The British Dam Society

Developing an Understanding of the Reservoir Safety Risks of Non-Statutory Reservoirs

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SYNOPSIS In 2022, Severn Trent Water (STW) appointed Arup to carry out a project to appraise the reservoir safety risks posed by 71 reservoir sites with capacities identified in the range 10,000 to 25,000m³ above natural ground level. Following the Flood and Water Management Act 2010, which amended the Reservoirs Act 1975 (the Act), it was anticipated that these reservoirs would likely be brought into the Act when the threshold is amended to 10,000m^3; this would increase the number of statutory reservoirs within STW's portfolio. By investigating and studying each reservoir, the project helped STW to understand the potential increase in financial risk which could occur because of additional regulation. This considered both operational requirements and capital works, to ensure the potential statutory reservoir safety risks posed by the reservoirs are minimised and managed in good time.

The paper explains the methodology that was applied to carry out the assessment, together with the key themes discovered, including common reservoir safety risks and recommended mitigation actions, as well as an exploration of the challenges and opportunities of the process. In conclusion, the recommendations made in relation to reservoir safety risks of the non-statutory reservoirs, how STW used the outputs to feed into their asset management planning process and the next steps that STW is taking to manage the risks identified are all described.

NEED FOR THE PROJECT

Whilst STW has over 60 statutory reservoirs of all types, there are some 700 smaller reservoirs, tanks and other water retaining structures in the business's asset portfolio. Discussions within the reservoir safety community indicated that it was likely that the Act's applicability would be extended in England by reducing the retained volume minimum criterion from 25,000m^3 to become consistent with Wales, at 10,000m^3. Since a large proportion of STW's smaller assets lay within this volume range, it was considered prudent to anticipate such a change in the legislation and carry out some further desk study work to understand the potential magnitude of future investment requirements at these assets, building on an earlier study by Mott MacDonald some ten years ago.

SCOPE AND METHODOLOGY

The main objective of the project was to help STW to understand the reservoir safety risks posed by a number of their reservoir sites with capacities identified in the range 10,000m^3 to 25,000m^3. For each site, Arup was commissioned to carry out a desk study, supported by a

site visit for the impounding reservoirs, and advise, from an All Reservoir Panel Engineer's viewpoint, on any potential issues which may become safety matters should each reservoir become subject to the amended volume criterion of the Act.

Supported by the previous Mott MacDonald study, STW carried out initial screening of their sites to provide a list of sites where the reservoir assets could fall within that range. The list comprised the following:

Table 1. Candidate, Non-Statutory, STW Reservoirs

Reservoir Type	Number in ARUP Study
Impounding	
Flood Storage	4
Other Impounding	1
Sludge Lagoon	7
Non-Impounding / Other	
Service	54
Tank	4
River Weir	1

Available data was provided by STW for each of the reservoir sites. This typically included a reservoir data sheet, schematics and information about the operation of the assets, internal inspection reports (for service reservoirs and tanks) and occasionally design and construction drawings and reports and monitoring data.

The project was overseen by two All Reservoir Panel Engineers (ARPE). Site visits were undertaken to the 12 open reservoir sites by these engineers, of which seven were found to contain more than one reservoir.

A spreadsheet report template was developed collaboratively and agreed with STW, as the main deliverable of the project for each site. The report template included a summary; list of data used; information about the reservoir; reservoir condition; findings and recommendations; and site visit notes and photos. Each spreadsheet report was approved by an Arup ARPE before issue to STW.

For each site, based on estimates of the total capacity of the reservoir and the capacity of the reservoir above natural surrounding ground level, the report indicated the likelihood of it being classed as a Large Raised Reservoir under a potentially amended Act. The accuracy of the estimates was limited by the information available; this typically included top water levels and tank dimensions from operational and inspection reports, which was sometimes augmented by as-built records. Google Earth Pro and LIDAR data were used to supplement the estimates.

Key information about the intrinsic and current condition of the reservoir assets was reported, and the resulting key risks to reservoir safety were determined. The Risk Assessment for Reservoir Safety guidance, RARS (EA, 2013) was used to help identify key threats and risks. Methods to mitigate each of the risks were reported, and recommendations to minimise or better understand these risks were made. The likely cost of implementing recommendations

was estimated, based on high / medium / low cost categories. Operational issues that could affect the implementation of each recommendation were noted in the reports.

Each recommendation was assigned a risk rating and, for the reservoirs that would possibly or definitely fall under a potentially amended Act, an indicative timescale for carrying out the recommendation was proposed. The indicative timescales were those which Arup ARPEs would typically suggest in an inspection report, itself completed after designation of the reservoir by the Enforcement Authority. Whilst actions on those reservoirs that were considered not likely to fall under an amended Act were not given timescales, a risk rating was still assigned, as ideally such recommendations would still be implemented to reduce identified risk.

A high-level screening was undertaken to help understand the likely 'high risk' / 'not high risk' classification for each reservoir, which would need to be confirmed at the time of designation. Ordnance Survey contour maps were used to understand the likely direction of flow in the event of a breach, taking a conservative approach to possible flow paths where topography was uncertain. Maps and satellite imagery were inspected to identify possible receptors along those flow paths. Where a potential impact of a breach on sensitive receptors, such as residential properties, community facilities and roads, was identified the reservoir was conservatively assumed to be 'high risk'.

Each draft report was submitted to STW to allow the relevant area teams to review and comment prior to a final report being issued.

OUTPUTS AND KEY THEMES

Volume Classification of Non-Statutory Reservoirs

The study found that, of 71 English reservoirs examined, 45 reservoirs are likely to fall under a potentially amended Act in England, i.e. if a large raised reservoir (LRR) is defined as having an escapable volume in excess of 10,000m^3. As shown in Table 2 below, there were an additional 15 reservoirs in the study where this was defined as 'possible'; in many cases this uncertainty was due to not having level data of sufficient accuracy. The study found two sites where open reservoirs were estimated to have volumes such that they may fall under the current Act. These two sites were: an impounding reservoir which had previously been modified to allow it to be discontinued; and a sludge lagoon of sufficient surface area to suggest that, if contents are proved to be flowable, could have sufficient volume to fall under the Act. Subsequent to the study, STW has carried out more detailed checks of the volumes of these reservoirs and proceeded with registration as appropriate.

Risk Classification of Non-Statutory Reservoirs

The high risk reservoir screening exercise determined that, of the 58 reservoirs that were assessed as likely to be classified as high risk, 15 were assessed as 'possibly' falling under a potentially amended Act, owing to the same uncertainty of their storage capacity above natural ground level described above. Table 2 presents the spread of these findings across different asset types. This screening was necessarily conservative and based on readily available basic data; however, it provided a high level estimate to help STW understand its potential liabilities with regards to reservoir regulation.

Table 2. STW sites reviewed considering the proposed changes to the Act, and outcomes of that review

Reservoir Type	Assets reviewed	Expected to be LRR and 'High Risk'	Possible LRR and 'High Risk'	Total 'High Risk'
Service reservoir	54	35	13	48
Tank	4	1	1	2
Flood storage reservoir	4	4	0	4
Impounding reservoir	1	1	0	1
River weir	1	0	1	1
Sludge lagoon	7	2	0	2
Total	**71**	**43**	**15**	**58**

Common Reservoir Safety Risks and Recommended Mitigation Actions

The report for each reservoir summarised key reservoir safety risks, potential mitigations and recommendations. Many of these risks related to service reservoirs or tanks and reflected common failure modes associated with buried tanks. In many cases, a lack of data meant that it was not possible to fully understand the extent of the risk: for example, not knowing the capacity of a service reservoir overflow pipe. Whilst STW maintains detailed records of their statutory reservoirs, it was found that less information was available for the non-statutory sites and, where this was available, in the case of service reservoirs the emphasis was generally more towards water quality issues. Common themes are summarised in Table 3.

Table 3. Reservoir Safety Risks and Mitigation Recommendations

	Reservoir Safety Risk	Mitigation / Recommendation	% of sites affected
1	Lack of data about reservoir design, construction, or current condition.	Collate available records and/or carry out surveys to understand reservoir design details and inspections to understand current condition.	93%; physical surveys at 75% of the sites
2	Overfilling due to unknown or insufficient overflow capacity leading to pressurisation of roof, structural damage and erosion of fill. Available information is not sufficient to confirm if the existing overflow is adequate.	Collect information about overflow arrangement and confirm or assess adequacy of overflow capacity.	92%
3	Deterioration of reservoir structure - floor and/or wall plus joints leading to leakage and erosion of supporting fill.	Regular internal inspection; "drop" tests; monitor for seepage; surveillance visits.	89%
4	Pressurised pipe failure leads to loss of supporting fill – extent of risk depends on type of inflow and position of the inlet / outlet valves.	Confirm route / condition of pipework / valves; monitor for leakage; surveillance visits.	89%

	Reservoir Safety Risk	Mitigation / Recommendation	% of sites affected
5	Inability to lower the reservoir level in an emergency due to insufficient drawdown capacity. Available information is not sufficient to determine drawdown provision.	Collect information about draw-off/scour arrangements and confirm or assess adequacy of drawdown capacity.	90%
6	Deterioration of underdrainage leading to washout of fill under perimeter walls, or blockage of drainage system. Available information is not sufficient to confirm drainage layout and condition.	Confirmation of washout / underdrain route; internal inspection (CCTV) of underdrains; monitor for seepage; surveillance visits.	80%
7	Excessive pressure variations due to rapid filling or emptying (in the case of a burst on the outlet of a tank) and insufficient vent capacity.	Confirm likely rapid drawdown extents and review ventilation provision.	90%

Magnitude of Cost

In order to prepare future investment plans, STW needed to understand the likely magnitude of cost for additional operational activities and capital work that could result from the candidate reservoirs being brought under the Act in the future. For some candidate reservoirs, there were some direct recommendations for remedial works; however, due to the available data, recommendations for the open reservoirs, service reservoirs and tanks were generally for additional studies or further information gathering.

It is likely that the recommended studies and surveys will comprise only the first stage of project work, although this is no reflection of the safety of the current structures. Remedial works at a proportion of the sites, for example overflow or drawdown capacity improvements, may be required as subsequent work stages to achieve full compliance with the Act. Due to uncertainty regarding the potential nature and extent of follow-on work, the cost of this was not estimated for each site.

Reservoirs that fall under the Act have a necessarily higher level of ongoing management expenditure. As well as general surveillance and maintenance activities, these reservoir-specific activities include:

- Periodic appointment of an ARPE to carry out initial and Section 10 inspections;
- Breach assessment to confirm High Risk/Not High Risk and inform the On Site Plan (if this is not carried out by the Enforcement Authority);
- Supervising Engineer appointment and supervisory duties;
- Preparation and maintenance of a Prescribed Form of Record and On Site Plan; and
- Possible Risk Assessment for Reservoirs Safety Assessment as STW's RARS programme matures.

Managing Risks for Dams and Reservoirs

Operational Issues

The identified operational issues were generally related to the ability to reduce each reservoir's water level to enable internal inspection and/or maintenance work. For many of the service reservoirs and tanks, there was information on the existence of a system bypass, but it was generally not possible to tell from that information whether network water supplies could be maintained whilst a cell was taken out of service. For each reservoir, such arrangements would need to be confirmed, and potentially improved with capital expenditure, to enable regular internal inspection.

Risk rating and timescales

Nominal timescales were assigned to each recommendation and were intended to be applied from the date at which the reservoirs are first inspected following a decision that the reservoirs fall under the Act, if that is confirmed to be the case. A small number of recommendations were assigned higher risk ratings to assist prioritisation of investigations and improvements in the period prior to the potential change in the Act, to reduce reservoir safety risk. For candidate reservoirs where the Act has not previously applied, the absence of an enforceable process of inspection, monitoring and maintenance means that sites may be less well understood and maintained, meaning that some sites have a number of existing issues.

Summary of Study Recommendations

The key recommendation from the study was for further data collection at the majority of sites, to improve understanding of key risks. The detailed next steps were:

1) Analysis of outputs from the study to understand portfolio-wide risks and likely cost of mitigation;
2) Analysis of outputs from the study to highlight any critical specific risks at reservoirs;
3) Topographical surveys to inform capacity assessment;
4) Collection of any additional asset information and data;
5) Internal structural surveys and pipework surveys to inform overflow and drawdown capacity assessments;
6) Overflow capacity assessments;
7) Drawdown capacity assessments;
8) Studies to confirm operational issues, e.g. ability to bypass reservoirs; and
9) More detailed breach assessments to understand if reservoirs would be designated as high risk and to inform emergency planning.

Use of Project Outputs in the Five-Yearly Asset Management Plan (AMP) Process

The project outputs were used in Severn Trent Water's Periodic Review (PR24) submission, to identify, scope, substantiate and price capital work on the current non-statutory asset base, including:

- Work that will be required to facilitate statutory Inspections, such as provision or improvement of ability to isolate cells or reservoirs;

- Supplementary asset information, likely to be required to assist a statutory inspection; this included CCTV surveys of drainage and scour infrastructure, topographical, bathymetric and measured structural surveys, further seeking and collation of asset information etc.; and
- Work items that were highly likely to be included as recommendations from an ARPE's Inspection, such as overflow / drawdown capacity calculation or improvement, instrumentation / monitoring improvements, increased reservoir surveillance.

At the time of writing, the PR24 submission is with OFWAT for review. The draft submission contained the following work elements, based on a balanced and risk-based view, which set out the need to tackle the highest risk assets, by:

- Undertaking a prioritised programme of statutory inspections on 45 of the reservoirs that are expected to fall under the amended Act as potentially being 'High Risk'. This includes the employment of specialist staff to carry out the inspections, together with smaller investments required to monitor these sites;
- Providing overflow upgrades at 13 service reservoirs and 5 lagoons to meet the likely enhanced asset standard required under the Act;
- Enhancing two service reservoirs to support the structural changes required to ensure that STW can discharge its duties in line with the amended Act; and
- Additional Environment Agency charges for the regulation of statutory reservoirs (e.g. registration, annual subsistence).

CHALLENGES AND OPPORTUNITIES

Output Format

A report was prepared for each site as the main deliverable of the project. STW requested that this be completed in a spreadsheet format so that it could potentially be easily integrated into a Prescribed Form of Record template, should the sites become registered under the Reservoirs Act. Formats for the open reservoirs and service reservoir/tanks reports were prepared on that basis, and included guidance notes and references to typical failure modes referring to table 7.2 of RARS (EA, 2013). Following the completion of the initial batch of reservoirs, the format was reviewed and amended to take on feedback from STW and the Arup project team. Due to the varied nature and formats of the data available about each site, it was not possible to fully automate the collation of data into the report format.

Background Data

Owing to the nature of the sites studied, positioned in the non-statutory range, the available recorded information varied in type, extent and quality from site to site. Whilst the sites are closely managed from a water hygiene standpoint (in terms of 10-yearly surveys, reservoir cleaning programme and bacteriological performance), the structural data holdings, including as-built records, structural surveys and inspections, are less well-developed. The additional historical complications of depot and office moves and closures, evolving boundaries of areas and responsibilities and data degradation also contributed to the challenge of locating and acquiring definitive records. Whilst digital business continuity plans generally maintained sufficient information for that discrete purpose on each asset (such as generalised

construction, levels and volumes), fuller engineering details and drawings are not routinely stored in this format. This necessitated extensive hard copy archive work at physical locations across the business, which benefitted the project through the acquisition of drawings and details for the majority of cases.

Data Uncertainty and Drawing Conclusions

The availability and quality of data impacted on the preparation of the reports for each reservoir. Several of the service reservoir and tank reports were prepared on very limited data which meant that the findings and recommendations were more generic and had to reflect typical concerns for that type of reservoir.

There were instances where there was conflicting data about a reservoir; for example, the capacity of a service reservoir may be stated differently on a key information sheet and an internal inspection record. Drawings were used to confirm information where available; otherwise, engineering judgement was used, and any differences were noted in each report.

Project Management & Execution

As a collaborative team, it was considered important that the following issues were resolved, ideally at a very early stage or even before the project started:

- A clear, resourced, project programme, with sites logically batched in terms of assessment and report delivery;
- Realistic programme time assumptions on initial background data sourcing and exchange;
- Ability to be light-footed within the programme to absorb time risks and maintain effective delivery;
- A small, dedicated team for consistency of reporting;
- Supporting resources for data seeking, arranging / hosting site visits and reviewing draft reports;
- A secure means of organising and sharing often quite large sets of digital data, and exchanging and collaborating consistently on many reports for drafting and review;
- The fullest possible data set for each candidate site, to enable the consultant to most effectively review, assess and report in one iteration; and
- A template output (in the case of this project, an Excel file with content loosely modelled on the Prescribed Form of Record) with scope to flexibly accommodate differing sites, inputs and outputs.

CONCLUSION

The study undertaken provided an initial assessment of STW's potential statutory reservoir holdings, and a priced evidence base to support STW's submission to OFWAT for the future safe introduction and management of these reservoirs. The study highlighted that, for a water company, the majority of reservoirs requiring regulation once an amended Act is implemented are service reservoirs and tanks. It also concluded that the collection of further asset information is required to be able to more fully understand the potential reservoir safety risks. The potential for sludge lagoons to be included in an amended Act means that additional

training could be required for the operational waste teams that manage these assets, assuming they are not as familiar with the requirements of the Act as raw water operational teams.

From each of the parties' standpoints, the study provided benefits in terms of:

- The client acquired clearer definition of additional tasks to be carried out, including further data seeking and substantiation, prior to the potential statutory change; and
- The knowledge of the consultant's engineers was improved on the wide variety, condition and age of service and other reservoirs typically operated by a water company.

REFERENCES

EA (2013). *Guide to risk assessment for reservoir safety management - Report SC090001* (RARS). Environment Agency, Bristol, UK