NTNU

Project Memo

Overview of existing studies and concepts and suggestion of relevant biophysical indicators

Deliverable of SusWater WP2

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SUMMARY

The SusWater work packages (WP) 2 and 3 aim to identify methods and indicators that can describe multiple user interests in regulated Norwegian river basins, and that can be used further in a decision support framework in WP4.
This project note documents the review of existing concepts and potential biophysical indicators for WP2 in connection with the user interest that were surveyed by WP3 for the two case areas Hordaland and Sira-Kvina.
The results clearly illustrate the importance of the river hydro-morphology in combination with the discharge and aquatic vegetation as key parameters for most of the user interests, including for a number of outdoor activities in rivers. A better representation of hydrological conditions ("Flow indices"), hydromorphology (e.g. "River types") and riparian vegetation is therefore a pre-condition not only for a better description of the ecological status in water bodies, but also for the description of the potential for many other user interests in rivers, such as water sports or bathing. These "HYMO" aspects are currently addressed within the on-going HYMO-project and/or WP6 in SusWater.

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Appendix 7.4 is delivered as separate table.

1 Background

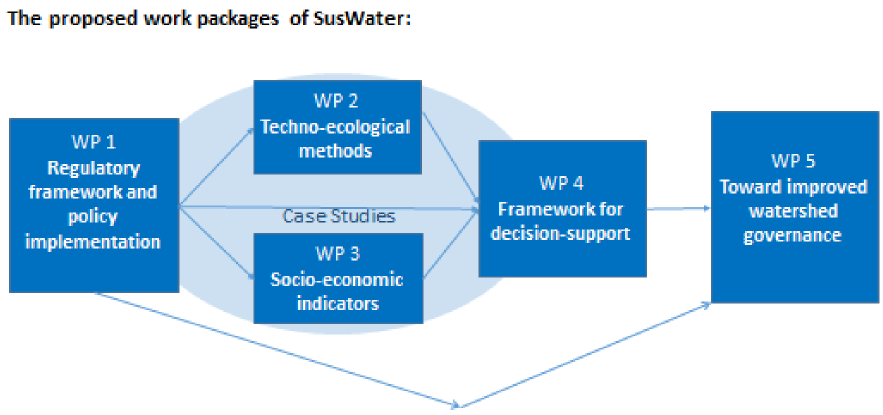

Figure 1-1: Work packages in Suswater.

The SusWater work packages (WP) 2 and 3 aim to identify methods and indicators that can describe multiple user interests in regulated Norwegian river basins, and that can be used further in a decision support framework in WP4.
This project note documents the review of existing concepts and potential techno-ecological (or better: biophysical) indicators for WP2.

2 Methods and data

The identification of techno-ecological indicators included the following main steps:

1) Review of relevant frameworks, concepts and studies related to biophysical indicators for rivers and lakes
2) Participation in case group user workshops and interviews organized by WP2, in order to get an overview of relevant user interests
3) Identification of physical key parameters that can be related to specific user interests
4) Review of relevant data which are commonly available for watershed administration processes
5) Suggestion of parameters / indicators that can be obtained from available data and used for the representation of specific user interests.

The complete list of relevant user interests in the SusWater case areas “Hordaland” and “Sira-Kvina” and related socio-economic indicators were identified by semi-structured interviews with stakeholders as part of WP3, led by Ingrid Nesheim. They are reported in separate project notes of WP3.

3 Review of existing studies and concepts

3.1 Definition of indicators

The term "indicator" can have several meanings, depending on the context. The glossary of the European Environmental Agency (EEA 2014) provides the following definition of "indicator":

> *"A parameter or a value derived from parameters that describe the state of the environment and its impact on human beings, ecosystems and materials, the pressures on the environment, the driving forces and the responses steering that system. An indicator has gone through a selection and/or aggregation process to enable it to steer action. "*

According to OECD (1993), the ideal indicator should have the following characteristics:

- Policy relevance and utility for users (e.g. provide a representative picture; be simple and easy to interpret; be responsive to changes)
- Analytical soundness (e.g. be theoretically well founded, be based on intern. standards)
- Measurability (readily available, or made available at reasonable cost; adequately documented; regularly updated)

3.2 Frameworks used for ecosystem service and sustainability assessments

A body of literature has developed on the quantification of the sustainability across different sectors. Usually, this literature promotes the idea of monitoring a range of sustainability indicators. Most of them are either very detailed, or they are policy oriented and aggregated for example on sector or country level (Fig 3-1).

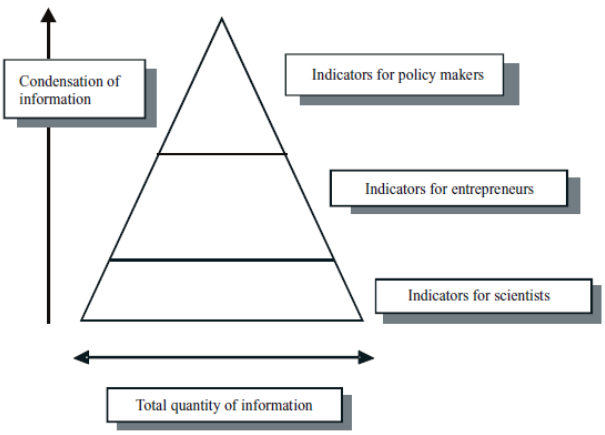

Fig. 3-1 Relationships between indicators. From Braat 1991, in Helming et al. 2008.

The following science-based valuation frameworks have been used for decision-making for land-use and related changes

- Ecosystem services (ESS) as applied in the Millenium Ecosystem Assessment
- Landscape functions (LF) identified through landscape ecology and
- Land use functions (LUF), a multifunctionality-based approach developed in the EU Integrated Project SENSOR

The ESS framework has been increasingly used and implemented, both in the EU and in Norway. A comprehensive report of a national expert panel (Lier-Hansen et al. 2013) assessed and valuated ecosystem services in Norway, based on a review of international and national studies.

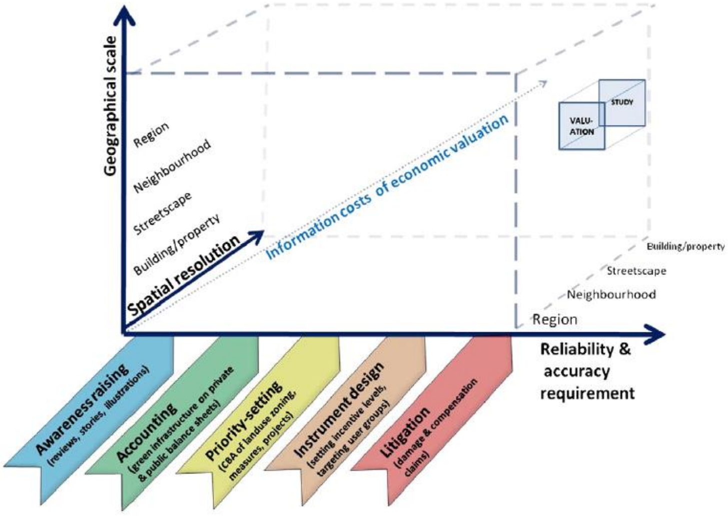

Figure 3-2: economic valuation of ESS in different urban planning contexts. From Gomez-Baggethun and Barton (2013).

Gomez-Baggethun and Barton (2013) presented an economic valuation of ESS in different urban planning contexts in Norway, hereby investigating important ESS in urban areas and underlying ecosystem functions and components (Figure 3-2).
Magnussen et al. (2015) investigated ESS for green structures in four Norwegian cities. One of their case areas was Ilabekken in Trondheim, i.e. an urban river. Here they identified the following ESS:
- Secure biodiversity
- Flood safety (“vannhåndtering”)
- Cleaning of water (maintain good water quality according to WFD)
- Recreation; mental and physical health
- Education and cognitive development
- Aesthetical values
- Local identity and cultural heritage

Large and Gilvear (2015) presented a methodology for reach-based ESS assement of the ESS functions using remote sensing data from Google Earth, hereby using reach scales between 500 m and 10 km (Table 3-1). A scoring system for individual and total ESS score on a 0-3 scale was derived, allowing to express the output in score per kilometer of river length.

A comparative review of the ESS, LUF and LF approaches suggested that the ESS were biased towards the environmental dimension of sustainability and best suited for long-term projections, whereas Landscape functions were aligned with the sustainability concept and met planning purposes, and LUF were a pragmatic way for stakeholder-driven sustainability assessment of land use changes (Schösser, Helming, and Wiggering 2010).

Table 3-1: ESS derived from river feature/attributes and land cover classes visible on Google Earth. From Large and Gilvear (2015).

Ecosystem service	Feature/attribute determined from *Google Earth*																		
	Sinuosity	Secondary channels	No. of tributaries	Active channel complexity	Slope	Valley side connectivity	River/river corridor ratio	Riparian/bank woodland	Floodplain habitat mosaic	Palaeochannels	Wetlands	Floodplain forest	Floodplain lakes	Agriculture	Woodland plantation	Urban	Embankments	Instability / naturalness	No. of features contributing to ecosystem service
Provisioning																			
Fisheries	■	■	■	■				■				■	■					■	8
Agricultural crops														■					1
Timber															■				1
Water supply			■								■		■					■	4
Regulating																			
Flood mitigation	■	■		■	■		■					■			■			■	8
Carbon sequestration										■	■	■	■		■			■	6
Water quality					■		■			■	■	■	■					■	7
Supporting																			
Biodiversity	■	■	■	■		■	■	■	■	■	■	■	■					■	13
Number of services provided by feature	3	3	3	3	2	1	3	2	1	3	4	5	5	1	3	0	0	6	

3.3 EEA indicators related to water

The EEA maintains a series of indicators (currently 137) that are designed to answer key policy questions and to support all phases of environmental policy making, from designing policy frameworks to setting targets, and from policy monitoring and evaluation to communicating to policy-makers and the public (EEA 2014). The selection of indicators was based on the OECD criteria for selecting environmental indicators (OECD 1993). The overall approach to indicators at the EEA is illustrated by the indicator eye and its three dimensions (see Figure 3-3). "The inner core (or CSI) comprises a small set of indicators, selected on the basis of their policy relevance, their regular updates and the quality of established or expected on-stream data flows. The outer core comprises regular indicators that fulfil minimum criteria as regards policy relevance and regular updates, and the stability and geographical scope of underpinning data sets. The third dimension comprises indicators of an irregular or even one-off character, developed by other organisations and used by the EEA in its assessment reports." (EEA 2014, p. 14).

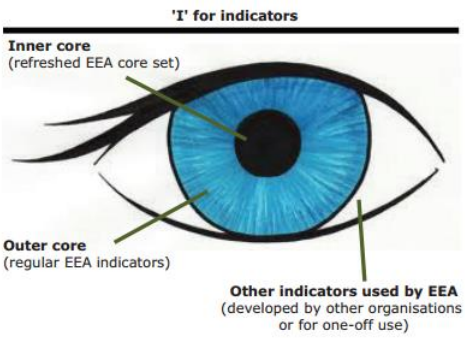

Figure 3-3: The EEA indicator eye. From EEA (2014).

The DPSIR framework (Drivers-Pressures-State-Impact-Response) is used by the EEA to help design assessments, select indicators and communicate results. The following themes are included by EEA: Air pollution, Biodiversity, Climate change, Energy, Environmental scenarios, Fisheries, Green economy, Household consumption, Land, Soil, Transport, and Waste Water. The EEA Water Indicators are provided in Table 3-2. Most EEA indicators are related to climate change. Some of them, such as "River flow", "River floods", "River flow drought" and "Water temperature", are also directly related to water bodies. For freshwater ecosystems, the following new indicators are under development:

- "trends in ecological status",
- "climate change impacts on water" (based on indicators 'river floods' and 'damages from weather and climate-related events') and
- "pressures on water" (based on indicators 'river flow drought', 'lake and river ice cover', 'agriculture: nitrogen balance' and 'pesticide risk")

Table 3-2: EEA Water indicators (EEA 2014). Indicator focus: for DIPSIR; indicator type: A = descriptive, C = efficiency

Indicator name	Indicator focus	Indicator type
Use of freshwater resources	P	A
Oxygen consuming substances in rivers	S	A
Nutrients in freshwater	S	A
Nutrients in transitional, coastal and marine waters	S	A
Bathing water quality	S	A
Chlorophyll in transitional, coastal and marine waters	S	A
Urban waste water treatment	R	A
Hazardous substances in marine organisms	P	A
Emission intensity of agriculture in Europe	P	C
Emission intensity of domestic sector in Europe	P	C
Emission intensity of manufacturing industry in Europe	P	C

The EEA hosts the indicator set developed under the Streamlining European Biodiversity Indicators (SEBI) process. A new EU Biodiversity strategy titled "Our life insurance, our natural capital: an EU biodiversity strategy to 2020" was adopted by the European Commission in May 2011 and provided a framework under which the EU could meet its own biodiversity objectives and its global commitments as a party to the Convention on Biological Diversity (CBD).

3.4 Parameters used within the WFD framework

The EU Water Framework Directive (WFD) requires that Member States differentiate the relevant surface water bodies with respect to type and that reference conditions are established for these types. The main purpose of typology is to enable type specific reference conditions to be defined which in turn are used as the anchor of the classification system. For each surface water category, the relevant surface water bodies within the river basin district shall be differentiated according to type. These types are those defined using either "system A" or "system B" (Annex II 1.1). The Nordic countries have preferred System "B", because it allowed a more free choice about how to designate types and type-specific conditions. Information about the WFD implementation in Norway can be found at:
www.vannportalen.no (methods for characteristic of water bodies, classification manuals, etc.)
http://vann-nett.no (maps and information sheets for selected water bodies and water districts)

Table 3-3: Overview of WFD typology factors, vann-nett codes and typology divisions for rivers and freshwater lakes in Norway. From Iversen & Sandøy (2015), translated.

Typology factor	Code	Divisions of each typology factor
Water category	R L	• River • Freshwater lake
Eco region (see map Figure 3.16)	E S W M N F	• Østlandet • Sørlandet • Vestlandet • Middle-Norway • Northern Norway (outer) • Northern Norway (inner)
Elevation above sea level (climate zone)	L M H	• Lowland: < 200 m asl (should not be used north of Saltfjellet) • Woodland: 200-800 m, or below the tree line • Highland: > 800 m asl., or above the tree line
Size of river - drainage area	1 2 3 4 5	• Small: <10km^2 • Medium: 10-100 km^2 • Medium to large: 100 – 1000 km^2 • Large: 1000-10 000 km^2 • Very large: > 10 000 km^2
Size of lakes – surface area	1 2 3 4	• Small: <0.5 km^2 • Medium: 0.5-5 km^2 • Large: 5-50 • Very large: > 50 km^2
Lime content, Alkalinity	1 2 3 4	• Very lime-deficient: Ca < 1mg/l, Alk < 0.05 meq/l • Lime-deficient: Ca = 1 - 4 mg/l, Alk = 0.05-0.2 meq/l • Moderate lime-rich: Ca > 4 - 20 mg/l, Alk 0.2-1 meq/l • Lime-rich: Ca > 20 mg/l, Alk > 1.0 meq/l
Organic content	4 1 2 3	• Very clear: Farge < 30 mg/l, TOC < 2 mg/l • Clear: Farge < 30 mg Pt/l, TOC 2 - 5 mg/l • Humic: Farge 30-90 mg Pt/l, TOC 5-15 mg/l • Very humic (rarely occuring): Farge >90 mg Pt/l,TOC >15 mg/l
Turbidity (only lowland water courses)	1 2 3	• Clear: STS < 10 mg/l (anorganic content at least 80%) • Glacier-affected: STS > 10 mg/l (anorganic content at least 80%) • Loam-affected: STS > 10 mg/l (anorganic content at least 80%)
Depth of lakes (mean depth)	1 2 3 0	• Very shallow: < 3m (if estimated: code = 4) • Shallow: 3-15 m (if estimated: code = 5) • Deep: > 15 m (if estimated: code = 6) • Unknown depth

Norwegian freshwater bodies are grouped into 6 ecoregions (Figure 3-4) depending on climate and biogeographic distribution patterns for various biological quality elements, such as fish or invertebrates. In particular fish has an immigration history that leads to a larger number of natural species in the ecoregions Østlandet and Øst-Finnmark than in Vestlanded and outer regions of Northern Norway (Lyche Solheim et al. 2004, Sandlund & Hesthagen 2011). The revised WFD typology (Table 3-3.) contains the obligatory WFD parameters (ecoregion, elevation, catchment size, Ca- and humic content as geological indicators) and information about the acid neutralising capacity (alkalinity) and mean depth of lakes as optional factors.

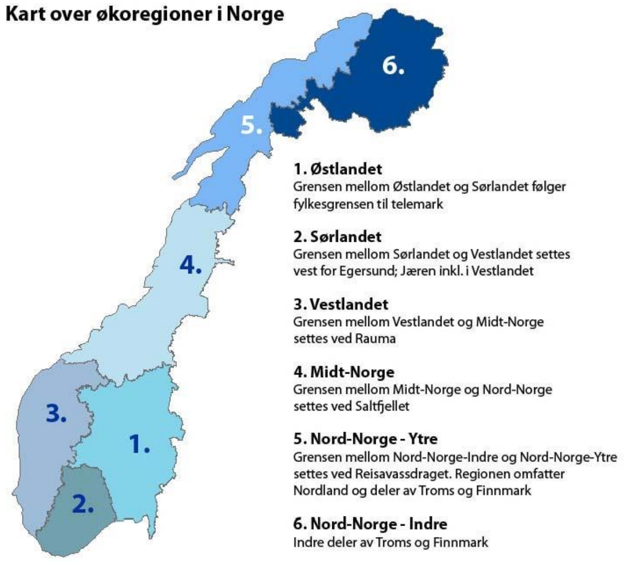

Figure 3-4: Freshwater eco regions in Norway. From Iversen and Sandøy (2015)

The following quality elements and indices/parameters are used for the classification of the ecological status in freshwater lakes and rivers (from Iversen and Sandøy 2015):

Table 3-4: WFD Quality elements in Norway (Iversen and Sandøy 2015).

Tabell 3.2 Innsjøer: Kvalitetselementer og indekser/parametere som det finnes klassegrenser for og relevante påvirkninger. Indeksene er nærmere beskrevet i kapittel 4.

Biologiske Kvalitetselementer	Parameter (indeks)	Påvirkning
Planteplankton	Klorofyll a (µg/l) Totalt algevolum (mg/l) Artssammensetning: PTI Cyanobakterier maksvolum (mg/l)	Eutrofiering
Vannplanter	Artssammensetning: TIc Artssammensetning: WIc	Eutrofiering Hydromorfologiske endringer: Vannstandsvariasjon
Bunnfauna	Artssammensetning: MultiClear, LAMI, Forsuringsindeks 1 Terskelindikatorer: Marflo, skjoldkreps, edelkreps	Forsuring Alle typer påvirkninger
Fisk	Abundans: WS-FBI Abundans: utbytte aure (CPUE) Abundans: bestandsnedgang (%) Artssammensetning: NEFI	Eutrofiering Forsuring Generell påvirkning Generell påvirkning

Fysisk-kjemiske Kvalitetselementer	Parameter (indeks)	Påvirkning
Næringssalter	Total fosfor (µg/l) Total nitrogen (µg/l) Siktedyp (m) Oksygen bunnvann (mg/l) Ammonium (NH4 + NH3) (mg/l)	Eutrofiering Eutrofiering Eutrofiering Eutrofiering / Organisk belastning Eutrofiering / Organisk belastning
Forsuringsparametere	pH ANC (µekv/l) LAL (labilt aluminium) (µg/l)	Forsuring
Miljøgifter (nasjonale spesifikke stoffer, for prioriterte stoffer, se kap. 9)	Konsentrasjon av kvantitativt betydelige miljøgifter (tungmetaller og organiske mikroforurensninger) som slippes ut i vannforekomsten	Miljøgiftpåvirkning
Hydromorfologiske kvalitetselementer	**Parameter (indeks)**	**Påvirkning**
Hydrologisk regime	Vannstandsvariasjoner: Reguleringshøyde (m)	Hydromorfologisk påvirkning: Oppdemming / nedtapping
Morfologi	Endringer i vanndekket areal	Hydromorfologisk påvirkning: Oppdemming / nedtapping

Tabell 3.3 Elver: Kvalitetselementer og indekser/parametere som det finnes klassegrenser for og relevante påvirkninger. Indeksene er nærmere beskrevet i kapittel 5.

Biologiske Kvalitetselementer	Parameter (indeks)	Påvirkning
Påvekstalger	Artssammensetning (PIT) Artssammensetning (AIP)	Eutrofiering Forsuring
Heterotrof begroing	Bakterier («Lammehaler») og sopp (dekningsgrad)	Organisk belastning
Virvelløse dyr	Artssammensetning (ASPT) Artssammensetning: RAMI, Forsuringsindeks 1, Forsuringsindeks 2 Terskelindikator: Elvemusling, edelkreps	Organisk belastning Forsuring Forsuring Alle typer påvirkninger
Fisk	Abundans	Generell påvirkning
Fysisk-kjemiske Kvalitetselementer	**Parameter (indeks)**	**Påvirkning**
Næringssalter	Total fosfor (µg/l) Total nitrogen (µg/l) Oksygen bunnvann (mg/l) Ammonium (NH4 + NH3) (mg/l)	Eutrofiering Eutrofiering Eutrofiering / Organisk belastning Eutrofiering / Organisk belastning
Forsuringsparametere	pH ANC (µekv/l) LAL (labilt aluminium) (µg/l)	Forsuring
Fysisk–kjemiske støtteparametre (nasjonale spesifikke stoffer, for prioriterte stoffer, se kap. 9)	Konsentrasjon av kvantitativt betydelige miljøgifter (tungmetaller og organiske mikroforurensninger) som slippes ut i vannforekomsten	Miljøgiftpåvirkning
Hydromorfologiske kvalitetselementer	**Parameter (indeks)**	**Påvirkning**
Hydrologisk regime	Vannstandsvariasjoner Vannføringsvariasjoner	Hydrologisk påvirkning (vannkraft)
Morfologi	Kontinuitet (vandringshindre) Endringer i vanndekket areal Struktur av kantsonen Struktur på elveleiet Substrattype	Morfologisk påvirkning (vannkraft, transport, landbruk, urbanisering)

3.5 Relevant EU projects

Table 3-5 provides an overview of recent EU projects that have developed frameworks or indicators which may be relevant for water course assessment.

Table 3-5: Overview of relevant EU projects

Project	Full name	Relevant findings
SENSOR (2004-2009)	Sustainability Impact Assessment: Tools for Environmental, Social and Economic Effects of Multifunctional Land Use in European Regions *http://www.sensor-ip.org/*	• developed the concept of Land Use Functions (LUF) • used a set of 40 key indicators tailored for cultural landscapes that prevail Europe to compare countries and large regions • reflected multifunctionality of land use as interplay between land use sectors and land use functions
STRIVER (2006-2009)	Strategy and methodology for improved IWRM - An Integrated Interdisclipinary Assessment in Four Twinning River Basins in Europe and Asia *http://cordis.europa.eu/result /rcn/47760_en.html*	• undertook activities related to water governance, environmental flows, water pollution, land and water use interactions, stakeholder participation, basic environmental data and interactions between scientists and local stakeholders • applied PIMCEFA for Øyeren in Norway
SEAMLESS (2005-2009)	System for Environmental and Agricultural Modelling, Linking European Science and Society *http://www.seamless-ip.org/*	• developed an Integrated Framework for Integrated Assessments based on linkage of individual components (models, data, indicators) that enables analyses of the environmental, economic and social contributions of a multi-functional agriculture and the effects of a broad range of issues (e.g. climate change, new policies, innovation)
REFORM (2011-2015)	Restoring rivers for effective catchment management *http://www.reformrivers.eu/home*	• proposed a process-based, multi-scale, hierarchical framework to support river managers in exploring the causes of hydromorpological management problems and devising sustainable solutions • suggested a simple (7) and extended (21) classification of channel configuration and river types, and a list of characteristics that can be extracted at different spatial scales, and works with nine types of flow regimes • came up with an analytical framework for valuating the ESS provided by European river corridors based on CORINE-type land surfaces, and a "morphological quality index" (MQI)
OPENNESS (2012-2017)	Operationalisation of natural capital and ecosystem services *http://www.openness-project.eu/about*	• aims to translate the concepts of Natural Capital (NC) and Ecosystem Services (ESS) into operational frameworks that provide tested, practical and tailored solutions for integrating ES into land, water and urban management and decision-making • case study in Oslo aimed to translate the concepts of NC and ESS into operational examples
DESSIN (2014-2018)	Demonstrate Ecosystem Services Enabling Innovation in the Water Sector *www.dessin-project.eu*	• demonstrates and promotes innovative solutions for water scarcity and water quality related challenges & demonstrates a methodology for the valuation of ecosystem services (ESS).

		• is centred around five demonstration sites with special focus on urban areas across Europe, where solutions are being tested and validated (e.g. Hoffselva, Oslo)
MARS (2014-2018)	Managing aquatic ecosystems and water resources under multiple stress *http://www.mars-project.eu/*	• assesses the impacts of multiple stressors on the provision of ecosystem services from freshwater ecosystems, under different climatic and land-use scenarios • has developed an innovative new assessment methodology – termed a 'cookbook' – to allow scientists, environmental managers and policy makers to quantify the relationships between multiple stresses and ecosystem service provision and value • case studies in the Vansjø-Hobøl and Otra catchments in Norway

In particular the MARS and REFORM projects provide inspirations. The MARS methodology includes the capacity of an ecosystem to provide a service (assessed using biophysical data), the actual flow of the services used by humans (assessed using socio-economic data), and finally the benefits that ecosystem services provide (Figure 3-6, 3-7). It builds on the DPSIR scheme. It is assumed that the State of the ES is related to the capacity of an ecosystem to provide services. A beneficiary can actually make active or passive use of Final ESS, bringing a benefit. Thus, there are biophysical indicators for ESS provision or "potential" (e.g. "suitability of a river for bading") and socio-economic indicators for ESS use (e.g. "number of people bading").

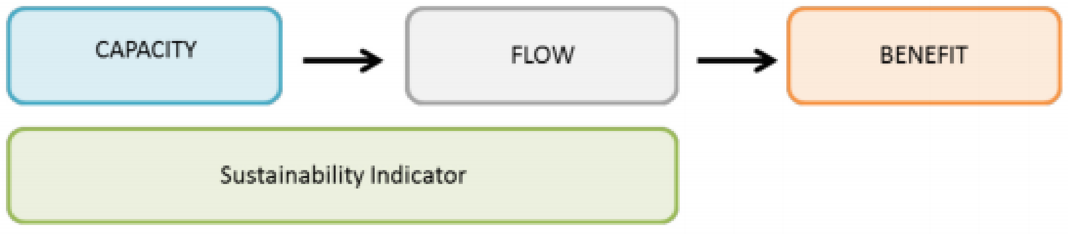

Figure 3-6: The MARS cascade model – quantifying the capacity, flow and benefits of ESS (MARS fact sheet #01)

In the MARS project, potential proxies/indicators for water ecosystem services were selected based on a literature review. The relevant ESS in MARS were afterwards assessed through questionnaire surveys. Eventually, a consolidated list of benchmark indicators was established based on the review and results of the questionnaires.

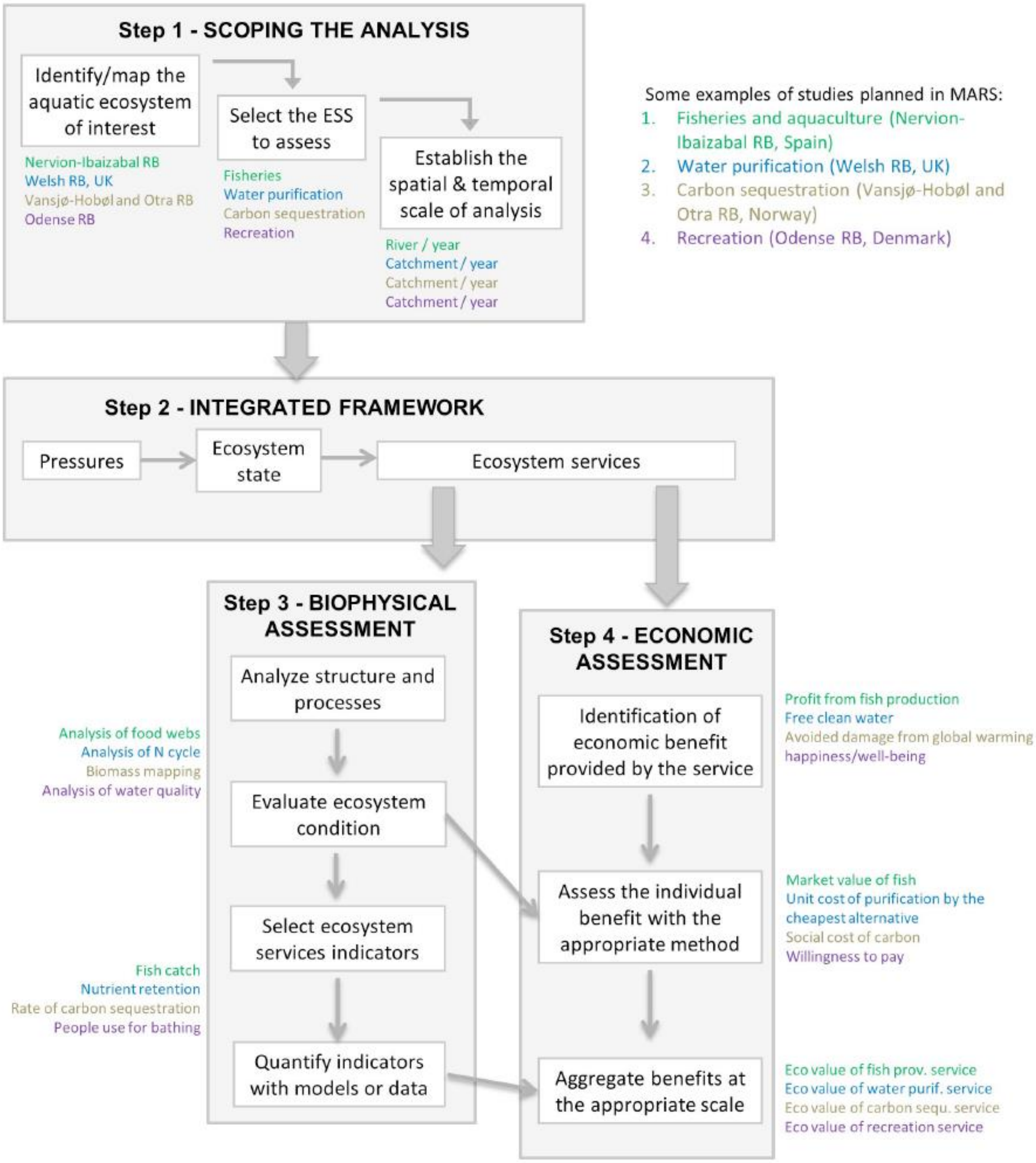

Figure 3-7: MARS Scheme of integration of biophysical and economic analyses. From Noges et al. 2014

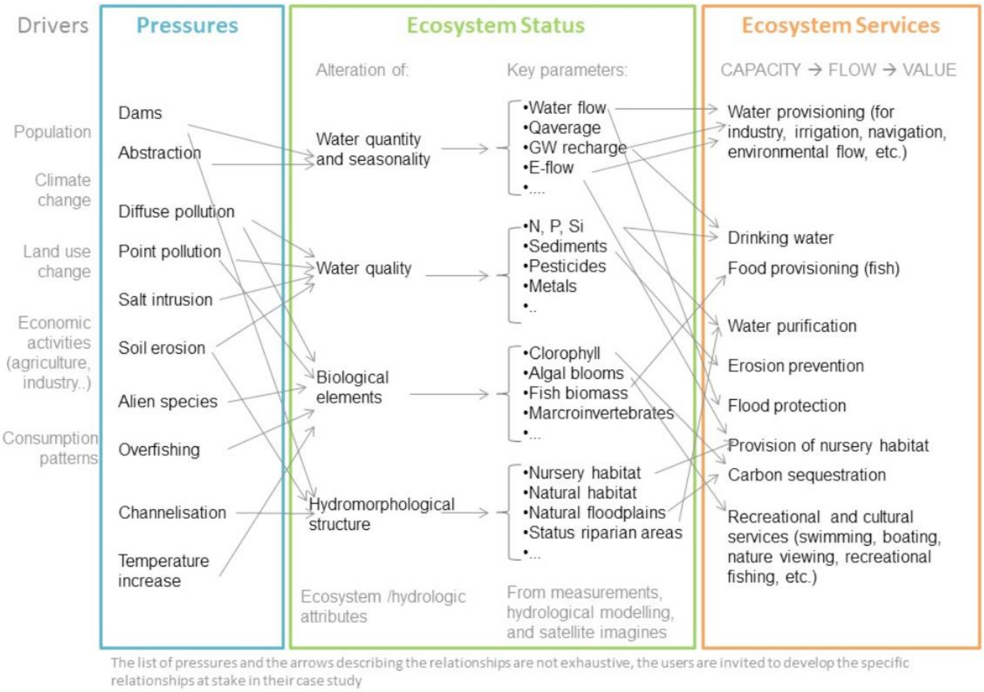

Figure 3-8: MARS Integrated framework for water ecosystem service assessment. From Noges et al. (2014)

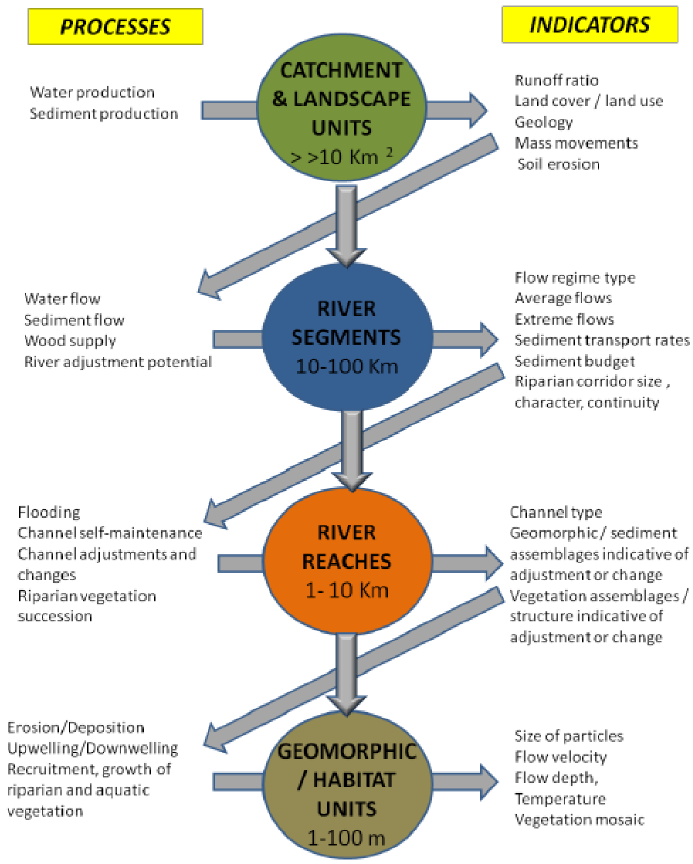

Figure 3-9: REFORM Indicators for rivers that represent processes at each spatial scale. From Gurnell et al. 2014

The focus of the REFORM project was on river hydromorphology. The project suggested a simple classification of channel configuration and river types based on confinement and planform that can be obtained from areal imagery. An extended typology contains 21 types. The report suggests a list of characteristics that can be extracted at different spatial scales. On the scale of the river segment, nine types of flow regimes are suggested based on the hydrological properties, and a series of flow regime characteristics is recommended for a hydro-morphological assessment. A list of key indicators for the current and past condition of a catchment is recommended, with the broad concept illustrated in Figure 3-9. The REFORM indicators are included in Appendix 7-4

The REFORM project came also up with an analytical framework for valuing the ESS provided by European river corridors (Vermaat et al. 2014). It was chosen to focus on the spatial scale of the river reach and “the real-world ecosystem as a whole in the form that can be perceived by riparian inhabitants and other stakeholders”. This empirical approach is considered as “best suited to a methodology that is to be applied for comparing restored and non-restored reaches” (p. 6, Vermaat et al. 2014). The analytical framework is structured as a series of subsequent questions and starts from the mapped habitat (geomorphic) units, which are regarded as service-providing unit and taken from CORINE-type land surfaces. It lists the potentially provided services for each of the elements according to a table, before it provides a cumulative estimate of the value of the services delivered by a river reach and adjacent valley floor. The report provides also an economic valuation methodology to put a monetary value on the ESS.

3.6 Natur i Norge and Norwegian Nature Index

"Nature in Norway" (in Norwegian: "Natur i Norge"; NiN) describes a system for the classification and systematization of nature in all areas of Norway (terrestrial, freshwater and marine areas) at different scales. The last version (NiN 2.0, Halvorsen et al. 2015) was completed in 2015 and defines nature very broadly as “a general and scale-independent term that is related to a defined area with the species that live there and the environment surrounding them, or just to the environment alone” (Halvorsen et al. 2015). The NiN system has been developed over several years by a number of Norwegian experts on behalf of the Norwegian Biodiversity Information Centre (Artsdatabanken, www.artsdatabanken.no). It is an integrated tool to classify and describe variation in the Norwegian nature and intends to meet the requirements of all potential users (e.g. municipalities, Public Road Administration, etc.), to support an integrated planning of nature use and to allow communicating recent knowledge about nature variation to the society. NiN covers all Norwegian territories including the marine zones and the Norwegian Arctic (Svalbard and Jan Mayen). NiN 2.0 describes the variation of nature at different scales based on scientific criterions by three main (primary) levels: Landscape Type, Nature System and Living Medium. In addition, the units Nature Complex and Nature Compounds are used to describe specific ecosystems (secondary level). A horizontal axis groups the nature types depending on the sources of variation, e.g. regional ecoclines or landform variation. Environmental variables are the base for the definition of the nature types. The state of knowledge or data quality is described by 6 classes (where 0 is the lowest and 5 the highest level). The NiN system is quite comprehensive, and its application requires expert knowledge and experience. For freshwater, the system is still under development and being tested.

Nature Index - Information from Norway’s Fifth National Report to the Convention on Biological Diversity (NMKM 2014):

The Nature Index is based on the international methodology for biodiversity indexes, but with a considerable amount of further development in Norway. Values are calculated for the state of biodiversity in major ecosystems relative to a reference state. For each ecosystem, a set of indicators has been chosen, for example data on populations of selected species. These are selected to be representative of the different ecosystems, and include both common and rare species and a range of species groups. Ecological status in freshwater bodies is assessed both through the Nature Index and under the Water Management Regulations. The Nature Index uses a weighted mean of the indicators for an ecosystem to produce a score, whereas the Water Management Regulations uses the "one out – all out" principle, meaning that the indicator or quality element that is most severely affected by human activity determines the overall ecological status. The regulations also use a rather narrower set of indicators than the Nature Index. As a result of these differences, the ecological status of freshwater bodies assessed by the Nature Index is considerably better than the status measured by the Water Management Regulations. (p. 32). Freshwater ecosystems are described by in total 42 indicators which represent species and organism groups that spend their whole life cycle or parts of it in freshwater.

Nybø (2010) points out that many indicators of the Nature Index are valuated based on expert assessments, and that it is necessary to establish monitoring. With respect to the WFD it is mentioned, that the financial means often do not sufficiently allow the monitoring of the WFD parameters, and that also has negative consequences for the data base of the Nature Index.

3.7 Materials from HYMO workshops

During the last few years there has been an increasing recognition that the existing Norwegian river classifications for river water bodies do not sufficiently include geo- and hydro-morphological parameters, such that it is very difficult to use them for the assessment of environmental flow requirements. A workshop with Norwegian and international experts was held on behalf of the Environment Agency in Trondheim on 29 January 2014 (Zinke and Sandlund 2014). Figure 3-10 presents the relevant hydro-morphological parameters which were suggested during the workshop. Parameters similar to obligatory or optional factors mentioned in System B of the WFD are marked in bold.

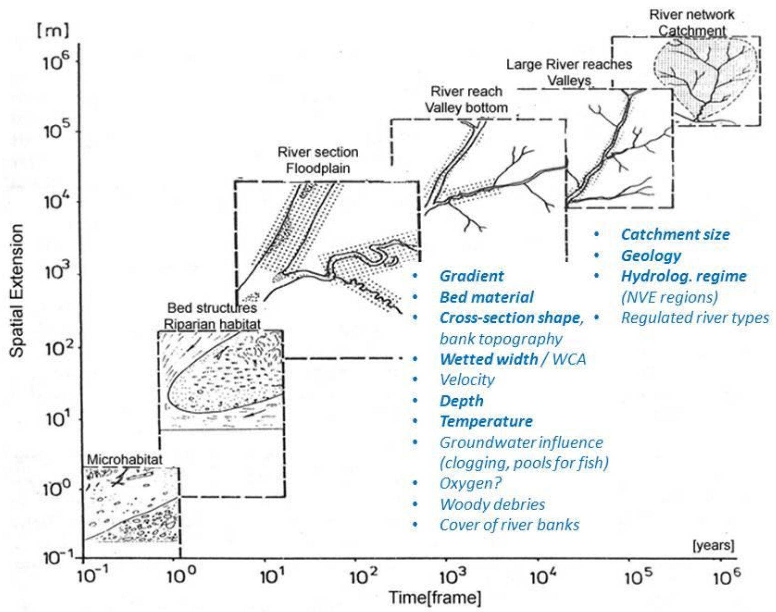

Figure 3-10: Necessary hydro-morphological parameters for different scales suggested during the workshop. Parameters similar to obligatory or optional factors mentioned in System B of the WFD are marked in bold. From Zinke and Sandlund (2014).

On 12 and 13 October 2015, around 70 participants attended the ECOSTAT workshop on "Hydromorphology and WFD classification" that was hosted by the Norwegian Environment Agency in Oslo, Norway. The workshop was organized jointly by ECOSTAT and REFORM representatives. The following are some highlights of the key workshop conclusions:

- Fish, macrophytes, macroinvertebrates and (more rarely) diatoms are the biological quality elements most used to detect effects of hydromorphological pressures.
- Many of the intercalibrated WFD methods are generic multi-metric indices responding weakly to specific hydromorphological pressures because they were not originally designed to be sensitive to such pressures. This can be improved by using more targeted indicators or an adjusted monitoring strategy. There are already good examples of Member States using such targeted indicators in their biological assessment systems.
- River typologies should reflect natural variability in hydromorphological characteristics and processes. This is crucial because differences in natural hydromorphology result in different reference conditions for the BQEs.
- BQE assessments need to be supplemented with information from the supporting elements in order to identify inconsistencies between hydromorphological and biological assessment, to diagnose problems and to identify effective restoration measures. A clear understanding of what is meant by "supportive element", how it should be used, how it is reported is needed.
- Until recently, there were few shared and standardized multiscale hydromorphological assessment methods. This has prevented a proper analysis of the linkages with BQEs so far. Recent scientific work (including the REFORM project) has resulted in new and better approaches and tools, which could now be used and further standardized.
- Data from remote sensing are increasingly available from many sources, including EU space programs. This data has a great potential to be used in hydromorphological assessments at different scales, in combination with field data and other existing relevant information. This is likely to result in a more robust and cost-effective implementation of the WFD. The main challenge is not data availability and acquisition, but to solve issues with data processing and interpretation.

3.8 Review summary: List of potentially relevant biophysical indicators

The literature review about potential relevant biophysical indicators from the previously mentioned data sources (without NiN) resulted in a list containing more than 240 parameters and is presented in Appendix 7-4. The parameters can be grouped into the following main groups:

1. Large scale or catchment characteristics (e.g. area of permeability classes)
2. Discharge characteristics (e.g. flow regime type, base flow index, hydropeaking frequency)
3. Hydromorphological characteristics (e.g. sinuosity index, bankfull channel width)
4. Riparian vegetation characteristics (e.g. vegetation along river shore, coverage of aquatic vegetation)
5. Fauna characteristics (e.g. average score per taxon)
6. Hydrochemical parameters (e.g. chloride, oxygen, turbidity)
7. Odours and sounds
8. Infrastructural properties (e.g. presence and route of paved trails)
9. Integrative sum parameters (e.g. ecological status, nature index)

4 Information related to river features for selected user interests

4.1 Input from workshops with stakeholders

A selection of potential key indicator groups ("river parameters") for the representation of various user interests were discussed during workshops with stakeholders in the two Suswater case areas Sira-Kvina and Hordaland.

During a group-work session in a workshop, the participants were asked to assess the relevance of 18 suggested river parameters for the following outdoor activities that WP3 had identified as relevant for the users:

- Fishing (salmon fishing, fly-fishing, inland fishing)
- Watersports (kayak/rafting, canoe, juving)
- Bathing / swimming
- Cycling
- Skiing
- Hiking / walking
- Hunting

The stakeholders were asked to classify the relevance of the river parameters as "very relevant" (2 score points), "relevant" (1 score point) or "not relevant" (score 0). Six groups participated (3 in each case area). Figure 4-1 shows the total sum of scores that were assigned to the key indicator groups during the two workshops.

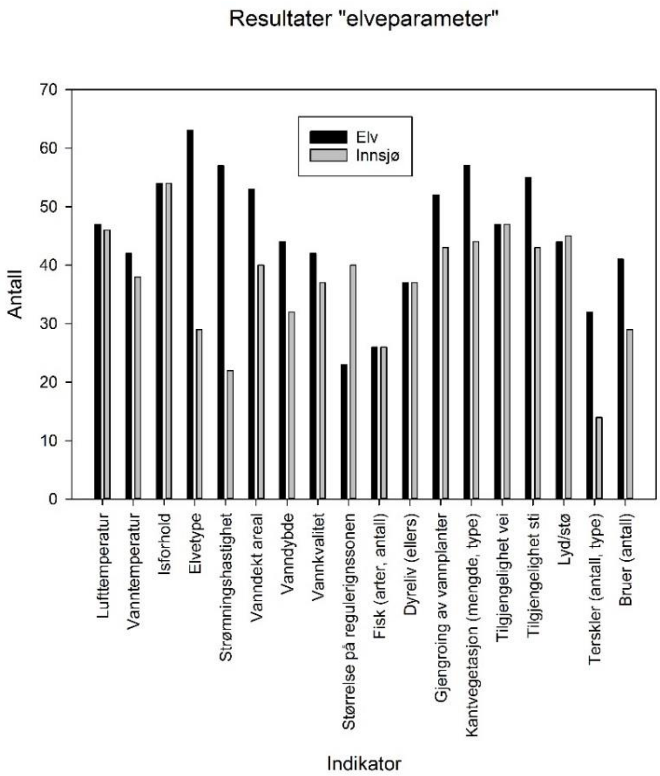

Figure 4-1: Sum of scores assigned to selected key indicator groups during the workshops in Hordaland and Sira-Kvina

The following indicators were regarded as most relevant by the stakeholders, when the total sum of scores is considered:

- For rivers: river type, flow velocity, river shore vegetation
- For lakes: Ice conditions, Air temperature, Accessibility by roads

These results are not generally representative. They reflect the opinion of a limited number of people and the local conditions, e.g. the fact that the lakes in the two case areas usually are located higher up in the mountains and are difficult to access without a car. However, they point to important features and are therefore included into the descriptions below.

4.2 Rafting, kayaking, canoe and canyoning

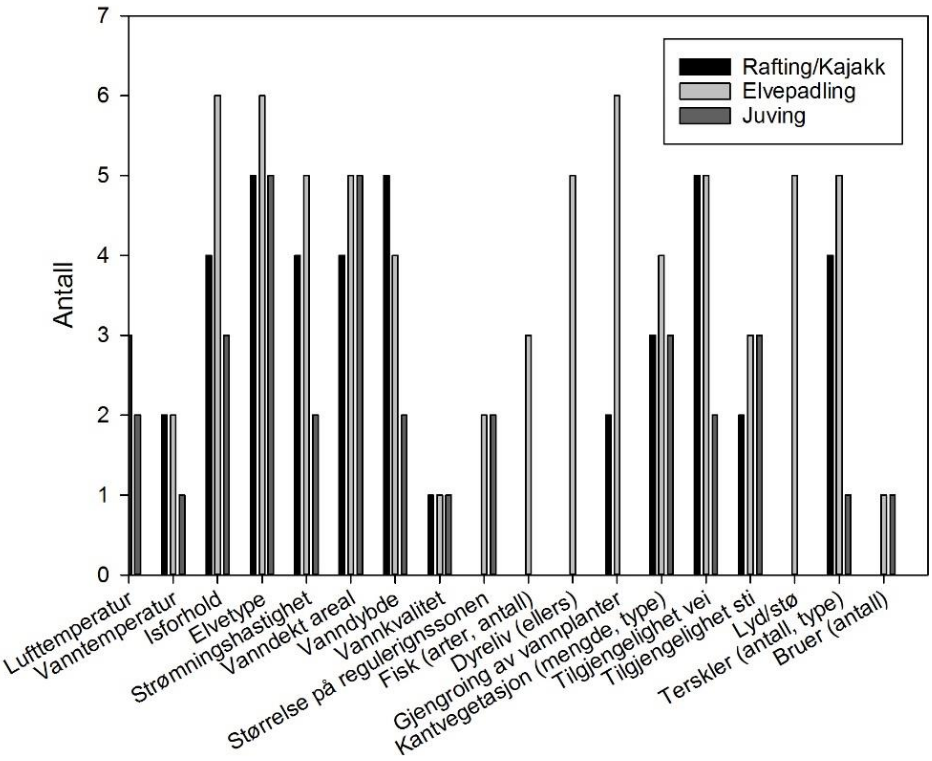

Figure 4-2: Importance of river parameters for rafting/kayak, canoe-padling and juving in rivers. Summary of case group workshop results (Spring 2016, 3 groups in each case area).

The interview with F. Solbakk (Voss elvesport, Hordaland case area) revealed that the local rafting and kayak experts have a very detailed knowledge of the discharge-dependent rafting and safety conditions in their rivers. They have established own gauge poles with different color zones indicating river-specific discharge threshold values.

The following thresholds for rafting conditions related to the local rivers and their gauge stations were provided:

- Strandaelvi: min 12 m^3/s, max 70 m^3/s
- Raundalselva (Kinne): min 14 m^3/s, max 50 m^3/s

According to F. Solbakk, there are different categories for rafting rivers, with alpine rivers and drop-pool-rivers as the main categories. Strandaelvi is for example a drop-pool river, with a good mixture of glides, some waterfalls, and some slowly flowing reaches – this gives many experiences and is at the same time very safe. The local kayak club provides maps and discharge information on its webpages. There is an own mobile application of the kayak club where paddlers can access the water levels at Raundalselva (Kinne), Strandaelva (Myrkdalsvatn) og Vosso (Bulken), cp. Fig. 4-3.

Figure 4-3: Rafting at Raundal River (left, Grade 3-5) and Stranda River (right, Grade 3-4). From ADREX (2016).

The International Scale of River Difficulty (Appendix 7-1) is an American system used to rate the difficulty of a stretch of river, or a single (sometimes whitewater) rapid (Walbridge and Singleton 2005). The grade reflects the technical difficulty and skill level required associated with the section of river. The scale is of use to various water sports and activities, such as rafting, riverboarding, whitewater canoeing, stand up paddle surfing, and whitewater kayaking (Cassady, Calhoun, and Cross 1999). There are six categories, each referred to as "Grade" or "Class" followed by a number. The scale is not linear, nor is it fixed. For instance, there can be difficult grade twos, easy grade threes, and so on. The grade of a river may (and usually does) change with the level of flow. Watters (1999) created an expanded class I scale, giving outdoor educators a much better way of distinguishing between the variations found in flat but moving water.

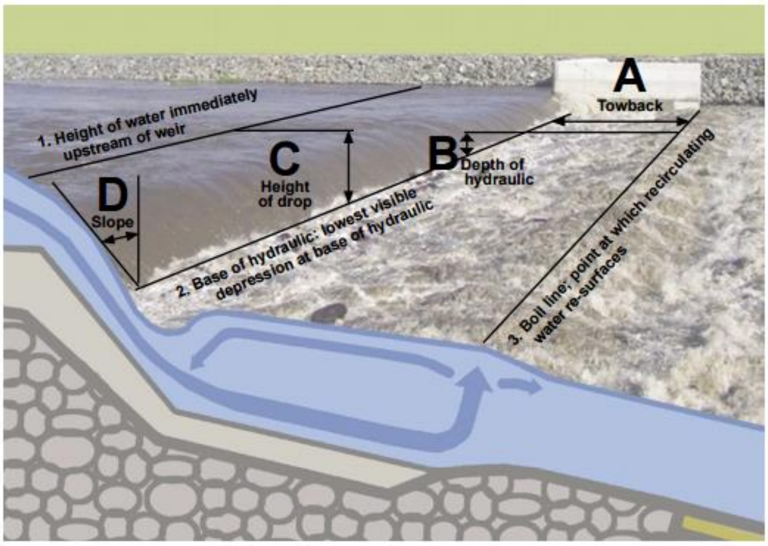

Figure 4-4: Weir features and hazards that are relevant for rafting and kayaking. From EAW (2009).

The occurrence and the types of hydraulic structures such as weirs highly affect the suitability of a river for rafting or kayaking ("Weirs are either straightforward or they kill you"), see Fig. 4-4 (EAW 2009).
A Norwegian study at the regulated Nidelva river in Trondheim ("easy grade 2") confirmed the importance of the discharge for kayaking. The river was found less attractive at minimum flows, and the users had developed temporal and spatial substitution strategies or avoided low discharges (Aas and Onstad 2013).

F. Solbakk mentioned that one has to distinguish between whitewater sports (kayak, rafting, canoe etc.) and paddling or roaring in slowly flowing waters ("flattvannspadling"). He specified the requirements for three activities during the workshop as follows:

Rafting:

- Accessibility by car, with boat trailer
- Discharge (often 15 m^3/s or more)
- Water depth (0.5 m or more)
- Slope ("not for large, not too small")
- Hydrological elements (runs, small waterfalls, waves, eddies, stones / hindringer)
- Not too long freshwater lakes in between, i.e. preferably long continuous river runs
- Waterfalls (or weirs) not too large (otherwise boats must be carried)
- Some backwater zones or pools that can be used for gathering and safety area, in order to reduce the risks

Kayak:

- Discharge (from 2 to 20.000 m^3/s)
- Slope (1 to 15 %)
- River type ("smooth bedrock or smooth boulders")
- Backwater zones (to stop, see before)
- Open vegetation
- Deep pools below waterfalls

Canyoning:

- Accessibility (road / path; less than 20 min away)
- Discharge (often less than 10 m^3/s)
- Slope / elevation differences (preferably high)
- River type (preferably bedrock, no or only few stones or gravel)
- Not too large freshwater lakes in between (shorter than 50-100 m)
- Not too large steep rock walls (max. 25 m)
- Good water quality (not too many slippery rocks)

Canyoning is travelling in canyons using a variety of techniques including "walking, scrambling, climbing, jumping, abseiling (rappelling), and swimming. Canyons that are ideal for canyoning are often cut into the bedrock stone, forming narrow gorges with numerous drops, beautifully sculpted walls, and sometimes spectacular waterfalls. […] Canyons can be very easy or extremely difficult, though emphasis in the sport is usually on aesthetics and fun rather than pure difficulty. A wide variety of canyoning routes are found throughout the world, and canyoning is enjoyed by people of all ages and skill levels." (Information from Wikipedia, accessed 02 December 2016).

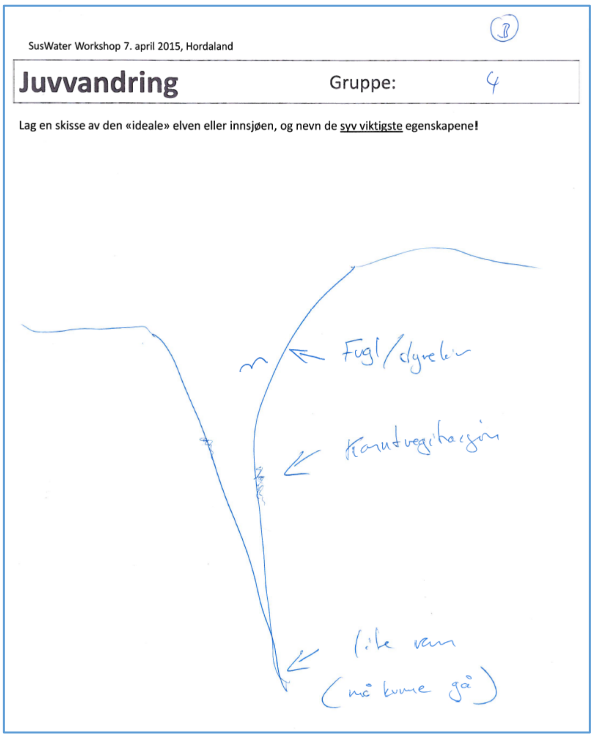

Figure 4-5: River features that are important for canyoning. Sketch of the case workshop participants in Hordaland (April 2016).

There are international classifications of difficulty for canyoning. The core format of the UKCG Canyon Rating System includes two digits, consisting of 4 grades (1 to 4) describing the "terrain / technical rope work" and four grades (A to D) describing the "water volume / current" in the canyon (Appendix 7-2). These ratings refer to descents in normal conditions, during what is considered the normal season for the canyon. Adverse conditions, such as higher than normal water volume or colder temperatures, will increase the difficulty of the descent. In addition, there are Skills Checklists covering recreational canyoneering skill levels 1, 2, and 3 to guide in a sequence of skills acquisition.

The following key parameters for rafting, kayak, canoe and canyoning summarize the information provided by the users or on the related webpages:

- "River anatomy" (see Fig 4-6: slope, bankfull width, substrate, curvature, vegetation, occurrence of water falls; i.e. river type)
- Seasonal distribution of discharge and related parameters (water level, flow velocity, wetted width, turbulence; hydraulic habitats)
- Hydraulic structures or obstructions in the river (e.g. weirs, fences)
- Aesthetical aspects of the scenery
- Longitudinal pattern and variation of river types
- Bank vegetation
- Wildlife
- Accessibility (road not too far away; parking spaces, good access to the river with the boat)
- Water quality

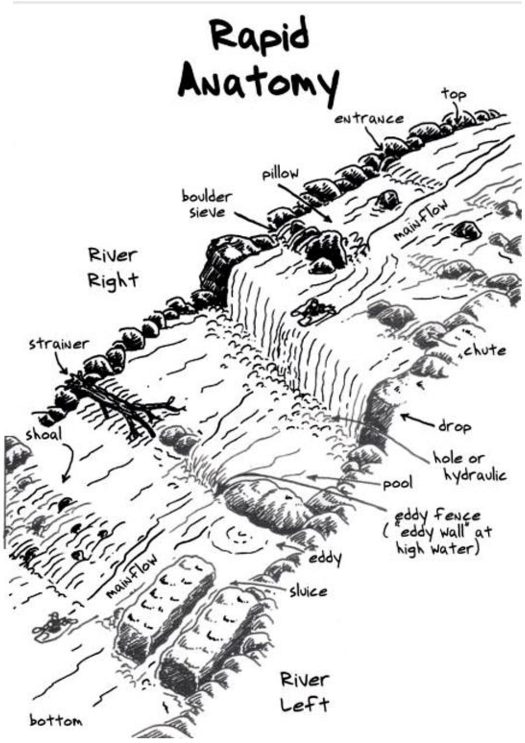

Figure 4-6: Illustration of terms used by rafting experts for the description of "river anatomy" . Drawing by H. Maertsch, from http://www.internationalrafting.com/2013/08/river-anatomy/

4.3 Bathing and Swimming

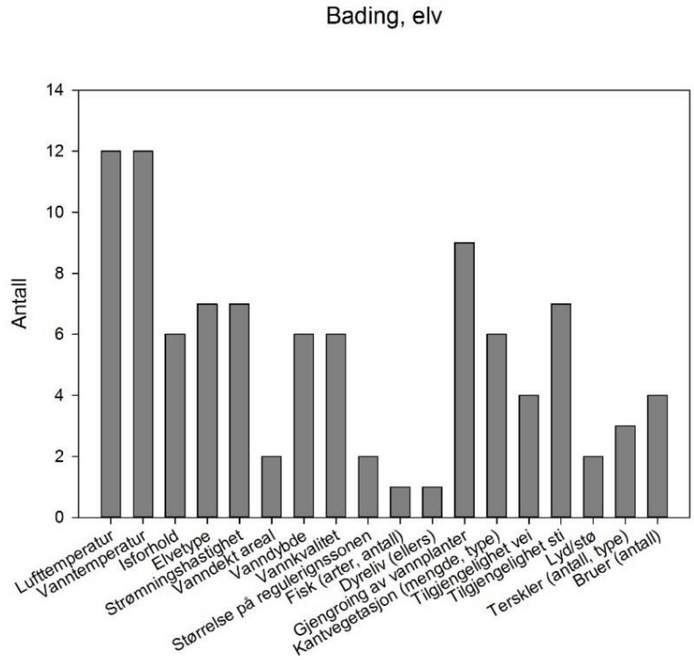

Figure 4-7: Importance of river parameters for bading or swimming in rivers. Summary of case group workshop results (Spring 2016, 3 groups in each case area).

An important factor is that people can swim without getting sick from contaminated water. The major health risk from swimming arises from ingesting disease-causing microorganisms (pathogens) through the mouth, nasal passages and ears. Norway applies often the EU Bathing Water Directive (EU-BWD 2006) in order to monitor and assess the bathing water for at least two parameters of (faecal) bacteria (Table 4-1).

Table 4-1: Faecal bacteria in bathing water for inland waters (EU-BWD 2006, Annex I)

	A	B	C	D	E
	Parameter	Excellent quality	Good quality	Sufficient	Reference methods of analysis
1	Intestinal enterococci (cfu/100 ml)	200 (*)	400 (*)	330 (**)	ISO 7899-1 or ISO 7899-2
2	Escherichia coli (cfu/100 ml)	500 (*)	1 000 (*)	900 (**)	ISO 9308-3 or ISO 9308-1

(*) Based upon a 95-percentile evaluation. See Annex II.
(**) Based upon a 90-percentile evaluation. See Annex II.

Webpages for outdoor swimmers (OSS 2016, WS 2016) mention the following parameters that are important for bathing and swimming:

- Water temperature
- Water depth (swimmers like deep water, non-swimmers should beware of sudden changes in depth)
- Possibilities for jumping and diving
- Current speed (depending on rainfall/discharge)
- Entry and exit points for downstream river swim
- Obstructions (rocks, fallen trees or other obstructions might potentially trap swimmers – but they are also welcome as resting places; rocks can be very slippery – one of the most common dangers)
- Weeds (to avoid; the term "weeds" is here used for all kind of aquatic vegetation)
- Blue-green algae (in lowland lake swimming; skin-irritating)
- Weirs (to avoid)

Table 4-2: Open water swimmer's experience of temperature, according to OSS (2016)

Temperature range (degrees)	**Name**	**Description**	**Note**
0 - 11	Freezing	Winter swimming; 1-2 minute swims; often less than 25 m	Can increase immunity
12 - 16	Fresh	One can swim comfortably for a while; not a problem for hardened open water lovers	At this temperature triathlon starts operating
17 - 20	Summer swimming	Still fresh on entry, but comfortable picnic lazy-hazy summer swimming	Reached in lakes and more mature rivers over summer, during hot spells
>21	Warm	It is possible to spend hours swimming without a wetsuit	
>30	Pool temp.	Arguable unpleasant	

According to OSS (2016), open water swimmers experience temperature in bands, as shown in Table 4-2. The human body acclimatizes to cold water. However, at around 16 degrees, for 10 hours or more, an untrained swimmer would get hypothermia. It is possible to swim in the polar regions. During the Ice Mile Event, swimmers take on a mile in water at 5 C or lower – but this requires expert knowledge and training and is potentially extremely dangerous (OSS 2016).

With respect to flow current and eddies (eddies are here defined as “areas where the water flows back upstream against the current”), the following recommendations are given by OSS (2016): http://www.outdoorswimmingsociety.com/swimming_outdoors/understanding_rivers/480-currents-and-eddies:

1. “If you can’t swim upsteam against the flow, then you will be unable to swim out of the way of objects downstream (e.g. bridges and trees).”
2. “Shallow water tends to have a rippled surface, while deep water will usually have a smooth surface (still waters run deep). It's a simple and effective trick to throw a stick or leaf into different areas of the water and watch how it behaves. This will make it easy to spot areas of faster flow, but also to see where the eddies are. At normal flow levels, eddies can be the wild swimmer's best friend.”
3. “An eddy might be a good spot for entering and exiting the water safely, because you won't have to deal with a strong current while clambering in and out. You will often find an eddy downstream from a large rock, and this will enable you to swim upstream.”
4. “Eddies in white water are far from safe; often they'll send you at speed into a strong current.”
5. “Don’t go into white water!”

These recommendations highlight that bathing suitability is closely related to specific river structures and flow types. The images on the webpages (WS 2016) suggest that the following river features are especially attractive for bathing and swimming:

- holes / pools
- bedrock rivers: near waterfalls and in round-washed pools
- slowly flowing rivers with varying structure elements (stones, bedrock outcrops, trees) along the shore

Advice no. 1 sets an upper limit for flow velocities in rivers suitable for bathing: The flow speed should be not higher than the swimming speed. Table 4-3 provides some values.

Table 4-3: Swimming velocities achieved by competitive and recreational swimmers.

Swimming velocity (m/s)	Stroke		Reference
1.64 m/s		Expert swimmer during sprint	Barbosa et al. (2010)
1.43 - 1.48 m/s	Crawl bout	Pubertal boys, competitive swimmers	Barbosa et al. (2013)
1.29 - 1.30 m/s	Crawl bout	Pubertal girls, competitive swimmers	Barbosa et al. (2013)
0.78 – 1.03 m/s	Breaststroke	Recreational female swimmers	Seifert et al. (2010)
1.04 – 1.26 m/s	Breaststroke	Competitive female swimmers	Seifert et al. (2010)

According to Barbosa (2010, 2013), swimming performance depends on the swimmer's anthropometric properties, technical abilities, gender and age. For a given distance and gender, Freestyle is the fastest stroke, followed by Butterfly, Backstroke and Breaststroke.
There are differences in the swimming speed and skill level between recreational and competitive swimmers (Seifert et al. 2010).

4.4 Other outdoor activities along rivers

Cycling, hiking, and hunting are activities taking place along the river and were by the users described as more dependent on non-riparian parameters (see Figure 4.4). Some users highlighted the importance of vegetation along roads which can reduce the aesthetical value or impression of waterfalls. For skiing, the ice conditions can be important.

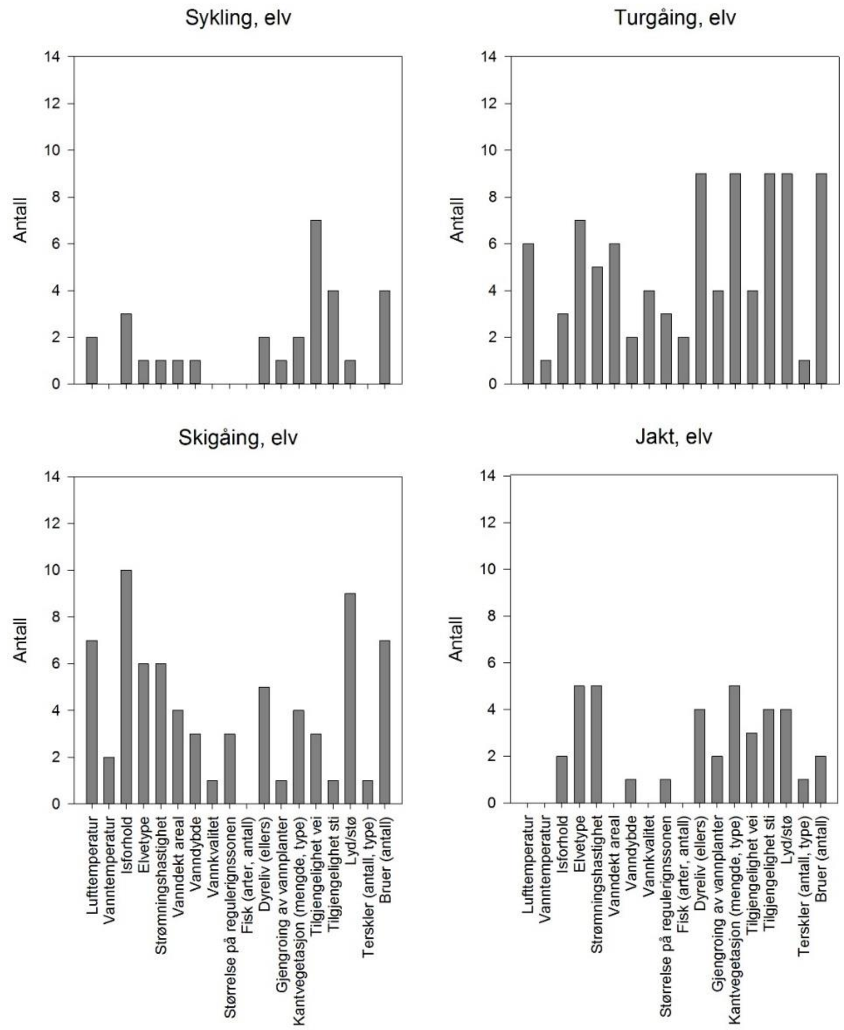

Figure 4-4: Importance of river parameters for outdoor activities taking place along rivers. Summary of case group workshop results (Spring 2016, 3 groups in each case area).

4.5 Agriculture

Agricultural user interests related to the river in the case areas include:

- Use of cropland or grassland on the floodplains
- Importance of streams as drinking water source and "natural fence" for sheep in mountain pasture areas (mentioned by Kåre Trefall, Haugen Gård, Eksingedalen)

Large-scale cropland areas are easily to identify in the topographical maps (cp. Vermaat et al. 2013) and often related to river types of partly confined or unconfined valleys (e.g. riffle-pool rivers, meandering rivers). User interests may be related to impacts concerning:

- Bank vegetation (buffer zone often missing)
- Floodplain structures and vegetation (disconnection/filling of oxbow lakes etc.)
- Water chemistry (use of fertilizers)
- Bank structure and erosion (often bank protection against erosion)
- Flood protection (often embankments against frequent flooding)

Information about the appropriate size of streams for the "fence" function was found on a webforum (accessed 2 Dec 2016) http://gardsdrift.no/forum/husdyr/sau-og-bekk:

- Sheep are not waders; river width is most important – but some sheep can swim 30 m
- The river and landscape morphology is important (landing conditions, startup length, bank vegetation)
- Pregnant sheep may be less sporty
- Breeds behave differently ("Spæl har meir kenguru-gen i seg enn norsk kvit. Dårleg dressert norsk kvit åring hoppar gjerne både ein meter høgt og to meter langt på ein god dag. Spæl klarer sikkert dobbelt så langt om den er av det lettskremte slaget.». Anonym gjest)
- A stream in bedrock with 2-3 m high nearly vertical walls at the most places and long reaches with deep water also at low flow worked fine as fence; this stream had some less deep zones where people could go through 2-3 times at very low water levels (no "spel"-breed).
- For a stream 1.5 to 3 m wide and 0.3 to 2 m deep, with many stones on the bed it was recommended to use rather another fence, because the sheep would cross it

4.6 Education

Education as user interest was mentioned in connection with activities to teach fishing to school kids. Magne Sørestand (Voss Jeger og Fisk) described the optimal river reach for that as follows:

- "appropriate with respect to discharge"
- Some pools ("noen kulper") that one can overlook (teacher must have overview over the kids, which wear a safety vest)
- Rather open banks, or sparsely vegetated (not too many trees – otherwise the fishhook gets stuck in the branches)
- Flow velocity is also important – the fishing hook should not be flushed away from the pool
- Gravel and stones is the best substrate (not too coarse); coarse gravel is OK;
- Not too much water vegetation

4.7 Fishing and Atlantic salmon

The "Handbook for environmental design in regulated salmon rivers" (Forseth and Harby 2014) includes the comprehensive knowledge that is available about the connections between physical habitat qualities and salmon production in Norway. The book provides tables showing the interrelations between mesohabitats, shelter, substrate etc. and suitability for different life stages of Atlantic salmon.

In summary, the following biophysical river indicators are important for Atlantic salmon:

- Discharge
- Wetted width ("water-covered area")
- Flow velocity
- River type (often gravel-bed rivers)
- Type and spatial arrangement of mesohabitats (degree of uniformity along a river reach)
- Substrate, with focus on spawning gravel
- Bed structure (shelter)
- Water chemistry (acidification; gas supersaturation)
- Water temperature
- Weirs and other mitigation obstructions

A study by Alfredsen et al. (in prep.) investigated the coupling between physical variables and fishing potential at the Surna river in Central Norway. The available preliminary results indicate a close relationship between mesohabitats (cp. Forseth and Harby 2014) and fishing preferences. For fly-fishing there are more specific requirements regarding the flow velocity, and habitats B1. B2 and partly G2 were most suitable. Fishing with hooks and baits had less specific requirements and was possible in a wider range of mesohabitats such as pools, backwaters, deep waters, or fast flowing reaches (C, A, G). Mesohabitats E and F were avoided. The study highlights the reduced potential for fishing in the investigated reaches of Surna river due to regulation.

Aas and Onstad (2013) showed that changes of the discharge during hydropeaking alters the fishing opportunities. Anglers applied tactical substitution, such as changing gear and tackle, and improving their skills specifically in response to unfavorable conditions.

Wading in rivers is only possible until a given current speed or water level is reached. The safety rules of the Swiss Army (SE 2013) suggest the following formula to determine whether wading is save for people or not:

Wading Index = Water depth (m) + Flow velocity (m/s)

The maximum values for the Wading Index are:

- 1.0 without holding rope
- 3.0 with holding rope, if the water depth is below 0.4 m
- 2.0 with holding rope, if the water depth is above 0.4 m

4.8 Biodiversity, endangered species and nature types

Protecting biodiversity is an overall national and global interest and the respective ESS have been studied a lot. Figure 4-5 illustrates the complex linkages between broad groups of biodiversity attributes, ESPs and ecosystem services for the 11 ecosystem services included in a literature review by Harrison et al. (2014). Species level attributes include species richness, diversity, abundance, size and weight; functional group level attributes include functional diversity and functional richness; community or habitat level attributes include community/habitat area, age, structure and successional stage; behavioral traits include flower visiting behavior and biocontrol; and biomass attributes include above and belowground biomass and litter or crop residue.
Large and Gilvear (2015) presented a methodology for reach-based ESS assessment of the biodiversity-related ESS in rivers using remote sensing data from Google Earth, hereby using reach scales between 500 m and 10 km.

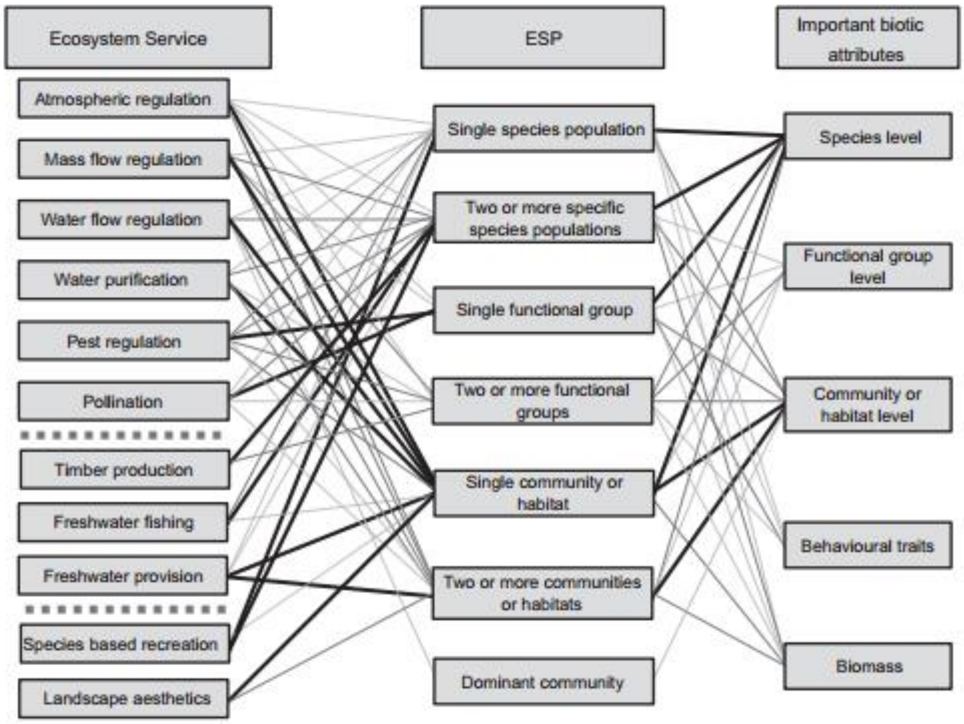

Figure 4-5: Linkages between broad groups of biodiversity attributes, ESPs and ecosystem services for the 11 ecosystem services included in the literature review. From Harrison et al. 2014.

Biotic elements and fish are part of the ecological quality elements to be used in the classification of ecological status according to the WFD (cp. Table 3-3).
As summarized in Zinke and Sandlund (2014), periphyton, zoobenthos and fish are the relevant quality elements in Norwegian rivers. Norway has no river water bodies with self-sustaining phytoplankton communities, and macrophytes (mainly mosses and higher plants) have so far not been included in the classification system for rivers. For periphyton (benthic algae), response curves and indices for classification of ecological status have been developed for the chemical parameters eutrophication and acidification. The relationship between hydromorphological changes and periphyton in rivers has not been considered.

The available indices for assessing the ecological status of zoobenthos in rivers also mainly relate to eutrophication (nutrients, organic load) and acidification. In some rivers, the status of the red-listed species river mussel (*Margaritifera margaritifera*) may be used as an indicator of hydromorphological changes. In Norway, chemical parameters such as pH and ANC (acid neutralizing capacity) have been used for decades in the monitoring of water quality in rivers and lakes impacted by acid precipitation. Consequently, there is a relatively good understanding of the relationship between acid water and fish.

The role of fish in the assessment of ecological status of limnic water bodies in Norway has been reviewed, and a number of systems for classification of different water bodies in relation to various environmental impacts have been proposed (Sandlund et al. 2013).

Some indices for reduced water flow and water covered area in regulated rivers are included in the WFD guidelines (Iversen and Sandøy 2015). The impact of reduced water flow (and thereby water covered area) is assumed to be most biologically relevant when measured as the seven-day minimum (Qmin7d) in winter and in summer.

Sandlund et al. (2013) suggest indices for the degree of fragmentation of rivers due to human encroachment, and for barrier effect of dams etc. to fish migration (Figure 4-5). The degree of fragmentation is the river stretch which was naturally accessible to upstream fish migration divided by the number of artificial barriers.

However, there are a series of remaining issues regarding fish as an ecological quality element and hydro-morphological changes in rivers. This regards both water flow/water covered area, sediment transport / sediment packing of substrate, and fragmentation/migration barriers/river discontinuities (Zinke and Sandlund 2014).

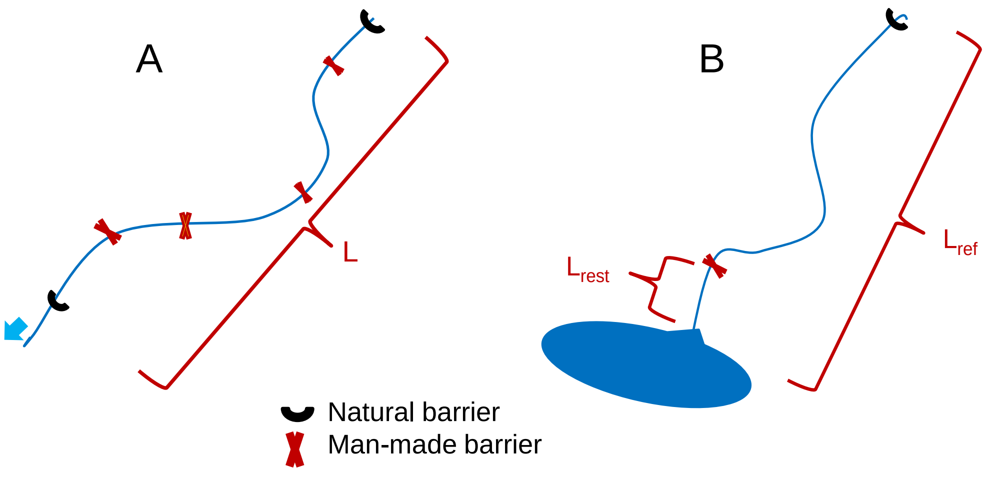

Figure 4-5: Schematic representation of degree of fragmentation (A); and barrier effect (B). From Sandlund et al. (2013)

Biodiversity in Norway can be linked to the classifications in NiN and the Nature Index (Chapter 3.6). Endangered Nature Types are classified in the NiN System, as shown in Table 4-4. Endangered species are dependent on the respective habitat or nature type and can be related to them, as it has been partly done in the Norwegian data base (Artsdatabanken).

Table 4-4: Some Red Liste Nature Types related to water courses, from Artsdatabanken

Tema	Name	Kategori	NiN Code type
Freshwater (Ferskvann)	River channel (Elveløp)	NT	LD-1
Freshwater (Ferskvann)	Oxbow lakes, meanders and flood channels (Kroksjøer, meandere og flomløp)	EN	LD-1
Wetland (Våtmark)	Flood mires, mire belt, mire woodlands (Flommyr, myrkant og myrskogsmark)	NT	NA-V7
Wetland (Våtmark)	Wetland massive (Våtmarksmassiv)	NT	LD-12
Forest (Skog)	Salix shrubs (Mandelpilkrått, Doggpilkrått)	NT	NA-T7; 2,4
Forest (Skog)	Continental woodland stream creeks (Kontinentale skogsbekkekløfter)	NT	LD-11

4.9 Review summary: Overview of relevant river parameters mentioned by users

The results of the user-interest-related review is summarized in Table 4-5.

Table 4-5: Summary of the most important aspects that were mentioned (without "biodiversity").

	Categ.	Raft.	Kay.	Cany	Bad.	Agric	Educ.	Fishi.	Salm
Discharge	HYD	x	x	x		F	x		x
Wetted width	HYMO/HYD					F			x
Flow velocity	HYMO/HYD				x		x	x	x
Water depth	HYMO/HYD	x			x			x	
Water surface structure	HYMO/HYD	x			x				
Slope	HYMO	x	x	x					
Substrate	HYMO						x		x
Boulders / obstructions	HYMO	x			x				
River type / profile	HYMO	x	x	x	x	F		x	x
Hydromorphic elements*	HYMO	x	x				x	x	x
Longitudinal structure**	HYMO	x	x	x			x		x
Floodplain land use	VEG					x			
Bank vegetation	VEG		x	x	x	x	x		
Aquatic vegetation	VEG			x	x		x		
Fish	FAU						x	x	
Wildlife	FAU			x					
Water quality	CHE			x	x	(x)			x
Water temperature	CAT				x				x
Landscape Aesthetics	all	x	x	x	x				
Weirs	INF/HYMO	x	x		x				x
Accessibility	INF	x		x	x				

**e.g. pools, backwater zones, waterfalls – i.e. river structures supporting specific hydraulic flow (mesohabitat) types*

***Distribution of river types and geomorphic elements along the river*

5 Suggestion of key indicators

5.1 Framework and connection with other SusWater work packages

Several SusWater stakeholders (e.g. Energi Norge, Miljødirektorat) regarded the ESS concept as "for complicated" and "difficult to handle". The LUF-concept has been shown to be a more pragmatic way (cp. Chapter 3.4) and is easier to communicate.
WP2 and WP3 agreed therefore on a simplified framework for the representation of different user interests, consisting of the economical (ECO), socio-cultural (SC) and environmental (ENV) dimensions (Figure 5-1). It builds on the main ideas of the LUF concept, but it integrates some basic ideas of the ESS framework and can be linked to it if needed.

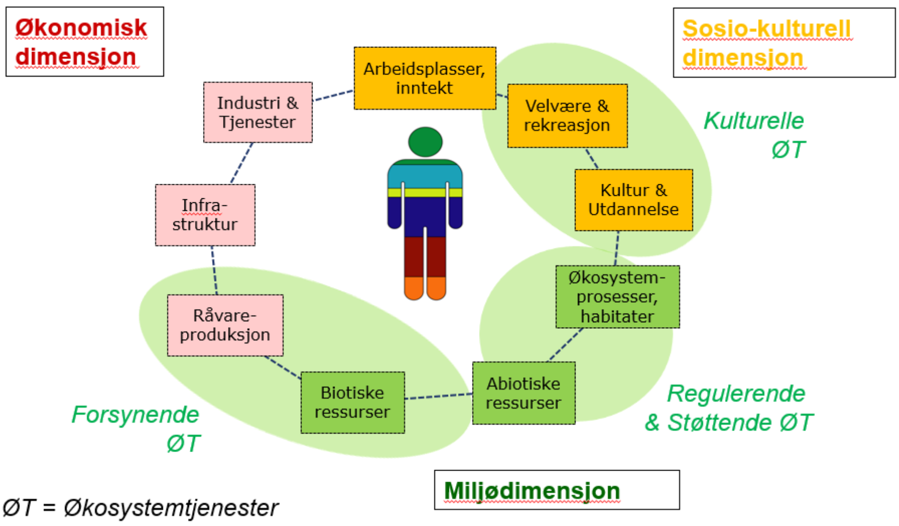

Fig. 5-1 Suggested framework for SusWater. ESS aspects are highlighted in green.

WP2 deals with physical and ecological indicators describing the potential or "capacity" of river sections for specific user interests. They will be coupled with socio-economic indicators representing the "flow" in WP3, and these indicators will finally be used within a framework for decision support (WP4), cp. Figure 1-1 and 3-6.

It is planned to apply Multi-criteria decision support (MCDA) methods in WP4. Such methods have been used in previous CEDREN projects such as OPTIPOL and EcoManage (e.g. Barton et al. 2015). Experiences showed that value scaling can be conducted both with stakeholders and technical experts. It is possible to construct project-specific value functions rather than standardized homogeneous criteria.
According to Köhler (pers. Comm.), the existing MCDA methods include

- PIMCEFA
- DRIFT (Brown et al. 2006)
- Multi-attribute valuation and
- Bayesian network models with MCA-elements

Figure 5-2 shows an example for the application of a Bayesian network model combined with MCDA for Mandalselva in Norway. The tool was used to assess the effect of weir removals with the goal to maximize both the profit of the power company, the salmon production, and other user interests such as aesthetics and fishing experience, as illustrated in Appendix 7-3. The MCDA model was based on results of hydrodynamic modelling (1D Hecras), modelling of the salmon life cycle (IB Salmon), and aesthetic assessments based on photo-scenarios, thus it required a very detailed data set including bathymetry, substrate, spawning habitat, and fish data as a pre-condition for the study.

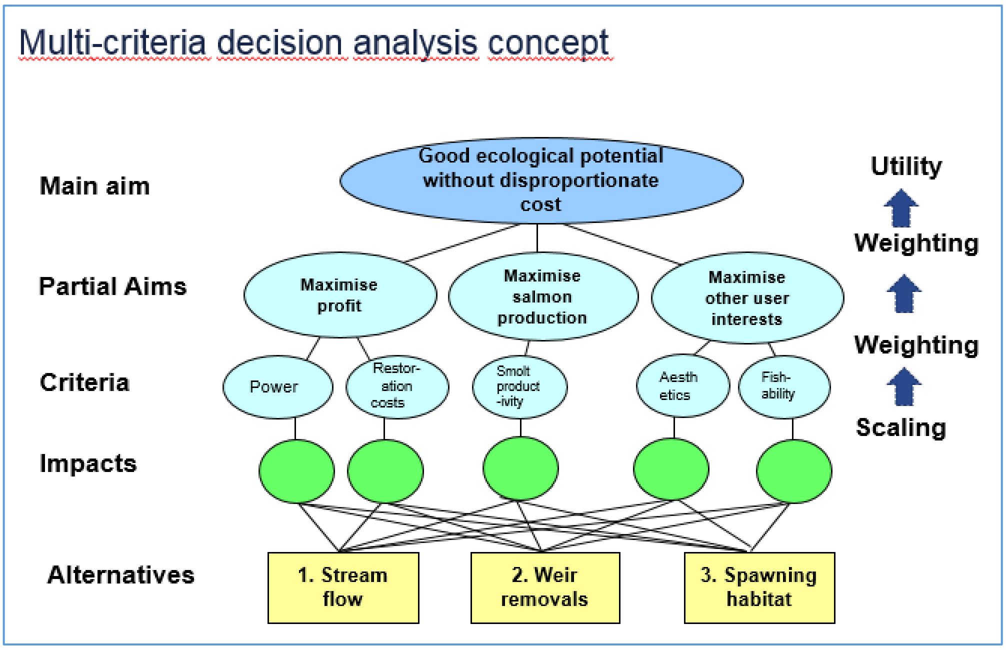

Figure 5-2: systematic structuring of MCDA decisions (Barton et al. 2015).

5.2 SusWater reaches for detailed investigations

For SusWater WP 2 and 3, it has been decided to conduct detailed investigations for the river reaches shown in Table 5-1.

The most important user interests in these reaches include (here in alphabetic order):

- Aesthetics /cultural identity (dry waterfall that was earlier an tourist attraction)
- Agriculture
- Bading? (Camping)
- Biodiversity / endangered species (Atlantic salmon)
- Fish habitat (Use of the river as growth habitat for stocked fish that can be caught later)
- Fishing and related outdoor activities (boat …)
- Flood security?
- Power production
- Rafting/kayak

Table 5-1: River reaches for detailed investigations in SusWater and main user interests. From I. Nesheim, after discussion in the working and case group

Case area	River Segment	Main user interests	Note
Teigdals-elva	Upstream from Kråkefoss	Rafting / kayak; some agriculture	
Teigdals-elva	Anadrom reach Teigdalselva	Endangered species (Vosso-salmon), fishing, camping	Measures to improve river bed structure have been conducted
Eksingedals-vassdraget	River reach around Flatekvål	Fish farming (use of river for fish); fishing/outdoor activities	problems with aquatic vegetation
Eksingedals-vassdraget	Lower part of Ekso – anadrom reach	Fishing; Endangered species (Vosso-salmon),	
Sira	Downstream from Handeland dam to Dorgefoss	Aesthetics, cultural identity? (Dorgefoss …)	
Sira	Ousdalsvann to Sira	Agriculture; Aesthetics?	Problems with nutrients and aquatic vegetation
Kvina	Narvestad reservoir to Rafoss (new anadrom reach)	Agriculture; Bading/Outdoor activities?; Fishing?; Endangered species (salmon)	Problems with aquatic/shore vegetation and sediments
Kvina	Litleåna downstream from Galdalsvatn	Agriculture, Flood security?	Not affected by large HPP; some erosion problems

It could be useful to set up and test a MCA-tool for at least one of these sites. For the majority of these reaches (apart from the new anadrom reach in Kvina) there is no or little detailed data about substrate, bathymetry etc. available.

5.3 Suggested spatial and temporal scales

Water management decisions have to be made at different spatial scales, as illustrated in Figure 3-10 and Table 5-2. For international summary reports, the results of the WFD implementation are often further aggregated and reported on the spatial level of the water region (Vannregion).

Table 5-1: Typical spatial scales of water management decisions in Norway

Task	Relevant spatial units	Typical mapping scales
Licensing small HPP (1-10 MW)	Influence area: Min. 100 m from HPP (Korbøl, Kjellevold, and Selboe 2009)	1:50.000 to 1:100.000 (overview maps); HPP site: ca. 1:5000 (recent proposal documents)
Planning or revision of large HPP systems	Size of regulated catchment area; length of regulated or minimum flow reaches	NVE database: 1:50.000; smaller scales for detailed reach or site studies
WFD water management	Water body (AE > 10 km^2) Average size: river WB: 24.5 km, lake WB: 1.89 km^2	Vann-nett: related to NVE-database; scale of suggested measures: broadly varying

International experiences show that it is useful to introduce different levels of intensity for survey procedures and impact assessment. The Swiss “Modular Stepwise Procedure” (EAWAG 2016), for example, is based on multidisciplinary survey procedures that are planned at three intensity levels. We suggest a similar distribution of the spatial-temporal levels also for Norway (Tab. 5-2).
Inspired by the EEA indicator eye (Figure 3-1), we suggest a set of “inner core” (IC) indicators in combination with “outer core” (OC) and “other” (O) indicators. The IC indicators could perhaps be related to Level I investigations, while OC and O indicators could be added for Level II and III investigations.

Table 5-2: Suggestions for three intensity levels for survey and assessment procedures, inspired by EAWAG (2016).

Level		Intensity of survey	Suggested application examples
I	Area-wide survey (e. g. country, district, water region)	Low (mainly based on existing data 1:50.000)	Overview in Water Management Plans
II	System scale survey (e.g. regulated catchments / river segments)	Medium (additional field or remote sensing surveys for pre-defined parameters)	Hydro power revision processes (large HPP)
III	Reach scale survey (river reaches)	High (resource-intensive targeted investigations)	HPP licensing?; construction measures etc.

5.4 Selection of key indicators and the need for better representation of HYMO parameters

The long list of potentially relevant indicators (Appendix 7-4) needs to be reduced to a limited number of clearly defined key indicators. The relevant river parameters could be grouped into the following main groups (cp. Appendix 7-4 and Table 4-5):

1. Large scale or catchment characteristics (CAT)
2. Discharge characteristics (HYD)
3. Hydromorphological characteristics (HYMO)
4. Riparian vegetation characteristics (VEG)
5. Fauna characteristics (FAU)
6. Hydrochemical parameters (CHE)
7. Infrastructure elements (INF)
8. Integrative sum parameters (e.g. ecological status, nature index)

The review results clearly illustrate the importance of the river hydro-morphology in combination with the discharge (here described indirectly using “flow velocity”, “water-covered area”, and “water depth”) and aquatic vegetation as key parameters for most of the user interests, including for a number of outdoor activities in rivers. A better representation of hydrological conditions (“Flow indices”), hydromorphology (e.g. “River types”) and riparian vegetation is therefore a pre-condition not only for a better description of the ecological status in water bodies, but also for the description of the potential for many other user interests in rivers, such as water sports or bathing.
These aspects are currently addressed within the on-going HYMO-project and/or WP6 in SusWater. HYMO investigates also the possibilities for coupling the NiN classification system with other river or mesohabitat classifications. This will allow to describe “green” user interests (such as the protection of valuable nature types and endangered species, or conservation of biodiversity) in riparian zones.

The importance of different river parameters and flow indices will be analyzed as a part of the HYMO-project. Eventually, a list of key indicators will be suggested.

Table 5-3 includes the aspects mentioned by the users (Tab. 4-5) and a suggestion of indicators for non-HYMO parameters. They are largely based on parameters which are well established within the Norwegian WFD typology (cp. Table 3-3 and 3-4) and/or readily available from exiting data sets of the Norwegian Mapping Agency (NMA), the Norwegian Water and Energy Directorate (NVE) or other sources.

Table 5-3: Suggested indicators and potential data sources for the user interests reviewed

Parameter group	Category	Indicator suggested	Data sources
Discharge	HYD	investigated within HYMO	under investigation
Wetted width	HYMO/HYD		
Flow velocity	HYMO/HYD		
Water depth	HYMO/HYD		
Water surface structure	HYMO/HYD		
Slope	HYMO		
Substrate	HYMO		
Boulders / obstructions	HYMO		
River type / profile	HYMO		
Hydromorphic elements*	HYMO		
Longitudinal structure**	HYMO		
Floodplain land use	VEG	Percentage of land cover types	NMA: N50 / AR5
Bank vegetation	VEG	Percentage of land cover types within 30 or 50 m buffer zone	NMA: N50 / AR5
Aquatic vegetation	VEG	WFD-indicators, in addition macrophyte abundance	See table 3-3, 3-4; abundance: field mapping / remote sensing
Fish	FAU	WFD-indicators	See table 3-3, 3-4
Wildlife	FAU	?	
Water quality	CHE	WFD-indicators	See table 3-3, 3-4
Water temperature	CAT	Air temperature**	Met.no
Landscape Aesthetics	all	? To develop	
Weirs / bridges	INF/HYMO	Weirs / bridges	NMA: N50 / AR5 ; NVE*
Accessibility	INF	Roads and paths	NMA: N50 / AR5

**for weirs, a national data base should be created*
*** correlations/models for relation between air temperature and water temperature needed*

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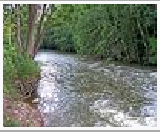
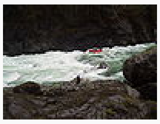
7 Appendix

Appendix 7-1: Description of the six grades of the International Scale of River Difficulty according to Walbridge and Singleton (2005). From Wikipedia (accessed 2 February 2016).

Class I: Easy	Fast moving water with riffles and small waves. Few obstructions, all obvious and easily missed with little training. Risk to swimmers is slight; self-rescue is easy.	
Class II: Novice	Straightforward rapids with wide, clear channels which are evident without scouting. Occasional maneuvering may be required, but rocks and medium-sized waves are easily avoided by trained paddlers. Swimmers are seldom injured and group assistance, while helpful, is seldom needed. Rapids that are at the upper end of this difficulty range are designated Class II+.	
Class III: Intermediate	Rapids with moderate, irregular waves which may be difficult to avoid and which can swamp an open canoe. Complex maneuvers in fast current and good boat control in tight passages or around ledges are often required; large waves or strainers may be present but are easily avoided. Strong eddies and powerful current effects can be found, particularly on large-volume rivers. Scouting is advisable for inexperienced parties. Injuries while swimming are rare; self-rescue is usually easy but group assistance may be required to avoid long swims. Rapids that are at the lower or upper end of this difficulty range are designated Class III- or Class III+ respectively.	
Class IV: Advanced	Intense, powerful but predictable rapids requiring precise boat handling in turbulent water. Depending on the character of the river, it may feature large, unavoidable waves and holes or constricted passages demanding fast maneuvers under pressure. A fast, reliable eddy turn may be needed to initiate maneuvers, scout rapids, or rest. Rapids may require "must make" moves above dangerous hazards. Scouting may be necessary the first time down. Risk of injury to swimmers is moderate to high, and water conditions may make self-rescue difficult. Group assistance for rescue is often essential but requires practiced skills. For kayakers, a strong roll is highly recommended. Rapids that are at the lower or upper end of this difficulty range are designated Class IV- or Class IV+ respectively.	
Class V: Expert	Extremely long, obstructed, or very violent rapids which expose a paddler to added risk. Drops may contain large, unavoidable waves and holes or steep, congested chutes with complex, demanding routes. Rapids may continue for long distances between pools, demanding a high level of fitness. What eddies exist may be small, turbulent, or difficult to reach. At the high end of the scale, several of these factors may be combined. Scouting is recommended but may be difficult. Swims are dangerous, and rescue is often difficult even for experts. Proper equipment, extensive experience, and practiced rescue skills are essential. Because of the large range of difficulty that exists beyond Class IV, Class V is an open-ended, multiple-level scale designated by class 5.0, 5.1, 5.2, etc. Each of these levels is an order of magnitude more difficult than the last. That is, going from Class 5.0 to Class 5.1 is a similar order of magnitude as increasing from Class IV to Class 5.0.	
Class VI Extreme and Exploratory Rapids	Runs of this classification are rarely attempted and often exemplify the extremes of difficulty, unpredictability and danger. The consequences of errors are severe and rescue may be impossible. For teams of experts only, at favorable water levels, after close personal inspection and taking all precautions. After a Class VI rapid has been run many times, its rating may be changed to an appropriate Class 5.x rating.	

Appendix 7-2: Description of the four grades of the UK Canyon Rating System (Based on the ACA Rating system). From http://www.canyonguides.org/technical-info/canyon-ratings/ (accessed 2 Dec 2016).

TERRAIN / TECHNICAL ROPE WORK

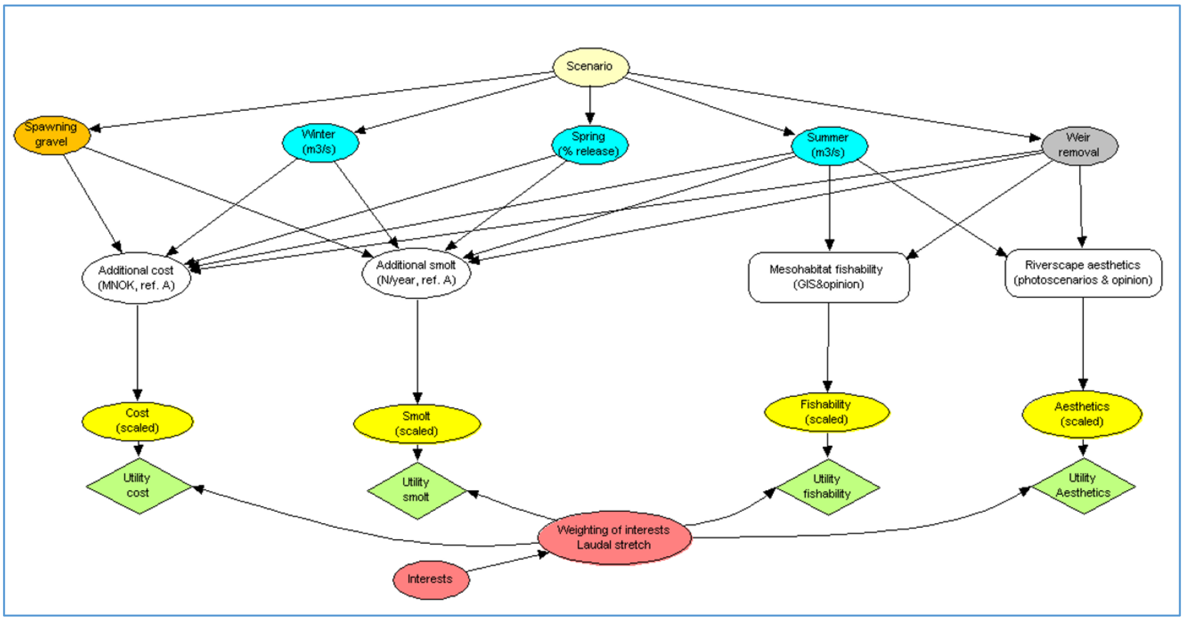
	1	**Gorge Walking and Gill Scrambling** Non-technical; no rope required. May involve some easy scrambling requiring the occasional use of hands for balance and support. Travel is possible up or down canyon. See route description for more information.
	2	**Basic Canyoneering / Gorge Walking / Gill Scrambling** Scrambling, easy vertical or near vertical climbing and/or down-climbing requiring frequent use of hands. Rope recommended for hand lines, belays, lowering packs and possible emergency use. Travel is possible up or down canyon. See route description for more information.
	3	**Intermediate Canyoneering (Single Pitch Canyon)** Exposed technical climbing. Down-climbing could be difficult and dangerous; most people will rappel. Rope required for belays and single-pitch rappels. Obvious natural or fixed anchors. Assess after each pitch is possible.
	4	**Advanced-Expert Canyoneering** Route may involve any combination of the following: 1) difficult and exposed free climbing and/or down-climbing, 2) climbing using direct aid, 3) multi-pitch rappels, 4) complex rope work (i.e. guided rappels, deviations, rebelays), 5) obscure or indistinct natural anchors, 6) advanced problem-solving and anchor-building skills. See route description for more information.

WATER VOLUME / CURRENT

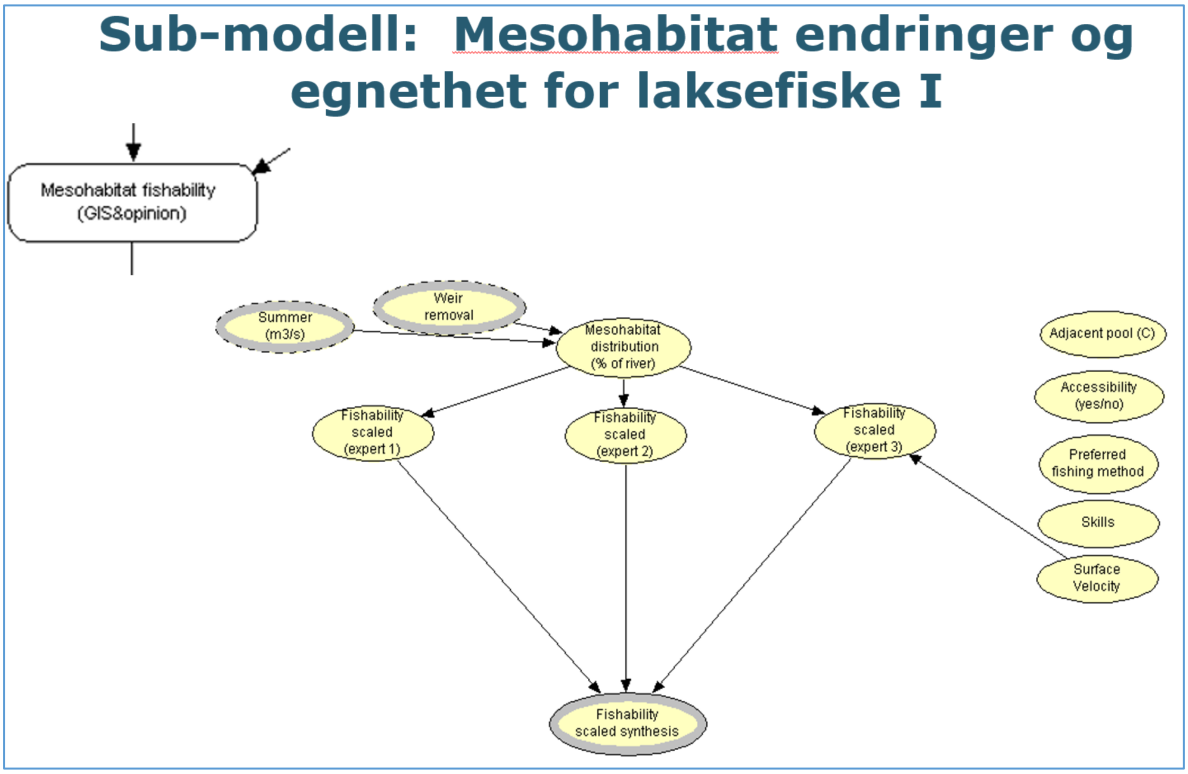
		A - Normally has water with light to moderate current. Easy water hazards. **B** - Normally has water with strong current. Water hazards like hydraulics and siphons require advanced skills and special care. **C** - Normally has water with very strong current. Dangerous water hazards. Experts only. **D**- Extreme problems and hazards will be difficult to overcome, even for experienced experts with strong swimming skills.

NOTE: Water level in any canyon can fluctuate greatly from year-to-year, season-to-season, even day-to-day. If, upon arrival at a canyon, you discover the water volume/current is greater than indicated by the rating, descent will be more difficult than suggested by the route description. It will be necessary to reevaluate your decision to attempt the descent.

Appendix 7-3: Examples for MCDA models that have been used for detailed studies in Norwegian rivers (unpublished data from CEDREN presentations)



MCDA model implementations related to the user interests "power production" (Cost), "fish" (smolt), "aesthetics", and "fishability" for the example case Mandalselva, removal of weirs no. 3,4,5 and 8 (Barton et al. 2015).



Suggested MCDA model package for the derivation of the fishability index (Barton et al. 2015).