



Department of Water
Government of Western Australia



Serpentine Dam Catchment Area and Serpentine Pipehead Dam Catchment Area Drinking Water Source Protection Plan

Water Resource Protection Series

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Serpentine Dam Catchment Area and Serpentine Pipehead Dam Catchment Area Drinking Water Source Protection Plan

Integrated Water Supply System

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Final Report

July 2007

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Contents

Contents.....	iii
Tables	iv
Preface.....	v
Summary.....	vi
1 Drinking water supply system	1
1.1 Existing water supply system	1
1.2 Water treatment	1
1.3 Catchment details	2
1.3.1 Physiography.....	2
1.3.2 Climate	2
1.3.3 Hydrography.....	3
1.4 Future water supply requirements	3
1.5 Protection and allocation	3
1.5.1 Existing water source protection.....	3
1.5.2 Current allocation licence	4
2 Water quality	7
2.1 Microbiological contaminants	7
2.2 Health related chemicals	7
2.3 Aesthetic characteristics	7
3 Land use and contamination risk	9
3.1 Potential water quality risks	9
3.2 Existing land uses	10
3.2.1 Private Land	10
3.2.2 Crown Land	11
3.3 Proposed land uses	14
4 Catchment protection strategy	16
4.1 Protection objectives.....	16
4.2 Proclaimed area.....	16
4.3 Priority classifications	16
4.4 Protection zones	17
4.5 Land use planning	19
4.6 Best management practices	19
4.7 Surveillance and By-law enforcement	20
4.8 Emergency response.....	20
4.9 Recommended protection strategies.....	21
5 Recommendations	56
Appendices	59
Glossary.....	61
References.....	64

Appendices

Appendix A — Water Quality..... 59

Figures

Figure 1. Serpentine Dam and Serpentine Pipehead Dam catchment locality plan ... 5
Figure 2. Serpentine Dam and Serpentine Pipehead Dam Catchment Areas..... 6
Figure 3. Serpentine Dam and Serpentine Pipehead Dam Catchments land use and
tenure..... 15
Figure 4. Proposed priority classifications and protection zones for Serpentine Dam
and Serpentine Pipehead Dam Catchment Areas 18

Tables

Table 1. Land use, potential water quality risks and recommended strategies 22

Preface

The Department of Water has prepared this Drinking Water Source Protection Plan to report on the activities and risks to water quality within the Serpentine Dam and Serpentine Pipehead Dam Catchment Areas and to recommend management strategies to minimise the identified risks.

A safe drinking water supply is critical to the well-being of the community and catchment protection is necessary to help avoid, minimise or manage risks to water quality. The Department is committed to protecting drinking water sources to ensure the continued supply of 'safe, good quality drinking water' to consumers.

The Australian Drinking Water Guidelines recommend a multiple barrier 'catchment to consumer' approach to protect public drinking water. The protection and management of drinking water catchments is the 'first barrier', with subsequent barriers implemented at the water storage, treatment and distribution stages of a water supply system. Catchment protection includes understanding the catchment, the hazards and hazardous events that can compromise drinking water quality, and developing and implementing preventive strategies and operational controls to ensure the safest possible raw water supply.

This plan details the location and boundary of the drinking water catchment, which provides potable water to the Integrated Water Supply System. It discusses existing and future usage of the water source, describes the water supply system, identifies risks and recommends management approaches to maximise protection of the catchment.

This plan should be used to guide State and local government land use planning decisions. It should be recognised in the relevant shire Town Planning Schemes, consistent with Department for Planning and Infrastructure's *Statement of Planning Policy No. 2.7 - Public Drinking Water Source Policy*. Other stakeholders should use this document as a guide for protecting the quality of water in the Public Drinking Water Source Area.

The stages involved in preparing a Drinking Water Source Protection Plan are:

Stages in development of a Plan		Comment
1	Prepare Drinking Water Source Protection Assessment	Assessment document prepared following catchment survey and preliminary information gathering from government agency stakeholders.
2	Conduct stakeholder consultation	Advice sought from key stakeholders using the assessment as a tool for background information and discussion.
3	Prepare Draft Drinking Water Source Protection Plan	Draft Plan developed taking into account input from stakeholders and any additional advice received.
4	Release Draft Drinking Water Source Protection Plan for public comment	Draft Plan released for a six week public consultation period
5	Publish Drinking Water Source Protection Plan	Final Plan published after considering advice received in submissions. Includes recommendations on how to protect the catchment.

Summary

The Serpentine Dam and Serpentine Pipehead Dam are located on the Serpentine River approximately 55 km south east of Perth and 10 km east of the town of Serpentine. They contain high quality potable water from largely undeveloped catchments.

The Serpentine Dam catchment is almost equally divided between the four local government areas; the Shire of Serpentine-Jarrahdale, the Shire of Murray, the Shire of Boddington and the Shire of Wandering. The dam and the Serpentine Pipehead catchment lie in the Shire of Serpentine-Jarrahdale. All private land in the Serpentine Dam catchment lies in the Shire of Boddington in the south-east of the catchment. The remainder of the catchment is State forest or National Park.

The townships of Serpentine and Jarrahdale are the closest regional centres with a combined population of less than 10,000. These townships service the surrounding agricultural area that extends over the Swan Coastal Plain and onto the Darling Scarp.

The objective of this plan is to propose strategies to ensure land uses and activities in the Serpentine Dam Catchment Area and Serpentine Pipehead Dam Catchment Area have minimal impact on the water quality in the Serpentine Dam and Pipehead Dam.

The Serpentine Dam Catchment Area and Serpentine Pipehead Dam Catchment Area are gazetted under the *Metropolitan Water Supply, Sewerage and Drainage Act 1909*. Water from the Serpentine Dam is released into the Serpentine Pipehead Dam and then into the Integrated Water Supply Scheme.

Potential risks posed to the water quality of this source have been carefully assessed recognising the only treatment for this supply is disinfection. Based on the potential risks posed by human contact with the water and the number of people that could potentially be affected, activities that require body contact with the water are not considered acceptable in this catchment. Activities that do not require contact with the water body generally pose less of a risk to water quality. Thus, outside of the Reservoir Protection Zone, they are generally considered acceptable with appropriate management conditions to ensure water quality protection objectives are met.

Land use in the catchment consists principally of State forest including the Frollett Pine Plantation. The State forest is vested with Conservation Commission of WA and is managed by the Department of Environment and Conservation on their behalf. A small area of private property, 25 km from the reservoir, is used for rural pursuits largely consisting of softwood and hardwood tree farming. Other private properties nearby are used for timber plantation or are currently under native vegetation. This plan recommends that the areas of these private land holdings not under native vegetation should be managed for Priority 2 source protection (see section 4.3 for more information on Priority Protection Areas).

There is also significant recreation activity in the catchment. Approved recreation activities in the catchment include orienteering, rogaining, picnicking, bushwalking and mountain bike riding. The Bibbulmun Track (with its authorised campsites) also passes through the catchment.

Unauthorised activities that occur in the catchment include fishing and marroning, swimming, undesignated camping and off-road vehicle use.

Other land uses in the catchment area include Western Power's Muja Northern Terminal Line and the major transport route of Albany Highway on the outskirts of the catchment.

Land use activities in the catchment may have the potential to contaminate the source and this plan outlines strategies that will manage these risks.

This plan has undergone extensive consultation during the development process. The Department contacted all private landowners and land managers in the catchment. These key stakeholders were given the opportunity to raise issues for consideration and comment on suggested strategies for water quality management.

The following strategies are recommended to protect the Serpentine Dam Catchment Area and the Serpentine Dam Pipehead Catchment Area.

- All Crown land should be managed for Priority 1 source protection;
- Private land should be managed for Priority 2 source protection, except for the parts of these properties that are under native vegetation, which should be managed as Priority 1 source protection;
- The catchments, including the Reservoir Protection Zones, should be recognised in the relevant land planning strategies and schemes, specifically the Shire of Boddington, Shire of Murray, Shire of Serpentine-Jarrahdale and Shire of Wandering Town Planning Schemes; and
- Best management practices for current or approved land uses in the catchments should be implemented.

1 Drinking water supply system

1.1 Existing water supply system

The location of the Serpentine and Serpentine Pipehead reservoirs and catchment areas are shown in Figure 1 and 2. The area of the catchment contributing to Serpentine Dam is about 664 km². The catchment extends for some 40 km in a south-easterly direction from the dam, located on the Darling Scarp on the western edge of the Darling Range. The catchment is up to 22 km wide and is bounded in the north-east by the Canning River Catchment Area, in the north by Wungong Brook Catchment Area and in the south by North Dandalup and South Dandalup Catchment Areas. Albany Hwy closely follows the north-eastern boundary and intersects it in several locations. The Serpentine Pipehead Dam Catchment Area is 28 km² in area and consists entirely of State Forest and Serpentine National Park.

Construction of the Serpentine Dam was completed in 1961 with a height of 55 m and a crest length of 424 m. The reservoir has a capacity of 194.5 gigalitres (GL). The current annual inflow to Serpentine Dam is estimated to be 37 GL. The 664 km² Serpentine Water Reserve was first proclaimed under the *Metropolitan Water Supply, Sewerage and Drainage (MWSSD) Act (1909)* in April 1917. In November 1982 the Serpentine Dam Catchment Area was proclaimed to replace the Water Reserve and on the same date the Serpentine Pipehead Dam Catchment Area was first proclaimed.

Serpentine Pipehead Dam was constructed between 1955 and 1957 to supplement natural flows into Serpentine Dam. Water from Serpentine Dam is released into the 28 km² Serpentine Pipehead catchment prior to piping from the Serpentine Pipehead Dam for the integrated water supply.

Currently all water sourced from Serpentine Dam must run through the pipehead catchment before entering supply mains. The Serpentine Pipehead Dam has a capacity of 2.6 GL.

Serpentine Dam is a water source of vital importance as it is relied on as a strategic source for the Perth Metropolitan area. Average annual combined water supply from the Serpentine Dam is 39 GL, including supplementation of up to 2.0 GL/year from Serpentine Pipehead Catchment Area.

1.2 Water treatment

The water abstracted from the Serpentine Pipehead Dam is disinfected by chlorination, and fluoridated, before supplying the Integrated Water Supply System (IWSS). Chlorination is often the final essential barrier used to ensure good quality public drinking water (NHMRC & ARMCANZ, 2004). Under low turbidity water

conditions, chlorination generally removes microbiological contamination from the raw water, particularly when sourced from undisturbed catchments.

It should be recognised that although dam storage and disinfection by chlorination generally removes all contaminants from pristine sources, treatment processes alone cannot be relied upon to provide a safe source of drinking water. Where possible, contamination should be prevented or reduced through appropriate land use or activity controls in the catchment area. This approach is endorsed by the Australian Drinking Water Guidelines (NHMRC & ARM CANZ, 2004), and reflects a best practice 'catchment to consumer' multiple barrier approach for the provision of safe drinking water to consumers.

1.3 Catchment details

1.3.1 Physiography

The Serpentine Dam catchment lies within the Darling Range. The Darling Range forms part of the Archaean Shield composed largely of granite which has some invaded linear belts of metamorphosed sedimentary and volcanic rocks, some isolated occurrences of which remain (Schofield, 1991). Thin sheet-like dolerite intrusions occur abundantly in the basement rock. Deep V-shaped valleys occur close to the Scarp, with shallow soils and frequent rock outcrops. On moving inland in an easterly direction, valleys are broader and more U-shaped.

Soils consist of granite covered by a weathered laterite hard cap and associated clays and include shallow sand over sheet laterite, gravelly duplex soils and grey sands. Upland laterites consist of sandy loams in a gravel matrix whilst gravels tend to become finer down slope, sometimes grading into sandy yellow earths in the lowest positions.

The majority of the catchment is covered by the Murray, Yarragil and Dwellingup vegetation complexes, and consists of open forest or woodland dominated by several *Eucalyptus* species. There are also some areas of private land that have been cleared for agriculture and other rural uses.

1.3.2 Climate

The area has a Mediterranean climate, characterised by warm and dry summers with cool, wet winters.

The long-term average annual rainfall for the catchment is approximately 1000 mm and most of this falls between May and September. There is considerable variability in rainfall across the catchment with the catchment lying between the 1300 mm rainfall isohyet in the west and 700 mm rainfall isohyet in the east. Serpentine Pipehead catchment lies largely within the 1300 mm rainfall isohyet. However,

average annual rainfall at Serpentine Dam has reduced by up to 20% from the long-term average since 1975.

This drop in rainfall was associated with a more than 40% reduction in average streamflow from the long-term average between 1975 and 2000. Average annual evaporation is between 1400 mm (at Karnet, just south of Serpentine Pipehead catchment) and about 1900 mm in the east of the catchment. Monthly evaporation at Karnet varies from almost 50 mm in June to 220 mm in January.

1.3.3 Hydrography

The catchment for the Serpentine Dam has an area of 664 km² and is located on the Darling Plateau. Elevation in the catchment is 217 m Australian Height Datum (AHD) at the dam wall to 500 m at Mt Cuthbert on the eastern boundary of the catchment. The catchment boundary is generally at about 350 m AHD. Serpentine Pipehead Dam catchment lies between 165 m AHD at the dam wall and a maximum of 340 m AHD at the catchment boundary.

Water inflow to the reservoir is mostly from surface runoff over the winter months. However, there is sub-surface flow year round due to the slow release of groundwater recharged by winter rainfall due to the gravelly soils. The average monthly flow in the winter months is significantly greater than in the summer months.

The long-term average volume of water entering the Serpentine Dam is 64.4 GL/year (1912-2000). However, since 1975 this has reduced by almost a half to about 37.1 GL/year. The Serpentine Pipehead Dam catchment currently contributes about 3.6 GL of flow to the Pipehead Dam. This has reduced from the long-term average of 6.2 GL/year (1912-2000). The current average annual combined yield from the two dams is 39.8 GL/year (1975-2000, Water Corporation).

1.4 Future water supply requirements

It is intended to continue to use the Serpentine Dam and the Serpentine Pipehead Dam for Perth Metropolitan drinking water supply. As demand increases (and rainfall decreases), other water sources will be brought on line to supplement supply to the IWSS. This will not affect the two Serpentine catchment areas.

1.5 Protection and allocation

1.5.1 Existing water source protection

The Serpentine Dam Catchment Area was proclaimed in November 1982 under the *Metropolitan Water Supply, Sewerage and Drainage (MWSSD) Act (1909)* to ensure protection of the water source from potential contamination. In order that the gazetted catchment represents the physical boundary, the Catchment Area was re-gazetted in 2000. The Serpentine Pipehead Dam Catchment Area was also gazetted

in 1982 and then re-gazetted in 2000 under *Metropolitan Water Supply, Sewerage and Drainage Act 1909*.

1.5.2 Current allocation licence

Water resource use and conservation in Western Australia is administered by the Department of Water in accordance with the *Rights in Water and Irrigation Act 1914*. Under the Act, the right to use and control surface and groundwater is vested with the Crown. This Act requires licensing of surface water abstraction within proclaimed surface water areas.

The current allocation licences within the Serpentine Dam Catchment Area are Surface Water Licence No. 0056737 for the Serpentine Dam and 0056738 for Serpentine Pipehead. The total allocation for abstraction from these sources is 51.0 GL/year and 2.8 GL/yr respectively. These licences are issued for the purpose of providing water for public potable water supply and irrigation. It is expected that these licences will be renewed upon expiration.

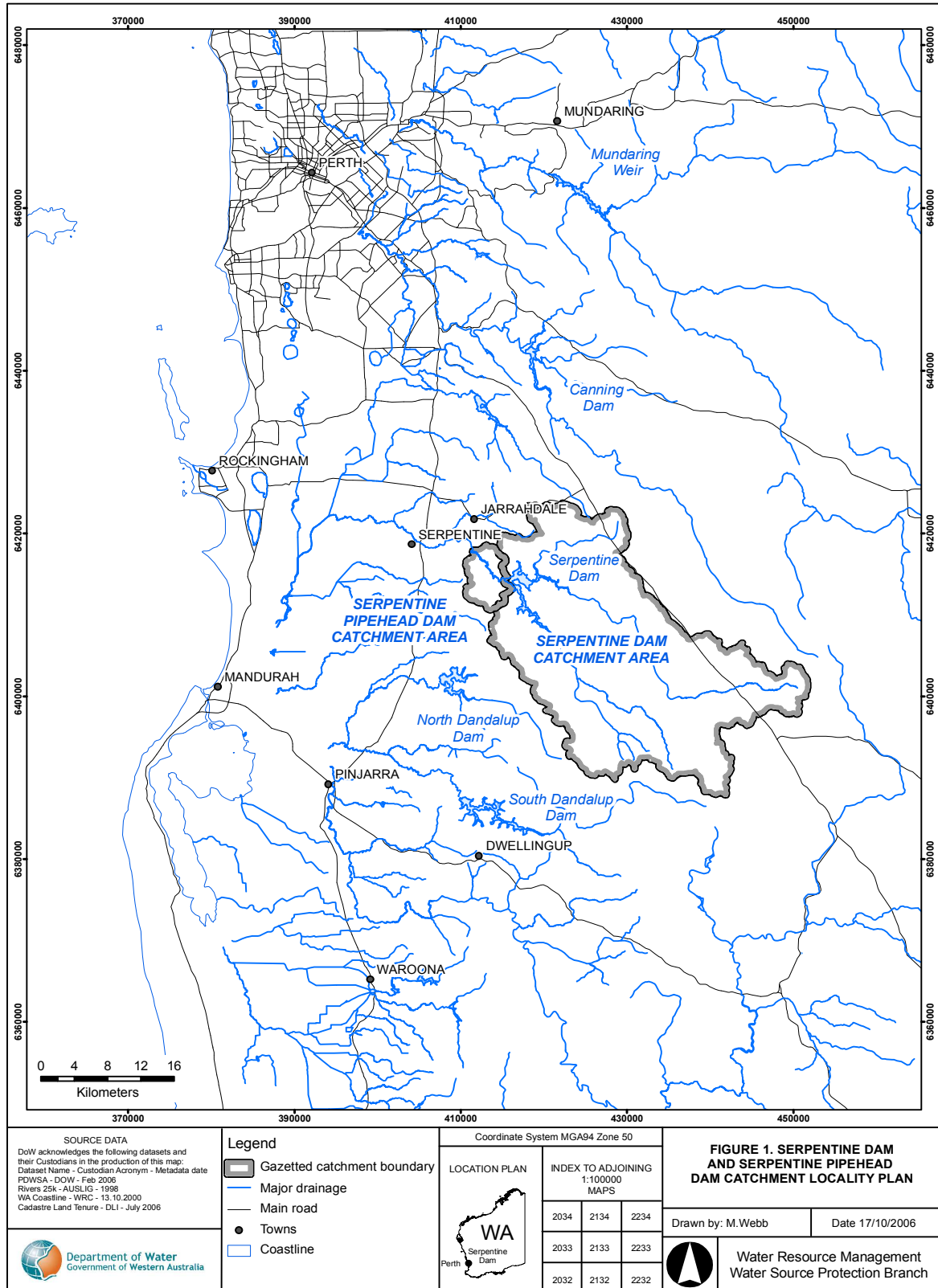


Figure 1. Serpentine Dam and Serpentine Pipehead Dam catchment locality plan

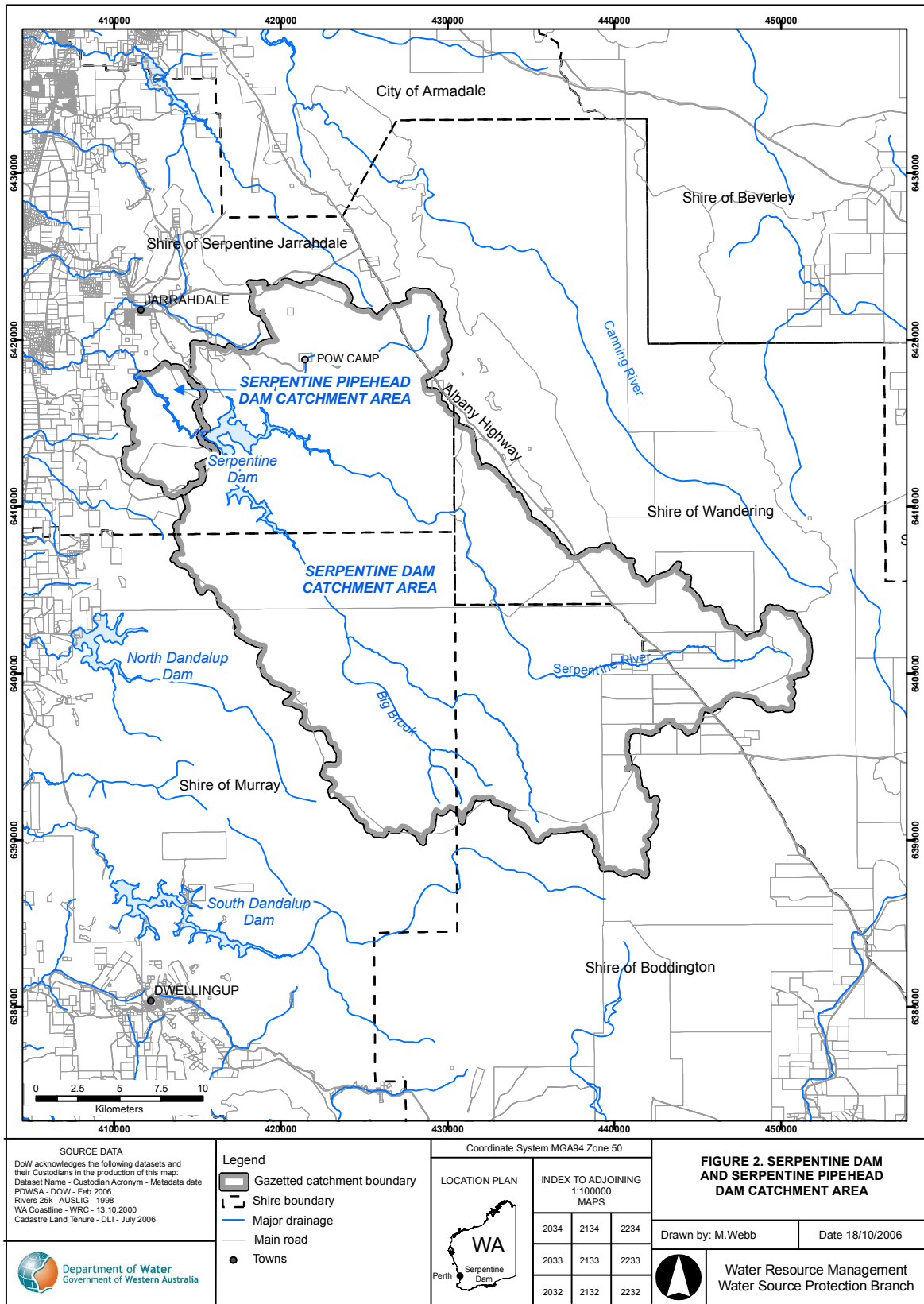


Figure 2. Serpentine Dam and Serpentine Pipehead Dam Catchment Areas

2 Water quality

A wide range of chemical, physical and microbiological properties can affect the health and aesthetic quality of drinking water.

Water quality in the Serpentine Dam is regularly monitored by the Water Corporation in accordance with Australian Drinking Water Guidelines (NHMRC & ARMCANZ, 2004). The samples are analysed for a comprehensive range of water quality parameters, including turbidity, colour, iron, manganese and aluminium.

A more comprehensive sampling program to include bacterial and chemical parameters was initiated in 1998 for the public water supply status of the Serpentine Dam. Details of typical water quality at the dam outlet are shown in Appendix A. The water quality results show the water in the Serpentine Dam to be of high quality.

2.1 Microbiological contaminants

Microbiological quality of water is measured regularly both before and after treatment. There is significant presence of thermotolerant coliforms or *Escherichia Coli* (an indicator for potential presence of pathogenic microbes) in the raw water (see Appendix A). Due to its smaller size Serpentine Pipehead Dam records a significantly higher proportion of samples with coliforms than does Serpentine Dam, which is of significant concern which necessitates more stringent management controls. At Serpentine Dam the proportion of samples with positive coliform counts is much less than some other surface water catchments on the Darling Scarp that have greater human activity in their catchments (see section 3.1 below for further discussion on this). Reservoir storage and disinfection by chlorination (following catchment protection measures) generally removes all trace of contamination.

2.2 Health related chemicals

Health related water quality parameters that have been measured at detectable levels are manganese and nitrate. Whilst being recorded at detectable levels they have not exceeded health guideline values (see Appendix A).

Historically raw water from the Serpentine Dam was monitored for pesticides on a quarterly basis. Dieldrin was the only pesticides to have been measured just above the detectable limit (Aug 1999). However, as the level remained well below the NHMRC health guideline values, testing ceased in 2001.

2.3 Aesthetic characteristics

Turbidity, iron and manganese are the only parameters to have been recorded above the Australian Drinking Water Guidelines aesthetic guideline level (NHMRC & ARMCANZ, 2004) at Serpentine Dam. On one occasion the pH was outside the aesthetic guideline value range.

Turbidity is caused by suspended particles such as soil and organic matter, in the water. Iron occurs commonly in soil and rocks as the oxide, sulfide and carbonate minerals. In water, it is present in oxidised forms as ferric (Fe(III)) or ferrous (Fe(II)) compounds. Manganese occurs naturally in water, but high levels may be a function of reservoir dynamics and poor quality of inflows. Manganese levels can also increase in water as a result of vegetation characteristics and erosion of the soil in the catchment. Iron occurs commonly in soil and rocks and is present in water in oxidised forms. A low pH may cause corrosion and encrustation of plumbing pipes and fittings. The results of the aesthetic related chemical testing are in Appendix A.

3 Land use and contamination risk

3.1 Potential water quality risks

The risks to water quality associated with activities in catchments include contamination from pathogens, turbidity, pesticides, chemicals, hydrocarbons and nutrients. Pathogens pose the most significant risk to public health.

Pathogen contamination of a drinking water source is influenced by the existence of pathogen carriers (ie humans and domestic animals, such as dogs or cattle) and opportunity for their subsequent transfer to the water source, the ability of the pathogen to survive in the water source and the concentration required to cause illness.

Pathogens may enter a surface water source through activities involving the direct contact of human and domestic animals with the water body or tributaries (ie illegal fishing, swimming), primarily through the transfer of faecal material, or indirectly through the presence of humans or domestic animals near the water body and its tributaries (ie runoff transferring faecal material).

There are a number of pathogens that are commonly known to contaminate water supplies worldwide. These include bacteria (eg *Salmonella*, *Escherichia coli* and *Cholera*), parasites (eg *Cryptosporidium*, *Giardia*) and viruses. The percentage of humans in the world that carry various pathogens varies. For example, it is estimated that between 0.6 to 4.3 per cent of people are infected with *Cryptosporidium* worldwide, and 7.4 per cent with *Giardia* (Geldreich, 1996).

The ability of pathogens to survive in surface water differs between species. For example, *Salmonella* may be viable for two to three months, *Giardia* may still infect after one month in the natural environment (Geldreich, 1996) and *Cryptosporidium* oocysts (cells containing reproductive spores) may survive weeks to months in freshwater (NHMRC & ARMCANZ, 2004).

The effects of pathogen contamination in drinking water varies significantly, ranging from illness to death, as was the case in Walkerton, Canada in 2000 where seven people died due to a pathogenic contamination of *Escherichia coli* in the town water source and supply. Preventing the introduction of pathogens into the water source is the most effective barrier in avoiding this public health risk.

Land use activities within the catchment can directly influence the effectiveness of water treatment. For example, off-road driving on unauthorised tracks contributes to erosion and the uprooting of vegetation. Erosion results in the mobilisation of soil particles, which are released into the air and tributaries and increase the turbidity within the water body. Pathogens adsorb onto these soil particles and may be shielded from the effects of disinfection. Increased turbidity also impacts upon other

environmental constituents, ie smothering riparian vegetation and reducing light transfer within the water column which affects plant growth.

Pesticides are toxic and some are potentially carcinogenic. Nutrients (such as nitrates) from fertiliser are toxic to humans at high levels, with infants less than 3 months old being most susceptible. Hydrocarbons (fuels, oils, solvents) and other chemicals are potentially toxic and carcinogenic, and harmful by-products may be formed when they are combined with chlorine.

3.2 Existing land uses

Land use and activities in the catchment consist of:

- 1 Land and forest management on Crown land, including timber harvesting;
- 2 Commercial land use such as mining and blue gum plantations; and
- 3 Recreation on Crown land.

Land use and tenure in the catchment is shown in Figure 3.

3.2.1 Private Land

There is some private land on the south eastern edge of the Serpentine Dam catchment. The area of private land is approximately 1355 ha. Parts of two lots are currently used for Tasmanian bluegum (*Eucalyptus globulus*) plantations (~80 ha), with two private dams and some pasture and remnant native vegetation making up the remainder of the properties within the catchment (~ 130 ha total). Until recently, Sotico owned the majority of the private land in the catchment. Most of this is under native vegetation, with the rest, about 100 ha, managed by Sotico as softwood (pine) timber plantation. A large portion of the property has recently been sold to the Boddington Gold Mine Joint Venture, with Sotico retaining the section utilised for plantation timber production. There is a substantial (~ 50 m) cleared buffer between the pine plantations and the native forest.

As part of the proposed Boddington Gold Mine (BGM) expansion near Boddington, some State forest will be disturbed. A condition of environmental approval of the expansion is that BGM will exchange with the Department of Environment and Conservation other areas of land of similar size and conservation value as the State forest to be disturbed. BGM have purchased the land from Sotico with the intent of using it as part of the land exchange. The land will become Crown land managed by the Department of Environment and Conservation once the land exchange is complete.

Waters and Rivers Commission freehold land

It should be noted that the ownership of all Waters and Rivers Commission land will pass to the Department of Water once the *Waters and Rivers Commission Act 1995* is repealed and legislation allowing for the operation of the Department of Water is enacted.

The Commission has freehold ownership of several properties in the north-west and south-east of the catchment. These properties would originally have been granted to private ownership and have since been reclaimed by the Crown. Those in the south-east are entirely native vegetation and are planned to be incorporated into the Monadnocks National Park (Commonwealth and Western Australian Regional Forest Agreement Steering Committee (CWARFASC), 1999, Conservation Commission of Western Australia, 2004). The Water Corporation manages the remainder of these properties for the Commission. The properties consist mostly of native vegetation although some parts have previously been cleared. One property in the north of the catchment has had some rehabilitation that has been largely unsuccessful and is subject to illegal recreation activities.

3.2.2 Crown Land

State forest and reserves

The 664 km² Serpentine Dam Catchment Area lies within State Forests Number 14 and 67. Within the State forest, jarrah (*Eucalyptus marginata*) and marri (*Corymbia calophylla*) forest dominate. Understorey species include *Banksia grandis* and *Allocasuarina fraseriana*. In the south-east of the catchment there is a significant occurrence of wandoo (*Eucalyptus wandoo*) woodland in the river valleys. A large portion of the forest in the central third of the catchment is designated as a dieback quarantine area. Portions of the State forest are periodically subject to timber harvesting and bauxite mining.

The State forest is vested in the Conservation Commission of WA under the *Conservation and Land Management Act 1984* (CALM Act) and managed by the Department of Environment and Conservation on the Commission's behalf. State forest is managed for the purposes defined in the *Forest Management Plan 2004-2013* as conservation, recreation, timber production, on a sustainable yield basis, water catchment protection and other purposes prescribed by the regulations. The *Forest Management Plan 2004-2013* is a statutory plan for State forests and recognises water catchment protection as a statutory purpose of indigenous State forest and water extraction as a legitimate activity.

A significant area of the Serpentine Pipehead Dam catchment has been included in the Serpentine National Park. This area includes a large part of Windsor State Forest Block, east of the Serpentine River, in the centre of the catchment and crossing the boundary into the Canning River Catchment Area.

A Special Mining Lease, granted to Alcoa World Alumina - Australia (Alcoa) in 1961, covers part of the Crown land in the catchment. Under the State Agreement Act, Alcoa has rights to extract bauxite from Crown land, with associated responsibilities to protect environmental values and rehabilitate mine sites. All of the 129 ha cleared since 1994 have been rehabilitated in Serpentine Dam catchment. Currently mining in the catchment is limited to the Jayrup Trial Mining Area, although plans are in place for Alcoa to expand its mining operations in the Serpentine Dam Catchment Area in the future. No mining has taken place in Serpentine Pipehead Dam Catchment Area. Alcoa has a comprehensive Environmental Management System which is certified to ISO14001 standard (White, 2001). Alcoa's operations are overseen by the Mining and Management Program Liaison Group. The Department of Water and the Water Corporation have representation on this group, enabling them to ensure Alcoa meet water quality protection objectives.

The Frollett pine plantation is situated in State forest south of Jarrahdale Rd in the north of the catchment, about 5 km from the reservoir. The plantation covers an area of about 105 ha (all in Serpentine catchment). Areas of the plantation are harvested when required.

Albany Highway passes through the Serpentine catchment. It skirts along the north-eastern border of the catchment, passing into and out of Serpentine catchment twice. Kingsbury Drive skirts along the catchment boundary between Serpentine Dam and Serpentine Pipehead Dam Catchment Areas.

A major Western Power transmission line, the Muja Northern Terminal Line, also passes through the catchment.

Land and forest management

State forest is managed for multiple uses that include timber production, water production, recreation and nature conservation as well as some apiary use and wildflower and seed harvesting. There is also widespread collection of firewood for private use. Firewood collection is controlled by licences issued by the Department of Environment and Conservation. Specific management activities include native forest timber harvesting, plantation timber harvesting and prescribed burning.

National Parks and Conservation Parks are not subject to timber harvesting activities, but facilities for recreational use of the forest in National Parks are generally improved or increased.

Approximately two thirds of the Serpentine Pipehead catchment consists of Serpentine National Park, which is managed by the Department of Environment and Conservation for 'natural environment' purposes according to the *Serpentine National Park Management Plan* (Brown *et al.*, 2000, CALM, 2000).

Recreation

Recreation in the State forest and National Parks is managed by the Department of Environment and Conservation.

A number of recreation activities occur in the catchment. Bushwalking occurs throughout the catchment, particularly along the Bibbulmun Track. The track passes through the catchment about 25 km upstream of the Serpentine Dam, to the south-east of the reservoir and also passes briefly into the catchment and skirts along the catchment boundary in the north-east of the catchment. There are two authorised campsites associated with the Bibbulmun Track that lie within the catchment; Monadnocks Campsite lies very close to the catchment boundary about 12 km north-east of the reservoir and White Horse Hills Campsite lies in the south-east of the catchment. Each of these sites has toilet facilities and a water tank.

The Munda Bidli Mountain Bike Trail passes through the north of the Serpentine Dam Catchment Area, passing along Balmoral Road within 2.5 km of the reservoir high water mark. There is no official camp sites associated with the trail in the Serpentine catchment.

The trail passes quite close to the Balmoral Road POW Camp Ruins site, which is situated 4 km to the north-east of the reservoir, on Thirty Nine Mile Brook, near the intersection of three major unsealed roads – Balmoral Road, Millars Log Road and Frollett Road. Facilities provided at this site include a car park, fireplaces, picnic facilities and a composting toilet. The Balmoral (or POW Camp) site is a designated recreation site with a walk track connecting it to Jarrahdale, but camping is not permitted at the site.

There is a fully serviced picnic area immediately downstream of Serpentine Dam (in the Serpentine Pipehead catchment) that is operated by the Water Corporation. The site is newly reconstructed with barbecues, toilets and parking all in close proximity to the Serpentine River. There are also serviced toilets and signage to help protect from contamination.

A horse-riding event has occurred in the north-west of the catchment with one event per year organised by the Western Australian Endurance Riders Association (WAERA). WAERA were informed that after the 2006 event, future horse events will not be approved if they pass into a drinking water catchment. This advice is consistent with the Waters and Rivers Commission Statewide Policy #13 *Policy and Guidelines for Recreation within Public Drinking Water Source Areas on Crown Land*.

One established motor sport event is held regularly in the Serpentine catchment in spring; the Darling 200 Rally run by the Light Car Club of WA Inc. under the Confederation of Australian Motor Sport (CAMS). Stages of the Darling 200 rally are run throughout areas in the north and east of the catchment. Practice stages for Rally Australia have also in the past been approved in the catchment. The 2006 Rally Australia is the last time the event is scheduled to be held in WA.

The reservoir and Serpentine River are illegally fished for marron. The legal Western Australian marroning season occurs during January and February. This coincides with when most illegal marroning occurs in Serpentine. Boating, fishing and swimming are prohibited in the reservoir for health reasons.

Tourism associated with recreation in the area is important to the local area, due to the proximity of the catchment to Perth.

3.3 Proposed land uses

It is anticipated that private land within the catchment currently under timber plantation will continued to be used for this purpose. This activity is compatible with the Priority 2 source protection classification proposed for the parcels of private land under plantation. The Boddington Gold Mine (BGM) Joint Venture recently acquired part of the private land within the catchment. The BGM Management Company has advised that this land is proposed to be a part of a land exchange with the Department of Environment and Conservation as part of BGM planned expansion. Under the exchange BGM Management Company hand over this parcel in exchange for permission to mine other areas of State forest currently managed by the Department of Environment and Conservation. As part of the arrangement, the land being exchanged must have equal conservation value of the land that is proposed to be mined.

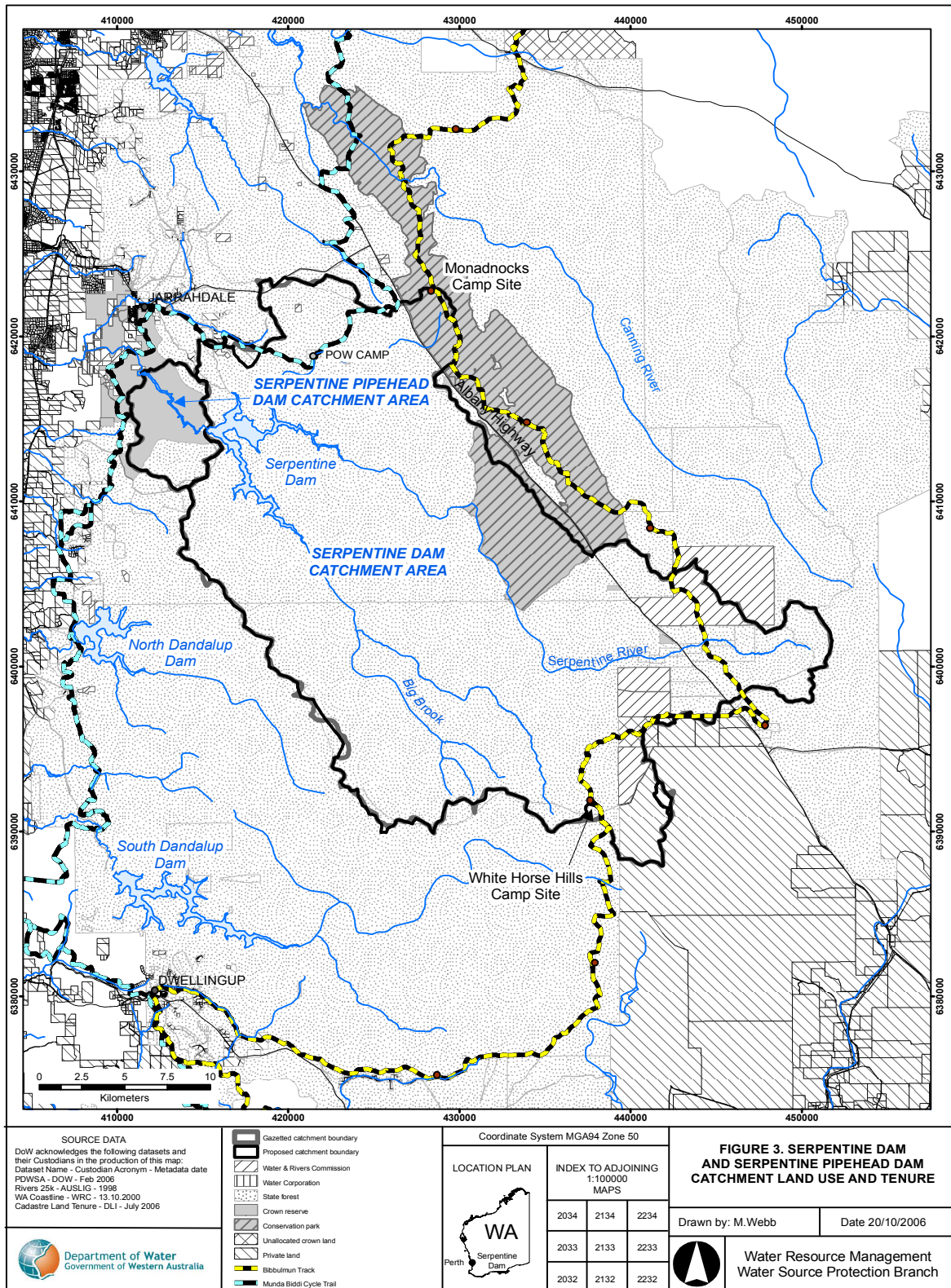


Figure 3. Serpentine Dam and Serpentine Pipehead Dam Catchments land use and tenure

4 Catchment protection strategy

4.1 Protection objectives

The objective of water source protection in Serpentine Dam and Serpentine Pipehead Catchment Areas is to preserve the high water quality at its current level and where practical, achieve an improvement, so as to continue to provide a safe drinking water supply.

This plan recognises the right of existing approved land uses to continue to operate in the catchments. Current freehold land uses are generally compatible with the Priority 2 classification. The Department will encourage the adoption of best management practice for water quality protection on freehold land.

Priority 1 source protection areas have the fundamental water quality objective of risk avoidance. Priority 2 source protection areas have the fundamental water quality objective of risk minimisation.

This plan aims to balance water quality protection and social and environmental needs and aspirations. Where constraints are required on recreational activities, opportunities for these activities should be catered for in other more appropriate locations.

4.2 Proclaimed area

The Serpentine Dam Catchment Area covers the whole of the Serpentine Dam Water Reserve (proclaimed in 1917). It was first proclaimed as a Catchment Area in November 1982 under the *Metropolitan Water Supply, Sewerage and Drainage (MWSSD) Act (1909)* to ensure protection of the water source from potential contamination. The Catchment Area was re-gazetted in 2000 to ensure that the gazetted catchment represented the physical catchment boundary. The Serpentine Pipehead Dam Catchment Area was also proclaimed in 1982 under *Metropolitan Water Supply, Sewerage and Drainage Act (1909)* and then re-gazetted in 2000.

Recent review by the Department of Water has indicated that the gazetted catchment boundaries require minor adjustments to further reflect the physical catchment boundaries. The proposed proclaimed areas are shown in Figures 2 and 4.

4.3 Priority classifications

It is proposed that the majority of the Serpentine Dam Catchment Area be managed for Priority 1 (P1) source protection. The objective is to preserve the high quality of this water by avoiding risks of contamination. This classification is justified on the following basis:

- Serpentine Dam is a strategic and important source of public drinking water for the IWSS, and should be afforded the highest level of protection;
- The existing water quality is of a high standard;
- Land is mostly in Crown ownership;
- Existing land uses are generally compatible with P1 or can be managed for P1 source protection objectives with the use of best management practices;
- The only treatment of water from the reservoir is disinfection by chlorination.

The private land in the catchment should be managed for Priority 2 (P2) source protection. The existing land uses are compatible with P2 source protection with the implementation of best management practices. However, land owned by the Boddington Gold Mine Joint Venture that is currently maintained as native vegetation should be classified for P1 source protection in agreement with the land owner. This classification is consistent with the plan to exchange this land with the Department of Environment and Conservation for conservation purposes (see section 3.3 above).

Figure 4 shows the proposed catchment area, priority classifications and protection zones for the Serpentine Dam and Serpentine Pipehead Dam Catchment Areas.

Guidance on land use compatibility for the P1 and P2 source protection classifications is contained with the Department of Water's Water Quality Protection Note *Land use compatibility in Public Drinking Water Source Areas* available at www.water.wa.gov.au select Water Quality > Publications > Water Quality Protection Notes.

4.4 Protection zones

To protect the reservoirs from immediate risks to water quality such as human contact, it is recommended that the catchments be managed with Reservoir Protection Zones (RPZ). This is a key barrier in the approach to protecting reservoir and drinking water quality.

A RPZ is usually defined by a two kilometre buffer area around the top water level of the reservoir, including the reservoir itself, and not extending outside the catchment area.

The development of organised events within the RPZ will be opposed, and general public access to the area will be prohibited in accordance with current By-laws. Existing activities within this zone will be reviewed for compliance with water quality protection objectives.

Figure 4 shows the proposed RPZs for the Serpentine Dam and Serpentine Pipehead Dam.

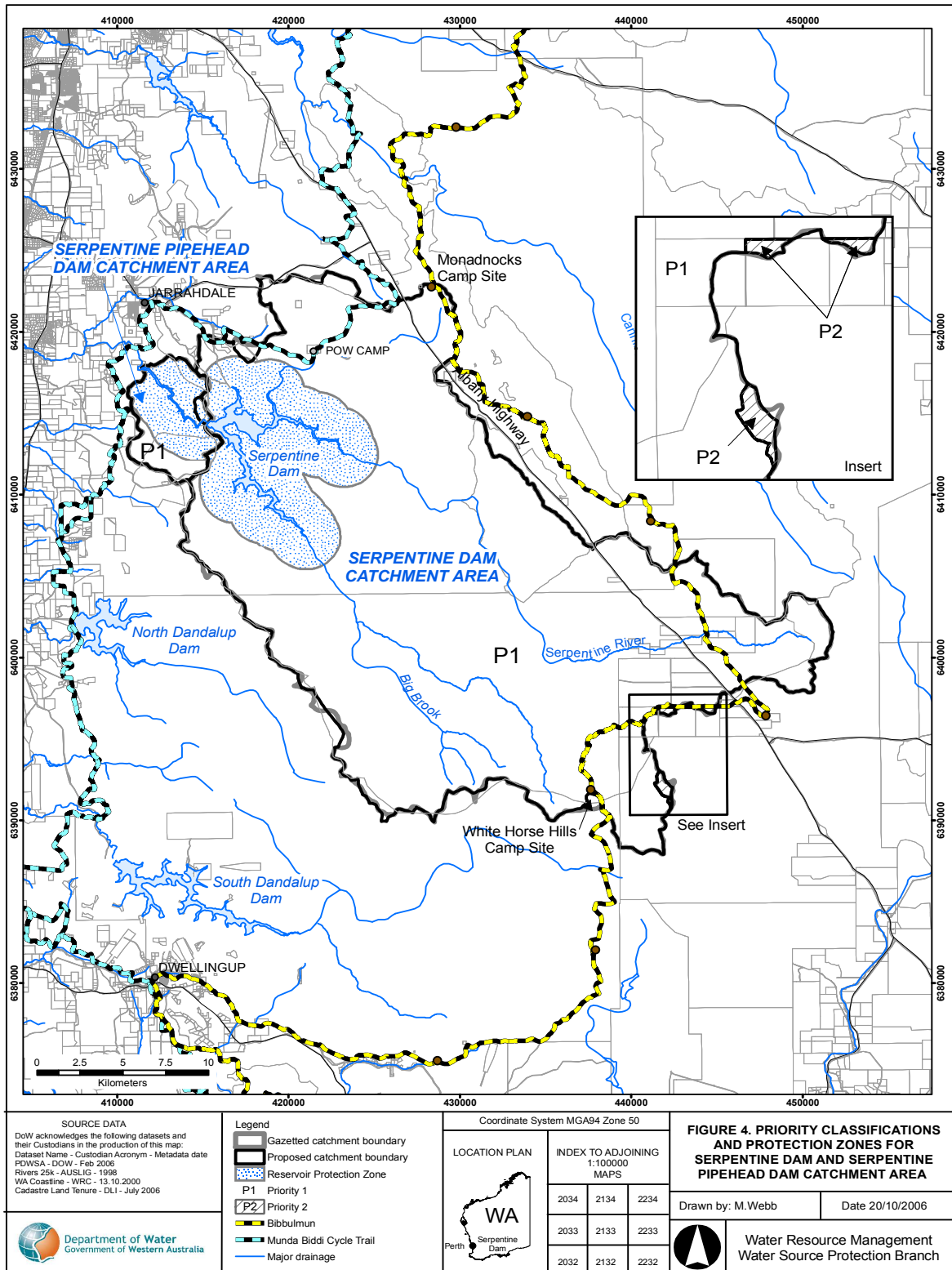


Figure 4. Proposed priority classifications and protection zones for Serpentine Dam and Serpentine Pipehead Dam Catchment Areas

4.5 Land use planning

It is recognised under the State Planning Strategy (Western Australian Planning Commission, 1997) that the establishment of appropriate protection mechanisms in statutory land use planning processes is necessary to secure the long-term protection of drinking water sources. As outlined in Statement of Planning Policy No.2.7: Public Drinking Water Source Policy (Western Australian Planning Commission, 2003), it is appropriate that the Serpentine Dam and Serpentine Pipehead Dam Catchment Areas, Reservoir Protection Zones and priority classifications be recognised in the Shire of Boddington, Shire of Murray, Shire of Serpentine-Jarrahdale and Shire of Wandering Town Planning Schemes. Any development proposals located within this area, or deemed likely to affect the protection objectives of the Serpentine Dam and Serpentine Pipehead Dam Catchment Areas should be referred to the Department of Water for advice and recommendations. Under Statement of Planning Policy 2.7, land uses and developments in all priority source protection areas that have the potential to impact detrimentally on the quality and quantity of public drinking water supplies should not be permitted unless it can be demonstrated, having regard to advice from the Department of Water, that such impacts can be satisfactorily managed.

Proposals within the Shire of Wandering should be referred to the Department's Swan Goldfields Agricultural Regional Office for assessment and advice. Likewise, development proposals inconsistent with the land use table within the Shire of Boddington, Shire of Murray and Shire of Serpentine-Jarrahdale should be referred to the Department's Kwinana-Peel Region for assessment and advice.

4.6 Best management practices

There are opportunities to significantly reduce risks to water quality by carefully considering design and management practices. The adoption of best management practices for land uses will continue to be encouraged to help protect water quality. On freehold land, the Department of Water aims to work with landowners to achieve best management practices for water quality protection through the provision of management advice, and assistance to seek funding if required.

There are Department of Water and other guidelines available for many land uses in the form of industry codes of practice, environmental guidelines or Water Quality Protection Notes (WQPN). These have been developed in consultation with stakeholders such as industry groups, producers, State Government agencies and technical advisers. Examples include the WQPNs *Toxic and hazardous substances – storage and use* and *Tracks and trails near sensitive water resources*, which are listed in the references section. The guidelines help managers reduce the risk of their operations causing unacceptable environmental impacts and are recommended as best practice for water quality protection.

Education and awareness (eg signage and information material) are a key mechanism for water quality protection, especially for those people visiting the area who are unfamiliar with the Serpentine Dam and Serpentine Pipehead Dam Catchment Areas. A brochure will be produced once this Plan is endorsed, describing the Serpentine Dam and Serpentine Pipehead Dam Catchment Areas, their location and the main threats to water quality protection. This brochure will be made available to the community and will serve to inform people in simple terms about the drinking water sources and their protection.

4.7 Surveillance and By-law enforcement

The quality of public drinking water sources within metropolitan areas of the State is protected under the *Metropolitan Water Supply Sewerage and Drainage Act (1909)*. Declaration of these areas allows existing By-laws to be applied to protect water quality.

The Department of Water considers By-law enforcement, through on-ground surveillance of land use activities in Public Drinking Water Source Areas as an important water quality protection mechanism. Surveillance is also important in raising the general level of awareness of the need to protect water quality. Communication with visitors to the catchment by Water Corporation Rangers assists in increasing public awareness of the need to protect water drinking water quality. Signs are erected to educate and guide the public and to advise of activities that are prohibited or regulated. Surveillance and By-law enforcement has been delegated to the Water Corporation.

4.8 Emergency response

Escape of chemicals during unforeseen incidents and use of chemicals during emergency responses can result in water contamination. The Shires of Boddington, Murray and Serpentine – Jarrahdale's Local Emergency Management Advisory Committees (LEMAC) through the Peel Emergency Management District and the Shire of Wandering LEMAC through the Great Southern Emergency Management District should be familiar with the location and purpose of the Serpentine Dam and Serpentine Pipehead Dam Catchment Areas. A locality plan should be provided to the Fire and Rescue Services headquarters for the Hazardous Materials Emergency Advisory Team (HAZMAT). DEC is the lead agency for wildfire control management for areas of the catchment outside of the gazetted fire emergency response zone. The Water Corporation should have an advisory role to any HAZMAT incident in the Serpentine Dam and Serpentine Pipehead Dam Catchment Areas.

Personnel who deal with WESTPLAN – HAZMAT (Western Australian Plan for Hazardous Materials) incidents within the area should have access to a map of the Serpentine Dam and Serpentine Pipehead Dam Catchment Areas. These personnel should receive training to ensure an adequate understanding of the potential impacts of spills on the water resource.

4.9 Recommended protection strategies

Table 1 identifies the potential water quality risks associated with existing land uses in the Serpentine Dam and Serpentine Pipehead Dam Catchment Areas and recommends protection strategies to minimise these risks.

Following publication of the final Serpentine Dam and Serpentine Pipehead Dam Catchment Areas Drinking Water Source Protection Plan, an Implementation Strategy will be drawn up based on the recommendations in Table 1. It will describe timeframes and funding sources for the recommended protection strategies and identify responsible stakeholders. This is reflected in the Recommendations section of this plan.

Table 1. Land use, potential water quality risks and recommended strategies

Land use / activity	Potential water quality risks		Consideration for management	Recommended protection strategies
	Hazard	Management priority		
Private land				
Tree farming <ul style="list-style-type: none"> Softwood timber plantation Hardwood timber plantation 	The water quality risks associated with these land uses include: <ul style="list-style-type: none"> Pathogen and nutrient contamination from human presence in catchment or inappropriate management of private dams; Chemical contamination from fertilisers and pesticides applied to plantations and firebreaks, or accidental spillage; Hydrocarbon contamination through fuel spills or oil spills from vehicles; Increased turbidity as a result of vehicle usage on unsealed roads, maintenance of extensive firebreaks, clearing and poor land 	High Medium Low Medium	It is recognised that use of private land for agriculture is an existing approved land use and is essential for the livelihood of owners. The existing agricultural activities on private land are low intensity plantation timber crops and much of the private land in the catchment remains under native vegetation Sotico own a portion of the private property in the catchment. An area of about 100ha of catchment is for pine timber plantation, the remaining section of Sotico owned land in catchment is under native forest. Approximately 130ha of other private land exists in the southeast of the catchment. Of this ~80ha is subject to management as <i>Eucalyptus globulus</i> plantation	<i>Existing land uses are acceptable with best management practices.</i> <ul style="list-style-type: none"> Encourage landowners to adopt best management practices including the <i>Code of Practice for Timber Plantations in WA</i> (Forest Products Commission (FPC), 2003) Provide information and advice to landowners on best management practices, particularly with respect to chemical applications to land. Assess and provide guidance on development proposals within the catchment to ensure that water quality protection requirements are addressed. Oppose intensification of land use through planning approval process. Ensure water quality protection objectives and priority classifications are shown as special control areas in the Town Planning Scheme of the Shire of Boddington. Ensure chemicals are managed according to the Water Quality Protection Note <i>Toxic and hazardous</i>

Land use / activity	Potential water quality risks		Consideration for management	Recommended protection strategies
	Hazard	Management priority		
	<p>management practices;</p> <ul style="list-style-type: none"> Increased stream salinity from water balance changes as a result of clearing 	Low	<p>(Tasmanian bluegum), with two private dams, some remnant vegetation and a small amount of cleared land (ex-pasture) making up the remainder. The risks associated with these activities can be managed through education and the adoption of best management practices.</p> <p>Private land in the catchment is currently zoned as rural “D” or “E”, according to the Town Planning Scheme of the Shire of Boddington. These types of zoning maintain a general presumption against subdivision.</p> <p>The rest of the private land in the catchment is owned by the Boddington Gold Mine Joint Venture (see below).</p>	<p><i>substances – storage and use.</i></p>

Land use / activity	Potential water quality risks		Consideration for management	Recommended protection strategies
	Hazard	Management priority		
Gold Mining (Boddington Gold Mine Joint Venture)	<p>The potential risks associated with this activity include:</p> <ul style="list-style-type: none"> • Turbidity from mining practices including clear felling, ineffective site management and waste management, and use of unsealed roads and tracks; • Hydrocarbon contamination through fuel spills from vehicles and machinery; • Pathogen contamination from increased human activity in the catchment. 	<p>Medium</p> <p>Low</p> <p>Medium</p>	<p>Mining operations are licensed by the Department of Industry and Resources (DOIR). In general, DOIR will refer projects that impact on water resources to the Department of Water.</p> <p>The BGM Environmental Management Liaison Group (EMLG) provides advice on mining operations, including water quality protection issues. DoW is represented on this group.</p> <p>BGM Management Company has indicated that they have acquired property in the catchment with the intent to use it as part of a land exchange with DEC. As a result, mining activities are unlikely to take place. However should this exchange not eventuate, this land may be used for mining activities, as such gold mining has been included in the risk assessment for this DWSP</p>	<p><i>Acceptable if operated in compliance with conditions imposed by EMLG.</i></p> <ul style="list-style-type: none"> • Ensure any conditions imposed by the BGM Environmental Management Liaison Group specifically pertaining to water quality are adhered to. • Ensure compliance with DOIR licence conditions. • Best management practices should be followed, including those laid out in the Department of Water's Water Quality Protection Guidelines <i>Mining and mineral processing</i>.

Land use / activity	Potential water quality risks		Consideration for management	Recommended protection strategies
	Hazard	Management priority		
State forest				
Plantation timber harvesting	<p>The potential risks to water quality include:</p> <ul style="list-style-type: none"> • Turbidity due to log handling and establishment practices, and construction, use and upgrading of unsealed roads and tracks; • Fuel spills from vehicles and machinery during harvesting and upgrading of roads; • Chemical contamination from fertiliser and pesticide application during plantation establishment. • Pathogens due to human presence, particularly due to increased public access from road upgrading and new roads • Acidity of soil waters from pine tree harvesting 	Medium	<p>The impact of plantation harvesting on water quality can be reduced through best management practices, including maintenance of roads, retention of vegetation buffers along watercourses, and appropriate minimal fertiliser and pesticide use.</p>	<p><i>Acceptable activity with best management practices.</i></p> <ul style="list-style-type: none"> • Ensure plantation harvesting occurs in accordance with the <i>Manual of Management Guidelines for Timber Harvesting in WA</i> (CALM, 1999) and the <i>Code of Practice for Timber Plantations in WA</i> (Forest Products Commission (FPC), 2003), including road construction and maintenance, appropriate retention of buffer zones along watercourses, use of sumps or drains for sediment control, fertiliser use and pesticide use. • Work with DEC and the FPC to restore vegetation buffers adjacent to reservoir and streamlines wherever practicable. • Review detailed harvesting and establishment plans during the planning phase to ensure water quality protection objectives are included. • Ensure protocols are in place between relevant agencies on harvesting issues such as pesticide and fertiliser use, stream monitoring, road routes and construction. • Pesticide used in accordance with Statewide Policy No. 2 <i>Pesticide Use in Public Drinking Water Source Areas</i>
		Low		
		Medium	<p>Turbidity from plantation harvesting can be considerable due to the clear-felling harvesting method, but the relatively small areas and</p>	
		Medium		

Land use / activity	Potential water quality risks		Consideration for management	Recommended protection strategies
	Hazard	Management priority		
			<p>location of the plantations in the catchment reduces the associated risks.</p> <p>Increased acidity of soil waters may affect transport of other contaminants but greater understanding of pine plantation effects is required.</p> <p>The use of table drains and sumps on plantation access roads is insufficient in some parts of the catchment (see Roads and tracks below).</p>	<p>(WRC, 2001) and <i>PSC 88 -Use of Herbicides in Water Catchment Areas</i> (DoH, 2007).</p> <ul style="list-style-type: none"> • Update timber plantation harvesting manuals in accordance with FPC, DEC, Water Corporation and Department of Water requirements. • Review road network and close roads not essential for forest operations and management or transport thoroughfare. • Establish protocols for joint field inspections between relevant agencies and inspect water quality protection measures on site. • Ensure contract specifications for harvesting operations recognise water quality protection objectives including use of chemical toilets on the site and appropriate monitoring of stream water quality. Chemical and other toilets are prohibited within the RPZ and within 100m of any waterways or wetlands. • Ensure monitoring of appropriate streams before and after harvesting and chemical application is conducted to identify any impact. • Ensure harvesting does not occur in high risk areas, such as areas of steep slope or adjacent to watercourses.

Land use / activity	Potential water quality risks		Consideration for management	Recommended protection strategies
	Hazard	Management priority		
Native forest timber harvesting	<p>The risks associated with native forest timber harvesting include:</p> <ul style="list-style-type: none"> • Increased turbidity due to log handling practices, and construction, use and upgrading of unsealed roads and tracks. Particularly use of heavy log transport vehicles and poor drainage control on unsealed roads; • Fuel spills from vehicles and machinery during harvesting and upgrading of roads; • Spread of forest disease by vehicle use of roads and tracks; • Pathogens due to human presence, particularly due to increased public access from road upgrading and new roads 	High	<p>The Forest Products Commission is responsible for supervising native forest timber harvesting, with surveillance carried out by DEC.</p>	<p><i>Acceptable activity with best management practices.</i></p> <ul style="list-style-type: none"> • Ensure harvesting occurs in accordance with the <i>Code of Practice for Timber Harvesting</i> (CALM, 1999), the <i>Contractors' Timber Harvesting Manual – South West Native Forests</i> (FPC, 2003) and the <i>Forest Management Plan 2004-2013</i> (Conservation Commission of WA, 2004), including road construction, and maintenance, use of sumps or drains for sediment control, appropriate retention of buffer zones along watercourses, fuel storage and handling and pesticide use. • Continue to review detailed (1-year and 5-year) harvesting plans during the planning phase to ensure water quality protection objectives are included. • Ensure protocols are in place between relevant agencies on harvesting issues such as pesticide and road routes and construction. • Continue to review road network to identify roads not essential for forest operations and management or transport thoroughfare. Close and rehabilitate those not required. • Ensure contract specifications recognise water quality protection
		Medium	<p>The impact of native forest timber harvesting on water quality can be minimised through proper management (including vegetation buffers along water courses and understorey vegetation left after timber harvesting). Water quality protection is a requirement of the CALM Act, which recognises the importance of water as a resource.</p>	
		Low	<p>A further critical requirement to reduce turbidity from timber harvesting is the proper maintenance of roads – particularly those required to carry heavy log transport vehicles.</p>	
		Medium	<p>Rehabilitation of roads and tracks following the harvesting</p>	

Land use / activity	Potential water quality risks		Consideration for management	Recommended protection strategies
	Hazard	Management priority		
			<p>process should be conducted to reduce public access and erosion problems.</p> <p>Baseline water quality data is frequently not available prior to harvesting, reducing the value of post harvesting monitoring. The issue of who, when and how monitoring is conducted needs to be addressed, to aid informed management of forestry in the catchment.</p>	<p>objectives, including the use of chemical toilets during periods of intensive activity on the site. Chemical toilets are prohibited within the RPZ and within 100m of any waterways or wetlands.</p> <ul style="list-style-type: none"> • Inspect water quality protection measures on site. • Baseline data should be monitored prior to harvesting. The issue of who, when and how monitoring is conducted needs to be addressed, to aid informed management of forestry in the catchment.
Bauxite mining	<p>The potential risks associated with this activity include:</p> <ul style="list-style-type: none"> • Turbidity from mining practices including clear felling, ineffective site management and waste management, and use of unsealed roads and tracks; • Hydrocarbon contamination through fuel spills from vehicles and machinery; • Pathogen contamination from increased human activity in the catchment. 	<p>Medium</p> <p>Low</p> <p>Medium</p>	<p>A multi-agency group, the Mining and Management Program Liaison Group (MMPLG) oversees the implementation of the State Agreement Act. This includes reviewing Alcoa's 5 year mine plan and enforcing environmental (including water quality protection) conditions where appropriate. The Department of Water and Water Corporation are represented on this group.</p> <p>Alcoa's Jaycup Trial Mining Area includes part of the</p>	<p><i>Acceptable if operated in compliance with conditions imposed by MMPLG.</i></p> <ul style="list-style-type: none"> • Ensure the conditions imposed by the MMPLG specifically pertaining to water quality protection are adhered to. • Ensure Alcoa continues to manage water protection in accordance with their <i>Environmental Management Manual</i> (updated bi-annually). • Ensure Alcoa operates according to the "Working Arrangements between Alcoa World Alumina – Australia, the Water and Rivers Commission and the Water Corporation Covering Alcoa's Mining Operations in the Darling Range". • Ensure Alcoa's monitoring program continues.

Land use / activity	Potential water quality risks		Consideration for management	Recommended protection strategies
	Hazard	Management priority		
			Serpentine Dam Catchment Area. This project involves research into the effects of mining in the intermediate rainfall zone, particularly in relation to salinity.	<ul style="list-style-type: none"> Ensure that the MMPLG considers water quality protection objectives when making decisions based on the results of the Jaycup Trial Mining Project.
Rehabilitation of mined areas	<p>The potential risks to water quality include:</p> <ul style="list-style-type: none"> Turbidity due to low vegetation cover in early stages and the possibility of break through of rip lines; The leaching of nutrients into drinking water from the use of fertilisers (due to altered drainage lines these would reach groundwater long before reaching tributaries or the dam); Fuel spills from vehicles and machinery; Pathogen contamination from increased human activity in the catchment. 	<p>Medium</p> <p>Low</p> <p>Low</p> <p>Low</p>	<p>A rehabilitation prescription is agreed to between Alcoa and DEC and is included in the DEC/Alcoa Working Arrangements. Annual rehabilitation reports are submitted to DEC to certify that Alcoa has achieved the required standards for rehabilitation success. To date, 0.2% of Serpentine Dam catchment has been mined, all of which has been rehabilitated.</p> <p>The rehabilitation program includes a monitoring program, with subsequent monitoring after rehabilitation at 9 months and 15 months. The use of fertilisers is minimal. Fertilisers are applied once initially in August following seeding.</p>	<p><i>Acceptable if operated in compliance with conditions imposed by MMPLG.</i></p> <ul style="list-style-type: none"> Ensure the conditions imposed by the MMPLG specifically pertaining to water quality protection are adhered to including compliance with Alcoa's Bauxite Mine Rehabilitation Completion Criteria. Ensure Alcoa continues to manage water protection in accordance with their <i>Environmental Management Manual</i> (updated bi-annually). Ensure Alcoa operates according to the "Working Arrangements between Alcoa World Alumina – Australia, the Water and Rivers Commission and the Water Corporation Covering Alcoa's Mining Operations in the Darling Range". Ensure Alcoa's monitoring program continues. Ensure compliance with policy statement No.10 <i>Rehabilitation of Disturbed Land</i> (CALM 1986).

Land use / activity	Potential water quality risks		Consideration for management	Recommended protection strategies
	Hazard	Management priority		
Fire Management <ul style="list-style-type: none"> • Fuel reduction and biodiversity burning • Fire control lines • Water points 	Prescribed burning and construction and maintenance of unsealed firebreaks have the potential to cause an increase in turbidity, particularly on steeper slopes close to the reservoir and tributaries, due to increased run-off and soil exposure.	Medium	Wild fire minimisation by fuel reduction burning is an established essential land management practice in the catchment, and should be managed to limit the potential for turbid run-off into the reservoir. Burning for biodiversity reasons can also reduce fuels. This burning is carried out in accordance with the <i>Forest Management Plan 2004-2013</i> and the <i>Serpentine National Park Management Plan</i> . Fire control lines are cut in the event of an emergency and are not cut on a routine basis. They may be constructed for pre-suppression purposes or to meet biodiversity outcomes. The input and mechanisms of increased organic carbon input to the dam following controlled burns, is as yet unquantified. The loss of vegetation buffers around the reservoirs and streams should be avoided.	<i>Acceptable activity with best management practices:</i> <ul style="list-style-type: none"> • Establish specific guidelines related to water quality protection for consideration in the burning prescription. For example, guidelines would include the location of fire access points, rehabilitation of fire control lines, the use of sumps or drains for sediment control and appropriate practices for the use of herbicides. • Liaise closely with DEC to ensure specific guidelines, such as <i>PSC-88 - Use of Herbicides in Water Catchment Areas</i> (DoH 2007), relating to water quality protection are incorporated within DEC's Fire Operations Manual and that protocols are put in place for effective communication between agencies managing the catchment. • Ensure stabilisation of soil excavated during construction of water points to prevent turbid run-off into watercourses. • Conduct post fire water quality monitoring of raw water.
	The risks associated with fuel reduction burns include carbon and nutrient contamination.	Low		
	Risks associated with the construction and access of water points for wild fires and controlled burns are turbidity, fuel spills from vehicles and machinery and pathogens from direct contact of firefighters with waterbodies.	Medium		

Land use / activity	Potential water quality risks		Consideration for management	Recommended protection strategies
	Hazard	Management priority		
Wild Fires	The risk associated with extensive burning by wild fire and emergency construction of fire control lines is primarily of turbidity.	High	Extensive burning from wild fires can be caused either naturally or following irresponsible human access.	<p>Wild fires cause a critical situation that requires quick decisions. In order for water quality considerations to be sufficiently addressed, a Water Corporation staff member should attend all fires in catchment areas.</p> <ul style="list-style-type: none"> • Where location, extent or intensity of a fire suggests the need, inspect sites following fire to assess need for turbidity mitigation works, and conduct these at the combined expense of the Water Corporation and the Department of Environment and Conservation. • Ensure sites that need permanent protection from wild fire have adequate fire access points and/or low-vegetation buffer zones to prevent the need for extensive earthworks or clearing at short notice during a fire. • Emergency fire control lines should be immediately rehabilitated. • Conduct post fire water quality monitoring to establish acceptability of raw water.
	There is an increased risk of pathogen contamination due to the loss of filtering vegetation.	High	Intense wild fire can cause turbidity issues from the ash made airborne during the burn, or through run-off when the burn is followed by rain.	
	There is also a risk of carbon and nutrient contamination from airborne and eroded ash	Low	<p>Water Corporation staff attends fires.</p> <p>The prescribed burning program run by DEC should reduce the incidence of wild fires.</p> <p>The chance of wild fires may increase with changing climate and increased public access.</p> <p>Fire control lines are established during emergency situations to help control fires.</p>	

Land use / activity	Potential water quality risks		Consideration for management	Recommended protection strategies
	Hazard	Management priority		
Firewood collection	<p>The risks associated with firewood collection include:</p> <ul style="list-style-type: none"> • Pathogen contamination through the presence of people near watercourses. • Rubbish dumping, including wastes containing hydrocarbons, as a consequence of public firewood collection. • Turbidity from the use of unsealed roads and damage to vegetation during off-road driving 	<p>Medium</p> <p>Medium</p> <p>Low</p>	<p>The primary concern is the potential for people to be in close proximity to the reservoir or tributaries during public firewood collection. Designated public firewood areas are established in State forest and timber reserves. Firewood collection is not allowed in nature reserves, national parks or conservation parks.</p> <p>The commercial collection of firewood is managed by the FPC. The non-commercial collection of firewood by the public, up to one tonne per trip, is managed by DEC.</p> <p>Rubbish dumping in the form of hydrocarbon waste from machinery is sometimes associated with public firewood collection points.</p> <p>Domestic animals often accompany people during firewood collection (see animal exercising below)</p>	<p><i>Acceptable activity with conditions.</i></p> <ul style="list-style-type: none"> • Ensure regional plans for public firewood collection areas give consideration to water quality protection objectives. • Promote firewood collection sites out of catchments. Where public firewood areas are approved within the catchment, establish designated public firewood areas outside the RPZ, away from the reservoir and tributaries, and restrict activity to the edge of the catchment. • Ensure the public firewood areas are regularly patrolled and rubbish dumped is removed. • Use signs and brochures to promote water catchment awareness and to ensure that the public are aware that dogs are not permitted in the catchment, unless on private property.

Land use / activity	Potential water quality risks		Consideration for management	Recommended protection strategies
	Hazard	Management priority		
<p>Private resource harvesting</p> <ul style="list-style-type: none"> • Apiaries • Wildflower picking • Seed Collection 	<p>The potential risk to water quality from these activities includes</p> <ul style="list-style-type: none"> • Pathogen contamination through the presence of people near the reservoir and tributaries, and associated camping; • Increased turbidity due to use of unsealed roads 	<p>High</p> <p>Low</p>	<p>The main concern from this activity is the potential for people to be in close proximity to the reservoir or tributaries, which needs to be controlled.</p> <p>Camping by apiarists requires use of a chemical toilet, is only allowed for one night at a time and is not allowed in the RPZ under DEC apiary site licence conditions. Licence conditions include other water source protection considerations for apiary sites in public drinking water areas as agreed with relevant agencies.</p> <p>Apiarists require water for their bees which on rare occasions may be being illegally sourced from the reservoir and tributaries, contributing to pathogen concerns.</p> <p>The low numbers of people involved, together with management controls, reduces the associated risks.</p>	<p><i>Acceptable activity with conditions.</i></p> <ul style="list-style-type: none"> • Ensure approved apiary sites are located outside the RPZ. • If water is required on site, ensure it is not sourced from the reservoir, but trucked in as per licence conditions. • Apply a condition of approval for apiarists that requires adherence to water quality protection objectives, including RPZ requirements. • Apply a condition of approval for wildflower picking and seed collection licences that requires adherence to water quality protection objectives including exclusion from RPZ and no camping in the catchment area. • Inspect water quality protection measures on site.

Land use / activity	Potential water quality risks		Consideration for management	Recommended protection strategies
	Hazard	Management priority		
Roads and tracks	<p>The risks associated with the use of roads and tracks include:</p> <ul style="list-style-type: none"> • Turbidity from erosion of unsealed roads and tracks; • Fuel and chemical spills from vehicles and machinery. • Roads and tracks also provide public access to the waterbody and catchment, which increases all associated risks of rubbish dumping, wild fires and pathogen contamination. 	<p>High</p> <p>Low</p> <p>Medium</p>	<p>Some roads and tracks are necessary for timber harvesting, fire management, general forest management and catchment management. However, it is essential they are well maintained to minimise the risk of erosion, and hence the impact on water quality.</p> <p>All roads and tracks in the State Forest could potentially be utilised by the public, and control of access is a major issue in the catchment. Uncontrolled public use of such roads and tracks is greatest in the north of the catchment. Public access to the water body increases all associated risks of rubbish dumping and pathogen contamination.</p> <p>The use of sumps and drains to control turbidity from run-off along roads is inadequate in some parts of the catchment (e.g. within the Frollett Block plantation area).</p>	<p><i>Accepted as necessary for proper land and forest management and requires best management practices.</i></p> <ul style="list-style-type: none"> • Adherence to DoW's Water Quality Protection Notes <i>Roads near Sensitive Water Resources</i> and <i>Tracks and trails near Sensitive Water Resources</i>. • Develop guidelines for the management of roads and tracks that address water quality protection objectives, such as appropriate adequate drainage and run-off control measures, and effective site management for gravel pits. • Review the road network to identify roads not essential for forest operations and management or transport thoroughfare. • Review regional public access to forest areas. • Set a definition of 'Public Road' and educate the public on definition and implication for By-law enforcement. • Consider enforcement of restricted access associated with Disease Risk Areas to limit public access to areas of the catchment. • Existing drains and sediment traps should be inspected regularly and accumulated sediments and debris removed.

Land use / activity	Potential water quality risks		Consideration for management	Recommended protection strategies
	Hazard	Management priority		
Rubbish dumping	<p>The potential risks associated with rubbish dumping include:</p> <ul style="list-style-type: none"> • Pathogen contamination from domestic rubbish; • Nutrient, chemical, heavy metal and fuel contamination from domestic building or industrial waste, and the dumping of stolen cars. 	<p>Medium</p> <p>Medium</p>	<p>Rubbish dumping is often associated with informal or unauthorised recreation or access to the catchment. Dumping is mostly localised in areas around tracks coming off Albany Highway as well as rest bays associated with the highway.</p> <p>As all roads and tracks in the State Forest are open to the public, control of access is a major issue in the catchment.</p>	<p><i>Rubbish dumping is prohibited in the catchment.</i></p> <ul style="list-style-type: none"> • Continue to develop a coordinated inter-agency plan and work with community groups and local governments to reduce rubbish dumping in the catchment. • Review road network and close roads not essential for forest operations and management or transport thoroughfare to limit public access. • Undertake surveillance with By-law enforcement. • Use signage and advertising material to ensure public awareness that rubbish dumping is not permitted
Gravel Pits	<p>The potential risks associated with the use and maintenance of gravel pits include:</p> <ul style="list-style-type: none"> • Increased turbidity from gravel extraction process associated with poor overburden management and/or drainage control and recreational use; • Fuel and chemical spills from vehicles and machinery; • Pathogens from human presence; 	<p>Medium</p> <p>Low</p> <p>Medium</p>	<p>Gravel pits used for road maintenance require effective site management to reduce risks to water quality. Old pits should benefit from an increase in vegetation cover through rehabilitation.</p> <p>Gravel pits are focal points for illegal and sometimes destructive recreation activities usually involving vehicles. Recreational activities may also be responsible for a failure of rehabilitation in</p>	<p><i>Acceptable activity with best management practices.</i></p> <ul style="list-style-type: none"> • Approval of gravel extraction proposals should include the conditions stated in the Department's Water Quality Protection Note <i>Extractive Industries within Public Drinking Water Source Areas</i>. • Ensure gravel extraction occurs in accordance with CALM's Policy Statement No.2 <i>Local Government Access to Basic Raw Materials from State forest and Timber Reserves</i> and Policy Statement No. 10 <i>Rehabilitation of Disturbed Land</i> and the <i>Guidelines</i>

Land use / activity	Potential water quality risks		Consideration for management	Recommended protection strategies
	Hazard	Management priority		
	<ul style="list-style-type: none"> Rubbish dumping often in the form of car bodies associated with the illegal recreation, also building and garden waste. 	Medium	<p>gravel pits (Burne 2001).</p> <p>Any pits established by DEC are rehabilitated after use.</p> <p>The Shire of Serpentine-Jarrahdale has created local laws, under the <i>Local Government Act 1995</i>, relating to extractive industries. Any gravel pits not on Crown land are to comply with these laws.</p>	<p><i>for Management and Rehabilitation of Gravel Pits – South West Forest Areas</i>, including immediate rehabilitation of the site where no longer in use.</p> <ul style="list-style-type: none"> During rehabilitation of sites with evidence of illegal recreation it is important to prevent access until vegetation is established. No gravel pits to be developed in the RPZ. Ensure contract specifications recognise water quality protection objectives and inspect water quality protection measures on site. Gravel pits on private land to comply with Shire of Serpentine-Jarrahdale local laws.
Research Projects	The use of the catchment and reservoir for research projects involves the potential risk of pathogen contamination from people remaining in the catchment for extended periods and increased turbidity due to the use of unsealed roads, particularly close to or on the reservoir.	Medium	<p>The risk associated with this activity is minimal due to the low numbers of people involved, management controls and the ease of education prior to the activity occurring.</p> <p>Projects are usually supervised by Water Corporation staff or Alcoa.</p>	<p><i>Acceptable activity with conditions.</i></p> <ul style="list-style-type: none"> Ensure education on water quality protection requirements is undertaken prior to activity. Apply a condition of approval that requires adherence to water quality objectives. Seek approval from DoW if research activities are proposed within the RPZ. Review sites following research to ensure water quality objectives are being met.

Land use / activity	Potential water quality risks		Consideration for management	Recommended protection strategies
	Hazard	Management priority		
<p>Feral animals and their control</p> <ul style="list-style-type: none"> • Feral Pigs • Foxes <p>(cats and rabbits are also present but are not perceived to pose significant risk to water quality)</p>	<p>Feral pigs create a large risk of</p> <ul style="list-style-type: none"> • Turbidity and • Pathogens from shedding of faeces, during wallowing. <p>Feral pig control occurs through Water Corporation rangers and through volunteer hunters licensed by DEC. This involves additional risks associated with pathogen contamination from feral animal carcasses, and from people and dogs remaining in the catchment for extended periods and associated camping.</p> <p>Illegal introduction of pigs and associated diseases by hunters is known to have occurred and increases all risks associated with the animals (see discussion on illegal hunting below).</p>	<p>Medium High</p> <p>Medium</p> <p>Medium</p>	<p>Under MWSS&D By-laws shooting, trapping or hunting of game is prohibited in catchment areas, as is the presence of dogs.</p> <p>Feral animal control reduces the risks associated with these animals, but may introduce additional risks to water quality if not properly managed.</p> <p>It is essential that feral pig control, in particular, be undertaken in a well-managed and organised manner, in order to minimise the potential impacts on water quality.</p> <p>The Water Corporation currently undertakes some feral pig control in the catchment, using the 'trap and shoot' method. This method significantly reduces the risks to water quality from this activity, as animal carcasses can be easily located and removed from the catchment.</p>	<p><i>Acceptable activity with conditions.</i></p> <ul style="list-style-type: none"> • Ensure feral pig control is performed by the 'trap and shoot' method only, without the use of dogs. • Review inter-agency guidelines for the managed eradication of feral pigs that address By-laws and water quality protection requirements, such as the presence of hunters, dogs and camping in the catchment and the burying of feral animal carcasses. • Commence detailed multi-agency data collation on the rate of pig capture to monitor success of control programs. • Ensure DEC protocol is followed to locate fox baits 100m away from the reservoir or tributaries. • Consider using 1080 to control feral pig populations as well as foxes.

Land use / activity	Potential water quality risks		Consideration for management	Recommended protection strategies
	Hazard	Management priority		
	Fox control occurs through baiting, and involves a risk of pathogen contamination from humans, animal carcasses and uneaten baits.	Medium	The bait used for fox control contains 1080 (sodium monofluoroacetate), which is a naturally occurring chemical that does not pose a risk to public health. Protocol followed by DEC is to ensure baits are not placed within 100 metres of waterbodies or reservoirs.	
Crown land – Recreation				
<i>All recreational activities within the catchment are to comply with Statewide Policy No. 13 Policy and Guidelines for Recreation within Public Drinking Water Source Areas on Crown Land (Water and Rivers Commission, 2003)</i>				
Swimming	There is a high risk of pathogen contamination associated with swimming, through direct contact of humans, pet dogs or horses with the waterbody and this risk is increased for the Serpentine Pipehead catchment due to the reduced residence time.	High	Human or animal contact with water poses an immediate threat to water quality as all catchment protection barriers are broken. Swimming, bathing, bodily contact with water and washing clothes in the reservoir and tributaries and presence in the RPZ are prohibited under MWSSD By-laws as they have the potential to pollute surface water supplies (NHMRC and ARMCANZ, 2004).	<i>Swimming is prohibited in the reservoir and tributaries in the catchment.</i> <ul style="list-style-type: none"> • Use signs and promotional material to ensure public awareness that swimming is prohibited in the reservoir and tributaries. • Undertake after-hours surveillance with By-law enforcement.

Land use / activity	Potential water quality risks		Consideration for management	Recommended protection strategies
	Hazard	Management priority		
Camping <ul style="list-style-type: none"> • Bibbulmun track • Mountain bike trails • Undesignated camping 	The potential risk associated with camping is pathogen contamination from people remaining in the catchment for extended periods: <ul style="list-style-type: none"> • Designated camping 	Medium	The risks to water quality are managed in designated campsites along the Bibbulmun track, as appropriate facilities are provided and there is no direct access to the waterbody. The use of the trails is increasing, and camping now occurs between designated campsites, with no facilities available. The risks associated with designated camping may decrease with installation of composting toilets. Undesignated camping poses a significant risk to water quality, as appropriate facilities are not available and sites are generally close to the reservoir or tributaries. Camping at undesignated sites is likely to involve additional risks associated with waste disposal and illegal activities, such as fishing and marroning. Camping in undesignated areas is prohibited under MWSSD By-laws and Conservation and Land	<i>Undesignated camping is prohibited in the catchment.</i> <ul style="list-style-type: none"> • Undertake a recreation planning exercise to identify camping opportunities outside of the catchment area. • Use signs and advertising material to ensure public awareness that camping is prohibited at undesignated sites, and to educate on the importance of protecting drinking water quality. • Undertake after-hours surveillance of the catchment with By-law enforcement. • Ensure designated camping sites are outside the RPZ and adequately cater for demand (particularly the toilet facilities). • Inspect permanent designated campsites regularly and ensure they are properly maintained. • Ensure responsibility for management of camping sites is clearly assigned and agreement made on audit procedures.
	The risk to water quality is increased considerably by undesignated camping, due to the lack of proper facilities and the sites generally being close to the waterbody. There are additional risks involved through the possibility of associated fishing and marroning. <ul style="list-style-type: none"> • Undesignated camping 	Medium		
	Rubbish dumping is a potential risk and difficult to control amongst such catchment users.	Low		
	Camping may contribute to the spread of forest disease	Low		

Land use / activity	Potential water quality risks		Consideration for management	Recommended protection strategies
	Hazard	Management priority		
			<p>Management Regulations 2002.</p> <p>Currently undesignated camping is considered rare and the risks to water quality are minimised due to catchment surveillance by Water Corporation rangers.</p>	
<p>Cycling</p> <ul style="list-style-type: none"> • Munda Bididi Mountain bike trail • Other informal activities 	<p>The potential risks associated with cycling are:</p> <ul style="list-style-type: none"> • Pathogen contamination from people remaining in the catchment for extended periods, particularly close to the reservoir or tributaries, and possibly camping. • Turbidity; • Rubbish dumping; • Spread of forest diseases, particularly if individuals do not keep to tracks. 	<p>Medium</p> <p>Medium</p> <p>Low</p> <p>Low</p>	<p>Cycling along designated tracks (such as the Munda Bididi Trail), can be managed through education, which reduces the risk to water quality. It is essential that designated tracks be regularly inspected and maintained to minimise the risk of degradation and erosion. DEC is responsible for the establishment of the Munda Bididi Trail which is promoted as a self-guided cycle trail, thus public use is largely informal. Mention of public drinking water catchment protection objectives in information brochures is essential.</p>	<p><i>Acceptable activity with conditions.</i></p> <ul style="list-style-type: none"> • No further trails to be developed in the catchment without consultation with relevant agencies (DoW, Water Corporation and DEC). • Undertake a recreation planning exercise to identify catchment cycling opportunities. • Ensure an environmental management plan is developed, implemented and audited for the Munda Bididi Trail, which addresses water quality protection objectives, such as regular inspections and maintenance of the trail. • Ensure cycling, including designated trails and informal activity, is restricted to trails outside the RPZ. • Use signs and brochures to educate on the importance of protecting drinking water quality and the MWSSD By-laws. • Consider alternative enforcement

Land use / activity	Potential water quality risks		Consideration for management	Recommended protection strategies
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			<p>The use by cyclists is uncontrolled and more likely to encourage off-track activity in the catchment.</p> <p>Cycling also usually has a greater impact than walking because there is a large rate of return to areas which members of the public are introduced to during organised events, and travel off marked trails is widespread, increasing the risk of erosion.</p>	options under <i>Environmental Protection Act 1986</i> (i.e. Environmental Protection Policy).
<p>Bushwalking</p> <ul style="list-style-type: none"> • Bibbulmun Track • Other informal activities 	<p>The potential risks associated with bushwalking are:</p> <ul style="list-style-type: none"> • Pathogen contamination from people remaining in the catchment for extended periods, particularly close to the reservoir or tributaries, and possibly camping. • Turbidity; • Rubbish dumping; • Spread of forest diseases, particularly if individuals do not keep to tracks. 	<p>Medium</p> <p>Low</p> <p>Low</p> <p>Low</p>	<p>Bushwalking through can be managed through approval and education, which reduces the risk to water quality.</p> <p>It is essential that designated or promoted tracks be regularly inspected and maintained to minimise the risk of degradation and erosion of the area.</p> <p>Organised activities may encourage later visits to the area by individuals with the possibility of camping, and this type of access can not be</p>	<p><i>Bushwalking is an acceptable activity with conditions on designated tracks and trails:</i></p> <ul style="list-style-type: none"> • No further trails to be developed in the catchment without consultation with relevant agencies (DoW, Water Corporation and DEC). • Undertake a recreation planning exercise to identify catchment bushwalking opportunities. • Ensure an environmental management plan is developed, implemented and audited for the Bibbulmun Track, which addresses water quality protection objectives, such as regular inspections and maintenance of the trail.

Land use / activity	Potential water quality risks		Consideration for management	Recommended protection strategies
	Hazard	Management priority		
			<p>properly managed.</p> <p>The Department of Water's recreation map shows walk trails within the region.</p>	<ul style="list-style-type: none"> • Ensure organised groups obtain approval for events, and proper management of the group is a condition of approval. • Ensure bushwalking, including designated trails and informal activity, is restricted to trails outside the RPZ. • Use signs and brochures to educate on the importance of protecting drinking water quality and the MWSSD By-laws. • Consider alternative enforcement options under <i>Environmental Protection Act 1986</i> (i.e. Environmental Protection Policy).
Orienteering and rogaining	The risk to water quality from these activities is pathogen contamination from people remaining in the catchment for extended periods, particularly close to the reservoir or tributaries. Camping is frequently associated with rogaining, increasing the contamination potential, although campsites are usually outside of catchment areas.	Low	<p>There are up to two organised events held in the catchment each year, which are subject to DEC and Water Corporation approval. These events are well managed, and the groups are very responsible, willingly promoting water quality issues.</p> <p>Orienteering and rogaining run by organised groups can be managed through approval and education. However, these events may encourage later visits by individuals, with the possibility of camping.</p>	<p><i>Acceptable activity with conditions.</i></p> <ul style="list-style-type: none"> • Ensure organised groups obtain approval for events, and proper management of the group is a condition of approval. • Ensure approved groups use trails away from the reservoir and tributaries. • Ensure approved events provide chemical toilets for participants. • Use signage and brochures to educate on the importance of protecting drinking water quality.

Land use / activity	Potential water quality risks		Consideration for management	Recommended protection strategies
	Hazard	Management priority		
Horse riding <ul style="list-style-type: none"> • Uncontrolled • WAERA organised event 	The risks associated with horse riding include: <ul style="list-style-type: none"> • Pathogen contamination from people and animals remaining in the catchment for extended periods and being in contact with waterbodies (for watering horses) resulting in faecal contamination. This would be further exacerbated if riders were to camp (refer to camping section above); • Turbidity from the use of horses and vehicles on unsealed roads and tracks. Horses compact ground, contributing to increased overland run-off and thus turbidity. • Fuel spills from vehicles accessing the trails. • Rubbish dumping is a potential risk, but not generally associated with organised events. • Horses are also responsible for spread of exotic plant species. 	Medium	Except by permission of DoW, it is prohibited to ride horses in the catchment under MWSSD By-laws except on public roads.	<i>Horse riding is prohibited in the catchment except on public roads or are part of historical events that have approval and are managed as a non-conforming use.</i> <ul style="list-style-type: none"> • No new events to be established in the catchments. • Undertake surveillance and By-law enforcement to discourage horse riding in the catchment other than on public roads. • Water Corporation and DoW work with WAERA to help find a suitable course for their annual event outside of drinking water catchments. • Undertake an inter-agency recreation planning exercise to identify horse riding opportunities outside of catchment areas. • Use signs and advertising material to ensure public awareness that horse riding is restricted to public roads outside the RPZ. • Have Water Corporation Rangers attend organised horse-riding events for education purposes.
		Medium	The risk is reduced where horse riding occurs along roads or tracks away from the reservoir and tributaries, and camping occurs at designated sites, but is increased by uncontrolled riding by individuals.	
		Low	Horse riding run by organised groups can be managed through approval and education. However, new events will not be approved in the catchments	
		Low	The Western Australian Endurance Riders Association currently runs an endurance ride through forest adjacent to and within the western edge of Serpentine catchment during one day in September each year. Conditions are applied and they are required to seek	

Land use / activity	Potential water quality risks		Consideration for management	Recommended protection strategies
	Hazard	Management priority		
			<p>approval for each event. WAERA have been advised that the 2006 endurance event will be the last time this event will be approved in the Serpentine catchment except on public roads.</p> <p>Events that been historically approved and cannot readily be relocated may be approved with conditions. For further information see the Department's Statewide Policy No. 13 - <i>Policy and Guidelines for Recreation within Public Drinking Water Source Areas on Crown Land</i>.</p>	
<p>Animal (dog) exercising on Crown Land</p> <ul style="list-style-type: none"> • Unorganised 	<p>The risk associated with this activity is from pathogen contamination from people and animals in the catchment, particularly close to the reservoir or tributaries.</p>	Medium	<p>As animal behaviour cannot always be controlled, even when on a lead, there is a risk of contamination associated with this activity, particularly close to watercourses.</p> <p>It is prohibited to bring or allow a dog into a catchment area under MWSSD By-laws, unless on a private property.</p>	<p><i>Presence of dogs is not acceptable in the catchment.</i></p> <ul style="list-style-type: none"> • Undertake surveillance with By-law enforcement. • Use signage and advertising material to ensure public awareness that dogs are not permitted in the catchment, except on private land.

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Picnicking	<p>The risks to water quality from this activity are:</p> <ul style="list-style-type: none"> • Pathogen contamination from people and potentially their pets. • Pathogen contamination from septic systems. • Rubbish dumping 	<p>Medium</p> <p>Medium</p> <p>Medium</p>	<p>Picnicking is not permitted in the catchment other than at designated sites. The risk of contamination is increased by proximity to the reservoir or tributaries being a desirable aspect of a picnic site. However, the risk is minimised where picnic sites and facilities are provided, away from watercourses.</p> <p>MWSS&D By-laws prohibit septic systems being within 100m of any prohibited zone or watercourse in a Catchment Area unless authorised by DoW.</p> <p>Two designated picnic sites occur in the Serpentine Dam and Serpentine Pipehead Dam Catchment Areas. One is downstream of Serpentine Dam wall known as Serpentine Dam, and one to the north of the Serpentine reservoir at the intersection of Balmoral and Millars Log Road, known as Balmoral POW Camp.</p>	<p><i>Picnicking is an acceptable activity at designated sites only.</i></p> <ul style="list-style-type: none"> • Undertake a recreation planning exercise to identify catchment picnicking opportunities. • Ensure additional designated picnic areas are outside the RPZ and include appropriate toilet facilities with no access to the waterbody or tributaries. If appropriate toilet facilities are not available, remove picnic sites. • Ensure existing toilets at picnic sites are properly maintained and in good working order • If any toilets within the catchment areas need to be replaced, then all replacement toilets need to be outside the RPZ and at least 100m from any watercourse. • Use signs and brochures to educate on the importance of protecting drinking water quality.

Land use / activity	Potential water quality risks		Consideration for management	Recommended protection strategies
	Hazard	Management priority		
			The risks are greater for undesignated picnicking than picnicking in designated areas.	
Recreational Hunting (illegal)	<p>The major risk to water quality associated with hunting is pathogen contamination from</p> <ul style="list-style-type: none"> Feral animal carcasses, and From people and dogs remaining in the catchment for extended periods and possibly camping. <p>Hunters have been known to illegally introduce pigs to the catchment to increase stock. This has the potential to introduce foreign diseases, as well as increase the inherent risks associated with feral populations (see earlier discussion on feral animals and their control for more information)</p>	<p>High</p> <p>Medium</p>	<p>Under MWSSD By-law 4.3.4: No person shall shoot, trap or hunt any game or catch, or attempt to catch, any fish or marron within a catchment area, without specific permission in writing from the Department of Water, to which it may attach any conditions that it deems necessary. Only hunting as part of a feral animal control program is likely to be given permission to occur.</p> <p>DEC approve hunting in the catchment for feral animal control by the trap-and-shoot method. Uncontrolled hunting and shooting introduce significant additional risks to water quality particularly due to associated camping and use of dogs.</p> <p>It is essential that any hunting in the catchment is by the trap-and-shoot method only, under</p>	<p><i>Recreational hunting is prohibited in the catchment.</i></p> <ul style="list-style-type: none"> Use signs and advertising material (through local shooting clubs) to advertise that recreational hunting is not permitted in PDWSAs. Continue surveillance of the catchment with By-law enforcement. Support DEC and Water Corporation managed feral animal control program.

Land use / activity	Potential water quality risks		Consideration for management	Recommended protection strategies
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			<p>authorisation as part of the feral animal control program, and is undertaken in an organised manner to minimise water contamination. All other hunting in the catchments is illegal.</p> <p>Surveillance by Water Corporation Catchment Rangers currently reduces the occurrence of illegal hunting and the associated risks, but greater surveillance would further minimise the activity.</p>	
<p>Motor rally events</p> <ul style="list-style-type: none"> Darling 200 run by Light Car Club of WA Rally Australia practice stages 	<p>The risks associated with motor rally events include:</p> <ul style="list-style-type: none"> Turbidity from erosion of unsealed roads and tracks, particularly on the steep slopes close to the reservoir; Turbidity is also increased by the import of fill materials for reconstruction and maintenance of tracks; Fuel and oil spills from vehicles; Pathogen and litter 	<p>Medium</p> <p>Medium</p> <p>Medium</p> <p>Medium</p>	<p>It is recognised that rallies in the area are national events of significance for the local area, and until such time as more appropriate locations are acceptable, approval will continue to be given to stage pre-existing events in the catchment.</p> <p>However, competitive motor rallying is not compatible with water quality objectives. As such Rally Australia and CAMS shall not be given approval to return discontinued</p>	<p><i>Existing events are acceptable with best management practices.</i></p> <ul style="list-style-type: none"> No new events to be established in the catchment and no extensions to established routes or stages for current approved events. Discontinued routes are not to be re-established. No events to be held during the winter months. Ensure an environmental management plan is developed for each event which explicitly addresses water quality protection objectives. The plan should provide particular consideration of road construction and maintenance

Land use / activity	Potential water quality risks		Consideration for management	Recommended protection strategies
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	<p>contamination from spectators entering the catchment;</p> <ul style="list-style-type: none"> • Spread of forest diseases. 	Low	<p>routes into the Serpentine catchment. The 2006 Rally Australia is the last time the event is scheduled to be held in WA.</p> <p>If any event is to be staged in the catchment, it is essential that a management plan be submitted for each event.</p> <p>The Water Corporation gives conditional approval each year, based on review of proposed routes and the Environmental Management Plan. They undertake a post-event inspection and discuss this with the organisers.</p>	<p>techniques, such as gravel selection, gravel compaction methods and construction of effective run-off control measures.</p> <ul style="list-style-type: none"> • Ensure road restoration and repair is implemented following events. • Prohibit vehicle maintenance in the catchment area. • Seek to minimise spectator and support crew access to the catchment area. • Water Corporation to continue post event inspection. • Work with organising bodies on assessment of water quality risks associated with events. • Conduct a catchment recreation planning process including identification of where recreational rally driving is acceptable.
<p>Licensed and unlicensed vehicle access</p> <ul style="list-style-type: none"> • Four wheel drives (4WD) • Off-road vehicles • Motor cycles • Unlicensed vehicles 	<p>The risks associated with vehicle access include:</p> <ul style="list-style-type: none"> • Turbidity from erosion of unsealed roads and tracks, particularly on the steep slopes close to reservoir and from damage to vegetation; • Hydrocarbon contamination from fuel spills from vehicles; 	<p>High</p> <p>Low</p>	<p>Off-road vehicle use is less intensive in the Serpentine catchment than in catchments closer to the Metropolitan area. The risks associated with this activity are significant, particularly with regard to erosion of unsealed roads and tracks.</p> <p>The Frollet State Forest block</p>	<p><i>Vehicle access away from designated roads is not acceptable in the catchment.</i></p> <ul style="list-style-type: none"> • Conduct a catchment recreation planning process including identification of where recreational 4WD and off-road vehicle use is acceptable (preferably outside PDWSA), and ensure all rangers, vehicle retailers, 4WD clubs and local Shire's are aware of the area in order to direct users to the designated areas outside PDWSA.

Land use / activity	Potential water quality risks		Consideration for management	Recommended protection strategies
	Hazard	Management priority		
	<ul style="list-style-type: none"> • Pathogen contamination from people remaining in the catchment for extended periods and possibly camping, and through contact with tributary water during vehicle crossings; • Contamination from vehicle dumping; • Spread of forest disease and the loss of filtering vegetation. 	<p>Medium</p> <p>Low</p> <p>Low</p>	<p>near Jarrahdale Rd is a reasonably well-used unauthorised off-road vehicle location, and includes additional risks associated with the dumping of stolen cars and camping.</p> <p>The possibility of industry management of off-road vehicle activities could be considered with a levy on off-road vehicles sold contributing to land rehabilitation funds.</p> <p>Under MWSSD By-law 4.7.2: No person shall drive a vehicle on any part of a catchment area other than a road or track which has a graded, gravelled, sealed, primed or other prepared surface without written approval of the DoW</p>	<p>These legal off road vehicle areas need to be well-managed to further encourage their use.</p> <ul style="list-style-type: none"> • Review road network and close and rehabilitate roads not essential for forest operations and management or transport thoroughfare to restrict access to off-road areas. • Consider enforcement of restricted access associated with Disease Risk Areas to limit public access to areas of the catchment. • Prohibit off-road vehicle activities on DoW owned land by applying trespassing laws or changing MWSS&D By-laws. • Rehabilitate DoW owned land to native forest to remove the temptation supplied by partially cleared property for illegal recreation. • Undertake surveillance to control off-road driving away from designated roads in the catchment and use signage to advertise that off-road driving away from designated roads is not permitted. • Liaise with Western Power and DEC to consider joint signage of access roads to prohibit public access to access roads and National Parks.

Land use / activity	Potential water quality risks		Consideration for management	Recommended protection strategies
	Hazard	Management priority		
<i>Water and Rivers Commission and Water Corporation freehold land</i>				
<p>DEC activities</p> <ul style="list-style-type: none"> • Softwood timber harvesting • Fire management • Feral animal control <p>Approved recreation</p> <ul style="list-style-type: none"> • Bibbulmun Track • Mountain Bike Trail • Orienteering and rogaining <p>Unauthorised recreation</p> <ul style="list-style-type: none"> • Camping • Bushwalking • Off-road vehicle use • Illegal Hunting 	<p>The potential risks associated with these activities have been discussed in detail in previous sections.</p>		<p>The Waters and Rivers Commission own several properties in the catchment, including two previous agricultural properties on Balmoral Rd in the north of the catchment that are still partly cleared. Three large properties at the south-eastern extremity of the catchment are also reserved for the WRC, but these are now listed as proposed National Park (Monadnocks National Park). Some activities associated with these properties pose potential risks to water quality.</p> <p>As discussed in previous sections, the forest and land management activities performed by DEC are generally acceptable with best management practices. In addition, recreation activities through approved organised groups are generally acceptable with conditions and controls.</p>	<p><i>DEC activities and approved recreation activities are acceptable with best management practices and conditions.</i></p> <ul style="list-style-type: none"> • Refer to previous section for protection strategies <p><i>Unauthorised activities are not acceptable on these properties.</i></p> <ul style="list-style-type: none"> • Continue to implement surveillance of DoW owned land, with associated By-law enforcement. Consider the use of trespassing laws if necessary. • Use signage to ensure public awareness of the private ownership of the properties. • Repair fences and gates to restrict access. • Rehabilitate cleared or partly cleared areas with native vegetation. • Ensure activities comply with <i>Conservation and Land Management Act 1984</i>.

Land use / activity	Potential water quality risks		Consideration for management	Recommended protection strategies
	Hazard	Management priority		
			<p>The proposed alignment of the Munda Biddi Mountain Bike Trail passes along Balmoral Rd, between two WRC owned properties in the north of the catchment. This may increase the risks associated with unauthorised recreation on the properties.</p> <p>However, the properties are used extensively for unauthorised recreation. These activities may be controlled through the use of trespassing laws. A transition period would be necessary before laws were enforced.</p>	
Other Activities				
<p>Major roads</p> <ul style="list-style-type: none"> • Shire roads • Main roads 	<p>The potential risks to water quality include:</p> <ul style="list-style-type: none"> • Pathogens from dumping of rubbish at rest bays. • Fuel and chemical spills from vehicles and their loads; • Herbicides from weed control on road verges; • Increased turbidity from erosion of unsealed 	<p>Medium</p> <p>Medium</p> <p>Medium</p> <p>Medium</p>	<p>The main road that intersects the catchment is Albany Highway. This road is a major haulage route, and is necessary for transportation and operations in the area. Kingsbury Drive is a sealed Shire Road that runs along the catchment boundary between Serpentine Dam and the Pipehead catchment.</p>	<p><i>Best management practices are required for all roads in the catchment.</i></p> <ul style="list-style-type: none"> • Restrict development of new roads through the catchment. Oppose the development of a linkage road between Albany Hwy and Brookton Hwy that runs through the water catchment area. • In partnership with the relevant Shires, develop a management plan for Shire roads that address water quality protection objectives, including weed

Land use / activity	Potential water quality risks		Consideration for management	Recommended protection strategies
	Hazard	Management priority		
	roads; • Imports of pathogens from motorists or their vehicle loads; • Import of forest diseases by motorists or their vehicle loads; • Increased turbidity created during construction and maintenance of roads and associated heavy vehicle movement.	Medium Low Medium	<p>The risks associated with these roads are reduced by the distance from the waterbody. Albany Highway passes along the north-eastern border of the Serpentine catchment, intersecting the boundary in two areas.</p> <p>Plans to seal a linkage road between Albany Highway and Brookton Highway (largely to the north of the catchment) would result in a third major haulage road bringing traffic to the catchment. This would increase all the risks associated with major roads in the catchment.</p> <p>A significant amount of rubbish, including human waste (nappies) is dumped at rest bays along Albany Highway. Local Government Authorities are responsible for managing rubbish at rest bays.</p>	<p>control and adequate control of run-off and spills.</p> <ul style="list-style-type: none"> • Undertake road construction and maintenance to avoid water source contamination risks (including consideration of alignment of road upgrades). • Ensure an operative emergency response process exists. • Maintain signs along roads to inform people of their presence in a public drinking water supply catchment, and display the emergency contact number in the event of a spill. • Improve the management of rest bays to ensure that they are regularly cleaned up. The location of rubbish bins should allow easy access (eg people can use them without getting out of their cars).

Land use / activity	Potential water quality risks		Consideration for management	Recommended protection strategies
	Hazard	Management priority		
Infrastructure maintenance <ul style="list-style-type: none"> • Power lines • Telephone lines and towers • Pipelines • Roads 	The major risk associated with these activities are: <ul style="list-style-type: none"> • Turbidity due to clearing of vegetation, use of unsealed roads and tracks and of heavy machinery on such tracks; • Herbicides from weed control; • Fuel spills from vehicles and machinery; • Spread of forest disease reducing vegetation buffers; • Pathogens due to the public using the roads. 	Medium Low Low High	Maintenance is necessary for the operation of the infrastructure. However, the risks to water quality associated with this activity need to be managed, particularly in close proximity to watercourses. Western Power liaises with Water Corporation staff when track maintenance or upgrade occurs. The Department's Statewide Policy No. 2 <i>Pesticide Use in Public Drinking Water Source Areas</i> should be considered when dealing with this hazard. There are also restrictions on the use of pesticides in catchment areas reflected in PSC88 (Department of Health, 2007).	<i>Best management practices are required for all infrastructure maintenance activities in the catchment.</i> <ul style="list-style-type: none"> • Ensure maintenance workers are aware of water quality protection objectives and adopt best management practices. • Inspect water quality protection measures on site. • Liaise with Western Power to ensure their work procedures consider water quality protection objectives. • Close non-essential access roads.

Land use / activity	Potential water quality risks		Consideration for management	Recommended protection strategies
	Hazard	Management priority		
Exporting Serpentine Dam water through Serpentine Pipehead	<p>Passing Serpentine reservoir water through the Serpentine Pipehead catchment prior to export into the IWSS.</p> <p>There is also a risk of adversely affecting water quality through improper management of the inflow and outflow system, which may result in inadequate mixing of the imported water.</p>	<p>Medium</p> <p>Medium</p>	<p>The Serpentine Pipehead Dam has a lesser capability than Serpentine main dam to pre-treat water through residence time in the reservoir, as it is relatively small. The catchment is also smaller, and thus has less buffering capability from contamination events in the catchment.</p> <p>However, Serpentine Pipehead Dam is particularly narrow and long, making short cutting of water through the reservoir less likely.</p>	<p><i>Necessary for water supply operations.</i></p> <ul style="list-style-type: none"> • Strictly control and manage land use and activities in the Serpentine Pipehead catchment. • Ensure management of the inflow and outflow system allows for adequate mixing of the imported water through the reservoir. • Investigate the possibility of creating a pumpback system with the Serpentine Pipehead Dam to return water to Serpentine Dam, and source water for the IWSS directly from Serpentine Dam.

5 Recommendations

- 1 The boundaries of the Serpentine Dam Catchment Area and the Serpentine Pipehead Dam Catchment Area should be amended under the *Metropolitan Water Supply, Sewerage and Drainage Act 1909*. (**Department of Water**).
- 2 Implement the recommended protection strategies as detailed in Table 1: Land use, potential water quality risks and recommended strategies of this Plan. (**Applicable stakeholders**)
- 3 Prepare an implementation strategy for this Plan describing responsible stakeholders, timeframes and funding sources for the recommended protection strategies. (**Department of Water**)
- 4 The Shire of Boddington, Shire of Murray, Shire of Serpentine-Jarrahdale and Shire of Wandering Town Planning Schemes should incorporate this Plan and reflect the identified Serpentine Dam Catchment Area and Serpentine Pipehead Dam Catchment Area boundary and the Priority 1 and 2 classifications. (**Shire of Boddington, Shire of Murray, Shire of Serpentine-Jarrahdale and Shire of Wandering**)
- 5 All development proposals within the Serpentine Dam and Serpentine Pipehead Dam Catchment Areas that are likely to impact on water quality and/or quantity, or are inconsistent with *Water Quality Protection Note – Land use compatibility in Public Drinking Water Source Areas* or *Statement of Planning Policy No.2.7 – Public Drinking Water Source Policy* should be referred to the Department of Water for advice and recommendations. (**Department for Planning and Infrastructure, Shire of Boddington, Shire of Murray, Shire of Serpentine-Jarrahdale and Shire of Wandering**)
- 6 Incidents covered by WESTPLAN – HAZMAT in the Serpentine Dam and Serpentine Pipehead Dam Catchment Areas should be addressed through the following:
 - The Boddington, Murray, Serpentine-Jarrahdale and Wandering LEMAC (Local Emergency Management Advisory Committee) are familiar with the location and purpose of the Serpentine Dam and Serpentine Pipehead Dam Catchment Areas.
 - The locality plan for the Serpentine Dam and Serpentine Pipehead Dam Catchment Areas is provided to the Fire and Rescue headquarters for the HAZMAT Emergency Advisory Team.
 - The Water Corporation provides an advisory role during incidents in the Serpentine Dam and Serpentine Pipehead Dam Catchment Areas.
 - Personnel dealing with WESTPLAN – HAZMAT incidents in the area have ready access to a locality map of the Serpentine Dam and Serpentine Pipehead Dam Catchment Areas and training to understand the potential impacts of spills on drinking water quality.(**Department of Water, Water Corporation**)

- 7 Surveillance should be increased to identify any incompatible land uses or potential threats within the Serpentine Dam and Serpentine Pipehead Dam Catchment Areas. The Department of Water continues to delegate responsibility for the surveillance and enforcement to the Water Corporation. (**Water Corporation**)
- 8 Signs should be erected along the boundaries of the Serpentine Dam and Serpentine Pipehead Dam Catchment Areas to define the location and promote awareness of the need to protect drinking water quality. Signs should include an emergency contact telephone number. (**Water Corporation**)
- 9 Investigate the options for Water Corporation Catchment Rangers and Department of Environment and Conservation Rangers to be trained and delegated authority to enforce By-laws and regulations policed by both agencies and cooperate to survey more of the Catchment Area. (**Water Corporation, Department of Environment and Conservation**)
- 10 New recreational events or activities in the catchment should only be approved in accordance with the requirements of the relevant agencies. New activities within the Reservoir Protection Zone should not be supported. (**Water Corporation, Department of Environment and Conservation, Department of Water**)
- 11 Environmental management plans should be developed, implemented and audited for approved or organised recreational activities and events in the catchments. Any new proposals would also require an approved environmental management plan. (**Recreational Stakeholder Groups, Government agencies**)
- 12 Agencies should meet to discuss the development of a recreation plan for this catchment. (**Water Corporation, Department of Environment and Conservation, Department of Water, Department of Sport and Recreation, Department of Fisheries, other interested agencies**)
- 13 A water quality risk assessment of the Munda Biddi bike trail should be completed and the risks addressed. (**Department of Environment and Conservation**).
- 14 Stream zones and other areas of catchment under Crown ownership should be assessed for the need for rehabilitation, and rehabilitation with native species carried out where necessary. (**Government agency that owns the land**)
- 15 Work with Main Roads to ensure that any linkage road between Brookton Highway and Albany Highway is as far from Serpentine Reservoir as possible, and preferably outside the catchment. Should the construction occur within the catchment, ensure it is planned, designed and constructed to mitigate water quality risks. (**Department of Water, Water Corporation, Main Roads WA**)
- 16 All rest bays within the catchment area should be regularly cleaned up. Ways to better encourage the use of rubbish bins, such as people being able to use them without needing to leave vehicles should be developed. (**Local Government Authority, Main Roads WA**)
- 17 Review the surface water quality monitoring program to ensure key characteristic parameters are measured at the appropriate frequency. Routinely review water quality analysis results to detect any increasing trends. (**Water Corporation**)
- 18 A review of this plan should be undertaken after 5 years. (**Department of Water**).

Appendices

Appendix A – Water Quality

Explanatory Note

Following storage in the Serpentine Dam Reservoir to gain the benefits of natural microbiological improvement, water from Serpentine Dam is transferred to Serpentine Pipehead Dam where it is disinfected by chlorination before being supplied to the public. The Water Corporation is required to comply with the health related guidelines of the Australian Drinking Water Guidelines (ADWG) but not aesthetic guidelines.

There have been some occasional exceedences of aesthetic water quality guidelines and no recorded exceedence of health related guidelines.

Aesthetic Water Quality Data

Aesthetic water quality analyses for raw water from Serpentine Dam are summarised in the following table.

The values are taken from ongoing monitoring for the period January 2000 to February 2006. All values are in milligrams per litre (mg/L) unless state otherwise. The water quality parameters that have on occasion exceeded the ADWG are shaded.

Parameter	Units	Aesthetic Guideline Value	Serpentine Main Dam		
			Range		Median
Turbidity	NTU	5	0.4	- 14	0.9
Colour	HU	15	2	- 9	3
Conductivity	mS/m	-	25	- 36	32
Iron (unfiltered)	mg/L	0.3	0.05	- 0.46	0.15
Manganese (unfiltered)	mg/L	0.1	0.002	- 0.22	0.026
Aluminium	mg/L	0.2	<0.008	- 0.14	0.038
Sodium	mg/L	180	35	- 51	44
Potassium	mg/L	-	0.8	- 2.2	1.6
Calcium	mg/L	-	2.4	- 4	3.2
Magnesium	mg/L	-	4.4	- 7	5.5
Alkalinity (as HCO ₃ ⁻)	mg/L	-	8.1	- 18.6	13.5
Chloride	mg/L	250	62	- 84	76
Sulphate	mg/L	250	8.5	- 13	10
Silicate (as SiO ₂)	mg/L	-	<2.2	- 3.8	3.1
Filterable Organic Carbon	mg/L	-	2	- 3.8	2.4
Hardness (as CaCO ₃)	mg/L	200	24	- 39	31
pH		6.5 - 8.5	6.3	- 7.58	7.23

Health Parameters

Raw water from Serpentine Dam is analysed for health related chemicals. Health related water quality parameters that have been measured at detectable levels in the source between May 2000 and February 2006 are summarised in the following table.

Parameter	Units	Health Guideline Value*	Serpentine Main Dam	
			Range	Median
Sulphate	mg/L	500	8.5 – 13	10
Manganese	mg/L	0.5	0.002 - 0.22	0.026
Nitrite plus Nitrate as Nitrogen	mg/L	11.3	0.011 - 0.19	0.04

* A health guideline value is the concentration or measure of water quality characteristic that, based on present knowledge, does not result in any significant risk to the health of the consumer over a lifetime of consumption (NHMRC & ARMCANZ, 2004)

Microbiological Analysis

Microbiological testing of raw water samples is conducted on a weekly to monthly basis, particularly during summer and autumn. *Escherichia coli* counts are used as an indicator of the degree of faecal contamination of the raw water from warm-blooded animals. A count of less than 20 colony forming units (cfu) per 100 mL is typically associated with low levels of contamination and is used as a microbiological contamination benchmark (WHO, 1996).

During the reviewed period of January 2000 to March 2006, positive *Escherichia coli* counts were recorded in 40% of samples, with 1% of the positive samples exceeding 20 cfu/100 mL.

Glossary

ADWG	The Australian Drinking Water Guidelines, outlining guideline criteria for the quality of drinking water in Australia.
Aesthetic guideline	NHMRC guideline level ascribed to acceptable aesthetic qualities of drinking water such as taste, smell, colour and temperature.
AHD	Australian Height Datum is the height of land in metres above mean sea level. For example this is +0.026 m at Fremantle.
Allocation	The quantity of water permitted to be abstracted by a licence, usually specified in kilolitres per annum (kL/a).
ANZECC	Australian and New Zealand Environment Conservation Council.
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand.
Augment	To increase the available water within a storage dam by pumping back water from a secondary storage/reservoir dam.
Catchment	The area of land which intercepts rainfall and contributes the collected water to surface water (streams, rivers, wetlands) or groundwater.
CFU	Colony forming units is a measure of pathogen contamination in water.
Diffuse source	Pollution originating from a widespread area eg urban stormwater runoff, agricultural infiltration.
Effluent	The liquid, solid or gaseous wastes discharged by a process, treated or untreated.
GL	Gigalitres (1,000,000,000 litres)
ha	Hectares (a measure of area)
Hydrogeology	The study of groundwater, especially relating to the distribution of aquifers, groundwater flow and groundwater quality.
kL	Kilolitres (1000 litres)
km	Kilometres (1000 metres)
km²	Square kilometres (a measure of area)
Leaching / leachate	The process by which materials such as organic matter and mineral salts are washed out of a layer of soil or dumped material by being

dissolved or suspended in percolating rainwater. The material washed out is known as leachate. Leachate can pollute groundwater and waterways.

m	Metres
mg/L	Milligrams per litre (0.001 grams per litre)
mm	Millimetres
NHRMC	National Health and Medical Research Council.
NTU	Nephelometric turbidity units are a measure of turbidity in water.
Nutrient load	The amount of nutrient reaching the waterway over a given timeframe (usually per year) from its catchment area.
Nutrients	Minerals dissolved in water, particularly inorganic compounds of nitrogen (nitrate and ammonia) and phosphorous (phosphate) which provide nutrition (food) for plant growth. Total nutrient levels include the inorganic forms of an element plus any bound in organic molecules.
Pesticides	Collective name for a variety of insecticides, fungicides, herbicides, algicides, fumigants and rodenticides used to kill organisms.
Point source pollution	Pollution originating from a specific localised source, eg sewage or effluent discharge, industrial waste discharge.
Pollution	Water pollution occurs when waste products or other substances, eg effluent, litter, refuse, sewage or contaminated runoff, change the physical, chemical biological or thermal properties of the water, adversely affecting water quality, living species and beneficial uses.
Public Drinking Water Source Area (PDWSA)	Includes all underground water pollution control areas, catchment areas and water reserves constituted under the <i>Metropolitan Water Supply Sewerage and Drainage Act 1909</i> and the <i>Country Areas Water Supply Act 1947</i> .
Reservoir	A reservoir, dam, tank, pond or lake that forms part of any public water supply works
Run-off	Water that flows over the surface from a catchment area, including streams.
Scheme supply	Water diverted from a source or sources by a water authority or private company and supplied via a distribution network to customers for urban, industrial or irrigation use.

Storage reservoir	A major reservoir of water created in a river valley by building a dam.
Stormwater	Rainwater which has run off the ground surface, roads, paved areas etc. and is usually carried away by drains.
TDS	Total dissolved salts, a measurement of ions in solution, such as salts in water.
Treatment	Application of techniques such as settlement, filtration and chlorination to render water suitable for specific purposes including drinking and discharge to the environment.
Wastewater	Water that has been used for some purpose and would normally be treated and discarded. Wastewater usually contains significant quantities of pollutant.
Water quality	The physical, chemical and biological measures of water.
Water Reserve	An area proclaimed under the <i>Country Areas Water Supply Act 1947</i> or the <i>Metropolitan Water Supply Sewerage and Drainage Act 1909</i> for the purposes of protecting a drinking water supply.

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