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Summary

In this paper, a number of parameters of importance to a determination of the function of running waters as transport channels for material from the continents to the sea are presented. We have assumed that retention mechanisms of material in the river and in the riparian zone will be covered by special investigations but tried to create a platform for such investigations by quantification of the extension of different main habitats. The choice of parameters has been made so that also the nature conservation value of the river can be preliminary established, and includes a general description of the river type and the inherent ecosystem. The material links directly to that presented in a previous report concerning site investigation programmes for lakes /Blomqvist et al, 2000/.

The parameters have been divided into five groups: 1) The location of the object relative important gradients in the surrounding nature; 2) The river catchment area and its major constituents; 3) The river morphometry; 4) The river ecosystem; 5) Human-induced damages to the river ecosystem. The first two groups, principally based on the climate, hydrology, geology and vegetation of the catchment area, represent parameters that can be used to establish the rarity and representativity of the system, and will in the context of site investigation program be used as a basis for generalisation of the results. The third group, the river morphometry parameters, are standard parameters for the outline of sampling programmes and for calculations of the physical extension of key habitats in the system. The fourth group, the ecosystem of the river, includes physical, chemical and biological parameters required for determination of the influence from the terrestrial ecosystem of the catchment area, nutrient status, distribution of different habitats, and presence of fish in the system. In the context of site investigation program, the parameters in these two groups will be used for budget calculations of the flow of energy and material in the system. The fifth group, finally, describes the degree of anthropogenic influence on the ecosystem and will in the context of site investigation programmes be used to judge eventual malfunctionings within the entire, or parts of, the ecosystem.

Altogether, the selected parameters will create a solid basis for determination of the river type and its representativity of the region where it is located, and of the function and eventual malfunction of the inherent ecosystem.

Sammanfattning

I denna rapport redovisas ett antal parametrar som är av betydelse för att de rinnande vattnens basala funktion som transportleder för material från kontinenterna till havet skall kunna kvantifieras. Vi har antagit att eventuella retentionsmekanismer för radioisotoper som transporteras med vattnet kommer att studeras i speciella program och därför endast sökt lägga basen för sådana studier genom att inkludera parametrar som kvantifierar den fysiska utbredningen av olika habitat. Parametervalet har gjorts så att det även möjliggör en naturvärdesbedömning av lokalerna, och innefattar en generell beskrivning av de rinnande vattnen och deras ekosystem. Materialet har lagts upp så att det direkt kopplar till det platsundersökningsprogram för sjöar som presenterats i en tidigare rapport /Blomqvist et al, 2000/.

Parametrarna har indelats i 5 huvudgrupper. Grupp 1 beskriver vattendragets läge relativt olika betydelsefulla gradienter i omgivande natur. Grupp 2 beskriver vattendragets tillrinningsområde och dess huvudkomponenter i form av andra ekosystemtyper. Dessa båda grupper av parametrar skall främst användas för att bedöma vattendragets raritet respektive representativitet för området så att såväl goda representanter för vattendragsbeståndet som ovanliga och skyddsvärda typer av vattendrag kan identifieras. Grupp 3 utgörs av morfometriska parametrar som främst skall användas för utformning av provtagningsprogram och för beräkningar av den fysiska utbredningen av olika huvudhabitat i ekosystemet. Grupp 4 innehåller parametrar med vars hjälp ekosystemets struktur och basala ekologiska funktioner kan beskrivas, och innefattar bland annat fysikaliska parametrar som vattenflöde och temperatur samt vattenkemiska och biologiska parametrar nödvändiga för bedömning av vattendragets näringsnivå och graden av påverkan från terrestra ekosystem i tillrinningsområdet. Grupp 5, slutligen, innehåller parametrar med vars hjälp graden av mänsklig påverkan på vattendraget och dess tillrinningsområde kan bedömas och innefattar fysiska ingrepp, föroreningar, främmande arter samt exploatering av artpopulationer.

Tanken bakom parametervalet är att de lokaler som skall beskrivas vid platsundersökningar skall kunna värderas utifrån en samlad kunskap om såväl tillgångar i form av intakt natur som skador. Det är författarnas bedömning att de föreslagna parametrarna tillsammans ger en solid bas för bedömningar av typen av vattendrag, dess representativitet inom den region där den är belägen, samt av den naturliga funktionen hos ekosystemet och eventuella skador på detta.

Contents

1 Introduction

"Rivers are the gutters down which flow the ruins of the continents"
/Leopold, Wolman and Miller, 1964/.

From a broad biogeochemical perspective, the water in rivers can be regarded as a transport medium by which the weathered dissolved and particulate components of the continents are brought to the sea. While the turnover of water on earth is typically a cyclic process, the transport of weathered products from the continents can be described as unidirectional. Hence, most of the continents will with time end up as marine sediments, before returning as new continents in the most long-term perspective geological cycling. From an abiotic point of view, streams can be described as transport pathways through which material is relatively quickly passed on to the sea, while lake basins act as temporary or permanent sediment traps for particles as well as for those inorganic nutrients which are assimilated into biota that subsequently settle out in the basin. The presence of an intact ecosystem in running waters slows down the transport of material both by assimilatory processes and by direct filtering of the water through dense stands of vegetation. A reduced loss of nutrients and particulate matter from the continents to the sea is characteristic also of the terrestrial ecosystems of the drainage area, which together with the aquatic ecosystems, creates the largest functional ecosystem unit of the continents, that of the catchment. Most human-induced disturbances of the ecosystems ultimately result in altered transport of material from the continents to the sea. A majority of the disturbances tend to speed up the losses, e.g. drainage of land, channelisation of streams for transportation, agriculture, urbanisation, forestry, and acidification, while others, e.g. construction of dams, typically result in decreased losses of material to the sea. Investigating the role of running waters as transportation channels for material on its way from the continents to the sea, a large number of internal and external factors must be included, e.g. the climate, geology, vegetation and higher biota of the drainage area as well as the river basin morphometry and characteristics of the inherent ecosystem and its key habitats. It is also essential to have good knowledge of the human-induced damages to the systems. Thus, in all studies aiming at understanding of a river ecosystem functioning from a biogeochemical perspective, the running water must be regarded as an integral part of the drainage area.

SKB, The Swedish Nuclear Fuel and Waste Management Company, is planning to continue the siting program for a deep repository of spent nuclear fuel during 2001–2008 with surveys of at least three potential sites, located in the communities of Östhammar, Oskarshamn and Tierp, are of interest. Previous studies carried out to identify suitable areas have mainly focused on geology and transport possibilities. By analysing site characteristics it will become possible to identify the most suitable areas for the siting program. The sites will be surveyed for data relevant to evaluate the construction and function of a planned deep repository. There are scientists from several fields of investigation preparing for the siting program. Variables that might be of interest to study from an ecosystem point of view have been compiled by Lindborg and Kautsky /2000/ and by Blomqvist et al /2000/, variables of interest for geological investigations are presented in Andersson et al /1998/, available climatological and oceanographical data are presented in Lindell et al /1999/, and available statistics for site studies in registers and surveys at Statistics Sweden are presented in Haldorson /2000/.

This report describes a selected number of river and river-related drainage area parameters required for a preliminary determination of the ecological functioning of the river ecosystem from a point of view of its functioning as a transport channel and temporary trap for radioactive compounds that may enter the biosphere in case of a leak of the containers holding the nuclear waste. The report has been outlined in order to connect directly to a previous report describing lake and lake-related drainage area parameters for site investigation program /Blomqvist et al, 2000/.

2 The location of the object relative important gradients in the surrounding nature

Even to a greater extent than what is the case for lakes, the physical, chemical, and biological properties of a river ecosystem reflect the conditions of the surrounding catchment area, from which the water originates. The climate of the area determines the drainage regime which is a key parameter determining the flow of water and transport of nutrients in the system. The bedrock and soils of the drainage area are the principal sources of many important plant nutrients in the water. Hence, the richer and more easily weathered the soils, the more nutrient rich and productive the water.

The vegetation and size of the drainage area are important determinators of the transport of terrestrial organic carbon into and through the river, a factor which in turn determines relative importance of autotrophic and heterotrophic processes in utilising nutrients and mobilising carbon energy at the base of the food-web; most rivers are net heterotrophic systems /e.g. Cole et al, 2000/. During the Quaternary period, Scandinavia has suffered at least four major periods of glaciation and subsequent meltoff of the glaciers. As a result of these dramatic changes, most geological layers between the Precambrian shield and Quaternary have been eroded and lost to the sea and settled there as marine sediments. Areas dominated by the Precambrian shield (bedrock) and its weathering products (soils), respectively, are characterised by scarcity of nutrients and a resulting low productivity of terrestrial as well as aquatic ecosystems. However, as a result of the depression of the peninsula into the crust of the Earth during last glaciation, large parts of Sweden have a substantial land-rise also today and this process brings more easily weathered and nutrient-rich soils back on land. Hence, land areas below the highest shoreline of the sea have a greater production potential than other areas, including also the lakes and streams. The Baltic Sea has passed through four major stages in shape and character after the last glaciation; first being a freshwater ice lake, then the Yoldia Sea, the Ancylus lake and, finally, the Littorina Sea, the present stage of which is entitled the Baltic Sea. As a consequence, there are several highest shorelines of “the Baltic” in the landscape /cf. Påsse, 1996/. Two of these shorelines are especially important to the distribution of post-glacial sediments on land because the glacier had almost melted off from Sweden when they were formed. They are the shoreline of the Ancylus lake (which is the highest of the four) and that of the Littorina Sea (below which marine sediments were settled). According to differences in the quantity and quality of soils that have been brought up by land rise, the drainage areas of Sweden may be divided into three regions regarding fertility; 1) above the very highest shoreline (VHS), 2) between VHS and the highest shoreline of the Littorina Sea (HSL), and 3) below HSL.

Although it may be claimed that each running water is unique, the similarities between rivers and streams are likely to increase with decreasing distance between systems, due to similarities caused by the factors described above. Hence, in the analysis of the rarity and representativity of river ecosystems, these factors can be used for sorting the rivers into main categories. As far as the authors know, there are no standardised ways to establish the rarity and representativity. We therefore propose a new method, based on regional non-river parameters, starting with the large-scale factors described in this chapter. Combined with the catchment area parameters described in Chapter 3, it will be possible to establish how many running waters in each area of Sweden intended for the site investigation program that have similar characteristics. Below follows a description of the large-scale factors, some of which are already available on the National SKB GIS. In the context of using the GIS for calculations of various parameters on the national and regional scales it has been assumed that the programme ArcView is the basis for storage and analysis of the data. The suggestions below are identical to those given for lakes /Blomqvist et al, 2000/ and we have assumed that data representing running waters will be stored in the same GIS as data regarding lakes.

2.1 Location relative major drainage regions

In accordance with what has been suggested for lakes, we suggest that the division of Sweden into nine major drainage regions (MDR) presented by Melin /1970/ is used also for classification of rivers:

MDR 1. The rivers of Nordkalotten: Rivers Torneälven and Kalixälven.

MDR 2. The northern alpine rivers of Norrland: Rivers Lule-, Pite-, Skellefte- and Umeälven.

MDR 3. The central alpine rivers of Norrland: Rivers Ångermanälven and Indalsälven.

MDR 4. The alpine and forest rivers of southern Norrland and northern Svealand: Rivers Ljungan, Ljusnan, Dalälven, and Klarälven.

MDR 5. The forest and coastal rivers of Norrland.

MDR 6. Rivers which represent a transition between northern and southern types: Rivers entering Lake Vänern from the north (except R. Klarälven) and rivers entering Lake Mälaren from Bergslagen.

MDR 7. Rivers in SE Sweden that enter the Baltic Proper.

MDR 8. Rivers in SW Sweden that enter Skagerack or Kattegatt.

MDR 9. The outlet rivers of the large Lakes: Norrström and Göta Älv except those parts that are members of MDR6 or MDR4.

2.1.1 Methods for data collection

The map can be constructed by aggregation of the main river systems of Sweden on the digital drainage area map available from the Swedish Meteorological and Hydrological Institute (SMHI) into nine major drainage regions (MDR). Using the overlay technique in the Regional SKB GIS, each drainage area within the sites intended for the site investigation program can be assigned to a major drainage area.

2.1.2 Costs

The digital drainage area map over Sweden can soon be bought from the Swedish Meteorological and Hydrological Institute (SMHI). The price is yet not available.

2.2 Location relative main river systems of Sweden

We suggest that the division of Sweden into main river systems follows that of the Swedish Meteorological and Hydrological Institute (SMHI), using the label 1 for River Torneälven and 118 for Snodeån.

2.2.1 Methods for data collection

The available digital map of drainage areas of Sweden can with GIS be aggregated into a map with main river systems.

2.2.2 Costs

See 2.1.2.

2.3 Location relative important terrestrial ecozones (naturgeografiska regioner)

We suggest that the division of the Nordic countries into important terrestrial ecozones (naturgeografiska regioner) by the Nordic meeting of the Ministers /NU, 1977/ is used. Out of a total of 76 such regions, 29 are found in Sweden.

2.3.1 Methods for data collection

A digital map of the ecozones, produced by the National Atlas of Sweden, is included in the National SKB GIS. In those cases when a drainage area extends into several eco-zones, the dominant (by area) zone is used for the classification.

2.3.2 Costs

The digital ecozones map over Sweden has been bought from the National Atlas of Sweden. The total cost for all maps (see also Sections 2.4.2 and 2.5.2, below) required from the atlas is ca. 3000 SEK.

2.4 Location relative main soil regions of Sweden

We suggest that the division of Sweden into 13 major soil regions established by Persson and presented in the National Atlas of Sweden is used /SNA, 1994/.

2.4.1 Methods for data collection

The map can be bought in digital format from the National Atlas of Sweden (SNA). In those cases when a drainage area extends into several soil regions, the dominant (by area) region is used for the classification.

2.4.2 Costs

The digital soil region map over Sweden has be purchased from the National Atlas of Sweden (SNA) (see Section 2.3.2).

2.5 Location relative marine limits

We suggest that the available digital maps of the very highest shore line of the Baltic (VHS), and the highest shore line of the Littorina Sea (HSL) is used for this classification. These maps are then combined, which gives a map with three areas; above VHS, between VHS and HSL, and below HSL. Using overlay technique in the Regional SKB GIS each local drainage area can be assigned to a particular location relative the marine limits. In those cases when a drainage area extends over several marine limits the dominant (by area) region is used for the classification.

2.5.1 Method for data collection

The digital map of the highest shoreline of the Baltic is available at the Department of Ecology and Environmental science, University of Umeå and the digital map of the highest shoreline of the Littorina Sea is available from the National Atlas of Sweden.

2.5.2 Costs

The costs for the digital map of the highest shoreline of the Baltic is free of charge and the digital map of the highest shoreline of the Littorina Sea has been purchased from the National Atlas of Sweden (see Section 2.3.2).

3 The catchment area and its major constituents

Knowledge about the characteristics of the land area (catchment area) from which water is transported to lakes and streams is of outmost importance for the understanding of the functioning of aquatic ecosystems. The catchment area is defined as the upstream area collecting the water that flows over any given cross-section of a running water. During the past decade it has been realised that carbon produced in the drainage area is metabolised during the passage through a river ecosystem to such an extent that most running waters can be regarded as net heterotrophic systems, i.e. producing carbon dioxide to and consuming oxygen from the atmosphere /Cole et al, 2000/. Particularly in the highly stained running waters dominating the boreal forest region, it is most likely that allochtonous organic carbon is more important for the total production of biota than carbon produced within the system. Hence, good knowledge about the catchment area is crucial to the understanding of the natural functioning of river ecosystems. The same line of reasoning can indeed be applied to understanding of man-made damages to the functioning of lakes and streams, as there are few damages to aquatic ecosystems that do not have their origin in terrestrial parts of the drainage area. The problems of physical damages, acidification, eutrophication, toxic substances etc., all have their origin in undertakings in the catchment area. Hence, in studies pertaining to understand the functioning and malfunctioning of running waters, including the aim of the material generated for the site investigation program, good knowledge about the catchment area is crucial. The description of parameters given below is analogous to the description of parameters proposed for the lake investigation programme /Blomqvist et al, 2000/ and we have assumed that data regarding running waters will be stored in the same GIS as the data regarding lakes.

3.1 Size and subdivision of the catchment area

The size of the catchment area is the needed basic parameter for determination of all other drainage area parameters described below. The size of the catchment area can be obtained by a variety of methods to determine the size of an area, manual (e.g. through planimetry) as well as automatic (see below). However, before any calculations can be made the location of the watershed must be established which requires manual work on a high-resolution topographic map and which sometimes must be complemented by field studies. Especially in lowland plains, establishment of the watershed may be a difficult task and require field verifications.

Depending on the specific aim of the study, it may become necessary to divide large catchments into smaller units. Exactly which subdivisions that may be used by SKB in the studies included in the site investigation program is not yet clear. However, we would like to suggest that the criteria of Brunberg and Blomqvist /1998/ are used already in an initial step in order to provide a solid base for design of general water chemistry sampling programmes, delineation of terrestrial study areas etc. The criteria that should be used are then:

1) As a framework for the division we suggest that the major catchments of Sweden established by the Swedish Meteorological and Hydrological Institute (SMHI) are used, labelled 1 for River Torneälven and 118 for Snodeån. Intermediate catchments, i.e. catchments that fall between the major catchments, should also be included in the data set and labelled 1/2 to 117/118.

2) Each larger catchment is then further divided into subunits so that each lake larger than 3 ha and each tributary longer than 10 km becomes a separate unit which then is characterised by the same parameters as the main unit. The resulting data set is then inserted into the regional GIS in a hierarchic form so that the pieces can be put together into the largest units.

3.1.1 Existing data

The Swedish Meteorological and Hydrological Institute (SMHI) has a digital map of the major drainage areas in Sweden, including some 11500 units. This map is already available on the Regional SKB GIS but not nation-wide. Furthermore, Brunberg and Blomqvist /1998/ includes a high-resolution drainage area map of Uppsala County with a total of 277 units, which covers all sites in the communities of Älvkarleby, Tierp, and Östhammar. This map is also available on the Regional SKB GIS. For the remaining areas of interest to the site investigation program, the larger drainage areas of the SMHI map should be further divided into subunits in the same way as for Uppsala County.

3.1.2 Methods for data collection

Performance

The watershed is tracked and preliminary marked with a pencil on the topographic map (Gröna kartan). In cases where the location of the watershed is not clear on this map, the high resolution topographic map (Ekonomiska kartan) is used as a complement. In cases where it is still not possible to locate the watershed, field studies are used to finally resolve the problem. After the watershed has been established it is finally drawn with a black Indian ink pen on the main topographic map (Gröna kartan). The information from this map is then digitised as described below.

Background data

Background data needed include topographic maps of Sweden (Gröna kartan) and access to the most recent version of the economic map (Ekonomiska kartan) which has also the topographic information.

Time schedule

Establishment of the watershed is done once and for all, unless major changes in river flow or man made disturbances, e.g. channelisation, alters the conditions completely.

Potential resources

Establishment of the location of the watershed can be carried out by hydrologists and limnologists as well as by physical geographers.

Data processing

For the communities of Älvkarleby, Tierp, and Östhammar, the drainage area information from Brunberg and Blomqvist /1998/, already available on the Regional SKB GIS is used. For other sites intended for site investigation program, the digital map of drainage areas available from SMHI is primarily used. Remaining drainage areas are made available from the topographic maps, scanned into the computer, and digitised. The area of each sub-catchment is calculated within the GIS and stored as an attribute value in a table linked directly to the map.

Uncertainty – Risks

The precision of the parameter size of the drainage area will to a great extent rely on the precision of the location of the watershed, which in turn depends on the type of topographic map used (scaling factor) and whether or not difficult sections have been verified by field studies. Hence, using the main topography map of Sweden alone may result in large errors, whereas by using the entire procedure described above, the precision will be determined by the resolution of the map from which data are scanned and directly proportional to the size of the drainage area.

Costs

Personnel involved in work with location of the watershed on maps and in the field are paid at an hourly or monthly rate.

3.2 Vegetation and land use in the drainage area

Once the size of the drainage area has been established (see 3.1, above), other characteristics of the area can be calculated using overlay techniques in GIS. The vegetation and land use in each drainage area are obtained using a combination of the following digital products already available on the Regional SKB GIS: Landsat satellite images (forest) and the topographic map of Sweden, “Lantmäteriets blå karta” (other kinds of land use). Using overlay technique in the Regional SKB GIS, the area of each kind of land use can be calculated and is then saved as attributes to the drainage area map. The resulting parameters from this step in the procedure include the size and relative contribution of forests, wetlands, open land, lakes, urban areas, and major industries within the catchment.

3.3 Bedrock in the drainage area

Once the size of the drainage area has been established (cf. 3.1, above), other characteristics of the area can be calculated using overlay techniques in GIS. The bedrock in the drainage area is obtained from the digital bedrock map, which is available from the National Atlas of Sweden. Using the overlay technique the area of each type of bedrock can be calculated and is then saved as attributes to the drainage area map. The resulting parameters from this step in the procedure include all different types of bedrock on the map.

3.4 Soils in the drainage area

Once the size of the drainage area has been established (cf. 3.1, above), other characteristics of the area can be calculated using overlay technique in GIS. The distribution of soils in the drainage area is obtained from the digital soil map, which is available from the National Atlas of Sweden. Using the overlay technique the area of each type of soil can be calculated and is then saved as attributes to the drainage area map. The resulting parameters from this step in the procedure include all different types of soils on the map.

3.5 Populations of humans and live stock and residences in the drainage area

Once the size of the drainage area has been established (cf. 3.1, above), other characteristics of the area can be calculated using overlay technique in GIS. Data on populations of humans and live stock and residences can be bought from SCB and is available for each km^2 of Sweden. The data are transformed to a digital map in a raster format and using the overlay technique, the number of humans and live stock and residences in each drainage area is calculated. The resulting data are then saved as attributes to the drainage area map.

3.6 Climate

Once the size of the drainage area has been established (cf. 3.1, above), other characteristics of the area can be calculated using overlay technique in GIS. The climate of the area is obtained using digital maps over average temperature, evaporation, and area-specific runoff, which are available from the National Atlas of Sweden. Using the overlay technique, area-weighted averages for each parameter and drainage area are calculated and subsequently saved as attributes to the drainage area map. The resulting parameters include average temperature, evaporation, and area-specific runoff.

3.7 Actual and calculated runoff

Once the size of the drainage area has been established (cf. 3.1, above), other characteristics of the area can be calculated using overlay technique in GIS. For all running waters in each site intended for the site investigation program in which the runoff is continuously measured, monthly average runoff data for the latest 30 year period are bought from SMHI and saved as attributes in the table linked to the drainage area map. For all drainage areas the annual average runoff is calculated using the area-specific runoff maps (cf. 3.6, above) and the resulting data are saved as attributes in the table linked to the drainage area map.

3.8 Drainage area morphometry

Once the size of the drainage area has been established (cf. 3.1, above), other area-related characteristics can be calculated using overlay technique in GIS. The drainage area morphometry, including maximal and average slope of the landscape, is calculated using the digital elevation model (DEM) already available on the Regional SKB GIS for the sites intended for the site investigation program. The resulting data are saved as attributes in the table linked to the drainage area map.

3.9 Total length of the main running water and of major (> 10 km) tributaries

Once the catchment area has been delineated and divided into subcatchments (cf. 3.1, above), the length of the main river and its larger tributaries can be calculated in the GIS.

4 River morphometry parameters

In Chapters 4, 5, and 6, we have outlined a number of river-specific parameters to be used within the site investigation program. We have not been aware of all the aims of the site investigation program but we have have assumed that all running waters passing through an area in which a deep repositiry might be located will be carefully monitored. We have furthermore assumed that stations for measurements of water transport and water quality parameters will be allocated to the section of a river where it enters the study area, to the mouth of each larger tributary which enters the river section where the repository might be allocated and to the mouth of the river as it enters the sea (or a larger river system). With such a set-up it will become possible to establish budgets for the transport of material in and out of an area of interest. We have furthermore assumed that detailed descriptions of the river morphometry, distribution of key habitats, and damages to the system only are necessary within areas of interest for location of a deep repository. For the running waters in their entirety we have assumed that the drainage area parameters outlined in Chapter 3, above, will be sufficient for a general description of the system. Hence, all parameters listed in the three following chapters relate to specific sections of a running water system.

The parameters described in this chapter are to be used for construction of a three-dimensional model of a section in a stream in which water from a deep repository may enter the surface.

4.1 Total length of the running water within a section of interest

4.1.1 Existing data

Since this parameter is unique to the site investigation programme data from previous studies are lacking.

4.1.2 Methods for data collection

Performance

The length of the section of the running water of interest to the site investigation program is measured directly in the field by marking points along the section using a DGPS equipment.

Time schedule

The length of the section of interest is measured once and for all.

Potential resources

This parameter can be measured by anyone who can use a DGPS equipment but measurement is only a minor part of the description of the section which requires a skilled physical geographer or running water limnologist.

Data processing

Coordinates of the endpoints and verticies along the section are imported to the GIS and the total length of the section is calculated.

Uncertainty – Risks

The accuracy of the measurement will be depending on the precision of the DGPS-equipment.

Costs

Costs in connection with measurements of the lenght of the section, as well as other parameters in Chapter 4, include travel and subsidence expenses and salary at an hourly rate of the person involved in the measurement.

4.2 Slope of the bottom in the deepest part along the section

4.2.1 Existing data

Since this parameter is unique to the site investigation programme data from previous studies are lacking.

4.2.2 Methods for data collection

Performance

The coordinates and the elevation (meter above sea level) is measured at profiles across the river at approximately 25 meters distance between each profile using DGPS. The elevation measurements should be made within closer distances in areas with stronger gradients.

Time schedule

The slope of the bottom of the section of interest is measured once and for all.

Potential resources

This parameter can be measured by a skilled physical geographer or running water limnologist or preferably a combination of one of each.

Data processing

The point data is imported to the GIS and combined with digital elevation data from "Lantmäteriet". A new digital elevation model (DEM) is calculated using Kriging interpolation method. The slope of the bottom is calculated in the GIS using the new DEM.

Uncertainty – Risks

The accuracy for DGPS-measurements of coordinates is always better than 5 meters and approximately better than 1 meter in open spaces. The accuracy of the elevation measurements are approximately 1 meter.

Costs

See 4.1.2.

4.3 Bottom substrate along the deepest part of the section

4.3.1 Existing data

Since this parameter is unique to the site investigation programme data from previous studies are lacking

4.3.2 Methods for data collection

Performance

The bottom substrate along the section is characterised into the categories gravel, sand, silt, clay and fine grained sediment with high organic content (gyttja clay or clay gyttja) and the borderlines between the different categories are marked using the DGPS.

Time schedule

The bottom substrate along the deepest part of the section of interest is characterised once and for all.

Potential resources

This parameter can be measured by a skilled physical geographer or running water limnologist or preferably a combination of one of each.

Data processing

The boarder lines between different bottom substrate categories are already in the field marked with an unique identification code for each type of boarder line (e.g. points along the border between sand and silt are marked with the identification code 1). The point data is imported to the GIS and the points for different boarder lines are connected to lines and the lines are converted to polygons to form a digital bottom substrate map**.**

Uncertainty – Risks

In shallow streams the measurement of this parameter should not involve any major problems, in deeper waters it may require a diver.

Costs

See 4.1.2.

4.4 The location of the highest shoreline along the section

4.4.1 Existing data

Since this parameter is unique to the site investigation programme data from previous studies are lacking.

4.4.2 Methods for data collection

Performance

The location of the highest shoreline is measured by analysing the vegetation along the shore and marking the location of the highest shoreline using a DGPS equipment.

Time schedule

The location of the highest shoreline along the section is measured once and for all.

Potential resources

This parameter can be measured by a skilled physical geographer or running water limnologist or preferrably a combination of one of each.

Data processing

The point data are imported to the GIS and the points are connected to form the highest shoreline and the lines are converted to polygons to show the area beneath the highest shoreline.

Uncertainty – Risks

Using well trained personnel, the precision of this parameter will mainly depend on the precision of the DGPS equipment.

Costs

See 4.1.2.

4.5 The location of the lowest shore line along the section

4.5.1 Existing data

Since this parameter is unique to the site investigation programme data from previous studies are lacking.

4.5.2 Methods for data collection

Performance

The location of the lowest shoreline along the section is measured using DGPS equipment. The study is performed at a time of the year when flow of water is minimal (i.e. when the running water has approached a standing water).

Time schedule

The location of the lowest shoreline along the section is measured once and for all.

Potential resources

This parameter can be measured by a skilled physical geographer or running water limnologist or preferably a combination of one of each.

Data processing

The point data are imported to the GIS and the points are connected to form the lowest shoreline and the lines are converted to polygons to show the area beneath the lowest shoreline.

Uncertainty – Risks

If the measurement is carried out by well trained personnel, the precision will mainly depend on the precision of the DGPS equipment.

Costs

See 4.1.2.

4.6 Transsect describing the height profile across the running water

4.6.1 Existing data

Since this parameter is unique to the site investigation programme data from previous studies are lacking.

4.6.2 Methods for data collection

Performance

The height profile across the running water is measured at regular intervals along the section of interest using DGPS (See 4.2.2)

Time schedule

The height profile across the running water is measured once and for all.

Potential resources

This parameter can be measured by a skilled physical geographer or running water limnologist or preferably a combination of one of each.

Data processing

See 4.2.2.

Uncertainty – Risks

Using well trained personell, the precision of this parameter will mainly depend on the precision of the DGPS equipment.

Costs

See 4.1.2.

4.7 Transsect describing the bottom substrate across the running water

4.7.1 Existing data

Since this parameter is unique to the site investigation programme data from previous studies are lacking.

4.7.2 Methods for data collection

Performance

See 4.3.2.

Time schedule

See 4.3.2.

Potential resources

This parameter can be measured by a skilled physical geographer or running water limnologist or preferably a combination of one of each.

Data processing

See 4.3.2.

Uncertainty – Risks

See 4.3.2.

Costs

See 4.1.2.

5 River ecosystem parameters

The structure and function of a running water ecosystem can be determined from a large number of parameters, physical and chemical as well as biological. Since the detailed aims of the site investigation program to be run by SKB are yet not known, the complete number of parameters necessary for the studies is also unknown. To present a complete list of all the possible parameters to be included in any kind of study of a running water is beyond the scope of this report. Therefore, in the outline below, we have chosen a number of parameters required for calculations of import of substances to and export of substances from a given section of the running water of interest in site investigation program (cf introduction to Chapter 4), and for an areal distribution of river and riparian zone habitats. We also suggest that a description of the fish community of each site is included in the studies.

In doing so we have assumed that the main aims of the site investigation program are 1) to establish budgets for the transport of material in and out of an area in which the deep repository for nuclear waste is located and 2) to measure the physical extension of different habitats in the area in which there might be a retention of contaminants. Regarding the latter, we have assumed that actual measurements of the retention of material in the river basin will be carried out as separate projects and therefore we have focused on studies that provide the necessary basis for ecosystem modelling.

5.1 Rate of flow and water discharge

The current velocity and transport of water over a given cross-section of a running water are key parameters in most studies of the functioning of running water ecosystems and for calculations of the transport of material from one point to another. The higher the resolution in time of the measurements, the more accurate the calculations.

5.1.1 Existing data

There are no existing official (SMHI) measurements of discharge in the counties of Tierp and Östhammar. In the county of Oscarshamn, the river Emån is running through the county close to the sea. For Emån there are measurements of discharge since 1901.

5.1.2 Methods for data collection

Performance

Measurements of water depth should be carried out using an automatic pressure gauge with compensation for air pressure connected to a data logger. The relationship between water depth and discharge (the rating equation) is established by repeated measurements of the water velocity at different water depths. The water velocity measurement schould be carried out by a current meter of propeller type. The calculation of the discharge is carried out with the water depths and the rating equation.

Time schedule

The automatic depth gauge should measure the water depth with one measurement per minute, but only store one average value per hour.

Potential resources

The installation and maintainance of the equipment will best be performed by a skilled physical geographer or hydrologist.

Data processing

Daily mean values of current velocity and water discharge can be directly transferred into a computer file from the data logger and stored in databases, using date of sampling as the only descriptor. The data in the database should then be printed in the form of a primary protocol and checked for errors. Both protocols should then be signed, using name and date of input, by the person in charge of the inlogging procedure and finally stored in a paper file.

Uncertainty – Risks

The instrument should be checked frequently for eventual malfunctioning.

Costs

Cost in connection with automatic measurements of water velocity and discharge are restricted to travel and subsidence costs and salary at an hourly rate of the person involved in checking the functioning of the instrument.

5.2 Water temperature

The annual variations in water temperature are tightly coupled to a large number of physical, chemical, and biological processes regulating the metabolism of the river ecosystem. Hence, good knowledge about the temperature fluctuations is fundamental to understand the functioning of the river ecosystem.

5.2.1 Existing data

Measurements of the water temperature in a particular running water are as a rule lacking. However, both within research projects and within local, regional, and national river monitoring programmes, measurements of water temperature may have been included. Such data can be found in reports and scientific papers at the universities and in reports published by the local, regional and national water authorities. As a rule, reports from local and regional authorities should be kept by the Regional Administrative Office of the County (Länsstyrelsen). National data can be accessed by Internet at http://www.ma.slu.se. For Uppsala County, references to data sources with a majority of the data generated up to 1997 are given in Brunberg and Blomqvist /1998/. However, as most of the monitoring programmes only include a single or a few observations per year, the resolution in time is not good enough for such data to be used alone. Thus, in connection with the site investigation program, new data on water temperature must be generated.

5.2.2 Methods for data collection

Performance

Water temperatures can be continuously measured with recording temperature probes or measured discretely with a thermometer inside a water sampler. The required precision of the instrument is ± 0.1 °C. We suggest one sampling point located in the middle of the main current to be used for the measurements.

Background data

Background data includes a map with instructions about the location of the sampling point.

Time schedule

We suggest continuous measurements of water temperatures.

Potential resources

Installation of equipment for continuous measurement of water temperatures require well trained personnel. A survey of water temperature at a given moment can be performed by any person with basic knowledge of aquatic systems. However, such surveys are almost exclusively carried out in connection with other measurements (e.g. water chemistry), which requires trained personnel (cf. 5.3–5.10, below).

Data processing

Average daily temperature data can be directly logged into a computer file from the raw (field) protocol and stored in databases, using date of sampling as the only descriptor. The data in the database should then be printed in the form of a primary protocol and checked against the raw protocol for errors. Both protocols should then be signed, using name and date of input, by the person in charge of the inlogging procedure and finally stored in a paper file.

Uncertainty – Risks

The instrument or thermometer should be calibrated regularly, using a certified reference thermometer for the appropriate temperature interval. Thermometers placed within water samplers have a tendency to break. Thermistometers must be thoroughly checked for batteries and calibrated before travelling to the field. Automatic thermistor chains must be continuously checked for function and well protected from sabotage.

Costs

Cost in connection with measurements of water temperature are restricted to travel and subsidence expenses and salary at an hourly rate of the person involved in the measurement.

5.3 The pH-value of the water

The pH-value is a standard parameter describing the acidity of the water, which in turn is coupled to the conditions of the bedrock, soils and vegetation of the catchment area. In areas where the soils have a high content of easily weathered substances, the pH-value of the water is generally higher than in areas with more refractory soils. If background levels are known, measurements of the pH-value can also be used to determine human-induced acidification of the system (cf. 6.2.2, below).

5.3.1 Existing data

Measurements of the pH-value of running waters have been frequently carried out in connection with monitoring of acidification of surface waters. Hence, both in connection with research projects and local, regional, and national river monitoring programmes, measurements of the pH-value may have been carried out. Data can be found in reports and scientific papers at the universities and in reports published by the local, regional and national water authorities. As a rule, reports from local and regional authorities should be kept by the Regional Administrative Office of the County (Länsstyrelsen). National data can be accessed by Internet at http://www.ma.slu.se. For Uppsala County, references to data sources with a majority of the data generated up to 1997 are given in Brunberg and Blomqvist /1998/. However, as most of the monitoring programmes only include a single or a few observations per year, the resolution in time may be low. Furthermore, most of the environmental monitoring with respect to pH-value of the water have been carried out in poorly buffered areas in the forested regions of Sweden. From other areas, including the localities chosen for the site investigation program, data from a particular running water may be very sparse. Thus, in connection with the site investigation program new data on the pH-value of the water must be generated.

5.3.2 Methods for data collection

Performance

Measurements of the pH-value of the water in connection with the site investigation program are best performed by taking discrete samples of river water in the middle of the main stream at a sampling station free of macrophyte vegetation. Such samples should also be used for the determination of all other water chemistry parameters described below. Water for analysis of all parameters described in 5.3–5.9 can be taken in the same bottle. Water for analysis of the concentrations of dissolved oxygen should be taken in separate bottles. The pH-value of the water should be measured on unpreserved water directly after transportation to the laboratory and preferably on the same day as the samples have been taken. The measurements should be performed according to Swedish Standard SS 02 81 22 mod.

Background data

Background data includes a map with instructions about the location of the sampling point.

Time schedule

A normal resolution in time is biweekly or monthly samplings throughout the year. If possible, sampling frequency should be increased during periods of high flow in order to increase the precision of the calculations of annual transport of substances through the system. Sampling of water for measurements of water chemistry (i.e. pH-value, alkalinity, colour, concentrations of particulate and dissolved organic carbon, concentrations of total phosphorus and soluble reactive phosphorus, concentrations of total nitrogen, ammonium nitrogen and nitrite+nitrate nitrogen, and chlorophyll a) should be coordinated with control of the functioning of instruments for continuous measurements of water velocity, discharge and water temperature, and with sampling for measurements of the concentrations of dissolved oxygen.

Potential resources

Sampling of water for measurements of water chemistry parameters of the water should be performed by trained personnel which are mostly to be found among limnologists. Measurements of the water chemistry should be performed by an accredited laboratory specialised on analyses of water chemistry of natural, unpolluted waters.

Data processing

Data on the water chemistry can be directly logged into a computer file from the analytical protocol delivered from the accredited laboratory and stored in databases, using date of sampling as the only descriptor. The data in the database should then be printed in the form of a primary protocol and checked against the raw protocol for errors. Both protocols should then be signed, using name and date of input, by the person in charge of the inlogging procedure and finally stored in a paper file.

Uncertainty – Risks

The precision of the measurements of different water chemistry parameters is affected by the precision of the sampling procedure and by the precision of the method of analysis by the accredited laboratory. The latter is given by the manual of standard procedures to be used in the context of the site investigation program (see above).

The main source of error during freshwater sampling is the same as during other types of sampling: poorly educated sampling personnel. Among the errors such personnel frequently give rise to, the following can be mentioned:

- Poorly rinsed and dirty sampling equipment is one common source of error.

  The most common places in which sampling equipment is contaminated is probably in cars during transportation (through contact with petroleum products), on the ground during transfer of the equipment from one vehicle to another (soil) or in the water inside boats (petroleum products, rotten fish etc.). To avoid this kind of contamination the entire sampling equipment should be kept in separate containers during transportation.

- Sampling is performed during a cold day and the personnel are wearing woollen or other kinds of gloves on their hands. From the gloves, and in particular from woollen gloves, a stream of dirty water runs into the sampling containers. The contamination is not only due to dirty gloves but also due to chemical compounds that have been used to impregnate the gloves or from different kinds of dyes. If warming gloves are needed, they should be covered with plastic gloves to prevent contamination.

- Another frequently occurring source of contamination is that the water sampler has been in contact with the bottom sediments or vegetation. To avoid this the sampled water should be checked before it is poured into the container. No visible turbidity is allowed in the lower part of the water sampler.

- If the water is sampled by a person walking in a small river, the sampling equipment should be turned upstream, in order to avoid contamination from disturbed (resuspended) bottom substrate or from boots.

Costs

Costs in connection with sampling of water for measurements of the pH-value include travel and subsidence expenses and salary at an hourly rate of the person involved in the measurement. Costs for analysis of the pH-value of the water by an accredited laboratory amount to ca 50 SEK per analysis.

5.4 The alkalinity of the water

The alkalinity of the water is a standard parameter describing the buffering capacity of the water against acidification, which in turn is coupled to the conditions of the bedrock, soils and vegetation of the catchment area. In areas where the soils have a high content of easily weathered substances, the alkalinity of the water is generally higher than in areas with more refractory soils. If background levels are known, measurements of the alkalinity of the water may also be used to determine human-induced acidification of the system (cf. 6.2.2, below).

5.4.1 Existing data

Measurements of the alkalinity of the water in running waters have been frequently carried out in connection with monitoring of acidification of surface waters. Hence, both in connection with research projects and local, regional, and national river monitoring programmes, measurements of the alkalinity may have been carried out. Data can be found in reports and scientific papers at the universities and in reports published by the local, regional and national water authorities. As a rule, reports from local and regional authorities should be kept by the Regional Administrative Office of the County (Läns-styrelsen). National data can be accessed by Internet at www//http.ma.slu.se. For Uppsala County, references to data sources with a majority of the data generated up to 1997 are given in Brunberg and Blomqvist /1998/. However, as most of the monitoring programmes only include a single or a few observations per year, the resolution in time may be low. Furthermore, most of the environmental monitoring with respect to alkalinity of the water have been carried out in poorly buffered areas in the forested regions of Sweden. From other areas, including the localities chosen for the site investigation program, data from a particular running water may be very sparse. Thus, in connection with the site investigation program, new data on the alkalinity of the water must be generated.

5.4.2 Methods for data collection

Performance

Sampling see 5.3.2.

The alkalinity of the water should be measured on unpreserved water directly after transportation to the laboratory and preferably on the same day as the samples have been taken. The measurements should be performed according to Swedish Standard SS 02 81 39 mod.

Background data

See 5.3.2.

Time schedule

See 5.3.2.

Potential resources

See 5.3.2.

Data processing

See 5.3.2.

Uncertainty – Risks

See 5.3.2.

Costs

Costs in connection with sampling of water for measurements of the alkalinity include travel and subsidence expenses and salary at an hourly rate of the person involved in the measurement. Costs for analysis of the alkalinity of the water by an accredited laboratory amount to ca 75 SEK per analysis.

5.5 The colour and the turbidity of the water

The colour of the water is a parameter related to the amount of dissolved, coloured, organic substances in the water. These, mainly humic, substances have their origin in the top soils of the catchment area and their amounts can be used as one expression of the influence of the catchment on the running water ecosystem. The presence of humic substances in the water affects the entire metabolism of the ecosystem via e.g. reduction of the light penetration, formation of iron-humus-phosphorus complexes that reduce the availability of P to biota, and by keeping various elements and pollutants in suspension.

Furthermore, the presence of large amounts of organic substances of external origin in the water alters the competition between organisms at the base of the aquatic food-web in favour of heterotrophs which may become the dominant mobilisers of carbon energy. Turbidity is a measure of how turbid a body of water is, and this parameter is thus related to the amount of substances transported with the river.

5.5.1 Existing data

Measurements of the water colour and the turbidity in running waters have been frequently carried out in connection with monitoring of the quality of surface waters. Hence, both in connection with research projects and local, regional, and national river monitoring programmes, measurements of water colour and turbidity may have been carried out. Data can be found in reports and scientific papers at the universities and in reports published by the local, regional and national water authorities. As a rule, reports from local and regional authorities should be kept by the Regional Administrative Office of the County (Länsstyrelsen). National data can be accessed by Internet at http://www.ma.slu.se. For Uppsala County, references to data sources with a majority of the data generated up to 1997 are given in Brunberg and Blomqvist /1998/. However, as most of the monitoring programmes only include a single or a few observations per year, the resolution in time may be low. From other areas, including the localities chosen for the site investigation program, data from a particular running water may be very sparse. Thus, in connection with the site investigation program, new data on colour as well as turbidity of the water must be generated.

5.5.2 Methods for data collection

Performance

Sampling see 5.3.2.

The colour and turbidity of the water should be measured on unpreserved water directly after transportation to the laboratory and preferably on the same day as the samples have been taken. The measurements should be performed according to the spectrophoto-metric method described by Chalupa /1963/, on unfiltered (turbidity) and filtered (colour) water, respectively.

Background data

See 5.3.2.

Time schedule

See 5.3.2.

Potential resources

See 5.3.2.

Data processing

See 5.3.2.

Uncertainty – Risks

See 5.3.2.

Costs

Costs in connection with sampling of water for measurements of the water colour include travel and subsidence expenses and salary at an hourly rate of the person involved in the measurement. Costs for analysis of the colour or the turbidity of the water by an accredited laboratory amount to ca 60 SEK per analysis.

5.6 The concentrations of total, particulate, and dissolved organic carbon in the water

The concentrations of dissolved (DOC) and particulate (POC) organic carbon in the water are important parameters needed to calculate the transport of organic carbon (TOC) through the river system. The concentration of POC in the water may be used as a course measure of the total amount of food available for filter-feeding biota. The concentration of DOC in the water is a measure of both coloured (cf. water colour in Section 5.5, above) and uncoloured organic substances in the water.

5.6.1 Existing data

Measurements of the concentrations of TOC, POC, and DOC in the water may have been carried out in connection with monitoring of the quality of surface waters. In connection with research projects and local, regional, and national river monitoring programmes, measurements of at least TOC may have been carried out. Data can be found in reports and scientific papers at the universities and in reports published by the local, regional and national water authorities. As a rule, reports from local and regional authorities should be kept by the Regional Administrative Office of the County (Läns-styrelsen). National data can be accessed by Internet at http://www.ma.slu.se. For Uppsala County, references to data sources with a majority of the data generated up to 1997 are given in Brunberg and Blomqvist /1998/. However, as most of the monitoring programmes only include a single or a few observations per year, the resolution in time may be low. From other areas, including the localities chosen for the site investigation program, data from a particular running water may be very sparse. Thus, in connection with the site investigation program, new data on the concentrations of DOC and POC of the water must be generated.

5.6.2 Methods for data collection

Performance

Sampling see 5.3.2. Filtration of the water in order to separate POC from DOC should be performed directly after transportation to the laboratory and preferably on the same day as the samples have been taken. The measurements should be performed according to Swedish Standard (the same for both analyses) SS-EN 1484.

Background data

See 5.3.2.

Time schedule

See 5.3.2.

Potential resources

See 5.3.2.

Data processing

See 5.3.2.

Uncertainty – Risks

See 5.3.2.

Costs

Costs in connection with sampling of water for measurements of the water colour include travel and subsidence expenses and salary at an hourly rate of the person involved in the measurement. Costs for analysis of the concentrations of DOC and POC of the water by an accredited laboratory together amount to ca 180 SEK.

5.7 The concentrations of total phosphorus and soluble reactive phosphorus of the water

Phosphorus is considered one key nutrient limiting the production of organisms in aquatic ecosystems. Phosphorus in unpolluted systems mainly originates from the soils of the drainage area. The concentration of total phosphorus is a standard parameter describing the nutrient status of the water, which in turn is coupled to the conditions of the bedrock, soils and vegetation of the catchment area. In areas which are characterised by easily weathered and fertile soils, the concentration of total phosphorus in the water is generally higher than in areas with more refractory soils. Phosphorus is also one of the key elements in human-induced eutrophication of surface waters. If background levels are known, measurements of the concentrations of total phosphorus in the water can also be used to determine human-induced eutrophication of the system (cf. 6.2.1, below). The concentration of soluble reactive phosphorus in the water is a course measure of how much phosphorus that is readily available to biota.

5.7.1 Existing data

Measurements of the concentrations of total phosphorus (TP) and soluble reactive phosphorus (SRP) of the water in a particular river or stream have been frequently carried out in connection with monitoring of quality of surface waters. Hence, both in connection with research projects and local, regional, and national river monitoring programmes, measurements of the concentrations of TP and SRP may have been carried out. Data can be found in reports and scientific papers at the universities and in reports published by the local, regional and national water authorities. As a rule, reports from local and regional authorities should be kept by the Regional Administrative Office of the County (Länsstyrelsen). National data can be accessed by Internet at http://www.ma.slu.se. For Uppsala County, references to data sources with a majority of the data generated up to 1997 are given in Brunberg and Blomqvist /1998/. However, as most of the monitoring programmes only include a single or a few observations per year, the resolution in time may be low. Furthermore, most of the environmental monitoring with respect to the concentrations of TP and SRP in the water have been carried out in eutrophicated lowland and urban areas of Sweden. From other areas, including the localities chosen for the site investigation program, data from a particular running water may be very sparse. Thus, in connection with the site investigation program, new data on the concentrations of TP and SRP in the water must be generated.

5.7.2 Methods for data collection

Performance

Sampling see 5.3.2. The concentrations of TP and SRP in the water can be measured on unpreserved water directly after transportation to the laboratory or, but only in the case of TP, after storage in a deep-freezer. The measurements should be performed according to Swedish Standard SS-EN 1198 and SS-EN 1189, respectively.

Background data

See 5.3.2.

Time schedule

See 5.3.2.

Potential resources

See 5.3.2.

Data processing

See 5.3.2.

Uncertainty – Risks

See 5.3.2.

Costs

Costs in connection with sampling of water for measurements of the concentrations of TP and SRP of the water include travel and subsidence expenses and salary at an hourly rate of the person involved in the measurement. Costs for analysis of the concentrations of TP and SRP of the water by an accredited laboratory amount to ca 125 and 100 SEK per analysis, respectively.

5.8 The concentrations of total nitrogen, ammonium nitrogen, and nitrite+nitrate nitrogen of the water

Nitrogen is together with phosphorus the two most important limiting nutrients which determine the production of organisms in river ecosystems. In contrast to P, which more or less entirely originates from the catchment, nitrogen can also be imported by nitrogen fixation, a process carried out by heterocytous cyanobacteria. Nitrogen may also be denitrified in bacterial processes and leave the system as molecular N_2. The concentration of total nitrogen is a standard parameter describing the nutrient status of the water, which in turn is coupled to the conditions of the bedrock, soils and vegetation of the catchment area. In areas which are characterised by easily weathered and fertile soils, the concentration of total nitrogen in the water is generally higher than in areas with more refractory soils. Nitrogen is also one of the key elements in human-induced eutrophication of surface waters and is, together with phosphorus, an indispensable parameter to judge the consequences of eutrophication on the production of biota. The concentrations of ammonium- and nitrite+nitrate-N in the water gives a course measure of how much nitrogen that is readily available to biota.

5.8.1 Existing data

Measurements of the concentrations of total nitrogen (TN), ammonium-nitrogen (NH_4-N) and nitrite+nitrate-nitrogen (NO_2+NO_3-N) of the water in a particular running water have been frequently carried out in connection with monitoring of quality of surface waters. Hence, both in connection with research projects and local, regional, and national river monitoring programmes, measurements of the concentrations of TN, NH_4-N and NO_2+NO_3-N may have been carried out. Data can be found in reports and scientific papers at the universities and in reports published by the local, regional and national water authorities. As a rule, reports from local and regional authorities should be kept by the Regional Administrative Office of the County (Länsstyrelsen). National data can be accessed by Internet at http://www.ma.slu.se. For Uppsala County, references to data sources with a majority of the data generated up to 1997 are given in Brunberg and Blomqvist /1998/. However, as most of the monitoring programmes only include a single or a few observations per year, the resolution in time may be low. Furthermore, most of the environmental monitoring with respect to the concentrations of TN, NH_4-N and NO_2+NO_3-N in the water have been carried out in eutrophicated lowland and urban areas of Sweden. From other areas, including the localities chosen for the site investigation program, data from a particular stream may be very sparse. Thus, in connection with the site investigation program, new data on the concentrations of TN, NH_4-N and NO_2+NO_3-N in the water must be generated.

5.8.2 Methods for data collection

Performance

Sampling see 5.3.2. The concentrations of TN, NH_4-N and NO_2+NO_3-N in the water can be measured on unpreserved water directly after transportation to the laboratory or, but only in the case of TN and NO_2+NO_3-N, after storage in a deep-freezer. The measurements should be performed according to Swedish Standard SS-EN ISO 4256, SIS 02 81 34, and SIS 02 81 33 – 2 mod., respectively.

Background data

See 5.3.2.

Time schedule

See 5.3.2.

Potential resources

See 5.3.2.

Data processing

See 5.3.2.

Uncertainty – Risks

See 5.3.2.

Costs

Costs in connection with sampling of water for measurements of the concentrations of TN, NH_4-N and NO_2+NO_3-N of the water include travel and subsidence expenses and salary at an hourly rate of the person involved in the measurement. Costs for analysis of the concentrations of TN, NH_4-N and NO_2+NO_3-N of the water by an accredited laboratory amount to ca 125, 100, and 100 SEK per analysis, respectively.

5.9 The concentrations of chlorophyll a of the water

The concentration of chlorophyll a in the water is a measure of the biomass of phytoplankton, which normally do not live and reproduce in running waters. However, in the case of presence of upstream lakes, the transport of phytoplankton from the lake to downstream reaches may be considerable. Knowledge about the transport of fresh organic carbon in the form of phytoplankton may be of great value to the understanding of production of higher biota in rivers and streams.

5.9.1 Existing data

Measurements of the concentrations of chlorophyll a of the water in a particular running water may sometimes have been carried out in connection with monitoring of quality of surface waters. Data may be found in reports and scientific papers at the universities and in reports published by the local, regional and national water authorities. As a rule, reports from local and regional authorities should be kept by the Regional Administrative Office of the County (Länsstyrelsen). National data can be accessed by Internet at http://www.ma.slu.se. For Uppsala County, references to data sources with a majority of the data generated up to 1997 are given in Brunberg and Blomqvist /1998/. However, it is highly unlikely that data on a particular stream will be found. Therefore, in connection with the site investigation program, new data on the concentrations of chlorophyll a in the water must be generated.

5.9.2 Methods for data collection

Performance

Sampling see 5.3.2. Filtration of the water in order to separate particles containing chlorophyll a should be performed directly after transportation to the laboratory. The filters may then be stored in a freezer for later analysis . The measurements should be performed according to Swedish Standard SS 02 81 46.

Background data

See 5.3.2.

Time schedule

See 5.3.2.

Potential resources

See 5.3.2.

Data processing

See 5.3.2.

Uncertainty – Risks

See 5.3.2.

Costs

Costs in connection with sampling of water for measurements of the concentrations of chlorophyll a of the water include travel and subsidence expenses and salary at an hourly rate of the person involved in the measurement. Costs for analysis of the concentrations of chlorophyll a of the water by an accredited laboratory amount to ca 240 SEK per analysis, respectively.

5.10 The concentrations of dissolved oxygen of the water

The concentration of dissolved oxygen in the water is a key parameter related to the total metabolism of aquatic ecosystems. It describes the net outcome of the sum of production and import of oxygen to the system and the sum of processes consuming oxygen at respiration of produced and imported organic matter. At periods when respiratory processes are strongly dominant, the entire system may face anoxia, with dramatic effects on different components of fauna. Anoxia is a more common phenomenon in lakes than in streams because of the high surface to volume ratio and turbulent character of the latter. However, lowland rivers with moderate flow of water during winter may well show oxygen concentrations low enough for sensitive organisms (e.g. salmonids among fishes) to die off. Furthermore, knowledge about concentrations of dissolved oxygen may give hints about groundwater, relative surface water, inflow along a given section of a running water. Groundwater is generally very low in dissolved oxygen due to consumption at decomposition in connection with percolation through the soils of the catchment area.

5.10.1 Existing data

Measurements of the concentrations of dissolved oxygen in the water in a particular running water have been carried out in connection with monitoring of quality of surface waters, especially during the 1970ies. Today this parameter is unfortunately more seldom used, partly as a result of that it should be measured at a period when oxygen stress is maximal (e.g. during winter). Nevertheless, both in connection with research projects and local, regional, and national river monitoring programmes, measurements of the concentrations of dissolved oxygen may have been carried out. Data can be found in reports and scientific papers at the universities and in reports published by the local, regional and national water authorities. As a rule, reports from local and regional authorities should be kept by the Regional Administrative Office of the County (Länsstyrelsen). National data can be accessed by Internet at http://www.ma.slu.se. For Uppsala County, references to data sources with a majority of the data generated up to 1997 are given in Brunberg and Blomqvist /1998/. However, as most of the monitoring programmes including data on dissolved oxygen are relatively old and since dissolved oxygen is a highly dynamic parameter, the situation may have changed considerably. Furthermore, most of the environmental monitoring with respect to the concentrations of dissolved oxygen in the water have been carried out in eutrophicated lowland and urban areas of Sweden. From other areas, including the localities chosen for the site investigation program, data from a particular stream may be very sparse. Thus, in connection with the site investigation program, new data on the concentrations of dissolved oxygen in the water must be generated.

5.10.2 Methods for data collection

Performance

Samples for analysis of the concentrations of dissolved oxygen in the water should be taken with a closing sampler (e.g. Ruttner sampler) at the same station as for other water chemistry parameters (cf. 5.3.2). The samples should be preserved directly in the field after sampling. The measurements should be performed according to Swedish Standard SS-EN 25813.

Background data

See 5.3.2.

Time schedule

See 5.3.2.

Potential resources

See 5.3.2.

Data processing

See 5.3.2.

Uncertainty – Risks

See 5.3.2.

Costs

Costs in connection with sampling of water for measurements of its concentration of dissolved oxygen include travel and subsidence expenses and salary at an hourly rate of the person involved in the measurement. Costs for analysis of the concentrations of dissolved oxygen of the water by an accredited laboratory amount to ca 75 SEK per analysis.

5.11 The areal distribution of stream and riparian zone main habitats

The areal distribution of main habitats within and along the running water is a parameter necessary for all kinds of modelling of the transport and retention of substances in the system. It describes the area distribution of main habitats of the aquatic ecosystem and the adjacent riparian zone and their dominant vegetation. In the context of the site investigation program, this is an extremely important parameter, because it can be used to estimate the retention of radionuclides in the river basin. We are not aware of any standardised way to perform the study but suggest that the measurements are performed using a DGPS so that data can be directly transferred from the field into the SKB Regional GIS.

5.11.1 Existing data

As far as the authors know there has be no data generated that can be used in the context of the site investigation program. Hence, new data must be generated for each running water section to be studied.

5.11.2 Methods for data collection

Performance

The areal distribution of main river and riparian zone habitats is obtained combining information about the river basin morphometry (Section 4, above), normal highest and normal lowest water level, and horizontal distribution of emergent and floating-leaved macrophytes. It is obtained using a DGPS equipment (precision 0.5 m) directly coupled to the basin morphometry unit of the Regional SKB GIS and should be performed in mid - late summer in connection with studies of the river basin morphometry. The field work includes the following steps:

a) Measurements of the location of the highest and lowest shore lines are performed using the DGPS by walking along the river section. This step is combined with the search for physical damages to the river ecosystem described in Chapter 6, below.

b) Measurements of the location of the outer edge of the combined emergent and floating-leaved macrophyte belt. This step is combined with the investigation of bottom slope and bottom substrate using a DGPS.

c) Characterisation of the dominant flora in each habitat (e.g. *Sphagnum*-mire, *Phragmites* -belt, *Alnus*-fen).

Using the information from step a), the riparian zone is defined. Using the information from step b), the open-water habitat is delineated from the macrophyte zone. The information from step c) is used as a basis for ecosystem modelling.

The area calculation procedures can be directly performed in the Regional SKB GIS.

Background data

Background data includes a map with instructions about the location of the sampling area.

Time schedule

The measurements should be performed at the height of the summer (July–August) in order for the macrophyte vegetation in the system to have completely established. Measurements can be performed once.

Potential resources

The measurements require extremely well trained personnel, mostly to be found among running water limnologists and physical geographers.

Data processing

The resulting areas of the different key habitats are calculated within the regional SKB GIS and saved as attributes to the “River Polygon Theme”.

Uncertainty – Risks

The precision of the measurements will depend on the precision of the instrument used (i.e. the DGPS), and on the skills of the personell in identifying water level marks and determine components of the flora.

Costs

Costs for measurements of the area distribution of main habitats include travel and subsidence expenses and salary at an hourly rate of the person involved in the measurement.

5.12 The fish community of the river ecosystem

Fish represent dominant and long-lived organisms in aquatic ecosystems, and are therefore excellent bio-indicators of water quality and long term stress on the system. With the exception of different forms of whitefish and char, fishes are also possible to identify to the species level by a well educated general limnologist or zoologist, which means that the reliability of the species identifications will be as high as possible – something which is not the case at any other level of the ecosystem. Furthermore, as most fish are top-line predators, or just below that level, in various food chains in the aquatic food-web, they are also excellent indicators of bioaccumulation of toxic substances (see Section 6.2.3 – Methods for data collection). For these reasons, we suggest that the species composition of the fish community and the abundance of each species is the only biological parameter including taxonomy to be included in the studies within the site investigation program.

5.12.1 Existing data

Data on fish surveys all over Sweden are available from the register kept by the Institute of Freshwater Research, in Örebro. This register also includes the studies running waters in Uppsala County presented by Gullberg et al /1993/. During that survey, which was carried out 1990, many smaller streams in the communities in Uppsala County that may be of interest for the site investigation program were covered. For other running waters in Uppsala County, as well as for most running waters in the other communities intended for the site investigation program, new data must be generated.

5.12.2 Methods for data collection

Performance

Inventories of species composition and abundance of the fish fauna should be performed using the standardised electro-fishing method described by Degerman and Sers /1999/ along the entire section of the running water of interest to the site investigation programme. Large, by size presumably piscivorous, individuals of the species pike (Esox lucius) and perch (Perca fluviatilis) should then be sorted out for sampling of muscle tissue for analysis of the content of mercury and radioactive ^{137}Cs (see Section 6.2.3, below).

Background data

Background data includes a map with instructions about the location of the sampling area.

Time schedule

Sampling is performed once in August–September by fishing the section three times according to the standard procedure.

Potential resources

The fish survey can be performed by a normally trained fisheries person, but the species analysis as well as the selection of individuals from which muscle samples should be taken needs to be supervised by a well trained fisheries biologist. Such personnel is best found at the regional offices of the National Swedish Board of Fisheries.

Data processing

The co-ordinates of the endpoints of each section fished are measured with DGPS. The location of the section is then stored in the Regional SKB GIS as line object using the endpoint co-ordinates. Data on the date and time interval of sampling and the species and number of individuals caught in the survey are taken from the raw protocol and included in "Electro-fishing line theme". The parameters are stored in the new "CPUE table" linked to the "River Polygon Theme" by the common field "River_Id".

Uncertainty – Risks

As with most other parameters describing large motile biota, the species composition and abundance of the fish community will include errors depending on the presence of the organisms in that particular section of the running water during the time interval when fishing was carried out. Nevertheless, by using the standardised technique, such errors should be minimised. Potential errors in the species identification due to varying competence among the personnel are minimised by the suggested leadership of the project by an experienced fisheries biologist.

Costs

Costs for studies of the fish community of the running water include travel and subsistence expenses and salary at an hourly rate of the persons (normally 2) involved in the electro-fishing and also salaries for the supervisor for planning of the study.

6 Damages to the river ecosystem

In order to understand the ecological functioning and production capacity of a running water ecosystem and to predict how it may evolve in a long-term perspective it is necessary to include also various forms of anthropogenic disturbances to the ecosystem in the study. In the context of the site investigation program for running waters, we suggest that surveys of human-induced damages are included. The methodology described below is similar to that suggested for the lake investigation program /Blomqvist et al, 2000/ although we have restricted the study to physical damages and pollution.

6.1 Technical encroachments

Technical encroachments include various forms of man-made physical disturbances to the river ecosystem such as construction of dams, constructions to facilitate flood control, constructions to facilitate transportation of timber, to prevent flooding or to facilitate navigation, and drainage of land. In the following description we have used three main groups of technical encroachments: dams, constructions along the shore-line, and drainage of land. All these forms of physical disturbances to river ecosystems must be proceeded by a permit from the Environmental Courts handling the water law (formerly the Water Rights Courts, Vattendomstolarna). However, especially regarding drainage of land, also many illegal projects have been performed.

6.1.1 Dams

Construction of dams, and particularly dams for regulation of the water level, is a major threat to river ecosystems world-wide. Among the many damages, partial or complete loss of aquatic and riparian zone vegetation, loss of migratory populations of fish, oligotrophication due to sedimentation of nutrients in upstream reservoirs, and decreased trapping of nutrients in the riparian zone are among the most threatening to ecosystem functioning /e.g. Brittain and Nilsson, 1996 and papers therein/.

Existing data

Construction of dams must be proceeded by a permit from the Environmental Courts (formerly the Water Rights Courts, vattendomstolarna) and these permits can be found in the files at each such Court. However, many of the dams in Sweden are much older than the water laws and are not regulated by any permit. To get hold of the number of dams in each area and their condition, inventories of dams have been carried out in many Communities and Counties in Sweden. Data can be found in reports published by the local, regional and national water authorities. As a rule, reports from local and regional authorities should be kept by the Regional Administrative Office of the County (Länsstyrelsen). For Uppsala County, references to data sources with a majority of data about dams generated up to 1997 are given in Brunberg and Blomqvist /1998/. However, many such inventories are old and conditions may have changed. Therefore, in the context of the site investigation program, the running waters should be inspected for the presence/absence of dams which means that complementary studies are necessary.

Methods for data collection

Performance

Inventories of dams include a description of the location of the dam, the type of construction (fixed or regulated) its height and length, the kind of material it is made of, its ownership and the number of the permit by which it has been constructed.

A drawing and preferably also a photograph of the dam should also be included. A reasonable methodology is presented by Syrén and Åse /1987/. Inventories regarding level of damage to the aquatic and riparian zone ecosystems can be performed in connection with measurements of the areal distribution of main habitats (cf. 5.9, above).

Background data

Background data needed include a topographic map over the section of the river of interest to the site investigation (either Gröna Kartan or Ekonomiska kartan), and eventual files from the water court

Time schedule

Inventories of dams are carried out at one occasion and can then be complemented with new information in the case of changes within a particular system.

Potential resources

Inventories of dams can be carried out by well trained physical geographers and limnologists. Inventories of degree of damage should be performed by an experienced running water limnologist.

Data processing

Location of the dams are measured with DGPS. Data from the dam inventory should be logged into the Regional SKB GIS as a point-object theme. Measurements and statements about the condition is stored as attributes to the "Dam theme table" and drawings and photographs are linked to the "Dam theme" with the "Hot Link Tool".

Uncertainty – Risks

The physical measurements and judgements of the conditions of a dam should involve small problems.

Costs

Costs in connection with dam inventories include travel and subsidence expenses and salary at an hourly rate of the person involved in the measurement.

6.1.2 Constructions to facilitate flood control etc.

Constructions to facilitate flood control, transportation of timber or navigation are major threats to ecosystem functioning in running waters. The damages include a decrease in the river and riparian zone area and a loss of wetland/littoral ecosystems, which in turn affect flood storage, retention of nutrients from surface and ground water, processing of pollutants, and the production of biomass and oxygen /Sandlund and Viken, 1997/.

Existing data

Construction of dikes must be proceeded by a permit from the Environmental Courts (formerly the Water Rights Courts, vattendomstolarna) and these permits can be found in the files at each such Court . However, some of the dikes or similar constructions in Sweden are older than the water laws and are not regulated by any permit. Inventories of dikes may have been carried out in some communities and counties in Sweden. Data can be found in reports published by the local, regional and national water authorities. As a rule, reports from local and regional authorities should be kept by the Regional Administrative Office of the County (Länsstyrelsen). For Uppsala County, some references to data sources up to 1997 are given in Brunberg and Blomqvist /1998/. However, in the context of the site investigation program, all rivers should be inspected for the presence/absence of dikes along the shores which means that complementary studies are necessary. Furthermore, an inspection of each running water is necessary in order to determine the degree of damage to the system. Inventories of constructions along the shore can be performed in connection with measurements of the habitat diversity of the ecosystem (cf. 5.9, above).

Methods for data collection

Performance

Inventories of constructions along the shores are carried out by examination of economic maps, and by visits to the running waters. When constructions have been identified their length, width, and height are measured and the reasons for their construction is sought by interviewing the landowner and by searching for the court permit regulating their construction.

Background data

Background data include economic maps covering the entire section of interest and its nearby surroundings, and eventual files from the Court.

Time schedule

Inventories of dikes are carried out at one occasion and can then be complemented with new information in the case of changes within a particular system.

Potential resources

Inventories of dikes and other constructions along the shore can be carried out by well trained physical geographers and running water limnologists.

Data processing

Location of the constructions are measured with DGPS. Data from the inventory should be logged into the Regional SKB GIS as a line-object theme; “Construction Theme”. Measurements and statements about the condition is stored as attributes to the “Construction theme table” and drawings and photographs are linked to the “Construction theme” with the “Hot Link Tool”.

Uncertainty – Risks

The physical measurements and judgements of the conditions of a dike should involve small problems.

Costs

Costs in connection with inventories of dikes include travel and subsidence expenses and salary at an hourly rate of the person involved in the measurement.

6.1.3 Drainage projects

Drainage of land is one of the most serious threats to running waters in Swedish lowlands /Wolf, 1960; Brunberg and Blomqvist, 2001/. Damages to running waters due to drainage of land typically include decreases in riparian zone area, changes in macrophyte vegetation, increased erosion of banks due to higher flow, and decreases in the capacity of the system to retain nutrients and various pollutants and is therefore of great interest in the site investigation program.

Existing data

Drainage of land must be proceeded by a permit from the Environmental Courts (formerly the Water Rights Courts, vattendomstolarna) and these permits can be found in the files at each such Court . However, many of the drainage projects in Sweden are much older than the water laws and are not regulated by any permit. To get hold of the number of drainage projects in each area and their effects on the systems, inventories have been carried out in some Communities and Counties in Sweden. Data can be found in reports published by the local, regional and national water authorities. As a rule, reports from local and regional authorities should be kept by the Regional Administrative Office of the County (Länsstyrelsen). For Uppsala County, in which the inventory is almost complete, references to data sources with all data generated up to 1997 are given in Brunberg and Blomqvist /1998/. However, the areal distribution of drainage of land in each case is not available and therefore, in the site investigation program, new studies of drainage of land must be carried out.

Methods for data collection

Performance

Drainage of land has occurred both legally (registered at the Regional Administrative Office of the County, Länsstyrelsen) and illegally (can be assessed from field observations of the banks of the running water). We suggest that sections affected by drainage of land are inspected in connection with measurements of the areal distribution of main habitats (cf. 5.9, above).

Background data

Background data needed include topographic or economic maps of the running water section and access to existing court permits describing legal drainage projects.

Time schedule

Inventories of drainage of land are carried out at one occasion and can then be complemented with new information in the case of changes within a particular system.

Potential resources

Inventories of drainage of land can be carried out by well trained physical geographers and limnologists.

Data processing

Sections affected by drainage are measured with DGPS. Data from the inventory of drainage of land should be logged into the Regional SKB GIS as a line-object theme; "Drainage Theme". Measurements and statements about the condition is stored as attributes to the "Drainage theme table" and drawings and photographs are linked to the "Drainage theme" with the "Hot Link Tool".

Uncertainty – Risk

The physical measurements of sections affected by drainage projects should involve small problems.

Costs

Costs in connection with inventories of drainage of land include travel and subsidence expenses and salary at an hourly rate of the person involved in the measurement.

6.2 Pollution

Pollution of freshwaters may be caused by hundreds of substances but has conveniently by the scientists behind the document of Sandlund and Viken /1997/ been divided into four major groups: eutrophication (pollution caused by excess input of plant nutrients), acidification (pollution by excess input of acid), pollution by toxic substances (including inorganic and organic compounds as well as radionuclides), and pollution by heat.

6.2.1 Eutrophication

Pollution of aquatic ecosystems by plant nutrients (eutrophication) has been a major concern in limnological research as well as in practical environmental management for several decades. High external loading of nutrients may result in high turbidity, excessive growth of macrophytes along the aquatic and riparian zones and anoxia in the water and subsequent fish-kills during critical periods (i.e. during winter). As a result of eutrophication, the capacity of the ecosystem to produce organisms may be greatly overestimated. Thus, in the context of the site investigation program, damages due to excessive input of plant nutrients are important to analyse. According to the scale constructed by Brunberg and Blomqvist /2001/ the following classification system for the levels of impact should be used:

- No damage (class 0) is defined as when the annual average concentrations of total phosphorus in the water does not exceed the estimated or calculated natural background levels.
- A minor eutrophication damage (class 1) is defined as a nutrient level higher than the estimated or calculated natural background levels but below 50 µg P l^{-1}.
- Nutrient concentrations higher than the estimated or calculated natural background levels and ranging between 50 and 100 µg P l^{-1} were classified as a moderate damage (class 2).
- A severe eutrophication damage (class 3) was defined as the situation when the concentrations of phosphorus in the water were higher than the estimated or calculated natural background levels and exceeded 100 µg P l^{-1}.

Existing data

Measurements of the concentrations of total phosphorus in a particular running water have been frequently carried out in connection with monitoring of the quality of surface waters. Hence, both in connection with research projects and local, regional, and national river monitoring programmes, measurements of the concentrations of total phosphorus may have been carried out. Data can be found in reports and scientific papers at the universities and in reports published by the local, regional and national water authorities. As a rule, reports from local and regional authorities should be kept by the Regional Administrative Office of the County (Länsstyrelsen). National data can be accessed by Internet at http://www.ma.slu.se. For Uppsala County, references to data sources with a majority of the data generated up to 1997 are given in Brunberg and Blomqvist /1998/. However, as most of the monitoring programmes only include a single or a few observations per year, the resolution in time may be low. Thus, in connection with the site investigation program, new data on the concentrations of total phosphorus in the water must be generated.

Methods for data collection

Performance

See total phosphorus in Section 5.6.1.

Background data

See total phosphorus in Section 5.6.1.

Time schedule

See total phosphorus in Section 5.6.1.

Potential resources

See total phosphorus in Section 5.6.1.

Data processing

The degree of damage due to pollution by plant nutrients can be calculated directly in the Regional SKB GIS and the resulting classification is then saved as attributes in a new “River Damage table” linked to the “River Polygon Theme” by the common filed “River_Id”.

Uncertainty – Risks

The classification system described above is course enough to give a meaningful distinction between degrees of damage without being difficult to apply.

Costs

Apart for costs in connection with sampling and analysis of samples for concentrations of total phosphorus, the costs are minimal.

6.2.2 Acidification

Acidification is one of the most serious threats to running water ecosystems in poorly buffered areas of Sweden, particularly in the SW part, and has received massive attention during the past decades. Consequences of acidification of rivers and their drainage areas include mobilisation of toxic compounds, loss of sensitive fauna and flora, and potentially also altered retention capacity for contaminants (e.g. in the form of radionuclides) in the system. Therefore, damages due to acidification should be of great interest in the studies to be included in the site investigation program. According to the scale constructed by Brunberg and Blomqvist /2001/ the following classification system for the levels of impact should be used:

– No damage due to acidification (class 0) is defined as when deposition of acidifying substances on the drainage area is less than twice the calculated background levels /Ahl, 1994; SMHI, 1999/.

– A minor damage by acidification (class 1) is defined as deposition of acidifying substances on the drainage area amounting to at least twice the calculated background levels despite lack of effects on the alkalinity and pH-value of the water. This definition is more stringent than if the concept of critical loading is used /Nilsson and Grennfelt, 1998/. Using the enhanced deposition as a criterion for damage takes into account the long-term perspective that the soils are slowly depleted of buffering capacity and important plant nutrients, e.g. Ca and Mg /Ripl,1995/.

– A moderate damage (class 2) is considered to occur if the deposition has caused documented reduced alkalinity and fluctuations in the pH values.

– A severe damage (class 3) is considered to occur with documented loss of alkalinity and decreased pH in the river water.

Existing data

Measurements of the pH-value and alkalinity of the water in a particular river or stream have been frequently carried out in connection with monitoring of acidification of surface waters (cf. 5.3.1, above). Hence, both in connection with research projects and local, regional, and national river monitoring programmes, measurements of the pH-value may have been carried out. Data can be found in reports and scientific papers at the universities and in reports published by the local, regional and national water authorities. As a rule, reports from local and regional authorities should be kept by the Regional Administrative Office of the County (Länsstyrelsen). National data can be accessed by Internet at www//http.ma.slu.se. For Uppsala County, references to data sources with a majority of the data generated up to 1997 are given in Brunberg and Blomqvist /1998/. However, as most of the monitoring programmes only include a single or a few observations per year, the resolution in time may be low. Furthermore, most of the environmental monitoring with respect to pH-value of the water have been carried out in poorly buffered areas in the forested regions of Sweden. From other areas, including the localities chosen for the site investigation program, data from a particular system may be very sparse. Thus, in connection with the site investigation program, new data on the pH-value of the water must be generated.

Methods for data collection

Performance

See Sections 5.3.2 and 5.4.2, above.

Background data

See Sections 5.3.2 and 5.4.2, above.

Time schedule

See Sections 5.3.2 and 5.4.2, above.

Potential resources

See Sections 5.3.2 and 5.4.2, above.

Data processing

The degree of damage due to pollution by acidifying substances can be calculated directly in the Regional SKB GIS and the resulting classification is then saved as attributes to the "River Damage table" (cf. 6.2.1 – Methods for data collection above) including all classifications of damages.

Uncertainty – Risks

The classification system described above is course enough to give a meaningful distinction between degrees of damage without being difficult to apply. Access to relevant background data is a key factor to the analysis. Hence, it is very important to gather all previous data from the systems.

Costs

Apart for costs in connection with sampling and analysis of samples for the pH-value and the alkalinity of the water, the costs are minimal.

6.2.3 Toxic substances

The Swedish "Observation List" , published by the Swedish National Chemicals Inspectorate (Kemikalieinspektionen) gives examples of ca. 250 substances or groups of substances that require particular attention and which are used to a large extent. Heavy metals and radioactive compounds are examples of pollutants which may reach levels that are harmful also to the human population, due to bioaccumulation in fish /e.g. Sonesten, 2000/. We suggest that analysis of the concentrations of radioactive caesium and mercury in the muscle tissue of fish are used in connection with the site investigation program as measures of the general situation regarding pollutants in the systems. According to the scale constructed by Brunberg and Blomqvist /2001/ the following classification system for the levels of impact should be used:

– No damage (class 0) is defined as when the concentrations do not exceed 0.5 mg Hg kg^{-1} or 800 Bq ^{137}Cs kg^{-1} in fish muscle, respectively, which corresponds to lowest limit for clearly elevated levels compared to the natural background.

– A minor damage (class 1) is defined as concentrations exceeding 0.5 mg Hg kg^{-1} or 800 Bq ^{137}Cs kg^{-1} in fish muscle, respectively, which corresponds to clearly elevated levels compared to the natural background.

– A moderate damage (class 2) is considered as concentrations ranging between 1.0–3.0 mg Hg kg^{-1} or 1500–10 000 Bq ^{137}Cs kg^{-1} in fish muscle, the lower levels corresponding to limits for marketing of fish in Sweden.

– Concentrations exceeding 3.0 mg Hg kg^{-1} or 10 000 Bq ^{137}Cs kg^{-1} are denoted as severe damage (class 3).

Existing data

Measurements of the concentrations of radioactive caesium and mercury in fish tissue in a particular river may have been carried out in connection with monitoring of quality of surface waters. Hence, both in connection with research projects and local, regional, and national river monitoring programmes, measurements of the concentrations of radioactive caesium and mercury may have been carried out. Data can be found in reports and scientific papers at the universities and in reports published by the local, regional and national water authorities. As a rule, reports from local and regional authorities should be kept by the Regional Administrative Office of the County (Länsstyrelsen). National data can be accessed by Internet at http://www.ma.slu.se. For Uppsala County, references to data generated up to 1997 are given in Brunberg and Blomqvist /1998/. From most areas, including the localities chosen for the site investigation program also in Uppsala County, data from a particular system may be very sparse. Thus, in connection with the site investigation program, new data on the concentrations radioactive caesium and mercury in tissue of fish must be generated.

Methods for data collection

Performance

Muscle tissue from consumption size fish are sampled from the fish material caught in the investigation described in Section 5.10.2. The fresh fish material is immediately after sampling brought to the laboratory and muscle tissue is sampled. The tissue is then analysed with respect to the concentrations of radioactive Cs and Hg according to the procedures described by Sonesten /2000/.

Background data

See Section 5.10.2.

Time schedule

See Section 5.10.2.

Potential resources

Sampling of fish see Section 5.10.2. The analyses of ^{137}Cs and Hg in the tissue of fish should be performed by an accredited laboratory specialised on measurements on fish.

Data processing

Data on the concentrations of ^{137}Cs and Hg in the tissue of fish should be linked to the table describing the entire fish material presented in Section 5.10.2. The degree of damage due to pollution by toxic substances can be calculated directly in the Regional SKB GIS and the resulting classification is then saved as attributes to the "Damage table" (cf. 6.2.1 – Methods for data collection) including all classifications of damages.

Uncertainty – Risks

The precision of the measurements of the concentration of ^{137}Cs and Hg in fish will be given by the manual of analysis used by the accredited laboratory. The classification system described above is course enough to give a meaningful distinction between degrees of damage without being difficult to apply.

Costs

The costs per sample for analysis of ^{137}Cs and Hg in fish tissue and amount to ca 250 and 300 SEK/sample, respectively.

6.2.4 Thermal pollution

Thermal pollution is a relatively new environmental problem occurring in connection with industrial uses of water. Its main consequences to river ecosystems include undesired shifts in species composition and ecosystem functioning. The shifts in species composition include establishment of populations of warm-water species, often mediated via deliberate or accidental introductions of non-native organisms. Since thermal pollution was not found in any lake in Uppsala County, Brunberg and Blomqvist /2001/ did not construct any scale for determination of the degree of damage. We nevertheless suggest an inventory of thermal pollution (based on permits to pump warm-water into lakes and streams) to be included in the site investigation program. In the case of presence of such a source of pollution we suggest the following classification to be used:

– No damage (class 0) is defined as when the calculated elevation of the water temperature given in the permit is less than 1 ^{o}C.

– A minor eutrophication damage (class 1) is defined as when the calculated elevation of the water temperature given in the permit is more than 1 ^{o}C.

– A moderate damage (class 2) is defined as when the calculated elevation of the water temperature given in the permit is more than 1 ^{o}C and occurrence of previously unknown organisms in the system has been documented.

– A severe damage (class 3) is defined as when the calculated elevation of the water temperature given in the permit is more than 1 ^{o}C and when previously unknown organisms in the system have established a strong and reproducing population.

Existing data and methods for their collection

Permits to use rivers as recipients for warm-water from different types of industries as well as reports on the occurrence of previously unknown species are gathered from the local, regional and national authorities. As a rule, permits should be kept by the Regional Administrative Office of the County (Länsstyrelsen).

The resulting data are classified using the system described above and saved as attributes to the “Damage table” (cf. 6.2.1 – Methods for data collection) including all classifications of damages.

Data processing

The resulting data on the presence of thermal pollution in the running waters are classified using the system described above and saved as attributes to the “Damage table” (see Section 6.2.1 – Methods for data collection) including all classifications of damages.

Costs

Costs in connection with search for data regarding thermal pollution include travel and subsidence expenses and salary at an hourly rate of the person involved in the studies.

References

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