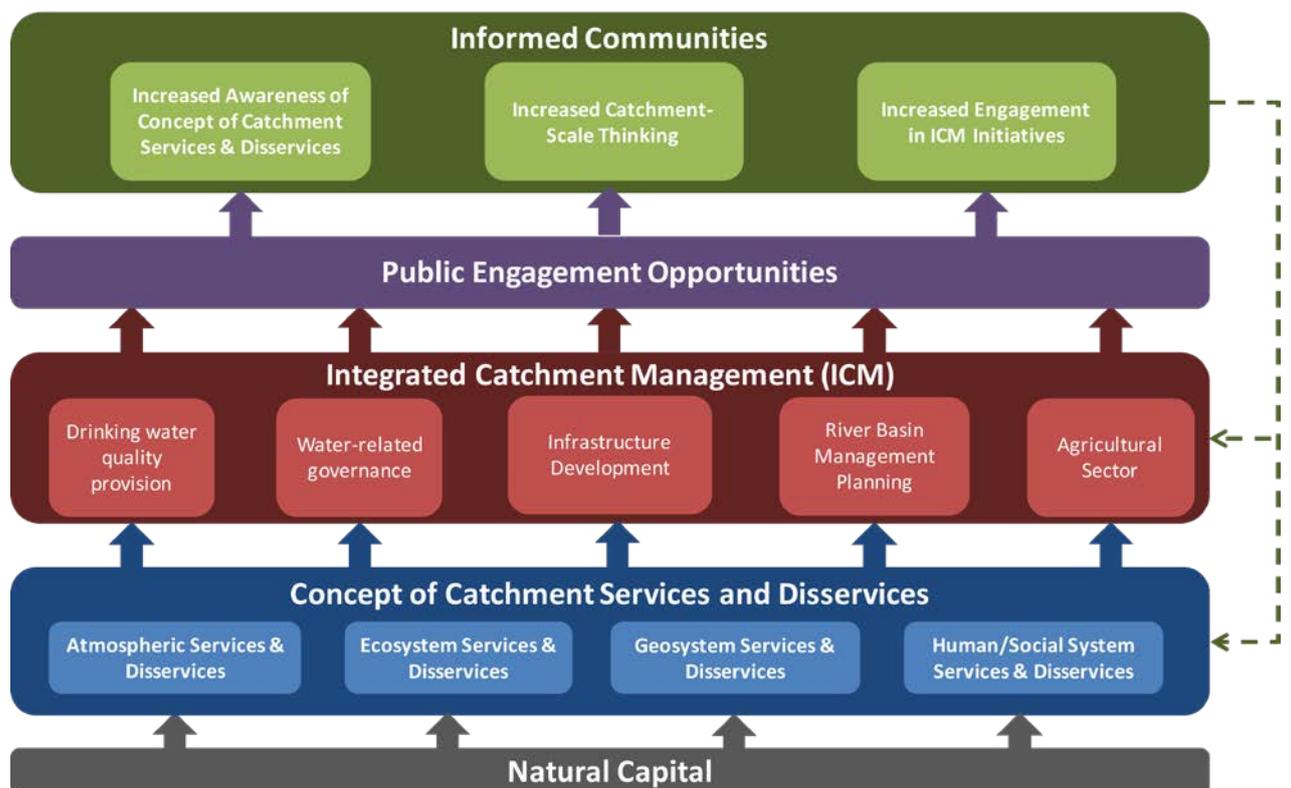


Developing the Concept of Catchment Services for Progress Towards Integrated Water Management (Extra TIME)

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- Office of Radiation Protection and Environmental Monitoring
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Cover image: Concept of catchment services and disservices.

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The EPA Research Programme addresses the need for research in Ireland to inform policymakers and other stakeholders on a range of questions in relation to environmental protection. These reports are intended as contributions to the necessary debate on the protection of the environment.

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Defining Catchment Services and Disservices

Throughout this report, the following definitions of the concept of catchment services and disservices and its key components of atmospheric services, ecosystem services, geosystem services and human/social system services are used:

- **Catchment services** are the benefits received by ecosystems and humans from resources and processes that are supplied by catchments (adapted from Wagener *et al.*, 2008). Catchment services are delivered within catchments but are not necessarily bound by the geographical area of a catchment. Catchment services comprise:
 - **Atmospheric services** – the physical attributes of climate, weather and the atmosphere that contribute to the functions and processes within a catchment, and have an impact on the services that catchments provide. Examples include wind, rain, sunshine, cloud cover, protection from solar radiation and the facilitation of gaseous exchange.
 - **Ecosystem services** – the benefits people obtain from ecosystems. These benefits can be apportioned into four distinct types of services: *provisioning services* (products obtained from ecosystems, including food, fibre, genetic resources, biochemical resources, natural medicines, pharmaceuticals and fresh water); *regulating services* (the benefits obtained from the regulation of ecosystem processes, including the regulation of climate, water and some human diseases); *cultural services* (the non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation and aesthetic experiences); and *supporting services* (the services that are necessary for the production of all other ecosystem services, including soil formation, photosynthesis, primary production, nutrient cycling and water cycling) (Millennium Ecosystems Assessment, 2005).
 - **Geosystem services** – the goods and services that contribute to human well-being specifically resulting from the subsurface (the zone below the earth's surface) (Van Ree and van Beukering, 2016). This excludes those areas that interact with overlying ecosystems (such as soils).
- **Human/social system services** – extending beyond cultural services (described above as part of the ecosystem service component) to also include the social associations derived from living in, working in and visiting a catchment area. Examples include community (housing, social linkages and sport); agriculture; energy production (hydroelectric, solar, wind and geothermal energy); transport (roads, rivers and canals); history (mythology, and natural and built heritage); industry (water mills, mining, quarrying and licensed pollution discharges); and wastewater treatment (Daly, 2015).
- **Catchment disservices** are the adverse consequences to ecosystems and humans resulting from resources and processes supplied by catchments, but not necessarily bound by the geographical area of the catchment. Catchment disservices comprise:
 - **Atmospheric disservices** – aspects of climate, weather and the atmosphere that are detrimental to functions and processes within catchments and to human well-being. Examples include episodic climatic events (e.g. heavy rainfall and tornados) and the dispersal of contaminants through the atmosphere (e.g. from natural events such as wildfires and volcanic eruptions, or from industrial accidents).
 - **Ecosystem disservices** – functions, structures and aspects of ecosystems that are perceived as being detrimental to human well-being (Lyytmäki and Sipliä, 2009; von Döhren and Haase, 2015). Examples include negative impacts of water, soil or air pollution on human health (von Döhren and Haase, 2015).
 - **Geosystem disservices** – aspects of geosystems that are detrimental to human

well-being, such as the natural delivery of contaminants from groundwaters to surface waters and the emission of radon gas by subsurface rocks.

- **Human/social system disservices** – aspects of human actions that are detrimental to

human well-being. Examples include pollution of water resources by diffuse and point source pollution; pollution caused by mining; and the flooding of infrastructure built in flood-prone areas.

Executive Summary

The overarching objective of the Developing the Concept of Catchment Services for Progress Towards Integrated Water Management (Extra TIME) Project was to identify mechanisms for the feasible delivery of the concept of catchment services and disservices in Ireland over the period 2016–2020. The Extra TIME Project successfully achieved the delivery of five work packages.

Work Package One reviewed national and international literature and initiatives that contribute to the concept of catchments as providers of both services and disservices (respectively beneficial and detrimental resources or processes in relation to ecosystems and humans). Services and disservices can be delivered through four key components: the atmosphere; ecosystems; geosystems; and human/social systems. Atmospheric services and disservices are the physical attributes of climate, weather and the atmosphere that contribute to functions and processes occurring within catchments and have an impact on the services and disservices that catchments provide. Ecosystem services and disservices are obtained from ecosystems and can be apportioned into four types: provisioning, regulating, cultural and supporting; geosystem services and disservices are the positive and negative contributions received from the subsurface; and human/social system services and disservices relate to the social associations derived from living in, working in and visiting a catchment area.

Work Package Two assessed the influence of multi-factorial scenarios on key components of the concept of catchment services and disservices. A framework for assessing the influence of three drivers of change (climate change, legislative/policy change and socio-demographic change) that is applicable at both the catchment and sub-catchment scale was developed. A number of key catchment services and disservices were identified through Work Package One and their sensitivity to climate change (and environmental stressors), legislative/policy change and socio-demographic change was assessed. Atmospheric services and disservices were not included in this assessment, as they are themselves integral

components of climate change projection outputs and are unlikely to be influenced by the national-scale policies and socio-demographic change assessed in this report.

Climate Change and Environmental Stressors

Catchment services were found to be typically more sensitive to key environmental stressors than were catchment disservices. The latter were generally more sensitive to future climate change projections. Cultural ecosystem services were typically less sensitive to both climate change and environmental stressors than most provisioning, regulating and supporting ecosystem services. Water balance/yield was the ecosystem service most sensitive to future climate change projections, while habitat was the ecosystem service most sensitive to environmental stressors.

Geosystem services were typically more sensitive to future climate change projections than to environmental stressors. Aquifer recharge was the geosystem service most sensitive to future climate change projections, while groundwater resources had the greatest sensitivity to environmental stressors.

Human/social system services generally had low sensitivity to both future climate change projections and environmental stressors. However, crop yield and water abstraction were found to have the highest sensitivity to both climate change projections and environmental stressors of all human/social system services.

Among catchment disservices, the over-abstraction of water resources, flooding and drought were found to be most sensitive to future climate change projections, while the delivery of contaminants from groundwater to surface water and abstraction points was the disservice most sensitive to environmental stressors.

Legislation and Policy

Environmental legislation and policy associated with catchment services generally aim to improve environmental quality and are less likely to negatively

affect the services provided by the catchments they target. In addition, legislation and policy associated with catchment disservices (such as flooding) typically aim to mitigate the impact of the disservice. As policy is more likely than legislation to change in the shorter term as a result of political and social change, it has the potential to both directly and indirectly have more frequent impacts on a wide variety of catchment services and disservices. Given the difficulties in predicting how policy and legislation may change in the future, the potential impacts (both direct and indirect) of three current catchment-related policies in Ireland [Food Wise 2025, Forestry 2030, and the Rural Development Plan (RDP)] were assessed. Given the likelihood that these policies would have little, if any, impact on atmospheric services at the catchment scale, atmospheric services were not included in this assessment (note: agriculture and forestry can affect climate services at wider scales than catchments/sub-catchments). Food Wise 2025 was found to directly affect the production of food and fibre, increasing crop yields and animal productivity, and increasing industry at national level. However, Food Wise 2025 may also indirectly influence change in the availability, timing and frequency of river flows (water balance/yield) as a result of changes in abstraction; the presence of habitats (and biodiversity) following changes in land use; levels of pollination due to increases and decreases in certain plant and crop species; and groundwater resources as a result of changes in abstraction and land management practices.

Forestry 2030 will probably increase the production of fibre, but may influence change in carbon sequestration; the aesthetic appeal of the landscape as woodlands and forests are planted; the enrichment of land leading to eutrophication; biodiversity and the presence of native and non-native species; and the delivery of contaminants to groundwaters, surface waters and abstraction points.

The RDP has a greater social focus than either Food Wise 2025 or Forestry 2030, while also encouraging sustainable agricultural productivity through agri-environmental schemes. The RDP will directly influence change in education and it aims to preserve heritage, but it may also indirectly result in changes in land use, for example drainage of wetlands.

Integrated policy development is needed to work across the land use and water management realms that underpin the principles of Integrated Catchment Management (ICM) and the concept of catchment services and disservices. Such integration will assist in optimising the delivery of and minimising negative impacts on catchment services, and help to remediate or negate the delivery of catchment disservices, in comparison with the current situation, in which fragmented sectoral policy development can lead to negative impacts on some catchment services.

Social Demographics

Ireland has undergone significant social demographic change throughout its history. Changes in population demographics can have important economic and social implications, and can have an impact on the delivery of both catchment services and disservices depending on land use change, social planning, agricultural productivity, labour supply, habitat protection and water resources management.

Ireland's population is projected to rise to 6.6 million by 2045, and the Greater Dublin Area is expected to account for 64% of the state's total population growth between 2011 and 2051. Population growth within the Greater Dublin Area will affect 9 of the 46 catchments (and 77 subsequent sub-catchments) delineated as part of the second round of European Union (EU) Water Framework Directive (WFD) river basin management planning. The greatest numbers of dwellings in this area, representing 28% of the national total, are located within the Liffey and Dublin Bay catchment. It is therefore likely that the Liffey and Dublin Bay catchment and its 17 sub-catchments will experience the greatest impacts of projected population growth. Such impacts may include habitat loss, increased infrastructure development, deteriorated surface water and groundwater quality, increased litter dumping, loss of agricultural area and increased urban sprawl. The mitigation of such impacts will be dependent on the relevant housing, infrastructure and social planning policies that are implemented to manage the projected population growth of the area.

Work Package Three identified the implications of implementing the concept of catchment services

and disservices for community engagement. Three overarching aims were outlined for developing a community engagement framework for the concept: (1) to increase awareness within communities of the concept of catchment services and disservices; (2) to increase catchment-scale thinking among local communities; and (3) to increase community involvement in catchment management initiatives. A total of 10 actions were identified that would assist in achieving these three aims, to be delivered across a range of levels of engagement, requiring a range of resources (from moderate to high) and requiring action within and external to the proposed WFD implementation structure. The 10 actions (in ascending order of required resources) are to:

1. ensure that an outline of the concept of catchment services and disservices is included in all community-attended catchment-related presentations;
2. provide information on the concept of catchment services and disservices on relevant agency websites;
3. engage relevant printed media to publish content related to catchment services/disservices;
4. include a requirement that community-led responses to relevant funding calls address projects' applicability to the concept of catchment services and disservices;
5. provide an informative leaflet summarising the concept of catchment services and disservices;
6. develop interactive web-based media with a focus on catchment services and disservices;
7. promote local community involvement in catchment management activities underpinned by the concept of catchment services and disservices;
8. hold community information sessions to share knowledge of specific catchments and current and future management actions related to the concept of catchment services and disservices;
9. monitor the socio-economic impact of catchment services/disservices-related policy and legislation, to understand their impacts on local communities and how communities are involved in their implementation;
10. implement a funding programme initiative that is open only to projects aiming to protect or enhance identified catchment services or mitigate identified catchment disservices (including community-based or community-focused funding initiatives).

While the development of an engagement framework is essential for the delivery of the concept of catchment services and disservices resulting in informed communities, it is also acknowledged that significant engagement is required within and external to the proposed WFD implementation structure in order to fully implement the concept. A five-phase approach is outlined to communicate the concept of catchment services and disservices within the WFD implementation structure and within local communities. The five phases will ensure that the concept of catchment services and disservices is used to underpin ICM in Ireland. They are: Phase One – communications preparation; Phase Two – initial engagement within the WFD implementation structure; Phase Three – further external engagement; Phase Four – expansive roll-out of the concept of catchment services and disservices; and Phase Five – review and follow-up.

Work Package Four investigated the implications for governance frameworks and regulations. An assessment was undertaken of the gaps that exist between (1) the ideal situation, where the concept of catchment services and disservices informs all aspects of water resources management in Ireland, and (2) the current governance framework for water resources management in Ireland. The overarching aim of this gap analysis was to identify pathways to increase awareness of the concept of catchment services and disservices, and to move towards identifying ways in which the concept informs all aspects of water resources management in Ireland. Thirteen key gaps were identified:

1. lack of awareness or consideration across (1) levels of governance and (2) local communities of catchments acting as a service provider;
2. lack of consistent and integrated catchment-scale thinking at both agency and community levels;
3. lack of a clear communications strategy for promoting the concept of catchment services and disservices;

4. lack of guidance on how the implementation of multiple regulations can affect the delivery of catchment services and disservices;
 5. lack of understanding of the differing values people associate with catchments and how these values diversify or diverge between different catchments and sub-catchments;
 6. lack of consistent co-ordinated cross-agency management at both the catchment and sub-catchment scales to accommodate issues relating to catchment areas that lie across multiple jurisdictional boundaries (note: this gap may be filled through the Regional Local Authority Structures outlined in the second cycle River Basin Management Plan);
 7. lack of understanding of how different socio-economic groups use and value their catchments and sub-catchments;
 8. limited number of ICM-focused initiatives that are driven by the concept of catchment services and disservices, and aim to improve targeted service delivery or remediate/negate targeted disservice delivery;
 9. lack of funding initiatives aligned with the concept of catchment services and disservices;
 10. need for suitable monitoring and evaluation of the impact of ICM initiatives on the delivery of catchment services and disservices;
 11. lack of quantitative data on many catchment services and disservices;
 12. lack of appropriate indicators, developed in an integrated manner between policymakers, catchment managers, and the scientific and social research communities, aiming to direct monitoring and evaluation of changes in catchment service/ disservice delivery;
 13. lack of national-, regional-, catchment- and sub-catchment-scale mapping of key catchment services/disservices provision.
- A wider focus on general water management is needed that includes actions not directly associated with WFD implementation and reporting.
 - Organisations involved in water management and key stakeholders associated with delivering the concept of catchment services and disservices in Ireland need to be clearly identified and their interactions mapped.
 - Greater interaction within and between stakeholders is necessary.
 - A wider definition of the term “governance” as including democratic dialogue, negotiation and citizen participation is needed, to move beyond the single definition of governance as a mechanism to implement legislation.

The implications for implementing the concept of catchment services and disservices on water-related regulations include that agencies implementing the regulations need clear guidance on how the concept can inform such implementation, and an understanding of how multiple services and disservices may be affected by the regulations and their enforcement.

Work Package Five assessed the feasibility of implementing the concept of catchment services and disservices in Ireland. The strengths, weaknesses, opportunities and threats (SWOT) of the concept were described. It was identified that the implementation of the concept is feasible, despite a number of legitimate weaknesses and threats to the concept. These weaknesses and threats can be mitigated by a combination of the development of a communications strategy for the concept; strong, frequent and inclusive stakeholder engagement; and clear and consistent communication and awareness-raising.

An important threat to implementing the concept is the ability of both individuals and organisations to cope with change. Implementing the concept of catchment services and disservices has the potential to introduce:

- change in understanding the role and function of a catchment;
- change in assessing the impact of management actions within a catchment;
- change in the design and delivery of projects;
- change in stakeholder identification and engagement;

The gaps suggest that a number of modifications are required in the current water governance structure in Ireland in relation to the delivery of the concept of catchment services and disservices:

- change in policy;
- change in organisational structure;
- change in roles and responsibilities.

How the concept of catchment services and disservices is communicated to individuals and organisations will be vital to ensuring that the negative impacts of such change described above are minimised.

Conclusions

The potential for promoting the concept of catchment services and disservices among both governing agencies and local communities, and using the concept to underpin key policy initiatives, will be high in the short-term future. The second round and future rounds of WFD river basin management planning, as well as the National Planning Framework (Ireland 2040 – Our Plan), provide opportunities to use the concept of catchment services and disservices to inform the development of key policies. Engagement within and external to the proposed WFD implementation structure is needed in order to achieve this.

The National Planning Framework shows that there is an existing base of understanding of the potential of the catchment as a geographical unit for management; the provision of services by ecosystems; and the potential for the delivery of services to be affected by climate change, legislation/policy change and socio-demographic change. This existing knowledge base can therefore be expanded and developed through targeted communication and engagement to assist in the delivery of the concept of catchment services and disservices.

In this manner, a key function of ICM in Ireland will develop, moving from a concept aimed primarily at delivering environmental benefits in order to implement the WFD in Ireland to a process that influences national policy at the highest level, underpinned by (1) the concept of catchment services and disservices; and (2) the use of the catchment as the geographical basis for infrastructure development, social development and water resources management in Ireland.

Recommendations

Given the feasibility of implementing the concept of catchment services and disservices to inform water

resources management in Ireland as identified in this report, the following recommendations are made:

1. Fill the key gaps that are currently present that prevent the concept of catchment services and disservices from informing all aspects of water resources management in Ireland, as listed under Work Package Four.
2. Undertake a five-phase approach to engagement regarding the concept of catchment services and disservices, as described under Work Package Three.
3. Prioritise the concept of catchment services and disservices as a key informative platform to facilitate integrated policy development; for example, utilise current opportunities to engage the relevant stakeholders to ensure that the concept informs the second round of EU WFD river basin management planning and the National Planning Framework, and is fully integrated into the third round of river basin management planning.
4. Undertake a cost–benefit analysis for the key actions required to fully implement the concept of catchment services and disservices.
5. Provide guidelines for regulatory authorities regarding how the implementation of multiple regulations can affect on the delivery of catchment services and disservices.
6. Undertake research to provide further understanding of the economic and social importance of the concept of catchment services and disservices:
 - (a) assess the economic value of key catchment services and disservices;
 - (b) assess the social value of key catchment services and disservices;
 - (c) assess how the economic and social values of key catchment services and disservices change within and between catchments, sub-catchments and socio-economic groups.

The results of these research investigations should form the basis for the development of guidance for the general public on recognising and prioritising the protection of catchment services and the mitigation of catchment disservices.

1 Work Package One: Review of National and International Literature and Initiatives that Contribute to the Concept of Catchment Services and Disservices

Work Package One describes the concept of catchment services and disservices through the review of associated literature, and identification of projects and initiatives that have incorporated key components of the concept.

1.1 Catchment Services and Disservices

A catchment area can be defined as all of the land that channels rainwater and groundwater into a river or stream, which then typically delivers water to coastal areas (Wilkinson and Brodie, 2011). River catchments and their multiple uses are typical examples of social–ecological systems where sustainability assessment requires integrated ecological, economic and institutional approaches that take account of institutional change (Mongruel *et al.*, 2011). Catchment services and disservices are the benefits and disservices received by ecosystems and humans from resources and processes that are supplied by catchments (Wagener *et al.*, 2008), and are delivered within catchments but not necessarily bound by the geographical area of a catchment. Catchment services include:

- **Atmospheric services:** the physical attributes of climate, weather and the atmosphere that contribute to the functions and processes within a catchment and have an impact on the services that catchments provide. Examples include wind; rain; sunshine; cloud cover; protection from solar radiation; and the facilitation of gaseous exchange.
- **Ecosystem services:** the benefits that are derived from ecosystems. These include crops; livestock; terrestrial and aquatic flora and fauna; pollination; riparian zones for water purification; soil ecosystems for attenuating pollutants and increasing crop production; and cultural values associated with wildlife.
- **Geosystem services:** the goods and services provided by geosystems that contribute to

human well-being specifically resulting from the subsurface (the zone below the earth's surface) (Van Ree and van Beukering, 2016). This excludes those areas that interact with overlying ecosystems. Geosystem services include aggregates from bedrock and gravel; groundwater for drinking water and geothermal energy; chemical and physical attenuating media for pollutants; geological heritage sites; minerals; oil/gas; caves; and cultural values associated with landscape features.

- **Human/social system services:** the variety of social and cultural services that contribute to the life within a catchment. These include housing; farming (both intensive and extensive); mining; quarrying; wind farms; water abstraction facilities; roads; landfills; industries; cultural values associated with historical features and buildings, such as ring forts, castles and holy wells; water mills; pathways along streams and canals; and other recreational facilities (Figure 1.1; Daly, 2015).

Catchment disservices include:

- **Atmospheric disservices:** aspects of climate and weather that are detrimental to functions and processes within catchments, for example episodic climatic events such as heavy rainfall.
- **Ecosystem disservices:** the functions, structures and aspects of ecosystems that are perceived as being detrimental to human well-being. These include negative impacts of water, soil or air pollution on human health; excessive primary productivity; the proliferation of non-native species; offensive-smelling decomposing organic matter; and water quality deterioration following landslides or bog bursts.
- **Geosystem disservices:** the aspects of geosystems that are detrimental to human well-being that extend more widely than geohazards, such as earthquakes. Examples include the delivery of contaminants from groundwaters to

surface waters and the emission of radon gas by subsurface rocks.

- **Human/social system disservices:** the aspects of human actions that are detrimental to human well-being. These include pollution of water resources by diffuse and point source pollution; pollution caused by mining; and the flooding of infrastructure in flood-prone areas.

Understanding catchment services can provide a new way to advance the understanding of the benefits for both humans and ecosystems that are derived from catchments, and how these benefits will change in a non-stationary world (Wagener *et al.*, 2008). With catchment-based initiatives in England estimated to cost over £100 billion between 2015 and 2030 (Indepen, 2014), the necessity to ensure understanding and recognition of the importance of catchment-based thinking and catchment services and disservices in Ireland is paramount to ensure cost-effectiveness of actions and engagement with, and ownership of, catchment-based actions by local communities. There are significant challenges associated with managing multiple services simultaneously, as, historically, ecosystem and catchment management that attempts to maximise the production of one ecosystem or catchment service often results in substantial declines in the provision of other services (Bennett *et al.*, 2009). For example, increasing timber and food services globally has frequently led to a decline in other services such as flood control, genetic resources or pollination (Millennium Ecosystem Assessment, 2005). Indeed, with pressures on river ecosystems likely to grow because of catchment land use intensification, increasing water resource demands and accelerating

climate change, understanding how services are both provided and compromised within catchments can significantly improve catchment management and planning (Durance *et al.*, 2016). Therefore, the value of catchment processes and their associated services is being increasingly recognised within the water industry as a method for facilitating improvements in water quality and quantity through catchment land management, rather than using the expensive approach of treating contaminated water abstracted from the lower regions of catchments (Everard, 2012). However, a lack of understanding of the processes that underpin catchment services has often led to mismanagement of catchments, resulting in negative economic and social consequences (i.e. disservices) (Durance *et al.*, 2016).

One of the criticisms of the ecosystem services concept is the differentiation between ecosystem functioning and ecosystem services, including the recognition that a minimal level of biotic and abiotic resources is required for an ecosystem to function, and that human well-being is ultimately dependent on these underlying processes (Cook and Spray, 2012). Therefore, the concept of catchment services and disservices attempts to bridge this gap by incorporating abiotic, biotic and human well-being processes within its four key components of atmospheric, ecosystem, geosystem and human/social system services. Given the complex nature of catchments and the multiple interactions of atmospheric, ecosystem, geosystem and human/social system services, developing an understanding of such interactions at the catchment level and communicating these interactions to instil catchment-level thinking at multiple levels (from governing agencies through to

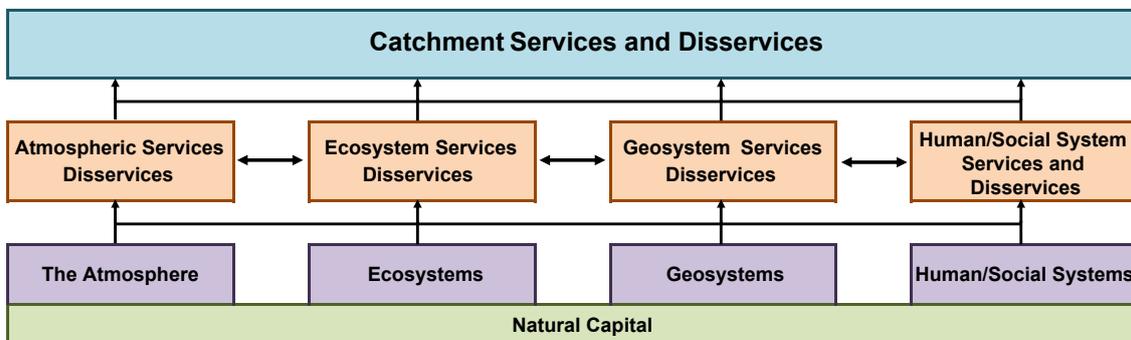


Figure 1.1. Natural capital forms the foundation upon which the atmosphere, ecosystems, geosystems, and human/social systems interact to deliver services and disservices that together form the holistic concept of catchment services and disservices (adapted from Daly, 2015).

the general public) is a significant challenge for the concept of catchment services and disservices.

1.1.1 Atmospheric services

In contrast to the other key components of catchment services and disservices, which are delivered *within* a catchment, atmospheric services are typically delivered *to* a catchment. The quality of the air plays a significant role in maintaining public health, providing quality of life and supporting the natural environment, including valuable natural resources (Everard *et al.*, 2013). In addition, human beings have developed mechanisms to harness energy from atmospheric services (e.g. wind and solar energy). Atmospheric services have loosely been included in attempts to value ecosystem services (e.g. Costanza *et al.*, 1997), although studies of ecosystem services have typically ignored the atmosphere (Thornes *et al.*, 2010). This may be a result of a tendency to treat the atmosphere as a source of hazard (i.e. atmospheric disservices) as opposed to benefit (Cooter *et al.*, 2013). There have been several attempts to align atmospheric services with the ecosystem services concept (Thornes *et al.*, 2010; Cooter *et al.*, 2013; Everard *et al.*, 2013), and Thornes *et al.* (2010) identified 12 atmospheric services that human beings rely on for their existence on Earth:

1. the air that we breathe;
2. protection from radiation, plasma and meteors;
3. natural global warming of 33°C;
4. the cleansing capacity of the atmosphere and dispersion of air pollution;
5. the redistribution of water services;
6. direct use of the atmosphere for ecosystems and agriculture;
7. combustion of fuel;
8. direct use of the atmosphere for sound, communications and transport;
9. direct use of the atmosphere for power;
10. the extraction of atmospheric gases;
11. atmospheric recreation and climate tourism;
12. aesthetic, spiritual and sensual properties of the atmosphere, including smell and taste.

In addition to the above services, the atmosphere also contributes disservices that can be detrimental to both ecosystems and human well-being. As well as extreme climatic events (such as storms, tornados, excessive heavy rainfall and prolonged periods without rainfall), such disservices can include wind influence on the path of coastal currents (Van Leuven *et al.*, 1999) and the dispersal of smoke and gases from wildfires (e.g. Kim and Sarkar, 2017), ash from volcanic eruptions (Colette *et al.*, 2011), and radioactive pollutants from industrial accidents (Kimura and Yoshikawa, 1988). Such atmospheric disservices can result in significant environmental, social and economic implications.

Valuing the services provided by the atmosphere is challenging because many of the services lie outside contemporary markets (Everard *et al.*, 2013). The total economic value of the atmosphere has been estimated to be at least between 100 and 1000 times the gross world product (GWP; estimated at £43 trillion in 2008), although this is likely to be an underestimate (Thornes *et al.*, 2010). Because of the significant economic, environmental and cultural value attributed to atmospheric services, such services have frequently been brought into legal consideration at both international and national scales, for example the various air pollution acts around the world (Everard *et al.*, 2013).

Given the critical role of the atmosphere in supporting life on Earth, and the role that atmospheric services and disservices have played in landscape formation, the linkages between atmospheric services and ecosystem, geosystem and human/social system services is strong. Therefore, atmospheric services are an integral component of the concept of catchment services and disservices and the holistic approach of Integrated Catchment Management (ICM).

1.1.2 Ecosystem services

Ecosystem services are defined by the Millennium Ecosystem Assessment (2005) as the benefits people obtain from ecosystems and, given its wide use, this definition will be used for the purpose of this review. The benefits derived from ecosystems can be apportioned into four distinct types of services:

- provisioning services;
- regulating services;
- cultural services;
- supporting services.

The cumulative value of global ecosystem services was estimated at between US\$125–145 trillion per year in 2011, compared with US\$16–54 trillion in 1995 (Costanza *et al.*, 1997, 2014). Despite these enormous and increasing values, in addition to losses of ecosystem services due to land use change (estimated at US\$4.3–20.2 trillion from 1997–2011; Costanza *et al.*, 2014), the social and economic values of ecosystems have been substantially overlooked in planning at all scales (Everard *et al.*, 2009).

While the ecosystem services concept has been fundamental in assessing and improving understanding of the contribution of biotic nature to human well-being, three key weaknesses of the concept are confusion over ecosystem functions and biodiversity; omission of disservices, trade-offs and abiotic nature; and the use of an economic valuation framework to measure and aggregate human well-being (Lele *et al.*, 2016).

A number of reviews have been undertaken of the ecosystem services concept (e.g. Costanza *et al.*, 2011; Harrison *et al.*, 2014; Lele *et al.*, 2016), and Feeley *et al.* (2017a,b) summarised the ecosystem services provided by freshwaters. Please refer to these sources for further detailed information on the ecosystem services concept.

1.1.3 Geosystem services

Geosystem services are the goods and services that contribute to human well-being specifically resulting from the subsurface (the zone below the earth's surface) (Van Ree and van Beukering, 2016). This excludes those geophysical areas that interact with overlying ecosystems (such as soils). Geosystems can be characterised by specific geological sequences, structures and landscapes, and the rocks, minerals and fossils that are present. In addition, Van Ree and van Beukering (2016) highlighted that additional features of geosystem characterisation relate to geophysical and geochemical drivers of change, such as the risk of specific natural hazards (e.g. earthquakes, landslides, liquefaction and subsidence, identified as geosystem disservices in this report), as well as specific anthropogenic pressures (e.g. subsurface

construction, mineral extraction and contamination, the last of which is a human/social system disservice associated with the former geosystem services). In some cases, the benefits from geosystems are direct (e.g. the provision of fresh water), while in others they are achieved through the influence that geological, hydrogeological, geomorphological or pedological factors and processes have on both landforms and the biodiversity they support (Gordon *et al.*, 2012).

The notion of geosystem services placed within the concept of catchment services was first discussed in Ireland by Daly (2015), who describes geosystem services as “the landscape geomorphology; bedrock and gravel; groundwater for drinking water and geothermal energy; soils and subsoils as chemical and physical attenuating media for pollutants; hydrometeorology (rainfall, evapotranspiration, wind); geological heritage sites; minerals; oil/gas; caves; cultural values associated with landscape features; etc.” The work synthesised here and presented in detail in the final report for this project, *Developing the Concept of Catchment Services for Progress Towards Integrated Water Management (Extra TIME)*, builds on this description, incorporating the work of both Daly (2015) and Van Ree and van Beukering (2016), while discussing the contribution of Gray (2004, 2008, 2011, 2012), Gray *et al.* (2013) and others to the development of the notion of geosystem services and disservices within the concept of catchment services and disservices.

The values associated with geosystem services are manifold and they represent a significant economic, environmental and cultural resource. Geodiversity was the specific reason for 39% of tourists visiting the Isle of Wight, England, accounting for approximately £11 million of the total tourist revenue for the island in 2004/2005. Between £2.6 million and £4.9 million of local income was generated by geodiversity, supporting between 324 and 441 full-time equivalent jobs (Webber *et al.*, 2006).

Increasing awareness of the services and disservices that geosystems provide, understanding how the delivery of geosystem services and disservices may change, and understanding the complex interactions with other components of catchment services represent key challenges in the delivery of the wider

concept of catchment services and disservices (Gordon and Barron, 2012; Comer *et al.*, 2015; Daly, 2015; Hjort *et al.*, 2015).

1.1.4 Human/social system services

Stakeholder and community consultation and engagement are integral components of water governance and the delivery of river and catchment management services (Akhmouch and Clavreul, 2016), playing a critical role in the development of policies and strategies and in determining levels of service for river and catchment work programmes (Waikato Regional Council, 2011). However, the human/social system services aspect of catchment services and disservices has a greater general focus than solely involvement in, or engagement regarding, catchment management actions.

Although difficult to define, the notion of human/social systems services within the concept of catchment services and disservices extends beyond these cultural services to also include the social associations

derived from living in, working in and visiting a catchment area, such as:

- community (housing, social linkages and sport);
- agriculture;
- energy production (hydroelectric, wind and geothermal energy);
- transport (roads, rivers and canals);
- history (mythology, and natural and built heritage);
- industry (water mills, mining, quarrying and licensed pollution discharges);
- wastewater treatment.

Therefore, human/social system services have intrinsic linkages across all of the components of the concept of catchment services and disservices. The inclusion of human/social system services within the concept highlights the role that local communities have in catchment management, thereby signposting that bottom-up as well as top-down approaches are relevant, giving a degree of ownership of the process to local communities and increasing the likelihood of desired catchment outcomes (Daly, 2015).

2 Work Package Two: The Influence of Multi-factorial Scenarios on Key Catchment Services and Disservices

Catchment services and disservices and their key components (atmospheric, ecosystem, geosystem and human/social system services/disservices) are likely to be affected by future change, whether climatic, legislative or social (demographic). Understanding how fundamental services and disservices that are provided by catchments may be affected by future change is essential for both undertaking ICM-focused initiatives and communicating the concept of catchment services and disservices.

2.1 Identifying Key Services and Disservices Provided by Catchments

A number of fundamental services and disservices provided by catchments were identified from the literature review undertaken through Work Package One (Table 2.1). Where possible, examples of indicators for each fundamental service have been provided. The sensitivity of these services and disservices to change is described below.

2.2 Outlining a Framework for Assessing Changes to Key Catchment Services and Disservices

Before the impact of multi-factorial scenarios on fundamental catchment services and disservices can be assessed, it is important to describe the operational framework that can be used to ensure that ICM processes can be implemented to help minimise the scale of potential changes to these services in the future.

Lavorel *et al.* (2014) outlined an operational framework for the identification and quantification of climate adaptation services.¹ This framework has been adapted to assess the influence of multi-factorial scenarios on the fundamental services provided by catchments (Figure 2.1). The intention is for this

framework to be applicable at the individual catchment and sub-catchment scales.

The first step in this adapted operational framework requires an understanding of current conditions within a catchment, including the natural variability (e.g. current and projected conditions of the key catchment ecosystems, and of rivers and streams) and social variability (e.g. population trends within the catchment) and the current natural and social management actions being undertaken within the catchment.

This enables the development of a conceptual understanding of current catchment functioning, which, in turn, allows a conceptual description of the fundamental services being provided by the catchment. However, difficulties in quantifying both natural and social variability may arise as a result of:

- insufficient data, which may mean that variability cannot be described for all parameters;
- a limited understanding of what constitutes natural and social variability;
- a lack of understanding of the impacts that may result in an unacceptable change in natural and social variability, which, in turn, can affect catchment functioning and therefore the fundamental services provided by a catchment.

Therefore, quantifying such variance is difficult and a qualitative, conceptual understanding may be sufficient.

The second step in the adapted operational framework (Figure 2.1) involves an assessment of the multi-factorial scenarios likely to be acting as drivers of environmental, social and land use change in the catchment in the future. These drivers include climate change, legislative and policy change, and social demographic change. Each driver can influence political change, which, in turn, can result in legislative and policy change (which can also feed back into political change). Developing a conceptual

¹ Lavorel *et al.* (2014, p. 2) defined climate adaptation services as “the benefits to people from increased social ability to respond to change, provided by the capacity of ecosystems to moderate and adapt to climate change and variability”.

Table 2.1. Examples of services and disservices provided by catchments and indicators for each service

Component	Subcomponent	Example service/disservice	Example indicator	
Atmospheric services		Air for respiration	Proportion of key gases (e.g. oxygen and carbon dioxide) in the atmosphere	
		Protection from radiation	Thickness of ozone layer	
		Wind	Wind speed	
		Sunshine	Hours of sunshine	
		Rain	Volume of rainfall	
Ecosystem services	Provisioning service	Water balance/yield	Proportional change in water balance/yield	
		Habitat	Area of defined habitat	
		Food	Crop production in tonnes	
		Fibre	Production of timber (cubic metres or tonnes)	
	Regulating service	Flood mitigation	Number of defined flood events	
		Climate regulation	Flux in atmospheric gases	
		Disease regulation	Infection rates	
		Water purification	Water contamination levels (e.g. <i>E. coli</i> concentrations in raw water supplies)	
		Water retention	Run-off	
		Carbon sequestration	Carbon sequestration capacity	
	Supporting service	Air quality regulation	Levels of pollutants in the air (e.g. sulfur dioxide)	
		Erosion regulation	Area of defined land lost	
		Nutrient cycling	Soil nitrate levels	
		Soil formation	Leaf litter decomposition rates	
		Primary production	Oxygen production over time	
		Pollination	Economic value of pollination	
		Cultural service	Recreation	Number of visitors per year
			Aesthetic appeal	Comparative value of real estate near nature
	Education		Number of school visits per year	
	Tourism		Number of tourists per year	
Geosystem services	Provisioning service	Spiritual	Value assigned to spiritual well-being	
		Heritage	Value assigned to heritage item	
		Aquifer recharge	Recharge rate (e.g. mm per year)	
		Surface water–groundwater connectivity	Stream base flow	
		Water purification	Water contamination levels (e.g. nutrient concentrations in raw water supplies)	
		Mineral resources	Amount of minerals abstracted	
		Oil and gas resources	Amount of oil and gas abstracted	
		Aggregate resources	Amount of aggregates abstracted	
		Geothermal energy	Energy production rate	
		Provision of construction materials	Volume of abstracted material	
	Regulating service	Aquifer recharge	Volume of water available for abstraction	
		Surface water–groundwater connectivity	Ecological condition of groundwater-dependent ecosystems	
		Nutrient attenuation	Nutrient load	
		Erosion and sedimentation regulation	Sediment load	
		Flood mitigation	Number of defined flood events	
		Surface water–groundwater connectivity	Number and location of groundwater-dependent ecosystems	
	Supporting service	Recreation	Time spent undertaking recreational activities	
		Aesthetic appeal	Comparative value of real estate near nature	
		Mythology/spiritual importance	Value assigned to spiritual well-being	
		Tourism	Revenue raised by tourist attraction	

Table 2.1. Continued

Component	Subcomponent	Example service/disservice	Example indicator
Human/social system services		Crop yield	Yield of crop per unit of land area (e.g. kg per ha)
		Animal productivity	Milk yield
		Water abstraction	Volume per unit time
		Recreation	Number of recreational visits per year
		Aesthetic appeal	Comparative value of real estate near nature
		Wastewater assimilation	Wastewater discharge flow rate
		Heritage	Value assigned to heritage item
		Sense of community	Value assigned to community membership
		Energy production (peat harvesting, hydroelectric power stations, wind and solar farms)	Energy production rate
		Transport	Volume of vehicles per unit time
		History	Value assigned to historical item
		Industry	Economic output
		Peat abstraction	Area of cut peat
Atmospheric disservices		Extreme climatic events	Frequency of extreme climatic events (e.g. heavy rainfall, storms, tornados, etc.)
		Dispersal of contaminants from natural events (e.g. wildfires and volcanic eruptions) and non-natural disasters (e.g. industrial accidents)	Concentration and distribution of pollutants (e.g. radiation, smoke, ash, etc.)
Ecosystem disservices	Provisioning disservice	Proliferation of non-native species	Abundance of species
	Regulating disservice	Carbon sinks turning to carbon sources	Carbon sequestration capacity
	Supporting disservice	Excessive primary productivity	Frequency of cyanobacteria blooms
	Cultural disservice	Offensive-smelling decomposing organic matter	Odour detection threshold
Geosystem disservices		Drying up of holy wells	Spring recharge rate
	Supporting disservice	Damage caused by earthquakes	Reconstruction costs
		Water quality deterioration following landslides or bog bursts	Sediment load
	Delivery of contaminants from groundwaters to surface waters	Contaminant concentrations in groundwaters and surface waters	
	Provisioning disservice	Water quality deterioration following natural contamination processes	Drinking water source contamination
Human/social system disservices		Over-abstraction of water resources	Number of abstractions
		Litter dumping	Extent and severity of litter pollution
		Enrichment of land leading to eutrophication of water sources	Soil fertility and nutrient application loads
		Pollution caused by mining tailings	Contaminant concentrations in stream waters
		Over-reliance on aquatic systems to disperse human and industrial waste	Wastewater discharge flow rate
		Drainage of wetlands	Area of drained land
		Peat abstraction	Area of cut peat
		Flooding	Frequency of flooding events
		Drought	Frequency of drought events
		Low-flow periods limiting hydroelectric power	River flow rates
		Allergen potential	Pollen count
		Urban sprawl	Area of urban land

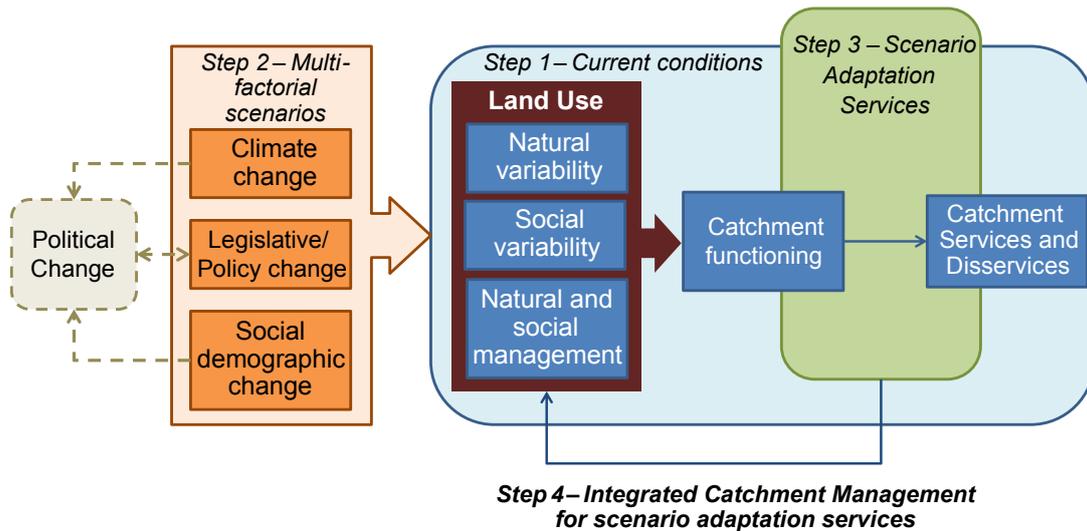


Figure 2.1. An operational framework for the identification and quantification of scenario adaptation services based on the operational framework for climate adaptation services outlined by Lavorel *et al.* (2014).

understanding of how future scenarios affect natural and social variability and their associated management within the catchment leads to a conceptual understanding of how key catchment services and disservices may be affected by future scenarios (i.e. there may be an increase or decrease in individual catchment services and disservices). Therefore, step three of the adapted operational framework involves the identification of the mechanisms by which nature and society may adapt to these changes in service/disservice delivery. These mechanisms include moderating or enabling levels of changes in catchment services and disservices, providing time for societies to adapt to change, providing novel livelihoods in response to change and slowing down natural responses to change (Lavorel *et al.*, 2014). The implementation of the mechanisms identified in step three form the crux of the adaptive ICM that is required to manage catchments in Ireland in the future, to ensure that the natural and societal impacts of changes to fundamental catchment services and disservices are minimal.

2.3 Assessing the Impact of Climate Change on Catchment Services and Disservices

2.3.1 Methodology

Two small workshops were held in October and November 2016 to harness participant opinion on the

sensitivity of key catchment services and disservices (Table 2.1) to future climate change projections for Ireland (Nolan, 2015). Participants' professional backgrounds included ecology, water resources management, hydrogeology and social sciences. Workshop participants (total $n=6$) were asked to reach a consensus on applying qualitative values, in the following manner:

1. The sensitivity of key catchment services/disservices (Table 2.1) to each stressor (Table 2.2) was estimated by assigning a qualitative value (1 = low sensitivity; 2 = moderate sensitivity; 3 = high sensitivity) and calculating an overall mean sensitivity score for each catchment service/disservice.
2. The sensitivity of catchment services/disservices (Table 2.1) to each future climate change projection for Ireland (Nolan, 2015) was estimated by assigning the qualitative values described in point 1 above and calculating the mean sensitivity score for each catchment service/disservice.
3. The mean sensitivity scores of catchment services/disservices to stressors and climate change projections were then plotted against each other, using the programming package R, to identify those catchment services likely to be most affected by future change.
4. Environmental stressors themselves can be sensitive to climate change. To incorporate this

additional factor, the sensitivity of stressors (Table 2.2) to future climate change projections for Ireland (Nolan, 2015) was estimated by assigning the qualitative values described in point 1 above and calculating a mean climate change sensitivity score for each stressor. This mean climate change

sensitivity score was then multiplied against the mean sensitivity scores determined in point 1 and plotted against the mean sensitivity scores calculated in point 2. No attempt was made to assess whether environmental stressors would respond positively or negatively to climate change projections.

Table 2.2. Stressors used in the qualitative evaluation of the sensitivity of catchment services/ disservices to climate change

Aspect	Stressor
Water quantity (flow modifications)	Quantity and frequency
	Groundwater abstractions
	Changes in runoff/aquifer recharge
Water quality (diffuse and point pollution)	Nutrients
	Chemicals (pesticides)
	Carbon (exported from soil)
	Pathogens
	Litter
	Groundwater salinisation
	Sediments, increased turbidity
Habitat	Hydromorphological alterations
Biota and biological communities	Alien species

All stressors were from Grizzetti *et al.* (2016) except aquifer recharge and carbon (exported from soil), which were included following input from expert stakeholders.

Atmospheric services and disservices were not included in this assessment, as they are integral components of climate change projection outputs.

2.3.2 Results

Sensitivity of stressors to climate change

The sensitivity of stressors to climate change projections for Ireland varied from low to high (Figure 2.2). Litter and groundwater salinisation were the stressors with the lowest sensitivity to climate change. Carbon (exported from soil) and changes in runoff/ aquifer recharge were the stressors identified as being most sensitive to climate change. Individual stressors will respond differently (i.e. in a positive or negative manner) to climate change projections, but no attempt was made to identify such positive or negative responses.

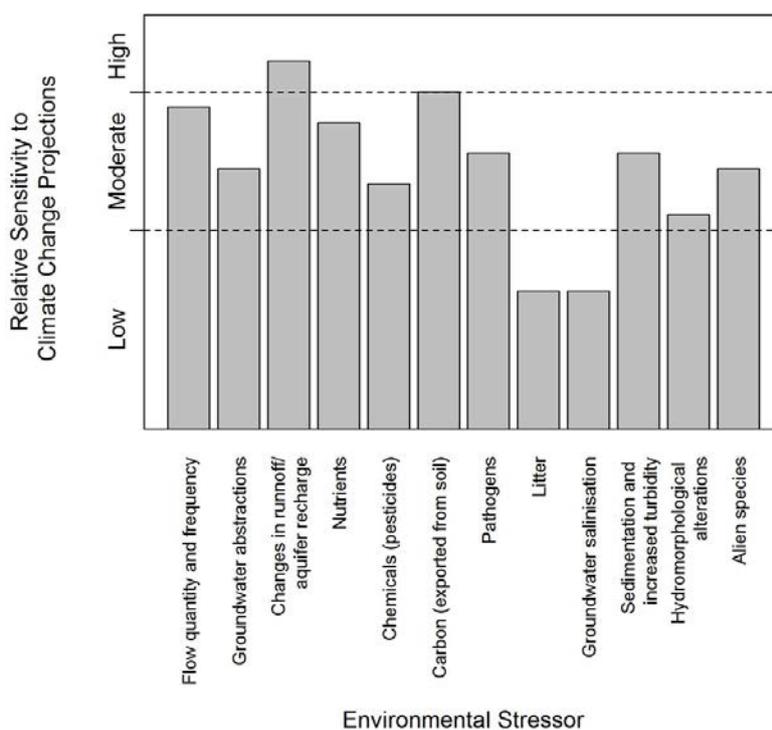


Figure 2.2. Qualitative sensitivity of environmental stressors acting on water systems to climate change.

Sensitivity of catchment services and disservices to climate change

Catchment services were typically more sensitive to environmental stressors than catchment disservices (Figure 2.3a). Catchment disservices were typically more sensitive to future climate change projections than to environmental stressors (Figure 2.3a). Incorporating the influence of climate change acting on environmental stressors resulted in an increase in sensitivity (to varying degrees) of many catchment services and disservices to the environmental stressors (i.e. the plotted points are further towards the right in Figure 2.3b than in Figure 2.3a).

Cultural ecosystem services were typically less sensitive to both climate change and environmental stressors than most provisioning, regulating and supporting services (Figure 2.4a). Water balance/yield was the ecosystem service most sensitive to future climate change projections, while habitat was the ecosystem service most sensitive to environmental stressors (Figure 2.4). Incorporating the influence of climate change on environmental drivers resulted in three catchment services (heritage, disease regulation and water retention) moving from low sensitivity to environmental stressors into moderate sensitivity.

Geosystem services were typically more sensitive to future climate change projections than to environmental stressors (Figure 2.5). Aquifer recharge was the geosystem service most sensitive to future climate change projections, while groundwater resources had the greatest sensitivity to environmental stressors (Figure 2.5). Incorporating the influence of climate change on environmental stressors resulted in two geosystem services (flood regulation and erosion and sedimentation) moving from low sensitivity to environmental stressors to moderate sensitivity (Figure 2.5b).

Human social system services typically had low sensitivity to both future climate change projections and environmental stressors (Figure 2.6). However, crop yield and water abstraction had the highest sensitivity to both climate change projections and environmental stressors of any human/social system services. Incorporating the influence of climate change on environmental stressors resulted in three human/social system services moving from low to moderate sensitivity to environmental stressors (wastewater

assimilation, animal productivity and recreation) (Figure 2.6b).

Catchment disservices were typically more sensitive to future climate change projections than to environmental stressors, with human/social system disservices representing both the lowest and most sensitive disservices to the climate change projections (Figure 2.7; Table 2.3). The over-abstraction of water resources, flooding and drought were the disservices most sensitive to future climate change projections, while the delivery of contaminants from groundwater to surface water and abstraction points was the disservice most sensitive to environmental stressors (Figure 2.7b; Table 2.3). Incorporating the influence of climate change on environmental stressors resulted in six disservices (drainage of wetlands, enrichment of land leading to the eutrophication of water sources, proliferation of non-native species, groundwater flooding, low-flow periods limiting hydroelectric power production and drought) moving from low to moderate sensitivity to environmental stressors (Figure 2.7b; Table 2.3).

2.4 Assessing the Impact of Legislation and Policy on the Delivery of Catchment Services and Disservices

Typically, environmental legislation and policy that is associated with catchment services aim to improve environmental quality and therefore, inter alia, are less likely to negatively affect the services provided by the catchments they target. Legislation and policy provide a directed focus for agencies and communities, particularly as certain catchment services (e.g. agricultural productivity) may be given priority over others. However, both legislation and policy potentially have indirect impacts on a variety of catchment services and disservices as a result of the often-unintentional consequences of management actions undertaken to implement the legislation or policy. As policy is more likely than legislation to change in the shorter term as a result of political and social change, it has the potential to both directly and indirectly have more frequent impacts on a wide variety of catchment services and disservices.

Given the difficulties in predicting how policy and legislation may change in the future, the potential

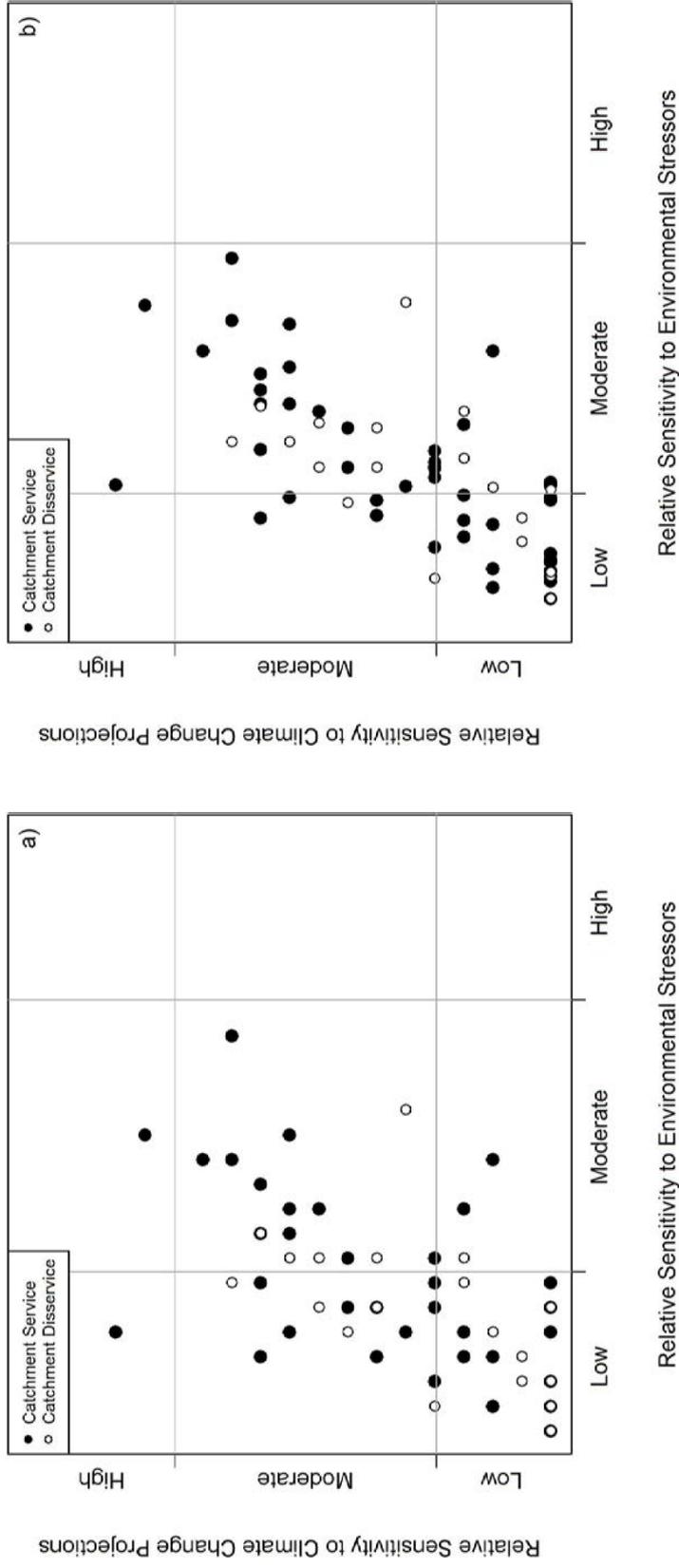


Figure 2.3. Sensitivity of catchment services and disservices to climate change and (a) environmental stressors excluding stressor sensitivity to climate change and (b) environmental stressors including stressor sensitivity to climate change.

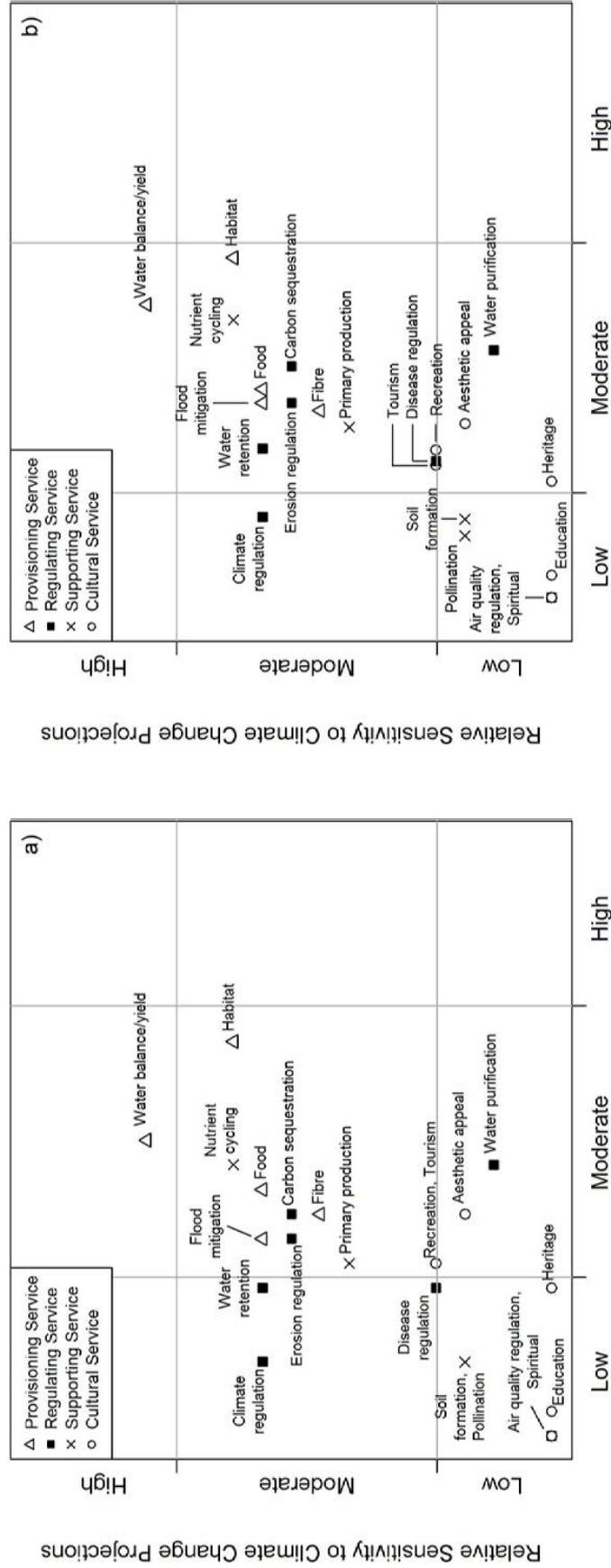
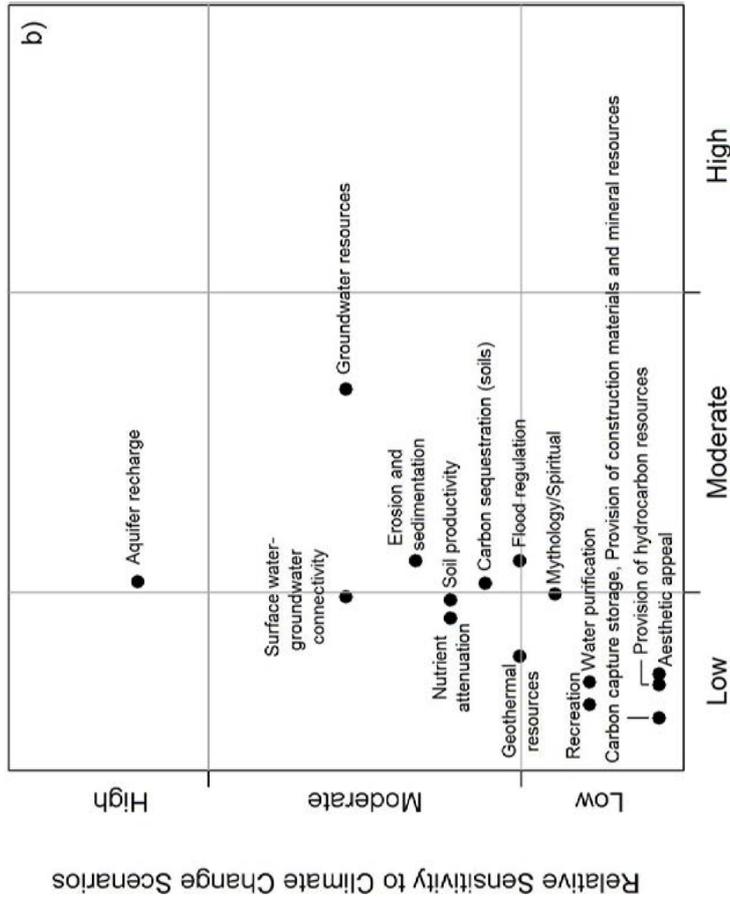
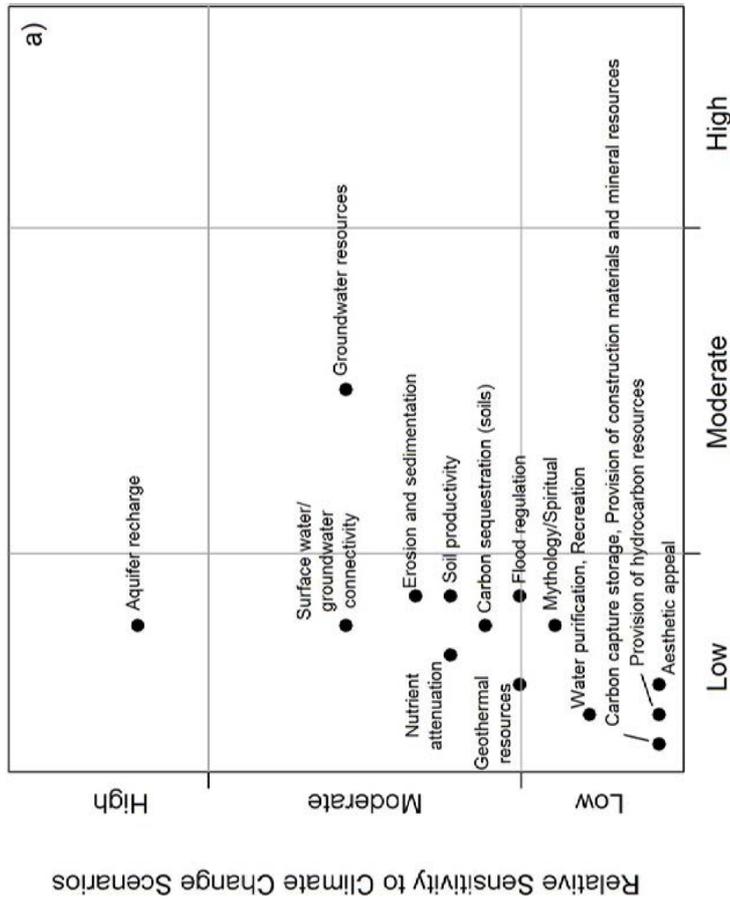


Figure 2.4. Sensitivity of ecosystem services to climate change and (a) environmental stressors including stressor sensitivity to climate change and (b) environmental stressors excluding stressor sensitivity to climate change.



Relative Sensitivity to Environmental Stressors



Relative Sensitivity to Environmental Stressors

Figure 2.5. Sensitivity of geosystem services to climate change and (a) environmental stressors excluding stressor sensitivity to climate change and (b) environmental stressors including stressor sensitivity to climate change.

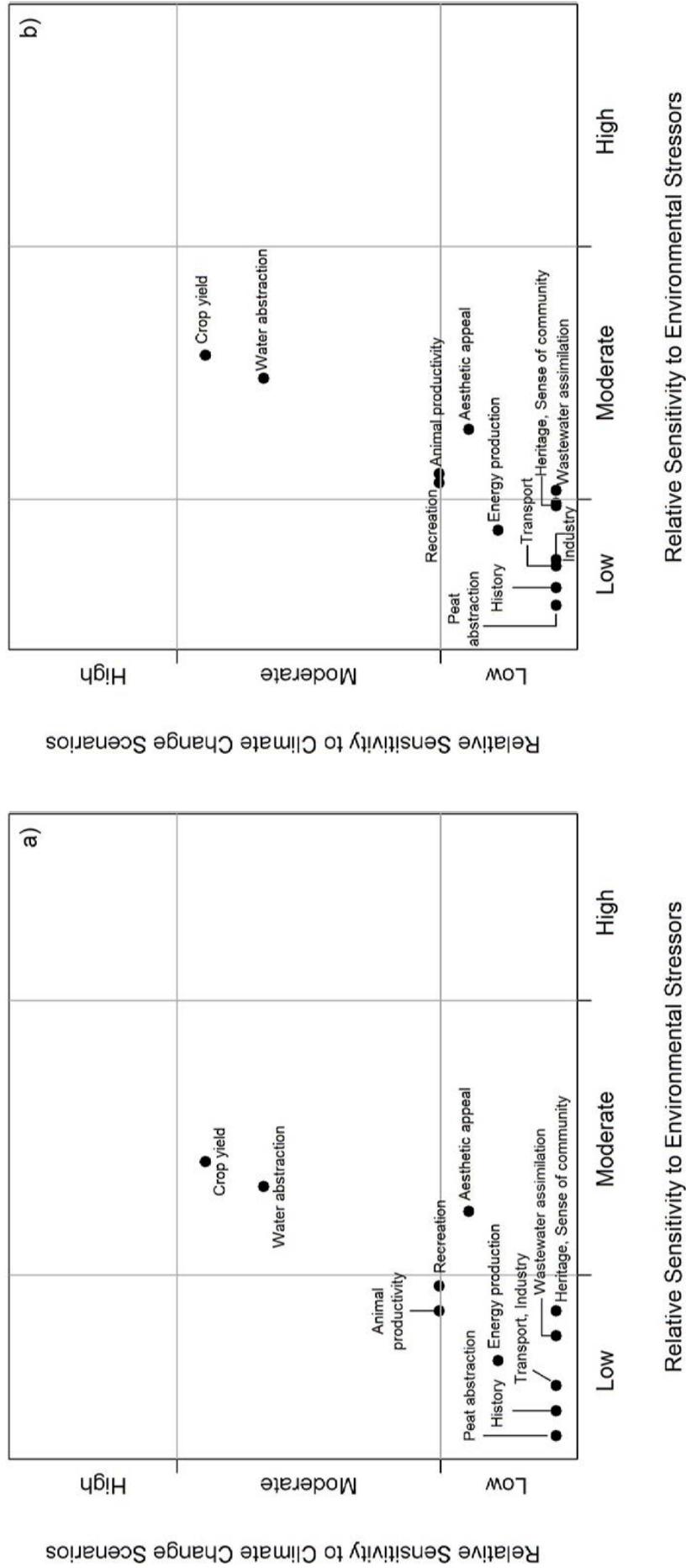


Figure 2.6. Sensitivity of human/social system services to climate change and (a) environmental stressors excluding stressor sensitivity to climate change and (b) environmental stressors including stressor sensitivity to climate change.

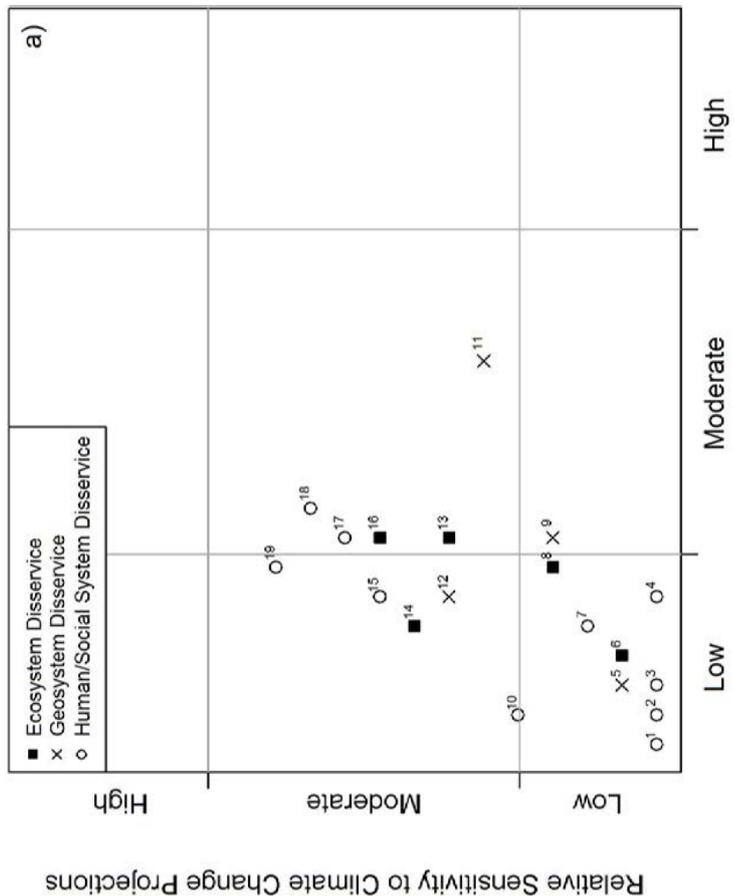
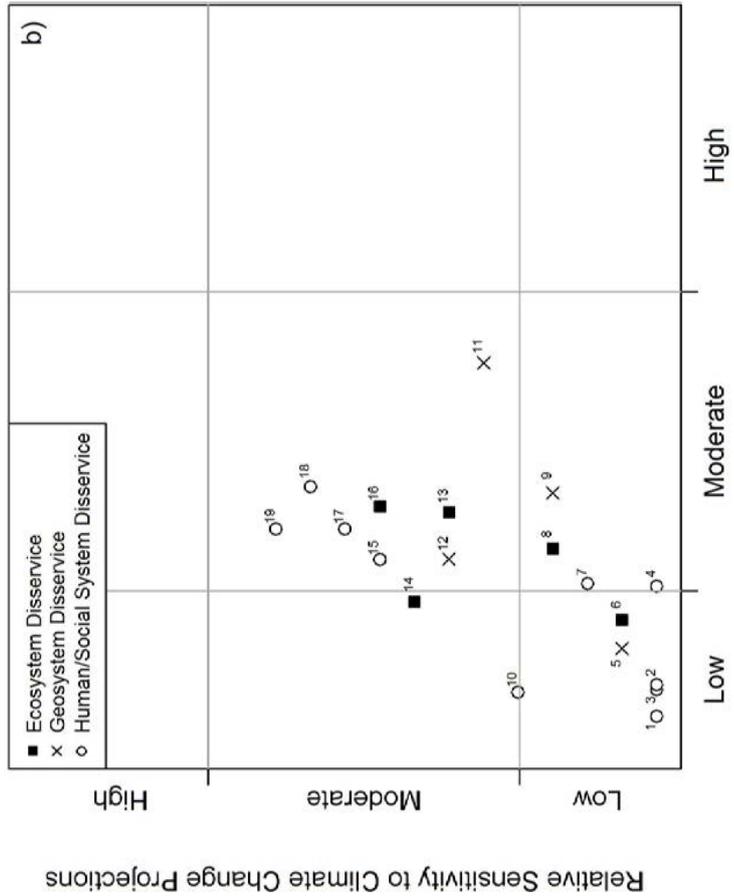


Figure 2.7. Sensitivity of catchment disservices to climate change and (a) environmental stressors excluding stressor sensitivity to climate change and (b) environmental stressors including stressor sensitivity to climate change. The key to data point labels is shown in Table 2.3.

Table 2.3. Key to data point labels in Figure 2.7

Label	Corresponding catchment disservice
1	Over-reliance on aquatic systems to disperse human and industrial waste Peat abstraction
2	Urban sprawl
3	Litter dumping
4	Drainage of wetlands
5	Radon gas
6	Offensive-smelling decomposing organic matter
7	Enrichment of land leading to eutrophication of water sources
8	Proliferation of non-native species
9	Water quality deterioration following landslides or bog bursts
10	Allergen potential
11	Delivery of contaminants from groundwater to surface water and abstraction points
12	Groundwater flooding
13	Excessive primary productivity
14	Drying up of holy wells
15	Low-flow periods limiting hydroelectric power production
16	Carbon sinks turning to carbon sources
17	Over-abstraction of water resources
18	Flooding
19	Drought

impacts (direct and indirect) of three current policies [Food Wise 2025, Forestry 2030 and the Rural Development Plan (RDP); DAFM, 2015a; COFORD, 2014; DAFM 2015b, respectively] are suggested in Table 2.4. For example, the objectives of Food Wise 2025 aim to directly change the production of food and fibre, increasing crop yields and animal productivity and therefore increasing industry at a national level. However, Food Wise 2025 may also indirectly influence change in, for example, the availability, timing and frequency of river flows (water balance/yield) as a result of changes in abstraction; the presence of habitat (and biodiversity) following changes in land use; levels of pollination due to increases and decreases in certain plant and crop species; and groundwater resources as a result of changes in abstraction and land management practices.

Forestry 2030 aims to significantly increase the production of fibre (Table 2.4), but may cause changes in carbon sequestration; the aesthetic appeal of the landscape as woodlands and forests are planted; the enrichment of land leading to eutrophication; and the delivery of contaminants to groundwaters, surface waters and abstraction points.

The RDP, while encouraging sustainable agricultural productivity through agri-environmental schemes, has a greater social focus than either Food Wise 2025 or Forestry 2030 (Table 2.4).

For example, the RDP will directly influence changes in education and aims to preserve heritage (therefore potentially resulting in a change in heritage deterioration), but may also indirectly result in changes to wetland drainage.

Understanding the concept of catchments acting as service providers, including the provision of catchment disservices, is necessary for the development of integrated legislation and policy that aim to protect and enhance Ireland's catchment resources and their management in the future. To this end, a number of measures can help to ensure that the concept of catchment services and disservices underpins the development of legislation and policy (Box 2.1). While it is recognised that many of these actions are on-going and that they contribute to Work Package Three (see Chapter 3 for the implications for community engagement), it is imperative to highlight them here to provide a focus on how policy and legislation development can have an impact on the delivery of catchment services and disservices.

Table 2.4. Examples of how a number of selected national-level policies can directly (D) or indirectly (I) influence change in the delivery of various catchment services and disservices or have no impact (–)

	FoodWise 2025	Forestry 2030	Rural Development Plan
<i>Catchment service</i>			
Water balance/yield	I	I	I
Habitat	I	I	D
Food	D	–	D
Fibre	D	D	D
Climate regulation	I	I	–
Disease regulation	I	I	–
Carbon sequestration	I	I	I
Primary production	D	D	I
Pollination	I	I	I
Aesthetics	I	I	I
Education	–	–	D
Heritage	I	I	D
Aquifer recharge	I	I	I
Surface water–groundwater connectivity	I	I	I
Nutrient attenuation	I	I	D
Soil productivity	D	I	I
Erosion and sedimentation	I	I	I
Groundwater resources	I	I	I
Crop yield	D	D	D
Animal productivity	D	–	D
Sense of community	D	I	D
Industry	D	D	D
<i>Catchment disservice</i>			
Excessive primary productivity in aquatic systems	I	I	–
Delivery of contaminants (anthropogenic and geogenic) from groundwaters to surface waters and abstraction points	I	I	I
Enrichment of land leading to eutrophication of water sources	I	I	I
Drainage of wetlands	I	I	I
Methane production	D	–	–

Atmospheric services and disservices are not included in this assessment, as they will not be affected by these national policies.

Integrated policy development recognises the need to work across the land use and water management realms that underpin the principles of ICM and the concept of catchment services and disservices (Box 2.1). Therefore, an understanding of the concept is necessary. This can be achieved only through the continued promotion of ICM and the concept of catchment services and disservices. Socio-economic assessment can monitor policy implementation progress and impacts while providing a financial assessment of changes in the delivery of catchment services and disservices as a result of policy implementation.

2.5 Assessing the Pressure of Social Demographic Change on the Concept of Catchment Services and Disservices

Ireland has undergone significant social demographic change throughout its history. Changes in population demographics can have significant economic and social implications and can affect the delivery of catchment services and disservices depending on land use change, social planning, agricultural productivity, labour supply, habitat protection and water resources management.

Box 2.1. Factors that can affect the delivery of catchment services with regard to policy development and policy implementation

Integrated policy development

- Recognition of potential conflicts between differing policies in terms of the delivery of catchment services and disservices
- Policy development underpinned by catchment-scale thinking where appropriate
- Holistic approach to policy development that encompasses land use and water management
- Alignment with higher level legislation
- Ensuring strategic environmental assessment undertaken where appropriate
- Clear public consultation process, including reasonable response period
- Connections with spatial planners developed

Socio-economic assessment of policy implementation

- Monitoring progress of policy implementation and providing guidance for future improvements
- Understanding socio-economic impacts of policy implementation
- Examining gaps in policy that result in change in the delivery of catchment service(s) and disservice(s)
- Enabling financial understanding of the impacts of policy on the delivery of catchment service and disservices

Promotion of concept of catchment services and disservices

- Recognition of the catchment as a service provider across each of the three key components (ecosystem, geosystem and human/social system services and disservices)
- Recognition of both catchment services and disservices
- Continued promotion of ICM
- Providing information to underpin legislation and policy development, as well as ICM actions at the national and local scales

Ireland's population is projected to rise to 6.6 million by 2045, and the Greater Dublin Area is expected to account for 64% of the total state population growth between 2011 and 2051 (CSO, 2013). Population growth within the Greater Dublin Area will affect 9 of the 46 catchments (and 77 subsequent sub-catchments; Figure 2.8) delineated as part of the second round of European Union (EU) Water Framework Directive (WFD) river basin management planning. The greatest numbers of dwellings in this area, representing 28% of the national total, are located within the Liffey and Dublin Bay catchment (Figure 2.8). It is therefore likely that the Liffey and Dublin Bay catchment and its 17 sub-catchments will experience the greatest impacts of projected population growth. Such impacts may include habitat loss, increased infrastructure development, deteriorated surface water and groundwater quality,

increased litter dumping, loss of agricultural area and increased urban sprawl. The mitigation of such impacts will be dependent on the relevant housing, infrastructure and social planning policies that are implemented to manage the projected population growth of the area.

2.6 Conclusions

The delivery of catchment services and disservices will vary in a changing world. Managing the impacts of such changes in service delivery will be dependent on the response of the atmosphere, ecosystems, geosystems and social systems to change. The development of adaptation strategies to potential change in service/disservice delivery has the potential to be a key factor of ICM in Ireland in the future. While it is possible to project how climate and social

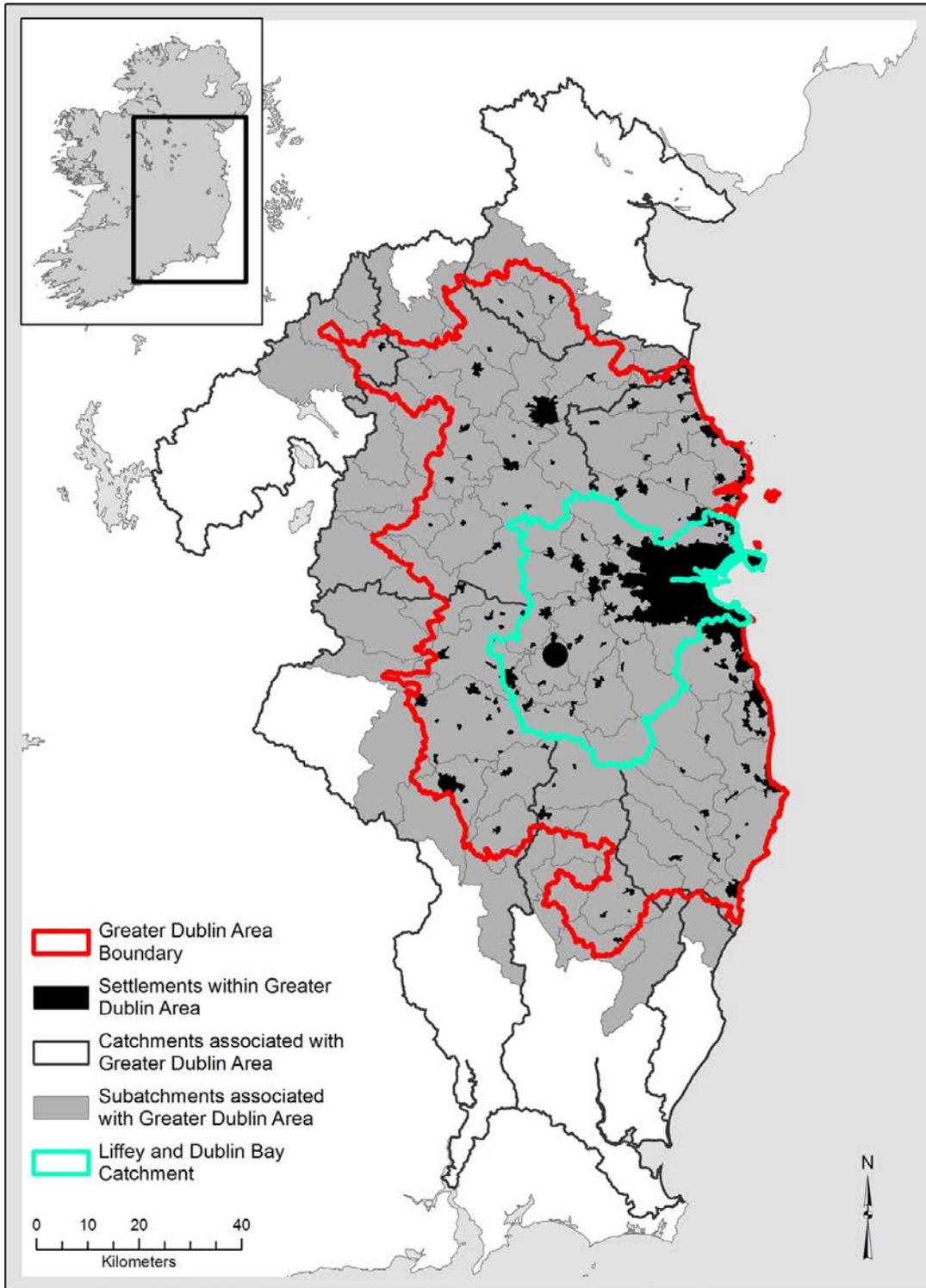


Figure 2.8. Settlements with legal boundaries within the Greater Dublin Area and the Liffey and Dublin Bay catchment where dwelling numbers are greatest.

demographics may change in the future (and therefore assess how such changes may affect the delivery of catchment services and disservices), predicting how legislation and policy may change in the medium to long term is more difficult.

Stakeholder identification and engagement will be an essential factor in the integrated delivery of the concept of catchment services and disservices. Ensuring that policymakers, planners and water managers across multiple agencies are aware of the

concept and how it can inform their bodies of work will be critical in ensuring the successful delivery of the concept.

The National Planning Framework (Ireland 2040 – Our Plan; DHPCLG, 2017a) represents an opportunity for the concept of catchment services and disservices to inform national-level planning policy and also publicly promote the concept at a national level. A longer term aim should be for the concept to inform all aspects of water management, catchment management, social management and spatial planning. This may require the updating of legislation – for example, the

concept also has the strong potential to be utilised in the Strategic Environmental Assessment (SEA) process for certain projects and programmes that may have a significant impact on the environment. Undertaking an SEA that includes addressing the delivery of catchment services and disservices within the geographical area of the project or programme could help to identify potential impacts that may not be highlighted under the current SEA process. However, the updating of SEA legislation and regulations would be required in order to enshrine the concept of catchment services and disservices in the SEA process.

3 Work Package Three: Implications for Community Engagement

3.1 Introduction

Community engagement is a planned process with the specific purpose of working with identified groups of people, whether they are connected by geographic location, special interest or affiliation, to address issues affecting their well-being (QDES, 2001). Effective engagement leads to decisions, delivery and evaluation of services that have been shaped by the relevant people and communities (Andersson *et al.*, 2011).

Engagement can be presented in a wide number of different forms, and community engagement actions can vary greatly within the water environment field, from consultation in the development of management plans (Fraser *et al.*, 2006) to formal involvement in data collection and monitoring (Liu *et al.*, 2014). The roles, shapes and outcomes of community engagement in water management of different catchments are influenced by the particular interplay of ecological, social, economic, institutional and political practices in which these catchments are embedded (Ferreyra and Beard, 2007). Indeed, when communities are truly engaged in the catchment management process, the planning unit becomes the human-managed area rather than the hydrological unit (Rhoades, 1998).

3.2 A Community Engagement Framework for the Concept of Catchment Services and Disservices

There are three overarching aims for developing a community engagement framework for the concept of catchment services and disservices:

- **Aim 1:** to increase awareness within communities of the concept of catchment services and disservices;
- **Aim 2:** to increase catchment-scale thinking among local communities;
- **Aim 3:** to increase community involvement in catchment management initiatives.

The concept of catchment services and disservices is supported by the implementation and development of the natural capital concept (Figure 1.1). In turn, the concept of catchment services and disservices underpins all aspects of ICM, for example the provision of drinking water and wastewater management; water-related governance; the development of infrastructure within catchments; river basin management planning; and management actions within the agricultural sector (Figure 3.1). Each management action undertaken as part of ICM presents public engagement opportunities within which there is the possibility of achieving the three key aims of the community engagement framework for the concept, as stated above. Achieving these three aims will lead to informed communities that engage with and take responsibility for local water management actions underpinned by the concept of catchment services and disservices. These informed communities can subsequently feed back into the delivery of human/social system services and disservices, and the ICM.

A number of actions (Table 3.1) can be undertaken to achieve the three overarching aims listed above. Each of these actions can also be linked to a corresponding level of engagement under the IAP2 Spectrum (see www.iap2.org; Table 3.1) and the relative level of resources required to undertake each action.

3.3 Acknowledging the Importance of Engaging within Ireland's Water Governance Framework

While the development of an engagement framework is essential for the delivery of the concept of catchment services and disservices resulting in informed communities, it must also be acknowledged that significant engagement is required within the current national water governance framework in order to fully implement the concept of catchment services and disservices.

Water governance in Ireland has undergone multiple revisions over the past 5 years, and the latest

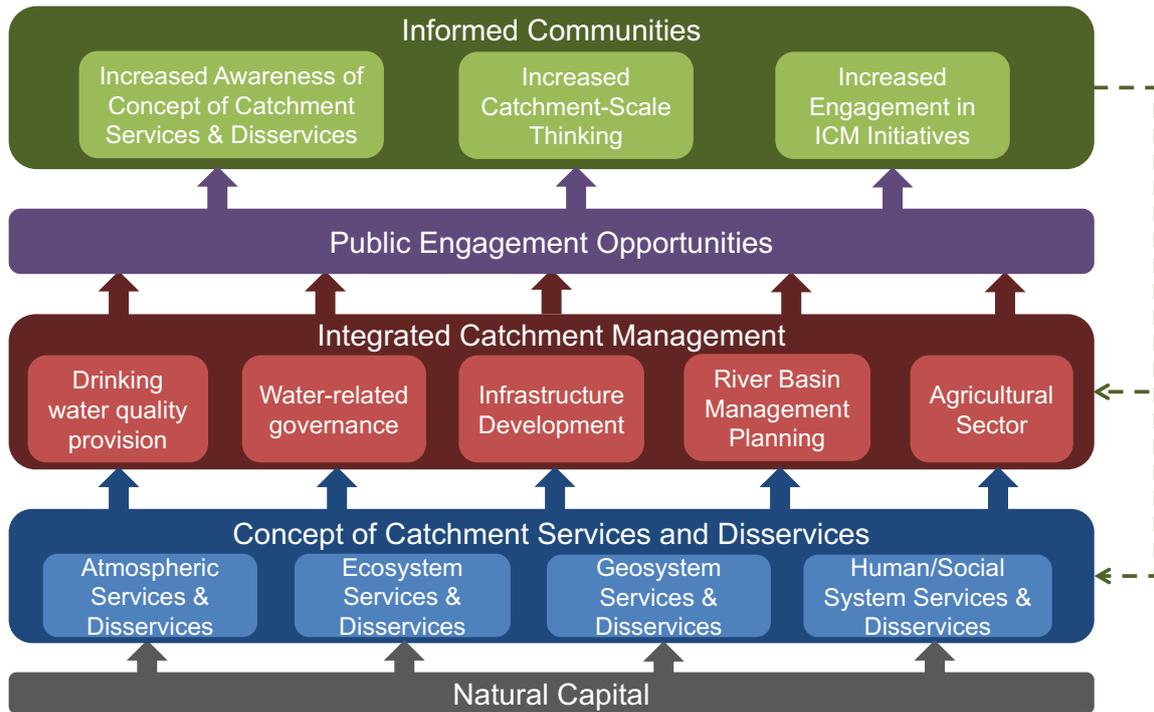


Figure 3.1. Conceptual diagram of how an engagement framework can lead to communities being informed by the concept of catchment services and disservices.

governance structure aligned with implementing the WFD is proposed in the second River Basin Management Plan public consultation document (DHPCLG, 2017b; Figure 3.2).

Engagement regarding the concept of catchment services and disservices within the revised governance framework is likely to be the responsibility of the Environment Protection Agency (EPA), in particular the Catchment Science and Management Unit, which is currently in the process of promoting and delivering ICM at the national level. Promotion of the concept of catchment services and disservices will be required laterally within the EPA, as well as across all components of the WFD implementation structure. Engagement with the Water Policy Advisory Committee would ensure high-level awareness of the concept across multiple government departments, state agencies, implementing bodies and other relevant stakeholders.

Further discussion on the implications of implementing the concept of catchment services and disservices on governance (and also regulations) is in Work Package Four (Chapter 4).

3.4 A Phased Approach to Engagement

Clearly, communicating the concept of catchment services and disservices to communities and also within the WFD implementation structure will be no easy task. A series of actions will be required that prepare for engagement: developing a communications strategy that includes acknowledging the concept's capacity for implementing change; delivering the engagement; and following up on the engagement to ensure that the concept of catchment services and disservices continues to be used to underpin ICM in Ireland.

Therefore, a five-phase approach is suggested to communicate the concept of catchment services and disservices, and to ensure that it is used to underpin ICM in Ireland (Figure 3.3).

3.5 Conclusions

The phased community engagement approach outlined in Figure 3.3 recognises the need to engage both local communities and governing agencies in

Table 3.1. Potential actions that could be undertaken to achieve the three aims of the catchment services community engagement framework

Action	Related aim(s)	Level of community engagement required	Level of resources required
Ensure an outline of the concept of catchment services and disservices is included in all community-attended catchment-related presentations.	1, 2	Inform	Low
Provide information on the concept of catchment services and disservices on relevant agency websites.	1, 2	Inform	Low
Engage relevant printed media to publish catchment services/ disservices-related content.	1, 2	Inform	Low–moderate
Include a requirement of community-led applications to relevant funding calls to address project applicability to the concept of catchment services and disservices.	1, 2, 3	Inform Consult Involve Collaborate Empower	Low–moderate
Provide an informative leaflet summary of the concept of catchment services and disservices.	1, 2	Inform	Moderate
Develop interactive web-based media (e.g. a catchment services-/disservices-related game or app).	1, 2	Inform Involve	Moderate–high
Promote local community involvement in catchment management activities underpinned by the concept of catchment services and disservices.	1, 2, 3	Inform Involve Collaborate	Moderate–high
Hold community information sessions to share knowledge of specific catchments, and current and future management actions related to the concept of catchment services and disservices.	1, 2, 3	Inform Consult Involve Collaborate	Moderate–high
Monitor the socio-economic impact of catchment services-/ disservices-related policy and legislation to understand their impact on local communities and how communities are involved in their implementation.	1,2,3	Inform Consult Involve Collaborate	Moderate–high
Implement a funding programme initiative that is open only to projects aiming to protect or enhance identified catchment services, or to mitigate identified catchment disservices (including community-based or community-focused funding initiatives).	1, 2, 3	Inform Consult Involve Collaborate Empower	High

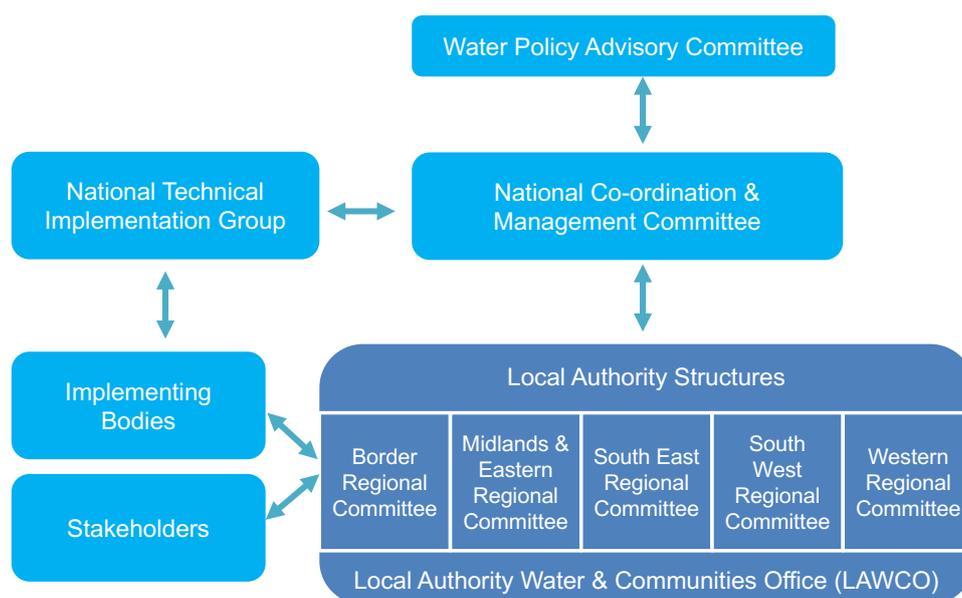


Figure 3.2. Proposed governance and co-ordination structures for implementation of the second cycle River Basin Management Plan (DHPCLG, 2017b).

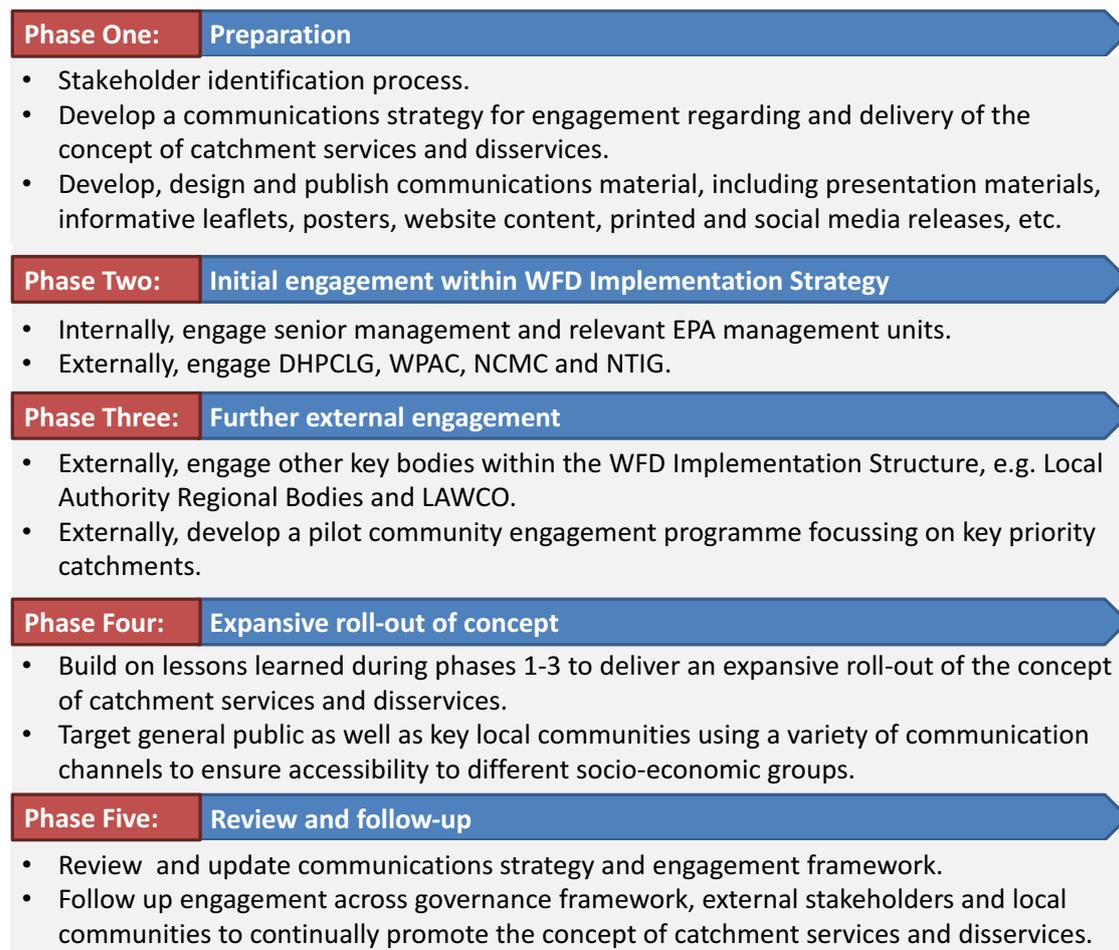


Figure 3.3. Five-phase approach suggested for communicating the concept of catchment services and disservices in Ireland. DHPCLG, Department of Housing, Planning Community and Local Government; LAWCO, Local Authority Water and Communities Office; NCMC, National Coordination and Management Committee; NTIG, National Technical Implementations Group; WPAC, Water Policy Advisory Committee.

order to communicate the concept of catchment services and disservices using varying degrees of technical information. It is recognised that a detailed technical understanding of the concept of catchment services and disservices is not required across all stakeholders to implement the concept. Rather, an understanding that a catchment can act as a service provider and that the delivery of services and disservices can change over time is more fundamental in increasing catchment-scale thinking at both national and regional/local levels.

The development of the communication strategy and the stakeholder identification process undertaken in Phase One will be critical to the successful implementation of the concept of catchment services and disservices. The communications strategy should therefore outline the varying degrees of technical detail

required to communicate the concept to the different stakeholders identified.

The monitoring and review of engagement processes that must be undertaken throughout Phases Two to Four to inform Phase Five will underpin the adaptive management strategy that will be required in order to deliver the concept of catchment services and disservices. Therefore, the nature of the engagement undertaken to implement the concept can assist in reinforcing ICM initiatives and help to deliver on ICM's own adaptive process. Therefore, the feedback loops incorporated into the adaptive structure of ICM can be informed by the implications of delivering the concept of catchment services and disservices on governance structure and regulations (Work Package Four; see Chapter 4).

4 Work Package Four: Implications for Governance Frameworks and Regulations

4.1 Water Resources Governance

The effectiveness and efficiency of environmental governance and management can be affected by challenges related to spatial scales and political influence (Rogers and Hall, 2003; Moss and Newig, 2010). The term governance can be interpreted in a number of ways; for some, governance is an instrument, a means to achieve certain ends and an administrative and technical toolkit that can be used in different contexts to reach a given objective, such as enforcing a particular water policy. For others, governance is a process that does not involve the implementation of decisions taken by experts and power-holders, but rather involves the debate of alternative, often rival, projects for societal development and the definition of the ends and means that must be pursued by society through a process of democratic participation (Castro, 2007).

Water governance in Ireland has undergone significant restructuring since 2014 as a result of the EU (Water Policy) Regulations 2014, leading to the development of a three-tier governance structure, which has subsequently evolved into the proposed WFD implementation structure outlined in Figure 3.2.

4.2 Catchment Services/Disservices and Governance

Water governance and water resources management take place on various spatial scales, frequently shifting either upwards towards the national or supranational or downwards towards the regional or local scale as a result of political interventions (Moss and Newig, 2010). The focus on ICM has identified the catchment as the geographical unit within which protection of nature, the environment and water takes place, local community and scientific involvement is integrated and appropriate organisational structures and policy objectives are put in place (Daly *et al.*, 2014). This catchment-scale water resources management feeds directly into the second cycle of national river basin management planning. Therefore, water-related governance in Ireland is driven by the delivery of the

WFD despite additional water resources management actions being undertaken to implement other legislation and policy that are associated with the delivery of ICM.

There is limited guidance for regulatory authorities regarding how the implementation of multiple regulations can affect the delivery of catchment services and disservices. One example of such guidance is the Guidelines on the Planning System and Flood Risk Management (OPW, 2009; available online at www.flooding.ie), which set out a framework for the consideration of flood risk at all stages of the planning process. The provision of similar guidelines for other catchment services and disservices would assist in raising awareness of the concept and the potential impact that the implementation of regulations and legislation can have on the delivery of catchment services and disservices.

4.3 Gap Analysis

To understand how the concept of catchment services and disservices can be incorporated into the governance of Ireland's water resources, an assessment has been undertaken of the gaps that exist between (1) the ideal situation where the concept of catchment services and disservices informs all aspects of water resources management in Ireland and (2) the current governance for water resources management in Ireland. The methodology used for this gap analysis follows that of Rolston *et al.* (2016). Thirteen key gaps were identified:

1. lack of awareness or consideration across (i) levels of governance and (ii) local communities of catchments acting as a service provider;
2. lack of consistent integrated catchment-scale thinking at both agency and community levels;
3. lack of a clear communications strategy for promoting the concept of catchment services and disservices;
4. lack of guidance regarding how the implementation of multiple regulations can

affect the delivery of catchment services and disservices;

5. lack of understanding of the differing values people associate with catchments and how these values diversify or diverge between different catchments and sub-catchments;
6. lack of consistent co-ordinated cross-agency management at both the catchment and sub-catchment scales to accommodate issues relating to catchment areas positioned across multiple jurisdictional boundaries (note: this gap could be filled through the Regional Local Authority Structures outlined in the second cycle of the River Basin Management Plan; see Figure 3.2);
7. lack of understanding of how different socio-economic groups use and value their catchments and sub-catchments;
8. limited number of ICM-focused initiatives that are driven by the concept of catchment services and disservices and aim to improve targeted service delivery or remediate/negate targeted disservice delivery;
9. lack of funding initiatives aligned with the concept of catchment services and disservices;
10. lack of suitable monitoring and evaluation of the impact of ICM initiatives on the delivery of catchment services and disservices;
11. lack of quantitative data on many catchment services and disservices;
12. lack of appropriate indicators, developed in an integrated manner between policymakers, catchment managers and the scientific and social research communities, aiming to direct monitoring and evaluation of changes in catchment service/disservice delivery;
13. lack of national-, regional-, catchment- and sub-catchment-scale mapping of key catchment services/disservices provision.

4.4 Conclusions

The concept of catchment services and disservices expands the ecosystem services concept, not only by incorporating atmospheric, geosystem and human social systems into its remit, but also by providing a geographic area (the catchment or sub-catchment)

within which the atmosphere and multiple ecosystems, geosystems and human/social systems can be assessed. The scale at which such catchment services and disservices are managed and delivered is important and can be affected by governance structure and regulatory enforcement. The delivery of the concept of catchment services and disservices across the multiple administrative boundaries that frequently lie within individual catchments is a challenge that will require integrated thinking, integrated management, and co-ordinated actions and responses.

The gaps identified in section 4.3 suggest that a number of modifications to current water governance in Ireland are required in relation to the delivery of the concept of catchment services and disservices:

- A wider focus on general water management is needed, which includes actions not directly associated with WFD implementation and reporting.
- Organisations involved in water management and key stakeholders associated with delivering the concept of catchment services and disservices in Ireland (such as planning authorities) need to be clearly identified and their interactions mapped. This can be achieved through the expanded membership of the Catchment Management Network or through an additional engagement initiative (to be identified through the communications strategy to be developed, as outlined in section 3.4) that aims to communicate the concept of catchment services and disservices.
- Greater interaction between stakeholders is necessary. The Catchment Management Network has provided local authorities and selected non-governmental organisations (NGOs) with information on ICM and its delivery in relation to the WFD. This engagement process can be increased by formally expanding membership of the network to the private sector, academia, other NGOs and selected community representatives, as one large network or through the development of a second network group.
- A wider definition of the term “governance” to include democratic dialogue, negotiation and citizen participation (see Castro, 2007) is needed to move beyond the single definition of governance as a mechanism to implement legislation.

5 Work Package Five: Feasibility Assessment of the Concept of Catchment Services and Disservices

Following the outputs of Work Packages One to Four, this final work package assesses the feasibility of rolling out the concept of catchment services and disservices to both governing agencies and local communities, and identifies the level of resources potentially required for such implementation. This has been undertaken through an assessment of the strengths, weaknesses, opportunities and threats (SWOT) involved in implementing the concept. Potential methods for mitigating identified weaknesses and threats are described.

5.1 SWOT Analysis

Assessing the SWOT of a concept/project is an established method for helping formulate a strategy that can build on the concept/project strengths, eliminate the weaknesses, exploit the opportunities and counter the threats (Dyson, 2004).

The SWOT analysis for the concept of catchment services and disservices is presented in Box 5.1.

5.1.1 *Mitigating weaknesses and threats*

Where possible, the mitigation of the weaknesses of and threats to the concept of catchment services and disservices can assist in the implementation of the concept. Many of the weaknesses and threats have the potential to be mitigated by the development of a communications strategy and the clear, simple communication of the concept to targeted stakeholders where necessary. In addition, the strategies outlined in Table 3.1 can increase awareness of the concept and assist in the mitigation of some weaknesses and threats.

5.1.2 *Is the concept of catchment services and disservices technically feasible?*

The concept of catchment services and disservices outlines the theory that the catchment delivers services and disservices across four key components: the atmosphere, ecosystems, geosystems and human/

social systems. Work Package One (Chapter 1) outlined the background information to each of these components and how the overall concept fits within the current ICM-based management of Ireland's water resources. Therefore, while there may be some academic debate regarding the inclusion of certain services and disservices within specific components of the concept, the underlying technical background to the concept is sound and the overall concept of the catchment acting as a service provider has widespread acceptance and has previously been subject to the peer review process.

5.1.3 *Is the concept of catchment services and disservices economically feasible?*

The economic valuation of ecosystem services has grown in popularity over the past decade, with The Economics of Ecosystems and Biodiversity (TEEB) approach arguably the highest profile assessment undertaken (see <http://www.teebweb.org> for further information). The ES Manage Project is currently in the process of assessing the value of freshwater-related ecosystem services in Ireland (e.g. Feeley *et al.*, 2017a,b). Understanding the value of services/disservices provided by a catchment as a whole and how values change within and between catchments is important in determining the impact of changes to the delivery of catchment services and disservices in the future. Therefore, assessing and understanding the economic importance of catchment services and disservices is a key knowledge gap that needs to be filled. While this knowledge gap does not undermine current river basin management planning processes, further information on the economic importance of catchment services and disservices is necessary. The resources required to undertake the engagement initiatives identified in Chapter 3 are unlikely to be prohibitive for the communication and roll-out of the concept; therefore, these are likely to be economically feasible. However, further investigation into the economic importance of catchment services and disservices is required and currently the resources

Box 5.1. Strengths, weaknesses, opportunities and threats (SWOT) for implementing the concept of catchment services and disservices in Ireland

Strengths

- Supports implementation of ICM processes
- Aligns with delivery of the second round of River Basin Management Plans regarding single River Basin District
- Aligns with the current development of the Natural Capital concept
- Has the potential to deliver awareness of the implications of actions across land and water
- Includes atmospheric, geosystem, social and economic components absent from ecosystem services concept
- Has the potential to be simply communicated using easy to understand language and diagrams
- Has the potential to remain as a foundational concept of water resources management in Ireland, regardless of policy, legislative or political change
- Provides a basis for identifying unnecessary policy conflicts and avoiding the creation of incentives for damaging catchment services

Weaknesses

- Some individuals may struggle with the complexity of the concept, such as understanding and interpreting geosystem and human/social system services components
- Requires an integrated approach to policy development and implementation of legislation (although an integrated approach is essential for delivering the concept of catchment services and disservices, a truly integrated approach to policy development may be difficult to attain)
- Requires champions of the concept across all levels of water resources governance in Ireland
- Requires significant engagement across both agency and local community levels to increase awareness of the concept
- Requires an acceptance of the theory of a catchment acting as a service provider
- Challenges academic perceptions of catchments, the atmosphere, geosystems, human/social systems and ecosystems, and their interactions

Opportunities

- May further develop the integration of water resources management in Ireland
- May significantly engage governing agencies and local communities to communicate catchment-scale management of resources
- May ensure that the concept is included as base information for all engagement initiatives aligned with the second round, and future rounds, of river basin management planning
- May further develop socio-economic assessments of the value of catchment services
- May address a number of concept weaknesses (listed above), for example developing an integrated approach to policy development and implementation of legislation

Threats

- May require significant resources to embed the concept into general catchment-scale thinking, particularly for governing agencies whose focus is not on water or catchments
- Competes against other, more well-established concepts, such as ecosystem services and natural capital, leading to 'concept fatigue'
- Governing agencies may resist change regarding implementing a new concept
- Academia may somewhat resist the delivery of a concept that competes with other, more established, concepts
- Establishing ICM as the underlying principle of water resources management in Ireland may provoke resistance

necessary for such investigations are yet to be identified.

5.1.4 Is the concept of catchment services and disservices operationally feasible?

Given the strong facilitation and communication of the catchment as the geographical basis for water resources management that is on-going in Ireland, the concept of catchment services and disservices underpins this ICM-focused process. While key data and information regarding catchment services and disservices – such as the values that communities place on specific services and disservices, and how these values vary within and between catchments – is not currently available, there is the potential for this data gap to be filled through targeted research projects that align with the second round of river basin management planning. The mapping of these values, in addition to the mapping of where key services and disservices are delivered within catchments, would provide a strong basis for the continued roll-out of the concept. Minimising the potential impact of changes in service/disservice delivery will require more understanding than this report provides of how delivery of services and disservices may change in the future, given climate, legislative/policy and social demographic change, particularly with regard to individual catchments.

The communication of the concept will be important to ensure that the concept underpins future ICM-focused initiatives, and the development of a communications and engagement strategy should be a priority action for the implementation of the concept. Availability of resources (budgets, time and personnel) has the potential to be a key limiting factor in the implementation of the concept. Aligning communication of the concept with current and on-going engagement initiatives, where possible, may reduce the need of additional resources. The development of template communication tools as part of the communication and engagement strategy would ensure consistent information delivery.

Helping champions of the concept would assist in ensuring that communication of the concept and its consistent inclusion in engagement initiatives can occur. The Local Authority Waters and Communities

Office (LAWCO) and local authorities should be active in the delivery of the concept to local communities. Champions within the EPA are likely to drive the delivery of engagement within the higher levels of the WFD implementation structure and to priority stakeholders involved in water resources management, but are external to the implementation structure.

Therefore, given sufficient resources, the concept of catchment services and disservices is operationally feasible.

5.1.5 What are the key timeframes for implementing the concept of catchment services and disservices?

The overarching objective of the Extra TIME Project is to identify the mechanisms for the feasible delivery of the concept of catchment services and disservices in Ireland from 2016 to 2020. The Extra TIME Project ran for the period March 2016 to March 2017; therefore, the timeframes presented in Box 5.2 are suggested to facilitate the implementation of the concept of catchment services and disservices through to 2020.

5.2 Conclusions

Work Package Five has identified that the implementation of the concept of catchment services and disservices is feasible, despite a number of legitimate weaknesses in and threats to the concept. These weaknesses and threats can be mitigated by a combination of the development of a communications strategy for the concept, strong, frequent and inclusive stakeholder engagement, and clear and consistent communication and awareness-raising.

A key limiting factor to the implementation of the concept is the level of resources available for the continued development of the concept and the delivery of engagement and research activities. This study has not attempted to identify the resources necessary for concept implementation. Therefore, such resource assessment has been identified as a key action in 2017 and will be required prior to the further delivery of other key actions identified in the timeframe described in section 5.1.5.

Box 5.2. Timeframes for implementing the concept of catchment services and disservices through to 2020

2016

- Initiation of the Extra TIME Project, identifying the mechanisms for the feasible delivery of the concept of catchment services and disservices
- Introduction and promotion of the concept at local, national and international meetings and conferences
- Promotion of the concept through social and printed media

2017

- Completion of the Extra TIME Project
- Submission and publication of a catchment services/disservices discussion paper in an international peer-reviewed journal
- Assessment of resources required to proceed with the implementation of the concept of catchment services and disservices
- Continued promotion of the concept of catchment services and disservices through social and printed media, and oral engagement initiatives
- Stakeholder identification processes undertaken as part of the development of the catchment services/disservices communication and engagement strategy
- Development and publication of concept communications and an engagement strategy for Ireland
- Engagement of key stakeholders within the WFD implementation structure and identification of potential champions of the concept of catchment services and disservices
- Alignment of the concept with the second round of river basin management planning
- Development of a research funding call relevant to the concept of catchment services and disservices (e.g. streamlining of aspects of EPA Water Research Pillar to incorporate catchment services-focused research projects)

2018

- Delivery of the 2018 catchment services/disservices-related research call
- Implementation of the communications and engagement plan
- Continued engagement of key stakeholders
- Continued promotion of the concept through social and printed media
- Initial introduction of the concept of catchment services and disservices to pilot communities, delivered through the champions identified in 2017

2019

- Continued promotion of the concept through social and printed media
- Continued engagement of key stakeholders
- Delivery of initial results of the 2018 research call
- Roll-out of second catchment services/disservices-related research call
- Frequent use of concept of catchment services and disservices to underpin ICM-focused initiatives
- Initial development of a roadmap for the delivery of the concept beyond 2020

Box 5.2. Continued

2020

- Concept of catchment services and disservices established as key concept underpinning ICM-focused initiatives
- Concept of catchment services and disservices incorporated into the third round of river basin management planning cycle
- Delivery of results of the 2018 and 2019 research calls
- Roll-out of the third catchment services/disservices-related research call
- Continued inclusive stakeholder engagement and concept promotion through social and printed media
- Continued development and finalisation of a road map for the delivery of the concept of catchment services and disservices beyond 2020

An important threat to implementing the concept is the ability of both individuals and organisations to cope with change. Implementing the concept of catchment services and disservices has the potential to introduce:

- change in understanding the role and function of a catchment;
- change in assessing the impact of management actions within a catchment;
- change in the design and delivery of projects;
- change in stakeholder identification and engagement;
- change in policy;

- change in organisational structure;
- change in roles and responsibilities.

How the concept of catchment services and disservices is communicated to individuals and organisations will be vital to ensuring that the potential positive impacts of such change are highlighted and the negative impacts described above are minimised. The development of a communication and engagement strategy, as well as the other actions identified in the timeline for implementation, will assist in the successful delivery of the concept.

6 Conclusions

The overarching objective of the Extra TIME project was to identify the mechanisms for the feasible delivery of the concept of catchment services and disservices in Ireland over the next 5 years (2016–2020). This has been achieved through the development of the Extra TIME project over the

course of 2016–2017 and was underpinned by the six supporting objectives outlined in Table 6.1.

The number of community engagement events regarding water resources management and local involvement in water management has increased

Table 6.1. How the Extra TIME Project’s six supporting objectives were achieved

Supporting objective	How it was achieved
To identify national and international concepts and the implementation of catchment services programmes	<p>Undertaking a review of the national and international literature in WP 1, which encompassed the key components of the concept of catchment services and disservices</p> <p>Identifying and describing a number of national and international projects that are associated (directly or indirectly) with the concept of catchment services and disservices (WP 1)</p> <p>Describing engagement actions through a phased approach that will increase awareness of, and work towards the full implementation of, the concept of catchment services and disservices (WP 3)</p> <p>Identifying the key gaps that exist between the ideal scenario of the concept of catchment services and disservices informing all aspects of water resources management in Ireland, and the current national water governance framework (WP 4)</p> <p>Assessing the feasibility of implementing the concept of catchment services and disservices (WP 5)</p>
To identify key components of the concept of catchment services and disservices in Ireland and how these may be affected by different climatic, legislative and social demographic scenarios	<p>Undertaking a review of the national and international literature in WP 1 which encompassed the key components of the concept of catchment services and disservices</p> <p>Describing key elements of change affected by climate, legislation, policy and social demographic change (WP 2)</p> <p>Undertaking two small workshops to assess the impact of change on selected catchment services (WP 2)</p>
To identify the implications of implementing the concept of catchment services and disservices for community engagement and catchment management in Ireland	<p>Describing engagement actions through a phased approach that will increase awareness of, and work towards the full implementation of, the concept of catchment services and disservices (WP 3)</p>
To identify the implications of implementing the concept of catchment services and disservices on governance frameworks and regulations	<p>Identifying the key gaps that exist between the ideal scenario of the concept of catchment services and disservices informing all aspects of water resources management in Ireland, and the current national water governance framework (WP 4)</p>
To identify the feasibility of implementing the catchment services approach in Ireland	<p>Utilising the outputs of WPs 1–4 to assess the feasibility of implementing the concept of catchment services and disservices for WP 5</p>
To increase both management and community awareness of the catchment services and ICM concepts in Ireland	<p>Promoting the Extra TIME Project and the concept of catchment services and disservices on social media (Twitter and Facebook)</p> <p>Publishing short articles in the EPA’s Catchments newsletter and the ES Manage Project’s newsletter</p> <p>Publishing correspondence in the journal <i>Nature</i> addressing key aspects of the concept of catchment services and disservices</p> <p>Promoting and describing the concept of catchment services and disservices at national and international conferences, as well as local community meetings</p>

WP, Work Package.

greatly over the past 2 years. This has been facilitated by a greater national-level focus on engagement activities, the implementation of the ICM concept, the formation of the LAWCO and also increased awareness of, and interest in, water issues as a result of the national debate regarding Irish Water and billing for consumptive water usage. In addition, the second round of river basin management planning is likely to facilitate greater engagement in, and awareness-raising of, national and local water resources management issues.

The potential for promoting the concept of catchment services and disservices among both governing agencies and local communities, and for using the concept to underpin key policy initiatives, will be high in the short-term future. The second round of EU WFD river basin management planning, as well as the National Planning Framework (DHPCLG, 2017a), provides opportunities to use the concept of catchment services and disservices to inform the development of key policies. Engagement within and external to the

proposed WFD implementation structure is needed in order to achieve this.

There is an existing base of understanding of the potential of the catchment as a geographical unit for management; the provision of services by ecosystems; and the potential for the delivery of services to be affected by climate change, legislation/policy change and socio-demographic change. This existing knowledge base can therefore be expanded and developed through targeted communication and engagement to assist in the delivery of the concept of catchment services and disservices.

In this manner, a key function of ICM in Ireland will develop, moving from a concept aimed primarily at delivering environmental benefits in order to implement the WFD in Ireland to a process that influences national policy at the highest level, underpinned by (1) the concept of catchment services and disservices and (2) the use of the catchment as the geographical basis for infrastructure development, social development and water resources management in Ireland.

7 Recommendations

Given the feasibility of implementing the concept of catchment services and disservices to inform water resources management in Ireland, as identified in this report, the following recommendations are made:

1. Fill the key gaps that are currently present that prevent the concept of catchment services and disservices from informing all aspects of water resources management in Ireland. These gaps are:
 - (a) lack of awareness or consideration across (i) levels of governance and (ii) local communities of catchments acting as a service provider;
 - (b) lack of consistent and integrated catchment-scale thinking at both agency and community levels;
 - (c) lack of a clear communications strategy for promoting the concept of catchment services and disservices;
 - (d) lack of guidance on how the implementation of multiple regulations can affect the delivery of catchment services and disservices;
 - (e) lack of understanding of the differing values people associate with catchments and how these values diversify or diverge between different catchments and sub-catchments;
 - (f) lack of co-ordinated cross-agency management at both the catchment and sub-catchment scales to accommodate issues relating to catchment areas that lie across multiple jurisdictional boundaries (note: this gap may be filled through the Regional Local Authority Structures outlined in the second WFD River Basin Management Plan);
 - (g) lack of understanding of how different socio-economic groups use and value their catchments and sub-catchments;
 - (h) limited number of ICM-focused initiatives that are driven by the concept of catchment services and disservices and aim to improve targeted service delivery or remediate/negate targeted disservice delivery;
2. Undertake a phased approach to engagement regarding the concept of catchment services and disservices:
 - (i) lack of funding initiatives aligned with the concept of catchment services and disservices;
 - (j) need for suitable monitoring and evaluation of the impact of ICM initiatives on the delivery of catchment services and disservices;
 - (k) lack of quantitative data on many catchment services and disservices;
 - (l) lack of appropriate indicators, developed in an integrated manner between policymakers, catchment managers, and the scientific and social research communities, aiming to direct monitoring and evaluation of changes in catchment service/disservice delivery;
 - (m) lack of national-, regional-, catchment- and sub-catchment-scale mapping of key catchment service/disservice provision.
3. Prioritise the concept of catchment services and disservices as a key informative platform to facilitate integrated policy development; for example, utilise current opportunities to engage
 - (a) Phase One: preparation (including stakeholder identification and the development of a communications and engagement strategy);
 - (b) Phase Two: initial engagement within the current water resources management governance framework for Ireland;
 - (c) Phase Three: further external engagement with agencies and organisations outside the governance framework;
 - (d) Phase Four: expansive implementation of the concept;
 - (e) Phase Five: review and follow-up.

the relevant stakeholders to ensure that the concept informs the second round of EU WFD river basin management planning and also the National Planning Framework, and is fully integrated into the third round of river basin management planning.

4. Undertake a cost–benefit analysis for the key actions required to fully implement the concept of catchment services and disservices.
5. Provide guidelines for regulatory authorities on how the implementation of multiple regulations can impact on the delivery of catchment services and disservices.
6. Undertake research investigations to provide further understanding of the economic and social

importance of the concept of catchment services and disservices:

- (a) assess the economic value of key catchment services and disservices;
- (b) assess the social value of key catchment services and disservices;
- (c) assess how the economic and social values of key catchment services and disservices change within and between catchments, sub-catchments and socio-economic groups.

The results of these research investigations should form the basis for the development of guidance for the general public on recognising and prioritising the protection of catchment services and the mitigation of catchment disservices.

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Abbreviations

EPA	Environment Protection Agency
EU	European Union
Extra TIME	Developing the Concept of Catchment Services for Progress Towards Integrated Water Management
ICM	Integrated Catchment Management
LAWCO	Local Authority Waters and Communities Office
NGO	Non-governmental organisation
RDP	Rural Development Plan
SEA	Strategic Environmental Assessment
SWOT	Strengths, weaknesses, opportunities and threats
WFD	Water Framework Directive

AN GHNÍOMHAIREACHT UM CHAOMHNÚ COMHSHAOIL

Tá an Gníomhaireacht um Chaomhnú Comhshaoil (GCC) freagrach as an gcomhshaoil a chaomhnú agus a fheabhsú mar shócmhainn luachmhar do mhuintir na hÉireann. Táimid tiomanta do dhaoine agus don chomhshaoil a chosaint ó éifeachtaí díobhálacha na radaíochta agus an truaillithe.

Is féidir obair na Gníomhaireachta a roinnt ina trí phríomhréimse:

Rialú: Déanaimid córais éifeachtacha rialaithe agus comhlionta comhshaoil a chur i bhfeidhm chun torthaí maithe comhshaoil a sholáthar agus chun díriú orthu siúd nach gcloíonn leis na córais sin.

Eolas: Soláthraimid sonraí, faisnéis agus measúnú comhshaoil atá ar ardchaighdeán, spriocdhírthe agus tráthúil chun bonn eolais a chur faoin gcinnteoireacht ar gach leibhéal.

Tacaíocht: Bimid ag saothrú i gcomhar le grúpaí eile chun tacú le comhshaoil atá glan, táirgiúil agus cosanta go maith, agus le hiompar a chuirfidh le comhshaoil inbhuanaithe.

Ár bhFreagrachtaí

Ceadúnú

Déanaimid na gníomhaíochtaí seo a leanas a rialú ionas nach ndéanann siad dochar do shláinte an phobail ná don chomhshaoil:

- saoráidí dramhaíola (*m.sh. láithreáin líonta talún, loisceoirí, stáisiúin aistriúcháin dramhaíola*);
- gníomhaíochtaí tionsclaíocha ar scála mór (*m.sh. déantúsaíocht cógaisíochta, déantúsaíocht stroighne, stáisiúin chumhachta*);
- an diantalmhaíocht (*m.sh. muca, éanlaith*);
- úsáid shrianta agus scaoileadh rialaithe Orgánach Géinmhodhnaithe (*OGM*);
- foinsí radaíochta ianúcháin (*m.sh. trealamh x-gha agus radaiteiripe, foinsí tionsclaíocha*);
- áiseanna móra stórála peitрил;
- scardadh dramhuisece;
- gníomhaíochtaí dumpála ar farraige.

Forfheidhmiú Náisiúnta i leith Cúrsaí Comhshaoil

- Clár náisiúnta iniúchtaí agus cigireachtaí a dhéanamh gach bliain ar shaoráidí a bhfuil ceadúnas ón nGníomhaireacht acu.
- Maoirseacht a dhéanamh ar fhreagrachtaí cosanta comhshaoil na n-údarás áitiúil.
- Caighdeán an uisce óil, arna sholáthar ag soláthraithe uisce phoiblí, a mhaoirsiú.
- Obair le húdaráis áitiúla agus le gníomhaireachtaí eile chun dul i ngleic le coireanna comhshaoil trí chomhordú a dhéanamh ar líonra forfheidhmiúcháin náisiúnta, trí dhírú ar chiontóirí, agus trí mhaoirsiú a dhéanamh ar leasúchán.
- Cur i bhfeidhm rialachán ar nós na Rialachán um Dhramhthrealamh Leictreach agus Leictreonach (DTLL), um Shrian ar Shubstaintí Guaiseacha agus na Rialachán um rialú ar shubstaintí a ídionn an ciseal ózóin.
- An dlí a chur orthu siúd a bhriseann dlí an chomhshaoil agus a dhéanann dochar don chomhshaoil.

Bainistíocht Uisce

- Monatóireacht agus tuairisciú a dhéanamh ar cháilíocht aibhneacha, lochanna, uisce idirchriosacha agus cósta na hÉireann, agus screamhuisec; leibhéal uisce agus sruthanna aibhneacha a thomhas.
- Comhordú náisiúnta agus maoirsiú a dhéanamh ar an gCreat-Treoir Uisce.
- Monatóireacht agus tuairisciú a dhéanamh ar Cháilíocht an Uisce Snámha.

Monatóireacht, Anailís agus Tuairisciú ar an gComhshaoil

- Monatóireacht a dhéanamh ar cháilíocht an aeir agus Treoir an AE maidir le hAer Glan don Eoraip (CAFÉ) a chur chun feidhme.
- Tuairisciú neamhspleách le cabhrú le cinnteoireacht an rialtais náisiúnta agus na n-údarás áitiúil (*m.sh. tuairisciú tréimhsiúil ar staid Chomhshaoil na hÉireann agus Tuarascálacha ar Tháscairí*).

Rialú Astaíochtaí na nGás Ceaptha Teasa in Éirinn

- Fardail agus réamh-mheastacháin na hÉireann maidir le gáis ceaptha teasa a ullmhú.
- An Treoir maidir le Trádáil Astaíochtaí a chur chun feidhme i gcomhar breis agus 100 de na táirgeoirí dé-ocsaíde carbóin is mó in Éirinn.

Taighde agus Forbairt Comhshaoil

- Taighde comhshaoil a chistiú chun brúnna a shainnaint, bonn eolais a chur faoi bheartais, agus réitigh a sholáthar i réimsí na haeráide, an uisce agus na hinbhuanaitheachta.

Measúnacht Straitéiseach Timpeallachta

- Measúnacht a dhéanamh ar thionchar pleananna agus clár beartaithe ar an gcomhshaoil in Éirinn (*m.sh. mórfheananna forbartha*).

Cosaint Raideolaíoch

- Monatóireacht a dhéanamh ar leibhéal radaíochta, measúnacht a dhéanamh ar nochtadh mhuintir na hÉireann don radaíocht ianúcháin.
- Cabhrú le pleananna náisiúnta a fhorbairt le haghaidh éigeandálaí ag eascairt as tairmí núicléacha.
- Monatóireacht a dhéanamh ar fhorbairtí thar lear a bhaineann le saoráidí núicléacha agus leis an tsábháilteacht raideolaíochta.
- Sainseirbhísí cosanta ar an radaíocht a sholáthar, nó maoirsiú a dhéanamh ar sholáthar na seirbhísí sin.

Treoir, Faisnéis Inrochtana agus Oideachas

- Comhairle agus treoir a chur ar fáil d'earnáil na tionsclaíochta agus don phobal maidir le hábhair a bhaineann le caomhnú an chomhshaoil agus leis an gcosaint raideolaíoch.
- Faisnéis thráthúil ar an gcomhshaoil ar a bhfuil fáil éasca a chur ar fáil chun rannpháirtíocht an phobail a spreagadh sa chinnteoireacht i ndáil leis an gcomhshaoil (*m.sh. Timpeall an Tí, léarscáileanna radóin*).
- Comhairle a chur ar fáil don Rialtas maidir le hábhair a bhaineann leis an tsábháilteacht raideolaíoch agus le cúrsaí práinnfhreagartha.
- Plean Náisiúnta Bainistíochta Dramhaíola Guaisí a fhorbairt chun dramhaíl ghuaiseach a chosaint agus a bhainistiú.

Múscailt Feasachta agus Athrú Iompraíochta

- Feasacht comhshaoil níos fearr a ghiniúint agus dul i bhfeidhm ar athrú iompraíochta dearfach trí thacú le gnóthais, le pobail agus le teaghlaigh a bheith níos éifeachtúla ar acmhainní.
- Tástáil le haghaidh radóin a chur chun cinn i dtithe agus in ionaid oibre, agus gníomhartha leasúcháin a spreagadh nuair is gá.

Bainistíocht agus struchtúr na Gníomhaireachta um Chaomhnú Comhshaoil

Tá an gníomhaíocht á bainistiú ag Bord Iáinimseartha, ar a bhfuil Ard-Stiúrthóir agus cúigear Stiúrthóirí. Déantar an obair ar fud cúig cinn d'Oifigí:

- An Oifig um Inmharthanacht Comhshaoil
- An Oifig Forfheidhmithe i leith cúrsaí Comhshaoil
- An Oifig um Fianaise is Measúnú
- Oifig um Chosaint Radaíochta agus Monatóireachta Comhshaoil
- An Oifig Cumarsáide agus Seirbhísí Corparáideacha

Tá Coiste Comhairleach ag an nGníomhaireacht le cabhrú léi. Tá dáréag comhaltáí air agus tagann siad le chéile go rialta le plé a dhéanamh ar ábhair inní agus le comhairle a chur ar an mBord.

Developing the Concept of Catchment Services for Progress Towards Integrated Water Management (Extra TIME)



Authors: Alec Rolston, Eleanor Jennings, Suzanne Linnane and David Getty

A river catchment is the geographical area within which communities, industry and ecosystems are driven by physical, environmental, economic and social factors.

The benefits and disservices received by people and ecosystems within catchments are called catchment services and disservices. Their delivery can be influenced by multiple factors including climate, legislative/policy and social (demographic) change. Understanding how catchment services and disservices may be affected by such future change is essential for undertaking Integrated Catchment Management-focused initiatives and communicating the concept of catchment services and disservices. Catchment services and disservices can be placed within four key components:

- Atmospheric services: The services and disservices that are derived from the atmosphere.
- Ecosystem Services: The services and disservices that are derived from ecosystems.
- Geosystem Services: The values, services and disservices associated with the subsurface.
- Human-Social System Services: A variety of social and cultural services and disservices which contribute to the life within a catchment.

Identifying Pressures

The research showed that the sensitivity of catchment services and disservices to future climate change projections varied, with water balance/yield, aquifer recharge, crop yield and water abstraction being the services most sensitive to climate change. The over-abstraction of water resources, flooding and drought were the disservices found to be most sensitive to climate change. As environmental and social policies influence catchment services in different ways, integrated policy development is needed to work across the land-use and water management realms that underpin the principles of Integrated Catchment Management. This will minimise negative impacts of future policy on the delivery of catchment services and help negate the delivery of catchment disservices. Ireland's future population growth will affect multiple catchment services and disservices. Impacts include habitat loss, increased infrastructure development, deteriorated surface water and groundwater

quality, increased litter dumping, loss of agricultural area, and increased urban sprawl. Mitigating impacts on catchment services and disservices will be dependent on future housing, infrastructure and social planning policies.

Informing Policy

The concept of catchment services and disservices has the potential to underpin environmental and social policy and legislation. Therefore, there are implications for current water governance and engagement across both agencies and communities. The research identified 13 key gaps that currently exist between 1) the ideal situation where the concept of catchment services and disservices informs all aspects of water resources management in Ireland; and 2) the current governance framework for water resources management in Ireland. For agencies implementing water-related legislation, clear guidance is required as to how the concept of catchment services and disservices can inform management actions. In addition, further understanding is required as to how multiple catchment services and disservices may be affected by the enforcement of relevant regulations.

Developing Solutions

The research identified that there are opportunities for the concept of catchment services and disservices to underpin key policy initiatives in to the future, such as current and future rounds of EU WFD river basin management planning, and the National Planning Framework (Ireland 2040-Our Plan). However, targeted engagement actions are required within and external to the proposed WFD Implementation Structure, to raise awareness of the concept of catchment services and disservices and how the concept can inform high level policy and management actions. The research has developed a five-phased approach for communicating the concept of catchment services and disservices in Ireland, and has identified a series of actions that will increase awareness of the concept across both governing agencies and local communities.