

Documentation, records and reporting: smart management of dam safety documentation and records

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1 ABSTRACT

Having a complete file of all relevant documents, records and reports of a dam is of vital importance for the safety of the dam. The collected documentation is the knowledge base that must contain the historic information of the dam to allow for comprehensive safety assessments and evaluations, as well as additional specific studies especially in case of existing dams.

This knowledge must be easily accessible and available to the technical staff involved. Further it is very important to continuously update the file. Nowadays technology provides a variety of tools to facilitate this challenge: digitization of all information, control tools, document manager in a web environment, application to BIM methodologies (Building Information Modeling), etc.

In this paper the advantages of a modern dam data management system are explained as well as possible further applications for dam surveillance activities.

2 THE TECHNICAL FILE OF A DAM

2.1 *What is the Technical File of a Dam?*

The Technical File of a dam comprises all relevant documents and data related to the project, construction, operation, maintenance, and ultimately the safety of the dam. ICOLD Bulletin 158 insists on the importance of this information: *“Dam records are of enduring value and are a critical part of the owners and operator’s archives, which constitute the institutional memory for these very long lasting facilities.”*

These documents may be on paper in one or more locations, and/or digital. Thus, there can be cases of all kinds: dams with little or no information, others that have it partially scattered in different locations, in other cases everything is only on paper and not well classified. On the other extreme there are dams with a complete and well organized digital file, even using specific data management tools with a centralized database.

It is the responsibility of the dam owner to collect, organize and update all documents and records and to allow to access and manage this information in an efficient way.

2.2 *Importance of the Technical File of a Dam*

Every engineer involved in preparing dam behavior reports or safety reviews of dams may have experienced how tedious and time-consuming it can be to search for documents and reliable data and validate them, especially if there is no central archive or chronological gaps. Often more time has to be invested for data collection and data preparation than for the actual behavior and safety analysis itself.

An incomplete documentation and data set with lack of information is also a source of uncertainty and may lead to poor or incorrect diagnoses, especially during emergency situations like floods. An example is an incident occurred in a Spanish arch-gravity dam. The 56.5 m high dam with a crest length of 322 m was constructed in the 1920s and severe floods caused overtopping in three occasions throughout this last century due to the insufficient spillway capacity. During the last flood that led to overtopping of the reservoir water over the entire dam crest (Figure 1) all of a sudden an uncontrolled outflow was detected through the dam wall close to the bottom outlet (Figure 2).



Figure 1. Overtopping of the dam crest.



Figure 2. Uncontrolled outflow next to the bottom outlet detected during overtopping.

During the flood emergency management the dam engineers and operators were trying to understand the origin of this outflow and to evaluate the possible consequences, including the progressive opening of the hole considering even a dam break scenario. All existing available documents, especially drawings were checked in order to detect any hint to be able to assess this emergency situation. Finally it was not after several days after the flood when documents appeared that showed a former pipe crossing the dam body where the outflow appeared. This pipe had been sealed and covered in the past and this information was not available in the official set of dam documents during the emergency, generating a very critical and stressful situation for the responsible dam personnel and even social alarm.

This example clearly evidences the importance of a complete dam documentation file and the possibility to access the information in an easy and efficient way. In case of dams with a life span of many decades and even centuries this is especially important to conserve and transfer the knowledge and information from one generation of responsible engineers and operators to the next one. Knowledge management over the years, especially in the case of dams with a lifespan of many decades, is essential to keep "memory alive". The Technical Archive is a key part of dam safety data management.

2.3 General aspects regarding the Technical Archive in the Spanish dam regulations

At present, the "Instruction for the Project, Construction and Operation of Large Dams" of 1967 and/or the "Technical Regulation on the Safety of Dams and Reservoirs" of 1996 is still applicable to many Spanish dams. Both regulations refer to Technical Archives of Dams, being mandatory for dam owners.

The Spanish dam safety regulations are currently under review and its draft versions have recently been submitted to a public information and scrutiny procedure. The final approval of this new dam safety framework by the Government is expected throughout 2020. Some of the general aspects contained in the draft, refer to dam data management:

- The owner shall be responsible for the compilation, classification, as well as availability and updating of all documentation included in the Technical Archive.
- The organization of the Technical Archive should ensure easy accessibility to its documents. Strict monitoring of all documentation shall be applied, indicating at least the date, author, version and location of the document.
- Public authorities in charge of dam safety are entitled to inspect the Technical Archive or collect any information contained therein.

The set-up and maintenance of a Technical Archive with all relevant documentation on the dam and its reservoir will be an obligation for all dam owners, both public and private.

3 INFORMATION MANAGEMENT OF DAM DOCUMENTATION AND RECORDS

3.1 Handling and classification of documents

ICOLD Bulletin 158 proposes how to arrange the documents and records:

“Nowadays, document management begins with the conversion of paper or other documents into digitized images or files that can be easily organized and quickly retrieved, indexed and archived. This operation should be carried out under the supervision of highly experienced dams engineers, geologists and hydro-mechanical personnel, to classify available information by specialty, importance, conservation period etc.

There are many ways that documents and records may be efficiently filed and maintained. Some characteristics of effective filing systems include:

- *well-designed file structures*
- *well-established procedures regarding what gets filed and how the files are managed*
- *well-defined roles and responsibilities for maintaining the files”*

The main message deals with the value of information: transforming data and papers into useful information for managing dam safety.

Having documents in paper format piled and mixed up, is almost like having nothing. Anyone related to the dam who wants to find something quickly will not be able to do it if there is no proper ordering.

The first step is to identify, locate, sort and classify the existing documents. Especially in the case of older dams and dams that changed the ownership, the documents might be scattered in different locations or even be missing (Figure 3).

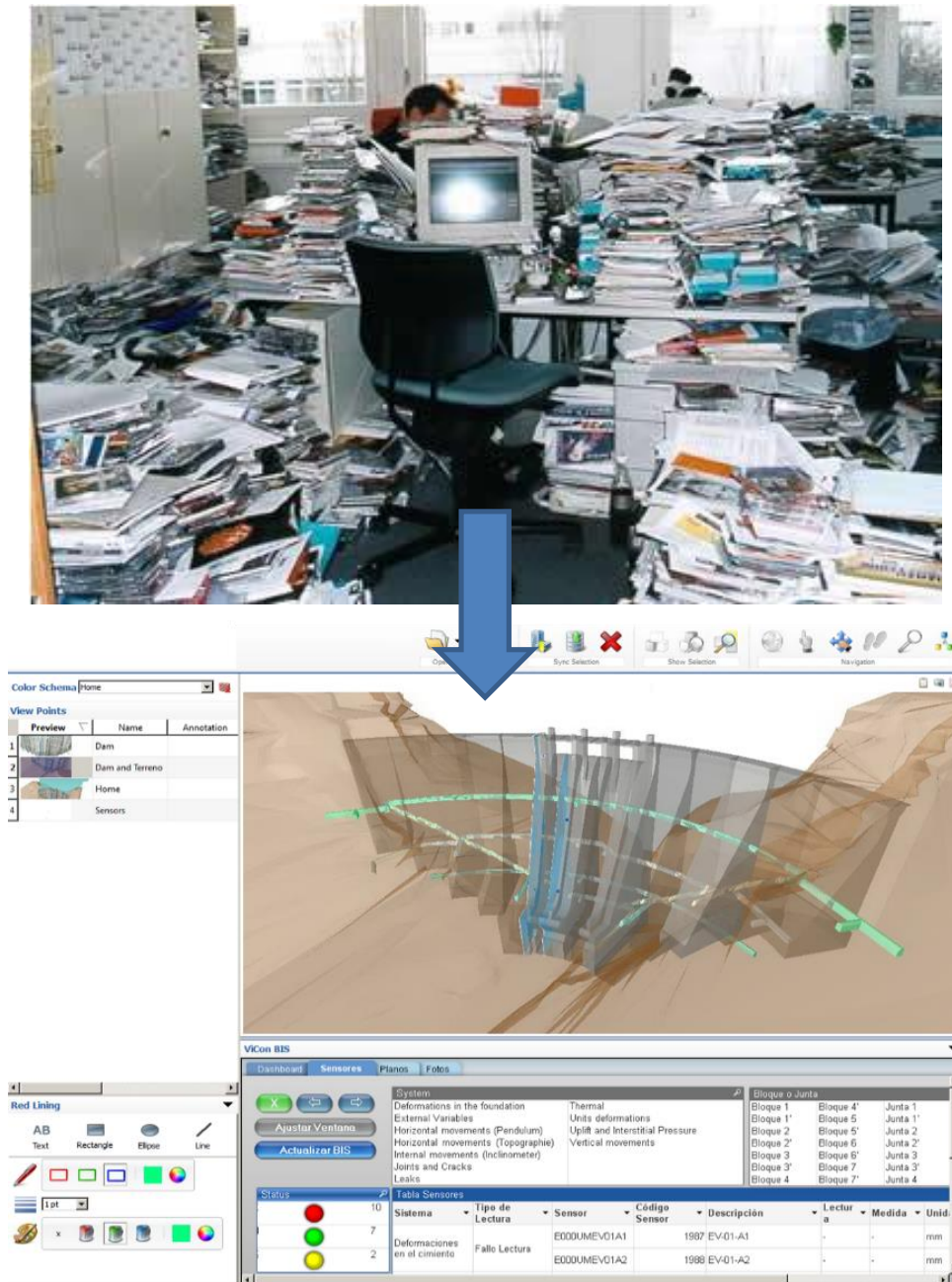


Figure 3. Digitization of existing paper documents using a dedicated information management system.

3.2 *Storage of documents*

For paper documents it is very important to store them in a suitable, clean, moisture-free place, well-classified to simplify document searches. A user control system should exist to avoid access of non-authorized persons.



Figure 4. Technical File of several dams in the province of Huelva (Spain) owned and operated by the Regional Government of Andalusia.

3.3 *Digitization and document management*

This process seeks to arrange the existing information in a digital and central database. The basic tools of the process to migrate from having a certain amount of unordered and scattered documents in paper format comprise:

- Digitization: applicable to the documents of the Technical Archive but also to the observations during surveillance tasks such as visual inspections and maintenance.
- Use of modern document management systems, preferably customized to the specific characteristics of dams.

Most of the recent developments of software tools to manage dam data and information are working in a web environment simplifying the user access throughout an internet connection and through multiple devices. As an example some features of such a document manager are shown, in this case the one developed by OFITECO as a module within the application DAMDATA.

- Allowing different levels of access depending on the user profile.
- Intuitive navigation tree to access the different folders and to access the command menus for visualization and editing.
- All types of data and information can be managed: numerical, text, images, etc. (e.g. inventories and O&M manuals of equipment and installations, photographs, monitoring and operational data, templates and sheets for visual inspections and maintenance tasks, etc.

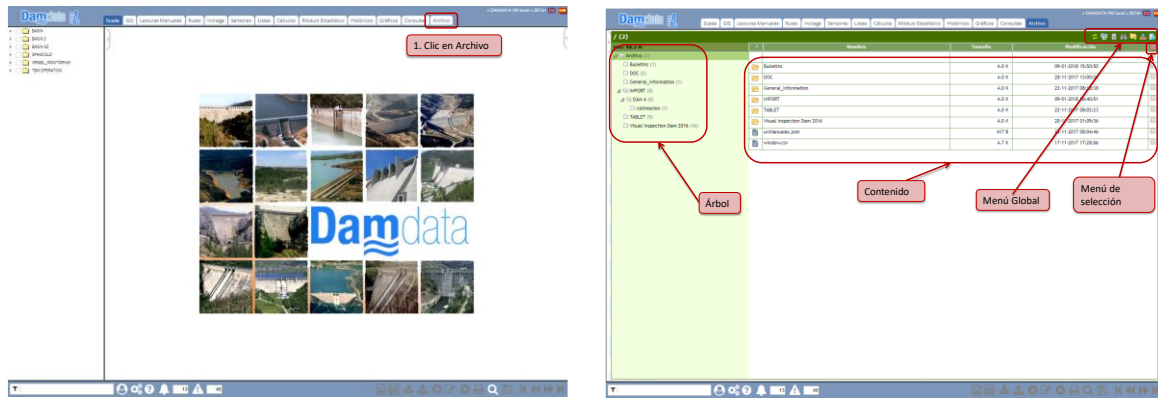


Figure 5. Dam document manager developed by OFITECO as a module of DAMDATA.

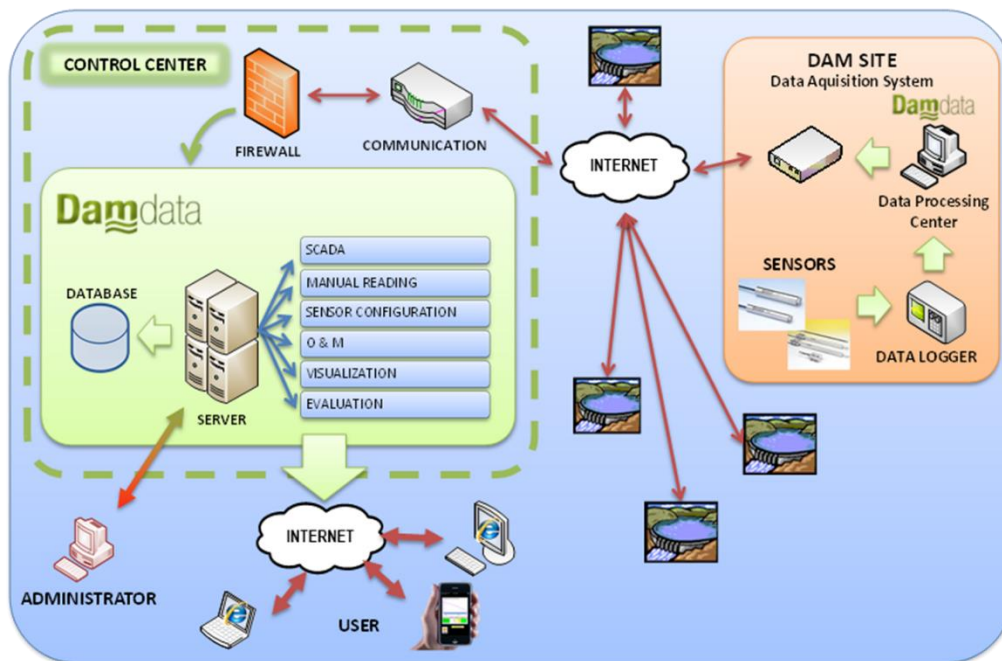


Figure 6. Conceptual design of the dam safety management tool DAMDATA, developed by OFITECO.

4 FUTURE TRENDS BASED ON DAM DOCUMENTATION MANAGEMENT

4.1 Asset Management Systems

An increasing number of dam owners are using asset management systems to handle efficiently the maintenance and operation of their infrastructures and installations. Asset management has already a considerable tradition in applications to industrial facilities and other civil infrastructures such as bridges and roads. Among dam owners, especially hydropower companies started to introduce asset management for dams. For that purpose, a digital technical file that faithfully reflects the inventory of all the works and installations of the dam-reservoir environment is a key element.

The main purpose of asset management is to maintain and preserve infrastructures to guarantee its functionality over time and to extend its service life within a sustainable context considering safety and social and economic aspects and also climate change adaptation.

The implementation and setup of an asset management system requires that the dam owner clearly defines the objectives and collects all available data and information. An initial approach may start with answering the questions of Table 1.

1	What do you own?	Detailed and updated inventories of dams and ancillary works
2	What is the worth?	Determination of the value of the assets
3	How are your assets?	Assessment of safety and operational conditions
4	What to do?	Design of rehabilitation and upgrade works
5	How much does it cost?	Preparation of cost estimations considering the service life of the works
6	When to act?	Definition of priorities of actions (risk analysis)
7	How to pay?	Development of a sustainable economic and financial model

Table 1. Asset Management: 7 questions for owners.

A complete and updated Technical Archive comprising the details of all the elements, i.e. an inventory is a necessary source to set up a management system.

Software tools are employed to organize and implement multidisciplinary strategies for preventive, corrective and predictive operation and maintenance tasks.

Dam safety aspects and the applicable regulations must be considered in asset management systems for dams. The conjunction of a dam and its foundation is a unique combination and the potential failure modes might be quite different, even for apparently similar dams. It is important to take into account this fact, which is quite specific to dams compared to other type of infrastructures or industrial facilities characterized by a higher repeatability of its behavior.

4.2 *On Line Dam Information System (ODIS)*

One of the biggest challenges for modern societies in the beginning of the 21st Century is to develop, implement and apply digitalization solutions to practically all type of industries and organizations. Dams are no exemption and some dam owners have already started to use powerful tools such as BIM not only for the design and construction of new dams, but also for improving operation and maintenance tasks of existing dams. There are solutions that allow access to any information interactively, providing access to data and observations in real time.

As an example, the ODIS system was developed by OFITECO a few years ago in the framework of an R&D initiative about the application of new technologies in the field of civil works. This tool allows the use of 2D and 3D models, facilitating to schedule and design O&M and inspection and monitoring tasks, to perform cost studies and budget follow-up as well as to link different processes of a project. It is a web platform where different multidisciplinary specialists have collaborated. The modular architecture of ODIS is shown in Figure 7:

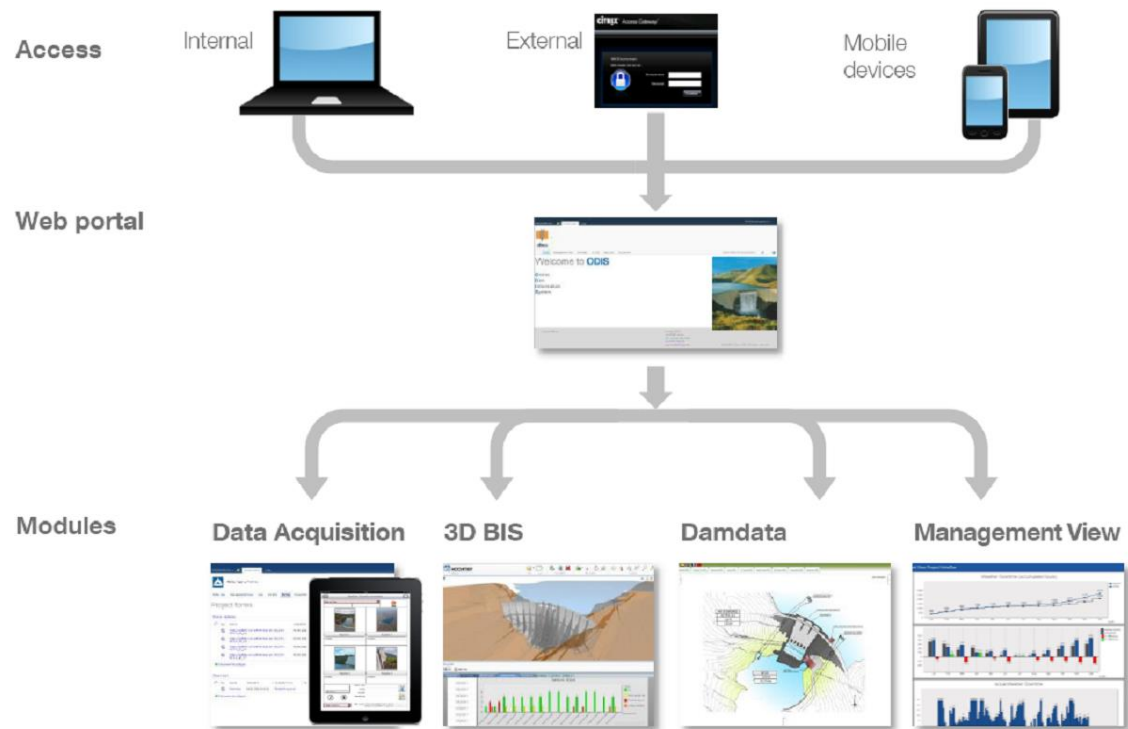


Figure 7. Modular architecture of ODIS.

The main features of such type of tools are the following:

- Increases accessibility to information.
- Inspection and maintenance sheets uploaded to the central database are available to all users, even on tablets during field work.
- Observations made during visual inspections such as photographs, videos, numerical data, comments, etc. can be uploaded easily during the inspections and are available in quasi real-time.
- Flexible evaluation tools.
- Improves knowledge about the dam safety conditions.

The following figures illustrate how visual inspections, field observations and monitoring data can be processed efficiently, interactively and in quasi real-time. The fact that all data records are stored in a centralised database avoids duplicities and uncertainties.

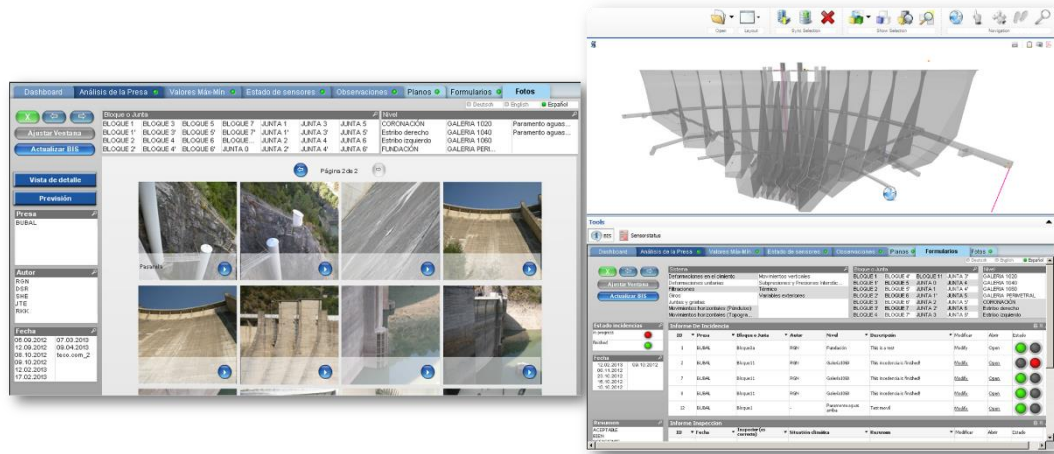


Figure 8. Processing of visual inspections, observations and monitoring readings linked to a 3D model data base.

4.3 Virtual reality

The existing software technology enables the display of 3D models in a realistic environment as Virtual Reality (VR) or Augmented Reality (AR). The necessary basis for such complex models is a complete and updated Technical File and data management system as described above.

The applications of VR and AR models in dam surveillance and safety activities are numerous and comprise predefined and system-guided inspection routes, online assistance to dam operators, access to previous records and observations, etc. A very important use is also training of personnel involved in the management of the dam, from engineers to dam attendants.



Figure 9. Examples of a VR dam model.

5 CONCLUSIONS

The key message of this paper is to point out the vital importance of a complete dam documentation file as the necessary basis to perform reliable dam safety evaluation and risk assessment studies.

To this end, a number of characteristics must be met, including the following:

- Easy access to the existing data and information for the authorized personnel.
- Sorting and classification of documents to allow finding any needed information easily.
- Permanent updating of the Technical Archive is fundamental.

Finally, the importance and potential of today's technology e.g. digitization, asset management systems, web document managers, BIM, Virtual and Augmented Reality based on 3D models etc. must be highlighted and should be applied more and more to facilitate modern dam management. Qualified and experienced dam engineers should lead the implementation of such tools in order to assure to take into consideration the specific characteristics of dams when customizing these solutions.

A final conclusion is that dam owners should invest in an adequate collection and organization of all documents, data and records and assure to update the data management system permanently. Especially for long-term infrastructure assets such as dams this is an aspect of vital importance and a means to transform the living memory into an efficient institutional memory allowing knowledge transfer to new generations.

6 REFERENCES

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