Session 5

IT'S NOT JUST ENGINEERING!

Managing the safety of very high consequence dams – is the UK doing enough? - A Brown and M Hewitt

Environmental Benefits of Reservoir Discontinuance – Hurst Reservoir Case Study – H Beeden and C Parks

Challenges of design and construction for reservoir safety improvements within an historic estate - D Neeve

Managing the Environmental Risk from Reservoir Draw Down - R Murray

Discussion

Stillwater Associates
Reservoir Safety & Water Consultancy

Managing the safety of very high consequence dams:

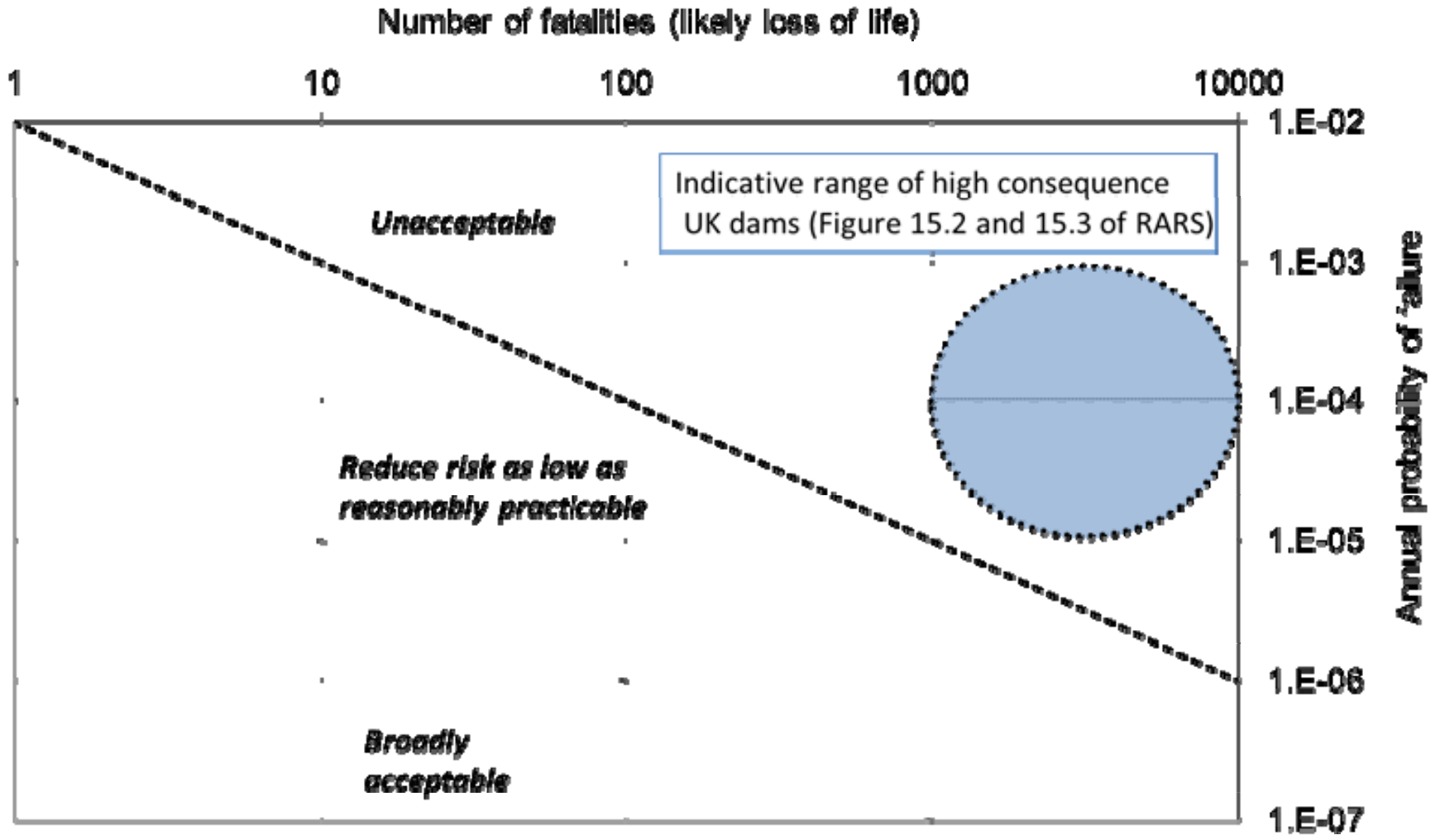
Is the UK doing enough?

Alan Brown & Martin Hewitt

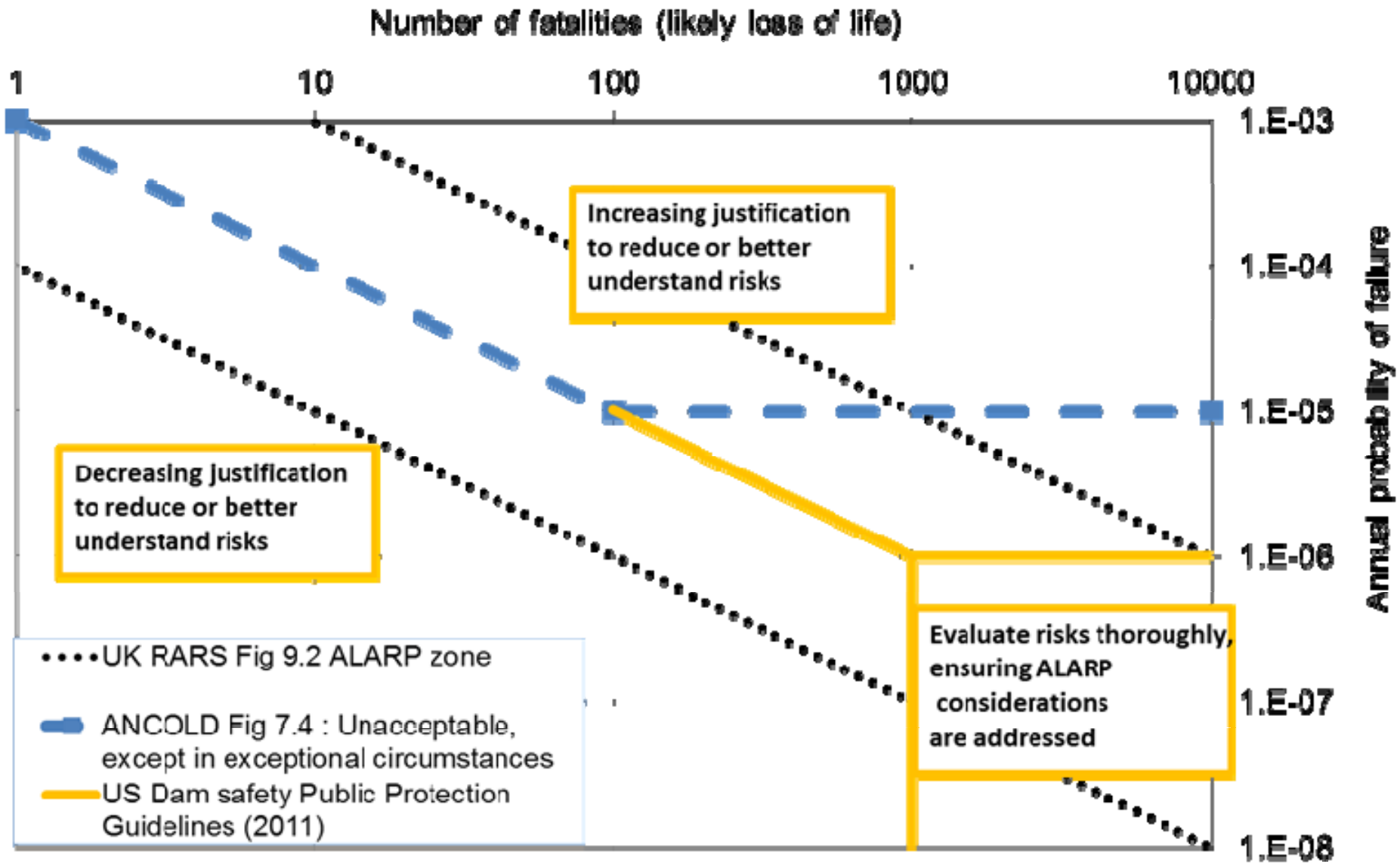
MOTT MACDONALD

- What is a very high consequence dam?
- How is the safety of these dams managed in other developed nations?
- Where could we learn from others to improve dam safety management in the UK?
- Are we doing enough to protect the public from very high consequence dams?

The issue


Number of fatalities (likely loss of life)
1
10
100
1000
10000
1.E-02
1.E-03
1.E-04
1.E-05
1.E-06
1.E-07
Annual probability of failure
Indicative range of high consequence UK dams (Figure 15.2 and 15.3 of RARS)
Unacceptable
Reduce risk as low as reasonably practicable
Broadly acceptable

International Risk based criteria for high consequence dams



Scope of periodic safety review in Australia, Canada and USA

Country	Frequency	Description of process (Source)
Australia	Comprehensive Inspection **every 5 years** Safety review as required	Dams engineer and specialist(s), inspection, evaluation of monitoring data, applying current and prevailing knowledge, possibly inspection of outlet/submerged works by draining/divers. (ANCOLD, 2003)
Canada	Dam safety review **every 7 years** for extreme consequences, 10 years for High.	Collection of all available dam records, field inspections, detailed investigations and possibly laboratory testing. It then proceeds with a check of structural stability and operational safety of the dam, beginning with a reappraisal of basic features and design assumptions. (British Columbia Dam Safety Regulation, 2011)
USA	**Every 5 years**	Team of highly trained specialists. Includes a review to determine if the structures meet current accepted design criteria and practices, and are performing as designed; detailed inspection, includes underwater structures affecting integrity. Risk informed decision making adopted by FERC/USACE/USBR. (FEMA Federal Guidelines for Dam Safety, 2004)

Deterministic standards approach: benefits and limitations

- Based on established rules, good practice and engineering judgement.
- Always some likelihood of failure: misconception that risk is tolerable/negligible
- Can result in uneven risk across failure modes/loadings
- No standards for certain failure modes: gaps in understanding

QRA approach: benefits and limitations

- Failure modes examined systematically
- Can be applied where a standards based approach has not been established
- Challenges in characterising dam system performance & consequence estimates
- Uncertainty in very low likelihood of failure estimates

Dam Safety Case

- Informed by QRA and deterministic assessments
- Clarity on benefits/ need for reservoir
- Application of ALARP/good practice
- Logical set of arguments to advocate safety position
- Scale of consequences may dictate extraordinary measures, e.g. multiple defensive safety features.

Practical implication for UK very high consequence dams

Aspect	Suggested Change	Benefits
Tolerability of risk	Modify to include “special case” very high consequence zone, requiring preparation of a “dam safety case”	Decisions are made taking account both risk informed and deterministic assessments, ALARP principles and good practice.
	Define modified FN chart to reflect above (LLOL 100 or 1000)	High consequence dams no longer in “intolerable zone”
Periodic safety review	Preparation of “dam safety case” by Dam Owner	Addresses observation that periodic reviews are more detailed in other countries
	Section 10 becomes audit of “dam safety case”	
	Take account of “dam safety case” within context of portfolio risk assessment	Efficiencies and overall reduction in risk across for Dam Owner
		Redundant assets likely to require removal

Summary

- Other developed countries have an enhanced periodic safety review for very high consequence dams.
- A risk based approach can suggest that the risk from some UK very high consequence dams is in the intolerable region.
- Consideration of current international practice suggests that the UK would benefit from identifying these as a special case, and developing good practice at a national level to manage the risk from these dams.

Environmental Benefits of Reservoir Discontinuance

Case Study: Returning Hurst Reservoir to the Landscape

Hurst Reservoir: Case Study

Helen Beeden
BSc(Hons) MSc FGS CGeol
Senior Geoenvironmental Engineer
United Utilities Plc

Dr Chris Parks
PhD BSc(Hons) ACSM CEng MIMMM
UK Registered Ground Engineering Adviser
Principal Geotechnical Engineer
United Utilities Plc

United Utilities Challenge: Restore or Repair

- Defects Identified
- Cost Benefit Analysis
- Direction from Panel Engineer: "Discontinue or Remedy Defects"
- Ultimately a Commercial Decision

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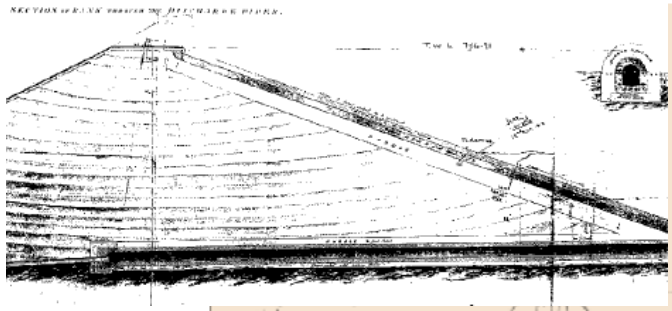
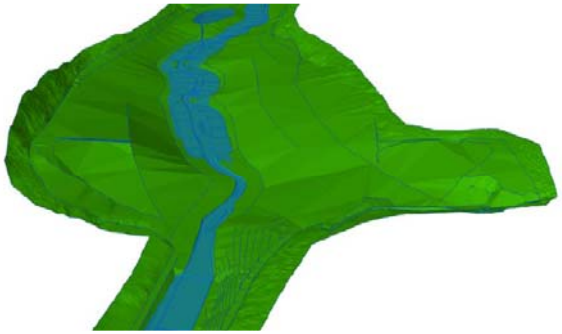
Developing the Restoration Plan

- History
- Inspections
- Site Investigation
- H&S / Access
- Weather constraints

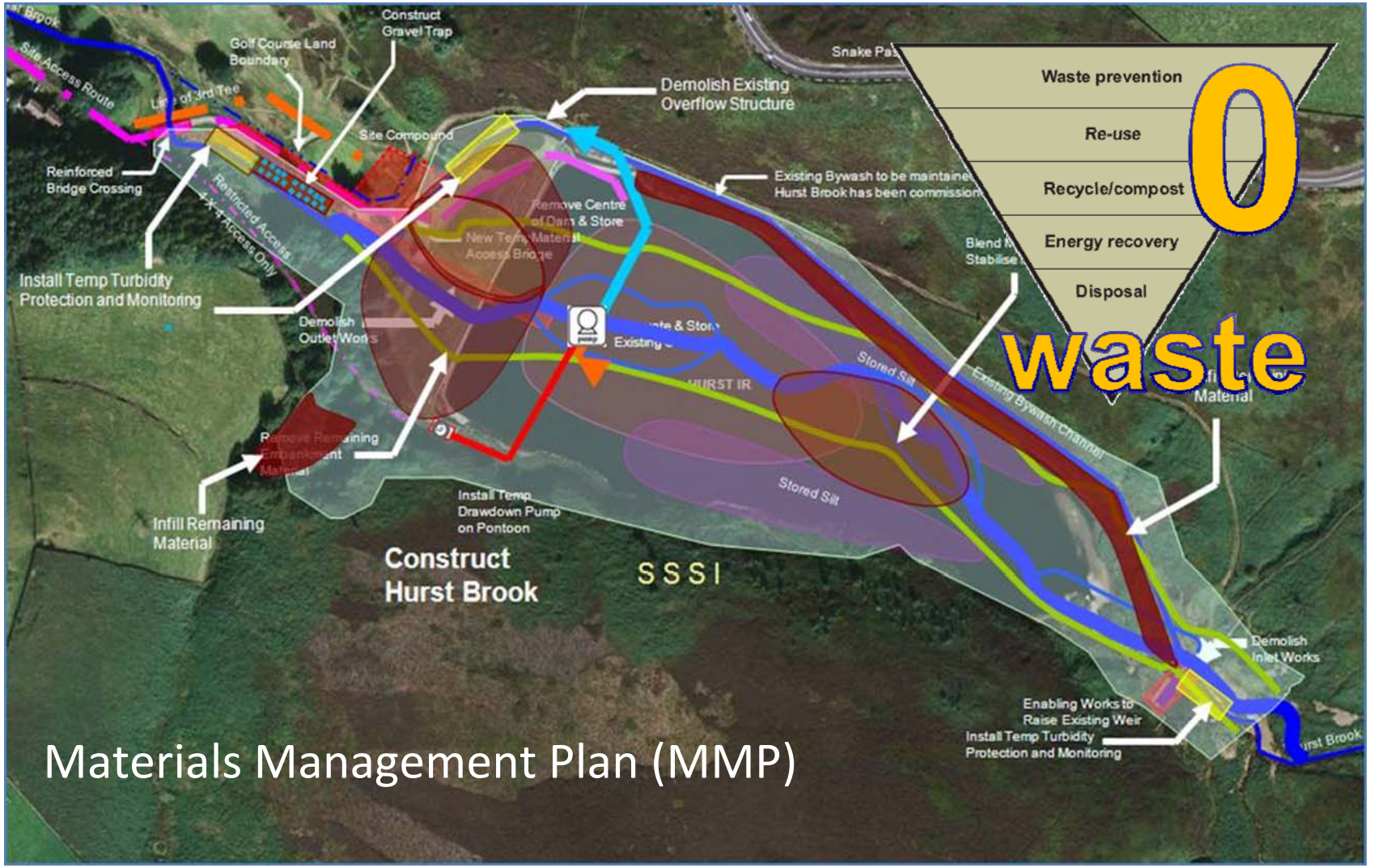


Environmental and Social Constraints

- Flooding and Hydrology
- Ecological: ground nesting birds, common lizard
- Habitats, Peak District National Park. SAC/SSSI
- Traffic & Access
- Feasibility of slope formation
- Landscape: Character & Visual Impacts
- Ground Contamination Risk Assessment
- Archaeology
- Planning approval: EIA development



Achieving Zero Waste



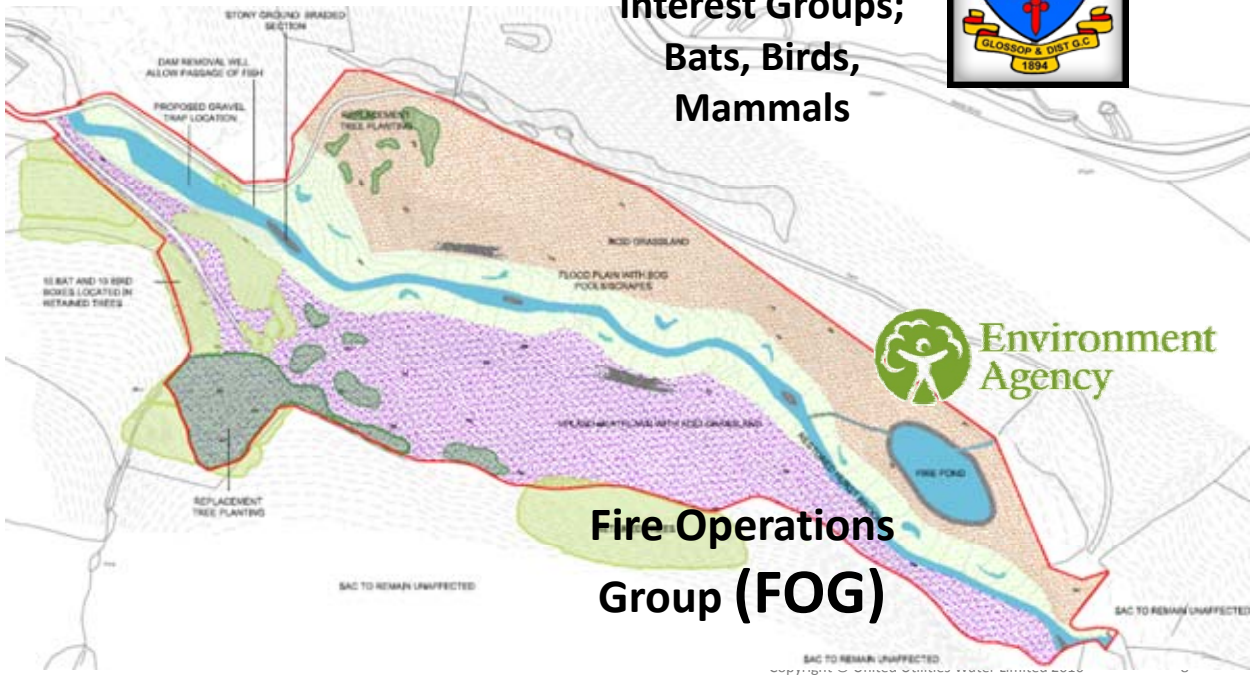
Letting nature take its course

- Stream course constructed to original design
- Reinstating high-energy flows
- Erosion and deposition changed stream course
- 15 year Management Plan costed in

Project Success and Sustainable Benefits

- Aquatic and Terrestrial Habitat Creation
- No increase in flood risk
- Restoration of landscape character
- Minimised transport impacts
- Good local relations

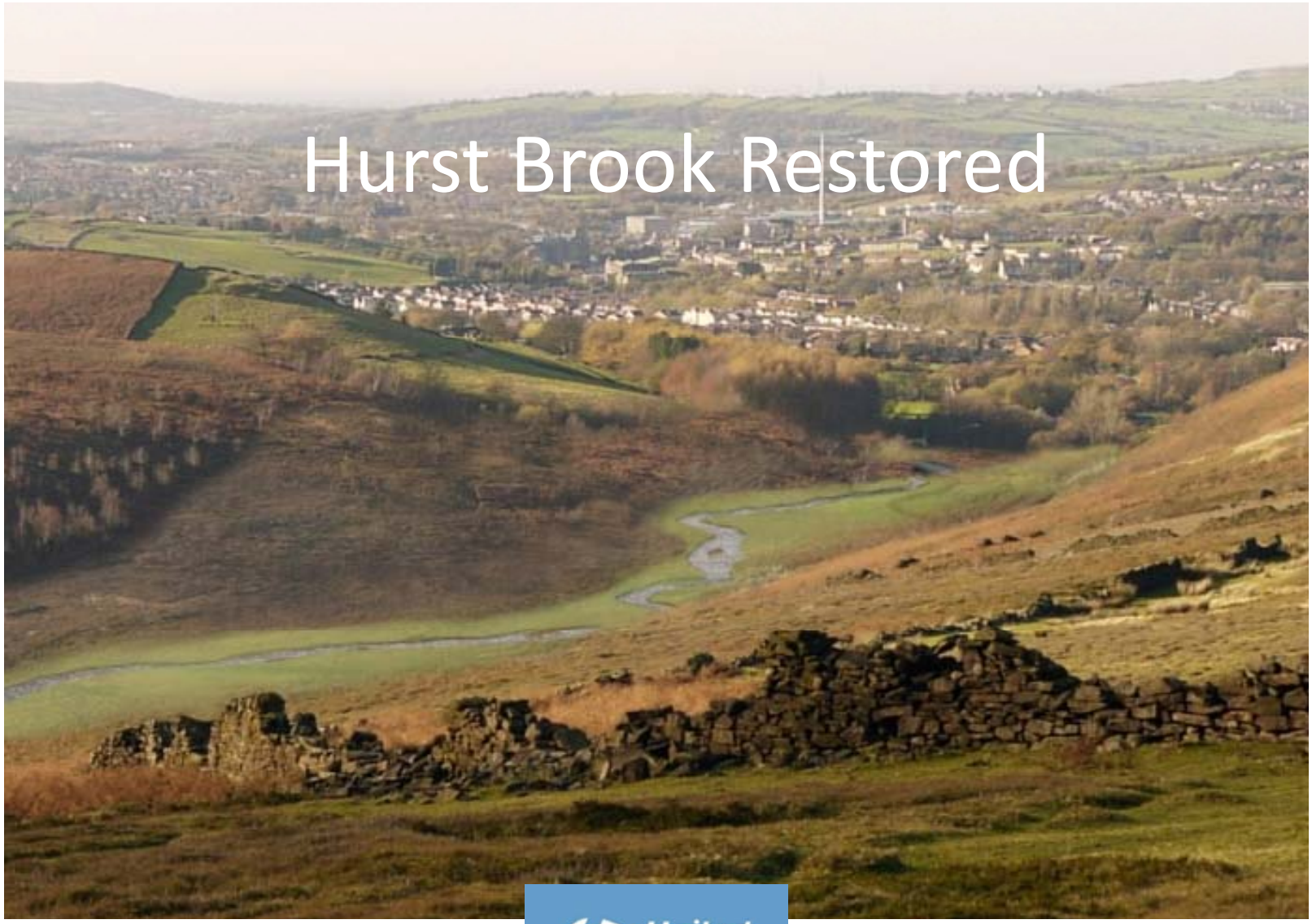
GROUND ENGINEERING AWARDS 2015
WINNER



Interest Groups; Bats, Birds, Mammals

Fire Operations Group (FOG)

Hurst Brook Restored



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Chatsworth Lakes

Challenges of Design and Construction within an Historic Estate

Fox

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Lake Locations

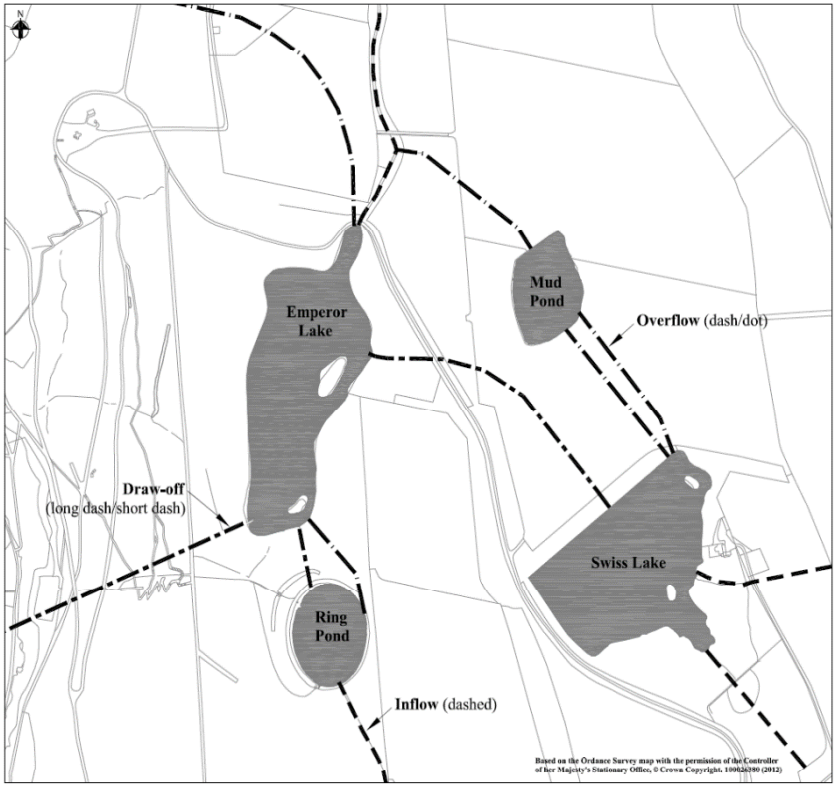
Lake Locations

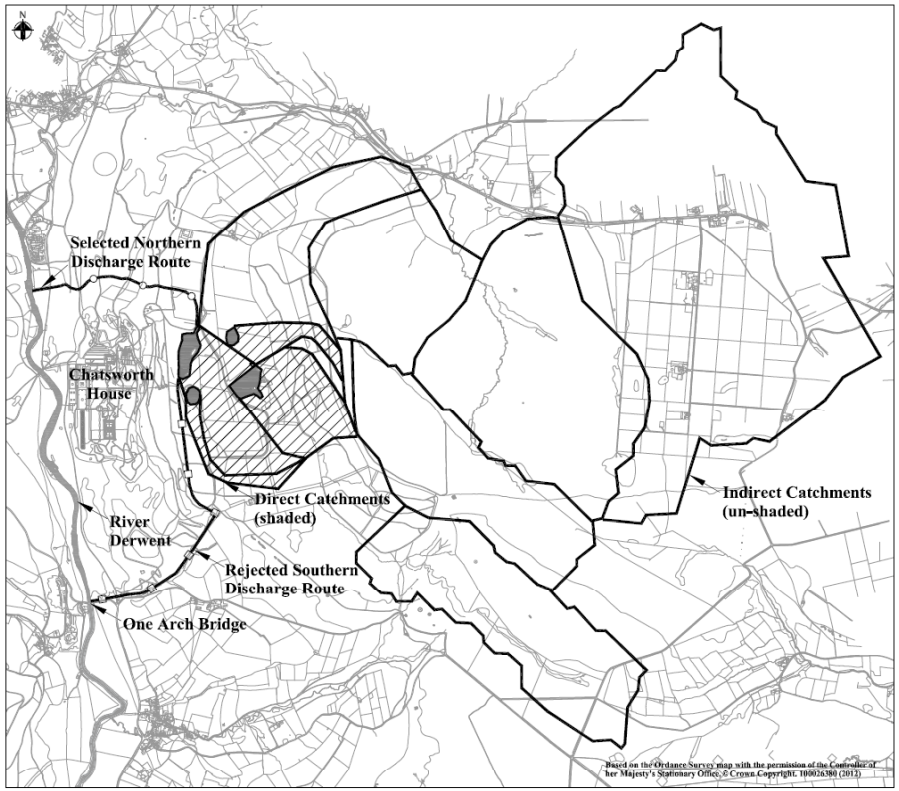
Dam and Reservoir Data

Reservoir	Dam Height (m)	Dam Length (m)	Capacity (m^3)	Pre-scheme outflow capacity*1 (m^3/s)	Design Flood (m^3/s)
Emperor Lake	6	420	72,000	1.7	15
Swiss Lake	3	320	56,826	1.6	4.5
Mud Pond	1.5	190	9,500	2.6	7

Catchment

Lake Connectivity
Discharge Route

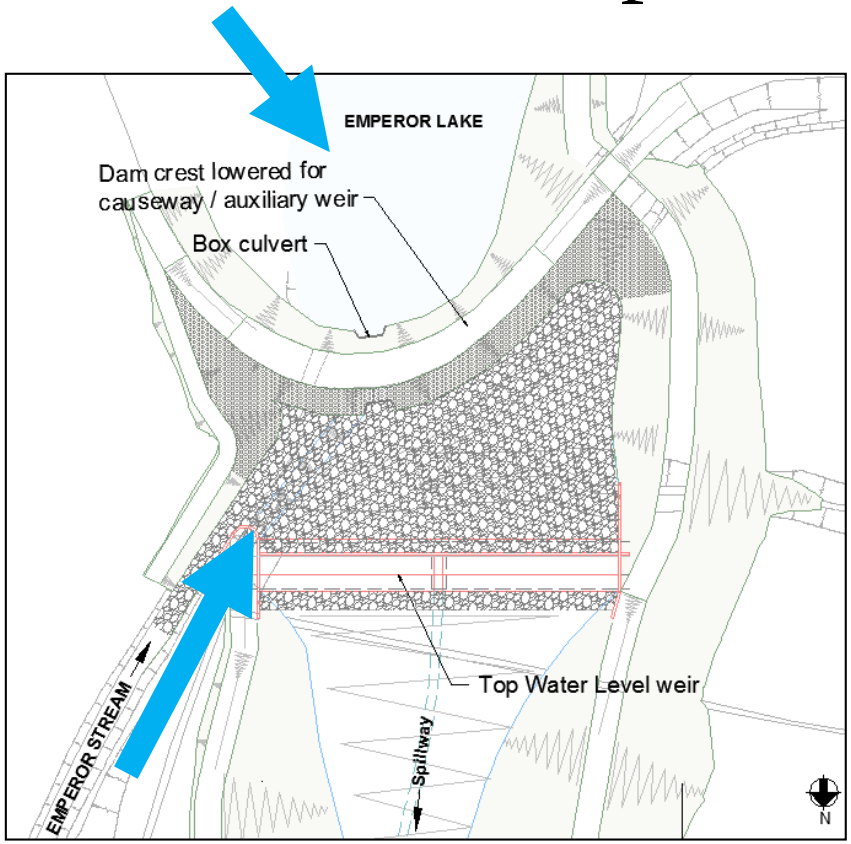


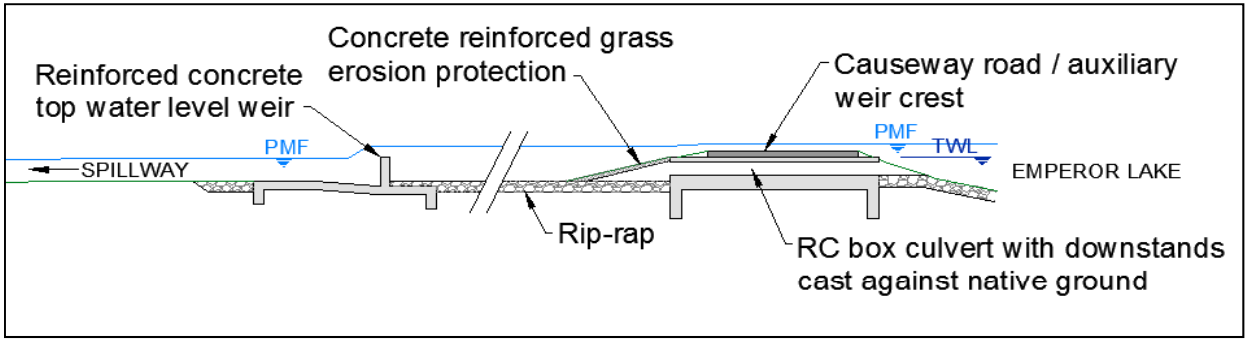


Flood Routing

Freeboard and Overflow Capacity

Solution - Emperor Lake





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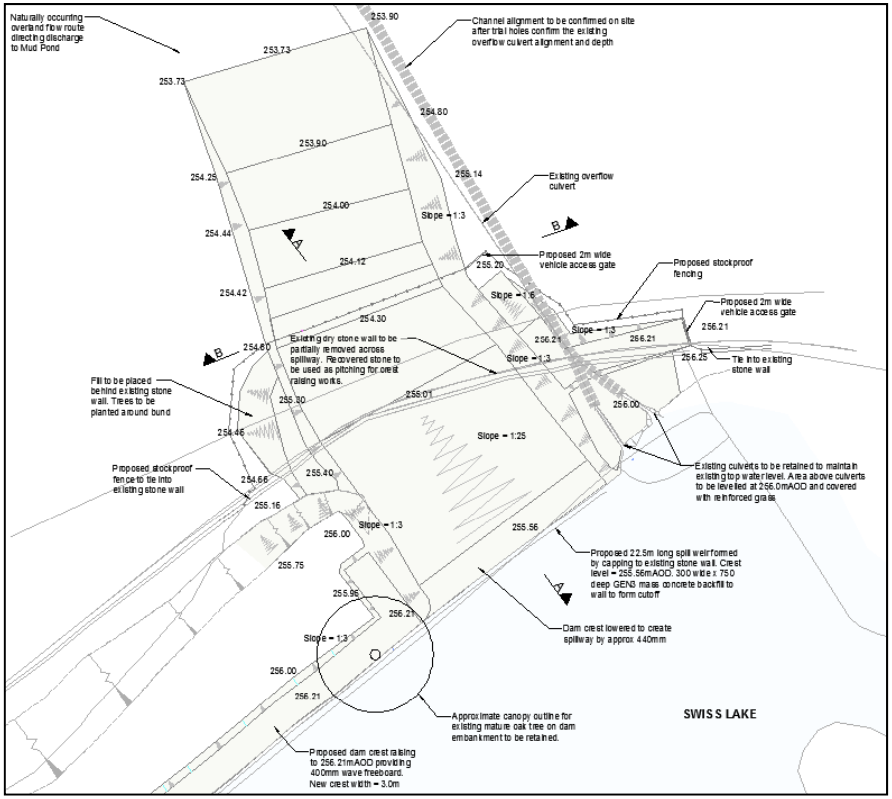
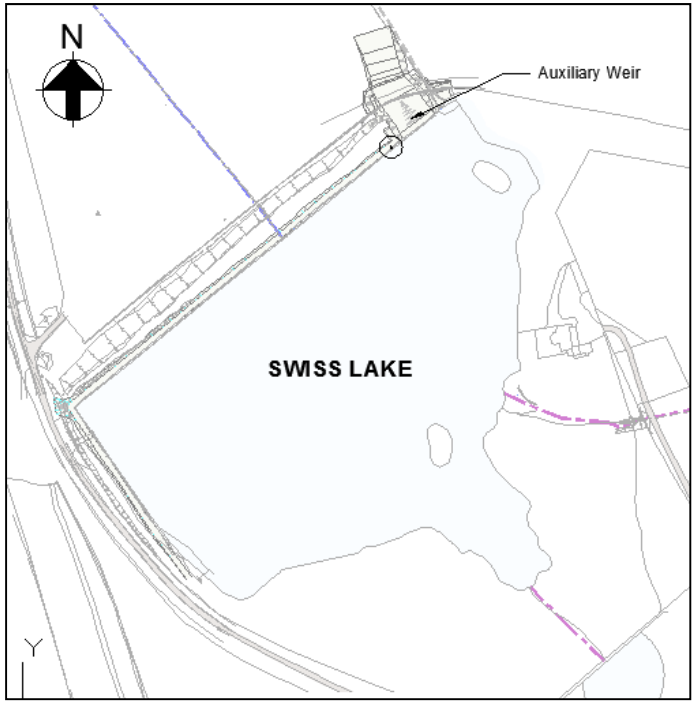
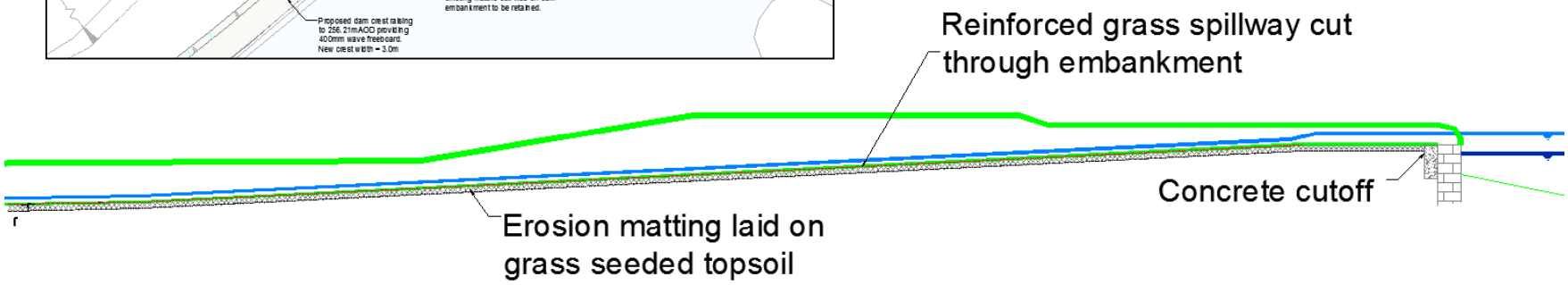
Solution - Swiss Lake







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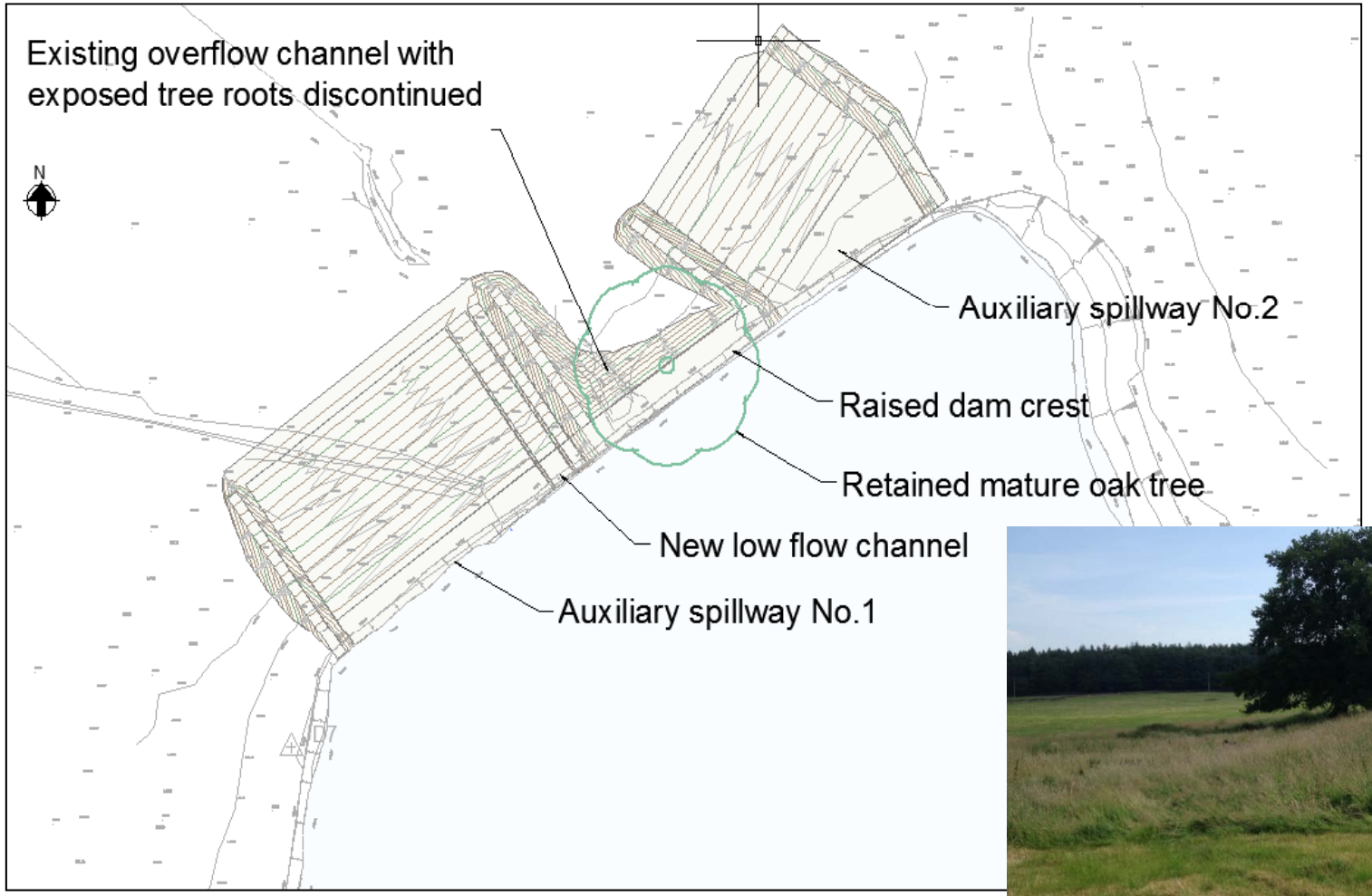
Solution - Mud Pond

Solution - Mud Pond



Materials

National Park & Historic Setting

Construction

Construction flood
Site access / public interface
Sequence of works
Japanese Knotweed

Emperor Lake Weir and Causeway

Built off-line
Breakthrough following QCE approval

Emperor Lake Weir and Causeway

Cut-off trenches and wingwalls

Emperor Weir and Causeway

Crest Raising

Sandstone blocks
Tree stumps

Swiss Lake

Cut-off weir
Drainage sough

Mud Pond

Oak Tree
Drainage Sough
Livestock
Void

Thank you for listening

Fox

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ARUP

Managing the Environmental Risk from Reservoir Draw Down

BDS Conference September 2016

D Armour

M Hewitt

J Malia

R Murray

Introduction

- Background – Pollution Incidents
- Hazards, Receptors & Risks
- ROMS Drawdown Work Procedure – What is it?
- Risk Assessment Process
- Monitoring and Mitigation
- Dam Breach Case Study
- Summary

Background

- Category 1 pollution incidents during reservoir emptying projects
- Silt pollution in rivers
- Fish kill
- Amenity impairment

Why did it happen?

- Inadequate silt capture/ removal
- Hazards and risks not understood
- 9-5, Mon–Fri monitoring

Lessons learned

- Need to identify hazards and risks
- Procedures need to be improved for drawdown projects

Background

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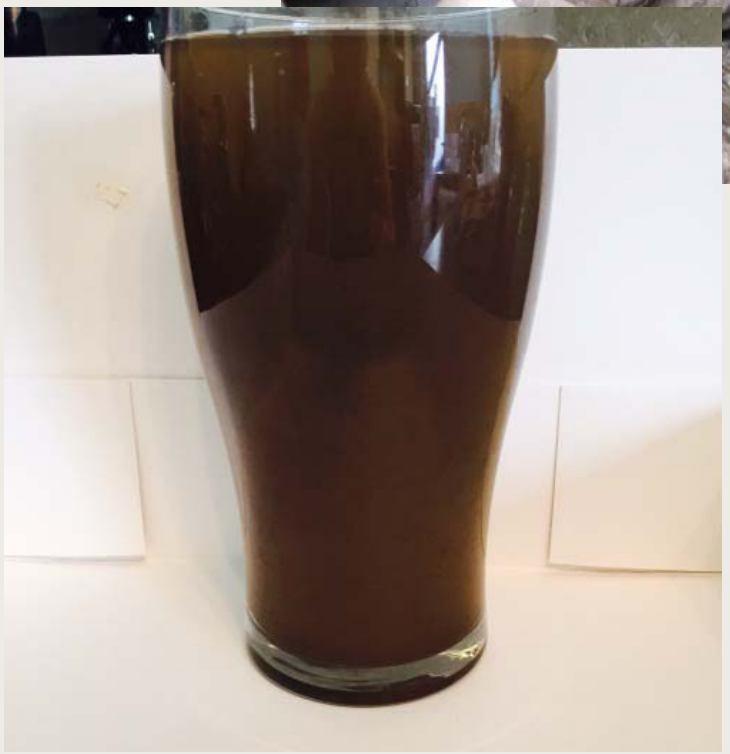

Why did it happen?

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Lessons learned

- Need to identify hazards & risks
- Procedures need to be improved for drawdown projects

Hazards

- Silt in reservoir bed
- Chemicals in silt
- Poor O_2 content at depth
- Flood risk from high scour flows

Receptors

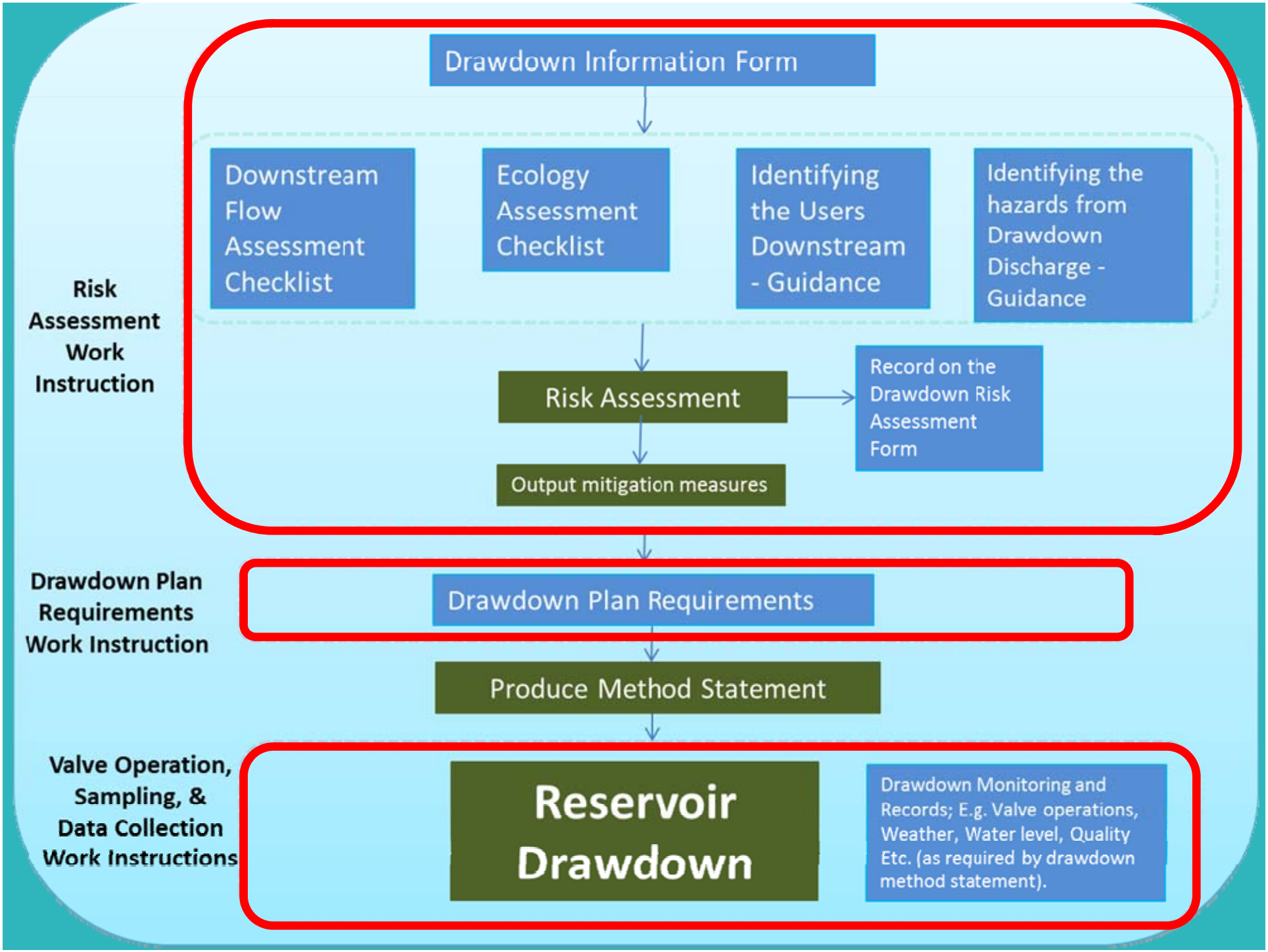
- Migratory/resident fish
- FWPMs
- Environmental designated areas
- Downstream abstractors
- Amenity users

Risks

- High ?
- Medium ?
- Low ?

ROMS Drawdown –
What is it?

- Reservoir Operation and Maintenance Strategy
- Drawdown Work Procedure
  - Data gathering
  - Risk assessment
  - Drawdown plan
  - Method Statement (by Contractor)
- Accountability
  - Key roles identified
    - Drawdown Manager
    - Drawdown Supervisor


Drawdown Information Form
Downstream Flow Assessment Checklist
Ecology Assessment Checklist
Identifying the Users Downstream - Guidance
Identifying the hazards from Drawdown Discharge - Guidance
Risk Assessment Work Instruction
Risk Assessment
Record on the Drawdown Risk Assessment Form
Output mitigation measures
Drawdown Plan Requirements Work Instruction
Drawdown Plan Requirements
Produce Method Statement
Valve Operation, Sampling, & Data Collection Work Instructions
Reservoir Drawdown
Drawdown Monitoring and Records; E.g. Valve operations, Weather, Water level, Quality Etc. (as required by drawdown method statement).

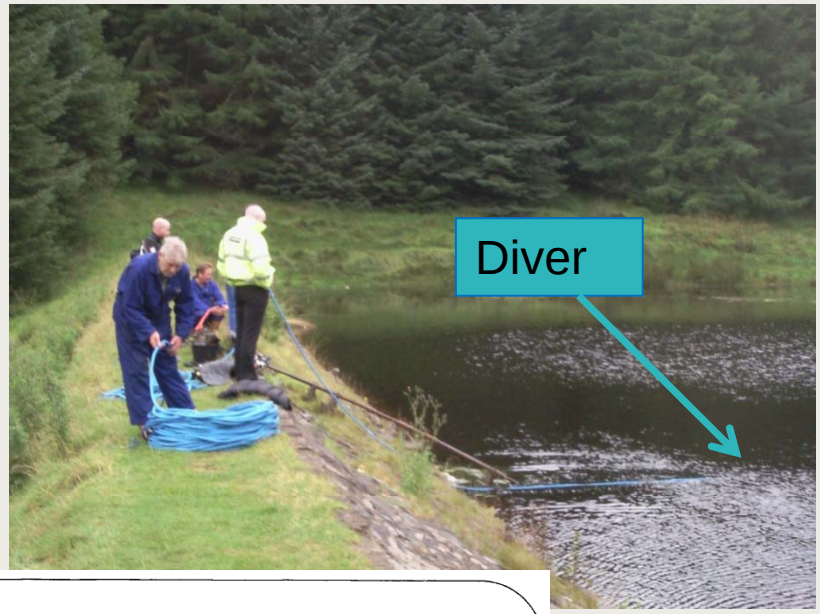
When does ROMS apply?

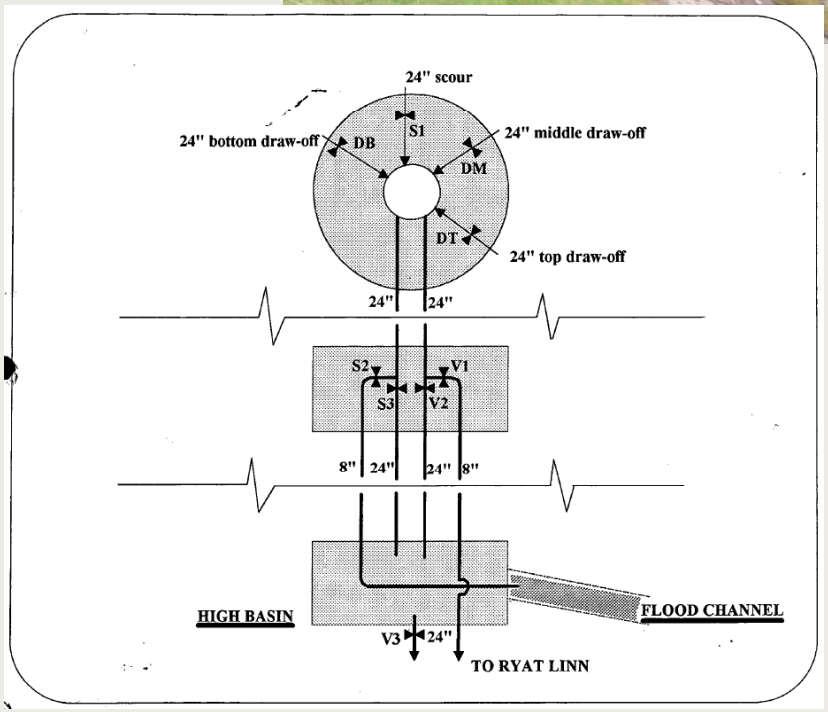
- A planned, forced, temporary drawdown to a required level/ duration to facilitate works;
  - Pitching / concrete repairs
  - Investigation / inspection
  - Spillway improvements
  - Dam breaching

- Three phases;
  - Drawdown
  - Maintaining level
  - Refill

Risk Assessment

- Data collection
- Identify Hazards
- Identify Receptors
- Workshop
  - High / med / low risk
  - Monitoring & Mitigation
- Level of effort ?



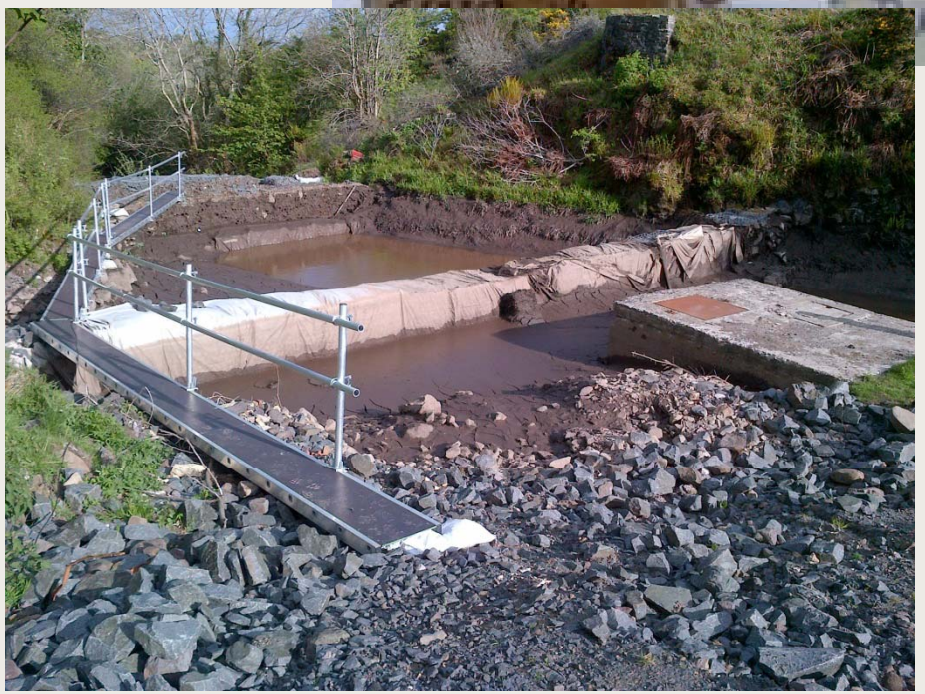


Monitoring

- Weather / water level / water quality / valve status
- Daily >>>> Continuous
- Keeping records

Mitigation

- Remove silt
- Bypass channel
- Silt nets
- Chemical treatment
- Storage lagoons



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ROMS Case study

Pundeavon Reservoir Breaching

New bypass channel

Cofferdam and flow diversion

New bypass channel

Slurry pump (dam part breached)

ROMS Next Steps

Regular Scour Testing?

Summary

- Knowledge gained from drawdown pollution incidents
- Scottish Water has developed a procedure to manage risk during drawdown
- Key roles have been identified to take ownership of drawdown process
- Emphasis on risk assessment and appropriate monitoring and mitigation
- Level of input to the process should be proportionate to risk
- Roll-out and testing was successful with useful feedback including from SEPA
- Scottish Water now implementing for all future drawdown projects

Thank you

British Dam Society Conference 2016 – Session 5
It's not just engineering!

Session Chair: **Tracey Williamson**
Technical Reporter: **Louise Ellis**

Managing the safety of very high consequence dams – is the UK doing enough? (Brown & Hewitt, p29 of the Proceedings)

Question: Jack Meldrum (Mott MacDonald)
In terms of international best practice for these high consequence dams; in Sweden every 30 years they do a complete reassessment of their structures. I thought that was a very good practice. They look at these dams properly in terms of stability using all their data sets. If you are looking at taking forward this approach, I would recommend looking at that sort of practice.

The second point is on the statistics side. Something that I find increasingly worrying when we are looking at these probabilities is that we are projecting these huge numbers or huge periods going forward based on a subjective view and on limited data sets. It's quite easy to say that we could work out the chances of winning Andy's competition if the playing field is level. However, when we are looking at hydrology and beyond, you can take 100 years of data and you think 'I can project it forward a bit, but how far forward can I project it and have confidence in what's going on?' I would like to ask the speakers if they have any comments they have on this.

Response: Martin Hewitt (Mott MacDonald)
I acknowledge your comments regarding statistics. This is why, in the very high consequence and very low probability zone, we are suggesting that a different approach is required. For reservoirs to get out of the unacceptable zone on the current FN chart for major loss of life, you have to get down to an annual probability of failure of 10-6 or 10-8. Issues over such low probabilities of failure include understanding the uncertainty in the estimation and confidence in the results: have we the tools to model the system; do we have that level of understanding of the make-up of the dam? That is why others, particularly the USBR, have adopted a different approach when you get into that zone. So I think we are saying the same thing when it comes to concerns regarding estimating very low probabilities of failure.

Response: Alan Brown (Stillwater Associates)
I think we are saying the same thing - that for these very high consequence dams we can no longer rely solely on probability, we move towards a dam safety case where you not only have a Quantitative Risk Assessment(QRA) but you also have deterministic assessment and other good practice, and it is a combination of all three of those. That is the only way to be comfortable for the very high consequence dams that we are doing a reasonable job in managing their safety. That is what we are suggesting that for the very high consequence dams, we move to a different approach that is a synthesis of different tools together and not relying on any one assessment methodology on its own.

Question: Richard Dun (Canal and Rivers Trust)
Just an observation really on the FN curve; obviously an alternative is to move to reduce the number of fatalities through a proper warning system through an offsite plan, so you can go on either of the axis to try and get into your tolerable zone and the effectiveness of that plan could be vital to achieving that.

Response: Alan Brown (Stillwater Associates)
I think in principle you are right and clearly as well as carrying out physical upgrades to reduce risk, there are all the non-structural measures. However, for very high consequence dams, evacuation is sometimes impractical. For example, if you are talking about 40,000 people in the likely inundation area, you have no time to evacuate them all. For very high consequence dams, evacuation and warning is a lot more challenging because of the large numbers of people involved.

Environmental Benefits of Reservoir Discontinuance – Hurst Reservoir Case Study (Beeden & Parks, p185 of the Proceedings)

Question: Ian Hope (Severn Trent Water)
First and foremost, I am keen to learn more about the economics involved. You mentioned £1.4 million and I would like more information of a breakdown of that in terms of studies, actual construction costs, and whether the 15 year site management costs are factored into that. I am also keen to learn whether that is split into OPEX, CAPEX, TOTEX and how this work has been funded. I also would like to gain an understanding of your long term strategy as why you decided to retain the site and not sell it. Finally, in the terms of the benefit of hindsight, what would you have done differently? Would you have challenged, for example, some of the constraints which were imposed on you?

Response: Helen Beeden (United Utilities)
The 15 year management plan was absolutely key to how it was budgeted and we were very strongly pushed from our operations landscape team and from our ecologists and landscape architects to find a way to make sure that the requirement to have that 15 year management plan, which are pretty standard for any EIA on a big environmental project, was in the CAPEX in the AMP 5 budget. There is a twist where the money, although it was seen as CAPEX, transfers to our friends in UU Landscape Management and Operations as long term monies. But when it comes to it, funding a landscape gang on site for a few days, maybe three to four times a year is nothing in comparison to the plant and machinery, and shipping all that sediment around during the construction project.

We have gone over to approaching projects on TOTEX basis. The part of the business case that was very sustainability-based and that went up to our internal review processes was very much about the long-term costs, such as the monitoring, Supervising Engineers' inspections, the considerable potential remediation costs, e.g. grouting of the Hurst dam, the partial discontinuance, and maintenance and safety, which were all costed to show how a relatively expensive construction project actually worked better for UU.

There was a very strong feeling that we should retain the site and we made a pledge during the EIA to carry on being land-owner of that area. The surrounding land is "Right to Roam" but it was decided that as the site is currently privately owned, with no public access, it will be retained like that. We could foresee that certainly in construction and the year after that, for safety reasons, we did not want trespassers across the site.

Response: Chris Parks (United Utilities)
There is longer term liability than just the immediate aftermath of the discontinuance. There is the requirement for us to maintain the site and manage its redevelopment.

In terms of the "Right to Roam" issue, returning the site to a sustainable and fantastic ecological area without people interfering in that recovery and disturbing that process, is actually a much better thing to do.

Response: Helen Beeden (United Utilities)
We don't see the outcome of an EIA as constraints imposed upon us. UU commissioned the EIA and used the outcomes to influence design. Sustainable outcomes and aims developed by Halcrow, via consultation between UU and regulatory and public stakeholders, were straightforwardly enshrined by the Planning Authority, the Peak District National Park. Any challenging of perceived constraints is best done early, within that EIA process.

Question: Robert Mann (Aecom)
From the Hurst paper what is not stated is what appears to be a decision made not to sell the reservoir, as it was, to anyone willing to buy it. I think that is a very commendable decision and I think it is an essential one for owners of reservoirs, because it is quite clear that anybody going to take on that reservoir should have a spare sum of money of the order of £1.4 million and a willingness to spend it if, or rather when, the reservoir reached a state where it was no longer economic to maintain it in a safe condition.

Response: Helen Beeden (United Utilities)
Tentative approaches were made between land agents to see if there was anybody interested locally but that was at the same time as the Inspecting Engineer's report came out and put the 'death knell' on the dam; that it was a threat downstream from flooding and the sale idea died away and the whole land had to be reassessed – "what do we do with it in light of the Inspecting Engineer's conclusions?"

Question: Miguel Piedra (Arup)
How do you manage to maintain or produce no net increase of flood risk downstream when you remove the dam?

Response: Chris Parks (United Utilities)
Modelling was undertaken which showed that removing the reservoir and thereby increasing the area of land the rain falls on, coupled with having native vegetation on the site and remodelling those slopes back to a more natural form, attenuates the rainfall and reduces the potential flood risk from that catchment which feeds into the model. So by actually not having the flow coming straight into the reservoir and discharging, but rather, being retained and slowed down during its process down the valley, the model can achieve the same end result - that there is no net increase in the flood.

Response: Helen Beeden (United Utilities)
There was a lot of complicated work also on design of the channel itself, which was an allusion to braided channels and gravel traps. These were clever mechanisms, each intended to allow the energy to be taken out of the flow. We were fortunately in the situation where we had quite a large change in elevation along the channel, to be able to come up with that design.

Question: Miguel Piedra (Arup)
Was the effect of this scheme reliant on a model which was essentially representing improvements on the catchment slopes to reduce runoff?

Response: Helen Beeden (United Utilities)
No I would say it is a balance. There is quite a lot of energy and flood capacity retained by developing those flatter marshland areas and gravel and boulder channel areas in the base of the valley. It was not one factor; it was the whole model which managed to pass. It underwent a long review between the Environment Agency and MWH, and went back up at least twice to influence and improve the design, before everyone was happy that there would be a "zero increase in flood risk" downstream.

It is not to say no flood risk; the channel downstream is constructed by mill owners and is sandstone and masonry-sided and flat bottomed in some places, and constrained by road bridges. It is that difference between a completely non-natural culverted situation and what we have developed, which gives the erosional energy and the flows somewhere to go.

Response: Chris Parks (United Utilities)
Do not forget that the area has been tested by nature (Winter 2015 to 2016) since we have discontinued the reservoir, and there were no reports of apparent increases in flooding downstream.

Challenges of design and construction for reservoir safety improvements within an historic estate (Neeve *et al*, p377 of Proceedings)

Question: John Foster (Mott MacDonald)
During the works at Chatsworth House how did you manage the unplanned floods? Did you have any contingency plans?

Response: Matthew Jenkins (Arup)
The 1 in 30 year flood event was evaluated and the drawdown managed for that level. The contingency measures were primarily to keep the existing overflows operational during the raising works so that they could operate at any stage throughout the construction phase and we only did that final fill in when the rest of the works had been signed off by the QCE. So effectively, it was almost business as usual for the embankment.

Response: David Neeve (Arup)
We also put in a water level marker within the lakes themselves to make sure that the flood rise from the construction bund would be contained within the reservoir basin itself. That was quite a bit of negotiation between Chatsworth House who needed as much water as possible to run their key features such as Emperor Fountain, which is a fountain about 150ft high. So they wanted the most head possible, but obviously we had to make sure the construction was safe and acceptable.

Question: Tracey Williamson (Arup)
I noted in your paper that you had to get consent for works in a Grade I listed park and I wondered what the differences are with getting consent within a park rather than a listed building. Are there any similarities or differences in the legislation? And what you have to do to gain consent?

Response: David Neeve (Arup)
We were lucky that part of Chatsworth House is owned by a trust and one of the stakeholders is the national park so they were involved right from the start. We did an outline design and then walked round the scheme with the drawings to explain what we are planning to do. They came up with things like not being allowed to use cement, and the natural materials have to be locally sourced. So when it went for planning permission it was fairly straightforward and we did not have many conditions left over, apart from obvious ones such as having the archaeologist on site to inspect works. If it had not been that way, it might have been a lot more difficult going through the process.

One thing I forgot to mention; I had a picture of one of the contractors in the slides, Fox (Owmby) Ltd, and they have had a history of working on reservoirs. They were incredibly diligent and incredibly helpful when we uncovered things and quite good in making sure that reservoir safety was not impacted with construction, so I did mean to thank them. Unfortunately, they could not be here today

Managing the Environmental Risk from Reservoir Draw Down (Armour *et al*, p281 of the Proceedings)

Question: Tracey Williamson (Arup)
Will regards to draw down, I was wondering in your risk assessments, do you consider when valves are seized in an open position, where you maybe only have one valve, and what effect that might have on the environmental impacts downstream?

Response: Rachel Murray (Mott MacDonald)
Part of the data gathering is looking at the valve schematics that are available and the history of the valve operations which feeds into the risk assessment process. It was something that was raised during a workshop with the Scottish Water Reservoir Engineers and also, trialling it on a number of their draw down projects, it was something that came up about how to take account of a valve becoming stuck open or not having the flexibility to close it if an incident happened.
The drawdown management plan of the work procedure includes contingency planning so if something were to happen, what you would do? It will be different on a site specific basis, but it should be a part of the thought process.

Question: Gareth Briggs (Aecom)
From our experience of reservoir draw down procedures and putting them into place, the biggest impacts have typically been in the impact in the reservoir itself and the biggest opposition we have had is the loss of water, the impact on the shoreline habitat, the impact on fish, swan mussels etc. and wondered is that contained in the Reservoir Operation and Maintenance Strategy (ROMS) as well?

Response: Rachel Murray (Mott MacDonald)
The ROMS process is very much looking at the downstream impacts. The starting point of the work procedure assumes that the drawdown has been decided as the best option, particularly when you are looking at a breaching project or a project where you have a significant draw down of the water level. So the starting point for the work procedure is that in deciding to draw the reservoir down those considerations have already been discussed.

Question: Peter Down (Mott MacDonald)
The paper is obviously biased towards major drawdown events for when major maintenance or capital works are needed on reservoirs. In normal operation of a reservoir there is a need to test the scour system. In my experience, there has often been restrictions placed on that by the owner or by others, where they consider that to manage the silt discharge the scour system has only been tested on balanced head which actually compounds the problem because then you end up with a build-up of silt and obviously the valves have limited operability because they have only ever been worked over a small range. If they are operated more fully then obviously when it comes to a major drawdown there should be less silt in the reservoir and therefore less impact when a major drawdown is required, and also less impact when regular scour valve testing needs to be done. I was wondering from your studies has anything come out of that which has then fed back into the general operation of the reservoirs and influenced the general operation regime.

Response: Rachel Murray (Mott MacDonald)

That is what we are currently working on with Scottish Water – we are drafting a procedure for the scour valve operation, for regular exercising of them. SEPA has put some draft guidance out and there is already some guidance on how Scottish Water should be operating their valves from SEPA. So it is taking those things into consideration and trying to get to a stage where the regular operation can happen – that is next in line for the documents. In terms of the reservoir drawdown, in the documents which have already been produced, there was a distinction made between what is carried out for a drawdown project and what is carried out for a scour valve exercise and that predominately comes from the difference in the time frame associated with the release.

Question: Robert Mann (Aecom)

I think with scour operation it is important to remember what nature does. When nature has a spate, it discharges silt and sediment down the river and if you can imitate that by timing your scour operation, it would seem from a nature identification point of view to be the best way to do it. The trouble is that it may not suit people's diaries and I am also not sure whether the regulator, SEPA, has actually got the message about that.

Response: Rachel Murray (Mott MacDonald)

I think that those are considerations for the set of documents that are coming up and the intention will be to engage with the regulator in preparing those documents.