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Abstract: Policy for the protection of water resources requires a more holistic and integrated approach to transcend disciplinary boundaries, to overcome fragmented governance, and to create ownership of solutions through collaborative planning. In this Australian case study I summarise critical water quality characteristics (salinity, acidity, nitrogen, phosphorus, carbon, turbidity, micro-pollutants and pathogenic organisms) and management options in the context of the needs of stakeholders. Stakeholder ...

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Water Resources in Australia: Deliberation on Options for Protection and Management

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Policy for the protection of water resources requires a more holistic and integrated approach to transcend disciplinary boundaries, to overcome fragmented governance, and to create ownership of solutions through collaborative planning. In this Australian case study I summarise critical water quality characteristics (salinity, acidity, nitrogen, phosphorus, carbon, turbidity, micro-pollutants and pathogenic organisms) and management options in the context of the needs of stakeholders. Stakeholders are: dryland and irrigation farmers; urban and industrial users; and the aquatic environment. Management options are: changes in land use; interception methods (such as filtration by riparian vegetation, use of artificial wetlands, and evaporation ponds); reliance on technological water treatment methods; re-use; and trading. Clearly, the protection of water resources is a 'wicked' problem. Critical decision-making requires greater emphasis on inclusive agricultural, ecocentric and technological thinking that includes: an understanding of the water cycle; consideration of interaction between stressors and use of systems approaches; better methods to value the aquatic environment; assessment of land use impacts on water resources; use of incentives to change behaviour; and community involvement to create sustainable futures through transformation and resilience practice. To their credit, Australians are working together to explore solutions and support is available. Some examples are provided.

Keywords: sustainability; watershed protection; conservation; valuation; governance; collaborative planning; resilience

Introduction

Protection of water resources is a major issue globally as demand for food and increasing urban and industrial needs place pressure on water supply, while river health continues to decline. In Australia the occurrence of a decade of drought and concerns about climate change have focused public policy on water scarcity. In the Murray-Darling Basin (MDB) , emphasis on water for the environment or 'environmental flow' has diverted attention from

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water quality issues while in urban areas the re-use of water for drinking has created major concerns for public health. In Australia and elsewhere the catchment has proved to be a useful geographical and social unit for planning, often with emphasis on biophysical issues such as water allocation, biodiversity and salinity management, while urban approaches often focus on technological solutions such as desalination and disinfection methods for water treatment.

Yet a broader approach that crosses conventional boundaries can be beneficial for several reasons. Firstly, as noted more than 30 years ago '*An important area of research is the comparison between the efficiency of water treatment and the efficiency of a range of land-use control measures and their various combinations'* (Mitchell & King 1980), p.52. This remains an important topic today as illustrated by the economic benefits of land use change compared with massive water filtration infrastructure for New York City (Daily & Ellison 2002). Secondly, a focus on one issue can have unintended consequences in another area, such as the effects of tree planting to beneficially manage salinity and carbon while detrimentally reducing water run-off. Thirdly, multiple and synergistic benefits will be missed when the focus is restricted, for example when assessment of the benefit of catchment management changes is restricted to pathogen control as opposed to erosion and eutrophication management.

In this Australian review the diverse needs of stakeholders for access to water of appropriate quality are considered and how these needs might be managed. The challenge is to synthesise the needs and develop options and opportunities for a sustainable future. From a policy and management perspective resources will always be limited so that the choice of investment options will need to reflect priorities. Also changing climate, increasing demand for water and new knowledge require adaptive and transformative approaches to collaborative planning. The issues are complex, but to their credit, Australian policy makers, managers, industries and communities are working together to explore solutions. Some key challenges and exemplars are provided.

Water characteristics, stakeholder needs, and management options

A review of water quality issues in Australia is summarised in Tables 1 and 2. (Further details and references are provided by Bowmer (2012)). For simplicity stakeholder classes are divided into: irrigation farmers and rural landholders with riparian rights to access water known as 'stock and domestic'; urban dwellers and industry with an emphasis on drinking water and public health safety; and aquatic ecosystems which includes water for aesthetic, spiritual, recreational and cultural purposes. Water quality characteristics are: salinity, acidity, nitrogen, phosphorus, carbon, turbidity, micro-pollutants, and pathogenic organisms. Management options are compared under categories of: prevention (including improvements to agricultural land management systems); interception (such as the use of salinity evaporation ponds, protection of the riparian zone and use of wetlands for effluent treatment and stormwater interception; and treatment and re-use (usually requiring disinfection, filtration and other technological solutions).

Clearly, the diverse range of needs and management options is a challenge to planners and managers who need to embrace a broad range of investment options as well as principles of public participation in decision making. Fortunately, in Australia, lawyers, sociologists, geographers and economists, as well as scientists and engineers, are being employed in public service planning positions. In the following section I expand on the challenges, provide examples of successful integration, and describe some of the strategies used.

Challenges to developing management options

Need to understand the water cycle

Chartres & Williams (2006) describe a suite of options that can be used to maintain run-off and river flow while reducing the amount of salt and pollutants reaching rivers and groundwater. These include: managing dryland land use; reducing consumptive water extraction; improving river flow regime by trading, regulation and dam management; reducing groundwater extraction to safeguard base flow to rivers; managing subsurface drainage to avoid accumulation of salt in the root zone; improving irrigation water use efficiency on farm; and increasing surface water re-use in irrigation and cities.

Costing these options requires an understanding and quantification of the water cycle. Regional Water Resource Assessments (NWC 2007), the National Water Account (NWC 2013) and the Sustainable Yields Project (CSIRO 2008) provide quantitative information for Australia on water balance at catchment scale. The latter includes trends and projections for different emission scenarios and land-use change. The reliability of these audits is limited by: uncertainty about unregulated tributary inflows; surface-groundwater interactions; soil-water balance; and, in many instances, the water that is actually extracted by users. Furthermore, they do not distinguish different land-use contributions to the water cycle. Water balance reporting does not separate the various classes of environmental water that are specifically allocated by planning and legislation, that are obtained by purchase, or that are left in the river after consumptive use. A better understanding of the water cycle at a catchment scale is required (NWC 2009).

Need to consider interactions between stressors

For convenience and simplicity I isolate eight water characteristics for review, but warn that a problem of this approach is that it is the *combination* of various stressors that affect the utility of the water or demise of river and estuarine health. For example, the development of an algal bloom can be affected by weir pool or river reach residence time, nutrient availability, the effect of turbidity on the light climate and by temperature. Other examples include the loss of seagrasses (a critical component of marine and brackish aquatic ecosystems) caused by the interaction of pollutant discharge from coastal cities with changing hydrological patterns (Harris 2006); and concerns about the effects of diffuse pollutants together with loss of natural wetland filtering systems on the Great Barrier Reef (Pittock 2010). As noted by Hamblin (2001 p. 130), in developing a short list of indicators for State of the Environment reporting, ‘the greatest challenge is developing the most suitable trade-off responses when several pressures interact’.

Need to use systems approaches

Planners need to be wary of ‘single-issue’ priorities that have been a feature of Australian natural resource management and investment. For example, in the last decade, media attention and investment priorities have focused in sequence on salinity, algal blooms, water scarcity, environmental needs (‘environmental flow’), public health concerns arising from re-use of water for drinking, water for food security and effects of coal seam gas on groundwater pollution. There are several problems in considering these single issues separately:

(1) Simplistic benefit-cost analysis applied to separate user groups may miss opportunities for synergy. For example, Syme & Nancarrow (2008) define ‘Water Benefits’ as ways in which water promotes well-being in both utilitarian and non-utilitarian ways, acknowledging that the same volume of water can deliver multiple benefits as it moves through a catchment. Hamstead (2007) also comments on the misconception that water is used either for environmental or productive environmental purposes, when both can occur.

(2) Highly specific and targeted investments can quickly become redundant. For example, current priorities are heavily coloured by a decade of drought but recent flooding may change priorities for salinity. Another example is the construction of desalination plants for Melbourne and Sydney in reaction to low storage levels; these have not been used and the dams are now full again.

(3) Adaptability is needed to cope with changes that include new scientific knowledge especially on resilience of aquatic ecosystems; effects of climate change and variability; new market-based approaches to water trading and infrastructure; adoption of new technology such as aquifer storage recovery and desalination; emergence of new industries such as coal seam gas; new policies on water interception and carbon pricing; increased re-use of water for drinking; and changing public perceptions, especially on public health and environmental values. In Australia water and catchment plans are reviewed and updated at intervals of 5-10 years, providing a balance between constant change and business uncertainty, and adjustment to new knowledge and needs. Support available includes: adaptive management frameworks (Baldwin et al. 2009; Tan et al. 2010); strategies and guidelines for achieving resilience (NSW NRC 2012; Walker & Salt 2012); and risk-based frameworks and modelling (Pollino & Henderson 2010).

Need for new methods to value the aquatic environment

In accord with global assessments of the value of ecosystem services provided for human well-being (Millennium Ecosystem Assessment 2005), there is growing recognition in Australia that the long-term sustainability and utility of riverine and estuarine systems requires that the ecosystem be protected with emphasis on avoiding damage in the first place, especially for rivers and streams that are currently in good condition (Rutherford et al. 2000). For highly-regulated ‘working’ or ‘entrained’ rivers there is still a need to maintain the resource in a productive condition and to avoid the prospect of an irreversible decline (Hillman 2008). Biological and hydrological indicators have been used effectively to integrate the combined effects of threatening processes on catchments or to give an easily-understood overview of stream or river condition (Davies et al. 2010).

Australia’s market-based approaches to water policy have tended to under-value the social functions of water, such as culture, spirituality, recreation, health and aesthetics. As noted in a recent *Special Issue Supplement of the Water Policy Journal* (2012), valuation of water for these social functions is complex but important. There is increasing evidence that communities are not prepared to accept a decline in river water quality and aesthetics, even if treatment for consumptive use is available and affordable. Syme et al. (2008) and Syme & Nancarrow (2008) have discussed the problem that social benefits from water extend through a sphere of needs from health and economics to social prestige, recreation and spirituality. These are all related especially as the same volume of water can provide for a number of needs or values at the same time. Thus they suggest that alternative quantitative units be used instead of dollar values. Specific criteria for improving these benefits in water quality and quantity terms can then be developed and participative management plans derived that meet criteria of procedural justice.

Clearly, more information is needed to assess the value of ecosystem services and the balance of public and private investment required to meet expectations, noting that resources are inevitably limited and must be targeted to stressed and/or highly-valued systems (NWC 2012, section 2.2; O'Keefe & Hamstead 2010).

Need to include land use in water planning

Agricultural land use affects water quality and the health and resilience of downstream aquatic ecosystems though the relationship is complex (Bowmer 2011). Land and water planning in irrigation areas, catchment action planning in New South Wales, river health planning in Victoria, and natural resource planning in South Australia and Queensland provide a systematic approach to governance (Hamstead 2010). However, land-water interactions have been downplayed by Australian water managers in recent years, reflecting an emphasis on water treatment technology ('end of pipe solutions') and over-riding concerns, until recently, about water scarcity. A re-integration of land and water management through catchment-based approaches is advocated (Bellamy et al. 2002; Griffiths 2009) and insights into decision making for land management practice and adaptation to change are provided by Pannell and Vanclay (2011).

Several examples of integrated land and water planning in Australia are available. For example, the Great Barrier Reef Plan required 650 graziers and 1000 cane farmers in Queensland to adopt individual environmental risk management plans and supported the use of techniques such as grass strips, controlled traffic to reduce compaction and sediment loss, and precision application of herbicides. The Plan manages diffuse pollution through the balanced use of targets, voluntary measures, incentives, regulations, monitoring, enforcement and funding, and is an exemplar for application to about 400 near-shore 'dead zones' that are threatened internationally (Pittock 2010). In Port Phillip Bay, near Melbourne, Victoria, observations on sediments determined the water treatment investments that were necessary to protect the aquatic ecosystems; contrary to expectations it was found that bioturbation in the sediments released nitrogen to the atmosphere, so reducing the need for expensive nitrogen removal measures in sewerage and stormwater (Harris 1996).

The audit of Sydney water supply catchment in New South Wales is an example of integrated catchment management to safeguard public health. Animal wastes from grazing livestock are significant sources of pathogens to water supplies so many urban catchments have strict land use restrictions (Apte & Batley 2011). More generally there is renewed interest in the benefits of watershed protection (Eichner 2010) and new guidelines for microbial safety of drinking water advocate the use of multiple barriers including land use regulation (NHMRC 2010). Other exemplars of integrated land use and water resource protection are available in the annual prizes awarded at the International Riversymposium (Anon 2013).

The Australian government recently commissioned a report on ecosystem services with a particular focus on their application to agricultural lands, concluding that one of the greatest benefits is the facilitation of dialogue about complex major policy challenges (Cork et al. 2012a). A review of the quality of ecosystem services showed that land management practices adopted by farmers have a direct impact on improving soil condition providing a range of ecosystem services to the broader community, including water purification and regulation of water flows (Cork et al. 2012b).

Need for incentives to change behaviour

Ways to change land-use practice and farmer behavior have been reviewed in many workshops and publications over the last decade (Haszler 2001; Hajkowicz et al. 2003). A Fenner conference on Agriculture for the Australian Environment concluded that ‘a key requirement is recognition from urban consumers for those farmers prepared to take a risk … to ensure that innovative practices become the norm rather than the exception’ (Wilson 2003, p.8).

A summary of financial incentive mechanisms, including benefits, disadvantages and case studies was prepared for Catchment Management Authorities (Comerford & Binney 2004). Mechanisms include grants, stewardship payments, cost sharing, auctions and tenders, subsidies, rate relief and tax concessions. Proctor et al. (2007) list a similar range of incentives, adding social recognition to affirm and promote local leaders and desired practices, regulation to restrict certain activities, and provision of information on benefits.

The use of incentive payments to encourage people to trial and adopt new practices is advocated (Pannell &Vanclay 2011; Gillespie et al. 2008). Cocklin et al.(2007) consider the conditions under which farmers can provide ecosystem services as well as being producers of food and fibre. They found that many landholders would be drawn to an initiative that gives recognition, support and financial assistance with regulation as a last resort. Williams & McKenzie (2008) propose a price premium for produce through ecolabeling and incentives that reward the grower and supplier for best practice in providing ecosystem services.

'Catchment Care' is a possible solution that moves beyond direct financial assistance to recognise the obligation of resource managers and farmers to avoid practices that harm the long-term interests of resource users as a whole (Hatfield-Dodds 2006). The principle combines disincentives, cost sharing by land-holders, assistance for mandatory conservation practices and incentives for voluntary conservation, resulting in higher overall environmental standards than could be achieved by each mechanism alone.

Need for community involvement

Developing priorities for investment requires that biophysical considerations should be better integrated with socio-economics. Notably, the effect of public expectation on driving or restricting the implementation of policy must be considered. These issues are complex, difficult and uncertain (Ross et al. 2012). Advantages of community involvement are that people can enrich expert knowledge, set their own priorties, find local innovative solutions and agree on monitoring regimes. In discussing the contentious issue of water allocation, Syme (2013) reports that people generally support concepts of long-term sustainability and intergenerational equity but uncertainty about the future requires that trust and fairness are explicitly included in water planning.

Critical issues in Australia include the effect of a ten year drought which stimulated the search for new water sources for cities and led to a strong and hostile reaction in the Murray-Darling Basin over increasing the allocation of water to the environment (Quiggan 2012). Community attitudes to re-use of water for drinking in cities have also been contentious (Lampard et al. 2010). To their credit, planners and governments are responding to these and other challenges though a range of collaborative planning processes. Support available for planners includes: comprehensive guidelines (IACSEA) 1998); profiling methodology (Hassall and Associates et al. 2003); a systems analysis template for integrating across social and environmental disciplines (Newell et al. 2005); multi-criteria analysis (Hajkowicz 2007); multi-objective optimisation methods (Xevi & Khan 2003) ; and 'Landscapes Futures Analysis' that integrates a stakeholder engagement process called envisioning with the development of a web-based planning interface (Meyer 2013). The Journal of Hydrology (2012) recently published a special issue of case studies and Tan et al. (2010) provide aids to select practical guides and tools that include stakeholder analysis, indigenous engagement, socio-economic impact assessment, best practice for managing climate risk, participatory mapping, and deliberative multi-criteria evaluation. The National Water Commission provides a comprehensive guide for environmental water management that includes a range of ideas, resources and examples of stakeholder engagement (NWC 2012, section 6.3). In a recent review Patterson et al. (2013) provide a conceptual framework for managing the 'wicked problem' of nonpoint source water pollution in catchments that includes history and contingency, institutional arrangements, collaboration, engagement, vision and strategy, knowledge building and brokerage, resourcing, entrepreneurship, leadership, reflection and adaptation.

The principles of watershed protection in Australia have evolved into strategies and programs for Integrated Catchment Management, Total Catchment Management, and Whole Catchment Planning (Ryan et al. 2010). Mechanisms for water allocation vary across the states though all contain elements of water sharing. They are: Water Sharing Plans (New South Wales and the Australian Capital Territory); Water Allocation Plans (South Australia); Water Resource and Resource Operations Plans (Queensland); Bulk Entitlement and Streamflow Management Plans (Victoria); Water Plans (Western Australia); and Water Management Plans (Tasmania). The Murray- Darling Basin Plan is being implemented through state water plans. These approaches provide a basis for public participation in decision making and priority setting, though they are criticised as limiting and 'top-down' (Jewitt 2002; Robins & Kanowski 2011). Also, in recent years watershed protection has evolved to include 'resilience thinking' to engage communities in planning for natural variation and extreme climate (Ross et al. 2012; Walker & Salt 2012). Fundamental paradigm shifts are required to achieve sustainability (Coffey & Marston 2013) and to incorporate the transformational pressure of carbon, water, food, energy, amenity and mining on land use and management (Bryan et al. 2013).

Conclusion

The integration of land and water management appears to have been downplayed and under-funded in recent years. Links between land use, downstream water quality and ecosystem resilience are difficult to quantify because of the interaction of many confounding factors. Also substantial past investment in water treatment technology has enabled urban Australians to access safe water for drinking and industry, to some extent removing the pressures for greater investment in watershed protection. However, as noted by Mitchell and King (1980, p. 52) 'while it is claimed the simplest solution to catchment solutions lies in water treatment because the technology is now so advanced, such technology is still not completely effective, can be extremely costly, and may be subject to human error’.

There is increasing interest in the resilience of riverine ecosystems and their aesthetic, cultural and ecotourism values so an emphasis on engineering solutions is no longer appropriate. It is timely to revisit the catchment-based approach to landscape sustainability and resilience in Australia and to extend planning to include the full range of management options.

In developing a priority-setting framework for water resource protection it is clear that biophysical considerations need to be better integrated with socioeconomics and that public expectation can drive or restrict the implementation of policy. These issues are complex, difficult and sometimes contentious. Examples include attitudes to re-use of water for drinking in cities and rejection of the Basin Plan by some rural communities. To their credit, planners and governments are responding to these challenges, a wide range of tools is being developed, and sharing of knowledge and experience is enhancing collaborative approaches to planning. Also, in recent years strategies and programs for watershed protection have evolved in Australia. For example ‘resilience thinking’ has been applied to the several catchments in New South Wales and Victoria to engage communities in planning for natural variation and extreme climate. As noted by Ross et al. (2012), in the face of change, a resilience perspective is required to foster each community’s and region’s strengths so they can plan effectively and make their own adaptations.

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Table 1. **Summary of stakeholder issues**

	Rural and Irrigation	Drinking and Industry	Aquatic Environment
Salinity	Salt in irrigation water disperses the soil causing impermeability and prevents leaching, damaging soils irreversibly so irrigators are highly dependent on upstream catchment managers to reduce salt loads in run-off. Oceanic saltwater intrusion into aquifers also causes irrigation problems in the Burdekin, Queensland.	The Murray-Darling Basin Salinity Audit estimates that the target of 800 EC units (critical for drinking water protection) will be exceeded in 2020 for 95% of the time if no action is taken, driving salt reduction activities upstream, including salinity interception, salinity trading by agencies, and large-scale evaporation ponds. The cost of salt damage to infrastructure including roads, houses and corrosion of pipes in power stations is substantial.	Aquatic macrophytes and invertebrates are most sensitive to salinity; some species are affected at 160 EC units. Murray-Darling Basin rivers are fair to average quality with a flow-weighted salinity generally below about 550 EC units. Saltwater intrusion is a threat in some estuaries, often caused by flow reduction rather than increase in salinity *per se*.
Nitrogen, Phosphorus Carbon	Newer filtration and pressurised irrigation systems require clean water; energy for back-flushing algae and biofilms (that are enhanced by nutrient enrichment and turbidity) is increasingly expensive. Stock watering and unregulated supplies are vulnerable to algal blooms and associated toxins	Taints, odours and toxins produced by blue-green algae are often treated with activated carbon filters or more expensive dissolved air floatation. There is a general view that through reliance on treatment technology we are learning to live with algal blooms. Groundwater contamination with nitrate exceeds Australian Drinking Water Guidelines in many areas sometimes by up to 10-fold.	Algal blooms in the 1990s occurred in the Darling River, Peel Harvey Estuary of Western Australia, and Queensland reservoirs, triggering the development of algal management plans at all levels of government. Recently algal blooms have affected over 800 km of the Murray River but research has demonstrated that flow, stratification and light penetration, not nutrient availability alone, are the triggers for blooms in south-eastern Australian rivers.
Turbidity		Turbidity increases the costs of filtration for drinking water and interferes with disinfection processes. More severe turbidity standards for drinking are being challenged by water utilities as impractical and expensive. Also although many cities and towns have invested in treatment plants to treat cyanobacterial odours and toxins, unregulated stock and domestic supplies remain vulnerable.	Shading caused by turbidity advantages buoyant blue-green algae and threatens the health of coral and seagrasses with major impacts in Port Phillip Bay, Moreton Bay, and Perth and Adelaide coastal waters. In inland rivers the threat to biodiversity increases when turbidity is combined with regulation to create constant flow.
Micro-pollutants and Pathogens	Concentrations of pesticides in irrigation water sometimes exceed safety guidelines. Intentional contamination is a risk to the reputation of clean food products for consumers and the export market, though the risks are countered by registration and approval processes that are well-developed.	New limits for 140 pesticides in drinking water are proposed but water utilities are concerned about monitoring costs. There are uncertainties about the toxicological impact of emerging categories of widely-occurring pollutants through more intensive re-use of water, even though risk should be reduced by advances in recent water treatment technology. Currently many inland communities drink water that has been recycled indirectly through river dilution and transport but direct recycling is contentious with policy bans or restrictions in several states.	Recycling or withholding periods before drainage is released can successfully manage contamination from rice and cotton pesticides. Integrated pest control methods and genetically modified cotton cultivars have much reduced cotton pesticide contamination. The Great Barrier Reef is threatened by combinations of diffuse pollutants. Fishing in Sydney Harbour is restricted because of dioxin contamination.

Table2. **Summary of interception and treatment options for water resource protection**

	Preventative Strategies	Interception	Treatment and Re-Use
Salinity	Deep-rooted crops and forestry prevent the rise of groundwater to the soil surface. Restriction of water application rates in irrigation. Discharge licensing and development controls in urban situations	Evaporation basins, but only for point discharges; ineffective for diffuse sources. Used in conjunction with state-based trading of salinity credits in the Murray-Darling Basin. Salinity trading is also practised in the Hunter River system.	Reverse osmosis and desalination for urban supplies.
Acidity	Application of lime, timing nitrogen fertiliser application to meet plant demand, avoiding long fallows, retaining crop residues rather than burning, replacing cations removed in agricultural commodities, and improving soil organic matter levels.	Levee banks used to protect wetlands from acid discharges. Restoration of flow for flushing.	Treatment with lime or dolomite. Exposure of acid suphate sediments prevented by permanent flooding; achieved by environmental water purchase and rain in the Coorong, South Australia.
Nitrogen	Effluent disposal guidelines are available for intensive rural industries. Some sewage is treated using methanol or biological methods.	Interception by riparian zone is ineffective for dissolved nitrogen. Nitrification and denitrification sequences in natural and constructed wetlands remove nitrogen in gaseous forms.	na
Turbidity Sediment Phosphorus	Over 85% of the sediment-bound phosphorus in Queensland is derived from hillslope erosion, whereas gully (subsoil) and river bank erosion dominates in south-eastern Australia. Consequently, the avoidance of surface soil exposure and erosion is particularly important in high rainfall areas.	Management of riparian zone (fencing and planting) can help when phosphorus is adsorbed to particles but trapping capacity is quickly exceeded. Off- river watering for animals avoids bank erosion. SedNet used to target hotspots for amelioration. Natural and artificial wetlands included in Water Sensitive Urban Design for cities.	Copper sulphate for algae in reservoirs. Gravity sedimentation, micro-sand embedded flocculation, and dissolved air flotation are used for drinking water. Costs increase when algae are present. Phoslok® modified clay used to sequester phospohorus, but expensive.
Carbon	Conservation farming is expected to increase carbon levels in soils, but also increases structure and water-holding capacity, reducing run-off.	Riparian zone fencing and planting can help but are largely ineffective for dissolved forms of carbon. Biochemical oxygen demand is reduced by wetlands.	Dilution of blackwater used where river operations permit. Treatment by ozonation and disinfection but with concerns about carcinogenic biproducts.
Micro-pollutants and Pathogens	Water utility practitioners emphasise the importance of best catchment management practice for protection of drinking water. Conservation farming systems retain soil particles that are associated with bacteria and viruses and are generally not subject to intensive grazing by livestock. Such systems are part of the multiple barrier or catchment-to-tap approach adopted by major urban water utilities.	Interception in riparian zone and filter strips. Capture and treatment of stormwater in wetlands. Recycling of effluents for irrigation and gardens including 'third pipe' systems. Sewage treatment methods including natural uv radiation, membrane filtration and reverse osmosis.	Activated carbon is used for toxin and odour removal. Sophisticated systems are available and effective for disinfection and removal of trace pollutants but public trust is low.