INTRODUCTION

My name is Crawford Munro, BSc CEng CWEM FICE FCIWEM, a Member of the Supervising Engineer's Panel under the Reservoirs Act since 1985 and I am a current member of Yorkley & District Angling Club.

I have over 40 year's experience of working on dams: design & construction supervision; assessment; repair and Statutory Supervision in the UK and overseas (Albania, Malawi, Nigeria etc.). I also have a successful track record as an expert witness in support of legal disputes related to dams and reservoir engineering. Following many years as Managing Director/Director of several of the UK's large engineering consultancy companies, I have operated independently as a limited company for nearly 11 years, specialising in dams and reservoirs.

The Forest of Dean was formerly a royal forest but it is now largely in public ownership, managed by Forestry England. The Lower Reservoir has been registered under the Reservoirs Act (the *"Act"*) for many years, but the Upper Reservoir has only recently been registered following a detailed capacity survey, which determined that the retained volume was >25,000 cubic metres and hence within the ambit of the Act. Forestry England is the undertaker on both reservoirs within the meaning of the Act.

Forestry England state that they are pursuing options to remove the dams and "re-wild" the reservoir areas, which they state will be beneficial. However, opposition to such a move is exceptionally high:

- Local MP (Mark Harper) has declared his support for the dams and reservoirs to remain,
- Local councillors (Forest of Dean District Council) voted unanimously for the dams and reservoirs to remain;
- The Verderers of the Forest of Dean voted by majority in favour of repairing the dams and retaining the ponds, at their meeting in January 2023;
- There is a petition for the dams and reservoirs to remain, currently with over 41,000 signatures.

Signatories include anglers, bird watchers, hikers, cyclists etc. who enjoy the tranquillity and diversity that the forest together with its lakes and watercourses provide. Removal of the lakes, which have a combined length in the watercourse of more than a kilometre, and replacing that length of "re-wilded" stream (of which there are already many kilometres in the forest) will significantly reduce the diversity of the forest and result in much lesser use and enjoyment by the public at large. This will adversely affect the local economy, particularly from the reduction in tourism.

I will restrict my focus to the dams & reservoirs safety aspects of Cannop Ponds below and leave environmental and other local concerns to those more experienced and able to do so.

I attended a meeting at The Speech House Hotel on 2nd February hosted by Forestry England but largely led by their consulting engineers (Arup). This meeting was most disappointing as it focussed on "airy-fairy" aspects and totally failed to touch on the critical aspect of whether the dams should be removed or repaired. At the close of the meeting I had a brief discussion on a one-to-one basis with Arup's reservoir engineer. There were two main items which I found surprising:

- I mentioned that I had heard that “re-wilding” would cost between £3m and £4m, only to be told “it would be much more than that”!
- Whilst I put forward technical solutions for substantial (but cheaper than rewilding) permanent repair of the Lower Pond dam, with potential benefit of reduced flooding downstream, it appeared that little thought had been given to repair options and negativity was expressed to my suggestions.

ARE RESERVOIRS SAFE?

Reservoirs can pose a risk of causing damage to persons and property downstream in the event of a dam failure. However, that generality must be considered in context. Prior to the Reservoirs (Safety Provisions) Act 1930 there was no legislation to govern reservoir safety. The 1930 Act was enacted then superseded by the Reservoirs Act 1975 and then amended by the Flood and Water Management Act 2010.

The 1930 Act was enacted after dam failures 5 years previous as set out below, together with another noteworthy dam failure some 60 years before:

- 1864 Dale Dyke Dam – 240 people killed,
- 1925 Skelmorlie Dam – 5 people killed,
- 1925 Dolgarrog Dam – 16 people killed,

Since the 1930 Act and its replacements were introduced there has been no reported loss of life from dam failures in Great Britain. There have however been the following incidents:

- 1984 Partial collapse of Carsington dam just before completion (i.e. the reservoir was largely empty). It is notable that Michael Kennard advised that the foundations were not suitable for the additional loading of the dam embankment before the collapse, but his good advice was sadly ignored – loss of life **ZERO**, damage downstream **ZERO**.
- 2007 Ulley Dam partial collapse of dam toe but procedures were put in place to reduce the water storage in the reservoir before a dam breach occurred. Recommended remedial work on the by-wash channel had not been carried out – loss of life **ZERO**, damage downstream **ZERO**.
- 2019 Toddbrook Dam partial collapse of spillway - but procedures were put in place to reduce the water storage in the reservoir before a dam breach occurred. Recommended remedial work on the spillway had not been carried out – loss of life **ZERO**, damage downstream **ZERO**.

There has been no loss of life in Great Britain from dam failures for almost 100 years. Major dam incidents during that period have been few and largely the result of failure to take and act on professional advice timeously. Incidents were addressed efficiently and the dams were not breached. It is generally accepted that loss of life from flowing water can be determined by a combination of depth of floodwater and its velocity. A rule-of thumb is "$6m^2/s$" i.e. the multiple of velocity (m/s) times depth (m) should exceed 6 to assess potential for loss of life e.g. more than 6m/s x 1m deep, or 3m/s x 2m deep etc.

All Reservoirs registered under the Act are now required to have an Emergency On-site Flood Plan. Reservoirs designated as "High Risk" by the Environment Agency (the majority of dams in Great Britain) have a statutory monitoring, inspection and reporting requirement, with the aim to assure reservoir safety. Other reservoirs which are designated "not High Risk" (the term low risk is not used) do not have these statutory requirements but the owners still have a "Duty of Care".

RE-WILDING VERSUS REPAIR

Some critical aspects of the comparison are:

- I understand that Forestry England have undertaken to apply for all requisite permissions related to planning, flood control, and all environmental protocols for the proposed work on the dams. With the ever increasing list of key objections against removing the dams – **why is this option even being considered at this stage?**
- If the cost of "re-wilding" is well in excess of £4m, substantial long term repair work could be carried out on both dams for a much lesser sum – **why are these repair options not being investigated in detail for comparison, with some urgency?**
- A group of local residents downstream of the dam have expressed concern regarding flooding from watercourses during heavy rainfall and have carried out investigations in the catchment https://www.youtube.com/watch?v=7Tgw9vavpF0 . **Why is Forestry England not engaging with this group to explore how repair work on Cannop Pond dams could assist in alleviating the flooding risk downstream from rainfall events. I understand that Gloucestershire County Council (the Lead Local Flood Authority) has engaged with the group.**

I have heard reasons put forward why Cannop Ponds cannot/should not be repaired:

- *The dams are about 200 years old!* **That is not exceptional as there are hundreds of embankment dams in Great Britain of this age (and older) and they are still in service, operating satisfactorily and regularly supervised for any indications of issues arising, with remedial work undertaken before greater problems become manifest.**
- *The Lower Pond dam was built as a railway embankment and was never intended to be a water-tight structure to retain a reservoir. It is likely that there is no formal cut-off into original ground at the dam's foundation.* **There is no sign of any deep-seated leakage appearing in the valley below and no evidence that this has been a problem in the past.** The following photograph shows one small damp area below the downstream toe, but the cause appeared to be the lack of a drainage path from the flat area, rather than water passing through the dam.

- *The dam has a long history of piecemeal reactive repairs to voids within the dam embankment, including areas under the overflow weir and spillway.* The following photographs bear testament to repair work in 1906 & 1973.

It appears that the repairs carried out historically have simply been to rectify damage that became apparent from time to time, rather than to address the main source of the problem! It is therefore not surprising that there have been repeated need for repairs.

The engineering knowledge of 200 years ago regarding hydrology and soil mechanics would have been virtually nil, or simply based on empirical formulae at best. For a dam of this type, age and contemporaneous construction techniques used, the main problems are likely to include:

1. Internal erosion through the dam embankment due to the likely absence of an impermeable core and cut-off into the foundation during construction.
2. Erosion initiating at the upstream face from many years of wave action.
3. Erosion initiating on the crest and downstream face from overtopping during severe storm events due to inadequate spillway capacity.

4. Erosion under the spillway base slab and around the walls due to poor design and construction.

All of the above could be progressive and, if not addressed in time, could lead to a breach forming through the dam embankment, with its ultimate failure and the uncontrolled release of the reservoir's contents.

During my recent visit and from an assessment of reported and recent repair work, only item 4 appears to have been problematic.

1. I saw no signs of damp areas or water seeping from the downstream face. I saw no sign of water issuing at the downstream toe area, although there was a very small amount of standing water due to inadequate surface drainage from the toe area.
2. The dam has an adequate crest width (particularly the western section) and the fetch for waves to generate in the sheltered area is relatively small. I believe that erosion from wave action is likely to be low risk.
3. I saw no signs on the crest or downstream face of previous overtopping. The freeboard from top water level to dam crest would allow little attenuation of flood water. However, the top water level could be lowered and/or the crest raised to reduce the risk of overtopping and provide greater stormwater attenuation (reducing the risk of downstream flooding).
4. The overflow weir and spillway shute is of poor design, which could lead to the following:
    a. Settlement of the embankment under the spillway slab leading to the creation of a water path underneath. Seepage over many years with material washout will cause voids under the slab with occasional collapses of the structure and sinkholes upstream. An embankment of this type may typically settle 2 or 3mm annually until the dam becomes fully consolidated.
    b. It is likely that the spillway walls are vertical, hence the interface with the dam embankment will have been poorly compacted during construction and a water path along the external walls would be expected. As above, occasional settlement, cracking and sinkhole formation would be likely.

There is evidence that many, if not all, of the historic and recent repair work has been as a result of item 4. I understand that voids have previously been located under the spillway slab and the voids filled with concrete or clay. I also understand that a GPR survey will be undertaken to detect any further voids.

A new spillway should be constructed (Item 4):

- **Preferably of the dam embankment on virgin ground to the east.**
- **The weir should be at the appropriate level and of adequate capacity (see comments below) and the base slab of the structure tied into a steel piled cut-off (or other).**
- **External side walls should be sloping such that construction plant can compact effectively up to the wall with the weight of the fill (clay preferred) assisting in keeping potential water paths sealed.**

A properly designed steel piled wall along the dam, or a bentonite cut-off, could provide an effective cut-off if further investigations deem necessary. This would provide a substantial long term repair to rectify the likelihood that the embankment was constructed without a core or other means to restrict the passage of water through the dam.

- *"Steel piles could rust over time and eventually fail!"* Yes but:
    - **corrosion will only take place in the presence of air and water – the former may be limited in the dam embankment;**

- **engineers have designed and used sacrificial protection techniques on metals for many years (including in the aggressive marine environment) i.e. "cathodic protection" by connecting sacrificial anodes to the piles and placing them in pits to facilitate easy replacement when required.**

Andy Hughes' Inspection Report on the Lower Pond dam in May 2021 states:

- "In the past the dam has been categorised as Category A as well as Category D. In general however, the criteria that the volume of the reservoir is likely to be less than 10% of the flood has been used but even so one Inspecting Engineer considered the 10,000 year event and another the 150 year event. Having looked at the consequences of failure, the likely mode of failure, **I consider the dam should be in Category C**.
- "I consider that **the dam is in good condition** on the basis of obvious visual evidence and the monitoring records……"

I believe that Stillwater's All Reservoirs Panel Engineer's Report of December 2022 (from redacted copy only) states that the Upper Reservoir should also be flood Category C but <u>because of the potential impact on the Lower Pond it was designated as the higher Category B</u>. This manipulation is totally without foundation in reservoir engineering. The period for appeal of this decision is now expired and the only way to change it would be to seek another Section 10 inspection.

I also understand that Forestry England and their advisers now consider that the Lower Pond should also be Category B. The differences between Category B & C are set out in the tabular extract below (from - Floods and Reservoir Safety – Fourth Edition). The key aspects are:

- Category B refers to loss of life downstream in the very unlikely event of a dam breach (see discussion above).
- Category B refers to "extensive" damage whereas Category C refers to "limited" damage. The difference is in the eye of the beholder but good engineering design of repair work could have a major impact on this by reducing the peak outflow (with enhanced attenuation) in event of a breach.
- The overflow weir and spillway capacity and hence size would require to be substantially greater for Category B than Category C.

Table 2.1 Flood, wind and wave protection standards by dam category

Dam category	Potential effect of a dam breach	Initial reservoir condition standard	Safety check flood conditions		Design flood conditions	
			Reservoir flood inflow	Concurrent wind speed for assessing wave overtopping	Reservoir flood inflow	Concurrent wind speed for assessing the freeboard required to contain wave overtopping, or minimum flood freeboard provision (whichever is the greater)
A	Where a breach could endanger lives in a community	Just full (i.e. no spill)	Probable Maximum Flood (PMF)		10 000-year flood	Mean annual maximum hourly wind speed, with minimum flood freeboard of 0.6 m
B	Where a breach (i) could endanger lives not in a community or (ii) could result in extensive damage	Just full (i.e. no spill)	10 000-year flood	Mean annual maximum hourly wind speed	1000-year flood	Mean annual maximum hourly wind speed, with minimum flood freeboard of 0.6 m
C	Where a breach would pose negligible risk to life and cause limited damage	Just full (i.e. no spill)	1000-year flood		150-year flood	Mean annual maximum hourly wind speed, with minimum flood freeboard of 0.4 m
D	Special cases where no loss of life can be foreseen as a result of a breach and very limited additional flood damage would be caused	Just full (i.e. no spill)	150-year flood		150-year flood	Mean annual maximum hourly wind speed, with minimum flood freeboard of 0.3 m

- design flood – the inflow that must be discharged under normal conditions with a safety margin provided by an accepted freeboard limit
- safety check flood – the inflow beyond which the safety of the dam cannot be assured (i.e. key components exhibit marginally safe performance for this flood condition).

(After ICOLD, 1992)

However, it is acknowledged that at the 'safety check' level of flood, some damage may occur to the dam due, for example, to overtopping by wave action, or by overflowing.

For the case of embankment dams not specifically intended and designed to withstand overflowing or overtopping, the design flood in Table 2.1 is the flood at which no significant wave overtopping of the crest or wave wall should be allowed to occur. An overtopping flow of 0.001 l/s/m, or less, is taken as being no overtopping.

For the case of a concrete or masonry dam, wave overtopping would be acceptable at the design flood in Table 2.1, assuming that it is founded on rock, although stillwater level should be below the dam crest or wave wall level unless a rigorous assessment of the founding

5

Some examples of flooded areas during dry days and wet days from a breach of the lower dam are shown in Appendix 1.

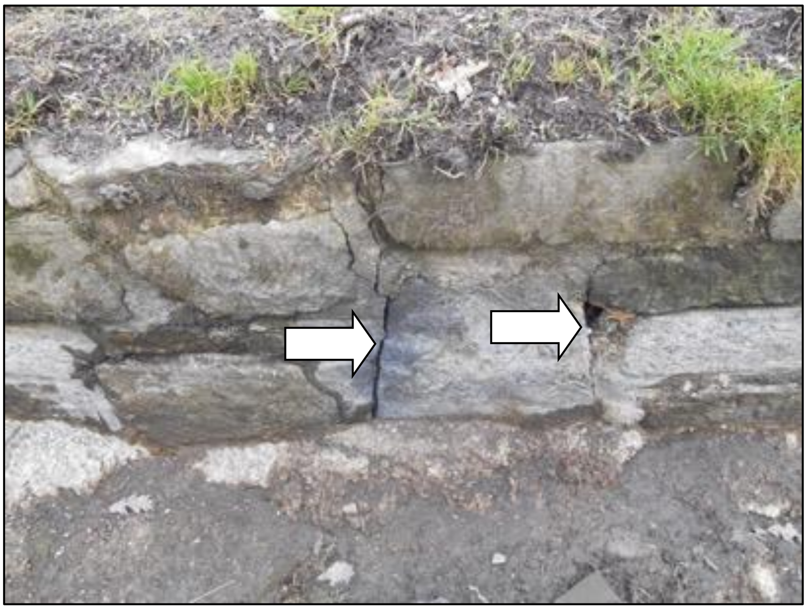
It appears to many people who object to any proposals to remove the dams, that since Andy Hughes' Report of 2021, Forestry England and their advisers have turned their backs on established dam repair techniques and seem intent on pursuing the "re-wilding" option whilst following an agenda to win over public support for this. **Why are alternative dam repair techniques not being considered and discussed with interested parties?**

PROVISION OF LONG TERM REPAIR AND ENHANCEMENT WORK ON LOWER CANNOP POND DAM

My comments are limited to Lower Cannop Pond dam meantime. A recent satellite image of the dam is shown below. There is good access to the site from the west off New Road. The Forest of Dean Stone Firms Limited's facility extends from the west to about the mid-length of the dam. The section of dam in this area is now massive and I am not aware of any seepage or settlement issues on this part of the dam embankment. Moving eastward, the dam crest is also substantial but to a lesser extent and about 10m wide

MAINTENANCE WORK

It appears that the frequency and standard of repair work has been poor, as evidenced by the following photographs, which show that in places there is scope for water to penetrate the dam with potential to cause internal erosion (in the current absence of a watertight core), leading to potential for void formation in the dam embankment from time to time (when the reservoir is returned to the overflow weir level) and the appearance of sink holes at the ground surface.



MAJOR REPAIR WORK

I believe that the main problem with this dam embankment arises from void and hence water path formation under the spillway base slab following settlement of the fill material over many years, together with flow path development along the outer walls. The absence of an effective cut-off core to restrict seepage of water through the dam may also be an issue. Long term seepage from both of the above can lead to material transportation from the dam causing internal erosion, structural cracking and sinkhole formation. If this is allowed to continue, and not addressed in time, then the dam is in danger of collapse with the uncontrolled release of water downstream.

I have suggested that the spillway should be reconstructed at a suitable location, level and capacity. I have also suggested alternative solutions to form an effective cut-off. Advice should be taken from suitably experienced geotechnical contractors, some with bespoke proprietary techniques, regarding suitability and cost of the cut-off. For example, if steel sheet piling was selected the requisite plan length would be around 40 to 50 metres ; tied into the massive dam section to the west, extending over the [1]spillway weir and into the right abutment. Access, site establishment and demobilisation costs would be a significant proportion of the overall cost. I estimate that the total cost to form a cut-off would be in the order of £300,000.

[1]The new overflow weir and/or spillway would require to embed the top of the piles over its length to avoid water passage at the interface.

I would expect a competent dam engineer to design the dam crest level, overflow sill level and length to fulfil the requirements of the Design Flood and Safety Check Flood as set out in the table above. The following variables should be considered:

- Permanent lowering of the top water level – such as illustrated in photographs above and below, taken during my visit on 1st February 2023. The water level had been drawn down to just above the hydro-turbine intake culvert's invert. I understand that this would be acceptable to the Angling Club and probably most, if not all, who currently enjoy the pond, as it appeared not to expose unattractive muddy areas around the pond's margins.

If the above work is carried out to a good professional standard, attention given to a regular supervision programme and any minor maintenance needs are addressed expeditiously; then the dam should operate safely for many years, with reduced flood risk from storm events downstream and continuity of enjoyment of the environment for all visitors to the site.

- Probably (in conjunction with the above); raise the dam crest level over at least a 2m width along the entire upstream face of the dam. The cost of this will be dependent on the extent but is unlikely to cost more than £100,000. This will allow the attenuation in the pond to increase, with potential to reduce downstream flooding from storm events. In the very unlikely event of a dam breach, the volume released downstream and hence the potential for damage should be reduced.
- A new overflow weir and some/all (subject to the results of a GPR survey) of the spillway outlet channel would need to be reconstructed. The simple solution is a common overflow arrangement to deal with the expected range of design flood flows. However, a competent dams and reservoirs engineer could utilise modern tried and tested techniques to minimise the construction cost and reduce the visual impact of civil engineering construction:
    - Consider the practicality of providing a labyrinth main weir arrangement, to provide a greater weir length per metre run and hence increase the capacity to discharge water (if suitable on this site).
    - Limit the main weir to only a proportion of the design flood outflows and create a [2]reinforced grass auxiliary overflow weir at a higher level. Grass can be reinforced by geotextile or proprietary open cell concrete in-situ slabs or blocks.

      [2]I can provide several reference sites where these techniques are currently in use. In particular, I am engaged on several Environment Agency owned flood alleviation dams (some within the Act) where both concrete and geotextile are used in conjunction with grass for the main overflows!
      The east side of the existing spillway, would require tree felling and some regrading work to allow this as illustrated in the photograph below. It is unlikely to be viable on the west side of the spillway unless the hydro- turbine facilities are removed.

    - It is difficult to estimate the cost of this work due to the large number of variables but it should be possible to complete it for between £1.5M and £2M

If the advice given by Arup or Stillwater is considered inadequate or lacking in appropriate and/or pragmatic and imaginative solutions; then I suggest that consideration be given to seeking advice from Andy Hughes to benefit from his knowledge from the inspection of the Lower Pond in May 2021, together with his general breadth of experience in dam construction and repair.

I would be pleased to prepare similar comments on the Upper Reservoir dam after satisfactory conclusion on its flood risk category. Some Photographs of the Upper Reservoir's dam are provided in Appendix 2.

CONCLUSION

It is accepted that Lower Cannop Pond's dam has a history of repair work to address visual damage which has appeared occasionally and the dam was constructed without a watertight core within the dam embankment. However, it appears that work has not been undertaken to address the fundamental cause(s) of the visual damage.

Upper Cannop Pond's Dam has numerous matters to be addressed to satisfy recommended Measures in the Interests of Safety (MIoS) under Section 10 or the Reservoirs Act.

Management of the national asset of the Forest of Dean is the responsibility of Forestry England. They seem pre-occupied with an ambition to remove both dams and "re-wild" the reservoir areas. There is huge public protest against such a move, to such an extent that it is incomprehensible that Forestry England is still pursuing this aim.

Dams and reservoirs in Great Britain have an excellent safety track record since the initial enactment of legislation in 1930 to govern reservoir safety. Effective long term repair work and compliance with reservoir legislation should ensure that these 200 year old structures remain fit for purpose for many years into the future.

It is suggested that Forestry England should instruct their engineering advisers to pursue dam repair options including a range of modern "tried and tested" techniques. Proprietary construction techniques should be considered, which can be constructed at a lesser cost than 're-wilding" with the "Win Win" benefit of reducing the flooding risk downstream during storm events, which is currently causing concern.

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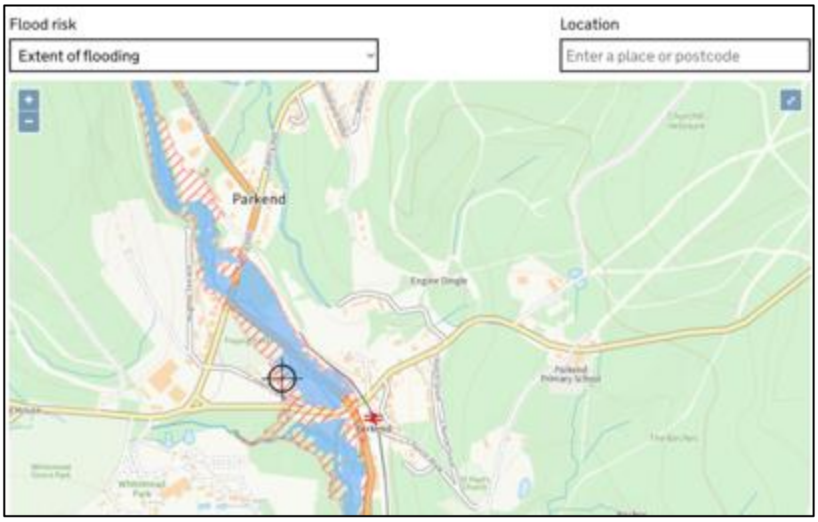
2nd March 2023

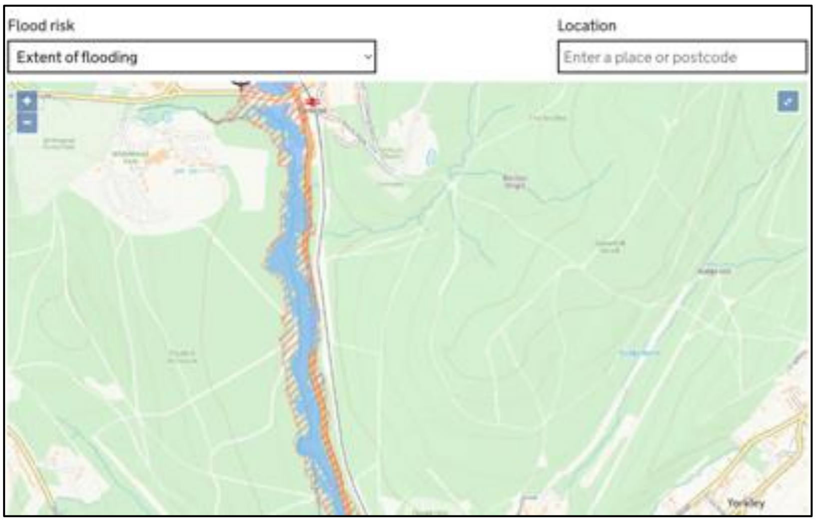
APPENDIX 1

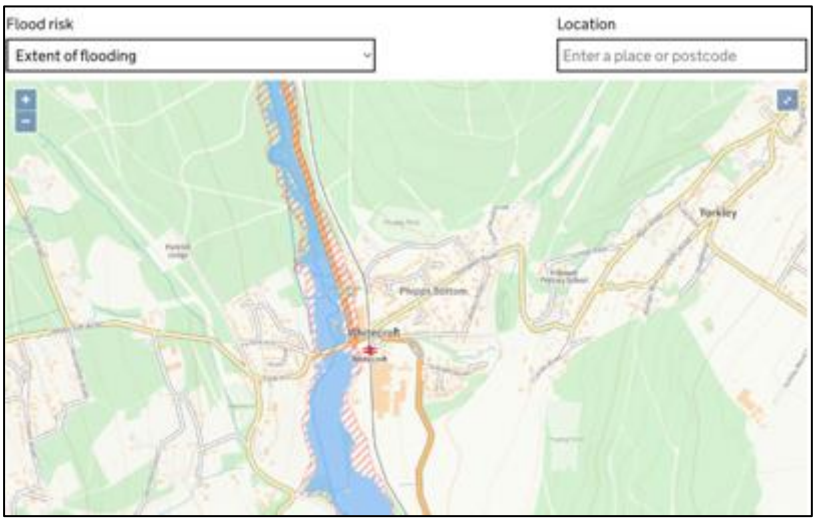
(blue shading signifies extent of flooding when river levels are normal and red hatching when there is also flooding from rivers.

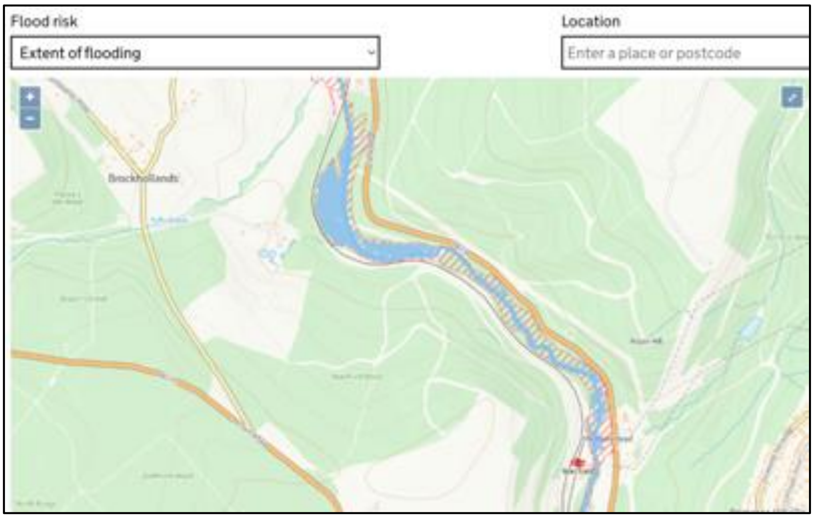
The flood plans can be accessed from the following website, using GL15 4JE and select Holmdale.

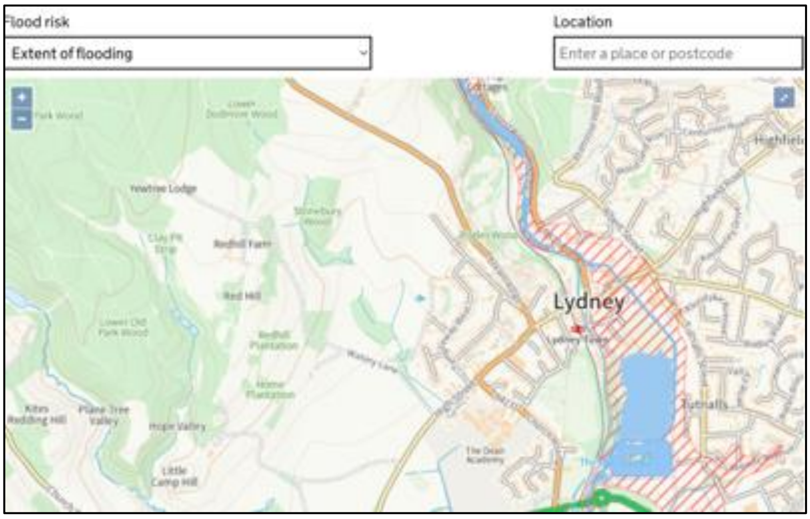
https://www.gov.uk/check-long-term-flood-risk?

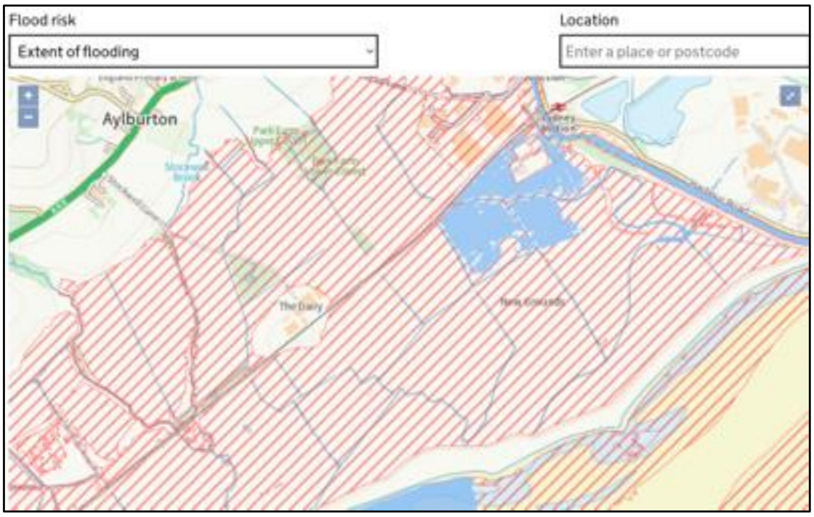







Flood risk
Extent of flooding
Location
Enter a place or postcode
Brockhollands


Flood risk
Extent of flooding
Location
Enter a place or postcode
Yewtree Lodge
Redhill Farm
Red Hill
Lydney
Lydney Town
Tutnalls
Hope Valley
Little
Camp Hill
Plane Tree
Valley


Flood risk
Extent of flooding
Location
Enter a place or postcode
Aylburton
The Dairy
New Grounds

APPENDIX 2

UPPER RESERVOIR'S DAM

Dam crest.

Overflow weir.

Spillway channel.

Downstream toe area.

Downstream toe.

Downstream toe area – no drainage due to absence of gradient away from dam toe.

Water from road to toe area.