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A descriptive ecosystem model – a strategy for model development during site investigations

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September 2003

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Abstract

This report describes a strategy for the development of a site descriptive model for the surface ecosystem on the potential deep repository sites. The surface ecosystem embraces many disciplines, and these have to be identified, described and integrated in order to construct a descriptive ecosystem model that describes and quantifies biotic and abiotic patterns and processes of importance for the ecosystem on the site. The descriptive model includes both present day conditions and historical information.

The descriptive ecosystem model will be used to supply input data for the safety assessment (the safety assessment modelling strategy is described in /Kumblad and Kautsky, 2003/) and to serve as the baseline model for devising a monitoring program to detect short-term disturbances caused first by the site investigations and later by the construction of the deep repository. Furthermore, it will serve as a reference for future comparisons to determine more long-term effects or changes caused by the deep repository.

The report adopts a non-site-specific approach focusing on the following aims:

1. To present and define the properties that will constitute the descriptive ecosystem model.

2. To present a methodology for determining those properties.

3. To describe and develop the framework for the descriptive ecosystem model by integrating the different properties.

4. To present vital data from other site descriptive models such as those for geology or hydrogeology that interacts with and affects the descriptive ecosystem model.

The properties are described under four different sections: general physical properties of the landscape, the terrestrial system, the limnic system and the marine system. These headings are further subdivided into entities that integrate properties in relation to processes. See Table 2-1 for a summary of all the described properties.

Summary

This report describes a strategy for development of a descriptive ecosystem model for the surface ecosystem on the potential deep repository sites. This description is needed to:

- Underpin safety assessments that describe and analyze different scenarios for radionuclide releases into the ecosystem and possible pathways for dispersal or accumulation of different radionuclides in the ecosystem.
- Detect changes caused by the construction of the repository.
- Establish a baseline for detecting long-term effects of the repository.

A descriptive ecosystem model will therefore be constructed for the potential repository sites containing all the necessary properties considered important for describing the site and supplying the safety assessment with the necessary input data. The methodology for the safety assessment of the biosphere is described in a separate report /Kumblad and Kautsky, 2003/.

This report adopts a non-site-specific approach focusing on the following aims:

1. To present and define the properties that will constitute the descriptive ecosystem model.
2. To present a methodology for determining those properties.
3. To describe and develop the framework for the descriptive ecosystem model by integrating the different properties.
4. To present vital data from other site descriptive models such as those for geology or hydrogeology that interact with and affect the descriptive ecosystem model.

The descriptive ecosystem model

The descriptive ecosystem model should be able to describe processes and quantify patterns of importance for the surface ecosystem at the site. In order to do this, we have to identify the biotic and abiotic processes that are of central importance for our purpose. In the safety assessment transport and accumulation of radionuclides will be modeled by quantifying biogeochemical pathways of carbon/nitrogen/phosphorus (CNP). The descriptive ecosystem model applied to a specific site should therefore be able to describe and quantify the primary processes affecting CNP at that specific site and also describe interactions with other site descriptive models, such as the one for geohydrology. The site descriptive model will also serve as the baseline model for devising a monitoring program to detect short-term disturbances caused first by the site investigations and later by the construction of the deep repository. Furthermore, it will serve as a reference for future comparisons to determine more long-term effects or changes caused by the deep repository or natural processes. Both of these aims are met by the descriptive ecosystem model because even though many of the results in this report are presented as flows or accumulations of matter, these data are based upon quantification of the different biota in the food web. The descriptive ecosystem model will concern present-day data as well as historical information.

Subdivision of the surface ecosystem

The surface ecosystem can be subdivided into different sections based on the presence of system-specific processes and properties and on the methods for collection, measurement and calculation of data that may differ depending on the system. Another reason for a subdivision of the surface ecosystem is that the modelling of transfer and accumulation processes in the safety assessment will employ a terrestrial model and an aquatic model to model the terrestrial and aquatic systems. The aquatic model will use different parameterizations for limnic and marine systems. The properties are described under the following the three subsystems.

1. *The terrestrial system* describes biotic and abiotic patterns and processes on all land and wetland areas.

2. *The limnic system* describes biotic and abiotic patterns and processes in lakes and rivers.

3. *The marine system* describes biotic and abiotic patterns and processes in the sea and brackish waters. However, the boundaries are not static and depend on e.g. water level changes.

The first section *"General physical properties of the landscape"* is a description of general properties of the landscape and the matrix surrounding the surface ecosystem, e.g. sediments, climate, topography. This description also includes the interface between the geosphere and 1, 2 and 3 (above), as well as between the three surface systems, e.g. through water flows.

These four sections are further subdivided into entities that integrate properties using processes, e.g. primary production, chemistry. See Table 2-1 for a summary of all the described properties.

Integration of subsystems in site descriptive model

The different systems all interact with one another to some degree. For example, the terrestrial environment around a lake acts as a catchment area for rainwater and affects the lake through the runoff of water to the lake. The discharge area in the near-shore marine system is affected by the output from the lake. The water flow in the landscape is considered essential to the connectivity of the different subsystems. The landscape is therefore divided into surface water catchment areas by water divides in the landscape. These catchment areas are considered to be the essential units at the landscape level when calculating flows of CNP (Figure 2-2).

This document should not be regarded as a definitive manual of how to analyze and present data. Rather, it is a preliminary proposal that will be developed and refined in the process of constructing a site descriptive model. Many of the properties will be further developed in separate reports using the available input data for each specific site. These reports will constitute the basis for constructing the final site specific models. Exactly how the properties should be put together combined and used in the final model will emerge gradually as further knowledge is gained of the relative importance of different properties. This report represents a first attempt to group and integrate properties.

Properties

The properties, e.g. biomass, production, geometry, chemistry are calculated using data collected at the specific site. In some cases it is not necessary to perform local measurements to determine the property with the desirable precision. In these cases, the data will be taken from literature that represents the local conditions as closely as possible or data adapted to the local conditions. For example, removal of berries due to berry-picking activities at a site is calculated based on the local abundance of the berry-producing species and a general estimate of the rate of removal. Some of the properties are straightforward, e.g. precipitation, whereas other properties need to be calculated using several different data sources. The properties dealt with in this report are listed in Table 2-1.

Sammanfattning

Den här rapporten beskriver strategin för framtagandet av en platskarakterisering av ekosystemen för potentiella platser för ett djupförvar av använt kärnbränsle. Karakteriseringen ska sedan utgöra ett underlag till en:

- Säkerhetsanalys som beskriver och analyserar olika scenarier för ett radionuklidutsläpp i de ytnära ekosystemen.
- Miljökonsekvensbeskrivning.
- Långtidsövervakning och utgöra basbeskrivning som referens till framtida förändringar (naturliga och antropogena) i ekosystemen.

I denna rapport beskrivs strategin för framtagandet av platsbeskrivningen utifrån ett generiskt perspektiv (ej platsspecifikt) samt utifrån nedan listade syften.

1. Att presentera och definiera de egenskaper som utgör den beskrivande ekosystemsmodellen.
2. Att presentera en metodik för kvantifieringen av de definierade egenskaperna.
3. Att beskriva och utveckla den struktur som platsbeskrivningen utgör genom integrationen av olika egenskaper.
4. Att presentera viktig indata till ekosystemsmodellen från andra ämnesområden, som t ex Geologi eller Hydrogeologi.

Ekosystemsmodellen ska kunna beskriva processer och kvantifiera egenskaper av intresse för det ytnära ekosystemet på platsen. För att kunna göra detta behöver vi identifiera de biotiska och abiotiska processer som är av vikt för våra syften. Säkerhetsanalysen kommer att använda en strategi där man utnyttjar biogeokemiska flöden för att modellera radionuklidtransporter. Platsbeskrivningen för en viss plats måste därför kunna beskriva och kvantifiera processer som påverkar kol, kväve och fosfor, samt de hydrologiska egenskaper som utgör drivkraft för transporter av ämnen. Platsbeskrivningen ska också fungera som en initialbeskrivning (ostörda värden) för ett övervakningsprogram av en eventuell förvarsplats, samt vara ett underlag till en miljökonsekvensbeskrivning. Båda dessa syften kan uppnås med den strategi för platsbeskrivning som beskrivs i denna rapport. Detta då kvantifiering av flöden och identifiering av processer bygger på god kännedom om de ekologiska egenskaper som en plats har. Platsbeskrivningen kommer att hantera dagens situation samt den historiska utvecklingen.

De ytnära ekosystemen kan delas upp i olika enheter baserat på närvaron av systemspecifika processer och egenskaper, samt utifrån datainsamlingsmetodik.

1. *Terrestra systemet* beskriver biotiska och abiotiska egenskaper och processer på land och våtmarker.
2. *Limniska systemet* beskriver biotiska och abiotiska egenskaper och processer i sjöar och vattendrag.
3. *Marina systemet* Beskriver biotiska och abiotiska egenskaper och processer i havet.

4. Det första kapitlet “*General physical properties of the landscape*” Är en beskrivning av abiotiska fysikaliska och kemiska egenskaper i landskapet tex, sediment, klimat, ythydrologi och topografi. Denna del innehåller dessutom gränszonen mellan geosfären och biosfären.

Dessa fyra delar är sen ytterligare indelad i entiteter som i sin tur beskrivs av egenskaper, se tabell 2.1 för en summering av de i rapporten beskrivna egenskaperna.

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1 Introduction

1.1 Background

In the process of siting a deep repository for spent nuclear fuel, SKB has the responsibility to investigate and present detailed proposals of how a deep repository can be built and operated. The extensive site investigations that have to precede the proposals comprise several different disciplines such as geology, hydrology, chemistry and ecology /SKB, 2001c/, which in the end all have to be integrated and evaluated in order to construct a proposal for a deep repository.

The site investigations covering the surface ecosystem started in 2002 and are aiming at providing a comprehensive description in order to:

- Underpin a safety assessment that describes and analyzes different scenarios of radionuclide release into the ecosystem and the possible pathways for dispersal or accumulation of different radionuclides in the ecosystem.
- Detect changes caused by the construction of the repository.
- Establish a baseline for detecting long-term effects of the repository.

A descriptive ecosystem model will therefore be constructed for each of the potential repository sites. The model will contain all necessary properties considered important for describing surface ecosystems in the area of interest for a deep repository.

There are a number of distinct steps in the work leading from the identification of areas to the construction of descriptive ecosystem models describing the surface ecosystem. A report by /Lindborg and Kautsky, 2000/ identified a number of properties that are of great interest in describing the potential areas. Later, two reports compiled existing information on these properties for both the potential deep repository sites, Forsmark and Simpevarp /Berggren and Kyläkorpi, 2002a, b/. These reports served as a basis for the planning and implementation of the site investigations in relation to ecosystems that started in 2002 /SKB, 2001c/. These site investigations provide the site-specific descriptive ecosystem models with the necessary input data. Each descriptive ecosystem model will then specify and integrate the properties that together will be used to describe the potential site, the so-called site description. Similar procedures are also used for the other disciplines e.g. geology, hydrology and chemistry (Figure 1-1). Next step is to use the site description as input to the safety analyses and environmental impact assessments. This however, is not described in this report.

The descriptive ecosystem model will serve as the main source in providing the safety assessment with input data relating to the present-day surface ecosystem. However, important properties belonging to other disciplines such as geology, hydrology and chemistry that not have been incorporated into the descriptive ecosystem model may also be important input data. In Kumblad and Kautsky 2003, the biosphere part of the safety assessment is described. That report handles future biosphere scenarios and the last modelling step; to run the actual safety assessment model and simulate release of radionuclides into the surface ecosystems in order to identify and describe the potential for radiation exposure to humans.

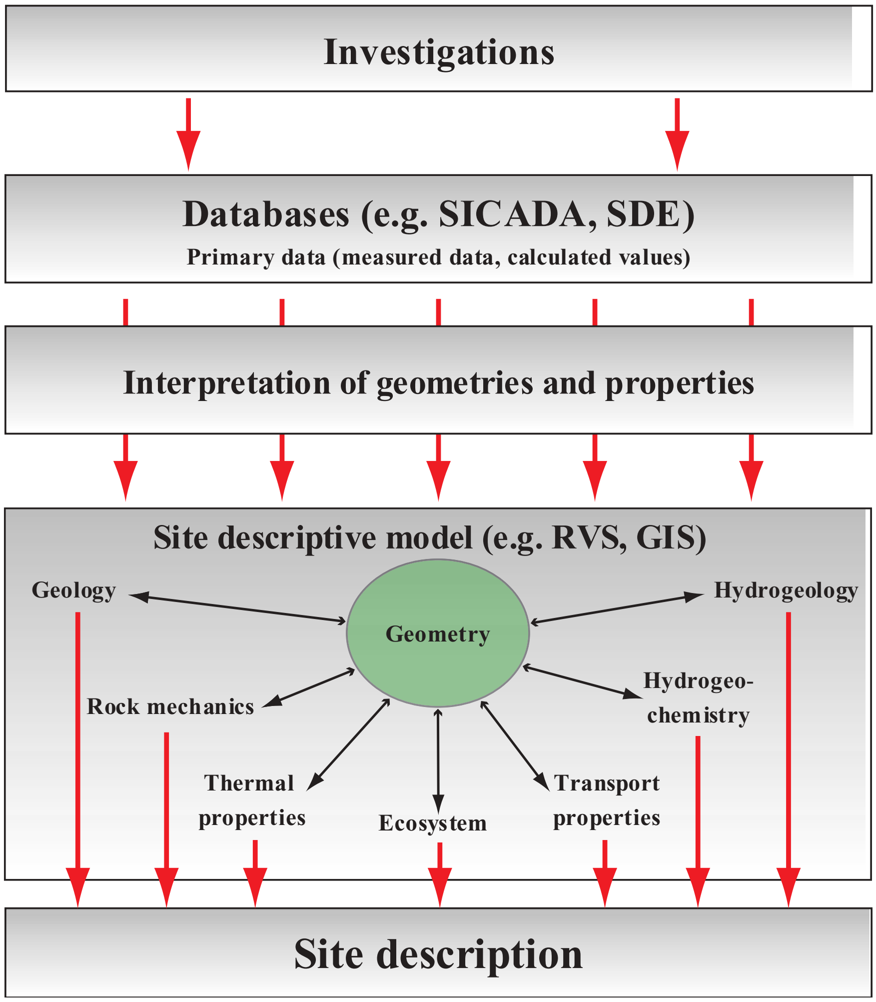

Figure 1-1. *The primary data from the investigations are collected in a database. Data are interpreted and presented in a site-descriptive model, which consists of a description of the geometry and different properties of the site.*

1.2 The aims of this report

This report adopts a non-site specific approach focusing on the following aims:

1. Present and define the properties that will constitute the descriptive ecosystem model, and later used in Safety Assessments and Environmental Impact Assessments. SA and EIA methodology is not described in this report.
2. Present a methodology for determining the properties.
3. Describe and develop the framework for the descriptive ecosystem model by integrating the different properties.
4. Present vital data from other site descriptive models such as those for geology or hydrogeology that interact with and affect the descriptive ecosystem model.

1.3 A descriptive ecosystem model

The descriptive ecosystem model should be able to describe processes and quantify patterns of importance for the ecosystem at the site. In order to do this we have to identify the biotic and abiotic processes that are of central importance for our purpose. The safety assessment will use an approach, among other, where transport and accumulation of radionuclides will be modeled by quantifying biogeochemical pathways of carbon/nitrogen/phosphorus (CNP) /Kumblad and Kautsky, 2003/. An exhaustive description of processes and interactions within an ecosystem important for a safety assessment was provided within the SAFE project /SKB, 2001b/. That report thereby identified the processes that have to be further described and quantified e.g. in terms of transport or accumulation. The descriptive ecosystem model applied to a specific site should therefore be able to describe and quantify those primary processes affecting CNP at that specific site and also describe interactions with other site descriptive models, such as the one for geohydrology. Moreover the descriptive ecosystem model concerns not only present day conditions but also historical information. A historical perspective is of vital importance for understanding future landscape development e.g. potential alterations to human land use and land uplift.

The site descriptive model will also constitute the baseline model for devising a monitoring program to detect short-term disturbances caused first by the site investigations and later by the construction of the deep repository. Furthermore, it will serve as a reference for future comparisons to determine more long-term effects or changes caused by the deep repository. In the extensive sampling program carried out at each potential site, reference samples are also collected and stored for future analysis. These reference samples will constitute a baseline for future comparisons of e.g. substances that are not considered important today or are not detected, or to check for the sudden appearance of new substances not present today.

Both the short term and long term detection of changes are met by the descriptive ecosystem model, because even though many of the results in this report are presented as flows or accumulations of CNP, these data are based upon quantification of the different biota in the food web. Similarly, will the descriptive ecosystem model also be applicable for the environmental impact assessment (EIA), although additional information is needed for the latter purpose.

This document should not be regarded as a definitive manual of how to analyze and present data. Rather, it is a preliminary proposal that will be developed and refined in the process of constructing a site descriptive model (Figure 1-1). Many of the properties will be further developed in separate reports using the available input data for each specific site. These reports will constitute the basis for constructing each final site specific model (Figure 1-2). Exactly how the properties should be combined and used in the final model will emerge gradually as further knowledge is gained of the relative importance of different properties. This report makes a first attempt to group and integrate properties. Moreover, the model for the safety assessment is still under development and there may be some changes in what properties are needed in the final version /Kumblad and Kautsky, 2003/.

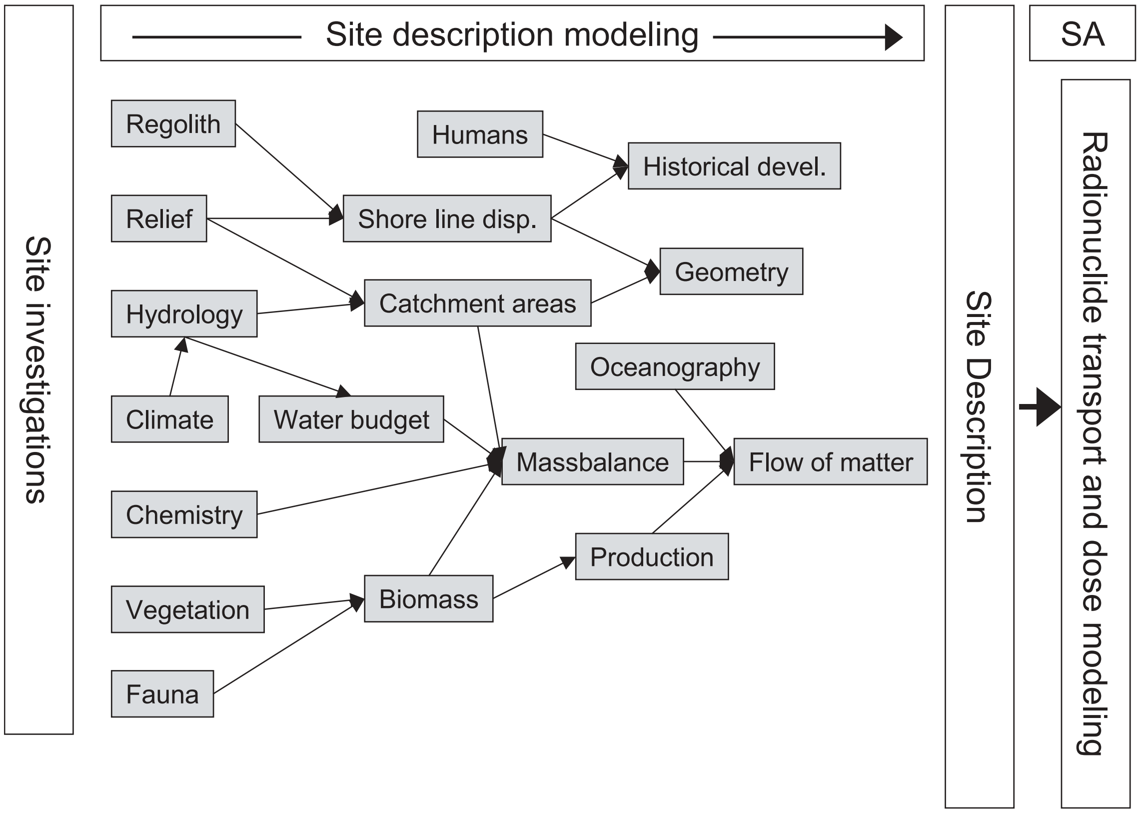

Figure 1-2. *A simplified schematic illustration of the work from site investigations to the final safety assessment, see Kumblad and Kautsky 2003 for SA methodology. An gradually increase of understanding and synthesis is gained in the different disciplinary sub reports during the site description stage.*

2 Description of surface ecosystems

The surface ecosystem will be described using a large number of properties which, when combined, will constitute the ecosystem site descriptive model. /Lindborg and Kautsky, 2000/ listed a number of properties considered to be important when describing an area. In this report, we present and examine those properties needed for the safety assessment and EIA which together will constitute the descriptive ecosystem model. The description of the surface ecosystem will be divided into the surface ecosystem of today and historical surface ecosystems. In the description of today, the information is mainly gathered at the site during field investigation, whereas mainly historical sources are used for the characterization of the past. The historical information will be an important source of knowledge when predicting the future landscape in the safety assessment scenario modelling.

2.1 Subdivision of surface ecosystems

The surface ecosystem can be subdivided into different subsystems based on the presence of system-specific processes and properties and on the methods of collection, measurement and calculation of data that may differ depending on the system. Accordingly, we end up with the three different subsystems:

1. The terrestrial systems are all the land and wetland areas.
2. The limnic systems are lakes and rivers.
3. The marine systems are the sea and brackish waters.

Another reason for the specified subdivision of the surface ecosystem is that the modelling of transfer and accumulation processes in the safety assessment will, among others, employ a terrestrial and an aquatic model to model these systems /Kumblad and Kautsky, 2003/. The aquatic model will be given different input data depending on whether a limnic or a marine/brackish context is being represented.

In the initial section called "General physical properties of the landscape" we have gathered properties describing the landscape containing the surrounding matrix of the subsystems e.g. sediments, climate, geometry. This description also includes the interface between the geosphere and the surface ecosystems, and between the three subsystems e.g. through water flows. This section serves to characterize abiotic processes affecting the three subsystems. Consequently, we end up with an ecosystem descriptive model divided into four different parts.

These four parts are further subdivided into entities that integrate specific properties using processes e.g. the entity 'chemistry' contains all the chemical descriptions. The properties are quantified or parameterized using one or several parameters (Figure 2-1). A further resolution of specific properties within the subsystems is focused on habitats, e.g. vegetation types within terrestrial systems, and many properties will accordingly present parameters that are habitat-specific for an area. This approach is used in the limnic and marine systems as well.

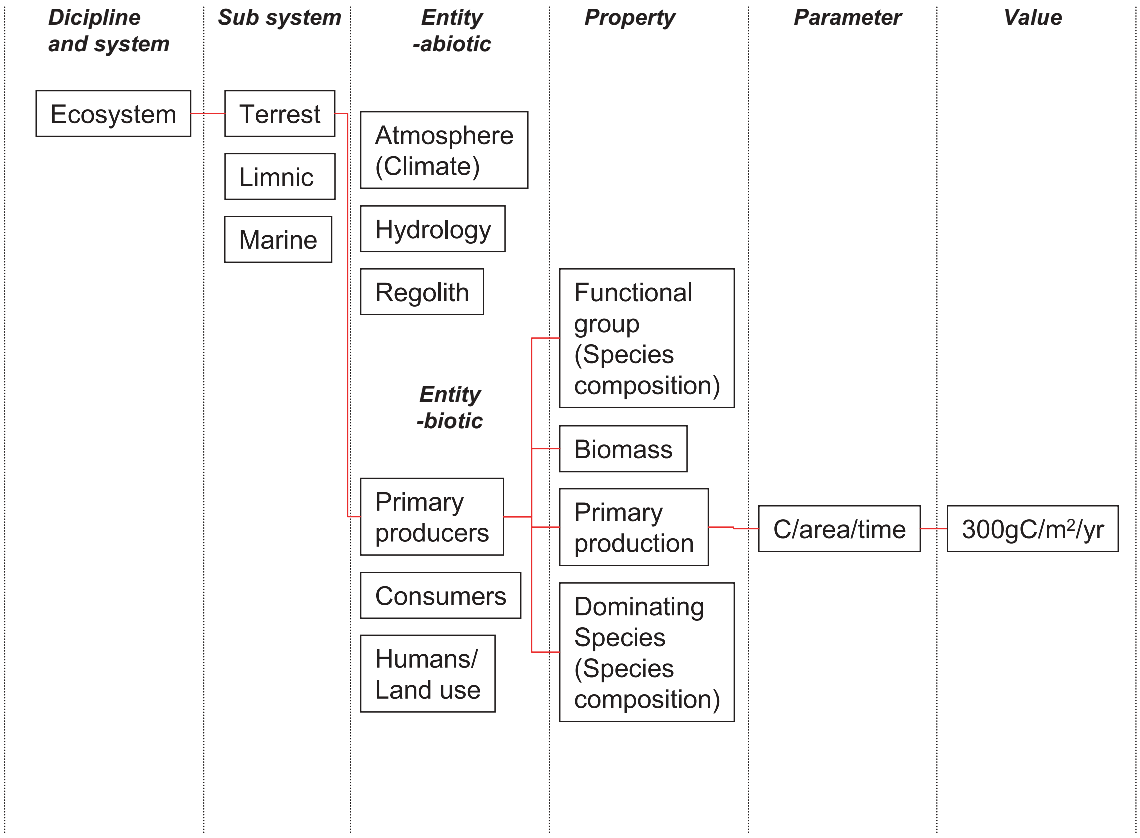

Figure 2-1. *An example of how the ecosystem is subdivided into a hierarchal structure. The ecosystem is subdivided in three subsystems, which are described using different entities (a sub sample of different entities is presented in this figure). The entity "primary producers" is characterized using a number of properties. The property primary production is described using a parameter describing the production of carbon in the appropriate SI-unit.*

The human impact on the different subsystems is quantified under each subsystem. The impact focuses on factors that affect the CNP budgets in an area and factors that are essential for calculating potential exposures to radionuclides. The human situation at each site will, however, be more thoroughly described in a separate report.

2.2 Integration of the subsystems

The different subsystems all interact with one another to some degree. For example, the terrestrial environment around a lake acts as a catchment area for rainwater and affects the lake through the runoff of water to the lake (Figure 2-2). The discharge area in the near-shore marine system is affected by the output from the lake. Hydrological processes in the landscape are considered essential to the connectivity of the different subsystems. The landscape is therefore divided into functional units defined by catchment areas that are constructed from water divides (interfluves) in the landscape. The flows of CNP in the landscape are considered to be hydrologically driven in this descriptive ecosystem model.

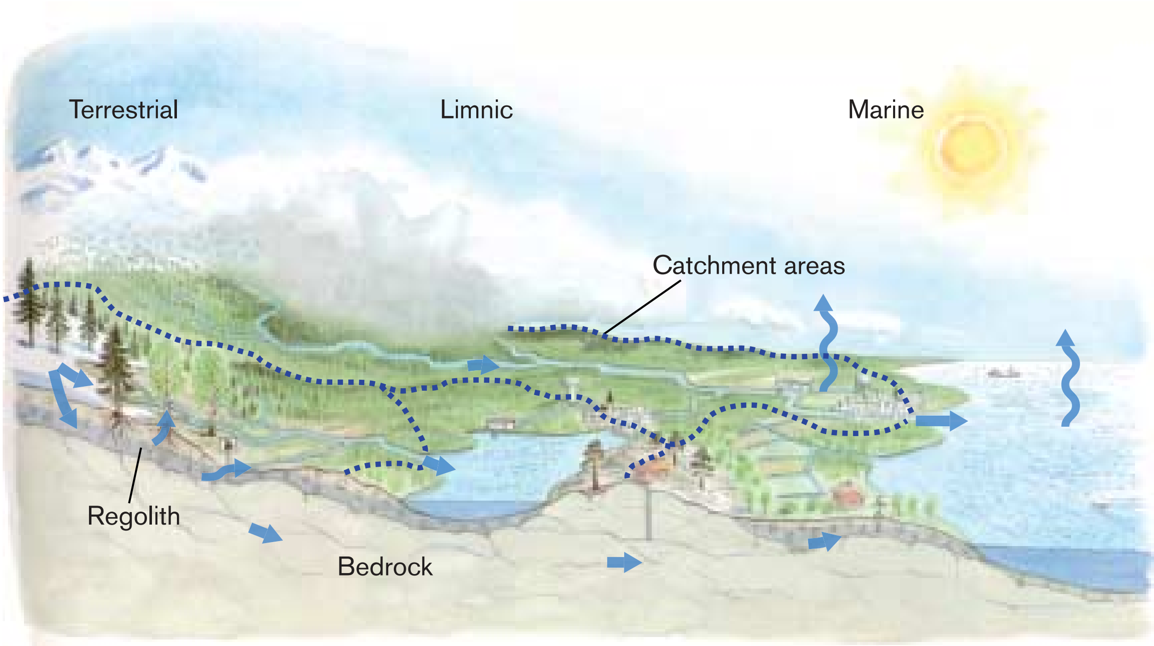

***Figure 2-2.** A schematic illustration of a descriptive ecosystem model where the three subsystems and the general physical properties of the landscape are integrated using catchment areas.*

The size of the site area is mainly chosen to meet the geological requirements for a deep repository. As a result, the regional and local site does not necessary correspond to the area covered by the descriptive ecosystem model. The area covered by the descriptive ecosystem model is based on the regional and local sites, but also takes into account the catchment areas (e.g. Figure 2-2).

2.3 Describing flows of matter

The energy fixed by photosynthesis supports plant growth and produces organic matter. Because of the relative constancy of carbon and energy contents of organic matter, carbon, energy, and biomass have been used interchangeable as currencies of the carbon and energy dynamics of ecosystems /Chapin et al, 2002/. Moreover, the proportions between carbon, nitrogen and phosphorous are often almost constant within system, but differ between systems, e.g. terrestrial and limnic systems /Elser et al, 2000/. Matter is recycled between organisms in the food web and the physical environment within the ecosystem. However, matter is leaching from the terrestrial ecosystem into streams following the watercourses into lakes and in the end discharging into the sea. Some matter is accumulated along this way, e.g. in lake beds. Matter may also be accumulated within the terrestrial system, e.g. peat. Accumulation often mean that the matter leaves the circulation and that some kind of disturbance has to occur to release it to circulation again, e.g. human starts to plough old lake beds or harvest peat.

The budgets of organic matter in terrestrial systems are described by means of biomass, primary production, secondary production, decomposition, mineralization and soil chemistry. These budgets are also divided into the most important functional groups within the food web (Figure 2-3). Investigations of water chemistry and hydrology will provide information concerning transport and accumulation (e.g. Figure 2-3). Data of

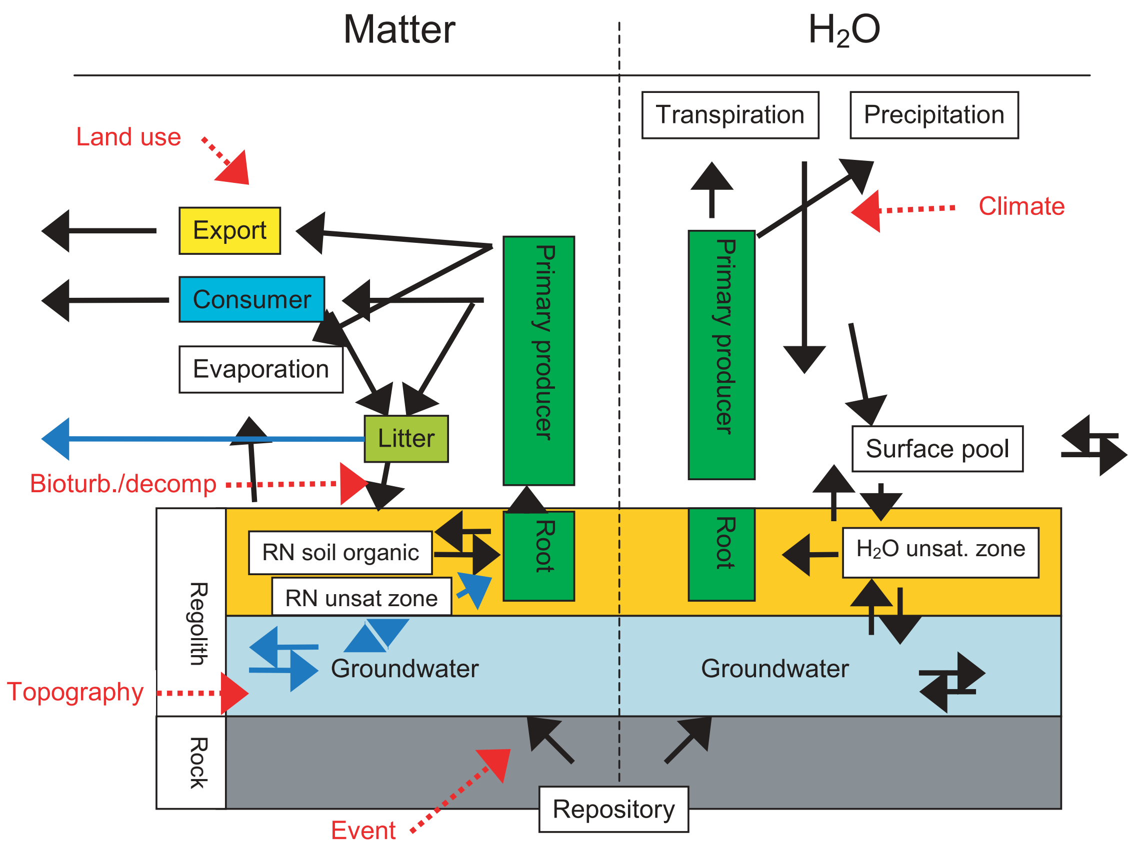

Figure 2-3. *An example of a terrestrial conceptual model, illustrating possible flows of matter and water. The figure is divided into two parts (Matter and H_2O), where hydrology and primary production are considered as the main driving processes for flows of matter.*

removal by forestry and agriculture will provide further information in describing the cycling of carbon, nitrogen and phosphorous. Budget calculations describing the flows of matter at the level of catchment area, will then be used to estimate transfers into running water and lakes. The aquatic systems are important for transport but also for accumulation of matter in the lake or the sea bed.

Measurements of matter transport in streams gives an estimation of the transfers from terrestrial systems by sub-catchment area (Figure 2-4). This will give us an opportunity to validate estimated losses and actual losses from terrestrial systems. It will also be possible to crosscheck using sums (e.g. 1+2=3 in Figure 2-4). Consequently, it will be possible to fine-tune the descriptive model in terms of actual transfers into the running water using terrestrial information such as vegetation, soil type and area of the sub-catchment. It will also be possible to identify important factors related to sources and sinks of matter in the ecosystem.

The budgets of organic matter in lake ecosystems are described by means of biomass, primary production, secondary production, decomposition and water chemistry (B in Figure 2-4). These budgets are also divided into the most important functional groups within the food web. Recharge and discharge (A and C in Figure 2-4) are also quantified, and thereby makes it possible to calculate and quantify input and loss of matter into and from the lake. Groundwater discharge into the lake is also an important transport route of, e.g. organic matter. Accumulation in the lake bed is quantified using bed samples. This will be related to terrestrial information from the catchment area of the lake, such as vegetation, soil type and area of the catchment area.

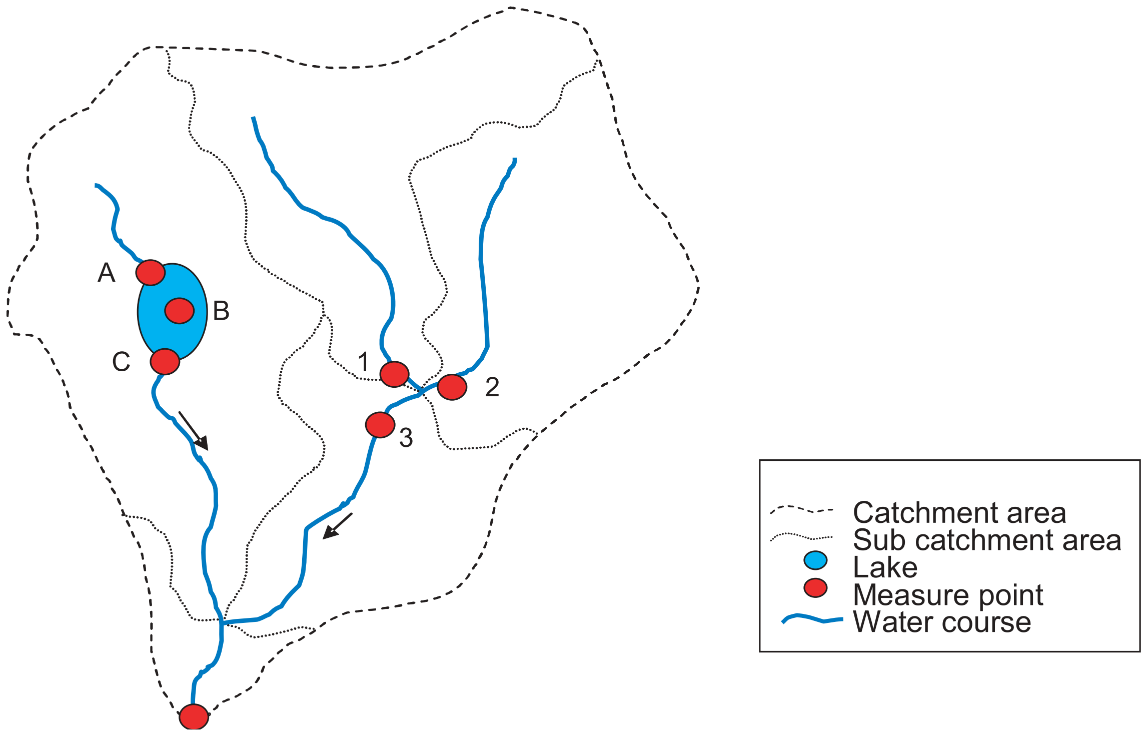

Figure 2-4. *The picture illustrates a catchment area containing a lake and flowing waters, and the sub catchment areas for these. The red points illustrates where field measurements of water chemistry are taken and flow monitoring are performed to be able to follow transport and accumulation of matter within the catchment area.*

The final recipient of the water together with transported matter is the sea where the water discharges, e.g. into a bay. Here we have an accumulation of transported matter with running water and shallow bays may typically have a large production due to high nutrient availability, which means that much matter is tied up there. However, the bay also serves as the interface to the open sea through which a large exchange of matter may occur depending on water currents and hypsography. The budgets of organic matter in the sea system are described in means of biomass, primary production, secondary production, decomposition and water chemistry e.g. /Kumblad, 1999/. These budgets are also divided into the most important functional groups within the food web. Discharge into the sea area, as mentioned earlier may add to the sea ecosystem budgets.

2.4 Properties

2.4.1 General outline

This report describes the type of background data that are needed from the site investigations and how the data can be processed to obtain the results that are needed to satisfactorily specify the different properties. This report does not concern the actual sampling methodology of the data used to describe each property.

The parameters are calculated using data collected in an area. In some cases, it is not necessary to perform local measurements to parameterize the property with the desirable precision. In these cases, the estimates are taken from literature that represents the local conditions as closely as possible or data adapted to the local conditions, e.g. removal of berries due to berry-picking activities in an area is calculated based on the local abundance of the berry-producing species and a general estimate of the rate of removal. Some of the properties are straightforward, e.g. precipitation, whereas other properties need to be calculated using several different data sources. The properties dealt with in this report are all listed in Table 2-1.

2.4.2 Quality assurance

Data uncertainty of the parameter value that describe the property may be caused by measurement errors, interpretation errors or extrapolation of primary data with few sampling points or great variation. These uncertainties may be characterized during the actual sampling or the parameterization of the model. Different preventive steps can be taken to assure that the primary data are correct, such as standardized procedures for handling and registration of primary data or resampling of registered data to check for errors. These are important steps because the model result will never be more accurate than the primary data. Data uncertainties associated with the parameterization of the site descriptive model are, however, of primary interest to us here.

Data uncertainty must not only be quantified using standard statistics, its origin should also be described. The origin of uncertainty is crucial in understanding how and whether the uncertainty can be reduced if necessary /Andersson, 2003/. It is therefore important to check data for large variation or small sample sizes and describe these if they occur. Each parameter has to be carefully evaluated, and circumstances affecting confidence should be fully described.

2.4.3 Processing of primary data

Primary data will be sampled at a temporal and/or a spatial scale appropriate to the estimation and quantification of properties. A straight forward way describing such data is by using a central value with a measure of variation, e.g. mean, median and standard deviation. Sometimes the extremes are of greater interest and maximum/minimum values are then a more appropriate description of variation. Similarly, cyclical patterns, e.g. within a year, are sometimes better described using diagrams. The diagram is also an important tool for extracting critical values, thresholds or periods from a larger data set.

Most of the data have to be gathered during a rather short time, which means it may be difficult to obtain long time series, whereas in other cases there may be long time series available, for example for climate properties. For some properties with long time series, one year with high resolution data can be used for studies e.g. climate, oceanography, hydrology. However, these values are mainly used for increasing the resolution within years, whereas variation between years has to be studied using several years.

Spatial variation should be estimated between different units describing a property, e.g. green biomass among the different habitat types. If the same units are replicated, this is presented as a central value with a measure of variation. Properties with spatial variation among units, e.g. habitat types, will be presented as geographically rectified digital maps, using a GIS (Geographical Information System), covering a specific area. This will make it possible to overlay a large number of properties if necessary during the later phase of spatially explicit modelling.

A parameter estimate describing a property may be associated with another parameter e.g. the green biomass and the different habitat types in the terrestrial system. This association, or the process of assigning the different habitats different values for a specific property, can be done in at least three ways.

1. A value can be assigned to each habitat using the central value of the samples representing each habitat. This procedure will not reflect the variation in the sample.
2. All samples are used and a resampling procedure assigns values to each habitat. This means that habitats within the same habitat category will be given different values representing the actual sample variation.
3. Habitats that are statistically distinct from each other are assigned unique central values, whereas non-deviating habitats are assigned a common central value.

The choice is very much dependent on sample size, the need to include variation in the modelling, and the ability of the specific safety assessment model to handle multiple values for each habitat category.

2.4.4 Database

Large quantities of data have to be collected to permit accurate calculation of the properties. All the data will be collected in two databases, numerical data in SICADA (Site Characterization Database, INGRES, Oracle) and spatial data in ArcSDE (Spatial database engine, ESRI, see SKB report TR-00-20 Geoscientific programme for investigation and evaluation of sites for the deep repository, chapter 6). This will facilitate continuous updating during the collecting stage and later during the modelling stage. All data will be tagged with information concerning location, collector, field activity etc. Moreover, log files associated with the data will describe the changes and recalculations that have been done since the sampling occasion. When it is time for the different modelling steps, the data will be frozen and tagged.

2.4.5 Describing a property

In this report, each property is described under the three following subheadings: Input data, Methodology, Results.

Input data

Here the type of data that can be of help or should be used to get the result is described. In determining a specific property, results from other properties are sometimes used and these are denoted using quotation marks, e.g. "Habitat types".

Methodology

This subheading contains or refers to a detailed description of how the input data are processed to obtain the result or results.

Results

This subheading presents the results obtained from processing according to the methodology. The result is sometimes presented in several different units, e.g. individuals m^{-2} and kg C m^{-2}. The units used are in accordance with the International System of Units (SI). The results are essentially presented as a map (GIS) if there is a spatial resolution, in diagrams if there is a temporal resolution or as a central value with a measure of variation. Some properties have several results presented here.

2.5 Table of properties

Table 2-1 presents all the properties that are used to construct the descriptive ecosystem model. The table also contains information on the page in this report where it is discussed, how the resulting parameter estimate is presented, the resolution, the statistical treatment, the use of generic and local data, if primary data is refined and the SI-unit for each parameter.

Table 2-1. A presentation of all the properties that together will constitute the descriptive ecosystem model. The following information is given for each property: Page in this report; how the resulting product is presented, GIS/Description in words/Point data/Species list; whether the property has a spatial or a temporal resolution S/T; statistical presentation, Cent=central value with a measure of variation, Diag=diagram; whether the result is based on generic or local data, G/L; whether the data have been processed, P=Primary data, C=the result is obtained by calculating data from different data sources; the SI units used for each parameter. Classification followed by a number within brackets shows the number of classes used.

Property	Page	Presention	Resolution S/T	Statistics	Generic/ Local data	Data P/C	Unit
Landscape properties	29						
Altitude and depth data	29	GIS	S	–	L	P	m
Catchment area / morphometry	30	GIS	S	–	L	C	m^2, m, %
Lower regolith, Genetic origin/texture	31	GIS	S	–	L	C	Classification (8)
Regolith thickness	33	GIS	S	cent	L	P	m
Stratigraphy/geometry	34	GIS	S	–	L	C	m, class
Hydraulic conductivity	34	GIS	S	cent	L	C	m s^{-1}
Kinematic porosity	34	GIS	S	cent	L	C	dimensionless
Specific yield	34	GIS	S	cent	L	C	dimensionless
Field capacity	34	GIS	S	cent	L	C	%
Chemical substances	35	GIS/P	S/T	cent/diag	L	P/C	See Appendix 2
Persistent Organic Pollutants (POPs)	36	P	S	–	L	P	See Appendix III
Radionuclides	37	P	S	–	L	P	See Table 3-3
Air temperature	38	P	T	cent/diag	G/L	P	ºC
Precipitation	38	P	T	cent/diag	G/L	P	mm y^{-1}
Global radiation	38	P	T	cent/diag	G/L	P	KW $m^{-2}day^{-1}$
Relative humidity	38	P	T	cent/diag	G/L	P	%
Vegetation period	38	P	T	cent	G/L	P	days $year^{-1}$
Wind velocity/direction	39	P	T	cent/diag	G/L	C	m s^{-1}, classification (8)
Ice freeze-up/break-up	39	GIS	S/T	cent	G/L	C	days y^{-1}, m
Ground frost and snow cover	40	GIS	S/T	cent	G/L	C	days y^{-1}, m
Evapotranspiration catchment area $^{-1}$	41	GIS	S/T	cent	L	C	m y^{-1}, m^3 y^{-1}
Water table	42	GIS	S/T	cent	L	C	m
Groundwater budget	42	GIS	S/T	cent	L	C	m^3
Specific runoff	43	GIS	S/T	cent	L	C	m^3 y^{-1}

Property	Page	Presention	Resolution S/T	Statistics	Generic/ Local data	Data P/C	Unit
Spatial distribution of surface water	43	GIS	S	–	L	P	–
Recharge and discharge areas	44	GIS	S	–	L	P/C	–
Terrestrial systems	45						
Soil type	46	GIS	S	cent	L	P	Classification, m
Grain size	46	GIS	S	cent	L	P	Classification
Bioturbation	46	GIS	S	cent	L	P	m
Root zone depth	46	GIS	S	cent	L	P	m
Hydraulic conductivity	47	GIS	S	cent	L	C	$m\ s^{-1}$
Kinematic porosity	47	GIS	S	cent	L	C	dimensionless
Specific yield	47	GIS	S	cent	L	C	dimensionless
Field capacity	47	GIS	S	cent	L	C	%
Humus layer	47	GIS	S	cent	L	P	Classification (6), m
Peat	48	GIS	S	cent	L	P	Classification, m
Habitat types	49	GIS	S	–	L	C	Classification
Species composition (flora)	49	GIS/Des/List	S	cent/–	G/L	P/C	Classification, individuals m^{-2}
Biomass (flora)	50	GIS/Des	S	cent	G/L	C	kg CNP m^{-2}
Primary production	51	GIS/Des	S	cent	L	C	kg CNP $m^{-2}\ y^{-1}$
Litter	52	GIS	S	cent	L	C	Kg CNP $m^{-2}\ y^{-1}$, kg CNP m^{-2}
Species composition (Fauna)	52	GIS/Des/List	S	cent	L	P	Classification, individuals m^{-2}, kg CNP
Biomass (Fauna)	54	GIS/Des	S	cent	L	C	kg CNP m^{-2}
Consumption (Fauna)	54	GIS/Des	S	cent	L	C	kg CNP $m^{-2}y^{-1}$
Heterotrophic respiration	55	GIS/Des	S	cent	L	C	kg CNP $m^{-2}y^{-1}$
Secondary production	56	GIS/Des	S	cent	L	C	kg CNP $m^{-2}y^{-1}$
Chemical substances	57	GIS/Des/P	S/T	cent	L	P/C	See appendix II
Persistent Organic Pollutants (POPs)	58	P	S	–	L	P	See appendix III
Radionuclides	58	P	S	–	L	P	See Table 3-3
Human population and settlement areas	59	GIS	S	–	L	C	Humans m^{-2}, humans catchment area^{-1}
Human occupation	59	List	–	–	L	P	Classification
Forestry	60	GIS	S/T	cent	L	C	kg CNP $m^{-2}\ y^{-1}$
Agriculture	60	GIS/Des/list	S/T	cent	L	C	kg CNP $m^{-2}\ y^{-1}$
Water suply	61	GIS/Des	S/T	cent	L	C	$m^3\ y^{-1}$, $m^3\ y^{-1}$ catchment area^{-1}
Utilized food resources	62	List	S/T	cent	L	C	kgCNP organism group$^{-1}\ y^{-1}$
Potential food resources	62	List	S/T	cent	L	C	kgCNP organism group$^{-1}\ y^{-1}$
Import	63	GIS/Des/list	S/T	cent	L	C	kg CNP y^{-1}
Export	63	GIS/Des/list	S/T	cent	L	C	kg CNP y^{-1}
Mining	64	GIS/Des	S/T	–	L	P	–

Property	Page	Presention	Resolution S/T	Statistics	Generic/ Local data	Data P/C	Unit
Limnic systems	64						
Water volume	65	P	S/T	cent	L	C	m^3
Residence time	66	P	S/T	cent	L	C	days
Running water	66	P	S/T	cent	L	C	m^3/year
Water balance	66	P	S/T	cent	L	C	m^3/year
Lake/river bed	67	GIS	S/T	cent	L	C	Classification, m
Organic deposits and deposition of matter	68	GIS	S/T	cent	L	C	kg CNP m^{-2}, m y^{-1}, kg CNP m^{-2} y^{-1}
Habitat distribution in lakes and rivers	68	GIS	S/T	–	L	P	Classification (5)
Species composition (flora)	69	GIS/Des/List	S	cent	L	P	Classification, individuals m^{-2}, kg CNP y^{-1}
Biomass (flora)	70	GIS/Des	S	cent	L	C	kg CNP m^{-2}
Primary production	70	GIS/Des	S	cent	L	C	kg CNP $m^{-2}y^{-1}$
Species composition (fauna)	71	GIS/Des/List	S	cent	L	P	Classification, individuals m^{-2}, kg CNP
Biomass (fauna)	72	GIS/Des	S	cent	L	C	kg CNP m^{-2}
Consumption/respiration/ decomposing (fauna)	72	GIS/Des	S	cent	L	C	kg CNP $m^{-2}y^{-1}$
Secondary production	73	GIS/Des	S	cent	L	C	kg CNP $m^{-2}y^{-1}$
Mass balance	74	GIS/Des	S	cent	L	C	kg CNPy^{-1}
Chemical substances	74	GIS/Des/P	S/T	cent	L	P/C	See appendix II
Persistent Organic Pollutants (POPs)	75	P	S	–	L	P	See appendix III
Radionuclides	75	P	S	–	L	P	See Table 3-3
Temp. and thermal stratification	76	P	S/T	cent/diag	L	P/C	°C
Light penetration	77	P	S/T	cent/diag	L	P/C	m
Utilized food resources group^{-1} y^{-1}	77	List	S/T	cent	L	C	kgCNP organism
Potential food resources group^{-1} y^{-1}	78	List	S/T	cent	L	C	kgCNP organism
Water supply	78	List	S/T	cent	L	P	m^3 y^{-1}
Marine/brackish system	79						
Sea level	79	P	S/T	cent	L	P	m
Water volume	79	Des	S/T	cent	L	C	m^3
Water exchange	80	P	S/T	cent/diag	L	C	Days, m^3/s
Sea bed	81	GIS	S/T	cent	L	C	Classification, m
Organic deposits and deposition of matter	82	GIS	S/T	cent	L	C	kg CNP m^{-2}, m y^{-1}, kg CNP m^{-2} y^{-1}
Habitat distribution in the sea	83	GIS	S/T	–	L	P	Classification
Species composition (flora)	83	GIS/Des/List	S	cent	L	P	Classification, individuals m^{-2}, kg CNP
Biomass (flora)	84	GIS/Des	S	cent	L	C	kg CNP m^{-2}
Primary production	84	GIS/Des	S	cent	L	C	kg CNP $m^{-2}y^{-1}$

Property	Page	Presention	Resolution S/T	Statistics	Generic/ Local data	Data P/C	Unit
Species composition (fauna)	85	GIS/Des/List	S	cent	L	P	Classification, individuals m^{-2}, kg CNP
Biomass (fauna)	86	GIS/Des	S	cent	L	C	kg CNP m^{-2}
Consumption/respiration/ decomposing (fauna)	86	GIS/Des	S	cent	L	C	kg CNP $m^{-2}y^{-1}$
Secondary production	87	GIS/Des	S	cent	L	C	kg CNP $m^{-2}y^{-1}$
Mass balance	87	GIS/Des	S	cent	L	C	kg $CNPy^{-1}$
Chemical substances	88	GIS/Des/P	S/T	cent	L	P/C	See appendix 2
Persistent Organic Pollutants (POPs)	89	P	S		L	P	See appendix 3
Radionuclides	90	P	S		L	P	See Table 3-2
Temp. and thermal stratification	90	P	S/T	cent/diag	L	P/C	°C
Light penetration	91	P	S/T	cent/diag	L	P/C	–
Utilized food resources	91	List	S/T	cent	L	C	kgCNP organism $group^{-1}$ y^{-1}
Potential food resources	91	List	S/T	cent	L	C	kgCNP organism $group^{-1}$ y^{-1}
Export	92						
Seawater use	92	Des/List	S/T	cent	L	C	KgCNP y^{-1}
Historical properties	93						
Land uplift	93	GIS	S/T	–	L	C	m y^{-1}
Sedimentation (sea)	93	GIS	S/T	Cent	L	C	m y^{-1}
Lake ontogeny	94	Des	S/T	–	L	C	m y^{-1}
Archeological remains	95	GIS/List	S/T	–	L	P	–
Vegetation and land use	95	GIS/Des/List	S/T	–	L	C	–
Human population and settlement areas	96	GIS/Des	T	Diag	L	P	individuals
Human occupation	96	List	T	–	L	P	–
Utilized food resources	97	List	S/T	cent	L	C	kgCNP organism $group^{-1}$ y^{-1}
Water level adjustments	97	GIS/Des	S/T	–	L	P	–

3 The Surface ecosystems today

The surface ecosystem starts where the deep bedrock ends except were the bedrock reaches the surface and thereby becomes a part of the surface ecosystem as outcrops. This chapter is mainly concerned with patterns observed at the time of the investigation of the area and does not take into account long-term changes in patterns, e.g. succession or shoreline displacement. These matters are dealt with in chapter four covering the historical perspective.

3.1 General physical properties of the landscape

This section deals with a number of properties that are used to describe the geometry and physical and chemical patterns of the landscape such as topography, sediments and water chemistry. The driving forces of many processes of the surface ecosystems are also described here, e.g. climatic and hydrological processes, and the interface between the bedrock and the surface, which is important in describing the transport of different substances from the bedrock up to the surface ecosystem. It is also central because it may in many respects set the boundaries of, and constrain the range of, potential ecosystems at the surface, e.g. a deep soil layer vs. a shallow soil layer. Consequently, this chapter deals with properties that are crucial for the integration of the different surface ecosystems into the final descriptive model.

3.1.1 Geometry

This entity describes the topography and the catchment areas, which are needed in the describing and understanding the site-specific surface hydrology. These properties will therefore make an important contribution to an understanding of accumulation and dispersal processes mediated by water movements at the site.

Altitude and depth data

This property describes the unified topography above and below the water surface.

Input data

- Elevation data covering the land.
- Sea depth data.
- Lake depth data.

Methodology

Land elevation data /Wiklund, 2002/ is combined with lake and sea depth data to produce a digital elevation model covering the whole area. It is important that the land elevation data cover more than just the intended site area, since this property is used to calculate the catchment area (see below).

Results

- A digital elevation model (DEM) covering land, lakes and local coastal waters.

Catchment area and morphometry

The catchment area is defined as the upstream area collecting water that flows out over a lake threshold or a given cross-section in a running water /Blomqvist et al, 2000/. This is a key property for describing transport processes dependent on water, e.g. transport of pollutants or radionuclides, and is an important factor in the functioning of aquatic ecosystems.

Input data

- Topographical maps.
- “Altitude and depth data”.
- Field validation data.

Methodology

The watersheds must be established using a high-resolution topographic map and the “Altitude and depth data”, which must sometimes be supplemented by field studies. Especially in plains, establishment of the watershed may be a difficult task and require field verification /Blomqvist et al, 2000/. The following morphometric properties are used to describe the catchment areas: area (m^2), highest and lowest level (m above sea level), difference in height (m), max. slope (%, height difference divided by the square root of the area), perimeter (m), form factor (the perimeter divided by the perimeter of a perfect circle with the same area as the catchment area).

Results

- The spatial location of the catchment areas that cover the site (the ‘site’ is not necessarily identical to that considered for repository location – as discussed earlier) presented as a map.
- The morphometry of the catchment areas presented in a table.

3.1.2 Regolith

In the characterization of the geomorphological landscape properties, the regolith, mainly Quaternary deposits, is one basic contributor. To a large extent the regolith covers the bedrock, even though bedrock outcrops exist. The regolith is the interface between deeper part of the earth crust, mainly bedrock, and the atmosphere (Figure 3-1). In this report, we separate the regolith in an upper (down to one metre below surface, which is an approximate value where an observable change in properties occurs) and a lower regolith (Figure 3-1). Physical and chemical processes, especially in the upper part (solum, Swedish *jordmån*), interact with biological conditions to form the soil-water-biota system. It is in these layers that most of the soil forming processes occurs, hydrological and biological conditions develop (e.g. water availability and transport) and the limits for the possible habitat type are defined.

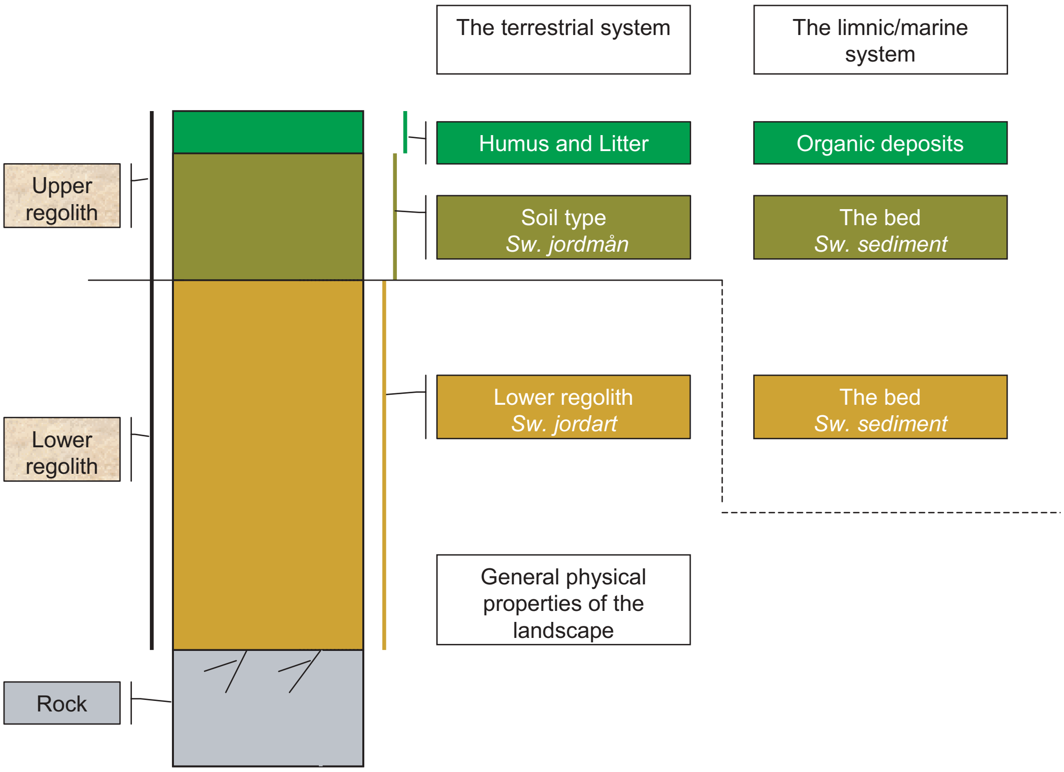

Figure 3-1. *A description of the regolith in the different subsystems and how it is named and subdivided in this report. Note that the upper part of the regolith is described in each subsystem respectively and that the lower regolith is present in all subsystems, but only described in the chapter "physical properties describing the landscape".*

Land use, such as agriculture and forestry, is dependent on soil conditions. For example, a stony and bouldery till is not ideal for agriculture, and the soil conditions would require site adaptation and selection of tree species for forestry.

The description includes both qualitative aspects such as genetic origin, texture, and stratigraphy and a quantification of the regolith such as thickness and spatial distribution. Properties describing e.g. potential flow or hydraulic conductivity are needed for prediction of water flows and transport of substances in regolith layers. Furthermore, the regolith is described with regard to chemistry and content of radionuclides. This description covers the whole landscape including the regolith existing below mires, lakes and the sea.

Environmental processes affect the upper regoliths, e.g. the soil type (solum, Swedish "*jordmån*"), including the humus layer of boreal forests and soft bottoms in marine systems. These upper regoliths are described under terrestrial (Soil type and Humus), aquatic (Bed and Organic deposits) and marine (Bed and Organic deposits) systems. The bed may be thicker than one meter and is thus a part of the lower regolith (see Figure 3-1). The regolith properties is then presented under the property "Bed" under liminc and marine systems respectively.

Genetic origin and texture

The genetic origin and the texture of the lower regolith describe both the glacial and postglacial formations and the grain size distributions.

Input data

- Soil texture classification e.g. using the terminology in /Lundin et al, 2002/.
- Regolith genetic origin classification e.g. using the terminology in /Lundin et al, 2002/.
- Soil map.
- Data from lake and sea bed inventory.
- Aerial photographs to identify outcrops of bedrock.
- Vegetation maps.

Methods

This property is handled by the geological modelling and is only described here to point out the information needed for the biosphere modelling.

Classification of soil texture and genetic origin (STG) following /Lundin et al, 2002/ are combined to provide a classification of grain size and soil formation (see Table 3-1, Lundin, unpubl.). Additional information concerning bedrock distribution can be obtained from aerial photographs. This information is compiled in a map showing the spatial distribution of grain size and soil formation for the area. The map is then compared with the vegetation map to identify associations between soil texture and genetic origin, and the different vegetation classes ("habitat types") found in the area (see below for more information concerning vegetation). This can be done by describing the distribution of soil texture and genetic origin classes among the different habitat types found in the area, taking the topography into account. A high association between these variables will allow extrapolation to the whole area using the vegetation map and the topography.

Table 3-1. Classification of soil texture and genetic origin.

Class	Genetic origin	Texture
Fine grained till	(3) Till	(6) Coarse silty (7) Silty (8) Clayey
Medium grained till	(3) Till	(4) Sandy silty (5) Fine sandy-silt
Coarse grained till	(3) Till	(0) Boulder in pit (1) Skeletal material (2) Gravelly (3) Coarse sandy
Fine grained sediment	(1) Highly sorted sediments (2) Moderately sorted sediments	(6) Coarse silt (7) Silt (8) Clay
Medium grained sediment	(1) Highly sorted sediments (2) Moderately sorted sediments	(4) Medium sand (5) Fine sand
Coarse grained sediment	(1) Highly sorted sediments (2) Moderately sorted sediments	(1) Boulder in pit (2) Gravel (3) Coarse sand
Bedrock	(4) Bedrock	
Peat	(5) Peat (also under the terrestrial system below)	

Results

- The result will be a map describing the spatial distribution of glacial and postglacial formations using the classes in Table 3-1, and also describing the relationships between these classes and the habitat types found in the area.

Regolith thickness

The thickness of the whole regolith from the bedrock to the ground surface at the site.

Input data

- Data from "genetic origin and texture" inventory.
- Data from soil type inventory.
- Outcrop map.
- Seismological measurements (seismic refraction).
- Percussion drilled boreholes.
- Core drilled boreholes.
- Data from lake and sea bed inventory.
- "Habitat types".

Methodology

Information from the first five sources can be used to construct a map describing regolith thickness at the site. This information can be combined and interpolated to the whole area using different geostatistical methods. If there is a congruent pattern between regolith thickness and habitat types, it should be desirable to associate regolith thickness with different habitat types using central values and a measure of variation of the regolith thickness. This association is probably more difficult to show in areas with higher regolith thickness.

Results

- The result is a map describing the regolith thickness (m) using central values and a measure of variation.

Stratigraphy/geometry

This property describes changes in the lower regolith texture with depth. A combination of the properties "Genetic origin and texture", describing the horizontal distribution, and "Regolith thickness" will give a three dimensional picture of the deposits. This property is handled by the geological modelling and is only described here to point out the information needed for the biosphere modelling.

Input data

- "Regolith thickness".
- "Genetic origin and texture".
- Field investigations concerning changes in regolith type/texture with depth.

Methodology

Field investigations will describe changes in regolith texture as a function of depth. If the sampling points are numerous enough, it is possible to describe the most common and significant transitions in genetic origin/texture with depth at the site. Adding information on the horizontal distribution of genetic origin and texture and the total regolith thickness will result in a three-dimensional map describing the volumes of the different "Genetic origin and textures".

Results

- An estimate of the thickness (m) and horizontal distribution (m) of the different soil layers at the site.

Hydrophysical properties

This is a description of a number of different properties of the regolith in the area. These are of importance for understanding the potential transport, permeability and retention of water in regoliths of different genetic origin and texture. Hydraulic conductivity is one property of water movement through the soil. The kinematic porosity of a soil texture class is the pore volume where water can flow freely. Specific yield is the volume of water that leaves the soil after free drainage. Field capacity (specific retention capacity) is the water volume a certain volume of soil can hold after gravity has drained all free water.

Input data

- Hydraulic conductivity.
- Kinematic porosity.
- Specific yield.
- Field capacity.
- "Genetic origin and texture".

Methodology

The measurements of the different properties should be designed to cover all the listed "Genetic origin and texture" classes found in the area (see "Genetic origin and texture").The hydrophysical properties should be associated with the different classes used under "Genetic origin and texture".

Results

- The different “Genetic origin and texture” classes in the area should be associated with a central value and a measure of variation for the above listed properties in the SI units given in Table 3-2.

3.1.3 Chemical properites in abiotic media

This entity includes the concentration of different chemical elements, POPs (persistent organic pollutants) and radionuclides in the abiotic media surface water, marine water, groundwater, precipitation and lower regolith. These results may be used for many different purposes. One important aim is to quantify different parts of the CNP budgets. Another aim is to describe the background concentrations in these abiotic media before any extensive work has started at the site and to establish a baseline for a future monitoring program. Furthermore, samples of the different media should be stored for future analysis, for example new POPs or substances may be described. The chemical signatures of the different waters may be used to estimate the degree of mixing of different water masses. This could be useful for estimating the potential degree of dilution and dispersion of radionuclides released from the repository – bearing in mind that a future environment may be similar, but not identical, to that at the present day.

Chemical substances

This property describes the presence of different chemical substances in the groundwater, aquatic and marine water, precipitation and deposits. A large number of important results can be extracted from this property, but not all of them are presented here. A number of examples are, however, presented under “Results” below.

Input data

- Groundwater samples from different catchment areas.
- Samples from different freshwater systems.
- Samples from the marine system.
- Samples from precipitation.
- Samples from the lower regolith.

Table 3-2

Regolith property	SI unit
Hydraulic conductivity	m s^{-1}
Kinematic porosity	–
Specific yield	–
Field capacity	%

Methodology

A comprehensive list of the analyzed chemical substances is found in Appendix 2 and the substances are presented separately for the five different sources. The method of obtaining the results will be partly dependent on how fine-grained the spatial and temporal resolution for sampling/analysis is for the different substances. The data are presented as central values with a measure of variation or as annual fluctuations in data with a high temporal resolution using tables and diagrams.

For groundwater sampling see /SKB, 2001/ for additional information. For limnic water see /Blomqvist et al, 2000, 2001/ for additional information. See /SKB, 2001/ for additional information concerning precipitation.

The lower regolith starts one metre below the regolith surface. Chemical properties above one metre are presented under the Terrestrial, Aquatic and Marine systems.

Results

- The concentrations of CNP in groundwater, precipitation, aquatic and marine water (kg CNP m^{-3}) with a central value and a measure of variation describing the annual mean and variation during the year.
- The concentration of CNP (kg m^{-3}) in the groundwater broken down among habitat types.
- The total content of CNP (kg) in the lakes and in the sea with a central value and a measure of variation describing the annual mean and variation during the year.
- The total deposition of CNP via precipitation (kg m^{-2}). Both with a central value with a measure of variation describing the annual mean and variation during the year.

POPs

This property describes the concentrations of different organic toxins in groundwater, aquatic systems, marine systems, precipitation and the regolith. This property will be a documentation of the status of POPs at the site. The aim is not to fully cover the whole area, which would result in a lower spatial and temporal resolution.

Input data

- Groundwater samples from different catchment areas.
- Samples from different freshwater systems.
- Samples from the marine system.
- Samples from precipitation.
- Samples from the lower regolith.

Methodology

The analyzed substances are listed in Appendix 3.

Results

- This list will cover most POPs known today using SI units as shown in tables in Appendix 3.

Radionuclides

This property describes the concentrations of different radionuclides in the different media.

Input data

- Groundwater samples from different catchment areas.
- Samples from different freshwater systems.
- Samples from the marine system.
- Samples from precipitation.
- Samples from lower regolith.

Methodology

The analyzed substances are listed in Table 3-3.

Results

- A comprehensive description of the quantities as kg m^{-3} for liquid media or kg kg^{-1} dry weight for solid material. The data may be presented as a central value with a measure of variation.

Table 3-3. Isotopes

Radionuclide	Groundwater	Aquatic systems	Marine systems	Precipitation	Lower regolith	SI unit
^{37}Cl	x	x	x	x	x	kg m^{-3}/kg^{-1}
d^{18}O Deuturium	x	x	x	x	x	kg m^{-3}/kg^{-1}
^{3}H Tritium	x			x		kg m^{-3}/kg^{-1}
^{10}B	x	x	x		x	kg m^{-3}/kg^{-1}
^{87}Sr	x	x	x		x	kg m^{-3}/kg^{-1}
^{34}S	x	x	x		x	kg m^{-3}/kg^{-1}
^{14}C	x	x	x		x	kg m^{-3}/kg^{-1}
Ra isotopes	x	x[1]	x		x	kg m^{-3}/kg^{-1}
Rn isotopes	x	x[1]	x		x	kg m^{-3}/kg^{-1}
Th isotopes	x	x[1]	x		x	kg m^{-3}/kg^{-1}
U isotopes	x	x[1]	x		x	kg m^{-3}/kg^{-1}

[1] Not measured in streams.

3.1.4 Climate

This entity describes a number of climate properties that characterize the climate at the site. Data are available from SMHI (Swedish Meteorological and Hydrological Institute), especially if some of their meteorological stations are situated near the site. SMHI often has long time series of data measurements with a high temporal resolution. However, it is also desirable to measure these properties at one or a few sampling points in the area. This low spatial resolution is considered adequate because of the low spatial variation in most of these properties. The local measurements can easily be compared regionally and nationally using data from SMHI.

General climate properties

A number of climate properties will have a low spatial resolution but a high temporal resolution that is generalized across the area.

Input data

- Regional data from SMHI for the properties listed in Table 3-4.
- Site-specific data for the properties listed in Table 3-4.

Methodology

The data should be presented with central values and measures of variation, and max./min. values at a temporal resolution that is in accordance with Table 3-4. The seasonal and the diurnal data can be presented graphically to facilitate the interpretation of the variation.

The long-term data available from SMHI should be used to put the short-term site-specific data into a long-term perspective. Thus, the available site-specific data must be compared with the data from the nearest meteorological station. If they agree, it should be possible to use the data from SMHI to characterize long-term fluctuations in the area.

Results

- The results are presented in the SI units given in Table 3-4 using diagrams and appropriate central values and measures of variation depending on the annual, seasonal or diurnal characterization.

Table 3-4

Property	SI units	Annual data	Seasonal data	Diurnal data
Temperature	°C	x	x	x
Precipitation	mm y^{-1}, m^3 y^{-1}	x	x	x
Global radiation	kWh m^{-2}	x	x	x
Relative humidity	%		x	x
Vegetation period	days $year^{-1}$	x		

Wind velocity/direction

This property describes wind velocity and wind direction at the site.

Input data

- Regional data from SMHI.
- Site specific data.

Methodology

The wind should be characterized using a wind rose that shows the average yearly distribution of wind velocity and wind direction /Larsson-McCann et al, 2002/. The wind direction is grouped into eight classes of 45° (N, NE, E, SE, S, SW, W, NW) and wind speed is classified in intervals of 3 ms^{-1}. The frequency of calm conditions is noted in the center of the wind rose. If the site is located on the coast it is important to note that there may be differences between inland and coastal localities as regards wind speed.

The long-term data available from SMHI should be used to put the short-term site-specific data into a long term perspective. Thus, the available site specific data must be compared with the data from the nearest relevant meteorological station. If the patterns agree, it should be possible to use the data from SMHI to characterize long-term variation in the area.

Results

- An average wind rose based upon the distribution of wind velocity and wind direction over a period of several years for the area.

Ice freeze-up/break-up

This property describes the ice dynamics on lakes, streams and the seacoast.

Input data

- General regional estimates made by SMHI.
- Field observations from lakes and streams.
- Field observations from the sea coast.

Methodology

Ice freeze-up/break-up is a function of size and depth of the water body, and water flow. Based on field observations it should be possible to rank lakes and streams according to when ice freeze-up/break-up occurs during the year. If some of the lakes and streams regularly freeze down to the bottom or disappear during the winter, this should be noted.

Results

- An estimate of the number of days ice is present and the mean dates for ice freeze-up/break-up should be presented in tables together with ice thickness (m) and information about which lakes regularly freeze down to the bottom.

Ground frost and snow cover

This property describes the number of days and the severity of ground frost, which is of importance for permeability of the upper regolith to groundwater discharge. Moreover, the presence of snow cover and its depth described on an annual basis in the area.

Input data

- Local measurements of ground frost.
- Regional measurements of ground frost.
- “Soil type” data at the sampling points for ground frost.
- “Water table”.
- “Recharge and discharge areas”.
- “Insolation”.

Methodology

The number of days and the depth of ground frost during a year should be described, and if possible an estimate should be obtained of the annual variation. It would be desirable to describe local differences in ground frost using the “Soil type” and “water table” and “Recharge and discharge” properties. This provides some understanding of how ground frost affects different soil types and potential discharge areas. This does, however, require a fairly large number of sampling points.

A number of different approaches may be used such as the coupled heat and mass transfer model for soil-plant-atmosphere systems /Jansson and Karlberg, 2001/ or a simpler ground frost model as described by /Hansson, 2002/. Another approach is to use extrapolate field data and make a potential ground frost map using GIS.

The number of days of snow cover and the depth during a year should be described, and if possible an estimate should be obtained of the annual variation.

Results

- Duration (days) and depth (m) of ground frost during a year as a central value and a measure of variation. If possible, a qualitative understanding can also be gained of how soil type affect this property and how ground frost affects potential discharge areas such as wells.
- Duration (days) and depth (m) of snow cover during a year as a central value and a measure of variation.

Evapotranspiration

This property describes the total evaporation and transpiration from the different catchment areas in the area. The measure includes evaporation from the soil, water bodies and the surface of the vegetation, as well as transpiration from the vegetation.

Input data

- "Precipitation" .
- "Catchment areas".
- Run off (Q) from catchment areas based on field measurements.

Methodology

The water balance for a catchment area is defined as,

$E_t = P - Q - G - \text{deltaS}$

where E_t is evapotranspiration, P is precipitation estimated using data from meteorological stations, Q is run off, G is groundwater movement and deltaS is the increase in the water storage for the particular catchment area (surface water and groundwater). During a hydrological year, deltaS can be set at zero (only on average – not for any one year), and similarly G can be set at zero under the assumption that no groundwater transport occurs between catchment areas. Evapotranspiration can therefore be calculated from the above equation as a mean value during a year for the whole catchment area.

Results

- The actual evapotran3spiration is presented for each catchment area as m y^{-1} (loss per m^2) and as the total loss in m^3 $year^{-1}$ catchment $area^{-1}$.

3.1.5 Hydrology

Precipitation is the driving input in surface hydrology. Precipitation evaporates from vegetation and soil, and transpires from vegetation and soil due to photosynthetic and decomposing activities. Evaporation and transpiration are determined mainly by wind speed, temperature, type of vegetation and occurrence of bare soil. The effective precipitation (precipitation minus evapotranspiration) on the land is divided between surface runoff (overland flow), infiltrating water that is transported to rivers and lakes in the zone above saturation (interflow), and water that percolates further down to recharge the groundwater in the zone of saturation. Important factors determining the partitioning of flow include different regolith properties. Regolith properties also affect the size of the groundwater reservoir and the groundwater table. The overland flow and the interflow coming from recharge areas all eventually discharge into lakes via e.g. watercourses, and these flows originate from precipitation. The groundwater may also discharge into wells, rivers and lakes and finally into the sea. The groundwater may also be affected by deep groundwater discharge. The surface hydrology is described and quantified by the ecosystem modelling using the properties listed below, however, the methodology used is described in /Rhen et al, 2003/ and a part of the hydrogeological modelling during the site description stage.

Water table

Describes level and fluctuations in the water table.

Input data

- Regular measurements of the water table using water stage recorder.
- “Genetic origin and texture”.

Methodology

Regular measurements from water stage recorder have to be used to calculate the groundwater fluctuations within and between years at the site using central values and measures of variation.

It should be possible to associate mean groundwater depth with different habitat types in combination with “genetic origin and texture”.

Results

- Depth to the water table (m) as central values with measures of variation describing both seasonal and inter-annual variation. The depth of the water table should also be associated with different habitat types.

Groundwater budget

This property calculates the volume of groundwater above the bedrock within a catchment area. Generally, this type of calculation is difficult /Knutsson and Morfeldt, 2002/. Here the method is based on a storage coefficient, the specific yield S_y, but storage coefficients are difficult to calculate /Rhén et al, 2003/. The specific yield is equivalent to the drainable porosity when the free water surface is under atmospheric pressure. Together with the location of the water table and the regolith thickness this would give an approximation of the available groundwater.

Input data

- “Hydrophysical properties” (Specific yield).
- “Water table”.
- “Catchment area”.
- “Regolith thickness”.
- “Stratigraphy/geometry”.

Methodology

Information on the regolith stratigraphy, hydraulic properties and thickness within the catchment area together with the water table height (and its fluctuations) make it possible to calculate the volume of the regolith that is water-drained. The specific yield for the different regolith classes within the catchment area can be used to calculate the groundwater volume for the catchment area.

Results

- The total volume (m^3) of groundwater for each catchment area as a central value with a measure of variation.

Specific runoff

This property describes the groundwater, interflow and surface runoff for each cell in a grid covering the site and the total budget for the catchment areas.

Input data

- "Altitude and depth data".
- Specific runoff from SMHI (Swedish Meteorological and Hydrological Institute, calculated for whole regions).

Alternatively, the last variable can be replaced by the three below that provide a better estimate of the local specific runoff.

- "Precipitation".
- "Habitat type".
- Constants describing how much of the precipitation recharges the groundwater, depending on the vegetation type.

Methodology

A digital elevation model (DEM) is used to calculate the water balance. See Appendix 1 for a detailed description of the calculations using GIS.

The result should be carefully compared with the figures used to calculate the mean evapotranspiration, because the mean evapotranspiration is based on the actual water discharge from each catchment area. The potential water flow is calculated here.

Results

- The potential net water flow, as groundwater, interflow and surface water, for each cell in the catchment area (m^3 s^{-1}).
- The potential net water flow, as groundwater, interflow and surface water, for the whole catchment area (m^3 s^{-1}).

Spatial distribution of surface water

This is a description of the spatial location and area of lakes and rivers.

Input data

- Available maps.
- Field observations.

Methodology

Suitable maps are rectified and controlled using field observations.

Result

- A map showing the spatial location and distribution of lakes and rivers.

Groundwater recharge and discharge areas

One possible way of finding potential recharge and discharge areas of groundwater is by modelling, using morphometric parameters extracted from a digital elevation model (DEM).

Input data

- "Altitude and depth data", morphometric parameters:
  - Elevation.
  - Slope.
  - Aspect.
  - Longitudinal curvature (intersecting with the plane of the slope, normal and aspect direction).
  - Profile convexity (intersecting with the plane of the Z axis and aspect direction).
  - Plan convexity (intersecting with the XY plane).
  - Cross-sectional curvature (intersecting with the plane of the slope, normal and perpendicular aspect direction).
  - Maximum curvature (in any plane).
  - Minimum curvature (in any plane).
  - Topographical index.
- Discharge areas, e.g. springs, in the landscape have to be identified using information from field investigations.
- "Water table".

Methodology

A model developed by Brydsten (after /Moore et al, 1993/) uses ten geomorphological variables to identify possible groundwater discharge areas. This model may be tested and calibrated using results from field observations of discharge areas and the measurements of the water table. The fluctuations in the water table can also provide an indication of periodical changes where a recharge area may turn into a discharge area and vice versa. The resulting map will describe the groundwater/land surface interaction.

Results

- Location of potential groundwater discharge areas.

3.2 The terrestrial system

The terrestrial system is defined as land above the sea that is not part of a lake. It extends one metre below the surface (the upper regolith), which is the part of the regolith layer that is most affected by climate, hydrology, vegetation and soil fauna etc (Figure 3-1). The terrestrial system also includes wetlands, such as wet land forests and mires. The biogeochemical pathways are described using functional groups constructed from species lists. Flows of carbon/nitrogen/phosphorus (CNP) along the pathways are based on estimates of important processes, such as net primary production, secondary production and decomposition etc, for the functional groups within the food web.

The net ecosystem production (NEP) is the net annual biomass (or CNP) accumulation in the ecosystem by plants (B_{plant}), animals (B_{animal}) and the soil (Soil Organic Matter) plus or minus lateral transport among ecosystems.

$$NEP = \frac{(\Delta B_{plant} + \Delta B_{animal} + \Delta SOM)}{\Delta t} \pm F_{lateral}$$

There are several different transport paths for CNP between plants, animals and soil. The second largest avenue of carbon loss from plants, after respiration, is the carbon flux to the soil $F_{pl-soil}$ through litterfall, secretion of soluble organic compounds by roots into the soil, and carbon fluxes to microbes that are symbiotically associated with roots e.g. nitrogen fixers and mycorrhizae /Chapin et al, 2002/. These are also the largest inputs to soil organic matter.

$$\frac{\Delta SOM}{\Delta t} = F_{pl-soil} + F_{anim-soil} - (R_{microb} + F_{microb-anim} + F_{CH_4} + F_{leach} + F_{soil-fire})$$

$F_{anim-soil}$ is the input of organic matter from animals, while respiration, consumption of microbes by animals, methane emission and leaching of organic and inorganic carbon to groundwater and fire are the carbon losses in the soil. The CNP in the dead organic materials in the uppermost soil layers is again available for the vegetation after decomposition if it is not emitted or leached. The accumulation and decomposition rate is affected by factors such as hydrology, soil type, soil chemistry, soil fauna and vegetation.

3.2.1 Geometry

This property describes the uppermost metre of the regolith (Figure 3-1). This uppermost part is greatly affected by climate, hydrology and organisms during a long period of time and is, moreover, an important zone for the accumulation of organic substances in a way that is dependent on hydrology and chemistry /e.g. Jobbágy and Jackson, 2000/.

Soil type

This property describes the developed soil type (swedish "Jordmån"). A rather new international classification, the World Reference Base for Soil Resources /WRB, 1998/, has been used and from this eight relevant soil types for Sweden have been selected: Histosol with a thick organic layer ("torvjord"), leptosol with thin soils on bedrock or sceletal soils with very high stone and boulder content ("tunt jordtäcke" – Lithosol), gleysol with reduced conditions in rather shallow soil layers and thereby limited amount of precipitated elements ("ungefär sumpjordmån"), podzol with the typical bleached horizon and a spodic B horizon with precipitated iron and aluminium ("podsol"), umbrisol on fairly well drained sites with an organic topsoil layer and high content of organic matter in the top mineral soil with a clear structure ("övergångstyp", "svag brunjord"), cambisol with a humus form being a mull or mull-like moder, high content of organic matter in the mineral soil and very good structure in these layers ("brunjord"), arenosol on sand with weak development of soil layers ("sandjord", "svag utveckling"), regosol having immature soil profiles lacking most of the diagnostic horizons (others, "övergångstyper", etc).

Input data

- Soil type samples.
- "Habitat types".

Methodology

This property uses a classification in accordance with /Lundin et al, 2002/. The soil types and their thickness are associated with the different habitat types found in the area. This can be done by describing the distribution of soil types among the different habitat types found in the area. A high association between these properties will allow an extrapolation to the whole area using the vegetation map.

Results

- The different soil types and their thickness (m) are associated, if possible, with the different habitat types in the area.

Soil type properties

This is a description of different properties describing the upper regolith. The different properties are grain size, bioturbation depth (mainly caused by earthworms), the root zone depth and parameters describing permeability transport and retention of water in the upper regolith (see text and Table 3-2 under "Hydrophysical properties" for a more exhaustive description).

Input data

- Grain size estimations.
- Estimations of bioturbation depth in the different soil types.
- Estimations of the root zone depth for the different soil types.

- Hydraulic conductivity.
- Kinematic porosity.
- Specific yield.
- Field capacity.

Methodology

These properties should be associated with the different soil types described under "Soil type" using means and a measure of variation. Grain size could use the classification under "Genetic origin and texture". Bioturbation and root zone depth are given in metres (m) below surface. The SI units for the "Hydrophysical properties" are found in Table 3-2.

Results

- A table associating the above calculated properties to the different soil types described under "Soil type" using means and a measure of variation.

Humus layer

A humus layer is the result of an accumulation process that may be more or less rapid depending on the decomposition rate. The humus type and the thickness of the organic layer are highly dependent on vegetation type and soil conditions. Humus is characterized into the following six classes; mor (1 or 2), moder, mull-moder, mull, peat and peaty mor /Olsson, 1986/. The humus type and layer thickness are important indications of organic accumulation and the quality of the organic material, which is also related to decomposition.

Input data

- Humus layer samples.
- "Habitat type".

Methodology

The humus classification is in accordance with /Olsson, 1986/ and is accompanied by a thickness measure. The humus types and their thickness are associated with the different habitat types found in the area. This can be done by describing the distribution of humus types among the different habitat types found in the area. A high association (in e.g. percentage) between these variables will allow an extrapolation to the whole area using the habitat types. The different habitat types are thereby assigned a humus layer and a central value with a measure of variation describing the thickness.

Results

- The spatial location of the humus layer classes associated with habitat types and estimates of central values and measure of variation for the humus layer thickness in different habitat types.

Peat

Describes the location of peat in the landscape. Peat is a heterogeneous mixture of more or less decomposed plant material that has accumulated in a water-saturated environment and in the absence of oxygen. It is formed as a result of the accumulation of organic matter, produced and deposited at a greater rate than it is decomposed. Peat is found in present peat lands or mires but is also found deeper down in former peat lands and mires.

Input data

- "Genetic origin and texture".
- "Soil type".

Methodology

The information from the properties "Genetic origin and texture" and "Soil type" are joined into a comprehensive description of the location and thickness of the peat in the area.

Results

- A map that describes the spatial location of the peat.
- A description of the thickness of the peat layer (m) as central values and measure of variation.

Habitat types

Habitat types in the terrestrial environment are defined using distribution and composition of dominant species of the vegetation. Habitat types will be an important means of characterizing the area and will also be an important tool for subdividing the terrestrial system into units that can be assigned different properties.

Input data

- A vegetation map based on satellite data.
- Data from the National Survey of Forest Soils and Vegetation, SLU.
- Forestry management plan ("*Skogsbruksplan*").
- Supplementary fieldwork identifying dominant species in the shrub, field and ground layers for the different habitat types.

Methodology

The resolution of habitat types in an area will be dependent upon the ability to differentiate different habitats using spectral signatures from satellite images. A ground resolution of 20x20 meters can be achieved with the methods of /Boresjö Bronge and Wester, 2002/. The number of habitat types identified will determine the number of categories into which the terrestrial system is divided.

The vegetation map is based on information from the tree layer, where such a layer is present. If it is not present, the spectral signature will be based on the bush, field and ground layers. Consequently, there will also be information on the four vegetation layers, tree, bush, field and ground (see /Boresjö Bronge and Wester, 2002/ for additional information). These four maps result in an overall vegetation map when combined.

Field observations to validate the map have to be made, showing how precise the resulting map is in its description of the landscape. This is also necessary to permit comparisons with future vegetation maps.

Results

- Habitat types.
- A vegetation map describing the spatial location of the identified habitat types in the area.
- Error calculations of the spatial localization of habitat types and accuracy of resulting map.

3.2.2 Primary producers

This entity characterizes the vegetation at the site and includes the tree, bush, field and ground layers. It also includes a contribution from the litter that may be the dominant component of the contribution from the ground layer. The vegetation constitutes a large portion of the living biomass in terrestrial systems and comprises the main primary producers. The change in plant biomass during a time step can be described as:

$$\frac{\Delta B_{plant}}{\Delta t} = NPP - (F_{pl-soil} + F_{herbiv} + F_{emiss} + F_{pl-fire} + F_{harv})$$

Net primary production (NPP) is described under "Primary production" and the flux of biomass to the soil is described under "Litter", whereas herbivory is described under "Consumption" ("Fauna"). Emission of volatile organic compounds to the atmosphere is not taken into account and neither are there any calculations concerning the flux of CNP in case of a fire. The removal of biomass due to harvesting is however calculated under "Forestry" and "Agriculture". Accumulation of CNP in the tree, bush, field and ground layers is described under "Biomass" and "Litter".

Species composition

This is a description of the taxa found at the site, consisting of species lists for various organism groups belonging to the plant kingdom, such as vascular plants, bryophytes, algae, lichens and fungi found in the area. The purpose of this property is to assist in the classification of functional groups, such as tree, bush, field and ground layer species, and the identification of dominant and co-dominant taxa, not to provide a complete list of all species in the area. However, this property will include all available information concerning species found in the area.

Input data

- Available inventories of different organism groups.
- Threatened species list for the area.
- Other available information, such as regional inventories compiled by local societies.
- "habitat types".

Methodology

Make a compilation of all possible records of species found in the area into species lists for vascular plants, bryophytes, algae, lichens and fungi and, if possible, associating these with the habitat types. Identify the dominant species of the bush, field and ground layer associated with the habitat types.

Results

- Species lists for the different organism groups and, if possible, associations with the different habitat types.
- Description of the tree, bush, field and ground layers for the habitat types.

Biomass

Biomass will be divided into dead, green and non-green biomass, and below and above ground. This property will assign a value for each of these classes and for each habitat type found at the specific site.

Input data

- Data covering the tree layer are obtained from the plots of the National Forest Survey that are located within the site.
- Additional fieldwork using the method from the National Forest Survey.
- Forestry management plan ("*Skogsbruksplan*").
- Additional fieldwork calculating standing crop for the bush, field, and ground layers.
- Estimates of how tree and bush biomass can be partitioned into green and non-green biomass.
- "Habitat types".

Methodology

The National Forest Survey calculates the volume of trees for Norway spruce, Scotch pine, contorta, birch, and other deciduous trees in the forest /Marklund, 1988/. This volume can be partitioned into dead, green and non-green biomass /Marklund, 1988/. These figures will be used to estimate the total biomass and the biomass partitioned into dead, green and non-green biomass for each habitat type in the area. The biomass is further transformed into kg CNP m^{-2} using standard conversion tables and extrapolated to the whole site using the habitat types.

Estimates for the tree, bush, field and ground layers are then added together, giving biomass estimates for the whole habitat type. It is desirable to have a number of biomass estimates for each habitat type, to give an indication of the variation between different localities assigned to the same habitat type. If possible, a central value of biomass with a measure of variation should be assigned to each habitat type.

No local information are available today on how crops are distributed on agricultural land at the sites. However, some regional information is available e.g. /Haldorsson, 2000/, see also /Berggren and Kyläkorpi, 2002a/. Comparable biomass figures for agricultural land can be calculated using area estimates (available from LRF or the local vegetation map), distribution of different cereals (from Lantbruksregistret, i.e. /Berggren and Kyläkorpi, 2002a/) and yield estimates from "Skördeuppskattningarna" for different crops /i.e. Berggren and Kyläkorpi, 2002a/. However, standing crop estimates have to be standardized for seasonal production and harvest.

Results

- Each habitat type or vegetation layer class has biomass values for dead, green and non-green biomass in kg CNP m^{-2} with a central value and a measure of variation that is presented as a map covering the site.

Primary production

This property describes the net primary production (NPP) for the different habitat types in the area. NPP is the net carbon gain by vegetation and is a function of gross primary production and carbon released by respiration from above and below ground (roots).

Input data

- Field data from the National Forest Survey and the National Survey of Forest Soils and Vegetation from the specific site.
- Additional fieldwork using the methods from the National Forest Survey and the National Survey of Forest Soils and Vegetation.

Methodology

The National Forest Survey calculates the production of the tree layer /e.g. Berggren and Kyläkorpi, 2002a/. Calculations of the NPP for the bush, field and ground layers are made by using coverage and dominating species for each layer. Production estimates can be found in the literature for the different species. They can also be quantified locally using different methods of harvesting above and below ground to calculate the biomass increase during a vegetation period /e.g. Gower et al, 1997/. The above-ground NPP can also provide an approximation of below ground NPP /e.g. Gower et al, 2001/.

The production of the agricultural land is the same as the standing crop estimates, since these are made on an annual basis. The data on the standing crop in the property "Biomass" covering agricultural areas can therefore be used to estimate the production.

Results

- Each habitat type is assigned a corresponding net primary production figure as kg CNP m^{-2} $year^{-1}$.

Litter

Describes quantities and production of litter, as this comprises an important transfer of CNP from the plants to the soil. Litter is separated into leaves/needles, branches and stem.

Input data

- Description of litter quantities.
- Samples estimating the litterfall, separated into leaves/needles, branches and stem, during a given time period.
- Estimation of the quantities of dead wood.

Methodology

Estimates of litterfall should be recalculated to give annual production of CNP. An estimate of the production of CNP from dead wood is more difficult to obtain because of the low frequency of dying trees. However, a measure of decay status of the encountered dead trees would give a coarse measure of the dynamics.

The litter data should be associated with habitat types giving an estimation of quantity and production of litter as a mean with a measure of variation for each habitat type.

Results

- Litter quantities in kg CNP m^{-2} for the habitat types.
- Litter production in kg CNP m^{-2} $year^{-1}$ for the habitat types.

3.2.3 Fauna

This entity characterizes the fauna at the site that represents most of the secondary production and consumption in terrestrial systems. Decomposition is included in this entity, although fungi are an important detrivore. The most important net allocations of animal biomass come from herbivory and detrivory. The soil fauna participating in decomposition are the important factor that recycles nutrients in the mineralization process. In many ways, the fauna are limited by factors dependent on vegetation conditions, which therefore affect species composition, dominant taxa, production and consumption etc.

Species composition

This is a description of the taxa found at the site, consisting of species lists for different organism groups, such as mammals, amphibians, reptiles and invertebrates. The purpose of this property is to assist in classifying functional groups and building food webs, not to provide a complete list of all species in the area. Information is also provided on abundance and important autecological information gathered, e.g. migration of fauna. Migration of larger animals or extensive migration of smaller animals or birds may be an important source of dispersal of substances accumulated in fauna. For example, hotspots for migrating birds may attract substantial numbers of individuals in the spring and autumn.

This information should also be assigned to the different habitat types, making a spatial localization of important and abundant taxa possible.

Input data

- Available inventories of different organism groups.
- Threatened species list for the area.
- Other available information, such as regional inventories compiled by local societies, hunting statistics etc.
- “Habitat types”.

Methodology

Make a compilation of all possible records of species found in the area into species lists for mammals, amphibians, reptiles and invertebrates.

The most abundant taxa should be identified and classified into the following functional groups:

- large carnivorous vertebrates (e.g. fox, lynx),
- large herbivorous vertebrates (e.g. elk, deer),
- carnivorous small vertebrates (e.g. mink, snake),
- small omnivorous vertebrates (e.g. hedgehog, frog),
- small herbivorous vertebrates (e.g. mouse),
- carnivorous invertebrates,
- omnivorous invertebrates,
- herbivorous invertebrates,
- detrivores in the soil.

Domestic animals

- herbivorous vertebrates (e.g. cow, horse),
- herbivorous invertebrates (e.g. bees).

This classification can be done using information in the literature. Abundance estimates should be gathered for dominant taxa and the taxa should also be associated with different habitat types described under the property “Habitat type”. Abundances are converted into kg CNP m^{-2}. For invertebrates it may be possible to use generic data in lieu of local estimates.

Identify resident migratory species that occur in substantial numbers and locate hotspots for migrating species in the area. Associate the species with habitat types. Estimate the total biomass of the potential migration using estimates of species-specific biomass from literature sources.

Results

- Species lists for the different organism groups.
- Provides the necessary information to build food webs for the terrestrial system and if possible to assign important taxa to "habitat types".
- An estimate of the density of the mammal and bird species as individuals m^{-2} in the area associated with the habitat types and presented in a table with central values and measures of variation.
- A total measure is also provided of all species as kg CNP m^{-2} associated with the different habitat types with central values and measures of variation.
- A map showing migrants as kg CNP m^{-2} y^{-1}.

Biomass

Describes the total biomass of vertebrates and invertebrates at the site.

Input data

- "Species composition".
- "Density of mammals".
- "Animal farming".
- "Habitat types".

Methodology

The information from the property "Species composition" is used to separate the biomasses into the functional groups presented under "Species composition". The biomass is measured in wet weight or dry weight for the dominant taxa and then converted into dry weights of C, N and P using standard conversion constants in the literature. For invertebrates in e.g. soil it may be necessary to use generic data to estimate biomass. These values are, if possible, associated with the habitat types (see "Habitat types" above). If this is not possible, the whole terrestrial system will be assigned a central value with a measure of variation.

Results

- Map describing the total biomass of vertebrates and invertebrates as kg CNP m^{-2} y^{-1} with a central value and a measure of variation for different habitat types.

Consumption

Consumption includes herbivory, predation and decomposition by detrivores, such as invertebrates, fungi and bacteria.

Input data

- “Habitat types”.
- “Species composition”.
- “Secondary production”.
- “Heterotrophic respiration”.

Methodology

Consumption is divided into herbivory, predation and decomposition. The estimates are all a measure of removal of biomass or flux of matter leaving one stage and entering another. The estimates should be presented in kg CNP m^{-2} $year^{-1}$ with a central value and a measure of variation.

Results

- Distribution of herbivory as a central value and a measure of variation, among the habitat types in kg CNP m^{-2} y^{-1}.
- Distribution of predation as a central value and a measure of variation, among the habitat types in kg CNP m^{-2} y^{-1}.
- Distribution of decomposition as a central value and a measure of variation, among the habitat types in kg CNP m^{-2} y^{-1}.
- Distribution of total consumption as a central value and a measure of variation, among the habitat types in kg CNP m^{-2} y^{-1}.

Heterotrophic respiration

This is an estimate of the heterotrophic respiration divided into soil respiration and animal respiration. The soil respiration may be further used as an estimate of the decomposition in the ground surface layer.

Input data

- Estimates of soil/ground respiration.
- “Species composition”.
- “Habitat types”.

Methodology

The estimates of the soil respiration in different habitats or ground layer types make it possible to extrapolate the results to a map covering the area. Extrapolation of animal respiration is possible using knowledge of the habitats in which dominant animal taxa are found.

Result

- Map describing the soil respiration as kg C m^{-2} y^{-1},
- Table describing the respiration of major taxa of the fauna as kg C m^{-2} y^{-1}.
- Map describing the total heterotrophic respiration as kg C m^{-2} y^{-1}.

Secondary production

Describes heterotrophic production as net accumulation of biomass or carbon by the fauna in the terrestrial system. Net heterotrophic production is equal to plant biomass eaten by herbivores (F_{herbiv}) plus the contribution from soil animals eating microbial biomass ($F_{microb\text{-}anim}$) minus losses to animal respiration and fluxes from animals to the soil due to excretion and mortality ($F_{anim\text{-}soil}$). Transfers of carbon within the animal component are often subsumed in the overall carbon budget equations /Chapin et al, 2002/.

$$\frac{\Delta B_{animal}}{\Delta t} = F_{herbiv} + F_{microb-anim} - (R_{anim} + F_{anim-soil})$$

Input data

- “Species composition”.
- “Biomass”.
- “Habitat types”.
- “Consumption”.
- “Heterotrohic respiration”.

Methodology

Data from the property “Biomass”, which is broken down into the functional groups presented under “Species composition”, are used. When the biomass is known for the different functional groups, it is possible to calculate secondary production using conversion factors in the literature. If the resolution of the functional groups allows an assignment of functional group values to the habitat types, this is desirable.

Results

- The secondary production subdivided among the different fluxes and the functional groups in kg CNP m^{-2} y^{-1}.
- The distribution of secondary production, as a central value and a measure of measure of variation, for the habitat types in kg CNP m^{-2} y^{-1}.

3.2.4 Chemical properties

This entity describes chemical properties such as chemical substances, POPs and radionuclides in representative taxa including flora, fauna, humus layer and upper regolith. Some measured quantities, e.g. CNP, are necessary to determine input in biogeochemical pathways while others, e.g. POPs, are important to document as reference data for future surveys. The samples that will be used to quantify flows along biogeochemical pathways have to be sufficiently numerous and adequately distributed to permit association of values with habitats/soil types and thereby allow an extrapolation of these data to the whole area.

Chemical substance

This property describes the concentrations of different chemical substances in the vegetation, fauna, soil type, humus layer and litter layer. The concentrations of certain substances can differ widely depending on the vegetation or the deep groundwater discharge source in the catchment area. This has to be taken into account when planning the sampling strategy.

Input data

- Samples from the vegetation.
- Samples from the fauna.
- Samples from the soil type.
- Samples from the humus layer.
- Samples from the litter layer.
- "Habitat types".

Methodology

The number of sampling points should be large enough to permit association of the values with e.g. habitats/soil types and thereby allow an extrapolation of these data to the whole area. Because of changes in soil type with depth also pH, Eh, total-N and total-C will change accordingly.

Vegetation and fauna

The measured substances are limited to lanthanides and environmental metals and will mainly serve as documentation.

Soil type, humus layer and litter layer

This information should be associated with habitat types, allowing an extrapolation to the whole area. A central value with a measure of variation should be presented for each soil and humus type and the measured substances denoted according to Appendix 2.

Results

- Quantities of the different substances in the different media in the area in the SI units given in Appendix 2. Some of the data may be presented as central values with a measure of variation or as annual fluctuations in data with a high temporal resolution using tables and diagrams.

POPs

This property documents the concentrations of different persistent organic pollutants in representative taxa including vegetation, fauna and humus layer. These samples should be selected using the criteria of potential accumulators or carriers of POPs.

Input data

- Samples from the vegetation.
- Samples from the fauna.
- Samples from the soil type layer.
- Samples from the humus layers.
- Samples from the litter layer.

Methodology

See Appendix 3 for the analyzed POPs and their SI units.

Results

- This list will include most toxins recognized today in SI units as shown in tables in Appendix 3 for the chosen representatives of vegetation, fauna, soil type and humus layer.

Radionuclides

This property describes the concentrations of different radionuclides in representative taxa from vegetation, fauna and humus layers. These samples should be selected using the criteria of potential accumulators or carriers of radionuclides.

Input data

- Samples from the vegetation.
- Samples from the fauna.
- Samples from the soil type layer.
- Samples from the humus layers.
- Samples from the litter layer.

Methodology

See Table 3-3 for the analyzed radionuclides and their SI units.

Results

- A comprehensive description of the quantities as kg m^{-3} for liquid media or kg kg^{-1} dry weight for solid material for the chosen representatives of vegetation, fauna, soil type and humus layer. The data should be presented with a central value and a measure of variation if enough samples are taken.

3.2.5 Humans

This entity includes properties that are directly related to anthropogenic effects on the surface ecosystem today. These activities and their extent are estimated for the present time and are based on the last ten years. For historical aspects see chapter 4.

Human population and settlement areas

This is a description of the human population at the site.

Input data

- Size of the human population.
- Spatial location of villages, buildings, roads etc.
- "Catchment area".

Methodology

The total number of humans living within the area is divided by the surface area in km^2. A map is drawn showing the spatial location of human settlements and the number of people living there (humans m^{-2}) distributed among the different catchment areas covering the whole area.

Results

- Number density of human beings inhabiting the whole area (humans km^{-2}).
- A map showing the spatial location and densities of humans per catchment area as humans km^{-2} .

Human occupation

Here follows a description of the occupation of the resident human population within the site, e.g. the number of persons working as farmers.

Input data

- Human occupation statistics.
- "Human population and settling areas".

Methodology

Different sources may be used to obtain the results. However, it may be difficult to establish exact numbers, and the emphasis should be on determining the occupations practiced within the area, e.g. agriculture, forestry, etc.

Results

- A list of occupations and number of people within each occupational category.

Forestry

This property indicates the removal of biomass due to forestry at the site. This is a difficult calculation that fluctuates from year to year due to economic factors or the stand structure in the area.

Input data

- Information from the Board of Forestry.
- Forestry management plan ("*Skogsbruksplan*").
- "Habitat types".
- Primary producers "Biomass".

Methodology

The timber cutting volume could be assigned to different habitat types in the area using statistics on timber cutting for the last ten years. In this case, it would be appropriate to use statistics for the last ten years covering a larger area than the actual area of interest, due to the long rotation period in timber cutting (~70–100 years). The total area can then be converted into biomass values using the estimated standing crop values in the property "biomass". The final result should be a central value for the last ten years with a measure of variation that is assigned to the different habitat types in question.

This value does not take into account large and sudden effects, due to timber cutting on a catchment area, e.g. increased nitrogen leakage and runoff. It only measures the removal of biomass.

Results

- A central value for the removal of biomass (kg CNP m^3 y^{-1}) from different habitat types with a measure of variation.

Agriculture

This property describes the potential crops that can be cultivated on the site and the actual crops cultivated on the site today. The crops cultivated today depend on the local climate, soil properties and economic factors that make some crops more profitable than others. The importance of the different crops on the site today is calculated based on their biomass production.

Input data

- A list of the different types of crops that can be cultivated in the area.
- Statistics describing the crops grown in the area (e.g. Lantbruksregistret).
- The data on crop production from the property “Primary production” under Primary producers.

Methodology

Production estimates are assigned to the different crops used today and production is calculated as a central value, in kg CNP year^{-1}, with a measure of variation for the last ten years.

Results

- A table with the different crops that are cultivated in the area and their production in kg CNP year^{-1} as a central value with a measure of variation.
- A table with the crops that could potentially be cultivated in the area today.

Water supply

Human water use may have implications for groundwater dynamics, lake levels and river flows, and consequently also for processes of dispersal or accumulation of substances transported by water.

Input data

- Number and spatial location of the wells in the area.
- Water consumption/use from wells.
- Water consumption/use from lakes and rivers.
- Water volume used for irrigation.
- “Catchment areas”.

Methodology

A desirable goal would be to break down the water use from wells, lakes and rivers among the different catchment areas. However, this requires highly specific and spatially differentiated information.

Results

- A map with the spatial location of the wells in the area.
- The total amount abstracted and the consumption of water in the area as $m^3\ y^{-1}$ and if possible also broken down among the different catchment areas.
- The total amount of water that is used for irrigation of farming land as $m^3\ y^{-1}$ and if possible also broken down among the different catchment areas.

Utilized food resources

This property concerns the use of local food resources, such as hunting and berry-picking, and presents species lists for animals, berries and fungi used on the site.

Input data

- Hunting statistics.
- Recreational activities (picking of berries and mushrooms).
- Generic estimates of picking of berries and fungi by humans.
- "Species composition" (Vegetation).

Methodology

The hunting statistics should be based on the last ten years and the total biomass should be presented for each species and as the total biomass, in kg CNP y^{-1}, with a central value and a measure of variation.

Estimates of the total production of berries can be made using field data quantifying the abundance of the species in question in combination with generic data for collection per individual. However, quantifying the biomass removed by humans may be difficult and generic data for Sweden may therefore be used /Eriksson et al, 1979; Kardell and Carlsson, 1982/. It will thereby be possible to create a map, using the habitat types, that shows production/removal of berries as kg CNP $year^{-1}$ in the area.

Fungi are more problematic due to inadequate knowledge of their autecology. There are generic data on the production of edible fungi in forests and also estimates of how much is removed by humans /Eriksson and Kardell, 1987/. It might be possible to assign production and removal figures to the woody habitat types using this data, thereby creating a map that shows production/removal of fungi in the area.

Results

- Species lists derived from hunting statistics.
- Species list of the known edible berries and fungi in the area.
- An estimate of the removal of biomass in kg CNP y^{-1} as an effect of hunting in the area.
- A map showing the production/removal of berries and fungi in kg CNP y^{-1} for the area.

Potential food resources

This property lists the potential food resources available within the site, such as animals, berries and fungi.

Input data

- "Species composition" (Primary producers).
- "Species composition" (Fauna).

Methodology

A table presents the potential species with their estimated biomass (kg CNP) within the area using literature sources of potential food resources.

Results

- A table presents the potential species with their estimated biomass (kg CNP) within the area.

Imports

Describes important anthropogenic sources of external input to the site that may affect biogeochemical flows of CNP.

Input data

- Imports of food.
- Imports of feed.
- Imports of fertilizers to agricultural land and forests.
- Imports of livestock.

Methodology

The four external sources above should be quantified in kg CNP y^{-1}. The quantity of fertilizers can be presented as a map covering the area estimating the input to the habitat type of agricultural land and forests. Food imports can be estimated based on human population data and standard conversion factors for consumption of food.

Results

- Amounts in kg CNP y^{-1} of food, feed and livestock imported to the area.
- A map showing imports of kg CNP y^{-1} to different habitat types in the area.

Exports

Describes four important anthropogenic sources of removal of CNP from the biogeochemical flows on the site.

Input data

- Exports of food.
- Exports of feed.
- Exports of fertilizers.
- Exports of livestock.
- Agricultural production from "Primary production" under Primary producers.

Methodology

These figures should be presented as kg CNP y^{-1} based on ten years and presented as a central value and a measure of variation.

Results

- The four sources above should be quantified in kg CNP y^{-1} in a table with a central value and a measure of variation.
- A map describing the removal of kg CNP y^{-1} from different habitat types in the area.

Mining

Here present mining activities in the area, such as open cast mining, are described.

Input data

- SGU (Swedish geological investigation).

Methodology

The spatial location and type of mining activity is described. Moreover, the spatial extent of the mining operation is also described.

Results

- A map showing the spatial location of the mining activities with additional information concerning the type of mining and its extent.

3.3 The limnic system

This subsystem includes a number of properties that are used to characterize limnic systems with respect to both water budgets and biological properties. Most of the properties described below have been thoroughly described in /Blomqvist et al, 2000, 2001/.

The limnic system comprises standing (lakes and reservoirs) as well as running (rivers and streams) surface waters. Whereas running waters are present in virtually all but the smallest catchments world-wide, lake basins are relatively rare and have usually been formed by some type of natural catastrophe. From a catchment point of view, and over a longer time perspective (e.g. years, decades), the running waters may be characterized as transport routes along which relatively little of the transported material is deposited. Lake basins, on the other hand, can be characterized as sedimentation traps in which particles and biodesirable nutrients (after uptake into biota) in the incoming water are deposited over geological time spans. Due to this sedimentation of particles, the lake basins are gradually filled with sediment. As the basin becomes increasingly shallow, the lake becomes a wetland and a forest or a raised bog. Because of this process, known as lake ontogeny /e.g. Wetzel, 2001/, lake basins may be regarded as ephemeral formations in the landscape. The duration of the lake stage is dependent on e.g. initial basin morphometry, the climate and geology of the surrounding area, and the size, fertility, and vegetation of the catchment area.

Solar energy and nutrients basically originating from weathering of the bedrock and soils of the drainage area constitute the basis for production of biota in lakes and running waters. However, water and gases (e.g. CO_2, N_2) that dissolve into the water during its transport within the hydrological cycle also participate in the production process. Despite the fact that C, H, and O are the macro elements required for the production of all biota, it is usually some element of less abundance in the cell, e.g. P and/or N but also trace elements such as iron, that is depleted first in the water and thereby limits production (the limiting nutrient concept). Primary production may also be limited by the availability of light, both on a daily basis and, particularly at higher latitudes, on a seasonal basis.

3.3.1 Geometry

Basin morphometry affects water volume, spatial distribution, rate of discharge, and water retention time, which are important abiotic characteristics of lake and river basins as they create the preconditions for the geographical delineation of the ecosystems and for their subdivision into smaller constituents (habitats). Due to large fluctuations in runoff both within and between years, both lakes and, in particular, rivers show major fluctuations in water level over time. Maximum water levels are reached in connection with heavy rainfalls and/or snow-melt, whereas minimum water levels are reached after prolonged periods of drought. During severe droughts, small watercourses may dry up completely. The water in lake basins, however, is held by the lake sill, and when this water level is reached no more runoff takes place. Nevertheless, the lake water level may continue to fall due to evaporation from the lake surface and, at least theoretically, lake basins may also dry up completely. The difference in volume and volumetric flow rate between low and high water levels, especially in streams, may be several hundredfold. It is therefore of the utmost importance that sampling programs are designed to take into consideration the fact that the transport of substances is related to rate of discharge and volume of the basin.

Water volume

Quantifies the water volume for the lakes.

Input data

- Lake area.
- Mean lake depth.
- “Digital elevation model”.
- Water level fluctuations.

Methodology

Multiply lake area and mean lake depth /Blomqvist et al, 2000/, taking into account the water level fluctuations, thereby describing the water volume changes during a year.

Results

- The water volume (m^3) in the lake as a central value with a measure of variation (max/min).

Residence time

Estimates the residence time for the water in a lake.

Input data

- "Lake volume".
- Size of the "catchment area".
- Area-specific "runoff".

Methodology

Divide the mean lake volume by the total runoff from the catchment area /Blomqvist et al, 2000/.

Results

- The theoretical residence time (days) for the water in a lake calculated over a year as a central value with a measure of variation.

Running water

The current velocity and volumetric transport of water over a given cross-section of a running watercourse are key properties in most studies of the functioning of running water ecosystems and for calculations of the transport of material from one point to another.

Input data

- Water depth.
- Water velocity.

Methodology

The relationship between water depth and discharge (the rating equation) is established by repeated measurements of the water velocity at different depths. The discharge is calculated using water depths and the rating equation /Blomqvist et al, 2001/.

Results

- Water discharge for each river presented in $m^3\ y^{-1}$ as a central value with a measure of variation between years.

Water balance

This property quantifies recharge and discharge for the aquatic system by dividing recharge into surface water discharge and groundwater discharge to the lake.

Input data

- “Precipitation”.
- “Running water” into the lake.
- Potential evaporation.
- Lake water discharge.
- “Water volume”.

Methodology

The total recharge is calculated by adding together precipitation and recharge of surface water into the lake (by totaling “running water” for watercourses discharging into the lake)

The total loss of lake water is calculated by adding the evaporation to the total lake water discharge.

The discharge of groundwater into the lake is calculated as total recharge less total loss less the change in water volume between t_1 and t_2. If the year-to-year variation in lake water volume is low, this variable can be set to zero. The discharge of groundwater into the lake can also be validated and compared by subtracting the surface water discharge into the lake from the total runoff from the catchment area of the lake.

Results

- The recharge into the lake (m^3/year) as a central value with a measure of variation.
- The total loss of water from the lake (m^3/year) as a central value with a measure of variation.
- The discharge of groundwater into the lake (m^3/year) as a central value with a measure of variation.

The lake/river bed

Describes the type and thickness of surface sediments at the bottom of the specific aquatic system.

Input data

- Bed classification.
- Bed thickness.

Methodology

Bed classification and thickness should be extrapolated to the whole basin. This can be done using the habitat types if they correspond well enough with the characteristics.

Results

- A spatial description of the type and thickness of surface sediments in the lake.

Organic deposits and deposition of matter

This property describes the organic deposits above the bed and quantifies the most important sedimentation processes within the area. The spatial location and amount of deposited matter will be an important factor contributing to an understanding of accumulation processes for radionuclides.

Input data

- Classification of the organic deposit layerA descriptive ecosystem model – a strategy for model development during site investigations.
- Thickness of the organic deposit layer.
- Estimates of deposition of inorganic matter.
- Estimates of deposition of organic matter.
- "Habitat distribution in lakes and rivers".

Methodology

The estimates describing the organic deposit layer should be recalculated to CNP dry weight using standard conversion factors. The estimates should be associated with the different habitats. A measure of deposition of matter will permit calculation of the accumulation rate of the sediments and their organic content. Because this rate is highly dependent on local conditions, it is important to characterize these conditions before using these rates in assessment modelling.

Results

- The biomass in the organic deposit layer in kg CNP m^{-2} for the habitat types.
- The accumulation/suspension rate in m $year^{-1}$ and habitat presented as a map.
- The deposition of organic matter as kg CNP m^{-2} $year^{-1}$ and habitat presented as a map.

Habitat distribution in lakes and rivers

The lake ecosystem can be divided into a number of key habitats, each with a characteristic set of organisms (for a review see e.g. /Wetzel, 2001/). The basin is normally first divided into three key habitats, whereby the open water habitat (the pelagic zone) is distinguished from the habitats at the bottom of the basin and the latter are subdivided into habitats with primary producers present (the littoral zone) and without primary producers (the profundal zone). However, many authors /e.g. Blomqvist et al, 2000; Brydsten et al, 2003/ champion a further subdivision of the littoral habitat into three habitats based on bottom substrate and presence or absence of emergent macrophyte vegetation. In the pelagic zone, production by phytoplankton and heterotrophic bacterioplankton utilizing allochthonous organic carbon originating from the drainage basin constitute the basis for production of higher biota. Consequently, the following five habitats should be distinguished: pelagic habitat, profundal habitat, wind-sheltered littoral habitat, wind-exposed hard-bottom littoral habitat and illuminated soft-bottom littoral habitat /see Blomqvist et al, 2000/.

The ecosystem of running waters is seldom divided into key habitats such as those described for lakes. Instead, a further subdivision is often based on the different zones created by water-level fluctuations /e.g. Blomqvist et al, 2001/. The zone which is always under water, i.e. the main river habitat, is thereby separated from the riparian zone (the area between the lowest and highest water levels).

Input data

- Habitats in lakes and rivers.
- Area distribution of the habitats in lakes and rivers.

Methodology

The total area of each habitat is calculated for each lake or river.

Results

- The total area (m^2) of each habitat type for each lake or river.

3.3.2 Primary producers

The vegetation is composed of the benthic macro- and micro-flora, and phytoplankton, which together constitute the primary production in the lake or river. This entity describes different aspects of the flora in the lake or river.

Species composition

This property consists of the taxa of macro flora and phytoplankton present in the lake or river. This information is valuable for characterizing the lake and understanding the food web in the lake or river.

Input data

- Species/genus list of the phytoplankton for the specific lake or river.
- Species/genus list of the benthic micro-flora for the specific lake or river.
- Species/genus list of the macro-flora for the specific lake or river.
- "Habitat distribution in lakes and rivers".

Methodology

The taxa are classified according to where they are found or are active in the lake or river. If possible, the primary producers should be associated with the five different habitats described under the property "Habitat distribution in lakes and rivers". Otherwise, a benthic and pelagic division may be sufficient. For the purpose of classification, it is desirable that information from the actual sampling occasion is used. However, it may also be possible to use generic information in the literature describing with what habitats the taxa are associated in lieu of lake-specific knowledge.

Results

- Map describing where the major micro- and macroscopic primary producing taxa are found in the aquatic systems on the site.

Biomass

This is a description of the total biomass for all primary producers in the lakes and rivers.

Input data

- Concentration of chlorophyll *a* in the water.
- Samples of the benthic floral biomass in the different habitats.
- Samples of the macro-floral biomass in the different habitats.
- "Habitat distribution in lakes and rivers".

Methodology

The biomass of phytoplankton is calculated based on the concentration of chlorophyll *a* in the water /Blomqvist et al, 2000/ and the macro-flora is sampled directly. The biomass is measured as wet weight or dry weight and then converted into C, N and P using standard conversion factors in the literature. These values are associated with the five different habitats (see habitat diversity above). Each of the five habitats is thereby assigned a central value with a measure of variation describing the biomass, and these values are then extrapolated to the whole lake/river using the property "Habitat distribution in lakes/rivers".

Results

- The distribution of the biomass, as a central value and a measure of variation, among the habitats in each lake or river in kg CNP m^{-2} for the benthic flora and kg CNP m^{-3} for the pelagic flora, presented as a map.

Primary production

Primary production is the conversion of energy by primary producers into CNP compounds that are available to heterotrophs, as well as to the producers themselves. This energy moves through the rest of the ecosystem, providing fuel for life at higher trophic levels.

Input data

- "Biomass".

Alternatively

- Calculations of primary production from C-14 or O_2.
- "Habitat distribution in lakes/rivers".
- Repeated biomass harvest.

Methodology

When the biomass is known, it is possible to calculate the primary production using generic conversion factors in the literature for the phytoplankton, benthic microflora and macro flora, respectively.

Alternatively, direct calculation from C-14 accumulation or O_2 production or biomass accumulation can be used to assign different values of primary production to the different habitats and the phytoplankton, the benthic micro-flora and the macro-flora (see also /Nilsson, 2001/ for a discussion of different methods for calculating bacterial primary production). These latter approaches would yield a site-specific figure for primary production.

Results

- The distribution of primary production, as a central value with a measure of variation, among the habitats and the three functional flora types in each lake or river, in kg CNP m^{-2} y^{-1} or kg CNP m^{-3} y^{-1} for the pelagic habitat.

3.3.3 Fauna

The plant biomass may be either consumed or decomposed. This is mainly taken care of by the faunal heterotrophs in the ecosystem, and these constitute the trophic level above the primary producers.

Species composition

This is a description of the functional aspects of the fauna in the lake and, if possible, also the spatial location of abundant taxa in the aquatic system on the site. This information is valuable for an understanding of the food web and for characterizing the lake or river.

Input data

- Species/genus list of the fauna for the specific lake or river.
- "Habitat distribution in lakes and rivers".

Methodology

The most abundant taxa can be classified into the following functional groups; pelagic grazers, pelagic carnivores, benthic grazers, benthic omnivores, benthic carnivores, filter feeders, detrivores, pelagic/benthic (herbivorous/omnivorous/carnivorous) fish using information in the literature. If possible, the taxa should also be associated with the different habitats described under the property "Habitat distribution in lakes/rivers". Otherwise the benthic and pelagic division may be sufficient. For this purpose of classification, it is desirable that information from local sampling is used. However, it may also be possible to use generic information in the literature in lieu of local knowledge.

Results

- Provide the necessary information to build food webs for the lakes and rivers and assign spatial locations (habitats) for important/dominant taxa.

Biomass

Describes the total biomass of the fauna in the limnic system.

Input data

- Biomass samples of the different functional groups listed under "Species composition" from the different habitats.
- "Habitat distribution in lakes/rivers".

Methodology

The information from the property "Species composition" is used to separate the biomasses into the functional groups vertebrates/fish, carnivores, omnivores, grazers and detrivores. The biomass is measured in wet weight or dry weight and then converted into dry weight for C, N and P using standard conversion factors in the literature. These values are, if possible, associated with the different habitats. Each of the five habitats is thereby assigned a central value with a measure of variation describing the biomass, and these values are then extrapolated to the whole lake or river using the property "Habitat distribution in lakes/rivers".

Results

- The distribution of the biomass, as a central value and a measure of variation, among the functional groups and the habitats in each lake or river in kg CNP m^{-2} for the benthic fauna and kg CNP m^{-3} for the pelagic fauna.

Consumption/respiration/decomposition

Consumption of organic matter and predation, respiration by fauna and decomposition are all important properties affecting the flow and circulation of CNP in the food web.

Input data

- "Species composition".
- "Biomass" (Fauna).
- "Habitat distribution in lakes/rivers".

Methodology

When the biomass is known for the different functional groups, it is possible to calculate consumption, respiration and decomposition using generic conversion factors in the literature. More site-specific calculations will require local measurements of consumption, respiration and decomposition (detrivore consumption) assigned to the different functional groups.

Results

- The distribution of consumption, respiration and decomposition, as a central value and a measure of variation, among the habitats and the four functional groups in each lake or river, in kg CNP m^{-2} y^{-1} or kg CNP m^{-3} y^{-1} for the pelagic habitat.

Secondary production

Describes the total production of the fauna in the lakes and rivers.

Input data

- "Biomass" (fauna).
- "Consumption/respiration/decomposition".
- "Habitat distribution in lakes/rivers".

Methodology

When consumption is known, respiration, feces production and predation are subtracted to give production within the trophic level or for the whole system. Feces production and predation can be calculated using standard conversion factors. Secondary production can also be calculated using different resampling procedures to determine the increase in biomass during a certain time interval. See also /Nilsson, 2001/ for a discussion of different methods used to estimate heterotrophic bacterial production. If the resolution of the functional groups allows an assignment of functional group values to the habitats, this is desirable.

Results

- The distribution of secondary production, as a central value and a measure of variation, among the habitats and the functional groups in each lake or river, in kg CNP m^{-2} y^{-1} or kg CNP m^{-3} y^{-1} for the pelagic habitat.

Mass balance

Total net production, including primary production, can be calculated using chemical data. This provides an independent measure of production and can be used to validate the above-calculated properties concerned with production.

Input data

- ΔO, change in oxygen between t_1 and t_{2v}.
- ΔN, change in total nitrogen between t_1 and t_2.
- ΔP, change in total phosphorus between t_1 and t_2.

Methodology

The changes in soluble oxygen, total nitrogen and total phosphorus will provide an estimate of the net production for the whole lake.

Results

- Total production in kg CNP y^{-1} for the whole lake.

3.3.4 Chemical and physical properties

The structure and function of the lake ecosystem can be determined from a large number of chemical and physical properties. This entity describes some of these abiotic factors in the sediments, deposits and biota of the lakes and rivers. These factors interact with important processes such as primary production and decomposition.

Water chemistry

See Appendix 2.

Chemical substances

Describes the chemistry of surface sediments and organic deposits at the bottom of the specific aquatic system. See Appendix 2 for the chemical substances.

Input data

- Samples from the lake bed.
- Samples from organic deposits (above the bed).
- Samples from the flora.
- Samples from the fauna.
- “Habitat distribution in lakes/rivers”.

Methodology

The bed and organic deposits

This information should be associated with either habitat types or bed classes, allowing an extrapolation to the whole area. A central value with a measure of variation should be presented for each sampled class (see above) and the measured substances listed in Appendix 2.

Flora and fauna

The measured substances are limited to lanthanides and environmental metals and mainly serve as documentation.

Results

- The quantities of the different substances in the different media in the area in the SI units given in Appendix 2. Some of the data may be presented as central values with measures of variation, e.g. CNP content.

POPs

Describes the quantities of persistent organic pollutants in some taxa of flora and fauna in the lake or river. These taxa should be selected from species that are sensitive to or accumulate these substances, e.g. species at higher levels in the food web for bioaccumulating substances.

Input data

- Samples from the lake bed.
- Samples from organic deposits (above the bed).
- Samples from the flora.
- Samples from the fauna.
- “Habitat distribution in lakes/rivers”.

Methodology

Appendix 3 lists the POPs that will be analyzed.

Results

- The quantities of the POPs in Appendix 3 in SI units. The quantities should be presented as a central value and a measure of variation for all taxa and POPs, if possible.

Radionuclides

Describes the quantities of radionuclides in some taxa of flora and fauna in the lake or river. These taxa should be selected from species that are sensitive to or accumulate these substances. Standardized samples are taken regularly by SSI at the Swedish nuclear power stations for a given set of biota that may be used. However, the environmental context is rather different, so it may not be appropriate to use an identical set of reference biota.

Input data

- Samples from the lake bed.
- Samples from organic deposits (above the bed).
- Samples from the flora.
- Samples from the fauna.
- "Habitat distribution in lakes and rivers".

Methodology

The analyzed substances are listed in Table 3-3.

Results

- The quantities of the radionuclides in Table 3-3 as kg m^{-3} for liquid media or kg kg^{-1} dry weight for solid material. The quantities should be presented as a central value and a measure of variation for all taxa and radionuclides, if possible.

Temperature and thermal stratification

The vertical distribution of temperature gives information about the thermal stratification of lakes, which in turn is closely related to a large number of physical, chemical, and biological processes regulating the biogeochemistry of the system. Knowledge of the vertical distribution of temperature and the stratification pattern is fundamental to an understanding of the functioning of the lake ecosystem /Blomqvist et al, 2000/.

Input data

- Measurements of the temperature in a vertical profile in each lake.

Methodology

The depth of the thermocline should be determined by examining the depth series of temperature data /Blomqvist et al, 2000/. Depending on the time interval between measurements, it is possible to describe the seasonal variation of the temperature and the thermal stratification. This should be done using a diagram describing the intra-annual variation and preferably with a measure of variation describing inter-annual variation for each sampling location.

Results

- The intra-annual variation of temperature presented in a diagram with an inter-annual measure of variation for each sampling location.
- Description of the thermal stratification during a year using a diagram.

Light penetration

Measurements of light penetration into the water column can be used to determine the thickness of the photic layer in the lake in which primary production can proceed. It is also the basis for calculation of the average epilimnetic light intensity (the effective light climate), a property of very great importance for an understanding of the variations in productivity among phytoplankton /Blomqvist et al, 2000/.

Input data

- Light penetration depth measured with a PAR (Photosynthetic Activity Radiation) probe.

Methodology

Draw a light penetration curve by plotting the light values against depth.

Calculations of the effective light climate can then be performed according to the following equation:

$$I_{\text{eff}} = \frac{1}{V_z} \sum_{i=0}^{n} I_1 \frac{1 - e^{-k_i \Delta z_i}}{k_i \Delta z_i} V_i$$

where z is the depth of the mixed layer, divided into n intervals, Vz the volume of the mixed layer, zi the upper depth of the depth interval i, ki the attenuation coefficient in the interval i, Δzi the depth of the interval i, and Vi the volume of the interval i. Hence, lake morphometry data and data on the depth of the thermocline are also needed for the calculation.

Results

- The light penetration depth (m) during a year presented graphically with a central value and measures of variation showing intra-annual variation.
- The variation of effective light climate during a year presented in a diagram for each lake.

3.3.5 Humans

This entity describes important effects of human activity on the lake or river ecosystem.

Utilized food resources

A description of the removal of biomass of organisms used for human consumption, such as fish, crustaceans or mollusks, in the aquatic systems on the site.

Input data

- "Species composition".
- Estimate of the biomass removal in the region.

Methodology

A general estimate for the region can be used to calculate the lake- or river-specific removal of biomass in lieu of more lake- or river-specific data.

Results

- A table listing the organisms used as human food today in the lake or river in the area with the removed biomass as kg CNP organism group^{-1} y^{-1} and water system.

Potential food resources

A description of the potential removal of biomass of organisms used for human consumption, such as fish, crustaceans or mollusks, in the aquatic systems on the site.

Input data

- "Species composition".
- "Biomass" of organisms potentially consumed by humans.

Methodology

A general estimate for the region can be used to calculate the lake- or river-specific removal of biomass in lieu of more lake- or river-specific data.

Results

- A table listing organisms of potential use as human food in the lake or river in the area as kg CNP organism group^{-1} y^{-1} and water system.

Water supply

Description of the total consumption of water at the site.

Input data

- Estimate of water removal from the lake or river by human activities.

Methodology

The different sources of removal of water – e.g. irrigation of agricultural land – should be listed and specified with an estimate of water removal on a per-year basis.

Results

- Description of the total amount of water removed from the aquatic systems in the area as m^3 y^{-1}.

3.4 Marine or brackish water systems

This subsystem includes a number of properties that are used to characterize marine or brackish water systems with respect to both water budgets and biological properties. The marine system is not as well delimited in space as the limnic systems, due to the limited portion that is more intensely studied, and it is therefore more difficult to estimate some properties, such as production and biomass. In this respect, the water exchange with the surrounding water masses is of the utmost importance. The marine system has many properties in common with the limnic system.

3.4.1 Geometry

The morphometry of the portion of the total basin located within the area may be important for the theoretical retention time of the water in the local basin and thereby for the transport of water masses to adjacent areas. This is of course true for accumulation processes and potential habitats as well.

Sea level

This is a description of the water level fluctuations in a coastal area.

Input data

- Water level fluctuations from different locations within the area.

Methodology

The water level fluctuations should be determined both within and between years as a central value with a measure of variation.

Results

- Variation within and between years with central values and measures of variation in meters (m).

Water volume

This is a description of the water volume that is included in the marine system.

Input data

- "Altitude and depth data".
- "Sea level".

Methodology

The total volume of sea water is calculated using depth and sea level data. The volume is presented as a central value with a measure of variation.

Results

- The water volume as a central value with a measure of variation in m^3.

Water exchange in the coastal area

In describing the water exchange processes of the coastal zone, those of the deeper open coast and those of the normally shallower and possibly land-locked waters near the mainland should be distinguished. In the open coastal zone, the water circulation is mainly determined by barotropic (sea-level-related) surface waves or baroclinic (density-difference-related) internal waves. The local wind exerts shear friction on the surface that induces vertical mixing leading to deepening of the surface layer /Stigebrandt, 1985/. Horizontal surface currents are also set in motion. Large-scale events such as up- and down-welling generated by Ekman dynamics in adjacent coastal areas normally affect the circulation in a particular section of the coast to a greater extent /Engqvist and Andrejev, 1999/. Such events manifest themselves by entering into a particular coastal section through its boundaries. This external influence may be imposed equivalently onto the interior of the domain as appropriately varying sea level and density profiles along the boundary. If a horizontal resolution that is several times greater than the depth is acceptable, the shallow water approximation is valid /e.g. Gill, 1986/. This allows a simplified formulation of three-dimensional models.

For the land-locked basins, adequate resolution of narrow straits may require a more sophisticated (non-hydrostatic) numerical model. In this case, a more attractive method is to parameterize the strait exchange /Stigebrandt, 1990; Dalziel, 1991/ and use hydraulically coupled discrete basin models to resolve the area /Engqvist, 1997/, but this limits the temporal scale that can be resolved. The straits interconnecting such a partition into discrete sub-basins may have various geometrical characteristics: lengths and depths and the existence/absence of a sill which will influence the exchange /Dalziel, 1992/. Straits connected to basins that receive discharged freshwater, consequently often display a notable estuarine circulation mode. Even with an established estuarine circulation flow regime, the varying density stratification in the offshore waters is often the dominant cause of ventilation of coastal basins /Engqvist and Omstedt, 1992/. The choice of appropriate models to simulate the water exchange depends on both the hypsography and how separate model areas are connected. The input data will be measured locally and some selected local data will also be used in the validation process. The water exchange will primarily be expressed as retention times of exogenous water /Engqvist, 1999/.

Model input data

- Bottom topography (in gridded form with specified resolution).
- Sea level fluctuations at the periphery of the studied area (i.e. the external border to other adjacent water bodies).
- Density fluctuations at the area periphery.
- Freshwater discharge (discrete or diffuse form) to the various discharge locations in the entire area.

- Wind velocity (at standard 10 m).
- Air pressure.
- Humidity.
- Cloudiness.
- Precipitation.
- Insolation.
- Air temperature.

Atmospheric forcing

- Surface temperature and thermal stratification of the water mass.
- Ice formation and melting events.

Methodology

A baroclinic 3D-model, AS3D, /Andrejev and Sokolov,1990, 1997/ will be set up for the offshore areas and run for the specified time period. If sufficient forcing data exist at the area border to open coastal water, these will be used to define the external causation of interior circulation. If sufficient boundary data do not exist, these will be provided by the same 3D-model applied to entire Baltic Sea /Engqvist and Andrejev, 1999/. This large-scale model will be interfaced to the local model along a geometrically simple demarcation line. If the surface temperature is known, the detailed atmospheric forcing data are not needed to compute the heat transaction through the surface. If land-locked areas exist with narrow straits connecting to the 3D-model domain, the forcing of the inshore section will be handled with an additional strait interface between the 3D-model on the external side and a model of hydraulically coupled basins on the interior side /Engqvist, 1997/. All models will compute salinity and temperature profiles, which may be validated against measured data. Sensitivity analysis with regard to variations of the forcing will be performed /Engqvist and Andrejev, 2000/.

Results

- Different retention time figures for the exogenous seawater as a function of depth and location in the coastal area (in days) together with their mean and standard deviation.
- Surface current vector plots from the modeled surface velocity distribution.
- Vertical cross section and surface distribution of salinity in the coastal area.
- Vertical cross section and surface distribution of temperature in the coastal area.
- The fluxes of water volumes entering and exiting the coastal area expressed in [m^3/s].

The sea bed

Describes the type and thickness of surface sediments at the bottom of the marine system.

Input data

- Bed classification .
- Bed thickness.

Methodology

A large number of sampling points have to be merged to give a picture of the whole landscape below water. If bed type and thickness are associated to the habitat types it is possible to use the habitat types for the extrapolation.

Results

- A spatial description of the bed type and thickness of the sediments in the marine system.

Organic deposits and deposition of matter

This property describes the organic deposits above the bed and quantifies the most important sedimentation processes within the area. The spatial location and amount of deposited matter will be an important factor contributing to an understanding of accumulation processes for radionuclides.

Input data

- Classification of the organic deposit layer.
- Thickness of the organic deposit layer.
- Estimates of deposition of inorganic matter.
- Estimates of deposition of organic matter.
- “Habitat distribution in the sea”.

Methodology

The estimates describing the organic deposit layer should be recalculated to CNP dry weight using standard conversion factors. The estimates should be associated with the different habitats. A measure of deposition of matter will permit calculation of the accumulation rate of the sediments and their organic content. Because this rate is highly dependent on local conditions, it is important to characterize these conditions before using these rates in assessment modelling.

Results

- The biomass in the organic deposit layer in kg CNP m^{-2} for the habitat types.
- The accumulation/suspension rate in m $year^{-1}$ and habitat presented as a map.
- The deposition of organic matter as kg CNP m^{-2} $year^{-1}$ and habitat presented as a map.

Habitat distribution in the sea

The three habitats hard bottom, soft bottom and pelagic should be identified and quantified. They should also be divided into belonging to the photic zone or the aphotic zone within the marine system in the area.

Input data

- An inventory of the habitats.
- “Light penetration”.
- “Altitude and depth data”.

Methodology

The habitat distribution is plotted using GIS and the total area of each habitat is calculated within the area. The photic zone, calculated from the light penetration values, as a separate layer would provide a brief description of the habitats that are of importance for primary production.

Results

- A map describing the distribution of the identified habitats within the area.
- The areas of the two bottom habitats (m^2) and the volume of the pelagic habitat (m^3).
- A division of the habitats belonging to the photic zone and the aphotic zone (m^2).

3.4.2 Primary producers

This entity describes the vegetation in the sea. Both macro-flora and plankton are included, which together constitute the primary production in the sea.

Species composition

This property describes the taxa of macro- and micro-flora present in the sea. This information is valuable for characterizing the marine environment and for understanding the food web.

Input data

- Species/genus list of the phytoplankton for the sea.
- Species/genus list of the micro-benthos for the sea.
- Species/genus list of the macro-flora for the sea.
- “Habitat distribution in the sea”.

Methodology

The taxa are classified according to where they are found or are active in the sea. If it is possible the primary producers should be associated with the different habitats described under the property "Habitat distribution in the sea". Otherwise, a benthic and pelagic division may be sufficient. For the purpose of classification it is desirable that information from local sampling is used. However, it may also be possible to use generic information in the literature in lieu of site specific knowledge.

Results

- Map describing where the major micro- and macroscopic primary producing taxa are found in the marine systems in the area.

Biomass

This describes the total biomass for all primary producers.

Input data

- Concentration of chlorophyll *a* in the water.
- Phytoplankton biomass samples for the different habitats.
- Micro-benthos biomass samples for the different habitats.
- Macro-flora biomass samples for the different habitats.
- "Habitat distribution in the sea".

Methodology

The biomass of phytoplankton is calculated using the concentration of chlorophyll *a* in the water and the macro flora is sampled directly. The biomass is measured in wet weight or dry weight and then converted into C, N and P using standard conversion factors in the literature /Kautsky, 1995/. These values are associated with the different habitats found. Each of the five habitats is thereby assigned a central value with a measure of variation describing the biomass and these values are then extrapolated to the whole marine system using the property "Habitat distribution in the sea".

Results

- The distribution of the biomass, as a central value and a measure of variation, among the habitats in the sea in kg CNP m^{-2} y^{-1} for the benthic flora and kg CNP m^{-3} y^{-1} for the pelagic flora presented as a map.

Primary production

Primary production is the conversion of energy by primary producers into CNP compounds that are available to heterotrophs, as well as to the producers themselves. This energy moves through the rest of the ecosystem, providing fuel for life at higher trophic levels.

Input data

- "Biomass".

Alternatively,

- Calculations of primary production from C-14 or O_2.
- "Habitat distribution in the sea".
- Repeated biomass harvest.

Methodology

When the biomass is known it is possible to calculate the primary production using generic conversion factors in the literature /Kautsky, 1995/. Alternatively, direct calculation from C-14 accumulation or O_2 production or biomass accumulation can be used to assign different values of primary production to the different habitats (see also /Nilsson, 2001/ for a discussion of different methods for calculating bacterial primary production). These latter approaches would yield a site-specific figure for primary production.

Results

- The distribution of the primary production, as a central value with a measure of variation, among the habitats and the different plant functional groups in kg CNP m^{-2} y^{-1} or kg CNP m^{-3} y^{-1} for the pelagic habitat.

3.4.3 Fauna

The plant biomass may be either consumed or decomposed. This is mainly by faunal heterotrophs in the ecosystem and these constitute the trophic level above the primary producers.

Species composition

This will describe the functional aspects of the fauna in the sea and if possible also the spatial location of abundant taxa. This information is valuable for an understanding of the food web and for characterizing the marine ecosystem.

Input data

- Species/genus list of the fauna for the marine environment.
- "Habitat distribution in the sea".

Methodology

The most abundant taxa can be classified into the following functional groups; pelagic grazers, pelagic carnivores, benthic grazers, benthic omnivores, benthic carnivores, filter feeders, detrivores, pelagic/benthic (herbivorous/omnivorous/carnivorous) fish using information in the literature /e.g. Kautsky, 1995/. If it is possible the taxa could also be associated with the five different habitats described under the property "Habitat distribution in the sea". Otherwise the benthic and pelagic division may be sufficient. For this purpose of classification it is desirable that information from local sampling is used. However, it may also be possible to use generic information in the literature in lieu of local knowledge.

Results

- Provide the necessary information to build food webs for the sea and if possible to assign spatial locations (habitats) for important taxa.

Biomass

Describes the total biomass of the fauna in the marine system.

Input data

- "Species composition".
- Biomass samples from the different functional groups.
- "Habitat distribution in the sea".

Methodology

The information from the property "Species composition" is used to separate the biomasses into the functional groups vertebrates/fish, carnivores, omnivores, grazers and detrivores. The biomass is measured in wet weight or dry weight and then converted into dry weight for C, N and P using standard conversion factors in the literature. These values are, if possible, associated with the five different habitats (see habitat diversity above). Each of the five habitats is thereby assigned a central value with a measure of variation describing the biomass and these values are then extrapolated to the whole marine system using the property "Habitat distribution in the sea". If association with habitats is not possible, the whole marine system is assigned a central value with a measure of variation describing the biomass.

Results

- The distribution of the biomass, as central value and a measure of variation, among the habitats and the functional groups in the marine system in kg CNP m^{-2} y^{-1} for the benthic fauna and kg CNP m^{-3} y^{-1} for the pelagic fauna.

Consumption/respiration/decomposion

Consumption of organic matter and predation, respiration by fauna and decomposition are all important properties affecting the flow and circulation of CNP in the food web.

Input data

- "Species composition".
- "Biomass" (Fauna).
- "Habitat distribution in the sea".

Methodology

When the biomass is known for the different functional groups it is possible to calculate consumption, respiration and decomposion using generic conversion factors in the literature. More site-specific estimations will require local measurements of consumption, respiration and decomposition (detrivore consumption) assigned to the different functional groups.

Results

- The distribution of consumption, respiration and decomposion, as central value and a measure of variation, among the habitats and the functional groups in kg CNP m^{-2} y^{-1} for the benthic habitats or kg CNP m^{-3} y^{-1} for the pelagic habitat.

Secondary production

Describes the total production of the fauna in the marine system.

Input data

- "Biomass" (fauna).
- "Consumption/respiration/decomposing".
- "Habitat distribution in the sea".s

Methodology

When consumption is known, respiration, feces production and predation are subtracted to give production within the trophic level or for the whole system. Feces production and predation can be calculated using standard conversion factors. Secondary production can also be calculated using different resampling procedures to determine the increase in biomass during a certain time interval. See also /Nilsson, 2001/ for a discussion of different methods used to estimate heterotrophic bacterial production. If the resolution of the functional groups allows an assignment of functional group values to the habitats this is desirable.

Results

- The distribution of secondary production, as central value and a measure of variation, among the habitats and the functional groups in kg CNP m^{-2} y^{-1} for the benthic habitats or kg CNP m^{-3} y^{-1} for the pelagic habitat.

Mass balance

Total net production, including primary production, can be calculated using chemical data. This provides an independent measure of production and can be used to validate the above-calculated properties concerned with production.

Input data

- ΔO, change in oxygen between t_1 and t_2.
- ΔN, change in total nitrogen between t_1 and t_2.
- ΔP, change in total phosphorus between t_1 and t_2.

Methodology

The changes in soluble oxygen, total nitrogen and total phosphorus will provide an estimate of the net production for the marine system.

Results

- The total production in kg CNP y^{-1} for the marine system.

3.4.4 Chemical and physical properties

The structure and function of the marine ecosystem can be determined from a large number of chemical and physical properties. This entity describes some of these abiotic factors in the sediments, deposits and biota of the marine system. These factors interact with important processes such as primary production and decomposition.

Sea water chemistry

See "Chemical properties" under "General physical properties" describing the landscape and Appendix 3.

Chemical substances

Describes the quantities of chemical substances in surface sediments and organic deposits at the bottom of the marine system, and in some taxa of flora and fauna in the sea. These taxa should be selected from species that are sensitive to or accumulate these substances, e.g. species with positions far up in the food web. See Appendix 2 for the chemical substances.

Input data

- Samples from the sea bed.
- Samples from organic deposits.
- Samples from the flora.
- Samples from the fauna.
- "Habitat distribution in the sea".

Methodology

The bed and organic deposits

This information should be associated with either habitats or sediment classes, allowing an extrapolation to the whole area. A central value with a measure of variation should be presented for bed and organic deposit classes (see above) and the measured substances denoted according to Appendix 2.

Flora and fauna

The measured substances are limited to lanthanides and environmental metals and mainly serve as documentation.

Results

- The quantities of the different substances in the different media in the area in the SI-units given in Appendix 2. Some of the data may be presented as central values with measures of variation.

POPs

Describes the quantities of persistent organic pollutants in surface sediments and organic deposits at the bottom of the marine system, and in some taxa of flora and fauna in the sea. These taxa should be selected from species that are sensitive to or accumulate these substances, e.g. species at higher levels in the food web.

Input data

- Samples from the bed.
- Samples from organic deposits.
- Samples from the flora.
- Samples from the fauna.

Methodology

Appendix 3 lists the POPs that will be analyzed.

Results

- The quantities of the POPs in Appendix 3 with SI units. The quantities should be presented as a central value and a measure of variation for all taxa and POPs, if possible.

Radionuclides

Describes the quantities of radionuclides in surface sediments and organic deposits at the bottom of the marine system, and in some taxa of flora and fauna in the sea. These taxa should be selected from species that are sensitive to or accumulate these substances, e.g. species at higher levels in the food web. Standardized samples are taken regularly by SSI at the Swedish nuclear power stations for a given set of biota that may be used.

Input data

- Samples from the bed.
- Samples from organic deposits.
- Samples from the flora.
- Samples from the fauna.

Methodology

The analyzed substances are listed in Table 3-3.

Results

- The quantities of the radionuclides in Table 3-3 as as kg m^{-3} for liquid media or kg kg^{-1} dry weight for solid material. The quantities should be presented as a central value and a measure of variation for all taxa and radionuclides, if possible.

Temperature and thermal stratification

The vertical distribution of temperature gives information about the thermal stratification of the sea and bays. Stratification is closely related to a large number of physical, chemical, and biological processes regulating the metabolism of the system.

Input data

- Measurements of the temperature in a vertical transect in the sea.

Methodology

Depending on the interval between measurements, it is possible to describe the seasonal variation of the temperature and the thermal stratification. This should be done using a diagram describing the intra-annual variation and preferably with a measure of variation describing inter-annual variation for each sampling occasion or on a per-month basis.

Results

- The intra-annual variation of temperature presented in a diagram with an inter-annual measure of variation for each sampling occasion or on a per-month basis.
- Description of the thermal stratification using a diagram.

Light penetration

Measurements of light penetration into the water column can be used to determine the thickness of the pelagic layer in the sea in which large parts of the primary production proceed.

Input data

- Light penetration depth measured with a PAR (Photosynthetic Activity Radiation) probe.

Methodology

See page 71, The Limnic system.

Results

- The light penetration depth (m) during a year presented graphically with a central value and measures of variation showing the inter- and intra-annual variation.

3.4.5 Humans

This entity covers important effects of human activity on the marine ecosystems.

Utilized food resources

A description of the actual removal of biomass of organisms used for human consumption, such as fish, crustaceans, crayfish or molluscs, in the marine system.

Input data

- "Species composition".
- Estimates of biomass removal from the sea.

Methodology

A general estimate for the region may be used to calculate the sea- or bay- specific removal of biomass in lieu of more lake- or river-specific data.

Result

- A table listing the organisms used as human food today in the sea with the removed biomass as kg CNP organism group^{-1} y^{-1}.

Potential food resources

A description of the potential removal of biomass of organisms used for human consumption, such as fish, crustaceans or mollusks, in the marine system.

Input data

- “Species composition”.
- “Biomass” of organisms potentially consumed by humans.

Methodology

A general estimate for the region may be used to calculate the sea- or bay- specific removal of biomass in lieu of more site-specific data.

Results

- A table listing organisms of potential use as human food in the lake or river in the area as kg CNP organism group^{-1} y^{-1}.

Export

One example of a potential export product is seaweed that has long been used as a nutrient additive in farming.

Input data

- “Species composition”.
- “Biomass” of seaweed of current (mainly *Fucus*) and potential interest.

Methodology

Estimate of the use of seaweed as a nutrient additive.

Results

- Biomass removed in kg.
- Potential biomass removed in kg.

Seawater use

Describes potential use of the sea water in the area.

Input data

- Local information.

Methodology

The result should be a list of activities with a description of each activity.

Results

- A list that describes the activities.

4 The historical surface ecosystem

This chapter introduces a number of properties with a historical perspective on the site. They include more long-term changes, such as land uplift, as well as more short-term human-induced effects. If we can understand why the landscape looks like it does today using historical information, we will have a valuable tool for predicting future landscape changes. This perspective also contributes a great deal of information of how the human population may live under different scenarios, for example how intensely the land can be managed during periods of poor conditions.

4.1 Landscape processes

This section describes various processes that act over long periods of time and that are of great importance for an understanding of how the abiotic characteristics of the landscape are formed. An understanding of where hot spots of sedimentation occur is also an important tool for predicting potential radionuclide accumulation in the landscape.

Shore line displacement

This is a description of the isostatic land uplift in the past and in the future. This property does not have to be quantified if the site is located inland.

Input data

- “Altitude and depth data”.
- Locally estimated land uplift.

Methodology

A model is constructed that uses the digital elevation model employing the known land uplift rate corrected by a time-dependent variable /Brydsten, 1999a/. The model should start at the time when the site is beginning to rise above sea level and end when the coast has left the site model area.

Results

- A visualization of shoreline displacement using GIS.

Sedimentation processes in the sea

A sedimentation model can be used to predict the type of regolith of the emerging land, e.g. fine sediments or bare bedrock, but also to correlate the simulations to the present situation to validate, and build comfort, in the selected model. A model /Brydsten, 1999b/ describing the sedimentation process will be used to make these predictions. This will also be an important step in predicting the future landscape using coastline transgression, and in understanding the rate of the succession of lakes into mires and finally terrestrial habitats.

Input data

- Rate of land uplift.
- Depth values in a regular grid (xy matrix).
- Wind speed, duration and direction at the upwind part of the basin.

Methodology

A model based on cartographic information is used to predict the hot spots of sedimentation. This model can be validated using the sediment maps covering the sea of today. See /Brydsten, 1999b/.

Results

- A map describing the location and possible thickness of sediments on the emerging land.

Lake ontogeny

This is a description of how lakes develop and how the succession process turns them into land, based on knowledge from the site.

Input data

- C-14 from samples is used to measure historical sedimentation processes in lakes or mires.
- Core samples from peat bogs.

Methodology

Estimate how fast the different phases of the lake succession proceed using the input data from a sample of lakes at or around the area.

/Brydsten, 2003/ has developed a mathematical model for simulation of lake basin filling processes that can be used to make predictions for the particular area. The output from this model may be validated using the empirical result from above.

Results

- Time estimates of the succession process.

4.2 Humans

Different properties are gathered that describe the human influence in historical time on the site. Some data are only available for the most recent period, whereas reliable older data are available for some of the properties.

Archeological remains

Identification of historical remains in the area may provide important information about human activities in prehistoric time at the site. They can also provide useful data on natural processes, e.g. depth of coverage with drifted sand deposits. Presumably recent effects of shoreline displacement and lake changes can be seen on successive editions of maps for the area.

Input data

- County Heritage Board ("*Länsantikvarieämbetet*").
- Topographical map ("*Topografiska kartan*").
- Economic map ("*Ekonomiska kartan*").
- National Survey Office ("*Lantmäteriet*").
- "Shoreline displacement".

Methodology

All available information should be compiled using GIS. Another approach could be to compile the information from different time periods in different layers, permitting comparisons to be made of changes over time.

Results

- Maps divided into e.g. several 100–500-year periods showing how historical remains have been distributed over the landscape with information on dates and what the remains indicate.

Vegetation and land use

Vegetation and land use are in many ways closely interconnected. However, their interaction may be more or less important depending on where the site is located in Sweden and the type of land use. /Jerling et al, 2001/ have described the development of vegetation in the Forsmark area as a consequence of postglacial land uplift. This property should describe changes in the vegetation with time based on historical information and relate this to land use.

Input data

- Pollen data from sediment cores.
- Cadastral maps from the 17^{th}, 18^{th} and the 19^{th} century ("*Häradskartor*").
- Land division maps ("*Skifteskartor*").
- Black and white aerial photographs from the 1940s.
- Soil map.
- "Habitat types".
- "Shoreline displacement".

Methodology

Changes in the vegetation can be followed using information from old maps. The change in vegetation units, determined by the resolution possible from the old maps, e.g. agricultural land from forest, are followed until recent time. Changes in total areas and the spatial location of the vegetation units can be used to identify and describe the hot spot areas for agricultural activities on the site. It is also possible to define the type of abiotic prerequisites for agricultural activities under different land use intensities.

Results

- Vegetation and soil types that have been used for agricultural purposes.
- How are the habitat types distributed under maximum land use?
- How are the habitat types distributed under minimum land use?

Human population and settlement areas

This is a description of the changes in the human population and the location of human villages and buildings in recent historical time in the area.

Input data

- Church books ("*Kyrkoböcker*").
- Parish books ("*Sockenförtäckningar*").
- Cadastral maps from the 17th, 18th and the 19th century ("*Häradskartor*").
- Land division maps ("*Skifteskartor*").
- Black and white aerial photographs from the 1940s.

Methodology

The number of humans that have been living in the area is described as far back as possible. All buildings are plotted on a map.

Results

- Diagram showing fluctuations in the human population from past to present.
- Map showing the location and uses of all buildings identified during historical time.

Human occupation

This is a description of the occupations and professions that have dominated in the human population in recent historical time using written sources.

Input data

- Church books ("*Kyrkoböcker*").
- Parish books ("*Sockenförtäckningar*").

Methodology

Describe the historical development of the occupations of humans living on the site.

Results

- A reconstruction of human occupations from past to present.

Utilized food resources

This property indicates the quantities of biomass from fishing, hunting and other human food sources.

Input data

- Statistics from SCB (Statistics Sweden) available from 1913.
- Livsmedelsverket.

Methodology

There may be difficulties obtaining site specific-data, but it is possible to use generic data for the region or e.g. the Baltic coast. The data should be converted into kg CNP.

Results

- Diagram showing how fish catches in kg CNP have varied over time, broken down into lakes, rivers and sea.
- Diagram showing how the hunting in kg CNP has varied over time in the area.
- Diagram showing how other food sources in kg CNP have varied over time in the area.

Water level adjustments

This property describes all kinds of water level adjustments made by humans in the area e.g. drainage projects, construction of dams or constructions to facilitate flood control or transportation of timber /see Blomqvist et al, 2000/.

Input data

- Historical data.
- Board of County ("*Länsstyrelsen*").
- Field inventories.

Methodology

A description of the water level regulations in the area.

Results

- The water level regulation history for each lake and river in the area.

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Appendix 1

A method for the calculation of water balance in drainage areas using ArcGis 8 (in Swedish)

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Den andel av nederbörden som är grundvattenbildande antas vara lika stor i alla celler i ett avrinningsområde. Då kan man utgå från den specifika avrinningen och beräkna årsmedelvärdet av flödet i varje cell i undersökningsområdet enligt metoden som beskrivs nedan. Om ett delavrinningsområde (t ex tillrinningsområdet till ett kontaminerat grundvattenutflöde) har ungefär samma markanvändningsfördelning som för det avrinningsområde som är underlag för beräkningen av specifika avrinningen bör flödesberäkningarna vara tillräckligt bra för modellering av radionukliddynamiken. Däremot, om markanvändningsfördelningen i delområdet skiljer sig markant från totala avrinningsområdet blir flödena över- eller underskattade beroende på den dominerande markanvändningen (t ex en extremt hög sjöprocent ger en överskattning då avdunstningen är högre från en sjöyta jämfört med en vegetationsyta).

Om inte ArcObjects Developer Kit är installerat måste det göras först. Programmet finns på ArcGis installations-CD i katalogen ArcObjects Developer Kit.

Starta ArcMap och läs in den aktuella höjdgridden. Om gridden innehåller negativa värden tillverkar du en ny grid med hjälp av Raster Calculator där ett tal adderas till den befintliga gridden som är större än det lägsta negativa värdet. Aktivera extensionen Spatial Analyst under *Tools < Extensions.* Ta fram dialogrutan för Spatial Analyst med *View < Toolbars.* Välj *Spatial Analyst < Raster Calculator* och utför additionen. Gör den nya gridden permanent genom att högerklicka på lagernamnet och välj *Make Permanent.*

Innan *Hydrology Modelling Extension* kan väljas under *Tools < Extensions* krävs att dess DLL registreras. Klicka på *Tools < Customize* och klicka på *Add from file* knappen. Navigera till ArcGis < Arcexe82 < ArcObjects Developer Kit < Samples < Spatial Analyst < Hydrology Modeling och välj esrihydrology_v2.dll, klicka *OK* och bocka för *Hydrology Modeling.*

Vid hydrologisk modellering i ArcGis får inte höjdmodellen innehålla några lokala sänkor, i så fall skulle det där förekomma sjöar. Sänkor i höjdmodeller beror oftast på fel i datat. Naturligt förekommande sänkor i höjdgridder med cellstorlekar större än 10 meter är ovanliga förutom i områden med glaciärer eller karst. Att fylla sänkorna skall därför betraktas som att ta bort oönskade fel i höjdmodellen. Fyll sänkorna upp till respektive tröskelnivå med funktionen *Hydrology < Fill sinks...* och välj att spara den som en permanent grid.

Nästa steg i beräkningsgången är att med hjälp av den fyllda gridden konstruera en grid som visar strömriktningarna för varje cell i gridden. I ArcGis beräknas stupningen (riktningen på den brantaste gradienten) för varje cell utifrån höjdvärdet på cellen och höjdvärdena på på de åtta omgivande cellerna. Det finns därför åtta möjliga utfall och klassificeras i den nya gridden med värdet 1 för norrut, 2 för nordost, 4 för österut (alltid en fördubbling av värdet) och så vidare till 128 för nordväst. Tillverka en flödesriktnings-grid med *Hydrology < Flow Direction* ... och ange att det är den fyllda gridden som utgör indata.

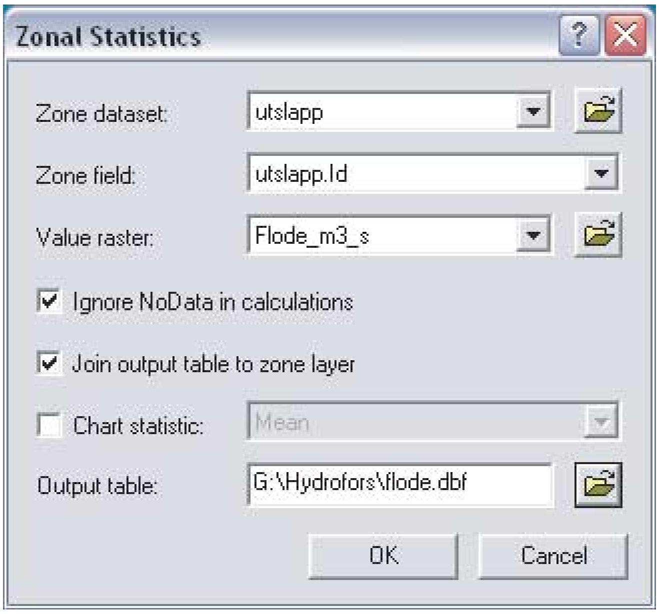
Med hjälp av gridden med flödesriktningar är det möjligt att konstruera en ny gridd som för varje cell anger hur många celler som ligger uppströms den aktuella cellen, det viss säga det accumulerade flödet för varje cell. Höga värden indikerar vattendrag eller utströmningsområden för grundvatten medan 0-värden eller låga värden indikerar lokala topografiska höjder. I ArcGis är det möjligt att ange en gridd som viktar varje cell, t ex hur stor andel av nederbörden som bidrar till grundvattenbildningen som i sin tur har starka samband med den vegetationstyp som dominerar cellen. Viktningen kan också inkorporeras i beräkningen senare med hjälp av *Raster Calculation.*

Det accumulerade flödet beräknas med *Hydrology < Flow Accumulation* ..där gridden för flödesriktningar anges som indata. Den resulterande gridden anger antal celler uppströms där den aktuella cellen inte är medräknad.

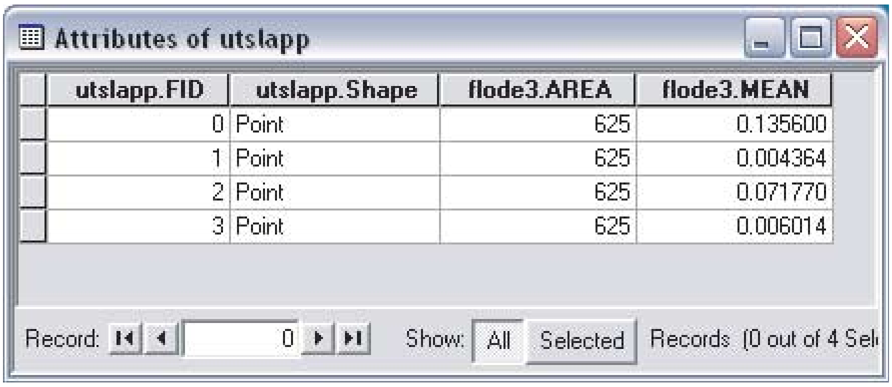
Utifrån gridden med accumulerade flöden är det möjligt att beräkna medelflödet av vatten i varje cell i höjdgridden med hjälp av avrinningsdata eller data för nederbörd och evapotranspiration. Det mest förenklade angreppssättet är att ansätta ett värde för den specifika avrinningen (l s^{-1} km^{-2}) över hela ytan. Gridden för flödesaccumulation multipliceras med cellstorleken i kvadrat och divideras med 1000000 för att ge resultatet i km^{-2}. Denna nya gridd multipliceras med den specifika avrinningen och divideras med 1000 för att resultatet skall få enheten m^3 s^{-1}. Antag att cellstorleken är 25 meter och att den specifika avrinningen är 7,5 l s^{-1} km^{-2} så blir uttrycket i *Raster < Calculator*

*([flowacc] * 25 * 25 / 1000000) * (7.5 / 1000).*

Antag nu att du har utsläppspunkterna i form av ett punktlager i shape-format. Vatten-flödet vid punkterna, i form av ett rent grundvattenutflöde eller ett grundvattenutflöde i ett ytvatten med ett flöde, beräknas med *Spatial Analyst < Zonal Statistics.* Antag att punktlagret med utsläppspunkter är namngivet till *Utslapp* som har ett fält med unika id-nummer som har namnet *Id* och gridden med flöden heter *Flode_m3_s,* så fylls dialogrutan i enligt nedan.



Tabellen till *Utslapp* har följande innehåll efter att *Zonal Statistics* har utförts:


Attributes of utslapp

utslapp.FID	utslapp.Shape	flode3.AREA	flode3.MEAN
0	Point	625	0.135600
1	Point	625	0.004364
2	Point	625	0.071770
3	Point	625	0.006014

där fältet flode3.MEAN är flödet i m^3 s^{-1} genom respektive cell (grundvatten plus eventuellt ytvatten)

En viss förbättring av modellen fås genom att inte anta samma specifika avrinning över hela gridden. Antag att SMHI levererar en digital karta som visar fördelningen av specifik avrinning i form av polygoner med jämna intervall. Kartan rastreras med samma utbredning och upplösning som accumulationsgridden. Det görs i *ArcToolbox < Conversion Tools < Import to Raster < Coverage to Grid*. I *Spatial Analyst < Raster Calculator* beräknas flödet med

*([flowacc] * 25 * 25 / 1000000) * ([specifik] / 1000).*

En ytterligare förbättring av modellen fås genom att transformera SMHI:s polygonskikt till rasterformat av kontinuerlig typ. Om kartan för specifik avrinning är i shape-format konverteras den till coverage-format och väljer att konvertera till linjer. Eventuellt måste du manuellt ansätta värden till det fält som anger specifika avrinningen. Använd linjerna som indata till en TIN med samma utbredning som accumulationsgridden.

Konvertera sedan TIN till en grid med samma utbredning och upplösning som accumulationsgridden. Beräkningen av flödet sker på samma sätt som metoden ovan.

En ytterligare förbättring av beräkningen av flödet förutsätter data rörande nederbördsfördelningen, en vegetationskarta och en parameter (GV) som anger hur stor del av nederbörden som är grundvattenbildande beroende på dominerande vegetationstyp. Till vegetationskartan, som är i vektorformat, länkas GV-parametrarna. Vektorkartan konverteras till en gridd med samma utsträckning och upplösning som accumulationsgridden och värdena i gridden utgörs av GV-parametern. Nederbördskartan konverteras till en kontinuerlig gridd med samma metod som ovan. Medelvärdet över året på grundvattenbildande vatten i enheten m^3 $år^{-1}$ och griddcell beräknas genom att multiplicera nederbördsgridden med GV-gridden och cellarean. Funktionen *Flow Accumulation* körs med flödesriktningsgridden som indata och GV-gridden som vikt och dividera med antalet sekunder per år för att erhålla enhetem m^3 s^{-1}.

Appendix 2

The chemical substances that are sampled to describe the chemical outline of the site.

The chemical substances sampled under general physical properties of the landscape

The chemical elements							
Element	**Distinguished into:**	**Ground-water**	**Fresh water**	**Marine water**	**Precipitation**	**Lower regolith**	**SI-unit**
Dissolved oxygen		?	x	x			mg/l, kg m^{-3}
pH		x	x	x	x	x	pH
Conductivity		x	x	x	x		mS/m
Alkalinity		?	x	x	x		mg/l, kg m^{-3}
Salinity		?		x			‰
Carbon	Total organic carbon, dissolved organic carbon, dissolved inorganic carbon, particulate organic carbon.	DOC	x	x	DOC	x	mg C/l, kg C m^{-3}, kg C m^{-2}
Phosphorous	Total phosphorus, soluble phosphorus, organic phosphorus, particulate organic phosphorus.	PO_4^{3-}	x	x	P_{tot}	x	µg P/l, kg P m^{-3}, kg P m^{-2}
Nitrogen	Total nitrogen, ammonium-nitrogen, nitrite+nitrate nitrogen, nitrite, nitrate, particulate organic nitrogen, organic nitrogen.	x	x	x	NO_3-NNH_4-N	x	µg N/l, kg N m^{-3} kg N m^{-2}
(HS^-)[4]		x	x	x		x	mg/l, kg m^{-3}
SiO_2 (Silicate)			x	x		x	µg/l, kg m^{-3}
Fe-ions	Fe(II), Fe(tot)[4]		x	x	x	x	µg/l, kg m^{-3}
S(tot)		From SO_4^{2-}	x	x		x	mg/l, kg m^{-3}
Cations	Na, K, Ca, Mg, Si, Fe, Mn, Li, Sr.	x	x	x	x	x	mg/l, µg/l kg m^{-3}
Anions	Cl^-, SO_4^-, F^-, Br^-, I^-.	x	x	x	Cl^-, SO_4^{2-}, Br^-	x	mg/l, kg m^{-3}
Lanthanides	Sc, Rb, Y, Zr, I, Sb, Cs, Hf, Tl, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, U, Th.	x	x[1]	x		x	Depending on element
Environmental metals and semi-metals	Al, As, Ba, B, Cd, Co, Cr, Cu, Hg, Mo, Ni, P, Pb, V, Zn.	x	x	x	Al	x	Depending on element

1 Not measured in streams.

The chemical substances sampled in the terrestrial system

Element	**Distinguished into:**	**Vegetation**	**Fauna**	**Upper regolith**	**Humus layer**	**Litter layer**	**SI unit**
pH				x	x	x	pH
Alkalinity				x			mg/l, kg m^{-3}
Carbon	Total organic carbon, dissolved organic carbon, dissolved inorganic carbon, particulate organic carbon.			x	x	x	mg C/l, kg C m^{-3}, kg C m^{-2}
Phosphorous	Total phosphorus, soluble phosphorus, organic phosphorus, particulate organic phosphorus.			x	x	x	µg P/l, kg P m^{-3} kg P m^{-2}
Nitrogen	Total nitrogen, ammonium-nitrogen, nitrite+nitrate nitrogen, nitrite, nitrate, particulate organic nitrogen, organic nitrogen.			x	x	x	µg N/l, kg N m^{-3} kg N m^{-2}
SiO_2 (Silicate)				x			µg/l, kg m^{-3}
Fe-ions	Fe(II), Fe(tot)[4]			x	x		µg/l, kg m^{-3}
Cations	Na, K, Ca, Mg, Si, Fe, Mn, Li, Sr.			x	x		mg/l, µg/l, kg m^{-3}
Anions	Cl^-, SO_4^-, F^-, Br^-, I^-.			x	x		mg/l, kg m^{-3}
Lanthanides	Sc, Rb, Y, Zr, I, Sb, Cs, Hf, Tl, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, U, Th.	x	x	x	x	x	Depending on element
Environmental metals and semi-metals	Al, As, Ba, B, Cd, Co, Cr, Cu, Hg, Mo, Ni, P, Pb, V, Zn.	x	x	x	x	x	Depending on element

The chemical elements sampled in the limnic and marine systems

Element	Distinguished into:	Vegetation	Fauna	Upper regolith	Organic deposits	SI-unit
Dissolved oxygen			x	x		mg/l, kg m^{-3}
pH		x	x	x	x	pH
Konductivity		x	x	x	x	mS/m
Alkalinity			x	x	x	mg/l, kg m^{-3}
Salinity				x		‰
Carbon	Total organic carbon, dissolved organic carbon, dissolved inorganic carbon, particulate organic carbon.	DOC	x	x	DOC	mg C/l, kg C m^{-3}, kg C m^{-2}
Phosphorous	Total phosphorus, soluble phosphorus, organic phosphorus, particulate organic phosphorus.	PO_4^{3-}	x	x	P_{tot}	µg P/l, kg P m^{-3} kg P m^{-2}
Nitrogen	Total nitrogen, ammonium-nitrogen, nitrite+nitrate nitrogen, nitrite, nitrate, particulate organic nitrogen, organic nitrogen.	x	x	x	NO_3-N NH_4-N	µg N/l, kg N m^{-3} kg N m^{-2}
(HS^-)[4]		x	x	x		mg/l, kg m^{-3}
SiO_2 (Silicate)			x	x		µg/l, kg m^{-3}
Fe-ions	Fe(II), Fe(tot)[4]		x	x	x	µg/l, kg m^{-3}
S(tot)		From SO_4^{2-}	x	x		mg/l, kg m^{-3}
Cations	Na, K, Ca, Mg, Si, Fe, Mn, Li, Sr.	x	x	x	x	mg/l, µg/l, kg m^{-3}
Anions	Cl^-, SO_4^-, F^-, Br^-, I^-.	x	x	x	Cl^-, SO_4^{2-}, Br^-	mg/l, kg m^{-3}
Lanthanides	Sc, Rb, Y, Zr, I, Sb, Cs, Hf, Tl, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, U, Th.	x	x[1]	x		Depending on element
Environmental metals and semi-metals	Al, As, Ba, B, Cd, Co, Cr, Cu, Hg, Mo, Ni, P, Pb, V, Zn.	x	x	x	Al	Depending on element

Appendix 3

The organic toxins that are covered by the property of persistent organic pollutants (POPs) under general physical properties of the landscape, the terrestrial system, the limnic system and the marine system

The measured organic toxins

Toxin
Polycykliska aromatiska kolväten (PAH)
Fenantren
Antracen
Fluoranten
Pyren
Benso(a)antracen
Chrysen
Benso(b)fluoranten
Benso(k)fluoranten
Benso(a)pyren
Benso(ghi)perylen
Indeno(cd)pyren
Summa 11 PAH
Hexaklorbensen (HCB)
Polyklorerade bifenyler (PCB)
PCB28
PCB52
PCB101
PCB118
PCB138
PCB153
PCB180
Summa 7 PCB
Total PCB
Hexaklorhexan (HCH)
a-HCH
b-HCH
g-HCH (lindan)
Summa HCH
Klordan
g-klordan
a-klordan
trans- nonaklor
Summa klordan, trans- nonaklor
Diklordifenyltrikloreten (DDT)
p,p-DDT
p,p-DDE
p,p-DDD
Summa DDT
Tot. extrah. org. t klor (EOCl)
Tot. extrah. persistent org. klor (EPOCl)
Tot. extraherbart org. t brom (EOBr)
Tot. extrah. persistent org. brom (EPOBr)