Upper Slad Valley Holistic Water Management Project

Outline of options and proposals, and discussion of implications

Adam Broadhead

Summer 2009

Water21

(Department of Vision21 Ltd)

30 St Georges Place

Cheltenham

GL50 3JZ

01242 224321

This paper responds to landowners in the Upper Slad Valley who wish to develop water resources on their properties and explores any opportunities that this may provide for flood attenuation with other significant biodiversity and economic benefits.

Contents

1 Summary

This paper responds to landowners in the Upper Slad Valley who wish to develop standing water resources on their properties and explores any opportunities this may provide for flood attenuation and other benefits.

It also demonstrates a simple methodology for identifying flood volumes and storage requirements.

By dispersing floodwater throughout the catchment, the attenuation sites can be smaller, much cheaper than conventional solutions, more acceptable to local opinion and share the benefit of water resources throughout the community.

This paper demonstrates that there is ample space for this dispersed upstream attenuation approach in the Upper Slad Valley with land available from the two landowners in question.

It is hoped that the Environment Agency will consider this community-led approach as a viable addition to the existing planned larger-scale alleviation works further down the catchment. If this additional upstream 'head water' is attenuated, it would provide a 17% reduction in floodwater at the bottom of the valley increasing flood protection here to that required for a one in 150-year flood event.

This approach also demonstrates a dispersed, low cost, inherently safe, biodiversity enhancing and economic resource producing, flood control model that could feasibly be applied throughout Gloucestershire and elsewhere.

2 Introduction

This paper outlines a possible approach to improving water management in the Upper Slad Valley, Gloucestershire.

Primarily it responds to the requests of the community to address chronic flooding issues, but also seeks to expand the scope of benefits through an embedded community-led, permanent, low-cost, naturalistic, holistic and catchment-scale water management solution.

The hydraulic estimates in this initial study suggests that the approach is entirely feasible in this location; moreover, with community backing it would be a desirable option to consider as a component of current flood management plans in this valley.

As a secondary purpose, this paper also serves as a demonstration of the approach of embedded holistic water management. The principles outlined could be applied across the region to provide complete hydraulic resilience (to both floods and drought), as well as provide other key social, economic and environmental benefits.

Figure 1. The use of soft engineered farm ponds as a low cost, robust method of flood and drought protection, which also improves agricultural productivity and biodiversity (Courtesy Lifeworks Foundation).

3 Background

The Slad Valley directs the Slad Brook (sourcing at SO 889 090) southwest towards the town of Stroud. Here it is culverted, and reaches the canal and River Frome at the convergence of the waters of the Five Valleys (in addition to Slad, there are the Ruscombe, Painswick, Chalford and Nailsworth valleys). The Frome then flows out from the limestone Cotswold escarpment (denuded at Stroud) and across the Severn Vale.

The region suffers from some chronic water problems. These include, but are not limited to:

- flooding from streams and rivers;
- flash flooding from hard-standing surfaces;
- drought-prone soils;
- erosion of topsoil from the arable farming on the high ground of the watersheds;
- erosion of the soils in the steep sided valleys;
- degraded soil quality in terms of structure, hydration, and carbon and nutrient content;
- chronic siltation issues in watercourses, contributing to lower water quality and blockages;
- degraded habitats and reduced biodiversity potential of the aquatic environment;
- development pressures encroaching on floodplains and watercourses;
- new developments contributing to increased surface run-off into watercourses;
- loss of nearly 200 historic water mill sites;
- damaging conventional water management by river straightening, vegetation clearance, canalisation and culverting;
- potable supplies mostly sourced from far away, while local abstraction has lowered the water table;
- wastewater infrastructure condemned as inadequate in 1971 (STROUD DISTRICT SEWERAGE COMMITTEE 1971), with no significant changes since then, and still using conventional energy-intensive systems;
- public health risk from sewer overflows throughout the Stroud area (into watercourses & onto land);
- hydrological issues risking further exacerbation by climate change.

These problems are not unique to the Slad Valley, or even the region, and are indicative of general mismanagement of watercourses (DEFRA 2005). Water management is largely a cultural problem.

3.1 The problem in the Slad Valley

The Slad Valley suffers particularly from flood risk, and it is this problem that has received most attention from the community, leading to the formation of the Slad Brook Action Group in order to promote a solution. Water21, the Environment Agency and other groups and organisations have been involved with this action group.

The following is reproduced from a report by the Environment Agency (2009: 3).

> *"The Environment Agency is proposing to reduce the risk of flooding from the Slad Brook in town of Stroud, Gloucestershire, National Grid Reference: SO 852 054. The area is a busy tourist destination and is known locally as the 'arts and crafts capital of the Cotswolds'. The Slad Brook gives its name to the Slad Valley, a steep natural limestone valley running up to the Cotswold ridge.*
>
> *The valley has a long history of involvement in the milling industry. However, where once a number of mill ponds would have existed in the valley, there are presently no such significant storage facilities.*
>
> *Slad Brook in its upper reaches flows predominantly through farm land. As the brook enters Stroud it is routed through gardens and sections of undersized culvert carry the brook under roads and property.*
>
> *Presently, the existing flood alleviation scheme consists of large culverted sections, (underground or covered channels) through the town centre. The capacity of this network is not sufficient to deal with the quantity of water that the catchment receives during flood events. The culverts restrict flow and where they are not covered; water overtops the channel and floods nearby properties* [sic].
>
> *The last major flood event occurred in July 2007 but incidences of flooding also occurred in February 2001 and August 2004. In 2007 the culverted section of the Slad Brook, at the southern end of Slad Road, exceeded capacity and flood water pooled back from Gloucester Street along the Slad Road causing 30 properties to flood. There is more regular flooding to around 6 properties and the Slad Road (B4070) itself."*

Additional information on the problems can be found in Pretto (2008) or may be obtained from the Slad Brook Action Group.

4 Possible solutions

This paper seeks to build on the work undertaken by the Environment Agency, which aims to provide flood protection by upstream attenuation. Based on the initial consultations, the Environment Agency's preferred option is the construction of "two embankment dams and associated flood storage capacity upstream of Stroud on the Slad Brook so to restrict flow downstream" (ENVIRONMENT AGENCY 2009: 17). Additional information kindly provided by the Agency shows that the design capacity is 58,000 m^3 and 119,000 m^3; sufficient for a 1 in 100-year return flood. These would be large dam-like structures, 5.7 m and 6.6 m in height, respectively.

Two landowners further upstream in the Slad Valley have expressed an interest in providing lakes and ponds for upstream attenuation, as part of the development of ecological resources of the watercourses. This paper identifies suitable locations for attenuation, and gives an indication of the additional flood protection capacity provided. It also demonstrates the methodology, which can be applied to neighbouring valleys, to identify additional storage where offered by landowners.

It is not intended to compete with the Environment Agency proposal, rather it highlights additional or alternative options for achieving the embedded, holistic water management approach, as a useful pathfinder exercise for application elsewhere.

4.1 The premise

By restoring the natural and historic water storage features within the landscape, floodwater can be attenuated and dispersed in smaller attenuations throughout the catchment. This is a lower impact approach than having two large civil engineered flood attenuation barriers. Furthermore, the water resource benefits associated with attenuation (such as hydropower, fishing, irrigation water storage and wetland habitat restoration) can be shared throughout the community. By holding water back in the landscape, there is improved infiltration of water deep into the soils and percolation through the limestone beds into the sandy aquifer layers beneath; this provides drought (and climate change) resilience, and also more fertile, erosion-resistant soils.

The Stroud Valleys derive their name from the old English "*ströd*", meaning a marshy place. This was likely hazel and willow (withy) woodlands and scrub. This "pre-human intervention" landscape – as defined in the Water Framework Directive (EUROPEAN COMMISSION 2000) – would have retained and infiltrated greater volumes of water than today. Development of the water-powered milling industry in the Stroud Valleys introduced many millponds to the region, which would have been actively controlled to ensure water rights, prevent blockages and minimise the impacts of flooding following heavy rains. In the Slad Valley alone, maps from the late 1800s indicate at least twelve mill sites, each with substantial storage in their associated millponds and leats (FIGURE 2).

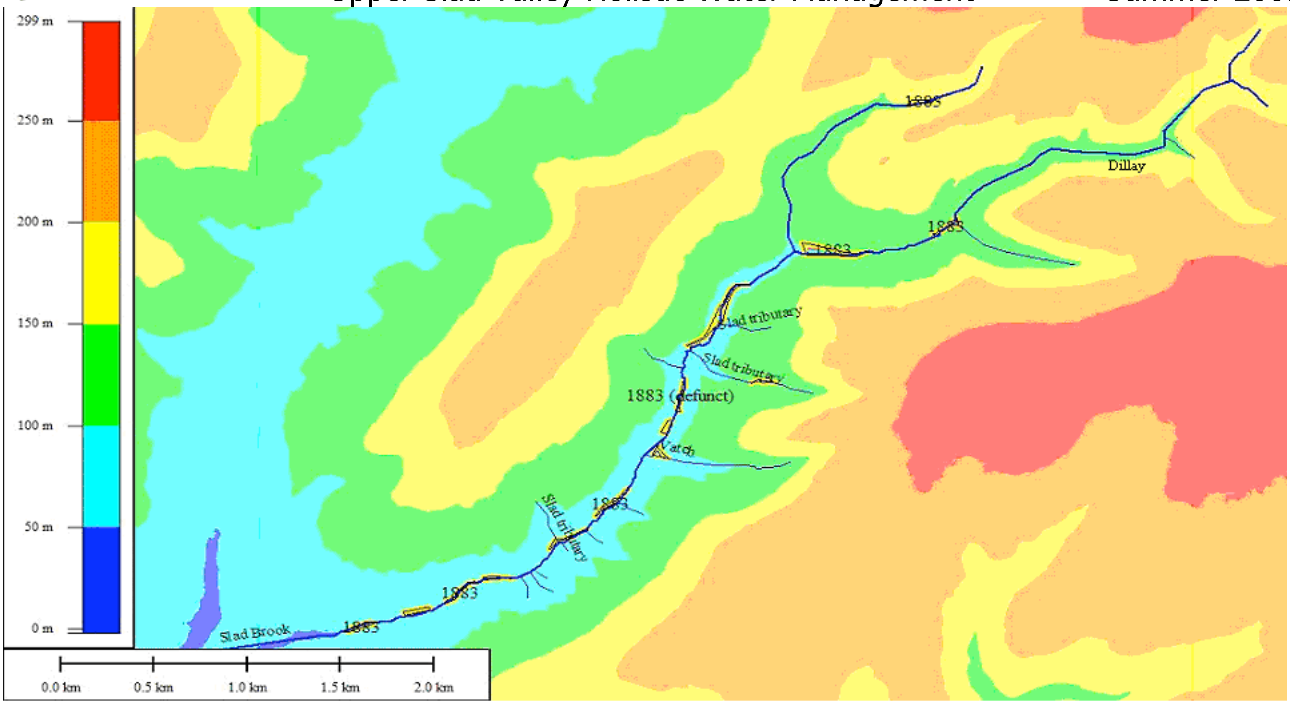


Figure 2. Map showing storage of water in millponds in the Slad Valley in 1880s. Most of this storage and active management has now gone.

Today, the catchment is very different. Gone are acres of wet woodland and wetland along the valley floors; woodland and scrub cover on the hill slopes and tops is reduced, giving way to large expanses of exposed arable farming. Just three millponds remain (although these are smaller and not actively managed fully). The story is similar throughout the Stroud Valleys. The capacity of the catchment today to attenuate flows via permanent storage with 'freeboard' (additional flood peak storage provided by lakes and millponds) and temporary storage (wet woodlands, flood meadows and marshy places) is comparatively small and significantly reduced from the historic provision here.

Deforestation and intensive arable farming have also reduced the interception and infiltration capacity of the soils; such that heavy rains generate proportionately more streamflow in the watercourses than before. Urban development and drainage schemes to direct runoff into watercourses has exacerbated the problems. Decades without active interest in and utilisation of the local water resources have resulted in loss of local water management knowledge, and the corresponding mismanagement and neglect of watercourses.

5 The methodology

Hydrological modelling is conducted to identify the volumes of floodwater that occur in the valley for a number of given return periods (from five-year to greater than 200-year return events). The Environment Agency kindly provided use of the Flood Estimation Handbook (FEH) software suite and data for an initial study (PRETTO 2008).

Once the catchment total flood volumes are identified, they can be dispersed using the same method to estimate how much water should be attenuated within each reach or sub-catchment in order to provide complete flood protection for the given flood event. This study examines potential for dispersed flood attenuation in the Upper Slad Valley; the updated hydraulic estimates provided by the Environment Agency are translated using ratios from Pretto (2008).

The Environment Agency typically works to a design standard of a 100-year plus 20% (climate change) return periods. This study seeks to go beyond this if possible.

The exercise is one of identifying suitable storage locations to comfortably provide this volume of storage, either as temporary or semi-permanent ponds, leaky weirs or wetlands, or permanent lakes with extra freeboard storage capacity for attenuation. A large factor of safety can be built in, so as to render any cumulative uncertainties or errors insignificant.

The methodology is then as follows.

- Working only on an opportunity basis, responding to the requests of householders, landowners and communities, rather than with any presumption of land availability.

- A community led, self-organising principle is critical to long term success. Focussing on the wider context of resolving critical risk (flooding) within a plan that makes use of water resources.

- The sites of interest are visited with the permission of landowners. Geo-referenced photo-surveys provide a useful starting point to infer the next steps.

- LiDAR data (kindly provided by the Cranham Local History Society (2009)) are displayed in GIS software (GLOBAL MAPPER 10.0 (2009)) along with raster overlays of Ordnance Survey maps at various scales.

- High-resolution contours are generated for the area of interest.

- Locations of potential water and storage (water resource uses discussed beforehand with landowners) are traced onto the maps, indicated by the contour shapes and by the photographs. Based on the elevation provided by the LiDAR, a volume can be calculated of the amount of water that can be stored for a given embankment height.

- A suitable storage location is one that connects the stream to its floodplain to make best use of natural storage capacity. The embankment width and height are sought to be kept as small as possible, in order to reduce the visual impact, environmental impacts and costs.

- This methodology is suitable for estimating the capacity of larger storage lakes (with embankments of around 3 metres high), as well as for small impoundment features (with embankments below 1 metre high). It provides useful initial estimates of storage. Although LiDAR is very high resolution and vertically accurate to within ± 15 cm (HORRITT ET AL 2006), the estimates provided by this methodology are insufficient to be able to work to narrow margins of error. (Specifically, dense vegetation cover at some points on the stream means that the LiDAR elevations underestimate the stream depth. This limitation actually works to an advantage as a conservative estimate of storage capacity.)

- Once a number of potential sites have been identified, they then require more detailed ground surveys with optical engineer's levels or electronic theodolites to refine the initial volumetric estimates and provide information for more detailed design of specific features.

6 The results

The results of hydrological modelling conducted for the Slad Valley can be found in the report by Water21 (PRETTO 2008) and in the accompanying data disks (available on request). The median flood (2-year return) was distributed throughout the catchment. For this size of flood event, 44094 m^3 of floodwater must be attenuated before the entry to the culvert at the bottom of the Slad Valley, in order to absolutely prevent flooding from the watercourse here. Breaking the catchment up into sub-catchments, the volumes of the direct runoff contribution within each is calculated, giving an indication of the amount of floodwater that must be attenuated and where, as part of a dispersed upstream attenuation approach. Using six sub-catchments above the location of the seventh at the bottom of the Slad Valley, upstream attenuation would mean that only 13135 m^3 of water would need be stored at the bottom for that given flood event. The volume of 4342 m^3 of floodwater must be stored within the Dillay Brook, and 1062 m^3 within the Slad Brook above Steanbridge in the Upper Slad Valley. Details of this are illustrated in APPENDIX 1.

The Environment Agency (2009) volumetric estimates of a 100-year return flood are compared to those of a 2-year return in Pretto (2008). Ratios are established and used to generate upper and lower volumetric estimates for the 100-year flood volumes in the Dillay and Slad Brooks in the Upper Slad Valley (TABLE 1).

	Volumetric estimates (m^3)		
Location	**2-year return**	**100-year return**	**Ratio**
Confluence (Slad source)	1062	*Low estimate [1062*5]= 5310* *High estimate [1062*10] = **10620***	-
Confluence (Dillay Brook)	4342	*Low estimate [4342*5] = 21710* *High estimate [4342*10] = **43420***	-
Painswick Slad Farm	<18076	184648	10.2
Bottom Slad Valley	44094	267287	6.06
End of Slad Brook	60988	320000	5.25

Table 1. Volumetric estimation for the Upper Slad Valley.

The two landowners in question in the Upper Slad Valley control parts of the Dillay Brook and the Slad Brook from source, up to Steanbridge Farm. The volume of 43420 m^3 of floodwater must be stored within the Dillay Brook, and 10620 m^3 within the Slad Brook.

If floodwater is attenuated within the Upper Slad Valley, it would provide an estimated 17% reduction in floodwater at the bottom of the valley for this given flood event.

Landowner A specifically expressed an interest in fully or partially restoring the historic millpond behind Steanbridge Farm (SO 878 078) for recreational fishing and habitat provision. Landowner B specifically expressed an interest in developing one or two lakes for recreational fishing and habitat provision in the upper reaches of the Dillay Brook. These were calculated using a range “fill levels” to give an estimate of not only the total capacity possible, but – critically – the freeboard capacity assuming a “normal conditions” water fill depth.

In addition, numerous locations for smaller seasonal storage have been identified. As suggested in the Environment Agency consultation paper, "creation of flood storage areas has the potential to deliver a range of enhancement measures, such as creating new ecologically valuable habitats such as lowland meadow, wet woodland and wetlands" (ENVIRONMENT AGENCY 2009: 6). These have been considered as part of this numeric flood storage estimation. Locations for further attenuation by "soakaway" buffer strip zones have been considered, although the specific additional attenuation capacities cannot be estimated using the available method.

If Landowner A used all the storage locations illustrated (APPENDIX 2), this could attenuate 35994 m^3 of water at a total wetted area of 23633 m^2. This assumes that the seasonal impoundments are normally no more than 2 m high. The two permanent features are lakes with an additional 2.5 m freeboard capacity beyond normal fill level of 2.5 m; figures chosen represent the historic millpond earth embankment height. Estimates are conservative.

The landowner also owns land on the Slad Brook above Steanbridge. In the same manner, there is capacity to store the significant volumes of floodwater, although specific locations have not been included in detail here.

If Landowner B developed two fishing lakes, both with 2 m freeboard storage, there could be 13576 m^3 of attenuation capacity here. Including a number of additional small seasonal impoundments (some of these extend beyond the land boundary but are included anyway to act as runoff intercepts), there could be an extra 14318 m^3 of attenuation capacity here (APPENDIX 3), resulting in a total of 28533 m^3 of storage. By no means are all potential small seasonal impoundment locations included in this estimate – there is space for more. They would reduce the high velocity erosive runoff that occurs after heavy rains in the steep valleys here. Storage capacity of soakaway buffer strips is not included in the estimate; these could provide additional flood storage and retention benefits especially in gullies on steep slopes.

Together, total storage capacity could be 63888 m^3 at a maximum inundated area of 42612 m^2. Storage capacity exceeds the upper estimate of floodwater volume for the catchment for a 100-year return flood, and thus a greater flood protection could be reasonably expected. The area of the Dillay Brook catchment is 6.1 km^2, thus only 0.7% of the land would need to be used for water storage with this approach. There is additional storage in the Dillay Brook with two other key landowners, but they would need to express an interest in this approach before Water21 presumed to suggest storage estimates to them.

7 Discussion

7.1 Flood attenuation

The available storage capacity within the Upper Slad Valley is sufficient to provide complete attenuation of floodwater sourcing from within the sub-catchment for floods of a 1 in 100-year return interval.

In practice, this means that the impoundments can be small and inexpensive if done in this dispersed manner. Clearly, not all will be needed or even desirable to the landowner, and so there is a wide choice of implementations available. Sites should be chosen to provide the greatest benefit for biodiversity, habitat, erosion reduction, practicability and aesthetics. Moreover, with many dispersed attenuations, the cumulative effects of catastrophic floodwater 'peak flows' would be minimised throughout the catchment, such that only small increases in water level and inundations may be noticed at any location. Avoiding extremely deep inundations would provide the best conditions for flood meadow and wet woodland ecologies. This achieves a similar hydraulic response throughout the catchment to that found in the pre-human intervention landscape.

The design specifications for these small impoundments needs to be detailed, and the Environment Agency have a role in determining standards here. Most can be constructed of reinforced raised earth embankments with a constricting through-flow culvert and grassed overspill, which could be passive or actively managed. There is the future possibility for a catchment-wide automated system to optimise available storage (as a refinement of widely implemented hydropower with associated water storage and controls).

The attenuation features should be naturalistic and cheap to construct and maintain, and have minimal visual impact. Ideally they would be practical for landowners to construct themselves, following established expert advice. Design principles for these features can be found in the highly regarded work of Australian P. A. Yeomans (YEOMANS 2008), as well as many others. Experience suggests that several small seasonal impoundments can be created with a hired digger and local materials in a couple of days. The larger structures would necessarily require more planning.

Adjusted for exchange rates and inflation, Anderson and Lewis (1997) suggest approximate costs of upstream attenuation by online impoundments in this manner could be £0.20 per m^3 of storage. This suggests that work in the Dillay Brook could be done for approximately £25000, work across the entire Slad catchment for approximately £64000 (based on 320000 m^3 of floodwater in a 100-year flood (Environment Agency 2009)). The larger Painswick sub catchment, at around twice the receiving area for rainfall of Slad, might comfortably be fully attenuated in this way for under £150,000.

Conventional land and watercourse management causes excessive incising of watercourse profiles, accelerating run-off and excessively dehydrating of the land. Thus, in additional locations, where occasional flooding can be safely allowed, increasing the hydraulic roughness of the streams using leaky weirs and encouraging the accumulation of natural growth of trees in and around watercourses would have a similar effect to impounded storage. This would also provide a range of aquatic habitats for freshwater benthic macro-invertebrates, diatom populations, and even water voles, thus improving the entire ecological status of the watercourse for the Biodiversity Action Plan (UKBAP 1994) and Water Framework Directive (EUROPEAN COMMISSION 2000). These would also help to maintain base flows during drought periods by hydrating adjacent land during any inundation.

Experience of this agricultural water engineering is established within a wide range of other environmental movements and organisations, including Permaculture, Biodynamic farming, Borough of Poole Bourne Stream Partnership and Healthy Soils Australia.

See Appendix 4 for a poster prepared about seasonal flood attenuations and semi-permanent lakes with freeboard storage.

7.2 Multi-benefits

For a truly holistic water management plan, the "hydraulic numbers" are not enough. At the commencement of any flood planning feasibility exercise, an economic valuation of potential water related resource usage needs to be undertaken to inform a flood planning process. This is critical for engaging with landowners in an informed manner, and realising the water related resources.

The initial multi-benefits are discussed here so that landowners can decide whether they wish to pursue the project. If so, more research can be done.

7.2.1 Fishing & aquaculture

The larger lakes can provide recreational fishing, and if developed as a small-scale enterprise they could provide self-funding for construction and maintenance. Stocking of fish could interfere with the natural aquatic ecologies. Density should be kept relatively low, and if stocking species were indigenous trout sourced from local hatcheries within the Stroud catchment (or migratory salmonids from the wider catchment), they could play a key role re-establishing and maintaining lost salmonid populations.

More intensive aquaculture, carp for example, may be feasible in 'off-stream' ponds. But potential problems associated with fish farming (disease and pollution risks) would require careful attention be paid to construction and operation.

7.2.2 Irrigation & food security

Scenarios for climate change in the UK indicate that winters will become wetter, but that summers will become drier (STERN 2007). A growing recognition of the need for improved food security places a fresh focus on water availability for irrigation; which could also be provided by the additional impoundments proposed in this study as a multi-purpose feature also providing additional 'freeboard' storage for floodwater.

Irrigation helps guarantee arable crop yields in dry years and increases yields (by typically 50 – 100%) in normal years. The 'loss' of a small area of farmland for reservoirs can thus increase food productivity, and the variety of crops, on remaining land, while also helping protect against flood damage to cropping areas elsewhere.

7.2.3 Small scale hydro power

In locations where there is an hydraulic head of over 2 m, small-scale hydropower could be economically viable (OSSBERGER 2009). This is particularly so for the millpond of Landowner A, where reconstruction of the original embankment could provide a 5-6 m head with significant storage to generate over 10 kW of power during winter (FIGURE 3). By ensuring fish-passes are embedded into the design of such schemes, the environmental impact could be positive; hydro-power sites elsewhere act as useful filters of rubbish that would otherwise be washed downstream and pollute watercourses (WATER-POWER ENGINEERING 2009). The environmental benefits, including for fish, can be seen at two working micro-hydro sites in the region (in Frampton Mansell and Coaley). The sites studied in this report are worth looking at in greater detail if requested, to determine the economic viability.

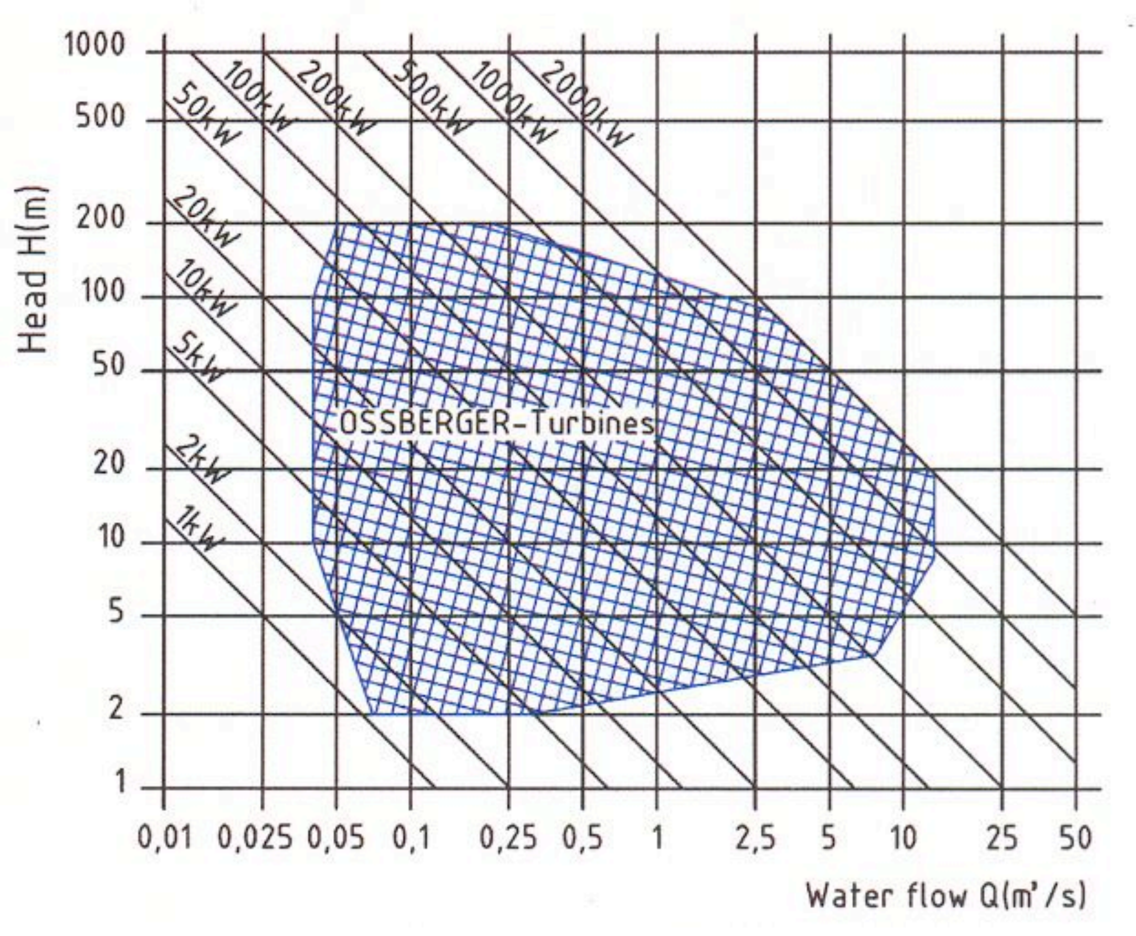


Figure 2. Crossflow hydropower turbine operating range and power output. Courtesy Ossberger.

7.2.4 Erosion

Interception of the occasional and erosive stormflow runoff would contribute to a reduction in the siltation issues in the watercourses downstream. Options to work with landowners to pilot best-practice as well as new Effective Micro-organism (EM) / Microbial Balancing Technology would also help to control this issue, and in doing so, providing additional flood protection through improved water retention of the soils (GREENWAY 2009).

7.2.5 Silt recovery

Hydrostatically bonded to silt particles are nutrients (nitrates, phosphates and potassium) leached from animal waste, fertilisers and natural vegetative decomposition. Also in the mixture can be a rich anaerobic microbial population and organic carbon. Silt is therefore not a problem, but a resource, which belongs to landowners and which they should be enabled to access. The flood attenuation structures will accumulate silt, and if designed to allow easy retrieval then provide an additional benefit.

To determine the value of this potential resource, research needs to be done to evaluate the volumes of silt in the system, the value of the silt as "fertiliser equivalent" or other measure, the means of recovering and the means of reapplying silt resources to the land. Landowners engaged so far have shown positive interest in recovering this valuable material, and further studies can be expected.

7.2.6 Biodiversity

Buffer strips would be ideally suited in the gullies on steep hillslopes. These would increase hydraulic roughness and promote infiltration, and while perhaps not storing significant volumes of floodwater, they would slow the hydrograph to reduce pressure downstream. Several sites could be considered by Landowner A and B, and are marked in the appendices. These could be achieved by preventing grazing in these locations and leaving to mature with wetland scrub, or alternatively planting some vegetation. In combination with good hedgerow management, a great benefit could be realised by improving these connecting networks for catchment-wide biodiversity.

Within the Dillay Brook, a nature reserve operated by Gloucestershire Wildlife Trust could provide additional temporary wetland storage, which allies particularly with an interest in biodiversity and water vole habitat improvement. The Trust could be engaged by the community to investigate options here.

7.3 Summary of multi-benefits

In addition to flood storage benefits, the approach seeks to realise the environmental water resources that belong to the landowners and the community as part of an embedded, holistic water management solution.

Key multi-benefits to landowners:

- reduces the erosion and loss of topsoil during heavy rains;
- trapped silt is easily recoverable in small attenuations;

- nutrient contained within the silt can be put to good use when composting to reapply to soil (there are some organic and low-cost methods to aid this involving EM "microbial balancing" (Greenway 2009));
- prevents nutrient enrichment downstream (associated with additional costs of drinking water treatment as far away as Bristol);
- provides wildlife habitat, especially when combined with buffer strips;
- provides landowners with a commercial opportunity for small-scale recreational fishing & aquaculture;
- improved water availability for irrigation & arable crop productivity;
- landscape and aesthetics;
- small-scale hydro opportunities could be developed privately or through a community supported co-operative utility.

Key benefits for the wider catchment and the Environment Agency:

- additional water storage to bolster Environment Agency flood attenuation design capacity;
- co-operative landowners have expressed interest in this, and not been pressured into providing land;
- silt traps in the upper catchment reduce substantial maintenance that would be associated with the two large, steep and inaccessible attenuations downstream as well as existing culvert blockages;
- this approach demonstrates a principle of embedded, holistic, community-led water management, which could revolutionise the way in which water is managed, the way in which water related resources are realised, flood and drought issues controlled whilst benefiting the rural economy and greatly reducing costs.

7.4 Critique and possible impacts for consideration

The Environment Agency has some reservations about the proposals suggested in this study. These criticisms are important, and should be addressed. The reservations surround the concept of online flood storage.

A proposed change in the Reservoirs Act 1975 may mean that a smaller volume of stored water (defined as above the normal ground level) will require a reservoir license and (expensive) panel engineer to design the impoundments. The Draft Flood and Water Bill (2009) proposes to reduce the volume threshold from 25,000 m^3 to 10,000m^3, and the stored volume would contribute cumulatively throughout the catchment. Thus several very small impoundments, which raise water level above normal ground level (i.e. the proposals suggested in this report) might fall under this issue.

The safety rationale behind this change in reservoir licensing has some dubious aspects. Whilst safety must always be paramount, there are concerns that the proposed changes in the Draft Flood and Water Bill are representative of a civil engineering industry lobbying for legislative changes to protect their commercial interests. The high cost of civil engineering planning often prevents schemes from going ahead, but this must be weighed against the safety implications of continuing to fail to protect communities from flood risk. Landscape architects and agricultural engineers are more appropriate for the soft-engineered solutions proposed here. The dispersed flood approach has an inherent safety factor implicit with this approach as flood peak flows are attenuated and accounted for throughout a larger scale system.

There is still scope to grant the reservoir license if the safety of the impoundments can be demonstrated (and indeed, soft-engineered approaches can be designed to the same standards as hard engineered structures). If the proposals can be shown to satisfactorily improve flood problems and are economically viable (accounting for the water related resources and wider social benefits from water management), then funding can be found to support the schemes; this could usefully be put towards covered costs associated with this licensing. Some major funding sources are available for wetland restoration with a habitat focus, for example through Natural England and the RSPB, but these could demonstrably work as part of the multi-benefit holistic solution.

The second implication of online storage is the ecological and environmental impact on relatively untouched sections of the Dillay Brook. The Environment Agency has expressed concern over the effect on fish passage of the impoundments, and the effect on biology of stocked fishing lakes. It is acknowledged that the permanent impoundments will affect the flows and sediment transport. However, the biodiversity enhancement within the water, in the surrounding floodplain and in the wider catchment is core to the holistic approach.

Fish passage is not actually a pressing issue in this upper part of the catchment, as migratory fish species are not present and passage for brown trout at spawning only required in the lower reaches. Fish passes would nevertheless be included to help restore the aquatic ecologies of the catchment as part of the holistic catchment-scale approach. Where possible, storage should not interfere with the passage of organisms at all during normal flow conditions. The design of the impoundments can be improved further, by working with various agencies and stakeholders to ensure the maximum benefits are derived through the low-cost, soft-engineered structures. It is also important to consider the benefits of leaky weirs, and offline storage in buffer strips as well.

The impacts of permanent lake storage in the upper reaches of a watercourse can be seen by using an adjacent analogue catchment. Online storage in ponds and lakes in neighbouring catchments such as Chalford and Nailsworth actually bring a benefit to wildlife and aquatic ecologies (and have correspondingly higher water quality status than the Slad Brook). The neighbouring Chalford Frome catchment is somewhat longer than the Slad, but the flow rates and valley shape are similar. Today it contains at least seventeen sizeable ponds and lakes above Frampton Mansell (downstream of here is the main concentration of mills). Many of these lakes are old millponds. Some appear to be more recent, and constructed since the late nineteenth century. There is a notable capture of silt in many of the ponds, even at the headwaters, which can be seen as a positive effect, for this silt is prevented from causing blockages in the vulnerable downstream areas. However, most of the lakes and ponds contain a notable abundance of wildlife (especially trout species), providing a range of habitats from open water, running streams, and significant areas of wet woodland, flood meadows and marsh. With the exception of millponds, this is likely to be similar to the original pre-disturbance coverage in the Slad Valley (FIGURE 4).

Particular optimism from the Environment Agency concerns the benefits of the Upper Slad attenuation for the proposals downstream, for which they are still trying to find adequate space for flood storage. Not only will these proposals provide a contribution to flood storage, the principles could be adopted across the Stroud Valleys projects to provide complete flood attenuation through this novel embedded holistic water management approach. In this manner, the design capacity of the Environment Agency proposals can be further improved. In addition, the benefits of trapping silt could significantly reduce the maintenance issues downstream.

Water21 has provided feedback of the Environment Agency's flood attenuation proposals. These are currently two large 6 m high dams in the lower catchment to store all of the catchment floodwater. Water21 did not recommend what has been proposed by the Environment Agency, but supports the Slad Brook Action Group and the Agency in completion of the project. It is not the intention of this paper to compete with these schemes, rather to highlight the feasibility of additional upstream attenuation for multi-benefit enhancement that is low-cost, long-term and holistic. The Water21 approach is also community-led, responding to landowners who wish to set aside land for this purpose. Asking landowners how they wish to use their land for water resources is a preferable method of operation, which initiates a long-term community connection and sense of ownership and responsibility for the scheme.

Since beginning this project, more landowners have come forward and expressed an interest in providing upstream attenuation as part of a multi-benefit development of the ecological resources of the watercourses. In addition to the Slad Valley, this approach has also been requested by the communities at Standish, Stonehouse, Ruscombe, Bridgend and Ryeford, which are represented in the Stroud Water Forum (as well as further afield in the United Kingdom). Alleviation of flooding in these locations all would reduce the burden of main river (Environment Agency responsibility) flooding downstream, as well as providing the Environment Agency with an opportunity to demonstrate its commitment to environmental enhancement. Importantly, it can be achieved through this community-led approach.

The full benefits of realising the water related resources on a community-led level are not fully acknowledged by the authorities or appreciated by many of the communities. Flood and water management is a cultural problem. It is time to move away from the mentality of coping with water, and instead towards realising its full value as a resource. This way, flooding or pollution issues are no longer distinct problems to fix, but instead – by focusing on maximising the water resource benefits within the rationale of resolving critical flood risks – the community will find the problems of today are resolved.

Figure 3 Photos of remaining online storage (millponds and lakes) in the neighbouring catchments, which demonstrate better water quality and biodiversity than the Slad Valley, even without fish passes.

8 Conclusion and next steps

This project has presented options for completely resolving flood runoff generated within the Upper Slad Valley for the multiple purposes of flood alleviation downstream, drought resilience, and realising the water related resources that belong to the landowners here. It has also demonstrated a principle which could be applied in other catchments. It is not at this stage a design specification.

The first stage is to get feedback from the two landowners engaged in the project, and to decide whether they still wish to develop the project.

Feedback from the community action group throughout is also important.

Water21 would then like to work with the Environment Agency in identifying how the initial ideas could be taken forward. Detailed scrutiny of design ideas can be investigated to ensure maximum holistic benefits and least cost. The estimates of flood volumes and storage can be improved with field surveys and expertise at the Environment Agency.

An important part of the study is moving beyond the hydraulic numbers towards developing the economic water-related resource model, which would form the basis of a novel approach to cost-benefit analysis for holistic water management. The principles of the multi-benefits are already well defined, but it is now necessary to quantify them.

9 References

Anderson, C. L. and L. Lewis (1997) *Working Paper 4: Siting and Design of Impoundments for Flood Control in the Red River Basin* (WWW) (http://www.rrbdin.org/communication/filebank/files/SitingandDesign.pdf; 01.10.2009).

Cranham Local History Society (2009) *Cranham Local History Society Lidar Survey Project* (WWW) (http://www.cranham.net/history/lidar.htm; 19.07.2009).

Defra (2005) *Making Space For Water: Taking forward a new Government strategy for flood and coastal erosion risk management in England*, London: Department for Environment, Food and Rural Affairs.

Environment Agency (2009) *Slad Brook, Stroud - Flood Risk Management Scheme Screening Consultation*, Tewkesbury: Environment Agency.

European Commission (2000) 'Directive 2000/60/EC (Water Framework Directive)', *Official Journal*, 327, 1-73, Brussels: European Commission.

Global Mapper (2009) *Global Mapper GIS Software* (WWW) (http://www.globalmapper.com; 19.07.2009).

Government – 2009 – draft flood and water bill

Green, R. (2009) *Stroud District Council Painswick Stream Hydraulic Model Report & Initial Option Discussion*, Birmingham: BWB Consulting.

Greenway, W. (2009) *EM / Microbial Balancing Technology Review*, Stroud: Water21.

Horritt, M. S., P. D. Bates and M. J. Mattinson (2006) 'Effects of mesh resolution and topographic representation in 2D finite volume models of shallow water fluvial flow', *Journal of Hydrology*, 329, 306-14.

Pretto, I. (2008) *Hydraulic and Hydrological Modelling in the Slad Valley*, Stroud: Water 21.

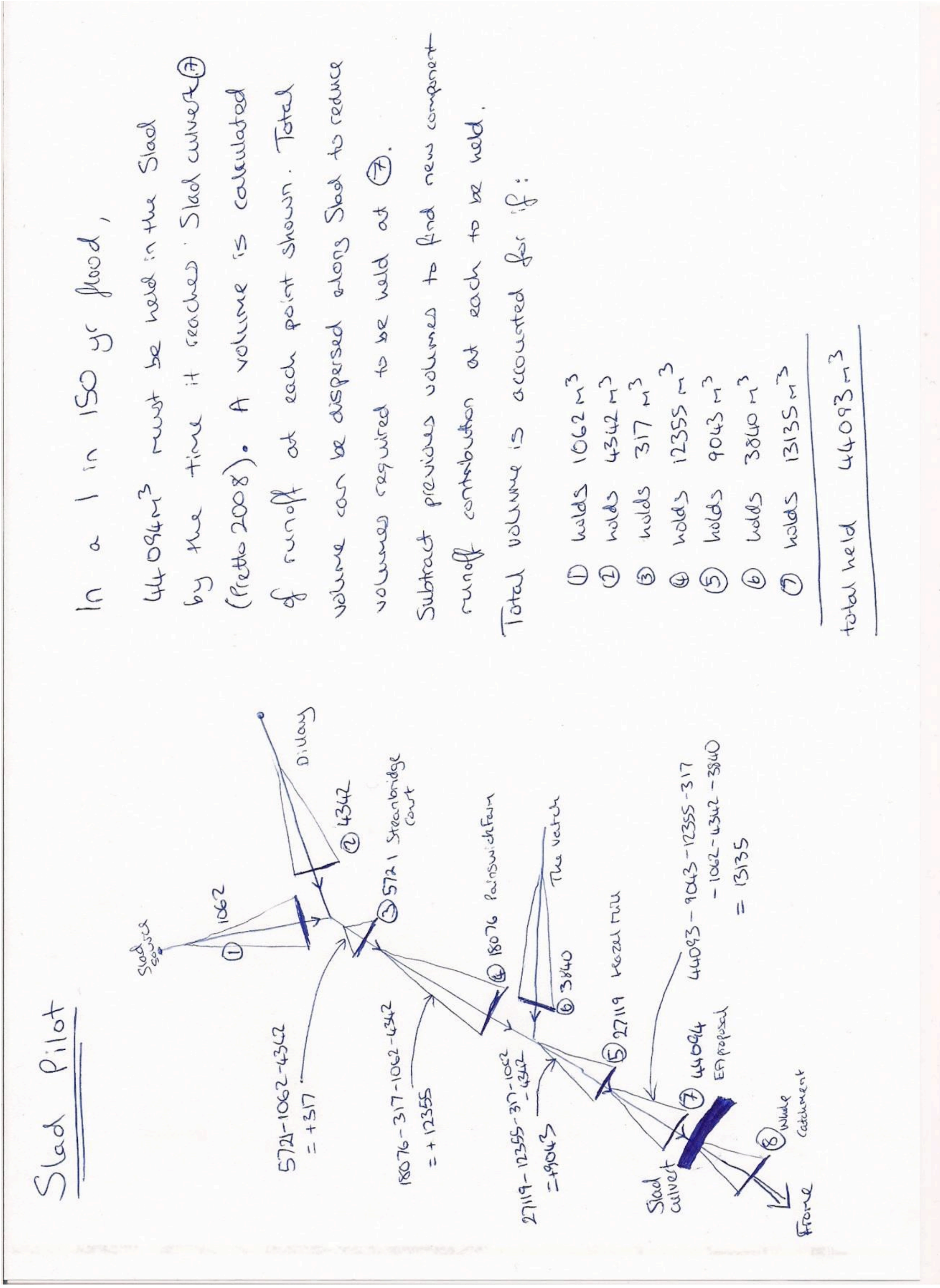
Stern, N. (2006) *Stern Review on the Economics of Climate Change*, Cambridge: University Press.

Stroud District Local Authorities (1971) *Stroud District Sewerage Committee Report*.

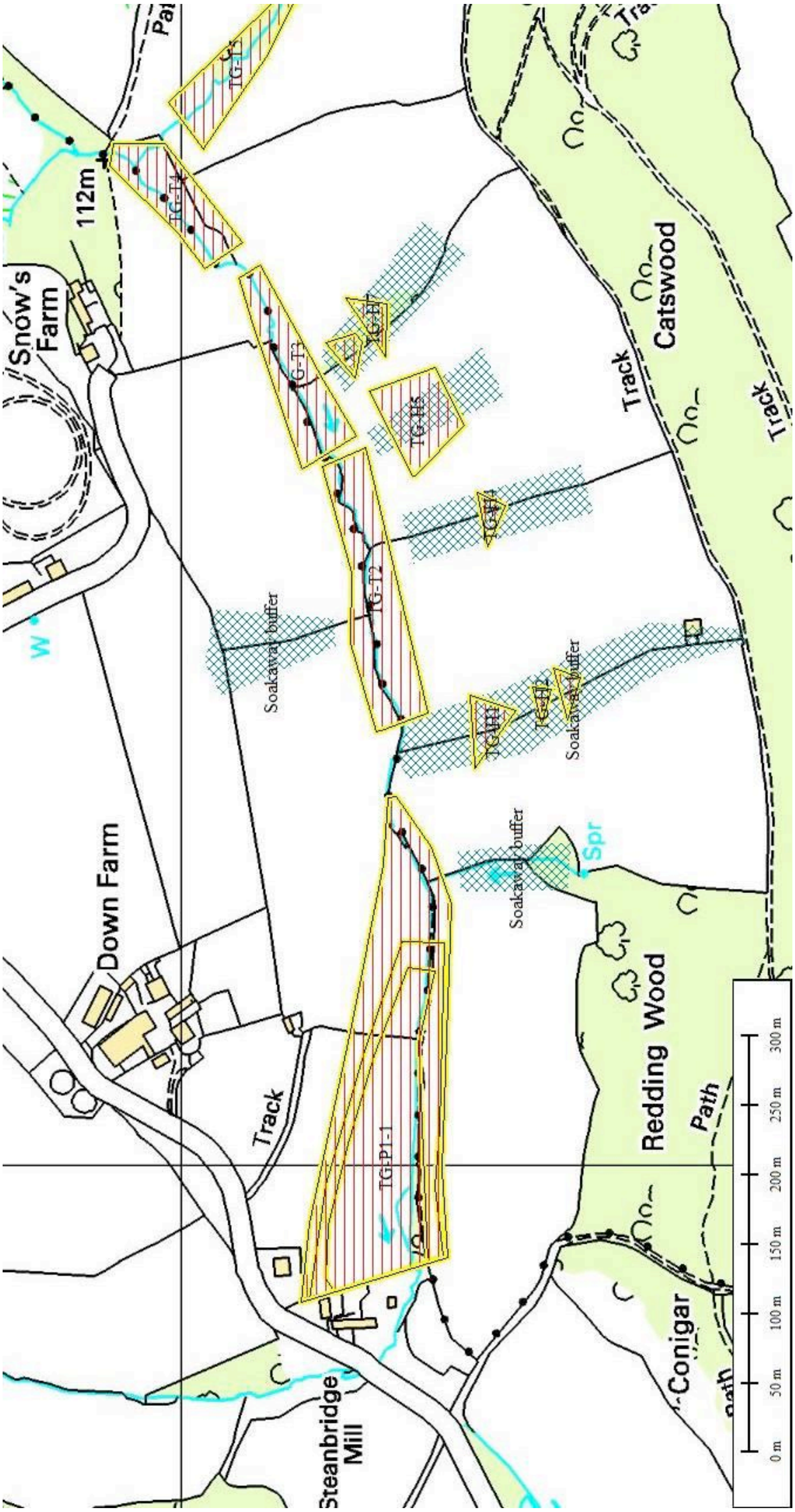
UKBAP (1994) *Biodiversity: the UK action plan*, London: HMSO.

Yeomans, K. (2008) *Water For Every Farm: P.A. Yeomans Keyline Plan*, Australia: Keyline Designs.

10 Appendix 1 – volumetric calculations



11 Appendix 2 – attenuation for Landowner A



#	Type	Approx. wall height (m)	Max. capacity (m^3)	Surface area (m^2)	Comments
TG-P1	Lake	2.5	4561	5170	
		4	15880	10160	
		5	28268	14180	
		2.5-5m freeboard	23707	9010	
TG-T1	Dry dam	2	2590	3495	
TG-T2	Dry dam	2	1535	2498	
TG-T3	Dry dam	2	1118	1699	
TG-T4	Dry dam	2	1535	2420	another landowner
TG-T5	Dry dam	3	2050	1646	another landowner
TG-T6	Dry dam	2	784	856	another landowner
TG-H1	Run-off intercept	3	851	565	or soakaway buffer
TG-H2	Run-off intercept	1.5	69	99	or soakaway buffer
TG-H3	Run-off intercept	1.5	134	155	or soakaway buffer
TG-H4	Run-off intercept	2	160	212	or soakaway buffer
TG-H5	Run-off intercept	4	1154	704	or soakaway buffer
TG-H6	Run-off intercept	2	129	133	or soakaway buffer
TG-H7	Run-off intercept	3	178	141	or soakaway buffer
		Total storage(P)	23707	9010	
		Total storage(T+H)	12287	14623	
		Total storage	35994	23633	

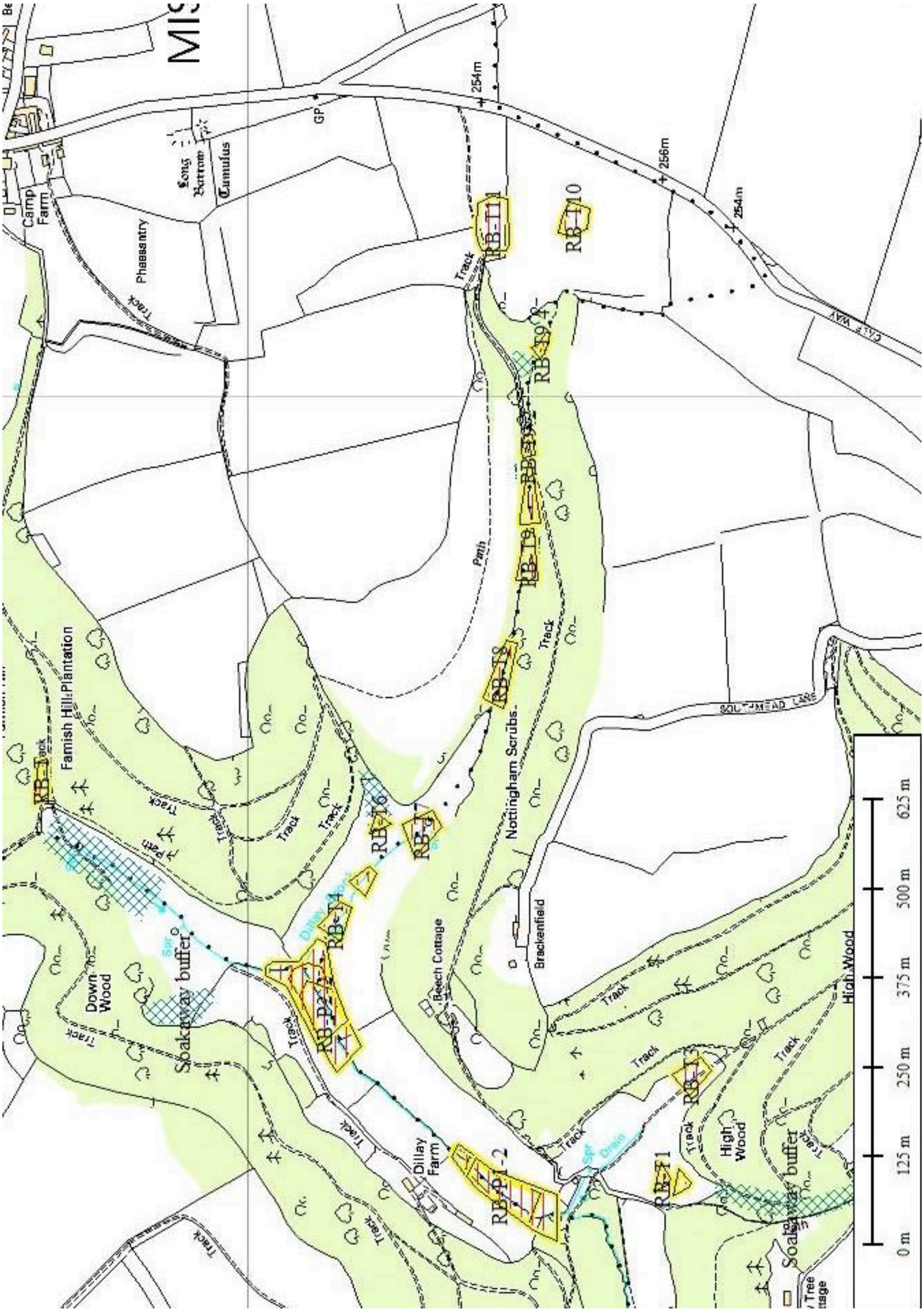
If the millpond (TG-P1) were restored to its original embankment height of five metres, it alone would provide substantial flood attenuation for the catchment. It could be operated to provide a normal dry weather depth of about 1 m at its deepest suitable for recreational fishing. During wet weather the embankment would be able to retain 2.5 m extra freeboard water depth. There is the potential to investigate small scale hydro power here, which can be operated to provide electricity, but during flood risk periods could be kept low to provide the freeboard flood storage. This would be a large feature which would need to be licensed under the Reservoirs Act 1975, and will require a panel engineer to ensure the design standards are sound.

Using this land instead for smaller flood storage features would still be beneficial. It is even possible to design an offline pond which only fills when the swollen stream overspills into it. A similar scheme has been installed at minimal cost by the landowner in the Chalford valley to compensate for new highways drainage into the river just upstream (FIGURE 5). The smaller seasonal impoundments would not in themselves require licensing, but under proposed changes in the Flood and Water Bill, they could cumulatively contribute to requiring a license. If their benefit can be demonstrated, the Environment Agency could arrange this.

Allowing some of the steep gullies in the hill sides to become overgrown, and by creating some small bunds, floodwater can be slowed, infiltrated and stored en route to the stream.

Figure 4 Offline flood storage in the Chalford Valley (Water21).

12 Appendix 3 – attenuation for Landowner B



#	Type	Approx. wall height (m)	Max. capacity (m3)	Surface area (m2)	Comments
RB-P1	Lake	3	3536	2674	
		5	11630	5560	
		2 m freeboard	8094	2886	
RB-P2	Lake	2	1034	1515	
		4	6516	4135	
		2 m freeboard	5482	2620	
RB-T0	Dry dam	1.5	305	424	
RB-T1	Dry dam	2	212	263	
RB-T2	Dry dam	2	269	283	
RB-T3	Dry dam	2	1003	1005	
RB-T4	Dry dam	2	819	930	
RB-T5	Dry dam	1.5	274	486	
RB-T6	Dry dam	2	166	213	
RB-T7	Dry dam	2	1500	1265	
RB-T8	Dry dam	2	1530	1118	Another landowner
RB-T9	Dry dam	3	1177	794	Another landowner
RB-T9.1	Dry dam	4	1579	911	Another landowner
RB-T9.2	Dry dam	1.5	277	293	Another landowner
RB-T9.3	Dry dam	2.5	339	276	Another landowner
RB-T9.4	Dry dam	2	639	325	Another landowner
RB-T9.5	Dry dam	3.5	260	190	Another landowner
RB-T10	Dry dam	1.5	865	1224	Another landowner
RB-T11	Dry dam	2	1770	2238	Another landowner
RB-T12	Dry dam	2	1334	1235	Another landowner
		Total storage(P)	13576	5506	
		Total storage(T)	14318	13473	
		Total storage	27894	18979	

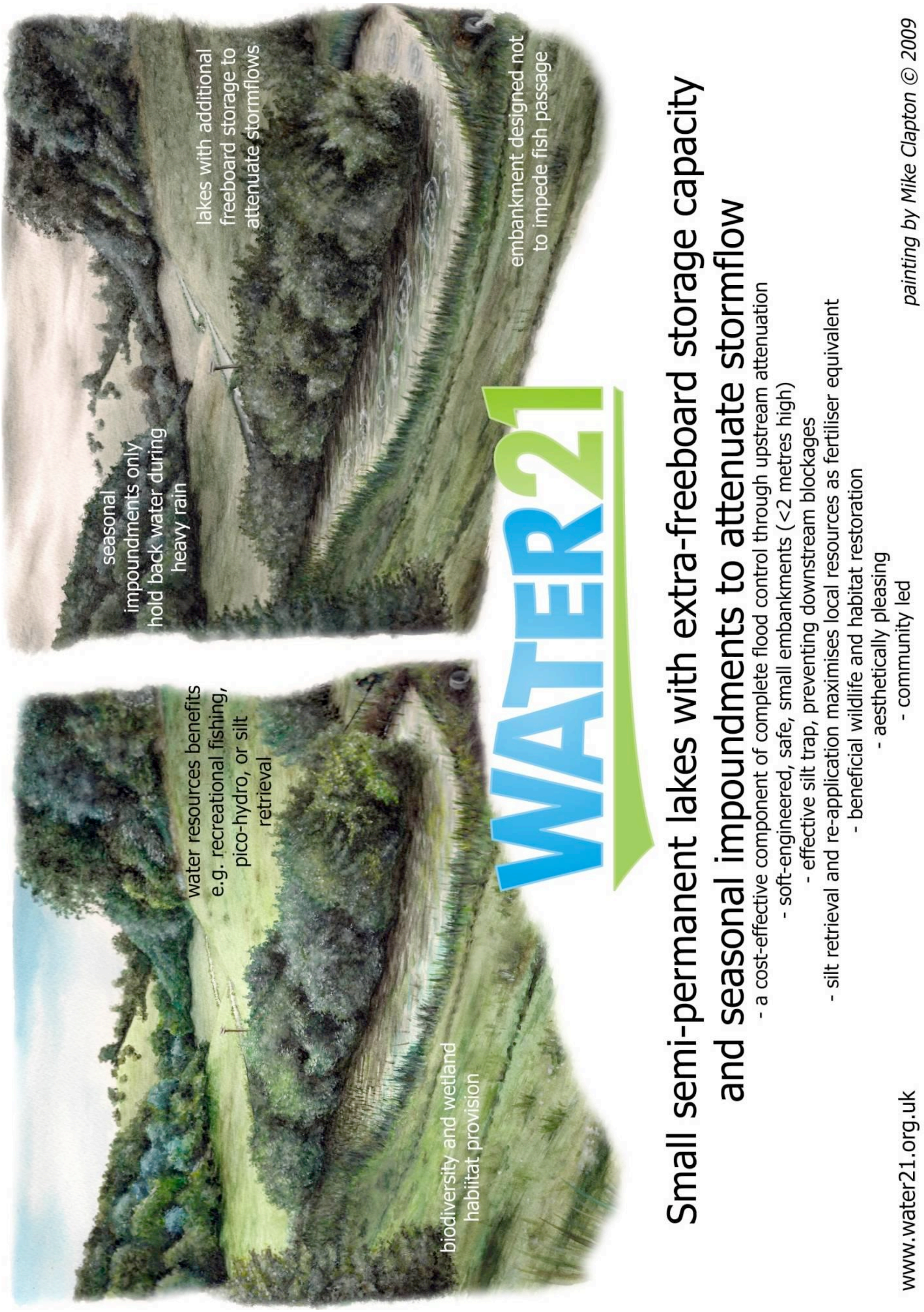
Two permanent lakes are feasible. The second is slightly more desirable because it is situated on an already waterlogged area which could easily be impounded, but would not provide the storage volume.

There is great scope for involving seasonal impoundments to provide substantial flood storage, particularly in the land (including some just beyond that of Landowner B) in the steep dry gullies above the actual springs. Storm runoff here is highly erosive (FIGURE 6). Capturing runoff here is feasible and would be beneficial.

Seasonal impoundments on the stream would be designed to have no impact on flows (and ecology) normally, but hold back water during times of heavy rain. Their visual impact would therefore be kept very low (APPENDIX 4).

Figure 5 Steep gullies above the spring levels still experience highly erosive volumes of runoff, which here have damaged a track. Slowing runoff here is feasible, because there is space for wet woodlands if small impoundments were created (Water21).

13 Appendix 4 – poster on water in landscape



Water21 Limited is a not-for-profit company limited by guarantee

Registered Office
135 Aztec West
Bristol BS32 4UB
Registered No. 9098337 in England & Wales

http://www.water21.org.uk/contact