CREW CENTRE OF EXPERTISE FOR WATERS

River Leven Catchment Initiative

Synthesis of current knowledge to help identify environmental management priorities to improve the water environment

Photo credit: Linda May, CEH

CREW CENTRE OF EXPERTISE FOR WATERS

Published by CREW – Scotland's Centre of Expertise for Waters. CREW connects research and policy, delivering objective and robust research and expert opinion to support the development and implementation of water policy in Scotland. CREW is a partnership between the James Hutton Institute and all Scottish Higher Education Institutes supported by MASTS. The Centre is funded by the Scottish Government.

This document was produced by: Linda May, Jan Dick, Iain Gunn & Bryan Spears
Centre for Ecology & Hydrology, Bush Estate, Penicuik, Midlothian EH26 OQB

Please reference this report as follows: May, L., Dick, J., Gunn, I.D.M. & Spears, B. (2018) River Leven Catchment Initiative: Synthesis of current knowledge to help identify environmental management priorities to improve the water environment. CD2018/2. Available online at: crew.ac.uk/publications

Dissemination status: Unrestricted

Acknowledgements: We thank staff at Scottish Environment Protection Agency, Forth Fisheries Trust, British Geological Survey and Fife Council for data and information provided.

Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

Contents

Executive Summary

Research questions

The study addressed six main research questions.

1. What is the current condition of all rivers, lochs and ground waters in the River Leven catchment, based on available information?
2. What are the main pressures on the aquatic environment and the sources of those pressures?
3. What are the environmental management priorities for improving the water environment?
4. What is the baseline socio-economic condition of the River Leven catchment?
5. What is the current condition of Loch Leven and its catchment, and how have improvements supported socio-economic development?
6. What are the gaps in evidence and how can they be addressed?

The output from this project provides a "first-pass" assessment of our understanding of the River Leven catchment. It is not intended to be a comprehensive review of all of the data and information available. Draft environmental priorities are suggested for further consideration.

Key findings

- The River Leven catchment contains six WFD baseline standing waters; three have met or exceeded their WFD ecological status target for 2021
- The River Leven catchment contains 17 WFD water bodies; seven have met their WFD ecological status targets for 2021 and ten require further improvement.
- Nine groundwater bodies lie within the River Leven catchment; three have met their WFD target for 2021 and six require improvement
- Pressures on water bodies within the catchment that are causing failure to meet WFD and conservation targets include barriers to fish migration, hydromorphological modification, invasive species, nutrient inputs and mine water discharges
- The Scottish Index of Multiple Deprivation (SIMD) showed 188 data zones falling within the River Leven catchment; four were among the 5% most deprived areas of Scotland
- The greatest socio-economic benefit would probably be gained from improvements to the water environment focused around Methil, Glenrothes and Levenmouth

Background

The River Leven catchment, spanning both Fife and Perth & Kinross, is one of the most deprived areas of Scotland. The SIMD indicates that 45% of the population in this area live within the three highest categories of deprivation. It has been suggested that levels of deprivation could be reduced by improving the environment in which people live and work. To create a better understanding of where to prioritise such improvements in relation to the water environment, this project summarised spatially referenced knowledge on the current condition of the water environment and levels of deprivation within the catchment. The overall aim was to provide the baseline information required to identify environmental challenges, set environmental management priorities and support evidence-based decision making in this area.

Research undertaken

All available water quality, hydromorphological and ecological data for the River Leven catchment were reviewed to identify water bodies that fail to meet Water Framework Directive (WFD) and conservation targets and could be improved through targeted management interventions. In addition, SIMD data were used to identify areas where high deprivation coincided with areas where water quality improvements are required to meet WFD and conservation objectives. The results are presented as maps and tables.

Recommendations

To identify areas in which to target improvements to the water environment and enhance human health and well-being, it is recommended that individual domains of deprivation are considered rather than overall SIMD values. This is because some of the domains of deprivation (e.g. income; crime; use of prescribed anti-depressants) are more likely to change in relation to environmental improvement than others (e.g. households with central heating; distance to a post office). Also, the individual indices are less likely to change from year to year than the combined indices, providing a more robust baseline for the quantification of change.

The greatest socio-economic benefit would probably be gained from improvements to the water environment that are focused around Methil, Glenrothes and Levenmouth. As all of the water bodies in the catchment are connected, these local scale improvements would also create more recreational and business opportunities, and less risk of flooding, for people within the wider catchment.

1 Introduction

The River Leven catchment (Figure 1.1), partly spanning both Fife and Perth & Kinross, is one of the most deprived areas of Scotland. The Scottish Index of Multiple Deprivation (SIMD) indicates that 45% of the population of the catchment live in areas that fall within the three highest categories of deprivation in Scotland.

In line with its *One Planet Prosperity* strategy, and in collaboration with its business, government and community partners, the Scottish Environment Protection Agency (SEPA) are beginning a major initiative to improve the environment for the people of the River Leven catchment. This aims to enhance the quality of life of many thousands of people by improving the natural environment of the area and the socio-economic benefits that it delivers.

To create a better understanding of where to prioritise improvements to the water environment, this project summarises the condition of the water environment and levels of deprivation in this area. The main aim of the study was to review and synthesise current knowledge relating to the water environment within the River Leven catchment, including the condition of its rivers, lochs and groundwater.

Outputs from this project will be used to identify environmental challenges, set environmental management priorities and support evidence-based decision making in this area to improve the water environment and, consequently, the quality of life for the many thousands of people that live there.

The study had six main objectives. These were to:

1. Assess the current condition of all Water Framework Directive (WFD) river, loch and groundwater baseline water bodies in the River Leven catchment (including non-baseline water bodies where they aid understanding of baseline water body condition) using existing information.
2. Assess the main pressures on the aquatic environment, and the sources of those pressures.
3. Identify potential environmental management priorities to improve the water environment.
4. Conduct a high-level assessment of the socio-economic condition of the whole River Leven basin, drawing on the Scottish Index of Multiple-Deprivation and other previous studies, to provide a baseline against which the potential benefits of improvement work can be estimated or quantified.
5. Summarise the condition of Loch Leven and its

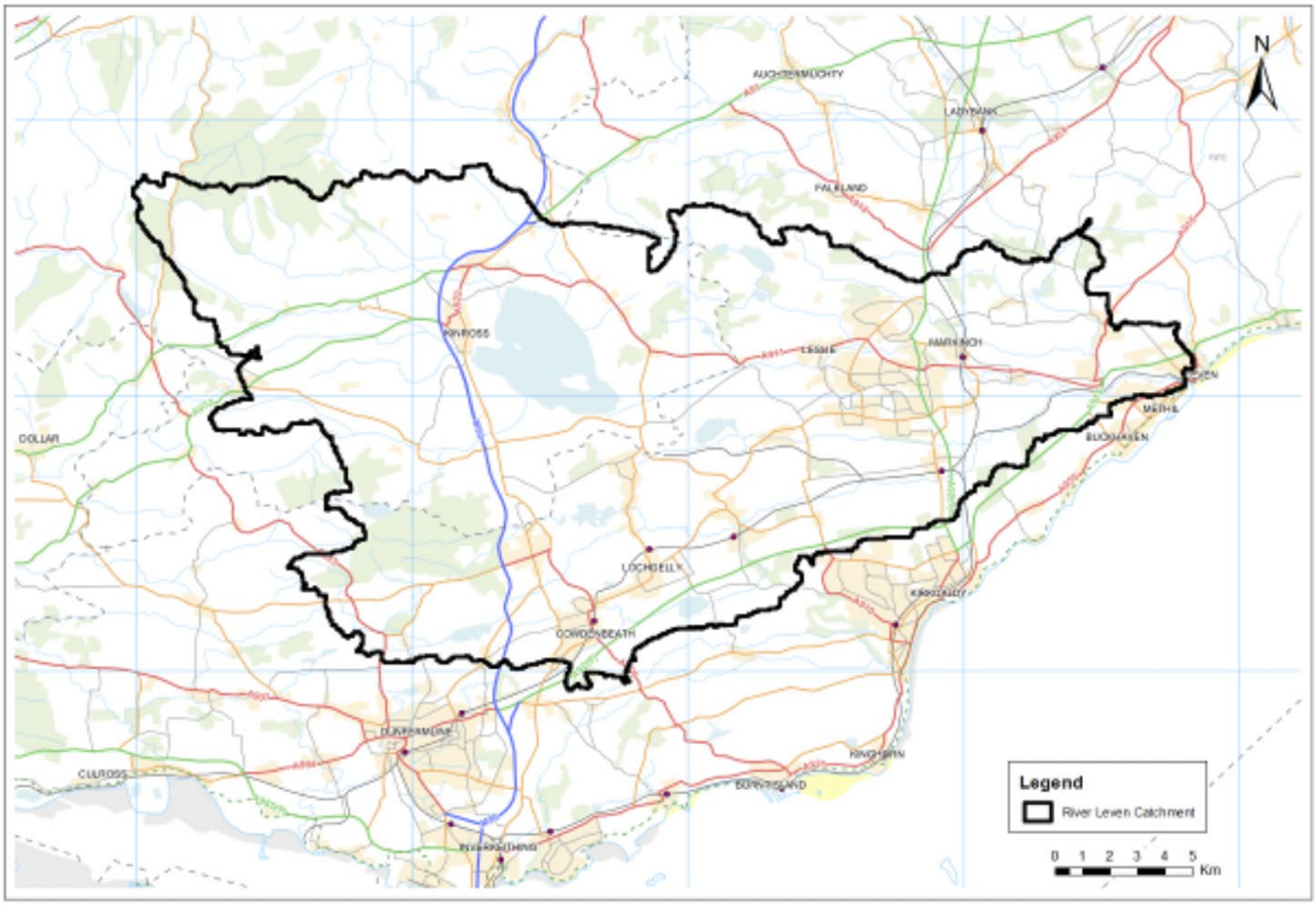

Figure 1.1 Location and extent of the River Leven catchment.
Some features of this map are based on digital spatial data (Morris & Flavin 1990, 1994; Moore at al., 1994) licensed from the Centre for Ecology & Hydrology, © NERC (CEH). Contains Ordnance Survey data © Crown copyright and database right 2018. All rights reserved.

catchment, and the pressures on it.

6. Summarise any gaps in evidence and opportunities to address them.

The outputs from this project are intended to give a "first-pass" assessment of our understanding of the River Leven catchment. It is not a comprehensive review of all the data and information available. Work focused on SEPA's data holdings for the catchment (in terms of pressures, monitoring data and modelling), but also drew on data and reports (using existing syntheses where possible) from other organisations (such as Scottish Natural Heritage (SNH), Centre for Ecology & Hydrology (CEH), Forth Fisheries Trust (FFT) and Fife Council). Areas where further exploration would have been beneficial have been identified.

2 Current condition of surface and groundwater baseline water bodies

The WFD requires all lochs, rivers and ground waters above a certain size to be defined as water bodies. For rivers, this includes all watercourses or parts of watercourses with a catchment area greater than 10 km2 and all small lakes connected to those watercourses that do not meet the WFD criteria for lakes. A water body comprises the main stem of the river plus the network of tributaries that drain to the main stem. For lakes, WFD water bodies include all lochs with a surface area greater than 0.5 km2 and smaller lochs that fulfil one or more of the criteria given in the UK guidance on the identification of small water bodies (UKTAG, 2003). Any short lengths of river that connect to a loch but do not meet the criteria for being classified as a WFD river are also included. Groundwater bodies are defined as all water that is below the surface of the ground in the saturation zone and in direct contact with the ground or subsoil (UKTAG, 2011).

2.1 Water Framework Directive baseline water bodies

2.1.1 Lochs

In terms of standing waters, there are six WFD baseline surface water bodies within the River Leven catchment. These are listed below, together with their 2017 quality status assessment as shown on SEPA's Water Classification Hub. Their locations are shown in Figure 2.1. The blue coloured standing waters represent non-WFD water bodies.

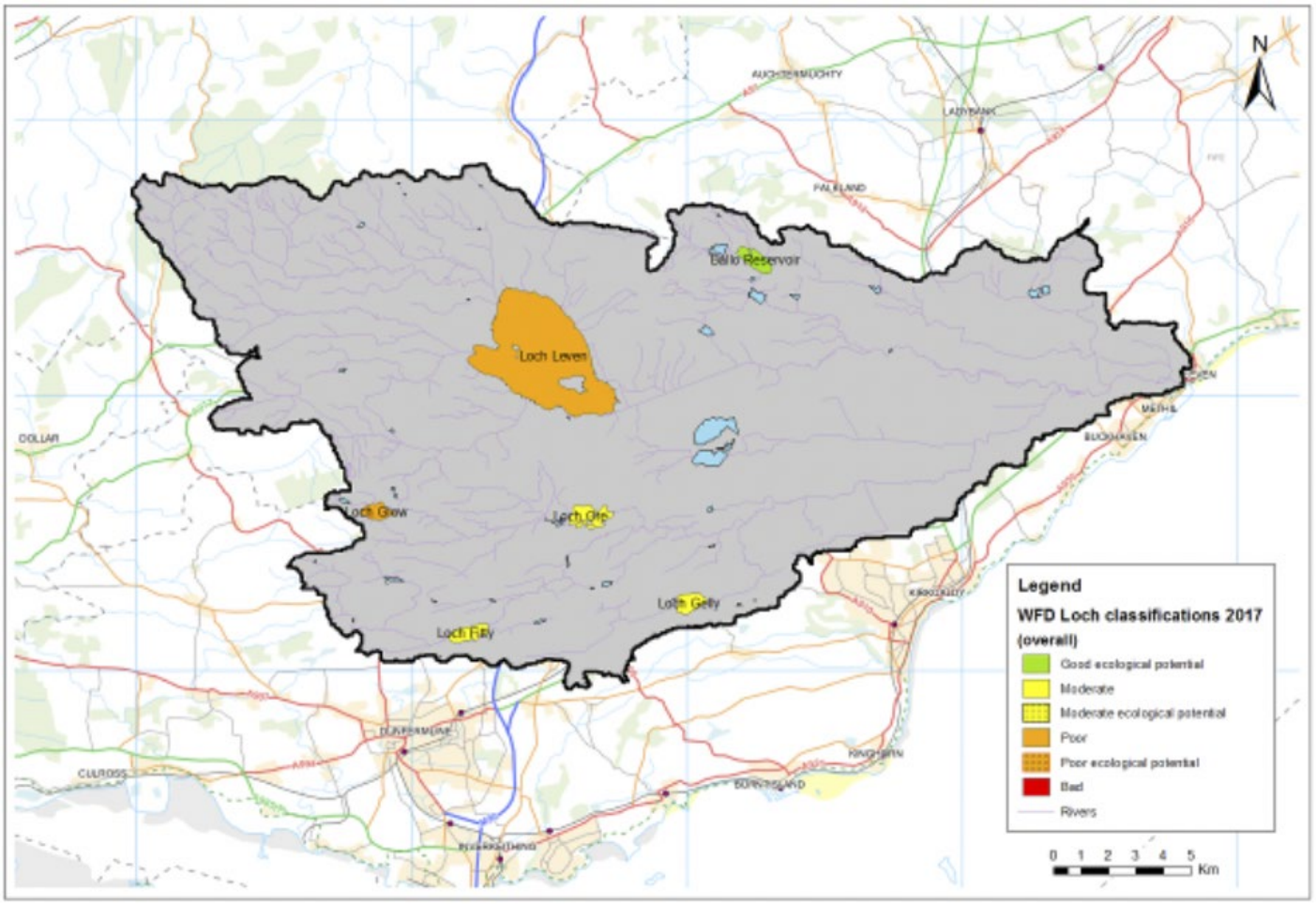

Figure 2.1 Overall status classifications for all WFD lochs in the River Leven catchment.
Some features of this map are based on digital spatial data (Moore at al., 1994; Morris & Flavin 1990, 1994) licensed from the Centre for Ecology & Hydrology, © NERC (CEH). Contains Ordnance Survey data © Crown copyright and database right 2018 and SEPA data © Scottish Environment Protection Agency and database right 2018. All rights reserved.

Ballo Reservoir (SEPA WFD ID: 100267; https://eip.ceh.ac.uk/apps/lakes/detail.html#wbid=24785) is used for water storage and drinking water supply. It is a large, deep, medium alkalinity loch with a surface area of 0.7 km2. The loch is designated as a heavily modified water body and is classified as having 'Good' ecological potential (2014-2017). However, its overall ecological status is currently rated as 'Poor' due to the presence of a complete barrier to fish migration in the form of a dam. It is assessed as being at 'High' status for its invertebrate community (although there was no invertebrate data from 2013-2016) and 'Moderate' status for its hydromorphology. The WFD target for this reservoir is to achieve 'Good' ecological potential 2021. Ballo Reservoir is also part of the Ballo and Harperleas Reservoirs Site of Special Scientific Interest (SSSI) and, on the basis of its aquatic macrophyte community, it has been assessed by Scottish Natural Heritage (SNH) as being in 'Favourable Declining' condition for a mesotrophic loch standing water feature because of its recent colonisation by non-native Canadian Waterweed (*Elodea canadensis*). The site has also been assessed as being in 'Favourable Maintained' condition in relation to its non-breeding population of Whooper Swans.

Loch Leven (SEPA WFD ID: 100269; https://eip.ceh.ac.uk/apps/lakes/detail.html#wbid=24843) is classified as a large, deep, lowland, high alkalinity loch with a surface area of 13.7 km2. In the past, the loch has suffered from serious eutrophication problems caused by excessive inputs of nutrients from agricultural, industrial and sewage sources within the catchment. However, following management intervention in the early 1990s, nutrient inputs were reduced by about 60% and the loch has undergone a slow but steady recovery. The water body was classified as being in 'Bad' status over the period 2009-2011, due to its high phytoplankton and chlorophyll a levels, and in 'Poor' status (2012-2017), primarily because of an impassable barrier to fish migration at the sluice gates that was installed on the loch's outflow in the mid-1800s. All the other measured WFD biological elements were assessed as being either at 'Moderate' or 'Good' status. The WFD target for this loch is to achieve 'Moderate' ecological status by 2021. Four of the inflows to the loch are also monitored for WFD purposes. These are the Greens Burn, the North Queich, the South Queich and the Gairney Water. In 2017, these were all classified as having 'Poor' ecological status, mainly due to the presence of barriers to fish migration.

In recognition of its high conservation value at local and international level, Loch Leven is also designated as a National Nature Reserve (NNR), a Ramsar si te, a Special Protection Area (SPA), a SSSI and a Natura 2000 site. Based on its aquatic macrophyte communities, Loch Leven is currently classified by SNH as being in 'Unfavourable Recovering' condition for its eutrophic loch natural habitat features in relation to its Ramsar and SSSI designations; this reflects recent improvements in the water quality and ecology of the loch that have occurred since nutrient inputs were reduced. In addition, a range of waterfowl assemblage bird features at Loch Leven were assessed by SNH as being in 'Favourable Maintained' condition. Loch Leven supports a recreational fishery that allows only boat-based angling.

Loch Glow (SEPA WFD ID: 100273; https://eip.ceh.ac.uk/apps/lakes/detail.html#wbid=25000) is a large, deep, mid altitude, medium alkalinity loch with a surface area of 0.5 km^2. The water body is currently classified as being of 'Poor' status (2007-2017), primarily because of barriers to fish migration although it is assessed as having 'High' status for both its hydromorphology and phytoplankton parameters. The WFD target for this loch is to achieve 'Moderate' ecological status by 2021. The loch has no conservation designations.

Loch Gelly (SEPA WFD ID: 100277; https://eip.ceh.ac.uk/apps/lakes/detail.html#wbid=25077) is a large, shallow, lowland, high alkalinity loch with a surface area of 0.6 km^2. In 2009-2011, the water body was classified as being in 'Poor' status due to its high phytoplankton and chlorophyll a levels. In 2012-2017, although its hydromorphology was assessed as being of 'High' status, the site was classified as having an overall status of 'Moderate'. The WFD target for this loch is to achieve 'Moderate' ecological status by 2021.

Loch Fitty (SEPA WFD ID: 100278; https://eip.ceh.ac.uk/apps/lakes/detail.html#wbid=25128) is a large, shallow, lowland, high alkalinity loch covering an area of 0.6 km2. The water body was classified as being at 'Poor' status in 2007-2014, because of its high phytoplankton and chlorophyll a levels. More recently (2015-2017), it has been classified as having 'Moderate' status, exceeding its WFD target of 'Poor' status by 2021.

Loch Ore (SEPA WFD ID: 100724; https://eip.ceh.ac.uk/apps/lakes/detail.html#wbid=25006) is a large, deep, high alkalinity, lowland loch with a surface area of 0.9 km2. The water body was classified as being at 'Poor' status in 2008-2011, mainly due to its high phytoplankton and chlorophyll a levels, and as being at 'Moderate' status in 2012-2017 although the site's hydromorphology was assessed as being at 'High' status. The loch has no designated conservation status, but forms part of the Lochore Meadows Country Park. As such, it provides facilities for a range of water based leisure activities.

The information given above is summarised in Table 2.1, together with an indication of any improvement needed to meet the WFD target for 2021.

Table 2.1 Summary of the WFD and habitat status of lochs within the River Leven catchment, and needs for improvement to meet WFD and Habitats Directive requirements.

Loch name	SEPA WFD ID	WFD status 2017	WFD target 2021	Condition assessment	Need for improvement
Ballo Reservoir	100267	Poor	Good	Favourable Declining	Removal of fish barrier; control of Canadian waterweed
Loch Leven	100269	Poor	Moderate	Unfavourable Recovering	Removal of fish barrier; further recovery of macrophytes
Loch Glow	100273	Poor	Moderate	No data	Removal of fish barrier
Loch Gelly	100277	Moderate	Moderate	No data	Improved phytoplankton; lower chlorophyll a levels
Loch Fitty	100278	Moderate	Poor	No data	Not specified
Loch Ore	100274	Moderate	Moderate	No data	Not specified

2.1.2 Rivers

The River Leven catchment comprises 292 km of classified watercourses, of which, a large proportion are upstream of the various lochs in the system. This makes them inaccessible to migratory fish due to weirs, dams and other constructions that form partial or complete barriers to fish migration. Much of the flow in the main stem of the River Leven is controlled by sluice gates that are situated on the outflow from Loch Leven. The river is canalised for the first 5 km downstream of the loch. Migratory fish cannot reach this part of the system at present due to obstructions between Markinch and Leslie. The River Leven catchment contains 17 WFD baseline rivers. These are described below and shown in Figure 2.2. Their status is summarised in Table 2.2, together with a note of the improvements required for each river to meet the 2021 target.

The lower *River Leven* (Markinch to Estuary) (SEPA WFD ID: 6300) is a medium sized, lowland river about 10.7 km in length. The WFD status of the river changed several times between 2007 and 2017, being classified at 'Poor' status in 2007 and 'Bad' status between 2008 and 2012 due to its hydromorphology, 'Moderate' status 2013-2015, and 'Poor' status in 2016-2017, due to problems related to the ecology of its fish community. The WFD target for this water body is to achieve 'Moderate' status by 2021. This part of the river has nine barriers to fish migration (dams, weirs, bridge apron) all of which are passable under certain conditions, such as high flows.

The upper *River Leven*, (between Loch Leven to Markinch) (SEPA WFD ID: 6301), is a medium sized lowland river of about 14.4 km in length that is designated as a heavily modified water body. It was classified at 'Bad' ecological potential due to its hydromorphology (2008-2012) and at 'Poor' ecological potential (2013-2017) because of its fish ecology and barriers to fish migration. Its hydromorphology has currently improved to 'Moderate' status and its invertebrate community has been assessed as being either 'Good' or 'High' over the monitoring period. The WFD target for this river is to achieve 'Poor' status by 2021. This stretch of river has eight impassable structures (weirs, dams, and sluice gates) and ten structures (weirs, dams, culverts, bridge apron) that are passable under certain conditions.

The *South Queich* (SEPA WFD ID: 6302) is a small, mid-altitude river about 17 km in length. The water body is classified at 'Poor' status (2008-2017), primarily because of barriers to fish migration. The hydromorphology and phytobenthos parameters are assessed as being 'Good' status and the invertebrates have been classified as being of 'Good' to 'High' status over the monitoring period. The WFD target for this river is to achieve 'Good' status by 2021.

The *Kennoway Burn* and its tributary, the *Back Burn*, (SEPA WFD ID: 6303) are small, lowland streams approximately 23 km in length that enter the main River Leven at Windygates, about 3 km from the sea. The water body has been designated as heavily modified and was classified at 'Poor' ecological potential in 2007 and at 'Bad' ecological potential between 2008 and 2012, due to its hydromorphology. However, between 2013 and 2017 its ecological potential improved to 'Moderate' status. The WFD target for these streams is to achieve 'Moderate' status by 2021.

The *River Ore* drains a large catchment to the south and west of the River Leven. The lower *River Ore* (between Cardenden to the River Leven) (SEPA WFD ID: 6304), is a medium sized, lowland river with a length of about 15.3 km. The water body was classified at 'Moderate' status between 2007 and 2012, at 'Good' status in 2013, and at 'Moderate' status between 2014 and 2017. The WFD target for this river is to achieve 'Moderate' status by 2021. This stretch of river has five weirs that are passable to fish only under certain conditions. This part of the river receives a number of ferruginous discharges that reduce its water quality. Locally, these discharges can have a severe negative effect on invertebrate fauna and fish populations. The other main tributaries of the Ore are the Lochgelly Burn and the Lochty Burn.

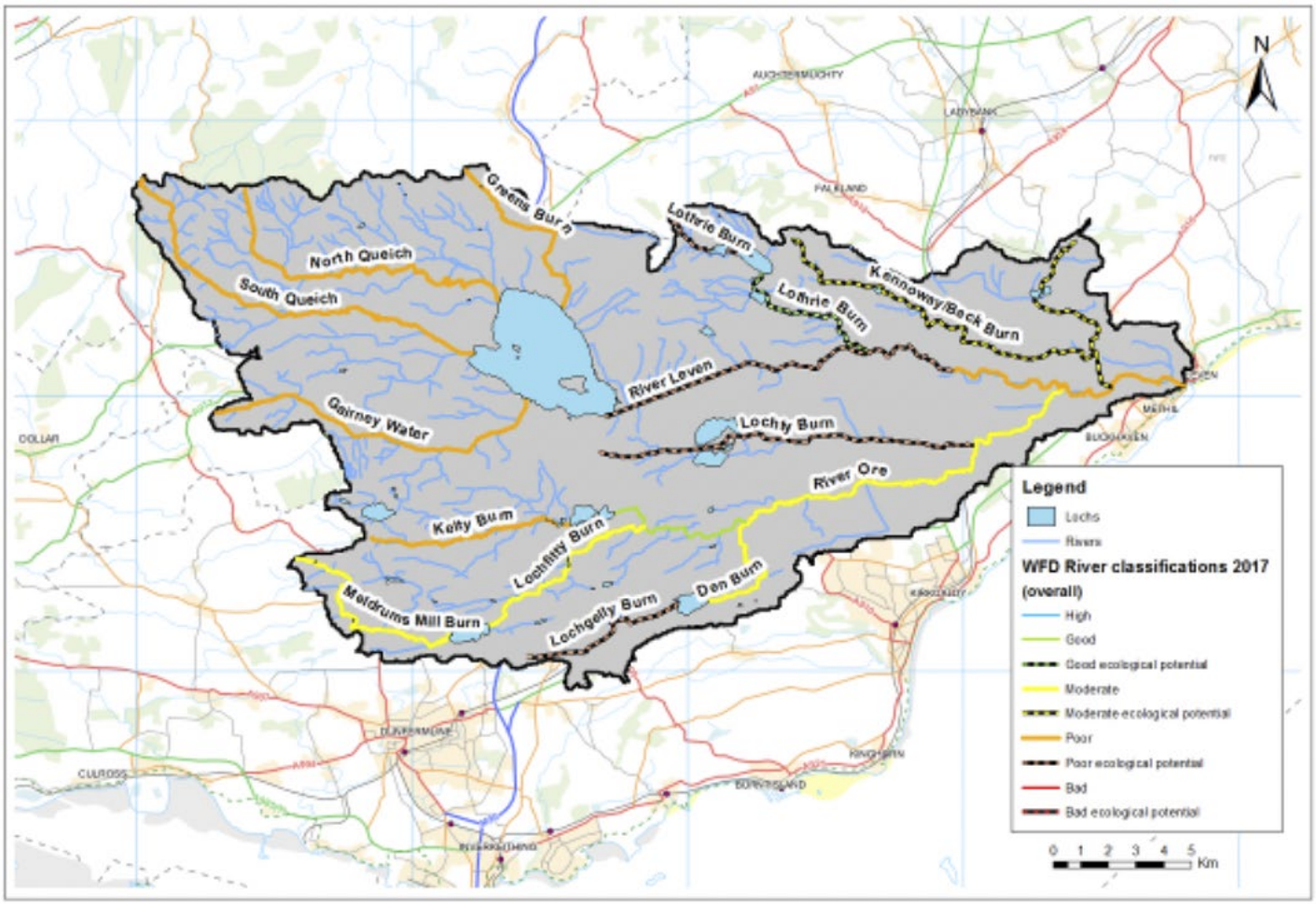

Figure 2.2 Overall status classifications for all WFD rivers in the River Leven catchment in 2017.
Some features of this map are based on digital spatial data (Moore at al., 1994; Morris & Flavin 1990, 1994) licensed from the Centre for Ecology & Hydrology, © NERC (CEH). Contains Ordnance Survey data © Crown copyright and database right 2018, and SEPA data © Scottish Environment Protection Agency and database right 2018. All rights reserved.

The upper *River Ore* (between Loch Ore and Cardenden) (SEPA WFD ID: 6305), is a small, lowland river of about 6.7 km in length. The water body was classified at 'Moderate' status 2007-2014 and at 'Good' status 2015-2017. The WFD target for this river is to achieve 'Good' status by 2021. This part of the river has one impassable weir, and two that are passable under certain conditions such as high flows.

The *Kelty Burn* (SEPA WFD ID: 6306) is a small, lowland stream about 8 km in length; the water body was classified at 'Good' status in 2007 and 2013-2015, 'Moderate' status 2008-2012, and 'Poor' status 2016-2017. The water body changed to 'Poor status' in 2016 to reflect improved understanding of fish barriers affecting the water body; the biological and hydromorphological parameters remained at "Good" status". The WFD target for the stream is to achieve 'Good' ecological status by 2021.

The *Lochfitty Burn* (SEPA WFD ID: 6307) is a small lowland stream about 8.3 km in length. Its WFD classification was 'Moderate' between 2007-2012, and 2016-2017. In this latter period, both the biological and the hydromorphology parameters were assessed as being in 'Good' status but the overall status was downgraded because of high manganese levels. The river was classified as being in overall 'Good' status between 2013 and 2015. The WFD target for this water body is 'Good' status by 2021. The river has two weirs that are passable to fish under certain conditions, such as high flows.

The *Meldrums Mill Burn/Linn Burn* (SEPA WFD ID: 6308) is a small, lowland stream, the main stem of which is about 9.7 km long. For the most part (2007-2013 and 2015-2017), this stream has been classified as being at 'Moderate' status due to its physicochemical elements although its biological and hydromorphological parameters were assessed at 'Good' status over this period. However, it was classified as being at overall 'Good' status in 2014. The WFD target for this stream is to achieve 'Good' status by 2021.

The *Den Burn* (SEPA WFD ID: 6310) is a small, lowland stream of about 5.4 km in length. The water body was classified at 'Moderate' status from 2007-2017. The WFD target for this river is to achieve 'Moderate' status by 2021.

The *Den Burn/Lochgelly Burn* (SEPA WFD ID: 6311) is a small, lowland stream about 6.6 km in length that has been designated as a heavily modified water body. The stream was classified as having 'Poor' ecological potential between 2007 and 2017, because of its hydromorphology. Nevertheless, its phytobenthos is currently assessed as being at 'Good' status and its invertebrate communities at 'Moderate' status. The WFD target for this river is to achieve 'Moderate' ecological status by 2021.

The main stem of the *Lochty Burn* (SEPA WFD ID: 6312) is a small, lowland stream that is about 14.4 km long. The river is designated as a heavily modified water body and has been classified, because of its invertebrate communities and high manganese levels, at 'Poor' ecological potential (2007-2008, 2012, 2015-2017) and 'Bad' ecological potential (2009-2011). The WFD target for this river is to achieve 'Poor' status by 2021. The burn has a weir that is passable to fish under certain conditions.

The lower *Lothrie Burn* (Ballo Reservoir to the River Leven) (SEPA WFD ID: 6313) is about 6.8 km in length, and is designated as a heavily modified water body. It enters the River Leven at Glenrothes and was classified at 'Good' ecological potential in 2007 and 2015-2017. In contrast, the stream was assessed as having 'Poor' ecological potential in 2008-2009 and 'Moderate' ecological potential in 2010-2014. The WFD target for this water body is to achieve 'Good' ecological potential by 2021.

The *Gairney Water* (SEPA WFD ID: 6315) is a small, lowland river of about 13.1 km in length. The water body was classified at 'Poor' status between 2008 and 2017, primarily because of barriers to fish migration. The WFD target for this water body is to achieve 'Good' status by 2021.

The *Greens Burn* (SEPA WFD ID: 6316) is a small lowland stream, about 7.9 km in length. It has been classified at 'Poor' status (2008-2017), primarily because of a weir that forms a barrier to fish migration under certain conditions, such as high flows. The WFD target for this water body is to achieve 'Good' status by 2021.

The *North Queich* (SEPA WFD ID: 6320) is a small, mid-altitude river about 14.4 km in length. It was classified at 'Poor' status (2008-2017), primarily because of problems with its fish ecology and the presence of fish barriers, although both its invertebrate and phytobenthic communities have been classified as being at 'Good' to 'High' status over the monitoring period. The WFD target for this water body is to achieve 'Good' status by 2021.

Table 2.2 Summary of the WFD and habitat status of rivers within the River Leven catchment, and needs for improvement to meet WFD and Habitats Directive requirements.

River name	SEPA WFD ID	WFD status 2017	WFD target 2021	Need for improvement noted
River Leven (lower)	6300	Poor	Moderate	Improved fish ecology
River Leven (upper)	6301	Poor	Poor	Removal of fish barrier; improved fish ecology
South Queich	6302	Poor	Good	Removal of fish barrier
Kennoway/Back Burn	6303	Moderate	Moderate	Not specified
River Ore (lower)	6304	Moderate	Moderate	Not specified
River Ore (upper)	6305	Good	Good	N/A
Kelty Burn	6306	Poor	Good	Removal of fish barrier
Lochfitty Burn	6307	Moderate	Good	Reduced manganese levels
Meldrums Mill Burn/Linn Burn	6308	Moderate	Good	Reduced reactive phosphorus levels
Den Burn	6310	Moderate	Moderate	Not specified
Den Burn/Lochgelly Burn	6311	Poor	Moderate	Improved hydromorphology
Lochty Burn	6312	Poor	Poor	Improved invertebrates and reduced manganese levels
Lothrie Burn (lower)	6313	Good	Good	N/A
Lothrie Burn (upper)	6314	Poor	Good	Removal of fish barrier
Gairney Water	6315	Poor	Good	Removal of fish barrier
Greens Burn	6316	Poor	Good	Removal of fish barrier
North Queich	6320	Poor	Good	Removal of fish barrier; improved fish ecology

2.1.3 Other water bodies

Some surface water bodies within the catchment are not monitored for WFD purposes. However, some water quality data are available for these sites, such as the site condition monitoring data collected for water bodies of conservation importance. These are listed below with information on their condition, as given on the Scottish Natural Heritage (SNH) SiteLink website. Their locations are shown in Figure 2.3, in relation to country parks, nature reserves and SSSIs. Table 2.3 summarises the current condition of these water bodies and any recommendations for their improvement, where necessary.

Black Loch (Cleish) is a very small, mid-altitude, shallow loch with a surface area of 0.04 km^2. It has been designated as a SSSI for its mesotrophic loch habitat feature. Based on recent site condition monitoring of its aquatic macrophyte community, this standing water feature was assessed by SNH as being in 'Favourable Maintained' condition although concern has been raised over the recent introduction of non-native Canadian waterweed (*Elodea canadensis*).

Camilla Loch is a very small, lowland, shallow loch with a surface area of 0.05 km^2. It has been designated as a SSSI partly due to its meso-eutrophic loch standing water feature. Based on recent site condition monitoring of its aquatic macrophyte community, this water body is in 'Unfavourable No Change' condition caused by nutrient enrichment.

Carriston Reservoir is very small, shallow, low altitude water body with a surface area of 0.1km^2. It has been designated as a SSSI in relation to its mesotrophic loch habitat feature. Based on recent site condition monitoring of its aquatic macrophyte community, it is in 'Unfavourable Declining' condition due to nutrient enrichment.

Dalbeath Marsh located to the south-west of Cowdenbeath, has been designated as a SSSI partly for its basic fen wetland feature. This has been assessed as being in 'Unfavourable Recovering' condition. Dalbeath Marsh is also a local nature reserve.

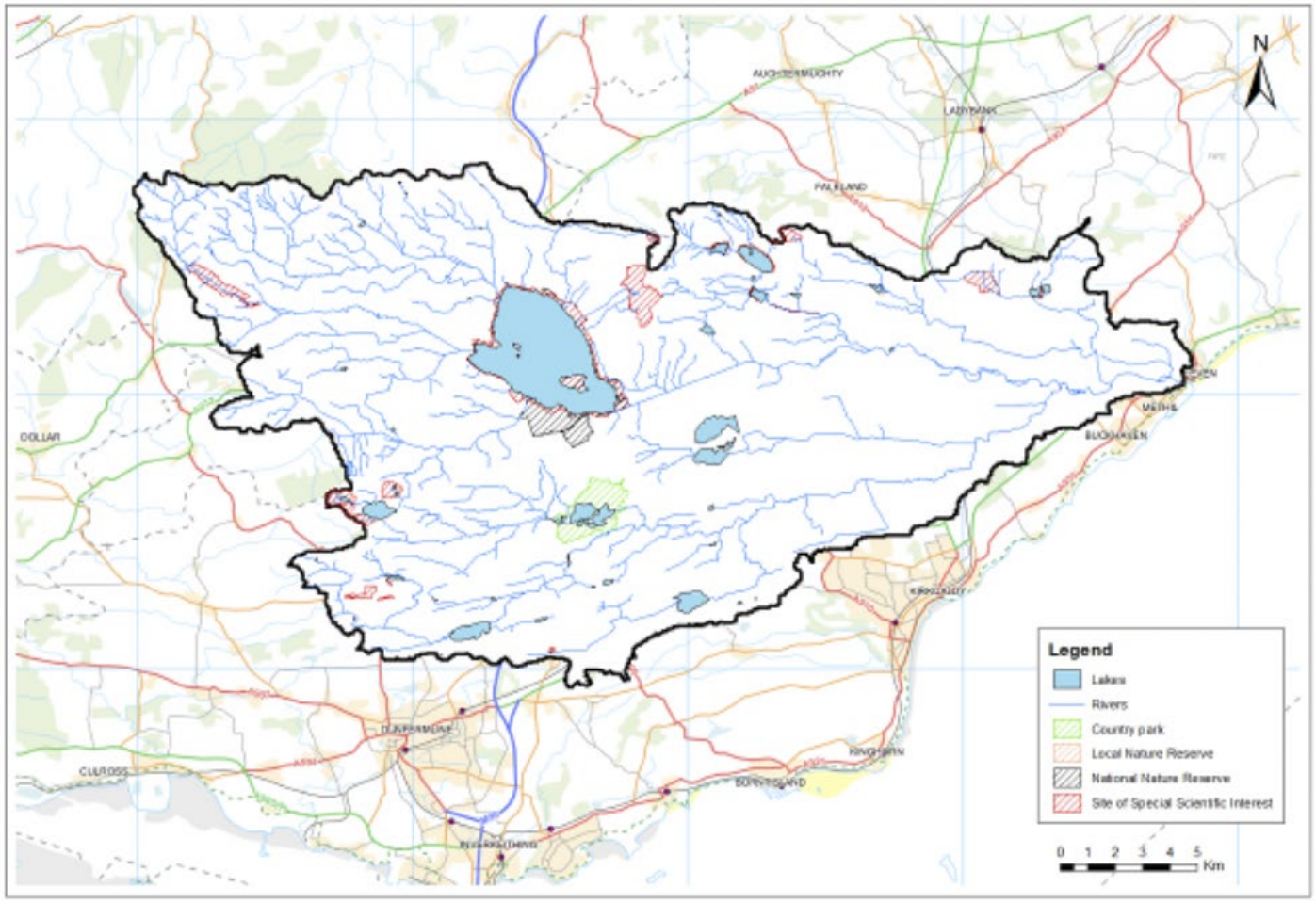

Figure 2.3 Map showing the locations of water bodies within the River Leven catchment in relation to country parks, nature reserves and SSSIs. *Some features of this map are based on digital spatial data (Moore at al., 1994; Morris & Flavin 1990, 1994) licensed from the Centre for Ecology & Hydrology, © NERC (CEH). Contains Ordnance Survey data © Crown copyright and database right 2018, © Scottish Natural Heritage. All rights reserved.*

Table 2.3 Summary of the condition of SSSI water bodies within the River Leven catchment and needs for improvement to meet Habitats Directive requirements.

Site name	Condition assessment	Need for improvement noted
Black Loch	Favourable Maintained	Possible need to control Canadian waterweed
Camilla Loch	Unfavourable No Change	Reduce level of nutrient enrichment
Carriston Reservoir	Unfavourable Declining	Reduce level of nutrient enrichment
Dalbeath Marsh	Unfavourable Recovering	Not specified
Lurg and Dow Lochs	Favourable Declining	Reduce risk of nutrient enrichment

Lurg and Dow Lochs, both 0.01 km² in area, are very small mid-altitude lochs. They are classified as very shallow and shallow, respectively. The lochs are very close to each other and form a SSSI that lies about 6 km SSW of Kinross, in the Cleish Hills. This SSSI is designated, partly, in relation to its oligotrophic loch habitat feature. Based on its aquatic macrophyte communities, it was recently assessed as being in 'Favourable Declining' condition due to a risk of nutrient enrichment. The site was also assessed as being in 'Favourable Maintained' condition for its open water transition fen.

According to WFD criteria, most of the targets for lochs and rivers in the River Leven catchment could be met by addressing issues related to barriers to fish migration. The status of these barriers is shown in Figure 3.1 (below).

2.2 Groundwaters

There are eleven WFD groundwater bodies that lie wholly or partly within the River Leven catchment (Fig. 2.4). Three have been assessed as having 'Good' water quality, and the remainder have been classified as having 'Poor' water quality. Assessments of their status are based, mainly, on modelled rather than measured data. Where ground waters have been assessed as being in 'Poor' condition, this is mainly due to 'interactions with surface water'. In general, a failure due to surface water interaction occurs if the surface water above the ground water fails WFD targets for any chemical parameter that the groundwater might also fail on. Further details are shown in Table 2.4.

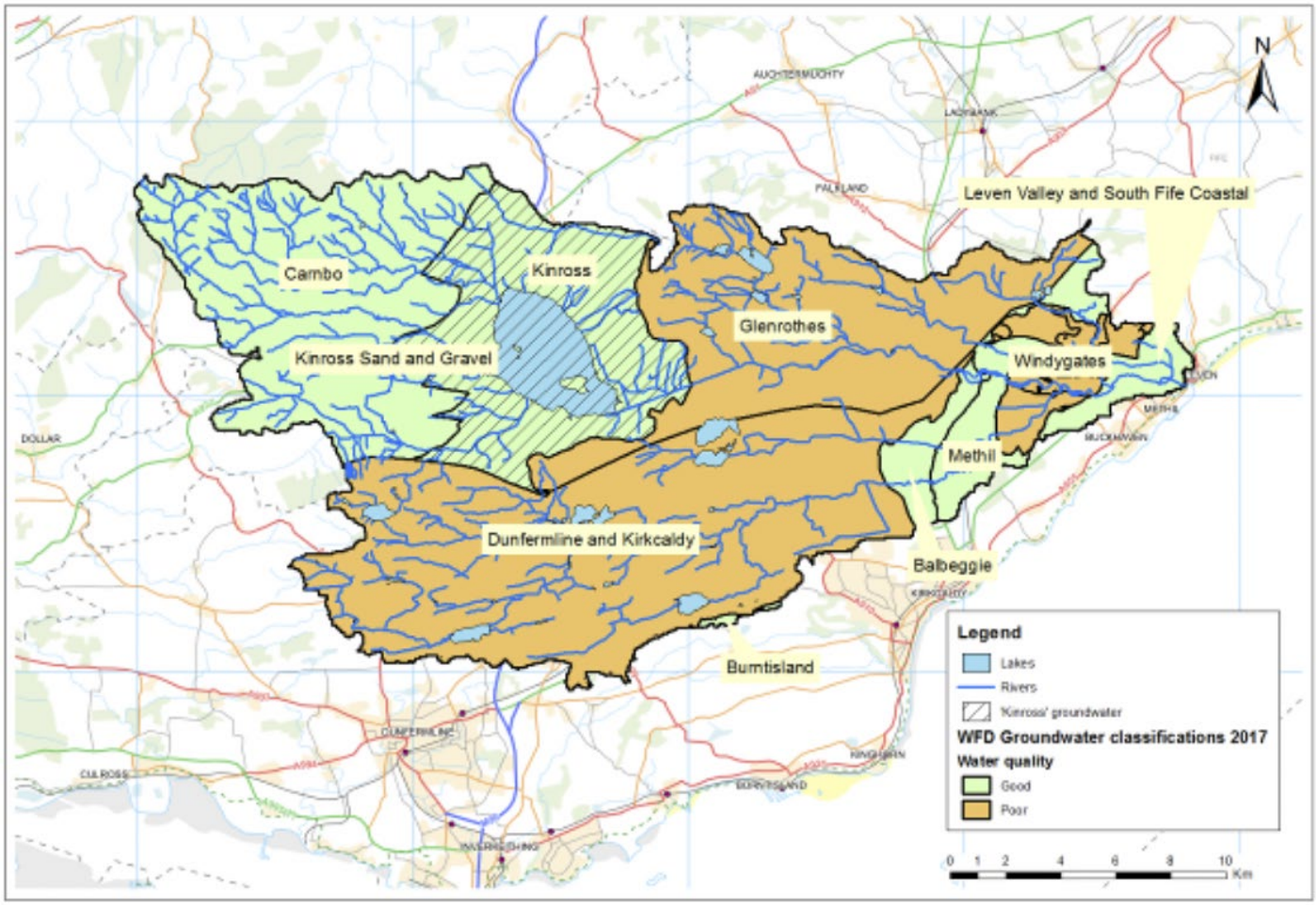

Figure 2.4 Groundwater quality within the River Leven catchment, with the 'Kinross' groundwater highlighted.
Some features of this map are based on digital spatial data (Moore at al., 1994; Morris & Flavin 1990, 1994) licensed from the Centre for Ecology & Hydrology, © NERC (CEH). Contains Ordnance Survey data © Crown copyright and database right 2018, and SEPA data © Scottish Environment Protection Agency and database right 2018. All rights reserved.

Table 2.4 Summary of the size and condition of groundwater bodies within the River Leven catchment, including WFD targets and reasons for 'Poor' status.

Name	SEPA WFD ID	Area within catchment (km2)	Overall water quality	WFD target 2021	Reason for 'Poor' status
Shallow groundwater					
Kinross Sand and Gravel	150781	35.12	Good	Good	N/A
Leven Valley and South Fife Coastal	150799	75.53	Poor	Good	Chemistry affected by interaction with surface water
Deep groundwater					
Windygates	150457	17.59	Poor	Good	Quantity and chemistry affected by interaction with surface water
Carnbo	150565	86.72	Good	Good	N/A
Balbeggie	150431	9.43	Poor	Good	Chemistry affected by interaction with surface water
Methil	150621	164.3	Poor	Good	Chemistry affected by interaction with surface water
Kinross	150548	70.04	Good	Good	N/A
Glenrothes	150562	81.9	Poor	Good	Quantity affected by interaction with surface water
Dunfermline and Kirkcaldy	150645	276.04	Poor	Good	Quantity and chemistry affected by interaction with surface water

There are no Nitrate Vulnerable Zones (NVZs) for the protection of either ground waters or surface waters within the River Leven catchment.

There appear to be very few monitoring data for groundwater bodies within the catchment. However, in 2004, the British Geological Survey (BGS) published a report (Ó Dochartaigh, 2004) relating to the hydrogeology of the Upper Devonian/Lower Carboniferous aquifer in Fife, part of which lies within the River Leven catchment. This is the 'Kinross' groundwater body, which covers the area around Loch Leven and Kinross (Fig. 2.4). The report notes that groundwater here is abstracted for public water supply, agriculture and industry. Within the Kinross groundwater area, the report suggests that there are six boreholes for which additional data may be available.

3 Main pressures on water bodies

According to the River Basin Management plan for 2015-2027 (Scottish Government, 2015), the main pressures on WFD water bodies across the Scotland river basin district are man-made barriers to fish migration (306 sites), modifications to physical condition (255 sites), rural diffuse pollution (246 sites), wastewater discharges (81 sites) and hydroelectric power generation (81 sites). The most difficult of these to address are diffuse pollution and physical modification.

It is generally accepted that reducing pressures and improving water quality will bring a range of benefits. These include reducing water treatment costs, supporting the expansion of businesses that rely on high quality water (e.g. tourism, fisheries, whisky production), regenerating urban areas by providing a high-quality water environment, and improving the health and range of wild plant and animal populations. The pressures on the water environment within the River Leven catchment reflect the wider Scottish context. More detail on each is summarised below.

3.1 Barriers to fish migration

There are many man-made obstructions to fish passage within the River Leven catchment; those listed on the SEPA database and their current classification are shown in Figure 3.1. Some improvements have been made recently. For example, a fish pass has been installed at Balgonie, where an old mill lade diverts water to the Balgonie Hydro Power Station; this has improved the potential for fish migration. A fish pass has also been installed at Markinch.

According to WFD criteria, most of the ecological status targets in the lochs and rivers in the River Leven catchment could be met by addressing issues related to barriers to fish migration. The status of these barriers is shown in Figure 3.1. However, care should be taken in implementing these changes because some of the upper catchment may be protected from the spread of fish diseases and invasive species by these structures.

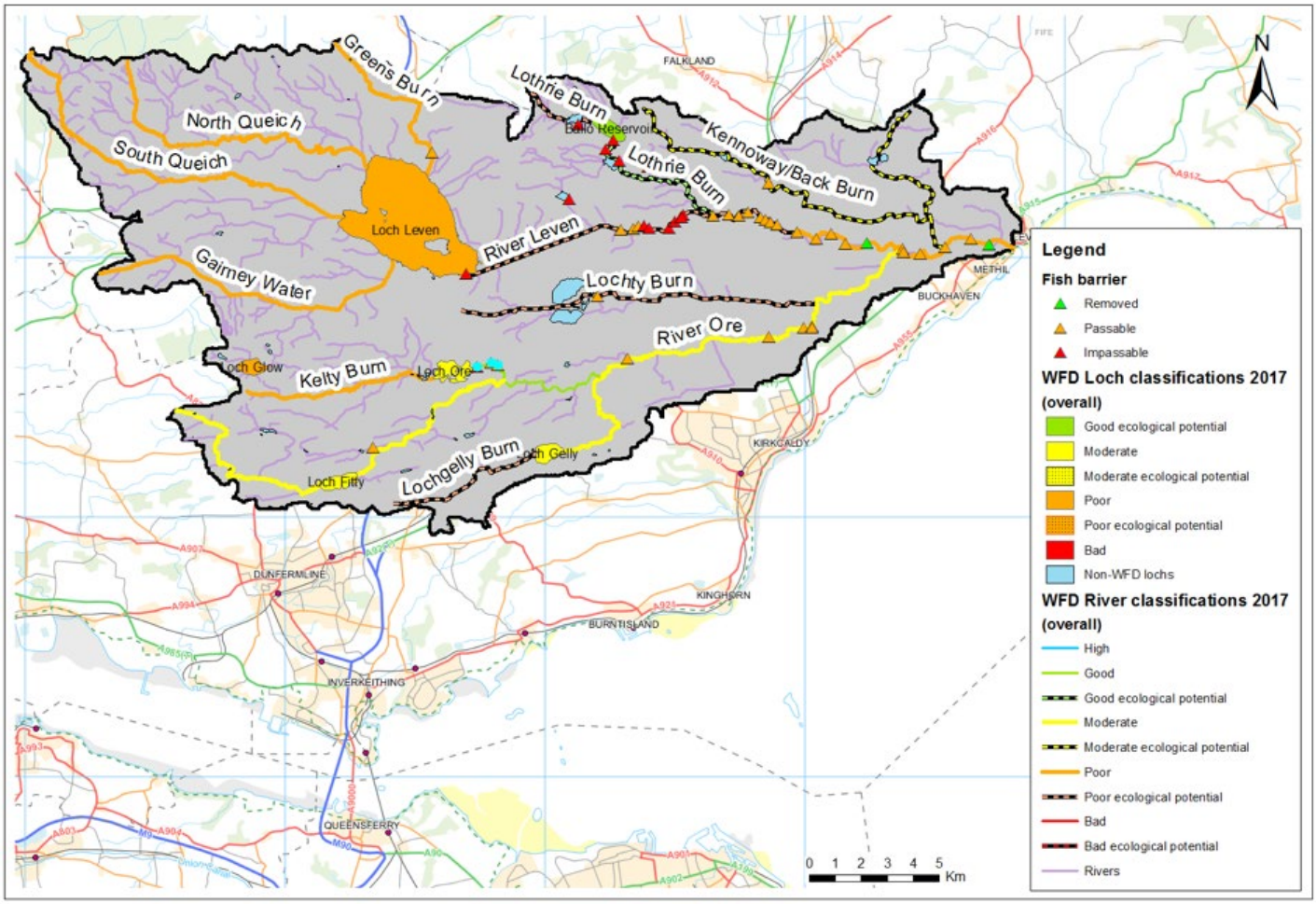

Figure 3.1 Locations and status of barriers to fish migration within the River Leven catchment.
Some features of this map are based on digital spatial data (Moore at al., 1994; Morris & Flavin 1990, 1994) licensed from the Centre for Ecology & Hydrology, © NERC (CEH). Contains Ordnance Survey data © Crown copyright and database right 2018, and SEPA data © Scottish Environment Protection Agency and database right 2018. All rights reserved.

3.2 Modifications to physical condition

Several of the rivers and standing waters within the River Leven catchment have been classified in terms of their ecological potential because they are highly modified water bodies. These include the Kennoway/Back Burn, the Lothrie Burn, the upper River Leven, the Lochty Burn, the Lochgelly Burn and the Ballo Reservoir (Table 3.1). Most of these water bodies have failed their WFD targets due to problems with barriers to fish migration, although the upper River Leven has also been straightened. This part of the river is known as the Leven 'Cut'.

3.3 Rural diffuse pollution

Phosphorus (P) and nitrogen (N) enter lochs, reservoirs, rivers and ground waters across the catchment causing eutrophication problems. Discharges from point sources have, largely, been addressed through the upgrading of waste water treatment works (WWTWs) or the diversion of their effluents (May et al., 2012). Discharges from industrial point sources have also been reduced (May et al., 2012).

However, losses of N and P from land to water (diffuse pollution) continues to be a problem and is the focus of SEPA's diffuse pollution initiative, a 5-year project that begins in 2019. This initiative aims to work with local land managers to identify the main sources of diffuse pollution and encourage the implementation of Best Management Practices to protect receiving waters and/or support their restoration.

Table 3.1 Summary of water bodies within the River Leven catchment that are designated as highly modified, showing the reason for the designation and the industry associated with that pressure (data provided by SEPA).

SEPA WFD ID	Water body name	Reason for designation as heavily modified	Industry associated with pressure	Progress with measures aimed at meeting good ecological potential
6301	River Leven (upper)	Agricultural land drainage	Farming	Complete
6303	Kennoway Burn/Back Burn	Urban land use	Not specified	Unknown
6311	Den Burn/Lochgelly Burn	Urban land use	Not specified	On-going
6312	Lochty Burn	Agricultural land drainage	Farming	Complete
100267	Ballo Reservoir	Water Storage - Drinking Water Supply; Wider Environment - Biodiversity	Water collection, purification and distribution	Complete

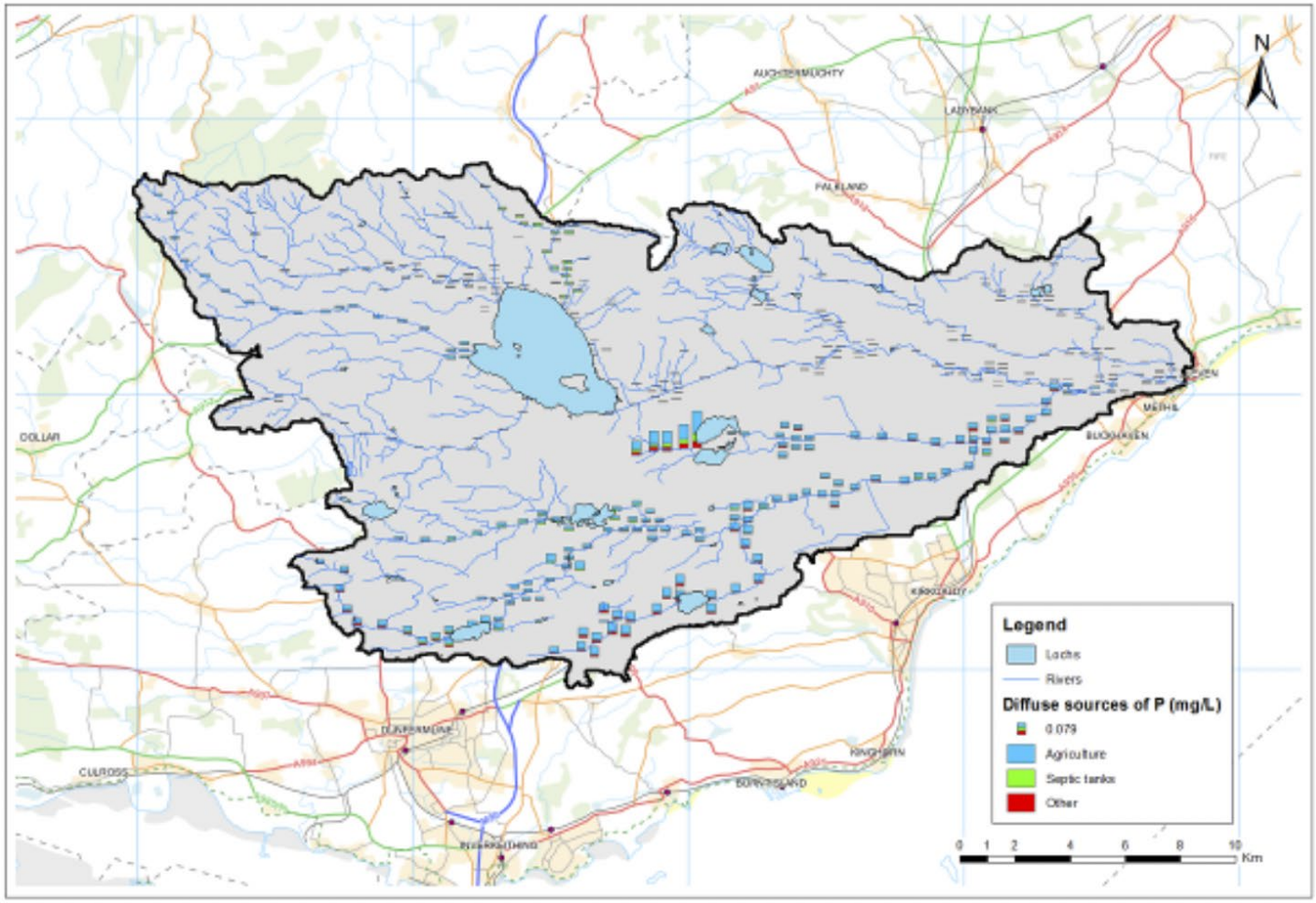

Figure 3.2 Size and level of contribution of diffuse sources of phosphorus (P) to riverine concentrations in the River Leven catchment.
Some features of this map are based on digital spatial data (Moore at al., 1994; Morris & Flavin 1990, 1994) licensed from the Centre for Ecology & Hydrology, © NERC (CEH). Contains Ordnance Survey data © Crown copyright and database right 2018, and SEPA data © Scottish Environment Protection Agency and database right 2018. All rights reserved.

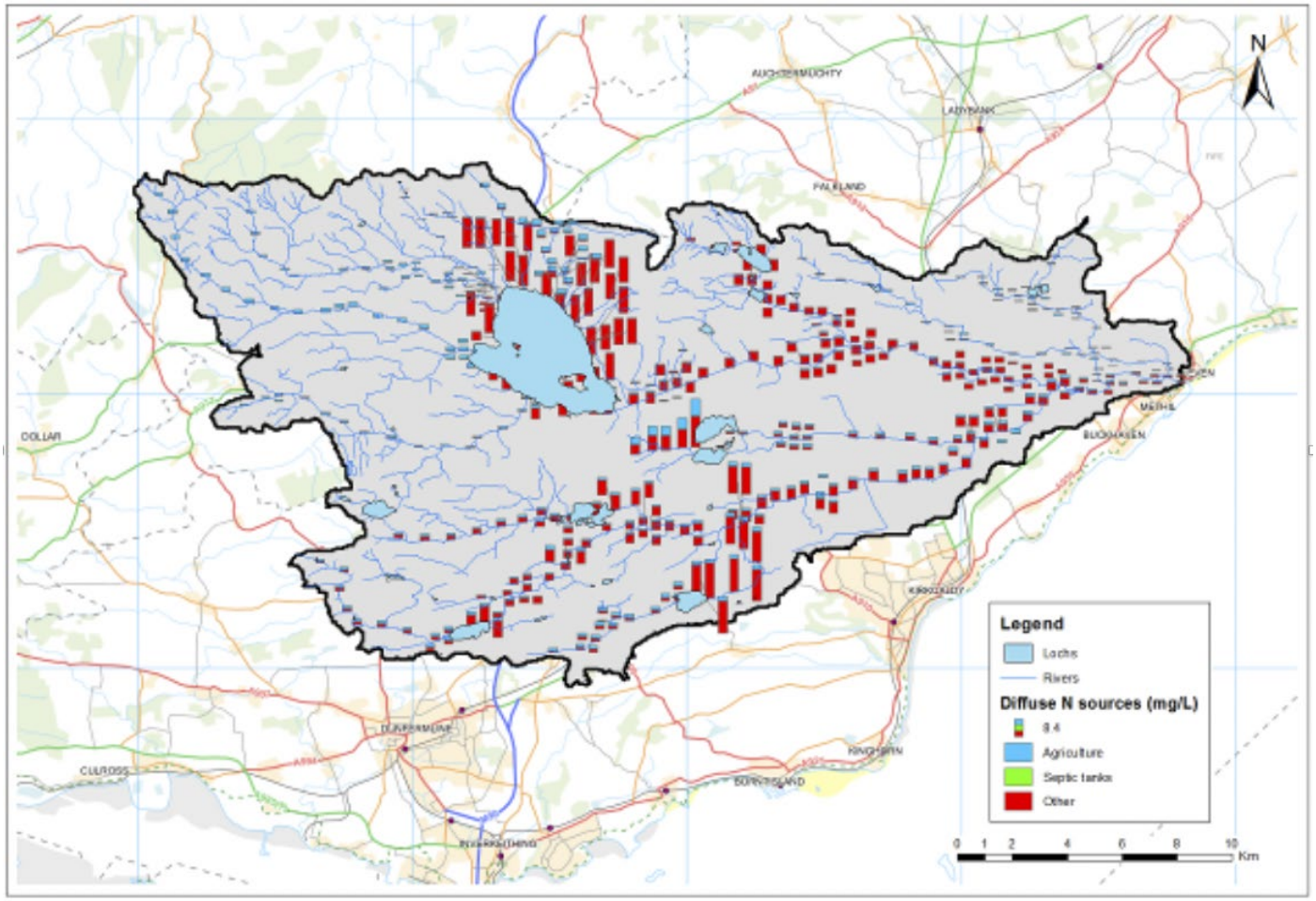

Figure 3.3 Size and level of contribution of diffuse sources of nitrogen (N) to riverine concentrations in the River Leven catchment.
Some features of this map are based on digital spatial data (Moore at al., 1994; Morris & Flavin 1990, 1994) licensed from the Centre for Ecology & Hydrology, © NERC (CEH). Contains Ordnance Survey data © Crown copyright and database right 2018, and SEPA data © Scottish Environment Protection Agency and database right 2018. All rights reserved.

Data from the SAGIS (Source Apportionment GIS) model were used to identify areas of the catchment where N and P concentrations were high due to diffuse pollution, and to provide an indication of the likely source. A description of the model, which is used operationally by SEPA, can be found at CEH.

Figure 3.2 shows that, for P, concentrations due to diffuse pollution entering watercourses were higher in the southern part of the catchment than in the northern part. This was especially true of the upper part of the Lochty Burn, where P runoff from agricultural sources dominates the inputs. Elsewhere, P concentrations are lower but still dominated by agricultural inputs. The amount of P entering the watercourses from on-site sewage treatment systems ('septic tanks') was, generally, modelled to be much lower than that from agricultural sources.

Figure 3.3 shows that the situation for N is quite different. The highest N concentrations in watercourses occurred to the north of Loch Leven, in the upper Lochty Burn, the Den Burn downstream of Loch Gelly and the upper River Ore, downstream of Loch Ore. According to the SAGIS model output, diffuse inputs of N from agricultural and septic tanks sources were relatively low and consistent across the catchment. In contrast, where stream concentrations of N were higher than elsewhere, other sources of N were predicted to be the cause. The main contributor to this high level of diffuse N from other sources was atmospheric deposition. The reason for the marked spatial variation in N deposition values was unclear from the data provided.

For the mapped SAGIS model output in Figures 3.2 and 3.3, 'Agricultural' include livestock and arable sources, 'Septic tanks' includes septic tanks and package treatment plants, and 'Other' includes highways, urban areas and atmospheric deposition sources.

3.4 Wastewater discharges

There are a number of wastewater discharges within the River Leven catchment (Figure 3.4). Many are discharges of untreated mine water, although the discharge to the River Ore is treated. SEPA has not collected any monitoring data for these discharges since 2006, although visual assessments of ochre impacts have been carried out periodically. Although some work on the ecology of the receiving waters work has been carried out in the past, the results of these surveys were not available at the time of writing this report.

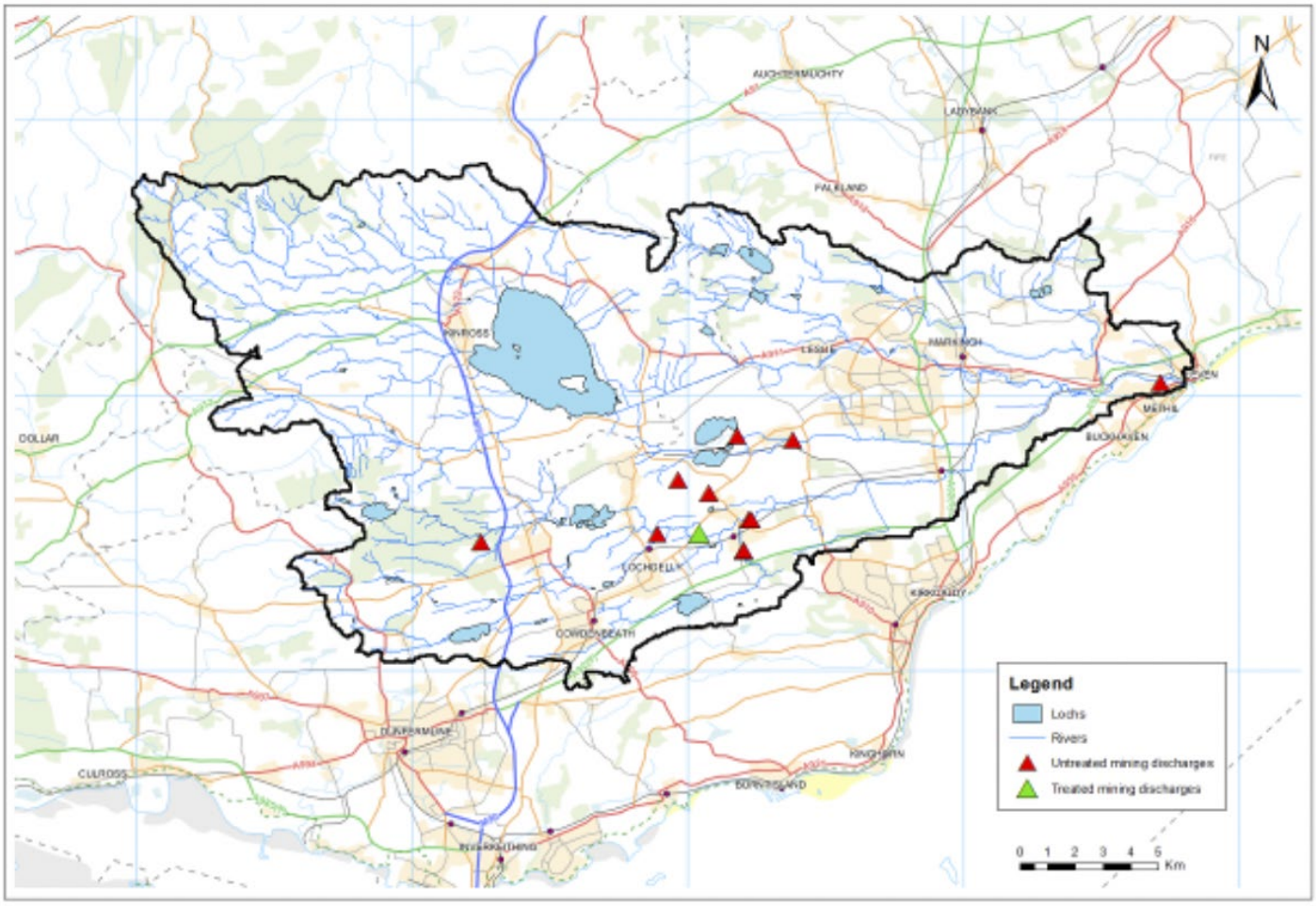

Figure 3.4 Locations of treated and untreated mine water discharges within the River Leven catchment.
Some features of this map are based on digital spatial data (Moore at al., 1994; Morris & Flavin 1990, 1994) licensed from the Centre for Ecology & Hydrology, © NERC (CEH). Contains Ordnance Survey data © Crown copyright and database right 2018, and SEPA data © Scottish Environment Protection Agency and database right 2018. All rights reserved.

The Coal Authority are believed to hold some monitoring data for these discharges, but we were advised that these could be very out of date and that a non-commercial data licence agreement between the Coal Authority and Centre for Ecology & Hydrology would be required to gain access to these data for use in this report. As a result, these data were not available within the timescale of this project.

3.5 Abstraction and hydroelectric power generation

Although there are some issues associated with abstraction and hydroelectric power generation within the River Leven catchment, it was not possible to obtain and analyse the data necessary to assess the scale and impact of this within the timescale of this project.

4 Socio-economic condition of catchment

The Scottish Government have developed a tool for identifying areas of multiple deprivation in Scotland. This is known as the Scottish Index of Multiple Deprivation (SIMD). The website incorporates a mapping function, which allows the data to be viewed spatially, and a data download function. The indices are broken down into different 'domains', or types, of deprivation such as income, employment, health, education, skills and training, geographic access to services, crime and housing.

Like many hydrologically defined river basins in Scotland, the River Leven catchment straddles several administrative and land management boundaries. The 'Data Zones' that are used within the SIMD data are no exception (see Fig. 4.1). This spatial mismatch between the catchment and some of the SIMD data zones adds a certain amount of complexity and uncertainty to the effective determination of potentially relevant socio-economic metrics for some areas.

However, within the limitations of the methodology, the SIMD 2016 data (published on 31 August 2016) have been used to characterise the socio-economic environment of the River Leven catchment and assess the extent to which these data are suitable for assessing the potential benefits of improvement work (Section 4.1) or providing a socio-economic baseline for targeting management actions (Section 4.2).

4.1 Major areas of deprivation within the catchment

The SIMD 2016 data for each data zone were used to identify areas of deprivation within the River Leven catchment. Each data zone comprises an area of approximately equal population size. In total, 130 data zones lay totally within the River Leven catchment and 58 were only partially within its boundary (Fig. 4.1).

An initial exploration of the data using the SIMD mapping tool revealed that most of the data zones containing multiple domains of deprivation lay completely within the River Leven catchment. As the overall SIMD is composed of multiple, separate indices, 'statistical cookie cutting' of the data to select only the data zones that lay completely within the River Leven catchment was considered inappropriate for identifying areas for targeted action and a more detailed approach was developed.

In total, 90% of the data zones were found to be in Fife and the remaining 10% in Perth & Kinross. The SIMD 2016 summary data showed several areas of multiple deprivation within the River Leven catchment, all of which fall within the local authority of Fife.

According to SIMD 2016, the total population living within all data zones that lie within the River Leven catchment is 141,152. The original source of the data from which this figure is derived is the National Records of Scotland (NRS) small area population estimate for 2014, published as unrevised figures in August 2015. The average population within each of the 188 data zones is 751. However, values for individual data zones ranged from 385 people in the Windygates and Coaltown area to 1,223 people in Kelty East. The distribution of people within different data zones across the River Leven catchment is shown in Figure 4.2.

It is important to note that the SIMD is a relative measure, i.e. it shows that one area is more deprived than another at the national scale. Also, it cannot be assumed that everyone living in a deprived area is underprivileged. Similarly, there may be people that are classified as deprived living in data zones that are ranked as not being deprived according to the SIMD index.

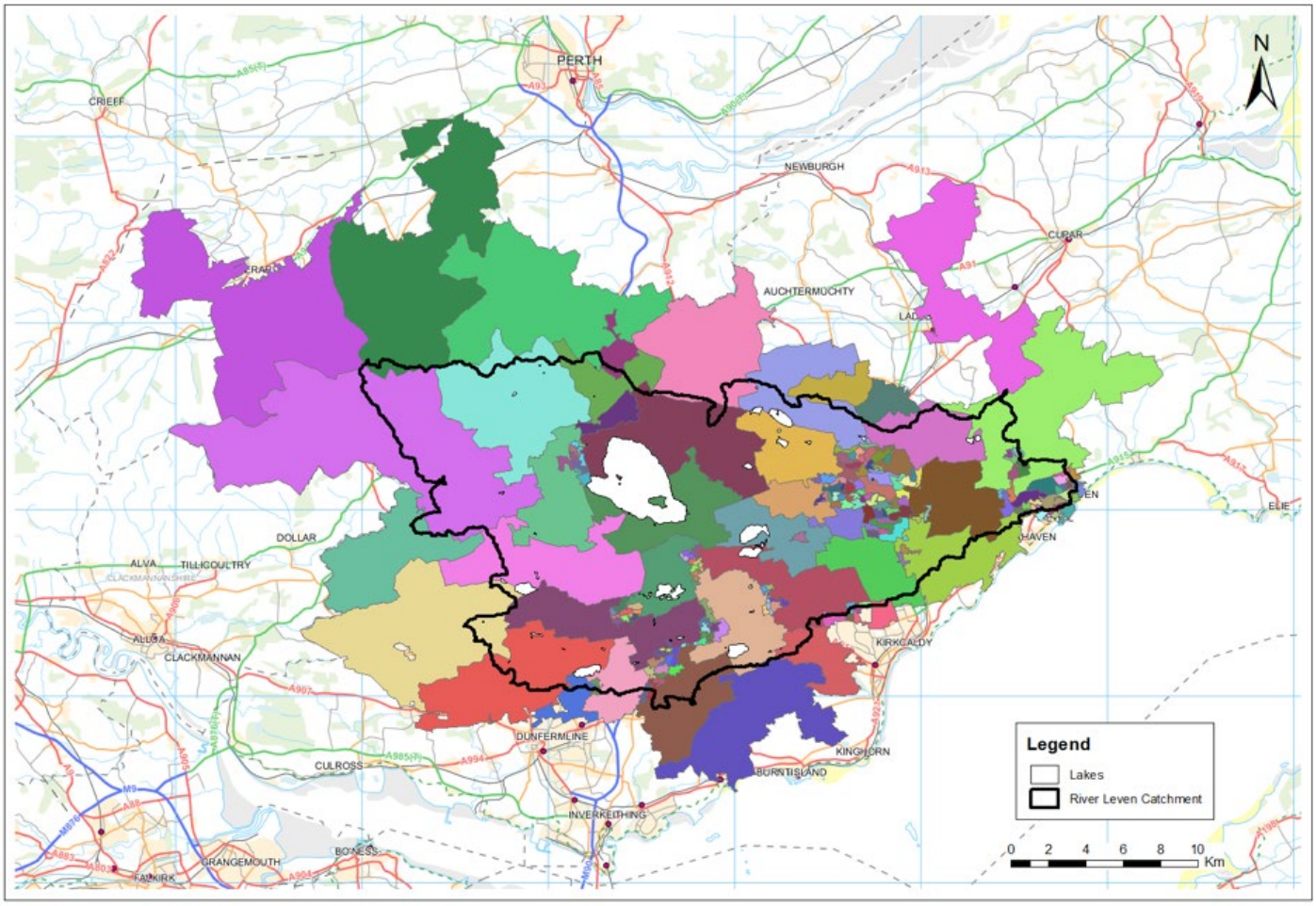

Figure 4.1 Date zones (coloured blocks) partially or completely within the River Leven catchment (outlined in black
Some features of this map are based on digital spatial data (Moore at al., 1994; Morris & Flavin 1990, 1994) licensed from the Centre for Ecology & Hydrology, © NERC (CEH). Contains Ordnance Survey data © Crown copyright and database right 2018, and Scottish Government and Ordnance Survey data © Crown copyright & database right 2012-6. All rights reserved.

The SIMD combines seven different domains (aspects) of deprivation into an overall assessment using a range of weighting factors (Table 4.1). The weightings applied in SIMD 2016 are the same as those used in 2006, 2009 and 2012. The overall SIMD provides a measure of relative deprivation at the data zone level, so it indicates that one data zone is more deprived than another but not by how much. Combining the seven domains into one SIMD allows the Scottish Government to rank each data zone in Scotland between '1' (most deprived) and '6,976' (least deprived).

There are four SIMD data zones within the River Leven catchment that fall into the 5% most deprived areas in Scotland. These zones include 3,131 people (i.e. 2.2% of total population of the Leven catchment); they are located in Ballingry (1), Methil West (1), and Methil East (2). The four data zones are ranked within the 5% most deprived areas for 3, 5, 4 and 2 of the seven separate domains of deprivation (Table 4.2), respectively. However, the data in Table 4.2 illustrate how the weightings given to each domain can influence the overall ranking of a data zone. For example, a data zone such as Methil East (S01009638) is ranked within the 5% most deprived areas across the whole of Scotland (i.e. overall SIMD ranking lower than 348) and yet the indices used for health and crime, and to a lesser extent employment, rank this data zone well above the 5% threshold. Similarly, none of these four data zones is ranked lower than 348 for the domains of housing and geographic access to services.

Table 4.1 The seven domains combined in SIMD 2016 and the weightings applied to each of them.

Domain	2016 Weighting	Percentage of overall SIMD
Income	12	28%
Employment	12	28%
Health	6	14%
Education, skills and training	6	14%
Geographic access to services	4	9%
Crime	2	5%
Housing	1	2%

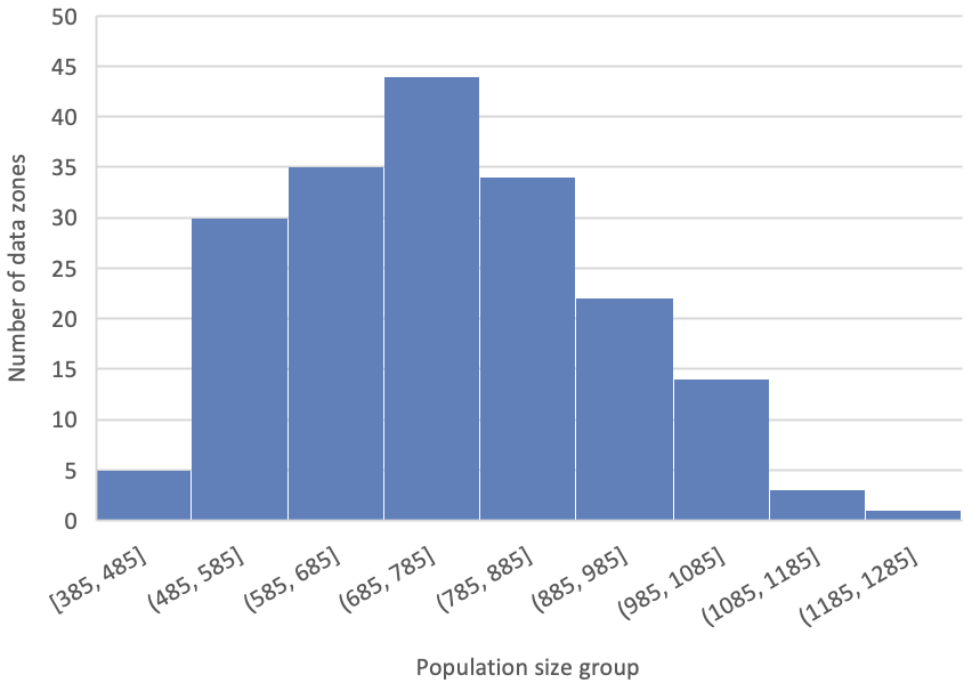

Figure 4.2 Distribution of population within data zones for the 188 data zones that are within, or intersect with, the River Leven catchment.

Table 4.2. Overall SIMD 2016 values and the individual ranks of the five domains of deprivation reported for the four most deprived data zones in the River Leven catchment.

	Overall SIMD 2016	Income domain	Employment domain	Education domain	Health domain	Crime	Total domains[1]
Ballingry (S01009435)	231	234	237	272	(414)	(1196)	3
Methil West (S01009633)	166	184	207	103	323	143	5
Methil East (S01009636)	183	267	142	113	(359)	270	4
Methil East (S01009638)	217	97	(353)	117	(647)	(723)	2

[1]Total number of domains ranked within the 5% most deprived areas of Scotland. Grey numbers in brackets are not within the lowest 5% of data zones for that domain, but are still within 10% most deprived areas of Scotland.

These analyses show that, to identify areas in which to target improvements aimed at enhancing human health and wellbeing, it is probably more appropriate to consider the individual domains of deprivation separately rather than the overall SIMD value.

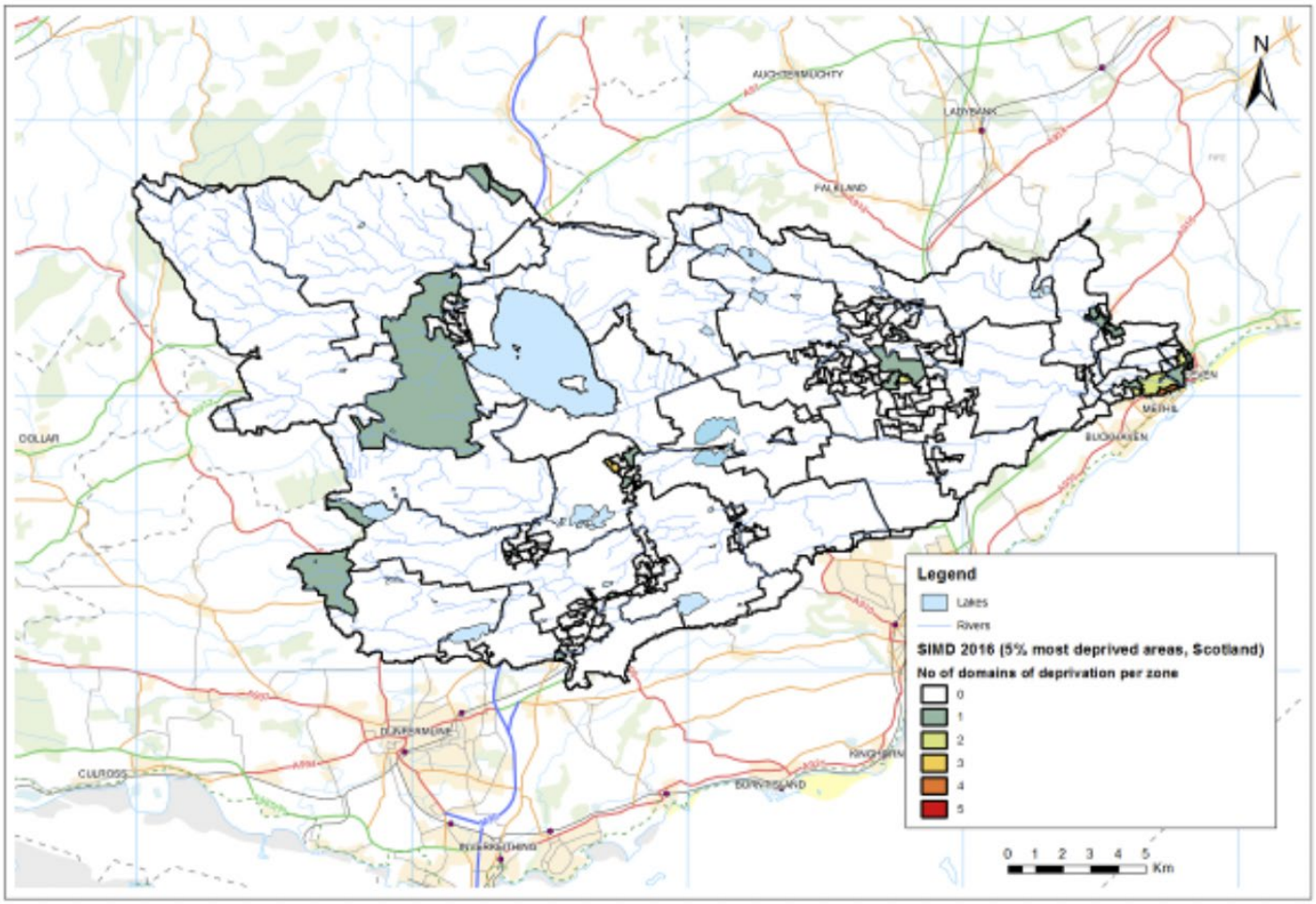

Figure 4.3 Data zones that are ranked in SIMD 2016 as being within the 5% most deprived areas of Scotland for one or more of the seven domains of deprivation shown in Table 5.1.
Some features of this map are based on digital spatial data (Moore at al., 1994; Morris & Flavin 1990, 1994) licensed from the Centre for Ecology & Hydrology, © NERC (CEH). Contains Ordnance Survey data © Crown copyright and database right 2018, and Scottish Government and Ordnance Survey data © Crown copyright & database right 2012-6. All rights reserved.

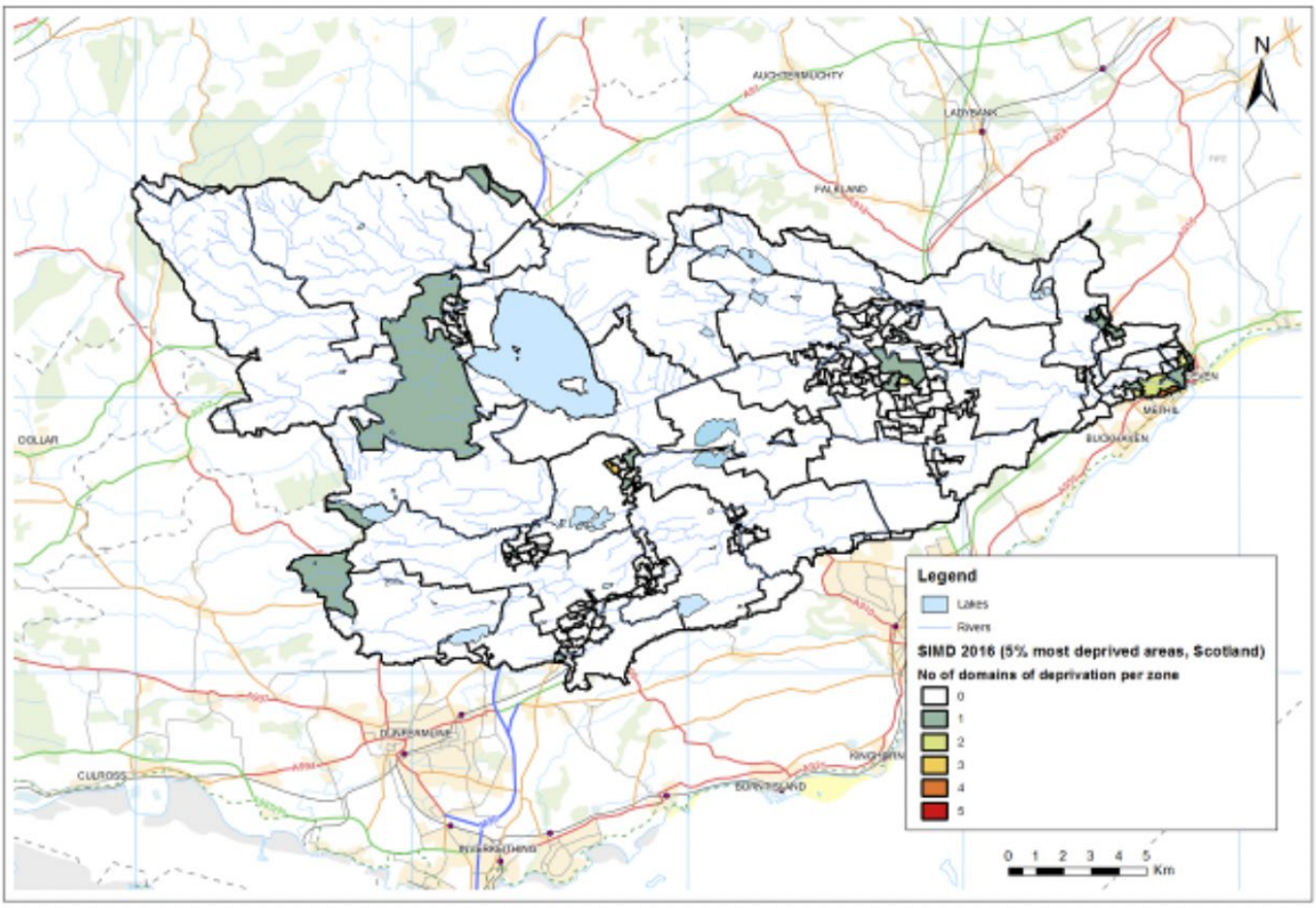

Figure 4.4 Data zones that are ranked in SIMD 2016 as being within the 10% most deprived areas of Scotland for one or more of the seven domains of deprivation shown in Table 5.1.
Some features of this map are based on digital spatial data (Moore at al., 1994; Morris & Flavin 1990, 1994) licensed from the Centre for Ecology & Hydrology, © NERC (CEH). Contains Ordnance Survey data © Crown copyright and database right 2018, and Scottish Government and Ordnance Survey data © Crown copyright & database right 2012-6. All rights reserved.

The areas with the highest number of domains within the 5%, 10% and 20% most deprived areas within the catchment are shown in Figures 4.3, 4.4 and 4.5. These boundary values were selected in accordance with SIMD guidelines, where they are referred to as vigintiles (5%), deciles (10%) and quintiles (20%).

Overall, 26 of the data zones within the River Leven catchment are ranked within the 5% most deprived areas of Scotland for at least one of the seven domains, i.e. 14% of the 188 data zones that overlap with or are contained in the River Leven catchment (Fig. 4.3). It is interesting to note that none of the data zones in this area were ranked within the 5% or 10% most deprived areas of Scotland in terms of housing. In addition, 58 data zones were ranked as falling within the 10% most deprived areas of Scotland (Fig. 4.4) for at least one of the SIMD 2016 domains (i.e. 31% of the 188 data zones) and 102 data zones (54%) were ranked within the 20% most deprived areas in Scotland for at least one of the seven domains of deprivation listed in Table 4.1 (Fig. 4.5).

To illustrate how action to improve the water environment could be targeted at areas where it could also enhance human health and wellbeing, a buffer zone of 500 m was drawn around rivers within the catchment that are monitored for WFD purposes (Fig. 4.6) and the deprived areas within those zones were identified (Fig. 4.7). It is common, especially when selling properties, to assume a walking rate of 80 m per minute when estimating the distance to a local amenity, such as a park or railway station. By selecting 500 m, it was assumed that people living less than 7 minutes' walk away from the river would be the most likely to benefit from its improvement. The WFD rivers, their ecological status and the 500m buffer zone used for this analysis are shown in Figure 4.6.

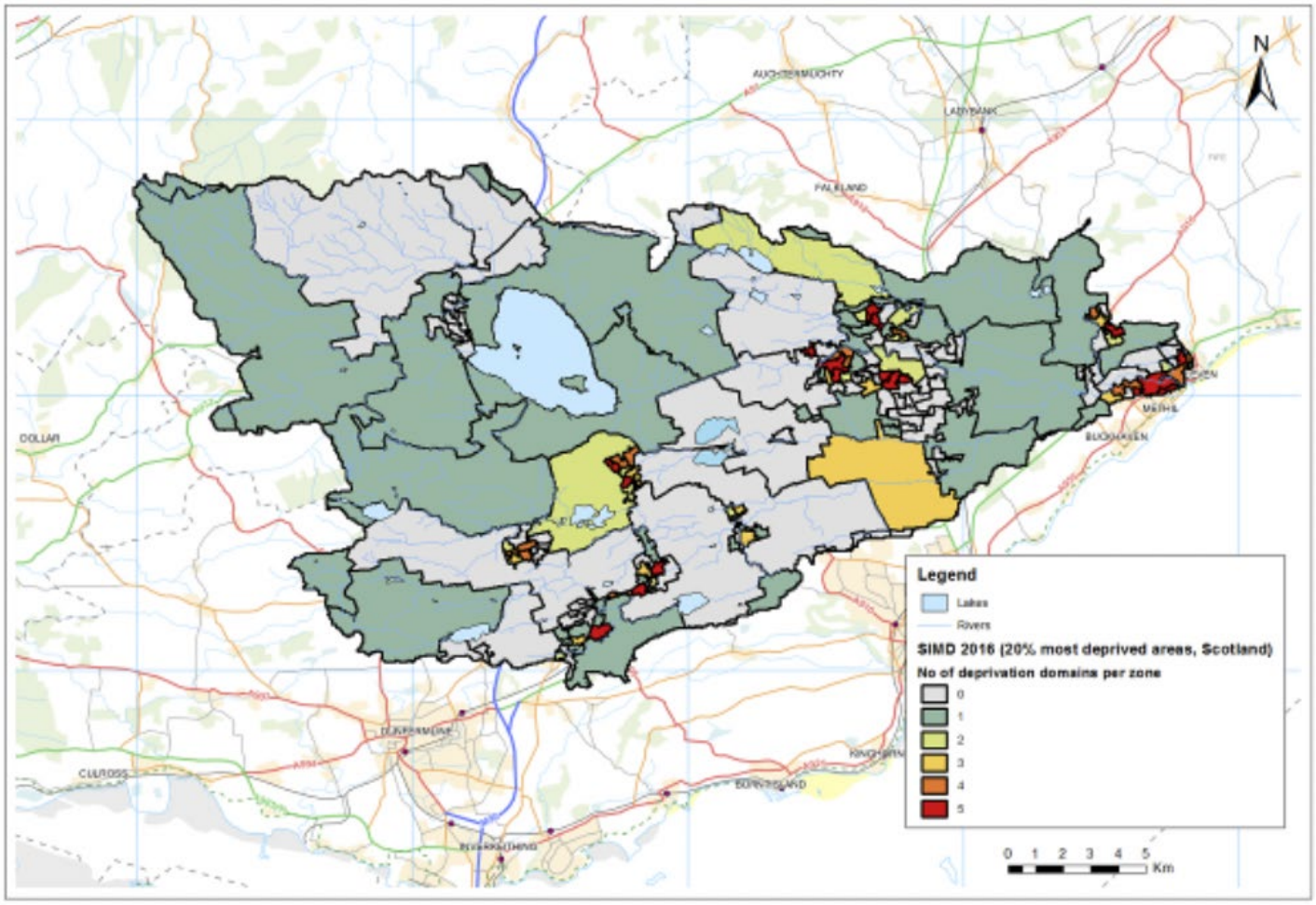

Figure 4.5 Data zones that are ranked in SIMD 2016 as being within the 20% most deprived areas of Scotland for one or more of the seven domains of deprivation shown in Table 5.1.

Most of the SIMD data zones within the catchment fall partly or completely within this 500 m buffer zone (Fig. 4.7). Although some may be in poor health and unable to do so, it was assumed, for the purposes of this high-level analysis, that all residents within each data zone would be able to walk to the river bank within 10 minutes. However, notable exceptions were the two larger data zones, i.e. S01009431, which covers an area between the Lochty, Kelty and Lochgelly Burns in the Lochore and Crosshill area, and S01009547, which is bounded to the north by the Lochty Burn and dissected by the River Ore in the Thornton and Kinglassie area. More detailed population data would be needed to estimate the number of people living within 500 m of the river in these areas. However, as the combined population of these two data zones is less than 5% of the total number of people living within the 500 m buffer zone, further investigation was not considered justified at this stage.

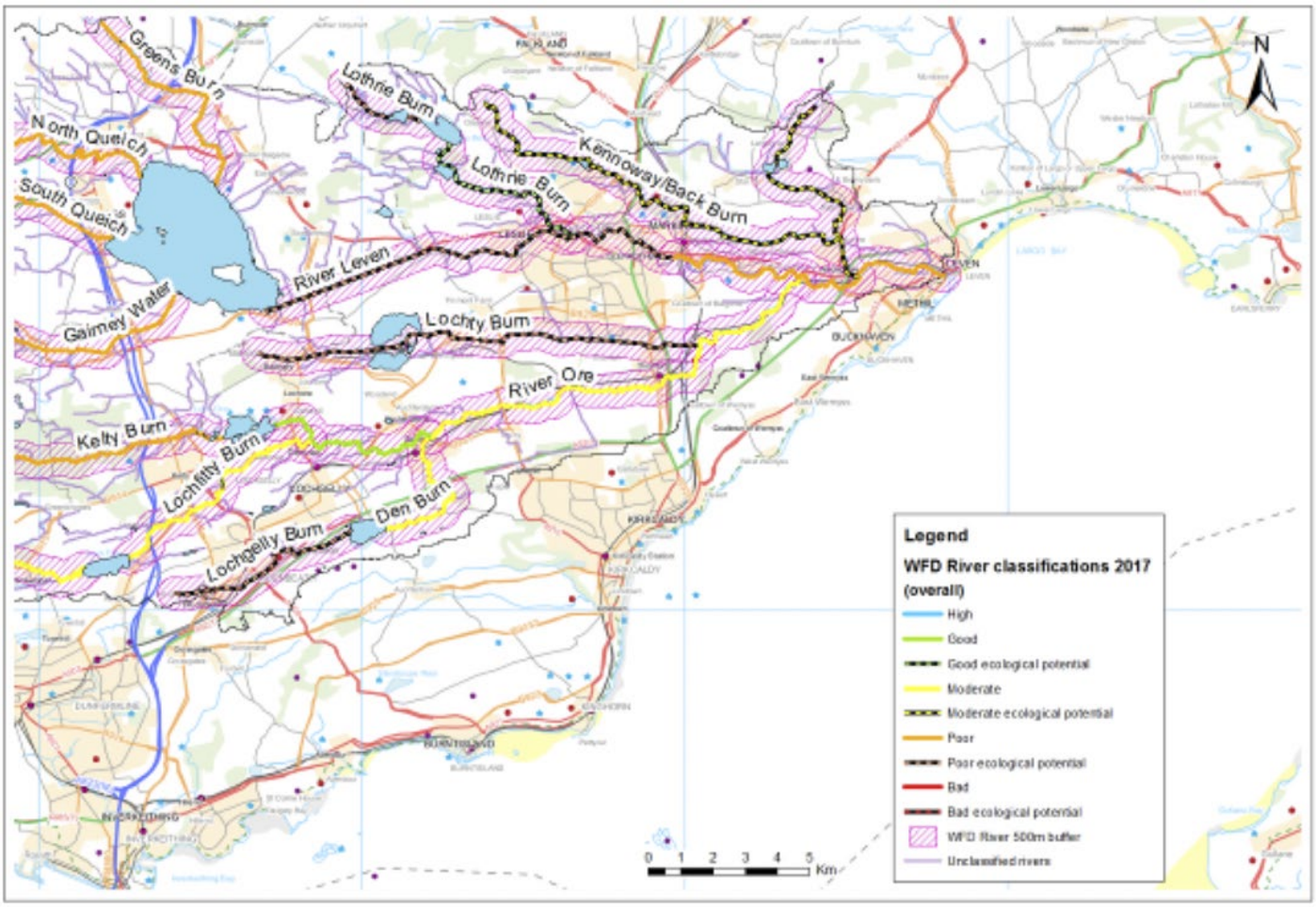

Figure 4.6 Map of lower River Leven catchment showing 500 m buffer zone around rivers monitored for WFD purposes.
Some features of this map are based on digital spatial data (Moore at al., 1994; Morris & Flavin 1990, 1994) licensed from the Centre for Ecology & Hydrology, © NERC (CEH). Contains Ordnance Survey data © Crown copyright and database right 2018, and SEPA data © Scottish Environment Protection Agency and database right 2018. All rights reserved.

Forty-two of the SIMD data zones that were ranked within the 20% most deprived areas (i.e. ranked within the lowest 1392 of data zones in Scotland), for at least two of the deprivation domains, also lie within 500 m of a WFD monitored river (Table 4.3). While the targeting of improvement actions by SEPA and their partners will depend on a wide variety of aspects, focusing on some of these areas would influence residents in data zones within easy walking distance of a river and potentially enhance employment by providing additional recreation and visitor facilities in some of the most deprived areas in the catchment.

Five of the ten rivers considered in this analysis (Table 4.3) are classified as 'Poor' or as having 'Poor ecological potential' according to the WFD classification for 2017.

Two areas on the River Leven were identified as potential areas to target for improvement. These comprised twelve data zones in the areas of Methil, Methilhill, Methil West, Methil East, Leven East and Leven West on the lower River Leven, and nine data zones in the areas of Leslie and Newcastle, Glenrothes Macedonia and Tanshall, Glenrothes Auchmuty, Glenrothes Cadham and Pitcoudie, further upstream on the River Leven (Table 4.4). In total, more than 8,500 people live in the areas identified above on the lower River Leven (6% of the total population of the River Leven catchment) and more than 6,500 live in the settlements further upstream (5% of the total population of the catchment). Closer examination of the individual domains of deprivation (Table 4.4) revealed that most of these data zones were ranked within the 20% most deprived areas in Scotland for the domains of income and employment, followed by the domains of health and education.

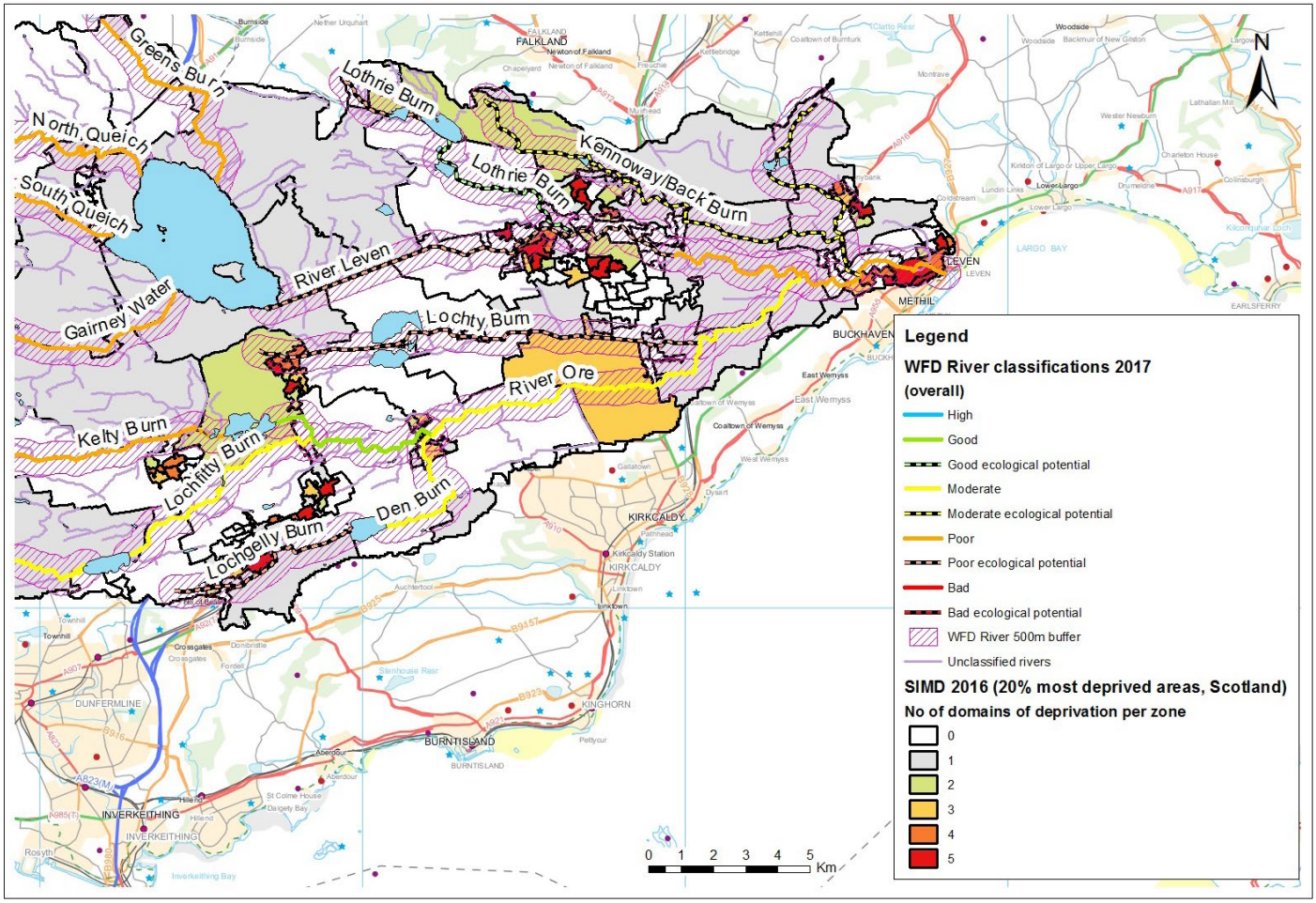

Figure 4.7 Map of lower River Leven catchment showing 500 m buffer zone around rivers monitored for WFD purposes and data zones that fall within the bottom quintile in relation to at least two of the seven domains of deprivation (see text for details).
Some features of this map are based on digital spatial data (Moore at al., 1994; Morris & Flavin 1990, 1994) licensed from the Centre for Ecology & Hydrology, © NERC (CEH). Contains Ordnance Survey data © Crown copyright and database right 2018, SEPA data © Scottish Environment Protection Agency and database right 2018, and Scottish Government and Ordnance Survey data © Crown copyright & database right 2012-6. All rights reserved.

The seven domains of deprivation utilised above were quantified using a combination of indicators that can be explored, individually, to provide a more in depth view of the catchment and its areas of deprivation (see http://www.gov.scot/Resource/0050/00504822.pdf for further details). Three of these indicators were selected for further exploration based on their potential relevance to the aims of this report. These were income, health and crime.

The income domain is calculated by adding five indicators together and dividing them by the (unrevised) 2014 mid-year population estimate (source: NRS). As might be expected, the areas with the highest percentage of adults affected is reflected in the results of the above analysis, highlighting that the areas surrounding the target areas identified are also characterised by low income (Fig 4.8).

Table 4.3 Monitored rivers within the River Leven catchment, their WFD 2017 classification, the number of data zones that fall within 500 m of these rivers, the total population living within these data zones, and the proportion of that population living within the catchment and falling within the bottom quintile of at least two of the seven domains of deprivation.

River	WFD River Classification 2017	Number of data zones	Total population	% Population of catchment
River Leven (lower)	Poor	11	8611	6.1
River Leven (upper)	Poor ecological potential	9	6654	4.7
Lochty Burn	Poor ecological potential	7	4937	3.5
Den Burn/Lochgelly Burn	Poor ecological potential	3	2538	1.8
Kelty Burn	Poor	2	1147	0.8
Back Burn	Moderate ecological potential	4	2820	2.0
Kennoway	Moderate ecological potential	2	1415	1.0
Den Burn	Moderate	1	899	0.6
River Ore (upper)	Good	2	1449	1.0
River Ore (lower)	Good	1	709	0.5
Grand Total		**42**	**31179**	**22.1**

The health domain comprises seven indicators that report on a variety of hospital admissions and provide information on drugs prescribed, proportion of low birth weights and indices of mortality. Figure 4.9 shows the proportion of the population in each data zone that is being prescribed drugs for anxiety, depression or psychosis. For the target areas identified above (Fig. 4.7), it is clear that there is also a higher incidence of mental illness in these areas, with about 20-30% of the population requiring medication for this.

Table 4.4 SIMD 2016 ranking for each of the seven domains of deprivation associated with the 42 data zones that lie within 500 m of a river within the River Leven catchment; figures in grey italics are above the quintile cut-off.

River	Intermediate Zone	Data Zone	Total population	Overall SIMD 2016 rank	Income	Employment	Health	Education	Housing	Access	Crime
Lower Leven	Methil Methilhill	S01009625	840	776	781	1123	1314	170	4868	2502	2461
Lower Leven	Methil Methilhill	S01009626	606	424	166	714	1133	278	1106	5391	1512
Lower Leven	Methil Methilhill	S01009629	1046	1279	1148	1538	2090	778	2378	3040	835
Lower Leven	Methil Methilhill	S01009630	781	731	998	599	1235	429	2045	2736	1622
Lower Leven	Methil West	S01009633	753	166	184	207	323	103	1382	6069	143
Lower Leven	Methil East	S01009635	859	1434	1482	1051	1429	1913	3742	5582	931
Lower Leven	Methil East	S01009636	902	183	267	142	359	113	2806	5638	270
Lower Leven	Methil East	S01009637	724	1584	1500	1352	1366	2057	4412	6154	869
Lower Leven	Methil East	S01009638	741	217	97	353	647	117	2457	5952	723
Lower Leven	Leven East	S01009641	794	1206	1296	1255	764	1625	3403	6502	202
Lower Leven	Leven West	S01009646	565	1733	1346	2076	2421	1013	1877	5565	1643
Upper Leven	Leslie and Newcastle	S01009553	829	970	978	927	1159	943	1538	5478	626
Upper Leven	Glenrothes Macedonia and Tanshall	S01009556	737	1029	1190	828	1022	1554	2820	2011	2088
Upper Leven	Glenrothes Macedonia and Tanshall	S01009557	651	680	558	435	1127	1056	2746	4632	2228
Upper Leven	Glenrothes Macedonia and Tanshall	S01009558	671	446	378	393	700	393	3371	5559	1956
Upper Leven	Glenrothes Macedonia and Tanshall	S01009559	833	866	964	755	1258	893	1811	4405	441
Upper Leven	Glenrothes Macedonia and Tanshall	S01009560	719	590	727	526	914	559	3836	2204	979
Upper Leven	Glenrothes Auchmuty	S01009574	942	1439	1341	1492	1844	1984	2470	5639	63
Upper Leven	Glenrothes Cadham and Pitcoudie	S01009600	619	673	690	726	333	2008	2537	2003	907
Upper Leven	Glenrothes Cadham and Pitcoudie	S01009601	653	1449	1002	1793	2530	1232	1837	2961	1432
Lochty Burn	Lochore and Crosshill	S01009428	642	1106	1491	775	916	1058	1938	4580	2191
Lochty Burn1	Lochore and Crosshill	S01009431	680	1240	1409	931	1475	1388	4076	2369	1884

River	Intermediate Zone	Data Zone	Total population	Overall SIMD16 rank	Income	Employment	Health	Education	Housing	Access	Crime
Lochty Burn	Ballingry	S01009432	777	528	527	643	1335	135	2337	2845	2026
Lochty Burn	Ballingry	S01009433	812	1062	1021	1254	1415	745	3043	3102	983
Lochty Burn	Ballingry	S01009434	526	1406	1768	1259	1755	662	1688	3128	3731
Lochty Burn	Ballingry	S01009435	735	231	234	237	414	272	3042	2343	1196
Lochty Burn2	Thornton and Kinglassie	S01009547	765	1175	1096	1231	2071	679	2258	1816	4241
Lochgelly Burn	Hill of Beath and Kingseat	S01009410	874	994	752	1731	1910	198	1651	3706	2805
Lochgelly Burn	Cowdenbeath South	S01009489	803	850	829	707	809	1142	3183.5	5804	822
Lochgelly Burn	Cowdenbeath South	S01009490	861	933	694	758	977	1683	3141	5351	1779
Kelty Burn	Kelty West	S01009419	569	1400	1509	1533	1512	1028	4007	1347	3682
Kelty Burn	Kelty East	S01009427	578	1127	1203	503	1379	2522	4483	5543	1222
Back Burn	Kennoway and Bonnybank	S01009655	812	1378	1791	1280	2075	423	2578	2960	3637
Back Burn	Kennoway and Bonnybank	S01009656	745	417	484	524	680	172	4308	3170	805
Back Burn	Kennoway and Bonnybank	S01009658	789	904	1107	1262	2138	206	4402	2326	525
Back Burn	Kennoway and Bonnybank	S01009659	474	1036	1251	621	1803	1495	4714	4627	288
Kennoway	Glenrothes Balfarg Pitcairn and Coul	S01009605	750	1280	1477	1110	980	2062	4045	1487	2138
Kennoway	Falkland and Freuchie	S01009671	665	4776	5119	5725	5368	5730	6055	746	1238
Den Burn	Cardenden	S01009439	899	1000	1058	924	1484	705	3353	2466	2553
Upper River Ore	Cardenden	S01009440	663	1412	1456	1170	1804	831	4325	6581	1641
Upper River Ore	Cardenden	S01009441	786	1563	1310	1381	2087	1101	2377	5743	3194
River Ore	Lochore and Crosshill	S01009430	709	1239	1434	979	1466	830	2109	5316	1541

[1] Data zone covers an area that lies between Lochty Burn, Kelty Burn and Lochgelly Burn; allocated to the Lochty Burn in this analysis as the greater proportion is covered by the buffer zone around the Lochty Burn.

[2] Data zone is relatively large, bounded in the north by the Lochty Burn and dissected by the River Ore; allocated to the Lochty Burn in this analysis because the River Ore is in good condition according to its WFD classification

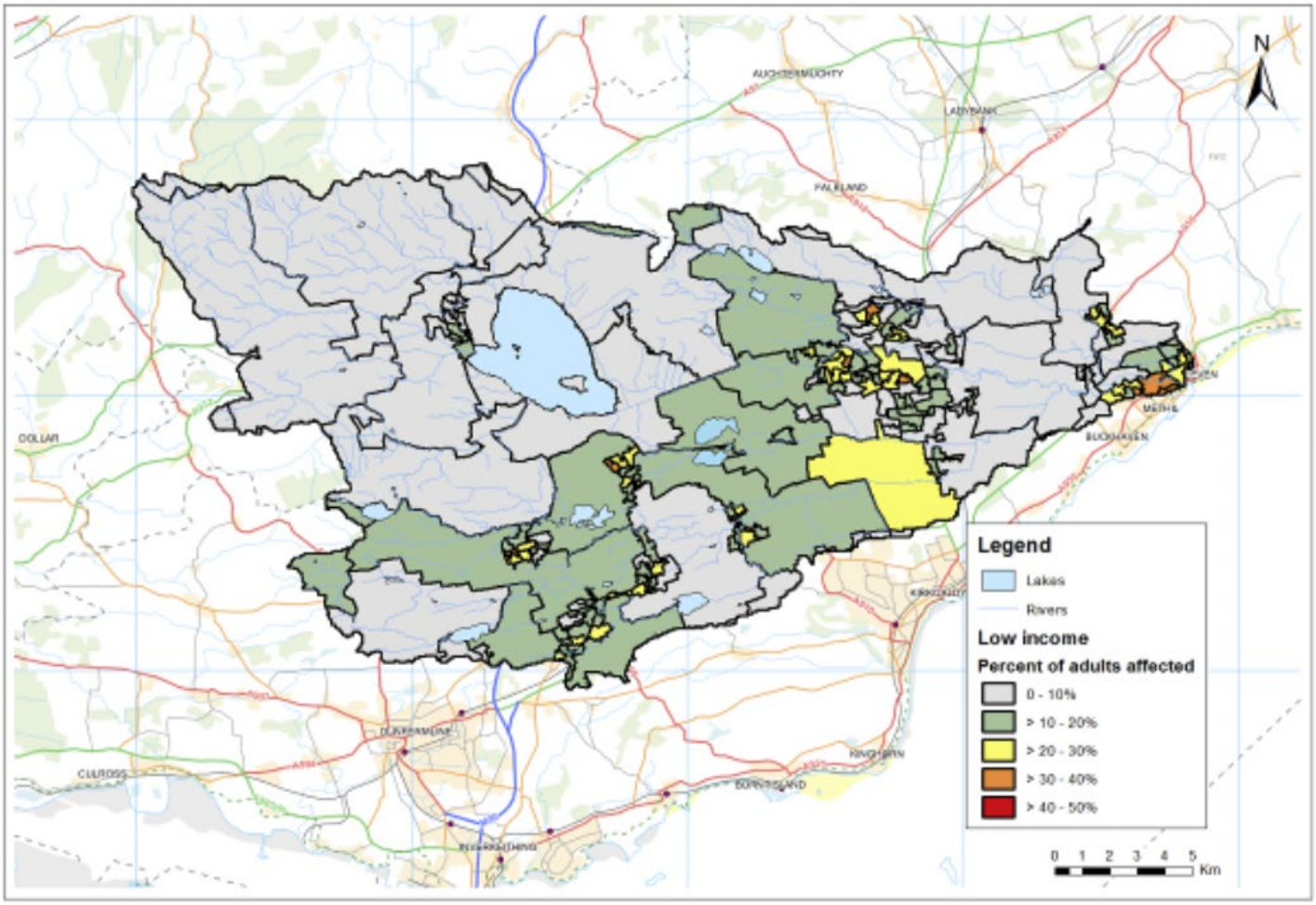

Figure 4.8 Map of the River Leven catchment indicating the percentage of adults who are income deprived per data zone.
Some features of this map are based on digital spatial data (Moore at al., 1994; Morris & Flavin 1990, 1994) licensed from the Centre for Ecology & Hydrology, © NERC (CEH). Contains Ordnance Survey data © Crown copyright and database right 2018, and Scottish Government and Ordnance Survey data © Crown copyright & database right 2012-6. All rights reserved.

Crime rate was explored in relation to the number of crimes of violence, sexual offences, domestic housebreaking, vandalism, drugs offences, and common assaults per 10,000 people in each zone (Fig. 4.10). This indicator illustrates the need to consider SIMD indicators individually, as well as collectively, because the crime map shows that data zone S01009574, in the Glenrothes Auchmuty area, has the highest crime rate in the River Leven catchment yet it falls within the 20% most deprived areas of Scotland in only two of the seven domains of deprivation. These are crime (ranked 63rd highest in Scotland) and income (ranked 1341th highest in Scotland). The reason for the higher crime rate in the large data zone west of Loch Leven is unclear, but is likely to be associated with the T-in-the-Park festival, which used to be located here, and/or the presence of a motorway service area within this zone.

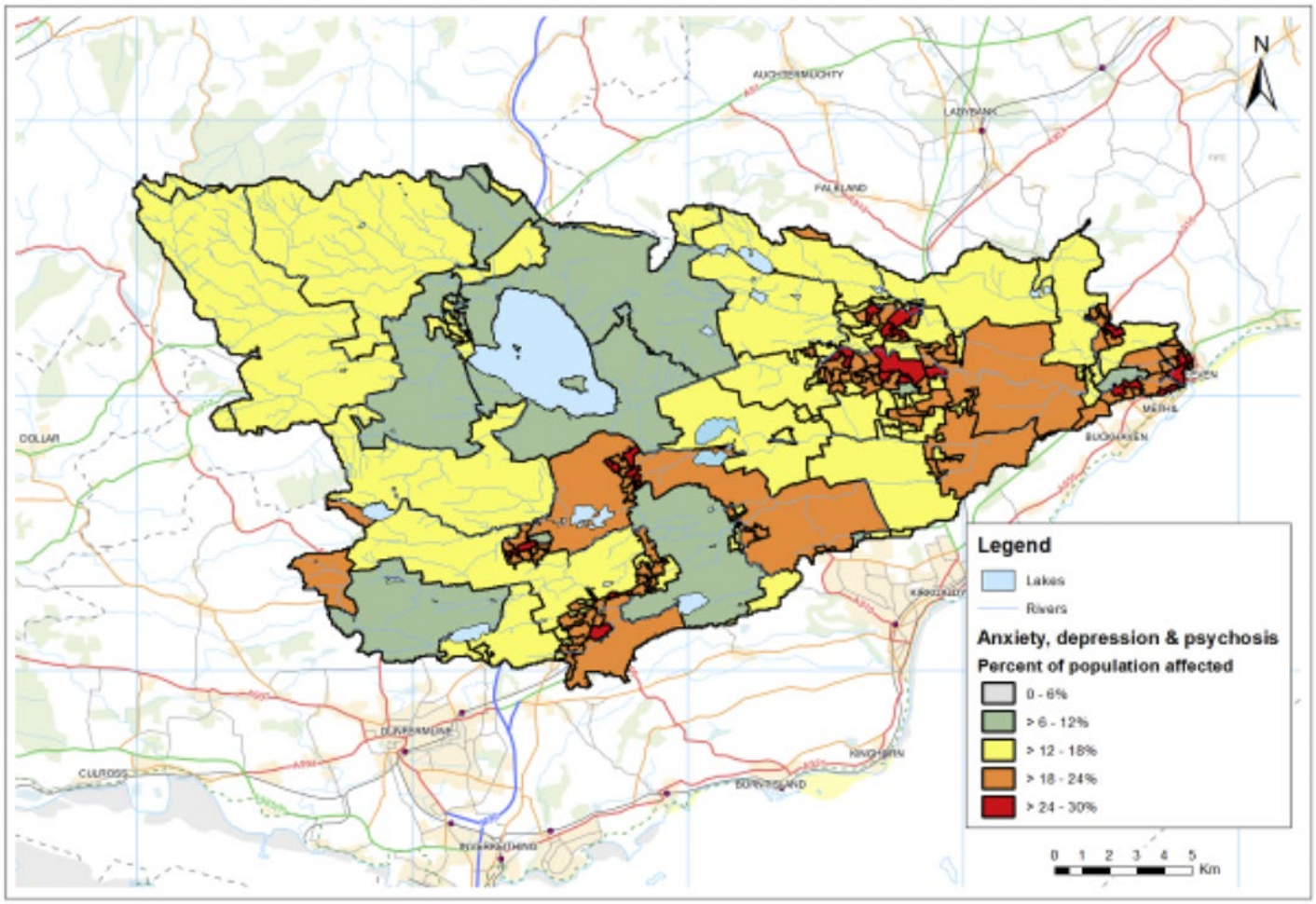

Figure 4.9 Map of the River Leven catchment indicating the percentage of the population in each data zone that are being prescribed drugs for anxiety, depression or psychosis.
Some features of this map are based on digital spatial data (Moore at al., 1994; Morris & Flavin 1990, 1994) licensed from the Centre for Ecology & Hydrology, © NERC (CEH). Contains Ordnance Survey data © Crown copyright and database right 2018, and Scottish Government and Ordnance Survey data © Crown copyright & database right 2012-6. All rights reserved.

4.2 Socio-economic baseline against which potential benefits of improvement can be assessed

The SIMD 2016 data were explored in relation to establishing a socio-economic baseline against which the potential benefits of environmental improvement could be assessed. In summary, it was found that SIMD data could not be used to provide a spatially or temporally robust socio-economic baseline to assess the successes of targeted actions going forward.

SIMD 2016 data are calculated using the 2011 data zone boundaries, which are based on the 2011 Census, and were introduced in November 2014. The 2011 data zone boundaries differ from the 2001 data zone boundaries that were used for previous SIMD editions. So, direct comparisons of indicators between 2016 and previous years are not possible. This limits the extent to which comparative analyses of historical data are likely to be meaningful, and there is no guarantee that the data zones will not be changed again in the future.

For SIMD 2016, changes have been kept to a minimum to ensure as much consistency as possible with the SIMD 2012 publication. Nevertheless, changes have been made that limit the value of comparisons made between the two data sets. For example, minor changes have been made to the indicators included in SIMD 2016 to reflect the way the national statistics are collected. There have also been improvements in data quality. A summary of the main changes made between SIMD 2012 and SIMD 2016 within each domain are shown in Table 4.5. If these data are used to develop indicators of change, it is recommended that single indices are used to create baseline data, as this will make it easier to interpret them if changes are made to the way that data are collected and interpreted in the future.

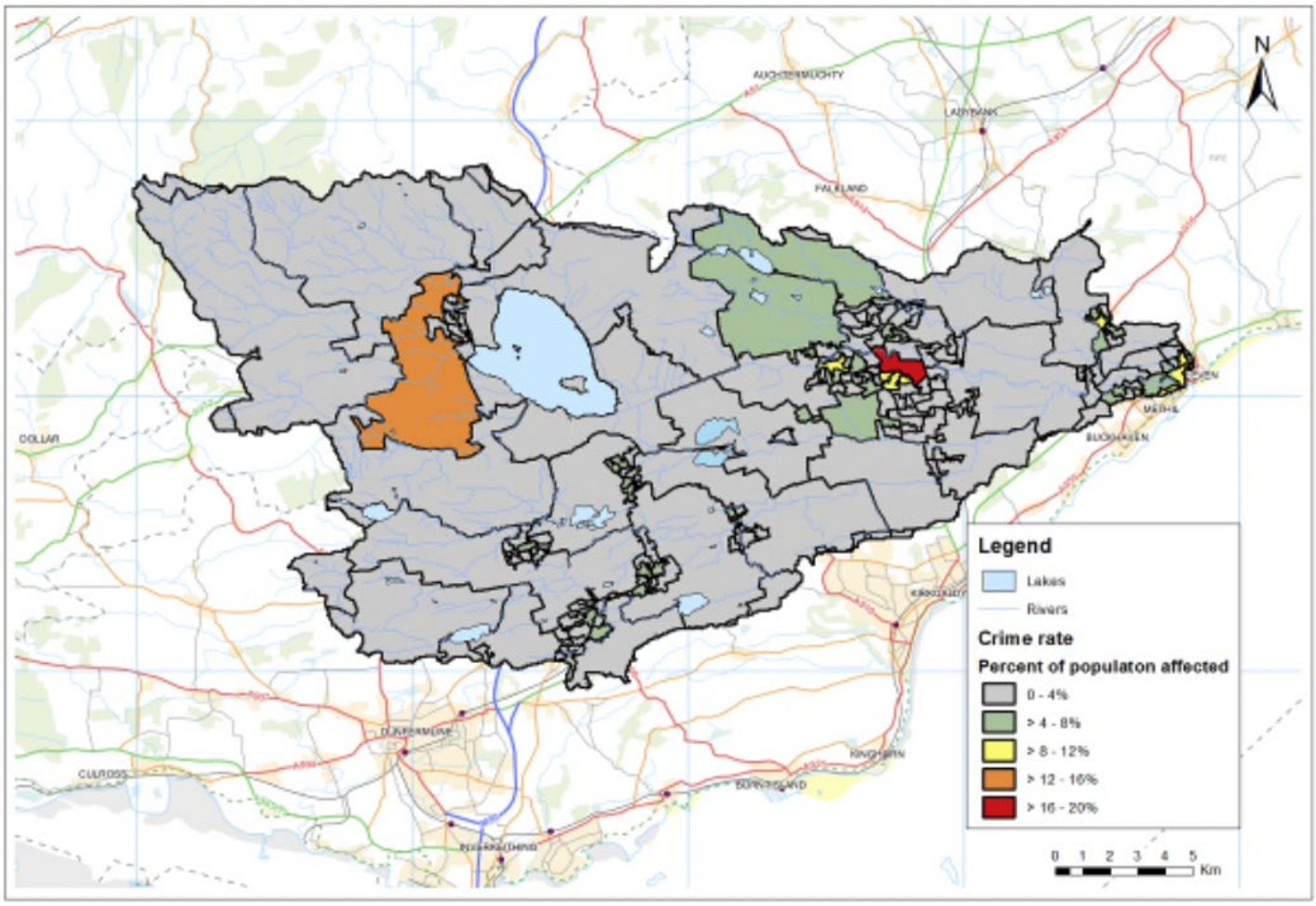

Figure 4.10 Map of the River Leven catchment indicating the percentage of the population affected by crime.
Some features of this map are based on digital spatial data (Moore at al., 1994; Morris & Flavin 1990, 1994) licensed from the Centre for Ecology & Hydrology, © NERC (CEH). Contains Ordnance Survey data © Crown copyright and database right 2018, and Scottish Government and Ordnance Survey data © Crown copyright & database right 2012-6. All rights reserved.

5 Business uses of water

5.1 Tourism and recreation

Within the River Leven catchment, there are a range of business and recreational uses of water. These are outlined below, together with the economic value of these activities where that information is readily available.

The River Leven flows eastwards from Loch Leven to the town of Leven. It provides about 20 km of (mostly) double bank fishing between Leslie and Levenmouth, and there is good access to most parts of it (http://riverlevenanglingclub.co.uk/). Most of the fish caught by anglers are brown trout and sea trout (*Salmo trutta*), although a small number of Atlantic salmon (*Salmo salar*) have also been caught. In 2017, a small number of Pacific (Pink) salmon (*Oncorhynchus gorbuscha*) were caught in the river. To prevent further invasion by this species, all pink salmon caught in the river must be notified to the relevant District Salmon Fishery Board (Forth DSFB, in this case) or the Forth Fisheries Trust. They must be killed humanely and passed on to the Forth DSFB for further inspection.

Table 4.5 Summary of changes made to domains and indicators between SIMD 2012 and SIMD 2016.

Income domain
Eligibility criteria of certain benefits changed, and Universal Credit introduced. The number of people claiming income related benefits and credits now determined through Universal Credit system.

Employment domain
No changes.

Health domain
Instead of estimating the 'Proportion of the population being prescribed drugs for anxiety, depression or psychosis', the indicator was improved to reflect the number of people who have been prescribed such drugs within the specified year. The previous indicator was an estimate of the average number of people taking such drugs on any one day during the year.

The 'Hospital stays related to alcohol misuse' indicator now includes the additional ICD-10 (International Classification of Diseases (10th revision)) category K852 (Alcoholic Induced Acute Pancreatitis).

Education domain
Two out of the five indicators in the education domain have changed considerably, and one indicator has changed slightly.

The 'School pupil attendance' indicator was improved to include only pupils with high attendance, rather than an average absence level for all pupils.

The 'Attainment of school leavers' indicator replaces the average Scottish Qualifications Authority (SQA) score used previously. The data for the SQA score is no longer available due to changes in the examination system. The new indicator considers the highest level of qualifications that a pupil leaves school with.

There were small changes in the 'Working age people with no qualifications' indicator. Age bands and age ranges for standardisation have changed and, due to a change in the wording of a Census question, the SIMD 2016 indicator counts people who have no qualifications, whereas the indicator in previous SIMD editions also included people whose qualifications were not listed in the response options.

Geographic access to services domain
The software used to calculate journey times has changed since SIMD 2012. As a result, most journey times are estimated to be lower in the SIMD 2016 data but are likely to reflect true travel times more accurately.

Crime domain
The indicators included in the crime domain remained the same between SIMD 2012 and SIMD 2016. However, new crime codes under the 'Recorded crimes of violence' category, such as 'Offences relating to Serious Organised Crime' and 'Causing serious injury etc. by culpable and reckless conduct' are now included in SIMD 2016.

Housing domain
No changes. The indicators included in the housing domain have been updated using 2011 Census data.

The River Leven Angling Club (RLAC; established in 2010) promotes fishing at an affordable price on the River Leven. It also helps to maintain the quality of the river by undertaking river bank maintenance in collaboration with local landowners. All fishing is undertaken on a "catch and release" basis. In addition to the River Leven, fishing permits also cover the River Ore, which is less accessible but provides an opportunity to catch brown trout, pike (*Exox lucius*) and perch (*Perca fluviatilis*). Fishing permits range from £10 for a day permit to £45 for a seasonal permit. In 2017, the RLAC sold 63 season tickets and 29 day tickets, amounting to an approximate annual income of £2,864.

Separated from the River Leven by a set of sluice gates, the fish in Loch Leven provide an additional source of recreational fishing within the River Leven catchment. The Loch Leven fishery allows angling from boats, only, and any number of trout over 28 cm in length can be kept, whilst smaller trout must be returned to the loch. Fishing boats can be hired from Loch Leven Fisheries for £21-£52 per day, and £20-£40 per evening, depending on the timing of the visit and number of anglers in each boat. The gross income of the fishery is estimated to be about £150,000 per year. Loch Leven has a long-standing international reputation for the quality of its fish and attracts anglers from all over the world. The loch is no longer stocked with fish and it has now reverted to be a natural (wild) brown trout fishery. Loch Leven also provides a well-documented example of how water quality can affect the amenity and economic value of a WFD water body in this area (see Section 8). In addition to angling, Loch Leven provides other recreational facilities, such as historical monuments, a National Nature Reserve, a bird reserve and a circular all-abilities trail around the shoreline of the loch. The area attracts more than 200,000 visitors per year, which contribute about £2,000,000 per year to the local economy (see Section 8).

Within the catchment, Harperleas, Holl and Drumain Reservoirs, which lie within the Lomond Hills Regional Park, are also run as trout fisheries (https://www.lomondhillsfishery.com/). They have 12 fishing boats for hire, and bank fishing is permitted at these sites. Every week, Harperleas and Holl are stocked with rainbow and blue trout; wild brown trout, perch and pike can also be caught at these sites. At Holl Reservoir (bank and boat), fishing permits cost £6-£20 per day, depending on the fishing method used, and anglers can keep up to five of any stocked fish caught; all brown trout and pike must be returned unharmed. Drumain Reservoir (bank fishing only), is run on a take what you need basis, with prices ranging from £10 for 2 hours to £25 for 8 hours. Harperleas Reservoir is wild brown trout only, with costs

ranging from £10 for a day ticket to £50 for a season ticket. Ballo reservoir, which is nearby, also provides fly fishing opportunities for brown and rainbow trout. This reservoir is now operated by Scottish Water and has 14 boats for hire, although the cost of hiring is unknown. The overall income from fishing at these sites is unknown. There is a circular path around all four reservoirs that is popular with walkers and provides bird watching opportunities.

Fishing is also available at Lochore Meadows Country Park (LMCP), which lies within the Lomond Hills Regional Park and covers more than 65 km2. It is part of Fife's highest and most heavily used open countryside, which provides other types of informal recreation for the local community and visitors. The area is managed by a local partnership that comprises various organisations including landowners, estate managers, farmers, public sector agencies, and individual stakeholders. In terms of the water environment, the park includes part of the River Leven Valley in the east and LMCP in the west. The LMCP has a visitor centre and outdoor education centre that hosts up to 400,000 visitors annually. A further 200,000 - 400,000 visits per year are made to other parts of the park. While the most popular activity in this area is walking, LMCP also provides facilities for water-based activities such as water sports, fishing and bird watching. There is a popular walking route around the loch.

Coul (Den) Reservoir is an abandoned and partially-drained water body lying to the north of Glenrothes, which was built originally to supply water to John Haig's Markinch Distillery. The reservoir was drained when the distillery closed and now comprises a series of shallow, landscaped ponds and a network of paths within the Coul Den Local Nature Reserve. Although there is no opportunity for fishing here, visitor facilities include rest and picnic areas near the waters' edge and a circular walk around the loch that is 0.9 km long.

5.2 Abstraction

Although abstraction of water for drinking water supply, irrigation and industrial use are features of some areas of the catchment, little data or information on this was available for analysis within the time scale of the project. Water levels and rates of flow from Loch Leven to the River Leven are still managed, as originally intended, to maintain a constant supply of water to downstream industry (Munro, 1994). However, many of those industries (e.g. paper mills, linen mills) no longer exist.

5.3 Hydroelectric power generation

There is little hydro-electric power generation on the River Leven or its tributaries. However, small systems are used by some industries. The details of these, or their environmental impacts, were not available to the project team.

6 Current development or management plans that affect the water environment

The River Leven catchment spans two local council areas, Fife and Perth & Kinross. Each of these has published a development plan. Where these plans include components that affect the water environment, either directly or indirectly, these are summarised below.

6.1 Fife Council

A 2016 development plan (SESplan) has been proposed by the Strategic Development Planning authority for Edinburgh and South East Scotland region (including the southern half of Fife). In Fife, it includes development along the northern arc of the Fife Circle railway line to regenerate the brownfield land that is associated with former mining communities in the Ore and Upper Leven valleys. The plan also identifies Green Network Priority Areas for the Ore Valley and Levenmouth, which are areas of great strategic importance for green network protection and enhancement.

Green networks comprise areas of green and blue infrastructure connected as part of a strategic land use planning process to deliver benefits to people and nature, and to add value to the economy by supporting sustainable growth. Green infrastructure includes parks, open spaces, playing fields, woodlands, wetlands, floodplains, roadside verges, allotments and private gardens. Blue infrastructure includes sustainable drainage systems, ponds, swales, wetlands, rivers and canals.

The SESplan sets out a Housing Supply Target of 10,404 new homes (both market and affordable) for the southern Fife area over the period 2018-2030. This target has been set to reflect housing needs as well as environmental and infrastructural capacity. A recreational (i.e. cycling and walking) route passing to the north of Glenrothes is also proposed as a contribution to the Scottish Government's vision for cycling and walking, as set out in their National Walking Strategy and Cycling Action Plan. The development of a Levenmouth rail link has also been highlighted as a potentially strategic improvement in transport that may be developed within the River Leven catchment.

The first Fife Local Development Plan (FIFEplan) was adopted by Fife Council in September 2017; this superseded previous local plans and sets out policies and proposals for the development and use of land across Fife. It comprises three elements:

1. strategy (what the FIFEplan aims to achieve within ten years of adoption by Fife Council)

2. policies (how land will be used and developed), and

3. proposals for specific settlements in Fife.

FIFEplan forms part of Fife's overall Development Plan, which also includes the SESplan and the Tay Strategic Development Plan (TAYplan; which includes the Perth & Kinross and northern Fife). The Fife Development Plan provides the statutory policy framework for land use planning, strategic development, and policy and decision making in Fife.

Within the FIFEplan is a spatial land use strategy, which recommends how Fife should be developed between 2016 and 2026. This is framed by the National Planning Framework and the SESplan and TAYplan. It is also shaped by other strategic policies such as the River Basin Management Plan for the Scotland River Basin District (which includes the River Leven and its tributaries) and SEPA's Flood Risk Management Strategy. The development proposals highlighted below fall within the River Leven catchment and have links to the freshwater environment.

There are green network opportunities associated with the legacy left by the Living Lomonds Landscape Partnership (LLLP) and the proposed St Ninian's restoration at Westfield. The LLLP was a landscape conservation programme that was delivered by various organisations in Fife, and Perth & Kinross. It aimed to reconnect people with the 'living legacy of the Lomond and Benarty Hills'. The programme created a number of linked walking paths and, although funding has finished, still offers a range of community based activities, volunteering opportunities and projects through the Living Lomonds website. Many of these paths pass very close by, or provide panoramic views of, water bodies within the area. These include Loch Ore, Ballo Reservoir, the Maspie Den Waterfall, Coul Reservoir and Loch Leven.

The SESplan also identifies Glenrothes and the Ore/ Upper Leven valleys as a focus for further development, with the aim of encouraging regeneration on and around the Fife Circle rail link. This is focused, mostly, on town centre regeneration in Glenrothes, Cowdenbeath and Kelty. However, there is also an emphasis on improving opportunities for leisure activities. This could be linked to local water bodies such as the River Leven, The River Ore and Loch Ore.

The Levenmouth Strategic Land Allocations focuses on providing new homes and supporting community facilities. Although there is no mention of linking to any improvements in the water environment in this area, the River Leven passes through the town and could provide a focus for the developing leisure activities or increasing the market value of homes.

In July 2018, Fife Council announced that it was embarking upon a feasibility study into a 'River Leven Green Infrastructure' tourism project, which would provide cycling and walking paths along the entire length of the River Leven, from its source at Loch Leven to its mouth at Leven. Fife Council, who are collaborating on this potential multi-million pound development with SEPA, SNH, Scottish Water and Efficient Resource Solutions, are planning to build the paths in three stages:

1. Leven to Windygates

2. Windygates to Leslie, and

3. Leslie to Loch Leven.

It is hoped that this project will provide a boost to tourism in this area of Fife, especially if it can be linked to the suggested reinstatement of the Thornton to Leven rail link and to ambitions to create a 'Leven Loop' walking path.

6.2 Perth & Kinross Council

The Perth & Kinross Council (PKC) Local Development Plan (LDP), which was adopted on 3rd February 2014, supersedes previous Local Plans. The LDP is a statutory document that guides all future developments and uses of land with the Perth & Kinross Council area. This Plan is currently under review following the preparation of Local Development Plan 2 (LDP2). LDP2 must be consistent with the current TAYplan, which was approved by Scottish ministers in 2017 and provides a planning vision for 2016-2036 for the Dundee and Perth area; this includes North Fife, parts of Angus, and Perth & Kinross. The TAYplan sets out policies that will affect how towns and the countryside will look like in the future. A concern is that the number of people living in the Perth & Kinross Council area is projected to increase from 487,720 in 2012 to 553,230 by 2036.

A Kinross-shire Area Spatial Strategy is highlighted within the Perth & Kinross Local Development Plan. The key environmental focus of this is Loch Leven. For many years, Loch Leven suffered from eutrophication caused by high inputs of nutrients (especially phosphorus) from its catchment. Water quality problems led to a multi-agency consortium publishing the Loch Leven Catchment Management Plan in 1999, which sought to identify and implement control measures aimed at reducing phosphorus inputs to the loch. Even today, keeping the amount of phosphorus entering Loch Leven to low levels is still a key consideration for any planned developments within the catchment. For example, under PKC Policy EP7 (https://www.pkc.gov.uk/media/23633/Local-Development-Plan/pdf/Adopted_LDP_Web_Version.pdf?m=636099646768900000) any new development within the catchment is required to connect to a publicly maintained waste water treatment system or to provide mitigation measures that are capable of removing the equivalent of 125% of the phosphorus likely to be generated by the development from effluent discharges. All

settlements that lie within the Loch Leven catchment must comply with Policy EP7 so as not to have an adverse effect on Loch Leven. These include Kinross, Milnathort, Balrado, Carnbo Cleish, Glenlomond, Greenacres, Kinnesswood, Ochil Hills Hospital and Wester Balgedie.

The TAYplan indicates that 71 houses will be needing to be built every year in Kinross-shire to take account of projected population increases. However, because of the potentially significant adverse effect that this may have on Loch Leven, the LDP proposes to reduce this number by 10%. Even at this lower rate of construction, the LDP will need to identify an effective supply of land for housing that can support 880 houses across Kinross-shire as a whole.

6.3 Westfield regeneration project

In October 2017, Fife Council granted outline planning permission, submitted by Hargreaves Services plc, for a new energy park and industrial estate on the 423-hectare site of the former Westfield opencast coal mine, near Cardenden. The developers claimed that up to 2,500 new jobs could be created by the development. However, during the consultation period, concern was raised about the potential environmental impact of the proposed development on local communities, facilities and infrastructure, especially in the neighbouring Perth & Kinross Council area.

Coal production at the Westfield site stopped in 1998 and, if the project goes ahead, it will take an integrated approach to restoring, regenerating and sustainably developing this large brownfield site to create an 'energy-producing powerhouse'. Development plans included a solar energy park, resource recovery facilities, light industrial units and agricultural greenhouses. The resources recovery park was seen as the 'anchor development' that would help to support renewable energy and other new businesses on the site. However, since planning permission was granted in principle, a proposal has been submitted by Westfield Energy Limited to Fife Council for a gas-fuelled power station to be located on the site, too. Concerns about environmental impact of the proposed development have been raised due to the sites' proximity to Loch Leven which is located close to the roads that are likely to be used for access during the building and operational phases.

6.4 Flood defence/mitigation strategy

Within the River Leven catchment, the town of Leven has been identified as a Potentially Vulnerable Area (PVA) in terms of flooding. The PVA covers 22 km2 and contains the towns of Leven and Methil, and the villages of Kennoway and Lower Largo. Although the area is at risk of river, surface water and coastal flooding, most damage (Annual Average Damages estimated to be c. £820,000) is expected to be caused by river flooding. The highest risks of river flooding are from the River Leven and the Scoonie Burn (north of the R. Leven) to Leven and Methil, with the highest risk of surface water flooding being in Leven. Approximately 1,280 residential properties and 90 non-residential properties are believed to be within the flood risk area. The main objectives for the River Leven PVA, as outlined in the Forth Estuary Local Plan District, are to reduce economic damage to property and risk to people in Leven as a result of flooding from the River Leven and the Scoonie Burn. It also aims to reduce the impacts of surface water flooding in Leven and Eastern Methil (where practical).

A study has been recommended to assess whether flood storage on the Scoonie Burn could be increased to reduce the risk of flooding downstream. Potential actions have been suggested; these include various combinations of conveyance modification, direct flood defences, improved management of sediment and natural flood management (e.g. river/floodplain restoration). Of interest is the recommendation that flood protection studies should consider the positive and negative impacts of proposed actions on the ecological quality of the environment and designated sites. For example, any natural flood management actions could help to improve the condition of rivers by linking them to river basin management planning. It has also been suggested that a surface water management plan/study should be carried out by Fife Council to identify the most suitable actions to improve management of surface water flood risk in the area. An integrated catchment study, carried out by Scottish Water in partnership with local authorities, is recommended to support the surface water management planning process by improving knowledge and understanding of surface water flood risk and its interactions with other sources of flooding, e.g. the sewer network, watercourses and the sea.

7 Opportunities for aligning development and/or management actions to achieve multiple benefits

7.1 Improving the water environment to meet regulatory targets

The main requirements for improving the water environment within the River Leven catchment are associated with the partial or complete removal of barriers to fish migration, the control of potentially invasive species and the reduction of inputs of nutrient and manganese. However, care should be taken to ensure that the possible dis-benefits of management intervention are taken into consideration before they are implemented. For example, the removal of barriers to fish migration may allow non-native species, e.g. plants, fish, etc., to spread into new areas of the catchment.

The reduction of nutrient inputs to impacted water bodies within the catchment is already being addressed by SEPA's plans for controlling diffuse pollution in this area over the next five years. The area has been designated a priority catchment for this from 2019 onwards. To support this process, SEPA will appoint dedicated priority catchment coordinators to investigate the issues of diffuse pollution and liaise with local land managers to implement Best Management Practices to protect receiving waters from nutrient enrichment and support their restoration.

7.2 Focusing on areas where social deprivation and degraded water quality overlap

Figure 7.1 shows areas of the River Leven catchment where areas of social deprivation overlap with areas of degraded water quality. The River Leven, for example, is classified as having 'Poor' ecological status along the whole of its length and passes through, or close to, areas of high deprivation in Glenrothes and Levenmouth. There are also areas of high deprivation around the upper end of the Lochty Burn and along the Lochgelly Burn, which have 'Poor' ecological status.

By combining the water quality and social deprivation data, it was concluded that improvements to the water environment should be focused on the areas around Methil, Glenrothes and Levenmouth in the first instance. However, as all the water bodies in the catchment are connected, broader scale improvements would create more recreational and business opportunities, and less risk of flooding, for people within the wider catchment. These areas are also the main foci of the FIFEPlan and the TAYPlan. This will attract visitors, such as walkers, cyclists, wildlife enthusiasts and anglers, into the area bringing increased levels of income to local businesses such as restaurants, hotels and bicycle hire companies. An illustration of how water quality improvements can help to provide such benefits to local people, based on a documented case study from Loch Leven, is given in Section 8.

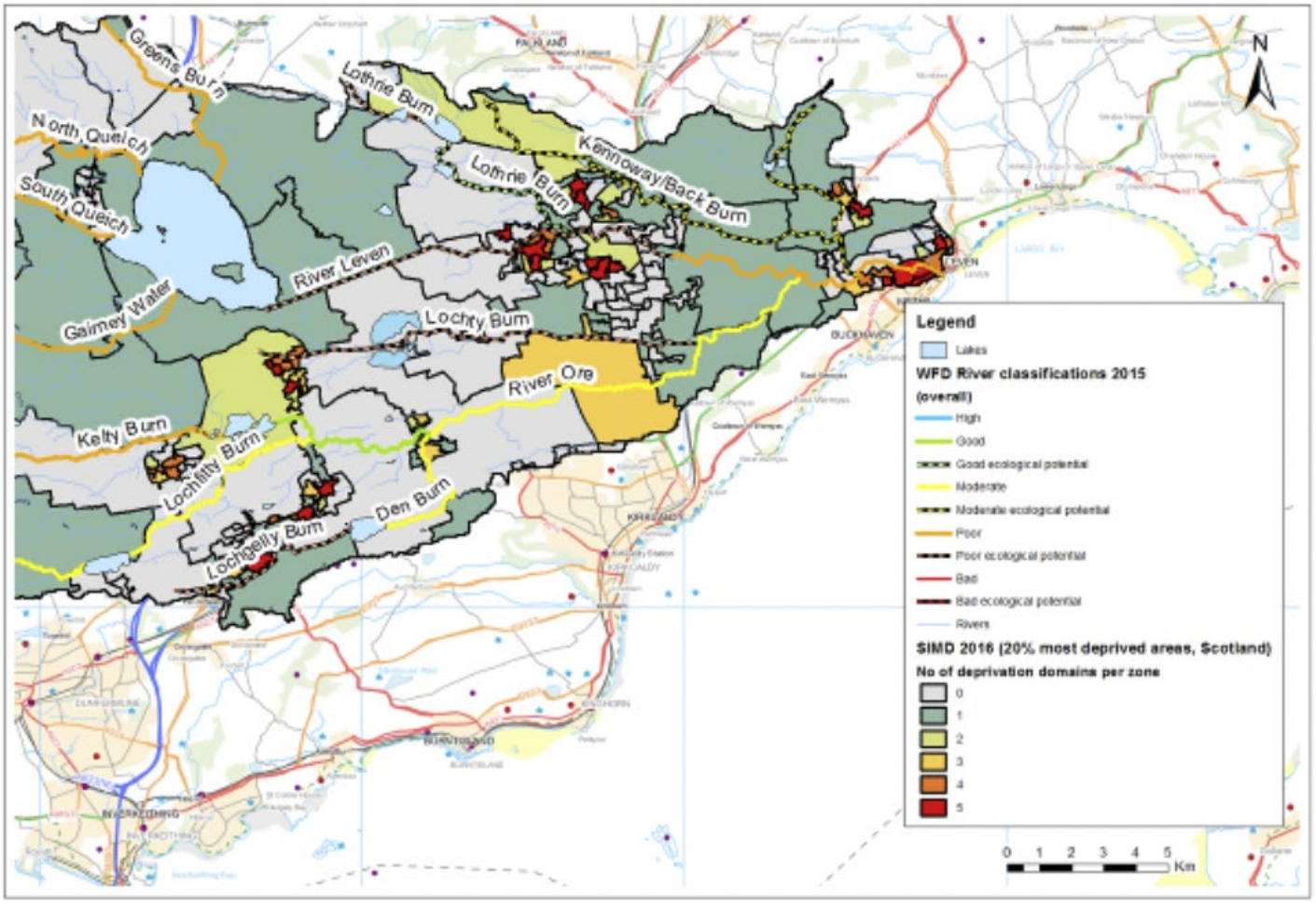

Figure 7.1 Relationship between areas of deprivation and WFD monitored rivers within the River Leven catchment.

7.3 Health risks associated with more recreational use of the water environment

Although increasing the level of contact between people and the water environment is generally considered to be beneficial, it also increases the risk of exposure to water borne diseases and to toxins associated with cyanobacterial blooms. So, there is a need to manage recreational access carefully, especially when there is a high risk to health. Although not a comprehensive list, the main health problems associated with the recreational use of water are summarised below.

A well-publicised issue relating to increased contact with water is the health risk to humans, farm animals and pets associated with water that is affected by cyanobacterial blooms. Cyanobacteria levels increase when plant nutrient levels in the water are high, temperatures are warm and flushing rates are low (Richardson et al., 2018). Cyanobacteria can produce toxins that kill pets and cause skin rashes, eye irritation, vomiting, diarrhoea, fever, and muscle and joint pain in humans. Water bodies are often monitored for the presence of cyanobacteria at concentrations that exceed the World Health Organisation guidelines for safe recreational use (WHO, 2003). Recreational users can also report potential problems directly to SEPA or via the Bloomin' Algae app, which can be downloaded at no cost. This app has been developed by CEH in collaboration with SEPA, Health Protection Scotland, the Environment Agency and Public Health England.

Weil's disease (Leptospirosis) is a bacterial infection that is carried by animals (usually rats and cattle, but also mice, foxes and badgers). It can be caught by humans through contact with water that has been contaminated with infected urine. People who participate in water sports, come into contact with untreated water or work in or near water, are at higher risk than others. According to Health Protection Scotland there were, on average, fewer than five reported cases per year of Weil's disease in Scotland between 2006 and 2014. However, concerns have been raised recently about a 21% rise in cases in England between 2016 and 2017 (Public Health England, 2018), part of which is thought to have been due to increased levels of participation in water based recreational activities.

Norovirus, often referred to as the 'winter vomiting bug', is a common cause of gastroenteritis in the UK. It causes nausea, vomiting and stomach pain. Transmission can occur via contaminated water, as was the case in Strathclyde Loch in June 2012 where water-based activities were temporarily suspended after a number of competitors were diagnosed with norovirus following a swimming championship race. Norovirus often occurs in water bodies that receive discharges from wastewater treatment works and other sources of contaminated human sewage.

Cryptosporidiosis is caused by a tiny parasite, *Cryptosporidium parvum*, which lives in the gut of many farm and domestic animals. The main symptom of cryptosporidiosis is diarrhoea, but this may be accompanied by vomiting and abdominal pain. The parasite can survive in water for long periods in the form of an oocyst. Humans can become infected by certain strains of the parasite if sufficient numbers of oocysts are ingested, e.g. during water sports. However, one of the main sources of human infection is drinking water that has been contaminated by agricultural or sewage sources and has not been disinfected effectively. Contamination of water supplies is a particular problem after heavy rain has washed oocysts into lochs, reservoirs and rivers. In Scotland, the number of confirmed cryptosporidium infections ranged from 443 to 711 between 2006 and 2014 (Data source: Health Protection Scotland).

8 Case study – socio-economic benefits from environmental improvement within the Loch Leven catchment

8.1 Pressures on the system and their sources

There are four main pressures on Loch Leven and its inflow. These are an impassable barrier to fish migration, changes in water level, nutrients inputs from the catchment and climate change.

8.1.1 Fish barriers

Loch Leven supports a successful recreational fishery. However, since the mid-1800s, migratory fish such as Arctic charr (*Salvelinus alpinus*), Atlantic salmon (*Salmo salar*) and flounder (*Platichthys flesus*) have been unable to gain access to the loch from the River Leven (Winfield et al., 2012). This is due to several barriers to fish migration (e.g. weirs, dams, culverts) at the outflow of the loch and further downstream on the main River Leven. Although many of these obstructions are classified as 'passable' by SEPA, the FFT believes that several are only passable under flow conditions that occur at times of year when fish are not migrating (Baker, *pers. comm.*). SEPA will review and discuss the fish barrier assessment with the FFT.

8.1.2 Water level

The level of the water in the loch is controlled by the sluice gates, which are manually adjusted daily (Sargent & Ledger, 1992). Although water levels vary widely in winter, they

are tightly controlled between April and September. The management of the sluice gates aims to achieve a water level of about 107.2 metres Above Ordnance Datum (mAOD) at the end of April followed by a steady decline over the summer period that reaches a minimum of about 106.7 mAOD towards the end of September. This regime was originally established to ensure a reliable water supply to downstream industry. However, in drier summers, this reduces the flushing rate and tends to increase the rate at which nutrients (especially phosphorus) are retained in the loch. During periods of heavy rainfall, the sluice gates can prevent water discharging from the loch quickly enough, causing local flooding of infrastructure and problems for wildlife.

8.1.3 Nutrient inputs

The loch is in a heavily farmed catchment. A very detailed nutrient loading study undertaken in 2015/16 (May et al., 2017) showed that the annual input of phosphorus and nitrogen from its catchment is currently about 11.8 t P y^{-1}, a value that is very similar to that obtained in 2005 (Defew, 2008). The 2015/16 data indicated that the main sources of P entering the loch were diffuse (83%), with point sources accounting for the remaining 17%. When this information was compared to historical loading records it was found that, while the overall phosphorus input had fallen, the main sources had also changed. By 2015/16, most of the phosphorus entering the loch was coming from diffuse sources and May et al. (2017) concluded that these should now become the focus of any plans to maintain or improve loch water quality.

8.1.4 Land use and climate change

The increase in phosphorus input to the loch from diffuse sources in recent years was found to be associated, mainly, with a marked increase in particulate phosphorus being transported by the inflows. This is likely to have been associated with changes in land use, including conversion of agricultural land to building plots, and the recent increase in heavy rainfall events (May et al., 2017). It has been suggested that the latter may be an effect of climate change.

Another effect of climate change on the loch is increased water temperatures (O'Reilly et al., 2015). This is likely to have affected the ecology of the loch, potentially encouraging algal blooms that increase under warm conditions and low flushing rates. However, it should be noted that higher temperatures can also have a positive effect on water quality by increasing the rate at which grazing by *Daphnia* removes algae from the loch (Carvalho et al., 2012).

8.2 Opportunities for water related socio-economic improvement

In 1992, a serious bloom of cyanobacteria occurred at Loch Leven, causing water based recreational activities to be cancelled. It was estimated that, over the three months that followed, this resulted in a loss of about £1m in income to local businesses. In addition, over the years that followed, income to the fishery from boat hire declined steadily from the equivalent of £400,000 p.a. in the 1980s (estimated at today's prices) to £80,000 p.a. in the early 2000s. From 2007 onwards, as water quality improvements became more marked, income from boat hire increased by about £38,000 per year. This indicates how changes in water quality can affect business income.

Anglers visit Loch Leven for a variety of reasons, as indicated by their responses to questionnaires that were completed as part of the EU funded OpenNESS project (http://openness.hugin.com/caseStudies/LochLeven_Habitat). The results indicated that the main attraction was the reputation and quality of the trout fishing, although anglers also liked to go fishing as a way of relaxing and enjoying nature suggesting that angling at Loch Leven improved their sense of well-being. A survey of anglers suggested that they were willing to travel up to 50 km to fish at the loch, with most (42%) travelling 20-30 km, including towns in the lower River Leven catchment.

The ecosystem services (ES) provided by the Loch Leven fishery were modelled within the OpenNESS study, using a Bayesian Belief Network (BBN) technique. The relationships between the ecological status of Loch Leven (in relation to WFD water quality targets), the quality of the recreational fishery, and the demand for the fishing service were explored (Smith et al., 2018). The case study linked the drivers of habitat quality (as measured by chlorophyll *a* concentrations) and the level of stocking with rainbow trout to the quality and provisioning of a recreational ES. The ES was assessed using two proxies: catch per unit effort (i.e. the number of brown trout caught per hour of fishing, as a measure of fishing quality) and overall effort (i.e. the annual number of hours of fishing, as a measure of the demand for the fishing service). It was found that habitat quality and rainbow trout stocking affected the reputation of Loch Leven and that this, in turn, influenced the level of demand for fishing.

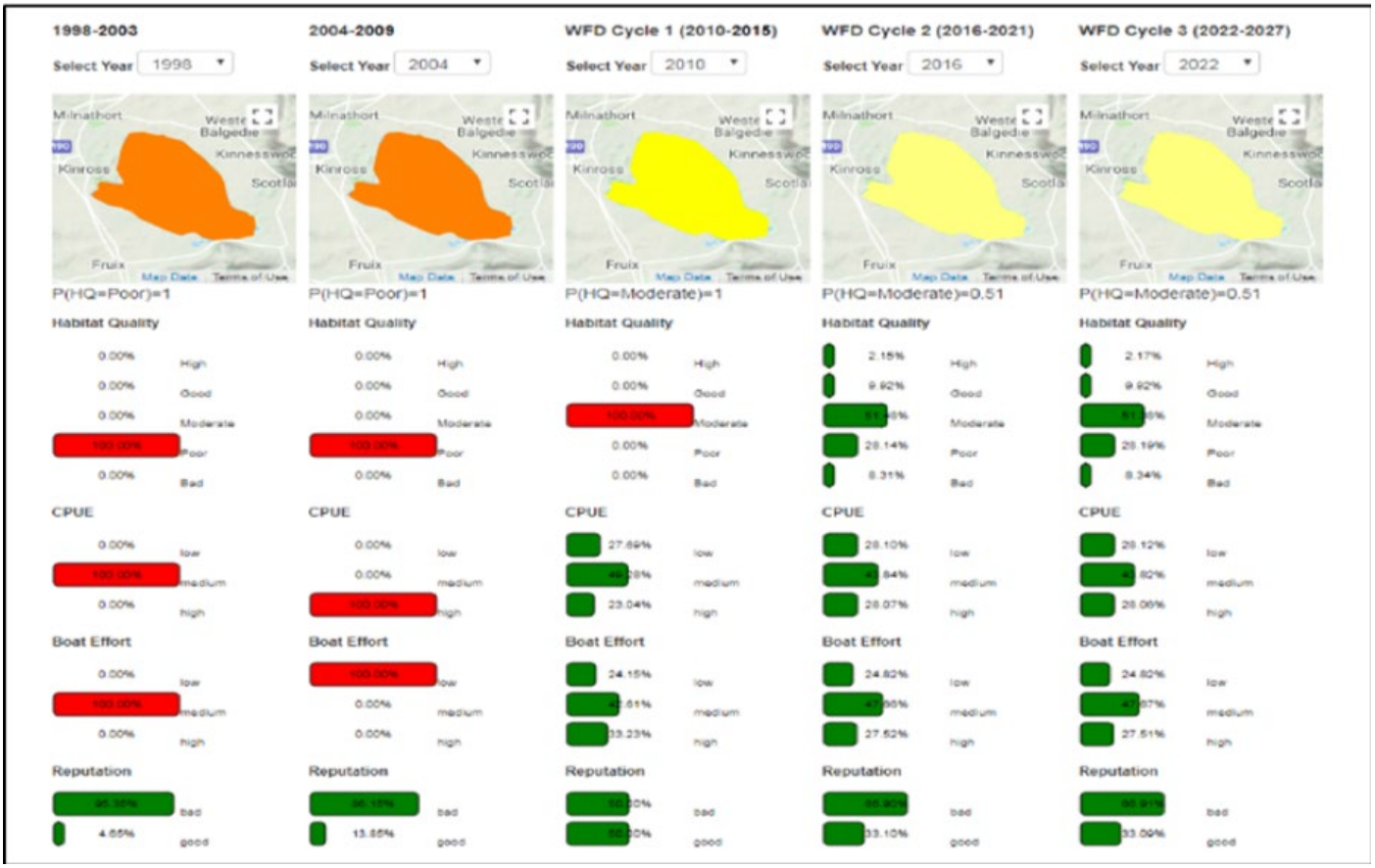

Figure 8.1 Screenshot of the results from the dynamic Bayesian Belief Network (BBN) for Loch Leven fisheries, with the loch colour related to WFD targets.
Contains Ordnance Survey data © Crown copyright and database right 2017, and map data © Google 2017.

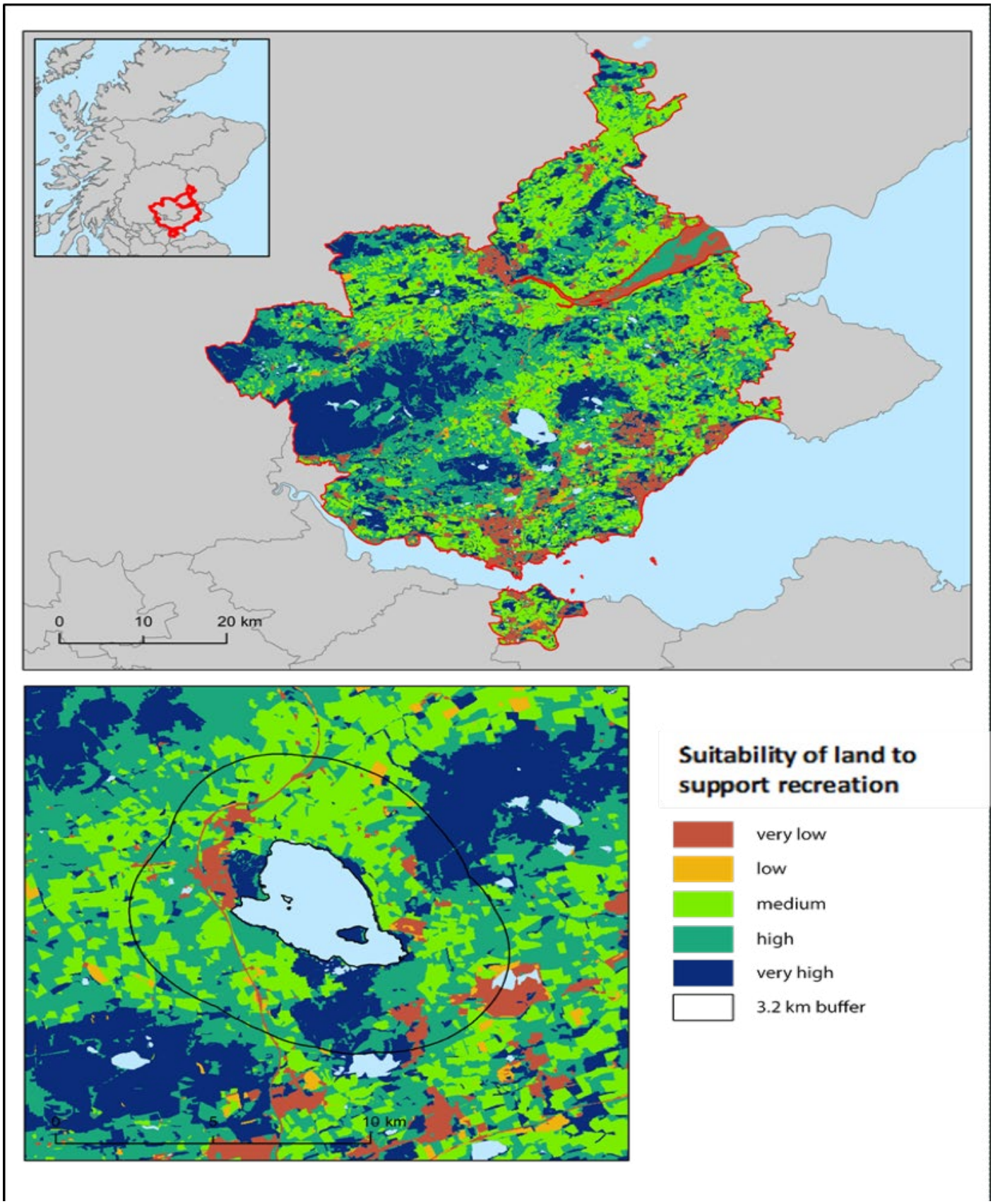

Figure 8.2 Suitability of land around Loch Leven to support nature-based recreation, as predicted by the ESTIMAP model.
Contains Ordnance Survey data © Crown copyright and database right 2016 and Corine land cover data (http://land.copernicus.eu).

Using a dynamic BBN developed for Loch Leven, Smith et al. (2018) were also able to model the likely effects of improving habitat quality over time on the management of the Loch Leven fishery. By entering different values into the model changes in habitat quality or fish stocking on fishing quality and demand for fishing (Fig. 8.1). For example, if 'Habitat' quality is set to moderate and 'Reputation' is set to bad for 2013, then habitat quality is expected to be moderate with a probability of 51.8% in 2016 and 51.4% from 2022, onwards. Although not part of the model, increased demand for fishing equates to greater income to local businesses.

The OpenNESS project also explored the recreational potential of land around the loch using a mapping tool (ESTIMAP; Zulian et al., 2014) (Fig 8.2). Data inputs included land use, historic land use assessment and high nature value farmland data. Each data source was scored according to its features associated with recreational value. An example of output from the model is shown in Figure 8.3. In general, 'very high' indicates land that is highly suitable for the development of nature based recreation in the area.

In addition, the degree of service available was estimated according to the proximity of various areas of land to roads and residential areas. The output (Fig. 8.3) shows the results of combining the potential opportunities offered by nature with proximity, to derive nine categories of service, i.e. three levels of provision (low, medium and high) and three degrees of proximity (far, proximal and near).

A practical demonstration of the value to the local community of improving the water environment, and the recreational infrastructure associated with it, is provided by the installation of a circular, all-abilities access trail around the loch perimeter. This was partially completed in 2009 and extended in 2014. The results from visitor surveys undertaken since 2007 (NFO WorldGroup, 2003; Scotinform Ltd., 2009; Scotinform, 2015) indicate that the availability of the path has provided welcome recreational access to the area with visitor numbers almost doubling between 2007 (100,000 per year) and 2014/15 (200,000 per year). The income to local businesses associated with these visits is estimated to have increased from £1.4m to £2.1m between 2009 and 2014/15 (Fig. 8.4). In the 2014/15 survey, respondents were asked whether using the trail had improved their physical and/or mental health. More than 80% strongly agreed that it had, a similar value to that returned by respondents in 2009. When asked which aspects of the natural environment were most important to them when visiting, more than 67% of respondents listed wetlands and clear water amongst the environmental assets that they valued. The most common activities undertaken by visitors in 2014/15 was walking (69%), and cycling (25%).

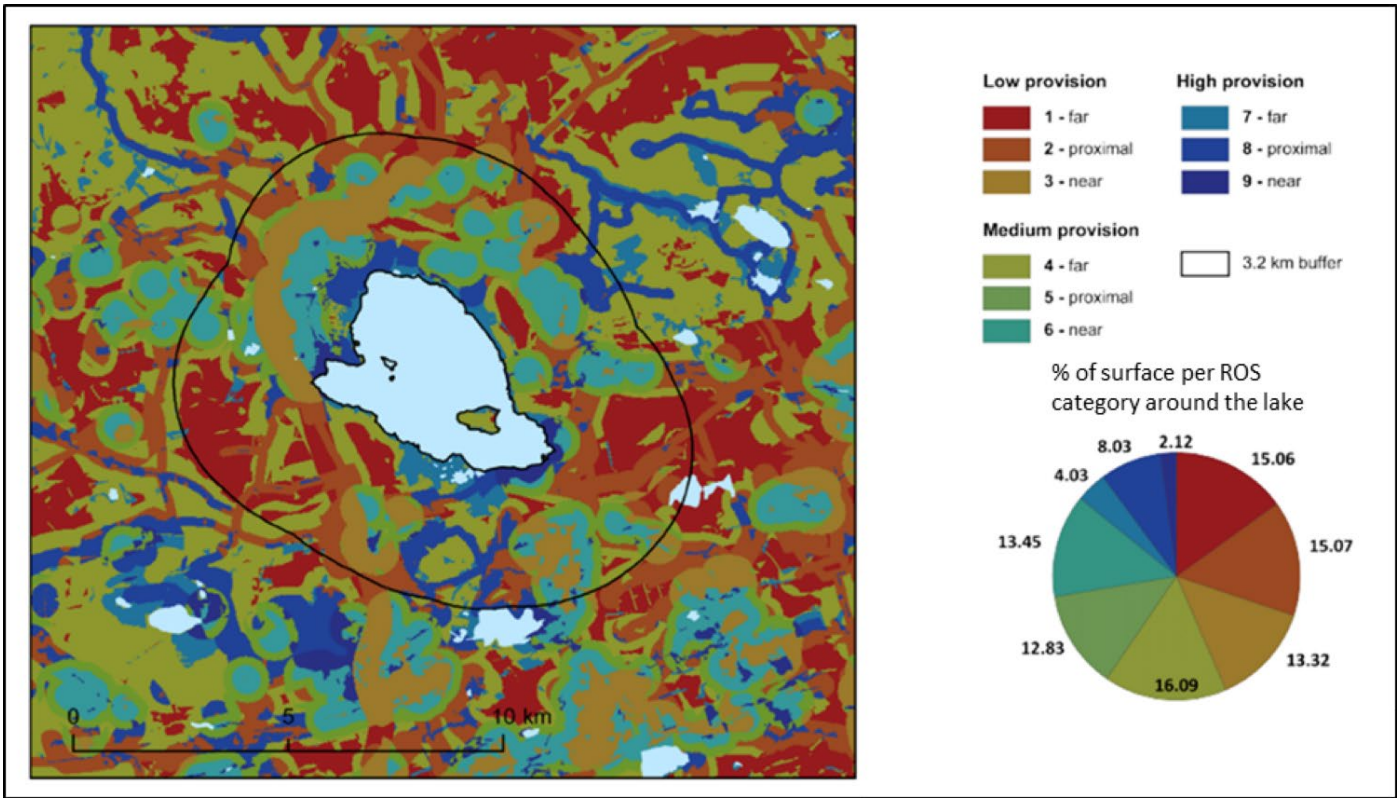

Figure 8.3 Recreation Opportunity Spectrum (ROS) map and a pie chart indicating the percentage in each ROS category in the local scale map (after Woods et al., 2016).
Contains Ordnance Survey data © Crown copyright and database right 2016 and Corine land cover data (http://land.copernicus.eu).

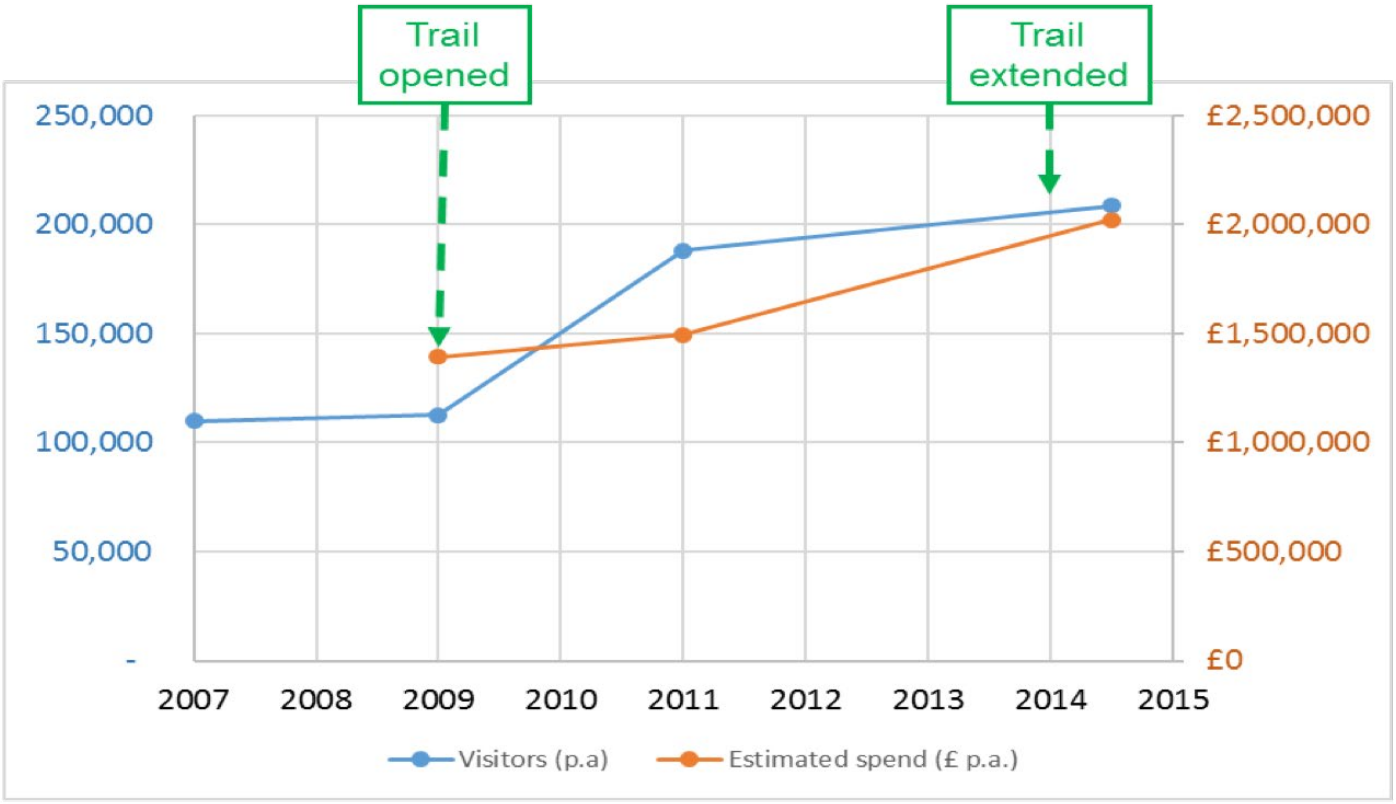

Figure 8.4 Visitors to the Loch Leven nature reserve, and their estimated contribution to the income of local businesses, 2007 – 2014/15.

9 Evidence Gaps

Several evidence gaps were identified during the course of this project. These are summarised in Table 9.1, together with potential methods of addressing them.

Table 9.1 Evidence gaps.

Evidence gap	Type	Potential method of addressing evidence gap
Monitoring data for groundwater	Dataset	Stakeholder engagement to obtain data for boreholes within the catchment, including those used for research purposes (British Geological Survey) and private water supply (local council and agency data)
Wastewater discharges and impacts	Dataset	Obtain water quality monitoring data from SEPA and more recent monitoring data from the Coal Authority (under non-commercial data licence); obtain ecological monitoring data from SEPA
Spatial distribution of resident populations within larger SIMD data zones	Dataset	Obtain more detailed Census or population data to enable spatial disaggregation of population figures based on data zones (e.g. proximity to water body)
Baseline income figures for businesses likely to benefit from improvements in the water environment	Dataset	Stakeholder engagement
Timing and levels of abstraction for water supply, irrigation and industrial use	Dataset	Engagement with Scottish Water, Fife council, farmers and industry
Regulation of water levels and supply from lochs and reservoirs using dams/sluice gates	Dataset	Water resource owners and managers; conservation and regulatory agencies; the River Leven Trustees
Water use/impact of hydroelectric power generation	Dataset	Engagement with industry and the River Leven Trustees

10 Discussion and conclusions

The River Leven catchment, which spans the Fife and Perth & Kinross administrative areas, is one of the most deprived areas of Scotland. The SIMD indicates that 45% of the population of this area live within the three highest categories of deprivation in Scotland. To create a better understanding of where prioritising improvements to the water environment would benefit the health and welfare of local people, this project summarises current knowledge on the condition of the water environment and the levels of deprivation in this area.

All available water quality and ecological data for the River Leven catchment were reviewed to identify areas in which failure to meet WFD and conservation objectives could be addressed through targeted management interventions. In addition, the SIMD data for the area were examined to identify areas of high deprivation that coincide with degraded water quality. The results were presented in the form of maps for use in the decision-making process.

The River Leven catchment was found to contain six WFD baseline standing waters. Of those, two have already met their WFD ecological status target for 2021, and one (Loch Fitty) has exceeded it. Of the remaining three lochs, Ballo Reservoir and Lochs Leven and Glow require the removal of barriers to fish migration to improve their WFD status. Ballo Reservoir also requires the control of an invasive aquatic plant species and Loch Leven needs further recovery of its aquatic plant communities to take place. In contrast, improvements at Loch Gelly need to focus on improving the phytoplankton community and reducing chlorophyll a levels if its ecological status is to be improved.

The catchment also contains 17 WFD watercourses, many of which are located upstream of the lochs in the system. Of these, seven have already met their WFD ecological status target for 2021, but 10 require further improvement. For the most part, this involves improving the ecology of the fish communities, especially by removing partial or complete barriers to fish migration. In addition to this, levels of manganese need to be reduced in the Lochfitty and Lochty Burns, and reactive phosphorus concentrations reduced in the Meldrums Mill/Linn Burns.

Although some waterbodies within the catchment are not monitored for WFD purposes, their condition is assessed in terms of their conservation status (e.g. Site of Special Scientific Interest). Four lochs, a reservoir and an area of marshland fall into this category. Of these, Black Loch is in favourable condition, although there may be a need to control Canadian waterweed at the site. Carriston Reservoir, and Camilla, Lurg and Dow Lochs, have documented problems with nutrient enrichment that may need to be addressed. Dalbeath Marsh, although officially classified as being in unfavourable condition, is recovering and not in need of any management intervention.

There are nine groundwater bodies within the catchment. Of these, three have already met their WFD target for 2021, whereas six are classified as being at 'Poor' status and in need of improvement.

These water bodies have been classified as 'Poor' because of their interaction with surface waters, in terms of quantity and quality. So, improving their WFD status can only be achieved by addressing the causes of degradation of nearby surface waters.

Overall the available data suggest that the main pressures on water bodies within the catchment that are causing failures to meet WFD targets, are barriers to fish migration, hydromorphological modification, invasive species, nutrient enrichment and high levels of manganese associated with mine water discharges. There are also issues associated with abstraction and small-scale hydroelectric power generation, but there were limited data available for this to be assessed in any detail.

The SIMD data are broken down into different domains, or types, of deprivation such as income, employment, health, education, skills, geographical access to services, crime and housing. Of these, levels of income and crime, and the use of prescribed anti-depressants, were chosen as the indicators that were most likely to change as a result of improving the water environment.

Analysis of the SIMD data showed that 188 data zones fell either partly or wholly within the River Leven catchment, with most of the zones containing multiple levels of deprivation lying completely within the catchment and within the administrative area of Fife. Of these, four of the data zones fell within the 5% most deprived areas of Scotland. Maps were prepared showing the spatial distribution of different SIMD indices within the catchment. However, it cannot be assumed that everyone who lives within an area of high deprivation is deprived, or *vice versa*. So, care must be taken when interpreting these indices.

To identify areas in which to target improvements to the water environment to enhance human health and well-being, it is recommended that individual domains of deprivation are considered rather than overall SIMD values. This is because some of the domains of deprivation (e.g. income; crime; use of prescribed anti-depressants) are more likely to respond to environmental improvement than others (e.g. number households with central heating; distance to a post office). Also, the individual indices are more comparable

from year to year than combined indices and provide a more robust baseline for the quantification of change.

By combining the water quality and social deprivation data, it was concluded that improvements to the water environment should be focused on the areas around Methil, Glenrothes and Levenmouth in the first instance. However, as all the water bodies in the catchment are connected, these local scale improvements would also create more recreational and business opportunities, and less risk of flooding, for people within the wider catchment. These areas are also the foci of the Fife Local Development Plan (FIFEPlan) and the Tay Strategic Development Plan (TAYPlan, which includes Perth & Kinross and northern parts of Fife). Plans include the development of green networks to deliver benefits to people and nature, add value to the local economy and create sustainable growth. The creation of these green networks includes the incorporation and/or improvement of blue infrastructure such as sustainable drainage systems, ponds, swales, lochs and reservoirs, wetlands, river and canals. Much of the proposed new networks of paths in the area will pass very close to, or provide panoramic views of, a range of different water bodies within the catchment. The case study on Loch Leven provides an illustration of how water quality improvements can provide socio-economic benefits to people.

References

Carvalho, L., Miller, C., Spears, B.M., Gunn, I.D.M., Bennion, H., Kirika, A. & May, L., 2012. Water quality of Loch Leven: responses to enrichment, restoration and climate change. *Hydrobiologia* 681: 35-47.

Defew, L. H., 2008. *The influence of high-flow events on phosphorus delivery to Loch Leven, Scotland, UK*. University of Edinburgh, School of Geosciences, PhD Thesis, 276pp.

McNeill, G.W., Anderson, J. and Elliot, T., 2003. Nitrate levels and the age of groundwater from the Upper Devonian Sandstone Aquifer in Fife, Scotland. *Environmental Geochemistry and Health* 25: 105-113.

May, L., Defew, L.H., Bennion, H. & Kirika, A., 2012. Historical changes (1905-2005) in external phosphorus loads to Loch Leven, Scotland, UK. *Hydrobiologia* 681: 11-21.

May, L., Moore, A., Woods, H., Bowes, M., Watt, J., Taylor, P. & Pickard, A., 2017. *Loch Leven nutrient load and source apportionment study*. Scottish Natural Heritage Commissioned Report No. 962.

Moore, R.V., Morris, D.G. & Flavin, R.W., 1994. Sub-set of UK digital 1:50,000 scale river centre-line network. NERC, Institute of Hydrology, Wallingford.

Morris, D.G. & Flavin, R.W., 1990. *A digital terrain model for hydrology.* Proc. 4th International Symposium on Spatial Data Handling. Vol 1 Jul 23-27 Zurich, pp 250-262.

Morris, D.G. & Flavin, R.W., 1994. *Sub-set of UK 50 m by 50 m hydrological digital terrain model grids.* NERC, Institute of Hydrology, Wallingford.

Munro, D., 1994. Loch Leven and The River Leven: a Landscape Transformed. River Leven Trust, 196 pages. ISBN 0952405504.

Ó Dochartaigh, B.É., 2004. *The physical properties of the Upper Devonian/Lower Carboniferous aquifer in Fife.* British Geological Survey Internal Report, IR/04/003. Available at http://nora.nerc.ac.uk/12638/

O'Reilly, C.M., Gray, D.K., Sharma, S., Hampton, S.E., Read, J.S., Rowley,R.J., Schneider, P., Lenters, J.D., McIntyre, P.B., Kraemer, B.M., Weyhenmeyer, G.A., Straile,D., Bo Dong, Adrian, R., Allan, M.G., Anneville, O., Arvola, L., Austin, J., Barabás, N., Baron, J., Brookes, J.D., de Eyto, E., Dokulil, M.T., Hamilton, D.P., Havens, K., Hetherington, A.L., Higgins, S.N., Hook, S., Izmest'eva, L.R., Jöhnk, K.D., Kangur, K., Kasprzak, P., Kumagai, M., Kuusisto, E., Leshkevich, G., Livingstone, D., MacIntyre, S., May, L., Melack, J.M., Mueller-Navarra, D.C., Naumenko, M., Nõges, P., Nõges, T., North, R.P., Plisnier, P-D, Rigosi, A., Rimmer, A., Rogora, M., Rudstam, L., Rusak, J.A., Salmaso, N., Samal, N.R., Schindler, D.E., Schladow, S.G., Schmid, M., Schmidt, S.R., Silow, E., Soylu, M.E., Teubner, K., Verburg, P., Voutilaine, A., Watkinson, A., Williamson, C.E. & Guoqing Zhang, 2015. Rapid and highly variable warming of lake surface waters around the globe. *Geophysical Research Letters* 42: 10773-10781. doi: 10.1002/2015GL066235.

Public Health England, 2018. Common animal associated infections quarterly report (England and Wales). Health Protection Report 12, no. 5. , pp. 1-7.

Richardson, J., Miller, C., Maberly, S.C., Taylor, P., Globevnik, L., Hunter, P., Jeppesen, E., Mischke, U., Moe, S.J., Pasztaleniec, A., Søndergaard, M. & Carvalho, L., 2018. Effects of multiple stressors on cyanobacteria abundance varies with lake type. Global Change Biology. https://doi.org/10.1111/gcb.14396

Sargent, R. J. & Ledger, D. C., 1992. Derivation of a 130 year runoff record from sluice records for the Loch Leven catchment, south-east Scotland. *Proceedings of the Institution of Civil Engineers Water, Maritime and Energy* 96: 71–80.

Scottish Government, 2015. *The river basin management plan for the Scotland river basin district: 2015–2027.* 44 pp.

Smith, R.I.; Barton, D.N.; Dick, J.; Haines-Young, R.; Madsen, A.L.; Rusch, G.M.; Termansen, M.; Woods, H.; Carvalho, L.; Giucă, R.C.; Luque, S.; Odee, D.; Rusch, V.; Saarikoski, H.; Adamescu, C.M., Dunford, R., Ochieng, J., Gonzalez-Redin,

J., Stange, E., Vădineanu, A., Verweij, P., Vikström, S., 2018. Operationalising ecosystem service assessment in Bayesian Belief Networks: experiences within the OpenNESS project. In: Synthesizing OpenNESS SI. *Ecosystem Services* 29: 452-464. doi:10.1016/j.ecoser.2017.11.004

UKTAG, 2003. *UK Technical Advisory Group on the Water Framework Directive: Guidance on the identification of small surface water bodies*. 13 pp. (http://www.wfduk.org/resources/identification-small-surface-water-bodies)

UKTAG, 2011. *UK Technical Advisory Group on the Water Framework Directive: Defining & Reporting on Groundwater Bodies*. 10 pp. (https://www.wfduk.org/sites/default/files/Media/Characterisation%20of%20the%20water%20environment/Defining%20Reporting%20on%20Groundwater%20Bodies_Final_300312.pdf)

WHO, 2003. *Guidelines for Safe Recreational Water Environments. World Health Organisation, Geneva*. http://www.who.int/water_sanitation_health/publications/srwe1/en/ [accessed 2018-03-22]

Winfield, I.J., Adams, C.E., Armstrong, J.D., Gardiner, R., Kirika, A., Montgomery, J., Spears, B., Stewart, D.C., Thorpe, J.E., Wilson, W., 2012. Changes in the fish community of Loch Leven: untangling anthropogenic pressures. *Hydrobiologia* 681: 73-84. https://doi.org/10.1007/s10750-011-0925-8

Woods, H., Carvalho, L. & Zulian, G., 2016. *Nature-based tourism and recreation: ESTIMAP model*. OpenNESS report, 5pp.

Zulian, G., Polce, C. & Maes, J., 2014. ESTIMAP: A GIS-based model to map ecosystem services in the European Union. *Ann. Bot. (Roma)* 4: 1–7.ONS (2018) Overview of the UK population: November 2018. https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/articles/overviewoftheukpopulation/november2018

CREW CENTRE OF EXPERTISE FOR WATERS

CREW Facilitation Team

James Hutton Institute

Craigiebuckler

Aberdeen AB15 8QH

Scotland UK

Tel: +44 (0)1224 395 395

Email: enquiries@crew.ac.uk

www.crew.ac.uk

The James Hutton Institute

Scottish Government gov.scot

CREW is a Scottish Government funded partnership between the James Hutton Institute and Scottish Universities.