Implementation of a Web Based Platform for Portfolio Dam Monitoring

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Abstract

For the efficient use of dam monitoring systems, the monitoring data has to be transformed into useful knowledge in order to give the dam owner valuable information about the safety status of his dams. This information should be updated and easily accessible for all technicians and engineers that are involved and responsible for the safety program and therefore directly linked to operation and emergency preparedness proceedings.

In this article, the main functions of a web based software for the acquisition, processing and evaluation of monitoring data is described. It runs in a conventional internet browser and does not require any installation of additional software. It provides appropriate tools for carrying out both a continuous control of the safety status and a detailed analysis of dam behavior.

In a case study, the experience gained during the implementation and more than 6 years of operation for the control of more than 50 dams of a Spanish public dam owner is shown. The implementation comprised a complete revision of the installed monitoring systems and recompilation of all available information. This was used as a basis for an updated and goal oriented definition of necessary variables, configuration of charts, SCADA views and threshold values. Theoretical and practical training of all stakeholders became a key aspect for a successful implementation.

The dam owner could achieve a more efficient use of the installed monitoring system and improve considerably the elaboration of safety reviews and the safety status of his dams.

Keywords: Dam Safety, Monitoring, Management, Instrumentation, Software.

1. INTRODUCTION

Monitoring is an important part of dam surveillance and plays a key role within the framework of dam safety. Dam surveillance is a key risk mitigation tool, providing a means of early identification to reduce the probability of undesirable events that could possibly cause failure from occurring (ICOLD, 2008). Due to aging dams worldwide, population expansion, and a growing demand for transparency, there is a need for increasingly intensive monitoring. This may include automation, telemetry, and information technologies. As a response, operators tend to progressively reduce their non-specialised onsite staff and centralise their technical knowledge.

This includes periodic reading of monitoring data and its evaluation. This is usually done by the means of periodic safety reports according to national and international guidelines. In many countries, reports have to be elaborated on a yearly basis and after extraordinary events like earthquakes and floods. In addition, the current behavior of dams should be controlled on a continuous basis. Monitoring systems offer many different solutions. Nevertheless, a perfectly working monitoring system that is not evaluated does not necessarily reduce risks. Therefore, it is essential to form an efficient connection between data reading and evaluation. The purpose is to transform raw monitoring data into valuable information, giving clear information about the behavior of the dam to the dam owner.

Many dam operators rely on ad-hoc solutions for data analysis, such as spreadsheets with manual data entry. However, a centralised database with specific dam surveillance features can help streamline these tasks, especially in large dam portfolios equipped with telemetry systems, where large amounts of data can make analysis inefficient and time-consuming. It can also allow analysis tasks for geographically dispersed portfolios to be centralised in a single technical office.

This article outlines the main functions of the web-based tool DAMDATA, which was especially programmed to manage dam monitoring data. A case study shows how the application is used for the control of more than 50 large dams of the largest river basin in Spain.

2. MAIN FUNCTIONS OF THE MONITORING INFORMATION MANAGEMENT TOOL

The first version of DAMDATA was programmed in Visual Basic in the nineties and was used for storing and visualization of monitoring data. The latest progress in information technology offered new possibilities in the field of dam monitoring and dam safety and lead to the development of a completely new version of DAMDATA including periodic updates and new functionalities at present. The development was carried out by the Spanish Consulting Company OFITECO in collaboration of public and private dam owners.

2.1. WEB-BASED AND CENTRALIZED DATA BASE

DAMDATA was designed as a web-based application that runs on conventional internet browsers and does not require any local software installation. Compatibility problems with new operating systems or other software are avoided. Maintenance, updates and upgrades are made on the server and do not affect the user's computer or mobile devices.

The following user requirements are fulfilled:

- All data is stored on a central database. Conflict with older versions, raw or invalid data is avoided.
- All users can simultaneously access the same data: dam owners (Dam Safety Engineers, Monitoring Experts and Operators) as well as external experts and stakeholders. Access to the different tools and data is controlled with passwords and predefined user profiles with different privileges.
- Dams are geographically spread. Hand-read data can automatically be uploaded from the site with mobile devices (see figure 1) or inserted manually via an internet browser, and is immediately available on the centralised database.
- The engineer in charge has flexible access to the updated data. They can access it from any computer or other mobile device with internet access. This is very important in the case of extraordinary situations and emergencies.

Figure 1: Data acquisition with mobile device

2.2. DATA ACQUISITION AND THE MANAGEMENT OF FIELD WORK

Data can be uploaded both manually and automatically. DAMDATA provides different protocols for communicating with the dam's data acquisition systems, both with local dataloggers and PLCs or local databases. Even data from accelerometers, that usually form a separate solution in most automated data acquisition systems, is automatically uploaded and combined with conventional monitoring data within the DAMDATA database (see figure 2).

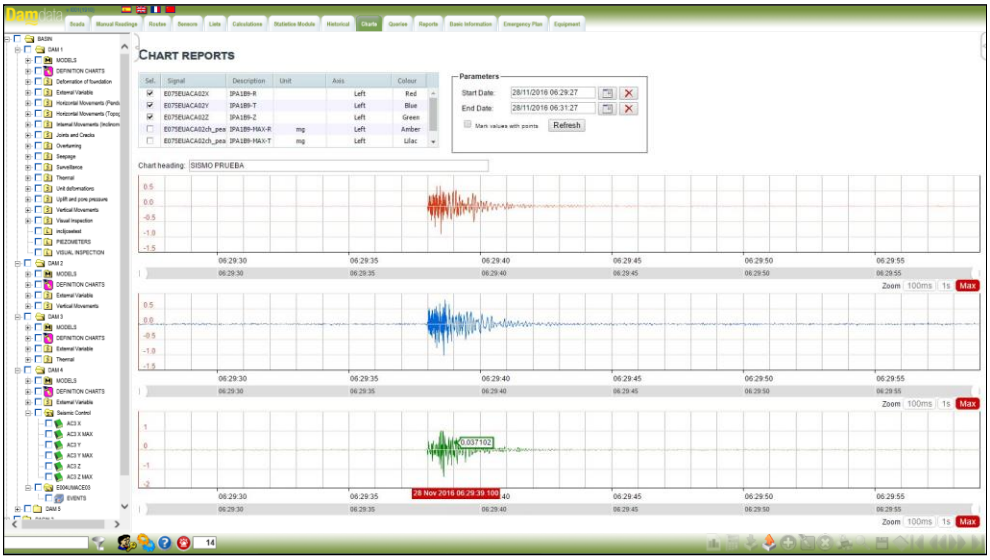

Figure 2: Graphical visualization of accelerometer data in DAMDATA

For new automation systems, a solution was developed that allows synchronisation of sensor configuration and historical data between the Datalogger or PLCs on the dams and the central database. Therefore, an open OPC-UA protocol was adopted in order to guarantee a secure transfer of data. In this way, modifications of the configuration of the data acquisition systems can easily be made through the DAMDATA interface and a backup copy of the configuration of the local data acquisition system is stored in DAMDATA. This simplifies maintenance works and future modernisations of the data acquisition systems.

Hand-read data can be typed in manually, via a predefined menu in the application, or imported from mobile devices (see figure 1). Moreover, output files from the reading devices of different manufacturers, such as data from inclinometers or total stations, can be directly uploaded without manual data processing. Forms for daily, weekly, or monthly reading routes can be prepared to facilitate hand readings. Forms can either be generated in PDF format and printed, or directly filled in on any mobile device synchronised with the central database.

In order to provide reliable data, it is necessary to perform periodic maintenance works of the monitoring system. DAMDATA facilitates the control and organisation of maintenance works and field campaigns. Time schedules, with periodic routes with tasks to be performed and devices to be read can be prepared, and are synchronised with mobile devices. In this way, the field technician receives updated information of pending readings and maintenance works. The required material and personnel can be assigned to each task.

2.3. DATA VALIDATION AND ALARM MANAGEMENT

The definition of thresholds is a key aspect of dam surveillance. The comparison of acquired data against predefined criteria can raise early alarms, detect device malfunctions and, in some cases, motivate the activation of an emergency action plan.

For each variable, various threshold values for operation, safety and emergency situations can be defined:

- Absolute values: maximum and minimum thresholds
- Gradients: changes in relation to anterior readings
- Functions: with a formula editor, equations can be defined in order to include the influence of other variables such as temperature, reservoir level and precipitation

To avoid alarms created by erroneous data, different procedures for data validation were implemented. Data is either quarantined, pre-validated or validated, and can only be approved by authorised personnel. All data modifications are registered by the system, including author information and the type of modification being made.

2.4. GRAPHICAL VISUALISATION

Most operators rely on graphical visualisation to evaluate monitoring data, especially when trying to detect trends and correlations in large amounts of data. Therefore, strong flexibility is necessary to represent this data in a clear way, allowing for the precise comparison and cross-referencing of data.

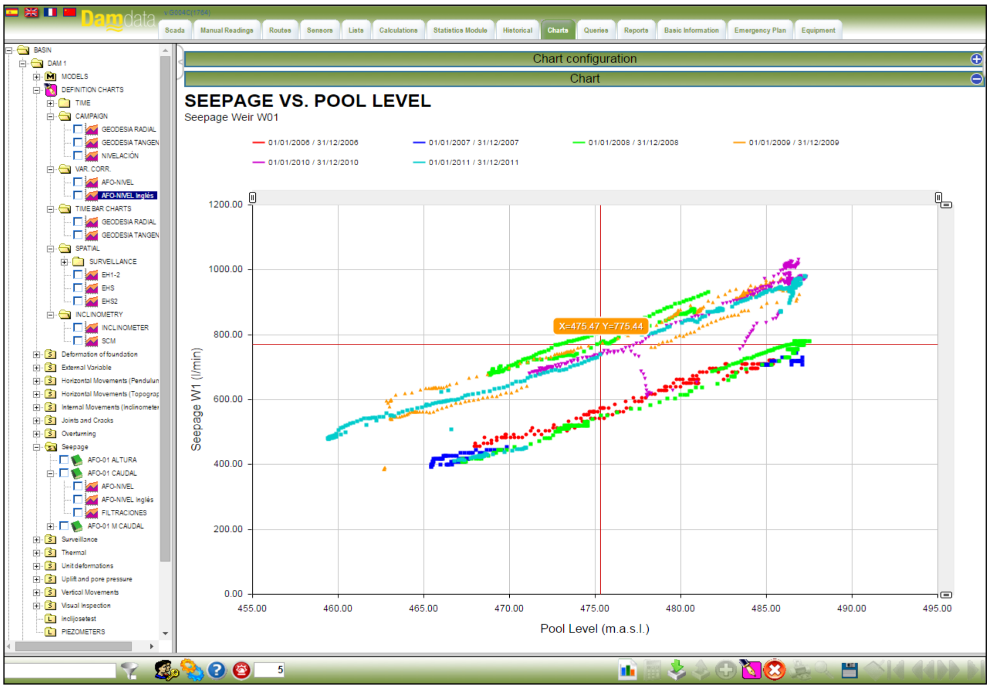

Figure 3. Visualisation of seepage as a function of pool level for different time periods

DAMDATA allows the user to individually configure each graph and chart. In addition to the classic representation of data as a function of time, the local distribution along the dam of isochronous data can also be displayed. This is very useful for visualising deformation along the dam crest or galleries, and for identifying differential deformation between adjacent blocks. Moreover, the relationship between two different kinds of variables can be visualised in dispersion graphs, which can be used to assess the influence of external variables such as temperature and reservoir level on the control variable (see figure 3).

It is also possible to configure layouts, arranging different graphs on a single page. In that way, all sensors in a control section can be compared with each other, or different information from one sensor type can be shown. Figure 4 shows the temporal evolution of the external variables (top), pore pressure (second), piezometric head (third), and the ratio between pore pressure and reservoir level (fourth) of seven different piezometers. In addition to graphs, sketches, sign conventions, and other information can also be added (see figure 7). These graphs are an essential interpretation tool for safety reports.

Each dam has a unique design with different characteristics. Larger dams require particularised monitoring systems tailored to their identified failure modes. It is then useful to have particularised information displays, in order to detect and monitor possible events.

DAMDATA allows the design of custom SCADA visualizations (see figure 5) with user-defined variables, graphs and images. This tool enhances the real-time features, allowing for instant verification of a particular control section or event. Besides the actual value, additional information such as date, time and alarm level are shown. In order to illustrate the tendency of a value, a graphic window showing the last values can easily be displayed with a single mouse click on the sensor.

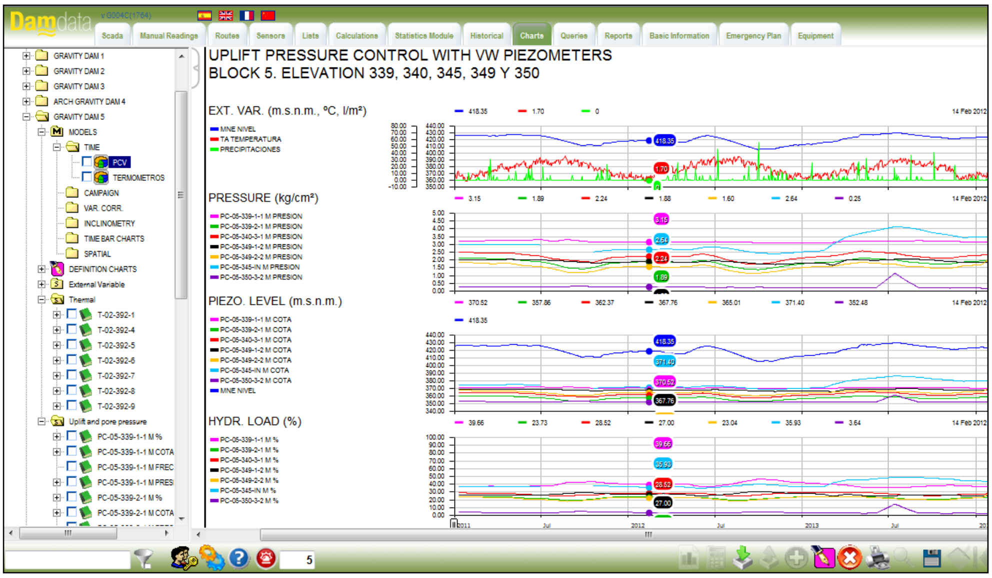

Figure 4. Time evolution of 7 piezometers, showing external variables (top), pore pressure (second), piezometric head (third) and the pore pressure / reservoir level ratio (fourth)

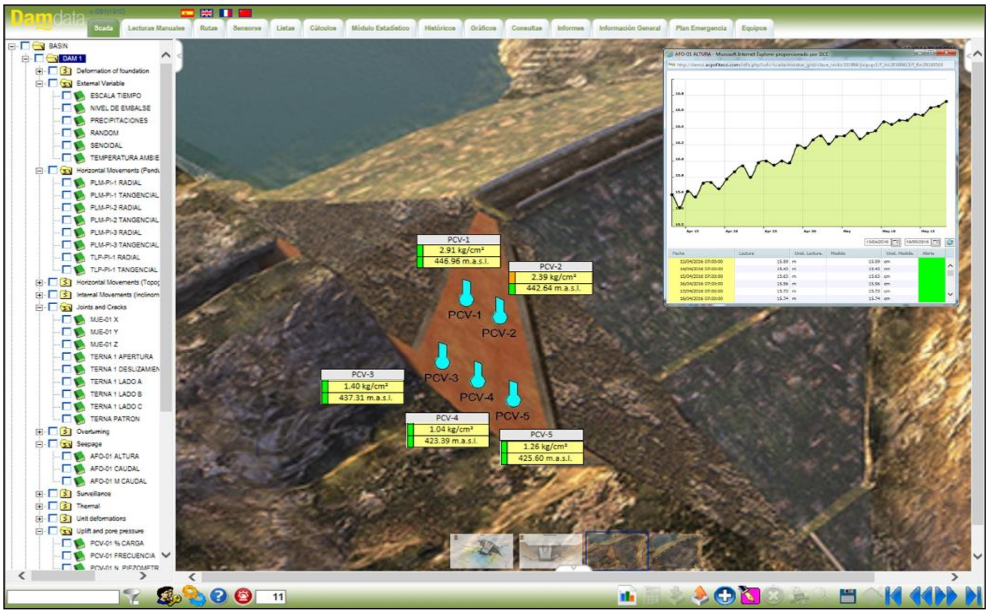

Figure 5. SCADA visualization of an embankment dam

2.5. STATISTICAL MODELLING OF VARIABLES

In some cases, safety assessment requires a detailed analysis rather than the direct measuring and observation of a simple event. This is particularly true in the analysis of complex effects, such as stresses and displacements in double-arch dams, where hyperstaticity and internal/external interactions make it difficult to establish cause-effect relationships.

For these detailed assessments, the statistical analysis application AUSMODEL has been integrated in DAMDATA. It was especially created for evaluating historic dam monitoring data, and controlling and forecasting phenomena related to dam behaviour.

The main goal is to find correlations between external values (e.g. temperature, reservoir level, etc.) and the monitoring data. The method is based on the consideration of three basic components:

- irreversible effects during time
- influence of reservoir level
- influence of annual thermic cycle

The model allows the isolation of the effects of each of these components and quantifies their impact on the behaviour of the control variable. In addition, the model can forecast the behaviour of the control variable by determining an expected value for different combinations of time, temperature, and reservoir level.

3. CASE STUDY OF THE IMPLEMENTATION OF MORE THAN 50 DAMS

As a case study the experience gained during the implementation of DAMDATA for the management of more than 50 large dams in the river basin authority is described in this chapter. The dams were arch, gravity and embankment dams. Some were older than 100 years while others had been constructed in the last decade.
The variety of the dams is reflected in the diversity of the installed monitoring systems. Some installations are quite simple and aged, while others have been modernised several times with new sensors, and are completely automated. Different systems from local and international manufacturers were installed.

The system was implemented together with a detailed revision of the complete monitoring system. The sensors were recalibrated and a functional analysis of the systems was carried out. An inventory of all installed sensors was set up. Installation details, technical documents and drawings were analysed and compared with the actual situation on the dam. Formulas and constants used for the calculation of the variables in the local software were also revised.

Figure 6. Training course during implementation phase and review of monitoring system

An important aspect of the implementation process is acceptance by the different users. Therefore, the interfaces had to be user-friendly and helpful for all specialists involved in surveillance tasks. The first step of the project was to involve the different users in the development process, documenting their needs and procedures, and requesting their input. The second step was to present the different features of the monitoring information system, motivating the users to work with it and providing feedback. Theoretical and practical training sessions were organised to show the importance of surveillance in aging dams and the role of each participant in the evaluation process. In addition, user manuals were prepared and training courses focusing on individual requirements were organised, depending on the different functionalities to be used by each user profile.

Approximately 7,000 sensors and 25,000 variables were configured for the software. Monitoring data from the last 30 years was processed and sign conventions were standardised. Some data was available in digital format and could easily be imported. Other data had to be entered manually from hand written field reports.

In addition, a total of 650 SCADA views where prepared (see figure 5). Colour drawings showing selected sensors in plan views, front views and cross sections of each dam were prepared and uploaded. These drawings show the real-time values of monitoring data and the alarms status of the visualised sensors.

In other words, by implementing DAMDATA in the whole river basin, all information related to dam monitoring was duly documented, updated, and consolidated into a single database.

The database was installed on the local server of the river basin authority. Via VPN Connection, the system could be configured and updated by OFITECO simultaneously from different locations.

The data from the automated systems is automatically updated and available in real time. For this, the communication network installed for the Automated Hydrologic Information System was used. Interfaces were programmed between DAMDATA and the different software types installed on the local data loggers of the dams. Hand-read data is directly inserted into the centralised database via customised menus by the local staff at the dam. Therefore, the dam owner's staff were trained to use the software. In addition, customised lists were prepared for each dam and type of reading (daily, weekly, monthly, annual), were prepared, displaying the sensors to be read in the optimal sequence.

Different threshold values from operation manuals and emergency action plans were configured for continuous control. These are constantly compared with all automatic and manual data. Values that exceed the threshold values are marked, and the system notifies the person in charge.

For the safety reports, 3,800 different graphics and layouts (figure 7) were configured to display the data in a clear and organised way, to provide the necessary information for its evaluation. These layouts can be exported in PDF format as a batch, showing a common predefined time period, for easy integration into the annual dam safety report.

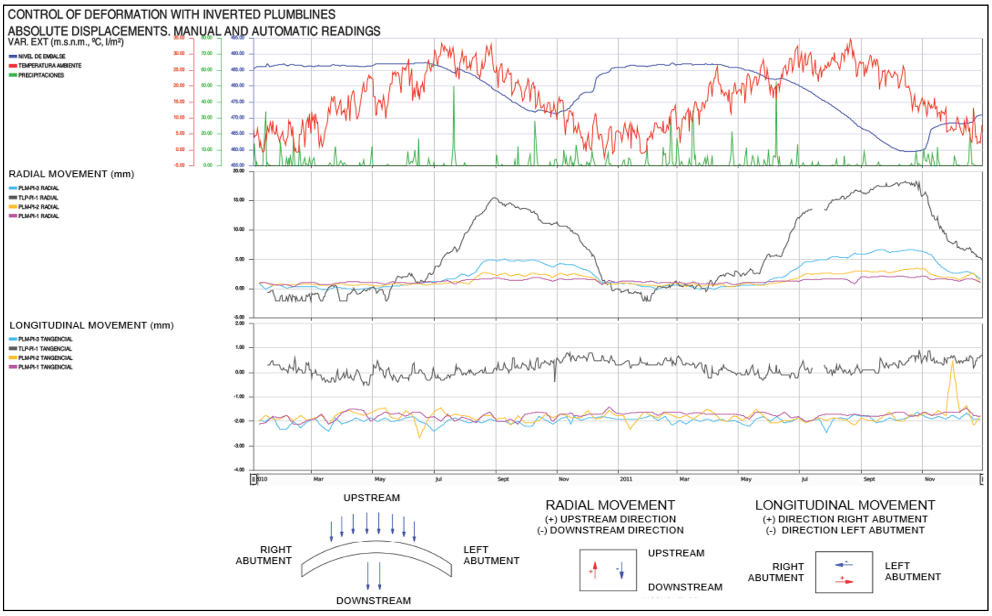

Figure 7. Layout example for a plumbline configured with DAMDATA

Currently, more than 100 engineers, site operators and other personnel involved in the dam owner's safety program have access to the data. Over the last 8 years, more than 400 annual and 50 extraordinary reports have been prepared using the application. After an earthquake in 2010, both the dam owner and external experts had immediate and easy access to the updated data of all affected dams, assisting them to make decisions about the measures that had to be taken.

4. BIM – Building Information Modelling

Building Information Modelling (BIM) offers additional possibilities for asset management. Within a new project, monitoring data provided by DAMDATA was combined with mobile forms for visual inspections and maintenance works and synchronized with a 3D model of a dam. In that way, a new tool for managing Dam Safety and Asset Information that offers added value to traditional management systems is achieved. In figure 8, the interface of ODIS (Online Dam Information System) developed in collaboration between Hochtief-Vicon and OFITECO is shown.

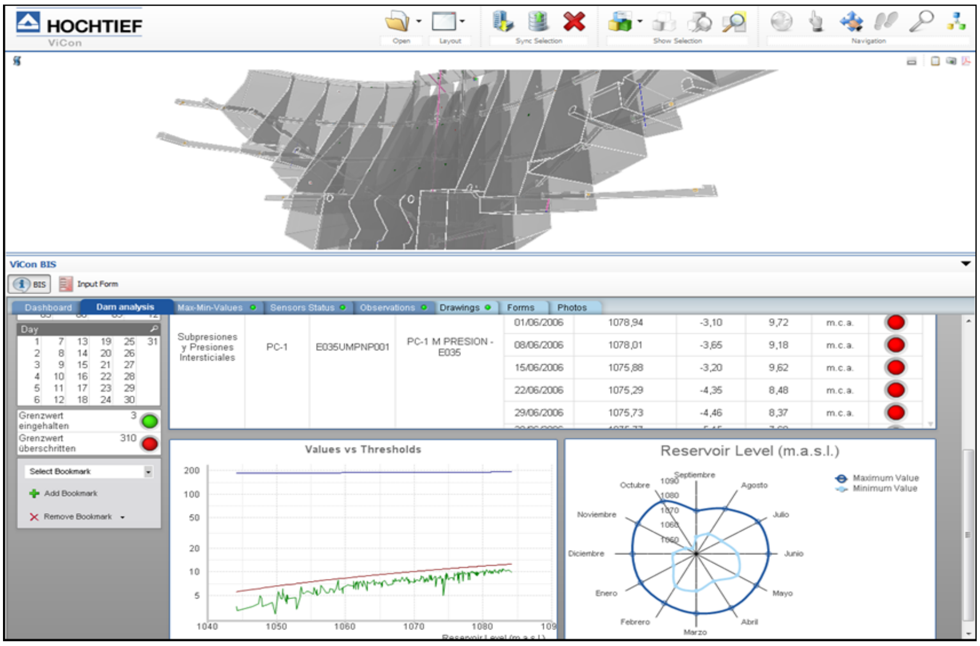

Figure 8. BIM Solution for Dam Safety Management

5. Conclusions

A centralised system with an online database and analysis functions provides dam operators with valuable support to streamline the surveillance process of a large dam portfolio, especially when the dams are geographically dispersed. Nevertheless, a good monitoring system that provides high quality data can only be successful in combination with a good maintenance program for all elements.

DAMDATA is an efficient tool for the evaluation and management of monitoring data. Dams can be operated in a safer and efficient manner thanks to the centralised management of the data and the possibility of having easy, flexible access to the whole monitoring system via the web. By offering different ways of displaying and analysing monitoring data, a target-oriented interpretation of dam behaviour is achieved.

In the case study of more than 50 dams, the evaluation process of monitoring data was optimised considerably, from data acquisition to the preparation of safety reports. The continuous surveillance and the understanding of the current behaviour of the dams was also improved. By implementing DAMDATA across the whole river basin, all information related to dam monitoring was updated and organised into a single database. Today, the system continues to work effectively and has been internalised into the dam owner's day-to-day operations.

6. References

1. International Committee on Large Dams ICOLD (2008). General approach to dam surveillance. Bulletin 138.