UK-EOF Statement of Need

Freshwater and Groundwater Observation Requirements

Alongside development of Towards a Statement of Need, the UK-EOF has also developed Observation requirements tables to capture information and help articulate:

- The UK's requirements for observing the natural environment
- Identify the questions that we need to answer
- How close we are to being able to provide the evidence via a balanced suite of observations.

For ease, information gathering has been split into environmental domains and for each domain, what the specific issues or sub issues that are of importance for the headline issues identified in the UK-EOF Statement of Need.

Information has been gathered from experts in their field via correspondence, a workshop and open consultation. The tables are not final and some gaps exist in the information. The UK-EOF will work to fill these gaps and revise the tables accordingly.

Some of the sub-issues identified fall under several fundamental issues and there are key dependencies with other environmental domains.

Observation requirements captured within the tables have not been prioritised in any way, nor has current capability been identified. Prioritisation will be addressed via a decision support framework which is also being developed under the UK-EOF and capability or current activities are searchable within the UK-EOF Environmental Observation Activity Catalogue (www.ukeof.org.uk).

Summary of Requirements (under each UK-EOF headline issue)

Pressure on all environments in the light of <u>Population Growth</u> and associated pollution.

The major issues associated with Population Growth for Freshwater and Groundwater relate to water resources and pollution. With a growing population there is concern whether there will be enough water (of good quality) to both sustain human population and activities whilst still enabling protection of freshwater habitats and ecosystems. To answer this question there is a need for frequent broadscale (for UK assessment) and targeted catchment scale (for management) monitoring of water quality and availability, and the associated ecology. The UK also has an interest in overseas development and observations play a role when considering the necessary infrastructure required to enable access to water, especially with a view to climate change.

With respect to pollution there are statutory drivers that require the monitoring of water quality to assess compliance. However, many current monitoring regimes involve monthly sampling which may be inadequate to detect exceedances or to enable the calculation of pollutant loads downstream. Additional biological

monitoring may be necessary to fully understand how water quality and the associated biodiversity are being protected.

Inputs from diffuse pollution remain an issue as do the detection and impacts of new polluting substances. To detect those coming from industry, monitoring must be timed to that of the discharge; for agricultural impacts, frequency needs to be increased because delivery of the pollutants may be tied to flow cycles.

With increasing populations, an increase in urbanisation has been seen. It is not fully understood what the impact (urban foot print) will be on water, land and air in either the immediate vicinity or the wider catchment. Wider networks of sensors in urban areas and monitoring up and downstream would provide more information for each urban area; however, the ability to extrapolate across the networks may be limited by high variability.

Support economic growth whilst reconciling with sustainable use of natural resources

Increasing demand for renewable or alternative energy sources could affect the freshwater & groundwater environments. To determine whether there are opportunities to increase the generation of hydropower, an understanding of flow and the potential impacts of altering any flow are necessary. Before increasing planting and production of biofuels or developing new wind farms the environmental impacts must be considered. Many new installations require measurements of high spatial and temporal resolution for flow, water quality, ecology and groundwater. For groundwater, there are thought to be issues with the resolution of current monitoring regimes and also - if assessing pollution - decisions are needed on what should be monitored (i.e. which pollutant).

Multiple use of aquifers is an issue; however, it is not clear exactly what can be measured to ensure that use is sustainably managed.

Better understanding of the inputs and impacts of agriculture and industry (including mining) would lead to the development of more efficient sustainable systems, which have minimal impact on the freshwater environment.

Understanding future states of the *Earth*, particularly the *Carbon Cycle* (but not excluding other element cycles)

Despite the title of this headline issue nitrogen and other element cycles should be included within this category.

There is a need to know what role freshwater bodies (lakes, wetlands & rivers etc) play as sources or sinks of both carbon dioxide and other greenhouse gases. Related to this is whether the quantity of dissolved carbon in natural waters is changing and whether there is an associated impact on ecosystem health. Underlying these issues is a requirement to understand the processes that occur. To be able to detect the changes in both chemistry and dissolved organic carbon, continuous in-situ sensors could be used. Some supporting observations on physical parameters may be currently collected but they are not thought sufficient to answer the question adequately.

For groundwater there is concern that there is a lack of understanding of the environmental impacts of carbon capture and storage (CCS) on aquifers. Upon setting up a CCS scheme, monitoring local to the site along with baseline 'comparison' would be necessary to assess the impacts and whether there was leakage into surrounding groundwater resources.

Fisheries, Agriculture, Food Security and Water Supply

Questions surround the affect of environmental change on water availability (for agriculture, aquaculture, water supply) and aquifer recharge. Observations are required at the catchment level - for which much information is already available - but this will need scaling up to a UK level. To be able to answer the questions fully, there is also a need to understand the level of water consumption, which is not adequately monitored (however water companies may hold some information) and the effect of the urban environment on the water cycle and water retention.

The changing environment may lead to changes in agricultural practices; any such changes would bring a requirement to understand the effect on water quality and corresponding compliance with legislation. Again this raises the issue of diffuse inputs and the lack of current observations to address them, along with the question of whether environmental change will affect the balance of accumulated sinks for pollutants in agricultural catchments. Many of these inputs are linked with flow, rainfall and temperature, therefore a sub-set of *in situ* sensors may be necessary to capture relevant information. Monthly observations may simply miss the input and result in underestimates of pollutant or input loads. This also applies to agricultural inputs to coastal waters, where analysis of daily samples at a sub-set of sites & weekly samples at other sites (for nutrient loads, C, N, P) would provide a good indication of the nature and timing of the delivery. Even though there is a view within the community that increased sampling would bring UK monitoring up to the standards of other European nations - the frequency of sampling itself raises issues regarding whether the information generated would be suitable for both research observations and monitoring.

Changes to land use management or crop type could have impacts on the hydrological cycle, although this may be local to the area in question; wide scale changes to management and planting could have wider impacts.

The changing environment will favour different species, which may lead to an increased risk of colonisation by non-native species. An assessment of their spread and its impact on both the ecosystem and commercially important species is necessary to inform risk assessments and also judge the success of any control measures.

Human Health, Wealth and Wellbeing

Several of the issues for human health, including droughts and flooding, overlap with those stated under extreme events.

The majority of the environmental issues for freshwater and groundwater under 'Human Health' relate to water quality or 'safe' water for humans. This includes contamination of drinking water supplies and bathing waters, both requiring monitoring for microbiology and physico-chemical parameters. This type of monitoring could also be used to assess the presence of disease vectors or

pathogens and in the long term would provide answers to questions on whether pathogen abundance was changing with environmental change. Some observations are already taken for various directives but the locations of samples may be limited.

For overseas territories, such as Monserrat, potential groundwater contamination from volcanic activity could be an issue and would require observations to assess the risk.

Understanding, avoiding and mitigating the effects of extreme events and disasters

In order to minimise the risk from extreme events such as flooding, droughts, storm surges or tsunamis an understanding of the extent of the risk (such as frequency and persistence) and the potential impacts must be established. This requires both national and local (catchment) information on variables such as flow rates, groundwater levels and rainfall. Although much of this information is already collected within the UK, the adequacy of the spatial scales of the networks, especially for groundwater, may not be suitable to meet the need. In addition, to assess the ecological impacts measurements of ecology and water quality would also need to be taken. To enable prediction, the information could be used to validate appropriate models.

Many of the questions associated with this fundamental issue are linked to whether there would be an increase in extreme events due to climate change and specifically with regard to flooding, whether infrastructure would be able to cope with increased flow and whether this could change the form of both natural and engineered rivers? Consideration should also be given to the associated consequences such as the impacts on not only the surrounding habitat but also property and infrastructure. Associated with increased flows is the potential for the flushing of accumulated pollutants into freshwater systems. Most of these issues are catchment based and would require continuous event based monitoring. Again, information could be used to inform predictive models.

Understanding and reducing the impacts of environmental change on marine and terrestrial biological diversity, ecosystems & services

There is much emphasis on understanding how ecological systems are changing with climate change and associated pressures. Information from the past can be obtained from palaeo-ecology and sediment cores can be compared with current measurements to assess the rate and extent of changes over long time scales.

There is a need to understand what the ecological thresholds are and what the response of the system will be; this could affect the UK's compliance with biodiversity related legislation and also ecosystem structure, function and associated services. Key indicators may also be affected by climate change, potentially altering their known response, which could have knock-on effects on corresponding management actions. Activities to assess the value of ecosystems are undertaken; however, impacts of environmental change on physico-chemical feedbacks, structure and functioning are currently unknown.

Changing environmental conditions will have impacts upon the species and biodiversity within different habitats. As a result, species ranges may change and

competition with migrating species or non-native species which favour the new conditions could add to pressures.

Understanding climate variability and climate change within earth system science

There is a need to determine what the feedback processes are from soil water, surface water and freshwater ecosystems to the atmosphere and climate. To achieve this regular (daily) measurements would need to be gathered on a wide scale so that they could then be fed into climate models. For ecosystems, measurements to allow the calculation of carbon & nitrogen budgets, along with gaseous & aqueous fluxes are required from representative water bodies.

The effects of climate change (such as changing seasonal flows, rising sea levels and increasing temperatures) on the freshwater environment are all issues that, other than on the coast, would require broadscale measurements. Also, there is a need to understand how climate change will affect the behaviour of other pressures such as pollutants within the freshwater system. Additional measurements of temperature and flow could be added to existing chemistry and biological monitoring to determine whether there are any links to observed changes.

Scientific and Technological Advancement/Innovation

The main requirement for technological advancement is in the development of new sensor technologies that increase sensitivity but use low power or low amounts of reagents. *In situ* sensors that are capable of continuous monitoring would be advantageous and could be used to extend national capability for high frequency pollutant monitoring. These technologies could be coupled to finding parameters which link directly to management issues - thus alleviating the need to monitor many different variables. It would be advantageous to test any new methodologies against old ones to assess whether direct comparisons are possible or whether other factors need to be taken into taken into consideration.

As earth observation data becomes more widely available, there is a need to improve the ground truthing of the data. For some variables this may involve improving the spatial scale upon which measurements are taken. A further issue with remotely sensed data is whether the sensitivity can be improved so that it is valuable at a local level.

Model development, from simple to complicated, would benefit the freshwater and groundwater communities. There are many types of models, those that would be of most benefit for freshwater and groundwater are models that best represent the environment, answer the questions posed and enhance understanding of the processes that are observed; as well as models that relate easily measured parameters such as land use to freshwater flow and supply issues. Models could also be used more explicitly to generate questions and design subsequent programmes of observation. These models are useful in planning, in linking issues quantitatively to measurements or for prediction.

Other Requirements and General Comments (Freshwater and Groundwater)

Issues that relate to observations but may not require direct evidence from observations generally fall within this category. For example the need for

knowledge exchange and an assessment of the adequacy of current ecological monitoring networks.

It is difficult to move away from refining and handling already known issues, there is however a need to answer how as a community the next environmental issues may be identified and relevant observations made for things we do not yet know. Innovation is often constrained by past successes because of a predilection to pursue the same (funded) path rather than untested ground. There is therefore a need to 'think outside of the box'.

Some general points raised whilst gathering information to complete the freshwater and groundwater observation requirements table include:

- Acknowledgement that it is important to match the scale of observation to those of natural processes.
- Data archiving: How continuous data should be archived – in their raw form or in a processed parameterized form? [Data storage is something that is being taken forward under the UK-EOF Data Initiative].
- There is a need to define '*ecosystem function'*, *'optimise', 'vulnerability to change',* and *'best'*. These could then be connected conceptually and quantitatively to observations (via a model of sorts). This relates to and emphasises the importance of having conceptual models to assist in the processes from need to monitoring; such modelling and planning is better than precipitately measuring what we know about or what we last had funds to do.
- Often there is a lack of information regarding the drivers for an observation programme (despite having detailed monitoring). It would be useful to capture information regarding the drivers in cases such as acid rainfall and air quality monitoring.
- Inadequate sampling may produce tensions within regulatory monitoring programmes that are linked procedurally to remedial measures. Without good sampling, it may be difficult or impossible to evaluate the effectiveness of remedial programmes. It may sometimes be worth doing expensive monitoring because costs often escalate when the wrong conclusions are drawn from weak monitoring.

Observation Requirement Table – Freshwater and Groundwater

Information captured in the table will help to articulate what the UK's requirements are for observing the natural environment, what the questions are that we need to answer and how close we are to being able to provide that evidence via a balanced suite of environmental observations.

For each environmental domain information has been collected on the specific issues or sub issues that are of importance for the headline issues identified in the UK-EOF Statement of Need.

Consultation with the community has led to the population and validation of the following table. The tables are currently 'work in progress' and will continue to be revised as requirements and priorities change. The requirements captured have not been prioritised in any way.

Issue	**Specific/Sub issue** This refers to the questions that we need to answer.	**Measurement Type** (variables that would need to be measured to provide evidence to address the specific issues)	**Frequency of collection** e.g. A continuous measurement for 1 week in Spring, repeated every 2 years. Or A spot measurement, once a week, every week throughout the year. Or Irregular measurements as required i.e. extreme event monitoring.	**What geographic coverage do we need?** A) UK B) England C) N. Ireland D) Scotland E) Wales F) Localised UK (e.g. part of Wales) G) Europe (non UK) H) Global I) Other (please specify) J) Ocean/Sea (please specify	**What is the primary use for the data?** A) Basic Science B)characterising environmental issues/ solutions (influencing policy) C) Direct env. Management D) Modelling & Prediction E) Complying with Legislation F) Development and Growth	**Are the current actions / measurements sufficient to provide the evidence needed to address the issue?** If known, please list the current programmes/sensors which are capable of providing the evidence (e.g. for Sea Surface Temperature AATSR, SLSTR. AVHRR, AMSR and Modis satellites are capable of measuring SST).
Population Growth (Understanding the pressures on all environments, particularly in the light of population growth and associated pollution)						
Water resources	Is there an equitable allocation of water resources to protect	Flow	Daily			National River Flow Archive (NRFA)
		Groundwater	Monthly	A, B, C, D, E (UK, assessment	A, B, C, D, E	National Groundwater Level Archive (NGLA)

	freshwater habitats and ecosystems on a long-term basis?	Water Quality (to determine exceedance of critical thresholds for toxic and persistent substances)	Weekly an/or daily at some sites?	is regional). F (catchments) is the level of management		WFD? (Diffuse inputs?)
		Ecology (including data describing wetlands?)	Twice yearly Ecological survey (annual?)			Ecology – probably?
		Abstraction quantities	Monthly/Annual		C, E	
	Are water resources being optimally used and managed to provide enough quality water?	Consumption by Sector	Continuous/metering	B, D, E, F (South & East England; Wales; Eastern Scotland)	B, C, D	Environment Agency's CAMS are a good start
	What are the demands and balance (with UK Levels) for hydro-power? (also see under Economic Growth and sustainability)	Policy Studies (Link to Societal requirements).	Frequency is related to science and public priorities			
	What are the overseas development considerations (with a view to Climate Change)?	Infrastructure		G – Areas with largest projections of extreme climate change. I Emerging economies		Remote Sensing Observations for consideration when installing infrastructure and maintenance.

Pollution	Ensuring compliance with legislation with respect to pollution.	Water Quality	Daily/	A, F (catchments) is the level of management	C, E	As above for Water Resources – WQ. EA initiatives to meet WFD requirements
	Is water quality and biodiversity being protected?	Chemistry e.g dissolved oxygen (night measurements)	Daily subset required (some determinants at night) other Weekly/Monthly	A (National) & F (Catchment Scale)	B, C, E, A, D	
		Biology	Weekly/Monthly			
		Microbiology	Monthly/Seasonally			
		Ecological Functioning	Monthly/Seasonally			
	What are the potential pollution impacts of new substances (especially in agriculture)?	Industrial inputs e.g. pharmaceutical manufacturing sites, refineries; Agricultural sites	Relative to periodicity of discharges from industrial sites Sampling at some (sub-set) of sites plus weekly (delivery tied to flow periodicity)	A	B	
		Agricultural inputs		A	B	
Land Use Change	How does land use change and changing land allocation affect	Hydrological cycle	Daily/continuous flow at subset of sites	A	All?	

	the hydrological cycle?	National level Statistics	Annual			
		National Level Planning				
Economic Growth & Sustainability (Support Economic Growth whilst reconciling sustainable use of natural resources such as aggregates, minerals & energy)						
Hydropower (including small scale)	What is the opportunity for increasing the contribution of hydropower?	Flow	Daily	A – E for assessment purposes. Regional but catchment specific	B, C	NRFA; NWA
		Ecology	Twice yearly			WFD (EA, SEPA), River Habitat Survey (RHS), RIVPACS.
		Water Quality	Weekly, plus sub set of sites sampled daily			EA, SEPA?
Biofuels	What is the likely impact of increased production of biofuels on freshwaters?	Flow	Daily	F (regional/ catchment specific)	A, B, C, D, E	NRFA; NWA
		Ecology	??			
		Water Quality	Daily?			Need high spatial and temporal resolution (not yet being achieved)
		Groundwater (level & quality)	Monthly?			For Groundwater there is an issue over what to monitor – for example for pollution need to consider what pollutants.
Urbanisation & Suburbanisation	What is the urban foot print (i.e. impact on air/water/land?)	As Above (for Biofuels) but in urban areas, plus:		A (UK), F – need much denser networks in		Extrapolation across networks may be limited due to the high variability in each urban area.

		Outputs to engineered system	Daily and monthly for surface groundwater flows respectively	urban areas.		UWWTD
		Inputs to engineered system	Daily and monthly for surface groundwater flows respectively			
	How do urban areas interact with the rest of the catchment and the marine environment?	Capture manmade water balances		A (UK) F – urban areas, upstream and downstream monitoring	B, C, D, E	
		Capture manmade solute balances			B, C, D, E	
		Water supply			B, C, D, E	
		Sewage			B, C, D, E	
		Chemical Flows			B, C, D, E	
Aquifers	How can we accommodate multiple use of aquifers (e.g. Energy, waste disposal, increased irrigation etc)	Groundwater levels Groundwater quality	monthly	F	B, C, D, E	NGLA
Land use Change – See population Growth						Change in quality and recharge to aquifers
Agriculture	Can we develop sustainable agriculture systems with minimal damage to freshwaters?	Farm Scale Nutrient budgets	Weekly	A (UK wide)	A, B, C, D, E	Change in quality and recharge to aquifers.
		Pollutant fluxes to freshwaters	Daily			

Mining & Industry	Can we manage the input of mining and industry on the freshwater environment?	Water Quality Quantity of water inputs (toxic and persistent substances, accumulation of contaminants in fine sediment stores downstream and release to the overlying water column (lagged) will be likely to be of significance ecological	Collection will be issue specific Daily plus storm events for delivery of toxic and persistent substances from these sites- highly variable and lagged.	A	C	
Wind Farms	What are the impacts of wind farm development on the freshwater environment?	Water Quality Ecology	Stratified?	F (Local)	A, B, C	Onshore wind farms (for offshore refer to the Marine Tables)
Carbon Cycle (Understanding the future states of the earth, particular the carbon cycle, but not excluding other element cycles)						
Carbon & Greenhouse Gas	What is the role of lakes, wetlands and	Physical Data	hourly/daily/monthly ?	A – E and F (specific lakes)	A, B, D, E	AWMN, UK-LEON, ECN, WFD

Sink/Source	rivers as a C sink/source and as a source of greenhouse gases? Is the role changing?	Chemistry	Continuous monitoring (inflows: freshwater and gaseous) & outflows (freshwater and gaseous) to determine source/sink function.			There is a requirement to understand processes to inform the decision on mandatory need
		Surveys of representative lakes, wetlands and river reaches	Survey			
		Dissolved Organic Carbon				
		Carbon Flux				
Dissolved Carbon	Is the quantity of carbon in natural waters changing and what are the implications for ecosystem health?	Dissolved Organic Carbon	Continuous??	F, All natural waters (wetlands, lakes rivers)	A, B, C, D, E	All Waters covered by the WFD
		Dissolved Organic Matter	Continuous (in situ sensors)			
		Water Quality	Weekly sampling (plus event based sampling – Qualitative and Quantitative analysis			
Carbon, Capture and Storage	What are the environmental impacts of Carbon Capture and Storage in Deep Aquifers?	Carbon Dioxide (in Groundwater)	Daily- monthly Then annually.	F: local to area around the CCS scheme. Elsewhere 'baseline' for comparison	B, C, D	

Fisheries, Agriculture, Food Security & Water Supply (Understanding the consequences of environmental change)						
Water Availability	How will environmental change affect water availability for agriculture, aquaculture and water supply?	Flow	Daily	A – E but building on specific catchments (F). This is also a global issue.	B, D	Much data already available (NWA etc) Requires large catchment studies and models (Source 2 Sea?). Needs up-scaling procedures for UK (JULES?)
		Groundwater (levels)	Monthly			
		Groundwater (salinity)	Annual			
		Soil Moisture	??			
		Rain fall				
		Water Consumption	?? Annual??	A: UK wide		Monitoring is currently inadequate.
	How will environmental change affect aquifer recharge (Surface water/Groundwater interactions)?	As Above				
	What is the effect of urban environments on the water cycle/water retention?	Rainfall	Monthly	A: UK Wide (however this is also a global issue)		
		Water Table			B, D	
Water Quality	How might changes in agriculture affect water quality and compliance with legislation?	Flow	Daily	A: UK wide, but building on specific catchments (F: localised UK)	E, C, B	NRFL: NWA
		Groundwater	Monthly			NGLA: NWA
		Water quality	Daily (acute impacts)			Daily sampling for total nutrient loads. Continuous sensing for Toxic persistent substances. Lack of observations with respect to diffuse inputs
		ecology	Daily			WFD??
		microbiology?	??			

		Temperature				Continuous sensing using in situ sensors would also be a possibility at a sub-set of sites
		Sediment transport	daily			Daily sampling for total sediment loads. Continuous sensing using in situ sensors would also be a possibility at a sub-set of sites
	How might changes in other imports (beyond agriculture) affect water quality & compliance with legislation?	As Above & Rainfall				Links with flow/rainfall & temperature.
	How might environmental change affect the balance of accumulated sinks for pollutants in agricultural catchments?	Nutrients (N, P, C)	Daily Event Based sampling – quantification at scale of fluxes	A: UK wide		
		Sediment				
		Sediment-associated pollutants				
Fisheries	Are populations of fish (for human consumption) healthy?	Fish passing over barriers (migration)		A	B	
		Flow	Daily			NFRL: NWA
		Channel Morphology	3-6 yearly			Lack of information
Alien Species	What is the extent and risk of spread of alien species (especially with Climate change)?	Fish populations	Annual	A, UK Wide		
		Food Chain interactions				
		Species abundance & distribution				

Downstream Impacts	Is the flux to coastal waters changing?	For agriculturally derived contaminants: C, N, P Total nutrient loads.	At the FW/SW interface (or just upstream): Daily (sub set of sites) Weekly (other sites)	A, UK Wide		
Changes in land use (and crop type) – see Population Growth				F: Macro, regional and agri-specific		
Human Health, Wealth and Wellbeing (Understanding consequences of environmental change for human health, wealth and well being)						
Droughts – see Extreme Events						
Flooding - See Extreme Events						
"Safe Water"	Do UK waters comply with legislation e.g. Bathing Waters?	Microbiology	Monthly	A	E	Bathing Waters Directive
		Physico-chemical parameters	Weekly	A	E	Bathing Waters Directive
	Risk of Eutrophication (causes, persistence etc)?	Flow	Hourly/ Daily in a subset of catchments and hourly in similar catchments	A Compliance F Localised UK (Catchment scale for management & impacts) Hotspots?	E, D, C	NFLA: NWA
		Groundwater	Yearly			NGLA; NWA
		Water Quality	Hourly/Daily			WFD? Mixed coverage
		Ecology	Hourly/Daily/Monthly (underpinned by system understanding)			Ecol/Microbiol – mixed coverage

		Chemical parameters- ***Is this different from water quality?***	Daily in a subset of catchments and hourly in similar catchments			WFD – but not to the frequency stated.
	What are the levels of harmful toxic chemicals?	As above (Eutrophication) plus:	Daily in a subset of catchments and hourly in similar catchments			
		Microbiology	Monthly	A Compliance F Localised UK (Catchment scale for management & impacts) Hotspots?	E, D, C	Bathing Waters Directive (but limited locations)
	Are disease vectors present? What is the cause?	As Eutrophication plus:		A Compliance F Localised UK (Catchment scale for management & impacts) Hotspots?	E, D, C	
		Microbiology	Monthly (or more frequent during an incident)			Bathing Waters Directive (but limited locations).
Water-volcano interaction	How does rainfall affect volcanic eruptions and how does volcanic activity affect groundwater?	Volcanic Activity	Minutes to Monthly	I – Local to Volcano e.g. Monserrat		
		Rainfall				
		Spring flow				
		Groundwater head				
Pathogens	Are the numbers of pathogens increasing with warmer, wetter winters?	Microbiology	At least monthly	A-E	A-E	
		Surface flow	Daily/monthly			
		groundwater	Daily/monthly			

Drinking Water	Will increased agricultural intensity increase the contamination of private water supplies?	Microbiology	Weekly, monthly??	A (UK Wide), F (Private water supplies)	E, B, D	
		Nitrate				
		Persistent Organic Pesticides & Pesticides				
Extreme Events & Disasters (Understanding, avoiding and mitigating the effects of extreme events and disasters)						
Floods	What is the risk of future flooding? (Assessment)	River Flow	Daily/Hourly	A, F (Catchments)	A, D, B	Flow - Yes (NWA)
		Groundwater	monthly			Groundwater - Yes (NWA). Scottish Network is developing, England & Wales – spatial network is inadequate (poor location, time resolution).
		Rainfall	Hourly-Daily			Covered
		Land Use & Change	Annual (years)			Land use focussed cross specific platforms (e.g. NWRPS (?), RRes etc)
	Improving flood forecasting	As above	As above	A, F (Catchments)	D, A	
	Will environmental change increase the frequency and severity of flooding (effect on potable water)?	As above and Groundwater head		A & I (UK & dependent territories)	A, C, D, E	
Droughts	Can we increase our understanding of the frequency & persistence of	Flow	Daily	A	B, C, D	Flow (NRFA; NWA)
		Groundwater	Monthly			Groundwater (NGLA; NWA)

	droughts?	Soil moisture	Daily			Gap: Spatial scale problem
	How can we predict future droughts?	As above			D	
	How will future droughts & temperature extremes affect food production?	As Above plus: Land Use & Change		A, F (Catchments)	D, C, A	
	What are the ecological impacts of droughts? [1]	As above (understanding frequency & persistence) and: Ecology	??		A, B, C	Ecology ???? AWMN, ECN, WFD
Pollution incidents	Are Storm surges/overflow tanks in sewage works & flushing septic tanks adequate in the face of Climate Change ?	Flow	Hourly ?	F (Catchment scale and urban areas)	E, C	Flow - Yes – EA/SEPA
		Groundwater	Monthly/Annual			Groundwater ?
		Water quality	Hourly			Water Quality – ?
		Ecology	???			Ecology ?
		Sediment Quality				

[1] This would require assessment and prediction to answer the question.

	How will/might changing distribution of extreme flow events affect the flushing of accumulated pollutant stores to and within freshwater systems?	Water Quality	Event based (hourly) in present of continuous sensor technologies	F (representative catchments in each major geoclimatic region)	A, B, C, D, E	
Storm Surge/Tsunami	Can long term observations be used to help in the prediction of extreme events?					Impacts & their duration are unknown.
High flow episodes in headwaters	Will future Climate change lead to an increase in high flow events/impacts on fisheries?	Discharge	Continuous (hourly or more)	A, I (uplands)	A, B, C, D, E	In groundwater fed streams monitor groundwater levels on monthly basis NGLA
		Chemistry in streams				
		Biology in streams				
Hydromorphic Stability	Natural & Engineered river form changes? Protection of habitats, property, Infrastructure.	(River) Form Survey	Event related monitoring (flow, sediment)	F & I (representative catchments in UK, also international and impacts on coastal systems)	A, B, C, D	
		Sediment monitoring				
		E.O.				
		Flow				
Ecology	How do extreme events (drought/flood) affect ecology?	Ecology	Monthly?		A, B, C, D, E	

	Problems exacerbated by human impacts	Discharges	Continuous flow where available, or daily flows – it is the distribution of extreme flows which imposes stress on the stream biota (both plants and animals)			
Biological Diversity, Ecosystems and Services (Understanding and reducing the impacts of environmental change on biological diversity, including ecosystems and the services they provide).						
Legislation compliance (& anticipating future legislation)	Potential impact of environmental change on compliance with 'biodiversity' related legislation in freshwaters? (Habitats Directive, Freshwater Fish, WFD, Urban Wastewater etc)	Condition Surveys	Annual Survey	A (UK and country wide)	E, B, C, D	
		Specific Species	As laid down in specific directive (but higher frequency may be required)			Habitats Directive
		Habitats	Annual? Plus following extreme flow events			Habitats Directive, River Habitat Survey
		Invertebrates	2 x year			WFD, RIVPACS
		Fish	3 x year			WFD, Freshwater Fish Directive
		macrophytes	annual			WFD
		phytobenthos	2 x year			WFD
		chemistry	Weekly, plus daily/hourly at a subset of sites			WFD, UWWTD – unlikely that either of these are currently being done to the stated desired frequency.
		hydromorphology	? Annual?			WFD

		Nutrients	Weekly, plus daily/hourly at a subset of sites			WFD, UWWTD, Bathing waters Directive - unlikely that these are currently being done to the stated desired frequency.
Ecosystem function	What will be the impact of environmental change on ecosystem function (e.g. how it works including services and wetlands) and structure (composition and linkages)?	All above + hydrology (for Rivers and Groundwater)	Continuous and regular at highest frequency possible![2] Groundwater - monthly	F (specific areas and catchments) up–scaling to A-E	A, D	Unknown but WFD monitoring, RHS, RIVPACS, ECN site Some specific examples (eg. CEH wetlands network)
Ecological Indicators	How healthy is the Freshwater?	Flow	Episodic (hourly/daily) Chronic (long-term, monthly)	H	B, E	
		Chemistry				
		Ecology				
Ecological Thresholds	If flow or water quality or an aspect of ecology changes – what is the response?	Flow	Episodic (hourly/daily)			
		Chemistry				
		Ecology	Chronic (long-term, monthly)	H	B, E	
Restoration	How can we measure success?	Species richness	Baseline (for comparison) & after	A (National Scheme)?	C, D	

[2] It may be difficult to maintain this frequency as there will be competition for resources with river management.

			event			
Vulnerability of Groundwater Fed Ecosystems[3]	What is the vulnerability of groundwater fed ecosystems to environmental change?	Ecology indicators ("usual suspects")	Minutes to monthly???	F; Local to wetlands and up to catchment scale		
		Groundwater Head			A, B, C, D	
		Groundwater Flow			A, B, C, D	
		Groundwater Temperature			A, B, C, D	
		Groundwater Chemistry			A, B, C, D	
Temperature	Will changing temperature affect species distribution?	Temperature	Continuous	A	A, C, D, E	
		Fish	Monthly			
		Invertebrates	Monthly			
		Plants	Monthly			
Ecological Change	How are systems changing (past, present and future) on a decadal scale?	All of the above (long term observations)	Daily to annual		A, B, C, D	Information will feed into modelling
		Palaeoecology	Irregular			
		Sediment Cores	Irregular			

[3] This issue could apply to all water fed ecosystems.

Alien Species	As a result of climate change, how will changing distribution of species (globally) affect native species distribution & abundance?	Species (all biotic groups)	Monthly – annual	A	A, B, C, D, E	WFD has some coverage
Climate Change (Understanding Climate variability and climate change within earth system science)						
Development and testing/validation of climate models	What data do we need to be able to test/validate models?	Flow	Daily	A (+ G and H ?)	D, A	NRFA; NWA
		Groundwater	Monthly			NGLA; NWA
		Soil Moisture	Daily			Lack of information - spatial scale problem
Land use Change[4]	What is the impact of land use change on aquifers (e.g. recharge change due to changing crops)	Land use (National register)	Annual Surveys			
		Flow (required to check models)	Daily			
		Groundwater Levels (required to check models)	Monthly		D, A	
		Unsaturated Zone (between soil and water table)	Daily			

[4] This issue is relevant for several of the fundamental issues including: agriculture, economic growth, population growth and biodiversity & ecosystem services.

Climate Feedback	What are the feedbacks between soil water & surface water to the atmosphere and climate?	Soil Moisture	Daily/Monthly	A (wide scale to link to climate models)		
Ecosystem (& Services)	How do Freshwater ecosystems respond to changing climate and what are are the physico-chemical feedbacks to the climate System?	C, N, P Budget (for whole ecosystem) Gaseous & aqueous fluxes	Daily	A (UK), F representative lakes, rivers and wetlands in major geoclimatic regions.		
Multiple Pressures	How does/will climate change interact with the behaviour of other pressures (pollutants etc)	Temperature	Continuous	A (UK wide, but especially at headwaters)	A, B, C, E	Temperature and Flow data could be added to existing Chemistry & Biology monitoring.
		Flow	Continuous			
		Chemistry	Continuous or hourly/daily			
		Biology				
Sea Level Rise	How will rising sea level impact on coastal/freshwater aquifers?	Groundwater levels	Monthly	A, F (UK wide but coastal focus)		
		Groundwater quality	Monthly	A, F, (UK wide but coastal focus)		

Climate Change Effects	How will climate change affect temperature of Freshwater Systems?	Temperature	Continuous	A (UK wide)	A, B, C, D, E	
	How will Climate change affect quantity & seasonal distribution of freshwater?	Discharge	Continuous	A	A, B, C, D, E	
	How will climate change affect water quality?	Water Quality	Continuous where in situ sensors are available, otherwise daily	A	A, B, C, D, E	
Scientific & Technological Advancement/Innovation						
Testing new observational methods against existing ones.		Water chemistry	Hourly	F (localised site based, catchments, lakes)		
		Ecological parameters	??			
		Soil moisture	Daily			
Earth Observation Data	There is a need for improved ground truthing of EO data.	Soil moisture	Daily	F (localised site based, catchments, lakes)	A	Lack of information – spatial scale problem
		Flow	Hourly			NRFA; NWA. EA/SEPA + existing CEH catchment studies + other catchment studies.
		Chlorophyll	Depends on whether a lake or a river. Suggest a minimum of weekly.			Chlorophyll little information (study lakes of CEH, ECN sites…..??)
		Chemistry	Hourly			Chemistry little information (study lakes of CEH, ECN sites, WFD?)

	Can sensitivity of EO data increase to be valuable at local level?	Temporal water quantity	Monthly	G (Global)	A, B, C, D, E	
New Sensor Technologies	Can we improve current monitoring technologies? (Sensitive, low power, low reagent)	Nutrients		F – Case studies to begin with	A	Need reliability, more for less, less environmental impact.
		Oxygen				
		pH				
		Carbon				
		Majors??				
Data Analysis/ Modelling	Can we extract all the information from the data?	Load estimates				
		Biological response				
		Pollutant residence times				
	Can we develop appropriate models to best represent the environment and answer the questions posed/understand the processes we observe in the environment?			A & G		To fulfil this need, there is a parallel need for improved understanding of the system.
Indicators	What is the effect of CC on existing indicators?	Temperature	??	A		Research and recalibration of temperature changes

Hydro-morphology	How can we better link hydromorphology to biology?					
Continuous Monitoring	Can novel insitu technologies be further developed to extend the national capability for high frequency pollutant monitoring? (Thus helping us to understand the environmental behaviour of Freshwater pollutants).	Toxic & persistent substances	Continuous	A, F UK wide; representative Freshwater environments	A, B, D, E	
		Dissolved organic contaminants				
		Gaseous emissions from Freshwater				
		Gaseous input to Freshwater				
Cheaper, more direct monitoring	Finding new (integrated?) things to measure which link directly to the management issues instead of having to monitor lots of different parameters.	Ecological quality		A, UK Wide	B, C	
		Biodiversity				
		Pollutant Toxicity				
		Pollutant Flux				
		Water Flux (soil)				

		Water Flux (groundwater)				
Others – Many of the issues below are peripheral questions to the UK's requirements for observations						
Strategic National Level thinking	How can we observe macro changes that may have consequential effects on Freshwater and Groundwater?	Population (growth?)	Annual	A, F (UK wide, regional for planning)	A, B, D, E	Require meta – analysis??
		Land Use				
Knowledge Exchange	How do you get the general public to value water?					
Enhancing Amenity of Water Spaces	Amenity Value					
Adequacy of Networks	How adequate are ecological monitoring networks compared with Water Quality, Discharge etc?					
Landscape						
Morphology						
Upcoming environmental issues	How do we spot the next environmental issue? Do we need to observe many things that we do not yet know we need to know?					

	Can we develop observation platforms which are sensitive to newly synthesised chemical released to the environment?	Nanomaterials				
		Pathogens				