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Groundwater Risk Management Using Data Logger for an Automated Information Retrieval

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Abstract

An extensive groundwater risk management, especially in large-scaled catchment areas, can only be achieved by a continuous observation of the groundwater level and indicating quality parameters. Because of the complexity of hydro-geological systems, the net of measuring points (groundwater gauging stations, climate stations, river gages) in such a catchment area is very dense. The maintenance and processing of the heterogeneous and distributed groundwater information requires a high level of manpower. As an aid, in this situation a specialized groundwater data logger can be used for automated information retrieval. Although data logger have been used for the monitoring of rivers for many years, the benefit of monitoring slow altering groundwater bodies has been controversial.

This paper describes the necessity of immediate supervision of groundwater bodies by presenting some critical groundwater situations. Data logger which store groundwater-specific data automatically and in short intervals, have to be integrated in a holistic groundwater management system. Therefore, the logged data has to be transferred, analysed, corrected, filtered and imported. On actual data, the relevant participant can be notified by the system if critical groundwater levels or detrimental effects occur. In addition, the decision makers receive automatically generated examined material and adequate suggestions for the correct countermeasures.

1. Initial Situation

Usually water supply companies administrate many groundwater objects. Most of them are unequally distributed in the catchment area to monitor the level and the quality of the groundwater body. Most of them are groundwater gauging stations where the groundwater level is measured and samples for the laboratory can be taken. The time intervals range from one week up to one month. The time required for the measurement process is high and needs to be undertaken by qualified staff members. In some cases up to date groundwater information is very important. The required intervals in these cases can decline to a daily readout.

Examples of crucial cases include supervision of:

- drinking water springs,
- drinking water wells situated in flood plains and
- emitting areas (e.g., chemical industry).

In these cases the use of data logger with elaborated sensors becomes more and more common.

2. Data Logger

In general data logger are used for an automated retrieval and storage of information from one or more transmitter for specific measurement categories. The log cycle of these measurements can vary between split seconds up to daily intervals. The intervals can be specified by user-defined events or time periods. The use of data logger for monitoring groundwater situations is still low due to high investment costs on

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the one hand and the mostly slow changing groundwater level on the other. The developments of late are changing this situation. The reasons for this are:

- Increasing personnel costs
- Increasing measurement stability for long-term measurement intervals
- Improvement of the electric power supply for data logger
- Development of methods for long-distance data transmission
- Shortening of measurement intervals through orders of governmental agencies
- In addition to the water level, elaborated sensors can collect pH-value, conductivity, turbidity, temperature and chemical parameters like oxygen, nitrate, chloride and ammonium.

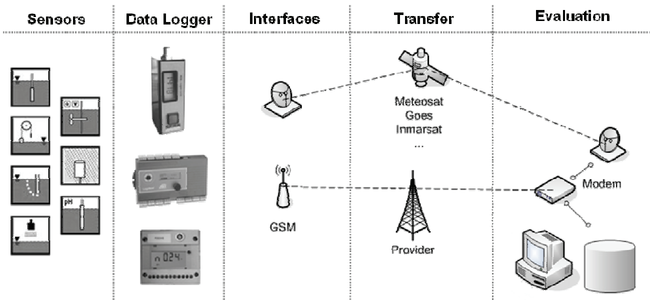

Fig. 1: Data Logger with automated data retrieval

Especially for early risk assessment and controlling of the groundwater situation up to date measurement data is needed, thus automated data retrieval gets more important (figure 1).

At present, the amount of measurement data is rising and enormous data pools are the result. Besides the benefits of the automated data collecting, this fact leads to an increasing complexity regarding the processing of raw-data and the assessment of the groundwater situation. Therefore appropriate methods for the examination, the error correction and the filtering of the measurement data are needed.

3. Components to integrate logger data

Independent of the proprietary formats of specific data logger producers, all log files need to be integrated into the target database (figure 2).

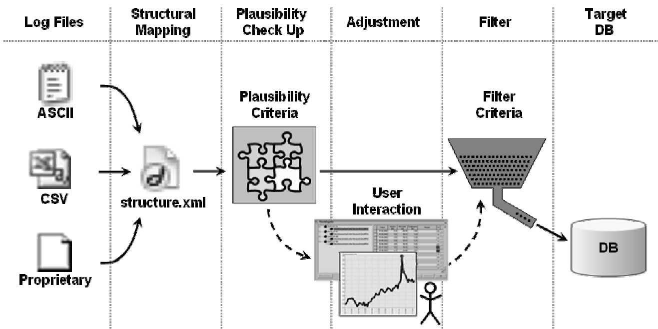

Fig. 2: System Architecture

As the first step, the specific data logger formats have to be mapped with the structure of the target database (chapter 0). All plausibility (chapter 0) and filter criteria (chapter 0) have to be defined in the next steps. If the plausibility check up runs successfully, the filtered datasets can be stored into the database (chapter 0). The imported datasets are triggered and checked by specific rules, which notify the related decision maker to initiate the correct measurements to avoid any dangerous consequences for the environment (chapter 0).

3.1 Mapping

There are different ways the measured data can get from the point of measurement to the analysing system. Data files can be stored on a central memory and be transferred by using remote data transmission or onto a notebook, handheld (by e.g. IrDA, Bluetooth, USB, SDI) or memory card in situ. Data logger of different producers are producing data in differing formats and structures. Therefore a dynamic import tool is designed to work with virtually any data logger file from any data logger, including different formats (ASCII, CSV etc.) and structures.

Flexibility is achieved by using an import wizard which supports easy mapping of data files. In this paper mapping is referred to as a conjunction between source- and target database. Every data file consists of a header and a body. The header defines the object identification and the body contains measurement data. In the first instance the skilled worker determines the header and body block using the import wizard. Secondly, the selection of the separator for each column (Tab, Space, Semicolon, Comma, or Other) needs to be chosen. Then the columns must be mapped to the attributes which are to be extracted.

Not matching attribute formats need some special treatment. E.g., the correct date format must be selected or not matching units can be converted into the correct ones through simple arithmetic. These settings can be stored in schemata and be reused for this or other similar data logger.

3.2 Plausibility Check up

Due to various reasons, logged data do not always have the required quality. Problems can arise from low equipment quality or inappropriate measurement methods. Measure points are placed very often in unobserved rough nature environments hence the most common reasons for mismeasurement are external impacts. The reasons of these impacts are widespread, e.g. vandalism, damage caused by game, drifted measurement points, frost and heat.

To realize and mark low quality data, the gained data undergoes a plausibility check up to upgrade the quality and to eliminate errors. Rules therefore have to be defined. Boundary values, spacing to the value measured before or analogy to coherent measurement points all based on existing experience values and evaluation material provide the basis for these rules. Additionally trivial check ups are also undertaken, e.g. measurement date is not after today, make up the plausibility tests.

Data which can not pass these tests are piped to graphical processing modules. This data can then be edited and corrected or expelled from the import process. Thus suitable treatment is offered for e.g. incorrect long term trends of a pressure sensor and temporary mismeasurements or measurement gaps respectively.

3.3 Filter Criteria

In comparison to manual information retrieval the usage of data logger, especially combined with remote data transmission will lead to a much higher log cycle and thus to an intense increasing number of measurements and amount of data. One measuring point e.g. produced one displacement measurement a month first. Often Data Logger operate with log cycles of one hour. This would increase the number of measurements at this measuring point by the factor of 700. The performance of analysing work depends on the amount of data. The optimum amount of data is often exceeded by using data logger files.

To achieve representative and a suitable amount of data filter criteria can be defined to reduce the number of measurements e.g., retain a fixed number of data points per log cycle time, extracting average values. These criteria can be defined separately for each measurement type in case one log file contains more than one. The raw data, the data from the data files before filtering, are getting saved on back up media for security reasons.

All defined filter criteria will be saved in a separate filter schema similar to the mapping criteria.

3.4 Data-Transfer

After the mapping and filter schema and the plausibility criteria are set for all concerned log files, the import of data into the groundwater management system database runs automatically in case no exception handling is triggered by the rule processing tool. But if so, the corresponding decision maker gets a specific notification and can correct and expel the data by supporting tools (chapter 4).

4. Risk Management

The governmental agencies define legal obligations, which include the amount of conveyance and infiltration masses as well as groundwater levels and quality parameters. Each water supply company has to regard these constraints. Because of the huge amount of collected datasets, the supervision of these demands is very complicated and often causes time delays with negative effects for the groundwater body. All legal obligations contain specific rules. All rules for all related objects (e.g., waterworks, gauging stations, climate measuring points), time periods and specific restrictions have been processed.

By modelling, optimising and storing these rules, the system becomes a knowledge management, which helps to build up a warning and risk management system (figure 4).

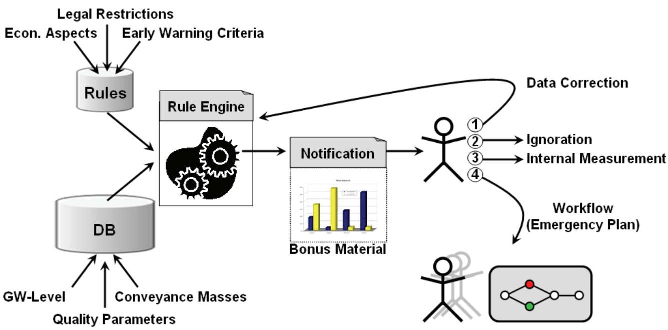

Fig. 3: Schema of the Risk-Management-System

6.1 Rule Definition

Monitoring groundwater information requires:

- An idealised condition: standard data specify an idealised situation. Reference values are set by legal restrictions of public authorities
- An image of the current state: collected data by data loggers describe the status quo
- Rules, to compare the current state with the idealised data

To guarantee a consistently basis for decision universal rules have to be defined. These rules are including legal restrictions like the conveyance masses of wells, the infiltration mass of infiltration facilities and boundary values for the groundwater level and quality parameters. Environmental and economic aspects can require additional rules for an early warning system. The rules are implemented as stored Procedures in the database in form of 'IF…THEN…' regulations.

Examples for rules that suggest a certain action are:

- If the measured data of the measuring points A, B and C are getting below the value of X, then the infiltration of facility D should start.
- If the groundwater table of the measuring point A reaches the value X, and the conveyance-mass of well B gets to the legal limit, it will be suggested to derate well B and to boost the flow rate of well C.
- If the value of measuring point A gets to the value X and well B doesn't reach its allowed conveyance mass, infiltration facility C should start to infiltrate in a way that well B can still work with its maximum allowed conveyance mass for at least the next 3 month.

All these regulations in combination with existing experiences, appropriate countermeasures and the related evaluation material are the basis for decisions for all involved participants.

6.2 In-House Notification Processes

Once the data from the data logger is stored in the database, the implemented triggers compare the new raw data with the defined rules. If a rule is broken, the responsible decision maker will be informed immediately by the local system.
To support the decision maker, specific evaluated materials (like groundwater hydrographs or contour line maps) are generated by the system automatically.

The decision maker has now the opportunities to:

1. Correct the data, if it is obliviously wrong
2. Ignore the broken rule
3. Initiate a suitable counter measure
4. Inform all related internal and external participants (chapter 6.3)

6.3 Workflow

If the occurred critical groundwater situation can not be handled by the decision maker himself, all related participants (e.g., governmental agencies, consultant engineers, other water supply companies, civil protectors, the public) have to be informed immediately. For all water supply companies specific emergency plans exist, which describe the correct workflows and measurements. Important in such emergency cases is real-time notification of all involved participants. Therefore a workflow component has been developed (figure 4). Emergency cases, participants, tasks, rights, processing time etc. have to be created dynamically by using a graphical component in the internet. During a running workflow process it is often necessary to involve new participants and to provide specific information for them. Therefore, the SVG technology has been used. The defined emergency-workflows can be started by a responsible decision maker. All involved participants will be informed over selectable media (e.g., eMail, SMS). All activities are logged in the database to supervise the progression and to reproduce special points of interest in critical situations [Rüppel, 2005].

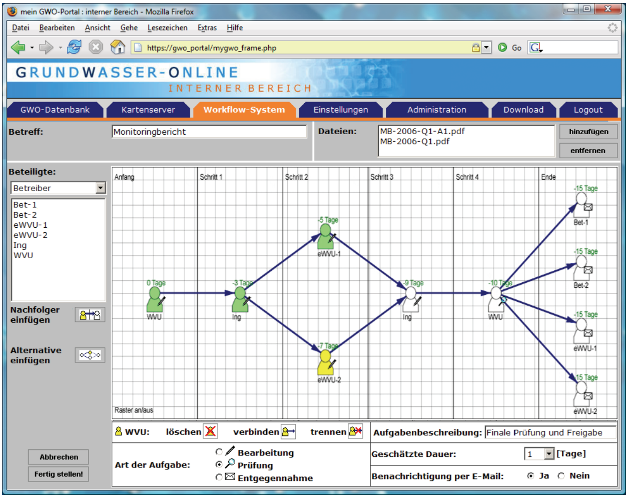

Fig. 4: Workflow-Editor

7. Outlook

As written above data logger are usually placed in hazardous environments. Plausibility check ups can not process and start an exception handling in case of incorrect measurement before the data files are in touch with the import wizard. Thus the frequency of sending data to the import wizard is the maximum possible elapsed time before an error will be noticed. An improvement of this situation and to shorten this maximum time would be to run the possibility check ups in situ directly after each gauging. In this vision 'intelligent' data logger control their own actions. In case of a presumable incorrect measurement or any other predefined exception, the corresponding decision maker gets notified via remote data transmission. This assumes data logger with or connected with sufficient computing power, which are too expensive at present for most use cases.

Bibliography

Boley, H., Tabet, S., Wagner, G. (2001): Design Rationale of RuleML: A Markup Language for Semantic Web Rules, Proc. SWWS'01, Stanford (www.ruleml.org), 2001.

Göbel, P., Gutzke, T., Seewald, G. (2005): Mapping heterogener Grundwasserbewirtschaftungsmodelle. In: Schley, Frank; Weber, Lars (Hrsg.): Forum Bauinformatik 2005 - Junge Wissenschaftler forschen, ISBN 3-934934-11-0, S. 9-16, Cottbus, Oktober 2005.

Gutzke, T., Meissner, I. (2003): Mobile Vor-Ort-Erfassung und Verarbeitung hydrologischer Umweltinformationen. In: Kaapke, Kai; Wulf, Alexander (Hrsg.): Forum Bauinformatik 2003 - Junge Wissenschaftler forschen, Shaker Verlag, ISBN 3-8322-2022-4, S. 360-370, Hannover, Oktober 2003.

Meißner, U. F., Rüppel, U., Gutzke, T., Seewald, G., Petersen, M. (2002): Internet Portal for a Distributed Management of Groundwater Information. In: Proceedings of the 27th General Assembly of the European Geophysical Society, Nice, Frankreich 2002.

Rüppel, U., Gutzke, T. (2004): Groundwater-Monitoring based on dynamic co-operative eGovernment-Processes. In: 10th International Conference on Computing in Civil and Building Engineering. ISBN 3-86068-213-X, S. 116-117, Weimar, Juni 2004.

Rüppel, U., Gutzke, T. (2005): An internet- and knowledge-based alert-system for groundwater disaster management. In: Proceedings of the 19th International Conference Informatics for Environmental Protection, ISBN 80-210-3780-6, S. 196-201, Brünn (CZ), Oktober 2005.

Söhner, K., Gutzke, T., Petersen, M. (2004): Internetbasierte Verwaltung und Visualisierung dynamischer Workflow-Prozesse. In: Zimmermann, Jan; Geller, Sebastian (Hrsg.): Forum Bauinformatik 2004 - Junge Wissenschaftler forschen, Shaker Verlag, ISBN 3-8322-3233-8, S. 130-142, Braunschweig, Oktober 2004.