Appendix 1: Planning a farm dam – a worked example

This section will demonstrate how to:

1. Calculate water storage requirements
2. Calculate required catchment area
3. Check if the dam size is permitted under the NSW Farm Dams Policy
4. Identify a suitable site for constructing a stable dam with optimum storage to excavation ratio

The information in this example is specific to the NSW Riverina and to four identified zones – Tablelands, Slopes, Plains and Western – but will have application in other areas.

This example will use a hypothetical 1000 ha (2470 ac) property at Illabo NSW in the Slopes zone, to demonstrate the calculations required as part of the planning processes.

The Illabo area has average rainfall of 550 mm/yr and an average evaporation rate of 1250 mm/yr.

Step 1: Calculate water storage requirements

The landholder of the Illabo property has decided that they need a new dam in the area of the woolshed to run 300 nursing sheep with up to 250 lambs, water a 0.25ha garden, and supplement the water requirements of the house and septic system.

They need to calculate the volume of water required, taking into account usage demands, Critical Storage Period and evaporation rates.

The water requirement for plants and animals varies significantly from day to day as well as throughout the year. Table 3 provides some average consumption figures, but this will vary depending on climatic conditions and, in the case of animals, the amount of water in their feed.

Table 3: Average water consumption data

STOCK	Average daily consumption (litres/head)	Average annual consumption (kilolitres/head)
Mature sheep on dry feed	7	2.7
Nursing ewes on dry feed	9	3.6
Fattening lambs on dry feed	2.5	0.9
Beef cattle	45	17
Calves	25	8.2
DOMESTIC		
House and septic (per person)	180 litres/person	63 kilolitre/person
Garden (per hectare)	68 kilolitre/ha/wk	1640 kilolitre/ha

Note – Average daily consumption for stock will vary during different seasons.

Table 4: Critical Storage Period for different levels of rainfall

Average Annual Rainfall (mm)	Critical Storage Period	Multiplication factor
More than 650	12 months or 1 year	1
450 - 650	18 months or 1.5 years	1.5
250 - 450	24 months or 2 years	2

Table 5: Allowance for average annual evaporation rates

Landscape zone	Evaporation allowance %	Multiplication factor
Tablelands	25	1.25
Slopes	30	1.3
Plains	60	1.6
Western	100	2.0

Note: Farm dam design will influence the rate of evaporation.

Worked example of calculating water requirements

From Table 1, the required water for one year is calculated as follows:

Item	Calculation	Total (kl)
300 nursing ewes 250 lambs House with 4 people with septic system 0.25 ha garden **TOTAL**	300 x 3.6 kl/head/year 250 x 0.9 kl/head/yr 63 kl/person/yr x 4 0.25 x 1640 kl/ha/yr	1080 225 252 410 **1967**
From Table 2, to allow for Critical Storage Period, the multiplication factor is 1.5	1967 x 1.5	2950
From Table 3, to allow for evaporation, the multiplication factor is 1.3	2950 x 1.3	3835

Therefore the landholder at Illabo requires a dam of **3.84 ML**

*Note: 1 kilolitre (kl) = 1000 litres = 1 m^3
1000 m3 = 1 megalitre (ML)

Step 2: Calculate required catchment area and peak discharge

Catchment yield

The Catchment yield equation can be used to determine the amount of runoff that can be collected from a catchment of a particular size.

Catchment yield (kilolitres) = Area (ha) x Rainfall (mm) x Percentage runoff (%)

To work out the area required to deliver a particular volume of water, the equation can be rearranged as follows:

Area (ha) = Catchment yield (kl) / (Rainfall (mm) x Percentage runoff (%))

Table 6 indicates the percentage runoff for a range of soil types in different parts of NSW.

Table 6: Percentage annual runoff from different soil types in NSW

	Annual Rainfall (mm)	Annual Evaporation (mm)	Soil Types			
			Shallow sand & loams	Sandy Clays	Elastic clays[1]	Clay pans, inelastic clays[2], shales
Tablelands	>650	<1400	5-7.5%	5-12.5%	5-10	10-15%
Slopes	450-650	1400-1500	2.5-5%	5-10%	2.5-5%	7.5-12.5%
Plains	250-450	1500-1700	0-2.5%	0-5%	0-2.5%	2.5-7.5%
Western	<250	>1800	0-very little runoff	0-2.5%	0-very little runoff	2.5-5%

Note 1: Elastic clays – clay soils that crack open when dry, e.g. grey clays on the Murrumbidgee River floodplain.
Note 2: Inelastic clays – when dry have a fine dust cover, which when wet, fill the gaps between larger soil particles, causing infiltration to decrease and runoff to increase.

Worked example of required catchment area

For the Illabo example, where 3835 kl of water is required (catchment yield), it will be assumed the soils are sandy clays with a potential runoff of 10%.

Thus: Area = Catchment yield (kl) / (Rainfall (mm) x Percentage runoff)

= 3835 kl / (550mm x 0.1) (ie. 10% runoff)

= 3835 kl / 55

= 70 hectares

Table 7: Catchment area required to obtain 1967 kl of water per year (as per the Illabo example) across the four landscape zones, assuming particular soil types.

Zone	Water required for one year (kl)	Critical storage period	Evaporation allowance	Dam volume required	Rainfall (mm)	Assumed soil type	Runoff percentage	Catchment area required (ha) estimate
Tablelands	1967	1 year	1.25	2460 kl (2.4 Ml)	650	Shale based soils	10	40
Slopes	1967	1.5 years	1.3	3840 kl (3.84)	550	Sandy surface, clay subsoil	10	70
Plains	1967	2 years	1.6	6300 kl (6.3)	400	" " "	5	360
Western	1967	2 years	2	7700 kl (7.7)	250	" " "	2.5	1260

Peak discharge and spillway width

It is also vital to understand the flood flows that a catchment can produce, as this will assist in forecasting how soon the dam is likely to fill as well as the spillway width required. Note that it is much better to have a spillway that is too wide than too narrow. Longer, wider spillways provide good opportunities for biodiversity improvements.

From Table 8 it can also be seen that a 1 in 2-year rain event will produce a flood that will produce 4680 m^3 of runoff, enough runoff water to fill the 3840 m^3 dam proposed for this catchment.

Table 8: Catchment flow characteristics for a 70ha catchment in the Illabo region, with associated peak discharge and required spillway with.

Annual Recurrence Interval[1]	Time of concentration[2] T_c (mins)	Rainfall Intensity mm/hour[3]	Coefficient of Runoff[4]	Peak Discharge (m^3/s)[5]	Spillway Width (m)[6]	Storm Runoff (m^3)
1 in 2	39.6	26	0.26	1.3	9	4680
1 in 5	39.6	35.1	0.26	1.8	9	6480
1 in 10	39.6	41.2	0.31	2.4	9	8640
1 in 20	39.6	48.8	0.35	3.3	9	11880
1 in 50	39.6	59.2	0.48	5.5	15	19800

Note 1: This describes the approximate time between rainfall events of the associated intensity. For example, a rain event of 35.1 mm/hr will come around once every 5 years.

Note 2: Time of concentration is the time it takes a drop of rainfall to travel from the furthest point in the catchment to the outlet of the catchment. For this catchment, it takes 39.6 minutes to reach the outlet. At this point in time the whole of the catchment is contributing to the runoff, and so the volume of runoff is at its highest and the flood is at its deepest.

Note 3: This is the rainfall intensity required to produce the maximum flood level for the catchment.

Note 4: This is the approximate percentage of rainfall that turns into runoff after the ground has soaked enough water, and all the depressions have filled, and the slope of the catchment has been overcome to allow water to flow.

Note 5– This is the maximum runoff volume that the 70 ha catchment will produce when the whole catchment area is contributing water to the flood.

Note 6: Farm dams are usually designed to last for about 20-30 years, so the design for this spillway is based on the 1 in 20 yr rainfall event. In this example the flow would pass through at about 1-1.5 m/s and about 0.3m deep. If designing for a 1 in 50-year event then the spillway needs to be 15m wide to pass 5.5 m^3/s of flow safely through the spillway with minimal erosion damage to the spillway.

Step 3: Check regulations on dam construction

The example Illabo property is 1000 hectares. Using the maximum harvestable right calculator on the Water NSW website, the MHRDC for the property is 65 Ml (megalitres). This means that the property can capture and store up to 65 Ml of water on first and second order streams on the property without a license.

The example property already has seven dams on the property, with a total storage capacity of 13 Ml as shown in the below diagram. The remaining harvestable right dam capacity can be calculated as follows:

Remaining capacity = MHRDC – existing capacity

= 65 Ml – 13 Ml

= 52 Ml

Therefore the proposed dam size of 3.84 Ml calculated earlier fits within the property's MHRDC. If proposed new dams exceed the MHRDC, then a license may be required to build new dams.

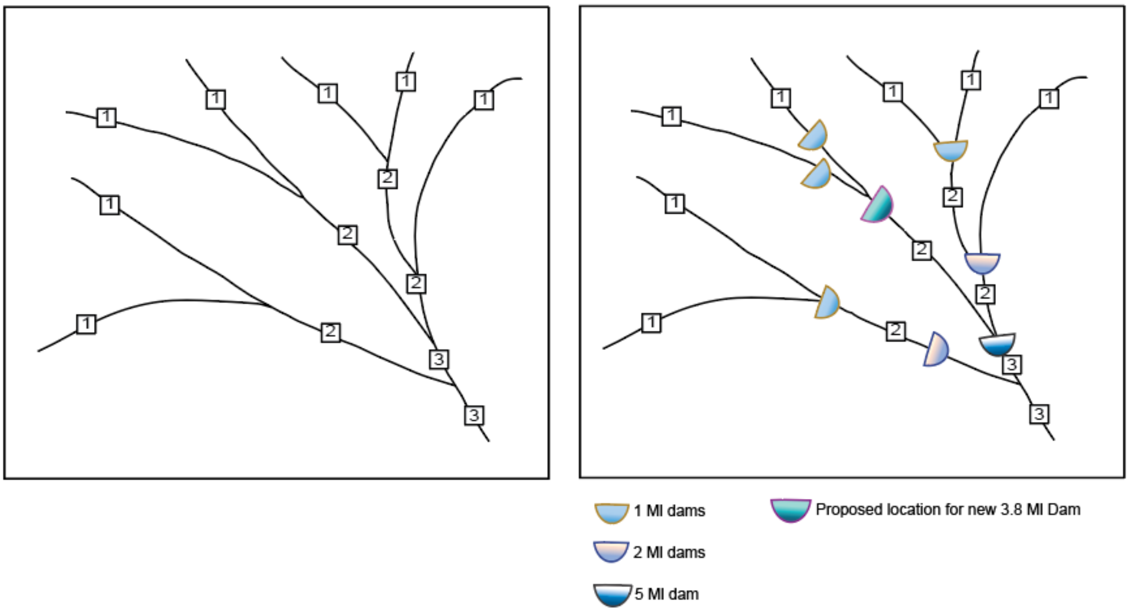

Figure 10: Streams are marked 1, 2 or 3, identifying them as first, second or third order watercourses according to the Strahler stream ordering method. Existing dams on the example Illabo property are shown, as well as the proposed new dam.

Note that for some small properties, the MHDRC may be less than one megalitre. Licences are not required for dams up to one megalitre in size on small properties where the property was approved for subdivision before 1 January 1999. However, no further harvestable right dams may be constructed and any new dams above this allowance must be licensed. Enhancement that increases dam capacity may also require a license.

Additional information on soil testing

Soil tests required to determine site suitability:

- *Dispersion percentage* is the amount of clay material that will dissolve in the presence of water. Less than 30% means clay particles will only disperse slightly, whereas at higher dispersion rates, the clay particles can help with sealing a dam.
- *Emerson Aggregate Test* (EAT) is a measure of the soil's structural stability and is a good indicator of stability in the presence of water. A rating of 1, 2(2), 2(3) shows that the soil will eventually dissolve in the presence of water and the dam will likely fail. A rating of 2(1), 3(1) and 3(2) shows slight to moderate dispersion and are ideal for dam sealing with compaction as the clay particles will move to fill voids between sand and silt particles. EAT results of 4, 5, 6 & 7 require specialist advice as the dam may leak.
- *Particle size analysis* enables determination of the relative proportions of clay (particles <0.002mm in size), silt (0.002 – 0.02mm) and sand (0.02-2mm). A clay content of at least

25%, silt 20% and sand 55%, with <30% dispersion of the clay particles, and an EAT of 2(1), 3(1) or 3(2) indicates a soil that will seal a dam.

- *Linear shrinkage* indicates the potential for soil to crack open when dry, potentially creating a seepage path through the dam wall. Higher values are of concern for dam construction.

Table 9: Soil tests required to determine suitability for dam construction, and the relationship of soil test results to tunnelling susceptibility.[1]

Dispersion %	Emerson Aggregate Test	Particle Size Analysis	Linear Shrinkage	Universal Soil Classification System	Tunnelling susceptibility[2] & construction recommendation
>33%	1 or 2(3)	Clay 15-30% Silt & fine Sand >50%	12-17%	ML & SM – inorganic silts & very fine sands, or very fine sand with little clay – these soils dissolve very easily in the presence of water due to little clay to bind particles	
>33%	1 or 2(3)	Clay >30% or coarse sand >30%	12-17%	SC – clayey sand mixes	Very highly susceptible, see last paragraph in the Ideal Soil summary below table for guidance. **Soil can be used with caution.**
>33%	1 or 2(3) or 2(2)	Clay 15-30% Silt & fine sand >50%	12-17	CH – inorganic clays with high plasticity, will shrink or swell, cracks when dry	Highly susceptible. Strong possibility that this soil will tunnel – **Soil ok for dam construction** - see last paragraph in the Ideal Soil summary below table for guidance.
<33%	2(1), 3, 4,5 or 6	Clay >30% Silt & fine sand <50%	<12%	CL – inorganic clays of low to medium plasticity, gravelly clays, sandy clays	No concern – construct dam with optimal compaction. **Soil ideal for dam construction.**

Note 1: The Universal Soil Classification System is based on identification of soils according to particle size distribution and basic engineering properties such as plasticity index and liquid limits, and the resultant compaction effort required to stabilise the soil for the desired engineering purpose. It gives guidance to which soils can be used for road embankments, building foundations and earthworks such as dams. There is a strong correlation between USCS classes and a soils ability to hold water in a dam.

Note 2: Tunnelling susceptibility is an indication of the soils potential to become unstable in the presence of water and therefore lead to a tunnel working its way through the wall and causing the dam to fail.

[1] Hazelton PA & Murphy BW (Eds) (1992) *What do all the numbers mean – a guide to interpreting soil test results*. DC&LM.