Session 6

DRAWDOWN AND DISCONTINUANCE CONSIDERATIONS

Discontinuance of Small Reservoirs in Scotland - L Dunne and R Morrin

The Discontinuance of Sunnyhurst Hey and Improvements to Earnsdale Reservoirs, Darwen, Lancashire - S Tennant and C Parks

Delivery of Drawdown Improvements at Anglian Water Reservoirs - R Pether and I Kirkpatrick

Scour Releases for UK Reservoirs – A Case study - A Pepper

Discussion

Discontinuance of Small Reservoirs in Scotland

Lesley Dunne - Atkins

Ross Morrin – Scottish Water

Scottish Water Impounding and Non-Impounding Reservoirs

Reservoir Capacity	No. of Reservoirs
>25,000m^3	276
10,000m^3 – 25,000m^3	29

- Recent work on regulated reservoirs
- Start to look at smaller reservoirs

Why Now?

- Reservoirs (Scotland) Act 2011
  - Threshold 25,000m^3 -> 10,000m^3
- Reduce risk
  - Reservoir and public safety
- Minimise commitments
  - Financial
  - Resources
- Consider breaching?

How?

- Identify & prioritise
- Determine scope
- Appraise options
- Develop a project

Issues & Challenges

- Land issues
- Environmental constraints
- Cost
- Stakeholder Requirements
- End Use & Re-sale

Case Studies – Discontinuance of 5 “Small” Reservoirs

- Bowling Reservoir
- Greenlands No.1 Reservoir
- Greenlands No.2 Reservoir
- Greenlands No.3 Reservoir
- Tighnabruaich Reservoir

Bowling Reservoir

- 11,000m^3 capacity
- Earth embankment, 7m high, 100m long
- Poor condition (leakage, risk of overtopping)
- Lack of maintenance
- No longer in use (previously water supply)
- Options Appraisal (discontinuance vs. restoration)
- Flood Study & Inundation Mapping
- Provides negligible flood protection d/s
- Considered a “Liability”
- Discontinuance considered best long-term solution

Dam Crest

Inlet Chamber

Valve tower access

Silt (>1m deep)

Overflow & Outlet (vandalised)

Overflow & Outlet (vandalised)

Scour Pipe

Possible leakage (d/s dam)

Scottish Water

ATKINS

Water levels fluctuate – no control

Scottish Water

ATKINS

Bowling Reservoir - Challenges

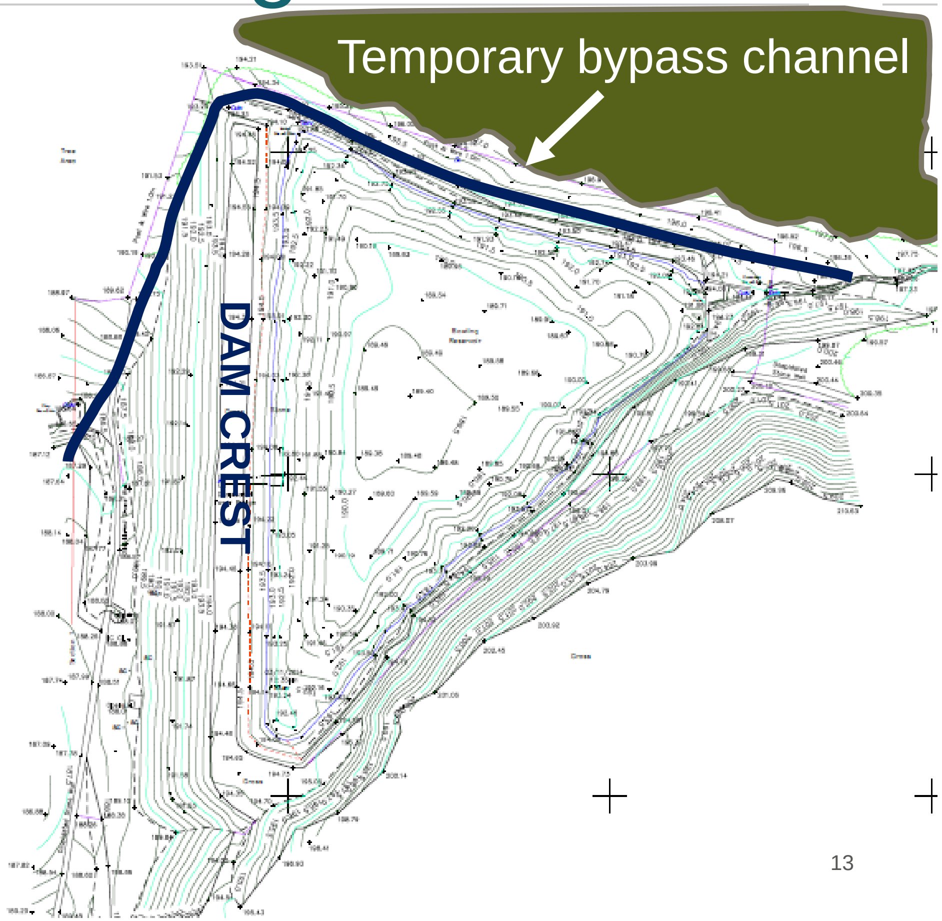
- Difficult Access

Bowling Reservoir - Challenges

- Difficult Access
- Restricted Working Area

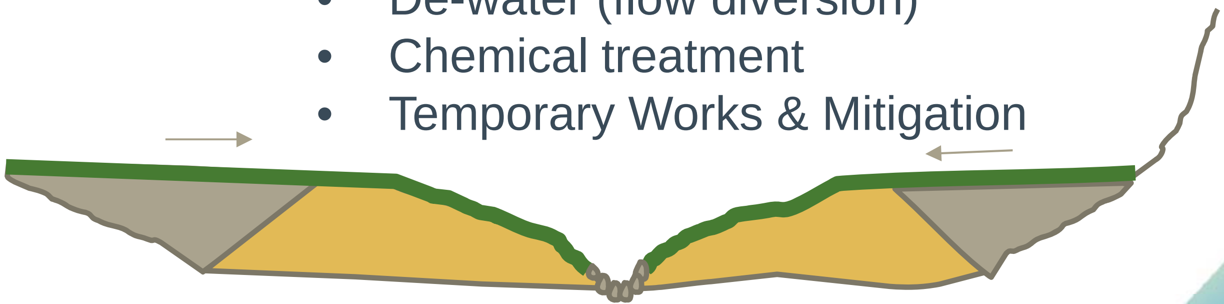
Bowling Reservoir - Challenges

- Difficult Access
- Restricted Working Area
- Reservoir Drawdown

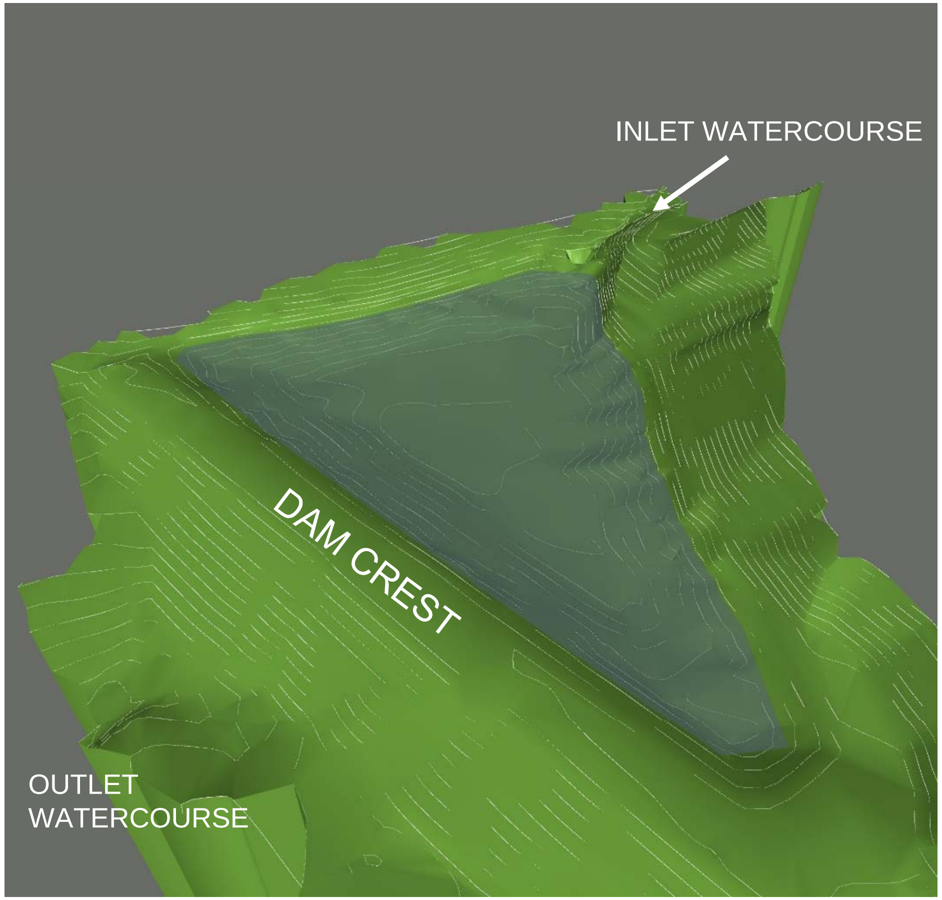


Bowling Reservoir - Challenges

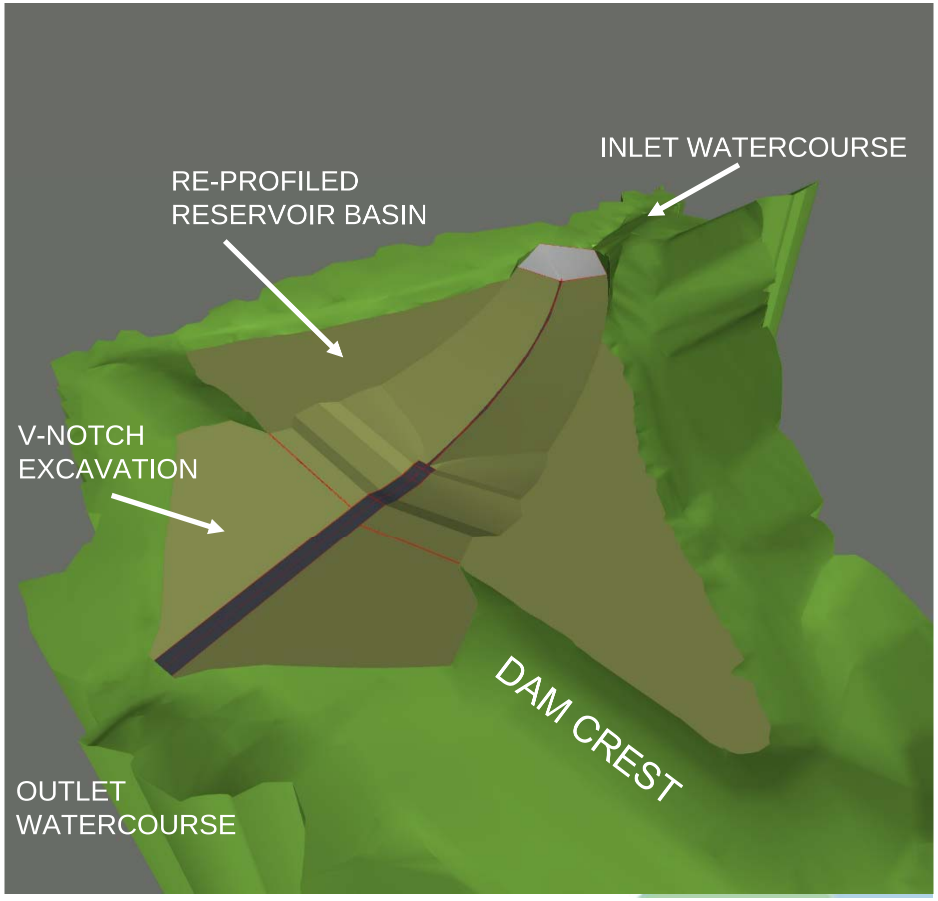
- Difficult Access
- Restricted Working Area
- Reservoir Drawdown
- Silt Management
  - Off-site removal
  - On-site treatment (downstream of reservoir)
  - De-water (flow diversion)
  - Chemical treatment
  - Temporary Works & Mitigation



Existing

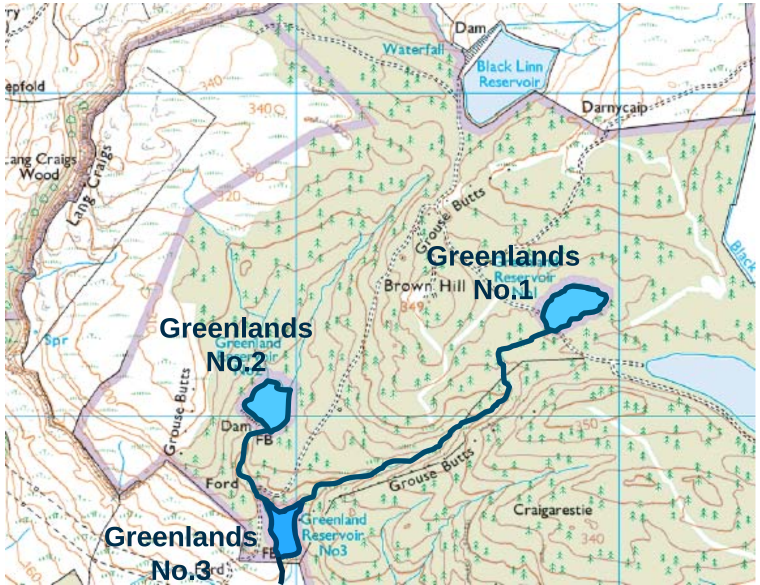


Proposed



Redundant Reservoirs Strategy – Greenlands No.1, No.2 & No.3 Reservoirs

Reservoir	Dam Type	Height	Length	Capacity
Greenlands No.1	Earth Embankment	4m	50m	15,500m^3
Greenlands No.2	Earth Embankment	9m	93m	23,750m^3
Greenlands No.3	Earth Embankment	10m	70m	19,000m^3



Aim:

- Develop strategy for long term management of Greenlands Reservoirs
- Reduce Scottish Water's risk, financial & resource commitments

Greenlands No.1 Reservoir

Damaged Spillway Crossing

Dam Crest - rutting

Blocked Spillway

Greenlands No.2 Reservoir

Discontinuance Works (2009)
43,000m³ – 23,750m³ capacity

Timber storage area

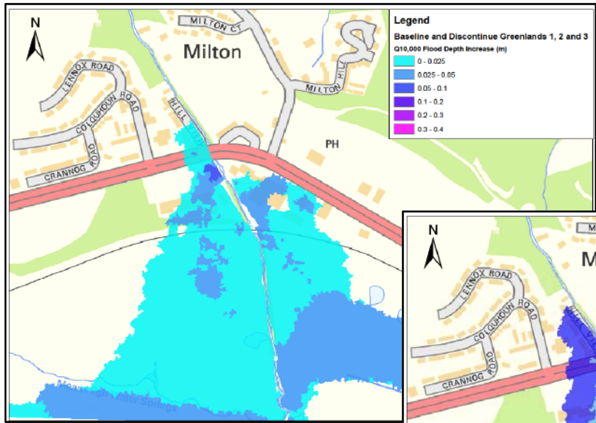
Greenlands No.3 Reservoir

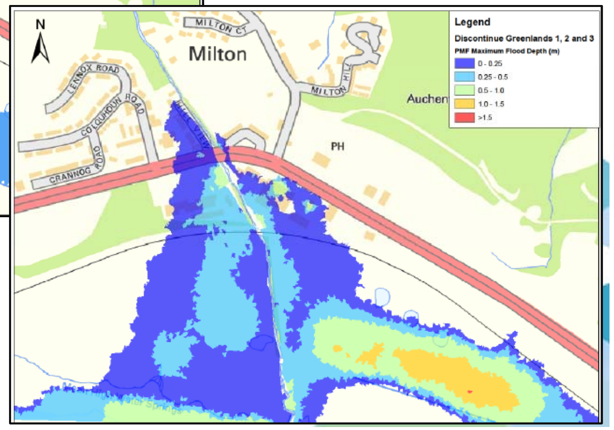
Flood Study & Inundation Mapping

- Flood impact on downstream communities if 1 or more reservoirs discontinued

- 15,630m^3 flood storage required to maintain existing level of downstream flood protection

	Modelled Scenario	Storage Volume (m^3) required to maintain current 0.5%AEP peak flows
1	Baseline (all dams retained)	0
2	Remove Greenlands Reservoirs Nos. 1, 2 and 3	15,630
3	Remove Greenlands Reservoir No. 1 only (Retain Greenlands Reservoirs Nos. 2 & 3)	760
4	Remove Greenlands Reservoir No. 2 only (Retain Greenlands Reservoirs Nos. 1 & 3)	10,900
5	Remove Greenlands Reservoir No. 3 only (Retain Greenlands Reservoirs Nos. 1 & 2)	1,860
6	Remove Greenlands Reservoirs Nos. 1 & 2 (Retain Greenlands Reservoir No.3)	13,635
7	Remove Greenlands Reservoirs Nos. 1 & 3 (Retain Greenlands Reservoir No.2)	5,115
8	Remove Greenlands Reservoirs Nos. 2 & 3 (Retain Greenlands Reservoir No.1)	12,220





Options Appraisal

- Option 1 – Retain & Upgrade Greenlands No.1, No.2 & No.3
- Option 2 – Discontinue Greenlands No.1, No.2 & No.3
- Option 3 – Discontinue Greenlands No.1 & No.3
- Option 4 – Discontinue Greenlands No.1, No.2 & No.3
  convert to flood storage reservoirs

Options Appraisal

- downstream flood risk
- environmental impact
- heritage issues
- visual impact
- constructability
- reservoir safety
- structural stability
- extent of restoration works
- sustainability
- health & safety
- stakeholder requirements
- current / future amenity value
- site accessibility
- long term maintenance & monitoring
- cost (construction, operation, maintenance, supervision,& inspection)

Tighnabruaich Reservoir – Discontinuance Again!!

- Earth embankment, (12m long, 5m high)
- 16,780m^3 capacity
- Discontinued before – therefore quick & simple 2nd time round?

Challenges

- Site Access Road – recently upgraded by Community Trust
- Significant rock excavation – plant previously brought to site by helicopter
- Downstream development – incl. recently commissioned hydro scheme

Conclusion

Don’t Underestimate!

“Small” reservoirs doesn’t always mean quick, easy, low cost discontinuance

The Discontinuance of Sunnyhurst Hey Reservoir and Improvements to Earnsdale Reservoir, Darwen, Lancashire

British Dam Society Biennial Conference, Lancaster. September 2016

Introductions

Stewart Tennant
Divisional Director, GHD Livigunn

- GHD Livigunn consulting engineers responsible for the detailed design.
- Contractors Geotechnical Advisor.
- Responsible for coordinating the various specialist design elements and providing on-site geotechnical supervision.

Dr Christopher Parks
Principal Geotechnical Engineer, United Utilities

- United Utilities (UU) owner and operator of Earnsdale Reservoir.
- Responsible for its safe operation under the Reservoirs Act 1975.
- UU provided the outline scheme design and specialist Reservoir Safety Engineering services.

The problem

- Sunnyhurst Hey and Earnsdale are adjacent reservoirs situated on the north-western edge of Darwen Moor, some 1.5km west of Darwen town centre.
- A history of seepage and settlement indicated an insufficient Factor of Safety (FoS)
- Detailed geotechnical assessment confirmed remedial works were necessary to reduce the risk of failure due to slope instability and/or internal erosion.

Discontinuance of Sunnyhurst Hey

- Sunnyhurst Hey Reservoir constructed in 1875, impounding 436 megalitres.
- 855m length embankment suffered history of seepage, damp areas and soft ground.
- Embankment had no ‘core’ or ‘cut-off’, contrary to historical information.
- Given extent of mitigation measures required to bring the reservoir to an acceptable safety standard, it was decided to permanently discontinue the reservoir.
- Main embankment notched at 1 in 3 slope to discontinue the reservoir with new concrete inlet screen structure and new concrete outlet weir.

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Earnsdale IR

- Earnsdale Reservoir situated on Darwen Moor, constructed in 1863.
- 433 megalitres with a 300m long, 24m high homogenous earthfill embankment.
- Provides drinking water to c. 100,000 UU customers in the Blackburn area.

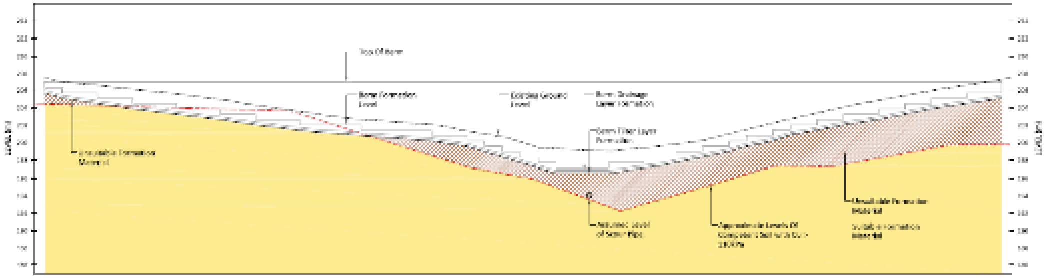
ⓘ Following investigation minimum failure criterion of 1:10,000 not met.

ⓘ Asset placed in the PRA 'intolerable' category.

ⓘ Project aim: to reduce the risk of failure due to slope instability and/or internal erosion.

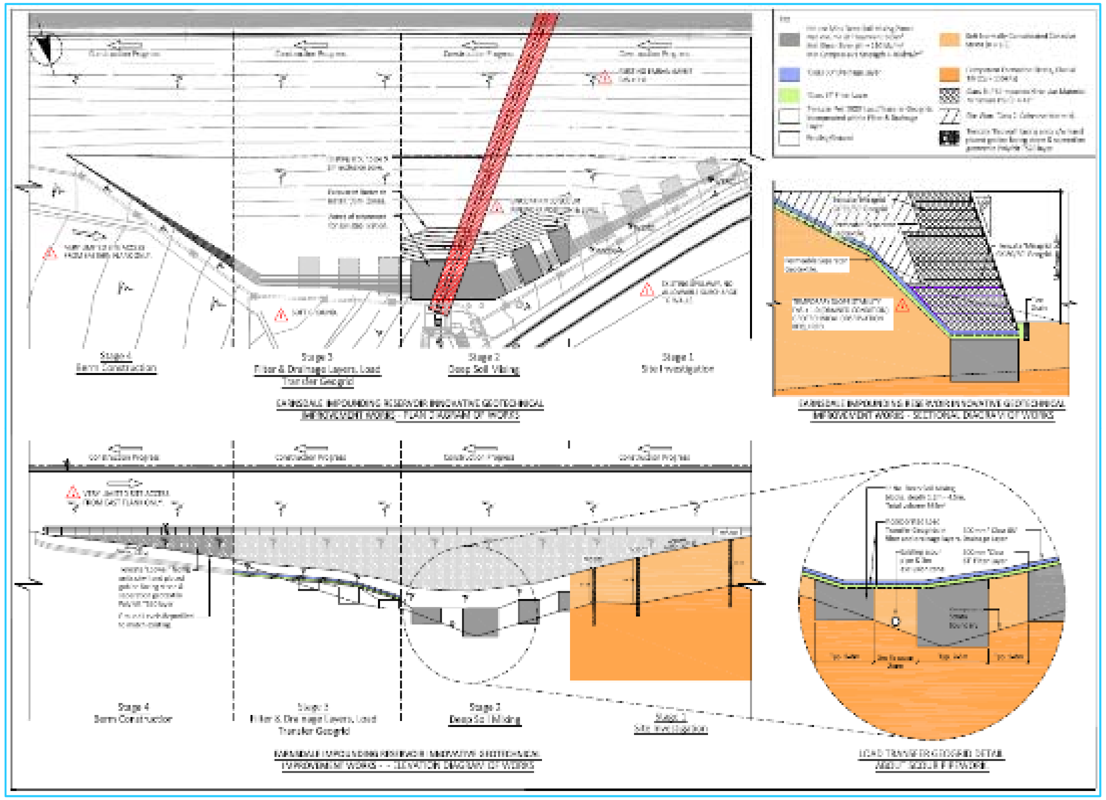
Challenges – site constraints, ground conditions and weather!

- Difficult access to base of embankment from eastern flank restricted loading.
- Frequently adverse weather conditions.
- Significant depth of normally consolidated cohesive made ground with insufficient bearing capacity at the toe of the embankment.
- Risk of shallow slips during temporary excavation – observational approach adopted.
- Existing scour main precise location unknown.



Innovation – our geotechnical design solution

- Notwithstanding the numerous constraints encountered, a unique solution was formulated, incorporating a geo-grid reinforced earth berm with basket/rock facing, constructed on a geo-grid reinforced load transfer platform that spanned between a number of deep soil mixed foundation cells and a filter to cover the downstream face of the dam.



- Volume of treated material reduced (600m³).
- Weighted filter material incorporated into load transfer platform.
- Transfer platform enables bridging of the scour main.

Our use of deep soil mixing and a load transfer platform represented a first for UK Dam engineering.

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Innovation – Deep Soil Mixing (DSM), load transfer platform

- DSM uses an “Allu” mixing arm mounted on a 35T excavator to mix cement binder and water into the ground to produce a cement stabilised block.
- Site trials demonstrated that a 10% binder mix would attain the required undrained shear strength of 110kPa at 14 days.
- Load transfer platform designed in accordance with BS8006:2010 using the methods ibn Cl.8.4 “reinforced embankments over areas prone to subsidence”.

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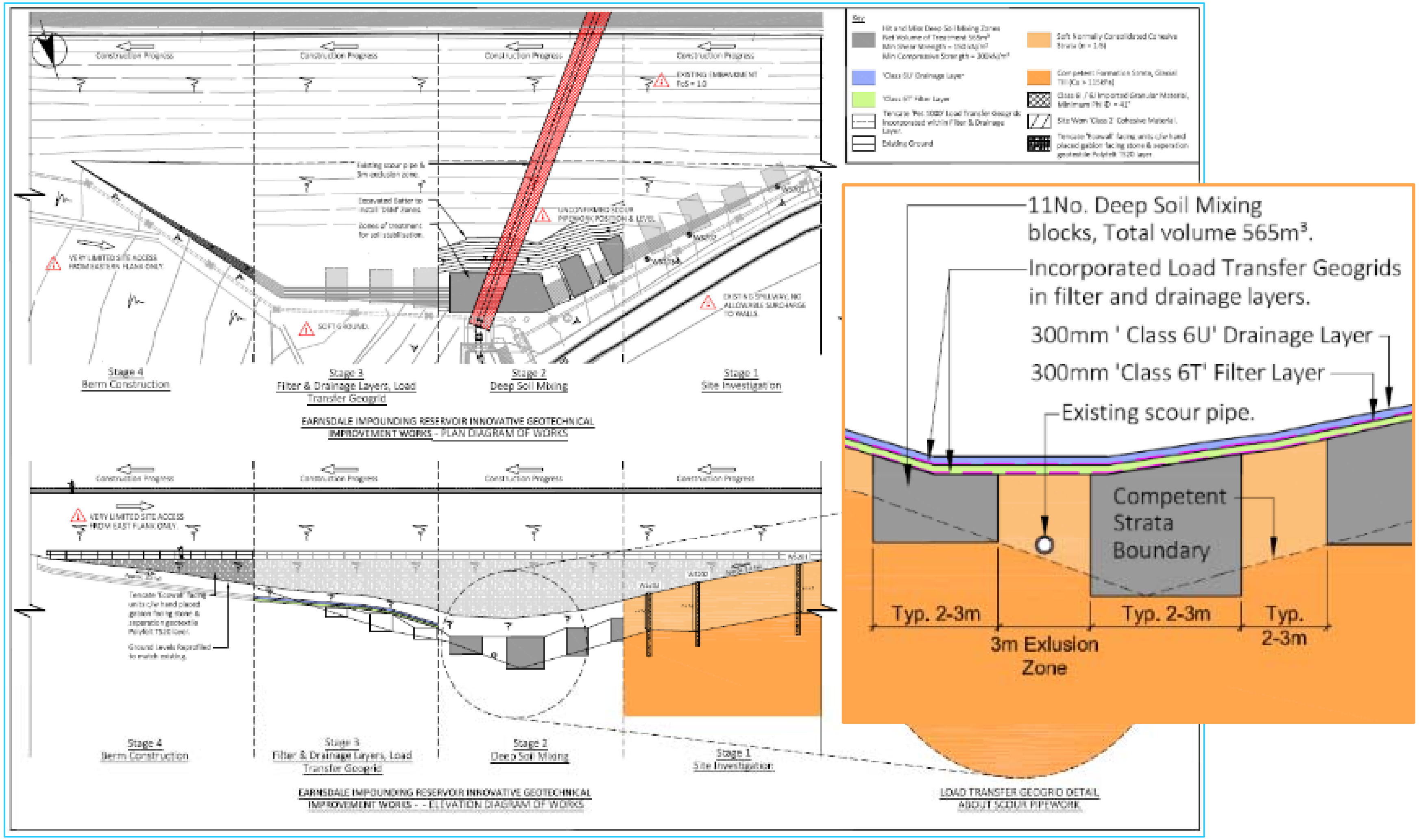
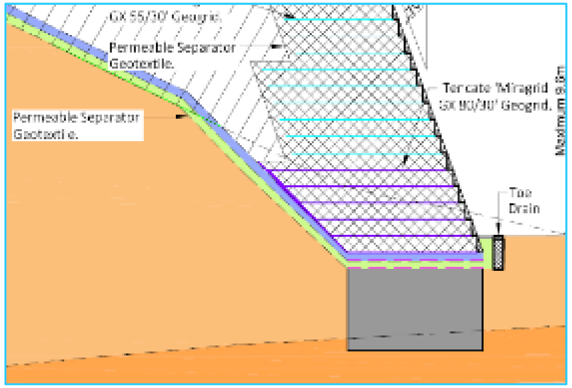
Innovation – Deep Soil Mixing



Eco wall – design and construction

- Reinforced earth stabilising berm comprised a “TenCate EcoWall” retaining system reinforced with Miragrid GX80/30 and GX55/30 geogrids.
- Front face 20° with galvanised steel mesh front filled with dry stone.
- Overall length of 140m and a maximum retained height of 9.6m.
- Traditional toe berm insufficient mass to stabilise the embankment due the limited space available so reinforced earthworks structure used.
- Reduced width of wall using enhanced fill to reduce temporary stability risk.
- First use in UK of reinforced earthworks on a geotextile reinforced load transfer platform over DSM cells improve the stability of an embankment dam.



Eco wall – design and construction

Summary – collaboration and third party impacts

- Understanding the Client's needs and the ecological and third party constraints
- Determination of project risks and in particular the geotechnical risks.
- Completing of complex civil and geotechnical construction project under challenging conditions with significant constraints.
- Providing continued innovation and delivery of efficiencies throughout the project.

Delivery of Drawdown Improvements at Anglian Water Reservoirs

Rachel Pether, Principal Engineer, Black & Veatch Ltd

Ian Kirkpatrick, Reservoirs Safety Manager, Anglian Water Services Ltd

- Project overview
- Assessment of adequacy of overflow facilities
- Rutland Water Appraisal
- Design options
- Valve testing challenges
- Conclusions/Summary

Project overview

- Study into drawdown capacity of 16 of Anglian Water's larger reservoirs - 2005
- Five reservoirs subsequently assessed as having insufficient capacity
- Capital projects completed at four of these reservoirs between 2010-15
- Rutland Water scheme ongoing

Assessment of adequacy of overflow capacity

- Initial study in 2005 – no industry standard guidance at that time
- BV initial suggested standard - 50% volume reduction in 10 days for impounding reservoirs, 20 days for non-impounding reservoirs
- Final decision on adequacy taken by ARPE following Section 10 inspection

Rutland Water

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Rutland Water drawdown capacity

- Existing: Maximum discharge 20 m^3/s giving drawdown of 0.17m/day, 37 days to reduce volume by 50%
- Hinks' formula: drawdown of 0.5m/day
- Draft Drawdown Guidance Basic Standard: 5%H/day = drawdown of 2m/day
- Maximum discharge during PMF event: 13.5 m^3/s

Rutland Water proposed scheme

- Current preferred option: 2 no. 1800mm siphons to be installed increasing total drawdown capacity to 41 m^3/s
- Initial rate of drawdown = 0.3m/day, 26 days to reduce volume by 50%
- Next Section 10 inspection due in 2020
- Project to be delivered by Anglian Water Alliance after 2020 (design and enabling prior to 2020)

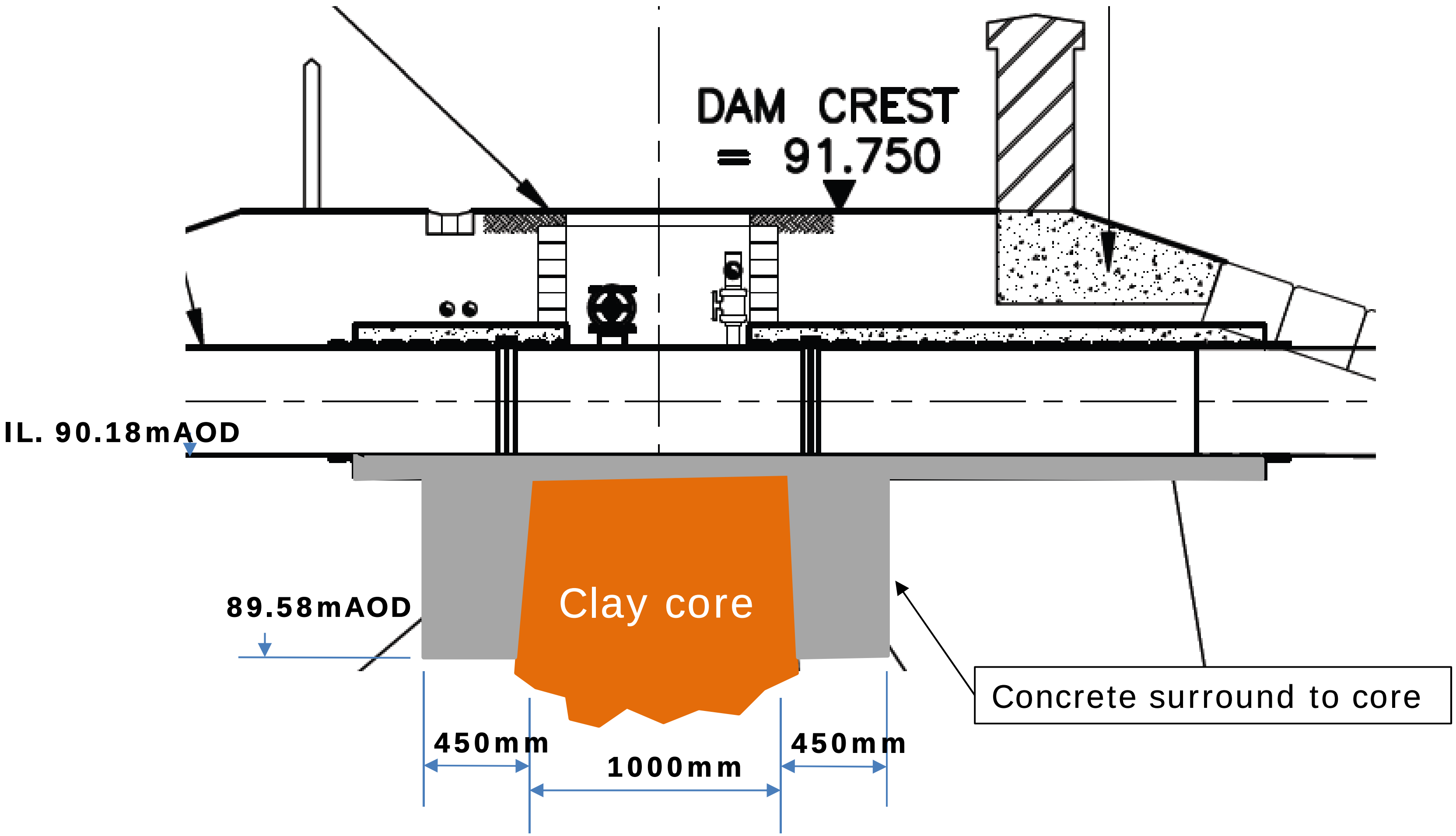
Design options - Pitsford

Option		Flow rate (m^3/s)	Max consent required (m^3/s)	PMF outflow (m^3/s)	Comments
Current situation	1 No. 300mm dia. existing scour	0.54	0.54	128	Achieves 50% draw-down in 20 days including flow to supply
Pitsford option 1	1 No. additional 762mm dia. scour in tunnel	6.74	6.2	128	Achieves 50% draw-down in 15 days including flow to supply
Pitsford option 2	3 No. additional 600mm dia. siphons	6.74	2.1	128	Achieves 50% draw-down in 15 days including flow to supply

Design options - Pitsford

1) One additional 762mm dia. scour pipe in tunnel from wet shaft
- confined spaces access issues
- integrity of existing brick bulkhead

2) Three additional 600mm dia. siphons
- only work over top 50% of depth
- need to pass through core and ensure integrity of core


DAM CREST
= 91.750
IL. 90.18mAOD
89.58mAOD
Clay core
Concrete surround to core
450mm
1000mm
450mm

Design options - Pitsford protection to core

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Design options - Rutland

Option		Flow rate (m^3/s)	Max consent required (m^3/s)	PMF outflow (m^3/s)	Q50 flow in receiving watercourse (m^3/s)	Comments
Current situation	4 No. existing pipes to Gwash	20.6	8.5	13.5	0.55	Achieves 50% draw-down in 37 days
Rutland option 1	2 No. additional 1.8m dia. siphons to Gwash	41.2	10.6	13.5	0.55	Hydraulic modelling revealed: no significantly increase of flooding in watercourse ; existing pipework restricted to $40m^3/s$, achieving 50% draw-down in 25.6 days
Rutland option 2	As option 1 but additional 2.5m dia. tunnel to Welland	41.2	20.6	13.5	1.00	Hydraulic modelling revealed existing pipework restricted to $40m^3/s$, achieving 50% draw-down in 25.6 days. Would require new 600m of 2.5m dia. Tunnel.

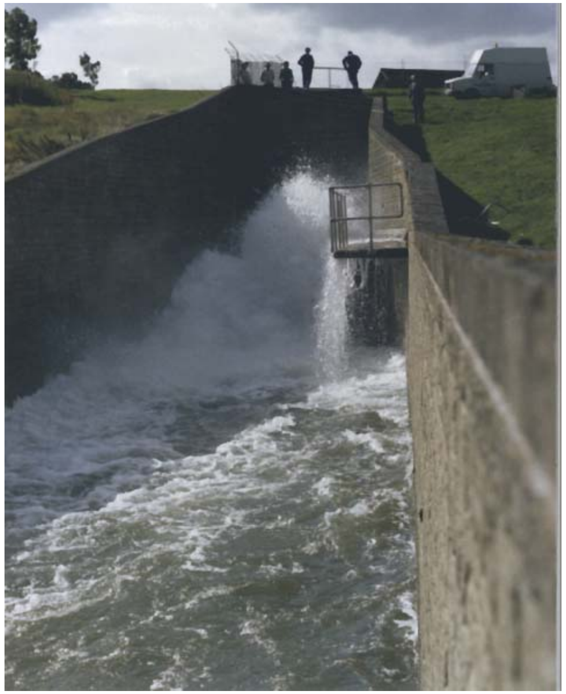
Design options - Rutland

1) **Two No. additional 1.8m dia. siphons to Gwash utilising existing inlets where possible**
   - max flow many times Q_{50} in receiving watercourse
   - testing flow could be half that of other option
   - may be able to utilise existing energy dissipation structure
2) **As option 1 but additional 2.5m dia. tunnel to Welland**
   - max flow many times Q_{50} in receiving watercourse
   - additional cost of 2.5m dia. tunnel 600m long to bypass inlet pumps
   - robust control/communication issues

Valve testing challenges

- **Option selected can be influenced by the consent flow required for testing**
- **Sampling and silt traps required for consents**
- **Invasive non-native 'Killer Shrimp' Dikerogammarus villosus (Dv) species:**
  - containing all valve testing flows and pumping back
  - delaying testing of valves annually despite ARPE's recommendation
- **Prevention of downstream flooding**
- **Operational constraints e.g. scour off inlet main**
- **Appreciation of operations training / refresher**
- **Temporary plant**

Valve testing challenges



Rutland

Grafham

Pitsford

Valve testing challenges - Silt traps / weirs

Rutland

Pitsford

Grafham

Summary and conclusions

Need to consider:

- Construction / age of reservoir
- Will design aid next Section 10 inspection
- Hydraulic capabilities of existing pipework through modelling
- Effects downstream
- Consents
- Constraints which may be imposed on testing

Scour Releases for UK Reservoirs – A Case Study

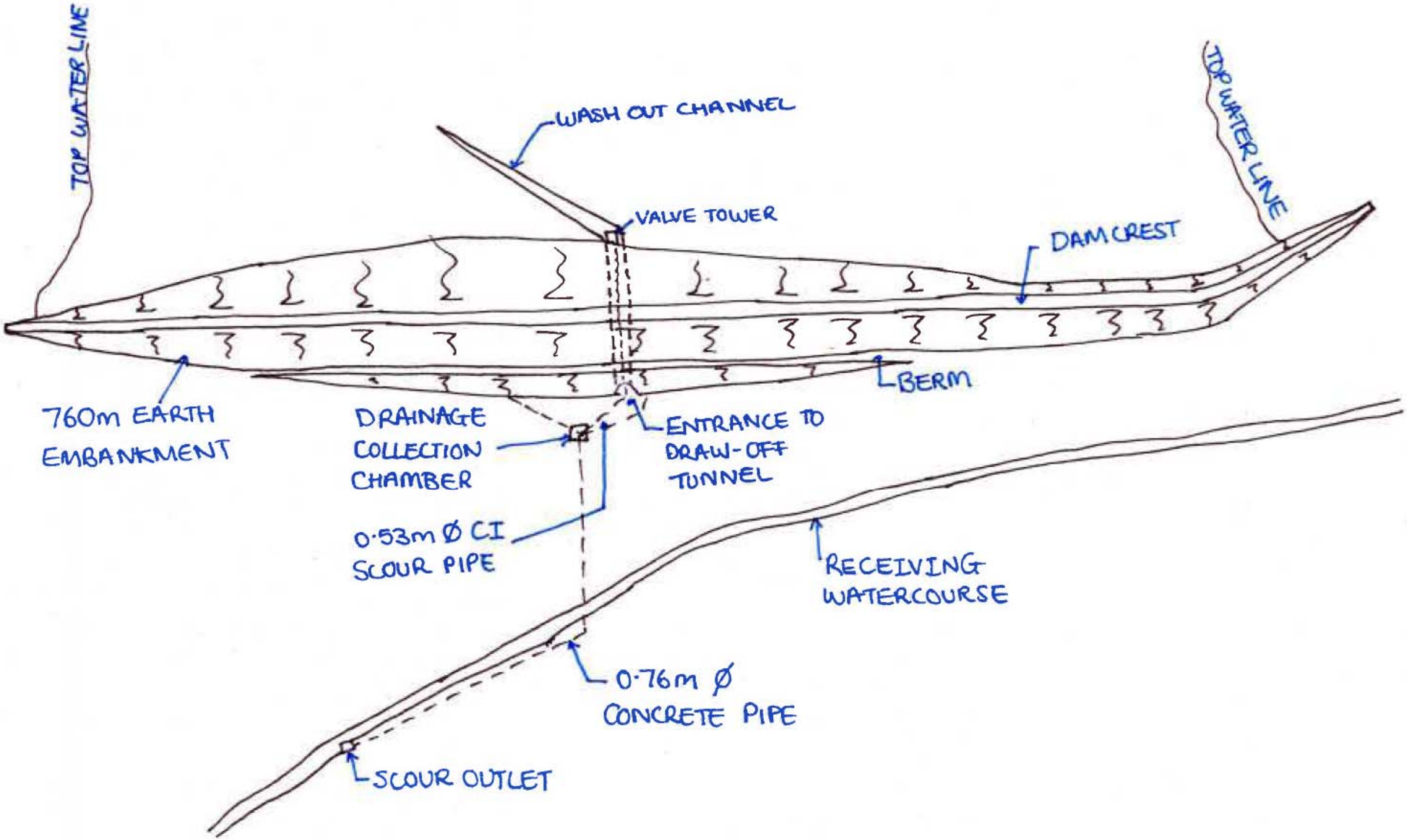
BDS Conference September 2016

Alison Pepper

Introduction

- Background
- Environmental concerns
- Mitigation measures
- Scour valve test
- Conclusions & lessons learnt

Site Description



Background

- Section 10 inspection
- Stakeholders
- Previous attempts

Environmental Concerns

- Ecology
- Macroinvertebrate survey

Environmental Concerns

- Sediment
- Flooding

Mitigation Measures

- Ecology
- Fish
- Sediment

Mitigation Measures

- Flooding & channel erosion

Scour valve testing regime

Step	Description
1	Test guard and duty valves independently under balanced head conditions.
2	Fully open the manual (upstream) valve.
3	Open automatic (downstream) valve to 100% and then close, for a maximum total time of 2 minutes and 30 seconds. Visually monitor turbidity.
4	Wait for water to drain through the straw bales then remove sediment deposits. Visually monitor turbidity.
5	Repeat steps 3 – 4 as necessary until scour water runs clear.

Scour Valve Test - Timing

Scour Valve Test - Closing

Scour Valve Test - Flooding

Scour Valve Test - Flooding continued!

Scour Valve Test - Sediment Impact

- Sediment successfully removed
- Bank erosion

Scour Valve Test - Sediment Impact

- Limited deposition

Scour Valve Test - Fish

- Environmental incident

Scour Valve Test - Fish

Conclusions and Lessons Learnt

- Successful opening of valve
- Importance of valve timing
- Location of valves in a confined space
- Staking of straw bales
- Importance of full head valve testing

Thank you

Session Chair: Ian Hope
Technical Reporter: Ranjit Singh Seehra

Guide to Drawdown Capacity – A Final Update (presentation by Andy Courtnadge, Jacobs)

Question: Neil Kempton (Mott Macdonald)
The slides showed categories A-D. Will that be published as it is or will it be changed into the categories of 'High Risk' and 'Not High Risk'? Also, if the new guidance produces an output of 2m drawdown per day target then what was the thought-process of limiting this to 1m per day? Furthermore, does the guidance state to what depth the drawdown must be achieved?

Response: Andy Courtnadge (Jacobs)
Yes, the guidance will be published with categories A-D as these are still recognised categories under Floods and Reservoir Safety and we are differentiating it from legislation which is 'High Risk' and 'Not High Risk', which being legal terms have different interpretations in different countries.

On the second point we had to cap the drawdown for dams over 20m height for practical reasons and also on the basis that higher dams usually conform to higher design, construction, management and maintenance standards.

Section 2.7 of the guide gives guidance on the depth of drawdown required. The depth required will depend on the critical failure mode and some typical examples are discussed in the guide. The decision of how far to draw the reservoir down in an emergency should be based on advice by an Inspecting Engineer. The advice is likely to be to lower the water level until the symptoms of failure cease, and then lower it by a further amount to provide a margin of safety, for example to prevent flood inflows reinitiating the failure mode. In most cases, lowering a reservoir by one third of its depth will significantly reduce the risk of failure progressing (this is equivalent to roughly halving the hydrostatic force).

Discontinuance of small reservoirs in Scotland (Dunne & Morrin, p227 of the Proceedings)

Question: Ian Hope (Severn Trent plc)
Would you please expand on the cost of discontinuance?

Answer: Lesley Dunne (Atkins)
At Greenlands Reservoirs the cost for the three reservoirs was at least £500,000 and was exceptionally high due to the difficult access and need to lay several kilometres of new or suitable track, and dealing with the silt disposal. Overall we had to weigh up the balance between the construction cost and Scottish Water's operational costs.

The Discontinuance of Sunnyhurst Hey and Improvements to Earnsdale Reservoirs, Darwen, Lancashire (Tennant & Park, p201 of the Proceedings)

Question: Alan Brown (Stillwater Associates)
A question on Earnsdale reservoir. It is noted that the hit and miss foundation means that there will be gaps in the foundation through which internal erosion could occur, and where vertical stresses are locally lower due to load being transferred over the gap (and thus more vulnerable to internal erosion). Could you please comment on whether consideration was given to installing a filter trench across these to inhibit internal erosion?

Response: Chris Parks (United Utilities) & Stewart Tennant (GHD Livigunn)
The initial design was a full face downstream filter covering the new berm. During the detailed design the filter was incorporated into the reinforced earth berm and therefore covers the entire downstream face of the embankment, all the way to the toe of the existing embankment, and is incorporated behind and below the berm and therefore rests on top of the DSM cells.

Erosion in the lower portion of the embankment or through the cut-off was assessed as being not critical, particularly as the length path for this mechanism is significantly longer. The downstream full-face filter addresses the potential for erosion through the body of the embankment only.

A filter collar was required around the scour pipe to address the potential for seepage erosion along the conduit. Originally this was intended to be installed behind the valve house but it proved difficult to construct and maintain the filter at this location, so the filter was constructed within the old valve house walls. The deep-soil mixing it is within the cohesive fill material largely beyond the toe of the embankment, which provides a satisfactory impermeable barrier.

Delivery of drawdown improvements for Anglian Water Reservoirs (Pether & Kirkpatrick, p255 of the Proceedings)

Question: Julian Welbank (Wessex Water)
A question about the decision-making process regarding the emergency drawdown provision at Rutland Water. The paper intimates that the detailed design cannot progress without a business case and that the business case cannot be signed-off without a Recommendation in the Interests of Safety. But the Section 10 inspection will not be carried out until 2020. Please could the presenter explain the decision-making process and how the owner is managing risk to minimise risk at all times.

Response: Ian Kirkpatrick (Anglian Water plc)
The 2005 investigation identified five reservoirs for improvement. Four of these had matters in the interest of safety and the recommendations made then by Black & Veatch gave us a view of what works would be required. The Section 10 inspection in 2010 for Rutland Water did not contain any matters in the interest of safety but did contain a need for a further study. This study has been completed and modelling carried out and we now know what works will be required.

The findings have been shared with the prospective Section 10 Inspecting Engineer and we have secured company approval for the detailed design during AMP6. The Inspecting Engineer may or may not recommend matters in the interest of safety, but in any case we will be seeking approval to carry out the construction work after AMP6.

Question: Alan Brown (Stillwater Associates)
In relation to the potential increase in drawdown capacity at Rutland I suggest that the following aspects of the new guide to drawdown capacity may assist with deciding whether to increase capacity:

1. Assess the erodibility of the soils within the body of the dam (appendix C of the new Guide), which could include erodibility tests such as the hole erosion test.
2. Using the above then assess the vulnerability to rapid failure by internal erosion (appendix D), and the theoretical rate of drawdown required to avert failure.

3. Estimate probability of failure in its current condition, and then the reduction in probability due to increasing drawdown capacity. Carry out an ALARP economic analysis to assess whether the cost of risk reduction measures is proportionate to the reduction in risk achieved, or grossly disproportionate?
4. Consider whether the dam is a very high consequence dam as defined in the paper by Brown & Hewitt at the Lancaster conference (LLOL> 100), and if so should the capacity be increased as part of the owner's safety case to provide multiple defensive features?

Response: Rachel Pether (Black & Veatch) & Ian Kirkpatrick (Anglian Water plc)
We would agree that the risk based methodology within the new guide to drawdown capacity may usefully be applied at Rutland.

Question: Sam Tudor (Dwr Cymru Welsh Water)
Considering the upcoming drawdown guidance will require scours with greater flows then consideration needs to be given to flood mapping of scour operations. Also Panel Engineers will need to consider this when advising on scour testing requirements, as their advice could potentially cause flooding of houses. When considering the discharge of the 41 m^3/s into a small stream has flood mapping been considered for scour tests at Rutland?

Response: Ian Kirkpatrick (Anglian Water plc)
We have used the Environment Agency model to predict the downstream impact and through this work we know which properties are at risk of flooding and where risk prevention works may be required.

Question: Jim Claydon (JR Claydon Ltd)
At Anglian Water's Pittsford Reservoir can the authors clarify why the new siphons only work down to 3m below top water level? Examples have been given of new siphons successfully installed to 5m below top water level.

Response: Ian Kirkpatrick (Anglian Water plc)
The siphons take water level down by 3m only because at that level 50% of the reservoir volume has been removed.

Scour releases for UK reservoirs – A Case Study (Pepper, p 267 of the Proceedings)

Question: Ian Hope (Severn Trent Water)
A very interesting presentation as we are going to be facing more of this work involving higher flow scour releases. Can you give an indication of the costs associated with the scour release?

Response: Alison Pepper (Mott MacDonald)
The costs for the test itself, including preparation of the receiving watercourse channel, such as installing Reno mattresses, straw bales, costs for the fish contractor, etc. were not disclosed by the Undertaker. However, the testing regime was designed such that the solution could be used in future years with minimal cost implications.

Question: Jon Holland (Stillwater Associates)
Thank you for your honest account of the scour valve testing! Can you tell me what you needed to do with the silt and were any consents required?

Response: Alison Pepper (Mott MacDonald)

Once removed from the channel, the silt was to be taken off-site. There were discussions between the Undertaker and a local farmer for him to spread it over his land to improve soil quality, but this was not fully concluded.