

Qatar Groundwater Resources Information System

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Abstract

In the last year, the Department of Agriculture and Water Resources (DAWR) initiated the development of the Qatar wide Groundwater Resources Information System (QaGWRIS). QaGWRIS is a centralized, GIS based, Web enabled integrated information management system that allows storage and management of all information on groundwater resources and the environment. The system integrates a comprehensive set of tools and applications that facilitate the efficient management of the Groundwater Resources of the State of Qatar. All historical groundwater resources from various sources and from various departments as well as from the recent nation wide well inventory campaign have now been compiled, quality controlled, and migrated into the central information repository.

QaGWRIS, which supports both the Arabic and English languages, is built as an Integrated Information Management system (IIMS) and hence designed to improve productivity by linking all relevant applications for data handling to a centralized data repository and management system. The IIMS approach promotes optimal use of data by all relevant applications and all legitimate users in an organization with minimal effort spent on data preparation and handling. In IIMS, data is generally stored in a central repository where security provisions are relatively easier to achieve, data redundancy is avoided and access to information is controllable.

Introduction

As a result of the United Nations Water Conference that took place in Mar Del Plata (March 1977), Qatar adopted the Mar Del Plata Action Plan. In recommendation A of that plan, the importance of acquiring greater information about the quantity and the quality of water resources was stressed. The plan also states that the data needs to be promoted and accompanied by a system for processing information. Consequently, Qatar designed and implemented its first groundwater information system and became one of the first six countries to implement such a system.

By late nineties, a telemetry system that allows remote collection of groundwater data was implemented together with its own database system. This information system (DEMASDB) is being managed from within the Department of Agricultural and Water Research (DAWR). By 2004, Qatar started its initiative to build

its own Water Resources Management and Development Strategy. This strategy, which is not yet finalized but one of its main components is currently implementing a water resources database to manage different water resources. Therefore, it becomes a pre-requisite to have a groundwater information system that will be directly linked to this national-level and sophisticated database.

In addition to that, lately Qatar has become one of the Arab world's leaders in applying the e-Government principles. Therefore, collecting all related-groundwater data and compiling it in a centralized and web based information management system to facilitate dealing with this highly precious resource has gained a paramount importance.

The Need for QaGWRIS

Decision makers and groundwater specialists need access to realistically precise data to allow them to monitor the precious groundwater resources, assess supply & demand, as well as maintain the integrity and reliability of all such information.

During the project "Studying and Developing the Natural and Artificial Recharge of the Groundwater Aquifer in the State of Qatar", data that is stored in different locations, has been collected in many different formats (digital and hard copies) and on maps in different scales and projections. These data has been compiled, quality controlled and imported into a centralized data management system in order to enhance the usability and accessibility of all available data. The developed Groundwater information system holds information on groundwater wells all over the State of Qatar. It also contains data from a wide variety of sources, including and not limited to the Center of Geographic Information Systems, the Rural Planning Authority, the Public Works Authority, the Ministry of Municipal Affairs and Agriculture, the Supreme Council of Environment and Natural Reserve and Qatar General Electricity and Water Authority.

The system not only stores and manages information of interest to groundwater management and investigations, but is also a useful resource for all environmental studies where interactions between surficial hydrological zones with the groundwater are of interest. QaGWRIS has been developed and deployed by Schlumberger Water Services (SWS) on behalf of the Department of Agricultural and Water Research (DAWR).

Architecture of QaGWRIS

The main goal of information gathering from any system is to attain a reasonable understanding of that system. In Water resources studies such activities are undertaken in order to assist in obtaining a sound understanding about the resources and ultimately for exploration, exploitation, monitoring, and protection of these resources. Figure 1 depicts a typical data workflow in the area of water resources in general and groundwater resources management in particular.

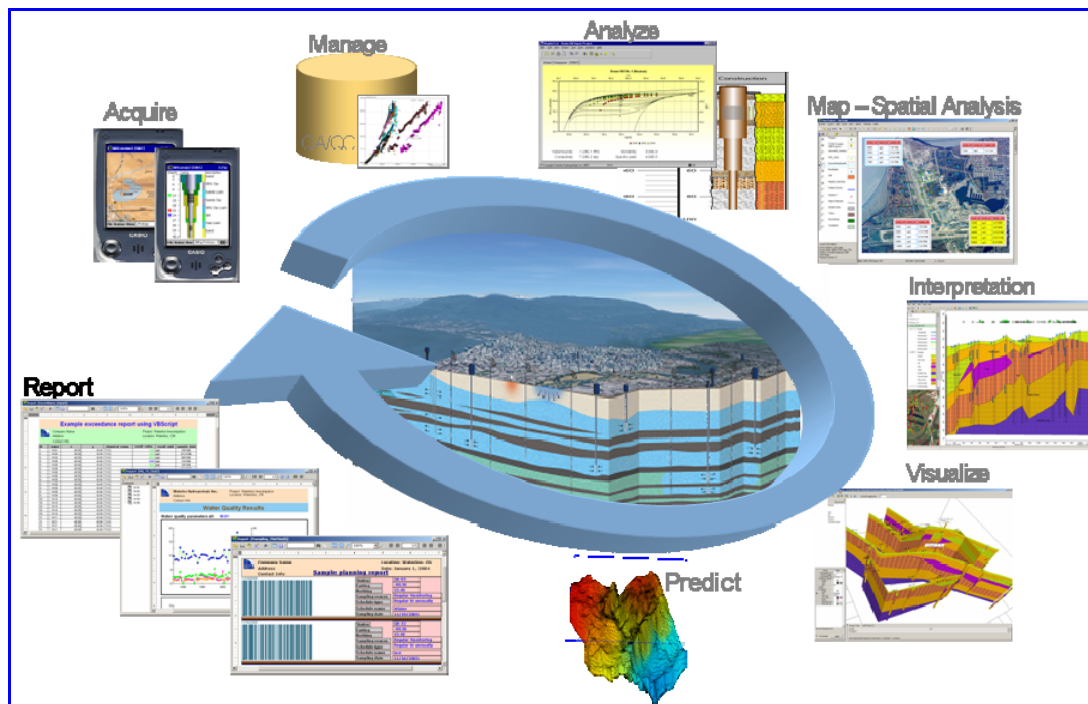


Figure 1 - Typical Data workflow

The data workflow depicted in the figure accounts for the complete workflow from data acquisition to reporting. A comprehensive integrated data management should integrate the complete workflow by providing tools and mechanisms for activities ranging from data discovery to delivery.

The Qatar Groundwater Resources Information System - QaGWRIS (hereafter also referred to as “The System”), whose architecture is depicted in Figure 2, is designed, developed and deployed to cover this workflow by providing the tools ranging from those provided for automated data acquisition to automated and dynamic reporting. The System has at its core a central, GIS based, Web enabled database built on the industry recognized and widely used Microsoft SQL Server platform. The database is designed to provide extreme flexibility allowing storage and management of wide range of environmental data types including surface water, groundwater, meteorology, geology, water, soil and air quality to mention just few.

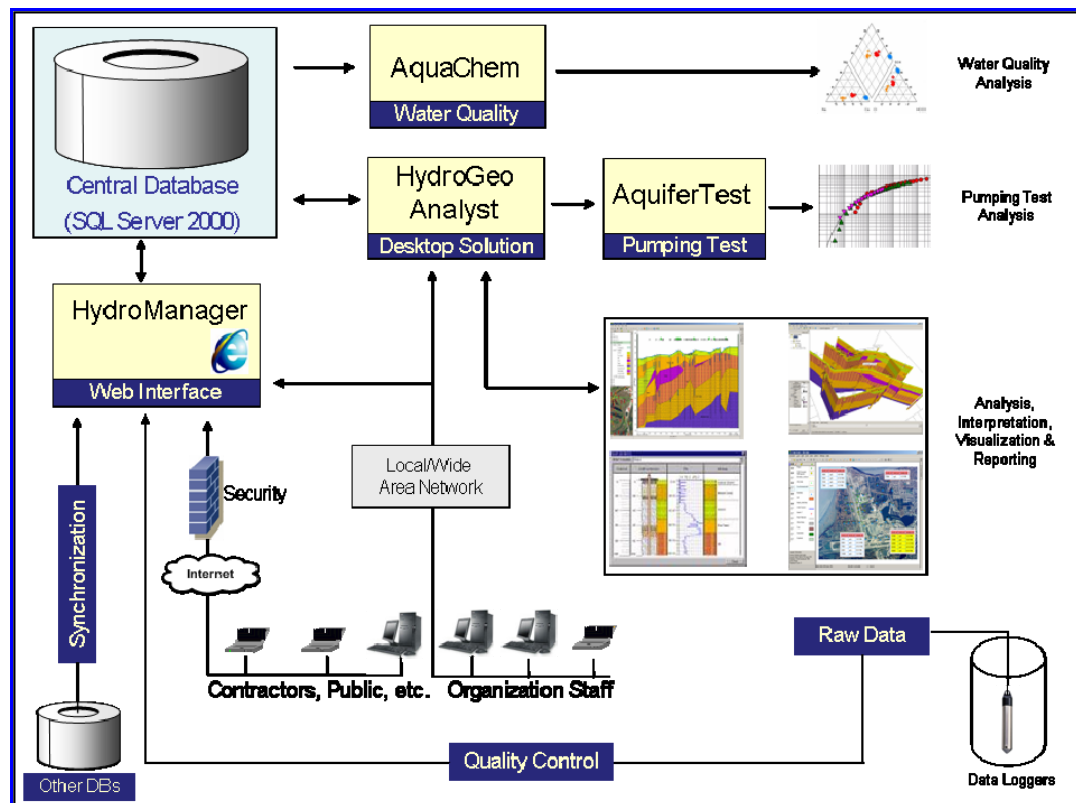


Figure 2 – Architecture of the QaGWRIS

In addition to integrating wide ranging data types, the system also brings together a number of tools that can be used to analyze, interpret, and visualize the information. QaGWRIS features the following main tools

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- Data acquisition (e.g. Universal data transfer system, automated data acquisition from data loggers, etc.);
- Data analysis (e.g. time series analysis, water quality analysis, statistical analysis, spatial analysis, pumping test analysis, etc.);
- Data interpretations (e.g. cross-sectional interpretation, spatial interpretation, water quality interpretation and modeling, etc.);
- Visualizations (e.g. Charting, GIS Mapping, Borehole logging, 3D fence diagrams, 3D Plumes display and animation, etc.);
- Conceptual model building environment (Pre-Processor for Visual MODFLOW, FEFLOW and other simulation environments; and
- Comprehensive and Dynamic Reporting.

Benefits of the QaGWRIS

Business strategy

There are three main key requirements for managing groundwater resources, namely:

- A comprehensive groundwater resources monitoring network,
- Regulations, and
- A centralized water information system

Through this project (QaGWRIS), DAWR aimed at developing a centralized groundwater resources information system that will:

- House all groundwater related data that is currently available scattered in a number of databases and spreadsheets
- Store all groundwater resources related information that will be collected in the future and hence enhance monitoring and reporting efficiency
- Build the system to support future activities such well permitting applications and approval processes among others

Benefits of the system

The system brings numerous advantages to DAWR in its effort to efficiently manage the Groundwater Resources of the country. In addition to addressing current issues facing the department, the proper planning and use of the system opens various opportunities in the future that will enhance productivity.

The efficient use of the system provides DAWR with the tools and mechanisms to monitor, control and enforce regulations set to protect the groundwater resources of the state of Qatar. Through QaGWRIS, the department now has the provisions to standardize various components of its activities and dealings with all stakeholders. For instance, it is now possible to standardize information exchange formats between drilling firms and consultants and the department and hence enforce proper reporting of activities that have direct or indirect impact on the Water Resources of the department.

Data acquisition

Groundwater Data is collected in various ways depending on the type, frequency, and use. For instance for water quality monitoring at contaminated sites, sampling locations and intervals are designed based on site conditions and the nature of contamination. Samples are then collected from the site often with quality control measures (e.g. duplicate sample, spiked samples, etc.) taken into consideration. The samples will then be sent to a laboratory for analyses from where results will be sent to the originator.

DAWR has established an extensive monitoring network for regular data collection on its groundwater resources and the environment. The network includes groundwater, surface water and meteorological monitoring points some of which are equipped with data loggers. Data from some of these loggers are remotely downloaded through telemetry while regular site visits and manual downloading are required for others.

Data gathered from all monitoring locations are imported into the central database through mechanisms provided in QaGWRIS which support automated and unattended data quality control and importing as well as traditional ways of manually importing data through rigorous quality control steps.

Data storage

QaGWRIS currently manages information gathered from more than 6,000 groundwater wells. DAWR is currently undertaking a well inventory survey which is expected to bring in more information on these wells. The flexibility of QaGWRIS allows adopting the database structure to any future requirements while continuing to allow all provided tools to function properly even with newly added data types.

As the system is implemented in the MS SQL Server platform, database size is only limited by the amount of storage available on the machine where the database is installed.

Data analysis

Analysis tools provide the mechanism to extract essential information from the raw data and in so doing provide insight into the system under study. The type of analysis the system provides include: statistical analysis, spatial analysis, water quality analysis, pumping test analysis, and time series analysis. All tools are designed to work with data stored in the central database and do not require exporting or formatting of the data. Data can be accessed directly and/or through queries and hence allowing various levels of intermediate data processing prior to data analysis. For instance if spatial analysis of statistically aggregated data (e.g. average water level over a specified time and specified area) is desired, data can be aggregated through the statistical analysis tools provided and passed to the spatial analysis tools all within the same system.

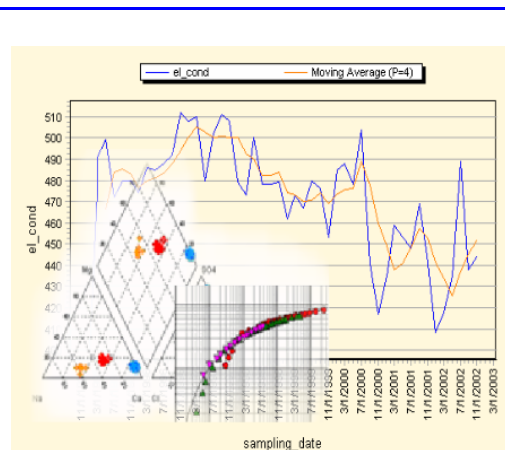


Figure 3 - Example analysis results

As these tools are working with live data stored in the central database and not with a copy, all updates to the database are reflected on all analysis tools in an automated manner hence a significant amount of time saving.

The system is integrated with the world renowned water quality analysis and modeling system, AquaChem (developed by Waterloo Hydrogeologic, a Schlumberger company). Similarly Waterloo Hydrogeologic's Pumping test analysis system, AquiferTest Pro, is used for pumping and slug test analyses. Both these tools are seamlessly integrated with the system.

Data interpretation

Most of the interpretation tools provided in the system are focused on groundwater resources. These tools include the Borehole log plotter and cross-section interpretation component. Both tools provide environments whereby subsurface data including geophysical investigation results, water quality profiles, geology, water levels, etc. can be displayed and interpreted by Hydrogeologists. Users have the ability to make cross-sectional interpretations based on lithology, hydrogeology and model layers. As such the system is also referred to as a conceptual model building environment.

All rules applicable to most groundwater simulation models (e.g. MODFLOW and FEFLOW) are embedded into the system allowing the easy-to-use GIS environment to develop model layers that are ready to be imported into a desired modeling (simulation) environment. The GIS environment also provides various tools

that allow creation of input data for use in such simulation models. Figure 4 depicts a typical two dimensional cross-section showing various types of information.

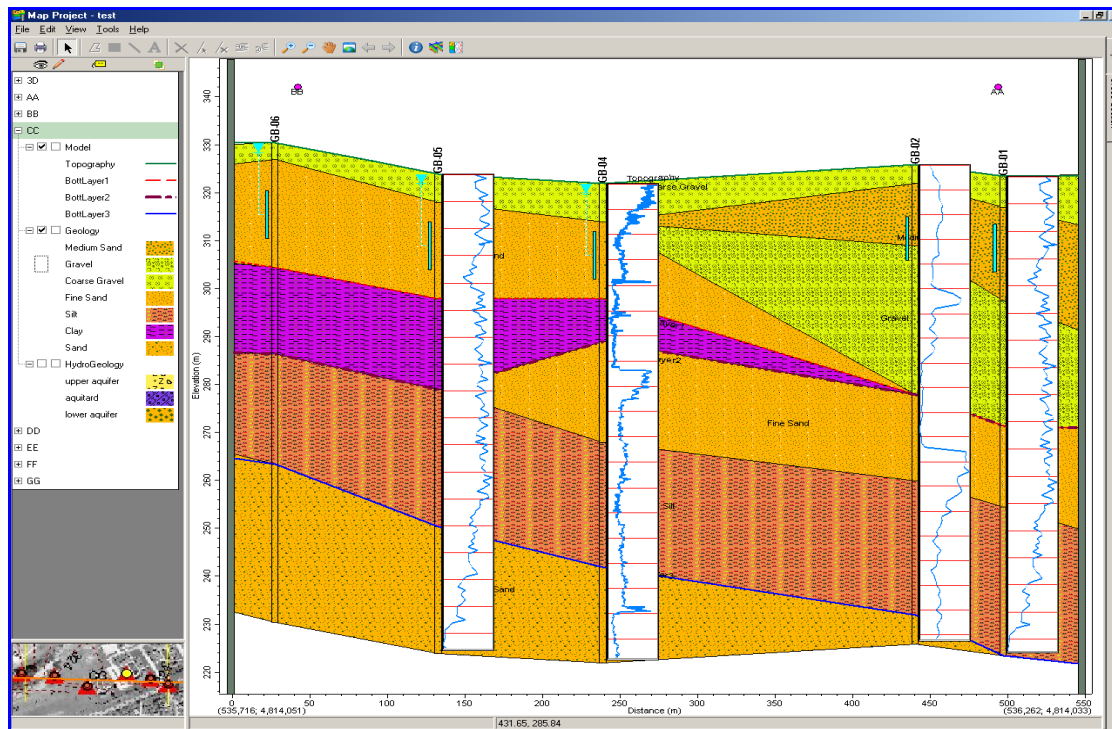


Figure 4 – Typical Cross-section interpretation in QaGWRIS

GIS Mapping

Groundwater related data is inherently spatial and as such the use of GIS for handling of such data is of paramount importance. However, most GIS environments in existence do not provide the ability to connect all environmental data to the GIS in an integrated manner. The QaGWRIS eliminates this hurdle by seamlessly integrating GIS with the central database containing all groundwater related information. The system allows displaying, analyzing and interpreting all relevant data right from the central database with all resulting information stored back in the same system while provisions are made for exporting such information to other systems and/or locations.

The GIS in QaGWRIS provides comprehensive set of functionalities most of which are not found in most GIS environments. For instance any data can be queried and displayed on the GIS map in tabular format for each desired station. The tables are connected with their corresponding stations (or similar objects on the map) through a customizable callout box. Data in these tables can be compared to either fixed value or values in other columns and exceedences can be highlighted in a desired color. Figure 5 depicts a typical view of a GIS map showing summary tabular data along with time series plots.

As the GIS system is integrated with the database, all such displays are optionally dynamically updated as updates to data are obtained. The GIS also supports data exchange with almost all GIS in use around the world.

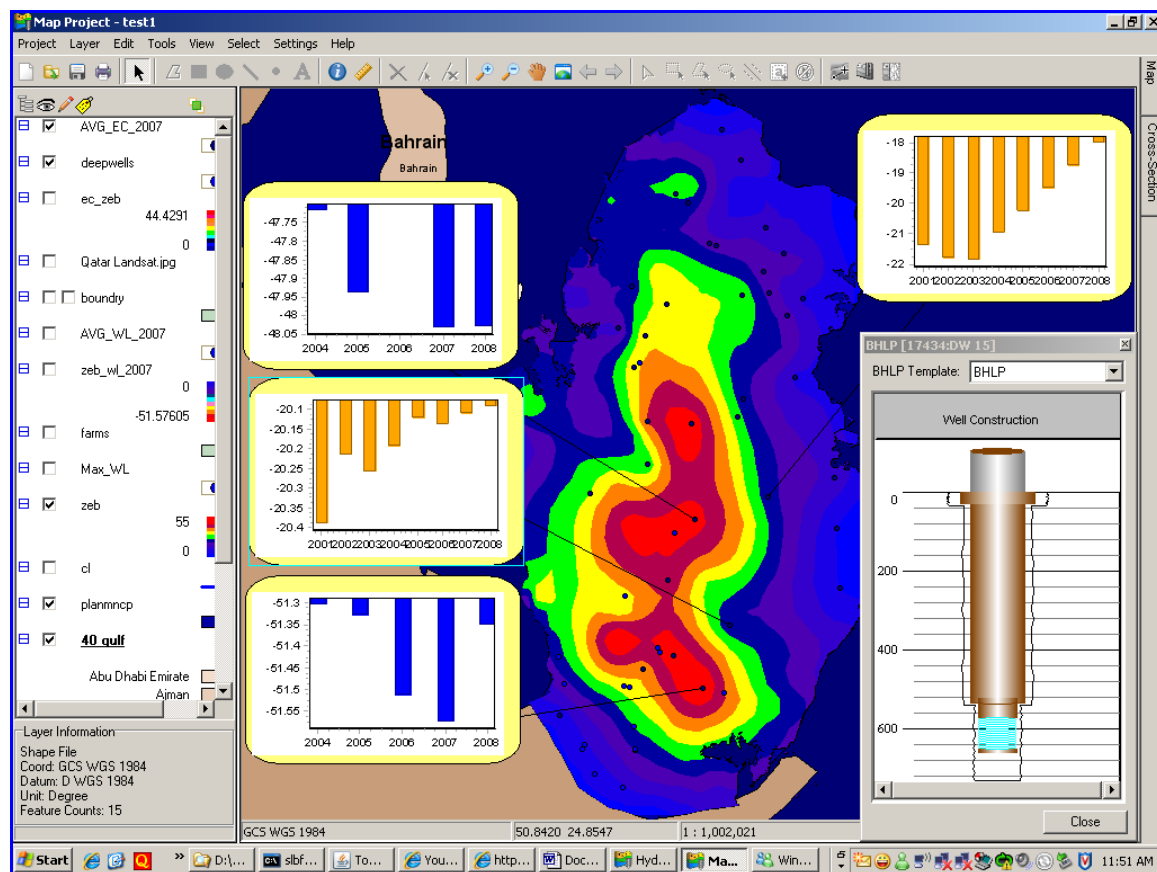


Figure 5 – Borehole log and time series data display in QaGWRIS

3D Visualization

QaGWRIS comes with a powerful 3D visualization system. The system allows for displaying fence diagrams, surfaces (e.g. topography, groundwater level, etc.), time series of plumes, and wells. Transient plumes can be created for any chemical for which there is historical data. The system allows for recording of 3D plume animations into a standard video format that can be displayed through various media players including power point presentations.

Plumes can be projected on any plane allowing visualization of water and soil quality data across selected boundaries. For instance when dealing with contaminated sites, the system allows tracing historical progression of the chemical(s) of concern. Plume projection can also be made along any cross-section line that is digitized on the map and displayed as a fence diagram.

The 3D system also allows for quick calculations of volume of soil contaminated with a selected chemical at a specified concentration. For instance, assuming the maximum allowable concentration of vinyl chloride to be 0.25 microgram/liter, the system can calculate from the data the volume of soil contaminated at this concentration.

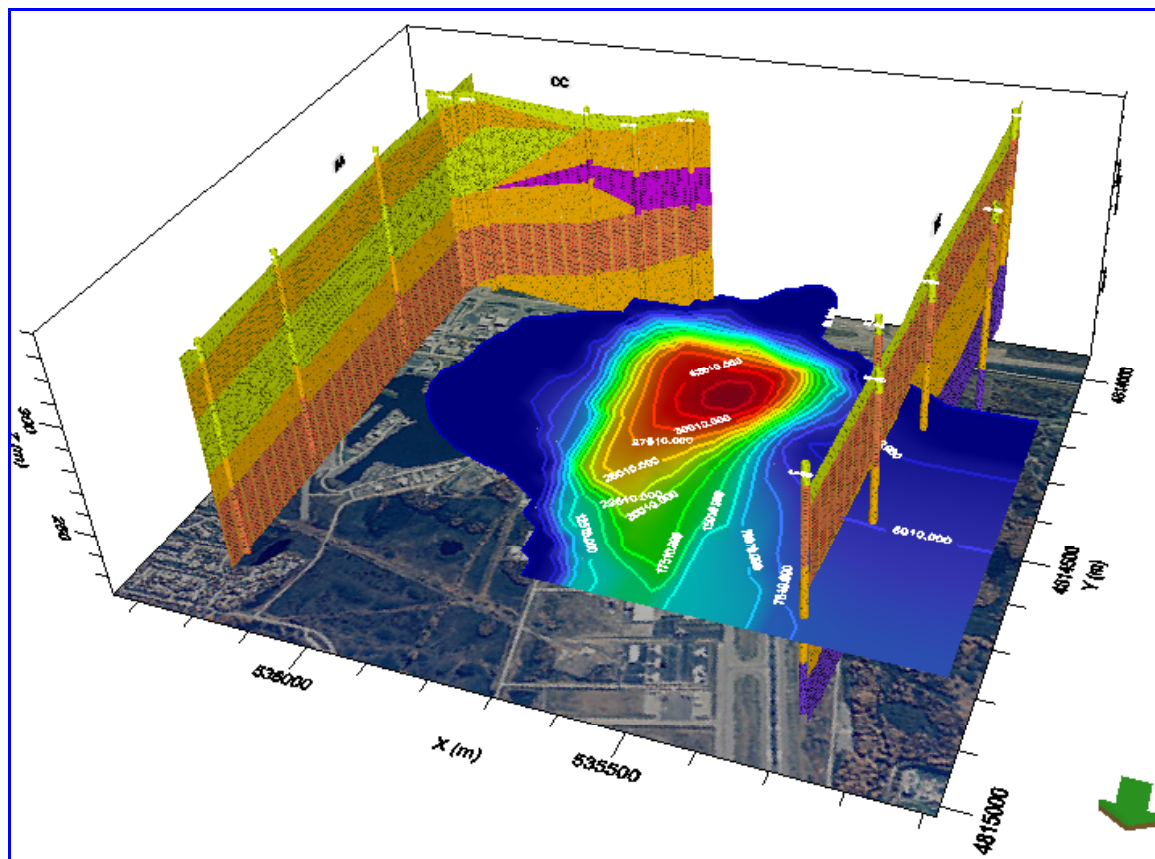


Figure 6 – Typical 3D depiction of a fence diagram and projected plume

Reporting

HydroGeo Analyst offers a dynamic reporting system that is used for reporting all raw as well as processed data. The report works on the principle of “design once” and “use often”.

Tabular reports displaying data as well as water quality standards can be generated and displayed. The system provides advanced features that allow for comparison of data to standards. Optionally all data in violation of specified standard(s) can be highlighted in various ways. Most data displayed on the report module can be updated dynamically again allowing for automated updating of reports. The report module may be used to generate multiple pages of report reporting data from multiple stations at once.

The report design can be stored and used whenever necessary while the generated reports can be exported to various formats for storage. The formats that are supported by HydroGeo Analyst include: Rich Text Format (RTF), Portable Document Format (PDF), Hypertext Markup Language format (HTML) among many others.

Figure 7 depicts sample reports that are generated through HydroGeo Analyst.

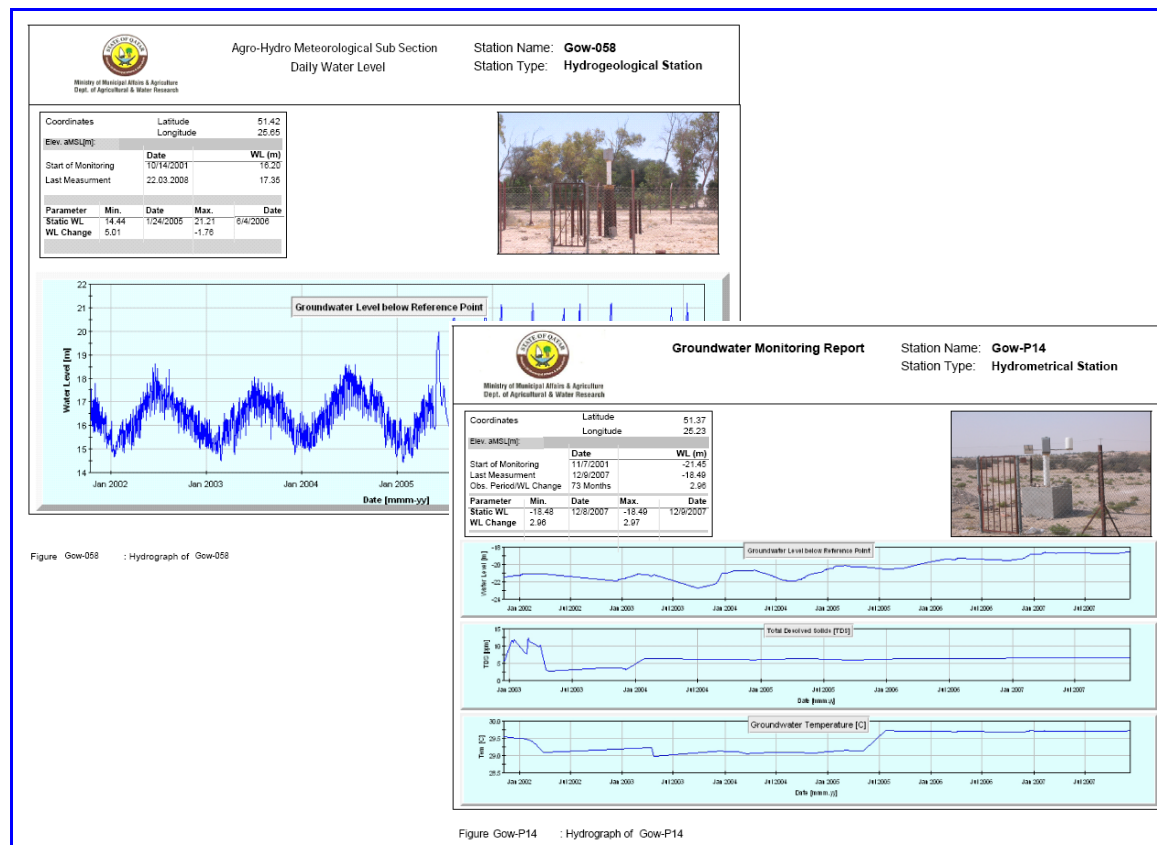


Figure 7 – Sample reports

Data accessibility over the Internet

All raw data as well as analysis, interpretation, and visualization results are made available over the Internet through the web interface provided in QaGWRIS. The web interface is built upon a flexible and yet user friendly web based data management system. It allows for navigation of results produced through all the other modules provide in QaGWRIS as well as creation of ad-hoc queries and reports over the Internet.

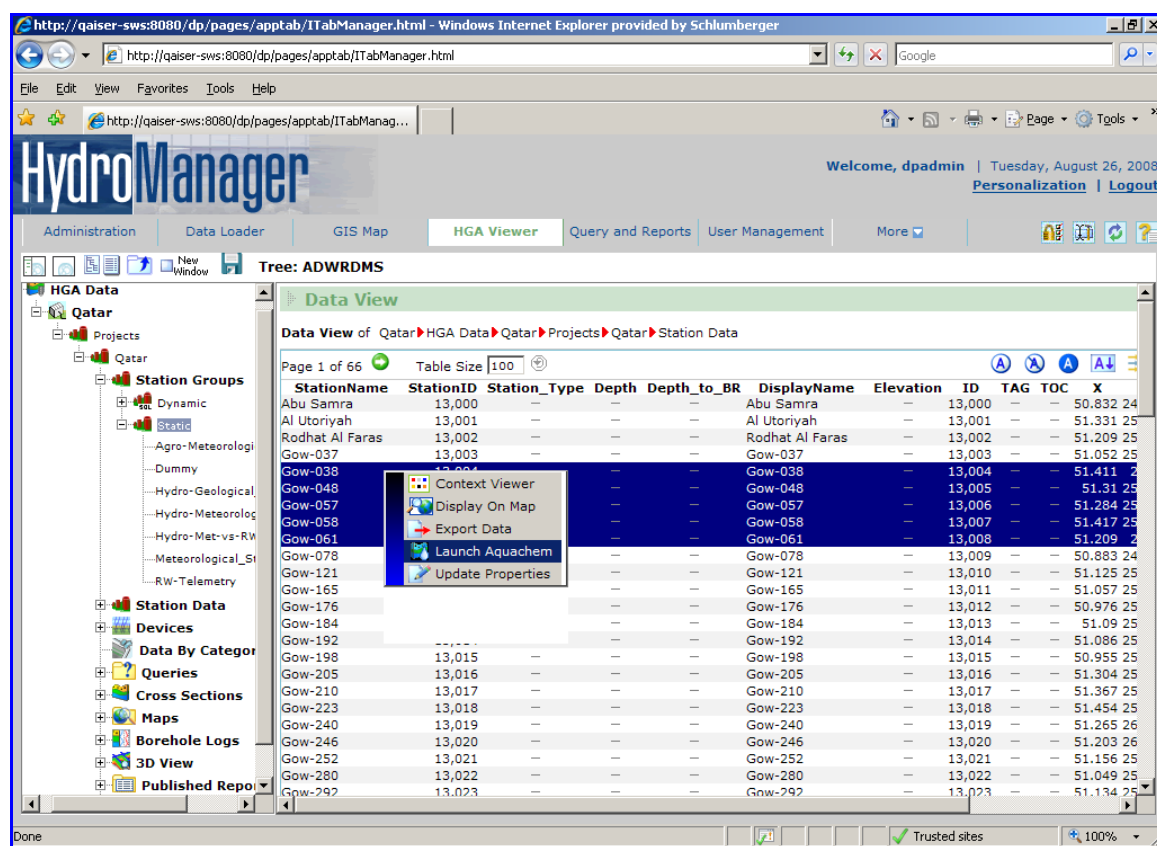


Figure 8 - Web data access through HydroManager

The web interface features controlled data access, GIS Mapping, data importing and exporting, data querying, time series plotting, among other functionalities.

QaGWRIS provides a customizable user interface including provision of choice of a desired language(s) for all user interfaces as well as data components. The current implementation supports the English and Arabic languages. The system can readily be extended to support more functionality such as document management, project management, and automated data acquisition through telemetry, alarms and notifications, to mention few.

Conclusions and Recommendations

Through QaGWRIS, DAWR has established the foundation for an effective and efficient management of the Groundwater Resources of the State of Qatar. In addition to that, it is considered as the corner stone for implementing the Integrated Water Resources Management approach that is fully adopted by the State of Qatar. This approach is recommended by the Water Resources Management and Development Strategy that was developed by the Permanent Water Resources. The system also brings wide range of datasets together in one centralized information management system while providing a comprehensive list of tools to manage the data.

Some of the next steps of the project should focus on the efficient utilization of the system to not only store and manage data but also serve as a medium for public awareness of the water resources. The system should also be upgraded to further

support the eGovernment initiatives in such areas as well permitting, consultant and contractor registrations, farm groundwater consumption monitoring, etc.