

Development of an Interoperable Groundwater Data Exchange Network between the United States and Canada



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ABSTRACT

The Groundwater Interoperability Experiment, initiated by the Open Geospatial Consortium's Hydrology Domain Working Group, was conducted to develop a mechanism for interoperable exchange of groundwater data between the United States and Canada. A framework was developed which incorporates a mediator to transform data in heterogeneous formats into a standard structure. A prime objective was to leverage open standards and information models. The experiment also informed the development of a Groundwater Mark-up Language. A hub-and-spoke architecture was implemented to demonstrate the mediation and exchange of groundwater data between internationally distributed repositories in real-time.

RÉSUMÉ

L'expérience d'interopérabilité sur l'eau souterraine (Groundwater Interoperability Experiment), initiée par le groupe de travail sur l'Hydrologie de l'Open Geospatial Consortium a été conduit pour développer un mécanisme d'échange de données sur les eaux souterraines entre les États-Unis d'Amérique et le Canada. Une infrastructure d'échange de donnée comprenant un médiateur qui transforme les données hétérogènes vers un format standard a été développé. L'objectif premier était de s'appuyer sur des standards de l'OGC et des modèles d'information existants. L'expérience a aussi permis de raffiner GWML (Groundwater Markup Language). Une architecture en étoile a été implantée pour faire la démonstration de la médiation et de l'échange de données en temps réel entre des entrepôts distribués internationalement.

1 INTRODUCTION

The lack of comprehensive cross-national groundwater monitoring has been recognized as a major data availability gap for managing groundwater resources in areas adjoining the US and Canada in areas adjoining the US and Canada. Timely accurate data is necessary for the proper management of water resources for communities, industries, agriculture, energy production and critical ecosystems that rely on water being available in adequate quantity and suitable quality. To meet this need, the U.S. has initiated a National Ground Water Monitoring Network (NGWMN), envisioned as a voluntary, integrated system of data collection, management and reporting that will provide the data needed to address present and future groundwater management questions. The Groundwater Data Portal (GWDP) is the access mechanism within the NGWMN that aggregates and exposes groundwater data from various sources through a single web-based application. The GWDP is based on work done previously by the Geological Survey of Canada (GSC) on the Groundwater Information Network (GIN) for groundwater data management and dissemination in Canada. The U.S. Geological Survey and the Geological Survey of Canada initiated an interoperability experiment within the Open Geospatial Consortium's (OGC) Hydrology Domain Working Group to evaluate

international data exchange standards as a means of federating groundwater monitoring networks across the U.S. and Canadian border.

2 RELEVANT WORK

2.1 U.S. NGWMN Data Portal

The U.S. NGWMN Data Portal is the means by which policy makers, academics and the public access groundwater data through one seamless map-based Web application from disparate data sources. Data systems in the United States exist at many geographic and organizational levels (national, state, local, academic, private); however differing data vocabularies and data structures have made data sharing and reuse difficult.

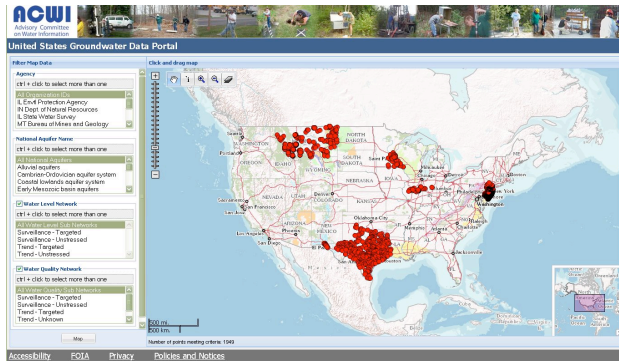


Figure 1. U.S. NGWMN Data Portal Application

The data portal facilitates the discovery, retrieval and access to groundwater data on an as-needed basis from multiple, dispersed data repositories. A hub-and-spoke architecture was implemented where users expose their raw data through web services and the portal aggregates, mediates and serves the disparate data sources in common data elements and terms. The portal leverages the GSC's mediator technology developed for GIN (Brodaric et al., 2010). With this approach, data providers retain ownership and control over monitoring data, reducing the challenges of collecting, aggregating and maintaining large amounts of dynamic data that are inherent with the formation of national data repositories. By implementing a mediation framework, the need for data providers to standardize their output is minimized, providing flexibility and a lower barrier for participation (NGWMN Results, In Progress).

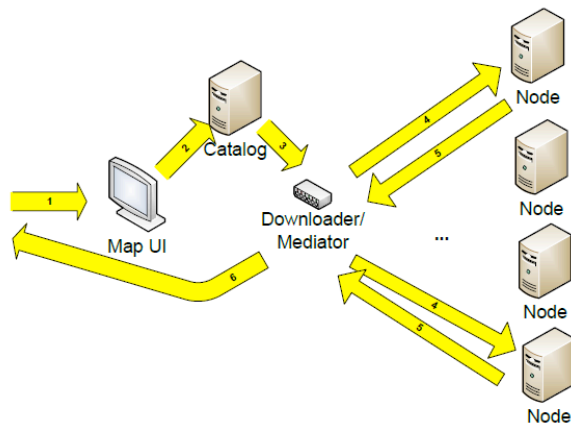


Figure 2. Hub-and-Spoke Architecture Schematic

The portal is capable of displaying water levels, well log data and water quality data in tabular and/or graphical formats and allows the user to bulk download all of the available data for a well in a single excel file. A tabbed window is used to display data of an identified well.

The 'Well Log' tab displays lithology and construction information, which contains a graphic that depicts the lithographic composition of the well bore and the respective lithographic intervals (Figure 3). Both the lithology and construction information are displayed in tabular form below the graphic as well. Furthermore, an internet link to the collecting organization, well latitude and

longitude, elevation and well depth are displayed. This information frequently comes from multiple data sources, which are aggregated by the mediator and then passed to the portal application, which generates the well log figure.

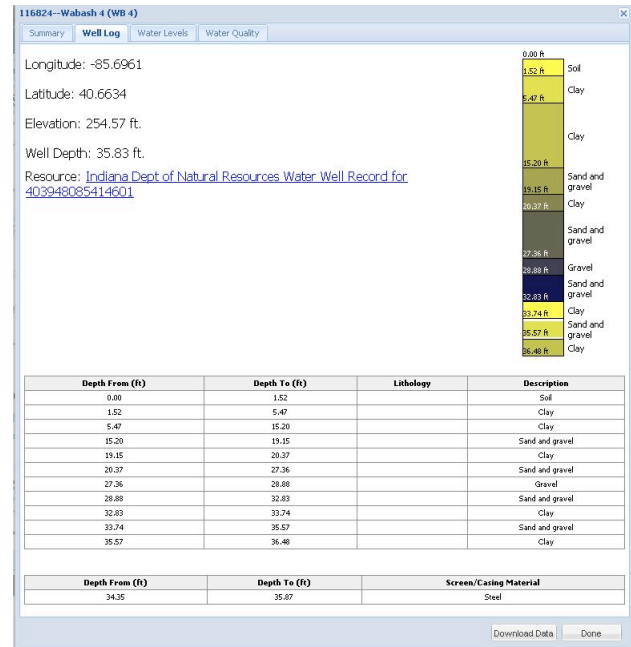


Figure 3. Screen capture of well log data display

The 'Water Levels' tab displays water level measurements both in graphical and tabular form. The hydrograph shows water levels over the period of record. Users can hover over a point on the hydrograph to see individual water level values. The data that populates the hydrograph and the chart are pulled from the data provider and transformed within the mediator to WaterML2.0, which in turn serves the data to the portal application. A screen-shot of the 'Water Levels' tab may be viewed in Figure 4.



Figure 4. Screen capture of water levels display

The 'Water Quality' tab operates in much the same as the 'Water Level' tab, however the data is only presented in tabular form at present. Data are pulled from the data provider and transformed within the mediator to WQX, which in turn serves the data to the portal application. Figure 5 show the current state of the 'Water Quality' tab within the portal.

Characteristic Name	Detection Condition	Measure Value	Units	Value Type
Alkalinity		351	mg/l CaCO3	Actual
Specific conductance		754	uS/cm @25C	Actual
Depth to water level below land surface		39.66	ft	Actual
Phosphate		0.01	mg/l as P	Actual
Total dissolved solids		0.59	ton/lac ft	Calculated
Total dissolved solids		433	mg/l	Calculated
Depth, from ground surface to well wat		11.8	m	Calculated
Iron		470	ug/l	Actual
Sulfate		67.0	mg/l	Actual
Chloride		2.7	mg/l	Actual
Potassium		2.40	mg/l	Actual
Sodium, percent total cations		20	%	Calculated
Sodium adsorption ratio		0.89	None	Calculated
Sodium		37.0	mg/l	Actual
Magnesium		39.0	mg/l	Actual
Calcium		67.0	mg/l	Actual
Total hardness -- SDWA NPQWR		328	mg/l CaCO3	Calculated
Phosphate-phosphorus		0.031	mg/l	Calculated
Nitrate-nitrite	Not Detected	Not Detected		Actual
Total solids		462	mg/l	Actual
Alkalinity		363	mg/l CaCO3	Actual
Carbon dioxide		25	mg/l	Calculated
pH, lab		7.7	std units	Actual
pH		7.5	std units	Actual
Oxygen		1.1	mg/l	Actual
Hydrogen ion		0.00004	mg/l	Calculated
Specific conductance		734	uS/cm @25C	Actual

Figure 5. Screen capture of water quality data display

2.2 Canadian Groundwater Information Network (GIN)

The Canadian Groundwater Information Network employs a hub-and-spoke architecture where a mediator serves at the hub to communicate with the local databases for each of the provinces and territories. Communication between the hub and spoke uses open standards developed by the Open Geospatial Consortium (OGC). The mediator itself is based on Apache Cocoon's open-source XML pipelining technology (<<http://cocoon.apache.org/>>). In addition to standardizing the format of the data, the mediator also performs semantic mediation by translating local terminology to a common terminology.

The mediator technology developed for GIN was utilized and advanced for implementation in both the U.S. NGWMN Data Portal and in the Interoperability Experiment (Brodaric et al., 2010).

3 INTEROPERABILITY EXPERIMENT

The primary goal of the OGC Groundwater Interoperability Experiment is to advance the exchange of groundwater data (water well characteristics and groundwater levels) between Canada and the USA, in the cross-border area of the Lake Superior basin and to do so in such a way that participants can dynamically and transparently access the data and utilize it with their respective information systems.

In order to achieve this goal, a data exchange mechanism was developed that incorporates common information models including WaterML 2.0, GWML and

OGC web services (SOS, WFS, WMS) (Boisvert and Brodaric, 2011a). Therefore, a secondary goal of the interoperability experiment is to advance the design of WaterML 2.0 and to test its compatibility with existing USGS and GSC data systems and OGC standards implementations (SOS, WFS, WMS, and CSW) (Brodaric and Booth, 2010).

3.1 Strategy & Architecture

The OGC Groundwater Interoperability Experiment federates the U.S. NGWMN Data Portal and Canada's GIN by adding an additional centralized hub for data aggregation and mediation between the two national hubs. Differing formats from state organizations in the U.S. and provincial authorities in Canada are mediated to nationally consistent formats and terms, and then further mediated to international standards. The internationalized data are then made accessible to the public via international web service standards.

International standards that were investigated in the experiment include WaterML 2.0 (Taylor, 2011) and the Ground Water Markup Language (GWML). Both standards were developed in an open community led design process. WaterML 2.0 is an evolving international standard for water observations based on the OGC Observations and Measurements (O&M) standard (Cox, 2007a, 2007b, 2011) encodes groundwater levels and is exchanged via the OGC Sensor Observation Service (SOS) standard (Na and Priest, 2007). Ground Water Markup Language (GWML) encodes well characteristics lithology and construction information (Boisvert and Brodaric, 2011a), and is exchanged via the OGC Web Feature Service (WFS) standard (Vretanos, 2011). Data exchange between distributed repositories has been achieved through the use of OGC web services and the GSC's central mediation hub, which performs both format (semantic) and nomenclature (syntactic) mediation of the raw data and outputs this information in a single common format.

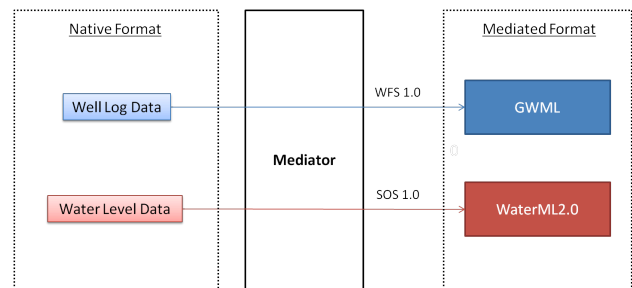


Figure 6. Architecture schematic

This architecture allows groundwater features (wells) and observation data from the United States and Canada to be accessed, mapped, re-organized and delivered through a single portal available as a web application.

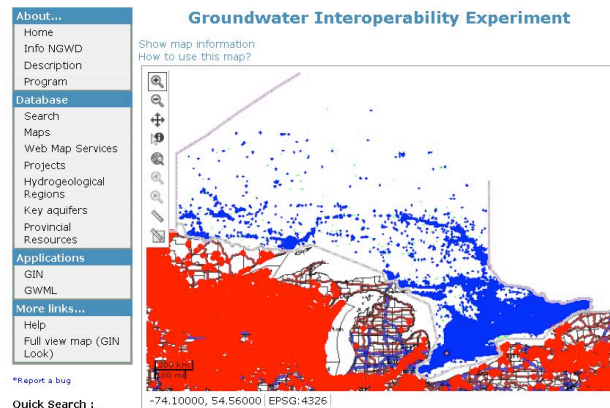


Figure 7. Screen Shot of GWIE Portal

4 CONCLUSIONS

Through the implementation of a service oriented architecture with a central mediation broker, the OGC Groundwater Interoperability Experiment demonstrates how groundwater data can be exchanged in real-time between U.S. and Canada and made publically accessible in common formats and nomenclature through a single web portal via international standards.

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