Criterion 4

Conservation and maintenance of soil and water resources

This criterion is concerned with the most fundamental resources of a forest environment: soil and water. Its five indicators assess the area of forest managed primarily for protective functions, and how the risk of soil erosion and the risks to soil physical properties and water quantity and quality are managed in forests.

Rainforest in a gully helps prevent erosion and protects water quality in the riparian zone.

Key findings

- Over 30 million hectares of public forests (20% of the total forest area) is managed primarily for protection, including of soil and water values. This is an increase of more than 8% over the reporting period.
- In catchments managed specifically for water supply, jurisdictions either do not allow disturbance activities to occur or limit and stringently control approved activities and/or public access.
- In most jurisdictions, activities that cause disturbances in forests are subject to codes of practice or other instruments that specify the measures to be taken to mitigate their contributions to soil erosion and their impacts on soil physical properties, and to maintain water quantity and quality. Compliance with such measures is generally high.
- Major wildfires during the period affected soil erosion and water quality across forest tenures, creating an increased challenge for forest managers. The resulting natural regrowth is expected to reduce water yields in affected catchments for decades.
- Water usage by tree plantations is the subject of increasing community attention and scientific research.

Indicator 4.1a

Area of forest land managed primarily for protective functions

Rationale

The area of forest land where priority is given to protecting soil and hydrological functions provides an indication of the emphasis being placed by society on the conservation of these values. This indicator includes areas managed to protect soil and water by excluding incompatible activities.

Key points

- Over 30 million hectares of public forests (20% of the total forest area) is managed primarily for protection, including of soil and water values. The area of forest managed primarily for protective functions increased by more than 8% over the reporting period.
- This area includes all public nature conservation reserves and those parts of multiple-use public forests in which harvesting and roading are not permitted, such as on steep slopes or certain soil types or in riparian zones. It also includes catchments managed specifically for water supply.
- In catchments managed specifically for water supply, jurisdictions either do not allow disturbance activities to occur or limit and stringently control approved activities and/or public access.
- The re-establishment, restoration and maintenance of native vegetation, including forests, for protective functions is being encouraged by government and non-government programs.

State and territory governments protect soil and water values through legislation, codes of practice, management prescriptions and special measures and standards relating to watershed protection, areas vulnerable to erosion and slope instability, and riparian zones. Codes of forest practice set out activities to be undertaken in or near waterways, erosion-hazard areas and water catchments to minimise the impacts of wood harvesting and roading. Legislation exists in all states and territories to control and limit forest disturbances in designated water-supply catchments.

The main disturbances that can directly affect soil and water values in forested areas are road construction and maintenance, timber harvesting, fire, grazing and recreation. In some places, the activities of feral animals, such as pigs, can also affect soil and water values.[1]

The identification of forest managed primarily for protective functions is not always easy. In large areas of forest, including most multiple-use public forests, the protection of soil and water is one of several formal management objectives; such areas are generally not included in the data presented here. In most jurisdictions, forests in public nature conservation reserves may be defined as 'managed primarily for protective functions' and are therefore included. In addition, some areas of multiple-use public forests, such as those on steep slopes, on erosion-prone soils or close to streams, are counted because harvesting is not permitted for protective reasons. Forests managed specifically for water supply are also included in this indicator; in some cases, disturbances such as timber harvesting are permitted in those forests, but soil and water protection remains the primary objective.

Area of public forest managed for protective functions

Table 47 shows the area of forest from which harvesting activities that potentially affect soil and water values were excluded in 2006. In all jurisdictions combined, more than 60% of public forested land was managed for protective functions in 2006, an increase of 8% over 2000–01.

In Tasmania, the area of forest from which disturbance activities are excluded increased by 117,000 hectares, or 8%, to 1.67 million hectares in the five years to 2006.

1 Research into the impacts of feral pigs is under way in Warragamba catchment and the adjoining national parks west of Sydney.

This consisted of increased informal reserves in multiple-use public forest, additions to nature conservation reserves (including national parks), and a large increase in conservation covenants on private land under the private forest reserves program.

Table 48 shows the area of forest specifically managed to supply water for human or industrial use, a subset of the data shown in Table 47. In New South Wales, about 80% of the 250,000 hectares of forest managed specifically for water supply is in locked catchments not subject to disturbance; the remaining area is available for wood harvesting subject to scientifically based mitigation measures to protect soil and water values. In South Australia, approximately 1,000 hectares of pine plantation is managed for soil and water protection in the catchments immediately surrounding Adelaide reservoirs. In the Northern Territory, the protected area shown in Table 48 comprises the Manton Dam and Darwin River Dam catchments. In Victoria, the 2.91 million hectares of forest in 'declared' water catchments is on land of all tenures used in the supply of surface water for agricultural, domestic and industrial purposes. Significant areas of forest are in closed water-supply catchments, mostly used for the supply of domestic water in Melbourne; access is restricted to management vehicles. These areas include the Upper Yarra, O'Shannassy, Wallaby Creek and Maroondah catchments. Different levels of restrictions are placed on land use within declared catchments; for example, 77,150 hectares, or about 3% of the total, is locked and not subject to disturbance.

Many of the forested catchments in Tasmania supply water for domestic or industrial use, although most are not managed explicitly as water catchment areas. Approximately 5,000 hectares within Wellington State Park and Mount Field National Park is managed to provide about 40% of Hobart's water. The remaining 60% is obtained from the Derwent River catchment, which is a mixture of agricultural land and private and public forest. This water is generally of a high quality due to the large proportion of the upper catchment covered by state forests and national parks.[2]

In Western Australia, the area excluded from harvesting increased to 3.6 million hectares. The area excluded includes nature conservation reserves, informal reserves and fauna habitat zones in multiple-use public forest. However, there has been minimal overall change in the state in the total area managed specifically to supply water for human or industrial use; the existing commercial pine plantation on Perth's Gnangara Mound will be replaced over time to increase the recharge of that water resource (Case study 28). Public drinking-water source areas include both underground water pollution control areas and surface catchment areas, including water reserves. Catchments identified as sensitive to rises in saline groundwater are managed to reduce the risk of such rises occurring (Case study 29).

Natural resource management programs

On 3 November 2000, the Council of Australian Governments endorsed the National Action Plan for Salinity and Water Quality. The plan included a joint commitment by the Australian, state and territory governments to provide $1.4 billion over seven years for regional solutions to salinity and water-quality problems. In addition, the Australian Government committed $1.3 billion to the Natural Heritage Trust to repair and conserve the natural environment and further the sustainable use of the nation's natural resources. By 30 June 2005, governments had approved $858 million

Table 47: Area of forest from which timber harvesting was excluded, 2006 ('000 hectares)

	ACT[a]	NSW[b]	NT[a]	SA[a]	Tas.[c]	Vic.[d]	WA[a]	Qld[a]	Total
Area	112	7,001	4,536	4,155	1,673	4,518	3,597	4,861	30,453

a Area of forested public nature conservation reserves in IUCN categories I–VI.

b Estimate provided by NSW agencies for public nature conservation reserves and state forest in IUCN categories I–VI; may include non-forested land.

c Includes forests in all formal and informal nature conservation reserves (public and private) and other areas of multiple-use public forest generally unavailable for harvesting.

d Includes all nature conservation reserve forest and multiple-use public native forest not in the current Timber Resources Plan and therefore excluded from harvesting.

Sources: NFI, state and territory agencies

Table 48: Area of forest in catchments managed specifically to supply water for human or industrial use, 2006 ('000 hectares)

	ACT	NSW	NT	SA[a]	Tas.	Vic.[b]	WA[c]
Area	112	250	29	1	5	2,909	949

a Area of multiple-use public forest managed by ForestrySA (pine forests on SA Water land); does not include native vegetation and grassland areas in reservoir protection areas.

b Forested component across all tenures of 'declared' water catchments under various legislation. Included in this figure is 77,150 hectares of locked catchments.

c Includes only the southwest of Western Australia.

Note: Data for Queensland were not available. In 2006, the Australian Capital Territory released a draft plan for the conversion of extensive areas of pine plantation to native vegetation for the protection of the local water supply.

Source: State and territory agencies

2 Hobart Water (2006).

of regionally focused investment through these programs. Of this, about $80 million has been spent on activities with a prime focus on native vegetation, including the development of almost 1,420 conservation covenants and agreements and vegetation enhancement and revegetation covering more than 180,000 hectares (Table 49). In addition, there have been other major new initiatives in tree-planting and the implementation of increased controls on clearing in salinity-risk areas.

Table 49: Approved investments with a prime focus on native vegetation under natural resource management programs approved to June 2005 ($'000)

Jurisdiction	Investment
ACT	1,260
NSW	24,100
NT	1,460
Qld	10,900
SA	15,600
Tas.	1,600
Vic.	22,100
WA	3,720
Total	80,740

Source: Commonwealth of Australia (2005a)

Caring for our Country

Caring for our Country is the Australian Government's new natural resource management program that will commence on 1 July 2008. It will integrate delivery of the existing natural resource management programs, the Natural Heritage Trust, the National Action Plan for Salinity and Water Quality, the National Landcare Program, the Environmental Stewardship Program and the Working on Country Indigenous land and environmental program.

Rehabilitation and reforestation for protective functions

Numerous organisations and community groups across Australia plant trees to protect riparian zones, counter rising watertables and salinity, and arrest soil erosion. These plantings include a large range of projects supported by governments and the private sector. Table 50 shows measures for protecting, enhancing or establishing vegetation achieved nationally with funds from the Natural Heritage Trust in 2004–05. Note that not all the vegetation protected or established was forest.

Table 50: On-ground vegetation improvement under the Natural Heritage Trust reported in 2004–05 (hectares)

Activity	Outcome
Native vegetation protected by fencing	15,496
Native vegetation enhanced/rehabilitated	5,286
Native vegetation planted	2,622
Exotic vegetation planted	3,737

Source: Commonwealth of Australia (2005a)

Greening Australia is one such organisation working to build natural resource management capacity in regional communities. In 2006, for example, the organisation reported that it had planted over 2.6 million seedlings; direct-seeded 1,780 kilometres of treelines; collected 4,090 kg of native seed; conserved 58,600 hectares of native vegetation (not all of it forest); erected over 700 kilometres of fencing to protect and conserve native vegetation; partnered with 1,192 landholders in on-the-ground projects; worked with 419 schools nationwide; trained and educated over 15,200 people; united with over 11,200 volunteers; and organised 582 volunteer events.

At a more local level, landowners in Western Australia's Avon region working with Greening Australia had by 2005 planted 676 hectares of native vegetation, established more than 750,000 seedlings, collected 369 kg of seed and constructed 600 kilometres of fencing to protect native bushland.[3]

Since 2003, Forests NSW has established 195 hectares of plantation forest in the Hunter Valley for mine site rehabilitation (Case study 30), green corridors, carbon sequestration and biodiversity; since 2001, the agency has established 20 hectares of forests in central western NSW for salinity mitigation, catchment management and biodiversity. South Australia reported tree plantings of over 122 hectares by forestry companies for erosion-control purposes in the Cudlee Creek Forest and plantings to protect wetlands near Penola. In Tasmania, tree planting funded by the Natural Heritage Trust was carried out on 234 hectares, including the re-establishment of vegetation along 46 kilometres of stream lines and the restoration of degraded native vegetation. Victoria reported that 170 hectares of log landings was replanted with trees in 2005–06.

References and further reading

Bari et al (2004), Commonwealth of Australia (2005ab), Hobart Water (2006), Webb and Haywood (2005), Webb et al (2007) (list at the back of the report).

3 www.nrm.gov.au/projects/wa/avon/2006-03.html (accessed 1 July 2007).

Dryland salinity in the Western Australian wheatbelt.

Case study 28: The Gnangara Mound

The Gnangara Mound is a significant groundwater resource that lies under Perth's Swan Coastal Plain. The mound supplies up to 60% of Perth's drinking water, as well as water for irrigation and environmental amenity. Wetland and groundwater levels on the Gnangara Mound have declined in recent years due to a combination of a drying climate, usage for irrigation and public water supply and the presence of native forest and pine plantations that reduce recharge.

The Gnangara land-use and water management strategy addresses the need for the long-term protection of groundwater quality and quantity. The strategy was produced through a whole-of-government approach and aims to protect the important groundwater and environmental features of the mound while allowing compatible development for the benefit of the community.

A major feature of the strategy is the recognition and proposed reservation of a large area of the mound as the Gnangara Park. The park will replace 23,000 hectares of existing pine plantations as they are progressively harvested over the next 20 years. Gnangara Park will protect water quality on the mound while offering opportunities for nature-based recreation, as well as conservation and timber harvesting activities.

It is estimated that the proposed reduction of pine plantations on the Gnangara Mound could increase groundwater availability by up to 20 gigalitres per year, depending on a number of external factors. These yield benefits would be realised gradually from about 2020 onwards.

Source: Department of Water (WA)

Case study 29: Dryland salinity in the Western Australian wheatbelt

Dryland salinity is a major water and land management issue in large areas of Western Australia's agricultural zone. It is caused by the clearing of native vegetation for agriculture, followed by inappropriate agricultural practices; groundwater levels rise as a consequence, bringing salt deposits to or close to the soil surface.

One way to mitigate this problem is to re-establish deep-rooted, perennial vegetation over significant portions of the landscape. The Forest Products Commission undertakes a tree-farming program in collaboration with farmers, investors and natural resource management groups to grow commercial tree crops on Western Australian farmland. The commission has developed tree farming and industry development plans for lower rainfall regions in the southwest, one aim of which is to encourage tree planting at a scale that can support internationally competitive forest industries while also providing an opportunity to reduce the problem of rising groundwater.

Source: Forests Products Commission (WA)

Case study 30: Mine site revegetation in the Hunter Valley, NSW

In April 2007, Forests NSW negotiated a three-year agreement with Rio Tinto Coal Australia to establish 80 hectares of eucalypt plantation on land around the company's Howick Mine in the upper Hunter Valley. The land is classified as 'buffer land' and is favourable for plantation establishment. Forests NSW research trials on adjoining land owned by Macquarie Generation are performing very well. This may be the first step in achieving a profitable involvement in the rehabilitation of mine sites in the Hunter Valley.

Source: Forests NSW

Narama Mine rehabilitation, New South Wales.

Indicator 4.1b

Management of the risk of soil erosion in forests

Rationale

This indicator assesses the extent to which the risk of soil erosion has been explicitly identified and addressed in forest management. The avoidance of soil erosion reflects the extent to which associated values, including soil fertility and water quality, are protected.

Key points

- Measures to mitigate the effects of forest activities, particularly timber harvesting and associated roading, have been developed based on a sound understanding of soils and the potential impact of forest activities on them.
- In most jurisdictions, activities that cause disturbances in forests are subject to codes of practice or other instruments designed to mitigate their contributions to soil erosion.
- The assessment of the risks posed by forest disturbance to soil erosion is comprehensive in multiple-use public forests.
- Compliance with soil mitigation measures for timber harvesting and associated roading in multiple-use public forest is high in most jurisdictions.
- Major wildfires increase the potential for soil erosion in the period immediately following the fire, providing a challenge for all forest managers.

Protecting soil and water values in forested areas is critical to maintaining most other forest values and thus is an essential part of sustainable forest management. The actions taken to manage soil erosion can vary greatly and depend to a large extent on the nature of particular forest soils and the activities being undertaken in the forest. This indicator reports on the preventive intent directed at mitigating soil erosion, together with the area of forest assessed for the risk to soil values and the internal and external auditing of compliance or performance in the implementation of mitigation measures. The focus of reporting is on multiple-use public forest and public nature conservation reserves because, in most jurisdictions, little information is available for other tenures. The performance ratings reported here are the result of self-assessment by the jurisdictions.

Measures to mitigate soil erosion have been implemented in some jurisdictions for up to 30 years. These include actions related to forest road alignment, density and drainage; operations in or near streams or riparian areas; extraction or other temporary tracks; landing size, placement and management; wet-weather shutdowns; traffic restrictions on slopes; restrictions on clearing on steep slopes; and facility development.

These measures are now generally prescribed in codes of forest practice or other regulatory instruments, which are reviewed periodically and improved as a result of ongoing research. In most jurisdictions, measures to mitigate soil erosion were in place for the full reporting period but were not necessarily applied across all forested tenures. In Victoria and Tasmania, however, such measures usually apply to all forest harvesting operations regardless of tenure. Audits are used to ensure compliance with the codes.

Codes of forest practice generally require that features most susceptible to erosion, such as landings, log extraction tracks and access roads, be rehabilitated after harvesting. In New South Wales, Queensland, Victoria and Tasmania, for example, log landings are drained, bark heaps dispersed, soils ripped and topsoil replaced before regeneration or replanting begins.

Recreational activities can also cause erosion, particularly around roads, walking trails, picnic areas and campsites; these are managed in various ways, including by the provision of duckboards on walking trails in high-use areas.

Fire can have direct effects on soils, such as causing the loss of carbon and nutrients, and indirect effects, such as rendering the soil more susceptible to erosion. These effects are much greater for intense fires, but even low-

intensity prescribed burns can increase the risk of erosion on erodible soils, especially where terrain is steep and there are subsequent intense rain events. Therefore, it is important to consider the risks to soils posed by prescribed burning across all tenures; although the extent to which such consideration occurs varies considerably, it is most comprehensive for multiple-use public forest.

The inability to control bushfires, for whatever reason, can pose serious soil erosion risks (see Indicator 4.1e for a discussion of the effects of the 2003 fires in the Australian Capital Territory). Managing the impacts of bushfires on soils is extremely difficult, although certain recognised steps can be taken. In Victoria, for example, mitigation measures were developed to protect soil and water values during timber salvage harvesting after the 2003 wildfires. They have been re-applied, with some changes, to salvage harvesting following the 2006–07 wildfires.

Instruments in place that address the risk of soil erosion

Table 51 shows, by jurisdiction, the soil protection themes addressed by codes of forest practice, other regulatory instruments and forest management guidelines.

The extent to which legally and non-legally binding instruments such as codes of practice, guidelines and forest management plans that address soil values exist across state and territory jurisdictions can be rated using the category descriptions in Table 52. The ratings for various jurisdictions in Tables 53 and 54 show that legally binding instruments are in place in New South Wales, Victoria, Tasmania and Western Australia. In Table 54, South Australia's ratings refer to the plantation sector's industry-endorsed *Environmental Management Guidelines for Plantation Forestry*. It recognised that, apart from fire impacts, there is far less disturbance activity and generally a lower risk to soil values in nature conservation reserves.

Table 51: Soil protection themes addressed by codes of forest practice, other regulatory instruments and forest management guidelines for multiple-use public forests, 2006, by jurisdiction

Content theme	ACT	NSW	NT	Qld	SA	Tas.	Vic.	WA
Planning								
Care of soils	✓	✓	✓	✓	✓	✓	✓	✓
Water quality and flow	✓	✓	–	✓	✓	✓	✓	✓
Site productivity	✓	✓	✓	✓	✓	✓	✓	✓
Timber harvesting plans	✓	✓	–	✓	✓	✓	✓	✓
Access to the forest								
Planning and locating roads	✓	✓	–	✓	✓	✓	✓	✓
Road design and construction	✓	✓	–	✓	✓	✓	✓	✓
Upgrading existing roads and tracks	✓	✓	–	✓	✓	✓	✓	✓
Road quarries and gravel pits	✓	✓	–	–	✓	✓	✓	✓
Bridge, causeway and ford construction	✓	✓	–	✓	✓	✓	✓	✓
Road maintenance	✓	✓	–	✓	✓	✓	✓	✓
Harvesting								
Design, planning and equipment	✓	✓	✓	✓	✓	✓	✓	✓
Wet weather	✓	✓	✓	✓	✓	✓	✓	✓
Log extraction tracks and landings	✓	✓	✓	✓	✓	✓	✓	✓
Water quality and stream protection	✓	✓	✓	✓	✓	✓	✓	✓
Salvage operations	✓	✓	–	✓	✓	✓	✓	✓
Steep country	✓	✓	✓	✓	✓	✓	✓	✓
Forest establishment								
Reforestation/afforestation	✓	✓	✓	✓	✓	✓	✓	✓
Maintaining forests								
Fire management	✓	✓	–	✓	✓	✓	✓	✓
Thinning	✓	✓	–	✓	✓	✓	✓	✓
Non-wood uses								
Recreation	–	✓	–	–	✓	✓	✓	–

Sources: State and territory agencies

Table 52: Category descriptions for rating the extent to which the regulatory framework requires the maintenance of soil values

Category	Category description
1	The instruments require the following components to be taken into account in addressing the risk of soil erosion from disturbance activities: rainfall intensity, slope, soil erodibility and management practice resulting in soil disturbance. They are also applicable for all erosion processes (wind, sheet, rill, gully, tunnel, stream bank, wave and mass movement).
2	The instruments address most of the components listed in category 1, and those not addressed are associated with low risks of soil erosion for the particular disturbance activity and geographical setting.
3	The instruments address most of the components listed in category 1 but do not specify all aspects or are limited in their application.
4	The instruments mention the need to address risks of soil erosion when conducting disturbance activities but do not specify the components listed above.
5	The instruments do not mention the need to address risks of soil erosion.

Table 53: Extent to which legally binding instruments address the risk of soil erosion due to forestry operations, road and trail works, and recreation activities

	Category[a]					
	NSW	NT	SA	Tas.	Vic.	WA
Multiple-use public forests and plantations	1	3	4	1	1	4
Public nature conservation reserves	2[b]	3	4	1	1	4

a Values refer to category descriptions in Table 52.

b Nature conservation reserves are not as stringently prescribed as multiple-use public forests due to the significantly lower risk of erosion and water pollution.

Sources: State and territory agencies

Table 54: Extent to which non-legally binding instruments address the risk of soil erosion due to forestry operations, road and trail works, and recreation activities

	Category[a]						
	ACT	NSW	NT	SA	Tas.	Vic.	WA[b]
Multiple-use public forests and plantations	3[c]	1	5	1	1	3	3
Nature conservation reserves	–	1	5	4	1	2	4

a Values refer to category descriptions in Table 52.

b National park management plans describe the geomorphology, soils and landform of the area and indicate potential threats. Some plans list strategies to avoid or minimise threats.

c Conservation management plans describe the soils and landforms of the areas and potential threats.

Sources: State and territory agencies

The New South Wales code of practice for timber harvesting in plantations was upgraded in 2005. In Tasmania, the *Reserve Management Code of Practice*, designed to be applied in conservation reserves, was approved in 2003.

There are limited legally and non-legally binding instruments in Western Australia, and those that exist do not address all aspects of the category descriptions. However, the Forest Management Plan 2004–13, which covers all of the main timber production areas in the state's southwest, places strong emphasis on the protection of soil and water values. The Western Australian Department of Environment and Conservation is currently reviewing the soil erosion measures in place for disturbance activities in multiple-use public forests and timber reserves.

Table 55 shows examples of mitigating activities generally included in codes of forest practice and other instruments to protect soil values.

Assessment of erosion hazard

The assessment of erosion hazard generally uses a combination of available information, including erosion hazard maps, and field verification. Many forest managers use similar parameters to those appearing in category 1 of Table 56 as a series of overlays in a geographic information system. This enables them to make such assessments and then seek advice from regulatory agencies if necessary. Table 57 shows the area of multiple-use public forest for which disturbance activities were planned in 2005–06, the proportion of that area that was assessed for risk to soil values, and the category of assessment. In New South Wales, South Australia, Tasmania, Victoria and Western Australia, virtually all areas of multiple-use public forest subject to disturbance were assessed for risk to soil values.

Table 55: Examples of mitigation activities directed at minimising soil erosion

Mitigating activity	Designed to mitigate soil erosion
Protection of riparian zones by buffers or filters	✓
Road drainage (bridges, culverts, table drains)	✓
Log extraction track drainage by cross-drains and grips	✓
Log extraction track arrangement (maximise uphill extraction to avoid downhill funnelling of water flow)	✓
Minimisation of stream crossings	✓
Rehabilitation of log landings (ripping, replacement of topsoil, planting) and log extraction tracks	✓
Exclusion of identified vulnerable areas (erosion hazard, landslip potential, karsts, swamps) from harvest zone	✓
Wet-weather operational closures	✓

Table 56: Category descriptions for rating the extent to which the risks of soil erosion are assessed in planning processes

Category	Category description
1	The soil erosion risk assessment system comprehensively takes account of rainfall intensity, slope, soil erodibility and management practice resulting in soil disturbance.
2	The soil erosion risk assessment system takes into account most of the components listed in category 1, and those not addressed are associated with low risks to soil values for the particular disturbance activity and geographical setting.
3	The soil erosion risk assessment system takes into account some of the factors listed in category 1 or only partly accounts for those factors.
4	The soil erosion risk assessment system is ad hoc and/or does not take into account any of the factors listed in category 1.

Table 57: Area of multiple-use public forest where disturbance activities were planned, proportion assessed for risk of soil erosion and category of assessment, 2005–06

Disturbance activity		NSW	SA[a]	Tas.[bc]	Vic.[d]	WA
Native forest harvesting and silviculture	Area (ha)	101,000	Not applicable	16,000	7,500	–
	Proportion assessed for risk of soil erosion (%)	100		100	85	100
	Category[e]	1		1	2	3
Plantation operations	Area (ha)	13,200	–	4,600	–	–
	Proportion assessed for risk of soil erosion (%)	100	100	100	90	–
	Category[e]	1	1	1	2	–
Road construction and maintenance	Area (ha)	–	–	–	–	–
	Proportion assessed for risk of soil erosion (%)	100	100	100	90	100
	Category[e]	1	3	1	2	3
Fire management	Area (ha)	–	–	–	–	–
	Proportion assessed for risk of soil erosion (%)	100	100	100	90	–
	Category[e]	1	3	1	2	–

a South Australia does not harvest native forest.

b Includes area being converted to eucalypt plantation.

c In Tasmania, 14,400 hectares of private native-forest operations and 25,800 hectares of plantation operations were also assessed for the risk of soil erosion.

d 25,298 hectares of private plantations in Victoria was also assessed for the risk of soil erosion.

e Values refer to category descriptions in Table 56.

Sources: State and territory agencies

Table 58: Knowledge base on soil erosion and soil physical properties, by jurisdiction

State	Soil knowledge base
NSW	A comprehensive soil assessment procedure designed to minimise soil erosion and protect soil physical properties is in place for multiple-use public forest. Extensive training is provided to staff to implement the procedure. For other tenures, the impacts of activities on soil values are reasonably well understood, but risk factors remain that need to be better understood.
SA	Land is classified into eight land capability classes. Key factors that determine capability class include water erosion potential, drainage and soil depth, degree of rockiness, soil fertility, and wind erosion potential.
Tas.	Soil types have been mapped statewide and erosion risks identified, mainly for multiple-use public forest. Soil physical properties are understood. The Forest Practices Authority provides forest managers with regular training. Knowledge base is more limited for other forest tenures.
Vic.	The impacts of a range of forest activities on soil erosion and soil physical properties are reasonably well understood. Some identified risk factors need to be better understood.
WA	The impacts of a range of forest activities on soil erosion and soil physical properties are reasonably well understood for multiple-use public forest, but a lower level of knowledge exists for conservation reserves.

Sources: State and territory agencies

Table 59: Category descriptions for rating the performance of forest managers in complying with prescribed erosion mitigation measures

Category	Category description
1	Fully compliant with all process requirements and environmental outcome requirements, with minimal adverse impacts
2	Generally compliant with all process requirements and environmental outcome requirements, with minimal adverse impacts
3	Fully or generally compliant with all process requirements and environmental outcome requirements, but with moderate adverse impacts
4	Not generally compliant with process requirements and environmental outcome requirements, with minimal adverse impacts
5	Not generally compliant with process requirements and environmental outcome requirements, with significant adverse impacts
6	Insufficient or no objective evidence to make a judgment
7	No formal audit conducted

As part of the planning process for timber harvesting, Forests NSW undertakes comprehensive soil assessment, comprising inherent hazard category (assessment of soil erosion and water pollution potential), mass movement assessment, dispersibility assessment and seasonality of logging operations. The inherent hazard level category determines the level of protection that is implemented to protect soil and water values.

All Forests NSW field staff and industry operators are trained, assessed and accredited in compliance with regulatory requirements in forest soil and water protection. Industry must implement the requirements of an Environment Protection Licence issued by the New South Wales Department of Environment and Climate Change in native-forest and plantation operations. In Tasmania, all forest practices officers receive specialised training on soil and water values; the training is updated periodically as a result of ongoing research. Soil and water protection training has also been completed by VicForests staff to guide the planning and implementation of operations in public native forests in Victoria. In Western Australia, 100% of multiple-use public forest proposed for disturbance activities is assessed for soil erosion using the *Interim Manual of Procedures for the Management of Soils Associated with Timber Harvesting in Native Forests* and the *Manual of Management Guidelines for Timber Harvesting in Western Australia*.

Soil erosion knowledge base

The potential impacts on soils of disturbance by machinery are well known, and the assessment of soil erosion hazard in multiple-use public forest is carried out according to science-based procedures. The impact of fire and its contribution to the erosion of forest soils is less well understood, although planned fire is known to make a much lower contribution than bushfire because of its generally lower intensity (Indicator 4.1e). Further knowledge of the impacts of forest activities on soil erosion is required across other tenures, and there remain some risk factors on public land that need to be better understood.

A boardwalk installed to prevent foot traffic from damaging vegetation and soil at a sensitive site.

Table 60: Compliance outcomes achieved in multiple-use public forests, 2005–06

	Category[a]				
Activity	NSW	Vic.	SA	Tas.[b]	WA
Native-forest harvesting	2	2	Not applicable	2	3
Plantation operations	2	2	2	2	4
Roads and trails	2	2	2	2	4
Fire management	2	2	2	2	4

a Values refer to the category descriptions in Table 59.

b Similar compliance outcomes were also achieved for the same activities in private forests.

Sources: State and territory agencies

Site preparation (ripping and mounding) on the contour prior to planting blue gums (*Eucalyptus globulus*) to minimise the risk of soil erosion.

Knowledge of erosion hazards continues to improve. In Tasmania, for example, a recent study of more than 400 headwater streams found that determining the type and width of riparian buffer zones using erosion hazard concepts was superior to using riparian slope alone (as is commonly required in codes of practice).[4] This work led to the development and adoption in Tasmania of new guidelines for the protection of Class 4 streams,[5] including better protection for headwater streams based on five graded prescriptions according to erosion risk.

Compliance with soil erosion mitigation measures

Compliance with soil erosion mitigation measures is assessed in various ways across Australia by internal and external audits. Using the category descriptions in Table 59, Table 60 gives an indication of the performance of some jurisdictions.

The compliance levels in Table 60 are the average across all multiple-use public forests where activity occurred. New South Wales, South Australia, Tasmania and Victoria generally achieved satisfactory outcomes. Audits and investigations of complaints are carried out by the Forest Practices Authority in Tasmania and by the state environmental protection agencies in New South Wales and Victoria. While compliance in Western Australia has not been rated as highly as in other states, recent improvements have been directed towards reducing potential soil erosion on log extraction tracks and fire trails.

Planting holes for a second-rotation eucalypt plantation being prepared in harvesting slash. The slash prevents the machine's tracks disturbing the soil and protects the soil from erosion.

Myponga reservoir, South Australia. Pines have been planted to minimise erosion of soil from adjacent slopes.

References and further reading

Bunce et al (2001), Davies et al (2005), Laffan et al (2001), McIntosh (2004), McIntosh and Laffan (2005), McIntosh et al (2005), Pennington et al (2001) (list at the back of the report).

4 McIntosh and Laffan (2005).

5 Under Tasmania's stream classification system, streams with catchments smaller than 50 hectares.

Indicator 4.1c

Management of the risks to soil physical properties in forests

Rationale

This indicator measures the extent to which the risk to soil physical properties in forests has been explicitly identified and addressed. The protection of soil physical properties, such as compaction and redistribution, affects soil integrity and as a consequence many associated values.

Key points

- Measures to mitigate the effects of forest activities, especially timber harvesting and associated roading, have been developed based on a sound understanding of soils and the potential impact of forest activities on them.
- In most jurisdictions, activities that cause disturbances in forests are subject to codes of practice or other instruments designed to mitigate impacts on soil physical properties.
- The assessment of the measures required to protect soil physical properties during forest disturbance activities is comprehensive, particularly in multiple-use public forests.
- Compliance with soil mitigation measures for timber harvesting and associated roads and tracks in multiple-use public forest is high in most jurisdictions.

Protecting soil physical properties is essential to the maintenance of forest productivity and contributes to the ongoing health of forest ecosystems. The actions taken to maintain soil physical properties vary greatly and depend to a large extent on the nature of particular forest soils and the activities being undertaken in the forest. This indicator reports on the measures directed at maintaining soil physical properties, together with the area of forest assessed for risk to soil physical properties and the auditing of compliance or performance in the implementation of mitigation measures. The performance ratings reported here are the result of self-assessment by the jurisdictions. The focus of reporting is on multiple-use public forest and public nature conservation reserves because, generally, little information is available for other tenures. The principal areas of concern for soil physical properties in forests, in particular soil compaction, are roads, trails, log extraction tracks and log landings.

Measures to protect soil physical properties have been implemented in multiple-use public forests in some jurisdictions for many years. They include actions related to log extraction operations in or near streams or riparian areas; cording and matting;[6] the construction and maintenance of extraction and other temporary tracks; the size, placement and management of landings; animal and recreational campsite compaction; wet-weather shutdowns; the selection of machines and tyres; traffic restrictions on slopes; restrictions on clearing on steep slopes; and facility development.

These measures are now generally prescribed in codes of forest practice or other regulatory instruments, which are reviewed periodically and improved as a result of ongoing research. In most jurisdictions, measures to protect soil physical properties were in place for the full reporting period but were not necessarily applied across all forested tenures; in Victoria and Tasmania, however, such measures applied to all forest harvesting operations regardless of tenure. Audits are used to ensure compliance with the codes.

Codes of forest practice generally require that the features most susceptible to compaction and mixing, such as landings, log extraction tracks and access roads, be rehabilitated after harvesting. For example, in New South Wales, Queensland, Tasmania and Victoria, log landings are drained, bark heaps dispersed, soils ripped and topsoil replaced before regeneration or replanting begins. Recreational activities can also affect soil physical

6 Cording is the practice of placing large (5–30 centimetre diameter) woody material on extraction tracks before harvesting to minimise erosion; matting is similar but involves smaller (<5 centimetre diameter) woody material.

properties, particularly around walking trails, picnic areas and campsites; these are managed in various ways, including by the provision of duckboards on high-use segments of walking trails.

Instruments in place to address risks to soil physical properties

The extent to which legally and non-legally binding instruments such as codes of practice, guidelines and forest management plans that address soil values exist across state and territory jurisdictions can be rated using the category descriptions in Table 61. The ratings for various jurisdictions in Tables 62 and 63 show that legally binding instruments are in place in New South Wales, Victoria, Tasmania and Western Australia. Apart from fire impacts, there is usually far less disturbance activity and generally a lower risk to soil values in public nature conservation reserves than in multiple-use public forests.

The New South Wales code of practice for timber harvesting in plantations was upgraded in 2005. In Tasmania, the *Reserve Management Code of Practice*, designed to be applied in public nature conservation reserves, was approved in 2003.

There are limited legally and non-legally binding instruments in Western Australia, and those that exist do not address all aspects of the category descriptions. However, the Forest Management Plan 2004–13, which covers all the main timber production areas in the state's southwest, places strong emphasis on the protection of soil and water values.

Table 64 shows examples of mitigating activities usually included in codes of forest practice and other instruments to protect soil values.

Table 61: Category descriptions for rating the extent to which the regulatory framework requires the maintenance of soil physical properties

Category	Category description
1	The instruments require the following components to be taken into account in addressing the risk to soil physical properties from disturbance activities: • site factors, including the soil properties of moisture content, organic matter content, soil type and texture; the presence of litter, trash or slash; slope; and rainfall distribution and intensity • management factors such as the timing of operations (season), harvesting system, harvesting pattern and slash distribution. Vehicle factors including machine configuration, vehicle weight, dynamic load, tyre size, tyre inflation pressure, wheel slip, tracks or wheels, vibration, number of passes, vehicle speed, area affected, and whether logs are dragged, lifted or carried.
2	The instruments address most of the components listed in category 1, and those not addressed are associated with low risks to soil physical properties for the particular disturbance activity and geographical setting.
3	The instruments address most of the components listed in category 1 but do not specify all aspects or are limited in their application.
4	The instruments mention the need to address risks to soil physical properties when conducting disturbance activities but do not specify the components listed in category 1.
5	The instruments do not mention the need to address risks to soil physical properties.

Table 62: Extent to which legally binding instruments address the risk to soil physical properties due to forestry operations, road and trail works, fire management and recreation activities

	Category[a]					
	NSW	NT	SA	Tas.	Vic.	WA
Multiple-use public forests	1	3	4	1	1	4
Public nature conservation reserves	2[b]	3	4	1	1	4

a Values refer to category descriptions in Table 61.

b Nature conservation reserves are not as stringently prescribed as multiple-use public forest due to the significantly lower risk of erosion and water pollution.

Note: Queensland has a *Code of Practice for Native Forest Timber Production* for public land and a *Private Native Forests Code of Practice*.

Sources: State and territory agencies

Table 63: Extent to which non-legally binding instruments address the risk to soil physical properties due to forestry operations, road and trail works, fire management and recreation activities

	Category[a]						
	ACT[b]	NSW	NT	SA	Tas.	Vic.	WA[c]
Multiple-use public forests	3	1	5	1[d]	1	3	3
Nature conservation reserves	3	1	5	4	1	3	4

a Values refer to category descriptions in Table 61.

b National park management plans describe the geomorphology, soils and landform of the area and indicate potential threats.

c Conservation management plans describe the soils and landforms of the areas and potential threats.

d Refers to the plantation sector's industry-endorsed *Environmental Management Guidelines for Plantation Forestry*. Some plans list strategies to avoid or minimise threats.

Sources: State and territory agencies

Table 64: Examples of mitigation activities directed at maintaining soil physical properties

Mitigation activity	Designed to maintain soil physical properties
Use of cording and matting or temporary culverts for log extraction tracks or minor logging roads in wet areas	✓
Minimisation of stream crossings	✓
Rehabilitation of log landings (ripping, replacement of topsoil, planting) and log extraction tracks	✓
Exclusion of identified vulnerable areas (erosion hazard, landslip potential, karsts, swamps) from harvest zone	✓
Wet-weather operational closures	✓

Assessment of soil physical properties

The assessment of the potential risk to soil physical properties is usually a combination of office-based assessment and field verification. Many forest managers use similar parameters to those appearing under category 1 in Table 65 as a series of overlays in a geographic information system to make such assessments and then seek advice from regulatory agencies if necessary. Table 66 shows the area of multiple-use public forest for which disturbance activities were planned in 2005–06, the proportion of that area that was assessed for risk to soil physical properties, and the category of assessment. In New South Wales, South Australia, Tasmania, Victoria and Western Australia, virtually all areas of multiple-use public forest subject to disturbance were assessed for risk to soil physical properties.

Assessments of the risk to soil physical properties are generally carried out by forest managers in conjunction with the assessment of soil erosion hazard using the various processes reported in Indicator 4.1b.

Table 65: Category descriptions for rating the extent to which soil physical properties are assessed in planning processes

Category	Category description
1	The soil physical properties risk assessment system takes into account all the following factors: • site factors, including the soil properties of moisture content, organic matter content, soil type and texture; the presence of litter, trash or slash; slope; and rainfall distribution and intensity • management factors, including timing of operations (season), harvesting system, harvesting pattern and slash distribution. Vehicle factors include machine configuration, vehicle weight, dynamic load, tyre size, tyre inflation pressure, wheel slip, tracks or wheels, vibration, number of passes, vehicle speed, area affected, and whether logs are dragged, lifted or carried.
2	The soil physical properties risk assessment system takes into account most of the components listed in category 1, and those not addressed are associated with low risks to soil physical properties for the particular disturbance activity and geographical setting.
3	The soil physical properties risk assessment system takes into account some of the factors listed in category 1 or only partly accounts for those factors.
4	The soil physical properties risk assessment system is ad hoc and/or does not take into account any of the factors listed in category 1.

Table 66: Area of multiple-use public forest where disturbance activities were planned, proportion assessed for risk to soil physical properties, and category of assessment, 2005–06

Disturbance activity		NSW	SA[a]	Tas.[b]	Vic.[c]	WA
Native forest harvesting and silviculture	Area (ha)	101,000	Not applicable	16,000	7,500	–
	% assessed for risk to soil properties	100		100	85	100
	Category[d]	1		1	2	3
Plantation operations	Area (ha)	13,200	–	4,600	–	–
	% assessed for risk to soil properties	100	100	100	90	–
	Category[d]	1	1	1	2	–
Road construction and maintenance	Area (ha)	–	–	–	–	–
	% assessed for risk to soil properties	100	100	100	90	100
	Category[d]	1	3	1	2	3
Fire management	Area (ha)	–	–	–	–	–
	% assessed for risk to soil properties	100	100	100	90	–
	Category[d]	1	3	1	2	–

a South Australia does not harvest native forest.

b In Tasmania, 14,400 hectares of private native-forest operations and 25,800 hectares of plantation operations were also assessed for the risk to soil physical properties.

c 25,298 hectares of private plantations in Victoria was also assessed for the risk to soil physical properties.

d Values refer to category descriptions in Table 65.

Sources: State and territory agencies

Soil physical properties knowledge base

The potential impacts on soils of disturbance by machinery are well known, and assessments of the risk to soil physical properties in multiple-use public forest are carried out according to science-based procedures. Further knowledge of the impacts of forest activities on soil physical properties is required across other tenures, and there remain some risk factors on public land that need to be better understood; Table 58 in Indicator 4.1b describes the knowledge base on soil erosion and soil physical properties.

Knowledge of the risks to soil physical properties continues to improve. In Western Australia, a recent study examined the impact of native forest harvesting on soil bulk density (compaction) at 18 sites with a known logging history of up to 50 years.[7] It showed increases in bulk density due to logging equipment, particularly on log extraction tracks and log landings, which when combined typically cover less than 15% of a logged area. Evidence of compaction persisted on some sites for up to 50 years after the harvesting event, whereas other sites on sandy soils showed little evidence of compaction. Continual improvements in forest management practices in recent decades probably mean that contemporary harvesting causes fewer compaction effects, although further research is required to verify this.

Compliance with measures to protect soil physical properties

Compliance with measures to protect soil physical properties is assessed in various ways across Australia by internal and external audits as part of the process of auditing the implementation of soil erosion mitigation measures, as reported in Indicator 4.1b.

References and further reading

Bunce et al (2001), Laffan et al (2001), McIntosh et al (2005), Pennington et al (2001), Whitford and Swinburn (2006) (list at the back of the report).

Depending on soil type and weather conditions, the choice of machinery, wheeled (above) or tracked (below) may determine the intensity of impact on soils during harvesting.

7 Whitford and Swinburn (2006).

Indicator 4.1d

Management of the risks to water quantity from forests

Rationale

This indicator measures the extent to which the risk to water quantity has been explicitly identified and addressed in forest management. Water quantity is important for ecosystem health and water supply for human use.

Key points

- Most jurisdictions have codes of practice and other regulatory instruments or management guidelines in place directed at managing water yields from forests.
- Practices such as the geographical dispersal of timber-harvesting operations, limits on the proportion of catchments subject to harvesting in a given year and thinning to increase water yield are employed to manage potential impacts on water quantity.
- The impacts of forest age and density on water yield are well understood, but the ability to predict results in specific circumstances is still developing.
- Water use by tree plantations is the subject of increasing community attention and scientific research.
- Major wildfires during the reporting period and the resulting natural regrowth are expected to reduce water yields in affected catchments for decades.

Copperlode Reservoir, far north Queensland.

With much of the country affected by drought during the reporting period, Australians have become increasingly concerned about maintaining water supply. Climate change may also result in rainfall deficits in southern Australia, reducing water yields (Indicator 3.1a). This concern has extended to the impact of forestry activities, particularly the impacts of plantation establishment and management, on water yields in drier parts of Australia. Recent research has focused on assessing the potential impacts of forestry activities on water yields and how those impacts can best be managed.

The age and structure of native forests and the establishment and growth of forest plantations can influence the level of stream flow in forested catchments. Recent large wildfires in southern Australia (Indicator 3.1b) and subsequent regrowth are expected to affect current and future water yields in burnt areas. Forest management activities can both increase and decrease water yields, as can deforestation (e.g. for agriculture) or major catastrophic events such as bushfires. The risks to water yield from fire may be as serious for nature conservation reserves as they are for multiple-use public forests; the effects can last for decades after the fire.

The practices likely to affect water yields from forests include the timing, scale and spacing of timber harvesting, thinning or clearing; fire management; woody weed control; modifications to rotation length; and land-use change.

Unlike fire, most activities carried out in nature conservation reserves have only minor effects on water quantity.

Table 67: Category descriptions for rating the extent to which the regulatory framework requires the maintenance of water quantity

Category	Category description
1	The instruments require the following components to be taken into account in addressing the risk to water quantity from disturbance activities: • local and regional requirements for water yield and the sensitivity of the water-supply system to changes in water yield • age structure of stands in forested catchments • the conversion of mature stands to regrowth • rotation lengths • stand density.
2	The instruments address most of the components listed in category 1, and those not addressed are associated with a low risk to water quantity for the particular disturbance activity and geographical setting.
3	The instruments address most of the components listed in category 1 but do not specify all aspects or are limited in their application.
4	The instruments mention the need for addressing risks to water quantity when conducting disturbance activities but do not specify the components listed in category 1.
5	The instruments do not mention the need to address risks to water quantity.

Instruments in place that address the risk to water quantity

Codes of practice and other regulatory instruments or management guidelines specify measures to be implemented to maintain stream flows and water quantity for particular locations and activities. Those instruments also provide the benchmark against which water quantity management measures can be assessed. Using the category descriptions in Table 67, Table 68 shows, by jurisdiction, the extent to which legally and non-legally binding instruments address the risk to water quantity due to forestry activities in multiple-use public forests.

Table 68: Extent to which legally and non-legally binding instruments address the risk to water quantity due to forestry activities in multiple-use public forest (including plantations), by jurisdiction

Instrument	NSW	SA	Tas.	Vic.	WA
Legally binding	2	2	1	1	4
Non-legally binding	Not applicable	5	1	1	5

Sources: State and territory agencies

In a number of states, the level of harvesting allowed annually in water-supply catchments is restricted to ensure that there are no major fluctuations in stream flow. These restrictions vary among and within jurisdictions and are influenced by the environmental conditions in particular catchments and by water supply and demand. In Tasmania, the code of forest practice restricts harvesting to no more than 5% of town water-supply catchments in any given year. In Victoria, a number of formal and informal limits apply to timber harvesting in catchments (including the Thomson, Tarago and Bunyip catchments) that supply water to Melbourne, restricting the area harvested annually to a very small proportion of those catchments. For example, the harvesting and regeneration of native forest in the Thomson catchment is limited to 0.3% of the catchment in any one year. The regulations and limits noted here are currently under review. These requirements are audited by the Environment Protection Authority Victoria.

In South Australia, commercial forestry in the lower southeast is prescribed as a water-affecting activity requiring a permit. The permit system is managed in concurrence with local-government development approvals.

In New South Wales, native-forest operations are required by law (as embodied in integrated forestry operations approvals, including environment protection licences) to be dispersed in space and time. Harvesting activities are generally restricted to about 1% of total catchment area in any one year.

In Western Australia, the forest management plan for the main timber production areas in the state's southwest includes a broad requirement to maintain water quantity.

In line with the management objectives for forested public nature conservation reserves, there is generally very little disturbance apart from fire in such reserves. Where planned disturbance occurs (such as during road construction, trail maintenance, fire management or facility development), legal instruments in all jurisdictions require the protection of water values.

Water quantity knowledge base

Knowledge of the effects of forest management on water quantity is well developed, particularly in New South Wales, South Australia, Victoria and Western Australia (Table 69). However, there is a limited capacity to model the effects of forest type, forest age, soil type and climatic variation on catchment water yields. Those issues are currently the topics of major research programs.

The ability to predict stream flow from forests has improved recently in Tasmania with the development of the TasLUCaS tool,[8] which helps predict changes to stream flow in regenerating native forest and after the conversion of grassland or native forest to plantations. The potential impact of proposed forest management actions on downstream water users can now be better taken into

8 Brown et al (2006a).

account and minimised during planning. The model has been independently tested in two subcatchments in northwest Tasmania.

Table 69: Water quantity knowledge base, by jurisdiction

	Water quantity knowledge base
NSW	Well-developed knowledge based on long-term (30 year) forest hydrology research on catchments in a number of locations. Research has been published. Regular training is provided to staff in order to retain accreditation.
SA	Reasonably good understanding of activity impacts on water quantity; includes local knowledge, training and codes of practice, published research and geographic information systems.
Tas.	Increasing knowledge of activity impacts on water quantity; includes local knowledge, modelling, research results, training and codes of practice.
Vic.	Good knowledge of activity impacts on water quantity; includes local knowledge, modelling, research, training and codes of practice.
WA	Well-developed knowledge, including published research, geographic information systems, decision-support tools, codes of practice, local knowledge, training and site-specific research models.

Source: State and territory agencies

In New South Wales, the results of research based on three long-term hydrological studies in three forest types have been published in recent years.[9] The studies all found an increase in water yield after harvesting disturbance. The increase persisted for at least three years, after which yield briefly returned to pre-harvest levels before progressively declining by up to 20% of pre-harvest yield at 16 years post-harvest. This relatively low decrease in water yield is expected to bottom out as the regenerating forest reaches about 20 years post-harvest and then to increase gradually as the forest matures and growth rates (and therefore water use) decline. This conclusion is supported by earlier work in *Eucalyptus regnans* forest in Victoria, which showed that sapwood area and hence growth rates and water use declined with age.[10]

In Western Australia, stream flows are reported every five years. Where shortfalls are identified, the reasons and trends are assessed and reported to the Conservation Commission and the Minister for the Environment.

There is a large body of research on the impacts of various forest management regimes on stream flow and groundwater in the southwestern forests of Western Australia. Two reviews summarised the studies undertaken in those forests based on the results of 27 experimental catchments.[11] The studies looked at the impacts of clearing for agriculture, timber harvesting and regeneration, thinning, tree dieback, reforestation, the interaction with rainfall zones and the effect of climate variability. Clearing for agriculture has resulted in a substantial increase in stream flow, groundwater levels and flood peaks. Timber harvest and regeneration results in a moderate transient increase in stream flow and groundwater levels. Thinning results in a more prolonged increase in stream flow, but the increase is dependent on the effectiveness of the control of regeneration. Increases are greatest in higher rainfall areas and with increased intensities of harvesting or thinning. A trial to assess the effects of various forest treatments on water yield is under way in the Wungong catchment (Case study 31).

Plantations

Forest plantations in Australia occupy only a small percentage of the catchments in which they occur.[12] Because rainfall and hydrological factors are highly variable, it is difficult to measure the impact of plantations on water yields in small catchments if the plantations occupy less than 15–20% of the catchment (this threshold is lower in larger catchments).[13] Nevertheless, the issue of water use by plantation forests has arisen in the past decade as it has become clear that the impacts of prolonged drought have affected the availability of water in many catchments. This has created policy questions about water allocation and entitlement to rainfall. Plantation development was therefore included as one of the land-use changes to be considered by the Intergovernmental Agreement on a National Water Initiative, which provides a framework for considering the impacts of activities that may intercept water. The location and management of plantations is subject to land-use policies and planning controls; sustainability considerations are encompassed within codes of practice and management prescriptions.

A review of groundwater resource condition in southeastern South Australia identified seven areas where rates of groundwater level drawdown exceeded 0.1 metres per year or salinity increase exceeded 10 milligrams per litre per year.[14] Groundwater levels in one of the areas were affected by forest disturbance following the 1983 Ash Wednesday bushfires near Nangwarry, and forest plantations were also recognised as users of groundwater through interception and uptake. Another recent study calculated the total available recharge in the region.[15] Recharge interception due to forest plantations and direct water use (where the watertable is less than 7 metres below the ground surface) was estimated to be 2.6 megalitres per hectare per year for pine plantations and 2.3 megalitres per hectare per year for eucalypt plantations. In the future, groundwater management is likely to become more adaptive, employing allocation systems that are sensitive to changes in groundwater resource condition.

9 Lane and Mackay (2001), Cornish and Vertessy (2001) and Roberts (2001).

10 Roberts et al (2001).

11 Bari and Ruprecht (2003) and Ruprecht and Stoneman (1993).

12 Gerrand et al (2004).

13 Parsons et al (2007b).

14 Brown et al (2006b).

15 Latcham et al (2007).

Case study 31: The Wungong catchment

The Wungong catchment is a drinking-water catchment southeast of Perth. The Water Corporation's Wungong Catchment Environment and Water Management Project commenced in 2005 as a 12-year experimental trial to increase stream flows into the Wungong Reservoir by carrying out silvicultural treatments in selected parts of the catchment. The project is testing the managed thinning of the overstorey as well as the removal of woody weeds and their subsequent replacement with local species to improve water yield.

Under the project, it is expected that approximately 62% of the 12,845-hectare catchment area will be managed by thinning existing forest to a target basal area of 12–15 square metres per hectare. This is a reduction in forest stand density from nearly 1,000 stems per hectare to 300–350 stems per hectare. The Water Corporation expects an additional average of 4–6 gigalitres per year of stream flow during the trial, which is 25% of the average stream flow into the reservoir.

Source: Water Corporation, Western Australia

References and further reading

Bari and Ruprecht (2003), Benyon and Doody (2004), Benyon et al (2006), Bren et al (2006), Brown et al (2006a), Brown et al (2006b), Cornish and Vertessy (2001), Gerrand et al (2004), Lane and Mackay (2001), Latcham et al (2007), Parsons et al (2007b), Roberts (2001), Roberts et al (2001), Ruprecht and Stoneman (1993), Webb et al (2007) (list at the back of the report).

Indicator 4.1e

Management of the risks to water quality in forests

Rationale

This indicator measures the extent to which the risk to water quality has been explicitly identified and addressed in forest management. Water quality is important for ecosystem health and water supply for human use.

Key points

- There is generally a good understanding of the potential impact of forest activities on water quality; this has enabled the development of sound mitigation measures and practices.
- In most jurisdictions, codes of forest practice or other instruments specify measures that must be carried out to help maintain water quality.
- Assessment of the risk posed by timber harvesting to water quality is reasonably comprehensive.
- Compliance with mitigation measures to protect water quality is generally high for timber harvesting operations.
- Major wildfires during the reporting period adversely affected water quality across forest tenures.

There is a public expectation that water leaving forests will be clean and good quality. For this reason, forest managers have commissioned research studies in experimental catchments and, in some forest areas, established monitoring programs to gain an understanding of the quality of water leaving forests. This indicator reports on the intent and implementation of mitigation measures that protect water quality. The focus of reporting is on multiple-use public forest and public nature conservation reserves because data are generally not readily available for other tenures in most jurisdictions.

Water quality is monitored at many sites across the states and territories to assess river condition and to determine whether water for different uses, including drinking water, meets the required standards. Not all these sites are located in forests; nor is it always possible to identify the causes of changes in water quality. Storm events can have significant impacts, even in pristine catchments. In southern Tasmania, for example, high turbidity levels, due mainly to organic matter, have been measured at the Warra Long-term Ecological Research Site during and after heavy rain in catchments that have never been roaded or logged.[16] Other research at the same site found considerable variation in turbidity among 15 monitored catchments, irrespective of forest treatment. Although turbidity levels at the site fall within the guidelines of the Australian and New Zealand Environment and Conservation Council (ANZECC) for upland rivers in Tasmania, they exceed drinking-water guidelines approximately 24% of the time.

It has been known for many years that roads, tracks and log landings are potential sources of suspended sediments that can increase turbidity in streams. The implementation of mitigation measures such as those listed in Table 55 in Indicator 4.1b to minimise soil erosion will also minimise the risk to water quality; such measures are included in the codes of forest practice and other instruments that help govern forest management in multiple-use public forests and some private forests.

Fires, both planned or unplanned, have the potential to affect water quality by increasing erosion risk (Indicator 4.1b). In recent years, the impacts of major fires on water quality have been demonstrated in Victoria and in the Australian Capital Territory, where fire burned more than 840 kilometres of riparian vegetation in 2003, about two-thirds at high or very high severity.[17] Vegetation cover was also lost in substantial parts of the east and northeast of the territory's water catchments. As a result, intense rainstorms in February 2003 washed massive amounts – an estimated

16 Ringrose et al (2001).

17 Carey et al (2003).

Table 70: Category descriptions and ratings applied in assessing the extent to which the regulatory framework requires the maintenance of water quality

Category	Category description
1	The instruments require the following components to be taken into account in addressing the risk to water quality from disturbance activities: stream and drainage lines (e.g. including exclusion zones); road drainage and stream crossings (e.g. cross-draining of log extraction tracks); slope; and sensitive aquatic habitat.
2	The instruments address most of the components listed in category 1, and those not addressed are associated with low risks to quality for the particular disturbance activity and geographical setting.
3	The instruments address most of the components listed in category 1 but do not specify all aspects or are limited in their application.
4	The instruments mention the need for addressing risks to water quality when conducting disturbance activities but do not specify the components listed in category 1.
5	The instruments do not mention the need to address risks to water quality.

27 years worth – of sediment and burnt organic and mineral material from riparian zones, stream banks and hill slopes into most streams in the catchment and into the Bendora, Cotter and Corin reservoirs. For the first time, sheet erosion became the dominant source of sediment in Corin Dam; it was estimated to comprise well over 50% of total sedimentation, compared to 7% before the fires. Territory water-supply reservoirs were sufficiently polluted by this sediment to be closed by water authorities.

Instruments in place that address the risks to water quality

The extent to which legally and non-legally binding instruments such as codes of practice, guidelines and forest management plans that address water quality exist across state and territory jurisdictions is rated in Tables 71 and 72 using the category descriptions in Table 70. Key mitigation measures include providing adequate drainage for roads, trails and tracks and maintaining streamside protection with buffer or filter strips that minimise soil movement into streams.

Legally binding instruments are in place in New South Wales, Tasmania and Victoria (Table 71). South Australia has non-legally binding guidelines for its plantation estate that seek to minimise the risk to water quality by considering streams, drainage lines, water bodies and slope and by specifying appropriate management practices and streamside buffers. In New South Wales, forest managers have statutory obligations to address water-quality risks in nature conservation reserves and in multiple-use public native forests and plantations.

In Victoria, the *Code of Practice for Timber Production* (revised in 2007), which applies to all timber production on private and public land, outlines specific requirements and mandatory actions designed to prevent soil sediments, nutrients, chemicals, petroleum products and fertilisers from entering waterways. Actions include the establishment of buffer and filter strips, the installation of appropriate drainage systems and stream crossings, restrictions on disturbances on steep slopes, the use of energy-dissipating structures or silt traps alongside roads, and road closures in wet weather. The *Code of Practice for Fire Management on Public Land* addresses the potential impacts of fire disturbance on water quality.

There are limited legally and non-legally binding instruments in Western Australia, but they do not address all the aspects listed in Table 70. However, the Forest Management Plan 2004–13, which covers all of the main timber production areas in the state's southwest, places strong emphasis on the protection of soil and water values. The soil erosion measures in place for disturbances in multiple-use public forest and timber reserves in Western Australia are currently being reviewed; any improvements that are implemented would be expected to have positive outcomes for water quality.

Table 71: Extent to which legally binding instruments address the risk to water quality due to forestry operations, road and trail works, fire management and recreation activities

	Category[a]				
	NSW	SA	Tas.	Vic.	WA
Multiple-use public forests	1	4	1	1	4
Public nature conservation reserves	1	4	1	1	4

a Values refer to category descriptions in Table 70.

Note: Queensland has the *Code of Practice for Native Forest Timber Production* for public land and the *Private Native Forests Code of Practice*.

Sources: State agencies

Table 72: Extent to which non-legally binding instruments address the risk to water quality due to forestry operations, road and trail works, fire management and recreation activities

	Category[a]				
	NSW	SA	Tas.	Vic.	WA
Multiple-use public forests	1	1	1	1	1 (native forest) 3 (plantations)
Public nature conservation reserves	1	Not applicable	1	1	4

a Values refer to category descriptions in Table 70.

Sources: State agencies

Table 73: Category descriptions and ratings applied in assessing the extent to which the risks to water quality are assessed in planning processes

Category	Category description
1	The water-quality risk assessment system comprehensively takes into account all the following factors: stream and drainage lines (e.g. including exclusion zones); road drainage and stream crossings (e.g. cross-draining of log extraction tracks); slope; and sensitive aquatic habitat.
2	The water-quality risk assessment system takes into account most of the components listed in category 1, and those not addressed are associated with low risks to water quality properties for the particular disturbance activity and geographical setting.
3	The water-quality risk assessment system takes into account some of the factors listed in category 1 or only partly accounts for those factors.
4	The water-quality risk assessment system is ad hoc and/or does not take into account any of the factors listed in category 1.

Assessment of the risk to water quality

The assessment of the risk to water quality posed by disturbance activities is generally a combination of office-based analysis and field verification and is usually carried out in conjunction with an assessment of the risks of the proposed activity to soil values. Many forest managers use similar categories to those listed in Table 73 as a series of overlays in a geographic information system to make such assessments and then seek advice from the relevant regulatory agencies if necessary.

Table 74 shows that, in most states, comprehensive assessments of the potential risks to water quality are conducted before harvesting, silvicultural and roading operations in multiple-use public native forests and plantations. In 2005–06, in those states for which data were available, 100% of proposed activities were assessed before the commencement of most operations.

Water quality knowledge base

The knowledge base required to maintain water quality in multiple-use public forest is generally good (Table 75) and continues to improve (Case study 32); it is highly dependent on knowledge of soil erosion and the implementation of appropriate soil erosion mitigation measures. The major indirect impacts on water quality that can arise from unplanned fire are clearly seen in the aftermath of the 2003 fires in the Australian Capital Territory, as described earlier. Improved fire and fuel management should reduce the risk of bushfire in water catchments and, therefore, the potential risk to water quality. Further knowledge is required across other tenures, and some risk factors on public land need to be better understood.

Table 74: Multiple-use public forest where disturbance activities were planned in 2005–06, proportion assessed for risk to water quality, and category of assessment

Disturbance activity		NSW	SA[a]	Tas.	Vic.[b]	WA
Native-forest harvesting and silviculture	% assessed for risk to water quality	100	Not applicable	100	95	100
	Category[c]	1		1	1	2
Plantation operations	% assessed for risk to water quality	100	100	100	95	100
	Category[c]	1	1	1	1	3
Road construction and maintenance	% assessed for risk to water quality	100	100	100	95	100
	Category[c]	1	1	1	1	2
Fire management	% assessed for risk to water quality	100	100	100	95	–
	Category[c]	1	1	1	1	–

a South Australia does not harvest native forest.

b Plantations privately owned and managed in Victoria.

c Values refer to category descriptions in Table 73.

Sources: State agencies

Table 75: Water quality knowledge base, by jurisdiction

NSW	Comprehensive knowledge base to assess the risks to water quality, supported by published research, ongoing monitoring, codes of practice, statutory obligations, local knowledge and training, geographic information systems and the employment of specialists.
SA	Reasonable understanding of activity impacts on water quality. *Environmental Management Guidelines for Plantation Forestry* in place.
Tas.	Good knowledge for multiple-use public forest and some private forest. Code of practice has specific requirements for watercourse and water-quality protection. Forest Practices Authority provides regular training to forest managers.
Vic.	Reasonable knowledge of impacts of activities on water quality, including local knowledge, training, codes of practice, statutory obligations, mapping of slope limitations, specialist research and development projects.
WA	Well-developed knowledge, including published research, geographic information systems, decision-support tools, codes of practice, local knowledge, training and site-specific research models.

Sources: State agencies

Compliance with water quality measures

The assessment of compliance with requirements for the protection of soil values and water quality is part of the process of assessing compliance with soil-erosion prevention measures (Indicator 4.1b).

In New South Wales, water quality in multiple-use public forests is measured and monitored in 35 small catchments in native and plantation forests. Typically, multiple paired catchments of unharvested and disturbed sites are monitored immediately before and after disturbance – which may include a combination of harvesting, burning and roading activities – as well as in the long term.

Victoria has a large network of streamwater-quality monitoring sites that record parameters such as acidity, dissolved oxygen, electrical conductivity, sediments/total dissolved solids, temperature, phosphorus and nitrogen. A number of the sites are in or downstream from forested areas.

In 2004, Victoria undertook its second statewide assessment of river health using the Index of Stream Condition. The index measures the environmental condition of 1,040 river reaches, representing 26,000 kilometres of Victoria's major rivers and tributaries in forested and non-forested catchments. The index has five subindexes (hydrology, streamside zone, physical form, water quality and aquatic life), comprising 19 key indicators. The assessment found that 21% of Victoria's river length is in good-to-excellent condition; the overwhelming majority of that proportion is in the forested regions of eastern Victoria.

References and further reading

ANZECC (2000), Bari et al (2004), Carey et al (2003), Cornish (2001), DSE (2007), ForestrySA (1997), McIntosh (2004), McIntosh and Laffan (2005), Ringrose et al (2001), Webb and Haywood (2005), Webb et al (2007) (list at the back of the report).

Case study 32: Recent research on reducing impacts on water quality

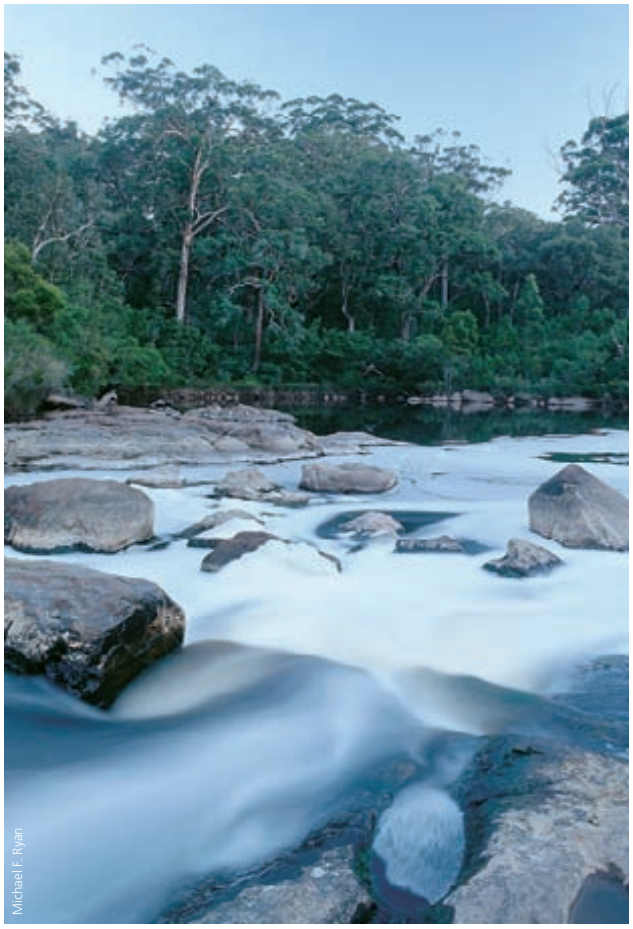
Data from a long-term catchment study at Karuah in northern New South Wales showed that road–stream connectivity was the most important factor in sediment delivery to streams in roaded catchments.[18] Harvesting in the absence of roads generally reduced turbidity levels, as did the implementation of prescriptions such as slope limits on logging and log extraction track construction, the retention of 20-metre wide undisturbed buffers on both sides of streams, and the rapid revegetation of catchments after logging. These findings led to the adoption of improved road drainage measures in the state's multiple-use public native forest, particularly aimed at intercepting road runoff near streams and diverting it to vegetation areas with good absorption characteristics. More recent small-catchment monitoring by Forests NSW has confirmed that the effects of forestry activities on water quality in both native forests and plantations are largely mitigated by the revised forest practices.[19]

In Tasmania, recent research led to the development of *New Guidelines for the Protection of Class 4 Streams*.[20] The guidelines include improved protection for headwater streams based on five graded prescriptions according to erosion risk.

In Western Australia, salinity levels in the Denmark River peaked at 1,520 milligrams per litre (total dissolved solids) at the Mount Lindesay gauging station in 1987, posing a threat to Denmark township's drinking water. Since 1991, stream salinity has decreased by an average of 8 milligrams per litre per year, due partly to a cessation of vegetation clearing and partly to the groundwater-lowering effects of tree plantations established after 1988.[21] By 2002, an area of 3,450 hectares of plantation had been established in the upper Denmark catchment. Further reductions in salinity are expected once all planned plantations are fully established, although the salinity target of 500 milligrams per litre at Mount Lindesay by 2020 might not be met. All salinity management works should be completed by 2010, but it will take a further 10 years before the full benefits of the work are known. Monitoring and evaluation of this work is ongoing, with the intention of producing five-yearly situation reports.

Forested catchments are critical to water quality in Australia.

18 Cornish (2001).
19 Webb and Haywood (2005), Webb et al (2007).
20 McIntosh and Laffan (2005).
21 Bari et al (2004).



Circular pool, Walpole, Western Australia.