



THE NATIONAL TRUST

Sediment Management & Dredging in Lakes

A report based on a workshop held at
Arlington Court, Devon
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Dredging in progress at Kedleston. Simon Hiley.

Edited & compiled by Katherine Hearn, Jon Flanders & Tamzin Phillips,
Conservation Directorate, The National Trust, Cirencester.
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1. SUMMARY

- There are *serious problems with siltation* in lakes – huge quantities of sediment, being delivered in short periods of time. The problems have become very much more severe in recent years. [Para No.] [3; 5]
- Lakes themselves and open water have various values*, including historical, archaeological, aesthetic, design and biological. Habitats which develop as lakes undergo the process of infilling have various biological values, in some cases higher than the lake itself. [4.1; 4.2; 4.3; Box 1]
- The sediment in situ has various values too* – chemical, biological and archaeological. [4.1; 4.2; Box 2; Box 3]
- Lakes should preferably not be dredged*. Dredging causes damage and loss to various interests, eg archaeological and biological. It is costly. It can destroy the lake lining. Disposing of the spoil is difficult – it is dangerous, can remain ‘weedy’ for long periods, the receptor site can be damaged, and lagoons etc. may be in place for several years. They can be extensive and unsightly. The spoil is rarely of significant value to agricultural land. There are many legal and other constraints. [4.1; 4.2; 8.1; 8.2; 8.3; Box 8; Box 10]
- Natural lakes* should never be dredged. They are unlikely to infill except over very long timescales, and if they do this should be accepted. For *artificial lakes which are part of a historic designed landscape*, there may be a case for dredging. For *artificial lakes with natural characteristics*, there may be a case but this is less likely. In all cases objectives should be examined critically. [3; 4.3]
- To avoid the necessity for dredging, *lakes should be kept as pristine as possible*, to reduce sedimentation generated from within the lake. There are various ways of mitigating sediment accumulation in lakes. [6.1; 6.2; Box 7]
- Look at the inflows and water sources* in the immediate catchment and ensure these are diffuse, to deliver water and sediment as slowly as possible to the lake, allowing flooding before the lake is reached. Repair and correct operation of control structures may be a necessity. [5.3; Box 2; Box 4; Box 5]
- Look to the catchment* and the main sources of water, sediment and pollutants – map drainage networks, estimate risks from different land-uses and sites, mitigate via Whole Farm Plans and other means. In some cases it will be necessary to investigate ground water sources as well. [5; Box 5]
- Look at the natural setting* such as geology, topography and the natural river system – these may predispose an on-line lake to sediment accumulation which is difficult to deal with without many problems. [5; Box 10]

If inputs of sediment cannot be prevented, there is a good reason to postpone dredging until they can be prevented or at least significantly reduced.

Look downstream – not only for legal constraints, but because National Trust lake management may be affecting water quality downstream (and there might be financial reward, or penalty!). [8.1; 8.2]

There are various ***‘good practice’ points associated with dredging***, including prior studies; partial dredging rather than wholesale in area; taking the upper layers only, leaving the lower; suction rather than bucket; leaving littoral fringe, and avoiding damage to edges. [4.1; 7.3]

The ***legal implications of ‘getting it wrong’ are serious***. [7.1; 7.2; 8.2]



2. INTRODUCTION AND PURPOSE OF REPORT

The National Trust owns a great number of lakes. Rapid infilling with sediment, and the perceived need to dredge, is a major issue at many of them, especially ornamental lakes. There are high financial costs associated with dredging (twelve lakes with dredging projects currently planned or in train, for example, have a combined cost of £863,000) and dredging has damaging environmental and other impacts.

There is little published work on this topic. A workshop was convened at Arlington Court in March 2002 to discuss the subject, and this report is based on presentations given at the workshop, with additional information. It is intended to provide information for National Trust staff involved in management of lakes, especially lakes in lowland landscapes currently threatened by excessive quantities of sediment.

3. THE PROS AND CONS OF SEDIMENT AND DREDGING - AN OVERVIEW

Sediment is a mixture of organic and inorganic material washed into lakes from the catchment and generated within the lake. By far the most abundant component in lowland lakes is silt (soil) washed in from the catchment. Sediment is natural in lakes, and its presence is inevitable.

In large lakes sediment is never an issue. All lakes infill, but in natural lakes it is very rare for infill to occur rapidly. As lakes do fill in, many interesting habitats occur – the process of infill itself is of interest and value and should ideally be allowed to proceed without interference.

Sediment in lakes has various valuable attributes. These are covered in Section 4, but in brief they include:

- a substratum for plants and hence many associated organisms;
- a source of energy for the lake ecosystem;
- a chemical buffering function;
- holding a historic record.

However, there are problems associated with sediment. Land use issues, poor catchment management and excessive erosion result in excessive quantities of sediment. Sediment accumulation results in the loss of open water which is a serious problem in landscape parks and other sites where retaining open water is important.

With the sediment come phosphate and nitrate which cause enrichment or eutrophication of the lake, very poor water quality and algal blooms. The sediment acts as a store of phosphorus, which ‘leaks’ out into the water, causing long-term pollution.

These can be real problems. There may also be perceived problems – a tendency to think that lakes are infilling fast when there is no evidence, and to assume that regular dredging is a normal aspect of lake management.

Should the sediment be dredged out, then? There is only one example known where dredging has solved a eutrophication problem (Lake Trummen in Sweden, but even this is not a straightforward case), because some sediment is always left behind. To solve eutrophication, a whole package of measures is needed to reduce silt input and sedimentation within the lake (see sections 5 and 6), although dredging may play a part in this.

Dredging may make eutrophication worse. The dredging operation and / or the spoil disposal process may damage habitats and soils in or near the lake. Huge quantities of spoil can be involved. It can be difficult to find a suitable receptor site for the spoil. If settling lagoons are needed, these are hazardous and ugly. The legal constraints are onerous.

Dredging can recreate the valuable landscape feature of open water. However, even this may be only a short-lived result if the sediment inputs from the catchment and / or the lake itself are not reduced.

Before undertaking dredging, the pros and cons should be examined carefully. Is there really a problem or can the sediment better be left *in situ*? Is change and infill necessarily a bad thing? If open water is desirable, could a new lake be created elsewhere? Is the sediment source and the rate of deposition known? Can the causes of infill be treated first? Is the lake itself managed appropriately? Is dredging and spoil disposal actually practicable, without seriously damaging the habitat and its surrounds? There will be cases where there are better long-term solutions to dredging.

As a rule of thumb:

Natural lakes – never intervene.

Naturalised artificial lakes – ideally don't intervene; weigh up the disadvantages carefully.

Artificial lakes which are part of a historic designed landscape – there may be a better case for dredging, but again, there should be thorough assessment of the pros and cons and the causes of infill should be addressed first.

4. THE INTERESTS AND CONSERVATION VALUES OF SEDIMENT

4.1. Ecological values and processes

- a. Sediment provides the substrate for rooted aquatic plants. Aquatic plants provide the 'architecture' of the habitat and are essential for good water quality and the healthy functioning of many types of lake. Many processes depend on aquatic plants which in turn depend on the sediment. Sediment which is loose, amorphous or regularly disturbed does not provide a suitable rooting medium for plants. Firm, structured sediments are characteristic of lakes in good condition.
- b. The sediment at the edges of lakes, in the littoral zone, supports 90% of the biodiversity of a lake. This is a particularly important zone to protect. It is richest where there is a gently sloping profile, as opposed to an abrupt edge. Marginal sediment helps protect banks from erosion.
- c. The habitats that develop on accumulating sediment may be more important than the open water itself, for example fen and reed bed, wet grasslands and wet carr woodland.

- d. Even the bare, dark sediments under deep water are important, eg. for oligochaete worms and Chironomid midge larvae. These provide food for bream and other predators, and when they emerge as adults they provide important food for birds and amphibians.
- e. Many chemical processes take place in lake sediments. Sediments are normally lacking in oxygen, except at their surface. Bacteria living in the anaerobic sediments utilise nitrate to meet their respiratory needs, in the absence of oxygen. This process turns nitrate, which can be a harmful pollutant in excessive quantities, into an inert form. Thus the sediments provide important 'factories' for de-nitrifying water, and act as chemical buffers. The same process occurs in waterlogged, anaerobic soils around the edges of lakes and these too are therefore valuable nitrate buffers.
- f. The sediments release nutrients into the water. Of these, phosphorus has a particularly important impact, causing algal blooms and a decline in water quality. The amount of phosphate released from the sediments will depend on many factors, such as pH, oxygen abundance, amount of iron and amount of organic matter. It can be released in quantity when deep, de-oxygenated sediments are disturbed and agitated. This can occur during storms, but disturbance is particularly severe when dredging occurs.
- g. 'Leakage' of phosphorous also takes place from bankside spoil after dredging – water draining from dredged sediment may be rich in phosphate and sometimes in nitrate (but from an agricultural point of view the sediment is not rich in these nutrients - see Section 8.3).
- h. The sediments provide nutrients for plants growing in the lake – both larger aquatic plants and microscopic algae. This is returned to the sediment in detritus when the plants die.

From an ecological point of view, lakes and ponds should be allowed to infill naturally. If open waters are required, new lakes and ponds should be created nearby. If this is not possible, loss of open water should generally be accepted. Nationally this is one habitat which has increased significantly in recent years, mainly due to gravel extraction.

Dredging lakes is hardly ever desirable on ecological grounds because of the damage caused to the lake and the surrounding land, and because of the interest of all the various stages associated with sediment accumulation and the 'terrestrialisation' of lakes. However, there may be an argument that removing the sediment will remove a source of phosphorous and improve water quality. This should not be assumed. Sediment characteristics and chemistry should be investigated first, along with other aspects of sedimentation.

If dredging is carried out, from an ecological point of view it is important to:

- leave the littoral fringe with marginal vegetation along a significant proportion of the banks;
- ensure there is a gently graded bank, rather than an abrupt one;
- leave part of the lake undredged so that propagules from aquatic plants can recolonise quickly;
- consider the best methods and time of year to do the work (see section 7.3).

4.2. Historical and archaeological values of lakes and lake sediments

Lakes and other water features are often of high archaeological and palaeo-environmental significance. Lakes in designed parks and landscapes are on the whole “man-made” and must therefore be considered archaeological monuments in their own right.

Lakes are significant for four main reasons:

- for their place in the history of the landscape;
- because of what they can tell us about construction techniques, drainage and water management;
- because waterlogged conditions are ideal for the conservation of organic remains, such as timbers, and palaeo-environmental evidence, such as pollen;
- because the remains in the sediment allow the reconstruction of the history of the lake and its surrounds.

The role of the archaeologist is to ensure that these features retain as much of their archaeological significance as possible, and that the evidence they contain can be used to inform their conservation, management and future use.

To plan the future of a lake, its past should be investigated first. Sediment is actually a collection of mineral grains and an amorphous ‘goo’ which contains pigments, for example from different algae. There are pollen grains and ‘fossils’ including diatoms and crustacean remains which can be used to reconstruct lake ecology. For example, in a reconstruction from Blea Tarn (Cumbria), a natural glacial lake which has sediments overlying glacial clay, deposited from 13,000 BC, diatoms show that fertility declines with time, because glacial lakes were inherently very fertile at the start, and then inputs declined as the landscapes vegetated and stabilised, this is contrary to the usual assumption that fertility has naturally increased overall since landscapes were populated by man. However, there is indeed a human-induced artificial fertility rise in recent centuries. The history of the Norfolk Broads, and the recent eutrophication phases, has been elucidated from the sediments.

Archaeological issues are illustrated by reference to three National Trust properties in the boxes which follow.

In summary, it is essential to consider the following points:

- Involve an archaeologist at the earliest stages of any proposed dredging operation or works likely to impact upon the structure of historic lakes – this is particularly relevant to lakes and other water features covered by Scheduled Monument designation;
- Recognise that dredging can have a considerable impact upon archaeological and palaeo-environmental evidence, and consider alternative solutions;
- Work and plan together to achieve shared objectives, eg nature conservation, archaeology, access and landscape conservation;
- Use archaeological and palaeo-environmental evidence to inform conservation and future management.

Box 1 Case study: Croome Park Lake, Worcestershire – Archaeological values of lakes

The landscape park at Croome was laid out by Capability Brown in the 1760s, and he created a lake and lakeside gardens from an area of previously marshy ground. Excavations around the site of the Grotto revealed an original land drain used to clear the marsh before landscaping could begin. Temporary lowering of the lake waters in 1998 revealed some of the construction details, including timber revetments around one of the islands, as well as stone sets laid into the bank used to both shore up the sides and stop cattle poaching along the lengths of the so-called Croome River. Also evident in the low waters were some of the surviving timbers from the boathouse. Subsequent excavation around the Grotto revealed how water was supplied to both the lake and the coade-stone nymph Sabrina, spirit of the River Severn.

If and when the lake is dredged then arrangements will be made for an archaeological watching brief.

Box 2 Case study: St John's Jerusalem, Kent – A moat and related features

A moated medieval site – dating back as early as 1190 when it was given to the Knights of St John of Jerusalem. The moat is on the line of the River Darent. Its dredging history is not known; there are no records of dredging except for one episode in 1984. However, recently it was decided that it should be dredged to recreate a Country Life picture of the 1930's, when it was clear of vegetation and almost a mirror pool. Dredging was started, until its status as a Scheduled Monument (SM) was noted, upon which the dredging had to stop.

Although SM Consent has now been received, fears have been raised over the sustainability of dredging. If there is excessive off-site soil erosion caused by intensive arable cultivation the moat could be re-silted within a matter of a few years. There have been problems with abstraction and low flows in the River Darent, so there could be doubts about adequate water supply. If there is archaeological value in the sediment it could be lost if the moat is dredged. The moat leaks; if a clay liner was present it may have been damaged by the dredging in 1984. Most importantly, there is a series of weirs and sluices that were used to steer the water around, through and off the property, possibly linked with old ponds and a water meadow system. These are in various states of disuse. In the past, high winter flows in the river would have been used to flush out the sediment.

A package of measures is likely to be needed here, rather than simply dredging. The Environment Agency (EA) has worked to restore adequate flows to the River Darent, and the supply is currently ample (even with a leaking moat), but this situation needs to be monitored with the EA. The sediment supply is not currently too great for management within the moat system, if the control structures work. Survey of the control structures, disused water features and river flows is needed. Following this, management measures may include:

- reinstatement of the control structures, ideally linked with restoration of the other water features as well as the moat;
- localised and careful dredging to enable efficient functioning of the control structures;
- localised repair of eroded banks to restore the original width of the moat;
- hand removal of some clumps of vegetation from the channel;
- coppicing of large trees that may damage and breach the moat edge.

A note on moats:

Moats should be treated with exceptional care. They are often puddled and this puddled lining is often very fragile. The exact location of the bed lining must be very carefully surveyed first before any interference. A cautionary tale is provided by a site in London. In an attempt to find the lining of the moat, a bulldozer was used which dug to 1 metre, then deeper, ultimately to 4 metres, without finding it. Later with a careful hand augering survey it was found at 70 centimetres. Meanwhile of course it had been totally destroyed and it is doubtful if it can be repaired.

Box 3 Case study: Lyveden New Bield, Northamptonshire – Elizabethan water garden sediments

This property has an Elizabethan garden with a series of moats which had infilled. English Heritage had approved Scheduled Monument Consent for dredging, but concern was raised over the archaeological value of the sediments and pollen record. A pollen analysis was carried out by Huddersfield University in advance of the dredging which revealed interesting sediments from lower in the sequence. The interesting layers contained a much lower component of surviving organic material, and were therefore a different (paler) colour and texture (i.e. the uninteresting sediment was black and sludgy). The pollen record revealed a vegetation history from the earliest period of planting in the 16th century up to the present day, including evidence of meadowsweet, anemones, bur-marigold and saxifrage, as well as herbs such as coriander, parsley, fennel and celery. As no documentary records survived of the early planting, this was the only evidence that survived of the early garden vegetation.

So the solution was to remove the upper, more recent sediments, leaving the lower sediments *in situ*. The dredging was done with a machine mounted on a floating pontoon. There was some archaeological supervision as the operator got used to the idea of the silt which had to be removed and that which had to be left. The removed silt was then field-walked, confirming that on the whole the appropriate material had been removed.

The value of the site to garden history is very much greater than its nature conservation value. Nevertheless nature conservation interests were taken into account throughout. It was thought important to formulate shared objectives.

Other initiatives here were:

- to leave a littoral fringe;
- to leave some woody debris in the water in places (for its positive effect on water quality)
- to use the opportunity to take out the fish, and to manage the moats as fish-free in the future (for the beneficial effects on water quality);
- to convert arable land in the (very small) catchment to permanent grass;
- to ensure that one-time inflows into the moat system, which are small ditches, are well wooded and very stable, and hardly functioning as conduits. This is an important principle, allowing water delivery by slow seepage through the soil, ensuring a more consistent supply year-round and better water quality.

4.3. The Values of Open Water - Lakes in Landscape Parks

Open water is a main focus in many gardens and landscape parks, and in these situations sediment is usually regarded as a problem, rather than a feature of any value.

It is important to maintain the qualities that make water special in gardens and landscape parks. Water and lakes have a special magnetism. There is animation of the water surface; reflections, and clear, mirror effects; feelings of space with water and sky.

Different types of water body have different characters. For some, such as in the very formal water gardens at Fountains Abbey, a clean, crisp outline and reflection are an integral part of the design. Formal canals are essentially tanks, and have straight, hard sides. On the other hand, water was one of the three main elements of the 18th century classical arcadia – grass, water and trees – and here nature is imitated with the creation of lakes.

Almost all waterbodies in designed landscapes are artificial – they are created by damming and slowing down streams or rivers and are therefore inherently liable to silt up.

Issues which may be linked with excessive sediment in lakes, and which need to be considered in relation to maintaining open water include:

- excessive numbers of geese and ducks, causing water quality problems and puddling of edges of water bodies (eg at Claremont and Winkworth);
- algal blooms and loss of reflections tend to detract from the ‘picture’ and visitors’ enjoyment;
- indirect effects of climate change: changing land-use in the catchment and increased run-off and sediment loads can affect gardens, such as Westbury Court Garden. Flooding is the main issue here, rather than sediment, but it raises the dilemma of the ‘sustainable’ solution, which may be to abandon a garden with its water courses and re-create a garden elsewhere, or re-direct resources to rescuing another similar garden.

It is important to identify the significance and the relative importance of different features and the individual qualities of each particular place. Then the costs of maintaining lakes as open water, which may be considerable, can then be assessed.

5. MANAGING SEDIMENT INPUT FROM THE CATCHMENT

Excessive sediment in lakes causes many problems. As already stated, most sediment in lakes is actually soil from the catchment. Phosphorus, which is one of the main causes of enrichment and eutrophication in lakes, exists as a compound attached to clay and other minerals in soil. Thus when soil is washed into lakes, phosphorus comes with it. Nitrate, the other main nutrient associated with pollution and enrichment, is soluble and arrives in inflows and run-off dissolved in water. To prevent pollution, and to reduce the need for dredging it is important that sediment inputs from the catchment are reduced.

Streams move through the landscape and accumulate and transport sediments. Lakes act as a ‘throttle’ on this moving stream of sediment. Canalisation of rivers means that they no longer flood and dump their sediment, and they now erode more fiercely and mobilise more sediment. There is more sediment in the system, and more of this is deposited in lakes.

Quantities of sediment from the catchment will vary according to the size of the catchment, the types of soil, the steepness of slopes, the nature of the stream channel, the ‘spateyness’ of the flow, the opportunity for flooding and deposition of sediment before the lake is reached, the type of farming and the farming techniques. There will be some catchments where features will combine to yield huge quantities, and in these cases major changes in land-use and /or the river system may be the only way of solving the problem.

The National Trust has a Soil Protection Policy (National Trust, 1999). One aspect of this is that the Trust should remedy the un-natural and greatly accelerated erosion of soil (sediment) that is affecting much of its land. This will have a significant effect in reducing or slowing the infill of lakes.

5.1. Managing sediment in arable landscapes

In arable landscapes soil erosion has increased significantly due to changes in arable rotations, increase in autumn cultivations, use of heavy machinery, irrigation, de-stoning of soils, and many factors which have rendered soil entirely unstable and unstructured.

There is a range of methods which can be used to reduce erosion, and to stop eroding soil reaching lakes. These include ensuring soil has a good organic matter content, retaining surface roughness in fields, sowing spring crops and leaving ground fallow in autumn and winter, and re-instating hedges, field ponds, grass waterways and other interceptors.

5.2. Managing sediment in livestock grazing systems

The sediment does not just come from arable landscapes, as may be suspected. In livestock-grazed landscapes, sediment source budgets show that poached stream banks are a major source of sediment, and that sediment from banks has increased very dramatically over recent years. This is due to increased grazing intensity, pasture management (re-seeding and fertiliser use changing soil characteristics) and the collapse of old stock watering structures, replacing these with barbed wire.

Mitigation is relatively straight forward, and can include reductions in stocking levels, careful siting of feeders and gateways, fencing of river and lake banks, retention of wetlands and 'spongy' features in the landscape, and a raft of measures to encourage good infiltration capacity in soils.

These issues should be addressed with tenants and through Whole Farm Plans and agri-schemes. There are many sources of further information, for example, the MAFF (now DEFRA) booklets 1997 – 1999 and the Environment Agency's Best Farming Practices manual (2000).

5.3. Pathways for sediment movement – streams and rivers

The movement of sediment in streams and rivers should ideally be slow, with many opportunities for flooding and deposition before the lake is reached. Restoration of natural channels from deepened, straightened channels can be an effective way of reducing silt input to a lake.

Artificial drains around lakes will accelerate delivery of silt. The more slowly water seeps into the lake, from multiple and diffuse points, the more effectively will it be stripped of the silt and pollutants that it carries. Restoring tile or historic drainage systems around lakes can therefore have damaging impacts.

5.4. Pathways for sediment movement – tracks, roads and other features

The pathways for movement of sediment in the catchment are not just rivers, streams, ditches and springs. They include roads and tracks, gullies within fields, gateways, compacted access routes and other features. Roads and farm and forestry tracks are particularly effective delivery systems for sediment. They may only be active during storms and heavy downpours, but this is when the sediment is moved extremely efficiently.

When problem areas are known, connections to streams can be diverted, or interrupted using settling ponds or physical barriers. Track surfaces can be kept well grassed wherever possible, and gateways can be moved. Wherever possible lakes should be isolated from all these pathways.

5.5. Erosion Risk Maps for catchments

The pathways for movement of sediment in the catchment should be mapped. As noted, pathways include roads, tracks and other features, as well as rivers and streams. The extent of the whole network is best seen and mapped after heavy rain.

As well as the delivery network, the map should show the factors contributing to risk of sediment erosion, particularly crop or farming type, soil type and slope angle. A Risk Map has been produced for the Penrose Estate, around Loe Pool in Cornwall, which provides a worked example (Haycock, 1999).

Reference to the Risk Map will highlight the key areas where mitigation measures should be put in place, land-use changed, or where delivery pathways should be altered. They should be prepared for all sites where infill or pollution of lakes is a concern. The large ‘tool kit’ of measures to prevent sediments reaching lakes can then be employed.

Box 4 Case study: Calke Abbey Catchment Study – A Simple Approach

The ancient park at Calke has a string of three medieval fish ponds created by damming a small stream. The catchment is wholly National Trust-owned. It is on clay soils, mainly used for dairying and pasture. Despite the relatively ‘unerodible’ soil type, a considerable amount of sediment washes down the water courses into the ponds. Having dredged one pond, a catchment appraisal was carried out before contemplating further dredging.

This was done by Nick Haycock of Haycock Associates and took one day to cover approximately 300 hectares.

A number of ‘hot spots’ were identified and mapped, which are yielding excessive amounts of sediment, and /or possibly polluted water. These included:

- poached pastures;
- one arable field adjacent to a stream;
- stock access to a stream;
- a farm track running down into a stream;
- a road haulage yard;
- a pond heavily stocked with ducks.

By contrast, a number of features were located which are already performing valuable roles in sediment retention, and which were therefore of particular value. These included:

- an undisturbed stream channel with an array of natural features (meanders, bars, etc.) and woody debris in the stream, all of which trap sediment;
- ‘grass waterways’ which are ditches with the ideal profile, ie very shallow bank, and 100% vegetation cover in the ditch;
- numerous small pools and ponds along water courses – mostly very small (a couple of metres across, for instance) but valuable sediment traps;
- pastures with ‘old grassland’ which was grazed without being poached;
- a poplar plantation, which was acting as a valuable sediment trap.

Mitigation measures were identified to deal with the problems. The overall finding was that with a series of fairly minor interventions a great deal of difference could be achieved in the sediment coming down into the lakes.

5.6. Management of Catchments outside National Trust ownership

It is possible to influence management to benefit National Trust lakes, most effectively in partnership with other bodies, and other owners or users affected by activities in the catchment. In the case of Loe Pool in Cornwall, partnership with the Environment Agency, English Nature, the Local Authority and others has resulted in new agri-scheme initiatives covering extensive areas of land above the Trust’s ownership. At Calke Abbey, the downstream owner, Severn Trent Water, financed lake management (in this case dredging) because of the benefits to a reservoir.

Issues of concern should be conveyed to the Environment Agency. If not addressed in the current Local Environment Agency Plan, they should be included in the River Basin Management Plans to be prepared under the Water Framework Directive. This is EU legislation introduced in 2000, under which all freshwater habitats – not just SSSIs – must be in, or restored to, a ‘good ecological state’.

Box 5 Case study: Croome Park Catchment Study – Is it possible to re-create a mirror lake?

The lake at Croome (see Box 1) has accreted 1 metre of sediment in 16 years, and there is now ‘aggressive’ reed and *Typha* growth. The visual aspiration is a mirror lake - totally open water, with no visible vegetation. For this, pristine water quality is needed. This places a huge demand on the water quality in this particular catchment (a stock and arable farming area, crossed by the M5 motorway), and makes it very important to hunt down all the sources of sediment and pollution in the catchment. This has been done.

The findings are:

- There are many high-risk sources of sediment in the catchment - cattle housing, rape fields, maize fields, and high numbers of sheep. Only part of the catchment is in National Trust ownership, and there is as yet no control on many of these inputs.
- The soil type is prone to erosion.

- The nutrient inputs, too, are very considerable from these sources. For nutrients, it is important to identify critical ground water areas as well as superficial drainage routes. These can be some distance away from the water body, as is the case here.
- The nutrient loadings are such that even under permanent vegetation and with a 70% reduction in stocking there will be pollution.
- Run-off from the M5 requires special interception measures.

A created wetland effective for the filtering of the measured quantities of water and sediment would need to be 3 hectares in size. This would reduce the flow of water into the lake. So added to water quality problems, there will be water quantity issues here too.

Croome is an excellent example of the scale and nature of the change that needs to be instituted to deal with the problem of lake silt. Even with a Grade 1 landscape there is an argument here that open water – let alone a mirror lake - is not a sustainable option at this point in time.

6. MANAGING LAKES TO REDUCE SEDIMENTATION RATE

Although most of the sediment in lakes comes from the catchment, as described in section 5, some of it is generated within the lake. Lakes in good condition have relatively slow sedimentation rates. On the other hand, excessive amounts of sediment are generated in lakes in poor condition. Lakes in ‘good condition’ have clear water and submerged plants present, and a scarcity or low availability of nutrients. ‘Poor condition’ is linked with excessive enrichment and high fertility (eutrophication), turbid water, low amounts of dissolved oxygen, few or no aquatic plants, and prolonged and frequent algal blooms.

Various factors influence the condition of lakes, as outlined in 6.1. These can be controlled by management. Ideally every National Trust lake should have clear water and submerged plants. There are also various measures, some acceptable and some not, which can be used to mitigate sedimentation and poor condition in lakes as outlined in 6.2.

A full and very readable account of this topic is given in Moss (1996).

6.1. Factors influencing the amount of sediment in lakes

6.1.1. Aquatic plants

A lake in good condition will have a good cover of submerged and / or floating aquatic vegetation, in water depths to about 3 metres, with several species present rather than a monoculture. These plants oxygenate the water. They also provide refuges for zooplankton (small crustaceans) which graze on the phytoplankton or microscopic algae, which otherwise proliferate and cause algal blooms.

The aquatic plants should be cherished. Cutting or removing them can cause the lake to become dominated by algae. Once this happens, the sediment becomes shaded by turbid water or mats of blanket weed, and it becomes loose and amorphous due to the ‘rain’ of detritus from dying algae. Both these factors make re-establishment of rooted aquatic plants very difficult.

Lakes dominated by algae can have a more rapid sedimentation rate. When the blooms die, the dying cells add considerably to the lake sediments and speed up infill.

If there are no submerged aquatic plants, and the water depth is suitable, efforts should be made to restore them. Unfortunately algal dominance can be a stable and long-term state and restoration of aquatic plants can be difficult.

6.1.2. Marginal vegetation

Fringing vegetation, too, is important for the health of the lake. It acts as a physical filter for incoming sediment (and phosphorus), and as mentioned previously vegetation in waterlogged sediment acts as a buffer against nitrate. Buffering the lake protects against algal blooms.

Fringing vegetation also protects the banks from erosion (by stock, geese and waterfowl, people or boats). Eroding banks can supply significant quantities of sediment.

There can be a dilemma with conserving marginal vegetation in lakes in which clear, crisp outlines are deemed important from a design point of view. Without marginal vegetation, water quality must be approaching pristine if the lake is not to suffer unacceptable algal blooms and a faster sedimentation rate.

6.1.3. Sediment disturbance

Although sediments 'leak' nutrients into the water all the time, the release of nutrients, particularly phosphate, is severe when sediments are disturbed. Undisturbed sediments in well oxygenated water have an oxygenated surface layer or 'crust' in which phosphate is bound and inert, and this layer helps prevent diffusion of phosphate into the water.

Disturbance of sediments during dredging is often followed by severe algal blooms.

6.1.4. Fish

Fish can cause enrichment problems via their effect on the aquatic plants. Bottom-feeding fish, particularly carp, disturb the lake sediments and make it difficult for plants to root. They can also enrich the water with their faeces. Large numbers of roach and rudd and some other species can deplete the beneficial zooplankton population, allowing the algae to bloom. Fish should be regularly removed from lakes to give the desired species composition and biomass. Further detail is given in the Trust's guidelines for the Management of Freshwater Fisheries (Lewis, 1999).

6.1.5. Birds

Large numbers of waterfowl - ducks, geese and swans - can cause serious eutrophication problems, particularly if they are in un-naturally high numbers because of artificial feeding or provision of nesting islands or platforms. They graze, trample and damage the aquatic plants, enrich, puddle and erode surrounding grassland, and directly enrich the water. It will be a high priority to reduce numbers if lake condition is to be improved.

6.2. Measures to mitigate sedimentation, and its effects, in lakes

The main mitigation measures will lie in the catchment, and in lake management as outlined above. However, there are useful mitigation measures, particularly silt traps and other structures as in 6.2.1. below. Most of the other methods are either damaging to the ecology of the lake, or expensive and / or not generally applicable.

6.2.1. Silt traps and constructed wetlands

It is most important to reduce catchment sediment inputs, and to allow flooding and spilling out of the main lake inflows before they reach the lake. There may be many natural silt traps in place already (see Box 4). However, with on-line lakes, construction of small shallow ponds or silt traps upstream, which can be easily dredged out, will help reduce siltation of the lake. Dry hollows can also be effective, or depressions behind barriers, eg. of railway sleepers. Constructed reed beds are also effective at trapping sediment.

6.2.2. Lake Bypasses

A lake with an on-line stream can be bypassed using a ditch, or a pipe system (see Boxes 6 and 7).

Box 6 Case study: The Dredging Programme and Associated Projects at Kedleston Hall, Derbyshire

The upper of two large on-line lakes in this Grade 1 Robert Adam landscape park was dredged on acquisition of the property in 1987. The dredgings were put in a quarry, which they filled. It cost £11,000. In ten years the lake had infilled again. This time, in 1997, the lake was drained down completely and about 35,000 cubic metres of silt were removed and spread on adjacent land within the park. This has been levelled and is grazed and topped. It was decided to undertake other works at the same time, e.g. repairing a boathouse, and clearing trees from the Island and re-boarding the edges.

Three years earlier, in 1994, a higher lake was dug out to act as a silt trap. This was dug to a depth of about 3 metres, thinking this would suffice for many years. The spoil was spread adjacent to the lake. It was covered with thistles and weeds for about three or four years, but is now grass-covered and grazed by sheep in the summer period. This silt trap, too, has now filled in and continues to silt up.

The catchment of the lakes is extensive, mainly in arable cultivation, and not owned by the Trust. Before any further works could begin on the lakes, it was decided that by-passing the lakes was essential. Several options were considered. Permanent spun concrete pipes were used. These were buried and the ground re-landscaped. Some pipes had crude sluice gates so that the flow of water could be regulated. They cost approximately £12,000 - £15,000 each. There are four in place, the longest being some 320 metres and the shortest 120 metres.

It has been agreed that a catchment land use appraisal is an urgent priority as soon as agreement with the owners can be obtained.

Box 7 Case study: Lake Bypass at Bosherton Lakes, Stackpole, Pembrokeshire

A three-armed lake system at Stackpole is a National Nature Reserve and SSSI with a very rich aquatic flora and fauna. The water quality has declined over the years due to sewage inputs and intensive agriculture in the catchment. Old fish ponds in the upper reaches of the system had infilled. Detailed studies and monitoring have been necessary to fully understand these trends.

Sediments, which are a major source of enrichment, have not been dredged from the main lakes because of the narrow valley topography, difficult access and the lack of anywhere suitable in the SSSI to put the dredgings. However, some suction dredging may be undertaken, with disposal outside the SSSI.

The problems have been remedied by various means:

- Work has been done in the catchment to reduce nutrient inputs from farmland (eg improved slurry storage). However, run-off from farmland remains the most serious problem (1,000 cubic metres of silt was taken out of silt traps after one wet winter).
- A major source of nutrient-enriched water from one lake arm has been piped to discharge to the sea, thus ensuring it does not back up and affect other better-quality arms. This was done using a 56 centimetres diameter polyethylene pipe, weighted with concrete sleeves, which was sunk on to the lake bed and connected with a sluice at the seaward end. Water is only diverted through the pipe during the late spring and summer when nutrient loadings are greatest due to low lake levels and lack of dilution.
- The old ponds, and some new ones further upstream, have been re-excavated to act as silt traps. Five main pools have been dug since 1993.
- Aquatic vegetation is harvested. This is done to help reduce the amount of recyclable nutrients. The vegetation is cut at a depth of 1 metre from a flat-bottomed punt and the cut material is taken on board. The work is extremely expensive (£30 per tonne, removing about 100 tonnes per year) and, more importantly, hazardous ecologically. If the vigour and variety of the vegetation declined, this could cause a fast and rapid deterioration in the quality of the site. The vegetation is carefully monitored.

6.2.3. Flushing out

Sluices and other structures, if in place, can be used to regularly flush out lakes and remove accumulating silt – see Box 2. Note that resuspension of silt could constitute infringement of the Water Resources Act 1991 (see section 8.2), so the Environment Agency must be consulted first.

6.2.4. Precipitators and other additives

Iron salts can be added to the water or injected into the sediment to bind to phosphate and suppress its release from the sediment. There are many problems with this practice (eg. keeping the salts *in situ*, adding adequate salts, high costs, unsightly iron-stained water and unknown long-term effects) and it should generally be avoided in Trust lakes.

The addition of ground chalk products is reputed to remove accumulations of organic matter in sediment by altering the pH and stimulating microbial activity. Artificial alteration of pH is undesirable, and such products should generally be avoided.

6.2.5. Use of barley straw

Barley straw can be used to control algal blooms in ponds and small lakes. This is a common practice, and can be effective. Information can be obtained from the Centre for Aquatic Plant Management (0118 969 0072; www.capm.org.uk).

6.2.6. Vegetation harvesting

Cutting and removing aquatic vegetation can reduce nutrient availability to a limited extent, but has many risks and should not be undertaken without a detailed ecological investigation. See Box 7.

6.2.7. Artificial aerators

These mix and oxygenate the water column, and disperse algal blooms. Such mixing is not natural, and long-term effects on lake ecology are not known.

7. PRACTICALITIES OF DREDGING – SCOPING THE PROJECT

Dredging and the disposal of the spoil is a complex operation with many legal and Health and Safety implications. This document is not an exhaustive account of all of these; there follows an outline of some of the considerations with reference to a case study. The Manual of Building provides relevant guidance (see References for recommended sections).

Box 8: The Arlington Checklist

Some details of the dredging project at Arlington Court, Devon are given in Box 10. This is a checklist, with some additions, outlining the scope of a dredging project. The lead-in time from initial Management Plan to starting the works was five years. Documentation has been kept relating to all the stages of the project.

SURVEYS AND PLANNING

- Initial surveys to establish significance and values of features relating to lake and surrounding land (Biological Survey etc.);
- Preparation of Property Management Plan or Conservation Plan, including specific objectives for the lake;
- Assessment of sedimentation processes – sedimentation rate and dredging history researched, including:
 - sediment sources – from catchment
 - sediment sources from within lake / immediate surrounds
 - river flow data, retention time and flushing rate calculated;
- Level Survey of lake bed and silt depth, and survey of surrounding ground;
- Identification of mitigation measures as part of assessments;
- Identification of related but separate projects to be carried out at the same time;
- Identification of downstream users and issues that might be affected, and consultation with Environment Agency on this;
- Feasibility study of all options, costed [at Arlington the options were: do nothing, dredging with installation of a lake bypass, and dredging without a bypass, with different time scales and area coverage for the dredging];
- Cost / benefit analysis of options with respect to objectives;
- Assessment of dam and water control structures, compliance with Reservoirs Act;
- Analysis of silt for toxic elements and other substances as required under Environment Agency Waste Management Licence Regulations (WMLR) (see 8.2 below);
- Archaeological analysis of silt cores to determine horizons of likely value.

Plans drawn up for area and depth of lake to be dredged (at Arlington the area / depth dredged was constrained by the interests of the SSSI and the need to comply with WMLR).

Initial Health and Safety Plan.

CONSENTS

- English Heritage or equivalent for Scheduled Monuments;
- English Nature or equivalent for SSSI's;
- DEFRA for European Protected species (see section 7.2 below);
- English Nature or equivalent for other protected species;
- Access consent for roads / bridges;
- Rights of Way may require Temporary Diversion Order from Highways Authorities;
- Water Abstraction Licence from Environment Agency if lake is to go 'off line' while work in process;
- Discharge Consent from Environment Agency could be required if resuspended silt is to affect downstream users;
- Discharge Consent from Environment Agency for liquid to flow from any lagoons;
- WLMR Exemption (note: can take two years to negotiate) (see 8.2);
- Land Drainage Consent from Environment Agency for 'development' of lagoons on flood plain;
- Derogation from Countryside Stewardship Scheme for construction of lagoons on scheme land;
- Planning permission from Local Authority for construction of features such as access tracks and lagoons;
- Construction (Design and Management) Regulations under Health and Safety Executive for construction of lagoons;
- Compliance with Reservoirs Act 1973 requires any work on a dam to be supervised by a Panel Engineer (any water body holding 25,000 cubic metres of water or more, above the natural level of the land, comes under the Reservoirs Act, enforced by the Local Authority);
- Notification of construction works to County Council under Reservoirs Act 28 days before work.

7.1. Health and Safety implications

There are many health and safety implications, including the following: Use of boats for initial survey of the lake requires a risk assessment. If divers are used, this requires compliance with the Diving at Work Regulations and amateur divers or local sub-aqua clubs should not be used.

As well as hazards arising from the use of excavating machinery there will be issues concerning emergency procedures (eg if the excavator gets stuck), prevention of public access, and health hazards for staff or contractors involved, eg Weil's disease, tetanus.

There are further implications for the disposal of spoil in lagoons – see below.

7.2. Protected species

There are two main categories of protected species:

7.2.1. Species protected under European legislation

These are listed in the 'Habitats and Species Directive' (1992), implemented by the Conservation (Natural Habitats etc) Regulations 1994. The European protected species which may occur in or by lakes and be protected under the legislation are:

- all bats
- great crested newt
- otter
- natterjack toad
- floating-leaved water plantain

If any of these species are present and any form of disturbance or development is proposed, a special licence may be needed from DEFRA (England), the National Assembly for Wales (Wales) or the Environment and Heritage Service (Northern Ireland). The licence will only be approved if there are satisfactory mitigation measures. In the first instance the statutory nature conservation body should be consulted for a preliminary site visit and advice.

7.2.2 Species protected under UK legislation.

Species are protected under the Wildlife and Countryside Act 1981, with enhancements introduced in the Countryside and Rights of Way Act 2000.

Birds: most birds are protected from intentional killing and their eggs and nests are protected. If a species is listed on Schedule 1 of the Wildlife and Countryside Act it has additional protection, ie from disturbance while nesting. Examples on Schedule 1 commonly found by National Trust lakes include kingfisher.

Other animals: If a species is listed on Schedule 5 of the Wildlife and Countryside Act it is protected from one or all of killing, taking, disturbance while it is sheltering, and disturbance, damage or destruction of places where it shelters. Species commonly found in lakes include water vole (full protection) and white-clawed or Atlantic crayfish. Other forms of protection apply to other animals.

Plants: All plants are protected from uprooting by unauthorised people. In addition plants listed on Schedule 8 cannot be picked or destroyed.

For species on the schedules it is necessary to obtain consent for the works from the statutory nature conservation body (English Nature, Countryside Council for Wales or Environment and Heritage Service (Northern Ireland)).

Box 9 Case study: White-Clawed Crayfish at Kedleston

In September 2000, during repair works to the weir between the middle and lower lakes, a strong population of white-clawed crayfish was found. This species is protected as regards taking from the wild. EMEC Consultancy (under licence from English Nature) were commissioned to translocate over 900 individual crayfish from the weir pool area, and, following the works, to investigate whether the crayfish survived at their transfer sites and successfully recolonised the weir pool.

The crayfish were transferred from the drained sections of the lake (between temporary bunds) near the weir to remaining lakeside habitats above and below the weir. Six months later only twenty crayfish were found, all restricted to an area just above the repaired weir, though four individuals were juveniles suggesting that a breeding population survives. There is no evidence that the translocated crayfish stayed in other areas of the lakes where much of the habitat was unsuitable due to high levels of sedimentation, extensive growths of filamentous algae, and a lack of suitable refugia such as loose rubble and tree roots where the crayfish shelter.

It is probably too early for the crayfish to have recolonised the weir pool, but EMEC Consultancy regard the addition of rubble in sufficient quantity, so that it does not get covered in silt, as likely to aid their recolonisation and survival.

7.3. Methods and timing for dredging

7.3.1. Methods

There are two main methods for dredging – bucket dredging and suction dredging. Bucket dredging involves bulk digging out of silt from the lake, drained if necessary, either with long-reach excavators from the shoreline or with excavators floated on barges on the lake, with the spoil being put either into barges or directly into trucks for removal.

Suction dredging involves removal of sediment by pumping out a slurry of water and sediment and piping this out of the lake. It has the advantage of being more ‘sensitive’ than bucket dredging, with less damage caused to shoreline profiles, and better-targetted removal of specified layers of sediment. However, bucket dredging can be accurate – see Box 3, Lyveden New Field case study.

7.3.2. Timing

Overall, the best time to carry out dredging is probably late summer.

There will be damage to aquatic wildlife at whatever time of year dredging (and drainage) is carried out. Some aquatic invertebrates are hibernating in marginal sediments in the winter, so winter is the best time from this point of view. For breeding birds and amphibians the period February to July should be avoided (from January to February for herons). For important aquatic plants least damage will be done in early spring before they are in full growth but when conditions are becoming suitable for root fragments to re-grow. Re-growth could also take place in the autumn if there are no early frosts. From a nutrient point of view, if plant material is removed in summer, some (albeit probably a very small proportion) of the lake nutrients will be removed in the plant material, so it would be beneficial to dredge at this time.

The most important consideration is probably damage to soils and surrounding habitat from heavy equipment, and so a period when soils are dry is best, ie in summer. There will be other considerations such as inconvenience for visitors, and the condition of the receptor site for the spoil, eg arable fields post-harvest.

8. DISPOSAL OF SPOIL

Disposal of spoil is a major and complex part of the dredging operation, as indicated by the Checklist of consents and other constraints outlined in Box 8. It may be the single constraint which prevents a dredging operation going ahead, or demands a better long-term solution – for examples see Boxes 7 and 10.

Huge quantities of spoil may be involved: for each centimetre of sediment removed from a hectare of lake bed, 1,000 tonnes of sediment slurry will need to be disposed of. This will settle to 100 tonnes of wet sediment, and then dry out to 10 cubic metres of material.

8.1. De-watering of spoil – lagoons

Spoil can be transferred direct to land, but it is usual to construct lagoons bounded by raised bunds in order to allow the sediment to dry out so that it is less bulky for disposal. Often an extensive series of lagoons is needed. The lagoons may need to be in place for 2 years or maybe more. Alternatively the bunds and the contents can be left in situ and levelled and the land restored. The rank and weedy vegetation that colonises spoil can take up to 25 years to disappear (experience from Clumber Park, Notts), although if grazed and cut intensively it can disappear in three years.

Constraints include:

Siting – lagoons cannot be sited on the floodplain of a river without consent from the Environment Agency. There will be other constraints such as accessibility, nature conservation, archaeology, landscape, and visitor access.

A Discharge Consent is required from the Environment Agency for the water and fine particles draining from the lagoon. This may be rich in phosphate and other nutrients and should not be allowed to flow straight back into the lake. A pathway and interception system may need to be devised to allow percolation through soil or vegetation.

Planning consent may be required from the Local Authority, as lagoons can be described as “building, engineering, mining or other operations in, on, over or under land” (Section 55 of the Town and Country Planning Act). Consent may not be needed if a lagoon is very small, but in each case the local development control officer should be consulted.

There are many Health and Safety considerations associated with the lagoons. The construction of the lagoons will require a site risk assessment if it is to be carried out by staff. Consideration needs to be given to staff competence to use the machinery involved. If contractors are to carry out the work, then either the “General Requirements for Building Work” or the “General Requirements and Conditions for Countryside and Garden Work” need to be used – see Manual of Building, 2002. If the construction involves building earth banks, or excavation, it is possible that the work will fall under the Construction (Design and Management) Regulations, with the required procedures which are best covered in the Manual of Building document “Practice Notes for Major Projects”.

Depending on the depth of the lagoon, and its location in relation to places the public can go, consideration should be given to preventing access by the public and warning signs.

There are also visitor safety aspects associated with the movement of heavy machinery around a property, hazards arising from work in proximity to overhead power lines, and hazards from underground cables and services if excavation is required.

Lagoons need to be fenced from stock access – even when seemingly dry, animals can become stuck and drown in the sediment.

Box 10 Case study: Spoil Disposal Dilemmas at Arlington, Devon

Arlington Lake was created by damming the River Yeo in the 19th century. The geology is Devonian slates; there are fine slatey soils with very little water retention before erosion takes place on slopes. The catchment area is large, and only 10% is National Trust-owned. There is maize and even vegetable cultivation in the catchment (on soils which should support pasture) and very heavy silt burdens come down the river (the sediment stays in suspension for up to 5-6 hours and rapidly deposits when the river slows down). The topography of the valley concentrates this flow and silt input.

The lake infills excessively rapidly and has been dredged several times. Every ten years 10,000 cubic metres needs to be removed, which equates to 3,000 truck movements (at 500 cubic metres = 150 truckloads). The lake is less than half its 'original maximum' size and in fact started to silt up rapidly soon after creation. The decision has been taken that it is important to retain some open water, at approximately its extent of the 1970's.

The recent dredging operation has utilised five bunded lagoons for the silt on the floodplain immediately below the lake, covering an area about the size of the lake (1.25 hectares). These lagoons will be in place for approximately two years for dewatering, then they and their contents will be left to receive more dredgings. The present lot of spoil cannot be removed because of its huge volume, the number of truck movements that would be involved (see above), and the very narrow track down to the site.

Future management

There is only space in the lagoons for one more load of dredged sediment. After this 'other means' of disposal would be needed. No one knows what these might be, unless technology is developed to pump sediment up hill!

The option of an up-stream silt trap has been rejected due to the heavy traffic which would be needed to empty it, i.e. 150 truck movements in and out per annum! There is no other suitable site further upstream on National Trust land due to the narrow nature of the valley.

The option of a stream by-pass round the lake has been rejected on the grounds of cost (£460,000 including dredging) and the disposal of the dredgings.

The option of doing nothing has many merits (environmental impact negligible; operating costs low; sustainable in the long-term). However, the lake falls under the Reservoirs Act which means that unless the 'reservoir' can be decommissioned, which itself might be very difficult and costly, the dam has to be maintained.

8.2. Legal implications of spoil disposal

The options for spreading spoil from lake or river dredging are on land, or as landfill.

For spreading on land, this can be:

- on adjacent bank/towpath, or
- off-site on agricultural land, or
- on a land reclamation scheme (if suitable).

Disposing in landfill should be regarded as a last resort only; it is expensive and capacity is restricted. Non-inert waste is likely to have to go to landfill.

8.2.1. Spoil and Waste Management Licence Regulations

Spoil or dredgings are 'controlled waste' as produced by premises used for recreation and require disposal under section 75 of the Environment Protection Act (EPA) 1990. A Waste Management Licence is needed under the terms of the EPA 1990, unless exemptions are granted. Conditions attached to the licensing are given in the Waste Management Licence Regulations (WLMR)1994. Exemptions are:

- the spreading of waste for soil improvement on land used for agriculture
- the spreading of waterway dredgings on banks or towpaths.

As a general principle any dredging project should obtain exemption and avoid the need for a Waste Management Licence under the terms of the EPA 1990.

8.2.2. Details of exemptions from Waste Management Licensing (notes from Schedule 3 of the Regulations):

Exempt Activity (para no.)	Description and Threshold
7. Spreading waste for soil improvement <i>(Occupiers or owners consent and register with WRA)</i>	< 5,000t/ha/yr, dredging from any inland waters. Related storage in secure container or lagoon, of septic tank sludge; other related storage at point of spreading only, liquids in secure containers or lagoons < 500t capacity.
25. Waterway dredgings <i>(Occupiers or owners consent and register with WRA)</i>	Depositing, and associated screening or dewatering, 50t/m/day* of: own dredgings or plant matter from inland waters on own banks or towpaths; same on any inland waterway bank or towpath for ecological or agricultural benefit; does not apply to waste deposited in a container or lagoon. *ie total amount of waste deposited on any day must not exceed 50 tonnes for each metre of bank of the watercourse being dredged
Note also exemption in para 15 may be relevant – see 8.4	

The tonnage of the material spread is as applied, whether wet or dry.

8.2.3. Applications for exemptions from WMLR

To apply for exemptions the Environment Agency will require the following (Schedule 3 from the WMLR):

- a map of the area showing the lake and disposal area;
- evidence of benefit to agricultural land. This will be a nutrient analysis of the soil and dredgings (pH, phosphorus (P), potassium (K), magnesium (Mg) and organic matter (OM)%) (see section 8.3 below);
- compliance with the overriding control of ‘relevant objectives’ of paragraph 4 of the WMLR, i.e. ensuring that the waste is recovered or disposed of without endangering human health and without using processes and methods which could harm the environment and in particular without:
 - risk to water, air, soil, plants or animals, or
 - causing nuisance through noise or odours, or
 - adversely affecting the countryside or places of special interest.

8.2.4. Other requirements of the Environment Agency

These are:

- no deposition in the flood plain of a river. Any deposit must be more than 7 metres from a watercourse;
- Discharge Consent – could be required if dredging is a regular event (‘regular’ would probably be in the order of twice a year). More usually an agreed method statement must be prepared with monitoring of any discharge of supernatant (liquid remaining after soils have settled) to a watercourse if using holding / settlement lagoons. Monitoring will be of pH, ammonia and turbidity (supernatant = liquid remaining after solids have settled);
- An Abstraction License would be required if the lake is to become ‘off-stream’ with a controlled structure.

8.2.5. Legal Implications of ‘getting it wrong’

Failure to obtain exemption from WMLR before spreading spoil could result in prosecution. In addition, offences can be committed under criminal law or civil law.

Under criminal law:

Resuspension of silt from a pond or lake could cause downstream water to become ‘poisonous’. It is an offence under section 85 (1) of the Water Resources Act 1991 if anyone “causes or knowingly permits any poisonous, noxious or polluting matter or any solid waste matter to enter any controlled waters”. It could cause fish mortalities downstream.

Under civil law:

It is an offence to cause interference with legitimate downstream users or riparian owners, for example fish farmers or angling clubs. Compensation could be payable and sums can be huge.

8.3. Spreading sediment on agricultural land – its nutrient value

It is often assumed that dredged sediment will be of value for its fertility, when spread to land.

The spreading of sediment spoil is covered by the Waste Management Licensing Regulations (WLMR)1994 as described above. To qualify for an exemption from licensing, to spread the spoil on agricultural land, there must be benefit to agriculture and no damage should be caused to the soil or its flora and fauna. All application of waste materials to soil must be in quantities and at frequencies which convey positive benefits. In order to keep within the terms of the exemption it will be essential to establish, on the basis of properly qualified advice, what application rate is appropriate for each site being dredged and each receptor site.

The starting point for a “Statement of Benefits” is chemical analysis of the sediment spoil and the receptor soil. Both sediment and soil are analysed for crop nutrients, pH and organic matter, and for potentially toxic elements (PTEs).

8.3.1. Possible benefits - how ‘useful’ is the sediment spoil?

Sample analyses on material from Croome Landscape Park, Arlington Court and Stowe Landscape Gardens

The results of these showed the spoil to be of negligible value in terms of crop nutrients.

- Nitrate and ammonium content (available nitrogen, i.e. that which is available for use by the current crop) – content extremely low, eg at Croome equivalent to 1–2 grams per tonne. This would be expected to disappear altogether during drying and composting. Compare this with 460 kilos of nitrogen per tonne of urea, 345 kilos per tonne in ammonium nitrate fertiliser, or 6 kilos per tonne in farmyard manure!
- Note that in Nitrate Vulnerable Zones (NVZs) total N has to be calculated. Total N includes all forms of organic nitrogen which may become slowly available over time. In NVZs, under the compliance rules, there is a 250 kg/ha limit on the total organic N which can be applied annually. This limit will be reached sooner than the max 5000 tonnes/ha/yr of dredgings that can be applied under the WMLR (see 8.2.2).
- Phosphorus (P) and potassium (K) content – low, similar in range to that found in most UK soils. The application rates would have to be huge if the spoil was used as a complete replacement for the annual P and K crop requirement. In terms of P, if the receiving soil had particularly low P then there might be a minor positive benefit of adding the spoil. For K, massive volumes of spoil would be needed. For example to meet the potassium requirement of winter wheat 1 tonne of spoil per square metre would need to be added.

8.3.2. Possible disbenefits of spreading sediment

Potentially toxic elements could be a problem. Because lake sediments contain the smallest sediment particles, there are often PTEs present and these can be concentrated to levels which could be unacceptable. There could be other undesirable elements or compounds in the spoil, depending on the geology and land-use upstream of the lake.

Canal dredgings could contain toxic residues from industry; use by pleasure craft which may have left a legacy of tri-butyl tin (from anti-fouling paints) and from sewage, before the “waste stations” were introduced. Copper and zinc levels may be high near outdoor pig units, and cadmium contamination is associated with phosphate fertiliser.

Other disadvantages would also arise: traffic movements transporting very large quantities of spoil would cause compaction and potentially severe and long-term damage to soils.

8.3.3. Conclusion

The concentration of plant nutrients in sediments analysed to date has been very low. To use the sediment spoil to supply crop nutrients at an agriculturally significant level, therefore, is not an option. With application rates in terms of hundreds of tonnes per hectare, the logistics and potential for soil damage are unacceptable.

However, a “Statement of Benefits” is required to qualify the spreading activity on agricultural land for exemption under WMLR. The regulations are written in a way which allows broad interpretation. Addition of organic matter from spoil would be of value in many arable situations - in this case one would need an application delivering more than 20 tonnes of organic matter per hectare to make a noticeable difference to soil organic matter. It could be argued that *any* application of spoil could assist in the maintenance of soil fertility.

It is possible that spoil might also be applied to *reduce* soil fertility with the objective of increasing biodiversity, but this has not yet been investigated.

The Waste Management Licensing Regulations (WMLR) are relatively recent and to some extent it is up to applicants for exemptions under “agricultural or ecological benefit” to define and establish precedents for interpretation of the Regulations.

8.4 Spreading sediment in gardens

It has been suggested by National Trust staff that dredged sediment could be used as a soil conditioner in gardens, possibly mixed with other materials, and composted. There is no obvious category of exemption from the Waste Management Licensing Regulations (see 8.2) for this use, and no Trust experience in trying to gain an exemption. However, the Environment Agency may view this use favourably and suggest that para 15 of Schedule 3 of the Regulations could be relevant. This states that “beneficial use of waste” can be exempt. Details should be discussed with the EA locally.

9. CONSULTANTS AND RECOMMENDED OPERATORS

The Dredging industry is huge and there are an enormous number of contractors who will do works on small-scale ornamental water bodies - as well as canals and ports. Contractors for all stages of the operation, and to oversee the whole project, can be found. Land and Water Services has equipment suitable for a wide range of sites and operations and has been recommended by several users (01483 202733; www.land-water.co.uk). The National Trust

contributors to this report listed at the end of the document may be able to advise other Trust staff on contractors and other aspects of dredging operations.

Box 11 Case study: The Wimpole Experience – What Can Go Wrong...

The Hall is situated in a Grade 1 Landscape created by a number of landscape architects including Capability Brown. There are three lakes, Upper, Middle and Lower. The upper one infilled some time ago and has not been re-instated but the Middle and Lower Lakes have been re-instated by dredging. Also the Lower Lake has had a replacement dam which had failed early in the 20th century

The dredgings from both the lakes were spread onto adjacent arable fields which were then reinstated to parkland pastures.

The issues arising from this were:

- Danger - the dredgings were deep and dangerous. It took three years before the disposal site could be walked over safely, so there were major health and safety implications for visitors, and cattle got stuck and had to be pulled out.
- Dredging changed the hydrology of the lower lake and resulted in many of the lakeside and nearby trees dying.
- Engineers levelled the dam/lake wrongly! When the work was done it was noticed that the lower lake had insufficient depth of water: almost one quarter was dry and one half was extremely shallow. More work was done to the new dam to raise water levels.
- The effect of grazing animals on the lake edges is a mixed blessing. On the plus side they can help create a gentle and stable profile to the lake edge, but on the negative side they generate a lot of sediment and can cause damage to earth dam walls and lake sides.
- Initially there were algal blooms resulting in very offensive smells and causing an unsightly mess, this cleared up after two years when the sediment settled.
- Carp were introduced to the lake as fingerlings. Unfortunately this has caused the re-suspension of phosphate-rich sediments with the result of algal blooms and loss of fresh water plants.

A moral: it is easy to lose biodiversity by dredging to keep open water. Obtain Biological Survey reports before work is done and look at the relative values of the wetland habitats. There was a suggestion that the Upper Lake, now a willow carr, should be restored. However, new biological information indicates that the Upper Lake has many rare 'ancient wetland' invertebrates, as well as water vole and occasionally otter. It has been agreed to leave this lake site undisturbed.

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CONTRIBUTORS TO THESE GUIDELINES

Bill Cove, Head Warden, Calke Abbey, East Midlands
Simon Damant, Property Manager, Wimpole, East Anglia
Richard Ellis, Head Warden, Stackpole Estate, Pembrokeshire, Wales
Jon Flanders, Undergraduate Assistant (Nature Conservation), Cirencester
Nick Haycock, Haycock Associates
Katherine Hearn, Nature Conservation Adviser, Cirencester
Simon Hiley, Head Warden, Kedleston Park, East Midlands
John Kay, Farm Waste & Resources Adviser, Cirencester
Bill Malecki, Gardens Adviser, Cirencester
Brian Moss, School of Biological Sciences, University of Liverpool
Steve Mulberry, Countryside Property Manager, Arlington Court, Devon
Mark Newman, Archaeological Adviser, Northern Territory
Tamzin Phillips, Environmental Practices Adviser, Cirencester
John Seaman, Environment Agency
Rob Woodside, Archaeological Adviser, Cirencester