The British Dam Society

Improving the quality of flood modelling studies for reservoir safety assessment

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SYNOPSIS Flood modelling studies underpin decision making on reservoir spillway capacities and dam freeboard allowances. Flood modelling is a specialist subject with many methodological decisions and assumptions that can significantly affect outcomes. It is often undertaken by third party consultants on behalf of the reservoir operator.

This paper describes the work undertaken by the Environment Agency over the past two years to improve the quality of flood modelling studies undertaken for reservoirs owned and operated by the Environment Agency. This has included developing standardised modelling scopes, reporting templates, and quality assurance procedures. We have also sought to improve guidance and accessibility of tools for undertaking calculations. Within the Environment Agency, we have introduced training materials and led webinars on flood modelling for reservoir safety studies to improve understanding across modelling and engineering professions. Together, these are improving the quality assurance of our flood modelling studies. However, there have been challenges, including the difficulties of completion of work within MIOS deadlines, and tensions between the role of modelling technical assurer and the role of the panel engineer. We make recommendations for collaborative ways of working to overcome these challenges.

INTRODUCTION

The Environment Agency has multiple roles in reservoir safety management, both as a regulator and as an undertaker. The Environment Agency also has a role as a statutory consultee in land use planning.

Regulatory roles:

- Under the Reservoirs Act (1975) the Environment Agency is the regulator responsible for managing and implementing reservoir safety regulations in England, and for enforcing safety requirements if needed.
- The Environment Agency prepares and publishes reservoir flood maps that show where water may go in the unlikely event of a dam or reservoir failure.

Managing Risks for Dams and Reservoirs

Undertaker roles:

- The Environment Agency is the owner and operator of 218 reservoirs, the majority of which are flood storage reservoirs.
- The Environment Agency designs and constructs new flood storage reservoirs through the Flood and Coastal Erosion Risk Management capital programme of work.

Statutory consultee roles:

- The Environment Agency is a statutory consultee for land use planning applications, including planning applications for constructing new reservoirs or altering existing reservoirs. The Environment Agency reviews the Flood Risk Assessment and any associated flood modelling and may object to planning applications on the grounds of flood risk impacts.

The Regulator, Undertaker and Statutory Consultee roles within the Environment Agency are kept functionally separate. This paper is presented from the perspective of the Environment Agency as the owner and operator of reservoirs (undertaker role), working with panel engineers to manage reservoir safety and undertake statutory inspections.

Reservoir modelling studies play an essential role in good reservoir management. For Section 10 inspections, the Environment Agency commissions and undertakes flood modelling studies to improve understanding of reservoir spillway capacities and dam freeboard allowances. Estimating the water levels and flows that may occur under flood conditions allows the assessment of risk of failure and design of appropriate management solutions. This may lead to remedial works as part of any recommendations for measures in the interest of safety (MIOS). However, if the modelling and supporting data and assumptions are not fit-for-purpose, the risk may not be appropriately managed.

Flood modelling is a specialist subject with many methodological decisions, assumptions and uncertainties that can significantly affect outcomes. The Environment Agency commissions many hundreds of flood modelling studies every year for different purposes, including flood zone mapping, appraisal and design of flood risk management schemes, flood warning improvements, and reservoir flood risks. Quality assurance procedures are already well established for many of these applications. These procedures are also applied to the several hundred flood models submitted as part of Flood Risk Assessments supporting planning applications, for which the Environment Agency is a statutory consultee under land use planning regulations.

This paper describes the work undertaken by the Environment Agency over the past three years to extend our quality assurance procedures to flood modelling studies undertaken for reservoirs owned and operated by the Environment Agency. This has included:

- Developing standardised modelling scopes, reporting templates, and quality assurance procedures.
- Improving guidance and accessibility of tools for undertaking calculations.
- Improving general and specialist reservoir modelling skills, including improving communication and understanding between technical and non-technical teams.

However, there have been challenges, including the difficulties of completion of work within MIOS legally binding deadlines, and tensions between the role of the modelling technical

assurer and the role of the panel engineer. We make recommendations for collaborative ways of working to overcome these challenges.

THE AQUA BOOK GUIDANCE ON QUALITY ANALYSIS

The government's approach to quality assurance is set out in the Aqua Book (H M Treasury, 2015). This sets out the following principles for quality assurance:

- Proportionality of response: The extent of assurance should be proportionate to the risks, including financial, legal, operational, and reputational impacts.
- Assurance through development: Quality assurance should be considered throughout the life cycle of analysis and not just at the end. Effective communication is crucial when understanding the problem, designing the approach, conducting the analysis, and reporting the outputs.
- Verification and validation: Quality assurance is more than just checking the analysis is error-free and satisfies the specification (verification). It must also check the analysis is appropriate and fit for the intended purpose (validation).
- Analysis with RIGOUR: Quality analysis needs to be:
    - Repeatable,
    - Independent,
    - Grounded in reality,
    - Objective,
    - Understanding and managing uncertainty,
    - Robustly answering the initial question.

These principles have been used to develop our quality assurance procedures for flood modelling studies. The goal of our quality assurance is to demonstrate that the flood modelling study is fit-for-purpose prior to its use in decision making, through robust and independent peer review.

THE BENEFITS OF STANDARDISATION

Standardisation of processes and tasks leads to well-known benefits across all industries. These include reduced ambiguity about what the task is and how to perform it, and reduced inefficiencies due to avoidable reworking, leading to faster higher quality and consistent outputs.

We have introduced new standardised documents and procedures for:

- Commissioning reservoir modelling studies. A standardised technical modelling scope (LIT 72263: Reservoir Modelling Scope), based on the NEC4 Professional Service Contract, has been developed. The scope includes standard clauses and requirements, as well as optional clauses which can be chosen depending on the study being undertaken. The standard scope saves time as project managers no longer draft scopes from the beginning. It provides consistency between modelling studies and ensures no aspects are overlooked at the scoping stage.

Managing Risks for Dams and Reservoirs

- Reporting hydrology calculations for reservoir modelling studies (LIT 65993: Flood Estimation for Reservoir Safety Calculation Record; and LIT 65996: Accompanying Notes). This provides a record of the hydrological context, the method statement, the calculations, the decisions made, and the results of flood estimation. It includes the estimation of the inflow hydrograph and its routing through the reservoir to calculate the discharge hydrograph and maximum stillwater level at the spillway. The report template aims to ensure that full calculation details, decisions, assumptions and limitations are reported, to provide a complete audit trail for quality assurance. This saves time as reviewers are provided with all details needed for checking, avoiding the need to request additional information. It provides consistency in reporting standards and clarity to consultants on expectations for reporting.
- Reviewing hydrology calculations for reservoir modelling studies (LIT TBC: Flood Estimation for Reservoir Safety Calculation Review Template). The review spreadsheet provides a record of what has been checked by the reviewer and any comments. The comments are categorised into "OK" (no change needed), "Green" (change request with negligible impacts on outcomes), "Amber" (change request with medium impacts on outcomes) and "Red" (change request with significant impacts on outcomes). It would be expected that all "Amber" and "Red" comments are addressed for the study to pass quality assurance. Additional columns provide space for consultant responses, and second and third rounds of review. This review spreadsheet directly follows the structure of the reporting template. This saves time as reviewers do not have to search a document to find the information for each item to check. It removes ambiguity over what will be checked during the review process and provides an audit trail of decisions during the review process.
- Quality assurance standard procedures (LIT TBC: Quality assurance of reservoir modelling studies). These standard procedures are aimed at internal Environment Agency staff and explain the reasons for undertaking quality assurance, how to request support from the appropriate Environment Agency technical team, at what stages quality assurance should be undertaken, communication and liaison, handling sensitive information and resolving conflicts. The standard procedures provide a common shared understanding of quality assurance within the Environment Agency. This ensures appropriate time and resource for quality assurance are included in project planning, reducing ambiguity about what quality assurance is needed at what stage of the project.

THE ROLE OF GUIDANCE AND OPEN TOOLS

Guidance leads to better quality analysis through a shared understanding of the correct decisions to make on data, methods, calculations, and analysis. Open tools shared by all support this by removing ambiguity over algorithm differences. They allow calculations to be shared for review without any software licensing restrictions. The Environment Agency is committed to improving accessibility and openness of tools and methods wherever possible (see Flood Hydrology Improvements Programme report (EA, 2024)).

One area of ambiguity in probable maximum flood (PMF) estimation for reservoir safety modelling has been the estimation of snowmelt. This is frequently underestimated. In February 2022 we issued a briefing note to raise awareness of the impacts of snowmelt on the PMF. This was followed in April 2022 with a full worked example of the PMF calculation

procedure and an Excel spreadsheet tool (LIT 58205: Probable Maximum Flood calculation spreadsheet) that includes snowmelt. This spreadsheet is freely and openly available on request from the Environment Agency, and the code can be adapted for other uses (e.g. batch applications).

In December 2022 we updated our Flood Estimation Guidelines and extended Chapter 6.5 on flood estimation for reservoir safety. These guidelines complement the recommendations in the Floods and Reservoir Safety 4th Edition. The guidelines were openly published on gov.uk in November 2023 to increase accessibility (EA, 2023)

In June 2024, we continued our commitment to providing open tools for calculations wherever possible, by releasing an Excel spreadsheet tool (LIT 72757: FSR-FEH and Pumped Rainfall Runoff spreadsheet) for applying the FSR/FEH rainfall-runoff method which may be used to estimate the 1 in 10,000 flood hydrograph for comparison with other methods. This spreadsheet is also freely and openly available on request from the Environment Agency.

SKILLS AND TRAINING

Quality assurance should be carried out by an independent reviewer who is not directly involved in the modelling project or programme. Good quality assurance relies on well trained and experienced staff who are able to efficiently review work and appropriately identify any concerns. Reviewers must have suitable training, qualifications, experience and supervision to carry out quality assurance. We have undertaken a programme of training to develop technical specialists within our pool of modelling staff. This has included webinars, recorded training videos and worked examples for self-led learning, attendance at external training courses, and mentoring on projects by more experienced staff. Our aspiration is to share this training more widely beyond the Environment Agency to improve skills across the industry.

In addition, we have sought to improve knowledge and understanding of flood modelling and quality assurance for project managers and engineers involved in reservoir studies who are not modelling specialists. This has improved understanding of the timescales, assumptions, risks and procedures for flood modelling and quality assurance.

CHALLENGES FOR QUALITY ASSURANCE

The principles of the quality assurance that we are now applying to reservoir modelling studies are not new. Similar procedures have been in place for many years for other types of modelling studies. Nevertheless, the extension of more rigorous quality assurance to reservoir modelling studies has led to some unexpected challenges that are unique to this application.

Firstly, reservoir modelling studies commissioned to fulfil recommendations made for measures in the interest of safety (MIOS) are legally required and must be carried out by the date given by the Inspecting Engineer, which is often 12 months. This timescale can be challenging when allowing for scoping and commissioning a study, collecting data such as survey information, undertaking analysis, and completing quality assurance. Within the Environment Agency, staff availability for quality assurance can also be affected by other high priority or statutory duties such as flood incident response and statutory consultation on land use planning applications. If quality assurance is left to the final few weeks of the programme, it is unlikely to be satisfactorily completed by the MIOS deadline if reworking is necessary.

Secondly, the Reservoirs Act places a legal duty on panel engineers to supervise and decide upon the safety of reservoirs. This legal duty overrides any comments or recommendations made by technical staff during the quality assurance procedure. The quality assurance procedure itself is not legally binding, and the comments made in the review are advice rather than instruction. The final decision on whether to accept the modelling study rests firstly with the project manager and finally with the panel engineer. If the panel engineer accepts the modelling study before the quality assurance process has been completed, this can create conflicting messages for the project team and have commercial implications for the contract. Flood modelling includes a number of subjective decisions around data and methods, and there may need to be a number of iterations as different solutions are tested and assumptions explored.

To overcome these issues, we recommend close collaborative working between the commissioning project manager, the consultant, the panel engineer, and the technical reviewer undertaking the quality assurance. This should occur throughout the project and not be limited to a single quality assurance review when calculations are already completed. Quality assurance discussions and actions should take place at the following stages in the project:

- **Scoping and commissioning.** The technical reviewer should be given notice of the upcoming study and can assist in reviewing the modelling scope and discussing any suggested edits or additional information needed.
- **Project inception.** An inception meeting between the reviewer, the modelling team and the panel engineer will provide an opportunity for the scope to be discussed and any questions raised. The quality assurance process should be explained, and work approaches agreed. Project timeframes should be reviewed so that work can be programmed and any constraints identified.
- **Method statement.** The consultant should submit a method statement for the hydraulic and hydrological modelling, which describes the catchment, the reservoir, the available data, and the proposed methods. This allows any questions over methodological approach to be addressed before calculations are completed.
- **Full calculations: first draft**. A first draft of the full calculations, model and report should be provided by the consultant for review, including all model files and details to allow calculations to be reproduced and the model to be re-run. The reviewer will check the calculations and provide comments and suggestions using the standard review template.
- **Full calculations: final version.** There are typically several rounds of review and discussions before the quality assurance process is completed. This allows consultants the opportunity to respond to comments and suggestions and where appropriate make edits to calculations and reporting. The review process therefore may take a number of weeks to complete. When ready, a final set of calculations, model files and the report should be agreed by the reviewer.

Good communication between the consultant and reviewer is essential. The review process is intended to be constructive and collaborative, rather than critical. Written text can be open

to misinterpretation and therefore meetings between the reviewer and consultant are encouraged to discuss the comments, suggestions and proposed actions.

The panel engineer should also play an active role in the quality assurance process by attending meetings and reading review comments. Their knowledge of the reservoir and catchment should be shared with the reviewer and consultant to improve the local representation of the model. The panel engineer should not accept the modelling study until the quality assurance process is complete. Where new works are proposed, there is an even greater need for close collaboration between the engineer, modeller, and reviewer to test solutions iteratively and explore assumptions.

CONCLUSIONS

This paper has described work undertaken by the Environment Agency to extend existing flood modelling quality assurance procedures to studies undertaken for reservoirs owned and operated by the Environment Agency. The procedures are intended to promote quality and consistency across modelling studies carried out by various consultancies through different procurement routes, where the Environment Agency is the client.

Flood modelling is a specialist and technical subject, and the outcomes of erroneous modelling may lead to incorrect assumptions and decisions over risk management. Reworking of incorrect modelling costs time and money, and delays improvements to reservoir safety. To promote quality analysis that is of a higher standard, we have introduced new standardised modelling scopes, reporting templates, quality assurance procedures, guidance, and accessible tools for undertaking calculations. We have introduced new training procedures and mentoring to increase the skills of technical reviewers, and we have also improved general knowledge of flood modelling amongst reservoir engineers and project managers. Many of the materials we have produced can be shared externally for use by other reservoir owners and operators to aid their own quality assurance procedures.

The challenges unique to reservoir applications include legally binding deadlines for MIOS studies, and the potential for conflict between the panel engineer and technical review process. Both challenges can be overcome by purposefully promoting a collaborative and communicative approach to quality assurance from the earliest stage of the project. It is hoped that a more rigorous approach to this particularly uncertain area of reservoir flood risk assessment will add confidence to our estimates. This should in turn make for better overall decision making for safety and sustainability of the chosen solutions.

REFERENCES

Available online:

H M Treasury (2015) *The Aqua Book: guidance on producing quality analysis for government.* H M Government, London, UK https://www.gov.uk/government/publications/the-aqua-book-guidance-on-producing-quality-analysis-for-government (Accessed 2 July 2024)

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Managing Risks for Dams and Reservoirs

EA, (2023) *Flood Estimation Guidelines.* Environment Agency, Bristol, UK. https://www.gov.uk/government/publications/flood-estimation-guidelines (Accessed 2 July 2024)

Environment Agency documents available on request:

LIT 58205: Probable Maximum Flood calculation spreadsheet

LIT 65993: Flood Estimation for Reservoir Safety Calculation Record

LIT 65996: Flood Estimation for Reservoir Safety Calculation Record Accompanying Notes

LIT 72263: Reservoir Modelling Scope

LIT 72757: FSR-FEH and Pumped Rainfall Runoff spreadsheet

LIT TBC: Flood Estimation for Reservoir Safety Calculation Review Template

LIT TBC: Quality Assurance of Reservoir Modelling Studies