Step-by-step monitoring methodology for SDG indicator 6.6.1

Change in the extent of water-related ecosystems over time

1. Monitoring context

1.1 Introduction to the indicator

Target 6.6 **By 2020 protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes**

Indicator 6.6.1 **Change in the extent of water-related ecosystems over time**

This indicator tracks changes over time in the extent of water-related ecosystems. It uses the imminent date of 2020 in order to align with the Aichi Biodiversity Targets of the Convention on Biological Diversity, but will continue beyond that date to align with the rest of the SDG Targets set at 2030. Whereas all ecosystems depend on water, some ecosystems play a more prominent role in the provision of water-related services to society. Consequently, for the purpose of global monitoring, the indicator focuses on the following ecosystem categories: vegetated wetlands (swamps, swamp forests, marshes, paddies, peatlands and mangroves), open water (rivers and estuaries, lakes and reservoirs) and groundwater aquifers. Note that this Indicator method defines "extent" as "the size or area of something" (McMillan Dictionary), thus going beyond spatial area to include other size (quantitative) measures of water-related ecosystems i.e. quantity, quality and also state of health.

Three principle sub-indicators describing aspects of these ecosystems are monitored to describe the extent for global comparison, with a fourth sub-indicator for more advanced in-country monitoring:

i. The **spatial** extent of water-related ecosystems
ii. The **quantity** of water contained within these ecosystems
iii. The **quality** of water within these ecosystems,
and…
*iv. The **health** or state of these ecosystems*

This indicator responds to Goal 6 in that it seeks to provide data and information to enable management and protection of water-related ecosystems so that ecosystem services, especially those related to water and sanitation, continue to be available to society. It responds to the Target which seeks to "protect and restore water-related ecosystems" by providing information on the spatial extent of these ecosystems, the quantity and quality of water *within them and their health. All of these components are necessary to provide sufficient information to protect and restore these ecosystems. However, of necessity, it does not cover every situation and there will be ecosystems related to water which are not included, or where certain impacts are not detected by the methods included here e.g. salt water ecosystems such as coral reefs and the coastal inshore are not included here. Nor are mountains, forests or drylands specifically targeted, but rather the water ecosystems themselves are examined. This may result in failure to detect issues related to these ecosystems where they do not impact on the water ecosystem, but it is intended that these issues will be covered by other Targets and Indicators.*

2. Target-setting for the indicator

The 2030 Agenda for Sustainable Development specifies that all SDG targets "are defined as aspirational and global, with each Government setting its own national targets guided by the global level of ambition but taking into account national circumstances." The global ambition of the target 6.6 is to "protect and restore" ecosystems (without any numeric specification), and it is up to each country to set their own targets in this regard, i.e. to determine what is an acceptable change in ecosystem extent, quantity and health, and when and how management intervention should be introduced.

For the purpose of this indicator, ecosystem change, in relation to its natural condition in terms of both quantity and quality, can be categorised as follows (for more details refer to section 5.2 below and also Annexure 1):

- **Unmodified natural** (class A), where the change is no more than 10 %
- **Largely natural** (class B), where the change is between 11 and 20 %
- **Moderately modified** (class C), where the change is between 21 and 40 %
- **Largely modified** (class D), where the change is between 41 and 60 %
- **Seriously modified** (class E), where the change is more than 60 %

3. Monitoring methodology

3.1 Monitoring concept and definitions

The ecosystems considered in this indicator are presented in Table 1 below. Data for each ecosystem are collected separately and should be kept separate to ensure proper understanding of changes.

Table 1 Ecosystems and indicators included in this method

Ecosystem category	Extent indicators
Vegetated wetlands (vegetation and water dominated ecosystems such as swamps, swamp forests, marshes, peatlands, paddies and mangroves)	Spatial extent/area Water quality Wetland health indices
Inland open waters (lakes and artificial reservoirs)	Spatial extent/area Quantity (volume) Water quality Ecosystem health or state
Rivers and estuaries (fresh and brackish water)	Quantity (streamflow) and environmental flows Water quality Biological or ecosystem health indices
Groundwater	Quantity (depth to groundwater table) Water quality

Monitoring the percentage of change relative to "natural" or "reference" conditions

Each of the sub-indicators in this 6.6.1 Indicator sets out to determine the percentage of change in a water-related ecosystem. This can only be done if there is some point of reference. The ideal situation is that reporting is done using the "natural" situation as the reference, however this "natural" situation is sometimes difficult to determine and instead an alternative "reference" condition can be used. Definitions of reference condition include:

- **"Natural" Reference condition** - the "minimally disturbed condition" from a time before large-scale impacts were imposed on a system. The natural condition however will still be subject to variability in terms of season and climatic variation so ideally is determined according to a standard statistic e.g. the mean extent over a number of "natural years". Where real data are not available to describe the natural reference, then a combination of extrapolation of data from pristine sites, historical data, models and expert judgement can be used to construct a reference condition. Comparison of the observed present condition with this natural reference provides the best and most complete indication of change over time and is the recommended reference for this indicator. <u>This is the general standard for SDG reporting.</u>
- **"Historical Reference" condition** - using historical data from a time when impacts on the ecosystem were less than the present situation. <u>This should only be used for SDG reporting where the Natural Reference cannot be estimated and should be indicated as such</u>. This reference is also appropriate for use by countries, where the earliest records could be used independently to set a Historical Reference condition that would be useful for more detailed management purposes. For example some countries have aerial photographs and other data-sets going back to the early 1900's that can be used to establish an accurate reference condition even though this may not be entirely natural. As technology advances, Earth Observation data could also be used to create a global database as a historical reference with an earlier date.
- **"SDG Baseline Reference" condition** - this makes use of the first survey for SDG purposes carried out in 2017 or soon after, which forms the Baseline dataset against which all future monitoring will be compared and is the minimum requirement for this indicator but must be clearly indicated. Clearly this reference will overlook any degradation that has historically taken place. <u>This is the interim reference condition for spatial extent, which synchronises with the approach of the Ramsar Convention on wetlands</u>. Over time a Baseline Reference will begin to gain relevance and will develop into an objective measure of change since the start of the SDG programme in 2017.

3.2 The Sub-indicators for Indicator 6.6.1

The following sub-indicators are included in this indicator:

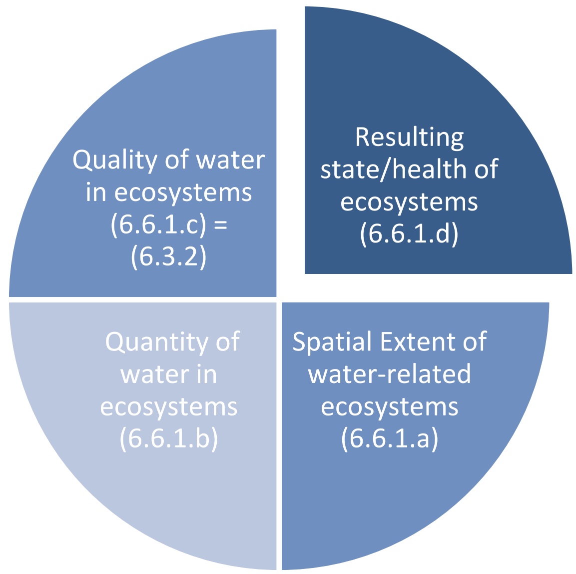

Figure 1 Sub-indicators for the Basic 6.6 Target used for global reporting i.e. 6.6.1.a + 6.6.1.b + 6.6.1.c. Sub-indicator 6.6.1.d is evaluated SEPARATELY and is used for National reporting – see Table 2 and Figures 2&3. The description of progressive monitoring in Table 2 defines the content of each sub-indicator.

Sub-indicator 6.6.1.a: Spatial extent of water-related ecosystems

This part of the indicator measures the geographic or spatial extent of vegetated wetlands (such as swamps, marshes and peat, and including mangroves, swamp forests and even rice paddies) as well as inland open water (rivers, floodplains and estuaries, lakes and reservoirs). Measurement of spatial extent is important as this provides an indication of the availability of these ecosystems and the potential they have to provide ecosystem services. Both Earth Observation (EO) and ground-based surveys provide data that are used to determine the change in the spatial extent of water-related ecosystems over time.

Sub-indicator 6.6.1.b: Quantity of water in ecosystems

The quantity of water in ecosystems in this indicator is that amount of water contained in rivers, measured as streamflow, together with the water stored in lakes and reservoirs and also beneath the ground. Water stored in shallow wetlands, soil water, ice and snow may be abundant but is difficult to measure so is excluded.

The quantity of water is the defining issue of most water-related ecosystems. Reduction in quantity through withdrawals of water causes the size of the ecosystem to be diminished (i.e. a lake gets smaller, a river shrinks, groundwater drops out of reach etc) and because of this the amount of service that these ecosystems provide to society is reduced; reduced water results in a change in water-related habitat, thus leading to a change in biodiversity and thus also a change in the ecosystem services provided.

A special perspective on the quantity of water in ecosystems is contained in the concept of Environmental Water Requirements (or E-flows) which describe the amount and timing of water that the ecosystem itself needs to survive if it is going to continue to provide services to society. Environmental Water Requirements are a component of Indicator 6.4.2 – "Level of water stress: freshwater withdrawal as a percentage of available freshwater resources". Knowledge of this amount of water allows a better understanding of the amount of water available for withdrawal in a sustainable way. In the 6.6.1 indicator, this information is used to help set targets for management.

Sub-indicator 6.6.1.c: Quality of water in ecosystems

Water quality is a key driver of ecosystem response and thus it is important that quality be included for a comprehensive understanding. Most water-related ecosystems are dependent on water quality of a defined type and range, and any deviation out of this range will result in changes to the ecosystem which are generally negative. The data here are produced under Indicator 6.3.2 Percentage of water bodies with good ambient water quality and is carried over for inclusion in the 6.6.1 aggregated score. This data in the 6.3.2 indicator are used to measure the percentage of compliance with a good water quality. This data are used to determine the change in the quality of water over time based on the assumption that 100% compliance would mean natural water quality.

The data from Indicator 6.3.2 is limited to a small number of variables (DO, EC, pH, OrthoP and TON) for surface water which, while being the most relevant from a general human pollution point of view, will not explain some situations where inferior water quality is a contributor to poor ecosystem condition. Thus, for example, the present water quality monitoring programme will not detect heavy metal or pesticide pollution. Results always need careful interpretation.

National Sub-indicator 6.6.1.d: State or health of ecosystems

Note that this sub-indicator does not form part of the aggregated 6.6.1 index, but is kept separate for National level reporting and to assist with restoration activities.

What is ecosystem health? Costanza and Mageau (1999) defined a healthy ecosystem as *"one that is sustainable – that is, it has the ability to maintain its structure (organization) and function (vigour) over time in the face of external stress (resilience)".* Health of the ecosystem is generally considered to be similar to the concept of state and both terms are increasingly being adopted by agencies around the world because of their intuitive meaning.

There are many ways to determine the health or state of water-related ecosystems and indeed many countries and regions have formal programmes to do so (e.g. European Water Framework Directive, Australian River Health Programme, South African River Health Programme, USA National Rivers and Stream Assessment, Mekong River Commission Ecological Health Monitoring etc). Most of these programmes are based on the *response* of the ecosystem to *drivers* of change. Thus, for example, by assessing the state of the macroinvertebrates in the ecosystem, this may give an indication of the state of all of the drivers that impact on the macroinvertebrates such as the water quality and quantity, the flow regime, the impact of anthropogenic use etc.

This sub-indicator method does not prescribe any one particular method for measurement of the health of water-related ecosystems because most of the existing methods are based on local ecological conditions that are not applicable at a global level. Also, the methods appropriate, for example, to palustrine wetlands, rivers and mangroves, etc. are all different and cannot be used interchangeably between different ecosystems. In order to make it possible to utilise these varied methods, this sub-indicator requires that for whichever method is used, the measurement of the present situation needs to be normalised by comparing to the "natural" reference condition as a percentage of change.

4. Steps for progressive monitoring

There are certain components of monitoring this 6.6.1 indicator that are more necessary in order to understand the overall status of water-related ecosystems than others. Table 2 illustrates the steps for "progressive monitoring" that provides the order of priority by which monitoring should be implemented. Countries should at a minimum implement Level 1 and should use these aggregated data to provide the 6.6.1 score at a global level. With increasing capacity countries should include monitoring of Steps 2-6. This data can also be uploaded to the global database, where the intention is that it should be used for national management of water-related ecosystems to ensure that the objectives of Target 6.6 are achieved, however these data are not used to calculate the score for Indicator 6.6.1.

Table 2 The steps for progressive monitoring, indicating the order of priority for monitoring of the sub-indicators for 6.6.1. NOTE that 1 is high priority and 6 low priority. Only Step 1 forms part of the global report.

Steps	Monitoring activity	Detail	Units of measurement
Step 1 represents the basic Indicator 6.6.1 used for Global Reporting			
1	Change in the spatial extent of surface water-related ecosystems	Each ecosystem type is assessed using a different method. Earth Observation methods are used where possible and require ground-based verification.	% change in area (km^2) from SDG baseline reference condition
1	Change in quantity of water stored in rivers and open water bodies	Change in the flow of rivers/estuaries, the volume of storage in lakes and artificial reservoirs.	% change in the volume of flow (Mm^3) from the natural reference condition. % change in volume (Mm^3) of water storage in lakes from the natural reference condition.
1	Change in quality of water in rivers and open water bodies	The quality of water in all ecosystems is a key driver of ecosystem change. This indicator is monitored as part of Target 6.3.2 and is linked here.	% change in water quality from the natural reference condition
The steps below are additional to the 6.6.1 basic indicator and are for reporting at a National level, not for Global Reporting.			
2	Ground based interpretation of ecosystem extent changes identified by Earth Observation	This activity adds value to the assessment of extent done at Step 1. Those water-related ecosystem that are identified by Earth Observation to have significantly changed are assessed at ground-level in order to determine the nature and cause of the change.	% change in area (km^2) from reference condition
3	Change in quality and quantity of	Quality and quantity characterise different aquifers and should be mapped. The quantity of water is represented by the depth to the groundwater table	% change in water quality and quantity from natural

	groundwater aquifers		
4	Ground based evaluation of ecosystem extent and also classification of wetland type	Delineation of ecosystem extent using ground-based survey. The advantage of this approach is that it allows classification of wetland type based on hydrogeomorphic or vegetation characteristics and assessment of the extent of wetland type. These techniques are used for priority ecosystems where more information is needed than can be provided by EO.	% change in area (km^2) from reference condition
5	Change in health or state of ecosystem health	Each ecosystem type is assessed using different methods e.g. benthic macroinvertebrates or fish in rivers or vegetation on a floodplain. Results need to be normalised as a percentage change from natural reference condition.	% change of biological indicator from natural reference condition

5. Data

5.1 Sources of data, Spatial and Temporal Collection

The collection of data is possible through the collaboration of international and national institutions (UNEP (GEMS Water); UNEP-WCMC; Biodiversity Indicators Partnership; Ramsar Convention; Convention on Biological Diversity; Convention to Combat Desertification; GEO/GEOSS, NASA, GRDC, etc), which provide the global networks required. Country agencies responsible for water resources and environmental management will play a role at a National level, and will be supported by industry, NGOs, civic associations and any others who collect the relevant data. For example Ramsar Parties will be required to report (for each COP, every 3 years, starting in 2017) on the extent in km^2 of the total wetlands surface. Table 3 provides useful global contacts for assistance and possibly data provision.

The data for this indicator need to represent *the percentage of change in extent of water-related ecosystems over time*. In order to do this, data are generally collected at a local, even site scale, from where it can be aggregated up to represent the situation for an ecosystem, or a sub-basin, or a complete basin or for the political boundary of a country. This indicator method does not prescribe the intensity of the monitoring that should be undertaken by a country. Clearly a substantial coverage of the water-related ecosystems in a country, both in terms of the spatial but also the temporal coverage, will allow for better management of those ecosystems. At a minimum, countries should monitor this indicator for each river basin, and then this data should be aggregated to cover the entire country. Note that the aggregation of data to represent a country is not area-weighted.

The objectives of SDG monitoring are long-term thus the SDG monitoring programme needs to focus on long-term change. However, natural (and unnatural) short-term and transient changes in the extent of water-related ecosystems do occur and are important aspects of the ecosystem and thus for management of the ecosystem at a local level. Data collection may thus be frequent (ranging from daily for stream-flow to seasonal and annual for other variables) but interpretation of change will need to be done considering longer time-frames.

The SDG reporting period of four years is short for documentation of a meaningful change in extent of most ecosystems, but as repeated monitoring cycles develop into a long-term time-series of data, this information will become useful. Valid changes should be apparent by the end of the 2030 SDG Agenda and more so beyond that date. Details are given for the spatial and temporal coverage appropriate for each sub-indicator below.

Table 3 International web sites for water-related ecosystems data and guidance

Inventory	Source
RAMSAR Convention on Wetlands	http://ramsar.org
WET Index resources	https://www.bipindicators.net/indicators/wetland-extent-trends-index
IUCN	www.waterandnature.org
Aquastat	http://www.fao.org/nr/water/aquastat/data/query/index.html?lang=en
Global wetlands	http://www.globwetland.org/ and more recent www.globwetland-africa.org
Global Lakes and Wetlands Database	http://www.worldwildlife.org/pages/global-lakes-and-wetlands-database Global surface water https://global-surface-water.appspot.com/ and CIFOR SWAMP (for tropics and subtropics) http://www.cifor.org/global-wetlands/.
Earth obs for wetlands	http://swos-service.eu/
World Water	http://worldwater.org/water-data/
WMO Hydrological Observing System	http://www.wmo.int/pages/prog/hwrp/chy/whos/
FAO Water	http://www.fao.org/nr/water/infores_databases.html
World Bank - Water Home	http://www.worldbank.org/en/topic/water
UNEP Live	http://uneplive.unep.org/ - the repository for SDG data
UNEP – GEMStat/Water	http://gemstat.org/ , http://www.unep.org/gemswater/
Global runoff	http://www.bafg.de/GRDC/EN/Home/homepage_node.html
Rivers & Lakes and Hydroweb (from LEGOS)	http://www.legos.obs-mip.fr/en/soa/hydrologie/hydroweb/) inland surface water levels from satellite altimetry.
River flows – there are many models that are being developed	WaterGAP2/3; CLM; DBH; DLEM; H08; JULES-TUC; JULES-UOE; LPJmL; Mac-PDM.09; MATSIRO; MPI-HM; ORCHIDEE; PCR-GLOBWB; SiBUC; SWBM; VIC
Global groundwater	http://www.un-igrac.org/global-groundwater-information-system-ggis
Global environmental flows	http://waterdata.iwmi.org/Applications/Global_Assessment_Environmental_Water_Requirements_Scarcity/

Data collection for spatial extent of water-related ecosystems

It is intended that the National reports to the Ramsar Convention will provide important data for SDG reporting. Country offices responsible for Ramsar reporting will in most cases be the main custodians of these data.

Earth Observation (remote sensing) – images and data describing the location and spatial extent of most water-related ecosystems are freely available at down to 10m resolution, which needs to be interpreted in order to determine ecosystem extent. This technology provides extensive (global) and almost continuous data and information and can be used globally or at a national or sub-national level. The costs of the data may be high to gather initially, but for users of the data is generally free of charge from the international space agencies. However there will be costs associated with the interpretation of the data at a country level. In addition, some ground based verification of Earth Observation (i.e. ground truthing) data is necessary to ensure valid results.

EO images are collected by the space agencies at regular (sub-monthly) frequency, thus assessments can be made as frequently as is appropriate for the ecosystem and country situation. Because of the natural seasonal cycles of wet-dry that occur in most parts, sufficient data needs to be gathered to cover at least the extremes of the wet and dry periods. However cloud cover may obscure the land and obstruct the collection of data (something that will soon be rectified by the new generation satellites), so care needs to be taken in generating seasonal estimates of extent. More frequent monitoring and assessment will indicate the change during the year and over multiple years but it is important that seasonal and temporary changes do not lead to false conclusions of the overall trend in ecosystems extent.

Ground-based surveys of spatial extent are used where ecosystems are local and suited to direct survey and should be carried out at appropriate intervals in order to verify the EO data but also to collect more detailed information. They are especially useful in that the characteristics and health of the ecosystem can be assessed at the same time. The approach used should be cognisant of seasonal and temporary changes in extent so that long-term changes are reported, for example indicators such as soil morphology should be used to indicate extent as this is not influenced by sporadic wetness. By their very nature, ground-based surveys will be done in-country by stakeholders in that country, generally by National agencies but in some cases by scientists in research organisations and agencies such as WWF etc.

Analysis of both EO and ground-based data can be carried out once in four years which would provide information that can be used for local management and submitted as the SDG report as well.

Data collection for quantity of water in ecosystems

In most countries it is government offices charged with the responsibility to monitor water resources that would maintain this data. There are also global assessments and repositories of river flow data. For example the Global Runoff Database at GRDC (http://www.bafg.de/GRDC/EN/Home/homepage_node.html) is a unique collection of river discharge data collected at daily or monthly intervals from more than 9,000 stations in 160 countries. This adds up to around 370,000 station-years with an average record length of 41 years. HydroWeb (LEGOS) is a database of water levels using altimetry (EO method), and changes to groundwater table/shallow aquifers are done by the Grace mission (NASA). There is also the Global Groundwater Information System (GGIS) of IGRAC which is part of UNESCO (http://www.un-igrac.org/global-groundwater-information-system-ggis).

Streamflow / discharge in rivers and estuaries: The volume or quantity of water in a river can and does change as the river flows downhill through its catchment or basin. The minimum monitoring effort would be to locate a flow measuring site at the exit from all significant basins. In addition, monitoring at the exit from all major tributaries adds a substantial level of information. Where there is a local impact on stream flow due to human influence, then it is recommended to monitor flow upstream and downstream of these areas so that the overall situation can be managed. This data can be aggregated to the basin and country level for SDG reporting.

The quantity of water in a river changes rapidly in response to rainfall, thus monitoring needs to be carried out at an appropriate frequency. Data on river flow should ideally be collected daily and this data used to determine the long-term trend. The quantity of water in estuaries may be significantly influenced by tidal inflows, thus this indicator is limited to the freshwater inflows to the estuary from the upstream river.

Streamflow can either be modelled based on rainfall and the prevailing land-use, or it can be directly measured in the river. Monitoring of the streamflow or discharge of rivers has been in place for decades in most countries and has generally involved the location and monitoring of streamflow stations at strategic points within a basin. These may be constructed gauging stations (weirs) or alternately the natural channel is “rated” so that a simple measure of depth can be used to calculate the flow.

Collection of streamflow data generates statistics that describe the volume of water in a river over time. This may include the total volume per year, the deviation between high and low flow, and the distribution of flow over the course of the year. All of these aspects are necessary to understand streamflow and its relationship to the ecosystem, however for the monitoring of long-term sustainability an annual statistic would suffice. At a national level, more detailed annual statistics may be effectively used.

The approach here may thus be either one of the two below, or a combination of both:

1. Direct monitoring of the flow in rivers and statistical interpretation of the change in flow from the “natural” reference condition. It is recommended that the mean flow statistic be used for these estimates although local circumstances may demand that an alternative statistic be used, but this should be consistently used in that situation. In this approach it may be necessary to model the “natural” flow if suitable historical flow data are not available. A five year rolling mean (of the most recent past i.e. the “present”) is used to smooth short-term variability.
2. Modelling the change in flow using one of the global models that make use of climate and land cover, amongst other data, to determine both the natural flow and also the present situation. In some countries these or similar models are developed for the local situation and such data may soon be globally available. These models should be calibrated using real measured data. Stream-flow data from models, especially global models, requires that a great deal of data is incorporated into the models in order to update them. Accordingly this data may be more than a year old before the model can be used to produce information for reporting. This poses a challenge for SDG reporting which will be done at four yearly intervals, in which case the results produced will have to be clearly date stamped.

The data are used to determine the change in the amount of water in rivers and estuaries over time, making use of a reference which is as close to “natural” as possible.

Volume in open water (lakes and reservoirs): It is not possible to monitor the quantity or volume of water in all water bodies, large and small, as there are simply too many of them (unless EO becomes capable at this role). This effort should be reserved for significant water bodies (countries will need to determine which are significant). Volumes of natural water bodies which are not subject to rapid withdrawals should be monitored at least at the extremes of the dry and wet seasons (water quantities can vary over time due to seasonal and wet/dry cycles, which should not be allowed to obscure the long-term changes). Volumes of significant artificial reservoirs subject to intensive management, should be monitored at least monthly.

The volume of water in lakes and man-made reservoirs is monitored using either Earth Observation to measure open water surface area and water surface height (above sea level), or ground-based surveys to measure area, surface level and bathymetric depth. The indicator is calculated using a combination of surface area and maximum depth or, for improved results, the contours of the lake bottom. Once the relationship between surface water height and volume is established, then measurement becomes a simple affair.

It is important that data on change of natural lakes should be kept separate from reservoir volumes as increases in the latter do not represent a holistic move towards sustainability. Interpretation of volumes collected from the monitoring of man-made reservoirs is confounded by the rapid changes induced by management practises, which may have no connection to long-term environmental change. Determining the long-term trends divorced from rapid operational changes may be difficult, however, the volumes of water stored in reservoirs may be substantial and these quantities need to be included in estimations of overall catchment storage and the changes over time.

The data are used to determine the change in the extent (quantity of water) in open water bodies over time, making use of a reference which is ideally as close to "natural" as possible. In the case of reservoirs, this would be the full supply level.

Groundwater depth / volume: Storage of groundwater is difficult to measure as in large parts of the world the aquifers containing groundwater have not been adequately mapped and/or characterised. However, in many parts of the world groundwater is the most important water resource and it is therefore crucial to be included in this Indicator. The challenge in setting up monitoring is the location of the boreholes (expensive to construct) and whether these adequately represent the total groundwater situation for an area. An estimation of the extent of the groundwater and the geographical boundaries of aquifers needs to be developed over time, and the number and location of boreholes suitably established. This will need to be done at a National and local level and should be designed to ensure that the data produced is of value to National and local governance.

The volume of water stored in aquifers has to be estimated from the aerial extent of aquifers, their saturated thickness and storativity / storage coefficient. Changes in volume of groundwater can be inferred from changes in groundwater levels which is traditionally monitored using boreholes. These data are used to determine the change in the amount of water in groundwater over time, making use of a reference which is ideally as close to "natural" as possible.

Groundwater levels change as a result of changes in groundwater recharge (affected by climate conditions, and land use) and by anthropogenic removals from the system (groundwater abstraction). Seasonal and wet/dry cycle influences need to be understood and hence monthly monitoring is optimal, but collection at least twice per year, in the wet and dry seasons, is necessary. Analysis of the results may be done less frequently to satisfy SDG reporting requirements.

Data collection for quality of water in ecosystems

Data on water quality will be copied from the 6.3.2 monitoring programme ensuring that the data are converted to represent the percentage change from natural. See Section 7.3.

Data collection for ecosystem health

In most situations this data will need to be collected at a National level where responsibility is often shared between water and environment departments. Some countries already have long-term monitoring programmes for these sub-indicators but where not, then one-off surveys can be undertaken. There are some promising sources of Earth Observation data, but none yet that are suitable for SDG monitoring of this sub-indicator.

Ecosystem health monitoring procedures are generally site-based i.e. data are collected by field visits to a site of interest. They provide a direct measure of the state or health of water-related ecosystems. With careful interpretation these results may be extrapolated to a larger area if there are no additional human influences, and in this way data can be reproduced for longer reaches of river length. The location of sites may be upstream and/or downstream of the location of human induced stress, which then provides information on the extent of change due to that human influence which in turn facilitates better management. Aggregation of this data to a basin level may be misleading where local ecosystem impacts are masked by basin scale data.

Natural ecosystems change over the seasons as part of their natural cycles so monitoring of ecosystem health can yield different results in these different seasons. While in some situations monitoring during the wet season can give spurious results due to the inundation of habitats, equally monitoring in the dry season may give spurious results in an ephemeral system. Careful consideration thus needs to be given to the appropriate frequency and also time of year for sampling, which should be selected to ensure the objective of monitoring the change in ecosystem health over time is reached. Monitoring at a regular time of the year, in some situations just before the onset of the wet season often provides the most revealing results. In cases where monitoring procedures are complex and also where the response time of the ecosystem to changes in the drivers is very slow, less frequent surveys of five yearly or even less frequently may be appropriate. An example of this would be riparian vegetation which generally changes slowly and will continue to respond to a hydrological change for decades.

5.2 Setting or Quantifying Targets

The immediate target is that by 2020 information from monitoring the indicators for 6.6.1 should guide countries to manage, protect and restore these ecosystems, in keeping with the Aichi Biodiversity Targets of the Convention of Biological Diversity which set out a number of objectives for ecosystem management which are to be achieved by 2020. There are three Aichi Biodiversity Targets that are of relevance here:

- **Aichi Target 5: By 2020, the rate of loss of all natural habitats, including forests, is at least halved and where feasible brought close to zero, and degradation and fragmentation is significantly reduced**. Two of the recommended and possible indicators are “Trends in extent of selected biomes, ecosystems and habitats” and “Trends in condition and vulnerability of ecosystems”. These indicators are addressed within Goal 6 by Sub-indicators 6.6.1.a and 6.6.1.d.
- **Aichi Target 14: By 2020, ecosystems that provide essential services, including services related to water, and contribute to health, livelihoods and well-being, are restored and safeguarded, taking into account the needs of women, indigenous and local communities, and the poor and vulnerable**. One of the recommended and possible indicators is “Trends in proportion of total freshwater resources used”. This indicator is addressed within Goal 6 by Sub-indicator 6.6.1.b. as well as Indicator 6.4.1 and 6.4.2.
- **Aichi Target 15: By 2020, ecosystem resilience and the contribution of biodiversity to carbon stocks have been enhanced, through conservation and restoration, including restoration of at least 15 per cent of degraded ecosystems, thereby contributing to climate change mitigation and adaptation and to combating desertification**. One of the recommended and possible indicators is “Status and trends in extent and condition of habitats that provide carbon storage”. This indicator is addressed within Goal 6 by Sub-indicators 6.6.1.a and 6.6.1.d.

That the setting of targets or objectives for water-related ecosystems extent has become a global priority, is documented by Davidson (2014) who noted that globally wetland conversion and loss is by as much as 87% since the beginning of the 18th century; wetland loss was up to 71% in the 20th Century alone (Gardiner et al., 2015) and Dixon et al (2016) showed a 30% loss in the years 1970-2008. The fate of the world's remaining wetlands is thus very uncertain, and would be supported by society making clear decisions on how much loss is acceptable. This is just the situation for one of the sub-indicators, and it is likely that all of the others are in a similar parlous state. The Millennium Ecosystems Assessment report (MEA, 2005) noted that "the use of two ecosystem services—capture fisheries and fresh water—is now well beyond levels that can be sustained even at current demands, much less future ones". There are many similar perspectives describing the plight of water-related ecosystems over the globe. Thus the setting of management targets or objectives for water-related ecosystems extent has become a global priority.

While the SDG process sets out to monitor the percentage change in water-related ecosystems extent over time, it will be incumbent on countries to actually set Targets for this change, to determine what is an acceptable change and when and how management intervention should be introduced. Clearly it is unreasonable for any country to simply accept a continual decline in the state of its water-related ecosystems as that continual decline must inevitably lead to a collapse in the services provided by those ecosystems.

Setting of a target for the extent of water-related ecosystems at a national level is seemingly simple but in fact is a complex issue. Some countries such as the USA, Canada, and South Africa have set a "no net loss" policy for the spatial extent of wetlands, requiring that any loss of wetland resources needs to be compensated by rehabilitation of a greater number of resources. The Ramsar Convention on Wetlands also refers in its COP11 (Doc 24) to the Limits of Acceptable Change, again prompting society to make a decision on how much change, or how much degradation, is acceptable. Reports are available from South Africa that document detailed target setting (Resource Quality Objectives) for wetland spatial extent as well as for ecosystem health, river flow and water quality (DWS, 2014).

To assist countries to set targets and objectives for management, table 4 provides a way of considering all ecosystem data relative to the "natural" or reference condition (see definitions in section 3.1). Each method, each sub-indicator, and indeed the overall 6.6.1 indicator, can be considered in terms of an Ecological Class, which describes the extent of deviation from the natural or reference condition and which in turn can be considered in terms of the implications for the sustainable use of that ecosystem. These categories and the divisions between them are purely subjective, but provide an aid to management. They can be applied to any assessment method used for this 6.6.1 Indicator, or for the sub-indicators or for the 6.6.1 result overall. Thus these Ecological Categories can be used to set targets, e.g. a catchment management agency may prescribe that a particular river flow should be in a B Ecological Class in order to sustain necessary ecosystem services to society.

Annexure 1 contains tables for each sub-indicator that reflect possible global and national targets. These targets should be considered as temporary and as recommendations, and a process of setting properly derived targets should become part of the global and national agenda.

Table 4 Ecological Classes that show the relation of the ecosystem to its natural condition (see section 3.1 for a description of "natural" and reference). These ecological categories can be applied to any assessment method used for this 6.6.1 indicator, or for the 6.6.1 result overall (based on the method of Kleynhans and Louw, 2008).

Ecological Class	Description	Deviation from natural*	Sustainability
A	Unmodified natural	0-10%	Highly sustainable

B	Largely natural with insignificant changes to the ecosystem.	11-20%	Highly sustainable
C	Moderately modified. Loss and change of natural habitat and biota have occurred but the basic ecosystem functions are unchanged.	21-40%	Locally sustainable but threatens global stability
D	Largely modified. A large change to habitat, biota and ecosystem functions has occurred. The ecosystem continues to provide services of value but is no longer representative of the natural situation.	41-60%	Border-line sustainability. Corrective actions are strongly recommended
E	Seriously modified. The loss of habitat, biota and ecosystem function is extensive and most services are lost to society.	61-100%	Unsustainable Urgent renewal is required

6. COMPUTATION OF THE INDICATOR

6.1 DATA REQUIREMENTS TO COMPUTE EACH SUB-INDICATOR

The 6.6.1 Indicator requires that all data are reported as the percentage of change from the Natural Reference condition (or alternative as stipulated). The percentage change of each method or sub-indicator needs to be calculated separately before aggregation into the total 6.6.1 indicator value.

Percentage of change is calculated for each sub-indicator (*i*) as follows:

$$C\%_i = (CPD/R)*100$$

$$CPD = |R - PD|$$

Where:

C% = Percentage change of the Present Day condition score from the Reference condition for sub-indicator *i*.

CPD = Change of Present Day condition score from the Reference condition

R = Sub-indicator score set for the Reference Condition (section 3.1)

PD = Sub-indicator score obtained for the Present Day Condition

6.1.1 DATA AGGREGATION TO COMPUTE THE INDICATOR

There is a single indicator for Target 6.6, which is described as the "Change in the extent of water-related ecosystems over time" and only a single quantitative measure should be used to indicate the status of this Target. As illustrated in Figures 1 and 2, the 6.6.1 indicator for Global reporting comprises aggregated data from a number of Sub-indicators 6.1.1.a (spatial extent), 6.6.1.b (quantity of surface water) and 6.6.1.c (quality of surface water). Additional data that is important and indeed essential for understanding of Target 6.6, which sets out to protect water-related ecosystems, for example quantity and quality of groundwater, and ecosystem health, should also be collected for use at a National level but does not form part of the 6.6.1 aggregated score. Thus, while it is necessary to aggregate the data from 6.6.1.a-c into a single figure, at a National level management responses should be based on the separate sub-indicators, including 6.6.1.d, which provide more meaningful data and information (see Figures 2&3).

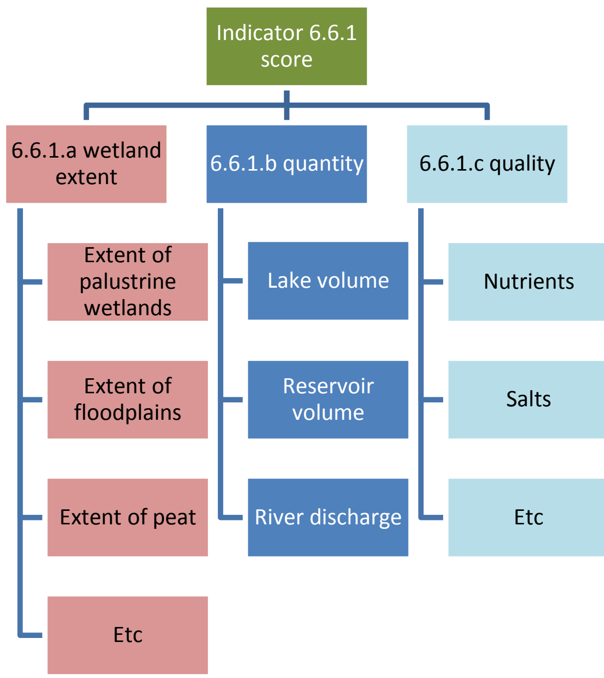

Figure 2 Example showing how sub-indicators are aggregated into the basic 6.6.1 score

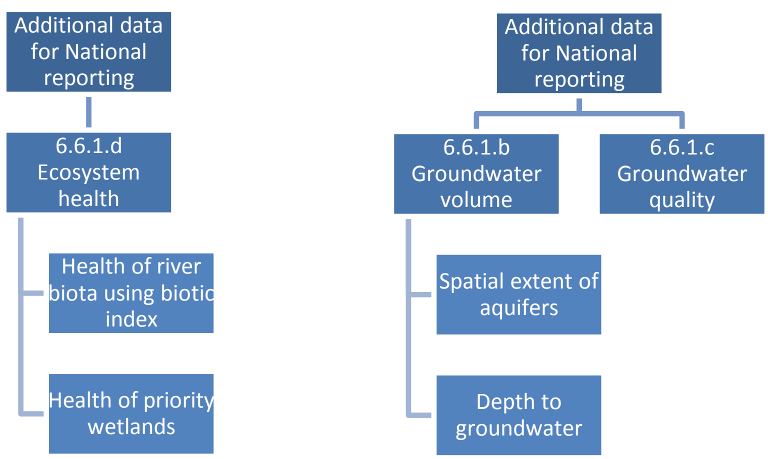

Figure 3 Example showing additional data collected at National level but not included in the 6.6.1 computation. These additional data provide important perspective at a National level to assist with ecosystem restoration.

The aggregation of results into a single figure is inevitably problematic as the final result may hide a number of important results that would otherwise be clearly evident. For example, one of the sub-indicators may be in a critically poor state, yet the averaging effect of the other sub-indicators may mask this result and hence warning about this critical state could go unnoticed. Also, in certain parts of the world some of the sub-indicators may be important while others are not, but this nuance would be lost when using insensitive aggregation. In another situation, where corrective actions are being implemented, one sub-indicator may improve, whilst another continues deteriorating, giving a false impression of stability. So, while each of the sub-indicators should not be of equal importance in contributing to the final result, for the sake of simplicity in reporting on the SDGs it is necessary to aggregate these sub-indicator scores, while the separate sub-indicator data will always be available for local reporting and should be used in this way.

The generally accepted solution during aggregation is to use a weighting system, where the different indicators are treated differently and those of greater importance are given greater weight. However weighting is risky when used for a global initiative such as the SDGs as it may be subjectively biased and can engender distrust in the result. Based on the precedent set by the likes of sustainability indicators already using the arithmetic approach, (CWSI, WPI, WSI etc), for the SDG 6.6.1 indicator method it is recommended that equal weighting be applied, while using the arithmetic aggregation approach. The results per sub-indicator are then averaged as different number of sub-indicators will be used at different locations. It is however possible that weighting can be adjusted for national level use by using expert judgement that involves water resource decision makers. The relevant formula is presented below (see a demonstration example in Table 5):

$$C\% = (\sum_{i=1}^{n} w_i \; S_i)/n$$

C% represents the mean aggregated percentage change of all sub-indicators,

n is the number of sub-indicators to be aggregated,

S_i is the sub-indicator for indicator *i* and

w_i is the weight of sub-indicator *i*.

Note that the results of this calculation suggest that 100% change would be the most undesirable from a management perspective showing a total loss of water-related ecosystems, and 0% would imply that no change had taken place from natural.

6.1.2 The direction of percentage of change

This indicator reports results as a percentage of change away from a reference condition, and is based on the principle that any change away from a natural reference condition is a negative change. While acknowledging that the best situation for society is not always the natural reference condition, the natural condition does however present a starting point for development which has a maximum potentiality. The 6.6.1 method thus uses the absolute number change from the reference, not discriminating whether an increase or decrease. For example there will be those situations where the ecosystem presently has more water than was the case for the natural ecosystem e.g. a river is inundated with excessive water. This may be damaging to the ecosystem and is thus also regarded as a negative. The same situation applies in the case of some indicators where a greater score is actually a negative ecosystem situation e.g. the depth to the groundwater.

Table 5: Example calculation of the mean score for Indicator 6.6.1 incorporating results of various sub-indicators (using fictitious data in this example). Note that no weighting has been used in the formula.

Sub-indicator	Sub-indicator components (for example)	Ref. val.	Pres. day val.	Change over time	% change	% change of sub-indic. over time
Change in the spatial extent of water-related ecosystems	Change in extent of palustrine wetlands	656 km^2	439 km^2	217 km^2	33	30.5
	Change in extent of floodplain wetlands	110 km^2	79 km^2	31 km^2	28	
Change in the quantity of water in water-related ecosystems	Change in river flow	108 Mm^3	93 Mm^3	15 Mm^3	14	8.5
	Change in lake volume	1121 Mm^3	1087 Mm^3	34 km^2	3	
Change in quality of water	Change in water quality index from Target 6.3.2	100	86.4	13.6	13.6	13.6
TOTAL change for 6.6.1						17.5

7. Step-by-step data collection and computation of the indicator

7.1 Sub-indicator 6.6.1.a: Spatial extent of water-related ecosystems

7.1.1 Step 1 – Select ecosystems to monitor spatial extent

Each of the water-related ecosystems listed below is important in its own right and is recommended for measurement of the spatial change in extent over time. However each will involve different means of measurement. Given the local and national situation, countries should make a decision on which ecosystems are important and may be subject to change, and prioritise these for monitoring.

- **Vegetated wetlands (swamps, swamp forests, marshes, peatlands, paddies and mangroves)**
- **Open water (lakes, ponds)**
- **Rivers and estuaries (only if subject to substantial changes in area)**

7.1.2 Step 2 – Use earth observation data to quantify the change in extent of water-related ecosystems over time

The Ramsar Convention on Wetlands has for several years managed a wetland inventory which is based on spatial extent. While there has been no regulation by Ramsar of the methods that are used, EO (Earth Observation) methods provide an important start although there is no single approach which can be considered the best for mapping wetland extent from Earth Observation data. The approaches tend to vary according to objectives and scale of the study, the sensor used and environmental settings. Generally wetland inventories should be carried out using a combination of multi-temporal optical- and radar derived indicators, combining the advantages of both sensors (minimizing their disadvantages). The higher frequency of observation stemming from the combined use of optical and radar acquisitions will contribute to the monitoring of seasonal dynamics which will help to provide a more accurate delineation of wetland areas.

New EO capabilities are soon to cause a paradigm shift in terms of securing a robust and reliable long-term operational capacity that will support users for decades to come. For example the Sentinel missions of the European Copernicus initiative will, amongst others, provide long-term access to enhanced high spatial resolution radar and optical observations opening a new era for the systematic mapping, assessment and monitoring of water-related ecosystems worldwide:

- The C-band radar of the Sentinel 1 mission will provide all-weather and day-and-night imagery that will be extremely useful for monitoring wetland ecosystems in cloudy conditions, and to follow the changes of surface waters.
- The footprint of Sentinel 2 along with its short revisit time and its systematic acquisition policy will allow rapid changes in ecosystems to be precisely monitored and is ideally suited to monitor sensitive habitats such as wetlands.
- The Sentinel 2 mission will ideally complement the longest continuously acquired collection of optical observations at high resolution made by the family of Landsat imagers (operational since 1972) which are freely accessible and offer a unique opportunity to assess the historical conditions of wetlands worldwide.

The Copernicus and also the Landsat (NASA) data policies, with their full and open data access for all users worldwide, are important incentives that will facilitate the uptake of EO technologies by the wetland community and in this case, for monitoring of SDG Indicator 6.6.1. A critical presumption in this regard is the ability of users to access data and algorithms. It is widely recognized the raw data required to produce national inventories can be challenging for many users to handle which is why there is an increased focus on the development of online platforms where users can process data on cloud computing platforms. A 2016 publication by Pekel et al (2016) provides a good example of determination of the extent of surface water bodies that can be used. Some of the global initiatives are listed below:

International Projects that provide guidance to using EO for monitoring of water-related ecosystems:

- **GlobWetlands ll** – initiated to assist with the establishment of GWOS but also included the production of a number of wetland related geo-information maps and indicators. http://www.globwetland.org/
- **GlobWetlands Africa** – a new project designed to demonstrate (using Africa as the pilot study) how to make the best use of satellite-based information on wetland extent and condition for better measuring the ecological state of wetlands and hence their capacity to support biodiversity and provide ecosystem services. One of the key deliverables under GlobWetland Africa will be the development of an open-source software toolbox with the full end-to-end image processing capabilities for producing large-scale inventories of wetland extent needed by national agencies for their standard monitoring and reporting requirements, including those under Target 6.6. of the SDGs. The web-page for GlobWetland Africa is www.globwetland-africa.org
- **Global Mangrove Watch** – URL: http://www.eorc.jaxa.jp/ALOS/en/kyoto/mangrovewatch.htm - intends to help safeguard against mangrove forest degradation, by revealing the locations as well as the causes of mangrove degradation.
- **Mediterranean Wetlands Initiative** - (http://medwet.org/) **and its Mediterranean Wetlands Observatory** (http://medwet.org/medwet/observatory/ **and** http://www.medwetlands-obs.org/**)** - to

ensure the effective conservation of the functions and values of wetlands and the sustainable use of their resources and services, and monitor them, within the framework of the Ramsar Convention..

- **GWOS (Global Wetlands Observing System)** – a global initiative collecting information on the status and values of wetlands and water in a way that can support policy processes and decision making at various geographic scales – will describe status and trends over time.
- **Global System Water Project** - GRaND and with socio-economic data Ciesin GRaND,
- **Global Landcover (open water) Facility** - http://glcf.umd.edu/data/watercover/
- **SWOS - "Satellite-based Wetland Observation Service"** - http://swos-service.eu/ SWOS has the objective to develop a monitoring and information service for wetland ecosystems for management.
- **Global Surface Water Project** using the Google Earth Engine.

7.1.3 Step 3 – Ground-based survey to verify earth observation data

There is always a possibility that the data and information provided by EO may be erroneous, especially when it comes to categorisation of wetland type and condition. A procedure for the verification of this data is necessary to compliment the use of EO data.

How much ground-based or *in situ* survey is necessary for verification of EO data? This decision is coupled to the confidence in the output, the more verification that is done, the greater the confidence in the final product. However it is useful to establish an optimum that could be used generally at a national level.

Ground-based verification (or ground truthing) will need to be done initially with some rigor, to ensure that the EO data that are being collected is sufficiently accurate. Ground-truthing of remotely sensed data can be done using Google Earth images or field surveys or a combination of both. The degree of verification will be related to the acceptable risk and the purpose to which the results will be put. Ultimately this will be a process whereby the amount of effort that is put into ground-based verification will be adjusted depending on the accuracy of the EO data. Where the data are accurate, and ground-based verification is concurring with the EO data, then a diminishing number or extent of water-related ecosystems will need to be verified.

Ground-based verification is essentially the comparison of the perimeter of the wetland using the ground-based survey method (see the section below) and the perimeter derived from EO. Where the perimeters are inconsistent, then it is worth evaluating the reason for the difference as care must be taken to ensure that the criteria for delineation are the same (e.g. each method uses a different measure of wetness). Adjustments to the results may be generally extended to other ecosystems that have not been verified, but so called "priority ecosystems" and also "hot spots" should always be verified on the ground.

7.1.4 Step 4 - Ground based survey to evaluate the change in extent of water-related ecosystems

Before the advent of EO technologies, ground-based delineation of the extent of especially palustrine (vegetation dominated) wetlands had become common practise. These methods continue to be appropriate for this SDG Indicator monitoring. However their limitation is a practical one, in that all of the wetlands in a basin or country cannot possibly be measured using these techniques.

Methods that may be used include monitoring the extent of soils reflecting saturation with water (such as USDA, 2010) and vegetation patterns reflecting the boundaries of the wetland (Environmental Laboratory, 1987). An assessment of the most appropriate method to be used is necessary as different approaches will suit different ecosystems. This wetland delineation procedure requires a detailed ground-based assessment of the perimeter of the wetland and capture of this onto GIS.

Part of this step will also involve the interpretation of EO data by ground-based survey. Hence, where EO has identified a substantial change in the extent of a wetland, a ground-based survey would help not only to verify that conclusion, but also it can be used to assess the nature of the change e.g. whether the hydro-geomorphological characteristics or the wetland type or the distribution of different vegetation types has changed. This information will provide substantial additional information compared to a simple extent assessment.

Other types of water-related ecosystems (mangroves, forests, deserts etc.) require a similar process driven by the nature of the ecosystem, which essentially involves mapping the perimeter of the relevant water-related ecosystem. These ecosystems are generally less complex when compared to palustrine wetlands as the defining features are more obvious and much easier to map (e.g. tree margins, lake perimeter etc.).

It is recommended that these methods be reserved for those situations where priority wetlands need to be managed and where greater accuracy is needed for management purposes.

7.1.5 Step 5 – Management of data on the percentage of change in the spatial extent of water-related ecosystems

Spatial data gathered from Earth Observation are too voluminous for countries to collect and manage themselves, hence the data can reside with the space agencies until needed. However once downscaled, then the data may be stored and used by countries. Data collected from ground-based surveys should be managed by the appropriate country agencies. Storage of long-term data showing the spatial extent of water-related ecosystems will allow for better comparison over time.

7.1.6 Step 6 – Calculation of the percentage of change in the spatial extent of water-related ecosystems

A requirement of the Target 6.6 indicator is to compare the change in extent of water-related ecosystems over time, i.e. in this case, to compare the Present Day spatial extent to an appropriate Reference spatial extent derived from an earlier date. In Section 3, definitions of the appropriate Reference Conditions are provided, including a notice that the SDG Baseline Reference is appropriate for estimation of the change in spatial extent, even though this means that prior losses will not be included. The reason for this is that, at the time of writing, there is no reliable dataset (EO images etc.) that could be used to describe the historical spatial extent of water-related ecosystems at a global level. It is anticipated, however, that such a global dataset may become available in which case the change in spatial extent at a global level will be re-calculated.

Country reporting will thus be as follows:

1. At the outset of the SDG programme, it will not be possible to estimate a change in extent over time, which will only be possible once repeat surveys have been carried out post 2017. For initial reporting (2017 or soonest thereafter) countries will only report on actual spatial extent which will become the SDG Baseline.
2. Each subsequent reporting will include a change in extent over time. This will become more robust as time passes.

3. Countries are encouraged to establish their own Historical Reference Condition to determine a more realistic change in spatial extent using the oldest reliable datasets that are available. This change in extent should be used for management and in particular the restoration of water-related ecosystems at a National level.

There are several ways that change in spatial extent over time can be computed. One way is using the existing Living Planet Index methodology for data collection and analysis (http://www.livingplanetindex.org/home/index). This consists of a number of stages including harvesting of time series data, codification and database entry, aggregation into sub-indices to reduce sampling bias, and further aggregation to create sub-global (ecologically and regionally specific) and global indices. The methodology is flexible to incorporating improved sources of information and data and thus provides a more comprehensive assessment of trends. This approach was demonstrated in the Wetland Extent Trends (WET) Index (Dixon et al, 2016).

Another approach was tested by the GlobWetland ll project and will be demonstrated by the GlobWetland Africa project which intends to develop an online toolbox for this purpose. Recent advances in the use of GIS to estimate changes in the extent of water-related ecosystems may also prove useful where spatial coverages of various ecosystem boundaries is used to calculate change over time, however it is important that a consistent coverage is used to evaluate change e.g. a buffer zone around wetlands may be included or excluded; soil moisture may provide a different extent to vegetation extent etc. It is recommended that one of the above approaches should be adopted for calculation of the percentage change in the spatial extent.

7.2 Sub-indicator 6.6.1.b: Quantity of water in water-related ecosystems

7.2.1 Step 1 – Select ecosystems to monitor the quantity of water in water-related ecosystems

Changes in quantity of water should be evaluated for each of the ecosystems below:

- **Rivers**
- **Open water (lakes and reservoirs)**
- **Groundwater**

7.2.2 Step 2 – Collection of data on water quantity

The flow of water in a river is best represented by collection of data from a flow measurement station, with long term (>50 years) being ideal. As an alternative the flow in a river may be modelled from one of the many available models that use climate and land-use data amongst others to estimate both natural and present day flows.

The primary interest is in the volume of water in the river. The deviation of mean (or median) annual flow from a natural reference flow, expressed as a %, is the basis of this indicator, using a five year moving average of the present day to smooth short-term fluctuations.

Volumes of lentic systems such as ponds, lakes and even reservoirs, are normally calculated by using the depth of the water-body multiplied by the surface area and multiplied by a factor to account for the sloping bottom (see below). More detailed bathymetric measurements would yield a more accurate volume measurement, which information is usually available for man-made reservoirs. Normally the measurement of the bottom of the water-body need only take place infrequently (decadal) unless there are major inputs of sediment. Earth Observation is then an ideal tool to measure the water surface height, which it can do to within 10cm accuracy, and also the surface water area.

Groundwater levels and thus volumes change as a result of changes in groundwater recharge (affected by climate conditions, and land use) and by anthropogenic removals from the system (groundwater abstraction). Storage of groundwater is difficult to measure as in large parts of the world the aquifers containing groundwater have not been adequately mapped and/or characterised. However, in many parts of the world groundwater is the most important water resource and it is therefore crucial to be included in this Indicator. The volume of water stored in aquifers has to be estimated from the aerial extent of aquifers, their saturated thickness and storativity / storage coefficient.

Changes in the quantity of groundwater as represented by changes in the depth to the water table below the surface is traditionally monitored using boreholes. However, the challenge is in the location of the boreholes (expensive to construct) and whether these adequately represent the total groundwater situation for an area. An estimation of the extent of the groundwater and the geographical boundaries of aquifers needs to be developed over time, and the number and location of boreholes suitably established. This will need to be done at a National and local level and should be designed to ensure that the data produced are of value to National and local governance.

Monitoring of groundwater (depth to the water table for unconfined aquifers / depth of groundwater pressure levels for confined aquifers) needs to be based on the location of important groundwater aquifers. The number of boreholes that need to be monitored cannot be prescribed because the distribution of groundwater can be variable depending on the location and characteristics of aquifers. It is recommended that sufficient boreholes to characterise the area should be monitored, with the capacity of the country being a factor in deciding how many would best represent the area. It is highly recommended that data should be taken from observation boreholes / monitoring boreholes (these are boreholes which are not equipped with pumps). Data from used (pumped) boreholes should be avoided. In case a pumped borehole needs to be used for measurements than it is crucial to allow for a sufficiently long recovery period in which the borehole is not used so that the groundwater level in the borehole can stabilise prior to the measurement.

Point measurements of changes in the depth of groundwater levels need to be integrated over the whole surface area of an aquifer (or if individual aquifers are unknown: over the surface area of a region/country). This can be done by means of interpolation (various interpolation techniques are available and the suitable technique depends on the amount and type of available data). Groundwater models can also be used to 'interpolate' point measurements and models have the advantage that they will calculated gradients based on aquifer characteristics, rather than on statistical methods only. IGRAC (UNESCO centre on groundwater) maintains a database on groundwater levels worldwide (Global Groundwater Monitoring Network), which is all available through the Global Groundwater Information System (GGIS)[1].

Seasonal and wet/dry cycle influences need to be filtered out for long term SDG monitoring and hence monthly monitoring is optimal, but at least twice per year is necessary to capture both the high groundwater levels (usually during the wet season) and the low groundwater levels (usually at the end of the dry season). Seasonal change information is also important for understanding the pressures on groundwater i.e. the seasons where there is most abstraction from the groundwater. Ideally the Natural Reference should be used for comparison. At a minimum, a

[1] https://www.un-igrac.org/global-groundwater-information-system-ggis

baseline of 2016/7 should be determined. These data are used to determine the change in the amount of water in groundwater over time, making use of a reference which is ideally as close to "natural" as possible.

7.2.3 Step 3 – Management of data on water quantity

Data collected on stream-flow, lake volume and groundwater depth will be stored by the appropriate National agency. Data on climate, land-use etc. on a global level are collated then stored by the developers of the global models for analysis of water resources. There are global databases available for these as well as at a national level. For example meteorological data are often kept by national met agencies and weather bureaus and often there is a national land cover map.

7.2.4 Step 4 – Calculation of the percentage of change of water quantity

Stream-flow

The calculation of the percentage of change of water quantity in rivers from their natural condition can be done in one of two ways, or in combination.

- Direct measurement of flow using stream-flow monitoring stations. It is recommended that the mean annual flow statistic be used with a five year rolling mean (of the most recent past i.e. the "present") to smooth short-term variability. In this approach it may be necessary to model the "natural" flow if suitable historical flow data are not available. Comparison of change is the relationship between the two.
- Using local and global models that make use of climate and land cover, amongst other data, to determine both the natural flow and also the present situation. Comparison of change is again the relationship between the two.

As noted earlier, for local management purposes knowledge of intra-annual variability in flow may be important for management of the ecosystem with environmental flows (E-flows) being one way that this is documented. This sub-indicator however is based on the simple bulk change over time.

There is a move to model water availability using global datasets. In the future it may be possible to access these results in an updated form from a global portal, but at present these models are not fully operational to provide this service. Guidance to these models is given in the Guideline document (Dickens et al, 2016). As an example, the WaterGAP global model is a distributed model that calculates the daily water balance in each grid cell (10 – 50 km grid sizes) either globally or for a country, a basin or a sub-basin. This is based on a time series of climate and gives consideration to physiographic information like slope, soil type etc. The climate input includes precipitation, air temperature and solar radiation. For each grid cell, runoff is generated and routed by a global drainage direction map to the catchment outlet.

Where a greater level of understanding is required that includes the seasonal variation in flow, the Water Depletion model (Brauman et al 2016) takes the WaterGAP outputs and adds in those quantities of water which are ecologically significant and thus goes beyond simple change in flow. For this reason this model provides additional understanding beyond what is needed for SDG reporting, yet is important for river management. So for example, while measurement of mean flow may suggest that a river is not substantially depleted, a single month in the dry season may be critically depleted thus having ecological and sustainability implications. This model will take that into account. One of the attractive aspects of this metric is that governments could use their own locally-derived data and water budgets/models to produce a more accurate rendering of this water depletion metric.

Lake and reservoir volume

This component documents the percentage change in the volume of water relative to the Natural Reference. The natural volume of a water body can be calculated by using records of the depth in historical times or by determination of the best possible reference depth. At a minimum the baseline should be set at 2017 but where possible an older reference should be calculated. For artificial reservoirs the reference used is the full supply level and the volume at the time of construction.

A recommended formula for calculation of lake volume is given by Taube (2000).

$$V = 0.5H*(A_1 + A_2)$$

Where: V = volume of water;

H = difference in depth between two successive depth contours;

A_1 = area of the lake within the outer depth contour being considered;

A_2 = area of the lake within the inner contour line under consideration.

The procedure consists of determining the volumes of successive layers of water (frustums), and then summing these volumes to obtain the total volume of the lake.

Groundwater volume

This method is based on estimating volumes of groundwater stored in aquifers, which can then be related to governance boundaries. Thus for the reference condition an estimation will need to be made of the total available volumes of groundwater in a country/region. Once that has been established then changes in volume can be calculated based on changes in groundwater levels.

Changes in (national) groundwater storage should be given as a fraction of the reference (national) groundwater storage, for a country with *n* aquifers considered:

$$Indicator\ 6.6.1.b\ (\%) = \frac{\Delta V_{aq1} + \Delta V_{aq2} + \cdots + \Delta V_{aqn}}{V_{aq1}^{ref} + V_{aq2}^{ref} + \cdots + V_{aqn}^{ref}} \times 100$$

Where:

$$\Delta V = A \times \Delta h \times S$$

$$V^{ref} = A \times b \times S$$

Where:

A: aquifer areal extent

b: average saturated aquifer thickness

S: Storativity / storage coefficient (see below)

Δh: average change in hydraulic head (average change in groundwater level measured in monitoring wells relative to the natural reference)

Ref: reference situation (either the Natural Reference or the baseline year 2016/2017)

S: Storativity (also known as Storage Coefficient) is the volume of water released from storage per unit decline in hydraulic head in the aquifer, per unit area of the aquifer. *S* is a dimensionless quantity and ranges between 0 and the effective porosity of the aquifer.

If local data on storativity values of the aquifers are available then these should be used. If no such data are available than values from literature can be used (see table 6). The storativity of a confined aquifer typically ranges from 5×10^{-5} to 5×10^{-3}; in unconfined aquifers, storativity typically ranges from 0.1 to 0.3. Table 6 presents representative values for various aquifer materials. For confined aquifers, storativity is calculated by multiplying the aquifer thickness (b) with the aquifer's Specific Storage (S_S).

Table 6 Generic representative storativity values for different aquifer materials.

Material	Storativity	
Unconfined aquifers		
Gravel, coarse	0.21	
Gravel, medium	0.24	
Gravel, fine	0.28	
Sand, coarse	0.30	
Sand, medium	0.32	
Sand, fine	0.33	
Silt	0.20	
Clay	0.60	
Sandstone, fine grained	0.21	
Sandstone, medium grained	0.27	
Limestone	0.14	
Dune sand	0.38	
Loess	0.18	
Peat	0.44	
Schist	0.26	
Siltstone	0.12	
Till, predominantly silt	0.60	
Till, predominantly sand	0.16	
Till, predominantly gravel	0.16	
Tuff	0.21	
Confined aquifers	**min**	**max**
Plastic clay	$b \times 2.56 \times 10^{-3}$	$b \times 2.03 \times 10^{-2}$
Stiff clay	$b \times 1.28 \times 10^{-3}$	$b \times 2.56 \times 10^{-3}$
Medium hard clay	$b \times 9.19 \times 10^{-4}$	$b \times 1.28 \times 10^{-3}$
Loose sand	$b \times 4.92 \times 10^{-4}$	$b \times 1.02 \times 10^{-3}$
Dense sand	$b \times 1.28 \times 10^{-4}$	$b \times 2.03 \times 10^{-4}$
Dense sandy gravel	$b \times 4.92 \times 10^{-5}$	$b \times 1.02 \times 10^{-4}$
Fissured rock	$b \times 3.28 \times 10^{-6}$	$b \times 6.89 \times 10^{-5}$
Sound rock	$< b \times 3.28 \times 10^{-6}$	
	where b = aquifer thickness	

Long term monitoring of groundwater requires updating the calculation above with the most recent measurement of change in groundwater depth. The annual mean based on monthly or at least seasonal measurements will be used so as to smooth seasonal changes. Understanding the seasonal and other short term changes is a necessary aspect of management of groundwater and but should be considered as part of the local management of the groundwater and is not included in global reporting.

Countries are encouraged to monitor changing groundwater depth at a scale that is appropriate for them. This is best done at an aquifer and then aggregated to the country scale.

Interpretation of the result needs to be carefully done, as the percentage change can be misleading. Thus, for a shallow well, a 50% change in depth would not be important as it may represent only a few meters. However, a 50% change in depth of an already deep well could make the water inaccessible to users and the surface ecosystem.

There will be few places where a real "natural" reference depth can be established, in which case there will need to be a careful setting of the most appropriate reference condition. As a minimum, the baseline of 2017 will be used as a future reference and it will only be over time that the real trajectory of change will become clear.

7.3 Sub-indicator 6.6.1.c: The quality of water in water-related ecosystems

The procedure for monitoring of water quality is documented in the SDG Indicator 6.3.2 and is not repeated here. However the format of the water quality data needs to conform to the principle of this 6.6.1 indicator i.e. it needs to represent a percentage change over time. Accordingly, the same data that are produced for the 6.3.2 indicator needs to be converted in the following way.

The 6.3.2 indicator is "Proportion of bodies of water with good ambient water quality". An assumption is made for the 6.6.1 indicator method that if 100% of the water bodies are in "good" condition that would approximate a natural reference condition.

Thus a 6.3.2 score of 65% (i.e. proportion of bodies of water with good ambient water quality), would equal a 6.6.1 score of 35% (i.e. a percentage change from the natural/good condition).

7.4 Sub-indicator 6.6.1.d: Health or state of water-related ecosystems

7.4.1 Step 1 – Select ecosystems to monitor the health of water-related ecosystems

It is necessary to prioritise which ecosystems are to be assessed. The list below are most suited to health evaluation but countries should consider what is meaningful for them. Monitoring of the health of river ecosystems is globally the most established approach but other ecosystems should be considered.

- **Rivers and estuaries**
- **Open water (lakes)**
- **Vegetated wetlands – suggest limit to priority wetlands only**

7.4.2 Step 2 – Select appropriate methods for monitoring the health of each type of water-related ecosystem

Ground-based methods used for monitoring health of water-related ecosystems are many and varied, are generally locally developed and applicable, and certainly are different for each type of ecosystem. These differences are appropriate because these methods are based on the components of that ecosystem, thus for example, the invertebrates that would be monitored in a river *vs* a palustrine wetland would be different, the means for collecting them would be different and the calculation of ecosystem health also very different. Furthermore, a method that may work in a northern temperate zone would be different from the method appropriate for a tropical zone. And lastly, within a region there may be methods that make use of the benthic aquatic invertebrates for example, which will produce complimentary but different results to an assessment based on fish or riparian vegetation. Most of these methods use “response” indicators i.e. they indicate the response of the ecosystem to any change, not necessarily measured, of the drivers of the ecosystem. Thus the response indicator uses the biodiversity, the abundance and the condition of fauna and flora to indicate the integrated impact of a range of driver components such as the flow or quality of water in the ecosystem.

It is recommended that those methods suited to the country of application should be used. Example sources of information include:

- US EPA - https://www.epa.gov/national-aquatic-resource-surveys/nrsa
- Australian River Assessment System AusRivAS - http://ausrivas.ewater.org.au/
- South African River Health Programme - https://www.dwa.gov.za/IWQS/rhp/index.html
- European Water Framework Directive - http://www.wfduk.org/resources/category/biological-standard-methods-201

  Ramsar Convention on Wetlands http://www.ramsar.org/resources/ramsar-handbooks-and-manual

Possible methods to measure this sub-indicator of change in the health of water-related ecosystems could include:

- **Habitat Integrity** – this only represents the habitat without the final inclusion of the biological response. Several such methods exist including Tiner (2002) for the USA which considers the possibility of Earth Observation techniques to assess watershed habitats.
- **Fish condition indices** – there are many such indices which include either or all of the community and population statistics, species diversity, size classes and physiological health of individual fish. Examples of fish indices include the Index of Biotic Integrity of the USA (USEPA, 2007) and Kleynhans (2007).
- **Benthic macroinvertebrate indices** –invertebrates have been used in most countries as a form of biomonitoring of rivers. The advantage of these indices is that the invertebrates are common and wide-spread, easy to collect, and the different families/species indicate the quality of the water and habitat availability. Examples include the SASS index (Dickens and Graham, 2002) for South Africa, SIGNAL (Chessman, 2003) for Australia, and Wright et al, (2000) with the RIVPACS model for the UK.
- **Diatoms** are used in a wide range of water ecosystems to indicate water quality conditions. The advantage of such methods is that diatoms are generally ubiquitous and common, with limited global diversity. The different diatom species respond differently to different perturbations, and thus are ideally suited to being indicators of water quality. The negative is that the method requires a high level of skill to implement. Examples include CEN (2003) for Europe, and Taylor et al (2007).
- **Vegetation** is a key aspect of most water-related ecosystems. Vegetation provides both a response to the prevailing drivers of change, and is also a driver that impacts on other biota that will subsequently develop in the system. Vegetation monitoring is most useful for those ecosystem types where it is a dominant part of the ecosystem e.g. palustrine wetlands, floodplains etc. It is less useful for lentic systems such as lakes although it does reflect variable surface levels in reservoirs. For rivers the vegetation tells a story of the ecosystem that is only a partial reflection of the health or state of the instream river, as riparian vegetation is subject to a number of non-river related stresses mostly related to land-based activities. There are many different riparian vegetation methods but there is considerable variation in the approach of these methods. Possibly the most useful for this monitoring are those that categorise the vegetation into classes illustrating vegetation cover, density, recruitment etc.
- **Wetland health indices** – there are several indices that have been developed that utilize the vegetation and other hydrogeomorphic characteristics of wetlands (generally of palustrine wetlands) to determine

wetland health. The Water Research Commission in South Africa (www.wrc.org.za) has published extensively on these.

- **Lake health indices** – traditionally these have been based on a simple Secchi depth measurement which indicates the clarity of the water, and also the measurement of chlorophyll concentrations which indicate the extent of algal growth and thus of eutrophication. There are also more complex indicators of lake health.
- **Groundwater ecosystems** – below ground ecosystems are poorly understood and are not appropriate for SDG monitoring although they may be locally important. The most relevant ecological indicator for groundwater is the interaction that the groundwater has with the surface water. This includes the provision of baseflow into the river especially during the dry season and also the extent of groundwater that is close to the surface and accessible to tree or other plant roots.

7.4.3 Step 2 – Implement methods to monitor health of water-related ecosystems

The guidelines for each method need to be followed during implementation. Any method used should have been subject to peer review in the literature, or should be the standard method of an implementing agent or authority.

Frequency of monitoring will differ depending on the ecosystem and the component of the ecosystem being monitored. Thus for example, benthic macroinvertebrates in a river may change with some rapidity (hours to be destroyed, weeks/months to recover) in response to changing water conditions. Fish would take longer to recover following a major incident (months to years) while riparian vegetation would generally reflect major changes over several years. However for SDG monitoring, the aim is not to detect short-term changes that may occur as a result of short-term impacts on the ecosystem, but rather longer term trends. Hence the frequency will be determined to obtain statistical reliability, to “smooth out” seasonal and other sources of variability, and to determine the long term trend.

7.4.4 Step 3 – Management of data on the health of water-related ecosystems

Most of the data on ecosystem health will be collected and stored at a local or national level. It is important that the raw data on ecosystems be kept to facilitate interrogation for meaningful management.

7.4.5 Step 4 – Calculation of the percentage of change of ecosystem health relative to natural

It is noted above that there are many different methods for assessment of the health of water-related ecosystems. As can be expected most of these produce a final quantifiable result which is seldom comparable to any other method. In order to change this to a situation suitable for SDG reporting, it is required that each method used be adapted so that the final score produced is presented as a percentage relative to natural where 100% equals the natural condition and 0% equals a situation where the services provided by the ecosystem are negligible (see Table 4).

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9. Annex 1: Summary recommendations for each sub-indicator

9.1 Indicator 6.6.1: Overall summary

	Global	National
Water-related ecosystems to be monitored	Vegetated wetlands (swamps, marshes, peatlands, forest wetlands, mangroves); Open water (rivers and estuaries, lakes and reservoirs); Groundwater aquifers.	
Reference condition – against which present observed data are compared as change over time	The Natural Reference is used as the foundation for this indicator. However for spatial extent these data are not available and the SDG baseline reference will be used.	Natural conditions are used as the reference for national level monitoring. Each country should use the oldest possible date to describe changes in spatial extent.
Sources of data	Multiple sources of data for each of the Sub-indicators	Countries will provide aggregated and disaggregated data for each of the sub-indicators below (making allowance for Progressive Monitoring or the Monitoring Ladder)
Spatial scale	A single value representing each country.	Data on water-related ecosystems should be available for significant river basins and ecosystems. These disaggregated data are important at a country level and may be aggregated for global reporting.
Frequency of survey	Once for each SDG reporting period.	
Method of analysis	Aggregation of the percentage of change for each sub-indicator to provide a single figure for Indicator 6.6.1.	
Targets	The global aspiration of Target 6.6 is to protect and restore ecosystems (in agreement with Aichi Biodiversity Targets 5,14,15) thus there should be no further degradation of water-related ecosystems from the 2017 baseline.	Countries may set their own targets but ideally there should be no further degradation of water-related ecosystems from the 2017 baseline. As in the Aichi Biodiversity Target 5, where countries have economic needs then degradation rates should be at least halved.

9.2 Sub-indicator 6.6.1.a: Spatial extent - summary

	Global	National
Water-related ecosystems to be monitored	Vegetated wetlands (swamps, marshes, peatlands, forest wetlands, mangroves); Open water (rivers and estuaries, lakes and reservoirs).	
Reference condition – against which present observed data are compared as change over time	Linking to the Ramsar Convention, 2017 data will be used as a Baseline Reference. In the future, a Historical Reference will hopefully become available at a global level at which time change in extent will be re-calculated.	Countries should determine their own Historical Reference based on the oldest data that are available to them. This should be used for management and setting of targets and will allow for a more useful comparison than the 2017 baseline. These data should also be used for restoration activities.

Sources of data	Many global agencies including GlobWetlands http://www.globwetland.org/ SWOS http://swos-service.eu/ Ramsar Convention http://www.ramsar.org/ Note that different ecosystems may require different EO systems for monitoring	Global web sites are listed. National Earth Observation monitoring if available. Analysis and digitisation of local aerial photographs, maps. Ground based surveys
Spatial scale	Global coverage via satellite	Global coverage. Local survey of important basins. Local survey of priority ecosystems (e.g. Ramsar sites)
Frequency of survey	Four yearly	Ideal is a bi-annual survey to show extremes of wet and dry season. Minimum requirement is to synchronise with SDG reporting requirements (4 yearly).
Method for analysis	The Wetland Extent Trend (WET) Index (Dixon et al., 2016) using observed data, EO data, and spatial analysis of extent over time.	Use the WET Index (Dixon et al, 2016) making use of EO and other data, or use GIS to estimate change in area over time.
Presentation of data	Aggregated to represent each country as a single figure showing percentage change over time.	Data of reference and present situation should be recorded at the finest possible resolution (10-30m) in GIS and use internally for basin management. Reporting of percentage change over time should be based on disaggregated data for basins, sub-basins or for priority wetlands, but without losing access to disaggregated data.
Targets	No-net-loss as promoted by the Ramsar Convention. Aichi Biodiversity Target 5 aims to reduce rate of loss almost to zero.	Many countries have set a no-net-loss policy as promoted by Ramsar. Countries may set an alternative target but this must be justified, and as described by Aichi Biodiversity Target 5, the rate of loss should at least be halved but ideally approach zero. Aichi Biodiversity Target 15 aims to restore 15% of degraded ecosystems that store carbon (wetlands, peat).

9.3 Sub-indicator 6.6.1.b: Quantity of water - summary

	Global	National
Water-related ecosystems to be monitored	Open water (rivers and estuaries, lakes and reservoirs). Groundwater aquifers (NOTE not as ecosystems but storage only)	
Reference condition – against which present observed data are compared as change over time	Natural reference condition either measured or modelled.	Natural reference for stream flow and water volumes determined either from observed data or modelled. Natural reference for lake volume. Full supply is the reference for artificial reservoirs. Groundwater Natural reference or baseline 2017.

Sources of data	Global hydrological models and databases e.g. Global Runoff Database at GRDC2 . Aggregation of country data. Global data on open water (lakes) from Global System Water Project (GRaND) and others. Groundwater data from the GRACE3 mission (NASA) and LEGOS (Hydroweb) as well as Global Groundwater Information System (GGIS) of IGRAC.	Flow gauging stations and field measurements of lake volume and groundwater depth.
Spatial scale	Single figure representing the country result.	All major rivers, tributaries, lakes and aquifers should be independently monitored. The minimum should be to monitor flows at the discharge from significant rivers, but upstream detail is useful for management. Lakes – only significant water bodies should be assessed, as determined by countries. Groundwater – all major aquifers should be monitored and sufficient data collected to characterise the country.
Frequency of survey	Global models are updated infrequently but should be done prior to each SDG reporting period.	Rivers should be monitored daily. Open water bodies should be surveyed to demonstrate seasonal changes (extremes of the seasons). Artificial reservoirs should be monitored at least monthly. Groundwater should be monitored monthly or at the extremes of the wet and dry season.
Method for analysis	Statistical analysis of quantity data to compare Natural reference to present day.	Streamflow – statistical comparison of mean (or median) flows from Natural reference to present day. A five year moving average should be used. Seasonal changes provide additional information where needed. Lake volume changes are estimated using water depth, bathymetric contours and surface water height. Statistical comparison of groundwater changes from Natural reference to present day. Seasonal changes provide additional information.
Presentation of data	Percentage of change over time from the Natural reference to the present day, of the quantity of water in aggregated ecosystems per country.	Percentage of change over time from the Natural reference to the present day, for each ecosystem of importance in the country.

[2] http://www.bafg.de/GRDC/EN/Home/homepage_node.html
[3] http://grace.jpl.nasa.gov/applications/groundwater/

Targets	The global ambition is to protect and restore ecosystems, thus water withdrawals should not damage the integrity of ecosystems. Aichi Biodiversity Target 5 promotes that habitat loss is reduced to zero (or at least to half), and Target 14 that essential ecosystems are restored and safeguarded.	Targets for quantities of water ideally should be established for each river and tributary, for lakes and groundwater, based on priorities in the basin and sub-basin. These should aim to protect the integrity of water-related ecosystems based on their environmental flow requirements. Aichi Biodiversity Targets also apply (5, 14)

9.4 Sub-indicator 6.6.1.d: Ecosystem health - summary[4]

	Global	**National**
Water-related ecosystems to be monitored	Vegetated wetlands (swamps, marshes, peatlands, forest wetlands, mangroves); Open water (rivers and estuaries, lakes and reservoirs).	
Reference condition – against which present observed data are compared as change over time	Natural reference condition i.e. a minimally disturbed category	Each ecosystem should independently be evaluated against the Natural reference condition.
Sources of data	Aggregation of country data.	Field surveys of ecosystem health.
Spatial scale		Significant ecosystems as determined by each country. The minimum would be a single data point to represent an entire ecosystem (e.g. a river or wetland) however at a country scale a finer scale is recommended to assess local ecosystem health issues.
Frequency of survey		Dependent on the ecosystem and the indicator, thus indicators based on invertebrates seasonally, but vegetation five-yearly.
Method for analysis	Aggregation of country data of all types.	There are multiple methods for several types of biota and habitat, the selection of which depends on the biodiversity of the local ecosystems and the resolution of results that is required.
Presentation of data	This data should be aggregated to represent each country.	Ecosystem health data should be converted to a percentage change from Natural reference to the present day. This should be done independently for each significant ecosystem in the country and then aggregated. Raw data should be retained.
Targets	The global ambition is to protect and restore ecosystems. Thus there should be no reduction of the 2017 baseline. Aichi	Targets for the health or state of ecosystems ideally should be established for key river, lakes and for priority wetlands based on priorities in the basin and sub-basin. The guideline presented in Section 5.2 may be used. Aichi Biodiversity Targets also apply (5, 14).

[4] For sub-indicator 6.6.1.C, kindly refer to the step-by-step methodological guide for SDG indicator 6.3.2

	Biodiversity Target 5 promotes that habitat loss is reduced to almost zero, and Target 14 that essential ecosystems are restored and safeguarded.	