Government of Western Australia
Department of Water and Environmental Regulation

Water quality protection note no. 53

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Dam construction and operation in rural areas

Purpose

This note describes the range of impacts private water supply dams constructed in rural areas can have on our water resources. It also recommends how dam owners can minimise the environmental impacts of rural dams.

The Department of Water and Environmental Regulation (DWER) is responsible for managing and protecting the state's water resources. It is also a lead agency for water conservation and reuse. This note offers:

- our current views on rural dam construction and operation
- guidance on acceptable practices used to protect the quality of Western Australian water resources
- a basis for the development of a multi-agency code or guideline designed to balance the views of industry, government and the community, while sustaining a healthy environment.

This note is intended to inform dam owners, government personnel, environmental consultants and community members on water quality protection aspects of rural dams from their initial design, through construction, operation and potential closure.

Appendices and other water quality protection notes (WQPNs) provide additional background and technical advice as follows:

- WQPN no. 4: *Sensitive water resources*
- WQPN no. 3: *Using water quality protection notes*
- WQPN no. 18: *Information required for the department to assess a proposed development or activity*
- Appendix A: Relevant statutes and administering agencies
- Appendix B: Unified soils classification
- Appendix C: Environmental impacts of dams
- Appendix D: Typical on and off-stream dam designs

Scope

This note applies to private water supply dams constructed on rural properties. The *Rights in Water and Irrigation Act 1914* defines a dam as ‘any artificial barrier or levee, whether temporary or permanent that does or could, impound divert or control water, silt, debris or liquid borne materials together with its appurtenant works’.

Dams may be constructed for a number of reasons including:

- aquaculture
- fire fighting
- irrigation of crops
- livestock drinking water supplies
- wash down supply for enterprises such as dairies
- reticulated farm water supply (other than drinking).

This note does not cover dams built for public drinking water supply, for irrigation schemes involving supplies to multiple properties or storage of mine tailings. Whilst this note is not intended to cover private drinking water supply dams, it may still offer some useful information for those planning to construct a dam for alternative or mixed use purposes. Our WQPN no. 41: *Private drinking water supplies* (see *References and further reading*) provides detailed information for those using dams for private drinking water supplies.

This note does not address technical aspects of dam construction. It is recommended that information be sourced from qualified people with expert geotechnical and engineering knowledge and experience before beginning construction. Further, dam safety is the responsibility of the dam owner.

Background

With the arid nature of much of Western Australia, it is often important to store water when it is more plentiful in the wet season for use during the dry season or droughts. Typically only a small proportion of dam water comes from direct rainfall, therefore catching runoff from the surrounding catchment is necessary. To capture water, dams are either built on or off natural waterways. On-stream dams are built across existing waterways and capture the stream flow. Off-stream dams rely on runoff diversion channels, drainage lines or paved catchments to capture rainfall or irrigation run-off, redirect water into the dam via pumping or are fed from groundwater seepage. As a result the nature of the environment surrounding a dam needs consideration. The water level in dams fluctuates due to rainfall, run-off, evaporation, water usage and sub-surface seepage. These factors can also influence contaminant transfer and concentrations.

Advice and recommendations

The following recommendations aim to prevent rural dams from harming the quality of water resources. They have been divided into several sections to reflect the types of risk including legal requirements, impacts on water resources, dam construction, operation and water quality.

Licensing and legal responsibilities

1. The location and design of the dam should ensure there are no harmful effects on upstream or downstream properties (except in accordance with a written agreement), including:

   a) a significant reduction of the seasonal stream flow that could affect other people's aquaculture, tourism ventures or water supplies

   b) flooding of neighbouring properties, access ways or reserves.

2. A water allocation licence, issued by DWER, may be required under section 5C of the *Rights in Water and Irrigation Act 1914* to take water from a waterway (see Table 1).

Table 1: When is a section 5C licence required?

Licence issue	Explanation
A water allocation licence is required	• used for commercial purposes in any proclaimed groundwater area • used for commercial purposes from proclaimed water courses or those within proclaimed surface water areas • from artesian (confined or semi-confined) aquifers anywhere in Western Australia
A water allocation licence is not required	• taking non-artesian groundwater in non-proclaimed areas • taking surface water from non-proclaimed areas or watercourses • taking limited quantities of surface water for stock (non-intensive), domestic and ordinary purposes (i.e. riparian rights) • water flowing from springs, until it passes beyond the boundary of the land on which the spring water rises

3. A separate permit authorising the disturbance of the bed or banks of proclaimed waterways may also be required under section 17 of the *Rights in Water and Irrigation Act 1914*. Our regional office (see www.dwer.wa.gov.au) can provide advice.

4. Clearing of native vegetation, including areas that will become flooded by the dam, may require a licence from DWER under the Environmental Protection (Clearing of Native Vegetation) Regulations 2004. Contact us for more information (www.dwer.wa.gov.au).

5. When a permit is issued under the *Rights in Water and Irrigation Act 1914* to interfere with a watercourse, this exempts the permit holder from requiring a clearing permit under Environmental Protection (Clearing of Native Vegetation) Regulations 2004, regulation 5, item 16. However the permit does not exempt the holder from clearing approval in environmentally sensitive areas.

6. Your local government may need to provide approvals, licences or permits under planning by-laws. Contact your local government for more information.

7. For detailed advice about the legal responsibilities of dam owners (including liability for flooding and dam safety), a qualified and experienced legal practitioner should be consulted.

Impacts on water resources

While acknowledging the benefits that rural dams provide, they can cause significant environmental costs. The dam's location, size, function and permeability of the banks and base will influence the impacts it has on the local environment.

Typically, the larger the dam, the greater the potential for an adverse environmental impact. However, small dams built near highly sensitive ecosystems may also cause significant impacts. A number of small dams built on one waterway will also have a similar effect to a large dam on total stream flow. How the proponent operates the dam could also affect how much of a risk the dam poses to water resources. Catchment land use practices have a strong influence on the quality of surface water sources.

The potential environmental impacts of rural dam construction on water resources include:

- changes in waterway flow regimes and water quality as a result of dam construction
- impacts caused during the operation of the dam e.g. release of contaminated water
- formation of a waterway barrier that impedes the movement of aquatic fauna.

8. Dam owners should make themselves aware of the potential downstream impacts of their dam. These impacts can affect both the quality and quantity of a water resource. Water quality has both aesthetic (e.g. taste, appearance and odour) and health-related components (e.g. pathogens, chemical and physical contaminants). For example, ensure that the water quality of the dam is suitable for the receiving environment before any discharges occur.

In summary, impacts may come from changes in ecosystem hydrology, release of sediment, land clearing, changes to aquatic species migration patterns, seepage, dam failure, translocation of aquatic organisms (particularly in aquaculture) and changes in water quality parameters including nutrients, turbidity, salinity and pathogen levels. The potential impacts of dams are described in more detail in Appendix C.

Design and construction

This section covers planning aspects, predicting environmental impacts and the physical construction of the dam. Most of these recommendations also apply if expansion or any other significant modification of the dam is carried out after it has been constructed.

The design of a dam is vitally important in reducing the undesirable impacts on water resources. Incorporation of appropriate design features into a dam to manage these impacts is recommended during the initial construction phase. It may be very costly and time consuming to later fix problems that have been encountered because of poor design.

Water quantity issues

9. Before constructing a dam, the applicant should review any relevant water allocation plans published by this department (see www.dwer.wa.gov.au).

10. Your nearest DWER regional office (see www.dwer.wa.gov.au) can also provide information on water availability within a defined allocation limit. Although water needs to be available within an allocation limit, this does not guarantee approval of the dam.

11. Environmental water provisions (EWPs) are an important component in determining if dam construction is likely to threaten aquatic ecological values within a catchment. EWPs are the water regimes defined via the water allocation planning process taking into account ecological, social and economic impacts. Water in excess of the EWPs may be available for consumptive use and defines the sustainable yield of water taken from managed waterways. If there is concern that a dam will diminish this yield and threaten the sustainability of downstream ecosystems, then this department may request a *water resource investigation* (WRI). If the WRI is not provided, this department may refuse to issue a licence to build the dam. More information is provided in Table 2.

Table 2: Water resource investigations (WRI)

The applicant for a water allocation licence should be aware that submission of a WRI report does not guarantee the issue of a water allocation licence.
When is a water resource investigation required?
• local water resource availability is unknown • significant water allocation is sought (over 1000ML/year) • evidence indicates that the planned water draw may not be ecologically sustainable • risk of detrimental impact to another person or water user, the water resource or its ecosystem or the environment in which the water resource is situated • when specified in a published catchment management plan
Who does the investigation?
• a suitably qualified and experienced person at the expense of the applicant for a dam licence.
Reporting
A general outline of what is required includes: • a location plan depicting the dam layout • plan and profiles of the water retaining structure, including its dimensions • calculated annual water yields and resource characteristics • water quality data (pH, salinity, nutrient and toxicology status) benchmarked against guideline criteria for the intended use (see reference 2a) • prediction of the impacts on waterway flow, other users, the local environment and overall sub-catchment water availability • proposed monitoring program (water balance ,quality parameters and testing frequency) • proposed environmental water requirements – further information see our Statewide policy 5: *Environmental water provisions policy for Western Australia* • evaluation of alternative water sources.

12. Dams should be positioned off-stream unless the proponent demonstrates that measures to construct an off-stream dam have been investigated and construction of such a dam is not technically viable. Dams constructed off the main waterway channel are likely to produce a more controllable impact on stream flow (provided the take is not from dry season flows and is within a defined take period and daily extraction rate). For typical layouts for on and off-stream dams, see Appendix D.
13. Dams constructed on-stream should have provision to maintain low stream flows and EWPs. These can be in the form of bypass channels with flow gates or stop boards. Under-wall outlet pipes with stop valves may be used for occasional wet season scouring of residues accumulated in the dam. The low-flow period will vary geographically depending on the seasonal climate. In southern areas of the state, November to April is normally the low-flow period during which less than 20 per cent of the annual waterway flow occurs. If there is any inflow to the dam during low-flow periods (typically as a result of a thunderstorm), then an equivalent amount of water should be released to maintain aquatic ecological functions downstream.
14. Dams should be designed to provide only the volume of water necessary for the specified usage, with allowance for evaporation, seepage and a safety factor for rainfall variability. This department normally opposes dams being built purely for aesthetic purposes as they are incompatible with efficient water use.
15. Rural dams should have a holding capacity appropriate to annual usage requirements (i.e. dams should not remove excessive amounts of water from the catchment). Expert advice should be sought to determine the appropriate size for a dam.
16. The Department of Primary Industries and Regional Development (www.dpird.wa.gov.au) provides guidance on water requirements for some types of livestock and crops (see *References and further reading*).
17. The Department of Primary Industries and Regional Development (www.dpird.wa.gov.au) can advise on requirements for aquaculture projects.
18. A cost-benefit analysis should be used to predict whether it is economically viable to build a dam with a capacity to meet anticipated water consumption (especially during dry years). Software packages are available to assist these analyses.
19. Dams should have appropriately constructed spillways and/or bypass channels to return water to the original waterway. These facilities should provide sufficient freeboard to prevent overtopping of the dam wall and reduce the risk of dam failure during periods of high or extended rainfall. They should be designed and constructed to reduce potential erosion and pressure on the dam wall.
20. Dam storage freeboard should provide for at least a 1 per cent AEP (annual exceedence probability) storm event.
21. The site investigation and selection should optimise the sustainable use of available water within a dam's catchment. The size of the catchment, soil and vegetation characteristics and path of surface run-off water determines what water is available within a catchment. Contour maps should be used to predict the path of rainfall and irrigation run-off within the dam's catchment.

22. Rainfall, evaporation and run-off data should be sourced online from the Australian Bureau of Meteorology (www.bom.gov.au) and Engineers Australia (see *References and further reading*). This data should be used to aid site selection, determine dam capacity and choose the optimum season for construction.
23. A dam water balance should be prepared that includes water inputs from rainfall and run-off, and outputs from evaporation, seepage and water use. The water balance will help identify whether the dam is capable of meeting the water requirements for its intended purpose.
24. The dam design should take into account statistical rainfall information for 'dry' years based on Australian Bureau of Meteorology records and climate variability predictions (see *References and further reading*).

Water quality issues

25. Rural water supply dams should not be constructed within priority 1 (P1) areas or reservoir protection zones of public drinking water source areas (PDWSAs) unless approved in writing by DWER. This is to minimise the risk of harm to water quality or availability of the drinking water source. P1 areas are managed using the principle of risk avoidance.
26. Rural dam margins should have a buffer zone of at least 100 m from septic tanks and other sources of faecal contamination to reduce the risk of pathogen and nutrient entry.
27. To reduce the potential damage caused by land clearing, only the minimum amount of vegetation necessary should be removed. This should match the footprint of the dam when full plus an allowance for dam protection linked to potential tree root intrusion. The benefits that vegetation surrounding a dam can provide should be considered. Our WQPN 6: *Vegetated buffers to sensitive water resources* provides more detail (see *References and further reading*).

Construction issues

28. The best available lining materials (imported to the site or from a local borrow pit) during the dam construction should be used to reduce the likelihood of the dam walls failing and flooding downstream areas (see WQPNs 26 and 27 in *References and further reading*).
29. Local soil types should be tested to determine their suitability for use in a water-retaining structure, (contact Department of Primary Industries and Regional Development, www.dpird.wa.gov.au for more information). Clay-based soils are generally considered the best for constructing dam embankments. The unified soil classification system also provides useful information in determining the suitability of soil types for dam construction (Appendix B).
30. Test drilling of soil and water should be carried out prior to construction to determine salinity levels. If salinity levels are excessive, then alternative sites may need to be considered. This issue is extremely important where fresh water sits over a saline aquifer or soils are high in salt. When the dam is constructed it may tap into these sources of salt, creating stored water that is unusable and an environmental hazard.

31. If an on-stream dam could block the migration of any aquatic fauna, then the design should include additional infrastructure to facilitate this movement, such as fish ladders (see Water note 26: *Simple fishways*, in *References and further reading*).
32. During construction, engineered bypass channels should be used to divert stream flow around the construction site to minimise sediment transport downstream.
33. Dams should be built during the dry season to allow construction without stormwater disturbing the earthworks.
34. Soil embankments should have consistent low permeability soil characteristics, be moisture conditioned and compacted and have appropriate shape and dimensions, so they are sufficiently sturdy to prevent failure of the structure. The amount of weight and subsequent pressure on the dam walls from the dam water should not be underestimated. Organic material in the dam wall, such as dead tree trunks, roots and plant matter, should be removed as the dam wall can weaken and fracture as the organic material decays.
35. Some seepage from the dam will inevitably occur. An infiltration rate of less than 1×10^{-9} m per second is an acceptable level of seepage. Soil compaction, material blending or additives such as concrete, bentonite, geotextiles and fabrics (artificial liners) should be used to reduce water loss through seepage (see our WQPN 26: *Liners for containing pollutants, using synthetic membranes* and WQPN 27: *Liners for containing pollutants, using engineered soils* in *References and further reading*). A cut-out trench under the dam wall, made using low permeability material, can also reduce seepage. The geology underlying the dam site will also influence seepage rates.
36. Dams built with fractured and porous rocks under the dam structure tend to have higher rates of seepage and a higher chance of the structure failing (see Romanov et al. 2003).
37. Grouting or water stops should be considered if weathered or fracture zones exist beneath the footprint of the water reservoir and at dam wall pipe penetrations.
38. The Department of Primary Industries and Regional Development can provide information about the construction of farm dams, see www.dpird.wa.gov.au.
39. For large reservoirs, in steep terrain or where dam wall may be affected by wave action, surface protection (e.g. rock armouring) should be used to minimise erosion.

Dam operation

Many of the potential impacts from operation of dams can be reduced if the dam is well designed and constructed (see previous sections).

40. Evaporation results in significant loss of water from dams. The use of windbreaks, such as trees, will reduce evaporation rates by decreasing wind velocity. Deep dams with low surface area to volume ratios will also have lower evaporation losses. Floating covers or suspended shade covers can also be used to reduce evaporation, particularly for smaller dams.
41. A number of measures may be taken to reduce the turbidity of dam water and control algal blooms, including:
    a) Dam wall construction using a low-permeability core, with rock-armoured outer banks.

b) Use of a well-compacted liner and embankment materials (see WQPN 27).

c) For large dams, the dam design and orientation should minimise wave action.

d) Where viable, avoid introduction of aquatic species into the dam that stir up sediment.

e) Filter or chemically treat dam water, if needed to remove suspended solids.

f) Use settling ponds or vegetation filters to improve the quality of any released water.

g) Use appropriately engineered inlets for off-stream dams (see Appendix D).

h) Control of livestock access to the dam by fencing and pumping water to stock troughs (see Water notes in *References and further reading*). This limits water contamination by pathogens and nutrients, and minimises bank erosion.

i) Use shallow-rooted vegetation cover, such as endemic species of perennial shrubs or grasses on dam embankments. Stockpiling topsoils during construction then spreading it across the dam walls after construction and seeding with grass can create a perennial vegetation cover.

42. Controlling catchment nutrient flows is a complex task. The best way to prevent nutrient build-up and algal blooms within dams is to ensure the surrounding catchment land uses follow best management environmental practice.

    Best practice examples that help control nutrient build up within dams include:

    a) Apply fertiliser sparingly on catchment cropland according to supplier's instructions and the target vegetation's nutrient requirements.

    b) Maintain vegetation buffers around the dam (see WQPN 6).

    c) For aquaculture dams, maintain sustainable aquatic stock densities and avoid overfeeding.

    d) Use barrier fences and well-located drinking troughs to prevent livestock access to the dam or its feeder streams.

43. Livestock access to dam feeder drains should also be controlled to prevent microbial contamination. Removing any dead animals from the dam surrounds and maintaining good animal husbandry practices to prevent stock from becoming diseased will reduce the risk of pathogens entering dam waters.

44. Treatment of the water before it enters the dam, via natural grass or wetland filters, will also reduce the likelihood of pathogens entering the water. If the dam is being used for livestock water supplies or for aquaculture filters can help reduce the risk of disease outbreaks. Knowledge of land uses in the catchment will help in predicting the risk of pathogen entry into the dam.

Operational water quality

45. Water quality testing should be carried out to determine if dam water contains toxins or pathogens that threaten the desired water use. If significant contamination is found, then urgent remedial action should be taken to control the contamination source.

46. Good management practice can play an important part in controlling fluctuations in water quality. Regular maintenance and monitoring of the dam quality is recommended. Regular testing and analysis of the water will provide a warning if changes are occurring

(such as algal blooms) and allow action to be taken prior to a significant problem emerging.

47. The water quality parameters of alkalinity, biochemical oxygen demand, dissolved oxygen, electrical conductivity (salinity), pH, temperature, turbidity, nitrogen as ammonia, nitrogen as nitrate, total phosphorus, orthophosphate, faecal coliforms, faecal streptococci and chlorophyll 'A' are commonly used for water characterisation (De Ceballos *et al*. 1998).

48. It is expensive and time-consuming to regularly test water quality. When deciding how often to test water quality and what parameters to test for, the sensitivity of the surrounding environment, the dam's function and catchment land uses should be taken into account.

49. National water quality management strategy papers such as the *Australian and New Zealand guidelines for fresh and marine water quality* (see *References and further reading*) provide detailed guidance on water quality for use in primary industries.

50. Our WQPN 2: *Aquaculture* provides parameters for the discharge of water used in small-scale aquaculture ventures and provides other useful information for those looking to construct a dam for direct or indirect use in aquaculture.

51. The Department of Primary Industries and Regional Development can provide guidance on controlling some specific water quality issues within dams (see Farmnote 41/04 in *References and further reading*).

52. Valved outlets fitted to scour the dam should not allow escape of aquaculture stock from the reservoir. Accessible screens and filters should be installed to manage on any water flowing from a dam holding exotic aquatic animals. Feral fish, crustaceans, molluscs and aquatic weeds present a major threat to natural ecosystems.

53. Generic guidelines to prevent chemicals, such as pesticides and fuels, from entering the dam and subsequently causing damage to water resources include:

    a) using appropriate, safe chemicals suited to the task at hand

    b) conforming to relevant Australian standards and codes

    c) following the manufacturer's instructions for chemical storage and use

    d) conforming to material safety data sheets for the chemicals in use

    e) using guidance provided in our WQPN 7: *Chemical blending*, WQPN 10: *Contaminant spills – emergency response* and WQPN 65: *Toxic and hazardous substances – storage and use*.

54. There are many different land uses across rural WA and so various chemical residues could enter dams. It is beyond the scope of this note to deal with each chemical individually, hence precautions should be taken based on chemicals likely to be used in conjunction with local land uses.

55. If an off-stream rural dam is filled by pumping from a waterway, no pumping should occur during low stream-flow periods.

56. If any pumps used on the dam are powered by generators, fuel and oil should be managed as recommended in our WQPN 65: *Toxic and hazardous substances – storage and use* and WQPN 56: *Tanks for above ground chemical storage*.
57. All operational data recorded for the dam should be archived for a minimum of two years for later reference. This includes plans, water resource investigations, water flow and usage data, the results from water quality tests and in situ water treatment. This allows analysis of this information that may show trends, such as changes in dam water parameters over time, and can be useful in providing information when problems are encountered. This information can also be reviewed when the dam is being decommissioned at the end of its useful life.

Dam removal

58. Removal of dams at the end of their useful life can cause environmental impacts. Local ecosystems should be assisted to recover to pre-dam conditions. However this may prove impractical as environmental damage caused may not be reversible.
59. The ability and effort expended to allow an aquatic ecosystem to recover may depend on its sensitivity as well as the length of time that the dam has been in place. Different parts of the ecosystem will recover at different rates, with riparian vegetation typically having the longest recovery time (Doyle et al. 2005).
60. Many of the problems encountered during dam construction will also be encountered during its removal. This includes the release of sediments, changes in water flow patterns, release of contaminated water and escape of aquatic species. Extensive planning should be undertaken and protective measures implemented when decommissioning a dam to reduce the environmental impacts.

Appendix A: Statutory approvals relevant to this note

What's regulated?	Western Australian statutes	Regulatory body/agency
Soil erosion control	*Soil and Land Conservation Act 1945*	Department of Primary Industries and Regional Development www.dpird.wa.gov.au
Aquaculture licensing	*Fish Resources Management Act 1994* Fish Resources Management Regulations 1995	
Discharging of materials into the environment	Environmental Protection (Unauthorised discharges) Regulations 2004	Department of Water and Environmental Regulation www.dwer.wa.gov.au
Licensing of prescribed premises that pollute	*Environmental Protection Act 1986* - Part V Environmental Regulation	
Land clearing, effects of erosion, salinity, land drainage & flooding	Environmental Protection (Clearing of Native Vegetation) Regulations 2004	
Licence to take surface water Permit to interfere with bed and banks of a waterway	*Rights in Water and Irrigation Act 1914*	
Land use activities in posing a risk to sensitive waters e.g. within public drinking water source areas and proclaimed catchments of waterways	*Metropolitan Water Supply, Sewerage and Drainage Act 1909 ;Country Areas Water Supply Act 1947* *Waterways Conservation Act 1976*	
Management of human wastes, community health issues Pesticides use, storage, handling & disposal (including herbicides) Possession and use of poisons	*Health Act 1911* Health (Pesticides) Regulations 1956 *Poisons Act 1964*	Department of Health www.health.wa.gov.au Local government

What's regulated?	Western Australian statutes	Regulatory body/agency
Transport, storage and handling of fuels, solvents, explosive and dangerous goods	*Dangerous Goods Safety Act 2007*	Department of Mines, Industry Regulation and Safety www.dmirs.wa.gov.au
Emergency response planning	*Fire and Emergency Services Authority of WA Act 1998*	Department of Fire and Emergency Services www.dfes.wa.gov.au
Impact on the values and ecology of land or natural waters	*Environmental Protection Act 1986* -Part IV Environmental impact assessment	Environmental Protection Authority www.epa.wa.gov.au
Land zoning and development approval including subdivision of land	*Planning and Development Act 2005*	Department of Planning, Lands and Heritage www.planning.wa.gov.au Local government

Relevant statutes are available from the *State Law Publisher* at www.slp.wa.gov.au.

Appendix B: Unified soil classifications

Symbol	Description
GW	Well graded gravels
GP	Poorly graded gravels
GM	Silty gravels
GC*	Clayey gravels
SW	Well graded sands
SP	Poorly graded sands
SM	Silty sands
SC*	Clayey sands

Symbol	Description
ML	Inorganic silts with low liquid limits
CL*	Inorganic clays with low liquid limits
OL	Organic silts with low liquid limits
MH	Inorganic silts with high liquid limits
CH*	Inorganic clays with high liquid limits
OH	Organic clays with high liquid limits
Pt	Peat and highly organic soils

* These soils are considered the best for dam construction.

Key to symbols used in the unified soil classifications			
First and/or second letter	**Definition**	**Second Letter**	**Definition**
G	Gravel	P	Poorly graded
S	Sand	W	Well graded
M	Silt	H	High liquid limit
C	Clay	L	Low liquid limit
O	Organic	Pt	Peat

Source: Adapted from Waters and Rivers Commission, 1993, WP 159: *Guidelines for the design and construction of small farm dams in the Warren Area*, Government of Western Australia, Perth.

Appendix C: Environmental impacts of dams in rural areas

For general information about protecting water quality, see WQPN no. 8: *Further reading*.

Construction impacts

Dam construction has been linked with a number of environmental changes. These include major impacts on the hydrology of waterway and wetland ecosystems by altering the timing, magnitude and frequency of water movement. The changes in water movement that a dam creates may threaten the ecological values of water-dependent ecosystems. These ecosystems require regular seasonal flow cycles to maintain aquatic biota and ecosystem processes (often referred to as environmental flows). Under this department's Statewide policy 5: *Environmental water provisions policy for Western Australia*, environmental water provisions (EWPs) will help determine if the ecological water requirements for an ecosystem are being fully or partially met. This, in turn, will demonstrate if a dam is likely to threaten the ecological values by reducing water flow. The need to maintain flows within a waterway is supported by provisions in the *Rights in Water and Irrigation Act 1914*. This act requires that dams do not make a sensible reduction (noticeable change) in the flow volume of a waterway.

Large dams have been implicated in the elimination of floods, resulting in changes to riparian vegetation. This reduces biodiversity and may cause major changes in food webs (Magilligan & Nislow 2005). While the types of dams necessary to cause such changes are much larger than those typically used in rural areas of WA, a series of small dams on a waterway can influence local flood patterns and consequently have significant environmental effects. Maintaining environmental flows requires not just minimum flows, but appropriate seasonal timing of flows for maintaining the ecosystem.

The Environmental Protection (Unauthorised Discharges) Regulations 2004 make it an offence to release sediment into the environment. This is particularly important during construction of the dam when earthworks are being carried out. The earthworks can expose topsoils and significant rainfall may lead to erosion and turbid water. Altering the path of a waterway during the construction of dam may also be necessary (such as diverting the flow around the dam site so that water is not entering the dam during construction). Any loose surface material in the path of the new flow may be carried downstream and contribute to altered flows in the waterway or sedimentation in downstream dams or pools.

The clearing of forested land to construct the dam could also cause the water table to rise, exacerbating the salinity risk to the dam. If the dam is built close to the water table, the risk of this happening is increased. Clearing for individual farm dams is likely to be limited and have minimal effect on the water table. The cumulative effect of clearing for a number of dams in a sub-catchment is more likely to create this type of impact.

Vegetation around the dam helps to prevent erosion, improve water quality, provide storm protection, retain nutrients and can restrict the growth of nuisance plants and algae. Dam construction can also destroy riparian and wetland vegetation and fauna habitat.

Dams constructed on-stream provide a detrimental physical barrier for the movement of aquatic species. This movement might be an essential part of their life cycle, such as an upstream fish migration to spawn.

Operational impacts

The potential threat to water resources from the operation of the dam includes failure of the dam structure, contamination of stored water or changes in water quality and subsequent release of this water, and escape of aquatic organisms from the dam. A number of measures can be taken to reduce the risks of these events happening.

Failure of the dam walls and subsequent release of water and construction debris has the potential to cause more damage than a flood. Poor compaction of the dam structure can lead to increased seepage and aid the transport of contaminants. This can also increase the erosion from the dam, resulting in sediment being transferred downstream.

Changes in dam water quality may occur for a number of reasons. Relatively still dam waters can act as a trap for nutrients. These nutrients may cause algal blooms within the dam. If nutrient-rich water leaves the dam, it can contribute to eutrophication downstream. Nutrients can be introduced to the dam from aquaculture effluent and livestock waste, the application of fertilisers around the dam and run-off from surrounding properties. The still waters of a dam can cause seasonal stratification to occur. This can lead to water temperature changes, particularly during summer, exacerbating ecological problems.

Changes in the turbidity and the level of suspended solids within the dam water may also damage downstream water resources. Turbid water can alter ecosystems in a number of ways. Shading of aquatic plants causing death, reduced visibility of aquatic organisms can affect their behaviour (such as detection of predators) and the benthic layer can be smothered as suspended particles settle out of the water column.

Scouring of the dam during maintenance, algal blooms, livestock access to the dam, sediment transportation from the upper catchment and erosion of dam walls can increase turbidity within the dam. If this turbid water escapes either through flow bypass or weir overflow it then has the potential to cause damage to the downstream ecosystem.

Dams may also reduce by the amount of sediment being transported in the waterway. Dams may trap sediment flows from upstream preventing normal downstream settlement, resulting in increased scouring and erosion of the waterway.

Erosion may cause plants to be uprooted resulting in significant damage to riparian vegetation. Changes in flow patterns over the life of the dam may also affect riparian vegetation, i.e. some species of flora rely on water movement for reproduction.

The salinity of dam water may increase over time as evaporation and refilling causes salts to accumulate within a reservoir base layer. The high evaporation and low flow rates occurring during summer will speed up this process within the dam. This coincides with low flows within waterways located in southern areas of WA when the capacity of the environment to assimilate the salts, should they be released from the dam, is reduced. This can result in proportionally larger changes in salinity.

Water may also become contaminated with chemicals used within the catchment. Examples include pesticides sprayed on grape vines and antibiotics used in aquaculture. The many different uses of land across WA means that a number of potentially harmful agricultural chemicals could be used near rural dams.

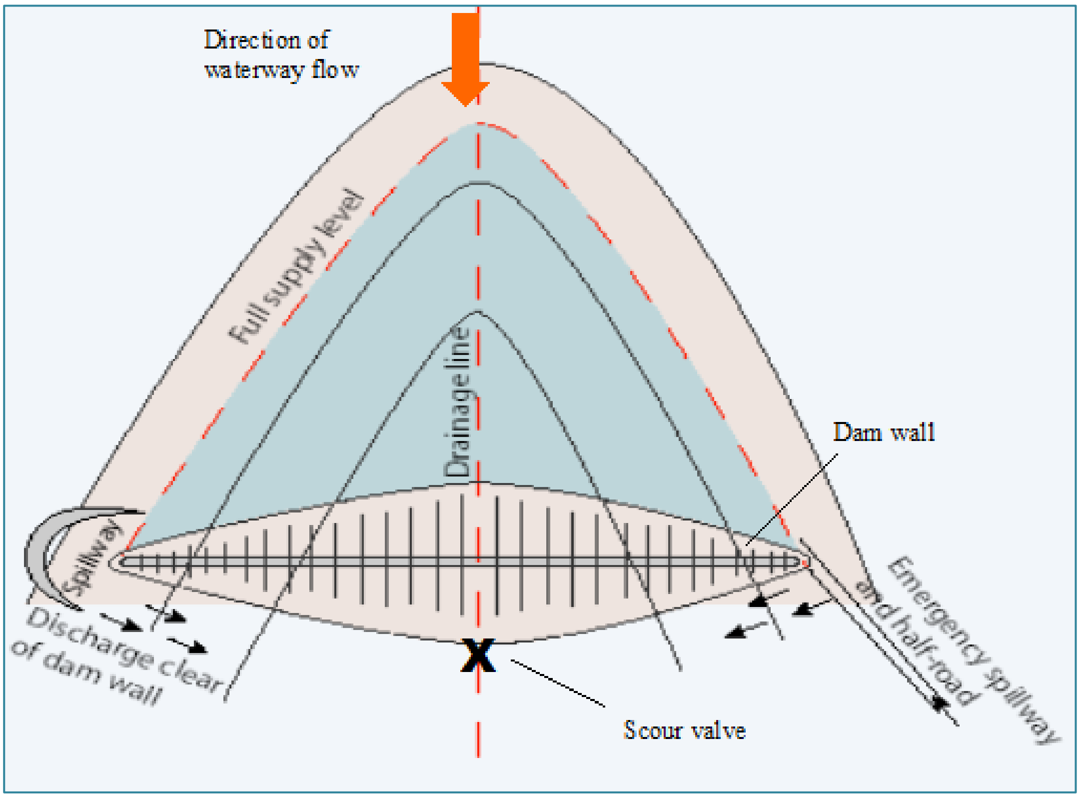
Aquatic animals that escape or are released in dam water can have significant adverse impacts on water resources. These animals can act as carriers for pathogenic diseases and cause disease outbreaks. They can often out compete indigenous species, increase water turbidity and contribute to nutrient enrichment of waters.

Pathogens introduced to the water by livestock could be released from the dam (through the dam overflowing or being drained) into nearby waterways. If these species are exotic they could alter the ecological balance and cause significant damage to the ecosystem if released. As an example, cow faeces may contain *Cryptosporidium* and *Giardia*, that are protozoa that cause gastric disease in human and animals. Both of these microbes were implicated in the Sydney water crisis of 1998. Allowing stock access to dams increases the risk of contaminants entering the dam and from there flowing into other water sources. Animal corpses that end up in dams may also introduce pathogens to the water.

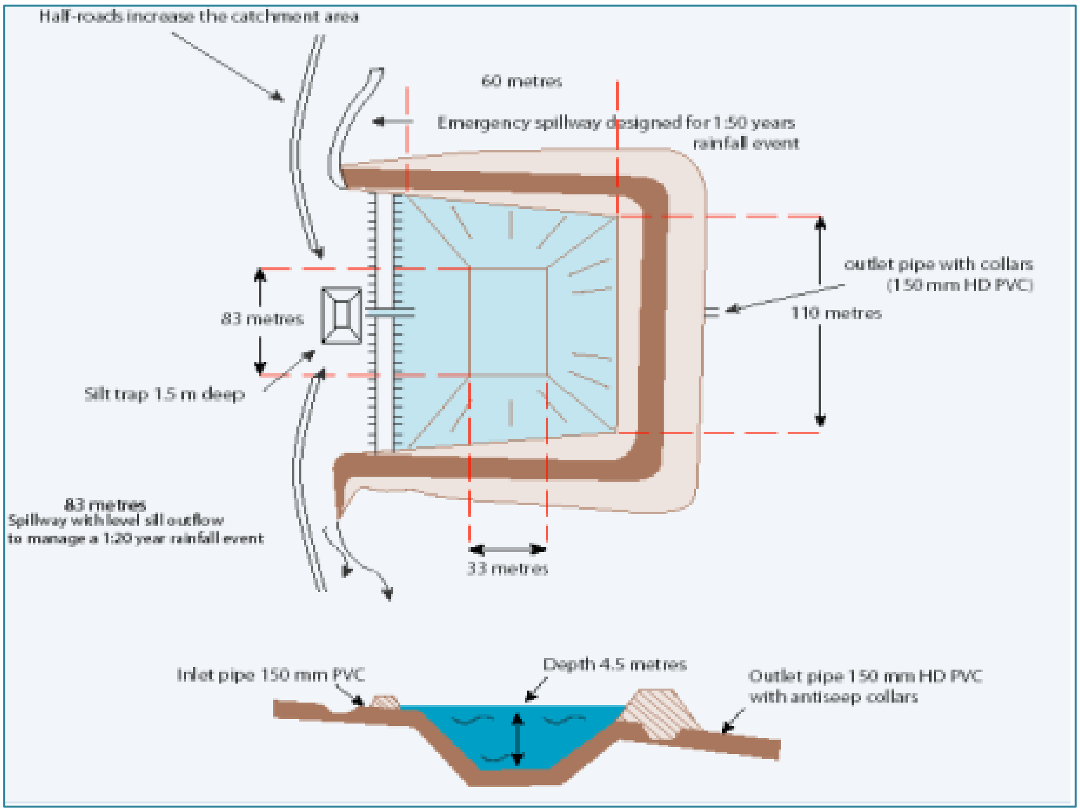
Seepage is very common, particularly for poorly designed and constructed dams, and can account for up to 50 per cent of water loss from a dam (Brainwood et al, 2004). It is also an effective pathway for nutrients, chemicals, pathogens and other potential pollutants to leave the dam and enter downstream water resources. Therefore controlling seepage is important in minimising any adverse environmental impacts from dams.

Appendix D: Typical on- and off-stream dam designs

On-stream (gully) dam:



Typical off-stream (hillside) dam in the south-west of WA



Source: Department of Primary Industries and Regional Development

References and further reading

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- *WQPN 2 Aquaculture*
- *WQPN 3: Using water quality protection notes*
- *WQPN 6 Vegetated buffers to sensitive water resources*
- *WQPN 7 Chemical blending*
- *WQPN 8: Further reading*
- *WQPN 10 Contaminant spills – emergency response*
- *WQPN 18: Information required for the department to assess a proposed development or activity*
- *WQPN 25 Land use compatibility in public drinking water source areas*

- *WQPN 26 Liners for containing pollutants using synthetic membranes*
- *WQPN 27 Liners for containing pollutants, using engineered soils*
- *WQPN 36 Protecting public drinking water source areas*
- *WQPN 39 Ponds for stabilising organic matter*
- *WQPN 41 Private drinking water supplies*
- *WQPN 48 Water supplies for rural lots (non-potable use)*
- *WQPN 56 Tanks for above ground chemical storage*
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- *WQPN 62 Tanks for underground chemical storage*
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- WF1 Water words
- WF4 Living streams
- WF5 Taking water from streams and lakes in Western Australia
- WF6 Algal blooms
- WF13 Flooding in Western Australia

- WF14 Floodplain management.

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- *WN6 Livestock management: Construction of livestock crossings*
- *WN7 Livestock management: Watering points and pumps*
- *WN8 Habitat of rivers and creeks*
- *WN10 Protecting riparian vegetation*
- *WN11 Identifying the riparian zone*
- *WN12 The values of the riparian zone*
- *WN13 The management and replacement of large woody debris in waterways*
- *WN14 Lamprey guides*
- *WN17 Sediment in streams*
- *WN18 Livestock management: fence location and grazing control*
- *WN19 Flood proofing fencing for waterways*
- *WN22 Herbicide use in wetlands*
- *WN25 The effects and management of deciduous on waterways*
- *WN26 Simple fishways*
- *WN29 Long-term management of riparian vegetation.*

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