Diffuse Pollution, Degraded Waters
Emerging Policy Solutions

Chapter 2

Economic costs and policy approaches to control diffuse source water pollution

This chapter looks at the impacts and costs of water pollution to society and argues who should pay for, and benefit from, improvements in water quality. The chapter lastly inventories the range of policies in place in OECD countries to manage water quality and discusses the importance of policy coherence across policy domains for the management of diffuse pollution.

Key messages

The cost of delaying further improvements in water quality is significant for OECD countries. Despite challenges with economic valuation, national estimates suggest that the cost of water pollution in OECD countries is likely to exceed billions of dollars each year. Such estimates serve to illustrate the existence of significant externalities and a need to adjust water, urban and agriculture management practices in order to reduce negative impacts on water quality.

A number of complex variables determine the impact of pollution on water bodies and therefore influence policy responses to control them. Pollution events are unevenly distributed, both spatially and temporally, and there are ecological and social response time delays that make management of water pollution, particularly diffuse pollution, a complex task.

Markets for agricultural commodities do not internalise water pollution externalities nor signal their value to producers or consumers. This market failure is a difficult policy challenge and one that justifies intervention by government or communities to achieve more economically, environmentally and socially optimal and sustainable outcomes. An important policy area to be examined is the increasing need to find cost-effective solutions and economic instruments that incentivise pollution reduction and fund water quality improvements, particularly given fiscal consolidation of government budgets.

Water quality improvements come at a cost. When developing policy to manage water quality, an important consideration is not only the measurement of the costs and benefits of water pollution reductions, but also on to whom these costs and benefits will fall. The Polluter Pays Principle has typically not been successful in the control of diffuse pollution because of the limitations on measurement, abatement measures, poor enforcement, and political resistance. The Beneficiary Pays Principle has had more success as an incentive to reduce diffuse pollution, particularly on a voluntary basis, but can cause equity issues if polluters are seen to be rewarded.

A lack of policy coherence across agricultural, urban, energy, industrial, economic, climate, environmental and water policies has failed to avoid conflicting signals and incentives to users of water. Special consideration of the cross-sectoral nature and potential trade-offs between climate policies and water quality will need to be managed as climate mitigation and adaptation policies are developed (e.g. bioenergy crops can increase water demand and decrease water quality and food security; afforestation of water catchments reduces soil erosion and local flood risk, and improves water quality).

The economic case for water quality management

Water quality risks

Poor water quality has many economic costs associated with it, including: *i)* degradation of ecosystem services; *ii)* water treatment and health-related costs; *iii)* impacts on economic activities such as agriculture, fisheries, industrial manufacturing and tourism; *iv)* reduced property values; and *v)* opportunity costs of further development (WWAP, 2012). For example, risks associated with deterioration of water quality to agriculture include unusable water resources for irrigation, irreversible groundwater and soil contamination, and health effects on livestock, plants and humans (OECD, 2013). Examples of water quality impacts to economic, social and environmental values are presented in Table 2.1.

Table 2.1. **Impacts of water pollution: Economic, social and environmental**

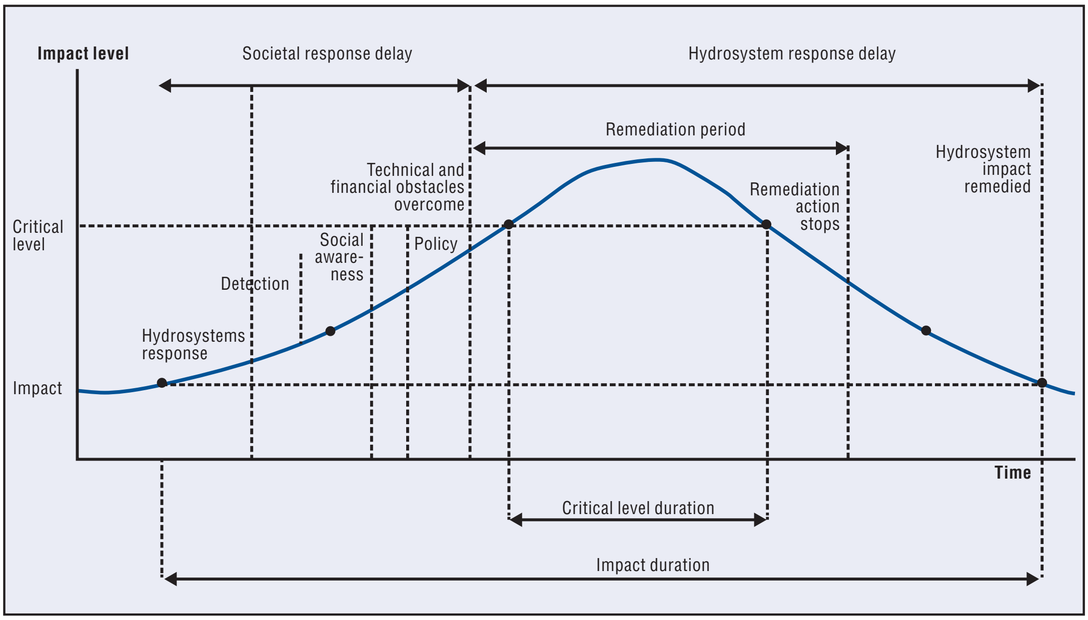
Impact	Examples
Human health	Polluted water is the world's largest health risk, and continues to threaten both quality of life and public health. Associated with this are health service costs, loss life expectancy, and emergency health costs associated with major pollution events.
Ecosystem health	Damage to freshwater and marine ecosystems (e.g. fish kill, invertebrates, benthic fauna, flora, habitat degradation) and loss of ecosystem services (including the ability to process pollutants), which may require investment in additional or different grey infrastructure alternatives to replicate these services.
Social values	Prohibition from recreational use (e.g. swimming, fishing, kayaking), beach closure, impacts on aesthetics, cultural and spiritual values.
Agricultural productivity	Exclusion of contaminated water for irrigation results in increasing water scarcity. Irrigation with contaminated water causes damage to, and reduced productivity of, pasture and crops, contamination of soil, impacts to livestock health and production, and scouring of infrastructure.
Industrial productivity	Exclusion of contaminated water for industrial use results in increasing water scarcity. Scouring of infrastructure, and clean-up costs from spills/accidents.
Commercial fisheries	Direct and indirect fish kill, contamination of shellfish.
Urban and domestic use	Increased water treatment and inspection costs, maintenance costs from scouring and premature ageing of infrastructure, increased wastewater treatment costs with implementation of more strict regulations. Emergency and clean-up costs from spills/accidents.
Tourism	Losses in fishing, boating, rafting and swimming activities to other tourism activities or to other ventures with superior water quality.
Property values	Waterfront property values can decline because of unsightly pollution and odour.

Exposure to risks associated with poor water quality depends on a combination of variables related to:

- The characteristics of pollutants, individually and in combination, the characteristics of the receiving water body, timing, distance to source of pollution, and the stochastic environmental conditions (as illustrated in Figure 1.2, Chapter 1).
- The vulnerability to water quality risks, which depends on the extent of any historic pollution, access to treatment or alternative sources of usable water, and institutional and policy mechanisms, including response-time delays (both societal and ecological). For instance: different ecosystems will respond differently to pollution; pollution detection, social awareness, policy development and remediation actions will cause further delays depending on local resources (Figure 2.1); and the rate and extent of ecosystem recovery is not uniform (Falkenmark, 2011; Hipsey et al., 2015). For example, in parts of Canterbury, New Zealand, research has shown that 30 to 60 years' worth of nitrate in the soil has yet to reach the groundwater system, which will have further impact on Canterbury's drinking water supply and lowland stream quality (Webster-Brown, 2015).

- Multiple sources and pollutants, from multiple actors and sectors, operating in parallel, which complicates water risk assessments and policy responses to improve water quality (Falkenmark, 2011). For example, although each pollution source may have relatively little impact individually, their cumulative effect can be highly damaging.

Figure 2.1. **Response time delays in water pollution abatement (societal and ecological)**



Note: The response times will be different for different ecosystems (hydrosystems), pollutants and local and national contexts.

Source: Falkenmark, M. (2011).

Market failure and water pollution

Economic theory suggests that under perfect conditions, markets will yield accurate incentives and foster efficient resource use. When particular conditions are not met, markets do not yield appropriate incentives and "fail" to achieve efficient resource use (Randall, 1983). Pollution of water resources is an example of market failure, an externality that is not accounted for in the market. For example, artificially low production costs in agriculture distorts the market and encourages over-production of food, feed and fibre that generates externalities such as nutrient runoff and eutrophication of water bodies that has economic, social and environmental costs to downstream users.

Moreover, water use is often a pure public good (non-rival and non-excludable, e.g. rivers) or a common pool resource (high rivalry, non-excludable, e.g. shared aquifers), which creates substantial transaction costs and can be subject to information gaps and uncertainties (Livingston, 1995). The market does not adequately supply public goods because private users cannot easily exclude non-paying beneficiaries and capture a return on investment. For example, it is not possible to exclude people living alongside a river from the benefits of improved water quality. The market also does not adequately provide for common pool resources because they are subject to overuse (high rivalry) in situations where strong common property resource institutions or resource user groups are not in place (OECD, 2015a).

Institutional (including regulatory, economic and voluntary policy instruments) and technical interventions are necessary to render efficient markets (Livingston, 1995) and internalise the negative externalities that lead to water pollution. The Polluter Pays Principle requires producers to pay the "full" cost (economic, social and environmental) of their production process, including externalities such as polluting water. The Beneficiary Pays Principle requires those who benefit from water quality improvements to pay for the costs incurred to do so.

However, in the event of market failure, public sector interventions or non-market approaches may not lead to the socially optimum solution. In many cases, non-market responses to market failures lead to less than optimal outcomes. This is in part because of the complex nature of water. For example, diffuse pollution is difficult to measure independently of the inputs that produced them, to pinpoint to individual land owners, and improved water quality can be difficult to prove/attribute to the uptake of best land management practices. Stock pollutants (with time delays in abatement measures spanning over more than one generation) and historic pollution (with those responsible no longer around) both pose complications in terms of who pays. Public policy distortions and spill-over impacts from other sector policies can also contribute to market failure. For example, policies aimed at protecting water quality may be at odds with other policies to increase and subsidise irrigation and intensive agricultural output for economic growth. Energy subsidies can encourage irrigation from groundwater sources, and cause saltwater intrusion with largely irreversible effects on groundwater quality.

It is therefore necessary for careful policy intervention to reduce the risk of market and government failure (such as policy distortions), and to overcome market imperfections such as uncertainty and information gaps that lead to negative impacts on water quality. A zero-pollution target is likely to be uneconomic and unaffordable (unless the risks are extreme), since the abatement cost of reaching it is likely to exceed the cost of the pollution itself. Instead, according to economic theory, the optimal pollution level from society's perspective is when the marginal abatement cost of pollution equals the marginal benefit from reducing the pollution level.

Economic valuation of ecosystems and water quality

Assessing the value, costs and benefits of water quality can assist policy makers in prioritising investments and determining policy options that provide the greatest potential societal benefit. For example, the debate over environmental protection is often about the trade-offs between the value of leaving areas in their natural state, and the opportunity costs of developing and exploiting them. Should a forest whose extensive root system reduces erosion, filters nutrients and provides many other environmental, social and recreational values be left un-cleared, or logged and converted to agriculture to contribute to economic growth, poverty alleviation and food security? Should wetlands that have high nutrient retention and the ability to remove bacteria, microbes, sediments and other pollutants, as well as providing other environmental, social and recreational values, be left in their natural state, or be drained and developed for housing, agriculture or other "productive" land uses? Economic valuation and cost benefit analysis (including determination of opportunity costs) can assist in answering such questions.

Economic valuation measures market and non-market values that people hold for freshwater ecosystems or for a certain standard of water quality. The concept of total economic value is a well-established and useful framework for identifying the various values associated with the environment (Table 2.2) (Atkinson and Mourato, 2015; OECD, 2006; IUCN, 1998).

Table 2.2. **Use values and non-use values of water ecosystems in relation to its quality**

Total economic value				
Use values			Non-use values	
Direct use values[1]	**Indirect use values[2]**	**Option values[3]**	**Bequest values[4]**	**Existence values[5]**
Drinking water Domestic use Agriculture Aquaculture, fisheries Energy production Industrial use Recreation Tourism Research Education	Nutrient retention Water purification / pollution abatement Habitat provision Climate regulation Soil erosion control	Future information Future uses (indirect and direct)	Values for legacy (future generations)	Freshwater biodiversity Ritual or spiritual values Culture, heritage Community values Aesthetic values Education and inspiration

Notes: 1. Value derived from direct human use of water of suitable water quality. 2. Value derived from the ecosystem services provided by freshwater ecosystems. 3. Value derived from the importance that people give to the future availability of freshwater of suitable quality for personal benefit (known or unknown), and for future value of information (e.g. untested genes of aquatic flora and fauna may provide future inputs into agricultural, pharmaceutical or cosmetic products). 4. Value attached by individuals to the fact that future generations will also have access to the benefits from species and ecosystems (intergenerational equity concerns). 5. Value related to the satisfaction that individuals derive from the mere knowledge that freshwater ecosystems and adequate water quality continue to exist.
Source: Adapted from IUCN (1998).

Determining the total economic value of the quality of a freshwater resource (use values and non-use values), whether it be a river, lake, wetland or groundwater aquifer, can be difficult, costly and time-consuming for a number of reasons:

- Although some of the negative externalities of degraded water quality are tangible, many are not, and their monetary quantification entails non-market valuation techniques (OECD, 2008). Even if there is a market value, this value may not reflect the "real" economic value due to market failure. For example, operating costs associated with wastewater treatment plants may not reflect the full social costs associated with pollution.
- Differentiating between point and diffuse sources of pollution through complex hydrological systems can be difficult. The separation of cause-and-effect by both physical distance and by time-lags adds complexity to the measurement and comparison of monetary values (OECD, 2012b).
- The "business as usual" scenario can be difficult to predict as many factors influence water quality. For example, the conversion of non-irrigated grassland to intensive irrigated dairy farming may occur with an increase in milk prices, and subsequently have a negative effect on diffuse nutrient pollution. Or the closure of a factory due to an economic downturn may lead to an improvement in water quality independent of policy intervention, as could the requirements of other legislation.
- Economics cannot fully account for all values (use and non-use values) attributed to a water resource. There are likely to be conflicting values, missing values and double counting identified during a total economic value study (IUCN, 1998). There are also uncertainties about the underlying environmental responses.

Furthermore, there is an array of different valuation methods which make comparison of different studies impossible. Such methods include: market prices, contingent valuation (willingness to pay or accept), hedonic pricing, travel cost method, change in productivity, loss (or gain) of earnings, opportunity cost, damage avoidance cost, and replacement cost, each of which have limitations. For example, contingent valuation is particularly controversial. There can be discrepancies between willingness to pay and willingness to accept: willingness to pay is often over-estimated due to loss aversion and the lack of requirement to actually pay; results are subject to survey design, instrument and starting point bias; and there may be limitations on information, and public education, risk perception and awareness that effect results (Hanley and Shogren, 2005).

The cost of water pollution and management options

Acknowledging the caveats around valuation in the previous section, the estimated cost of water pollution in OECD countries is substantial and attempts at estimating national costs have been reported in literature (Table 2.3). Note that a variety of methodological approaches have been used in the various studies, including in relation to whether they are reporting marginal, average or total costs. As such, results are difficult to interpret out-of-context, and cross-country or cross-study comparisons can be misleading. Furthermore, the true costs of pollution are also likely to be greater than the estimates suggest given the difficulty of calculating non-market values. Despite this, the valuation estimates serve to illustrate the existence of externalities and a need to adjust water management practices in order to reduce negative impacts on water quality.

Over many years, policies to address water pollution from agriculture across OECD countries, and to reduce the economic, environmental and social costs of pollution, have cost taxpayers in the order of billions of dollars annually and provided mixed results (OECD, 2012a). The lack of quantitative information about the benefits of reducing pollution is an obstacle to the formulation of efficient water quality objectives. Indeed, monetary estimates of the advantages are needed if water quality improvement targets are to balance costs and benefits. In an OECD survey on *Reducing water pollution and improving natural resource management,* six countries reported that a lack of information about benefits is a serious problem for water quality reform and recommended further efforts to better quantify them (Denmark, France, Italy, Sweden, Switzerland, United States) (OECD, 2005).

The fundamental challenge for policy makers is to develop water quality policy measures that can achieve environmental goals with the least overall costs for a given level of acceptable risk, including polluters' compliance costs and policy-related transaction costs, taking into account equity and other social factors (OECD, 2015b). Several studies compiled by the United States EPA (2015) have documented in-lake mitigation measures and their costs to remove nutrients from bottom sediments and the water column and their resultant algal blooms. For an individual water body, these costs range from USD 11 000 for a single year of barley straw treatment to more than USD 28 million in capital and USD 1.4 million in annual operations and maintenance for a long-term dredging and alum treatment plan (US EPA, 2015).

Table 2.3. **Estimated annual national costs of water pollution: A selection from OECD countries**

Country	Type of water quality impact	Annual cost (millions) National currency	EUR	USD	Source
Australia	Algal blooms associated with excessive nutrients in freshwater	AUD 180 - 240	109 - 145	116 - 155	Atech, 2000
Belgium	Drinking water treatment costs		120 - 190	167 - 264	Dogot et al., 2010
France	Eutrophication of coastal waters (loss of tourism revenue and cost of cleaning up algae)		100 - 150	139 - 208	Bommelaer and Devaux, 2011
	Agricultural nitrate emissions and pesticides		610 - 1070	695 - 1219	Marcus and Simon, 2015
Korea	Reducing chemical contamination of drinking water			106	Kwak and Russell, 1994
Netherlands	Nitrate and phosphate pollution		403 - 754	371 - 695	Howarth et al., 2001
Spain	Nitrate and phosphate pollution		150	208	Hernandez-Sancho et al., 2010
Sweden	Coastal eutrophication Baltic Sea eutrophication		860 492 - 1466	1257 719 - 2143	Huhtala et al., 2009
Switzerland	Agricultural pollution	CHF 1000	608	690	Pillet et al., 2000
United Kingdom	Drinking water treatment costs, agricultural pollution of surface water, estuaries	GBP 229	335	458	Jacobs et al., 2008
England	Total cumulative cost of water pollution (point and diffuse sources)	GBP 700 - 1300	840 - 1560		National Audit Office, 2010
Europe	Human health and ecosystem impacts from nitrogen pollution of rivers and seas		40-155		Van Grinsven et al., 2013
	Health costs of nitrate in drinking water – colon cancer		1000		van Grinsven et al., 2010
United States	Freshwater eutrophication Protecting aquatic species from nutrient pollution Lakefront property values from nutrient pollution Recreational use from nutrient pollution		1500	2200 44 300 - 2800 370 - 1160	Dodds et al., 2009
	Drinking water impacts from nitrogen pollution Impacts of nitrogen pollution on freshwater ecosystems			19000 78000	Sobota et al., 2015
	Drinking water costs of nitrate contaminated wells			12000	Compton et al., 2011
	Pesticide contamination of groundwater		1610	2000	Pimentel et al., 2005
	Marine algal blooms		32 - 46	34 - 49	Anderson et al., 2000
	Cleaning up leaking underground petroleum storage tanks			800 - 2100	Nixon and Saphores, 2007
	Controlling highway runoff from major highways			2900 -15600	Nixon and Saphores, 2007
	Freshwater pollution by phosphorus and nitrogen			4300+	Kansas State University, 2008
	Health benefits of improving drinking water quality			130-2000	US EPA, 2006
	Costs of gastrointestinal illnesses attributed to drinking water			2100-1380	Garfield et al., 2003
	Health benefits associated with reducing arsenic from 50µg/L to 10 µg/L			140-198	US EPA, 2001
	Health benefits associated with reduction of nitrate exposure to legal safety standards			350	Crutchfield et al., 1997

Source: Updated from OECD (2012b); OECD (2008).

There are also substantial costs associated with restoring impaired waterbodies, such as developing: *i)* total maximum daily loads, minimum water quality standards or nutrient caps; *ii)* catchment management plans, and *iii)* pollution charges, or nutrient trading and pollution offset schemes (US EPA, 2015). For example, there are several trading and offset programmes in the United States that have been developed specifically to assist in nutrient reductions. One developed for the Great Miami River Watershed in Ohio for nitrogen and phosphorus had estimated costs of more than USD 2.4 million across 3 years (US EPA, 2015).

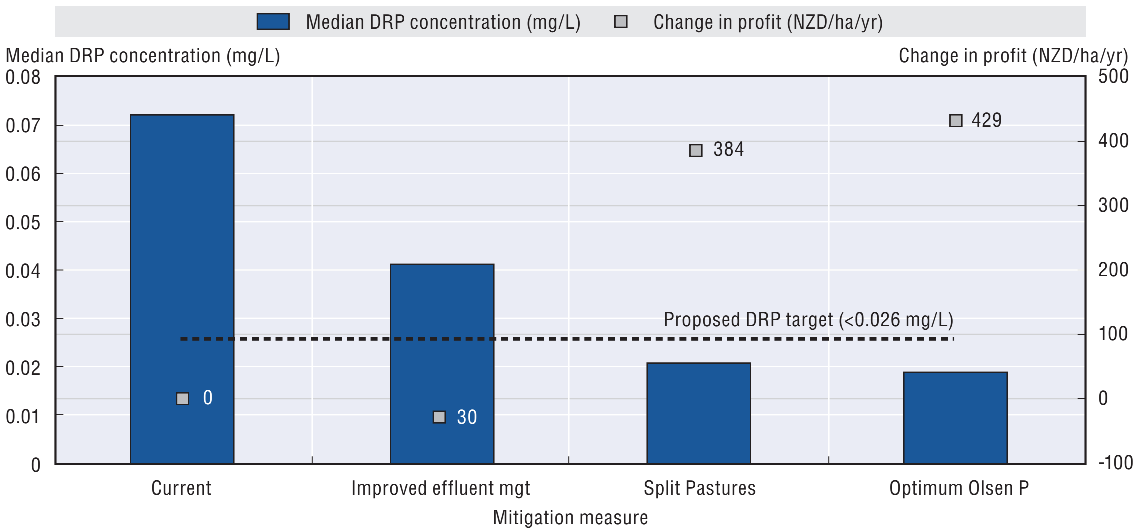
Prevention of diffuse pollution is often more cost effective than treatment/restoration options. In New Zealand, there are 18 recognised management practices that can reduce phosphorus losses from a range of farming enterprises, and each of them have varying cost-effectiveness (Table 2.4). Figure 2.2 shows the change in farm profit from the implementation of three mitigation measures to meet regional policy requirements in a catchment draining a dairy farm in southern New Zealand. In particular, soil testing to ensure optimal fertiliser applications is cost effective in reducing a) fertiliser costs, and b) nutrient losses associated with excess use.

Table 2.4. **Range of cost and effectiveness of management practices to mitigate phosphorus losses from New Zealand dairy farms**

Strategy	Main targeted P form(s)	Cost-range (USD/kg P conserved)	Effectiveness (% total P decrease)
Management			
Optimum soil test P	Dissolved and particulate	(highly cost-effective)[a]	5-20
Low P farming system	Dissolved and particulate	(330)	25-30
Low solubility P fertiliser	Dissolved and particulate	0-20	0-20
Steam fencing	Dissolved and particulate	2-45	10-30
Restricted grazing of cropland	Particulate	30-200	30-50
Greater effluent pond storage / application area	Dissolved and particulate	2-30	10-30
Flood irrigation management	Dissolved and particulate	2-200	40-60
Low rate effluent application to land	Dissolved and particulate	5-35	10-30
Amendment			
Tile drain amendments	Dissolved and particulate	20-75	50
Red mud (bauxite residue)	Dissolved	75-150	20-98
Alum to pasture	Dissolved	110->400	5-30
Alum to grazed cropland	Dissolved	120-220	30
Edge of field			
Grass buffer strips	Dissolved	20->200	0-20
Sorbents in and near streams	Particulate	275	20
Sediment traps	Dissolved and particulate	>400	10-20
Dams and water recycling	Particulate	(200)-400	50-95
Constructed wetlands	Particulate	100->400	-426-77
Natural seepage wetlands	Dissolved and particulate	100->400	<10

Notes: Numbers in parentheses represent net benefit, not cost. a) Depends on existing soil test phosphorus (P) concentration.
Source: McDowell et al. (2016).

Figure 2.2. **Change in median dissolved reactive phosphorus concentration and profitability 5 years after the consecutive implementation of three mitigation strategies in a catchment draining a dairy farm, Otago, New Zealand**



Note: Mitigation strategies to mitigate P loss a mixed model : 1) improving effluent management to prevent ponding and discharge of effluent-P through artificial drainage; 2) splitting mixed pastures into monocultures to have low-P requiring species in runoff producing areas with lower soil Olsen P; 3) lowering fertiliser inputs such that soil Olsen P test concentrations across the rest of the catchment that are no greater than the agronomic optimum. The proposed target refers to the Otago Regional Council policy requirement: <0.026 mg dissolved reactive P (DRP) per litre median concentrations in emissions at baseflow (thereby avoiding variability associated with stormflow).

Source: McDowell et al. (2016).

In a study of benefit to cost ratios of diffuse pollution mitigation measures to reduce agricultural pollutants (nitrogen, BOD, *E. coli* and *Cryptosporidium)* in the United Kingdom, Rothamsted Research (2005) found the most cost effective measures were characterised as relatively low cost and common sense solutions that work within the bounds of current agricultural practice. For example, the integration of manures with fertilisers when planning nutrient applications and avoiding spreading fertiliser at times of high risk. The measures that are least attractive are typically expensive when expressed as a cost-benefit ratio. For example, the reduction of livestock numbers on a farm or retiring land from production.

Modelling can help in determining the most cost-efficient mitigation measures and when and where to best apply them. Modelling demonstrates that the cost-effectiveness of mitigation practices tends to decrease the farther away from the pollution source a practice is implemented (e.g. McDowell and Nash, 2012). Targeting mitigation measures to the right place (i.e. vulnerable areas such as permeable soils, or land in close proximity to a water body) and at the right time (when losses from vulnerable areas are greatest, such as during high rainfall events and the rainy season) can increase farm profitability and reduce pollution mitigation costs. Mitigation measures targeted at one pollutant must also be assessed for potential impacts on other pollutants. For example, soil cultivation or tillage may reduce losses of dissolved reactive phosphorus, but may increase nitrogen losses.

The expected benefits (environmental, social and economic) of a policy response to address water pollution needs to outweigh its expected costs (environmental, social and economic). The cost of not intervening (Table 2.3) must also be taken into consideration in the analysis. Whether policy responses bring larger benefits than costs is an empirical question and has to be examined for each case. Natural capital accounting has the potential to be an effective tool in assessing the costs and benefits of protection of freshwater ecosystems and improvements in water quality. Experience from the United Kingdom is described in Box 2.1. Advances in this area will improve water quality valuation in the future.

Box 2.1. **Natural capital accounting as a tool to value natural resources and ecosystem services: Experience from the United Kingdom**

Natural capital accounting (NCA) provides a basis for valuing natural capital assets, and the ecosystem services they provide, by quantifying the "costs and benefits" of resource management decisions (Clothier et al., 2013; Mackay et al., 2011). Profit and loss statements reflect the cost of externalities of consuming natural resources, and investment in natural capital can be evaluated and weighed up against investment in engineering solutions. Ecological economics and NCA can also guide issues of sustainable development, intergenerational equity, irreversibility of environmental change, uncertainty of long-term outcomes and exploitation of natural resources for short-term profit (Faber, 2008).

The United Kingdom is experimenting with using NCA. They face issues of water scarcity in places, high demand and environmentally unsustainable abstraction in certain regions; and surface and groundwater quality problems from diffuse agricultural and urban pollution, in particular high levels of nitrates and pesticides, despite major investment in point source control. The NCA approach naturally aligns with a catchment-scale approach and demonstrates that multiple benefits can be derived from investing in ecosystems services and natural capital, such as forests, floodplains and wetlands.

The Office for National Statistics (ONS, 2016) uses natural capital accounting to:

- Quantify the losses, gains and relative importance of services provided by natural assets; the development of monetary accounts enables the value of different services to be monitored and comparisons to be made with the value of other economic assets.
- Highlight links with economic activity and pressures on natural capital.
- Inform priorities for resourcing and management decisions.

In a first attempt to develop initial experimental statistics on UK freshwater ecosystem assets and ecosystem services, estimates of the monetary values of UK wetlands and open channels were based on a number of indicators, and the condition of freshwaters between 2008 and 2012 (Khan and Din, 2015). The monetary value of UK freshwaters was estimated at a total of GBP 39.5 billion in 2012, 10% higher than in 2008 (this was mainly due to an increase in the monetary value of UK open waters) (Khan and Din, 2015). These estimates exclude other valuable services such as the traded price of electricity generated by hydropower, which was over GBP 300 million in 2012; GBP 8 million worth of navigation licences, which were issued in England and Wales in 2012/13; and landscape amenity values, which are also important benefits (e.g. property price premiums in close proximity to canals and rivers).

Table 2.5 **Asset values of UK freshwater ecosystems (wetlands and open channels) 2008-12**

(GBP, 2012 prices)

	Freshwater ecosystems GBP billion				
Services	**2008**	**2009**	**2010**	**2011**	**2012**
	Provisioning services				
Fish extraction	1.1	0.9	0.8	1.2	0.9
Water abstraction	18.5	18.7	19.3	20.8	23.9
Peat extraction	0.3	0.3	0.3	0.3	0.2
	Cultural services				
Recreational visits	16.2	15.8	14.9	14.9	14.5
Educational visits[1]	0.0	0.0	0.0	0.0	0.0
Total	36.1	35.8	35.3	37.1	39.5

Note: Results are a gross underestimate of the true value of UK freshwater assets and ecosystems services due to limitations with data. A number of freshwater ecosystems are not included in this valuation. 1. The actual figures for the NPV (in GBP) of educational visits are as follows; (2008) 1.0 million, (2009) 1.0 million, (2010) 1.0 million, (2011) 1.0 million and (2012) 0.9 million.

Sources: Clothier et al. (2013); Faber (2008); Khan and Din (2015); Mackay et al. (2011); ONS (2016); Water UK (2013).

Table 2.6. **Regulatory, economic, and voluntary pollution control mechanisms, directed at source and end-of-pipe**

	Regulatory approaches	Economic instruments	Voluntary / Information instruments
Source-directed approaches	**Standards** E.g. Planning requirements (i.e. environmental impact assessments, nutrient accounting, nutrient management plans, protection zones) Mandatory use of best management practices (i.e. manure storage, riparian zones) Restrictions or bans on the use of chemicals Pesticides and hazardous chemicals registration Cap on modelled diffuse pollution Restrictions on pesticides, fertiliser, manure, effluent, biosolids application rates and timing Input quotas per hectare and restrictions on livestock densities Land retirement requirements (such as riparian buffer strips) Standards to induce the use of new tools, including monitoring and information communication technology. **Liability rules** E.g. Negligence liability rules **Performance labelling** Government requirements for labelling on level of environmental performance	**Taxes** E.g. Taxes on chemical and solvent purchases Taxes on fertiliser or pesticide purchases Taxes on manure applications Taxes on domestic products such as personal care products, detergents **Subsidies** Subsidies that reward inputs, practices, or technologies that prevent pollution Agricultural land retirement subsidies Subsidies for R&D or to induce uptake of new technologies, including monitoring technologies. **Payment for Ecosystem Services** E.g. payment by downstream users to upstream users, in exchange for practices that reduce pollution and protect water quality.	**Contracts/Bonds** E.g. Land retirement contracts Contracts involving the adoption of conservation practices Contracts involving the adoption of nutrient management practices **Best Environmental Practices** E.g. best practices for fertiliser and pesticide applications to reduce runoff **Advisory services** E.g. Farm advisory services and demonstration projects to encourage greater uptake of best environmental practices and improve productivity **Environmental labelling** Products that meet certain environmental standards can be marketed and sold at a premium and/or subsidised. **Corporate Social Responsibility** Investment in practices that reduce pollution to improve corporate image, water stewardship metrics and ISO water footprint standards. Covenants and negotiated agreements Industry code of conduct Private standards (e.g. food and beverage companies requiring suppliers to comply with certain environmental conditions) **Benchmarking** Publicising and ranking polluter's performance **Self-regulation** Polluters acting to regulate themselves Community-based regulation and co-operation agreements **Research and knowledge building** Private and public research to improve understanding of water quality risks Knowledge sharing and problem solving at the community level **Information campaigns** E.g. targeted at households to reduce disposal of chemical waste and unused pharmaceuticals in toilets
End-of-pipe approaches	**Standards** E.g. Permits for discharges with quantity and quality conditions Restrictions on modelled diffuse pollution (i.e. nutrient loadings) **Non-compliance penalties and fines** Non-renewal of resource permits or greater restriction on current permits	**Taxes** E.g. Taxes on volume of point source discharges Taxes on modelled diffuse pollution (i.e. nutrient loadings) Taxes on estimated soil loss **User charges** Sewer surcharge (can incentivise reductions in wastewater from businesses and households and raise revenue to finance wastewater treatment plant upgrades) **Markets** Water quality trading of point discharge permits Water quality trading of modelled diffuse pollution discharge permits Point-non-point trading **Loans** E.g. For investment in WWTPs or artificial wetlands **Subsidies** Subsidies for inputs, practices, or technologies that reduce pollution Subsidies for R&D or to induce uptake of new technologies, including monitoring technologies **Water quality offsets** Liability for pollution and payment for compensation of damage	**Cost-sharing programmes** E.g. PPPs for investment in wastewater treatment plants or decentralised wastewater reuse systems
Cross-sector approaches	**Minimum environmental flows** (for pollution dilution)	**Removal of harmful subsidies** **User charges** Water charges (marginal cost pricing can reduce excessive water use and consequent pollution; and can also raise revenue for drinking water treatment plant upgrades) **Taxes** Taxes on atmospheric pollutant emissions (which can lead to water pollution, i.e. acidification)	

Sources: Adapted from Shortle and Horan (2001); Metz and Ingold (2014).

Generally, reductions in pollution loads, typically by regulatory and voluntary approaches, in OECD countries appear not to have been done so at the lowest cost (Shortle et al., 2012; NAO, 2010; OECD, 2005). The costs of regulation and control of point source pollution have been sizeable in many OECD countries. For example, in the United States, the Environmental Protection Agency considers that the Clean Water Act, which regulates point source discharges through a permitting system, has provided benefits in line with costs. But other authors have found benefit-cost ratios of 1:6 (Freeman, 2003) or even 1:20 for those Clean Water Act regulations that have been subject to regulatory impact assessment between 1981 and 1996 (Hahn, 2000b). Olmstead (2010) argues that the Clean Water Act brought net benefits up to the late 1980s, but that afterwards the incremental costs exceeded the incremental benefits. The costs of preventing the degradation of water quality should receive similar attention.

Appropriate targeting of both point source and diffuse source pollution are key factors that must be taken into account to overcome policy inefficiencies. There is a case for the utilisation of cost-effective prevention and abatement practices that could yield more beneficial results in terms of water quality improvements and control-cost savings (Shortle et al., 2012; Shortle and Horan, 2013). Innovative approaches, such as water quality trading and other economic instruments, offer the possibility of improving the effectiveness and efficiency of water quality programmes (OECD, 2015b; Shortle and Uetake, 2015).

Water pollution control mechanisms in OECD countries

Government intervention to reduce pollution typically takes any one, and almost always a combination of, three basic forms:

1. *Regulation:* setting performance or technology standards to reduce pollution. For example, quantitative limits on the quality and volume of discharge may be specified by a permit and enforced by law. Technology standards may include the specification of minimum technological standards for wastewater treatment plants, such as a requirement for tertiary treatment and the removal of nutrients, using technology such as biological nutrient removal, sand filters or chemical precipitation. There may bans on certain harmful chemicals, restrictions on land use activities and mandatory use of best management practices.
2. *Economic instruments:* taxing environmentally harmful products, pollution charges on emissions, providing economic incentives (i.e. subsidies), and designing tradable permits, to reduce pollution and negative externalities, and/or raise revenue to pay for research, mitigation, adaptation and treatment of poor water quality.
3. *Voluntary or information instruments:* guiding and supporting households, farmers or industry to reduce pollution voluntarily. For example, farmers may be encouraged to fence off stock access to water courses and to provide a riparian strip aimed at interrupting the movement of diffuse nutrient and sediment transfer from agricultural land to surface waters. At the catchment and sub-catchment scale, resource users and industry can be supported in planning for better collaborative outcomes. Households may be informed and encouraged to reduce their impacts by using alternative cleaning products, such as low-phosphate laundry detergent.

With water quality continuing to deteriorate, OECD countries are progressively looking to manage diffuse pollution sources (e.g. the EU Water Framework Directive, US Clean Water Act and New Zealand's National Policy Statement for Freshwater Management). Examples of regulatory, economic, and voluntary pollution control methods are presented in Table 2.6. They are distinguished between source-directed approaches (targeted at reducing or preventing the source of pollution) and end-of-pipe approaches (targeted at reducing the impact of pollution). Chapter 3 will discuss in more detail selected policy instruments to manage diffuse water pollution.

Determining who pays for pollution abatement and water quality improvements

The three primary actors to cover the costs of providing water quality management are: *i)* the polluter; *ii)* the beneficiary; or *iii)* government as outlined below:

- *The Polluter Pays Principle* creates conditions to make pollution a costly activity and to either influence behaviour to reduce pollution, or generate revenues to alleviate pollution and compensate for social costs (OECD, 2012a). Examples include pollution charges, taxes on inputs (such as fertilisers and pesticides), and sewer user charges.
- *The Beneficiary Pays Principle* allows sharing of the financial burden of water quality management. It takes account of the high opportunity cost related to using public funds for the provision of private goods that users can afford. A requisite is that private benefits attached to water resources management are inventoried and valued, beneficiaries are identified, and mechanisms are set to harness them. (OECD, 2012a).
- *Public budgets* (i.e. from general taxation) often cover the costs of providing water quality management functions that serve the public more generally (OECD, 2015c).

There are several challenges that result in the Polluter Pays Principle not frequently being applied in the control of diffuse pollution (it is more commonly used with the control of point source pollution) (Table 2.7). However, despite strong political opposition from polluters, in the instances where high levels of taxes have been applied to inputs to comply with the Polluter Pays Principle, often coupled with a mix of other policy measures, they have usually led to reductions in input use without loss of farm production or income (OECD, 2012c).

The Beneficiary Pays Principle is used to some extent to control diffuse pollution from agriculture, usually on a voluntary basis. For instance, through Payment for Ecosystem Services schemes from downstream utilities to upstream farmers in exchange for land management practices that reduce pollution (OECD, 2015d). However, equity concerns can arise if payments are seen to “reward polluters” while neglecting producers already demonstrating best practice (OECD, 2013). Requiring that minimum regulatory standards to reduce pollution be met before payments are made is one way to overcome equity issues, combining both the Polluter Pays and Beneficiary Pays Principles. A summary of the advantages and challenges of the Polluter Pays and Beneficiary Pays Principles for the control of diffuse pollution are outlined in Table 2.7.

Table 2.7. **Advantages and challenges with the Polluter Pays and Beneficiary Pays Principles for the control of diffuse pollution**

	Polluter Pays Principle	Beneficiary Pays Principle
Advantages	Internalises the external cost of pollution. Provides an opportunity to prevent pollution. Provides an opportunity to adopt best management practices. Provides an opportunity to raise revenue for water quality management. Demonstrated success with high level input taxes have led to reduction in input use and water pollution without loss of farm production.	Allows sharing of the financial burden of water quality management with users that benefit. Provides an opportunity to adopt best management practices. Provides an opportunity to raise revenue for water quality management. Demonstrated success with payment for ecosystem services by downstream utilities to upstream farmers in return for land management practices that reduce pollution.
Challenges	Poor enforcement of existing regulations on diffuse pollution. Diffuse pollution sources are not easily directly measured at reasonable cost with current monitoring technologies (although computer modelling is a cost-effective alternative). Difficulty with identifying and targeting the polluters. Undefined property rights. High transaction costs associated with multiple polluters. Difficulty with determining reliable estimates of potential costs and benefits. Strong political opposition from polluters.	Seen as "rewarding" the polluter. Beneficiaries of water-related services do not usually pay the full cost of the provision of ecosystems, or may free ride. Difficulty with determining reliable estimates of potential costs and benefits. Private financiers are not guaranteed to benefit from payments and may have a reduced incentive to support them: changes in land use management may not lead to water quality benefits, long time-lag before improvements are visible, landowners or their managers may not comply. Difficulty with identifying and targeting the polluters. Undefined property rights.

Sources: OECD (2015c,d; 2013; 2012a,b); Smith and Porter (2010).

When developing policy to manage water quality, an important consideration is not only the measurement of the costs and benefits of water pollution reductions, but also on to whom these costs and benefits will fall. Box 2.2 outlines under which type of policy instrument the costs fall upon.

Box 2.2. **Who pays for, and who receives the benefits of, water quality improvements?**

Water quality improvements come at a cost, and those benefitting from improvements in water quality are not necessarily those who pay for the cost of pollution reduction, and those that pollute do not necessarily pay damage costs. For example, diffuse pollution from agriculture is loading costs onto other sectors as well as the environment. Who bears the costs and reaps the benefits of water quality improvements typically depends on the policy instrument used:

- *Regulations, taxes and markets*: improvements in water quality are usually at the cost of the polluter, the costs of which can be passed onto the consumer.
- *Economic subsidies and incentives*: improvements in water quality are at the cost of the tax payer.
- *Environmental labelling and Corporate Social Responsibility*: improvements in water quality are at the cost of producers, and corporations who sell and manage commercial goods. The cost is ultimately passed onto the consumer.
- *Payment for Ecosystem Services*: changes in management practices that improve water quality are at the direct cost of the beneficiaries.

Without effective policy instruments to reduce pollution, the cost of pollution typically falls on drinking water utilities (and subsequently households) and downstream water users, such as downstream industry and agricultural users, eco-tourism operators, recreational users, and waterfront property owners.

The need for policy coherence

There is a need for coherence across a number of policies - agriculture, energy, industry, economic, spatial and urban planning, waste, construction, transport, climate, and environment (water, air, land and biodiversity). For example, a management approach considering air, water and land management practices to manage nitrogen loading has the potential to be more cost-effective and provide environmental co-benefits[1], as illustrated in Box 2.3.

Box 2.3. **An example of the importance of policy coherence for water quality, Chesapeake Bay, United States**

Agricultural runoff is not the only source of diffuse nitrogen pollution to impact waterways, fallout of atmospheric pollutants also contribute: nitrogen oxides (NOx), sourced primarily from energy and transport emissions, and ammonia (NH_3) sourced primarily from agriculture (in particular, volatilisation of stock manure and effluent).

In one scientific study of Chesapeake Bay, Birch et al. (2011) showed that the damage costs from nitrogen air emissions are much larger in the watershed than those from the whole of land and water emissions. The case demonstrates that a unique focus on metrics relating to the Bay water quality could result in a missed opportunity to prioritise actions on air quality that could have larger benefits, including health, throughout the entire chemical cascade and a much broader geographical area.

In essence, the reduction of Chesapeake Bay damages from nitrogen loading (including freshwater and estuarine impacts) may benefit more from a more strict control of air pollution (at the airshed level) rather than from more strict water pollution controls (at the watershed level) (OECD, forthcoming). Thus, a management approach considering air, water and land management practices to manage nitrogen loading has the potential to be more cost-effective and provide environmental co-benefits.

Sources: Birch M.B. et al. (2011); OECD (forthcoming).

Policy coherence is also required to avoid conflicting signals and incentives, in particular to farmers in achieving sustainable water management (Parris, 2012). Some government non-environmental programmes and subsidies inadvertently work in opposition to efforts to improve water quality. For example, policies that support agriculture production encourage greater land use change and intensive use of inputs, such as fertilisers, pesticides, irrigation, and fossil fuel use (Shortle et al., 2012). Input subsidies can also encourage more intensive use of potentially environmentally harmful inputs. An example of perverse incentives causing an increase in water pollution is presented in Box 2.4.

As water quality is intrinsically linked with water quantity, and both are affected by climate change, the use of various policy instruments in urban water management, and the food, energy, and industrial sectors, can have wider environmental and social impacts. Cities can also be a part of the solution. For example, taxes on impervious surfaces in urban areas can incentivise reductions in stormwater runoff and finance a greater proportion of urban land to be connected to a drainage system with stormwater treatment. In Austin, Texas, drainage fees are used to reduce risks of flash flooding, erosion and water pollution (City of Austin, 2016). In Santa Monica, California, stormwater property taxes are used to fund the city's watershed management programme and it's obligation to comply with federal and state Clean Water Act regulations (City of Santa Monica, 2016).

Box 2.4. **Perverse subsidies for bioethanol production, United States**

While biofuels may yield renewable fuel benefits, there could be downsides in terms of water quality and other environmental stressors.

US government support for ethanol production has resulted in higher corn prices globally. In turn, this has incentivised intensification and extensification of corn production. As a result, nutrients and pesticides entering US water bodies has increased, and conservation land has decreased. Increased corn production in the Midwest of the US is also thought to have increased nutrient loading to the Gulf of Mexico.

Higher corn prices attributable to the US ethanol policy are estimated to reduce land offered into the US Conservation Reserve Programme by about 5%. In addition, about a third of land currently enrolled in the programme is likely opt-out to take advantage of higher corn prices if there were no penalties for doing so. This not only impacts biodiversity, but also reduces the water filtration ecosystem services that conservation land provides. Furthermore, despite the good intentions of biofuels to reduce greenhouse gas emissions and mitigate climate change, global emissions of greenhouse gases are likely to have actually increased as ethanol policies may have created global changes in land use by reducing forest land and grassland that act as greenhouse gas sinks.

Sources: Hanley et al. (2013); Hellerstein and Malcolm (2011); Searchinger et al. (2008); Secchi et al. (2011); Shortle et al. (2012).

Special consideration will need to be given to policy design to ensure that policies are responsive and flexible in adapting to future changes, and particular consideration be given to the effects of climate policies on water quality. The following section elaborates on the potential trade-offs and the need for policy coherence between climate and water quality policies. Similarly, there will also be trade-offs between policies with other sectors, in particular agriculture and energy.

The potential effects of climate change mitigation and adaptation policies on water quality

Some measures to reduce greenhouse gases and adapt to climate change may conflict with existing efforts and regulations to improve and maintain water quality (Fezzi et al., 2015; IPCC, 2014; OECD, 2014). Such trade-offs have received little consideration in decision-making, policy design and academia (Fezzi et al., 2015). For example, climate adaptation by way of increased irrigated agriculture can generate significant adverse impacts on water quality. In Great Britain, the area of land at risk of high nutrient loading in water bodies is projected to increase by 30-40% as a result of climate change adaptation measures taken by farmers (Fezzi et al., 2015). Hydropower can modify the natural flow of watercourses, which may have some effects on capacity for dilution of point source pollution and on freshwater ecosystems. Carbon capture and storage may decrease groundwater quality, causing acidification of freshwater aquifers due to leakage of pipes, and salt water intrusion of freshwater aquifers due to displacement of saline formations (IPCC, 2014).

A summary of the potential trade-offs and co-benefits between climate change mitigation/adaptation measures and water quality are presented in Table 2.8. The impacts on water quality demonstrate the importance of anticipating trade-offs and the wider impacts of climate change mitigation and adaptation measures when designing environmental policies. Conversely, when climate change mitigation and adaption policies are well-designed and the trade-offs managed, they can produce multiple benefits for food and water security, human health, air and water quality, and natural resource management. For example, soil carbon sequestration can increase nutrient and water retention and resilience to droughts and flooding (OECD, 2014). Riparian vegetation can provide cooling effects on in-stream temperatures (Davies, 2010), as well as enhance biodiversity, provide erosion control and filter pollutants (Pittock, 2009).

In order to create the conditions needed for win-win outcomes, better integration and implementation of policies and programs at all scales is required (Measham et al., 2011; IPCC, 2014). Furthermore, more studies are required to establish baselines to isolate the water quality impacts derived from climate change from other anthropogenic pollution causes, and to assess the vulnerability and ways of adapting to those impacts (IPCC, 2014). Modelling of various scenarios can offer a way forward but management decisions need to account for uncertainties around climate change projections regionally and locally, and the impacts on water quality.

Table 2.8. **Examples of potential trade-offs and co-benefits between climate change mitigation/adaptation measures and water quality**

Climate change mitigation	Climate change adaptation
Trade-offs	***Trade-offs***
Construction of hydropower dams and dykes can impact freshwater ecosystems, contribute to thermal pollution and may cause some sediment loads when sediment is released. Bioenergy crops increase water demand and decrease water quality and food security. Carbon capture and storage can decrease groundwater quality, causing acidification of freshwater aquifers due to leakage of pipes, and salt water intrusion of freshwater aquifers due to displacement of saline formations. Concentrated solar power as a form of renewable energy requires substantial volumes of water for cooling (EWEA, 2014) and therefore can contribute to thermal pollution of water bodies. Fracking for shale gas can contaminate aquifers with hydrocarbons and other toxic pollutants, and can lead to groundwater salinisation, potentially putting drinking water supplies at risk.	Increased intensive and irrigated agriculture can lead to greater loads of nutrients, pathogens, pesticides, sediment and other pollutants, and reduce environmental flows in rivers for pollution dilution. Increased groundwater abstraction can cause salt water intrusion, and if used for irrigation, can cause salinization of soils and groundwater contamination from leaching of nutrients, pathogens, pesticides and other pollutants. Construction of irrigation dams and dykes can impact freshwater ecosystems and cause a sudden flux of sediment when sediment released. Impounded storage may have some effects on environmental flows and capacity for dilution of point sources. Urban wetlands designed primarily for flood control can promote mosquito breeding.
Co-benefits	***Co-benefits***
Conservation and afforestation of water catchments reduces soil erosion and local flood risk, and improves water quality (nitrogen, phosphorus, suspended sediments) and instream habitat quality. Conservation of wetlands provides multiple benefits, such as water purification, water supply, flood regulation and biodiversity. Stacking water quality credits with carbon credits increases the profitability of carbon sequestration practices, and vice versa. For example, the provision of CO_2-eq offsets through reductions of nitrogen fertiliser applications or through the establishment of green riparian buffer strips may not profitable without water quality credits. Allowing stacking increases participation and uptake of mutually beneficial environmental practices. Soil carbon sequestration and build-up of soil organic matter can increase the capability of the soil to filter and retain water and nutrients. Conservation tillage and agroforestry can reduce soil erosion and improve water quality. Precision agriculture (irrigation and nutrient) can reduce runoff of nutrients. Nitrogen inhibitors can reduce nitrate losses to water bodies.	Precision agriculture (irrigation and nutrients) and water use efficiency can improve water quality. Soil carbon sequestration and building up organic matter can improve soil moisture and nutrient retention. Development of adaptation plans to maintain optimal farming conditions are also an opportunity to combine with water quality objectives. Wastewater reuse can provide a reliable source of water for irrigation, and returns nutrients to the land without the need to discharge effluent directly to water bodies or use synthetic fertilisers. Water efficient cultivars reduce water consumption and therefore potentially water pollution.

Sources: EWEA (2014); Lankoski et al. (2015); Millennium Ecosystem Assessment (2005); OECD (2014).

Note

1. Co-benefits from the water quality perspective: additional benefits beyond improvements in water quality resulting from pollution mitigation measures. Examples of potential co-benefits may include improved ecosystem and human health, reduced greenhouse gas emissions, improved air quality etc.

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From:

Diffuse Pollution, Degraded Waters

Emerging Policy Solutions

Access the complete publication at:

https://doi.org/10.1787/9789264269064-en

Please cite this chapter as:

OECD (2017), “Economic costs and policy approaches to control diffuse source water pollution”, in *Diffuse Pollution, Degraded Waters: Emerging Policy Solutions*, OECD Publishing, Paris.

DOI: https://doi.org/10.1787/9789264269064-6-en

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