Ground Water Information System Uploaded to the Internet
Case Study: Rio Minho Basin, Jamaica

Authors

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Abstract

All ground water information from one of ten hydrologic basins of Jamaica has been transferred into a dedicated, object-oriented Ground Water Information System (GWIS). The GWIS stores information on lithology of wells, water quality over an extended period of time, evolution of water levels, abstractions for irrigated agriculture (notably sugar cane), domestic water supply, and industrial uses. Numerous maps and dedicated diagrams, graphs, and cross sections are made a part of the GWIS. The interpretation and analysis of data is assisted with the tools that are integrated into the GWW software. The data are presented in "four" dimensions: two spatial dimensions, time and depth.

After the GWIS was created and information interpreted, it was decided to transfer all data to a dedicated website and make the data public. The site is at URL http://www.geocities.com/kkaranjac. The site contains about 14 MB of raw data, maps, diagrams, good quality printouts and textual interpretation. The highlight of the Internet-based presentation is the discussion and graphical interpretation of the vulnerability of the ground water in this basin of Jamaica.

This is a joint project of the International Centre for Environmental and Nuclear Studies (ICENS) of the University of the West Indies and Water Resources Authority of the Ministry of Water and Housing of the Government of Jamaica.

1. Introduction

1.1. Purpose of the Project

The Ground Water Information System (GWIS) for the Rio Minho Basin was recently created as a part of ICENS activities in mapping the vulnerability of ground water (aquifers) to pollution. The following was identified as the purpose of the project.

(a) To transfer all available ground water and environmental data into one relational database.
(b) To analyze, interpret, cross reference data and turn data into information, that is, to establish a ground water information system.
(c) To share data and interpretation of data with all interested in ground water of Jamaica by uploading GWIS to the Internet.
(d) To use data and information to address the issues such as the vulnerability of Jamaican aquifers, ground water management, and monitoring eventual effects of industrial and agricultural contamination.

The Rio Minho Basin in south-central Jamaica (Fig. 1) was selected for the pilot study. Its GWIS, which is uploaded to the Internet at the above URL, is the subject of this presentation.

The Rio Minho Basin is the major ground water producing basin in Jamaica. Its annual abstraction may reach about 400 million cubic metres (MCM) in one year. Most of the water is consumed by agriculture (sugar cane field irrigation). Domestic water supply and industrial use for refining bauxite to alumina are the other two major consumers.

1.2. Methodology

Phase 1.

- The transfer of data from various digital formats and hand written notes (spreadsheet, database, document, ASCII text, paper reports, etc.) into a relational database using a ground water dedicated software. The software used is the United Nations Ground Water for Windows[1] (GWW) package.

Phase 2.

- Processing of all data and turning the data into information. For data visualization, the following software is used: GWW (GWIS software) and ArcView (GIS software).

Phase 3.

- Writing chapters on geology, hydrogeology, water quality, abstraction (pumping), water levels and water balance and uploading all this to the Internet. Preparing maps and other graphics to place them on a web site. The software used is Multimedia's Dreamweaver, Adobe's Photoshop, ESRI's ArcView and GWW.

1.3. Potential Users of the Rio Minho Web Site

- Government agencies responsible for water and soil usage and protection of natural resources. In the case of Jamaica, these are Water Resources Authority (WRA) of the Ministry of Water and Housing, Ministry of Agriculture (MA) and National Resources Conservation Authority (NWCA).
- Major users of ground water and owners of production wells: Sugar Company of Jamaica (SCOJ), National Water Commission (NWC), National Irrigation Commission (NIC), and Jamaica Aluminium Company (JAMALCO).
- University students, notably in geology, water resources management, chemistry, and geography.
- Non-governmental groups concerned to preserve the environment.
- Members of the National Commission on Science and Technology which is chaired by the Prime Minister.

2. Ground Water Information System (GWIS)

The data base established for the Rio Minho basin of Jamaica contains data from about 500 wells (Fig. 2), 30 springs, 300 chemical analyses, over 100 time series of major indicators of ground water quality over the last 20 years, 160 abstraction (pumping) graphs in the last five years, water levels monitoring (monthly measurements of water in wells), etc. With green is shown the extension of alluvial deposits.

[1] Mentioning of software packages does not imply a specific endorsement of such products. Other software packages could be used to create an information system or produce graphics required.

Differences between a database and a GWIS.

An information system contains raw but checked-for-quality data, just as any database. What differs an information system from a data base is addition of many preprocessed maps, lithological cross sections, well logs, chemical diagrams, hydrographs, pumping test graphs, abstraction diagrams, etc.

The maps, named and saved as objects serve for (a) interpretation, (b) cross referencing, and (c) as graphical tools for selection and displaying some property (e.g. a water level diagram, a chemical analysis, an abstraction graph, or lithological log). Fig. 3 shows a location map with water-quality-monitoring wells and one of time-series diagrams for a selected well.

The time series graph (upper part of Fig. 3) is displayed if one clicks with the mouse on the circle at the site of the well RM-434.

Vulnerability of Aquifers in the Rio Minho Basin

Increasing population, agriculture and industry competing with domestic demands for ground water, closeness of the sea coast, karstic nature of the limestone aquifer, all this poses a threat to ground water in limestone and alluvial aquifers of this basin.

Some wells have been already abandoned due to increased salinity; others produce the water of not so good quality even for agricultural use. Industrial waste ponds with water enriched with sodium and metal impurities from the bauxite-to-alumina refining process are located in the middle of the alluvial plain in the midst of many wells pumping water for domestic supply and agriculture. In other basins of Jamaica, such industrial operations are known to have contaminated limestone aquifers.

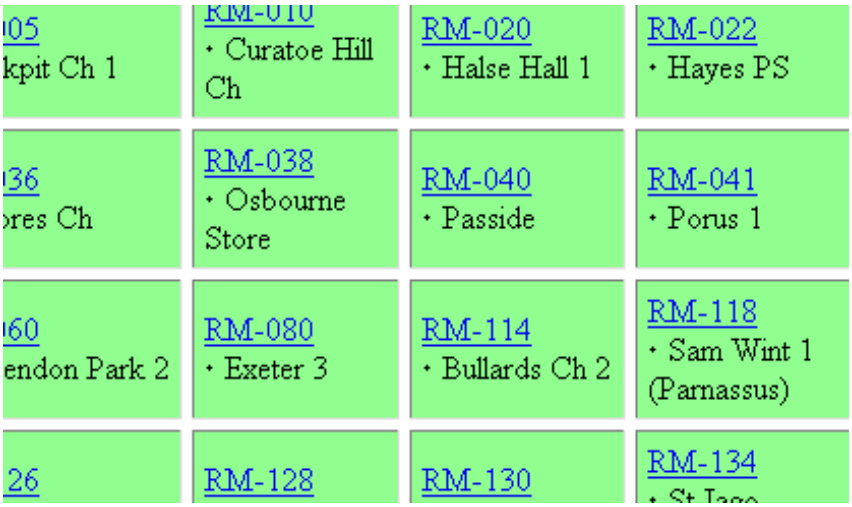
The GWIS and related interpretation places an emphasize on the vulnerability of aquifers in the basin and documents the environment with numerous lithological logs and time series of water quality in wells near such waste ponds. The Internet-uploaded GWIS discusses in general data requirements to map vulnerability, suggests a vulnerability ranking system for the Rio Minho basin, and points at specific issues of importance in the basin.

3. Uploading GWIS to Internet

Instead of writing a classical report or a "ground water study" with limited distribution and expensive color graphics, which is a time-stamped report or "up to date" only for the time the data are prepared, uploading the GWIS to the Internet makes data, information and associated graphical data visualization and presentation available to anybody interested. Benefits are obvious. Not everybody has the software required for

establishing GWIS and interpreting results installed in computers. Not too many people have the knowledge of using such software. Internet provides links to data interpreted and prepared for direct use in discussing various natural processes and/or management decisions.

A part of the main page is reproduced above with a table in which separate data entities are listed. Links are provided to textual interpretations supported by numerous graphics. Under lithology, and in crosslinks to other kind of information (e.g., ground water quality), 66 lithologic and construction wells logs are uploaded and available for immediate display. The selection is made by clicking the mouse on a circle



that represents the site of a well on the map or on the well name/number in a table. A portion of the table with "available" well logs is reproduced below.

A click on the well RM-020 displays its lithologic and construction log as shown in Fig. 4.

Ground water quality component contains dedicated diagrams for various parts of the basin, such as Piper diagram (points at the origin of ground water and general composition of water), Wilcox diagram (classifies water according to its suitability for irrigation), Stiff diagram (shows major ions in one water sample), and Schoeller diagram (groups several samples and shows ranges of variation of individual ions). One of Internet-uploaded graphics is shown in Fig. 5. This is the Wilcox diagram for SCOJ wells. The table below is a part of the chapter dealing with ground water quality. There are many links to maps (e.g. electrical conductivity of water), individual chemical diagrams (Stiff, Piper, Wilcox, and Schoeller), and to time changes of water quality or "time series." The diagram in Fig. 5 is obtained by clicking on the link Sugar Company of Jamaica (S.C.O.J.) in the table.

Map showing all sampling sites
Electrical Conductivity:
ArcView map of individual values of electrical conductivities
GWW contour map of electrical conductivities
Typical STIFF Diagrams
Two Piper Diagrams: (a) from limestone, (b) from alluvium aquifer.
Wilcox Diagrams for wells belonging to and operated by

National Irrigation Commission (N.I.C.) and Sugar Company of Jamaica (S.C.O.J.)
Schoeller's diagram for samples from NWC wells.
General discussion of ground water quality
Time series of some chemical parameters/constituents for selected wells.
Nitrates in Ground Water.

Abstraction (pumping) from aquifers is an important part of any GWIS. Over-abstraction may lead to deterioration of water quality (e.g., seawater intrusion in coastal aquifers of Jamaica). In this Internet-uploaded GWIS, abstractions are documented as (a) individual graphs for the period 1995-99 for about 20 wells and (b) cumulative graphs (year by year, for major water users, as volumes and daily rates). One of cumulative graphs for 1999 distinguishes between water uses (domestic supply, agricultural, and industrial use). It is shown in Fig. 6. Notice that the agriculture is the prime consumer.

Fig. 7 is one of typical displays on the Rio Minho web site. It shows abstractions from an individual well and provides links to lithological well log, chemical analysis of the water, and time series of major parameters.

4. Conclusions and Recommendations

Uploading ground water and environmental data and information to the Internet is a relatively newly started practice. Until recently, complete reports and studies have been uploaded either in document formats or as pdf (portable data format by Adobe Acrobat) files. This GWIS, in the form in which it is uploaded to the Internet, offers to a viewer an interaction. A map is displayed and the viewer selects a well and displays its various graphs.

The raw data are uploaded as spreadsheet and document files for anybody's own interpretation, updating and reporting.

Some issues remain unresolved. In order to reduce the downloading time for some complex maps and graphs, they have been optimized for the web. This means that a reduced quantity of information (pixels) is available for reproduction. While this does not affect much the screen display, the printouts are of inferior quality. The last entry in the table on the main page links to several good quality graphics.

Another issue is the monitoring of ground water quality near industrial sites. In the case of Jamaica, this means near the sites where bauxite is refined into alumina. Metal impurities from bauxites such as cadmium, arsenic, zinc, lead, iron, manganese, titanium, etc. may enter the ground water system if the drainage and leachate collection facilities fail. The GWIS points at such sites and offers a background information against which the newly collected data would be compared.

The permission to upload the data and information to the Internet was granted by WRA. It is recommended that the staff of WRA takes over this web site, appoints a web site manager, and keeps uploading new data (collected during the year 2000 and on) and making additional interpretation and visualizations. Ground water data from other major basins of Jamaica will soon be uploaded to Internet. The work on the Black River basin, to the west of the Rio Minho Basin, is currently underway.

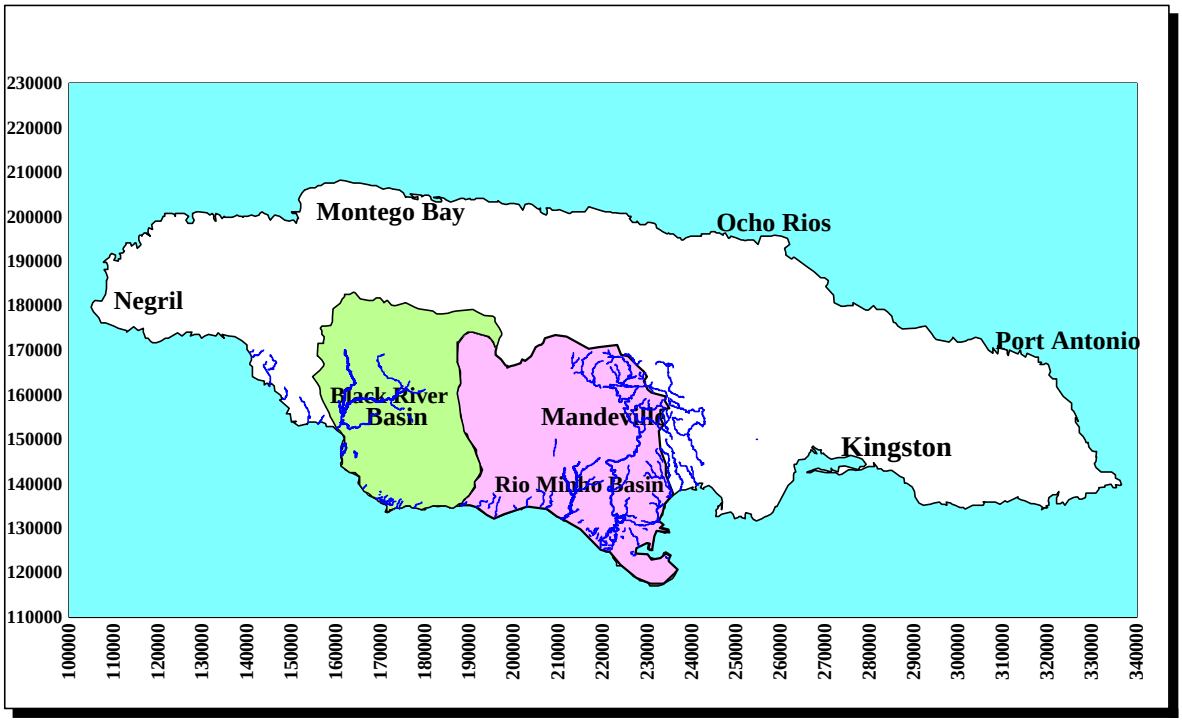


Fig. 1. Rio Minho and Black River basins in Jamaica. Shown are also rivers in these basins.

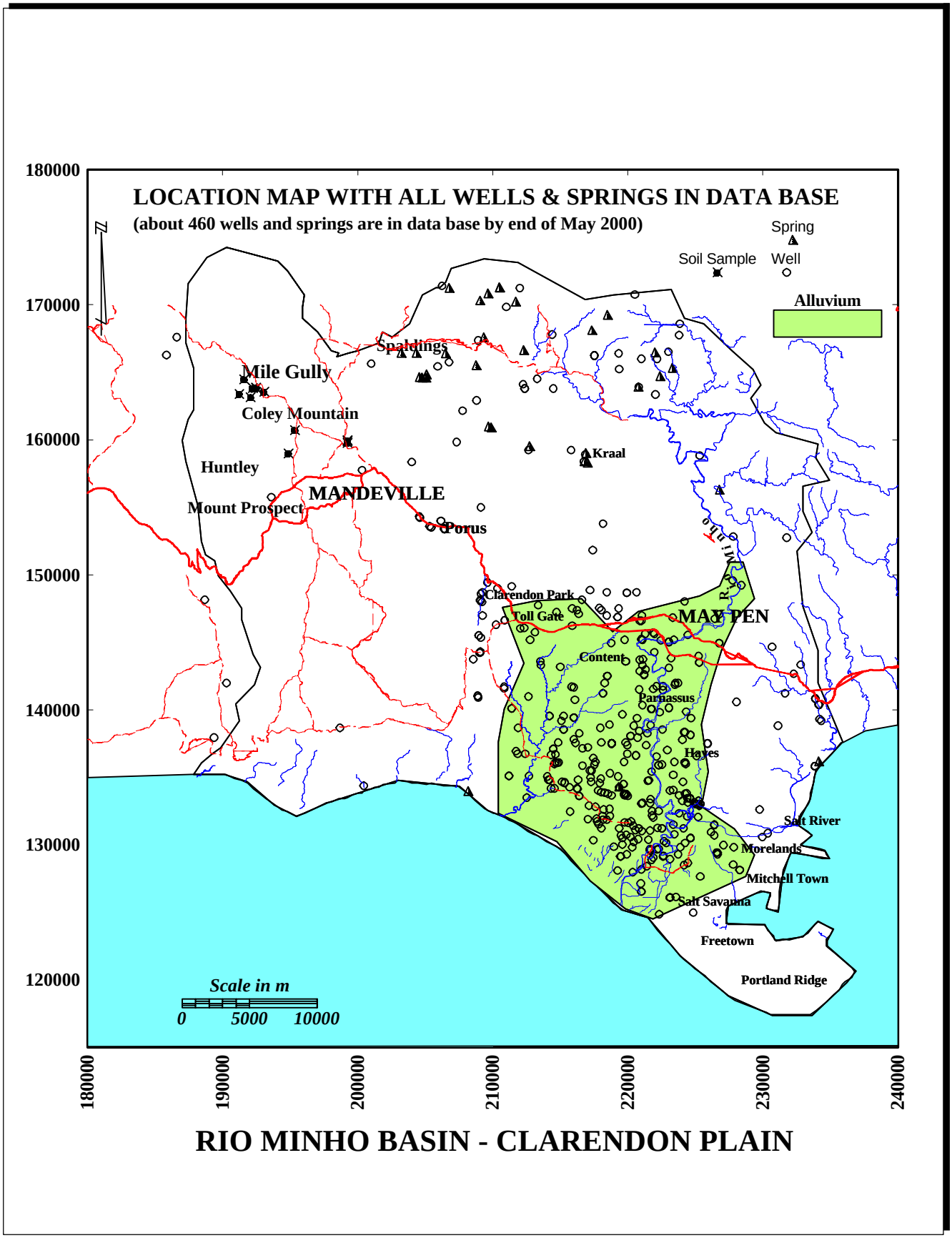
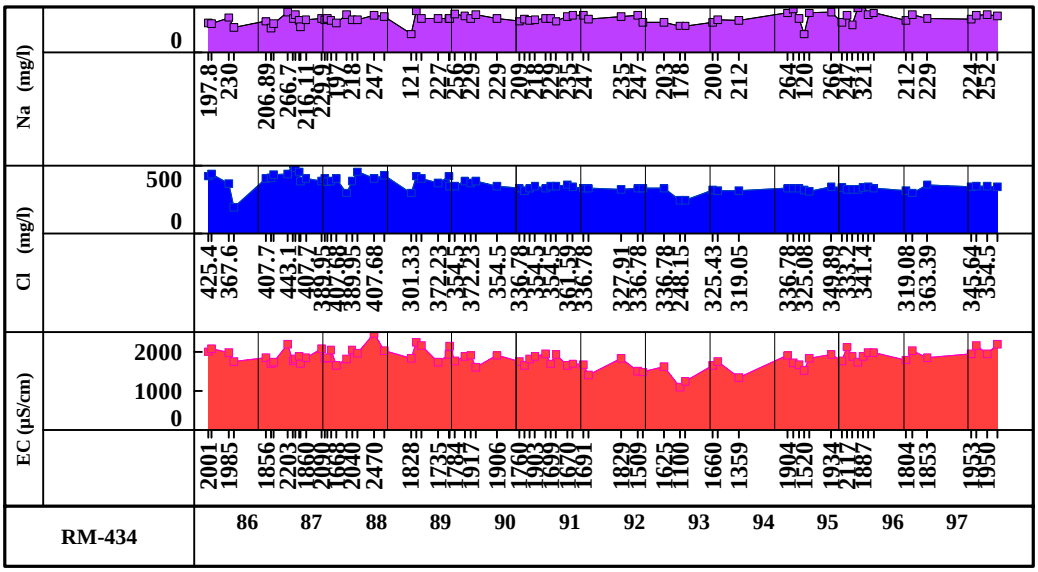


Fig. 2. Wells and springs in the Rio Minho Basin.



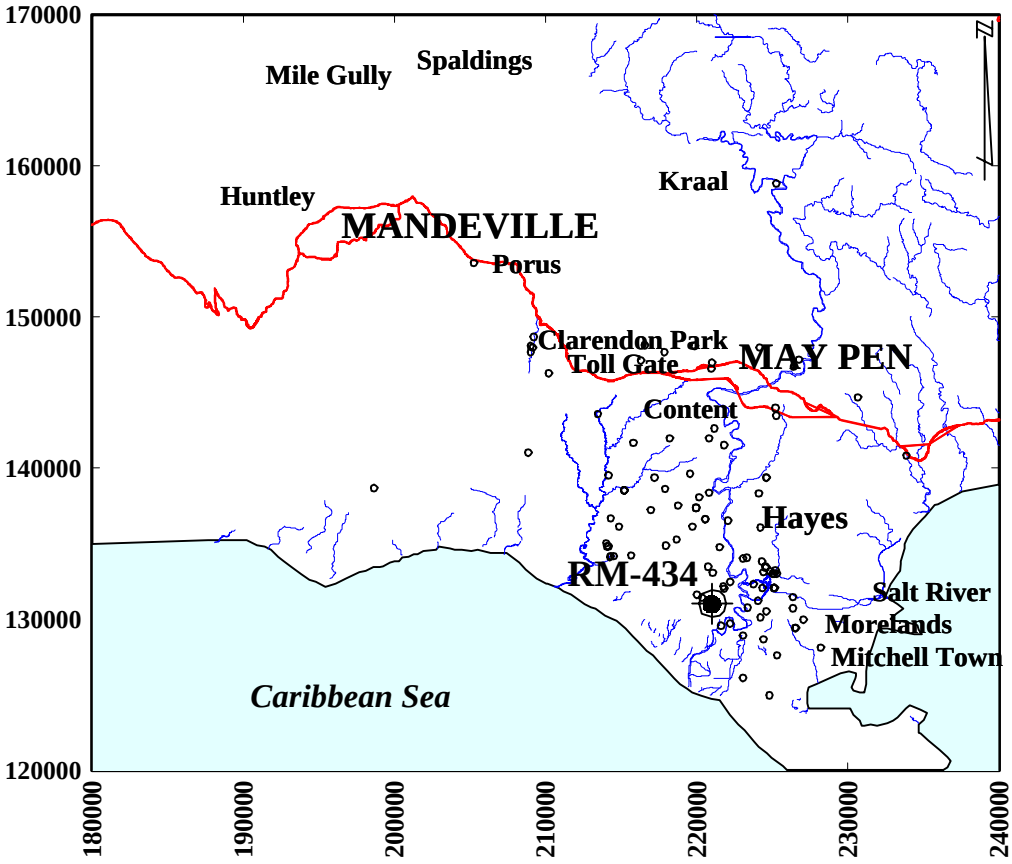


Fig. 3. Location map with ground water quality monitoring wells. One of time series graphs.

Well Log: Lithology & Construction

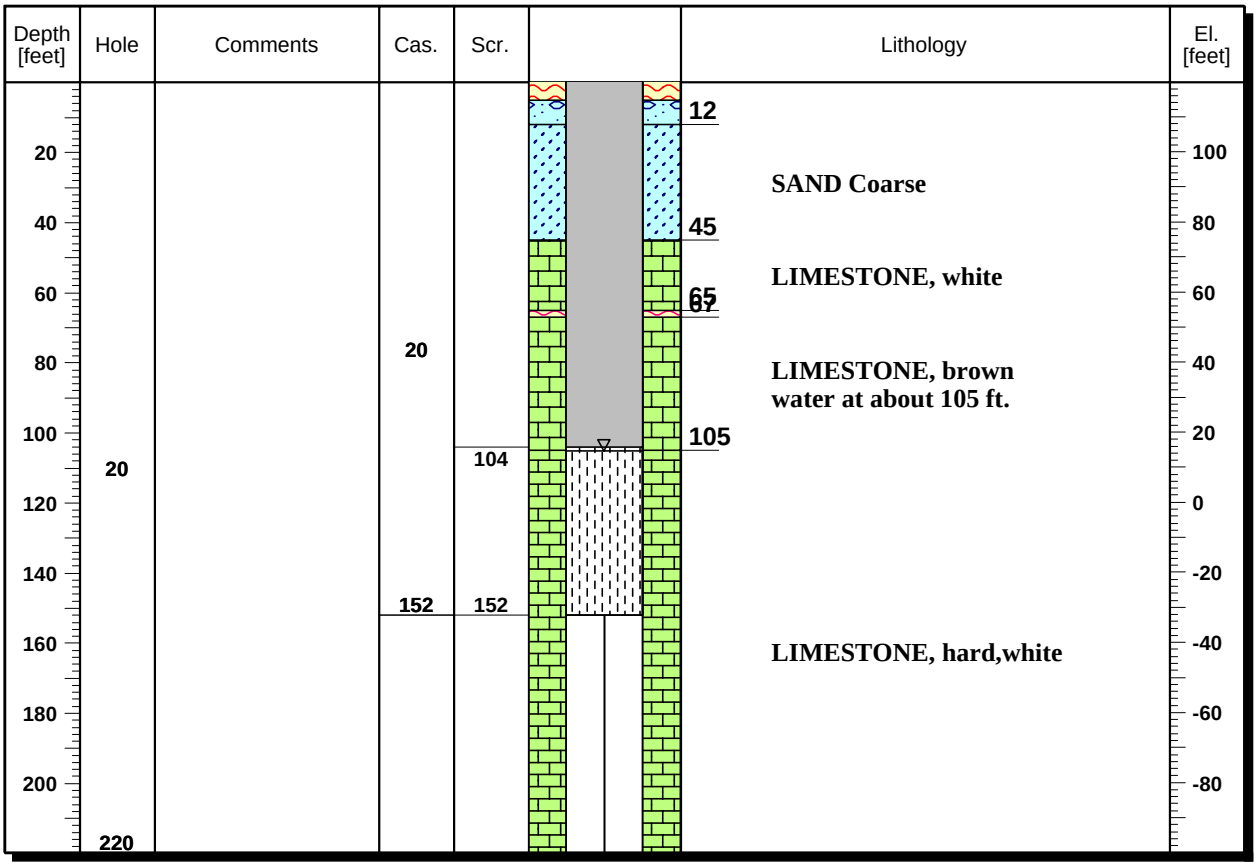
Well Ident	Name
RM-022	**Hayes (PS)**

Drill. Method	Drill. Dates
	June 1961

Easting (m)	Northing (m)	Gr. Surf. El. (m)	Meas. Pt. Elev. (m)
224245	**136103**	**36.5**	**36.5**

Coordinates are in meters. Hole and casing diameters in inches. Depth and Elevation columns are in feet.

Static Water Level (feet AMSL): **14.70**



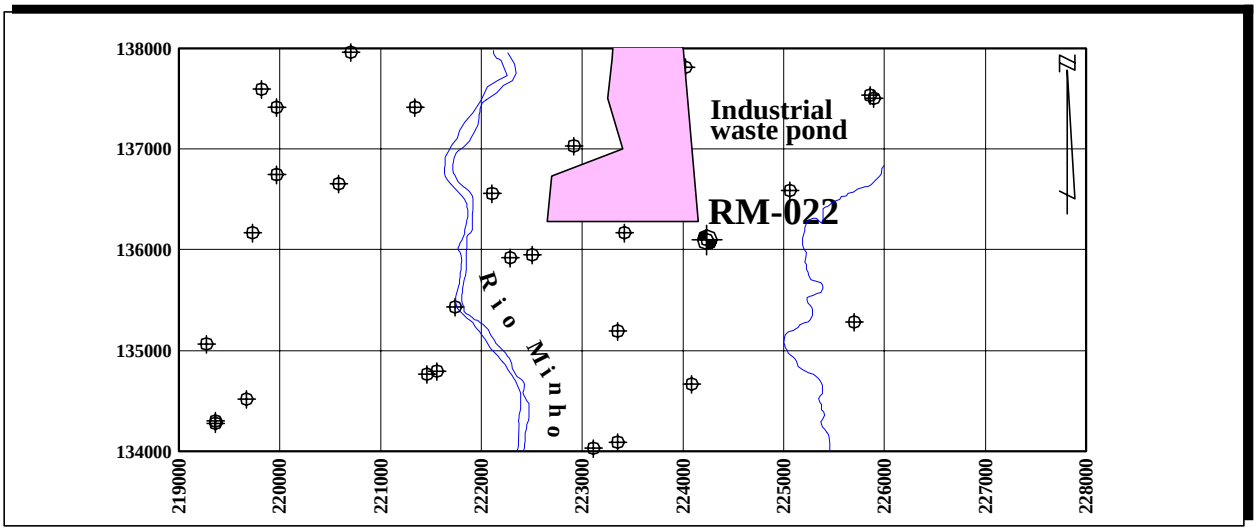
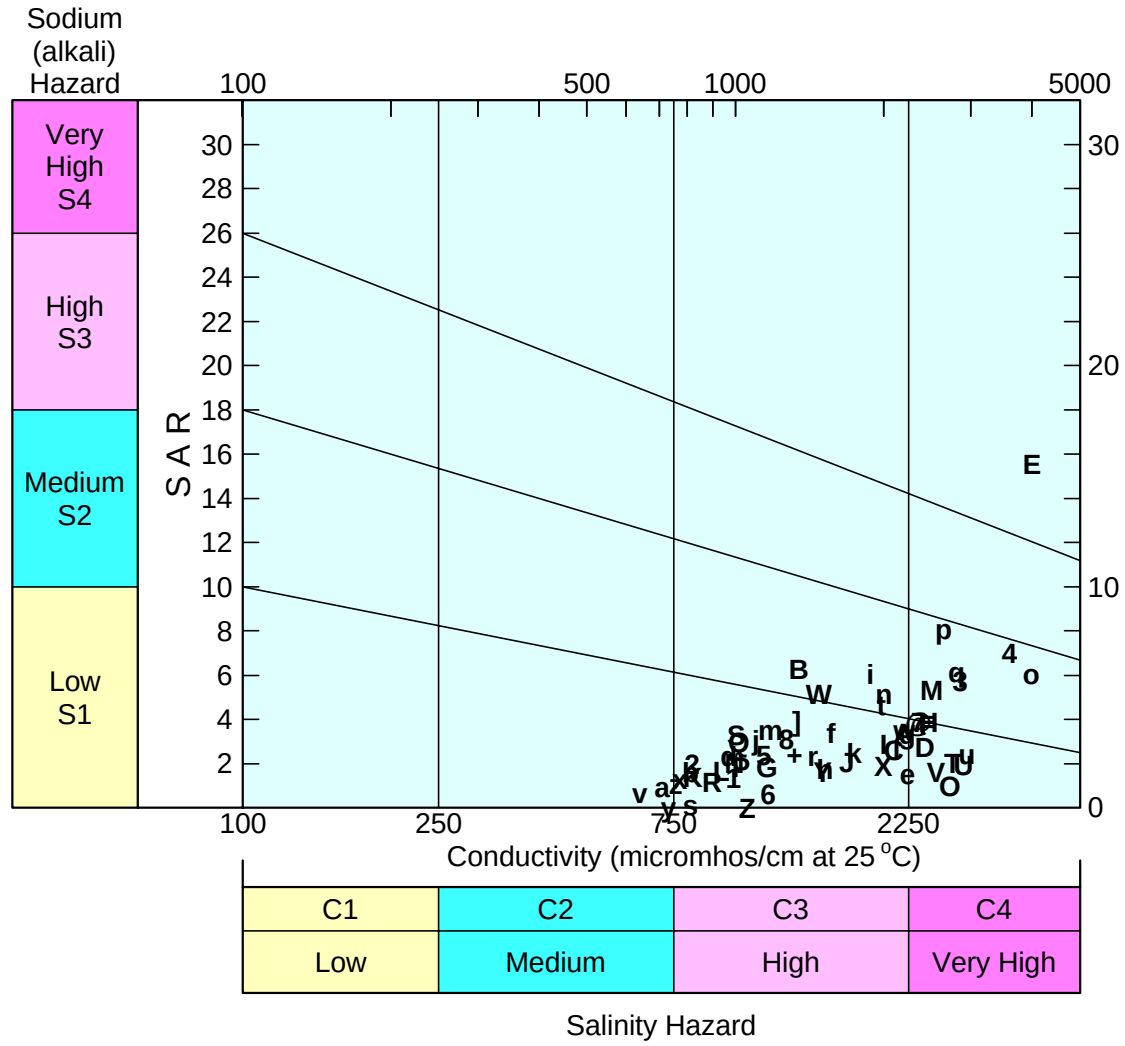


Fig. 4. Lithologic log and location of well RM-022 at Hayes.

Wilcox Diagram



1	RM-013	7	RM-055	D	RM-073	J	RM-094
2	RM-014	8	RM-056	E	RM-077	K	RM-095
3	RM-028	9	RM-067	F	RM-080	L	RM-096
4	RM-029	A	RM-070	G	RM-088	M	RM-1031
5	RM-042	B	RM-071	H	RM-091	N	RM-145
6	RM-054	C	RM-072	I	RM-093	O	RM-159

Fig. 5. Wilcox Diagram for Wells belonging to Sugar Company of Jamaica

Abstractions in Rio Minho Basin in 1999

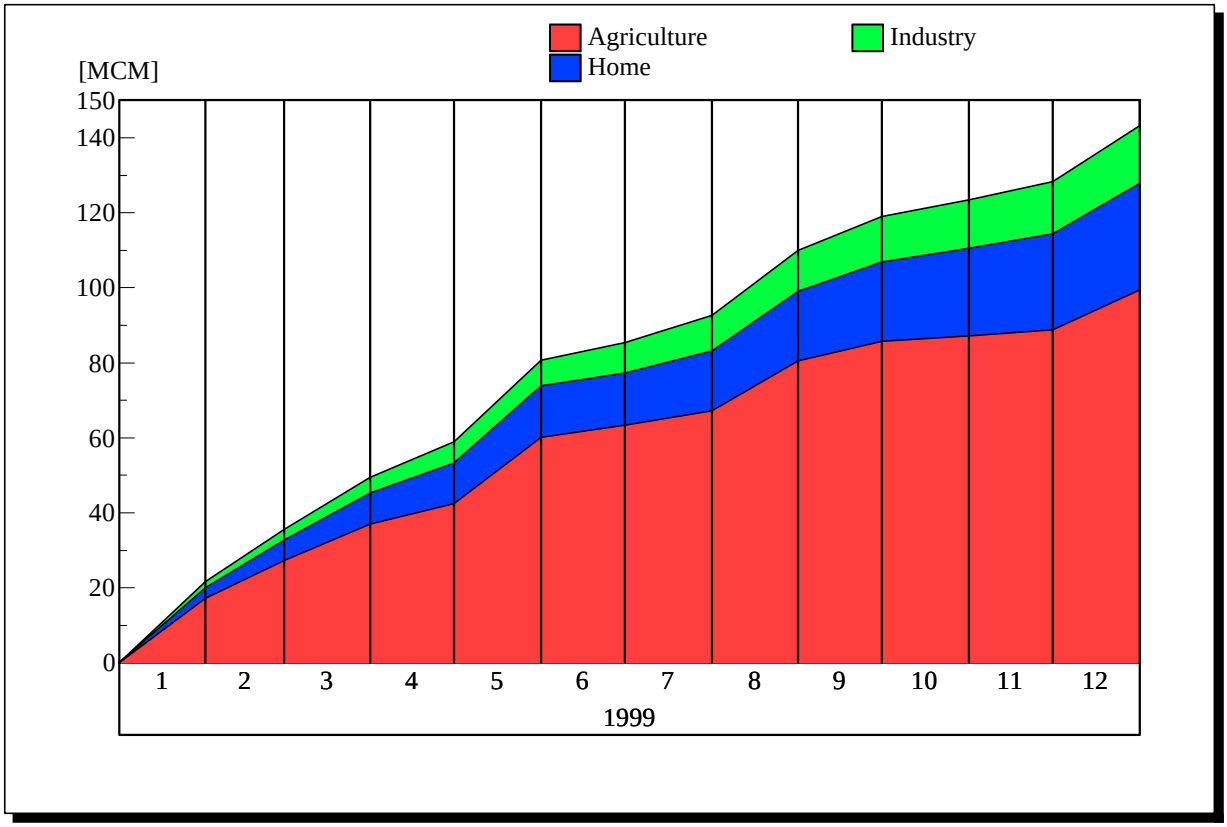


Fig. 6. Abstractions in 1999.

Well 276 Raymonds 6

You may display lithological log and/or chemical analysis by selecting one of links below.

Lithological log of this well displays limestone aquifer overlain by marl.

Chemical analysis points at water of inferior quality for drinking and agricultural use. Electrical conductivity of over 2100 μ S/cm makes this water above upper limit for irrigation. Both sodium and calcium are high pointing at water of mixed origin. This particular sample shows an extremely high nitrate content, pointing at the vulnerability of limestone and improper filtering function of clay and marl above the limestone.

Time Series of major chemical constituents indicate a more or less constant water composition over the years.

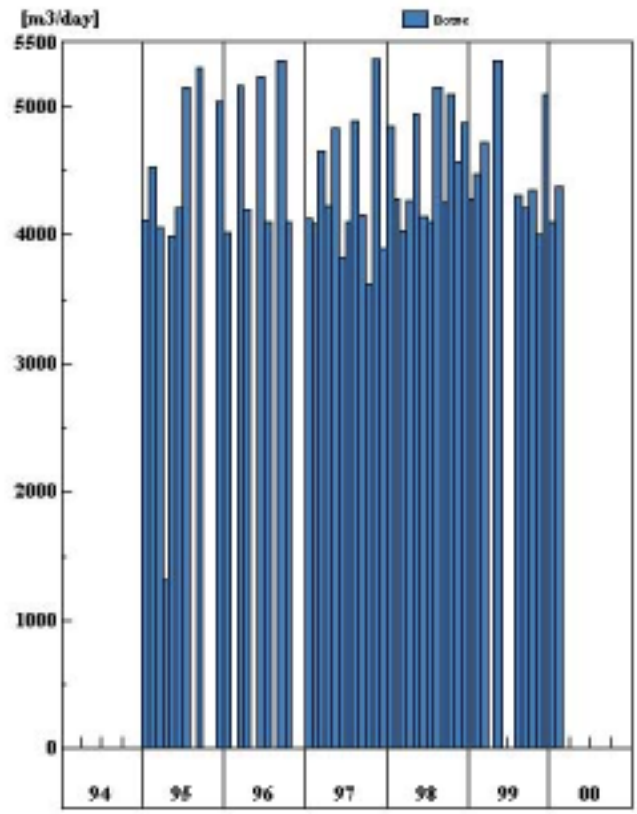


Fig. 7. Abstraction data for a selected well. Links to lithology and water quality.