Freshwater Resources Management – First Steps Towards the Characterisation of New Zealand's Aquifers

Alexander KMOCH, Hermann KLUG and Paul WHITE

Abstract

New Zealand has 16 regional councils responsible for freshwater management working under a common national legal framework. However, management of water quality, water consents and water quantity measurement is a regional responsibility and so is data collection and storage. In order to provide a seamless spatial view of collected groundwater related datasets, regional councils have been visited and stakeholders involved in workshops. Basic cross-regional hydro(geo)logical datasets have been identified and harmonised according to OGC and ISO compliant standards. This is the basis for the data portal and attached three-dimensional web visualisation tool outlined here.

1 Introduction

New Zealand's freshwater resources are extremely valuable and currently these resources (surface water and groundwater) are under pressure from development. However, the understanding of these resources, particularly groundwater, is less than required to meet current and future management challenges (WHITE 2006). For example New Zealand's groundwater resource properties, like storage capacities or groundwater recharge, are not well known which can lead to unsustainable groundwater allocation. Thus the SMART project (www.smart-project.info) aims to establish a valuable basis for groundwater analysis and decision support tools.

The SMART project develops a state-of-the-art groundwater portal in order to connect and harmonise scattered hydro(geo)logical datasets, that were created in different formats and storage representations. A main criterion is open and easy access. There is much data that is publicly available, e.g. by manual downloads in pdf-report form or in Excel spread sheets, GNS Science Geothermal and Groundwater database with data of National Groundwater Monitoring Program (GGW/NGMP)(1), Environment Waikato data portal (EW)(2) or Environment Canterbury download page (ECAN)(3). But this does not enable fast and easy visualisation of the data in the web. Constraints like parameter naming, units and data organisation differ across applications and data tables. Manual download and preparation in specialised software applications needs high technical knowledge and represents a barrier to easy data re-use.

Therefore new interfaces and data transformations have to be implemented and OGC/ISO compliant web services (WMS – web map service, WFS – web feature service, WCS – web coverage service, SOS – sensor observation service, CSW – catalogue service for the web

Jekel, T., Car, A., Strobl, J. & Griesebner, G. (Eds.) (2012): GI_Forum 2012: Geovizualisation, Society and Learning. © Herbert Wichmann Verlag, VDE VERLAG GMBH, Berlin/Offenbach. ISBN 978-3-87907-521-8.

(OGC 2012) are used to publish hydro(geo)logical feature and coverage data, time series and meta data in the groundwater portal. Furthermore the open and standards-based architecture provides the necessary interoperability and contributes to the on-going efforts of the New Zealand Geospatial Office (NZGO)[(4)] to establish a nation-wide SDI (Spatial Data Infrastructure). To exchange hydro(geo)logical data and time series within the SMART project and with other organisations, common data exchange formats should be agreed on. Several GML-based (Geographical Markup Language) application schemas (GeoSciML, GroundwaterML) and encodings for exchange of time series and observations (O&M, WaterML) gain outreaching attention in the international context (BERMUDEZ & ARCTUR 2011, BRODARIC & BOOTH 2011, ATKINSON et al. 2012, KESSLER et al. 2009). Finally the collected data and data sources including their respective metadata should be discoverable and therefore interoperable catalogue services (OGC CSW) provide the required capabilities.

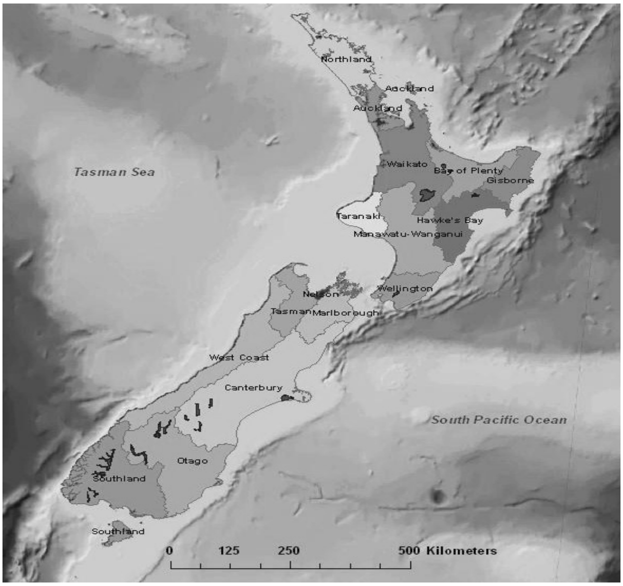

Fig. 1:
New Zealand and its regional government boundaries

As aquifers are inherently three dimensional in their geometry (WHITE 2009, WHITE & REEVES 1999), properties like groundwater volume may vary with time. For all aspects of this project, databases and visualisation systems that support the storage, rendering and publishing of 3D models and time-series (4D) data are required. As the project constraints require easy and open access, proprietary software is not an option. Furthermore the national NZ open data initiative requests the free publication of governmental-funded data collection. For web-based visualisation of 3D models, several technologies are emerging to be standards candidates within OGC and ISO, like X3D, the successor of the ISO standard VRML97 or the OGC 3D web services (WPVS web perspective view service and W3DS web 3D service) (REITZ et al. 2009).

This research aim will build upon established NZ and EU systems and best practices such as GNS NGMP, NZGO Geospatial Strategy, EU INSPIRE Directive, EU projects

GENESIS, GIGAS (PORTELE et al. 2009, SMOLDERS et al. 2011, DIRECTIVE 2007/2/EC)) and meet the needs of stakeholders in terms of open access, interoperability and ease of use. Existing implementations and the proceedings of similar projects like GeoNET (NZ)[5], AuScope (AU)[6] or CUAHSI (North America)[7] will be regarded, too. Web enablement of real-time in-situ sensors (BRÖRING et al. 2011) and their integration into the groundwater data portal will be used to obtain data for groundtruthing the methods to be developed in other research aims within the SMART project.

2 Methods

To effectively and efficiently characterise New Zealand's groundwater resources stakeholder meetings have already been held in order to inform regional councils, water-related business companies, research organisations and universities about the project and to involve them in the development of a common groundwater portal. Especially the last stakeholder workshop at the Hydrological Society Conference New Zealand involved 57 participants. This meeting established an overview of presently scattered data and knowledge resources and gathered feedback about stakeholder needs in hydrological data management. The summary has been extended by further dedicated stakeholder meetings. These meetings addressed the questions: “What kind of databases and tools, standards and services are already in place to characterise New Zealand's groundwater resources?” and “What are the missing elements presently preventing stakeholders and scientists in proper characterisation of New Zealand's groundwater?”.

The design of the products is generally based on open source products and open standards. To conform to the project requirements of easy and open access from the client side, the portal user interface is completely web-based (ZHANG et al. 2011). So there will be no need for a specialised desktop client to discover and explore the published data sets. Recent web browsers are ubiquitously available. Some modern browsers even support the 3D visualisation technology X3D almost natively (BEHR et al. 2009), depending on the capabilities of the graphics card in the computer.

The portal’s data structure has been designed as a service-oriented architecture (SOA) to be extensible and to connect to and provide multiple services and data sources (HILDEBRANDT & DÖLLNER 2010, GIULIANI et al. 2011). It consists of well-proven building blocks. Knowledge from the INSPIRE process and OGC water-related manuscripts have been reviewed and taken into account for database setup. A spatially-enabled project core database supplies robust storage facilities to a variety of server implementations. An OGC conformant core geo-server delivers available datasets via WMS, WCS and WFS. The WMS provides simple map viewing capabilities for the user. Users may also access and download the raw data via WCS and WFS services and in a few common file formats. As multiple existing databases are not spatially enabled by design, a data-source specific interface layer is created to publish data via OGC-compliant web service and to integrate in the SMART portal. This is very specific for each source dataset, as they have different data models with a range of application around New Zealand’s consultancy companies, research institutes and regional councils.

Another server component comprises the sensor interface in the sensor observation service specification of the OGC (OGC SOS). This interface delivers descriptive sensor information in a standardised format (OGC SensorML), observations and measurements (OGC O&M; ISO/DIS 19156) and gathers/receives measurements from hydro-climate sensors (BRÖRING et al. 2011). These sensors may transmit their observations via different means e.g. GRPS, UMTS, satellite connections or via manual data logger import. The data collection may occur on regional or national level. The interoperable design allows the integration of multiple sensor networks that not necessarily need to be under control of the SMART program, as long as they comply with the same open standards (OGC SOS and O&M).

To enable analytic features within the portal, an additional web processing service (OGC WPS) is set-up. This service can be loaded with multiple algorithms and procedures and perform various calculations on the registered datasets (SMOLDERS et al. 2011). The portal's 3D visualisation component prototype will provide pre-compiled 3D scenes from existing geological data models, e.g. created by sophisticated modelling tools. In the later course of the development, the models should be generated from the database (REITZ et al. 2009, BREUNIG & ZLATANOVA 2011). Time series are visualised via graphs and tables in this implementation.

Finally a catalogue service web (OGC CSW) is provided. An OGC/ISO compliant CSW 2.0.2 server implementation is used to register all SMART data sources as New Zealand uses ISO 19115/19139 metadata standard as national standard. Additionally, more hydrological and geographical data publishing web services (OGC WMS/WFS) from participating regional councils can be registered and added to the interface.

The CSW provides two possibilities to contribute its stored metadata to the national SDI, either via providing a downstream search capability to the national SDI catalogue service or other cascaded catalogue services, or by getting harvested by other catalogue services on a regular basis.

3 Results

3.1 Existing groundwater resources knowledge extracted from stakeholder workshops

The regional councils in New Zealand as well as research institutes and consultancies use a variety of tools, applications and databases to manage hydro(geo)logical data (Table 1). The Data Tamer™ application suite from the Hilltop software company is very popular among the regional councils to manage and work with hydrological time series data. The Hilltop software is the successor of TIDEDA™ and is now used by almost 80% of the regional councils. The demand after publishing and consuming of hydrological time series data is increasing. The Hilltop developers announced, that with the anticipated approval of the WaterML2.0 encoding scheme for hydrological time series, they will release an update to support these new standards. The Kisters company with its products Wiski™, Hydstra™, HydroTel™ and the KIWIS™ framework (Kisters Web Interoperability Solution) is also prepared for the arrival of WaterML2.0. Regional councils evaluate either commercial or free and open source software for geospatial data to publish publicly available parts of their data via OGC web services. Regarding sensor information and integration there is a great variety around New Zealand. Research organisations and regional councils, as well as private companies, do drilling, pump tests, water sample analysis, flow recording with manual data entry or sensor-based systems. HydroTel™ is the most common sensor network system in place for hydrological data, incorporating data loggers and real-time (wireless) upstream data transmission.

Table 1: Overview of main hydro(geo)logical data management systems in NZ

Tool	Description
TIDEDA™	DOS/Windows-based database and reporting application for hydrology related time series data, uses special file formats, prequel to Hilltop, now maintained be NIWA *http://www.niwa.co.nz/software/tideda-time-dependent-data*
Hilltop Data Tamer™	Windows-based database and reporting application suite for hydrology related time series data, uses special file formats, server system which provides REST-style XML access, can import HydroTel™ data, OGC SOS 2.0 interface planned *http://www.hilltop.co.nz/*
Hydstra™	Database and reporting application for hydrologic time series data, Australian-based company was acquired by German-based company Kisters around 2003 that promotes Wiski and provides data migration path *http://www.kisters.com.au/english/html/au/homepage.html*
Kisters Wiski™	Full-fledged data management and reporting system for hydrological data and time series, Kisters is working on WaterML2.0 and took part in the OGC surface water interoperability experiment *http://www.kisters.net/wiski.html* Kisters OGC news *http://kiwis.kisters.de/KiWIS/*
HydroTel™	Telemetry / Sensor system from New Zealand based iQuest company (Hamilton), which was acquired by Kisters in 2007 *http://www.iquest.co.nz/telemetry-systems-monitoring.php* Kisters and HydroTel interoperability tests *http://www.iquest.co.nz/environmental-monitoring-blog/index.php/2011/10/05/kisters-using-new-ogc-standards*
Oracle™ and Spatial/Locator™	Multiple regional councils and agencies use Oracle database with and without its spatial extensions and implemented different, independent data models to store hydro(geo)logical data, bore, wells, springs etc., e.g. NGMP/GGW, EW bore database

3.2 Groundwater Portal Implementation Architecture

Instead of a monolithic application, a service-oriented concept has been realised to be easily extensible and as interoperable as possible (Fig. 2). Multiple interfaces provide the means to deliver and consume hydro(geo)logical data. The main processing, transport and mediation happens within the "Data Interface and Services Layer". Project-related new data will be stored in the backend's project main repository, a spatially enabled database that has an appropriate data model in place to support the different needs of the project's researchers including data delivery and visualisation. Additionally, existing data providers can be registered and connected to the infrastructure, either via standardised OGC web services or via mediation interfaces. An example mediation interface has been implemented to attach the GGW to the portal. Also sensors and sensor networks can be attached.

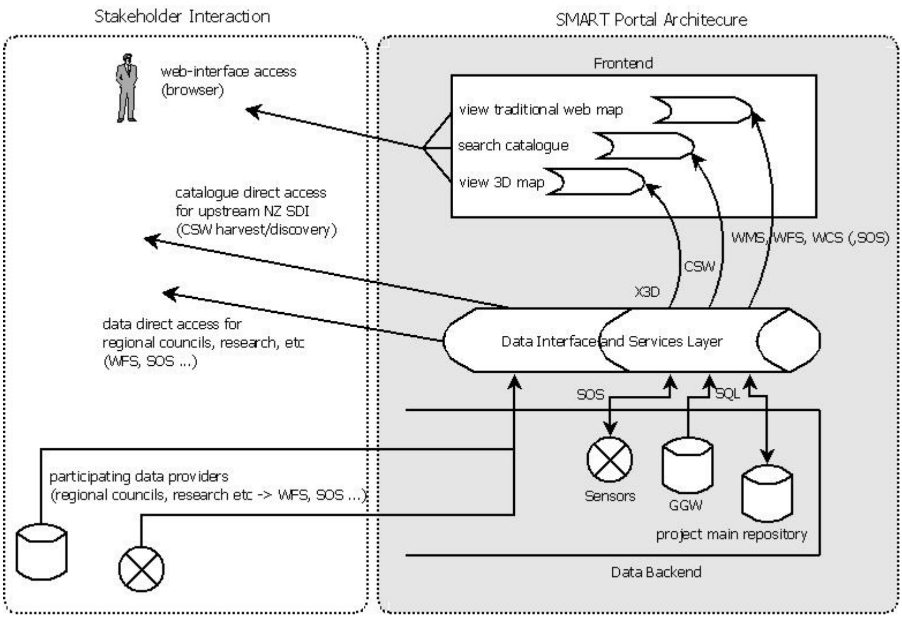

Fig. 2: SMART Portal architecture overview and stakeholder interaction

The web-interface, also referred as frontend or user interface, is the visible part of the WebGIS and takes the data services from the "Data Interface and Services Layer" and comprises a web application that provides the essential data viewing capabilities, like traditional 2D web maps and data graphs and attribute tables. Furthermore the frontend includes a user interface to the portal catalogue to query, search and discover registered datasets. The data is available via direct data access for sophisticated users who wish to use and analyse datasets within GIS and hydrological software applications. The connection parameters and metadata are contained in the catalogue and can be queried.

To prototype the 3D WebGIS capabilities, a 3D data set of the upper Waikato region of New Zealand (WHITE et al. 2011) has been manually modelled and imported. This is a static sample translation from the model grid layers into the X3D scene graph description format, which then is stored in the data backend's main repository. Further development and alignment with international proceedings aim at dynamic renderings and interpolation from e.g. borehole data.

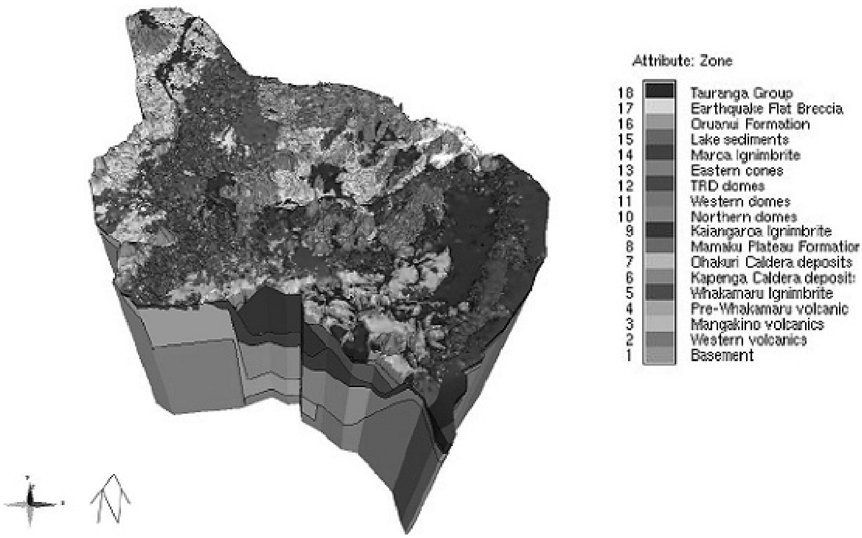

Fig. 3: A 3D model of the upper Waikato region

4 Discussion and Conclusion

The stakeholder workshops have been recognised as extremely important since holistic and integrated transdisciplinary knowledge about tools and data resources for hydro(geo)logical assessment are not yet well established. With the priority datasets we could demonstrate the value of cross-regional council mapping. This is of benefit for consistent and transparent catchment-wide approaches and for analysis at the national level.

3D web-modelling capabilities in New Zealand are presently rare and most 3D models established are based on expensive proprietary (desktop) software solutions. With the 3D WebGIS component we enable stakeholders and decision makers to obtain insight into the subsurface and thus an overview of water resources available for allocation purposes.

The integrating of in situ measurements and time series will characterise the processes and function of the catchment and thus will provide insight in input and output relations in near real-time. Furthermore, the SMART project incorporates water-related methodologies and techniques from remote sensing to identify groundwater-surface water interaction, actual evapotranspiration, soil moisture and groundwater mass changes using GRACE (Gravity Recovery And Climate Experiment). Altogether, the SMART project provides multiple synergising and partly overlapping methodologies and techniques which will be represented in the WebGIS. The dedicated tools and services that are developed and datasets that are collected within this project will be provided freely to users.

Data harmonisation is an important concern because the many data collectors (e.g. consultants, regional councils and research organisations) are independent. OGC services seem to be one of the most accepted transmission specifications and application schemes for data encoding need to be agreed. The GML application schemes GeoSciML and GroundWaterML are promising candidates, but they have to be streamlined to each other and to the latest GML specification. The European INSPIRE model is another good example. For exchange of hydrological time series WaterML2.0 is the most promising candidate. Development on these standards should be incorporated in the technological foundation of the SMART groundwater portal to enable highest interoperability as possible. With the first prototype and the stakeholder feedback we will demonstrate that data harmonisation and seamless visualisation is valuable for understanding and characterisation of New Zealand's groundwater resources.

5 Outlook

After the first year of the SMART project we achieved a first prototype. This needs to be discussed and tested with the involved stakeholders to tailor the tools to the needs of the groundwater industry in New Zealand. Developments will integrate in situ real-time sensor information within the database and the WebGIS.

The catalogue service for groundwater data that provides metadata according to OGC and ISO compliant standards is under development. This will enable searches for datasets via spatial and temporal extent. At that point the groundwater portal and SDI in the background will enable the visitor to discover, visualise and download published datasets, whilst data acquisition, management and legal constraints still remain with the data holders and regional councils.

Acknowledgements

The authors wish to acknowledge the six year funding (07/2011 – 06/2017) of the Ministry of Science and Innovation (MSI), New Zealand. We are also very thankful to the stakeholders participating in this project and providing valuable input for the tool developments.

References

Web References

(1) http://gns.cri.nz/Home/Our-Science/Environment-Climate/Water/Research/New-Zealand-Groundwater-Quality
(2) http://www.waikatoregion.govt.nz/Environment/Environmental-information/REDI/
(3) http://www.ecan.govt.nz/advice/your-water/pages/default.aspx
(4) http://www.geospatial.govt.nz/
(5) http://www.geonet.org.nz/
(6) http://auscope.org.au
(7) http://his.cuahsi.org

Article References

ATKINSON, R., DORNBLUT, I. & SMITH, D. (2012), An international standard conceptual model for sharing references to hydrologic features. Journal of Hydrology.

BEHR, J., ESCHLER, P., JUNG, Y. & ZÖLLNER, M. (2009), X3DOM: a DOM-based HTML5/X3D integration model. Proceedings of the 14th International Conference on 3D Web Technology. Darmstadt, Germany: ACM.

BERMUDEZ, L. & ARCTUR, D. (2011), OGC® Engineering Report: Water Information Services Concept Development Study. Open Geospatial Consortium.

BREUNIG, M. & ZLATANOVA, S. (2011), 3D geo-database research: Retrospective and future directions. Computers & Geosciences, 37, 791-803.

BRODARIC, B. & BOOTH, N. (2011), OGC® Groundwater Interoperability Experiment – FINAL REPORT. Open Geospatial Consortium, Inc.

BRÖRING, A., ECHTERHOFF, J., JIRKA, S., SIMONIS, I., EVERDING, T., STASCH, C., LIANG, S. & LEMMENS, R. (2011), New Generation Sensor Web Enablement. Sensors, 11, 2652-2699.

DIRECTIVE 2007/2/EC Directive 2007/2/EC of the European Parliament and of the Council of 14 March 2007 establishing an Infrastructure for Spatial Information in the European Community (INSPIRE).

GIULIANI, G., RAY, N. & LEHMANN, A. (2011), Grid-enabled Spatial Data Infrastructure for environmental sciences: Challenges and opportunities. Future Generation Computer Systems, 27, 292-303.

HILDEBRANDT, D. & DÖLLNER, J. (2010), Service-oriented, standards-based 3D geo-visualization: Potential and challenges. Computers, Environment and Urban Systems, 34, 484-495.

KESSLER, H., MATHERS, S. & SOBISCH, H.-G. (2009), The capture and dissemination of integrated 3D geospatial knowledge at the British Geological Survey using GSI3D software and methodology. Computers & Geosciences, 35, 1311-1321.

OGC (2012), OGC STANDARDS. http://www.opengeospatial.org/standards: Open Geospatial Consortium.

PORTELE, C., HOBONA, G., PERCIVALL, G., HEYLEN, C., HORN, A. P. V. D., BORREBAEK, M., USLÄNDER, T., KLIEN, E., COX, S., FIERENS, F., SOTIS, G. & WOOLF, A. (2009), GIGAS Technical Note – D2.2b Data Harmonisation and Semantic Interoperability. GIGAS – GEOSS, INSPIRE and GMES an Action in Support, GIGAS is a Support Action partly funded under the 7th Framework Programme of the European Commission.

REITZ, T., KRÄMER, M. & THUM, S. (2009), A processing pipeline for X3D earth-based spatial data view services. Proceedings of the 14th International Conference on 3D Web Technology. Darmstadt, Germany: ACM.

SMOLDERS, S., ALEGRE, C., GIANFRANCESCHI, S., GILLES, M., RESCH, B. & EVERDING, T. (2011), GENESIS Employing Web Processing Services and Sensor Web Technology for Environmental Management. 14th AGILE International Conference on Graphic Information Science. Utrecht, (NL).

WHITE, P. A. (2006), Some Future Directions in Hydrology. Journal of Hydrology (NZ), 45, 63-68.

WHITE, P. A. (2009), Avon River springs catchment, Christchurch City, New Zealand. Australian Journal of Earth Sciences, 56, 61-70.

WHITE, P. A. & REEVES, R. R. (1999), Waimea Plains aquifer structure as determined by threedimensional computer modelling. J. Hydrol. NZ, 40, 49-75.

WHITE, P. A., TSCHRITTER, C. & CAMERON, S. (2011), A 3D Geological Model of the Upper Waikato River Catchment with Associated Hydrogeological Parameters. New Zealand Hydrological Society Conference. Wellington.

ZHANG, Y., LI, W. & LIU, L. (2011), Building the Virtual Reality GIS based on Browser/Service. 19th International Conference on Geoinformatics, Geoinformatics 2011. Shanghai.