study area to ensure accurate representation of groundwater flow.

The USGS-WRD has been the principal repository for aquifer characteristics information in the VI. The USGS-WRD has generated a series of reports of groundwater studies during the past 20 years, which will provide values for groundwater gradient, hydraulic conductivity, aquifer transmissivity and porosity. Information on pumping rates is obtainable from the PWSS. WAPA, for example, keeps daily records on wellfield production (not for individual wells, however). These generalized aquifer parameter data will be used for initial calculations for WHPAs until time and monies are available to refine estimates.

In general, the more complex the model chosen, the more expensive and time consuming the model will be to use, however this increased complexity usually results in a more accurate representation of actual field conditions.

Choice of the delineation method will be dependent upon several factors including: 1. population served by the well or wellfield, 2. threat of contamination to the well or wellfield, 3. amount and quality of data available.

Related Research:

The Water Resources Research Institute, in conjunction with the Virgin Islands Department of Planning and Natural Resources, has several ongoing research projects which will provide relevant information for this project. Among these are:

a) *DPNR Demonstration Project* – a project that has demonstrated the effectiveness of a constructed wetland as an alternative On-site Sewage Disposal System (OSDS).
b) *Coral World Demonstration Project* – a project which will utilize an alternative OSDS in a commercial application.
c) *Extended Monitoring of the Alternative OSDS* – intended to further quantify the effectiveness of the DPNR Demonstration Project.
d) *Sewage Disposal Regulations* – drafting of proposed regulations for the use of alternative OSDS, when public sewerage is not possible and conditions are not conducive to construction of traditional OSDSs.
e) *Virgin Islands Conservation District/OSDS* – drafting of proposed regulations for the construction of traditional OSDSs.

Additionally, the Department of Planning and Natural Resources' Pesticide Program, in conjunction with the University of the Virgin Islands Agricultural Extension Program has engaged in two projects that will be applicable to this study.

a) *Identification of Aquifers* – an inventory of all aquifers on the island of St. Croix. This project has been completed.
b) Inventory of Farmers that Apply Pesticides – an ongoing inventory of farmers on St. Croix who are certified to apply pesticides on their farms.