Version	Comments
1.0	First released version of WFD aquatic monitoring strategy

Scotland's WFD aquatic monitoring strategy

1.0 Introduction

SEPA has many years' experience in monitoring the aquatic environment, historically concentrating on water quality. The EU Water Framework Directive introduces a holistic approach to monitoring for a range of different pressures.

The Water Framework Directive is a wide-ranging and ambitious piece of legislation with the ultimate overall aim of ensuring that water bodies don't deteriorate in status and that all water bodies achieve at least good status by 2015, unless it is demonstrated that less stringent objectives should apply. We have defined "at risk" to mean water bodies at risk of failing to meet the objectives of the WFD.

Implementation of the WFD has introduced substantial changes in the overall management and monitoring of activities which influence our aquatic environment.

The "Water Environment and Water Services (Scotland) Act 2003", which implements the requirements of the WFD in Scotland, subjects many previously unregulated activities to regulation. New risk-based regulatory systems have been put in place, designed so that the extent and intrusiveness of this legislation is as low as possible, whilst ensuring Scotland meets the long-term quality objectives identified under the WFD.

The role of the monitoring strategy is to ensure that sufficient environmental information is gathered, to enable progress towards attainment of the WFD objectives to be measured and reported with adequate statistical confidence and confirm whether SEPA's regulatory approach is delivering as planned.

The Scottish network was designed within the framework of the WFD using guidance from an EU group on monitoring (the Common Implementation Strategy guidance) and principles laid down by a UK Technical Advisory Group (UKTAG).

Within Scotland a Scottish Freshwater Monitoring Strategy Group was set-up with representatives from the Scottish Executive, stakeholders and relevant NGOs. This group was consulted on the freshwater monitoring strategy and some site details and provided useful comments.

The marine monitoring network was designed in consultation with the marine section of the Fisheries Research Service and the Scottish Executive. Groundwater scientists worked closely with both UKTAG colleagues and the Scottish Executive.

The WFD works on six-year cycles; we are obliged to submit our first classification to the EU in 2009, with the next classification in 2015. For reporting within Scotland, SEPA will classify all water bodies annually.

2.0 Monitoring design

2.1 WFD requirements

The WFD requires all water features in a category (i.e. rivers, lochs, transitional waters, coastal waters and groundwater) above a certain size threshold to be defined as water bodies. For Scotland, this was carried out using a combination of typology data and data on ecosystem health (from both SEPA data and consultation with external stakeholders). Water bodies are by definition of the same typology and overall quality along their length.

Surface water bodies are grouped into different types, according to their physical and chemical characteristics. These types indicate, in very general terms, the flora and fauna likely to be found in those types of water bodies, in undisturbed conditions.

The WFD requires that the quality status of every WB must be reported in each successive 'River Basin Management Plan' (RBMP); the monitoring network has to be designed to ensure that this requirement is efficiently delivered.

The WFD specifies three categories of monitoring which have different but complementary purposes: surveillance, operational and investigative. The surveillance and operational networks will be used for status assessments and must produce classifications of "adequate confidence and precision".

1. Surveillance – a geographically distributed network designed to:

- Supplement and validate the impact assessment procedure
- Ensure efficient and effective design of future monitoring programmes
- Assess long-term changes in natural conditions
- Assess long-term changes due to widespread anthropogenic activity

The surveillance monitoring network will remain fundamentally unchanged for the foreseeable future, further extending existing datasets (some of which already have 40 years of data). Surveillance monitoring data will be used in quality status assessments.

2. Operational – driven by risk assessments based on pressure information and located in areas of known risk. Operational monitoring is designed to:

- establish the status of those bodies identified as being at risk of failing to meet their environmental objectives
- assess any changes in the status of such bodies resulting from the programmes of measures.

The operational monitoring network will provide much of the data required for WFD quality status assessment. It is intended that changes to the initial network will be limited, but it is inevitable that the network will change. If investigative work reveals that a new (or newly recognised) pressure on a water body is putting it at risk of not attaining its quality objective, then it must become the subject of relevant operational monitoring. Conversely, as 'Programmes of Measures' are implemented, and water bodies improve to the extent that operational monitoring results demonstrate that they are meeting their quality objectives and are consequently no longer at risk, then direct operational monitoring may cease.

3. Investigative – a more variable network responsive to unplanned events and emerging risks, where the source of the risk (the pressure), is not always well understood. Investigative monitoring shall be carried out:

- where the reason for any exceedances is unknown,
- where surveillance monitoring indicates that the objectives set out in Article 4 for a body of water are not likely to be achieved and operational monitoring has not already been established, in order to ascertain the causes of a water body or water bodies failing to achieve the environmental objectives
- to ascertain the magnitude and impacts of accidental pollution,

Investigative monitoring will also be put in place to meet other monitoring requirements, e.g. work to achieve biodiversity objectives and monitoring of water bodies below the WFD reporting size threshold.

The investigative network is, by its nature, reactive and transient. Consequently this network will continue to evolve to meet new monitoring requirements.

The future investigative monitoring network will consume a larger proportion of SEPA resources than its equivalent pre-2007 programme. During the first RBMP it may also encompass method development work, and for the foreseeable future will have substantial emphasis on detailed diffuse pollution studies and the assessment of water resource impacts especially in identified 'priority catchments'.

All water bodies will be classified in time for the first RBMP, although it has been necessary to postpone some surveillance monitoring for a limited number of parameters until later in the period due to resource availability. Environmental work related to engineering aspects will be phased in as revenue streams from this new regulatory regime build up and enable us to recruit more staff and the investigative monitoring network will increase as more is learnt from the results of the operational and surveillance work.

2.2 Priority substances in freshwaters

SEPA has developed its analytical capabilities significantly to enable monitoring of WFD 'priority substances' and UK 'specific pollutants'. Currently, thirty out of the thirty-three priority substances can be monitored. Ongoing method development work will aim to incorporate priority substances and relevant specific pollutants into the monitoring network within the first cycle.

Scottish Pollutant Release Inventory returns and effluent screening are being used to ensure that all discharges of 'priority substances' and significant discharges of 'specific pollutants' have been identified. The results of this and current investigative monitoring will ensure that all receiving waters are subject to risk-based operational monitoring in accordance with UK guidelines

Surveillance monitoring sites will be similarly subject to risk-based monitoring. Priority substances and relevant specific pollutants will be monitored at 60 larger river, bottom-end of catchment surveillance sites across the country. Substances that are only likely to be present in certain areas of the country (e.g. pesticides related to a specific land-use) will be monitored at a relevant subset of surveillance sites.

2.3 Revision of existing networks

SEPA's pre-2007 monitoring networks were reviewed in order to free up resources for the new WFD responsibilities. In particular, WFD monitoring requires confidence and precision to be stated along with assessments of status (necessitating more frequent sampling than is currently the case), as well as requiring more biological elements to be monitored.

SEPA has created a 'characterisation database' which holds details of every water body and the pressures upon it. These pressures are separated into primary (likely to cause failure of a water body to meet good status by 2015) and contributory (not, on their own, likely to cause failure to meet good status, but may act in synergy with other pressures to cause failure).

The monitoring and reporting needs of other EU directives, the UK Environmental Change Network, Clean Seas Assessment Programme, Harmonised Monitoring (of rivers), Urban Waste Water Directive, European EIONET, and DEFRA and Scottish Executive long-term datasets reporting have all been incorporated into the new WFD network.

3.0 Monitoring network design

The risk assessments published in the 'WFD Characterisation' reports in 2005, have been continually updated since then, and the latest numbers are given in Table 1 below. These risk assessments drive most of the monitoring needed, as outlined in section 2.

Water body category	Risk category	Total number of water bodies
River	1a - definitely at risk	653
	1b - probably at risk	336
	2a - probably not at risk	349
	2b - definitely not at risk	1049
Total		**2387**
Lake	1a - definitely at risk	152
	1b - probably at risk	28
	2a - probably not at risk	43
	2b - definitely not at risk	111
Total		**334**
Transitional	1a - definitely at risk	19
	1b - probably at risk	7
	2a - probably not at risk	7
	2b - definitely not at risk	17
Total		**50**
Coastal	1a - definitely at risk	32
	1b - probably at risk	23
	2a - probably not at risk	80
	2b - definitely not at risk	322
Total		**457**
Groundwater	1a - definitely at risk	161
	1b - probably at risk	35
	2a - probably not at risk	69
	2b - definitely not at risk	78
Total		**343**

Table 1. The number of WFD water bodies in different risk categories.

Since the characterisation report was published in 2005, SEPA has been gathering data to increase confidence in our risk assessments; consequently the numbers of water bodies in "probably at risk" and "probably not at risk" categories have decreased, compared to the 2005 report.

Only 12% of coastal water bodies are in the "at risk" categories. For all of the remaining water types approximately 50% are at risk, with the remainder not at risk. The table shows the most current risk assessments, updated after the further characterisation work. It is the 'at risk' water bodies which must be subject to operational monitoring.

3.1 Rivers

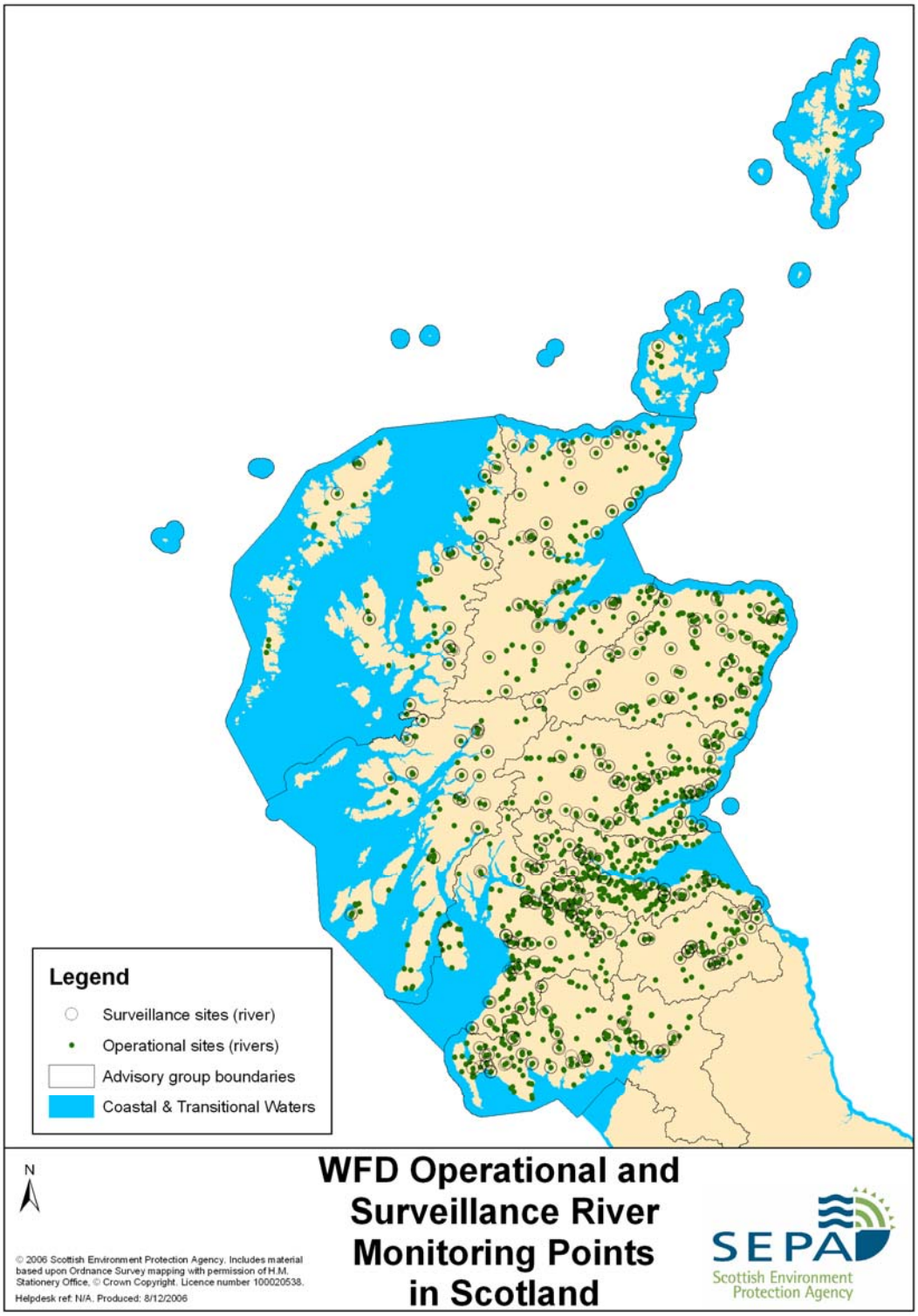

Figure 1. Operational and surveillance monitoring network for Scottish rivers.

As this is a risk-based network, the majority of sites are concentrated in areas of high population density or agricultural activity. Surveillance sites are dispersed over the country and cover 253 water bodies. For the operational network there are 900 monitoring sites for physico-chemistry and 1060 for ecology. The difference is due to water bodies only affected by hydromorphological pressures, in which only ecology is monitored.

3.1.1 Surveillance network

The bulk of the new surveillance monitoring network comprises long-established sites meeting the needs of OSPAR, other EC directives, UK Environmental Change Network, UK Harmonised Monitoring and long-term quality trend assessment. Additional sites were added to represent smaller catchments. The distribution of water bodies represented by all these sites was then analysed to ensure they represented the WFD risk categories, WFD typologies and the pressure profile acting on Scotland's water bodies.

The surveillance network consists of 253 water bodies dispersed across Scotland (just over 10% of the total number of water bodies). These sites will be monitored for all relevant quality elements as listed in the Directive. Fish population data will be collected from 2007, though as in most EU member states, the methods for fish populations' quality classification have not yet been decided upon. Methods for monitoring fish populations in large deep rivers still have to be defined. Collected data will be incorporated into classification outcomes once the metrics to be used are finalised. Hydrology data will be modelled for some of the sites.

3.1.2 Operational network

The location of operational monitoring is determined by the risk of a water body failing to meet the requirements of the Directive. Operational monitoring has also been deployed to assess the status of those water bodies which are not currently at risk, but could be at risk of deterioration.

All ~50 river water bodies which are at risk from point source pressures (i.e. discharges for which the input point to the water body is known) will be monitored for both physico-chemistry and biology. A monitoring point (or points) representative of the status of the water body has been identified and will be monitored for those quality elements most sensitive to the pressures on the water body (Table.2).

There are approximately 198 river water bodies which are at risk of failure due to diffuse pollution pressures. Many of these have also been selected for monitoring as part of the point source network; those remaining were grouped (according to geographical proximity and typology) and a representative monitoring site selected. This representative site will be monitored for the quality elements most sensitive to the pressure, and the classification extrapolated to the other water bodies in that group.

Historically, very few EU states have assessed the impact of morphological or hydrological pressures on ecological quality. In the UK, biological classification techniques quantitatively responsive to hydromorphological pressures are still being developed. Consequently, physical status surrogates are being employed to classify all river water bodies at risk of failing due to hydromorphological pressures. Half of those water bodies which are categorised as "probably at risk" from morphological pressures will be monitored using macrophyte techniques, thought to be sensitive to morphological pressures. Of the water bodies at risk from hydrological pressures, 17% will be subject to macrophyte monitoring.

The majority (59%) of Scotland's river water bodies are not at risk of failing to meet good status standards. However, some may still be at risk of deterioration (e.g. from high to good status), so are being monitored under the operational monitoring network. These water bodies were grouped together, based on geographical proximity and being of a similar typology. Once grouped, 20% of the water bodies were selected for monitoring; the group will be classified using data extrapolated from the monitored sites. Macroinvertebrates and the standard suite of chemical

parameters will be monitored at these sites, as these tools are sensitive to the widest range of pressures.

3.2 Lochs

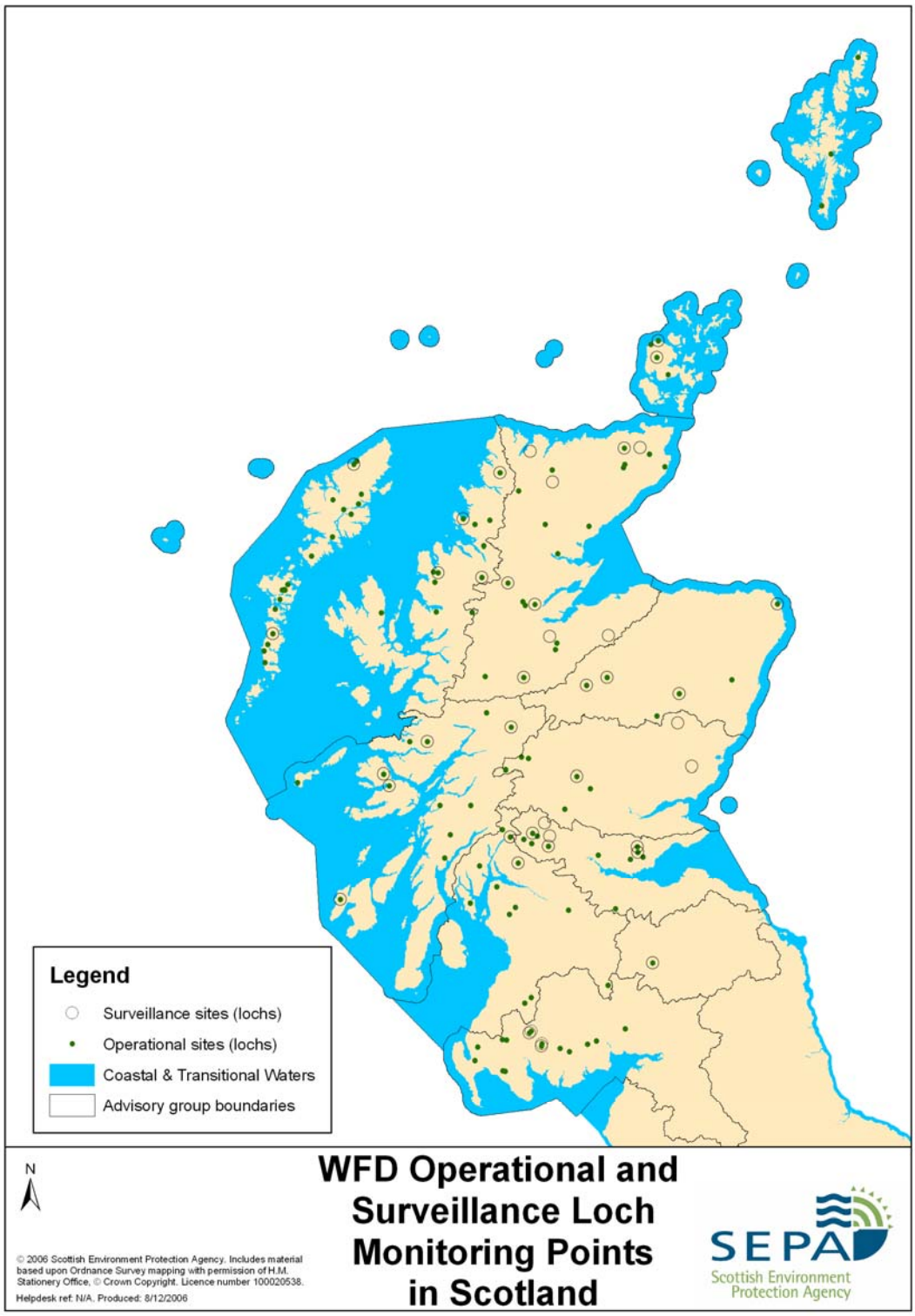

Figure 2. Operational and surveillance monitoring network for Scottish lochs.

Historically, SEPA has only classified a limited number of lochs, using physico-chemistry. The WFD requires a variety of biological tools to also be applied to

determine their ecological status. Across Scotland, 130 lochs are monitored as part of the operational network.

3.2.1 Surveillance network

To create a surveillance network, 40 lochs were selected using existing data and expert judgement to ensure they represent the WFD risk categories, WFD typologies and the pressure profile acting on Scotland's lochs. They will be monitored for all biological elements listed in the Directive, although the method to be employed for fish monitoring is not yet defined. As with the river surveillance network, the monitoring of priority substances will be risk-based and hydrology data may be modelled for some of the lochs, rather than directly monitored in the loch.

3.2.2 Operational network

Subject to access constraints, all loch water bodies at risk from point source pressures have been selected for both biological and chemical monitoring.

Four other main categories of pressure acting on lochs were identified; diffuse pollution due to acidification, diffuse pollution due to agricultural pressures, hydrology pressures from impoundment and hydrology pressures from abstraction and flow regulation. Morphological pressures were also identified, although in the first RBMP all lochs will be classified for morphology using a surrogate rather than monitoring a biological quality element directly. Where the hydromorphological pressures meet the criteria specified in Article 4(3) of the Directive, then they are being identified as heavily modified, and if there are no other pressures, further monitoring is not required.

Lochs were grouped with others of the same primary pressure category, risk category and the same sub-typology (the WFD loch typology was refined to give 7 different end-groups). For lochs at risk from diffuse agricultural or acidification pressures, 50% of them are monitored. For the lochs at risk from hydrology pressures, 17% are monitored. Of those lochs probably at risk of failure from morphology pressures 17% are monitored for macrophytes, as this is believed to be the biological element most sensitive to morphological pressures. Monitoring effort at 50% and 17% was judged to provide adequate confidence and precision in the overall status assessments whilst maximising the efficiency of the network.

Not at risk lochs are grouped according to typology and 20% of them selected for monitoring; the results obtained will be extrapolated to classify the whole group. These lochs will be monitored using the standard suite of chemical parameters, plus the Chironomid Pupal Exuvae Technique (CPET) which is believed to be the biological tool most sensitive to the widest variety of pressures.

3.3 Groundwater network

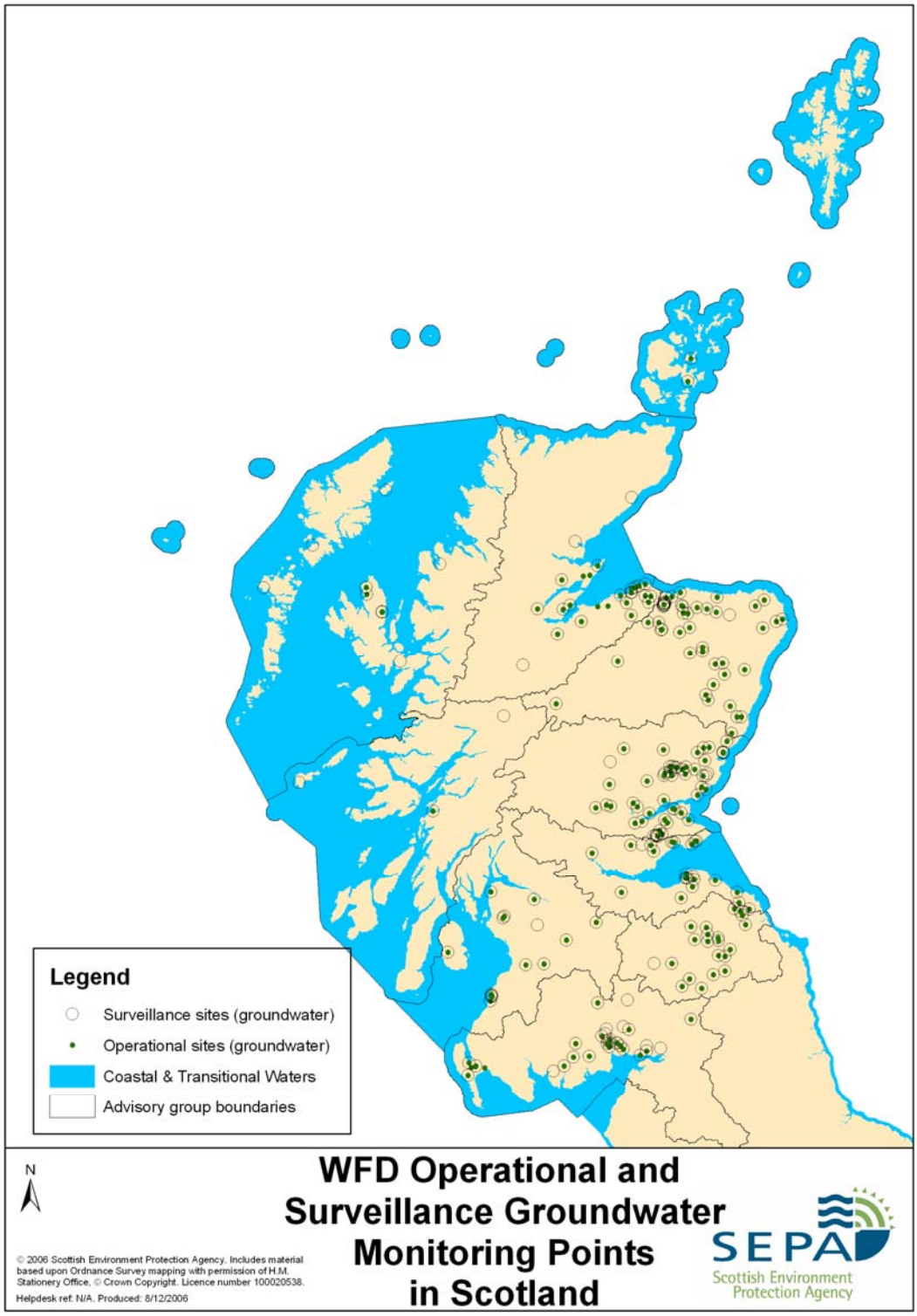

Figure 3. Operational and surveillance network for Scottish groundwater quality.

The majority of groundwater monitoring sites are both surveillance and operational. As the network is risk-based, the majority of sites are on the Eastern side of the country, where there is more intensive arable agriculture. There are currently 210 operational sites, and 198 of these are also used for surveillance monitoring. SEPA

will continue to increase the number of groundwater monitoring sites as our understanding of the pressures on groundwater improves.

3.3.1 Surveillance network

As recommended by UKTAG guidance, high-yielding boreholes will be employed for surveillance monitoring; this effectively limits the surveillance network to public water supply boreholes plus any available sites selected to be representative of key land use and groundwater pathway characteristics.

Groundwater bodies have been grouped and the data obtained will be extrapolated between them.

As well as a core suite of determinands, additional parameters will be selected in accordance with risk assessments and will generally be sampled quarterly.

From January 2007, surveillance monitoring will continue at existing key sites as described above and SEPA will continue to develop the groundwater surveillance network during the coming years. The initial surveillance network will comprise 195 sites, with a further 150 sites to be added during 2007 and 2008 as SEPA refines the network. Quantitative monitoring is being undertaken at a sub-set of sites.

3.3.2 Operational network

The operational network was designed by revising and building on the existing network of Groundwater Regulations and the Nitrates Directive monitoring sites. SEPA has undertaken an extensive programme of drilling new boreholes; this is ongoing and the network is expected to be complete by 2009. The initial operational network will encompass 185 sites, with a further 30 sites to be added during 2007 and 2008. The new borehole sites have been identified based on geological and pressure context, as well as data on levels and flow direction. Monitoring has also been undertaken where surface water interactions are significant. These groups will be classified by the data obtained from the representative monitoring points.

A core suite of chemical parameters has been selected for monitoring at each site, plus additional risk-based parameters.

3.4 Marine (Coastal and Transitional Waters) Monitoring network

Figure 4. Operational and surveillance network for Scottish marine water bodies (transitional and coastal)

Surveillance monitoring is shared with Fisheries Research Services. River inputs are used, where appropriate, to aid classification of small estuaries and lagoons. There are 100 sites in the transitional operational network (for both biology and physico-chemistry). The coastal operational network comprises 300 physico-chemistry sites and 270 biology sites. The surveillance networks for transitional and coastal waters

comprise 35 and 140 sites respectively, covering 6 transitional and 36 coastal water bodies.

3.4.1 Surveillance network

The marine surveillance monitoring network has built on the long-established "UK National Marine Monitoring Programme" network of sites and aims to monitor each water body type in proportion to its occurrence. The network is representative of all the risk categories and pressure profiles acting on marine waters and has been sub-divided into two tiers, with different monitoring frequencies for certain quality elements. Monitoring effort will be shared between SEPA and Fisheries Research Services, who will report the data they gather into SEPA information systems.

SEPA will be monitoring a network of water, sediments and biota; all quality elements listed in the Directive will be monitored. Some priority substances will be monitored less frequently than outlined in the Directive (the Directive recommends sampling 12 times a year for at least one year in 6); following a risk-based screening, some water bodies will be monitored less frequently. Although monitoring will be at a frequency of 4 times per year it will be ongoing; consequently within a RBMP period 24 samples will have been taken.

3.4.2 Operational network

A total of 66 out of the 81 water bodies (i.e. the majority of those judged to be at risk of failing to achieve good status by 2015) are being monitored for the quality element most sensitive to the relevant pressure. Exceptions are very small estuaries which have been grouped according to their pressure profile.

'Not at risk' water bodies have been grouped within coastal sediment transport cells (a relevant geographical unit for marine ecosystems) and then by the pressure profile which may be acting on the water bodies. 5-10% of these water bodies are monitored and the classification extrapolated across the group.

The relatively large number of monitoring sites shown on the map are a consequence of the UK assessment methods. In contrast to many of the freshwater methods, these require multiple samples to be taken from across a waterbody and the results combined for classification purposes.

4.0 Monitored parameters

The WFD requires that all quality elements listed in the Directive are monitored for in surveillance water bodies. For the operational network, the "most sensitive element" to the pressures on that water body must be monitored. Following discussions at UKTAG, SEPA has made a judgement on the most sensitive elements to different pressures thought to be acting on Scotland's water bodies.

Quality element	Media	Minimum number of samples needed to classify per RBMP	Monitored in situations where:
Priority substances and specific pollutants	All media	As per physico-chemical parameters	Monitoring is undertaken in water bodies where there are quantities of the PS or SP.
Physico-chemical parameters	Groundwater	12	Suite tailored to pressure(s) on water body
Diatoms	Lochs	4	Surveillance lochs only
Fish	Lochs	TBC	TBC
Macroinvertebrates	Lochs	2	Acidification is a pressure
Macroinvertebrates (chironomids)	Lochs	3	Organic/nutrients are a pressure
Macrophytes	Lochs	1 (5 locations at site)	Nutrients; possibly hydromorphology are pressures
Physico-chemical parameters	Lochs	36	Suite tailored to pressure(s) on water body
Phytoplankton	Lochs	6 or 24	Nutrients are a pressure
Angiosperms	Marine	TBC	TBC
Benthic macroinvertebrates	Marine	5	Organic and toxic pressures
Macroalgae	Marine	3	Nutrients are a pressure
Physico-chemical parameters	Marine	4	Suite tailored to pressure(s) on water body
Phytoplankton	Marine	8	Nutrients are a pressure
Saltmarsh	Marine	TBC	TBC
Diatoms	Rivers	4	Nutrients are a pressure
Fish	Rivers	TBC	TBC
Macroinvertebrates	Rivers	4	Organic and toxic pressures; acidification pressures if sampleanalysed to species level
Macrophytes	Rivers	1 (5 locations at site)	Possibly hydromorphology pressures
Physico-chemical parameters	Rivers	36	Suite tailored to pressure(s) on water body
Phytoplankton	Rivers	No monitoring	No monitoring will be undertaken for phytoplankton in rivers
Fish	Transitional	6	Hydrology and morphology pressures

Table 2. Parameters to be monitored for different pressures and frequency of monitoring.

The table above shows the quality elements to be monitored and the minimum frequency with which they will be monitored in the first RBMP. Loch phytoplankton volume (chlorophyll *a*) will be monitored 24 times per RBMP, taxonomic composition 6 times per RBMP. For the first RBMP, where suitable historic data are available they will be incorporated into the classification (e.g. physico-chemical data will be monitored monthly for the two years, and one year of historic data also used to classify).

All the quality elements listed for a particular media will be monitored at surveillance sites, with the exception of phytoplankton in rivers. Fish monitoring in freshwaters has yet to be finalised.

In the first RBMP, monitoring will be carried out at the above frequency (as a minimum). Where there are suitable historic data available, it will be used for classification. For the 2015 and subsequent RBMPs, with 6 years to collect data in, the greater number of data points which will accrue will enable status assessments to be determined with greater confidence.

4.1 Classification of HMWB and artificial water bodies

The WFD sets different environmental objectives for artificial and heavily modified water bodies (HMWB). These water bodies are physically changed in order to allow important human activities such as flood defence, navigation and the storage of water for hydropower and water supply. The Directive recognises that we cannot achieve good status for such water bodies and instead defines a requirement to achieve good ecological potential. HMWBs will be monitored using broadly the same

suite of analyses as non-modified water bodies, but for classification the quality standards will be different for those biological elements directly affected by the modification (e.g. a canal would be expected to have the same physico-chemical quality as a river, but the morphological requirements would be relaxed).

5.0 Cost and affordability

SEPA has carried out a fundamental reappraisal of its predecessor monitoring programmes and put in place an integrated and cost-effective programme. This exercise has released resources for the new network, which, supplemented by new income arising from the point-source regime and the newly regulated abstraction and engineering activities, will deliver the minimum programme required to adequately meet our WFD obligations. It is intended that the network should be affordable on an indefinitely long-term basis.

6.0 Conclusion

The WFD is a wide-ranging and ambitious piece of legislation. SEPA has designed cost-effective monitoring and classification networks to meet the demands of the WFD and to provide data of sufficient quality and quantity to enable changes in water quality status to be detected and the efficacy of programmes of measures to be determined.

19th of March, 2007