Thinking about an irrigation reservoir?

A guide to planning, designing, constructing and commissioning a water storage reservoir

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Building a reservoir – the right option?

"A reservoir is now an essential part of my toolkit for securing water" **– a comment from a farmer who irrigates field-scale vegetables and has built a reservoir to store winter water and avoid the uncertainties of summer abstraction licence restrictions. It is also a valuable tool for others who require a reliable water supply for their business such as those in the sports-turf and amenity sectors.**

Do you need a reservoir?

A reservoir can help to secure your water supply. It can give you a marketing advantage and add capital value to your business. But it can also be a risky and expensive investment. So it is wise to plan carefully and weigh up the pros and cons before you make the commitment.

Water for high quality fruit and vegetables

Storing water on-farm is becoming increasingly important for those farm businesses in the drier regions of England that depend on irrigation to supply high quality fruit and vegetables to the nation's supermarkets. Water is at the heart of this industry – without it many farmers would simply not be able to meet the exacting standards of quality and continuity of supply demanded by supermarkets and consumers – arguably one of the most sophisticated markets in the world. But many catchments in the country now only have water available for abstraction during times of high flow.

Recent droughts and the longer-term threat of climate change – with hotter drier summers, reduced water availability, and increasing demand – only heighten concerns about the reliability of future supplies for irrigated agriculture.

Water for first-class sports surfaces

Many sports-turf and amenity businesses also rely on irrigation to provide high quality playing surfaces, to maintain the aesthetic quality of turf, and to deal with the vagaries of our summer weather. For example, a dependable water supply is essential for golf clubs to enable them to maintain the quality of fine turf areas on the greens, tees and approaches; race courses need regular watering to provide optimum racing conditions or 'going', and stadia require irrigation to create the right playing surfaces where bounce and ball speed are critical for sports such as tennis, rugby, and football. Many of these businesses are turning to water storage reservoirs to meet their demands for more secure, reliable irrigation water supplies.

Hall Hunter Partnership grows soft fruit for the major supermarkets and relies extensively on reservoirs for secure irrigation water supplies.

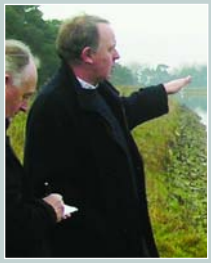
In 2006, over 50 golf courses were subject to total bans on irrigation abstraction. Many have since built reservoirs to cope with future droughts.

JE Piccaver & Co, based near Holbeach, grow baby leaf salads and rely on stored mains water for irrigation because the groundwater is too saline

The 'twin-track' approach

Water resources are under increasing pressure and so it is incumbent on everyone – domestic users, industry, the environment, agriculture, and sport and amenity users to use water wisely. The Environment Agency and Government now promotes the 'twin-track' approach for all water users – firstly managing demand and where this is not enough water - developing new resources. Effective management of water demand (more crop per drop) is considered best practice and will be a requirement for licence applications, changes, and renewals. Where demand management is not enough, storing high flows for use in the summer will be an important option to consider for increasing supply.

Case Study – Geology is king



Lindsay Hargreaves

Lindsay Hargreaves, farm manager at the Elveden Estate Thetford, irrigates 1,500 ha of field scale vegetables potatoes, onions, parsnips, and carrots. In order to avoid the uncertainties of summer abstraction restrictions and buffer water resources from one year to the next he built two 450,000 m³ (each 100 million gallons) clay lined reservoirs.

Following thorough site investigations both reservoirs were sited on boulder clay – a good material for building reservoirs but not without its problems. At one site the natural boulder clay was left undisturbed in the bed of the reservoir. But water seeping through into the underlying chalk led to the discovery of sand lenses in the clay. This was eventually resolved by reworking the clay bed and compacting it at a later date when the reservoir was empty.

At the second site the boulder clay contained large quantities of calcium carbonate. When water was added to the clay to aid compaction during construction, any over-wetting immediately turned the clay from a solid material into a running mud. So construction had to be carefully supervised to make sure the embankments were properly compacted.

But boulder clay is not all bad news. At one site a pocket of 5,000 tons of flints was uncovered during excavation. This was stockpiled and subsequently used to armour the embankments to limit the effects of wave erosion.

"Water is only going to become more expensive and less reliable. In my opinion, we should be filling all the holes we dig with water and not using them as landfill"

Robert Smith,
Russell Smith Farms, Cambs.

Increased water security

A reservoir provides security and flexibility by enabling you to balance water supply with demand. You can abstract water when it is readily available and store it for the times when you need it.

You can take advantage of groundwater and high river flows when water is more plentiful and reliable and store it for use in the summer. Charges for abstraction during the winter months (November to March) are a tenth of the cost of summer abstractions.

If your annual abstraction licence is limited you can take advantage of wet summers by storing water from one year to the next.

You can store low flows from small streams and low-yielding aquifers and use it at much higher rates for shorter periods to meet peak demands.

You can store water as an 'insurance policy' to meet unexpected irrigation demands late in the season.

A reservoir can provide a marketing advantage, increase the asset value of your business, and offer an opportunity for additional business income through water trading or amenity use.

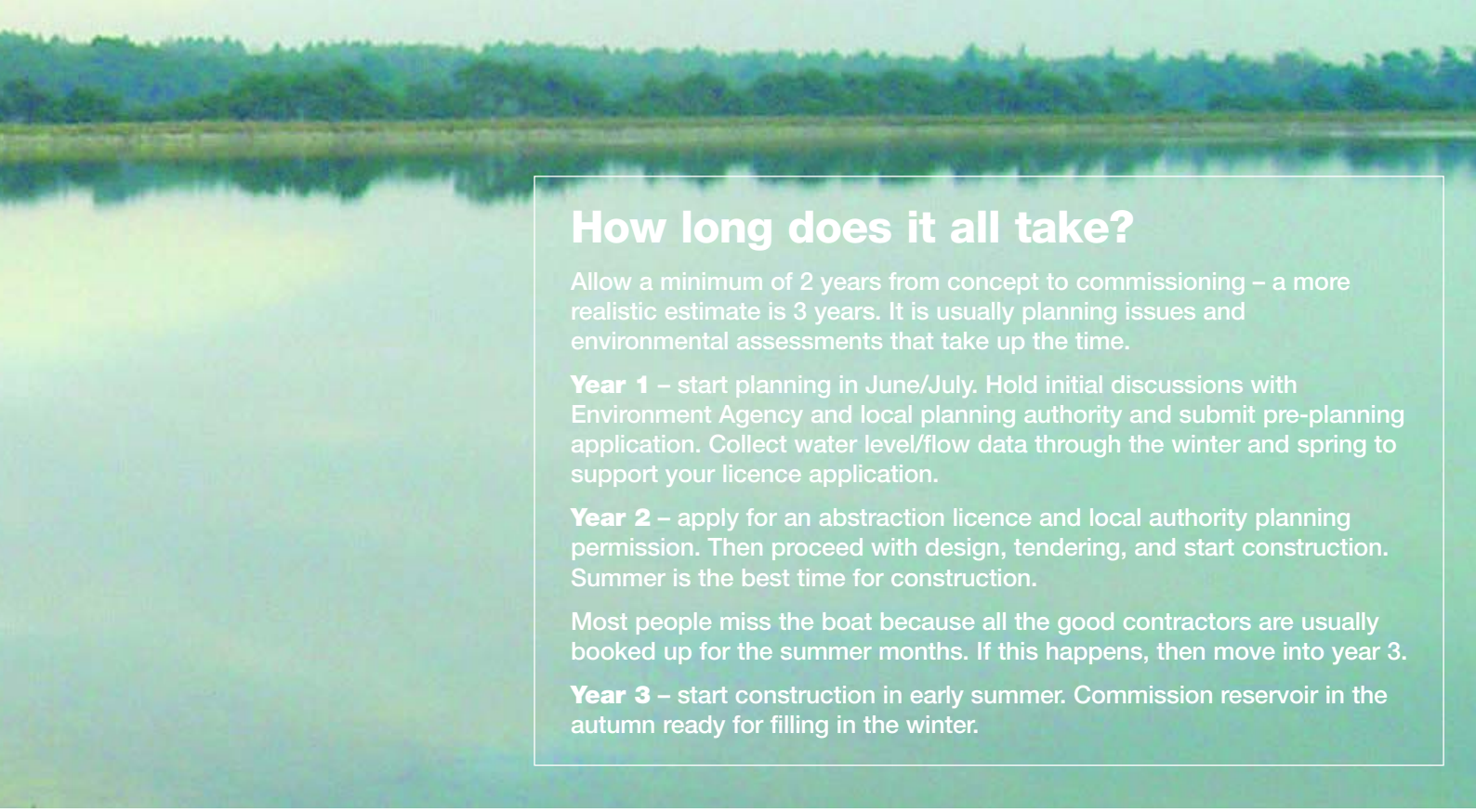
It can help reduce the environmental impacts of summer abstraction, and reduce the risk associated with potential water conflicts in your catchment.

Whatever your reason for building a reservoir, you will have much better control over your water supply – once the water is in your reservoir, it's yours to use as and when you wish.

Concept to commissioning

Taking the right approach to building your reservoir and doing things in the right order can save you money. Essentially you should first plan thoroughly, then obtain all the necessary permissions from the various regulatory and planning authorities. Finally, you can proceed with the detailed design, construction, and commissioning.

Planning	Permissions	Design, construction, and commissioning
Water requirement	Abstraction licence	Reservoir design
Water availability	Planning permission	Soils and geology
Reservoir size	Environmental approval	Lined or unlined
Choosing a site	Archaeology	Design features
	Access	Safety
	Legal agreements	Selecting a contractor
	Mineral extraction	Construction
		CDM Regulations
		Commissioning



How long does it all take?

Allow a minimum of 2 years from concept to commissioning – a more realistic estimate is 3 years. It is usually planning issues and environmental assessments that take up the time.

Year 1 – start planning in June/July. Hold initial discussions with Environment Agency and local planning authority and submit pre-planning application. Collect water level/flow data through the winter and spring to support your licence application.

Year 2 – apply for an abstraction licence and local authority planning permission. Then proceed with design, tendering, and start construction. Summer is the best time for construction.

Most people miss the boat because all the good contractors are usually booked up for the summer months. If this happens, then move into year 3.

Year 3 – start construction in early summer. Commission reservoir in the autumn ready for filling in the winter.

Case Study – Planning takes time!

Michael Paul

Building an irrigation reservoir near the Deben estuary – a site protected by a raft of national and international conservation designations – was always going to be a difficult call. So it proved to be for Michael Paul, farm manager at Lodge Farm in Kirton, Suffolk.

Michael farms cereals but he also irrigates 125 ha of field vegetables using a direct (summer) abstraction licence of 160,000 m^3 (35 million gallons). However, because of his concerns about future licence restrictions he built a 273,000 m^3 (60 million gallons) reservoir. This is bigger than his annual abstraction licence allowing him to carry water over from one year to the next.

He employed a reservoir engineer to help him through planning and design, and to successfully apply to change his direct (summer) abstraction licence to a high (winter) flow one bringing his total abstraction up to 190,000 m^3 (42 million gallons).

A gently sloping site was selected close to the Deben but protected from view by surrounding trees. The underlying London clay was ideal for a clay-lined reservoir. As more than 25,000 m^3 (5.5 million gallons) was stored above the surrounding lowest ground level the design and construction came under the Reservoirs Act 1975.

A pre-planning application was submitted to the local authority in spring 2005 but there were long delays because of the highly sensitive nature of the site, and the summer holidays which held up decisions. Several environmental organisations were consulted as well as local archaeologists.

But it was spring 2006 before the reservoir engineer finally brought all the parties together to agree a way forward. This was a crucial meeting that finally led to the approval of the plan but with many provisos. An extensive archaeological survey was requested which cost around £70,000 and additional temporary embankments were specified to protect wildlife from the noise and sight of the construction work. Construction started in late August 2007 and filling began in December the same year.

Getting good advice

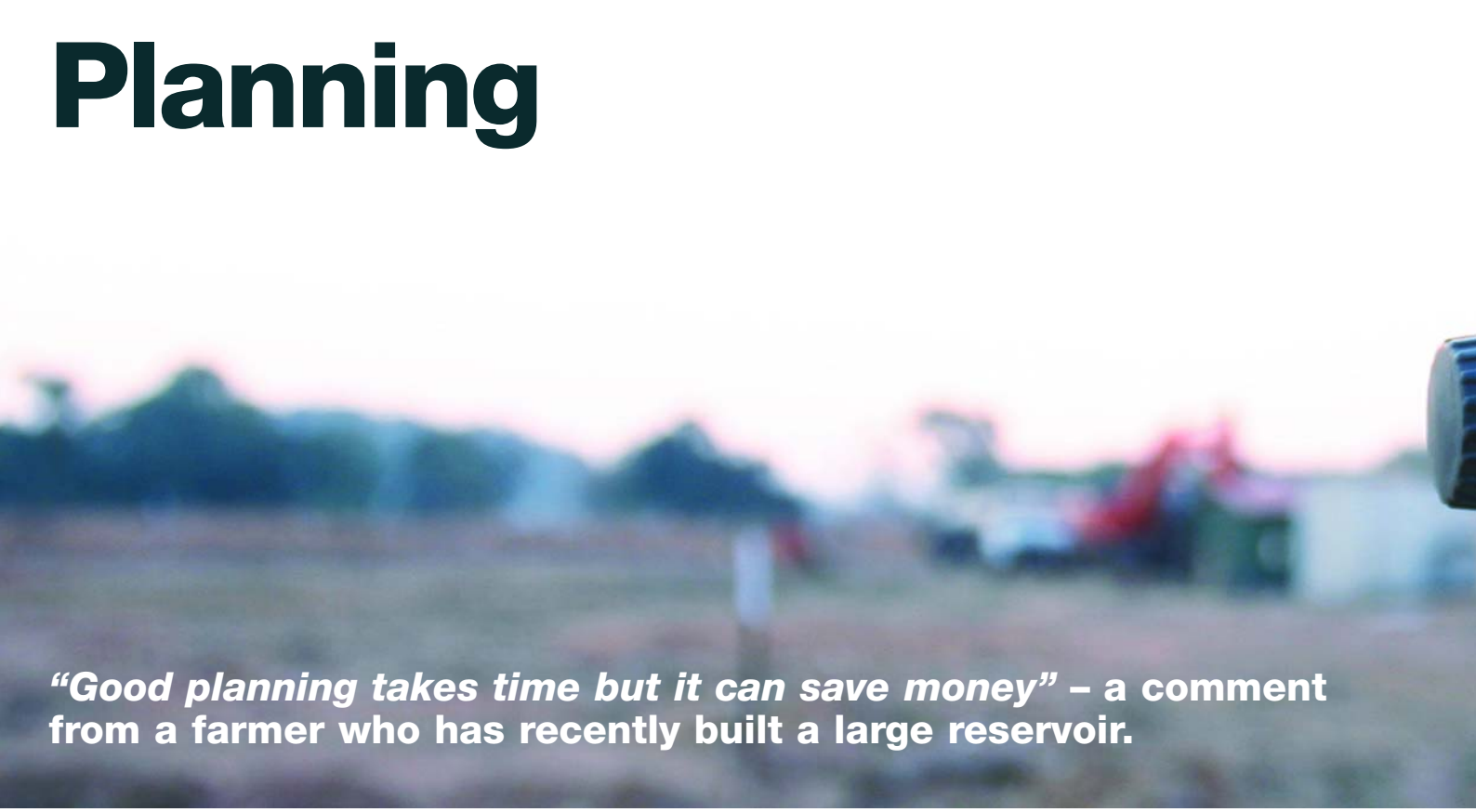
You will need specialist technical expertise at the later stages but it can be very useful to bring it in at the planning stage as well. There are two options available:

Hire a reservoir engineer – preferably a Chartered Engineer. They will give you professional, independent advice on every aspect of reservoir building from concept through to commissioning. Reservoir engineers do not construct reservoirs; rather they plan and design them. They help you to find a suitable contractor using competitive tendering and they will supervise the construction to make sure your reservoir is properly built. Essentially the reservoir engineer is your eyes and ears and their experience can be invaluable, particularly when disputes occur say during planning or between you and the contractor.

Hire a 'design-and-build' contractor – they too will have engineering expertise but they provide a complete 'turn-key' package – planning, design, construction, and commissioning. You may seek tenders yourself to get the best package but you would have to prepare this yourself and judge which one offers the best deal for you. All the costs of planning and design will normally be included in the lump-sum price.

Which to choose? – Whichever you choose it is wise to select an engineer or contractor with experience of the kind of reservoir you are planning and of the local geology and soils. Seek third party references from others who have recently built a reservoir. This is a most useful way of finding out whether a particular engineer or company is likely to meet your expectations.

Planning



***"Good planning takes time but it can save money"* – a comment from a farmer who has recently built a large reservoir.**

To plan your reservoir you will need answers to some basic questions.

How much water do you need?

If you already irrigate you will have a good idea of the amount of water you currently use and your likely future needs. You will also need to make sure you are using existing supplies as efficiently as possible. If you are new to irrigated farming there are guidelines available to help you assess the amount of water you will need for different crops in different localities. These take into account the various soil types on which different crops can be grown, typical irrigation schedules, and the local agroclimate.

However, you will also need to consider how you plan to irrigate in the foreseeable future. Will you use the stored water for your own irrigation or do you plan to sell some or all of it to neighbours?

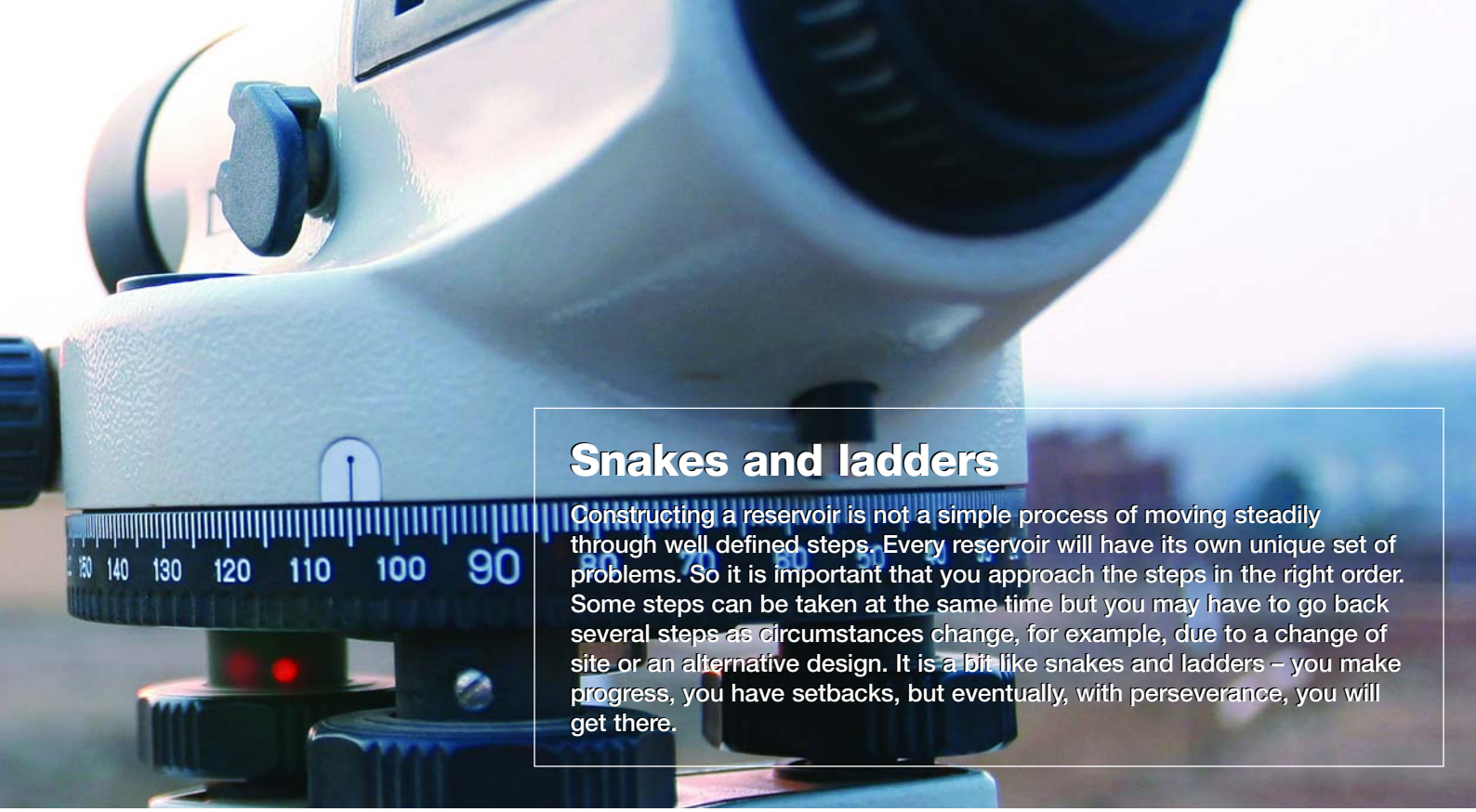
If your business is sports and amenity you will need to assess your water needs based on the kind of turf surfaces you require. A golf course in south east England for example, irrigating greens and tees may require up to 12,000 m^3 each year depending on the weather conditions. However, this is only a guide for early planning. A more detailed assessment of individual water needs is required.

Is water available?

Before proceeding too far, make sure you will have an adequate water source. Most substantial streams and rivers, and groundwater aquifers are already gauged by the Environment Agency and so early discussions with the Agency is essential. The Agency can give you advice on licensing and the expected reliability of your existing and proposed abstractions. Additional low (summer) flow abstractions may not be available. But most rivers still have water available for abstraction at times of high (winter) flow.

Smaller streams may require gauging if you wish to make a good case for abstraction. You can install a simple gauge board in the stream or on a culvert but a weir or acoustic 'doppler meter' is a more accurate measuring device. You may require consent to do this from the Agency or the local Internal Drainage Board. The Agency can also help you select a suitable flow measuring site. Measure the flow at least over a winter. Presenting some flow data is better than none – the more you can substantiate the stream flows, the more likely you are to get an abstraction licence as well as speeding up the process. It will also help you to design your reservoir.

Most irrigating farmers will already have a summer abstraction licence. Some may just require a reservoir to balance regular low abstractions with peak demands. However, for more secure supplies you will need a winter licence as well so you can fill your reservoir when supplies are more plentiful and cheaper. What is most likely is that you will be encouraged to trade in your summer licence for a winter licence.



Snakes and ladders

Constructing a reservoir is not a simple process of moving steadily through well defined steps. Every reservoir will have its own unique set of problems. So it is important that you approach the steps in the right order. Some steps can be taken at the same time but you may have to go back several steps as circumstances change, for example, due to a change of site or an alternative design. It is a bit like snakes and ladders – you make progress, you have setbacks, but eventually, with perseverance, you will get there.

How big a reservoir?

It is tempting to simply assume that the reservoir capacity and the annual volume on the abstraction licence must be the same and both match the total irrigation need in a dry year. But do consider the benefits of larger or smaller reservoirs.

The “right” size of reservoir will be a compromise of engineering, financial, and agronomic issues. But the main starting point will be your total seasonal irrigation need in a dry year for a chosen return period (the probability of a dry year occurring). This depends on the various crops you grow and their total irrigated area. Allowing for future expansion or changes in cropping intensity is also something you need to consider.

A larger reservoir provides further scope for expansion or selling water and will give more protection against climate change. It also means you can carry water over from one year to the next. This ‘buffering’ may mean you can cope with a smaller abstraction licence or use a less reliable water source. However, if you can keep a direct summer abstraction licence, then a small reservoir may be all that you need as an ‘insurance policy’ for periods during the season when short-term abstraction restrictions come into force.

Choosing a site

It is useful to identify several possible reservoir sites as some may later prove to be unsuitable. A clay-lined reservoir will generally be 2-3 times cheaper than a plastic-lined reservoir, so identify areas where there is suitable underlying geology.

Look for

- Suitable clay soils
- Fairly flat areas
- Sites central to the irrigated area(s)
- Land of low agricultural value
- Proximity to adequate electricity supply
- Good access for construction traffic

Avoid

- Sites of scientific or environmental value
- Sites of archaeological interest
- Flood plains and areas with high water tables
- Proximity to housing, particularly where children might be attracted to play
- Public Rights of Way, overhead power lines, underground pipes
- Skylines where the embankments will be very visible
- Sites that require water pipes to cross railways, major roads, gas/oil pipelines, and buried electricity or fibre optic cables.

Permissions

You will need legal permissions from the Environment Agency and your local planning authority before you can proceed. But you will also need to work closely with other organisations that can greatly influence the final planning decision.

Permissions

Getting the necessary permissions is not always easy and straightforward. But knowing what is needed will make it much less stressful. It will also enable you to factor in any additional costs.

An abstraction licence

The Environment Agency is responsible for managing water resources in England and Wales to ensure abstractions do not damage the environment and to protect existing water supplies.

Under the Water Resources Act 1991 most surface and groundwater abstractions over 20 m^3 per day will require a licence. If you have an existing summer licence you may need to vary this to include abstraction during winter months. In some more environmentally sensitive areas the Environment Agency may ask you to provide an assessment of the impact of your proposed abstraction on the environment.

Contact the Environment Agency to discuss your proposal as early as possible. Your application may require advertising and so the process can take several months. The Agency has published a useful guide on how to apply for an abstraction licence. You should also consult your local CAMS (Catchment Abstraction Management Strategy) report. This provides information on water availability in your catchment. Both documents are freely available from the Environment Agency website.

For golf courses, small horticultural sites, or for livestock drinking water, up to 20 m^3 per day pumped continuously into a reservoir may be enough. You will not need an abstraction licence for this.

However, you will still need to be sure that enough water will be available from your source and that you will not adversely affect others or the environment, as you will have liability for any damages your abstraction causes.

Planning consent

Local Authority planning consent is required for most reservoirs. But some reservoirs can be constructed under the Town & Country Planning (General Permitted Development) Order 1995. This provides scope for certain minor agricultural developments to take place without planning permission.

If planning consent is required your application will need to demonstrate that you have thoroughly thought about all the impacts that your scheme will have on the surrounding environment.

Pre-planning application

Obtaining planning permission can be costly and time-consuming. So it is worthwhile submitting a pre-planning application. Local authorities do not charge for this but it could cost up to £2,000 to prepare it – more if detailed environmental and archaeological reports are requested.

The local authority will want to see your outline plans. They will consult with other interested parties, such as the Environment Agency, Natural England, and local archaeological interests, to see if there are objections to your proposals or changes to be made.

This can be a very helpful process and once all the parties involved agree in principle, your full planning application is likely to succeed. Note, however, that pre-planning is rather open-ended and it can take up to 6 months or more to complete. So it needs continual monitoring to keep up the momentum. Full planning now has a strict timetable in which the application must be considered.

Your local planning authority will need:

- An outline reservoir design
- Anticipated noise levels
- Details of compliance with Construction, Design and Management (CDM) regulations
- An access plan
- Details of any special landscape or natural value of site
- Local archaeological interests
- Impacts on local employment and livelihoods
- Secondary benefits – fishing, leisure

Sharing your reservoir

If you plan to share your reservoir with others, you (and they) will want to have clear legally binding agreements in place. Who will pay for what and get what? What happens if the reservoir cannot be filled? There are many different ways to organise a shared reservoir and while trust is essential, a clear agreement will help to avoid disputes.

Sharing your reservoir may also mean sharing the capital costs and it may open opportunities for funding from the Rural Development Programme for England (RDPE).

Case Study – Keeping the greens green

Stephen Clarke

At Spalding Golf Club in Lincs, Head Greenkeeper Stephen Clarke was concerned that future droughts would threaten his ability to keep the course in top condition for its members.

In 2001 the club approached a consulting engineer for advice on how best to secure future supplies, and the costs involved. He recommended changing the club's direct abstraction licence for a high (winter) flow licence and constructing a 15,000 m^3 lined reservoir. This would meet the peak demand (6,000 m^3) for the greens and tees in a very dry summer together with spare capacity to irrigate the approaches if required.

A suitable low-lying 0.75 ha site was located not too close to the river and well above the water table to avoid problems during construction. But site investigations revealed archaeological remains and so to avoid costly investigations an alternative nearby site was chosen. Local residents did not object nor were there any concerns from local environmental groups. The consultant prepared the design and a contractor was selected using a process of competitive tendering. The most important consideration was the earthworks. Lining costs from different suppliers tend to be very similar but earthworks costs can vary considerably - by as much as 100%! Constructing properly compacted embankments is a skilled job so care was needed to select the right contractor. Construction took place in the dry 2003 summer. It was completed in the autumn and filled during the winter.

The site was fenced for safety reasons. The whole process took over two years to complete from the first proposals being put to the Greens Committee in 2001 to commissioning the reservoir in 2003. The total cost was about £175,000.

Environmental approval

The local authority will send your pre-planning application to various statuary bodies for consultation. Environmental protection agencies such as Natural England may ask you to undertake an environmental assessment, particularly if your reservoir is going to be in an environmentally sensitive area. These organisations will want to see how your plans will enhance the local landscape and the natural environment. There are many ways you can incorporate environmentally desirable features into your plans and these are described in more detail on pages 14 and 15.

Public consultation

The local authority may also seek public opinion, although this does depend on where the proposed development is located. The public are not usually interested if reservoirs are small and are not close to housing settlements.

Archaeology

The local authority may also request an archaeological investigation if your proposed reservoir site is in an area of archaeological interest. This is quite separate from the environmental assessment but the two investigations can run concurrently to save time.

The minimum requirement for an archaeological investigation is a watching brief during topsoil removal. However, if more detailed investigations are needed then evaluation trenches are excavated across the site. Investigators can only legally insist on investigating areas that will be disturbed by reservoir excavations. Typically a site covering about 0.2 ha requiring 12 trenches can cost around £6,000. If a full archaeological investigation is demanded then this can cost up to £50,000 and more.

Estimates suggest that up to one third of clay reservoirs will need an archaeology report.

Access

Public access is difficult to supervise and it can lead to problems with safety and vandalism. But access by private groups such as bird-watchers, and the local fishing club, may have the benefit of alerting you to potential problems. Storage reservoirs are rarely safe for swimming and most are too small for boating.

Other permissions

You may need other permissions. For example, will you want access across a neighbour's land for construction traffic, maintenance, pipelines, electricity supply? Will you need to divert public rights of way? Are there special health and safety considerations? Are there protected habitats to preserve?

You will also need a Site Waste Management Plan for any construction project over £300,000. If you move materials off- site you will also need a Waste Transfer Note from the Environment Agency.

Design and construction

Building a reservoir is rarely straightforward – each one has its own unique design and construction problems and you will need an experienced engineer to help you solve them. The biggest problems often lie below the soil surface. It is all about managing the risks.

Design and construction requires lots of decisions

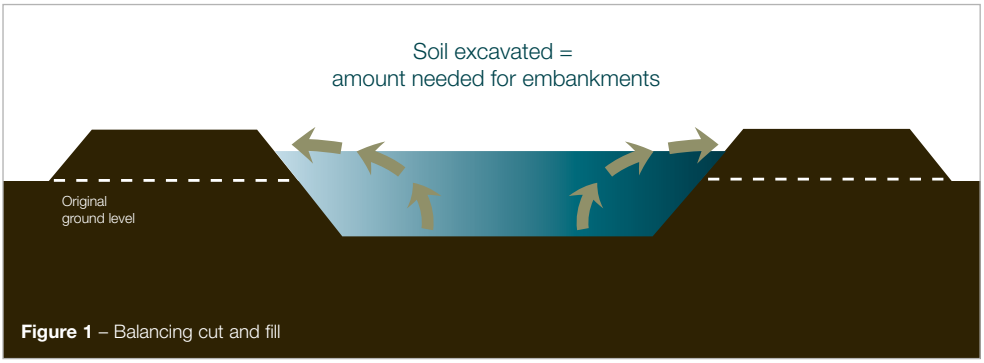


Figure 1 – Balancing cut and fill

Soils and geology

Finding out what lies below the soil surface and understanding the local geology is crucial to building a strong, water tight reservoir. The soils will tell you what kind of material is available to build your embankments and if a lining is needed. Equally the geology will tell you if it is safe to build. A thin clay layer overlying gravel, for example, may not be enough to stop water seeping through. Similarly underlying limestone can quickly dissolve creating large passages for water to escape through the rock. Maps showing the solid and drift geology in your area are available from the British Geological Survey (BGS).

Money spent on site investigations is never wasted. It can greatly reduce the risk of nasty surprises when construction begins. Unforeseen problems at that stage can be very expensive. A reservoir engineer can advise on what needs to be done. Typically trial pits excavated across the reservoir site are the only practical way of finding out what lies below the surface. A typical minimum requirement is five trail pits some 3-4 m deep but more pits and deeper ones may be needed depending on what is discovered with the first excavations. Even so you can never be 100% sure of what problems you may face until you open up the full excavation.

Lined or unlined?

Clay is a very good material for building strong, impermeable reservoirs. When clay is plentiful a reservoir can be constructed entirely in clay. But even when there is only a limited amount it can be used to advantage. One method is to line the reservoir with a clay blanket some 3-6 m thick to stop seepage through embankments constructed from more permeable material. Another is to construct an impermeable clay core within the embankments and a cut-off trench filled with clay to key the embankments into the original foundation material.

Sands and gravels are also very useful for building embankments but as water can quickly seep away a lining will be needed. This can be a clay lining if clay is available from another part of the farm. An alternative is a synthetic lining such as butyl or polypropylene. The lining will be the major cost of the reservoir and so one objective is to minimise the area of the lining per volume stored. Liners do deteriorate over time, mainly due to solar radiation. But most liners now come with a 20 year life guarantee.

Usually clay-lined reservoirs are cheaper to build than synthetic-lined reservoirs but if clay has to be imported then costs will inevitably rise.

Balancing cut and fill

The ideal reservoir, and the cheapest from an earthworks point of view, is one where cut and fill are in balance – soil excavated from within the reservoir area is balanced with the amount needed to build the embankments (Figure 1). When this is not possible costs rise because of the need to either bring in additional soil from another part of the farm or dispose of unwanted soil from the excavation.

Dead storage

You will need to allow for some storage which you cannot use. All reservoirs lose about 300 mm of evaporation during a dry summer and clay reservoirs typically need an additional 200 mm for seepage losses. A further 300 mm of 'dead water' will also be needed to prevent a clay base drying and cracking or to hold down a liner. Additional water depth will be needed for fish.

There are risks in constructing reservoirs. It is as well to be aware of them and to find ways of minimising them before you start.

Reservoirs Act 1975

This Act ensures the safety of dams and embankments for reservoirs holding more than 25,000 m^3 of water above the lowest natural water course. In such cases design and construction must be supervised by an independent Panel Engineer. There must also be regular inspections by a Panel Engineer and the design and inspection details must be submitted to the Environment Agency as the authority responsible for compliance with the Act. The reservoir owner must also keep and submit records of all water inputs and withdrawals.

Design can run concurrently with obtaining permissions to save time. But there is a financial risk if, for some reason, your application is not approved.

Other things to consider

Safety

Existing Health and Safety legislation applies to reservoirs and so it is prudent to always erect a perimeter fence to keep out farm animals and the general public. Linings can also be easily damaged by vandalism or large animals trying to drink. Fences are less conspicuous if placed at the bottom outside edge of embankments. Synthetic-lined reservoirs are almost impossible to climb out of. So escape routes such as ladders made from old tyres roped together are essential. They also help to hold down the liner.

Tendering

It is wise to obtain three competitive tenders for earthworks construction, though there is less variation in lining costs so two may suffice. Make sure they are truly independent, and the quotes cover the same items and specification so that you can compare like with like.

Construction

Summer is the best time to construct a reservoir. Access to the site is usually much better than in winter and it is easier to control the earthworks which are crucial to a well built reservoir. However, be aware of any environment restrictions on timing, such as nesting birds.

Removing topsoil is one of the first steps. This is not suitable material for construction but it can be stockpiled for landscaping when construction is complete. Clay reservoirs require high standards of construction in order to build strong, stable, water tight embankments. The type of clay, how it is placed and compacted in layers for the embankments, and its moisture content during compaction all need careful attention – factors that are all easier to control and manage during the summer.

The Institution of Civil Engineers Conditions of Contract (www.ice.org.uk) are commonly used to effectively manage the construction. It is also essential that the work is properly supervised by an experienced reservoir engineer to make sure all the work is done to the agreed design and specification and the embankments are safe.

CDM Regulations

Safety must be paramount. The reservoir construction must also comply with the Construction, Design and Management Regulations (CDM). These aim to improve the overall management and co-ordination of health, safety, and welfare throughout all stages of construction (www.hse.gov.uk). You should be clear who is responsible for adhering to the CDM Regulations at the outset. The role of CDM Coordinator is often given to the reservoir engineer but it can be the main contractor or a specialist CDM consultant. If you do not specifically appoint someone you will assume the responsibility by default.

Commissioning

Commissioning is the final stage of construction. The reservoir engineer will make a thorough final inspection of all the work before filling the reservoir and make sure all the pipework, pumps, and control systems are all properly tested.

Make sure you receive a full set of ‘as-built’ drawings and construction photographs, and a record of the ‘as-new’ normal readings on all pressure gauges, meters, etc. for later reference.

Costs

Reservoirs can be expensive, both to build and maintain. Most of the costs will be upfront whether or not you use the water. Knowing what it is likely to cost is a key factor in calculating their financial viability.

Figure 2 – Clay lined reservoirs – earthworks costs only (2008 prices)

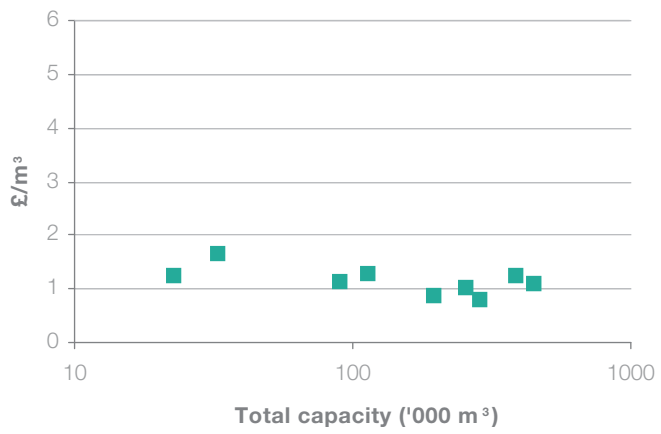
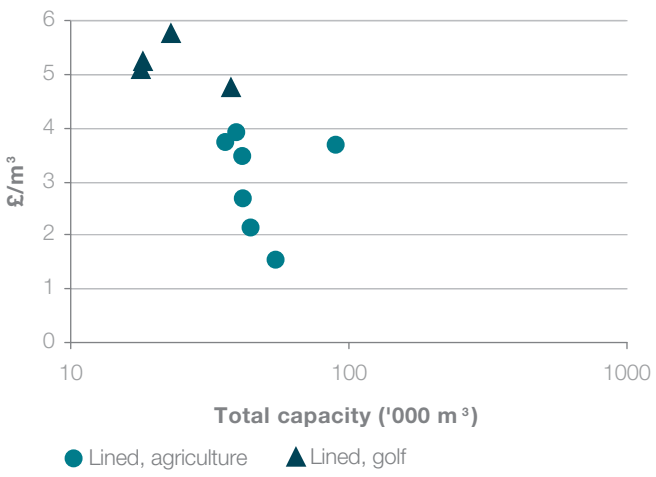


Figure 3 – Artificially lined reservoirs – earthworks and lining costs only (2008 prices)



Construction costs

The cost of constructing a reservoir depends on a wide range of site factors, but particularly on whether you are able to construct it with local clay or need to use a synthetic liner. Experience shows that choosing the right site with the engineer's advice is critical.

Figures 2 and 3 compare the earthworks and lining costs for 20 reservoirs constructed in the last ten years. The costs have been updated to 2008 prices using construction industry price indices. Construction costs generally are rising much faster than consumer prices, and the price of the lining particularly reflects higher oil prices.

Typically, earthworks cost for a clay reservoir is about £1-1.25 per m^3 of gross storage capacity (Figure 2). There are some economies of scale, so average costs are slightly lower for larger reservoirs.

Lined reservoirs cost considerably more (Figure 3). For the farm reservoirs, the earthworks plus liner costs varied from £2-4 per m^3 stored. The lined reservoirs constructed on golf courses were even more expensive – up to £6 per m^3 – perhaps reflecting a restricted choice of sites.

These figures do not include the costs of obtaining the various permissions, site investigation, and professional fees. Site investigation, design and supervision fees, and statutory provisions to 'Final Certificate' stage can add around 15% to the construction costs of the larger clay reservoirs. Environmental impact assessments can be very expensive on contentious sites. Many of these costs will be lost if the site has to be abandoned.

There are also associated engineering works to consider, such as the inlet and outlet works, additional pumps and underground pipes, access roads, landscaping, fencing, and drainage. Those who already irrigate may be able to use existing underground mains, abstraction points, etc. New irrigators, or those developing new water sources, can face substantial additional investments. Obtaining 3-phase electricity, for example, can cost £20,000 or more if an adequate supply is not already available near the pumping station. However, the savings made by good site selection will more than compensate for the costs of moving water or power.

Remember to allow for future irrigation plans when sizing and costing your reservoir as well as the 'dead storage' required for evaporation, seepage, and recreational use.

Case Study – the potential to share

Robert Smith

Collaborating with neighbouring farmers to construct a large shared reservoir was not straightforward, reflects Robert Smith from Russell Smith Farms, at Duxford (Cambs).

He specialises in growing premium quality vegetables – potatoes, onions, sweet corn, parsnips, red beet and artichokes – for the leading supermarkets on 800 ha of undulating light sandy loam soils where irrigation is essential. "Growing high value, high risk crops without a guaranteed water supply can only be described as commercial suicide" says Robert. "In the early 1990s we were subjected to a total ban on irrigation abstraction halfway through the growing season – that was a disaster. It became clear that we needed to secure our water supplies in order to protect the business"

The farm's licence for summer abstraction from the River Cam and some boreholes was becoming increasingly unreliable. So Robert investigated high (winter) flow storage, but it proved to be difficult to find a suitable site that was both near the River Cam and not too far from the existing irrigation command area. Eventually in 2007, following extensive investigations, work finally started on the excavation of a 500,000 m^3 (110 million gallons) reservoir and the installation of 24 kilometres of underground irrigation mains. However, it will require new mains to be installed under a trunk road, a motorway, a river, and a railway. Obtaining all these easements caused major delays in planning and has added significantly to the project costs.

All this has the potential to supply 10 irrigation machines operating simultaneously. But Russell Smith Farms is not the only business to benefit – up to 18 other local farmers will share the resource. The additional water supply will unlock another 3,000 ha of land for irrigation and enable longer rotations and less dependency on pesticides. For Robert it's all about security. "Once it is in the reservoir, it is our water". Even during a drought, the business could continue to grow crops without concerns about crop failure.

The reservoir development is expected to be completed in 2010. It is part-funded by the East of England Development Agency (EEDA).

Operating costs

Although capital costs are always the main focus of attention it is important not to neglect the year on year costs of operating and maintaining your reservoir.

Annual repair and maintenance costs for a clay reservoir will be about 1% of the overall capital cost of the reservoir and ancillary works.

Synthetic liners may only require occasional repairs if they are damaged accidentally or by vandals. However their shelf life is limited to about 20-25 years and replacing them can be expensive. One way to deal with this is to make an annual provision for this.

For reservoirs that come within the 1975 Reservoirs Act, inspection fees can be up to £5,000 over a 10-year period.

Energy costs will rise because you will need to pump water twice, adding 10m or more to the total pumping head. But there are some small savings if off-peak electricity can be used, and from the lower water abstraction charges for winter abstraction (currently 10% of the summer rate).

There is also a cost associated with the loss of productive land occupied by the reservoir. This can be considered either as a capital cost – if the land has to be purchased – or an operating cost – as an ongoing crop loss. However, this may be offset by the increase in value of land that can now be irrigated and the additional income from irrigated production.

Funding opportunities

The Rural Development Programme for England (RDPE), run by the Regional Development Agencies (RDAs), aims to help farming and horticultural businesses diversify, add value, and strengthen their market position. Water resources development is one of their priorities and this includes reservoirs. Funding will focus on multiple benefits such as sharing reservoirs and delivering environmental and social benefits. Abstractors interested in RDPE funding should contact their local RDA.

Environment

An irrigation reservoir is primarily a 'business' asset. But it can also significantly enhance the local landscape and the natural environment. Incorporating measures to promote biodiversity when planning your reservoir will also encourage interested stakeholders to support your development plans.

"Farm reservoirs are just another form of human development that alters an existing habitat"

The Suffolk Coast and Heaths AONB Reservoir Design Guide

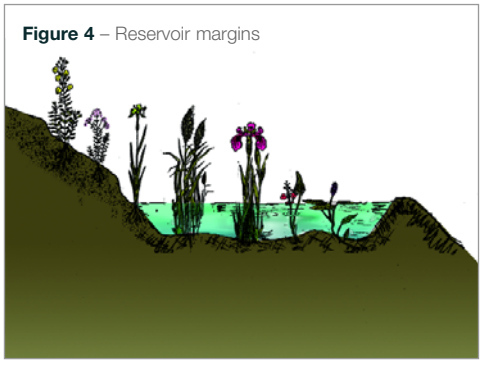


Figure 4 – Reservoir margins

The countryside is a mosaic of habitats mainly developed through farming practices over many hundreds of years. Reservoirs are just another human intervention that can change these habitats and provide new opportunities for plants and animals.

Reservoirs are not like natural lakes and ponds. Features that can improve the environment need to be deliberately built into them and this is best done at the early planning and design stages rather than later as an afterthought. Clay reservoirs, for example, can incorporate shallow muddy margins for plants and wildlife (Figure 4), and deeper areas for fish. Though synthetic lined reservoirs offer few opportunities to create natural water habitats there are still many opportunities to improve the surrounding area. Whatever features are planned they must complement the primary function of the reservoir which is to store water for irrigation. Here is a range of options to consider.

Siting

The availability of clay will largely determine the general location of your reservoir. Nevertheless you will need to safeguard the distinctive quality of the local landscape by blending your reservoir profile with the local topography rather than just masking it by planting. Try to avoid breaking the skyline. An irregular outline is preferred to formal rectangular shapes as straight lines are rare in nature.

Keep away from Public Rights of Way both for safety reasons and to avoid disturbing nesting wildlife. Avoid steep slopes and sites near existing semi-natural habitats such as a wet meadow. Such sites are also best avoided from a construction point of view. Excavating below the water table can create lots of costly engineering problems.

Designing for wildlife

Seek to link habitats to allow wildlife to migrate through the area and build on typical habitats and species already found in the locality.

Plant trees and shrubs around a reservoir to provide shelter and nesting areas, particularly on the north and east side – but not on the embankments. Trees will also help to blend a reservoir into the surrounding landscape. Your local FWAG officer can advise on appropriate species.

Sow embankments with traditional grass and wildflower mixes.

Create shallow margins around the whole reservoir and plant reeds and rushes.

Shape them to retain water and keep plants moist even when water levels are drawn down.

Allow plants to colonise margins to provide seed for breeding and over-wintering wildfowl. Marginal planting may also reduce wave erosion.

Use gentle embankment slopes for easy access and management. A hummocky surface will also create more natural shapes and make the reservoir less obvious.

Arrange natural runoff from summer showers to keep margins wet. When possible use water from roofs and hard-standings.

Stakeholder engagement

"Wildlife and landscape friendly features can be incorporated into reservoir design for little extra cost and can reap dividends in terms of gaining 'additionality' in the planning process and avoiding objections from statutory consultees." Neil Lister, Suffolk Coast and Heaths Area of Outstanding Natural Beauty.

Plants that cope with seasonal water level changes

- Pond water crow foot
- Broad leaved pond weed
- Yellow water lily
- Yellow iris

Establish floating islands at least 30m from the shore to provide a safe nesting area away from the shore to keep out weasels and stoats. Cover with shingle for nesting terns and plovers or vegetation for ducks.

Dig small, deep holes as refuges for aquatic life when the reservoir levels are very low in late summer.

Create a shallow wildlife pond, scrapes, and a boggy area alongside the main reservoir as a refuge for wildlife when water levels are low.

Fish

Think carefully before introducing fish as they can reduce your reservoir's value for wildlife. Fish can be voracious predators and bottom feeding fish can disturb silt and make the water permanently cloudy.

If you do wish to stock your reservoir with fish you will need consent from the Environment Agency in accordance with Salmon and Freshwater Fisheries Act (Section 30). You may also wish to seek specialist advice.

Managing your reservoir

The natural environment will also be influenced by the way you manage your reservoir. So develop your operation and maintenance activities at the planning stage. They will depend on the particular flora and fauna you wish to encourage. You may need to seek specialist advice on this but in general it is the timing of activities that is crucial to avoid disturbing the life cycles of species at critical times.

Maintaining good water quality is important to avoid problems such as blanket weed and algae, excessive weed growth, bad smelling cloudy water, sewage fungi, and a poor invertebrate life. Low intensity farming around your reservoir margins will also improve its conservation value.

Avoid overgrazing the area surrounding your reservoir. Fencing may be desirable not only from a safety point of view but also to prevent cattle reaching growth around the reservoir margins. Locate it away from the crest so it is less obtrusive.

Control vegetation by cutting and removing in the autumn or winter, and rotating the regime so that no more than one third of the area is cut in any one year. Similarly, aim to cut between one fifth and one third of the marginal and water plants each year. Seek advice before using chemicals in or near reservoirs.

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Further information:

A more detailed technical report on all aspects of reservoir planning and development complements this booklet. Copies of this booklet and the report are available from the Environment Agency and can be downloaded from the UK Irrigation Association website (www.ukia.org).

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Note: This booklet is for information purposes only. Always seek independent professional advice at all stages of planning and construction.

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