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primefacts

FOR PROFITABLE, ADAPTIVE AND SUSTAINABLE PRIMARY INDUSTRIES

OCTOBER 2009 PRIMEFACT 781 (REPLACES AGFACT E5.7)

Building a farm dam

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Building a farm dam is not a case of digging a hole and waiting for it to fill with water. Many farm dams fail because they were not planned or built properly.

Most farm dams are compacted earth structures built at depressions, gullies or hillsides. Farm dams should be planned and built with the same care you would apply to building a house.

There are several things to consider when planning a dam. These can limit the size of the dam that can be built without a licence, or they can impact on its location:

- Government regulations that apply to your dam, including the maximum allowable size;
- Size of your dam, allowing for farm water needs and evaporation losses;
- Where to build your dam.

There are also several things to consider when building a farm dam, such as:

- Who should build your dam;
- Preparing your site;
- Building your dam;
- Maintaining your dam.

Government regulations

The NSW Government has been reforming water management across the State since the 1990s and has introduced a range of changes that may impact on the size and location of new farm dams.

The NSW Office of Water (formerly Department of Water & Energy) manages water access and licensing and has prepared a range of information sheets to update and guide landholders who intend to construct dams. These can be accessed through the NSW Office of Water website at:

www.water.nsw.gov.au

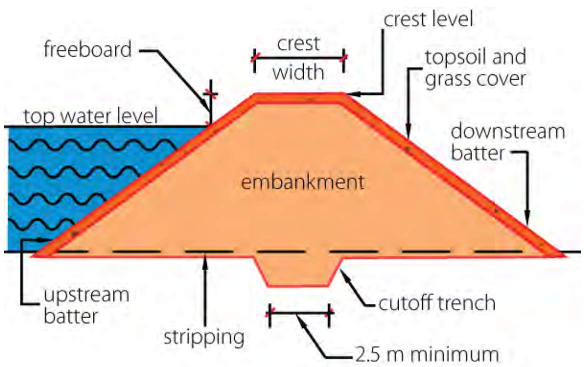
These links outline the Maximum Harvestable Right for Farm Dams where this is relevant, and the rules in the Western Division of the State.

The NSW Office of Water can advise as to what size you can build without needing a licence. If a larger capacity is needed, then a licence may need to be issued. In addition to criteria based on volumes, there are exemptions to the rules which may apply to you. The Office of Water can advise about these exemptions.

Some councils require a development application for every dam built in their area. Check with your local council to see if you must comply with a development control plan.

Farm dams can be built on minor watercourses (lower order streams) but not on larger streams, unless they are approved by the Office of Water. The Office of Water website contains information on where dams can be built (see the above website). On some watercourses a dam may require provision for fish passage under the Fisheries Management Act 1994 for dams. Your local Industry & Investment NSW office will be able to refer you to someone who will be able to provide further advice.

Figure 1: A cross-section of a typical dam



NSW GOVERNMENT Industry & Investment

Under the *Native Vegetation Act 2003*, land in, or within 20 metres of, the bed or bank of a prescribed stream is regarded as 'Vulnerable Land' and clearing of native vegetation is generally not permitted. You can confirm the status of the stream and associated native vegetation with your Catchment Management Authority (CMA) or at: info@nativevegetation.nsw.gov.au .

For more information on Native Vegetation Act see: http://www.nativevegetation.nsw.gov.au/index.html

Sometimes, special permits are issued to allow tree removal. It is advisable to check with the Office of Water before you start building, as they can confirm whether or not a dam can be constructed at the proposed site. The Office of Water also assess the suitability of works at, or near a watercourse, lake or estuary. A permit is required for any excavations, placement of fill or construction in or near these areas. You should approach the Office of Water to find out if your dam is affected. A useful checklist can be found at the Office of Water website listed above.

Some dams may need to be registered with the Dam Safety Committee, which considers the consequences of dam failure. Although registration is required for very few farm dams, you should check the need for registration by contacting the Dam Safety Committee at the Parramatta office of the Office of Water.

Telephone: 02 9895 7363
Facsimile: 02 9895 7354
Email: dsc@damsafety.nsw.gov.au
Website: http://www.damsafety.nsw.gov.au

Size of your dam

When determining dam size you will need to consider farm water requirements. If these exceed your Maximum Harvestable Right or the rules for the Western Division of the State you will need to obtain a licence or consent from the Office of Water.

Maximum Harvestable Right allowances vary across the State and depend on property location and property size. A calculator for them can be found at the Office of Water website shown above.

Water requirements also vary considerably depending on crop type, geographic location, stock type and stock numbers. For example, pastures grown at Bega usually need less irrigation water than pastures grown at Dubbo. Similarly, 100 sheep need less water than 100 cows.

Determine how much water you need and the allowable capacity before you start building.

The Office of Water have a work sheet on estimating stock and domestic water needs at the Office of Water website listed above.

If the dam will be used for irrigation, this may increase its size considerably, depending on what proportion of the crop's water needs the storage will hold.

Indicative average annual irrigated water requirements across the State are:

- pastures: 4–6 ML/ha a year
- vines: 2–3 ML/ha a year
- vegetables: 3–5 ML/ha a year
- stone fruit: 3–4 ML/ha a year

1 m^3 = 1 cubic metre = 1 kilolitre = 1000 L
1 ML = 1 megalitre = one million litres

Remember, these figures are for guidance only and may be quite different for your particular situation. Further advice is available from your local Irrigation Officer or District Agronomist.

Evaporation losses

Evaporation losses from the dam must also be considered in the size of the storage. Evaporation losses from a storage are not constant and vary from month to month and from location to location. Higher evaporation losses can be expected in summer than in winter and higher losses can be expected inland than on the coast. Average evaporation losses could be as low as 1,400 millimetres per year on the coast and as high as 3,600 millimetres per year inland. This equates to annual evaporation losses of around 14–36 ML per ha of water surface.

There are several options available for the reduction of evaporation losses from farm storages; initially the most desirable is to make the storage as deep as possible to reduce its surface area.

Once built, the options to reduce evaporation all present a barrier between the water surface and the atmosphere. The barriers are either physical or chemical; some of the options to limit evaporation from dams are outlined in the section 'Some maintenance tips' at the end of this Primefact.

Where to build your dam

Once you have estimated how much water you need, the next thing to do is to establish where to put the dam. Remember the dam site you choose will determine its success.

A gully is usually a good place to site a dam because it reduces the amount of earthworks and the overall cost. However, not everyone has the advantage of a gully site on their property; many farm dams are built on hillsides.

Two important considerations, the catchment yield and the soil type at the site, will help you to choose the best location for your dam, but you need to make sure that stream order is appropriate, by checking with local Office of Water licensing staff, who can also advise on any licensing or approvals that may be required.

The yield of the catchment

Unless your dam fills from a spring or by pumping from a river or bore, the source of water will be rainfall that runs off the catchment. The catchment is the area that collects rainfall run-off and directs it to the dam. The catchment can be natural, like fields and forest, or it can be artificial, like roads and roofs. Generally, as catchment area increases, so does the volume of run-off water.

The amount of run-off also depends on several other factors, including:

- ground slope
- rainfall intensity
- type of ground cover
- soil type
- existing drainage patterns.

If the catchment is not likely to provide the amount of run-off water you need, then you may be able build catch drains. These drains collect run-off water from outside the dam catchment area and direct it to the dam. The drains need to be built carefully to ensure a grade towards the dam and they should be sealed with a covering of grass to avoid erosion.

In some areas ‘floodplain harvesting rules’ may prevent diversions. Office of Water licensing staff and local government authorities will be able to advise you as to the location and purpose for which you can capture overland flow in your area.

Table 1 will help you to estimate the likely yield of your catchment. For example, if your average annual rainfall is around 750 mm and your catchment area is 4 ha, then you could expect an average 3 ML yield from the catchment annually.

Remember, the tabulated yields have been derived using assumptions regarding:

- slope
- soil type
- ground cover
- catchment geometry
- drainage paths.

Table 1. Catchment yield

Average annual rainfall (mm)	Average annual yield per hectare of catchment (ML)
500	0.35
750	0.75
1000	1.45
1250	2.00

An accurate assessment of your catchment yield can only be made after investigation of the characteristics of your catchment.

The type of soil at the site

The embankment must be structurally stable and able to hold water. This means that the soil used to build the embankment must also be structurally stable or impermeable – preferably both.

The soil type that usually satisfies both these criteria is clay. However, not all clays are suitable for dam embankments. For example, some clays disperse when wet and result in tunnels forming in the embankment. Thus, the soil must be tested to determine its behaviour.

To do the tests, samples of the soil must be obtained from the excavation area including the borrow pit which will provide much of the earth for the embankment (shown in Fig 6). The samples can come from auger holes or backhoe trenches. The sampling depth should extend at least to the depth of anticipated excavation. Sampling the site will also give you an idea if there is enough soil in the excavation area to build the embankment.

The samples should be tested by someone experienced with soil behaviour in dam construction.

Who should build your dam?

It is worthwhile to choose an earthmoving contractor who has experience and a good work record. Not every contractor has the experience or the ability to build a dam.

Try to find someone who specialises in dam construction. For example, you could ask neighbours who have had dams built if they are happy with the results.

Once you have found a few dam builders ask them to show you some of their recent work. If possible, talk to the owners of these dams and ask their opinions of the work.

If you choose an experienced dam builder with good references, you can reduce the chance of problems occurring during and after the building of your dam.

It may be worth seeking advice from the NSW Soil Conservation Service in your area: www.lands.nsw.gov.au/soil_conservation/conservation_earthworks

Preparing your site

The embankment and spillway should be set out with markers, such as painted timber stakes, which are easy to see.

The features of the works that markers should be used to locate are:

- upstream toe of the embankment
- downstream toe of the embankment
- spillway inlet and outlet widths
- top water level
- crest level
- centre-line of the embankment
- extent of the excavation area and borrow pit (see Figure 6).

Before building starts, the area to be covered by the embankment, spillway and excavation should be stripped of all topsoil, roots and vegetation (including trees and stumps). Store the topsoil for use in the completion of the embankment and spillway.

Building your dam

The successful completion of an earth dam relies heavily on achieving a well-compacted embankment.

Apart from soil compaction, other major construction considerations include:

- the cut-off trench
- exposed rock
- spillways
- clay cores
- embankment batters
- freeboard
- settlement of the embankment
- crest width
- topsoil use.

The cut-off trench

Dams lose water through seepage, but with good construction methods seepage losses can be reduced.

One method is to build a cut-off trench along the entire length of the embankment. Usually the trench does not need to extend across the spillway. The trench should be taken at least 600 mm into impervious soil and backfilled with good clay that is thoroughly compacted. All farm dams should have a cut-off trench.

Soil compaction

At the correct moisture content, soil compaction helps to provide structural stability to the embankment and is another way of reducing seepage losses. The soil used to backfill the cut-off trench and to form the embankment should be placed in layers, with each layer thoroughly compacted before the next layer is placed.

Preferably, compaction should be achieved with a sheepsfoot roller. However, a scraper or bulldozer may be satisfactory, depending on the soil behaviour and the layer thickness. A layer not more than 150 mm of loose thickness (for a sheepsfoot roller) or 100 mm of loose thickness (for a bulldozer or scraper) is recommended.

The number of passes that should be made by the compacting equipment depends on the soil type, but it should be at least four. Generally, embankments lower than 2–3 m may be compacted satisfactorily with a bulldozer or scraper.

The soil used to build the embankment should not be too wet or too dry. If the soil is too dry when it is compacted there is a good chance that air voids will result and the soil will be permeable. Compaction will also be hampered and produce an unsatisfactory result if the soil is too wet.

A good guide to soil moisture content can be obtained from a simple field test. When soil moisture is at the best level for effective compaction, you should be able to roll the soil between your palms into a thread (about the thickness of a pencil) that just begins to crumble on further rolling. If the soil thread crumbles before it reaches pencil thickness, it is too dry. If the thread can be rolled to a thickness much less than a pencil, then it is too wet.

If the soil is too dry a water cart can be used to wet it before it is used in the embankment. The best way to do this is to rip the excavation area, wet the soil, allow it to stand for 24 hours, check its moisture content using the field test described previously; and if that is right, place the soil in the embankment. Try to avoid wetting the embankment to increase the soil moisture during construction, as this usually causes very uneven soil moisture and uneven compaction.

If the soil in the excavation area is too wet, the drying process can be accelerated by ripping.

Exposed rock

Maximise the storage by obtaining as much soil as possible to build the embankment from below top water level. Remember that some soil will also be available from the spillway excavation. Rock, sand or gravel exposed below top water level should be covered with at least 300 mm of compacted clay to prevent seepage.

Spillways

Spillways reduce erosion damage to the embankment and help prevent dam failure. They are used to pass floodwater around the dam that would otherwise go over the embankment or erode a new channel around the embankment. Most farm dams have a grass-lined earth spillway. Spillways can also be concrete-lined, cut into stable rock or made of gabions (rock-filled wire baskets). Sometimes, the spillway is supplemented by a pipe built through the embankment. If you don't know what size spillway to build, seek expert advice.

A **clay core** may be required if there is not enough suitable material at the excavation area to build a homogeneous clay embankment. In these cases, the clay core is used to provide the impermeable barrier and the balance of the material in the embankment provides the structural stability.

The core can be located between more permeable material or it may be constructed at either the water or non-water face. Typical core arrangements are illustrated in figures 2, 3 and 4.

Figure 2. A central clay core

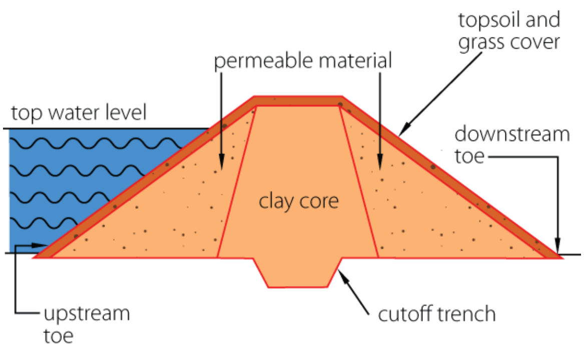


Figure 3. A typical upstream clay core

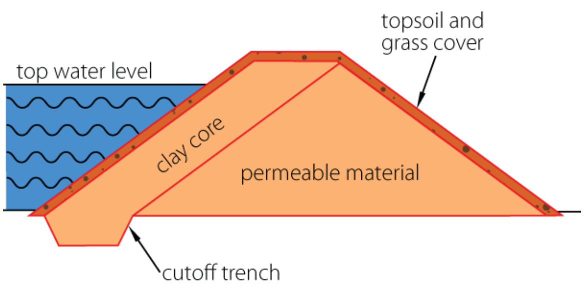
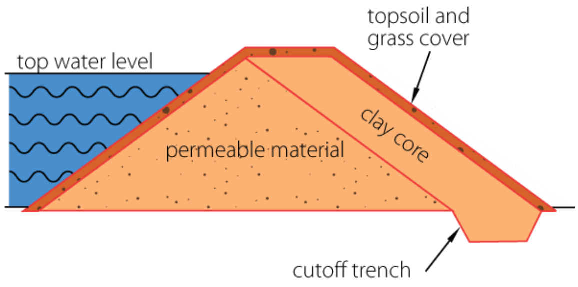


Figure 4. A typical downstream clay core



The batter (slope) of the embankment needed for dams depends on soil type, embankment height, stored water depth and other factors.

If the embankment is more than 4 m high at its highest point, seek engineering advice on appropriate batters. If the embankment is less than 4 m high and is sitting on a stable foundation, batters 3:1 upstream and 2.5:1 downstream will cater adequately for most soil types.

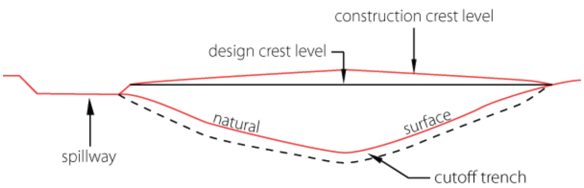
The freeboard (see Figure 1) is the height of the embankment above top water level (or spillway level). The freeboard must be enough to prevent water overtopping the embankment when the spillway is working and/or when winds cause waves on the storage. The freeboard must be at least 750 mm; sometimes a freeboard of more than 2 m is required.

Settlement of soil banks is common and an allowance must be made for settlement of the dam embankment.

The embankment could settle to a level where it is overtopped by water and failure will result. To avoid the likelihood of this type of failure the crest level must be built higher than the design level.

Clay soil can settle more than 10%, but well-constructed clay dam embankments are not likely to settle more than about 5%. You should allow 5% of the height of the embankment (along its length) to cater for settlement. For example, if the intended maximum height of the crest is 5 m, the embankment must be built to a height of 5.25 m (an additional 5%) to allow for settlement to a design crest height of 5 m. A typical allowance for settlement is shown in figure 5.

Figure 5. The front view of a dam showing the construction crest



Crest width. The required crest width is a function of the stability requirements of the embankment. At the same time, the minimum crest width must allow the safe operation of construction equipment.

In the absence of engineering design, a good guide to estimating the required crest width of the embankment is to adopt a minimum width of 2.5 m for embankments up to 5 m high. For embankments higher than 5 m, allow an additional 0.2 m for every metre in height greater than 5 m. For example, if the maximum height of the embankment is 7 m, the crest width would be 2.9 m (the sum of 2.5 + 0.2 + 0.2).

Topsoil

The embankment should be completed with 100 mm or more of compacted topsoil and the spillway should be cut about 100 mm below top water level and built back to that level with topsoil. The embankment, spillway and the spillway outlet should then be planted with a good holding grass such as kikuyu. If the stripped areas do not provide enough topsoil, then it should be imported.

Maintaining your dam

To allow the storage to fulfil its function it is important to carry out regular maintenance. It also helps to observe the following.

Ensure topsoil cover of at least 150 mm.

Establish a grass cover on the embankment and spillway as soon as possible. A grass that mats, such as kikuyu, is preferable to a grass that tufts.

Do not let trees or shrubs grow on the embankment, spillway or spillway outlet slope. Roots might disturb the compacted soil and provide a seepage path for water, while trees or shrubs in the spillway area will restrict the flow of flood water.

Some maintenance tips

Topdress areas that become bare of topsoil as soon as possible. Fertilise and water grass cover regularly. Slash grass regularly on the spillway and outlet slope to promote a dense groundcover.

Avoid using the spillway and outlet slope for vehicular access, to reduce potential erosion.

Maintain a sealed catchment to minimise the potential silting-up of the dam. A permanent pasture is ideal.

Reducing evaporation

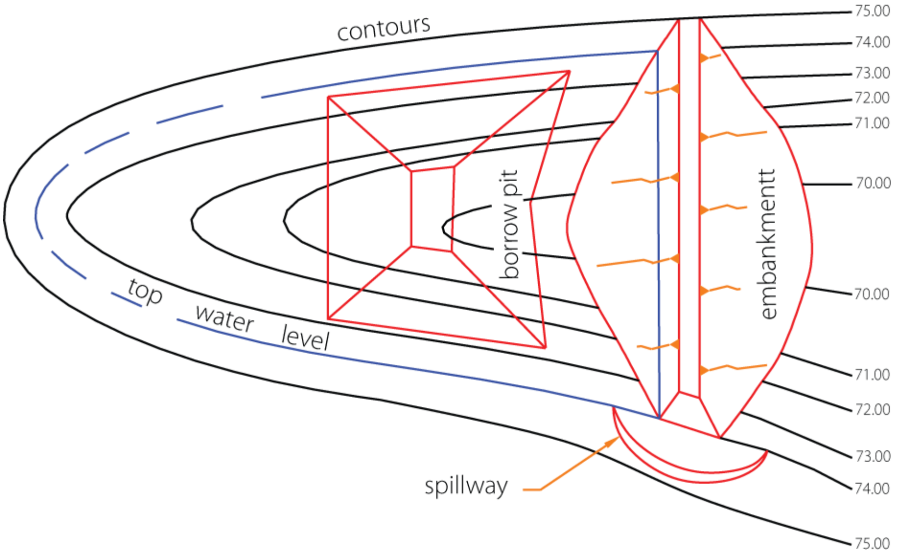
There are several options available for the reduction of evaporation losses from farm storages. In addition to making the dam as deep as possible, it has been suggested that windbreaks are effective as they reduce wind movement and provide shade. A range of engineered options exist that present a barrier between the water surface and the atmosphere. The barriers are either physical or chemical and include floating covers, modular covers, monolayers and polyacrylamides.

Floating covers have shown potential evaporation savings of 90% while suspended covers had potential evaporation savings of 70%.

Modular covers form a floating physical barrier on the water surface to reduce water evaporation. This technology is best suited to storages with water in them all year.

Monolayers are chemical products which create a thin film on top of the water surface and are self spreading. They break down in two to three days and do not reduce evaporation as much as permanent structures but have the advantage of only being applied when needed.

Figure 6. The plan view of a typical earth dam



Polyacrylamides are chemical binding products added to water to increase viscosity and reduce evaporation. This technology does not reduce the evaporation as much as the permanent structures but it has the advantage of only being applied when evaporation is high or there is water in the storage.

Field trials and research conducted by Craig et al, 2005, with the University of Southern Queensland (USQ), suggested that floating covers are the most appropriate form of evaporation control on storages with less than one hectare of surface area. Potential evaporation savings averaged 80% and installation costs (not confirmed) are likely to average $5 per m^2.

Typical operating and maintenance costs were not provided in the research findings.

Obviously there will be a range of factors (e.g. location, cost, value of water, size of storage, etc.) to consider in deciding whether to use evaporation control, or which method to choose. Your local Irrigation Officer or advisor may be able to help you.

Further information

Each dam site is different and this Primefact is not intended to replace the advice of qualified consultants. For further information, you can also contact your local office of Industry & Investment NSW.

Office of Water website information

www.dnr.nsw.gov.au/water/dams.shtml

www.dnr.nsw.gov.au/water/factsheets.shtml

Farm Dam Harvestable Right calculator:

www.farmdamscalculator.dnr.nsw.gov.au/cgi-bin/ws_postcode.epl

Western Division Lands information on farm dams:

www.dnr.nsw.gov.au/water/pdf/fd_in_western_division-e.pdf

Native vegetation information:

www.nativevegetation.nsw.gov.au/index.html

www.nativevegetation.nsw.gov.au/fs/fs_07_a.shtml

www.nativevegetation.nsw.gov.au/fs/fs_11j.shtml

NSW Soil Conservation Service:

www.lands.nsw.gov.au/soil_conservation/conservation_earthworks

Evaporation information

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Heinrich, N. & Schmidt, E. (2006) Economic Ready Reckoner for Evaporation Mitigation Systems Reference Manual. Final Report to National Program for Sustainable Irrigation. ER061197

downloads.lwa2.com/downloads/publications_pdf/ER061197.pdf

National Program for Sustainable Irrigation Fact sheet: Controlling evaporation losses from farm dams

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ISSN 1832-6668

Replaces Agfact E5.7

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Job number 8658 PUB08/80