The Discontinuance of Dams – it's not easy and it can be expensive!

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SYNOPSIS. This paper seeks to examine the issues associated with proposals to discontinue dams. The paper will examine the significant number of issues that need to be considered and show that the process of discontinuance can be long, often protracted and expensive. The paper, via case studies of a number of dams which have been discontinued, will demonstrate the issues that have been considered at the sites which are very different. It will illustrate that the sites can be left in different states depending on the location and that the process can often be found to be very acceptable to those who judge.

INTRODUCTION

The discontinuance of dams is an issue that the dam engineering as a profession is having to at least consider as a means of addressing problems at existing dams. The 'discontinuance' of a dam, under Section 13 of the Reservoirs Act 1975 requires an owner to reduce a reservoir's capacity to a volume that is less than 25,000 m^3. In some cases, owners choose to reduce the capacity to say 24,500 m^3 to avoid being subject to the requirements of the Reservoirs Act 1975 whilst some owners will choose to remove or breach the dam completely with no water then being retained. If we move to legislation based on risk and consequence of failure then we could see a move towards more sites discontinued where no water at all is retained.

Often, as part of the process of looking at remedial works at dams to upgrade them to meet current standards of dam safety, it is common to assess risks if 'nothing is done' – the 'do nothing' scenario – but this is normally not permitted because it will be a statutory requirement but also to remove or discontinue the dam and take it out of service and remove it from the ambit of the Act.

The process of discontinuance would involve using a Qualified Civil Engineer (QCE) from the appropriate panel (AR, NIR, SR) to oversee a project to carry out the works to reduce the capacity/removal of the structure through a process of design, and construction of works. The process would be completed with a Certificate of Discontinuance. On receipt of a Certificate under Section 13 of the Act the Enforcement Authority will remove the reservoir from its register and there is no need for a Supervising Engineer or the services of an Inspecting Engineer.

Historically there has been adverse public option when new dams have been proposed but it is also true that there can be adverse reaction when it is proposed to discontinue a dam. Dams are built for a number of reasons – water supply, flood alleviation, industrial use, amenity etc. In some cases the original use for the dam has perhaps changed/gone which makes the use of the dam redundant. Equally the rationalisation of systems and reduction in use of small resources leads to making a number of sources redundant. Often the geographical location, the degree of public access, land value and possible future land use, how the site is to be left and public opinion etc will dictate the way in which a dam is discontinued.

The issues highlighted above will dictate which 'third' parties need to be included in the consultation process. Some issues which need to be considered include the following:

- If the reservoir is an impounding reservoir and provides any alteration to the protection afforded to the area downstream, then the Environment Agency will often wish to be involved and require analysis to show the effect of the removal of the reservoir on the flood risks downstream. In some cases the EA might even object to the removal if the affects of removal increase the possibility of flood risk. They may even ask for other flood mitigation infrastructure.

- Silt in the reservoir – if there is silt in the reservoir, and recognising that the amounts are likely to be relatively small, this silt will have to be dealt with. It will not be acceptable to discard silt to the downstream area, either during the discontinuance works or once the works have been done. Plans will also be have to be made to deal with silt that is left within the basin for a number of reasons:-

    - to ensure it is not eroded and transferred to the stream downstream
    - that it remains stable
    - that perhaps re-vegetates

  - that is safe in that it allows public access for fishermen etc and it is not polluted

- Public access – thought has to be given to future public access to the site if this is to be allowed or even encouraged. The access will have to be safe, not put people at risk from deep water, soft sediments, steep slopes etc. Consideration will have to be given to public use of any residential body of water and the access they require.

- Materials used – in discontinuing a dam it is usual either to remove the dam completely or to partially breach the dam. The majority of dams in the UK are earthfill embankments and this will involve excavation of earthfill, removal of upstream protection facilities which might be masonry, or concrete etc. In some cases the material is buried or spread in the basin, in other cases the fill is sold, particularly where it is dressed stone, and in rare occasions moved off site where landfill costs will be incurred.

  The final form of the basin may involve a residual water body formed. It is often necessary to reform the original stream in the bed of the reservoir and often opportunity is taken to meander the stream and induce provision for fish, marginal plants etc. Whatever the form of the basin it is common for some sort of erosion protection within the stream bed and therefore in the breach or point at which it crosses any cutoff. The 'best' and perhaps most acceptable schemes are likely to use 'natural' or local materials rather than systems such as wire gabions etc.

Communication

In any civil engineering project communication must be a key element. It is essential once the draft proposal is fairly well defined that the public and land use organisations are involved. This is not only to get those people to 'buy' into the proposals but also to get agreement to the proposals perhaps more importantly have an input to the scheme. They will often have a significant amount of knowledge and experience relevant to the project or indeed may well have suggestions for improvements and changes. Often the dam engineers do not have those skills so the communication process is essential.

At the time of the works there is often much to be learned. It might be that the discontinuance process involves demolition of the structure, which if done in the planned way, can yield useful information on how our old dams were built, the condition of pipes and valves after many years of use, core materials – sampling and establishing core materials etc.

There is an opportunity to inform the public about the site – perhaps about the former use particularly if the dam formed part of our industrial heritage, about the construction of the dams and the features seen on site. The opportunity should be given to industrial archaeologists to study the site prior to and during the breaching process. Communication forms might include pamphlets, story boards, information books, information packs depending on the site – its size and extent and the degree of public access.

CASE HISTORIES

The following case histories describe five projects involving the discontinuance of reservoirs which are very different in nature but which have achieved the objectives set by the client.

Westworth Reservoir

Location	-	Guisborough
Owner	-	Northumbrian Water
Dam	-	Earthfill, 11.3 metres high, 118 metres long
		Reservoir capacity 69,200 cubic metres

Westworth Reservoir was owned by Northumbrian Water and was situated some 3 kilometres south east of Guisborough. It was used for water supply but in 2001 the company decided to look into the possibility of discontinuance.

Westworth dam construction was completed by 1875 to supply water for Gisborough Hall and the town of Guisborough in the Cleveland Hills, close to Teeside. The water supply system was replaced in the early 1970's but the reservoir retained as it was thought to be a useful forestry fire fighting water supply. However by the 1990's vandalism to the dam's structure was becoming a problem and fires were being lit to dry clothes after swimming in the reservoir; to cook etc. thus creating a fire risk.

Westworth dam was built following a Water Order in 1871, but at a revised location chosen later by the consulting engineer Sheriton Holmes of Newcastle and constructed during 1874 to 1875. Westworth's reliable yield was less than 2Mld and in dry weather was not able to support Guisborough's water demand. In 1878 proposals were made to increase the reservoir inflows with catchwaters, subsequently carried out with puddle clay lined channels.

The recorded details gave Westworth's capacity at 69.2 thousand m^3, a surface area of 11,800 m^2 and maximum height of 11.31 m with 105m crest length. The overflow weir was 6.1m long giving 2.45m freeboard to the top

of the embankment. There were three 7" draw-offs connecting into the 12" valve shaft pipework and linked into the 12" scour draw-off horizontally to two downstream 12" valves allowing flow to treatment or to the river.

The dam had been inspected routinely since the 1930 Act. The last inspection recommended that the reservoir be taken out of the 1975 Act's juristiction or that remedial works were carried out to allow the reservoir to remain in use. The land owner, Lord Gisborough, did not want any water retaining and accordingly plans were made for the dam to be breached and the area landscaped. North Yorkshire National Parks became keenly interested and wanted the water area retaining as they said it was a migratory bird resting place, although strangely the Supervising Engineer could not remember seeing any birds resting there since his first visits in 1978.

The downstream face had a slope of 1 in 2.2 with a berm about 3 m wide at one third height. The upstream face was covered by stone pitching and had a slope of 1 in 3. The crest had a width was 4 m wide and was supported by a substantial vertical stone wall between 1.0 and 1.5 m high.

The options studied into the future of the reservoir included:-

- repair and retention
- discontinuance by breaching the full height of the embankment
- discontinuance by partial breaching the full height of the embankment
- discontinuance by partial filling of the reservoir
- abandonment by the construction of an embankment diversion pipe or culvert.

There was an overflow at the left hand end of the dam some 6.1 m wide with a stone channel running away from the river. A masonry valve shaft was located at the toe of the upstream slope at the mid part of the reservoir.

The condition of the dam was adequate but major works had been identified including:-

- complete refurbishment of the valve tower with the inclusion of an access bridge
- lining of the scour pipe
- repairs to the pitching and inclusion of rip-rap protection
- repair the spillway

An ecological and environmental study was undertaken. The study found that the aquatic habitats of the reservoir were somewhat impoverished due to acidifications and it supported an extremely limited fauna with no aquatic macrophytes. The key habitat around the reservoir was upland heath with areas of wet heath and heather moorland. Upland heath is a key habitat in the UK Biodiversity Action Plan whilst wet heath is a priority habitat in the EU Habitats Directive. The area is also designated as 'criteria moorland' under the 1981 Wildlife and Countryside Act as part of the National Park Plan for the North Yorkshire Moors.

Objections to Discontinuance

As it happened no one from North Yorkshire National Park (NYNP) had visited the reservoir and they had made an uninformed comment – later they admitted the water did not support either aquatic plants or fish and so was no attraction to birds.

Then the local County Archaeologist wanted the whole site preserving (again he had never visited the site) and had visions of a gravity buttress dam with granite blocks. After being shown the site he concluded that it was not what he thought and was happy with a descriptive panel showing it 'as it was' and leaving the valley abutments to indicate where the dam was. Clearly the breaching of the dam and restoration of the site would result in the loss of open water habitats and marginal habitats but because the reservoir had relatively limited nature conservation value it was recognised as not being significant.

The recommendations of the various parties were:-

- minimise construction impacts on adjacent heathland by prescribing working area
- create a land form which retains wet areas alongside streamside
- establish heather and grassland on the site by transfer of cuttings
- control any bracken invasion of the new landform.

Demolition eventually commenced in summer 2002 and progressed well once the contractor learnt to deal with clays and not top soil. The dam was breached by autumn 2002 and the stub ends of the dam trimmed with a toothless excavator bucket. This revealed the well-formed puddle clay core which was still well defined, very pliable. The core width increased by about the classic 1" horizontally for 1' depth on each face. However of much more interest was the defined shape of the original dam and the later clay addition as the dam was raised. The first dam's upstream toe was also discovered with the original stone valve tower base. This tower stonework

had been re-used to form the later tower and only the original base was left within the original embankment.

The valve tower was partially dismantled to make it safe and the pipework removed. The pipe material was in excellent condition although being vertically cast illustrated clearly the incorrect alignment of the inner and outer moulds. The valves were to James Nasmyth patent (developed in 1839 at the request of the East London Water Company) and remained in operational condition.

Reinstatement of the reservoir area was confined to spreading and grading the dam material. No 'artificial' seeding was carried out to encourage native species to colonise the area. This led to the spread material being exposed for a long time – and still not fully green – so the material became incised as stream paths developed with the eroded fine material deposited in the original stream beds that became quite fertile. Relatively lush growth has established in the streams retaining in flowing material and now water moves in a stream-delta formation towards the new outlet weir.

The cost of the works was of the order of £100k.

Fig 1: Disused Westworth Reservoir

ENSURING RESERVOIR SAFETY

Lightwood Reservoir

Location	-	Buxton, Derbyshire
Owner	-	Severn Trent Water
Dam	-	Earthfill, 13.4 m high, 105 m long Reservoir capacity: 73,363 m^3 (large reservoir); Less than 25,000 m^3 (smaller reservoir).

Haswell Consulting Engineers were commissioned by the Undertaker, Severn Trent Water (STW), in March 2004 to investigate the feasibility of decommissioning Lightwood Reservoir (actually 2 reservoirs) and removing it from the ambit of the Reservoirs Act 1975.

Lightwood Reservoir was situated on the northern outskirts of Buxton, Derbyshire, just outside the Peak District National Park. The reservoirs consisted of a cascade of an upper and lower reservoir, divided by an earth embankment, with connecting weir. Water passed through the upper reservoir flowed over the weir into the lower reservoir. Spillage from the lower reservoir took place over the main outlet weir which discharged into the bywash channel. The lower reservoir was impounded by an earth embankment which was brick lined on the upstream face and which extends above top water level to form a wave wall. The original purpose of the dam was to impound water, for water supply, for the town of Buxton.

The Reservoirs were fed by Hogshaw Brook via a penstock into the top (small) reservoir. A bywash channel existed to the Western side of the reservoir to take excess flow when the reservoir was full. The construction of the reservoirs was concrete lined with brick facing on the lower basin & stone facing on the older upper reservoir. (Fig. 2)

Fig. 2: Upper reservoir looking in a southerly direction

Problems

The issues associated with the discontinuance of Lightwood Reservoir are detailed below.

Social/Environmental

The reservoir was an attractive feature in the local landscape, and was used for legitimate purposes such as dog exercising and walking. However, the water bodies also attracted less desirable activities, such as outdoor parties, camping, and swimming with associated problems such as alcohol and drug abuse.

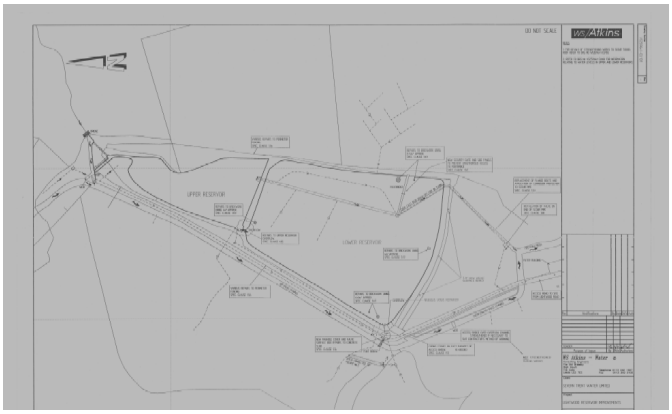

Fig. 3: Lightwood Reservoir Plan

The local residents in the roads leading up to the site were worried about the loss of habitat from the complete disappearance of the water bodies, but also were aware that if the reservoirs were removed, the anti-social behaviour would be greatly reduced, if not cease altogether. They therefore supported the discontinuance, but requested that some water remained for the birds and other form of wildlife which inhabited the reservoirs.

Fig. 4: Lower Reservoir Construction

Design considerations

The Landscape Architect to the consultants, in consultation with the ecologist, agreed that the normal approach to reservoir discontinuance (ie: to

just form a V-notch in the dam wall), would not be appropriate in this case, and that the entire base and sides of the reservoirs should be demolished and the whole site returned to a natural valley.

Due to the presence of a significant number of water-loving bird species and before demolition of the main reservoir, a small pool was formed at the top of the site within the curtilage of the small reservoir to allow birds to return for breeding (some actually continued to breed during the major earthmove!)

The scope of the project was to drain down the existing reservoirs, break out the concrete and brick liners, demolish the water tower and valve chambers, cut a V-notch in the lower dam wall, and using the arisings from the dams to re-profile the sides of the reservoir to form a natural valley shape, with a stream at the base feeding 4 pools, which were created to encourage wildlife and aquatic vegetation. (Fig.5) All the materials arising from the earthworks including the concrete and brick were buried on site.

Fig. 5: View from position of top reservoir looking south

Scheme recognition

This discontinuance has won 2 awards since its completion. The first was a platinum award at Severn Trent Waters' Corporate Responsibility Awards in 2006, and the latest was a Commendation at the Landscape Institute's Awards in 2007. The judges for the Landscape Institute Awards, which is an International Awards Programme, commented that *'It artfully removed a negative activity by re-establishing the power of the landscape. Low budget, high impact. Demonstrates the subliminal art of landscape.'*

Barbrook & Ramsley Reservoirs

Location	-	Nr Chesterfield, Derbyshire
Owner	-	Severn Trent Water
Dams	-	Earthfill, 10m high at Barbrook/ 8.65m high at Ramsley, Reservoir capacities 310,000 m^3 (Barbrook) 76,800 m^3 (Ramsley)

Barbrook Reservoir is situated on Big Moor, approximately 12 km northwest of Chesterfield,and had a catchment area of 3.4 km². (Fig. 6) The reservoir, formed by two earth embankments, had the main dam running NE/SW across Bar Brook, and the side dam at right angles to it, running SE/NW. Both dams had a central puddle clay core. A masonry step-overflow weir was situated at the north east end of the main dam, with the spillway channel running down the northeast mitre where it joined the tunnel tailbay channel. (Fig. 7).

Draw-off arrangements were incorporated into a cast iron segmental valve shaft built into the upstream face of the main embankment (Fig. 5). Three levels of draw-off were connected to a downpipe and a common draw-off main laid within a cast iron, segmental tunnel, which has now been capped off. The main had been severed at the downstream end of the tunnel where water discharged into the tailbay and brook, which ran into the downstream and still existing Little Barbrook Reservoir. The iron and steel components of the tunnel shaft had become so severely corroded that safe operation of the draw-off valves was no longer possible. At the foot of the dam was the site of a water treatment works which was demolished many years ago. The reservoir had not been used for water supply since the mid seventies. The reservoir was also located within the Peak National Park and had been designated a SSSI.

Description of Works

The work involved the breach of the main embankment by excavating a 'V' shaped full height void and demolition of existing structures. At the deepest point, a 4m wide channel was formed to take the stream flow, with the sides of the breach graded to slopes of 1:3. The work comprised of the execution of the following:

- Protection of existing services
- Demolition of the Draw Off Tower and Walkway
- Excavation in the reservoir basin
- Excavation in the reservoir embankments
- Re-profiling of reservoir embankment
- Landscaping works

Project Aims

- Discontinuance
- Habitat Creation
- Flora and fauna
- Sustainable Result

ENSURING RESERVOIR SAFETY

- Minimum Maintenance
- Minimal impact of construction

Project methodology
Silt traps installed downstream.
Reservoir drained over a period of 4 weeks.
Water monitored for sediment content.

Fig. 6: Valve tower and Bridge

Fig 7: Masonry step overflow weir

In order to maintain the flow of the Bar Brook during the excavation work a 'V' notch was cut to one side of the draw off tunnel and the stream allowed to flow through the tunnel. This was sealed upon completion.

The course of the brook was allowed to form naturally through the reservoir basin (Fig 8). From historical records the brook appeared to return to a similar course to that which existed before the dam was built.

Fig. 8 Course of stream allowed to follow natural course

Fig. 9: Stone weir discovered buried

There was a flexible approach to the work on site. The stone weir shown below was discovered buried in the silt after work started. It was decided to utilize it as part of the reinstated water course and to form a pool near the head of the reservoir.

Fig. 10: Pools created in reservoir basin

As part of the habitat creation work clay excavated from the core of the dam was used to create pools in the reservoir basin. (Fig. 10). One of the aims of the project was to retain and reuse materials on site as far as possible. In the event only scrap metal from the draw off tower and some timber had to be removed from site.

Ramsley Reservoir (1880 to 2003) is situated on the edge of Ramsley Moor, approximately 10 kilometres northwest of Chesterfield, Derbyshire, Ramsley had a small, direct catchment area of 52.6 hectares. Additional inflow came from water imported via a 300 mm (12") diameter earthenware pipeline from Little Barbrook Reservoir, which has now been capped off, some 2.5 kilometres away. The earth embankment dam had a puddle clay core with the upstream face of the dam having stone pitched armouring. The embankment had settled unevenly during its life and there were some visible signs of slight but continuous seepage. Changes to the overflow and spillway were made in 1990 and a sleeved outlet pipe was installed in 1985. Despite these improvements, the reservoir, in its present form, could not meet today's standards and it was uncertain whether it would withstand an extreme flood.

The reservoir was originally used as a source of supply to Smeekley Treatment Works, Crowhole Reservoir and Linacre Upper Reservoir. Smeekley has since been abandoned and Crowhole discontinued. The reservoir was also located within the Peak National Park and had been designated a SSSI.

A single contract was let for the discontinuance of both Barbrook and Ramsley reservoirs. The project aims at Ramsley were similar to those at Barbrook but on a smaller scale. (Fig. 11). It also did not have the problem of having a sizeable water course running through the basin.

Fig. 11: Pools created in reservoir basin

Stanley Moor Reservoir

Location	-	Buxton, Derbyshire
Owner	-	Severn Trent Water
Dam	-	Earth embankment with clay apron on Upstream face, 13.7m high, 630m long Reservoir capacity 244,100 cubic metres.

Stanley Moor Reservoir was a small, rectangular, impounding structure, formed on three sides by earth embankments and founded partly on limestone and partly on millstone grits. The whole of the inside was lined with puddle clay with a protective layer of masonry pitching. The reservoir had not been used as a water supply source for over twenty years. The principal feeds were two nearby streams, to the west and to the north; the flow being intercepted and directed through aqueducts to the intake chute, by the operation of "leaping weir" sluices.

On first filling, appreciable leakage occurred due to defects in the clay blanket. Strenuous but unsuccessful attempts were made to overcome the inherent problem caused by the underlying material being honeycombed by solution holes and caverns. Eminent dam engineers of the period, including Sir Alexander Binnie & William Binnie, were all involved by giving their advice or by making statements, as expert witnesses, in the action taken by Buxton Council against the Engineers. A statement from one of the experts that *"I have never seen better work than that showed in the Stanley Moor Reservoir; and I have never seen a site so plainly and almost hopelessly bad"* seems to summarise all the opinions voiced at the time.

Finally, the working top water level was reduced by 10 feet and, in 1946, the original overflow weir and spillway was superseded by the construction of a low level weir channel and 36 inch overflow culvert, passing through the embankment. The capacity was thus reduced from 450,000m³ to 275,000m³. The works comprised of:

- Breach of the embankment by excavating 26,000m^3 of material.
- Demolition of Draw Off Tower, Walkway and reinforced concrete Draw Off Culvert.
- Demolition of Overflow Structure
- Landscaping

Contract value £178,000

The embankment was breached by cutting a 'V' notch in the embankment at the position of the draw off tower and culvert and forming a channel through the notch to allow all incoming waters to exit the reservoir basin into the spill channel at the toe of the dam (Fig. 12). Before work could start an inlet diversion ditch had to be dug to divert the inlet water from the inlet weir to the spill channel (Fig. 13).

All the excavated material and masonry lining resulting from the formation of the notch was retained on site to line the bottom of the reservoir, pools and scrapes for habitat creation and embankments within the reservoir basin. The masonry lining removed from the area of the 'V' notch was used to line the new channel and the surplus buried under the mounding formed from the excavated material. It was not considered economic to sell the surplus stone.

Fig. 12: Spill channel

Fig. 13: Inlet diversion ditch

('V' notch location)

Fig. 14: View of the reservoir from the west showing the 'V' notch, pools and embankments formed in the reservoir basin.

SUMMARY AND CONCLUSION

This paper illustrates via case histories that the discontinuance of dams is often not a cheap or easy option.

It is clear that when a dam is discontinued it can be carried out in a variety of ways and the way in which this is done will often de dictated by the final result and land use that is required. It will always be necessary to communicate and consult with the public and other interested parties to achieve the 'most acceptable' result.