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„Forestry and Areas of Ecological Importance in Norway"

GIS-based documentation on the amount of forest area set a side by certification

By

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Disclaimer

I certify that this thesis, and the research to which it refers, are the product of my own work, and that any ideas or quotations from the work of other people, published or otherwise, are fully acknowledged in accordance with the standard referencing practices of the discipline.

The work has not been presented previously for any degree, nor is it at present under consideration by any other degree awarding body.

Trondheim, 29 July 2008 _____

(Heidrun Miller)

Abstract

Nowadays certification is an important marketing issue for forestry and in Norway the revised version of the national scheme, the Living Forests Standard, has brought a lot of attention to forestry and how it attends to biodiversity and sustainability. One aspect of the Living Forests Standard (LS) is setting aside at least 5 % as Areas of Ecological Importance (AEI) of the productive forest. According to the requirements of the standard logging in these areas is restricted to either no logging or to nurturing intervention.

The Norwegian Forest Owners Association, as a major stake holder for private small-scale forest owners in Norway, assumes that with today's requirements sections of the LS the necessary amount of area is already set aside. In order to prepare statistical data to test this assumption the available geodata on municipality level will be analyzed. The aim is to find out for which requirement sections the actual amount of area set aside can be extracted or created from existing geodata. It is expected to be able to calculate the area for demanded buffer zones to water, mire and cultivated landscape. Additionally, there is a dataset on Administratively protected areas and data on Key habitat appraisals in forests available as geodata.

On the basis of these assumptions it is expected that a new dataset on AEI can be created that is sufficient to document the requirement on area set aside by the LS. A conceptual model will be established based on the analysis of the requirement sections and on the geodata depending on their level of standardization. This model is the approach to generalize the possibility of documenting AEI for other municipalities in Norway

The analysis of the different geodata will first be executed for two test municipalities in different geological and climatic regions. This will take into consideration that the model has to be adaptable in some parameters, which can change in different locations, like local occurrences of special nature types as for example boreal rainforests or rich low land mires. In order to document the assumptions and calculations sufficiently, a workflow model within ArcGIS's ModelBuilder will be implemented which makes all selections and geoprocessing operations repeatable. In addition, the workflow model can then be used to calculate AEI for any other municipality in Norway.

Sammendrag

Levende Skog standarden, som er sertifiseringsgrunnlag i norsk skogbruk, er veldig viktig i den internasjonale markedsføringen for norsk skogbruk. Under revisjonen av Levende Skog standarden har det vært økt fokus på hvordan biodiversiteten i norske skoger skal ivaretas og hvordan bærekraftig skogbruk skal oppnås i Norge. En av hovedendringene i den reviderte standarden er kravet om å sette av minst fem prosent av den produktive skogen som Biologisk Viktige Områder (BVO). I områdene som blir definert i kravpunktene skal det ikke tillates hogst, med unntak av eventuelle inngrep til skjøtselsformal.

Norges Skogeierforbund, som er en av hovedaktørene for norske småskala skogbrukere, hevder at, det allerede blir satt av minst fem prosent Biologisk Viktige Områder fra den produktive skogen med dagens kravpunkter av Levende Skog standarden. For å støtte antagelsen skal eksisterende geodata og kravpunktene i standarden analyseres for å finne ut om datagrunnlaget er tilstrekkelig til å dokumentere Biologisk Viktige Områder på kommunenivå. Det er forventet at det kan dokumenters areal for kravpunkter som verneområder, nøkkelbiotoper, buffersoner mot vann, myr og kulturlandskap.

Det er forventet at et nytt verdifullt datasett for dokumentasjon av BVO kan skapes ut fra eksisterende geodata. Geodataene blir i denne oppgaven beskrevet med tanke på standardiseringen av hvert datasett. Deretter blir en konseptuel modell presentert, som dannes på grunnlag av forholdene mellom kravpunktene i Levende Skog standarden og de mulighetene geodataene tilbyr for å generalisere dokumentasjonen av Biologisk Viktige Områder. En slik generalisering gir videre grunnlag for å kunne gjennomføre lignende dokumentasjon for andre kommuner i Norge.

Analysen blir gjennomført for to testkommuner: Løten i Hedmark og Snåsa i Nord-Trøndelag. De to regionene er ulike i forhold til geografiske forutsetninger, klimatiske forhold og med hensyn på intensiviteten som skog- og landbruk blir drevet. Gjennomføring av analysene i disse områdene vil ta høyde for at modellen må kunne tilpasses forskjellige forutsettinger for noen av geodatasettene og forskjellene i regionale forhold. En workflow modell blir implementert i systemet ModelBuilder i ArcGIS. Dette sørger for tilstrekkelig dokumentasjon på hvordan analysen blir gjennomført, samt at analysen kan gjentas og også utføres for andre kommuner.

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List of Abbreviations

AEI	Areas of Ecological Importance
daa	Decare (typical unit of area in Norway (1 daa=1000 m^2)
DN	Norwegian Directorate for Nature Management
FSC	Forest Stewardship Council
GIS	Geographic Information Systems
KHA	Key habitat appraisal
LS	Living Forests Standard
NFLI	Norwegian Forest and Landscape Institute
NFOA	Norwegian Forest Owners Association
NGOs	Non-Governmental Organisations
OGC	Open Geospatial Consortium
PEFC	Program for the Endorsement of Forest Certification Schemes
SQL	Standard Query Language
WMS	Web Map Service

List of Symbols

Source / Input data

Derived data / Often the result of an operation

Parameters or Values / Input value chosen when executing the model

Tool / Process

Data connector / Connects data with tool and vice versa

Precondition connector / Determines the order of running processes

1. Introduction

In Central and Northern Europe the importance of timber as a carbon dioxide neutral source of both energy and building material has been growing over the past few years. The forestry sector is benefiting from public focus on climate change, environmental protection and sustainability. Given this focus there is also a growing demand for documentation of how forestry manages the environment in their work, particularly in logging operations. This demand is first and foremost coming from the public especially via various non-governmental organisations (NGOs) worldwide.

The Norwegian Living Forests Standard (LS), as a basis for the guarantee of sustainable forest management and certification, was agreed on for the first time in 1998. It was the result of a long negotiation process between several stakeholders with a background in for example the timber processing industry, timber production, environmental and non governmental groups as well as in outdoor recreation associations. Between 2003 and 2006 a revision of the standard was accomplished involving all these interest groups as well (Levende Skog, 2006).

One of the main changes in the revised LS is the demand for documentation that a minimum of 5 % of the forest area is to compromise and set-aside as Areas of Ecological Importance (AEI). These areas are either set aside from all logging operations or forestry coupe is allowed only in order to preserve special habitats and living conditions.

The Norwegian Forest Owner's Association (NFOA) as the main stakeholder for small-scale forest owners in the negotiation of the standard is arguing that today's standard is already setting aside of the requested amount of forest area. Since approximately 80 % of forest area in Norway is in private hands and the average privately owned forest property is between 20 and 100 hectares in area it is hard, or even impossible, to document the amount of area set aside without an extremely expensive evaluation of each property. The Living Forests Standard therefore allows regional documentation for the AEI.

The NFOA assumes that at least 5 % of the forest area treated as Areas of Ecological Importance on a regional level can be documented using already existing data and

results from earlier forest and biodiversity appraisal in each municipality. In order to prepare statistical data to test this assumption of the NFOA, adequate methods for extracting the necessary statistics, required to document the standard's regulations, must be developed. Most data from forest and biodiversity appraisal nowadays is digital geodata and available to the forest owner's organisations. Geographic Information Systems (GIS) can therefore be used to extract, analyse and document areas listed in the Living Forests Standard as Areas of Ecological Importance. Further, GIS can be used to document the parameterisation of the extraction and analysis, making the process of documentation reliable, transparent and repeatable. In addition, local forest owners associations will need to document the area set aside for each municipality where they want to sell timber from and they will need a tool to carry out the documentation without unreasonable cost to their members.

1.1 Objectives

In a pilot project the NFOA encouraged the local forest owner's associations to analyse available data in order to verify their assumptions concerning the amount of area set a side from forestry use in line with the Living Forests Standard's requirements. The results in this thesis show that the available geodata at municipality level is standardized enough and is sufficient to document Areas of Ecological Importance as defined in the standard. In addition, a workflow model is to be established on the same basis to make the analysis of the pilot project transferable to other regions and to allow the same documentation for other municipalities in Norway. The objectives of this thesis are to:

- ➢ Analyse the available geodata on terms of their:
  - o Level of standardization
  - o Available attributes concerning the requirement sections of the Living Forests Standard
  - o Geographical accuracy
  - o Availability for forest owners and
  - o Accessibility of the data with the available software.
- ➢ Establish a conceptual model to extract and create AEI from the existing geodata.
- ➢ Document 5 % AEI based on available geodata in the test municipalities.
- ➢ Implement a workflow model to document AEI for other municipalities in Norway.

The final documentation for each municipality in the pilot project can be amplified by manual editing of geodata or digitizing of additional information on AEI. This produces new data and information that is not available in a standard form. Treatment of such data is not covered in this thesis and these data will only be mentioned when considering including them in the workflow model. To present the results of the Areas of Ecological Importance some calculations will be done using spreadsheeting software. These calculations and the tools used are not covered in the thesis since the focus of this work is on the geodata, the geoprocessing operations and the implemented workflow model.

1.2 Approach

In the LS several requirement sections directly relate to treatment of forest areas as AEI. These include sections on buffer zones towards rivers and brooks and sections on the demand for regional appraisal of special elements of biodiversity and key habitats. Together with standard data from Statens kartverk, the national survey institution in Norway, and Forest inventory data, provided by the municipalities or by the local forest owners associations, it is expected that the areas which the standard refers to can be extracted from the existing data and that the available attributes in these data are sufficient for assessment of AEI. Basic geospatial manipulation methods such as buffer and overlay operations, GIS analyses and attribute assessment will be used in this thesis to extract and evaluate the data. The existing data are also expected to be standardised enough for a workflow model within a GIS to be implemented on the basis of extracted requirements and attributes. The workflow model allows the generalisation of the documentation of AEI for different areas and municipalities in Norway. Graphical programming tools such as ModelBuilder, within the ArcGIS software package, suit the need for both the documentation and the implementation of the workflow model.

To cover local differences in climate, geology and other biological conditions the pilot project areas are located in the municipalities Snåsa, in the middle of Norway, and Løten in the south-eastern part of Norway. For both test projects, data from the FKB-dataset (Felles kartdataBase) provided by the national survey institute, Forest inventory and Key habitat appraisal for forest areas data are available. In addition communal data on wildlife and nature type registrations collected in the Naturbase dataset will be considered according to quality and transferability between the municipalities.

The National Forest Inventory is a Forest inventory on county level in Norway. Sample areas at the size of 250 m^2 are distributed in a grid of three kilometres throughout all counties. In these areas timber resource, forest maturity and some key elements on nature types and key elements for biodiversity are registered. In the two regions the buffer zone areas towards rivers and brooks, key biotope registration, marshland forests and old tree habitats have a range from 7 to 21 % of the forest area (Skog og landskap, 2007). Since the National Forest Inventory is only a statistical estimation based on sample areas and the classification is slightly different than in Forest inventory on municipality level for young aged and low productivity forests a percentage this high is not likely to be reached in the analyses. Nevertheless, it is expected that the assumption of the NFOA of a minimum of 5 % AEI in the test areas can be documented with the GIS analyses and that a workflow model can be developed which can extract and create the data on AEI needed for documentation in other areas.

1.3 Structure

In this thesis an understanding of some aspects of forestry, biological diversity and certification will be necessary to follow assumptions, arguments and judgments made in the process. The introduction and Chapter two focus on explaining the problem and giving the reader without forestry education enough knowledge to understand the problem, the conclusions and the solutions proposed in this work. For the terms, assumptions and solutions presented on geographical information a general understanding of the reader on geographic information sciences and systems is required.

Chapter three contains an overview of the geodata and GIS in Norwegian forestry and the methods available in geospatial analysis. In addition the options and advantages of workflow modelling will be explained, together with the potential of graphical modelling languages.

After this material, the methods used in the thesis will be the focus of Chapter four. First, the requirement sections of the LS that apply to the AEI will be explained. Second, the introduction of the available geodata and assessment of their usability in the documentation will be given. Third, a short introduction on the geographical location and climatic conditions in the project areas will be summed up. Finally the Chapter connects the requirements from the LS, the available geodata and the parameters from

the test areas to develop a conceptual workflow model to calculate AEI. The geospatial analyses methods needed to extract the areas and the processes used to evaluate them are brought together in the conceptual workflow model.

Chapter five takes the assessments of the LS, the geodata and the conceptual model to the implementation. The conceptual model is adjusted at some places to fit the available tools and to fit the data formats used for the implementation of the workflow model. The adjusted conceptual model is then implemented in a workflow model with the help of a graphical model language in ModelBuilder. Tools, data and some workarounds to deal with limitations of software, data or both will be described. Chapter six contains the results of the test projects and a sum up on the implementation.

A discussion of the results and a sensitivity analysis follows in Chapter seven. Conclusions, perspectives and ideas for further work in order to extract and present additional information on AEI is discussed in Chapter eight.

2. Certification

2.1   Global framework

"Wise forest managements therefore have to evaluate forests (…) in a
timely manner and take advantage of them to the fullest
extend, but in a way that future generations can profit from
them to the same degree as the current generation."

"Jede weise Forstdirektion muß daher die Waldungen (…),
ohne Zeitverlust, taxieren lassen, und sie zwar so hoch als
möglich, doch so zu nutzen suchen, daß die Nachkommenschaft
wenigstens ebensoviel Vortheil daraus ziehen kann, als
sich die jetzt lebende Generation zueignet."

(Carlowitz von, 1713)

As the quotation above shows the people have thought about sustainable forest management in Europe since Hans Carl von Carlowitz, son of a German forestry manager, wrote what is thought to be the first book for forestry sciences - Sylvicultura

Oeconomica- in 1713 (Grober, 1999). This book introduces and explains the term sustainable forest management, vital to prevent wood shortage in his century. However, sustainability first achieved global awareness after the Earth Summit conference in Rio de Janeiro in 1992 from which resulted documents such as the Statement of Forest Principles and the United Nations Convention on Biological Diversity.

In the same spirit several groups focused on the need for certification to achieve sustainable forestry. In contrast to the term sustainability introduced by Carlowitz in 1713, the term now encompassed not only avoidance of deforestation but avoidance of decrease in biological diversity as well. With special attention given to tropical areas NGOs mounted some campaigns to get publicity and inform the public about rainforest resource exploitation.

First successful outcome of this attention was the establishment of an umbrella organization for certification. A group of timber users, traders and NGOs from several countries agreed on the need for a global consensus on what good forest management meant. This organisation, "Forest Stewardship Council" (FSC), was developed as the first certification body working mainly in South-America at first (Forest Steward Council, 2008).

In Europe a similar need for certification was agreed on, but the consensus of the FSC, being developed to meet the needs and problems in rainforest regions, was not transferable to the different climatic, geographic and structural conditions in Europe. In addition some small scale forest owners and the timber industry felt that the NGOs dominated the FSC organisation. Within this content the Pan-European Forest Certification was established in 1999. Since then this program has enlarged to become a world-wide organisation as well, and in 2003 they changed their name to the Programme for the Endorsement of Forest Certification schemes (PEFC) (PEFC, 2008).

There is, and has been, a lot of discussion around the quality of both certification schemes over the years. A lot of papers and reports exist comparing the schemes and their associated eco labels. Full coverage of that discussion is beyond the scope of this brief introduction. The following is therefore only a summary; the organisations and the people closely involved in the organisations have different perspectives especially, for example, when discussing biodiversity. In the end though, certification is an agreement with the crucial requirement of providing broader access to the market for the certified

industry parties. To increase market access, that is to expand the certified forest area, to get more publicity, to get access to bigger markets with certified timber products. Some major adjustments to both of these two certification schemes have been made during the past years. Despite remaining different in several areas the requirements of the two schemes have been converging and are nowadays far more difficult to tell apart.

2.2 The Living Forests Standard

Established for the first time in 1998, the Living Forests Standard in Norway is one of the first standards for sustainable forest management in Europe. Stakeholders for different interest groups including the timber processing industry, timber production, environmental NGOs as well as outdoor recreation associations have participated in defining the standard. The standard defines how sustainable forest management should be accomplished in Norway. The main objectives of the standard are to:

- Preserve environmental quality of old-growth natural forest;

- Conserve the diversity of forest ecosystems;

- Provide a basis for the active utilization of forest resources for profitable commercial activities and economic growth;

- Create a green reputation for Norwegian forest-based products on the international market;

- Ensure that those who work in forests have a working environment in which their health and safety are protected;

- Ensure that Norwegian forests provide the basis for varied outdoor recreation where nature can be experienced in all its richness (Levende Skog, 2006).

This standard became the basis of the PEFC certification scheme shortly after it was established. As a result, most local forest owners associations certified as ISO 14 001 compliant with the LS as the environmental basis for the certification. As they therefore committed only to buy and sell certified timber, the forest owner has to follow the LS in order to sell the timber through his local forest owners association. However, the Living Forests Standard does not form a basis for FSC certification. FSC certified at that time

on a forest management[1] units which are divided in lots of very small parcels in Norway. At that time the FSC scheme did not have the capability of certifying small-scale forest owners, as they are the majority in Norway, on a regional level and the NFOA did not think it realistic to certify each forest owner independently. Every forest owner would have had to go through an *individual audit* on the level of the forest management unit to be able to sell timber to an FSC certified organization.

During a revision period from 2003 to 2006, several evaluation reports on the influence of the LS on forest and reports comparing LS to other standards have been written. Comparing LS to an interim Norwegian scheme that was established in order to certify some big industrial forest owners according to the FSC standard in 2001, Savcor Indufor Oy (2005) studied the effect and efficiency of the these schemes on Norwegian forests. The report emphasises that both schemes have enhanced sustainable forest management and that they have put a stronger emphasis on ecological sustainability than on social and economic aspects. The main difference found between the schemes is the requirement of a blanket 5 % set aside area for each forest owner under the FSC based scheme whilst PEFC focuses on AEI on a regional level, independent from parcel structures. Under PEFC single parcels can have an AEI percentage considerably below the 5 % mark given by the FSC. Compared on a regional level though, the report did not find significant difference between the actual amounts of set aside area in the chosen study area. In addition the report points out that the PEFC certification scheme was successful in enhancing sustainable forest management in applicable extent since the support from the local forest owners associations forced a large number of forest owners to manage their forests to conform to the LS while the FSC certification was mostly obtained by only a few single large forest industry owners where the single audit costs involved were irrelevant.

Another report Arnesen et al (2004) focusing mainly on the processes around the project that led to the Living Forests Standard in 1998 concluded that the process was too disorganized and that in some stages of the discussion the objectives with the standard were not clearly defined. However, the parties where motivated to seek a common consensus, and all parties made large efforts when the process temporarily stalled. Some of the conclusions of the report were that NGOs should be more involved on an

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[1] Forest management unit usually is one property consisting of at least one or more parcels

administrative level during the revision period and that to facilitate communication after the revision a permanent council should be set up.

The revised standard was agreed in October 2006, and a permanent institution, the Living Forests Council, was formed consisting of one member from each group involved in the revision. The Council is implemented as an instrument to communicate and to foster trust among the stakeholders. In addition, today's LS consists of requirement sections, which focus mainly on the environment, harvesting methods and regeneration, herbicide and waste management, working conditions for forest workers and a pledge to maintain outdoor recreational value (Levende Skog, 2006).

In today's Living Forests Standard there is still more focus on the environmental aspects compared to social and economic aspects, as pointed SAVCOR INDUFOR OY's report from the revision period. Despite the lack of a blanket percentage of set-aside forestry area before the revision, several requirement sections define Areas of Ecological Importance as areas free from harvesting and forest coupe. These are, specifically the requirements on (I) Key habitat appraisal (II) Forests protected in Nature reserves and forests protected in National parks pursuant to the national Nature Conservation Act (III) Natural old growth and mature forests (IV) Pasture woodland (V) Sump and bog forests (VI) Costal spruce forests (VII) Broadleaved temperate forests (VIII) Buffer zones to rivers and brooks (IX) Buffer zone to agricultural landscape (X) Buffer zone to marshes and mire (XI) Economically unproductive forest bordering on key habitats and other AEI in productive forests (Levende Skog, 2006).

Currently, there are insufficient data available on how much forest area these requirements sections of the Living Forest Standard actually refer to, and what corresponding financial losses the private forest owners certified by the standard have to compensate for. The National Forest Inventory can give an approximate area of AEI according to specific set of requirements at county level. The test projects are part of the counties Hedmark and Nord-Trøndelag and the numbers given for these by the National Forest Inventory vary between 7 and 23 % for the productive forest area (Levende Skog, 2006). These numbers satisfy neither the NGOs nor the NFOA, nor the local forest owners associations, since the requirement sections are not matching well with the methods of the National Forest Inventory. It is therefore the objective of this thesis to provide more detail documentation on AEI on municipality level

3. Additional benefits of using GIS

3.1   Geodata Infrastructure in Norway

The national Geodata Infrastructure (GDI) in Norway has two basic elements. One is the national standard for the exchange of geodata called SOSI (Samordnet Opplegg for Stedfestet Informasjon), which was introduced for the first time in Norway in 1987. It is developed mostly as an exchange format between GIS or a basic geodata storage format. The standard is permanently reviewed and enhanced. The latest version SOSI 4.0, introduced in 2007, appears to be converging towards the ISO/TC 211 standard, but to reach conformance between these two standards more adjustments will have to be made in the future (Statens kartverk – SOSI, 2008).

The second important element is the GEOVEKST agreement, a nation-wide program for co-operation on collecting and managing digital geographic data in Norway. "The basic concept is pooling of funding into jointly-executed projects for collecting, improving, maintaining and administrating large scale digital geographic data" (Høstmark, 2002). The Norwegian Mapping Authority is the key party in the agreement, in which local authorities, the ministry of agriculture, the road department and electrical and telecommunication companies also participate. GEOVEKST is already the second agreement in the GDI, the previous one, AREALIS, only gave access to public institutions, while other interest groups can now get access to data collected under the GEOVEKST agreement. The GEOVEKST program is reviewed continuously and guidelines, documents and manuals for the production of geodata are updated and developed. The modification of the SOSI standard for data within the GEOVEKST agreement is revised in close cooperation with the updates of the GEOVEKST agreement (GEOVEKST veiledingsdokumentasjon, 2006).

The datasets covered by the agreement is very versatile. Mainly they are so called FKB-data, which are large scale datasets defined in their own section of the SOSI standard. FKB-data include everything from Cadastral data and full Land cover dataset to Water and Elevation data. In addition GEOVEKST includes a smaller- scale dataset at municipality level. Old topological raster data are included and the GEOVEKST

agreement also contains orthophoto series (GEOVEKST veiledingsdokumentasjon, 2006).

GEOVEKST covers pricing guidance and it defines data vendors (GEOVEKST veiledingsdokumentasjon, 2006). Important within the GEOVEKST agreement for the small-scale forest owners is that it states that landlords own all rights to use the geodata concerning their properties. This also means that they can put data from GEOVEKST in the hands of a third party, like the forest owners associations, which can establish their offers and products for the forest owners based on these geodata without having to pay for them (GEOVEKST veiledingsdokumentasjon, 2006).

3.2   GIS in forestry

Forestry in Norway has been using Geographic Information Systems since the late 1980's mainly in proprietary systems and those developed specially for forestry needs. Data capture at this time was mainly done by appraisal in the field and digitalizing of captured data in the office. Until the late 1990's nearly all data collected were directly connected to forest stands, to timber inventory and to forestry roads for timber transport. The data from the inventory was almost exclusively used for the preparation of analogue forestry management plans for forest owners. None of the collected data was systemised or organised following a standard in order to update with information on logging or other forestry measure.

Due to the increased interest in sustainability towards biodiversity as well as to the interest on timber related information in the forests, the Forest inventory changed and started collecting environmental key elements and biotopes together with the forestry related data in the appraisal. This extension to the data collected in Forest inventory increases the amount of data considerably. In addition in the late 1990's data capturing for forests started using photogrammetrical tools, which increased the effectiveness of inventoried area and amount of data was growing. Not only the amount of covered area but the amount of disk space and the amount of valuable attributes as well. However, the typical use of the collected data did not change yet. Even though forest management plans and maps give a lot of valuable information to forest owners and municipalities, the data, once collected are not analysed further and are hard to update with current situation. This is mainly because of insufficient data management systems, which

cannot communicate with each other so spatial data, attributes, calculated attributes and data for visualizing in maps are kept in different systems (Anker et al, 2002). This report from SINTEF (Anker et al, 2002), the largest independent research organisation in Scandinavia, points out the number of different tools as a key weakness of the forestry GI systems. It reports to that most forestry appraisal organisations intend to invest in a new tool to solve a problem without checking communication between systems and instead of investing in improving the systems already in use.

The SOSI standard also defines a set of rules for Forest inventory data, which could be used to convert the data between the different GIS tools. This could have been a powerful solution for the communication problems between the systems, but there turned out to be only very limited possibilities to extend pre-existing, often heavily locally customized software with the necessary interfaces for converting from the different software to the Norwegian standard format. SOSI data produced in these systems is often insufficient with many mistakes and with risk of information loss in the converting processes (Anker et al, 2002). Figure 1 shows how SOSI data are provided in many GIS used in forestry. GIS tool 1 is not communicating with GIS tool 2 but GIS tool 2 can read SOSI data with out mistake, presented by a continuous line. Writing SOSI data with GIS tool 2 in contrast is only possible with information loss, indicated by the dashed line. GIS tool 1 is reading SOSI data directly but in order to prepare SOSI data additional software had to be implemented. That additional software, Conversation software tool 3, writes SOSI data without information loss but the pre-existing GIS tool 1 gives limited opportunity to add an extension that can write its data to Conversation software tool 3.
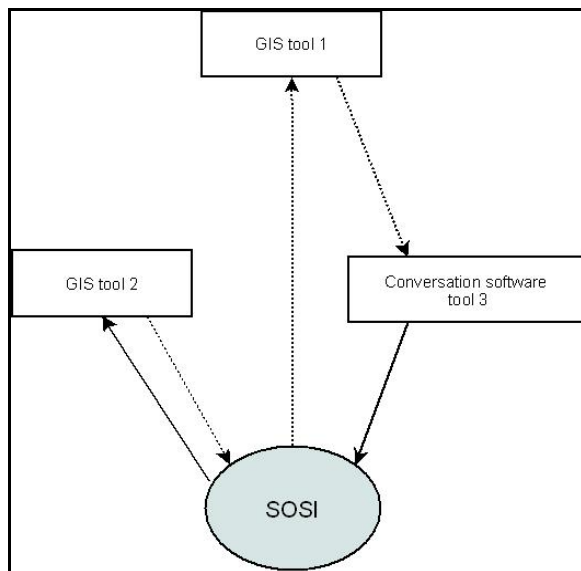
Figure 1: Communication between GIS and conversation tools in use and SOSI format (Source: Anker et al, 2002- modified)

Nevertheless, there is a pool of valuable data stored and waiting to be further analysed within Geographic Information Systems. For example, there have been analyses in Nord-Trøndelag county on mature forest sites in steep terrain on the efficient use of cable way logging. These were very useful to planning authorities, forestry and cable way companies. There is no doubt that even with the problem of incompletely standardized forestry data there is additional value in the Forest inventory data, which can be used to extract and create more information for specific purposes from the large amount of stored data. The workflow model for calculating Areas of Ecological Importance developed in this thesis is such an analysis in which, through a set of different spatial data manipulation and geodata analyses, a whole new set of valuable data will be created, not only relevant for forestry and certification issues, but showing the further potential and possibilities of the data and of the analysis tools.

3.3 Geodata analysis and spatial data manipulation

How to best represent a part of the real world in a data model within a GIS depends first and foremost on a decision regarding what is to be presented or analysed. Two fundamental ways to catch and store the demanded information should be considered when planning a representation as geographic data.

Use of the continuous field view is common and advisable for surfaces, which have an attribute that changes its value continuously across the surface. In this representation a

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finite number of variables have values for every possible position at the surface. This data view shows the value and with that the variation of a single attribute throughout the surface, creating a more or less smooth transition between the measured and stored positions. Continuous field view is most often represented by raster data. Raster data present the measured values of the attribute mostly in rectangular array of pixels. Raster analysis tools offer tremendous possibilities for analysing trends in the data. There are also many possibilities to combine the single attributes from each raster layer with other raster layers (Longley et al, 2005).

Discrete object data view is, for many people, quite a natural way to present part of the real world. "The discrete object view represents the geographic world as objects with well-defined boundaries in otherwise empty space" (Longley et al 2005, p.71). The subject of interest is picked out of the real world and its properties can be described by attributes connected to each object. This view is very often presented as vector data in a GIS where the different objects can be stored as point (0-dimentional), line (1-dimentional) and polygon (2-dimentional) type features. The best dimension to chose depends on the scale of entry and the scale of visualisation as much as the expected use of the data, like the purpose of the analysis. The discrete data view representing objects, especially polygons with a sharp border determining what is part of the object and what is not can have drawbacks. The covered area enclosed by the object boundary is represented as being the same for the whole area of the object and it stops suddenly at the border line. This characteristic on one hand makes this data view less applicable for natural conditions, which do not change suddenly but are more smoothly dispersed over a region (Longley et al, 2005). However, the ability to adapt various attributes to the object, not only makes up for the problems described above, but makes this data view a very strong foundation of geodata representation. All datasets used in this thesis are discrete object representations and following chapters do not consider raster representations.

3.3.1 Geodata analysis

With the help of the connected attributes the user can interrogate the geodata within a GIS in various ways, either on a single attribute field or using enhanced combinations and conditions. The simplest way to do this is manually by sorting and searching in the attribute table or by clicking in a map view on the object in question. For more

complicated attribute analysis in many GIS the Standard Query Language (SQL) can be used for this kind of analysis. SQL can not only be used for interrogation but to create, alter and delete relational database structures as well. Since the ISO/IEC 9075 version of the ISO standard that covers SQL, geographic capabilities are included in this query language (Longley et al, 2005).

The Simple Feature Access Specifications of the Open Geospatial Consortium (OGC) specifies nine different ways to test spatial relationships between two geometries using Boolean operators (Open Geospatial Consortium Inc., 2005). Testing means here that the spatial relationship is queried only returning true or false as a result of the operation. Possible spatial relationship queries are: (I) Equals – if the geometries are spatially equal (II) Disjoint – if the geometries do not share any spatially common point (III) Intersect – if the geometries spatially intersect (IV) Touch – if the geometries spatially touch, but do not cross (V) Crosses – if geometries spatially cross each other at any point (VI) Within – if a geometry lies spatially within another geometry (VII) Contains – if a geometry spatially contains an other geometry (VIII) Overlaps – if geometries of the same dimension overlap each other spatially and (IX) Relate – tests if there is any spatial relationship but does not test what kind it may be (Smith et al, 2007). These relationship queries are used select existing geometries from a layer that relate to other geometries in the same or in another layer. The geometries returned in the result have the same shape as the original and no new geometries are created. This is why these operations are often referred to as "Select by location" operations.

There are other SQL syntaxes for spatial operators that do not only return true or false but new geometries as a result. Examples are like Distance, Buffer, Convex Hull and some overlay operations (Smith et al, 2007). The list of available operators depends on the database in use, as not all databases and not all GIS implement all SQL syntaxes.

3.3.2 Spatial analysis and transformation

"Spatial analysis is in many ways the crux of GIS because it includes all of the transformations, manipulations and methods that can be applied to geographic data to add value to them […] – in other words, spatial analysis is the process by which we turn raw data into useful information" (Longley et al 2005, p.316).

In the section above, the direct interrogation possibilities using attributes and spatial Boolean operators were discussed. In this section the focus is on transformation and overlay operations. The most common and important transformation available to GIS users is the buffer operation (Longley et al, 2005). Buffering is the process of creating one or more border zones around selected features, within a pre-specified width. In most GIS this operation is implemented as Euclidean distance from the features, but there are variations between the implementations among the different Geographic Information Systems. Mostly, point, line and polygon features can be buffered producing a polygon feature as result. Differences occur considering whether the buffer zone can be negative and concerning whether the result must be symmetrical or can create asymmetrical buffers zones for the features. Some systems give the option to choose only right- or left-sided buffering of lines and polygons. Most implementations do give the user options if the resulting polygons are to be merged together ("Dissolve") in the case of overlap so no area is covered by several features or if the result data has to be containing one polygon for each feature independent of any overlap that might occur (Smith et al, 2007).

"[…] the most important feature of any GIS is its ability to combine spatial datasets, to produce new maps that incorporate information from a diversity of sources. Generically, this process has been given the name *map overlay*" (O'Sullivan & Unwin 2003, p.285).

"One of the most basic of operations is that of determining whether a given point lies inside a polygon. […] Related problems include line in polygon and polygon in polygon tests. […] The standard algorithm for determining point in polygon in a vector model is to extend line vertically upwards and then count the number of times this line crosses the polygon boundary. If the line crosses the boundary an odd number of times it lies inside the polygon" (Smith et al 2007, p.85). Further in map overlay, sometimes called topological overlay, one layer A is placed on the top of another layer B and a layer C is created according to the choices supported by the GIS in use. Normally in vector GIS layer A would be of point, line or polygon dimension while layer B in most cases is a polygon layer. Even basically being directly related to the point in polygon algorithm the polygon overlay has been one of the greatest barriers to the development of vector GIS" (Smith et al 2007, p.89).

"From the discrete object perspective, the task is to determine whether two area objects overlay, to determine the area of overlap and to define the area formed by the overlay as one or more new area objects" (Longley et al 2005, p.331).

"Polygon-on-Polygon overlay, which is a relatively common procedure, frequently creates very small thin polygons known as *slivers*. These may be a genuine result or more often they are artefacts, created as a result of differences in the original data" (Smith et al 2007, p 91). Slivers are one of the reasons why overlay operations were hard to implement in early GIS since their number increases dramatically the more precise the vector data is. One way of dealing with this is the setting of a tolerance level for the overlay operation. The operation than treats points and vertices identical provided they lie within the specified tolerance of each other. In other solutions, slivers have to be treated in post-processing operations in order make the results visualized presentable.

As mentioned above results in layer C can include not only different geometries but also different attributes from the source layers. Focusing on polygon overlay the following operations are the most important and can generally be found in GIS:

- "Clip": The resulting layer C contains geometries where layer A is covered by input layer B. Geometries that are partially covered by layer B are cut and only the part that is covered by layer B is passed on to the result layer C. Only the attributes from input layer A are passed on to result layer C;

- "Intersect": The resulting layer C includes all geometries and attributes from both source layers A and B where both layers overlap;

- "Union": Includes geometries and attributes from all source layers including areas which don't overlap. All attributes are retained and the attributes can be tracked whether geometries were part of source layer A or B or both;

- "Not/Erase": This operation can be understood as the opposite of the "Clip" operation. The result layer C contains geometries and attributes from source layer A that are not covered by geometries in source layer B

- "Exclusive/XOR": Implementations of this operation can be understood as the opposite of the "Intersect" overlay. The resulting layer C contains geometries and attributes that are covered by either source layer A or B but not by both.

This short list by no means covers all possible and implemented overlay operations within different GIS, but the use of different naming conventions and differences in implementation makes an exhaustive list inappropriate here.

The slivers problem mentioned earlier is not the only difficulty in map overlay operations. Whilst the slivers are mostly a technical problem making the overlay processes more difficult and more time consuming for large datasets, there are several other aspects which must be considered and which the GIS user must be aware of when interpreting the results.

Determining the input source layer has to be thought through very thorough. Two main approaches are to be found in literature. There are: either a knowledge-driven approach, which includes expert appraisal in the field to prepare the data for the map overlay; or a data-driven approach, wherein criteria are defined on the basis of data availability. Especially in the data-driven approach used in the thesis, the different layers should be checked to ascertain how well they can be combined and what to expect from the result (O'Sullivan & Unwin, 2003). One way of checking is trying to find information about the dataset for original purpose of registration or digitizing, registration scale, accuracy and contractor. A dataset with a scale of 1:5 000 can be overlaid with data digitized with a 1:50 000 scale, but the result will not be meaningful when represented in a 1:5 000 scale afterwards. GIS users have to be most careful when using data that have been generated from such different source layers in further overlay operations. In addition, the attributes stored with the geometries in a source layer can often be classified or stored as an average for the original geometry. Even recalculating with the new area of a split geometry in the resulting layer does not make these attribute accurate.

Map overlay is always not only a technical question of combining source layers to new and better fitted geometries but a more difficult matter of data quality assumptions and uncertainty as well.

3.3.3 Uncertainty

"In GIS, the term uncertainty has come to be used as the catch-all term to describe situations in which the digital representation is simply incomplete, and as a measure of the general quality of the representation" (Longley et al 2005, p.128)". In the next to sections a short explanation of uncertainty in terms of *geographical vagueness* of the

representation in a GIS and *ambiguity*, which implies uncertainty in attributes, linked to geometries is given (Longley et al, 2005). Other aspects of uncertainty also implied as data quality such as geographical accuracy, logical consistency and completeness of the data is only discussed when examining the datasets used in this thesis.

A lot of the attributes that are attached to geographical objects are based on some kind of classification. These classes are already *not without ambiguity* even before they are assigned to any phenomena because the taxonomy itself does not determine concrete classes and two people can easily sort the same phenomena into two different classes even though both people may be experts in that field (Longley et al, 2005).

Vagueness describes the fact that a phenomenon might not be represented very well if it is for example modelled in a discrete object view within a GIS. A lot of phenomena are not very well presented by a point, line or a polygon with a clear and sharp border (q.v. 3.3). Nevertheless, in order to simplify the world and to attempt to capture the most important characteristics for a particular purpose many phenomena are best modelled in a discrete object view (Longley et al, 2005). An attempt to model phenomena that are very vague in the discrete object representation is to use the *fuzzy logic* approach

In this representation the objects are not completely inside or outside of a class but they can be assigned to classes according to a probabilistic interpretation which would normally peak at a maximum likelihood value and abate more and more with distance from that (Longley et al, 2005). This seems very intuitive at first but there are several difficulties, which limit the usefulness of the approach. To be able to make comparable analyses and statements the layers would have to be brought together using, for example, map overlay operations. This was studied in detail by Zhan and Lin (2003) *"Overlay of two simple polygons with indeterminate boundaries"*. In this paper the author studies map overlay with two simple fuzzy objects. A high amount of over 1000 possible topological configurations of the resultant area implies that map overlay with fuzzy objects is not a simple matter and is not easily done for a large amount of polygons (Zhan & Lin, 2003). Another problem, besides the amount of possible topological configurations shown by Zhan, is the fact that objects represented in a fuzzy representations do not become less uncertain. The different probabilistic regions can be divided differently by another expert. The difference of fuzzy logic is that it is easier to visualize and raise awareness of the fact of uncertainty in the representation.

3.4 Workflow models

"Flowcharts are used for the visualization of models and analysis processes in a wide range of applications. Normally this kind of graphic representation is simply focused on the illustration of the model structure and information flow but doesn't directly control underlying processes" (Netherer el al 2002, p.1).

This is often a problem, since the expert with special knowledge of a certain subject has to trust on that her or his thoughts and knowledge can be transferred into the actual analyses or models. "The translation of the flowcharts into a software executable code is, for the user, an irrelevant, yet especially error-prone, process" (Riedl & Kalasek 1998, p.2 (translated)). In order to reduce this source of error, and to open the capabilities of expert systems up to a broader range of users, several flowchart inspired programming languages have been developed commercially, such as the ERDAS IMAGINE software (Maguire D et al, 2005).

In 1998 MapModels was introduced at the AGIT Symposium in Salzburg. In MapModels the analysis processes, the input data and the applied functions are linked together in a flowchart-like programming environment. In theory this was a directed acyclic graph with nodes representing the functions to be applied to the data and the graph edges representing the data and the flow direction. It was implemented as an extension to the, at the time common, commercial GIS ArcView 3.0. Figure 2 shows a simple model represented in MapModels and as ArcView-Avenue-Code. The advantages of the flowchart-like programming are (Riedl & Kalasek, 1998):

➢ The syntax and the flow of the analysis are easy understood.

➢ Even for more complex models the flow will be intuitive.

➢ Methodical problems are discovered without difficulty.

➢ Expansions and modifications can easily be applied.

➢ The representation is basically self documenting and comprehensible for others.

Flowchart   **Programm**

```
inGrid    = av.GetActiveDoc.FindTheme("DHM").GetGrid
minHoehe  = 750.AsGrid
outGrid   = (inGrid>minHoehe).Con(1.AsGrid,0.AsGrid)
outTheme  = GTheme.Make(outGrid)
outTheme.SetName("Query Result")
av.GetActiveDoc.AddTheme(outTheme)
```
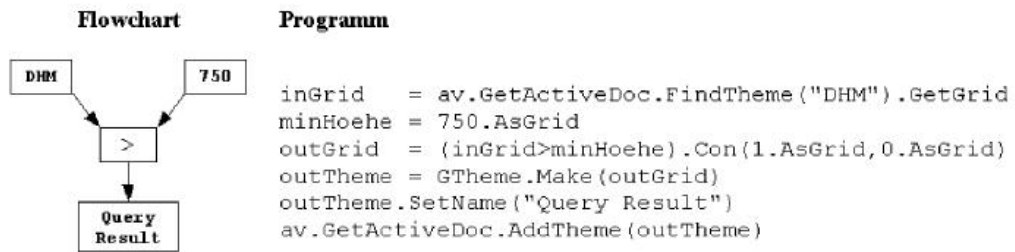
Figure 2: Example model represented in MapModels (left) and in Avenue-Code (right)
(Source: Riedl & Kalasek, 1998)

Today several commercial GIS have some kind of workflow programming environment based on the idea of modelling and programming in a flowchart style. Workflows can be understood as a kind of programming framework – a kind of "reduced" programming language. A workflow management system consists of a workflow engine and a workflow editor. The workflow engine executes the workflow, which is defined either interactively using the workflow editor or automatically. A simple workflow can often be created using drag-and-drop within the workflow editor (Petzold et al, 2006).

Without doubt this kind of programming language has opened up many more opportunities for GIS users. Before this development, GIS users who are often very familiar with the possibilities of the GIS and who often have a good understanding of what they want to analyse, didn't have the opportunity to take greater advantage of the GIS because they could not program additional software.

With the current workflow modelling possibilities there are easy ways to implement analyses that reveal something new about the real world known or that try to find out more about how much we actually know or don't know about a system as well as testing the likely consequences of the decisions we might make (Maguire D et al, 2005). The most important advantage though, is the fact that the workflow models can be used for automatic documentation. They are transparent and self explanatory informing other professionals or a broader public about the analysis. More over the modelled analyses are reliable and repeatable, which is a requirement for all proper scientific work and is a very big advantage when performing GIS analyses. Analysis in GIS tend involve many steps and a lot of temporary results and intermediate steps, which have to be managed. When using workflow models these can easily be accommodated alongside the final results and traced back to their origins when necessary.

On the other hand, a flowchart-like model from a workflow environment can influence the public a great deal without necessarily being correct. Users that don't have a thorough knowledge of the subject they are modelling can easily create incorrect results with documentation that only looks impressive at first sight. Further, when using workflow models mistakes in the model can be hard to spot, especially when the mistake only produces a temporary result. Riedl and Kalasek use the example that it is easily possible to calculate slope on consecutive numbering of, for example, municipalities. This makes absolutely no sense but the mistake might not be easily revealed when the step is executed in the middle of a complex model (Riedl & Kalasek, 1998)

Being aware of these challenges workflow modelling is a powerful tool to the GIS user community, which contributes to ad additional benefit from GIS. The extreme amount of geodata collected over time is only waiting to be analyzed and it can be turned into more valuable information for several purposes.

4. Basis, assumption and method

The main aspect of this thesis is the analysis of the Living Forests Standards requirement sections and the geodata available for forest owners and forest owners' organisations. On basis of this analysis the test municipalities are introduced in order to find additional information that is important for the documentation process of the Areas of Ecological Importance. These three sections are decisive for establishing a conceptual model for extracting AEI.

4.1   Requirement sections in the Living Forests Standard

The current, 2006 revised, version of the Living Forests Standard has 25 requirement sections attending to a wide range of forest activities from waste management and the use of fertiliser and herbicides to the protection of cultural monuments and environments, as well as requirements dealing with Sami rights.

In a comparison study by Savcor Indufor Oy (2005) of different certification schemes a clear overweighting of ecological aspects in all schemes was discovered. In the Living Forests Standard there are several main requirement sections emphasising ecological sustainability. In the following sections the relevant requirements covering the set aside or specially treated forest area are introduced. These sections also cover what is internationally often referred to as "High Conservation Value Forest". Parts of sections in the following subchapters are taken from the *Living Forests Standard brochure* (Levende Skog, 2006).

4.1.1 National parks and Nature reserves

Like most certification schemes the Living Forests Standard (LS) is based on the national law, in this particular case on the articles of the Forestry Act. They contain sections protecting ecological diversity in National parks and Nature reserves. National law prohibits all intervention affecting forests, flora and fauna inside the protected areas.

4.1.2 Mountain forests

The requirement covering special treatment for Mountain forests is also part of the Norwegian Forestry Act. It defines mountain forest as nature protection forest for protection against natural damages. In terms of forestry the Mountain forests have to be treated in special ways, as they protect from rougher climate coming from the mountains, landslide and avalanches. The LS states that logging areas cannot exceed 0.5 hectares and that the forests after logging must still be classified in development class 4 or 5. Development classes in Norwegian forestry are divided in 5 classes. Development class 4 and 5 describe mature forest that is the most valuable to forestry, in addition, these development classes often imply high biodiversity.

4.1.3 Buffer zones

"This section of the Standard is intended to ensure the protection or development of stable buffer zones along bogs, lakes, rivers, streams, brooks and cultural landscape" (Levende Skog, 2006). The minimum size of locations requiring a buffer zone is 0.2 hectares, or for rivers and brooks a minimum of 1 metre breadth. "Buffer zones have a number of vital ecological functions and serve several purposes related to biodiversity preservations, water quality, the landscape and outdoor recreation" (Levende Skog, 2006).

The role of Buffer zones function is to:

➢ Create stable corridors between older forests in the landscape.

➢ Be a habitat for species requiring the buffer zones' special environment, such as stable light, shade and temperature conditions.

➢ Create opportunities for concealment for species living in transitional zones between river, lakes, streams, bogs or cultural landscape.

➢ Provide nutrients to the water in the form of litter and micro-fauna but also to filter out nutrient seepage from harvesting sites.

➢ Add an aesthetic element to the forest landscape.

A typical buffer zone will be between 10 metres wide. Local adjustments should be made according to forest conditions. As an example, a buffer zone in broadleaved

temperate forests, tall-herb and tall-fern forests as well as in swamp forests should be wider, while the buffer zone for streams narrower than 2 metres or for bogs smaller than 0.5 hectares can be narrower. For the purposes of outdoor recreation, e.g. fishing, the buffer zones may be opened up in some places, but only if their ecological function will be preserved in other places.

In a buffer zone multi-layered forest shall be maintained or developed. Individual trees in a buffer zone may be harvested, yet not so many that the buffer zone cannot maintain its function, and not so many that the buffer zone loses its multi-layered condition if existing. Logging in older single-layered forests may take place to establish a multi-layered buffer zone. In single-layered forests in development classes 3 and 4 thinning should be used to establish an adequate buffer zone in deciduous forests prior to final harvesting. Buffer zones should be established and developed as naturally as possible.

4.1.4 Bogs and swamp forests

LS requires the maintenance of the ecological function of bogs, bog forests and swamp forests.

"Bog and swamp forests mean forests on peat land or swampy soil where the vegetation is dominated by hydrophilic species and an element of bog plants. Bog forests are primarily the vegetation type *wooded ombrotrophic bog*. Swamp forests are primarily the vegetation types *poor swamp forest* and *rich swamp forest*" (Levende Skog, 2006). Bog and swamp forests can be divided into productive forest and unproductive forest land.

The establishment of new drainage ditches in bogs and swamp forests is not permitted. Drainage maintenance and supplementary ditching are permitted as long as there will be no need for restoration of key habitats in this vegetation type.

Provided that considerations regarding the stability and regeneration of present tree species permit, selective cutting may be used in swamp and bog forests. Where there is natural support for it, silviculture and logging activities should preserve or develop a multi-layered buffer zone around bogs. An effort must be made to maintain the indigenous tree species mix within the buffer zone. "Forest management shall attach importance to protecting the ecological functions of all bogs and swamp forests,

irrespective of size. Brush vegetation is particularly important. However, the establishment of buffer zones and adaptation of cutting method are relevant only for bogs and swamp forests larger than 0.2 hectares" (Levende Skog, 2006).

4.1.5 Key habitat appraisal

Key habitat is a term for areas that have important characteristics and functions to preserve or recreate biodiversity. They are inventoried, selected and managed as part of Areas of Ecological Importance in accordance with one of the approved methods for Key habitat appraisal (KHA). In the current LS there are two different approved methods for the appraisal: The "Miljøregistering i Skog - Environmental Inventory in Forests" Method or the "Siste Sjanse - Last Chance" Method.

4.1.6 Mature forests / Natural growth forests

Mature forests fall within development classes 4 and 5. Forests, to be set aside as Areas of Ecological Importance, must have qualities that will enable them to become key habitats at some point. Setting aside these special areas can be seen as an attempt of restoration. Such forests are usually characterised by a multi-layered and varied age structure. "Natural old-growth forests have a dynamic that is considered to be dominated by natural disturbances and that evinces little in the way of human impacts" (Levende Skog, 2006).

Calcareous forest or calcareous low-herb forest is a special vegetation type. Where restoration has been initiated in younger forests to protect species diversity, calcareous forests, and also younger calcareous forests that are managed according to a plan to protect species diversity, may be counted as Areas of Ecological Importance.

Other areas of mature or natural growth forest may count as Areas of Ecological Importance if they are in development classes 4 and 5 with skidding distance[2] longer than 2500 metres. Areas in development classes 4 and 5 with slopes steeper than 50 % and skidding distances longer than 1000 metres, and areas in development class 5, with skidding distances longer than 1000 metres, of site quality class count as economically productive forest.

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[2] Skidding distance: Distance the timber has to be transported from the logging site to the next forestry road that is accessible with usual tractors

4.1.7 Broadleaved temperate forests

Broadleaved temperate forests are forests dominated by temperate broadleaved species such as elm, ash, beech, oak, lime, Norway maple and black alder.

Such areas may count as Areas of Ecological Importance if they are at slopes steeper than 50 %, in addition to areas at slopes steeper than 33 % and skidding distance longer than 500 metres.

4.1.8 Pasture woodland

Older woodland in a cultivated landscape that is classified at productive forest area and can be assigned to development classes 4 and 5 may be counted as an area of ecological importance.

4.1.9 Coastal spruce forests / Coastal pine forests

Coastal spruce forests are found in ravines and in humid areas along the coast in Trøndelag and in Helgeland. They are characterised by lichens and mosses in the *Trøndelag element*. Several of the species found in these forests are considered as threatened on the Norwegian Red List.

Coastal pine forests exist in various subtypes rare both in Norway and internationally. Their main distribution is in the area from Rogaland to the north until Møre og Romsdal. Important subtypes are the *Bell heather-pine forest*, L*ow-herb-pine forest* with I*vy and holly*, *pine-hazel forest with well-developed lichen flora* and so-called M*ineral-rich pine forest* in Møre og Romsdal. Both forest types Coastal spruce forests and Coastal pine forests are often referred to as the nature type *Boreal rainforests*.

Silviculture in Coastal spruce and Coastal pine forest is restricted. Some logging may be carried out in buffer zones, which are an important part of the location, provided that the microclimate in the core area of the biotopes is not altered or destroyed.

4.1.10   Unproductive forest land

Unproductive forest land means older forest with production of less than 1 m^3 wood per hectare per year, with a minimum of 60 trees per hectare that are at least 5 m high. Unproductive forest land may be on solid ground or bog and swamp forests.

The classification unproductive is only hence to economic aspects. This forest is still regular forest area because it maintains all the biological functions of forest in the same way as economically productive forest does, but it is not profitable for the forest owner to harvest in that forest. In addition these areas are often in direct connection to productive forest area, which gives them a biologically important function as they are the connecting the forest areas and often older mature forests with each other. That means they are a natural retreat area if there is e.g. logging in neighbouring stands. Up to 25 % unproductive forest land may be considered as area of ecological importance in the documentation. The amount that will count as AEI is added to the AEI in productive forest land. The amount also has to be added to the sum of productive forest land in the area of analysis.

4.2   Available geodata

4.2.1 FKB – dataset

The FKB-dataset is a large scale vector-dataset defined in its own section of the SOSI standard. This includes everything from cadastral data and full Land cover dataset to Water and Elevation data collections. The data are produced for scale levels from 1:500 to 1:20000 and are meant to be used for all administrative duties of the municipalities, the road traffic department and power authorities. Produced and usually only available in SOSI format, it was decided through the GEOVEKST collaboration that the FKB-dataset will also be available in the much used ESRI (Environmental Systems Research Institute) shp-format. The standard, however, defines the dataset on basis of SOSI format only, and the available shp-format is a converted copy. Quality and attributes presented in this chapter are specified for the original data in SOSI format.

The FKB-dataset is used in executive work, project management, production of digital and analogue maps as well as analysis in a GIS. The key principle is that none of the data covered by the FBK-dataset are to be gathered more than once in the same geographical area (Statens kartverk SOSI, 2002a)

Unless otherwise specified the rest of this chapter is extracted from Statens kartverk SOSI (2002a)

The level of detail in the area of a municipality varies from a great deal of detail in urban areas to rather less detail in rural or in wilderness areas. For this reason the current SOSI standard defines six detail levels in the section covering the FKB-dataset. Each detail level has four different classes for different objects according to whether they are classified as 'Very well definable', 'Well definable', 'Blurred' or 'Naturally diffuse' objects. The object classes within the detail levels define the geographical accuracy.

➢ FKB-A is the detail level with the data gathered in most detail covering the needs of urban areas and urban development and includes features as pavement, eaves and patios. The FKB-A level includes detailed information on the elevation of objects and can be used for three-dimensional representations. The minimum accuracy is between +/- 0.14 metres for "Very well definable" objects and +/- 0.51 metres for "Naturally diffuse" objects.

➢ FKB-B1 and FKB-B2 are mainly used in urban development where there are no current building projects, but where the area is part of the development scheme of the municipality. FKB-B1 level detail is used for urban development or infrastructure development outside urban core areas. The gathered objects and details are the same as in FKB-A. FKB-B2 is manly used for development of infrastructure in rural areas and for development schemes. Objects are gathered with less detail than in FKB-B1. The required accuracy for the FKB-B1 and FKB-B2 is within +/- 0.19 – 0.55 m according to the different object classes.

➢ FKB-C1 is less detailed and is mainly used for rural areas containing newer settlements or infrastructure where digitising from older topological raster datasets is not sufficient. In such an area FKB-data would most likely be gathered through photogrammetrical mapping with the FKB-C1 detail level with a required accuracy for the different object classes between +/- 0.37 – 0.9 m.

➢ FKB-C2 is as detailed as the FKB-C1 level but is used only in rural areas where woodland and scattered settlement characterise the area. Most of these data are gathered through digitising of topological raster datasets. In this class the required accuracy for all object classes is +/- 2.0 ..

➢ The least detailed level is the FKB-D level, which is used in low productivity, wilderness and mountain areas. Data in this class is of very low priority and it is gathered at very low cost. Most of these data in this detail class are gathered from other, small scale datasets that were collected in other, often nationally-based, projects. Accuracy on this detail level varies from +/- 10-50 m.

The different detail levels can be used as a patchwork quilt all over the municipality but each area must only be covered once to ensure that the first principle of no data being gathered twice is maintained. The level of detail in an area can change over time where the development scheme is adjusted. In Figure 3 an example shows how a municipality might be divided in areas of different detail levels. The wilderness area detail level FKB-D (D) is for instance established around an area with a new development scheme in detail level FKB-B2 (B).

In each mapping and data gathering project carried out by the GEOVEKST collaboration (q. v. 3.1) the involved groups will agree on which level of detail is to be chosen for each area. If one group has a significantly higher demand for a more detailed level this group usually has to finance more of the data gathering costs of the project.
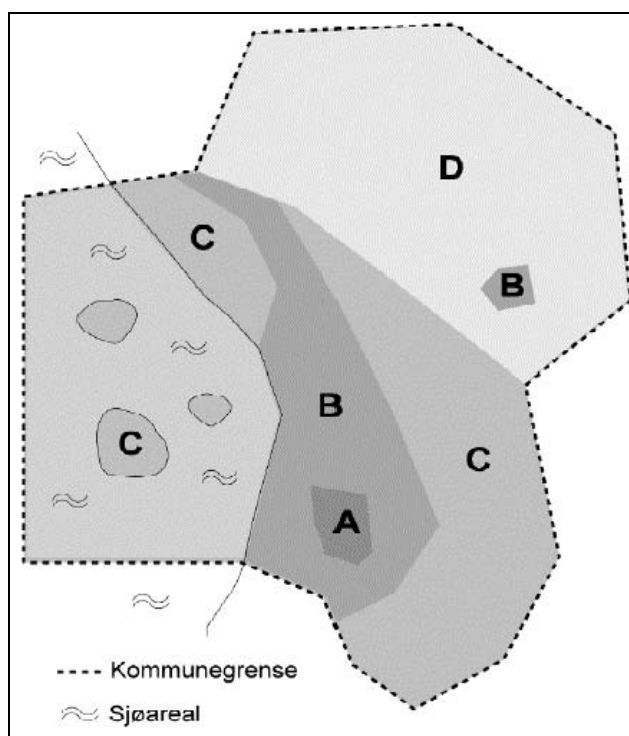
Figure 3: Example of the arrangement of the different levels of detail in the FKB-dataset (Source: (Statens kartverk SOSI, 2002a)

The FKB-dataset contains the following data collections: (I) Elevation data as equidistant isohypses with a separation of between 1 and 25 metres depending on the level of detail; (II) Water data consisting of coastlines, lakes, rivers and brooks; (III) Communication and transport data including streets, train lines, airports, pavements, trails etc.; (IV) Land cover data; (V) Buildings and installations; (VI) Cadastral data; (VII) Data covering Administratively protected areas; and (VIII) Names of places as a geocoded text file.

In the following sections only the data collections that are expected to be relevant to the requirements of the LS (q.v. 4.1) are described.

4.2.1.1 <u>Water data</u>

Data covering coastlines, the sea, lakes, rivers and brooks are collected in this dataset. The ocean is only covered where it has influence on development and management of other objects in the FKB-dataset. Otherwise marine data are not part of the FKB-data.

The three object classes ("..OBJTYPE") 'HavFlate', 'ElvBekk' and 'Innsjø' are relevant to the documentation of Areas of Ecological Importance. The ocean included, as mentioned above, is registered in the object class "HavFlate". Rivers with breadth of more than 3 metre are registered as 'ElvBekk'. Lakes are included as the 'Innsjø' class if they exceed an average minimum area of 10 m^2. These classes are polygon object classes. In addition there is a line object classes, such as 'ElvBekkMidtlinje' or 'KanalGrøftMidt", which gathers all data on rivers, brooks and ditches over the municipality that are not already covered by the 'ElvBekk' object class. In Table 1 an example of some of the attributes and some of their possible values consistent with the given object classes is given.

The attribute "..KVALITET" refers to accuracy tolerances specified in the FKB detail level. On the other hand the water data section in the FKB specification expands the tolerance a little for of the FKB-C1 and the FKB-C2 detail levels. The FKB-specification refers here to that the water data is mostly gathered from raster topology data and the level of accuracy is depending on that. The FKB specification expects a localisation accuracy of +/- 2.0 metres in most cases. The "..KVALITET" example in Table 1 is given for data gathered by digitisation of a paper map ('55') and a +/- 2 metre accuracy tolerance ('200') (Statens kartverk SOSI, 2002b). Other more general

attributes used in other SOSI datasets are like the "..KVALITET" attribute as well defined in *SOSI Del 1 Praktisk bruk, geometri* (Statens kartverk SOSI, 2002b)

Attribute name	Possible value 'HavFlate'	Possible value 'Innsjø'	Possible value 'ElvBekk'	Possible value 'ElvBekkMidtlinje'
..OBJTYPE	'HavFlate'	'Innsjø'	'ElvBekk'	'ElvBekkMidtlinje'
..FTEMA/ ..LTEMA	'3001' Not in use	'3101' Not in use	'3201' Not in use	Not in use '3211'
..VANNBR	Not in use	Not in use	'2' = water breadth 1-3 metres '3' = water breadth less than 15 metres '4'= water breadth more than 15 metres	'1' = water breadth up to 1 metre '2' = water breadth 1-3 metres '3' = water breadth less than 15 metres
..DATO	Current date	Current date	Current date	Current date
..KVALITET	'55 200'	'55 200'	'55 200'	'55 200'

Table 1: Example of object class attributes for water data considered for documentation

4.2.1.2 Land cover data

The Land cover dataset is the national basis for classification of farming land, woodland and other types of areal land use. By definition it is a full cover dataset. Where other FKB-data like water data already exist, the geometry of the existing objects is copied into the Land cover dataset to insure equal boundaries. The attributes are simplified and adapted to the available attributes in the Land cover data.

In the Land cover dataset the polygon object class 'Markslag' is the most interesting for the AEI documentations. It consists of several attributes to classify economically productive and unproductive wood land as well as information on bogs and cultivated landscape. Some of the attributes, such as "..OBJTYPE", "..FTEMA", "..DATO" and "..KVALITET" are consistent with the attributes described in the Water data section. These are general attributes attending to all parts of the SOSI standard Del 3 (Statens kartverk SOSI, 2002a).

Other attributes are only defined by special parts of the SOSI standard. Land cover data is specified in SOSI DEL 2 (Statens kartverk SOSI, 2002c.

Three attributes in this dataset are particularly important for the documentation of the Areas of Ecological Importance:

➢ "ATIL": This is the main attribute classifying the land cover type. Table 2 shows the most important values for analysing the data in this context. An exhausting list can be found in SOSI DEL 2 (Statens kartverk SOSI, 2002c).

Value	Explanation
11	Bog or Mire
12	Bog with coniferous trees
13	Bog with coniferous and broadleaved trees
14	Bog with broadleaved trees
22	Cultivated landscape
23	Other farming land
24	Coniferous woodland
25	Broadleaved woodland
26	Coniferous and broadleaved mixed woodland

Table 2: List of "ATIL" values from the "Markslag" object class for Land cover data

➢ "ASKOG": This classification defines the land cover type in terms of the potential timber growth on the respective site. This site quality attribute defines a classification value for economically unproductive woodland. For productive sites there are values for nine growth classes of the three dominate tree species-spruce, pine and birch. In addition, there are general classes if the main dominating tree species is undefined. Table 3 shows the values for the site quality where no dominating species is classified. Value '12' is classification for unproductive forests, while '13'-'15' often are productive forest sites. An exhaustive list can be found in SOSI DEL 2 (Statens kartverk SOSI, 2002c).

Value	Explanation
12	No dominant tree species classified – Low wood growth (0.1 – 0.3 m^3/year)
13	No dominant tree species classified – Medium wood growth (0.3 – 0.5 m^3/year)
14	No dominant tree species classified – High wood growth (0.5 – 1 m^3/year)
15	No dominant tree species classified – Very high wood growth (> 1 m^3/year)

Table 3: List of "ASKOG" values for site quality where no dominating species is defined

➢ "TSKOG": This attribute is not necessarily used in the land cover classification but if used it gives additional information about the forest condition or contains special notes on the site quality. Table 4 contains just the two most important values extracted from a long list of possible additional values.

Value	Explanation
11	Forest on bog land
12	Forest with wrong (often planted) coniferous species on bog land

Table 4: Example possible values of the "TSKOG" attribute for Land cover data

Other attributes in the Land cover dataset refer to other areal land use, such as agricultural land or wilderness areas. As mentioned in the beginning of this section on Land cover data this dataset also contains a quality attribute that describes the level of detail and the accuracy tolerance. Even so SOSI DEL 3 (Statens kartverk SOSI, 2002c) has its own section on quality that states that the quality of the Land cover dataset is manly based on digitisation from topological paper map or raster data. This is why the dataset overall has a level of detail of FKB-C2 and an accuracy tolerance of +/- 2.0 metres.

4.2.1.3 Data covering Administratively protected areas

This dataset includes polygon data for areas that are administratively protected in National parks, Landscape preservation and Nature reserves. The object class important for the AEI documentation is 'VernNatOmr'. Attributes store information on, for

example, the paragraph under which protection is given ("VERN_LOV"), the name of the protection area ("NAVN"), the date when the protection status was given ("VERNEDATO") and the purpose of protection ("FORMAL"). Other attributes of this object class are mostly geared towards administrative duties and responsibilities so they will not be explained further in this thesis.

Level of detail is as for the Land cover dataset defined to be in FKB-C2 level for the whole dataset. Accuracy tolerance is +/- 2.0 metres, but if border lines from other, more accurate, datasets can be used these should be copied and used as borders of this object class.

4.2.2 Forest inventory data

As was pointed out briefly in Chapter 3.2, there is a part of SOSI defining Forest inventory data. This part of the SOSI standard never became accepted in common areas of use. None of the main stakeholders in Forest inventory, such as the forest owners organisations and the municipalities, had the tools to produce or use the data that would result of the standard. The forestry sector authorities did not see any easy and effective way to establish digital data from Forest inventory for their needs and they preferred analogue maps for a long time (Norsk institutt for jord- og skogkartlegging (NFLI), 1998). The organisations and institutions carrying out forest inventories used tools and software that could not be adjusted to the demands of the SOSI standard. Attempts to develop new applications typically became too expensive and resulted when completed in substandard products (Anker et al, 2002).

In 2006 the Norwegian Forest and Landscape Institute (NFLI), an autonomous institute under the Ministry of Agriculture and Food, issued a specification for the delivery of Forest inventory data that refers only to the most important attributes and objects of the Forest inventory. Further the NFLI requires all geodata delivered to be in ESRI shp-format (NFLI, 2006). The most important values and attributes for AEI documentation are translated and explained in Table 5. An exhaustive list can be found in the specification for the delivery of Forest inventory data (NFLI, 2006).

Field name	Value	Explanation
MARKSLAG	6-29	**Site productivity classification system** ("H40"- describing the expected tree heights at the age of 40) 3 metres interval from 6-29 for productive forest sites
	30	Bog/Mire
	41	Unproductive forest
	42	Mountain area
	43	Infrastructure
	44	Water
	45	Other
BONTRE		**Dominant tree species** defining which H40 system in attribute "MARKSLAG" should be used
	1	Spruce
	2	Pine
	3	Birch/Broadleaved
HKL		**Maturity class** (productive sites only)
	11	Forest regenerating, satisfactorily cleared
	12	Forest regenerating, unsatisfactorily cleared
	21	Young forest, satisfactory density
	22	Young forest, unsatisfactory density
	31	Younger production forest, satisfactory density
	32	Younger production forest, unsatisfactory density
	41	Older production forest, satisfactory density
	42	Older production forest, unsatisfactory density
	51	Mature forest, satisfactory density
	52	Mature forest, unsatisfactory density
ALDER	Value	**Average age** for the stand
AREAL	Value	**Area of the stand** in Norwegian decare (daa) 1 decare = 1000 m^2

Table 5: Key attributes of Forest inventory data specified by the NFLI

4.2.3 Key habitat appraisal data

The Key habitat appraisal (KHA) is a part of the Living Forests Standard certification program since 2001. The local forest owners associations can choose between different methods of registration. Two main systems for the appraisal are approved today: The "Miljøregistering i Skog - Environmental Inventory in Forests" method or the "Siste Sjanse - Last Chance" method. The method "Environmental Inventory in Forests" is the scheme developed by the NFLI and is also the method frequently use for carrying out Key habitat appraisal registrations on municipality level. The "Environmental Inventory in Forests" method focuses on registration of habitats and biotopes that are suited for species with special needs, the "Last Chance" method focuses more on registration of species that are classified as threatened (Levende Skog, 2006).

The specification (NFLI, 2006), referred to in the previous section, also contains a section for Key habitat appraisal. The most important attributes are listed in Table 6. The specification can be used for either method of KHA.

After the registration of the Key Habitats in a municipality all locations are compared to each other by a forest biologist, people conducting the appraisal and other stakeholders. The most valuable habitats are given the status 'selected' in the filed "UTVALG" and these are treated as either set aside areas or are assigned a special maintenance plan in order to keep the habitat stable.

Attribute	Value	Explanation
KOMMUNE	Value	**Municipality ID code**
PROSJEKT	Value	**Unique project ID from the conducting company**
LIVSM		**Habitat**
	1	Standing dead trees
	2	Fallen dead trees
	3	Trees with High-pH value in the bark
	4	Trees with fruticose lichens
	5	Older succession of deciduous forest
	6	Old tree specimens
	8	Forest fire area
	9	Calcareous forest
	10	Rock wall
	11	Clay Gully
	12	Stream Gully
VEGTYPE	Value	**Vegetation type** according to listings from the NFLI
TOPOGR		**Topography**
	1	Flat land on top of knolls
	2	Hill or slope towards the south
	3	Hill or slope towards the north
	4	Basin
ARTNAVN1	Text	**Name of threatened species**
UTVALGT		Registered features are either **selected/chosen,** and if so treated with special care, **or not** after the registration of a municipality
	1	Selected
	2	Not selected – forestry in agreement with the LS
REGDATO	Value	**Registration date** (YYYYMMDD)

Table 6: Key attributes of Key habitat appraisal specified by the NFLI

4.2.4 Naturbase

Naturbase is the database into which data from: (I) Nature type mapping; (II) Wildlife species demanding special care; (III) Wildlife species that are economically of great importance; (IV) Threatened species; (V) National parks, Landscape preservation and Nature reserves; (V) Suggested Nature reserves and (VI) Biodiversity registrations in general are collected and administered in one database.

The Norwegian Directorate for Nature Management (DN) assembles, administers and publishes theses data in a web client and as a Web Map Service (WMS). But the directorate is not responsible for the gathering of the data. This is the duty of the municipalities and the respective county government.

Whilst the data in Naturbase, covered by a part of the SOSI standard, are reliable within the definitions given there the accuracy of data, for example on wildlife habitats, is often unknown. The uncertainty regards both the accuracy of the habitat registration and the data's geographical position. Habitats are often registered on basis of less detailed scales and there are often no metadata in on the origin of this data available in the WMS publication.

4.3 Test area and test data

4.3.1 Snåsa – Nord-Trøndelag County

The Snåsa municipality is located in the middle of Norway. The region containing Snåsa is called Trøndelag, literally describing the vicinity to the town Trondheim, which has been a regional capital and a cultural centre for the region over centuries. In many ways Snåsa is a typical Norwegian municipality with a small population and a large extent consisting manly of rural, forest and wilderness area. In the map shown in Figure 4 the main map view shows the location of the municipality in relation to Trondheim in the south-west corner of the map. The extent of the rectangle of the main map within Norway is shown in the small overview in the bottom right corner.

At lower altitudes the climate of the municipality is sub-oceanic to slightly continental at higher altitudes in the East and South-East of the municipality towards Sweden. Snåsavatnet (Snåsa lake) is a considerable water body that has, together with the most

north-eastern parts of the Trondheimsfjorden, a substantial impact on the climate, such that the sub oceanic climate dominates. At lower altitudes the temperature varies from at with an average of 4.3 °C to the higher altitudes with only 3.1 °C. Precipitation varies between 900 and 1000 mm per year. Sheep farming and milk production are dominating land use and forestry covers a large area in the municipality (Norwegian Meteorological Institute, 2007), (Elgersma & Asheim 1998).
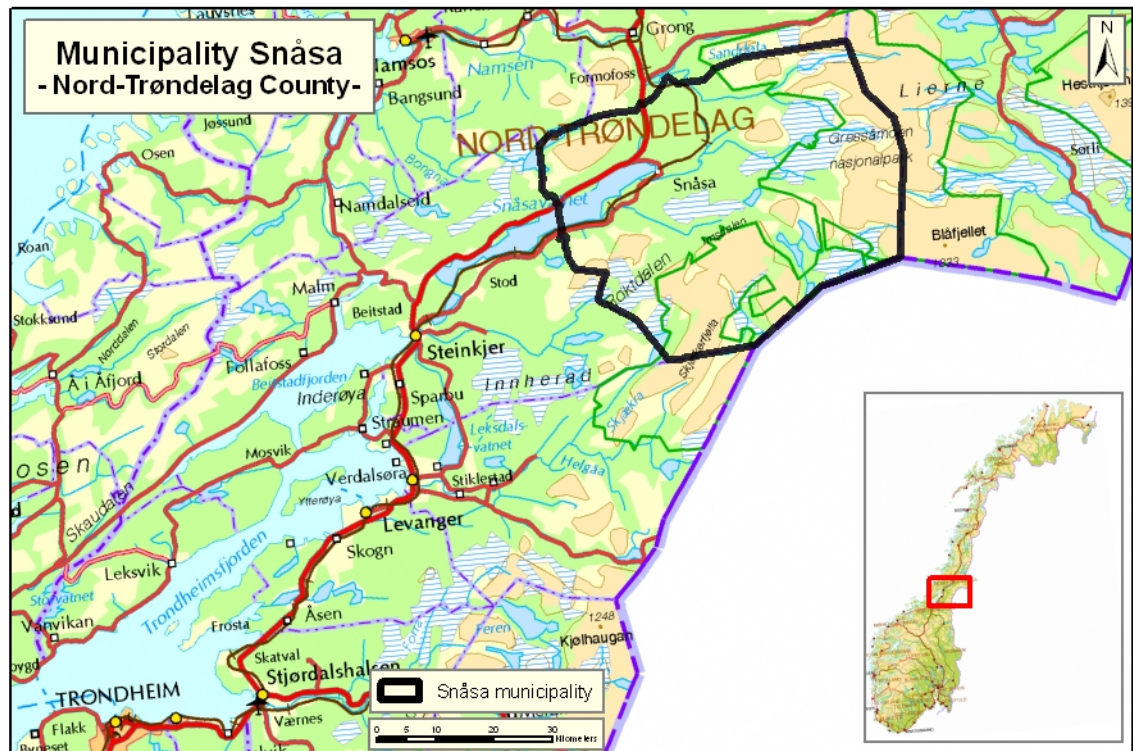
Figure 4: Location of the municipality Snåsa in Nord-Trøndelag County Source data: WMS-service Statens kartverk -adjusted)

Snåsa municipality covers an area of 2 341 km^2 – 66 % of this area is over the tree line and only 1.4 % is cultivated land, leaving 32 % forest and other rural area. The population is about 2000 inhabitants and the administrative centre the town Snåsa is located at approximately 12°21'E 64°15'N (Snåsa municipality, 2008).

The latest Forest inventory and Key habitat appraisal data are from the year 2003-2004. This appraisal did not cover the whole area of the municipality. Forest inventory only covered about 633 km^2. This covers the most productive forest areas in the parts of the municipality at lower altitude shown with light orange in Figure 5. The area in dark orange in this map is classified as forest in the Land cover data. Most of this dark orange forest area is not classified as economically productive forest. In some places this is because of site classes with less ability for wood production but often also

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because of too long distances from forest roads making it economically unprofitable to conduct logging in these areas. There are also productive forests belonging to mountain farms included in the dark orange area. These are nowadays part of the Græsåmoen-Skjækerfjell National Park. Table 7 shows the percentage distribution of the different data and forest coverage within the municipality.
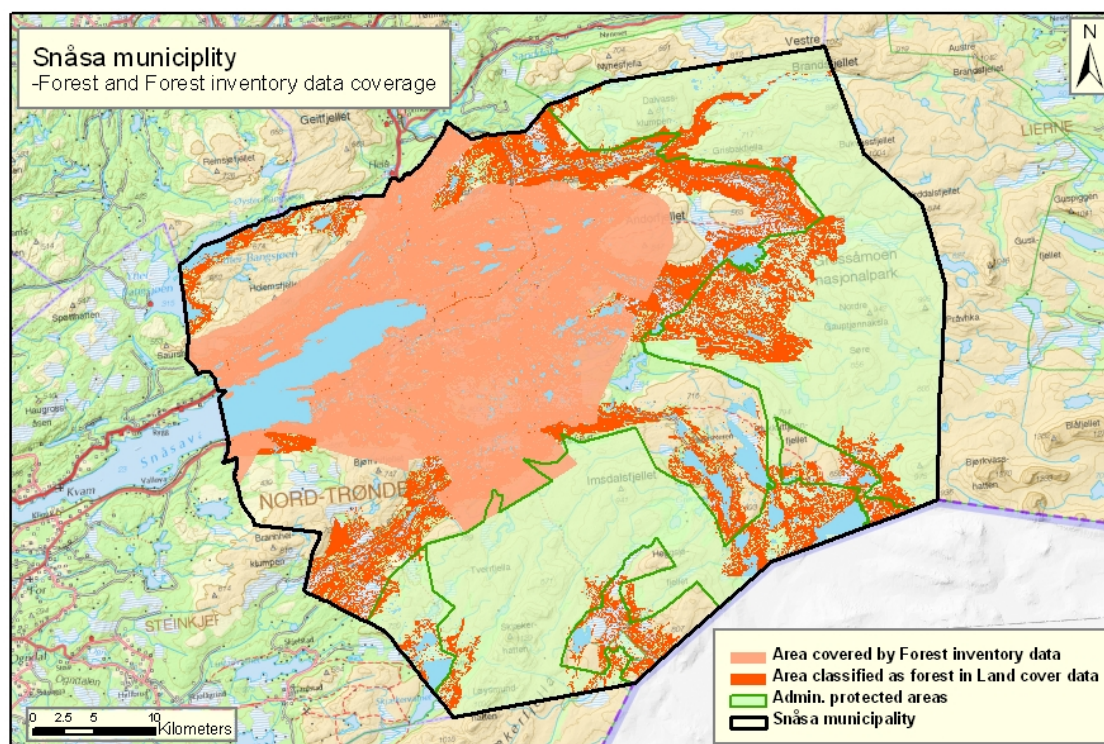
Figure 5: Map of Snåsa municipality showing forest cover classified by Land cover data and area covered by Forest inventory

	daa	% of the total area of Snåsa municipality
Area Snåsa municipality	2 341 396	
Area covered by Forest inventory	633 071	27
Productive forest area	270 400	11
Area classified as forest in Land cover data	752 429	32
Area classified as forest in Land cover data not covered by Forest inventory	356 101	15

Table 7: Comparison of municipality area and forest area

Geographic and geological conditions in the area allow to make a few assumptions as to what to expect in terms of biodiversity in the municipality. *Mature forest* and a variety of *bog forests* are expected. There are limestone ledges in the area. These are rare in Mid-Norway, and the nature type *Limestone Forest* is expected. Additionally occurrences of the rare nature type *Boreal rainforest* are expected (NFLI, 1998b).

4.3.2 Løten – Hedmark County

Løten is, with the area of 369 km^2 a smaller municipality in the south-east part of Norway. Løten is situated close to Norway's biggest lake - Mjøsa. The population is about 7000 and most people are living in the western parts of the municipality at lower altitudes. The urban centre Løten is located at approximately 11° 20' E 60° 50' N. Figure 6 shows the location of the municipality in Norway (Løten municipality, 2008)
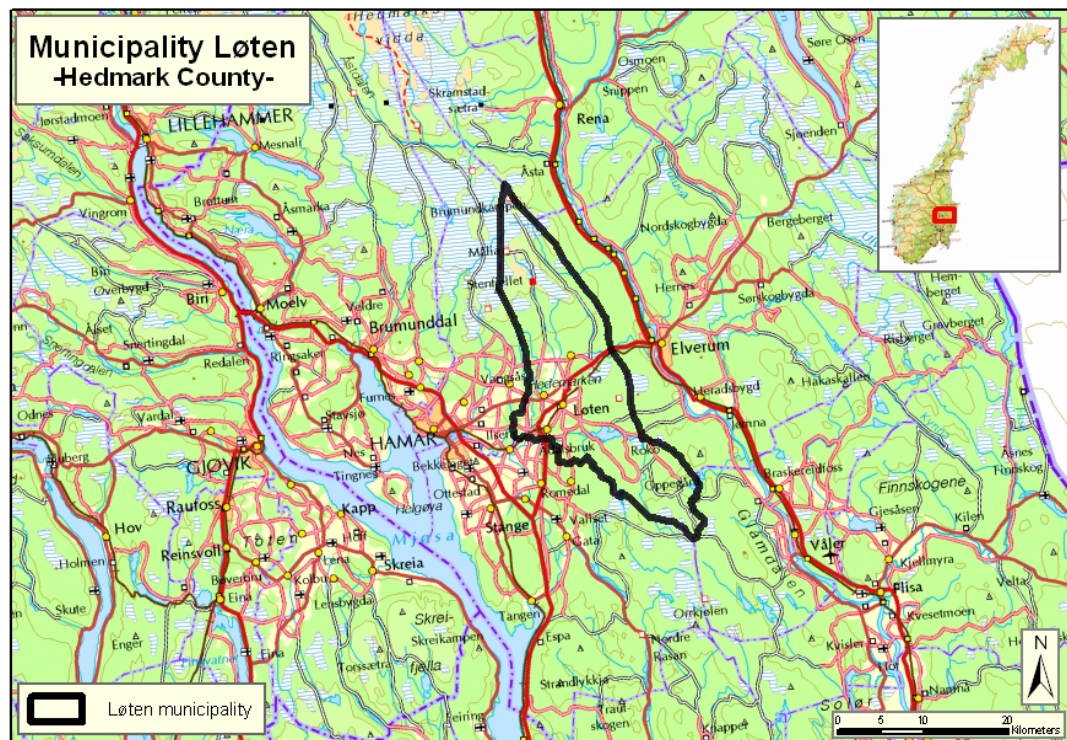
Figure 6: Location of the municipality Løten in Hedmark County (Source data: WMS- service Statens kartverk -adjusted)

This municipality is known to have a continental climate and the average temperature is 3 °C with an average precipitation of 600-1000 mm per year. In the last few years there has been a tendency for less snow in winter, which implies more rainfall within the growing season. The variation within the municipality is significant and the municipality contains several different nature types. The elevation ranges between 160 and 850 m height above sea level, and the parts of lower altitudes are part of the

Silurian and Lake Settlements in the east part of Norway type. These areas are the best farming land in the country. Big farms with monumental timber architecture producing grain and potatoes for centuries are typical here. Farming is possible up to 600 m above sea level (Norwegian Meteorological Institute, 2007).

The other nature type in Løten is *Mountain forest of Southern-Trøndelag*. This nature type is more common further north in Norway, but the south-east part of the municipality that is at higher altitudes is part of that nature type. Mires and bogs are quite typical for this nature type but also summer mountain pasture characterizes this nature type. Today summer farming is not as common any more and the places of summer farming are often left to natural succession. This naturally grown back forest is often ecologically very diverse and important. Where the summer farming land is still maintained that is often done in association with tourism, mountain cabins, hunting and fishing. About 60 % of the district is productive forest, and farming land represents around 10 % of the municipality area (Elgersma & Asheim 1998), (Bekken, 2003).

Forest inventory and Key habitat appraisal data in Løten municipality have been produced in 2005-2006. The Forest inventory covered close to 90 % of the municipality area. Only a few forest owners did not take part in the inventory. In Figure 7 the forest area in dark orange shows forest from the Land cover data where no Forest inventory has taken place. In this municipality that includes a Nature reserve and areas belonging to several forest owners who didn't participate in the registration. Table 8 lists the percentage of forest land and productive forest land in the municipality.
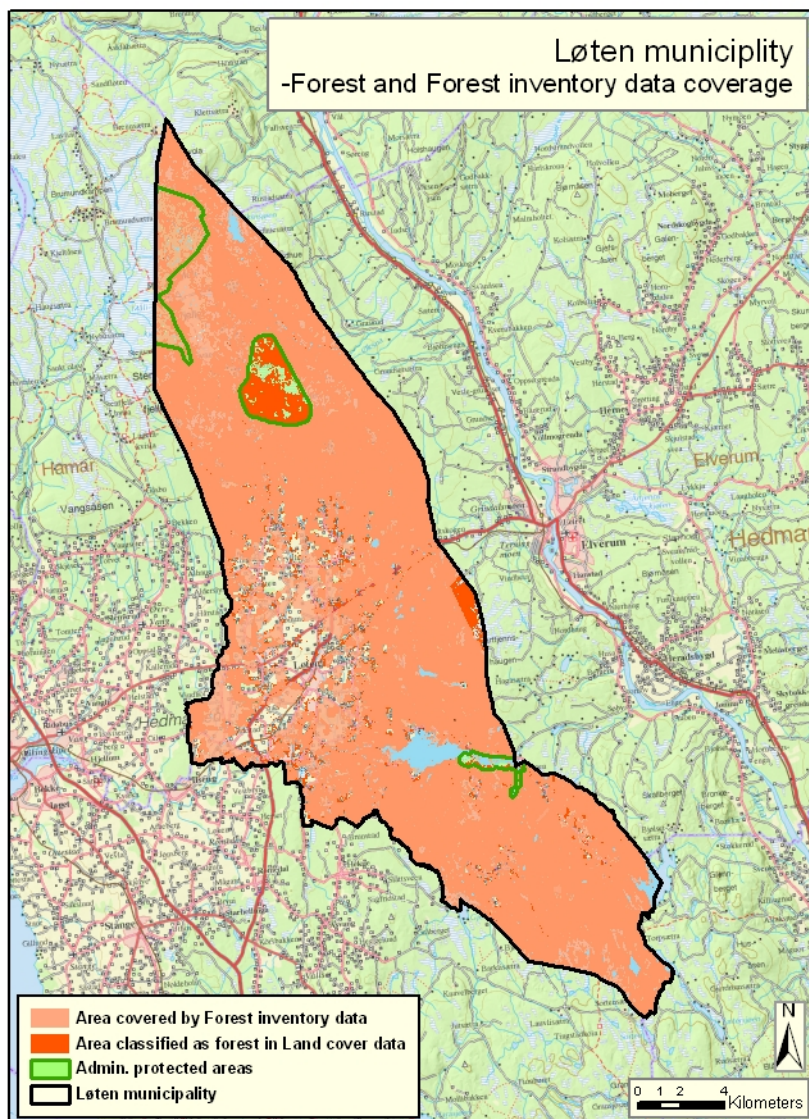
Figure 7: Overview map of Løten municipality showing forest cover classified by Land cover data and the coverage area of Forest inventory

	daa	% of the total area of Løten municipality
Area Løten municipality	369 298	
Area covered by Forest inventory	321 564	87
Productive forest area	224 200	60
Area classified as forest in Land cover data	279 649	75

Table 8: Comparison of municipality area and forest area

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4.4 Conceptual workflow modelling

4.4.1 Gross area calculation and reduction to net area

In the previous sections in this Chapter the basis for the documentation of Areas of Ecological Importance have been introduced. In Section 4.1 the requirements in the Living Forests Standard for protecting biodiversity have been explained. Section 4.2 gave an overview over geodata that are standardized and accessible for forest owners' organisations in Norway while Section 4.3 gives an introduction of the test areas their location, geological and climatic conditions and the assumptions made concerning nature types and occurrences of special habitats. In this last section a conceptual model will be developed that connects the given conditions and requirements for documenting AEI within a municipality.

From each of the datasets mentioned in Section 4.2 areas most likely high ecological importance can be extracted or constructed. Some of the AEI can simply be extracted using an attribute query in the dataset, while others are input to a geographical analysis in order to extract and create wanted areas. Figure 8 shows the conceptual model of obtaining a gross Area of Ecological Importance[3]. All input datasets for this model are expected not to have overlapping features in each dataset. A quality control of this condition is not included in the model.

All workflow models in the remaining parts of the thesis are built up with a similar structure. The model can be read from left to right and the processes are run in that order. Processes in horizontal rows can be run independently from other processes in other rows as far as they are not vertically connected and there is no indication to the contrary. Dark blue ellipses symbolize existing data which are given as a basis. Yellow rectangles represent an action that can be an attribute search, a field update or a geographical operation. The light blue ellipses are parameters of the model that can be adjusted before running the workflow model. The green ellipses represent the results of an action. Often these results are to be reused in the next action and are temporary results or they are a final result of the workflow.

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[3] Figures of the conceptual model in an overview are shown in the appendix
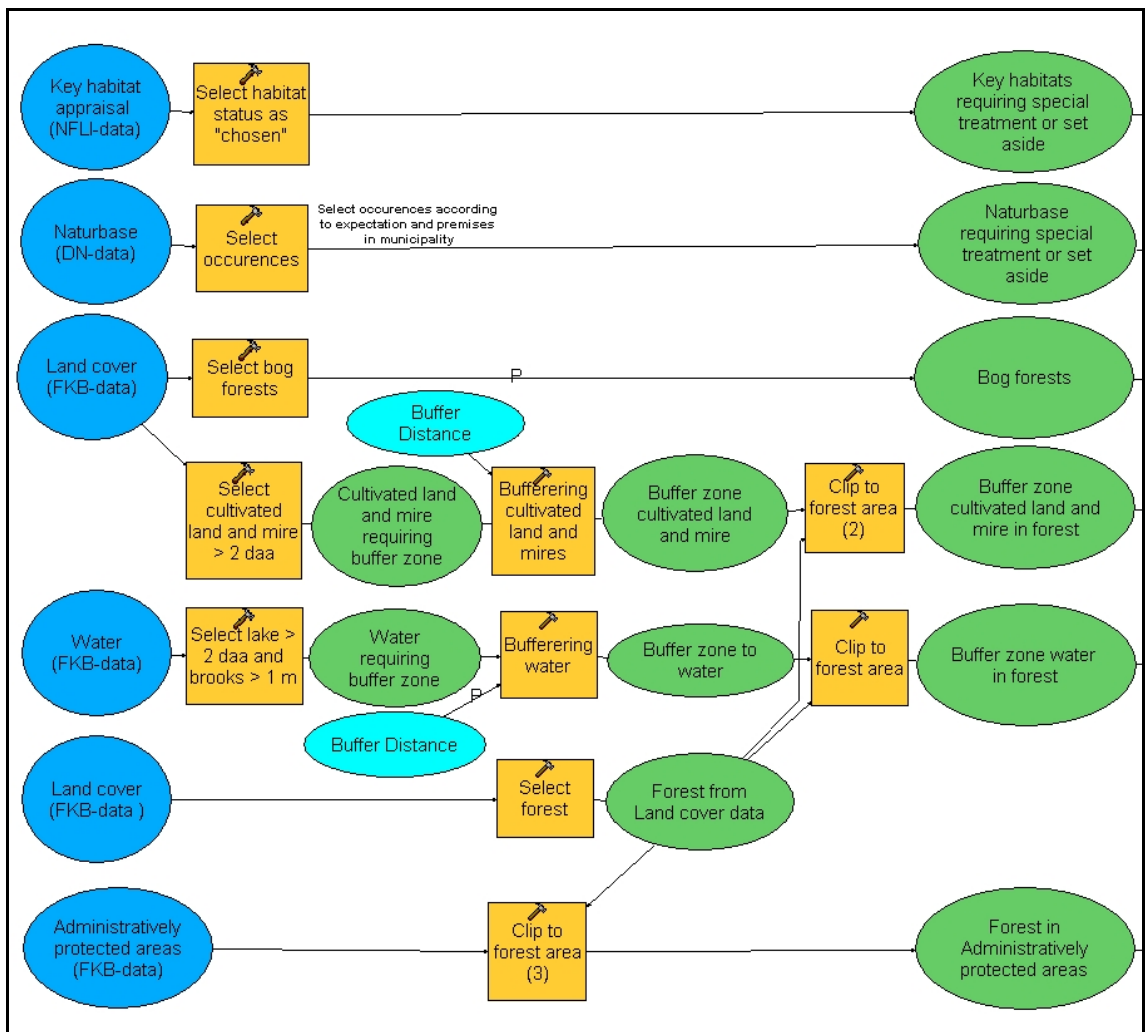
Figure 8: Conceptual workflow model for extracting the gross Area of Ecological Importance

From the Key habitat appraisal dataset the 'selected features are extracted. These are the habitats that have been set aside or were assigned a special maintenance plan after the registration in the municipality (q. v 4.2). In the Naturbase data the occurrences that are special to the municipality and the occurrences regarding forest and forestry must be selected before being counted in to the gross area. Another simple selection based on attributes is the extraction of bog forest from the Land cover data. The fields "ATIL" and "TSKOG" give the necessary information to set up this extraction (q. v 4.2).

Other areas that relate to the requirement sections can be extracted with some additional processing steps. The Land cover data can be used to extract cultivated land and mires and is the basis for the calculation of buffer zones around these to land types. The water data, also from the FKB-dataset, can be used to extract the lakes, rivers and brooks that require a buffer zone. Ocean 'HavFlate', Lakes 'Innsjø' with an area more than 2 decare and rivers 'ElvBekk' are selected. In addition brooks 'ElvBekkMidtlinje' with at least 1

m breadth require a buffer zone according to the LS. On both datasets requiring a buffer zone the geographical operation "Buffer" is run (q. v. 3.3.2), but a further step to get the buffer zone area that is actually forest is required. From the Land cover data all forest-covered land can be extracted using the attribute "ATIL" (q. v. 4.2). This new polygon dataset is used to subtract only the forest land within the created buffer zones. The two resulting datasets are the forest land buffer zone for cultivated land and mires and the buffer zone in forest for lakes, rivers and brooks. The created forest-covered land file can also be used to extract forest from the dataset of Administratively protected areas.

Given the requirement sections from the LS and the available geodata six different kinds of areas can therefore be extracted that qualify to be Areas of Ecological Importance according to registered purpose, their location or according to the attributes defined in the dataset. In this first conceptual step the processes necessary to extract the gross area have been described.

The next step is to reduce the gross area to remove any overlaps between the different extracted files of gross AEI. Figure 9 is a direct continuation to the right from Figure 8. First Figure 9 shows that a new field is added and updated to each of the different AEI files. This is done in order to keep an easy way to relate the different areas to their origin AEI after reducing to net area. Using the spatial operation "Union" (q. v 3.3.2) the files can be prevented from overlapping. The operation will keep areas from each input file as well as all attributes from the original data for the overlapping parts. The result is the net Area of Ecological Importance that can be extracted from the available geodata.
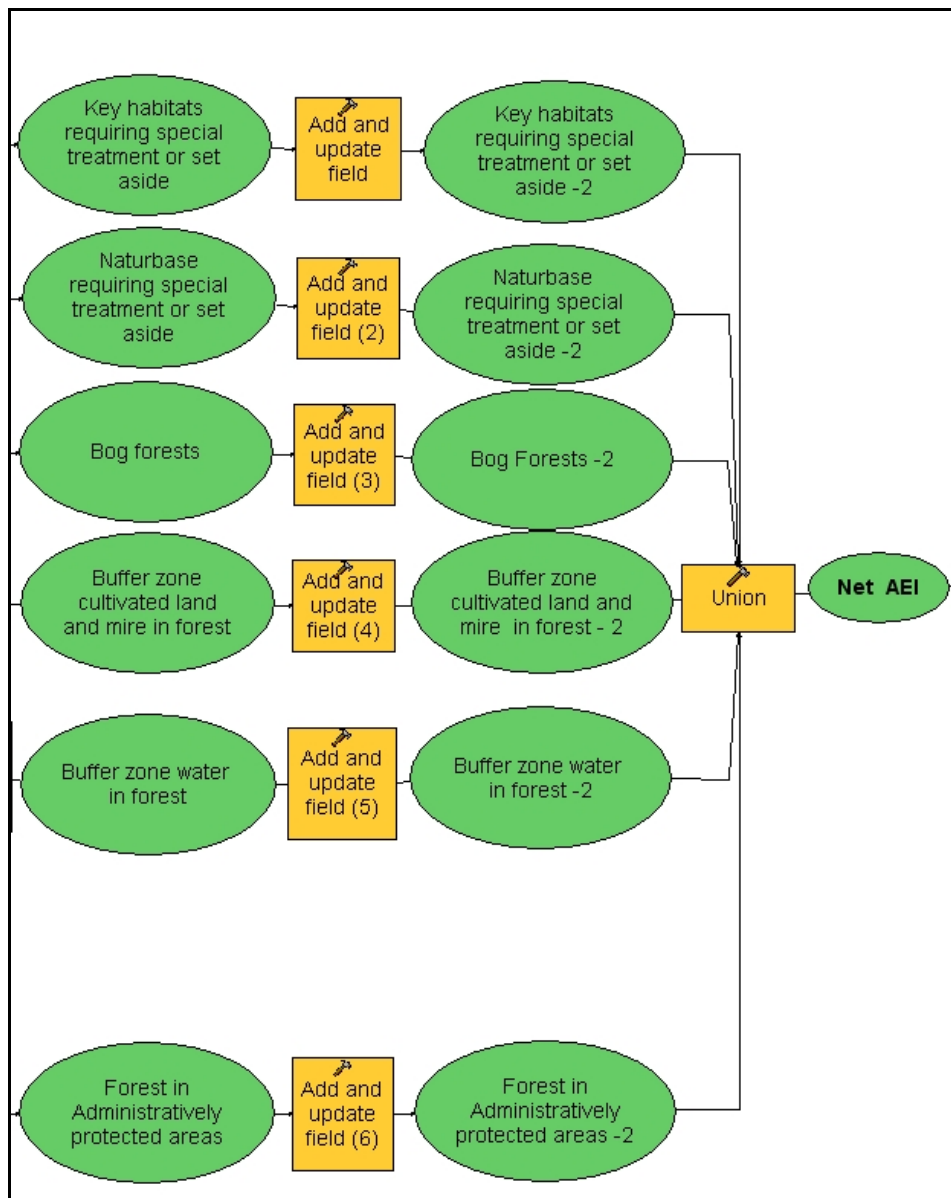
Figure 9: Conceptual workflow model for going from gross to Net AEI

4.4.2 Deletion of unmanageable polygons and update of forest attributes

The next step is to quality control that the net areas actually are an entity that is manageable on its own in forestry. In other contexts, e.g. the Environmental Inventory, 2 decare is considered to be the minimum area manageable as a separate entity. The workflow model contains steps to reduce standalone polygons that are less than 2 decare from the dataset, as shown in the continuation of the conceptual model in Figure 10. To ensure that only small standalone polygons are deleted the polygons sharing a border in the Net AEI dataset are first "Merged" together. In this new temporary dataset the area in each polygon is recalculated and only polygons up to 2 decare in area are selected.

Polygons from the Net AEI dataset at the same locations than the polygons up to 2 decare from the temporary dataset can then be chosen by the geographical selection "Are contained by" and deleted from the original Net AEI dataset.
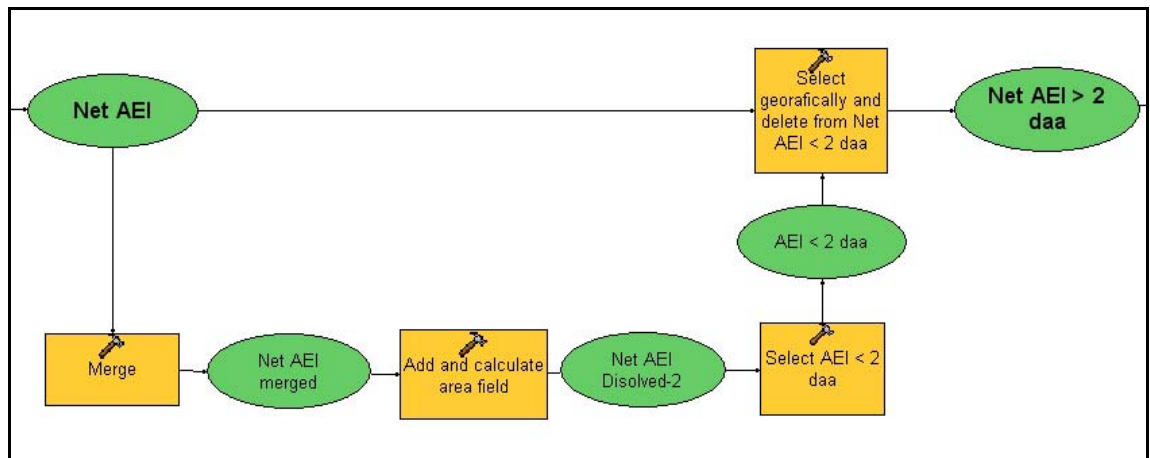
Figure 10: Conceptual workflow model for reducing AEI of unmanageable polygons

The last step needed, to obtain an AEI dataset that can be interpreted and evaluated in terms of ecological importance, is to incorporate attributes from the Land cover dataset and from Forest inventory. Attributes from forest in the Land cover dataset can be united using the geographical operation "Intersect" (q. v. 3.3.2). When uniting the attributes from the Forest inventory with the AEI dataset, the "Union" operation has to be used in advance of deleting the features not belonging to the AEI in the next step. This is necessary since the Forest inventory does not necessarily cover all AEI locations. For example, Administratively protected areas can be left out by the Forest inventory as can be seen in Løten municipality in Chapter 4.3.2. Figure 11 shows the operation necessary in the conceptual model. The result dataset includes all available attributes on forest, site quality and other related remarks available in the geodata that are input to the workflow model.
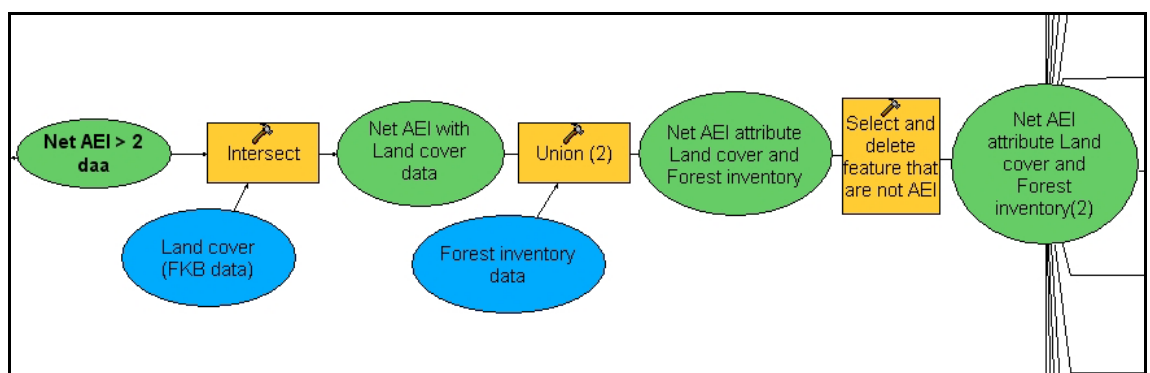
Figure 11: Conceptual workflow model for adding attributes from Land cover data and Forest inventory

4.4.3 Evaluation and selection by the ecological value

The dataset resulting from the conceptual workflow model in Figures 8 to 11 will be further examined in order to divide it into sites that are either productive forest or economically unproductive forest and to determine the ecological value of the different locations. Figure 12 shows how the different kind of special habitats are selected from the Net AEI dataset. Selection from this dataset with the given and updated attributes from earlier steps can make sure that the different selections in the sum still stay the net area and none of the locations is counted several times. Overlaps with other types make the location more valuable but in the statistic the location can only be counted once.
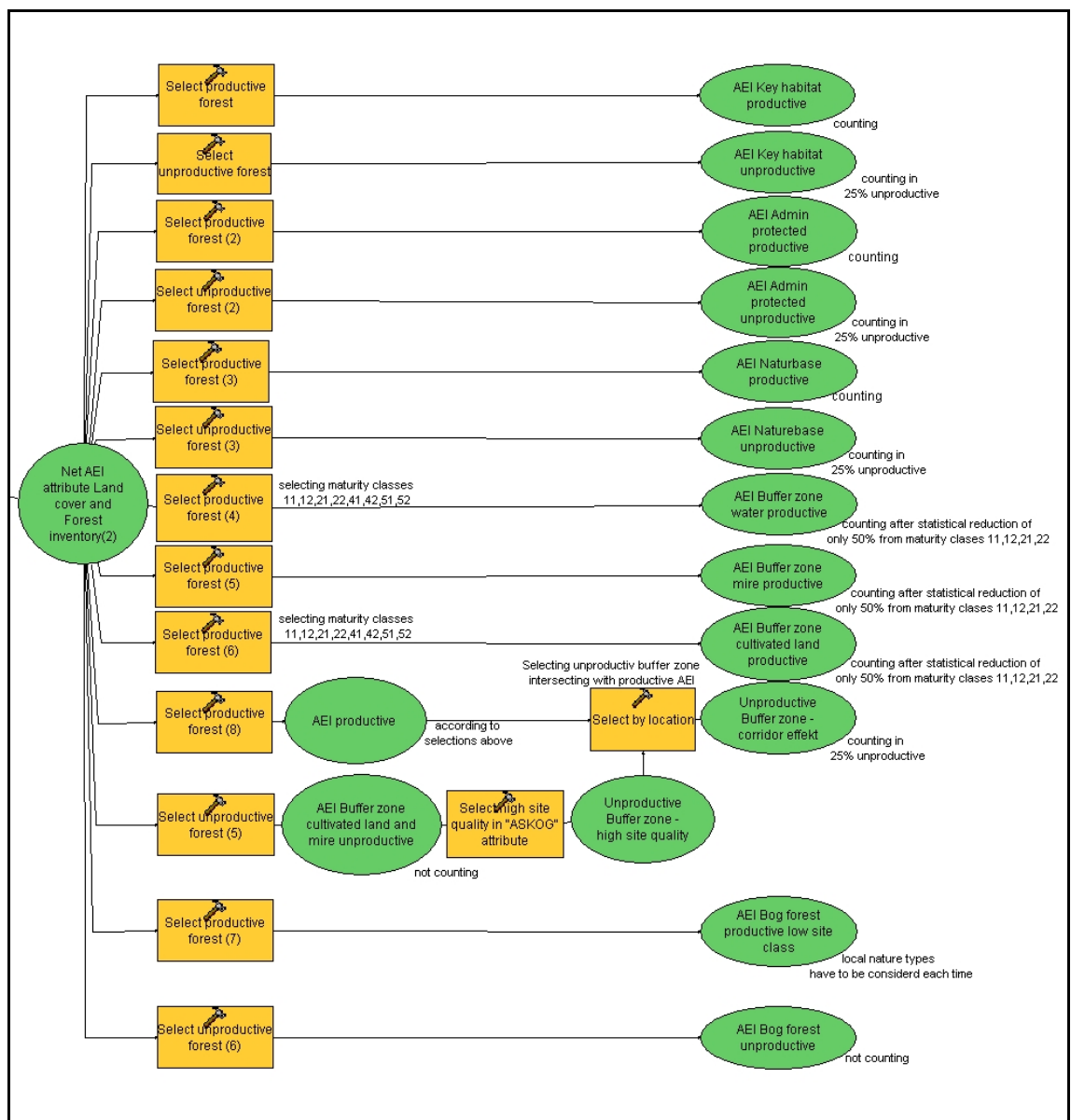
Figure 12: Conceptual workflow model for the division into origin classes and extraction of Complementary buffer zones for the documentation

The resulting datasets have different impact on the documentation. First of all the area of each dataset will be counted separately in productive and unproductive forest. Further, the value of the locations will be discussed. Whilst all AEI from Key habitat appraisal, Administratively protected areas and areas from Naturbase will count in the documentation without discussion, since these data were collected with this intent, the other datasets have to be evaluated with help of the attributes from both Land cover data and Forest inventory data.

Buffer zones around water, mire and cultivated land in productive forest area are always a basis for important ecology systems. However, not all of these areas can be counted as AEI because not all of it is currently treated as special. In 2004 a report by Hobbelstad et al (2004) evaluating the Living Forest Standard investigated at what percentage buffer zones have been taken into account in logging. It shows that in logging sites, currently in maturity class '11', '12', '21' and '22', only about 50 % of the sites still have an intact buffer zone. At the other sites the buffer zone is not intact due either to bad conditions of the site before logging, forest owners not following the certification, or to the fact that this maturity class also includes logging sites that have been arranged before 1995, i.e. before the LS was established (Hobbelstad et al, 2004) For this reason only 50 % of the area of maturity classes '11', '12', '21' and '22' counts as AEI. Maturity classes '31' and '32' do not count at all since these sites were established many years before the LS and most of the stands are expected to be monoculture stands with little diversity even in the buffer zones. Maturity classes '41', '42', '51' and '52' count completely, since old forests are the most valuable in biodiversity and here future logging must follow the LS where the forest owner wants to be able to sell timber through a certified organisation.

The bog forest class is also not counted completely as AEI. Although the LS requires special treatment of these locations due to high biodiversity there are doubts to the quality of the data in this class. Often et al. (2004) states that 90 % of the originally registered bog forest is gone, mostly due to drainage of higher site classes before the LS. In this class there is a lot of geographical variations expected so for different locations depending on, for instance, the site class, the age of the stand, areas might be counting as AEI in one nature type but not in the other.

The living forests standard also specifies that up to 25 % of the AEI in the final documentation can be economically unproductive forest. Locations with middle and higher site classes from the "ASKOG" attribute inside Administratively protected areas or within registrations in the Naturbase or else outside the Forest inventory area are most likely of high ecological value. Other than that a high ecological value is expected in Complementary buffer zones. These are the buffer zones in direct contact with the AEI in productive forest that are most likely to have high biodiversity. The Complementary buffer zones typically have a corridor function, which is very important for connecting high ecological value AEI from productive forest sites with each other. To extract the corridors a geographical selection of all buffer zones in unproductive forest that intersect with AEI in productive forest, described in the previous section, can be performed and the result area added to the documentation. The conceptual model of this evaluation process is included in Figure 12.

To sum up the areas that will count in the documentation of Areas of Ecological Importance within the certification system of the Living Forests Standard, the labels in Figure 12 point out which areas are deemed to be of ecological high value and which areas are not taken into account. Of the possible AEI areas in productive forest Key Habitat appraisal, administratively-protected area and Naturbase registrations are completely counted. Whether buffer zones count depends on the maturity class of the locations. Bog forests have to be evaluated with respect to the nature type of the municipality and other local differences. Unproductive forest sites can enlarge the AEI by up to 25 % of the AEI in productive forests. Unproductive areas for Key habitat appraisal, Administratively protected areas, Naturbase registrations and Complementary buffer zones can be part of this group.

Preparing and analysing the geodata through this model will give the statistical foundation for documentation of the Areas of Ecological Importance to be treated specially or set a side through the Living Forests Standard. Further calculations can be done with spreadsheeting, such as Excel. In particular, comparing and contrasting the data from the different requirement sections and their share of the sum of total AEI will be very interesting for further development and negotiation of the standard. It is on the contrary not very likely that a visualisation in maps or overviews over the municipality is informative. The structures within the different locations can be very small, bearing in mind that parts of the location might have values from two or more original datasets.

That and the size of the locations compared to the size of the municipalities are the main reason why documentation on a map is unlikely to be revealing. Plotting of map series, in for instance, a scale of 1:10000 would be a possible solution to visualise the data, but at this point the different locations must not be connectable to particular forest owners, making a map series undesirable for by the NFOA. Detailed maps can be quite efficient for use in some contexts. Large scale maps should be used in some cases to explain special coherences but with this type of map it is difficult to present a representative section of the municipality and in addition it has to be ensured that there are no recognizable landmarks on the map so the land can not be connected to a forest owner.

5. From conceptual model to implementation

The results from analysing the available geodata and the requirement sections were the basis to establish the conceptual model presented in Chapter 4.4. In this chapter these results are adjusted to the available software used for the implementation. Furthermore, the selections designed in the conceptual model are adjusted to the geodata format used in the implementation.

5.1. Using available data in the test municipalities

5.1.1 FKB dataset

As mentioned in Chapter 4.2.1 the FKB-dataset is available in two formats through the GEOVEKST agreement. SOSI format which is an entirely text based format and ESRI's proprietary shp-format. For the implementation the use of shp-format is preferable. Shp-format can be included easier into the workflow model tool and since data specified by the NFLI has to be in shp-format. The main difference in the context of this thesis between using the data as SOSI-format data or shp-format data is that SOSI-format can include point, line and polygon objects in one file while for the shp-format it has to be one file each. For most of the used data that doesn't make a big difference since the main data to analyse are polygon features and datasets. But in case of the water data, polygon as well as the line dataset will be used to create required buffer zones. From the FKB-dataset these files will be used:

> Land cover dataset (polygon features)

> Administratively protected areas (polygon features)

> Water dataset (polygon features)

> Water dataset (line features)

As pointed out in that same section of Chapter 4.2.1, the entire data listed above is specified to be in FKB level of detail C and an accuracy of +/- 2.0 m even if some of the features may be copied from other datasets with a higher detail level and higher accuracy.

5.1.1.1 Land cover data (polygon features)

A lot of information can be obtained from the Land cover dataset. As described in Chapter 4.2.1.2 the most interesting attributes are the "ATIL", "ASKOG" and "TSKOG" attribute. Four important datasets can be extracted from this file with SQL attribute queries. All SQL following queries on the source data are based on the fact of using shp-files in ArcGIS environment and the syntax is chosen according to that.

Forest (economically productive and unproductive)

SQL/VB statement 1: Selection of forest area

"ATIL" = 24 OR "ATIL" = 25 OR "ATIL" = 26 OR "ATIL" = 12 OR "ATIL" = 13 OR "ATIL" = 14

The forest dataset is an important reference file for further calculations on percentages of the forest area and it is a reference to extract forests out of other datasets as described in 4.4.1.

Cultivated land

SQL/VB statement 2: Selection of cultivated land

("ATIL" = 21 OR "ATIL" = 22 OR "ATIL" = 23) AND "AREAL_M2" >2000

Cultivated land is extracted to create the required buffer zones around this land cover type. The selection is limited to a minimum area for each patch of 2 decare.

Mire

SQL/VB statement 3: Selection of mire

"ATIL" = 11 AND "AREAL_M2" > 2000

Mires are extracted to create the required buffer zones to this land cover type. The selection is limited to a minimum area for each patch of 2 decare.

Bog forest

SQL/VB statement 4: Selection of bog forests

([TSKOG] = 11 AND ([ATIL] = 12 OR [ATIL] = 13 OR [ATIL] = 14 OR [ATIL] = 24 OR [ATIL] = 25 OR [ATIL] = 26)) OR [ATIL] = 12 OR [ATIL] = 13 OR [ATIL] = 14

Areas qualifying to be bog forests according to their attributes are selected. Further evaluation of the actual quality of the sites will be part of the evaluation process for the net area. (q. v. 4.4)

5.1.1.2   Administratively protected areas (polygon features)

The protected areas are represented by full covering polygons and no differences of land cover types inside the protected areas are made. Of the attributes mentioned in Chapter 4.2.1.3, the purpose of protection "FORMAL" is relevant to the AEI modelling since some protection areas, like groundwater protection, do not put any restrictions on forestry except usual sustainable forest management. Since this attribute does not have a fixed set of possible values, it has to be interrogated in each municipality for protection areas that don't restrict forestry and these have to be filtered out. In both test municipalities all polygons in the files are Administratively protected areas that put restrictions on forestry so in both cases no additional queries to filter out other areas are necessary.

Furthermore the forest covered land has to be extracted from the protected areas. The selection forest from the Land cover dataset can be used for this intention. That dataset suits the purpose best since for example Forest inventory might not cover Administratively protected areas even if geographically within the Forest inventory area as can be seen Figure 7 in Chapter 4.3.2, where Forest inventory simply left a hole where the protected area is.

5.1.1.3   Water dataset (polygon features)

The polygon water dataset is used to create buffer zones, which are restricted by the LS. Similar to the screening of mire and cultivated land the selection on this dataset will also be limited to polygons from 2 decare and more for lakes ('Innsjø') and in some cases ocean bordering on mainland ('HavFlate'). Rivers ('ElvBekk') characterized and digitalised as polygon features are always belonging at least to the breadth class 2, which classifies rivers between 1 and 3 m as listed and explained in Chapter 4.2.1.1 The SQL selection extracting that data is listed below:

SQL/VB statement 5: Selection of rivers, lakes and ocean polygons

("OBJTYPE" = 'ElvBekk' OR "OBJTYPE" = 'Innsjø' OR "OBJTYPE" = 'HavFlate') AND AREAL_M2 >=2000

5.1.1.4 <u>Water dataset (line features)</u>

The line dataset water is as well basis to create buffer zones, restricted by the LS. From this dataset all rivers and brooks ('ElvBekkMidtlinje') and breadth class 2, which classifies brooks with at least 1 metre breadth is the minimum that requires buffer zones, get selected as shown in the SQL statement below. Features that represent rivers broader than 3 m are represented in the polygon dataset as well and because of that not included in this selection. Other data that might be contained in this dataset, like ditches or channels will not be selected.

SQL/VB statement 6: Selection for brooks with minimum breadth 1 metre

"OBJTYPE" = 'ElvBekkMidtlinje' AND "VANNBR" = 2

5.1.2 Data from Forest inventory and Key habitat appraisal

Forest inventory and Key habitat appraisal data are both specified to be in shp-format and with the attributes described in Chapter 4.2.2 and 4.2.3 by the NFLI. The data from Forest inventory will mainly be used as reference data to calculate percentage of AEI in comparison to productive forest. A second main reference task is the evaluation of the AEI to find more information on the sites like maturity classes, site productivity classification and dominating tree species. For unproductive sites the Forest inventory can give some additional information. Forest inventory data will be used both as a complete file where all information is included and to extract a file for productive sites only for which the SQL query below is applied.

SQL/VB statement 7: Selection of economically productive forest in the Forest inventory

"AKTUELTMAR" < 30 AND "AKTUELTMAR" <> 0

The Key habitat appraisal data is one of the main data for AEI since its registration was focused on exactly the matter of special habitats and living conditions in the forest. The registration procedure allows that after registration some sites that turn out not to be rare in the municipality or sites with low biological value, can remain unrestricted forest

area. These areas are given the value '2' in the attribute "UTVALGT" and will not be included in the workflow of the AEI model. Value '1' is for restricted areas and with the help of the SQL statement below only those will be part of the documentations process.

SQL/VB statement 8: Selection of key habitat sites that where especially valuable

"UTVALGT" = 1

5.1.3 Data from Naturbase

According to the description introduced in Chapter 4.2.4 the data in the Naturbase file is very versatile and collects different data from different sources in one file. Naturbase is because of that also the least standardized dataset, which is used in the workflow. Prior to use this dataset is has to be examined to decide if the data or what parts of this dataset can be used. Problematic can be the unknown scale of the registrations and as a consequence, or in addition, the unknown accuracy of the data in this file. Very helpful for this examination is the description of the different municipalities as given in Chapter 4.3, the contact to local authorities and, if available, former registration instructions. There is no fixed set of possible values for the most important and descriptive attribute "NATURTYPE", which makes it impossible to set up a query in advance. The decision which registrations to use has to be made after examining the data before the model is run.

The following SQL/VB statement 9 is the query that is used for running the workflow model in Snåsa municipality. The Naturbase dataset for this municipality is an extraction from the WMS-service providing data from Naturbase. The evaluation which values should be included is based on the description of the climate and nature types in Chapter 4.3. From the registration it is known that the digitalisation was carried out on older topographical raster maps from the FKB-dataset. Thus it can be assumed that the registration scale is suitable. All selected nature types are specially mentioned in the Living Forests Standard and part of the AEI that have to be set aside.

SQL/VB statement 9: Selection from Naturbase for Snåsa municipality

"NATURBAS_5" = 'Bekkekløft og bergvegg' OR "NATURBAS_5" = 'Gammel barskog' OR "NATURBAS_5" = 'Gammel lauvskog' OR "NATURBAS_5" = 'Gråor-heggeskog' OR "NATURBAS_5" = 'Kalkskog' OR "NATURBAS_5" = 'Sørvendte berg og rasmarker'

SQL/VB statement 10 is for the Naturbase file that was given to disposal from Løten municipality. The occurrences depending on nature types have been verified through information from the municipality. In addition wild life registrations have been carried out recently and these are part of the Naturbase file in Løten. A few registrations of the nature types in the file can be ignored in the AEI calculation, apart from these all registered features are set aside from regular forestry.

SQL/VB statement 10: Selection of Naturbase for Løten municipality

"NATURTYPE" <> 'Viktig bekkedrag' AND "NATURTYPE" <> 'Kilder og kildebekker' AND "NATURTYPE" <> 'Kroksjøer, flomdammer og meand'

5.2. Implementation tool

The basic principals of graphical programming environments have been introduced in Chapter 3.4. ESRI's ModelBuilder is an implementation of these principals and it developed into a powerful geoprocessing tool since its introduction in ArcView Spatial Analyst in 2002. For the implementation of the geoprocessing model in this thesis ModelBuilder in the ArcGIS 9.2 service pack 4 environment is used. The workflow editor in ModelBuilder is a drag-and-drop flowchart inspired framework and models can easily be build, stored, documented and shared (ArcGIS 9.2 Desktop Help).

Licensing within the ArcGIS software is divided in three licensing levels. ArcView and ArcEditor licenses give only limited access to geoprocessing tasks within the software package, while ArcInfo is the all inclusive version for ArcGIS. However, for the implementation only ArcEditor is available, which means there are a few restrictions on use of geoprocessing operations. Other limits of the implementation are due to the software ArcGIS rather than about ModelBuilder it self as well. ArcGIS is still a native 32-bit application running in 64-bit environments of Windows operating systems. It can not make use of the expended memory space available in the 64-bit systems (ESRI technical article, 2005). This causes some detours especially when using large files for modelling whole municipalities.

After pointing out the systems weaknesses, ModelBuilder is a very intuitive environment to implement and automate geoprocessing tasks. The drag-and-drop framework gives the opportunity to implement quite complex models without loosing the big picture and it is easy to follow the main flow of the conceptual model. Another

main advantage of the ModelBuilder is the possibility of sorting and systematizing temporary results including flagging of short-term data as intermediate data and then have the program deleting it when the model has finished successfully (ArcGIS 9.2 Desktop Help).

5.3. Adjustments to the conceptual model

The conceptual model in Chapter 4.4 has been developed on basis of the requirement sections of the Living Forests Standard and the available geodata, depending on data's purpose of registration and depending on their attributes. In the implementation adjustments due to the covered extent of the different datasets, the different file formats and data types have to be made.

As clearly shown in Figure 5 (Chapter 4.3.1) the different data do not always have the same geographical extent, as for example the Forest inventory is limited to the more productive areas since the gain in the low productive areas is far less then the costs. Because of this an area of analysis is added that defines the geographical area for which the model is run. All source data will be clipped to the area of analysis dataset. This will also be very helpful for running the model on special interests if, for instance, only one single forest owner should be evaluated.

Through the differences between the data formats it was defined in the first part of this Chapter that mostly polygon data will be used. The exception is the water data for the buffer zone analysis where two datasets, line and polygon files, have to be included in the model. The buffer zones can be united with a "Union" operation after running the each buffer operation is carried out.

In Figure 13 all adjustments from the previous sections in this chapter can be seen in an adjusted version of the conceptual model. The line dataset from the water data is included to create a buffer zone. In addition there is an option to select Administratively protected areas in case the file includes areas that put no restriction on forestry. Further a "Clip" operation has been added between each source data and the area of analysis, which was introduced in the section above.
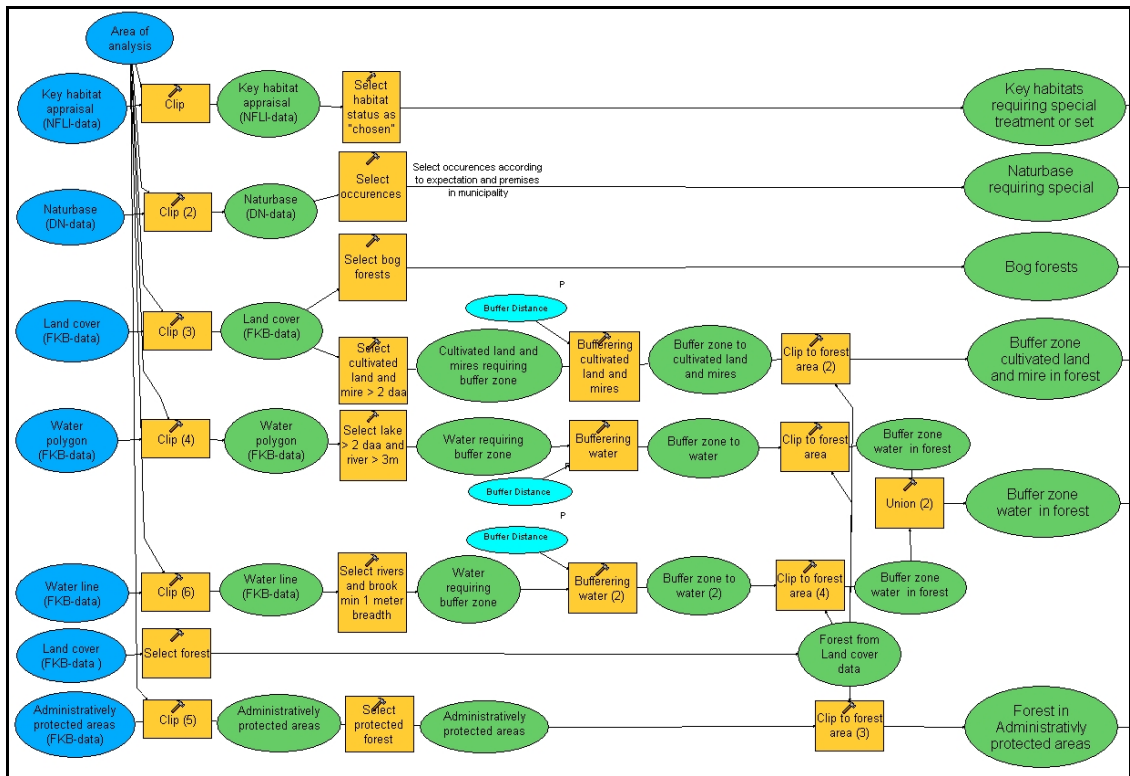
Figure 13: Adjusted conceptual workflow model for the gross Area of Ecological Importance

5.4. Implementation

On the basis of the adjusted conceptual model an implementation in ModelBuilder within the ArcGIS environment is build. First of all, to ensure the model can be shared with other users, a structure for the model and its environment has to be defined. All model concerning components will be stored in one folder. The toolbox for ArcGIS containing the model will be stored directly in this folder, which is called "LevendeSkog". In addition, a subset of folders will be arranged in the "LevendeSkog" folder. These folders are for temporary files "Temp", for data that is a fixed component of the model "Data" and a folder for queries used in the model "Utvalg". Second, some basic parameters can be set in the model properties. This includes a property that ensures that all paths in the model are stored as relative path names, which can be arranged in the "General" properties of the model. It also includes environment settings where paths for current workspaces and the workspace for temporary files can be arranged. To ensure the current workspace and the temporary workspace will always be available to the model these to parameters are set to the shared model folder "LevendeSkog" for the current workspace and to the "Temp" catalogue with the path "LevendeSkog\Temp" for the temporary workspace. As relative pathnames this is visualized with "." for the current workspace and with ".\Temp" for the temporary

workspace. Intermediate and temporary data in the whole model can now be stored in the temporary workspace by defining the location in the model as "%scratchworkspace%\" as path for all intermediate data. With this basic setup a model can be shared between different users, computers and working environments.

The model properties in the ModelBuilder give the opportunity for setting several other values to apply to the whole model, for example the possibility to define the extent of all analyses in the model. This would be an option to use instead of working with the area of analysis file inside the model. One reason not to use this option is that some data, like the Land cover dataset, can be interesting both inside and outside the Area of analysis. In addition, documentation on the extent of the Area of analysis is easier when it is implemented in the model it self instead of using a parameter in the environment settings.

The implementation of the main workflow will follow the conceptual model closely where this is possible. Some parts of the concept, however, where not straight forward and had to be implemented through extra steps or other workarounds. In the following figures the implemented model is shown in parts to visualize some important steps[4]. In the model only the visual names have been translated to English for documentation in the thesis. In the original implementation all file names, selections and documentation in the model are in Norwegian only.

In the arrangement of the workflow a geodatabase will be created where all results and all other data regarding the result will be stored. The geodatabase has three feature datasets for "Reference files" ("ReferanseFiler"), for instance forest from the Land cover data, "Gross area" ("BruttoArealer") feature dataset and a "Net area" ("NettoAreal") feature dataset for the result files. The location of the geodatabase, the name of it and the coordinate system of the feature datasets is implemented as parameters that can be defined before each time the model is run. Considering the coordinate system it is specified that all source files and all results have to be in the same coordinate system and the same projection for each time the model is run. In Figure 14 the first steps of the model can be followed up. Creating the personal geodatabase and feature datasets is the first step in the left middle part of the diagram.

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[4] Figures of the wokflow model in an overview are shown in the appendix

The feature dataset "Referansefiler" is then updated with data from Forest inventory and forest data of the Land cover dataset in the upper middle part of the picture. Blue and light blue shapes that are marked with a "P" are parameters that must be specified by the user when running the model.

5.4.1   Gross area selections

In this part of the model bog forests, Key Habitats, relevant Naturbase locations and relevant Administratively protected areas are extracted according to the SQL statements as described in Section 5.1. With the geoprocessing "Clip" the selected files are clipped to the area of analysis. All geoprocessing models in the implementation are not only connected to the input and their output file but to a parameter for the XY tolerance as well. The XY tolerance is implemented as a parameter that the user is requested to choose each time the model is run. After the selection are clipped to the area of analysis they will be imported in the "BruttoAreal" feature dataset of the geodatabase created in the first step. All files in the "BruttoAreal" feature dataset, also the buffer zones that will be presented in the next section, get a field update. The field will be used later in the Net area file to define overlapping values from different Areas of Ecological Importance. The field names are given according to the AEI the location belongs to. For example the field of the KHA will be named "HensynMIS", which has a similar meaning as "AEI_KHA". All other gross area files get a new field following that system. The field type is a short integer and will simply be updated with the value '1' for all features in the feature class. That means all features in the KHA feature class get the value '1' in the field "HensynMIS". With this system all features can easily be traced back to their primary origin even after running further geoprocessing operations.
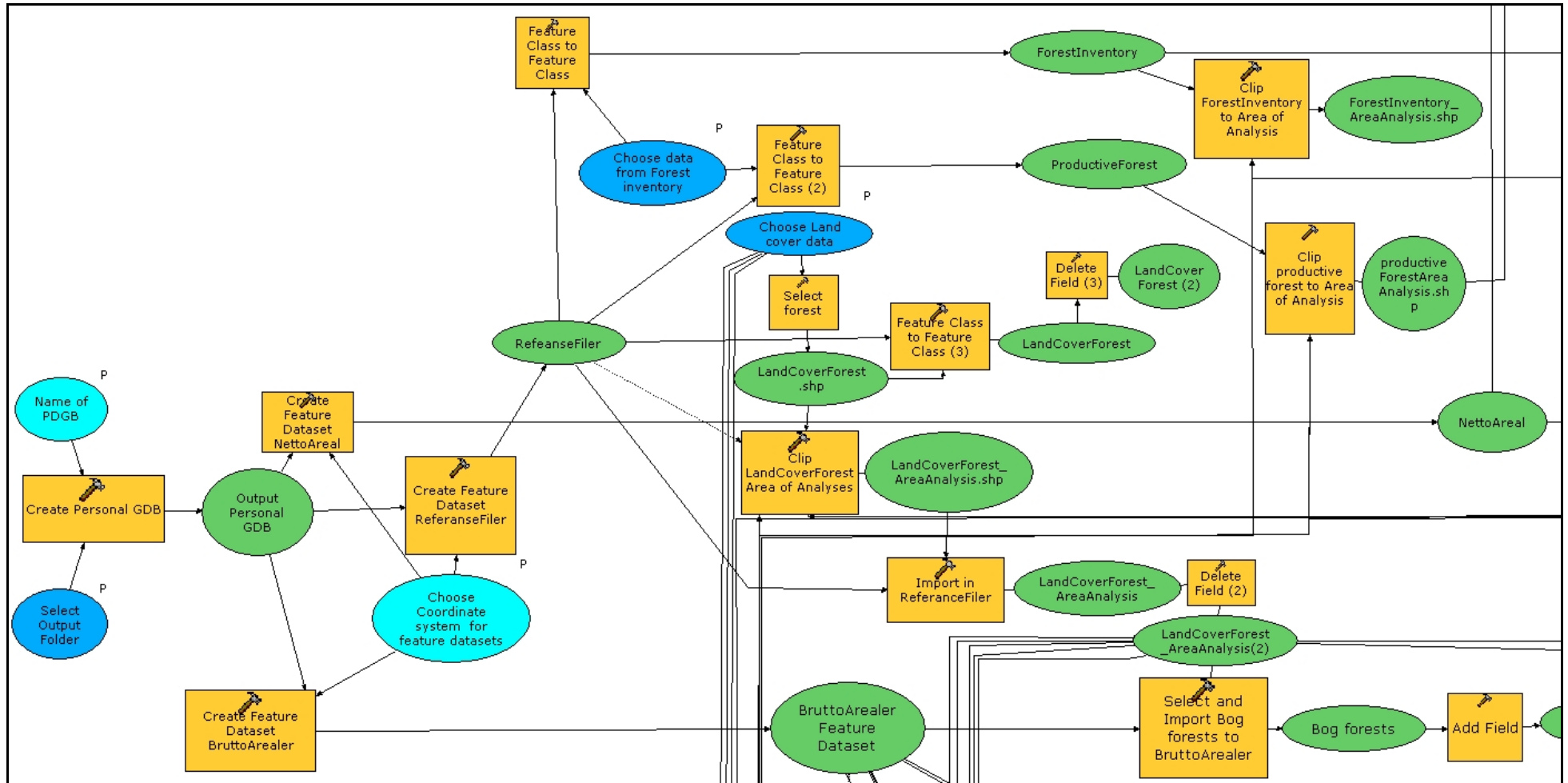
Figure 14: First step of the workflow model; Creation of a geodatabase and feature datasets

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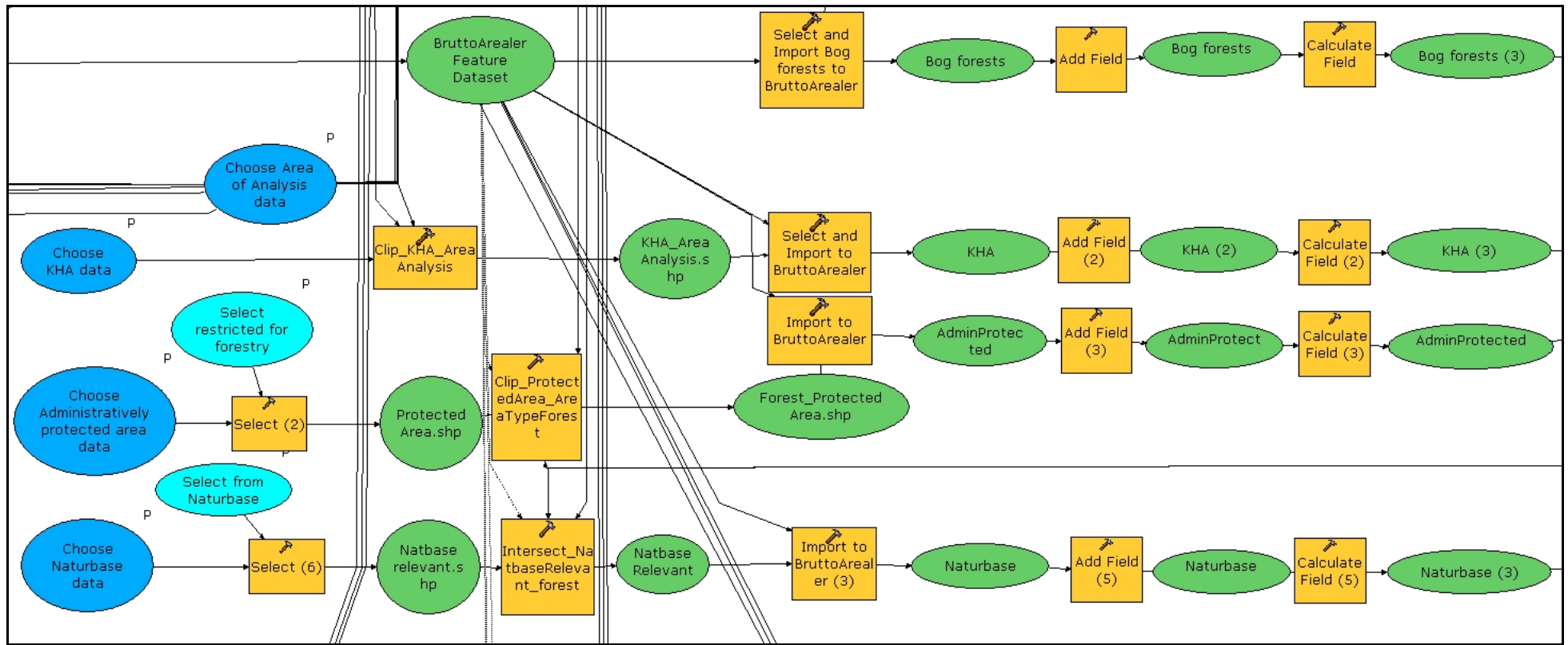
Figure 15: Gross area selections

5.4.2 Buffer zones

The selection of areas requiring special care or set a side from using does not cause any problems of realization in the model. The first challenge is the realization of the buffer zones to the datasets water polygon and mires from the Land cover data. These two datasets consist of very detailed and often complicated structures. Especially in bigger municipalities they contain a lot of complex polygons. In ArcGIS buffer operations can be run with the option of dissolving all buffer polygons in order to make sure that the resulting data file does not contain any overlapping areas. This option has to be used for all the buffer operations in the model since the calculation of the AEI are obviously depending on none overlapping features. The buffer operation using this option fails. This happens for both the water polygon dataset as well as the dataset that selected mires from the Land cover data. As a solution both datasets have been divided into two temporary datasets each according to the polygon area. The minimum size for requirement of a buffer zone is 2 decare. Therefore each file is divided in a dataset from 2 to 10 decare, SQL/VB statement 11 is used for the water polygon data and SQL/VB statement 13 is used for mires from the Land cover data. These datasets still include many of the complex features but the buffer operations runs without failing. The other datasets are for polygons more then ten decare, SQL/VB statement 12 for water polygon and data SQL/VB statement 14 for mires.

SQL/VB statement 11: Selecting lakes between 2 and 10 daa

AREAL_M2 < 10000 AND AREAL_M2 >=2000

SQL/VB statement 12: Selecting lakes lager than 10 daa

AREAL_M2 >= 10000

SQL/VB statement 13: Selecting mire between 2 and 10 daa

"ATIL" = 11 AND "AREAL_M2" > 2000 AND "AREAL_M2" <=10000

SQL/VB statement 14: Selecting mires larger than 10 daa

"ATIL" = 11 AND "AREAL_M2" >10000

Afterwards, a "Union" operation is implemented for the two buffer zones from the divided water polygon data set. This results in a complete buffer zone for the water polygon dataset. The two mire datasets are aswell joined together by a "Union"

geoprocessing operation and the result is the buffer zone dataset on mires. The entire process of creating the buffer zones is documented in Figure 16. First the water data selections and all following geoprocessing operations can be traces. The second part in the middle of the figure shows the implementation on creating the buffer zones for mires. And in the lower part the buffer zone creation around cultivated landscape can be traced. In addition each geoprocessing operation is not only connected to input and output data but also to the XY tolerance parameter described in the sections on gross area selections.

After updating the attributes as described in the section above, the gross area of AEI has to be turned into a none overlapping net Area of Ecological Importance file. This is a multi step procedure in ModelBuilder using the ArcEditor license. This license allows the "Union" operation only with two files for each operation. It therefore takes six "Union" operations to combine the seven different data files of the gross AEI to one none overlapping file.
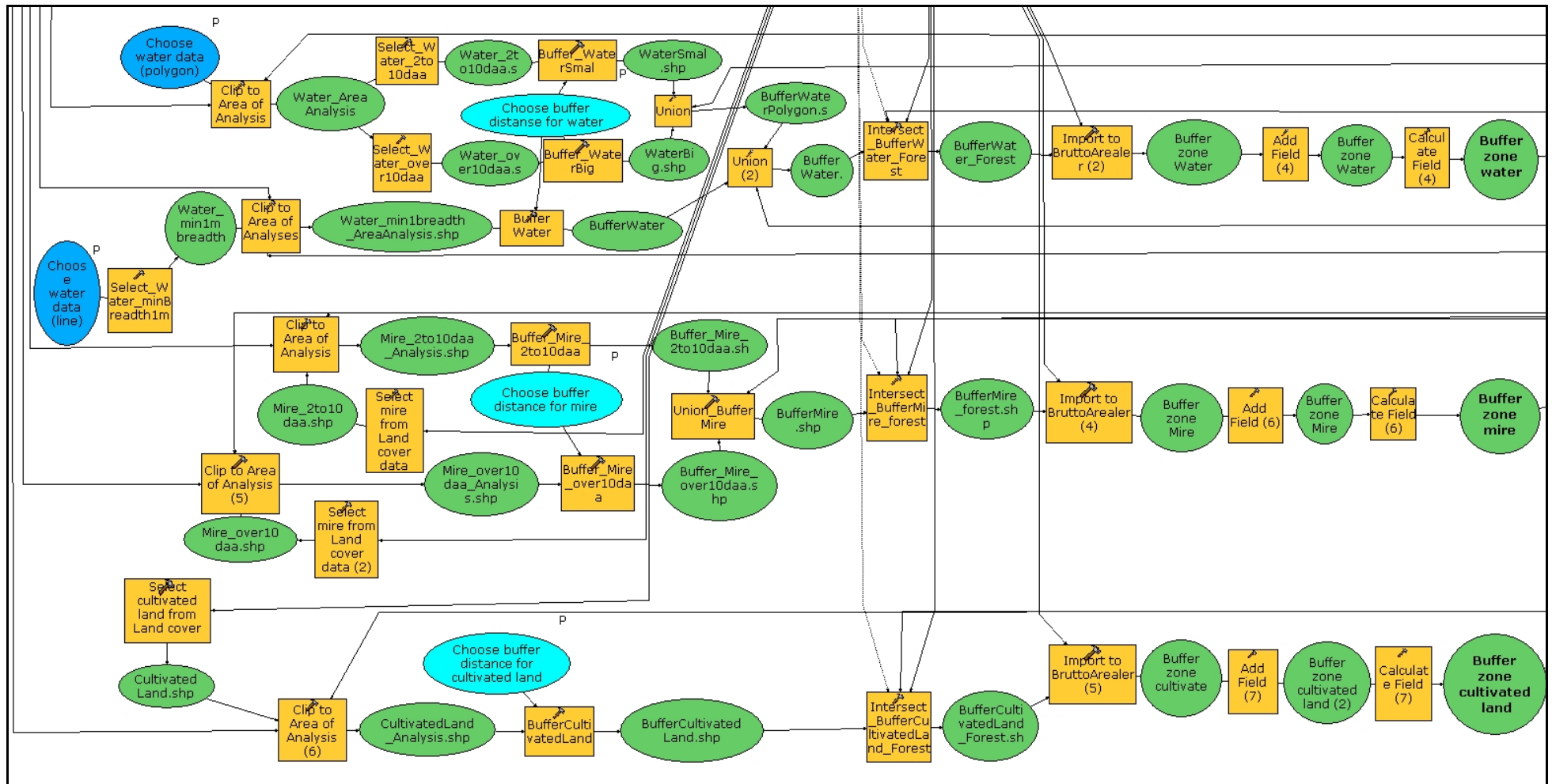
Figure 16: Buffer zones for water, mire and cultivated land

5.4.3 Deleting unmanageable polygons from the Net AEI

In order to extract the areas that do not have a manageable size, all features have to be merged together. It has to be made sure that all the polygons are standalone polygons and no multipart features are in the dataset. Multipart features would give a wrong result since here the area of many very small standalone polygons is calculated as one feature. The multipart features can have an area bigger than the manageable minimum value but in reality each small polygon is placed alone all around the municipality. Unfortunately, the buffer operations with the dissolve option, as described in Chapter 5.4.2, resulted in a lot of multipart features and subsequently a "Multipart to singlepart" operation has to be run. This should be just a simple step but nowadays implementation of ArcGIS does not have enough memory to perform this operation on so many detailed and complex features as in the AEI net area file. A solution to this limitation was discovered in the "Clip" operations from the conceptual model where the created buffer zones are clipped to forest data file in order to only extract buffer zones that are forest land. Using an "Intersect" operation instead of the "Clip" operation changes the complex features of the buffer zone operations so much that there is no longer a memory limitation problem for the "Multipart to singlepart" operation. It can also be seen in Figure 16 that all "Clip" operations between the buffer zones and the forest dataset have been replaced with "Intersect" operations in the implementation.

On basis of the now produced singlepart features for the Net AEI the polygons smaller than the manageable size will be deleted. In the conceptual model this is contemplated as a merging of all features without creating multipart features. In the ArcGIS ModelBuilder this normally can be done with a "Dissolve" operation. Unfortunately, ArcGIS can not use all resources of the 64-bit environment and due to this it reaches its limit faster and this resource demanding operations cannot be executed on the Net AEI dataset. The workaround presented in the implementation is based on the tiling system which ArcGIS should be using if all resources would be used. The idea is to dissolve first within smaller areas and then continue to bigger area. As mentioned, the tiling system does not work as intended in the 64-bit environments and this idea is realized manually in the model. As can be seen in Figure 17, two "Intersect" operations are run. First with an index file ordinance survey on a 1: 5000 scale and the second one with a

scale of 1: 10000. These two files are available in the "Data" folder, they cover all of Norway and they will be distributed together with the model. The "Dissolve" operation will be conducted on attributes of these files. For the 1: 5000 dataset the attribute for the "Dissolve" operation is "R_KART" and for the 1:10 000 dataset it is "R_KART_10". The result of the dataset merged like this, is considered to be sufficient for the purpose of extracting and deleting unmanageable polygons and the rest of the concept is implemented. A new field is required to calculate the areas of the dissolved polygons. Next all polygons smaller than 2 decare are selected by creating a layer view. Another layer view is created from the singlepart file before it was dissolved and "Selection by location" operation on both files can be run. Polygons from the AEI singlepart dataset can be selected with the spatial query "Contained By" where they are within the features that are smaller than 2 decare in the dissolved AEI dataset.

The resulting selection is deleted from the AEI singlepart file (AEI_Single) and the result is imported into the "NettoAreal" feature dataset, which was created in the geodatabase described in Section 5.4. This is the result Net AEI file on which all additional interpretation and evaluation will be based on. Figure 17 visualizes the described workflow for this part of the model. Worth noticing in this workflow diagram is the thinner dashed line reaching from the "make layer view" to the polygons smaller than 2 decare. This is a precondition connection that can prevent the model from conducting an operation without the necessary variables available. In this case the "Select by location" operation can only be carried out if the datasets on both sides are available and the precondition line is controlling the order of it. This kind of precondition symbols can be found several places in the model where it is necessary to make sure that an operation is not run before others are carried out.
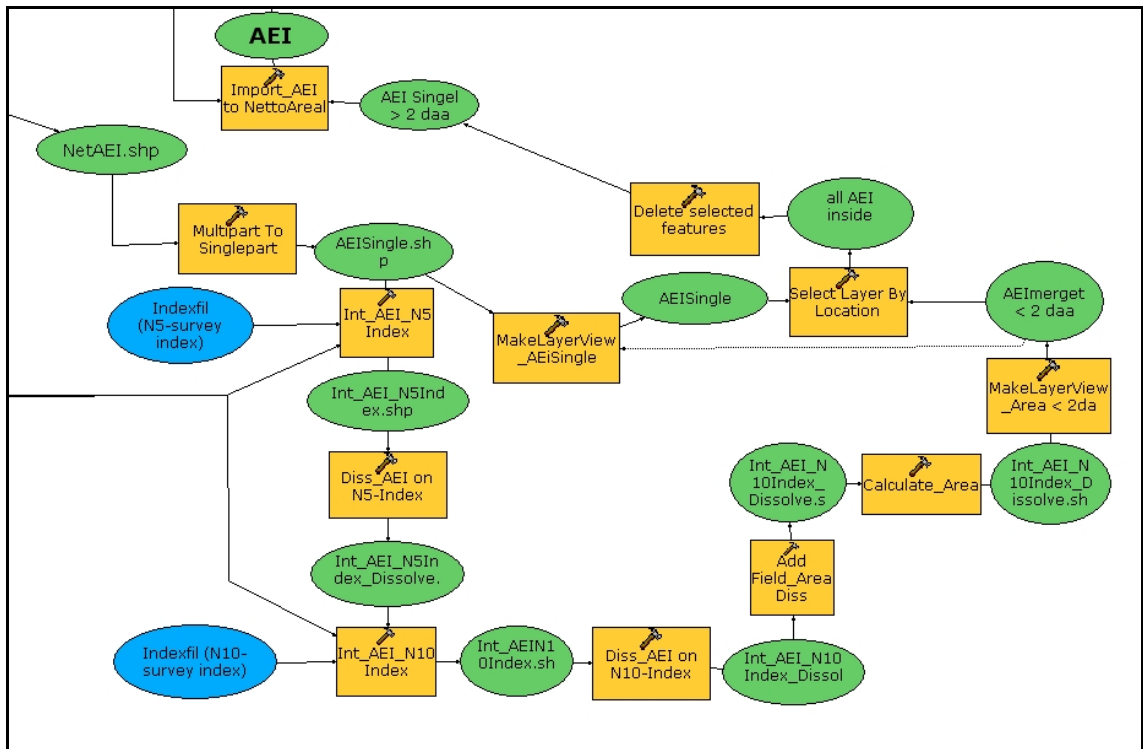
Figure 17: Deletion of locations smaller than a manageable size threshold

5.4.4 Presentation of result data

In order to have the possibility to interpret the resulting data on AEI that are treated with special care or set aside from forestal use, the attributes in the dataset have to be updated. Through the many geographical operations and combinations of different datasets the amount of attributes has been increasing. The management of these attributes was no longer possible because of fieldnames that were changed automatically by the software. The changes are partly random and not consistent from one run of the model to the next. The field map option that defines fields to be imported to a geodatabase did not work correctly when there are many attributes in one file. Because of this, attributes were reduced to the essential ones during the different operations in the model. The "Union" operation of the buffer zones where executed without keeping attributes. At the beginning of the model several fields that are not important to the documentation, such as from the Land cover dataset, are deleted before further use of the dataset. The result AEI file, after deleting unmanageable polygons, in the "NettoAreal" feature dataset contains only fields from the field update of the gross area files (q. v. 5.4.1). First step in order to make the dataset more interpretable is to update it with a new field "HovedHensyn". This new field will be updated with

information of the primary AEI origin of each polygon. The fields created in the gross area files allow this update with the Visual Basic statement shown below:

SQL/VB statement 15: Updating the attribute "HovedHensyn"

Dim hen as string

If ([HensynMIS] =1) Then
hen = "MiS"
Elseif ([HensynKVan] =1) Then
hen = "KantsoneVann"
Elseif ([HensynKMyr] =1) Then
hen = "KantsoneMyr"
Elseif ([HensynKDyr] =1) Then
hen = "KantsoneDyrket"
Elseif ([HensynNatV] =1) Then
hen = "NaturVernOmr"
Elseif ([HensynNatb] =1) Then
hen = "Naturbase"
Elseif ([HensynSump] = 1) Then
hen = "Sumpskog"
Else hen = ""
End If

This field update makes it obvious for all users of the dataset to determine from which gross AEI dataset the polygons has its primary origin. In addition this field will allow selections to make sure that each polygon will only be selected in one query while checking for any double AEI status is easily done on the original fields from the gross area update.

Further there is an "Intersect" and an "Union" operations run. The "Intersect" operation is run with a selection of the most important fields of the forest dataset extracted from the Land cover dataset. The "Union" operation, as described in Chapter 4.4.2, will be carried out on a selection of attributes from the Forest inventory. These additional steps make a complete dataset on the AEI that can be further investigated and evaluated.

In order to prepare for further evaluation the AEI file is updated with a new field for the polygon area of each feature in the common Norwegian unit decare. Afterwards it can be divided in different files that are expected to make the best starting point for

calculating the perceptual amount of AEI area in the municipalities like shown in the final part of the model in Figure 18[5]. In addition the selection on Complementary buffer zones is implemented in this step of the result presentation.

The complimentary buffer zones are created on the basis of the corridor effect that these areas have. The connection between the different AEI that these locations present is very valuable in biological dynamics. By selecting first unproductive buffer zones with middle and higher site class a layer view is created for this selection. In addition, a selection is run that selects all AEI in productive forest as they are selected form the Net AEI. The "Select by location" operations "Intersect" that selects all unproductive locations, which are intersecting with the productive locations, gives a result dataset to take into further reckoning on AEI by for example spreadsheet calculations.

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[5] The SQL statements for the selections are listed in the appendix
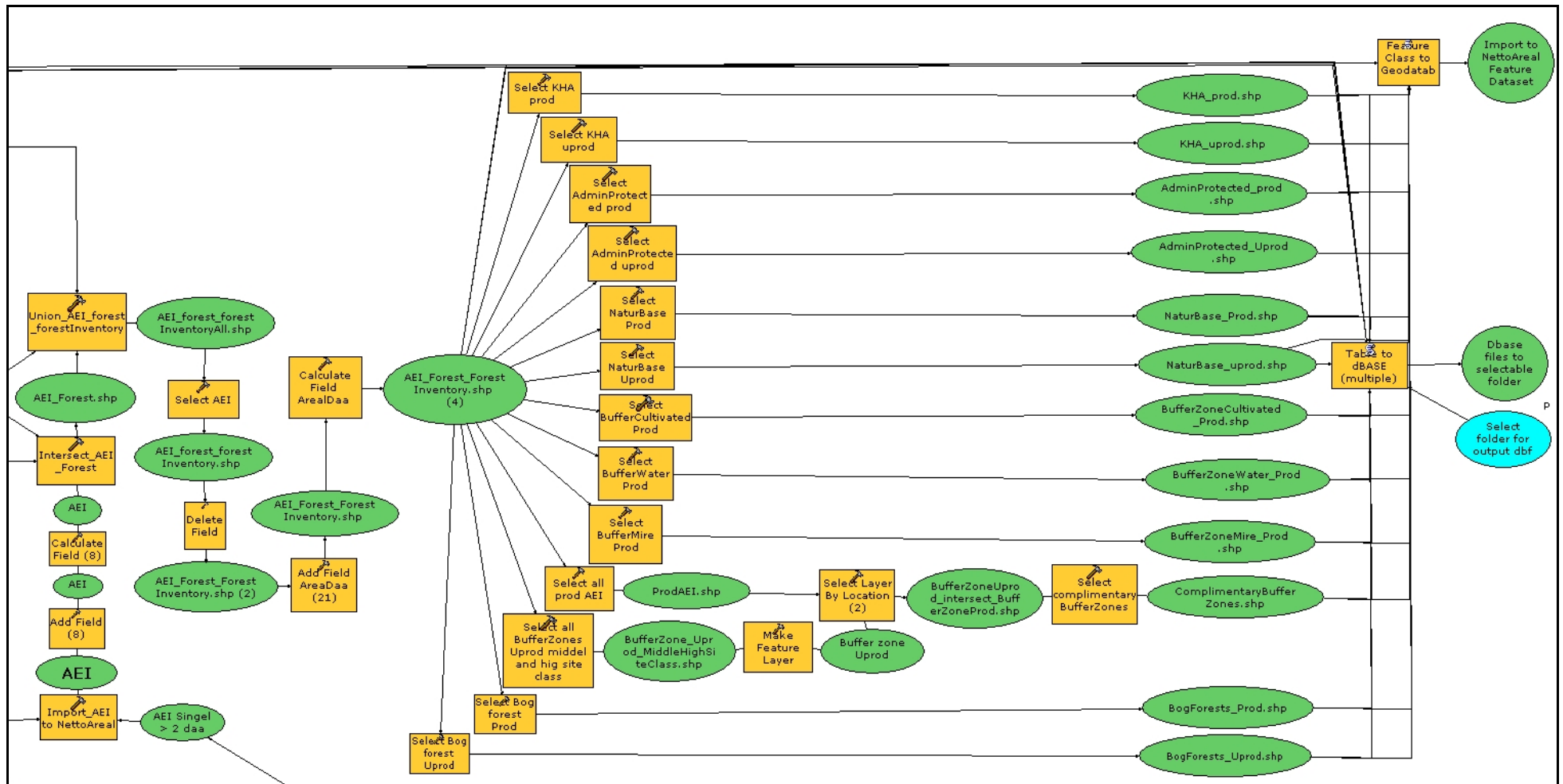
Figure 18: Presentation of the result data

6. Results

The assumption made by the Norwegian Forest Owner's Association leading to this thesis, was to be able to prove with existing geodata that the AEI on a regional level is at more than 5 % as required by the Living Forests Standard. According to the demands given by these requirement sections the following different AEI can be extracted or created from the available geodata.

- ➢ Areas from Key habitat appraisal
- ➢ Administratively protected areas
- ➢ Areas registered in Naturbase
- ➢ Buffer zones to water
- ➢ Buffer zones to mire
- ➢ Buffer zones to cultivated land
- ➢ Bog forests

All source data for the areas mentioned in the listing, except the data from Naturbase, is either standardized through SOSI, the Norwegian geodata format and standardization scheme, including the GEOVEKST agreement or the Norwegian Forest and Landscape Institute. Naturbase data is a none standardized dataset that the Norwegian Directorate for Nature Management assembles, administrates and publishes. It contains amongst others data on nature types, wildlife habitats and threatened species. This dataset can be used where data quality and accuracy are satisfactory. For other requirement sections like Mature forest or Pasture woodland no standardized geodata is available to be included in the calculations at this moment.

6.1 Area of Ecological Importance in the test municipalities

After the introduction of the municipalities in Chapter 4.3 and the description of the implementation with the available and accessible data, the calculation of the Area of Ecological Importance has been carried out for both boroughs. The test was run with two quite different municipalities in Norway. Placed at climatic and geologically very different areas in Norway, there is also a difference between utilisation possibilities of the areal between agriculture, forestry and wilderness area. The areas of analysis are the

same as the extent covered by Forest inventory but including Administratively protected areas.

In Table 9 the areas from the different requirement sections in Snåsa municipality have been calculated and summed up. The seven different AEI classes are cleared from any overlapping area and they have been evaluated and reduced according to the evaluation explanations given in Chapter 4.4.3. Most important point of that Chapter was the reduction of the area of the buffer zones with 50 % of maturity class '11', '12', '21'and '22'. The foundation for that was in an evaluation report of the LS (q.v. 4.4.3). Another reduction is conducted on the bog forest AEI. The location of the municipality in Norway and the climatic and geographical conditions do only account for bog forest in maturity class 5 to be particularly valuable in terms of biological diversity. Younger forests are expected to be on drained into highly productive sites in the past production period. These drained often planted monocultures let little room for biodiversity.

The result in the municipality Snåsa in Table 9 shows with 10.7% a much higher percentage of AEI for the whole municipality than required. This is not unexpected for this municipality as pointed out in Chapter 4.3.1 the climate is very rough in the region and agriculture and forestry are in large parts of the municipality only extensively driven. In the table the percentage of AEI in comparison to productive forest area only is also summed up. This number can be an interesting assessment as well and it is in this municipality with 8.8% still very high over the required 5%, even without unproductive forest can be included (q. v. 4.1.10).

AEI net area	Area in daa
KHA productive	3110.36
Administratively protected productive	1593.45
Naturbase productive	1367.07
Buffer zone water productive (reduced maturity class 1+ 2 with 50%)	9327.16
Buffer zone mire productive (reduced maturity class 1+ 2 with 50%)	5816.76
Buffer zone cultivated land productive (reduced maturity class 1+ 2 with 50%)	1365.92
Bog forest productive (reduced to maturity class 51 and 52)	1248.03
Productive AEI	**23828.75**
% AEI of productive forest	**8.81**
KHA unproductive	21.27
Administratively protected unproductive	2333.68
Naturbase unproductive	58.56
Complementary buffer zones	3425.33
Unproductive AEI	**5838.84**
Reduced (if more) to max 25 % of productive AEI	**5838.84**
Sum AEI	**29667.59**
Productive forest area	270400.46
Forest area (Land cover data) in Area of analysis	399843.99
productive forest area + unproductive AEI	**276239.30**
AEI % Snåsa municipality	**10.74**

Table 9: AEI in Snåsa municipality[6]

The summary for Løten municipality is listed in Table 10. The same sections are listed as for the other test region. The result for Løten is with only 5.4% much lower than in Snåsa and it only reaches slightly over the 5 % mark demanded in the certification. Løten is geographically and climatically completely different from the other

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[6] Crosstabulation calculations for Table 9 and 10 are listed in the appendix

municipality and the area is known to be intensively driven. Løten as described in 4.3.2 is a region that is very well suited for agriculture and intensive farming has been found there for centuries. This applies for the forest area too, which is still the dominating land use in that area.

AEI net area	Area in daa
KHA productive	2059.29
Administratively protected productive	692.40
Naturbase productive	1307.01
Buffer zone water productive (reduced maturity class 1+2 with 50%)	3859.28
Buffer zone mire productive (reduced maturity class 1+2 with 50%)	972.80
Buffer zone cultivated land productive (reduced maturity class 1+2 with 50%)	768.29
Productive AEI	**9659.06**
% AEI of productive	**4.36**
KHA unproductive	91.52
Administratively protected unproductive	9784.84
Naturbase unproductive	2335.94
Complementary buffer zones	2032.18
Unproductive AEI	**14244.48**
Reduced (if more) to max 25 % of productive AEI	**2414.76**
Sum AEI	**12073.82**
Productive forest area	221403.13
Forest area (Land cover data) in Area of analysis	277862.70
productive forest area + unproductive AEI	**223817.89**
AEI % Løten municipality	**5.39**

Bog forest (Land cover data) productive	5020.81

Table 10: AEI in Løten municipality

The major difference between the two sum ups is the part of the bog forests. As described in Chapter 4.4.3 the data of this land cover type is doubtable in some parts of the country. As for Løten municipality a disappearance on this land cover type has been discovered in an environmental report, establishing that 90% of this land cover type had disappeared prior the Living Forests Standard. In Løten it is with the current knowledge and data not possible to connect the remaining 10 % to a certain land cover type, site class or maturity class. This is the reason why the area from this requirement section is not counted into the final percentage and is only listed last in the table without being added up in the result.

Another reason for a quite low result in Løten is the high amount of unproductive forest in the Administratively protected areas. In Figure 7 in the introduction of Løten municipality it is visualized that Forest inventory did not cover the whole area of the borough. One of the not inventoried areas is an Administratively protected area in the north of the municipality. From the location and altitude of this protected area it could be estimated that at least 30 % of this area are productive forest. Both arguments the missing bog forests and additional productive forests from Administratively protected areas could be added to the documentation after more forest-biological evaluation. However, it is not the scope of this thesis to evaluated and manually add other data to the documentation.

6.2 The AEI Workflow Model

By no means are the two test municipalities a representative selection of Norwegian municipalities. Because of this the enforcement of the calculations for the test areas is implemented as a workflow model. This model can be run for all municipalities in Norway if this way of documenting AEI gets approved by the Living Forest Council (q. v. 2.2).

The conceptual model, presented in Chapter 4.4, together with the adjustments to the different data types in Chapter 5.3 has been developed on the conditions of the requirement sections of the LS and the available and accessible geodata for municipalities in Norway. Implementation within ArcGIS' ModelBuilder created several challenges that demanded some workaround to fully implement the calculations within a geoprocessing model. The complete implementation with all the workarounds

is described in Chapter 5.4. The resulting implementation is a model "BVO_generisk" in a toolbox for ArcGIS called "LevendeSkog". The user interface shown in Figure 19 is from a copy of the model that was translated to English in the parts concerning the user interface and the diagrams used for the documentation in this thesis. The whole file structure behind the interface and the help documentation is not translated but in Norwegian only.
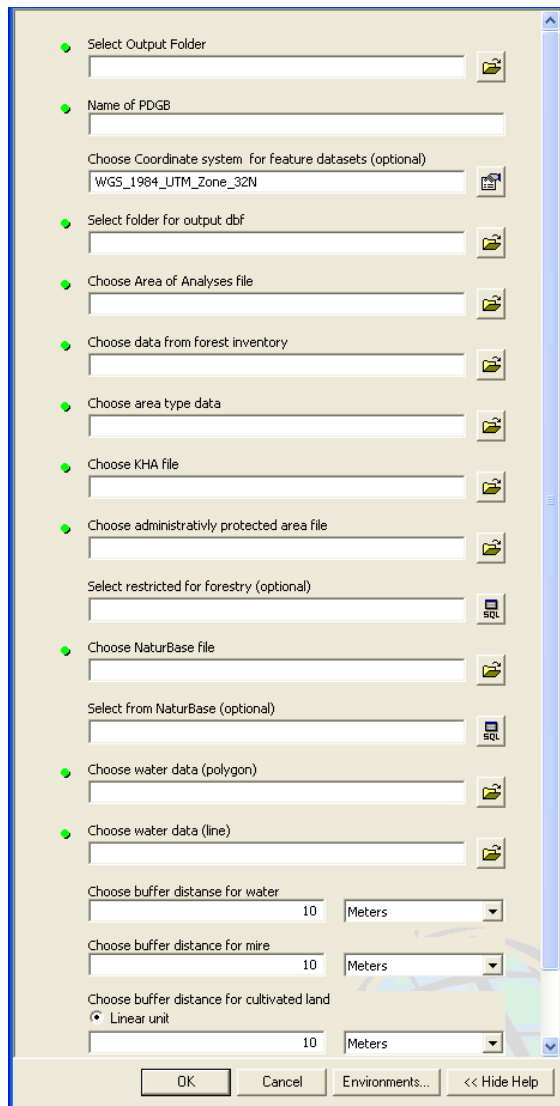
Figure 19: Workflow model user interface

In the user interface the result directories and the name of the result geodatabase can be chosen together with all source data needed in order to run the model. For the data on Naturbase and for the administratively protected area there is also an optional field to select only a part of the data with a SQL statement. The query can either be typed directly in the upcoming dialog or it can be prepared and stored in advance, when the data is investigated. Another parameter that the user is requested to choose is a value for

the buffer zones on water, mire and cultivated landscape. The default value for the buffer zones is the usual average of 10 metres but it can be adjusted to, for example, investigate how the result would change the amount of AEI.

With this workflow model the foundation for the documentation on Areas of Ecological Importance can be prepared for other municipalities in Norway.

7. Sensitivity analysis

The sensitivity analysis of the result on AEI is necessary:

➢ To investigate if the chosen parameters in the model have a considerable impact on the result.

➢ To find out if results will turn out significantly different if the parameters chosen for some of the requirements of the Living Forests Standard are different.

Since geographical and climatic differences are considered to be less important for comparing different parameters the sensitivity analyses are only calculated and evaluated in the municipality of Løten. For the sensitivity analyses on geoprocessing tolerances and for the analyses on slivers, the comparison is on the level of the Net AEI dataset. The comparison is easier before the selections for the evaluation on the biological value are performed and an assessment on this dataset only is much easier to review.

7.1 Tolerances in geoprocessing operations

For all geoprocessing operation XY tolerance can be chosen before running the operations. The tolerance should be the best adjustment to, on one hand, the need of accuracy and the detail of the data and, on the other hand, the optimal reduction of slivers created by these operations (q. v. 3.3.2). The results presented in the previous Chapter where all computed with an XY tolerance of 0.5 metres. In the following the results of model runs with different XY tolerances are presented.

Table 11 shows the resulting AEI for the workflow model in Løten municipality at 0.2 metres, 0.5 metres, 1 metre and 2 metres. The latter is the minimum accuracy specified for the source data (q.v. 4.2) and is therefore considered to be the maximum of tolerance

that is reasonable for this data. The table shows a decrease of the Areas of Ecological Importance with increase of the XY tolerance. This is especially significant for the step from a tolerance from 1 metre to 2 metres XY tolerance. Meanwhile this proportion is different for the number of polygons. Here the most significant decrease is between the XY tolerance of 0.5 and 1 metre.

Area in decare	XY Tolerance in metres			
Main AEI reason	0.20	0.50	1.00	2.00
Buffer zone Cultivated land	4484.98	4475.45	4422.05	4185.34
Buffer zone Mire	5707.70	5700.11	5683.30	5590.56
Buffer zone Water	12441.36	12427.86	12369.80	2154.18
KHA	2150.36	2150.81	2152.51	2154.18
Naturbase	3646.53	3642.95	3643.66	3652.27
Admin protected areas	10474.57	10477.23	10489.08	10551.75
Bog forests	14925.70	14924.54	14920.98	14939.07
Total	53831.21	53798.96	53681.38	52998.68

Number of polygons	44000	42000	36000	35000

Table 11: Comparison of AEI after running with different tolerances

With the results of Table 11 it is shown that the XY tolerances of the geoprocessing operations in this model do not have a major impact on the result as long as they are chosen within the defined accuracy level. The question how to choose the correct tolerance level is not only a question of numbers in the result table but also a biologic-professional one. Even the difference in the total amount of AEI is not that big, it makes biologically a difference. In Figure 20 an arbitrary section of the results in the municipality is shown with all the different XY tolerance layers. The reduction of the buffer zones to not connected areas is biologically a most important difference. It can been seen clearly that the blue buffer zone with the 0.5 metre tolerance level is creating a connected buffer zone on both sides of most rivers, while the light green area with a XY tolerance of 1 metre has undesired openings. The differences between the 0.5 metre tolerance and the 0.2 metre tolerance are in contrary only minimal and in most parts they can only be seen in a much more detailed scale. Because of this the previous

executions of the workflow model for the result presentation is the best decision with an XY tolerance of 0.5 metres.
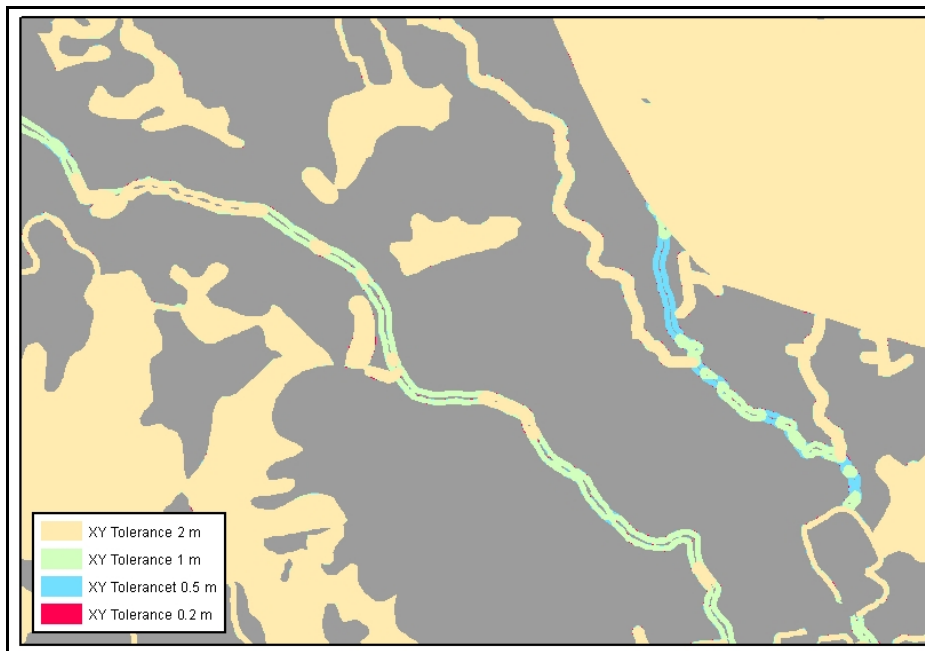
Figure 20: Arbitrary extent showing the disappearance of buffer zones with higher tolerances

The results from Table 11 and the map in Figure 20 show that the selection of the right XY tolerance level does make a difference in several points of the AEI calculations. Although the different tolerances do not affect the results based on the spreadsheet calculations a lot it definitely makes a difference for the biological value of the calculated areas.

7.2   Slivers

Slivers produced in geoprocessing operations are in direct correlation to the XY tolerance used in the geoprocessing environments. The identification of slivers, which are nothing else then artefact polygons, can be done interrogating different attributes. Mostly the area of the polygon is an important indicator to identify slivers but also the length of the outline or a ratio created by the length of the outline and the area. For the datasets produced with the different tolerances a shape index has been calculated to add information of compactness of each polygon in order to investigate if other values than the size of the polygons have to be considered when identifying slivers. The shape index was calculated by the following equation:

$$\text{Shape-Index} = p / 2* \sqrt{(\pi * a)}.$$

For this sensitivity analysis the first selection on slivers has been done by the size of the polygon. The amount of polygons smaller than 0.05 decare is increasing with a decrease of the tolerance, see Table 12 for the result numbers according to the different XY tolerances. While the amount of slivers is clearly decreasing with the increasing of the XY tolerance the amount of area of the slivers is not reduced as much.

Tolerances in metres	Number of slivers (<0.05 decare)	Area in decare	Mean Shape-Index
0.2	11258	197	2.03
0.5	9016	182	1.7
1	6640	161	1.5
2	3755	114	1.4

Table 12: Numbers of slivers, selected by area, for different tolerance levels

In the next selection only small polygons of less than 0.05 decare with low compactness, that means a shape-index more than two, have been selected. Low compactness of a polygon can often be a good indicator for artefact polygons that have been created due to none covering boundaries of the different datasets.

Table 13 shows the number, area and mean Shape-Index of this selection. With this way of identifying slivers a lot less polygons are considered to be artefact and the covered area of those is not significant for the whole municipality.

Tolerances in metres	Number of slivers (<0.5 decare AND Shape-Index >= 2)	Area in decare	Mean Shape-Index
0.2	4137	66	2.9
0.5	2306	46	2.6
1	772	21	2.3
2	79	3	2.2

Table 13: numbers of slivers, selected by area and shape-index, for different tolerance levels

Both selections of slivers show that the amount of area is not significant for the AEI calculations of the workflow model. Furthermore even being artefacts this small polygons are expected to be in direct connection with other AEI since small stand alone polygons of AEI have been deleted before intersecting the Areas of Ecological Importance again with the two forest datasets. Because of this connection the slivers are as valuable as other polygons and deleting them would only cause openings between the

other areas. How to deal with the slivers in order to make reduce the numbers of polygons and the improve visualization on a map will be discussed in the conclusions.

7.3 Parameters from the Living Forests Standard

Besides parameters connected to Naturbase and different Administratively protected areas, which are embedded in the workflow model as SQL selection parameters, the most important parameters are the breadths of the buffer zones created around water, mire and cultivated land. The Living Forests Standard demands a 10 metres buffer zone for these three classes with some exceptions to extend or reduce the breadth. Depending on the conditions at the sites the buffer zones have to be between 5 and 15 metres.

Due to the possibility of different breadths for the buffer zones the model has been run with different values. The results are listed in Table 14. The different breadth values have been selected regarding to the demanded size of the buffer zones and the accuracy of the data, which is +/- 2 metres for the FKB dataset used for the selection of features to be buffered. (q.v. Chapter 4.2.1.)

Area in decare			
Size of buffer zone	Total	productive (without Maturity class 3)	none pod
3	4820.92	1772.74	3048.18
5	8552.76	2509.04	5273.48
8	14080.24	5766.69	8313.55
10	17582.01	7493.57	10088.44
12	20940.65	9226.41	11714.23
15	25747.36	11845.21	13902.16

Table 14: Buffer zones with different breadth

As expected, changing the buffer zone value has a major impact on the amount of area in the AEI. Comparing the value on which the presented results in Chapter 6 were based, the amount of AEI with the lowest value of 3 m in table 14 is just about a fourth of the buffer zone area presented as the result. The share of buffer zones in the result accounts for about 40 % of the AEI in the productive forests. Because of this major impact the results have been summed up for the lowest buffer zone value to be presented in the same way as the results were presented in Chapter 6. The lowest buffer

zone value (3 m) is based on the minimal buffer zones breadth and a maximum accuracy error. A summary identifies, if the demand of 5 % of AEI is still given with this minimal buffer zone used for the whole municipality.

With a buffer zone of only 3 m the percentage of AEI in Løten municipality is down to only 3 %. Given the results in Chapter 6.1 for the municipality it is not surprising that the 5 % mark is no longer achieved. It is on the other hand not expected that a buffer zone with only 3 m will be created all over the municipality. Both 3 m and 5 m buffer zone are only expected occasionally. It is, however, very interesting how the results change for the average 10 m buffer zone, if reduced by the maximum accuracy tolerance specified for the FKB-data. To get an impression on the sensitivity of the result on this parameter the model has been run with an 8 m buffer zone. In Table 15 the new areas for the different buffer zones in productive and unproductive forest are replaced, all other values are the same as in Chapter 6.1.

The result of the model run with this reduced buffer zone indicates that the 5 % mark for Areas of Ecological Importance has not been reached. Still the areas discussed in Section 6.1 on bog forest and some of the Administratively protected areas that were not part of Forest inventory will be able to be included manually after professional evaluation and it is expected that the final result than will just reach the 5 % mark.

8 metres buffer zone	Area in daa
KHA productive	2059.29
Administratively protected productive	692.40
Naturbase productive	1307.01
Buffer zone water productive (reduced maturity class 1+2 with 50%)	3041.68
Buffer zone Mire productive (reduced maturity class 1+2 with 50%)	720.81
Buffer zone cultivated land productive (reduced maturity class 1+2 with 50%)	543.38
Productive AEI	**8364.57**
% AEI of productive forest	**3.78**
KHA unproductive	91.52
Administratively protected unproductive	9784.84
Naturbase unproductive	2335.94
Complementary buffer zones	1681.05
Unproductive AEI	**13893.35**
Reduced (if more) to max 25 % of productive AEI	**2091.14**
Sum AEI	**10455.71**
Productive forest area	221403.14
Forest area (Land cover data) in Area of analysis	277862.70
productive forest area + unproductive AEI	**223494.28**
AEI % Løten municipality (buffer 8 metres)	**4.68**

Table 15: AEI results with 8 metres buffer zones

8. Conclusions and discussion

8.1 Summary

Through modifications in the revised Living Forest Standard the question about the percentage of Areas of Ecological Importance that are set a side in Norwegian forestry has become a major issue for forest certification in Norway. In this thesis data for two representative test municipalities have been analysed to provide documentation of the amount of AEI on municipality level. In addition the data have been analysed to determine if the level of standardization of geodata on municipality level is sufficient to develop a workflow to provide the same documentation for other municipalities in Norway. With this intention a conceptual model has been designed on the requirements given by the available geodata and by the requirements of the LS. Furthermore the conceptual model has been implemented in ModelBuilder within the ArcGIS software environment to be able to run the documentation process for any other municipality.

The available geodata on municipality level have been analysed in matters of:

- ➢ Standardization,

- ➢ Available attributes concerning the requirement sections of the Living Forests Standard,

- ➢ Accuracy,

- ➢ Availability for forest owners and

- ➢ Accessibility of the data with the available software.

On the basis of this evaluation of the geodata and on account of the requirement sections of the LS a conceptual model has been designed to extract and create Areas of Ecological importance valid for all Norwegian municipalities. In the conceptual model seven different AEI types have been extracted or created.

- ➢ Areas from Key habitat appraisal
- ➢ Administratively protected areas
- ➢ Areas registered in Naturbase
- ➢ Buffer zones to water
- ➢ Buffer zones to mire
- ➢ Buffer zones to cultivated land
- ➢ Bog forests

Each of these AEI types is treated differently in the final evaluation of these areas. Key habitat appraisals, Administratively protected areas and selected areas from the Naturbase dataset have unquestionable ecologically high value since this data is created for exactly that purpose. Buffer zones in contrast do not necessarily have a very high ecological value on the whole created data file. This is the reason why only a selection of it is counting in the sum up of AEI. The data on the last AEI kind, the bog forests, are in some areas not reliable enough, where they are found in intensively driven areas in Norway. These sites are often drained and turned into highly productive forest sites whose ecological value is not about average. Otherwise bog forest can have especially high biological value in mature forests on low productivity site classes.

Executing the documentation process for the two test municipalities Løten, in Hedmark county, and Snåsa, in Nord-Trøndelag county, it was found that the amount of AEI is at least 5 % of the productive forest area in each borough. For Løten, which is an intensively used area in terns of farming and forestry, the amount of AEI did not exceed the 5 % mark by much. Considering then the possible inaccuracy of 2 metres of the geodata the 5 % mark was not reached and the AEI result was only at 4.7%.

In the discussion of the result it was shown that the final result of AEI will always need some professional evaluation of forest areas, which can not be part of the workflow model. These exceeding biological evaluations vary according to geographical and

climatic conditions on a detailed level within each municipality. In the case of Løten municipality the AEI productive area would be enlarged by parts of the Administratively protected areas that are now counted as unproductive, simply because Forest inventory did not take place in these areas. Including these considerations, the amount in Løten municipality is also expected to reach the 5 % mark. These professional evaluations, on productive or unproductive forest sites in protected areas are not part of this thesis and therefore not further investigated. For Snåsa municipality the amount of AEI calculated by the workflow model is 10.7 %. Thus no additional professional evaluations are necessary.

The implementation of the generic model, as a tool to document AEI in different areas, has been done with a graphical programming language in ModelBuilder which is part of the ArcGIS software environment. The implementation turned out to be a complex model. The implementation of the conceptual model was challenging in itself and limitations of the software required several workarounds and detours.

Two main limitations were encountered when implementing the workflow model. First a major limitation is that ArcGIS software is a native 32-bit application and the software can not use all of the virtual memory that today's 64-bit processors have available. This puts limitations on memory intensive operations such as "Dissolve" or transforming "Multipart to singlepart features". To solve this problem the datasets or operations had to be split in several steps or operations. The second challenge was the limitation of the software licence available. The available ArcEditor licence from the ArcGIS software package is used by several main actors in the local forest owners' associations that have interest in the AEI workflow model. With this license some out-of the-box solution, like the "Union" operation on several files, are missing and these operations had to be divided into several steps, too.

In conclusion this thesis brought together and analyzed the different requirement sections of the Living Forests Standard and the available geodata on municipality level. On this basis different Areas of Ecological Importance can be extracted and created. The implementation of the generic workflow model with the help of a graphical programming language in ModelBuilder gives the opportunity to run the documentation process for other municipalities of interest or to repeat the documentation of the test boroughs at any time or with different parameters.

8.2 Discussion

The major advantage for implementing the workflow model with a graphical programming language was expected to be the visual documentation value of the implementation and the opportunity given to non geo-informatics specialists to implement a model without having special programming competence. The latter assumption was fulfilled and the necessary software skills were easily acquired, even though some challenges and limitations of the software had to be solved by workarounds. In contrary, the visual value of the implemented model is less than expected. The fact, that many parts, for instance adding and calculating a field, have to be done in several steps plus the workarounds, have made the visual impression of the model very complex.

In addition, the complexity of the visual impression has been increased by setting up parameters, which are connected at many points of the model, and by a few preconditioning connections that make sure that the timeline in running the model is correct. For this reason the model was only presented in parts in this thesis, which were following the structure given in the less complex conceptual model. The implemented model is not expected to have presentation value for none GIS specialists and the level of the conceptual model will be used for this task. Nevertheless using this way of programming simplifies the understanding of the documentation process for other GIS professionals. With this understanding the model can be extended and enhanced.

An issue that has not been discussed yet in the thesis is the up-to-dateness of the used data. In matters of the requirements this is not considered an issue for the conceptual model and the implementation. However, it can have an impact on the availability of the data in the first place. Forest inventory data, for example, are originally data that are supposed to be collected with a ten year cycles. In reality the available data can be much older than this. It is therefore recommended before running the model to evaluate if the data has the required up-to-dateness to calculate AEI in the municipality.

The value of the implementation in matters of how much area the requirement sections of the LS actually refer to is indisputable. In addition there can be made estimations based on of the Forest inventory data on how much timber is contained in these areas and subsequently what the estimated economical losses are for the forest owners.

On the other hand the value of this implementation in terms of the actual biological value for all this area referred to in forestry certification is highly controversy. In the end only field inventory could determine the actual biological value of each site and if this value is of special ecological importance. Even so, certification schemes can at this point not demand a field inventory on every addressed section in their schemes, since that would result in extremely high audit costs. At the moment the gained advantages on the market are not justifying such high costs for the certification. So in the end it will be a mainly political decision of the different stakeholders if documentation on this level is sufficient or not.

8.3 Prospects and improvements

Throughout the implementation and discussion of the workflow model a few future developments and improvements have been brought to attention. First mentioned are improvements that can be included in the existing workflow model. Secondly improvements in separate models could be implemented in order to investigate and check the quality on the source data before running the model.

As for the improvements within the already existing model the buffer zone parameter that is now the only difference between the three major groups water, mire, cultivated land should be considered to be implement with several options, such as smaller buffer zones for the smaller mires or the smaller sites of cultivated land. These operations are already run as two different steps in today's model and the adjustment could be made according to that.

Another major issue in order to improve the model is the reduction on slivers. As discussed in Chapter 7, slivers are all together not a considerable amount of area but deleting them would cause small openings in the AEI, which are most valuable if they are connected. So for the results of the spreadsheet calculations of the AEI the slivers are not making a big difference. For potentially visual presentation of some different areas the slivers would make any map very difficult to present. Unfortunately, only the complete license for the ArcGIS package has an option for this operation available. The theoretical possibility is to merge slivers, for example, under a certain size, together with the neighbouring polygons that they share the longest border with. It is possible to customize ArcGIS and the models in ModelBuilder with scripting in Python or Visual

Basic. For further improvement of the AEI workflow model it should be attempted to extend the model with such an process. This improvement would not change the actual amount or proportions of the AEI severely but it would improve the model a lot in terms of presentation of the result and it would give the result layers and tables an easier manageable amount of polygons.

The developments outside the existing model could cover quality control of the source data. A model could be implemented to make sure the source data are in the same projection. Furthermore, another model could control that the required fields used in the AEI model exist and last but not least a pre-investigation model should be implemented to make sure that none of the source data in each file contains overlapping features. This is not detected and included by any part of the now existing AEI model, which only deals with overlaps for the extracted or created AEI.

9. References

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Appendix I

SQL selections of result presentation

KHA productive

("HovedHensy" = 'MiS') AND ("AKTUELTMAR" > 0 AND "AKTUELTMAR" < 30)

KHA unproductive

"HovedHensy" = 'MiS' AND ("AKTUELTMAR" = 0 OR "AKTUELTMAR" >= 30)

Administratively protected areas productive

"HovedHensy" = 'NaturVernOmr' AND("AKTUELTMAR" >= 6 AND "AKTUELTMAR" < 30)

Administratively protected areas unproductive

"HovedHensy" = 'NaturVernOmr' AND("AKTUELTMAR" = 0 OR "AKTUELTMAR" >= 30)

Naturbase productive

"HovedHensy" = 'Naturbase' AND ("AKTUELTMAR" > 0 AND "AKTUELTMAR" < 30)

Naturbase unproductive

"HovedHensy" = 'Naturbase' AND ("AKTUELTMAR" = 0 OR "AKTUELTMAR" >= 30)

Buffer zone cultivated productive

"HovedHensy" = 'KantsoneDyrket' AND ("AKTUELTMAR" > 0 AND "AKTUELTMAR" < 30) AND("HKL" <= 22 OR "HKL" >= 41)

Buffer zone water productive

"HovedHensy" = 'KantsoneVann' AND ("AKTUELTMAR" > 0 AND "AKTUELTMAR" < 30) AND("HKL" <= 22 OR "HKL" >= 41)

Buffer zone mire productive

"HovedHensy" = 'KantsoneMyr' AND ("AKTUELTMAR" > 0 AND "AKTUELTMAR" < 30) AND("HKL" <= 22 OR "HKL" >= 41)

AEI productive

((("HovedHensy" = 'KantsoneDyrket' OR "HovedHensy" = 'KantsoneMyr' OR "HovedHensy" = 'KantsoneVann') AND ("AKTUELTMAR" > 0 AND "AKTUELTMAR" < 30) AND (("HKL" >= 11 AND "HKL" <= 22) OR "HKL" >= 41)) OR ("HovedHensy" = 'MiS' AND ("AKTUELTMAR" > 0 AND "AKTUELTMAR" < 30)) OR("HovedHensy" = 'NaturVernOmr' AND ("AKTUELTMAR" > 0 AND "AKTUELTMAR" < 30)) OR ("HovedHensy" = 'Naturbase' AND ("AKTUELTMAR" > 0 AND "AKTUELTMAR" < 30)) OR("HovedHensy" = 'Sumpskog' AND ("AKTUELTMAR" > 0 AND "AKTUELTMAR" < 30) AND "HKL" >= 51)

Buffer zone unproductive middle and high site class

("HovedHensy" = 'KantsoneDyrket' OR "HovedHensy" = 'KantsoneMyr' OR "HovedHensy" = 'KantsoneVann') AND("AKTUELTMAR" = 0 OR "AKTUELTMAR" >= 30) AND ("ASKOG" = 13 OR "ASKOG" = 14 OR "ASKOG" =15)

Bog forest productive

"HovedHensy" = 'Sumpskog' AND ("AKTUELTMAR" > 0 AND "AKTUELTMAR" < 30)

Bog forest unproductive

"HovedHensy" = 'Sumpskog' AND("AKTUELTMAR" = 0 OR "AKTUELTMAR" >= 30)

Crosstabulation calculation for AEI Snåsa municipality

KHA productive

HKL	8	11	14	17	20	Totalt
21-22		5.89	4.27			10.16
31-32		61.42	18.51	27.87	9.83	117.63
41-42	30.87	173.18	369.02	219.44	165.45	957.95
51-52	522.05	766.30	326.96	270.80	138.51	2024.63
Totalt	552.93	1006.80	718.76	518.10	313.78	3110.36

Admin productive

Sum av ArealDaa	AKTUELTMAR						
HKL	6	8	11	14	17	20	Totalt
11-12				70.40			70.40
21-22		7.66	210.28	475.48	86.39	8.77	788.58
31-32		4.88	2.83	134.78	64.81	2.12	209.43
41-42			33.42	104.67	33.94		172.03
51-52	12.98	69.78	68.60	181.78	19.88		353.01
Totalt	12.98	82.32	315.13	967.10	205.02	10.90	1593.45

Naturbase productive

Sum av ArealDaa		AKTUELTMAR						
HKL2	HKL	6	8	11	14	17	20	Totalt
Grupper1			52.91	298.18	96.50	8.47	19.04	475.10
31	31			33.45	84.55	82.55	20.22	220.77
32	32		0.91	2.90	7.03	10.34	1.53	22.71
41	41			7.65	48.72	21.57	12.11	90.05
42	42		53.10	8.48	17.27	10.10		88.95
51	51	9.23	47.53	151.11	197.06			404.93
52	52	1.67	44.16	17.16	1.57			64.57
Totalt		10.91	198.61	518.93	452.71	133.03	52.90	1367.07

Buffer zone water productive

ArealDaa		AKTUELTMAR								Reduced maturity class 1+2
HKL2	HKL	6	8	11	14	17	20	23	Totalt	
Grupper1	11	5.10	5.28	117.38	96.89	19.10	0.65		244.41	
	12	1.71	0.23	1.65	1.19	6.40	0.73		11.93	
	21	12.43	154.01	991.91	1153.40	280.07	10.25		2602.07	
	22	4.04	99.46	116.88	170.24	58.43	7.44		456.50	1657.45
41	41	8.42	151.22	390.87	340.97	229.40	114.11		1234.98	1234.98
42	42	81.68	734.20	381.54	175.11	152.11	43.13		1567.77	1567.77
51	51	40.92	568.86	1226.43	773.77	143.31	6.76		2760.06	2760.06
52	52	181.60	1273.53	484.19	154.47	12.22	0.79	0.11	2106.91	2106.91
Totalt		335.90	2986.78	3710.86	2866.04	901.04	183.87	0.11	10984.61	9327.16

Buffer zone mire productive

ArealDaa	AKTUELTMAR							Reduced maturity class 1+2
HKL	6	8	11	14	17	20	Total	
11-12	9.44	3.71	61.96	28.52	1.11		104.74	
21-22	29.43	221.02	687.43	425.15	41.13		1404.17	754.46
41-42	126.47	845.57	430.82	134.96	27.80	0.89	1566.51	1566.51
51-52	311.28	1751.97	1130.18	291.05	10.21	1.09	3495.79	3495.79
Total	476.62	2822.27	2310.40	879.69	80.25	1.98	6571.21	5816.76

Buffer zone cultivated productive

ArealDaa	AKTUELTMAR								Reduced maturity class 1+2
HKL	6	8	11	14	17	20	23	Totalt	
11-12		0.42	6.05	35.01	15.46	0.87		57.81	
21-22	3.74	14.30	107.43	222.45	192.28	30.01	0.22	570.44	314.12
41-42	1.76	31.03	101.78	253.29	309.08	115.64	1.25	813.84	813.84
51-52	1.01	20.17	81.13	102.90	27.12	5.15	0.48	237.96	237.96
Totalt	6.51	65.91	296.40	613.65	543.95	151.67	1.95	1680.04	1365.92

Bog forests productive

Sum av ArealDaa	AKTUELTMAR						
HKL	6	8	11	14	17	20	Totalt
11-12	9.92	19.69	25.22	49.94	4.74	1.02	110.52
21-22	70.12	384.44	648.52	419.00	85.32	0.23	1607.65
31-32	16.67	169.95	452.36	397.13	188.47	4.37	1228.95
41-42	58.77	444.55	344.51	273.93	95.72	7.50	1224.99
51-52	127.42	557.66	305.35	241.42	15.57	0.60	1248.03
Totalt	282.90	1576.29	1775.97	1381.42	389.84	13.73	5420.14

KHA unproductive

Sum av ArealDaa	ASKOG				
ATIL	11.00	12.00	13.00	14.00	Totalt
12	1.87				1.87
24		3.59	4.02	1.27	8.88
25			0.00	1.04	1.04
26			9.48		9.48
Totalt	1.87	3.59	13.51	2.31	21.27

Admin unproductive

Sum av ArealDaa	ASKOG				
ATIL	11	12	13	14	Totalt
12	153.84	1.77			155.62
14	1.12				1.12
24	71.14	1744.18	309.18	28.06	2152.56
25			21.44	2.68	24.12
26	0.26		0.02		0.27
Totalt	226.36	1745.95	330.63	30.74	2333.68

Naturbase unproductive

Sum av ArealDaa	ASKOG				
ATIL	11	12	13	14	Totalt
24	6.93	29.19	4.69	10.40	51.21
25				3.82	3.82
26				3.53	3.53
Totalt	6.93	29.19	4.69	17.75	58.56

Complimentary buffer zones

Sum av ArealDaa	ASKOG		
ATIL	13	14	Totalt
12	23.43	0.30	23.74
24	1811.28	1036.14	2847.41
25	132.66	193.04	325.69
26	60.67	167.82	228.49
Totalt	2028.04	1397.29	3425.33

Crosstabulation calculation for AEI Løten municipality

KHA productive

Sum av ArealDaa	AktueltMar							
Hkl	6	8	11	14	17	20	23	Totalt
11-12			0.83	1.37	3.00	4.15	0.08	9.43
21-22		4.19	1.16	8.13	8.40	0.11		21.98
31-32		0.02	2.78	16.31	48.04	4.08	2.38	73.61
41-42	5.77	3.86	101.34	86.67	143.34	132.45	3.66	477.10
51-52	120.06	567.01	361.74	311.85	91.70	16.82	7.99	1477.16
Totalt	125.83	575.08	467.84	424.34	294.48	157.61	14.10	2059.29

Admin productive

Sum av ArealDaa	AktueltMar					
Hkl	6	8	11	14	17	Totalt
21		0.09		7.02	0.13	7.25
31			16.22	28.65	9.36	54.23
41				33.25		33.25
51	149.70	289.57	146.43	11.94		597.64
52	0.03					0.03
Totalt	149.73	289.66	162.65	80.87	9.49	692.40

Naturbase productive

Sum av ArealDaa	AktueltMar							
Hkl	6	8	11	14	17	20	23	Totalt
11			0.00	0.84			1.54	2.38
21		3.87	16.75	71.38	12.62	11.36		115.98
22			0.58	4.92			1.54	7.04
31		39.64	122.80	118.32	29.34	14.76	12.76	337.63
32			5.22	40.58	0.72			46.52
41		18.82	26.33	47.82	5.14	3.04		101.15
42						0.38		0.38
51	78.21	152.03	367.47	60.41	1.13	2.26		661.52
52	7.93	7.71	18.77					34.41
Totalt	86.15	222.08	557.92	344.27	48.96	31.80	15.84	1307.01

Buffer zone water productive

ArealDaa	AktueltMar								Reduced maturity class 1+2
Hkl	6	8	11	14	17	20	23	Totalt	
11	9.07	20.35	14.62	30.28	29.12	5.23	2.69	111.37	
12					2.12	3.54		5.66	
21	2.53	567.79	844.40	1084.12	299.52	32.85	0.43	2831.64	
22	1.49	6.61	72.65	11.58	21.83	7.51	1.12	122.78	1535.72
41	3.94	119.46	318.29	305.64	262.74	68.75	1.22	1080.05	1080.05
42	11.07	5.90	6.51	0.15	2.76	3.67		30.05	30.05
51	59.92	442.44	382.98	222.71	54.27	2.86	0.01	1165.19	1165.19
52	33.48	1.12	7.42	4.57	1.69			48.27	48.27
Totalt	121.50	1163.67	1646.86	1659.04	674.05	124.41	5.46	5395.00	3859.28

Buffer zone mire productive

Sum av ArealDaa	AktueltMar							Reduced maturity class 1+2
Hkl	6	8	11	14	17	20	Totalt	
11		4.49	10.04	12.65			27.19	
21	1.00	47.15	78.70	115.27	6.32	1.66	250.10	
22		12.32	8.21	2.02	0.00		22.55	149.92
41	5.69	41.60	34.99	36.07	23.53	0.50	142.38	142.38
42	3.57	2.82	1.05	0.92			8.37	8.37
51	93.19	254.73	196.58	72.31	3.57		620.38	620.38
52	33.10	7.44	4.03	7.18			51.74	51.74
Totalt	136.55	370.56	333.60	246.43	33.42	2.16	1122.72	972.80

Buffer zone cultivated productive

ArealDaa	AktueltMar								Reduced maturity class 1+2
Hkl	6	8	11	14	17	20	23	Totalt	
11			4.01	5.60	10.88	20.79	2.18	43.47	
12				2.31	3.93	5.54		11.78	
21		3.18	32.66	69.76	141.42	56.95	1.84	305.81	
22		1.57	7.82	5.01	26.03	13.35	0.05	53.82	207.44
41		2.75	19.30	46.16	193.09	139.20	8.45	408.95	408.95
42				3.76	3.62	5.27	2.31	14.97	14.97
51	2.26	22.31	31.31	36.27	22.90	15.75	0.02	130.82	130.82
52			1.24	1.84	1.09	1.95		6.11	6.11
Totalt	2.26	29.81	96.33	170.70	402.96	258.81	14.86	975.73	768.29

Bog forests productive

Sum av ArealDaa	AktueltMar						
Hkl	6	8	11	14	17	20	Totalt
0		1.11					1.11
11	0.43	0.82	45.67	9.68	3.55	0.13	60.26
12					6.48		6.48
21	87.18	229.33	153.31	286.52	50.94	2.04	809.32
22	11.62	11.96	13.91	9.58	20.45	4.66	72.19
31	8.14	181.42	593.45	568.60	101.11	2.69	1455.41
32	36.72	28.04	70.75	28.70	8.59		172.80
41	25.56	179.76	603.40	368.27	121.84	23.17	1322.00
42	15.47	17.57	0.51	0.29		4.88	38.73
51	179.56	400.74	274.38	135.10	28.11	0.02	1017.92
52	30.51	34.09					64.60
Totalt	395.18	1084.84	1755.39	1406.74	341.06	37.59	5020.81

KHA unproductive

Sum av ArealDaa	ASKOG				
ATIL	11	12	13	14	Totalt
12	16.08		0.83		16.90
14	4.91				4.91
24	8.01	13.51	10.96	19.83	52.31
25			0.87	0.72	1.60
26	4.75			11.05	15.80
Totalt	33.75	13.51	12.66	31.60	91.52

Admin unproductive

Sum av ArealDaa	ASKOG				
ATIL	11	12	13	14	Totalt
12	2533.29				2533.29
13	557.80				557.80
14	150.06				150.06
24	2157.79	2612.94	1459.29	64.26	6294.27
25	155.55	46.25	16.63		218.43
26	30.99				30.99
Totalt	5585.48	2659.19	1475.92	64.26	9784.84

Naturbase unproductive

Sum av ArealDaa	ASKOG				
ATIL	11	12	13	14	Totalt
12	2025.61	3.23			2028.84
13	2.18				2.18
14	7.16				7.16
24	30.47	77.12	110.60	17.13	235.32
25		4.88	0.01	8.69	13.58
26	4.04		4.28	40.54	48.86
Totalt	2069.45	85.23	114.89	66.36	2335.94

Complimentary buffer zones

| Sum av ArealDaa	ASKOG		
ATIL	13	14	Totalt
12	10.57	116.65	127.23
13	3.40	4.21	7.61
24	870.20	798.04	1668.24
25	26.94	70.20	97.14
26	14.57	117.39	131.96
Totalt	925.69	1106.49	2032.18

# Conceptual model and workflow model as overview in two parts
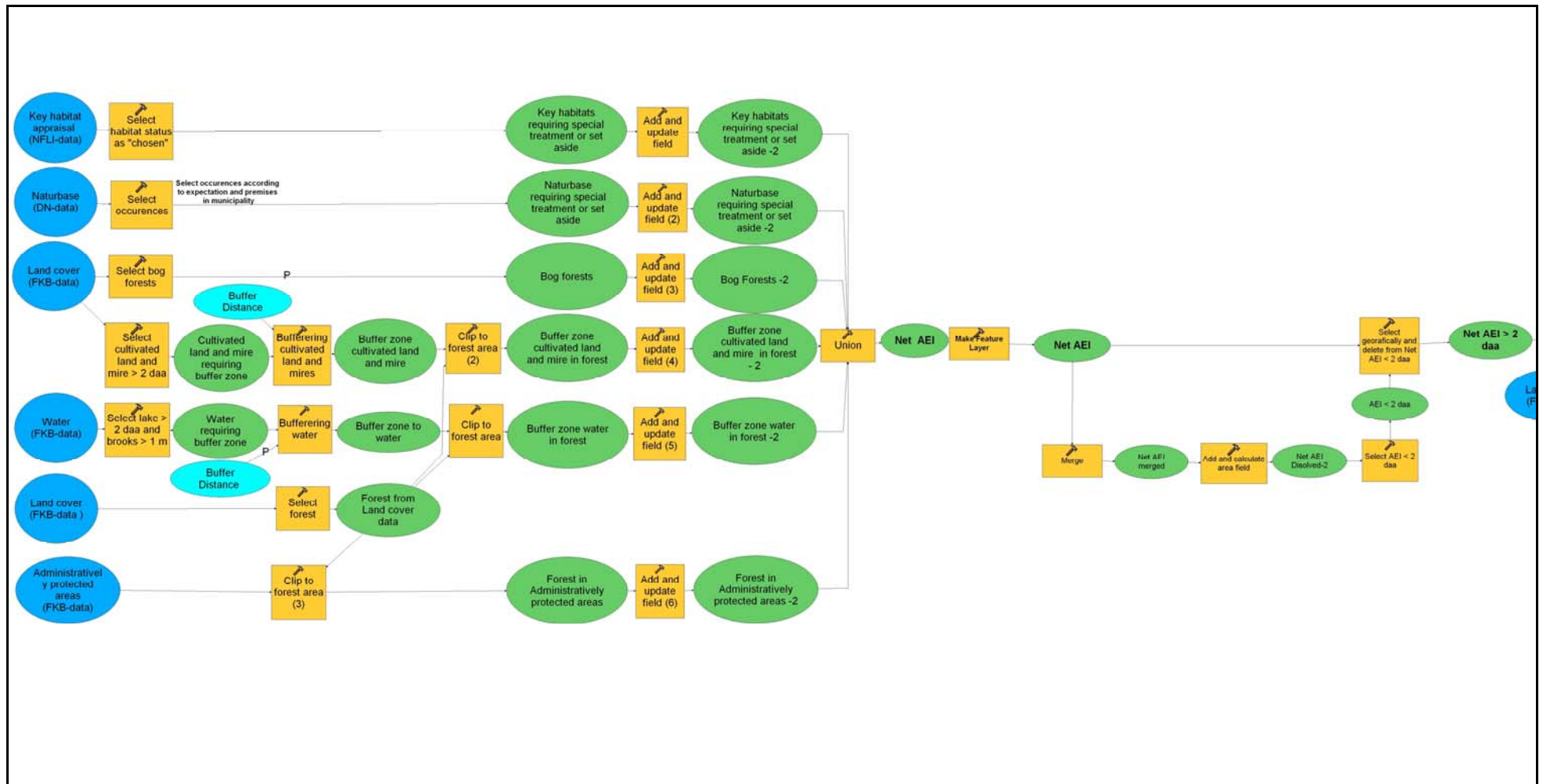
Conceptual model part 1: Larger extend showing the first part of the conceptual model
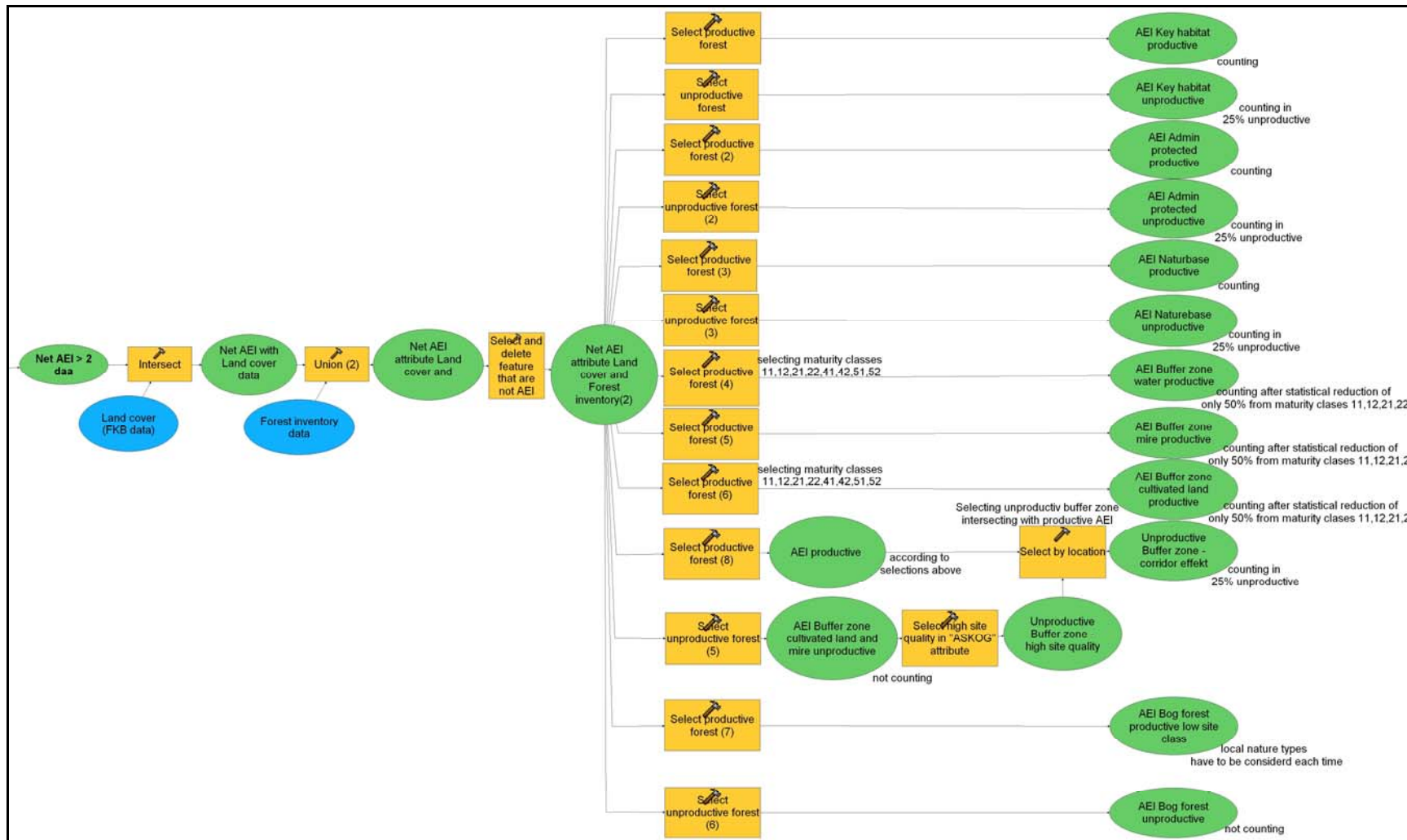
Conceptual model part 2: Larger extend showing the second part of the conceptual model
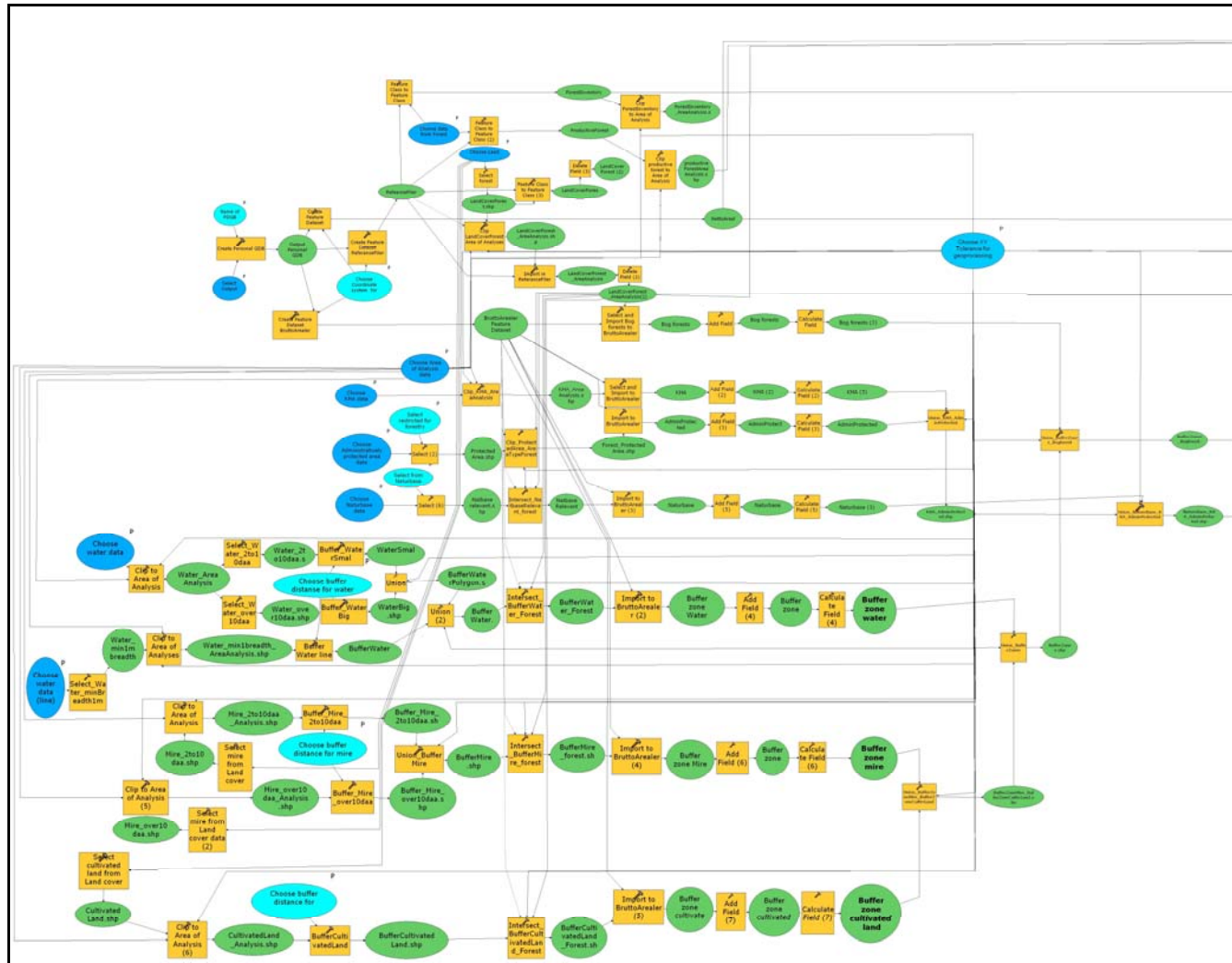
Workflow model part 1: Larger extend showing the first part of the workflow model. Includes buffer zone operations and gross AEI selections
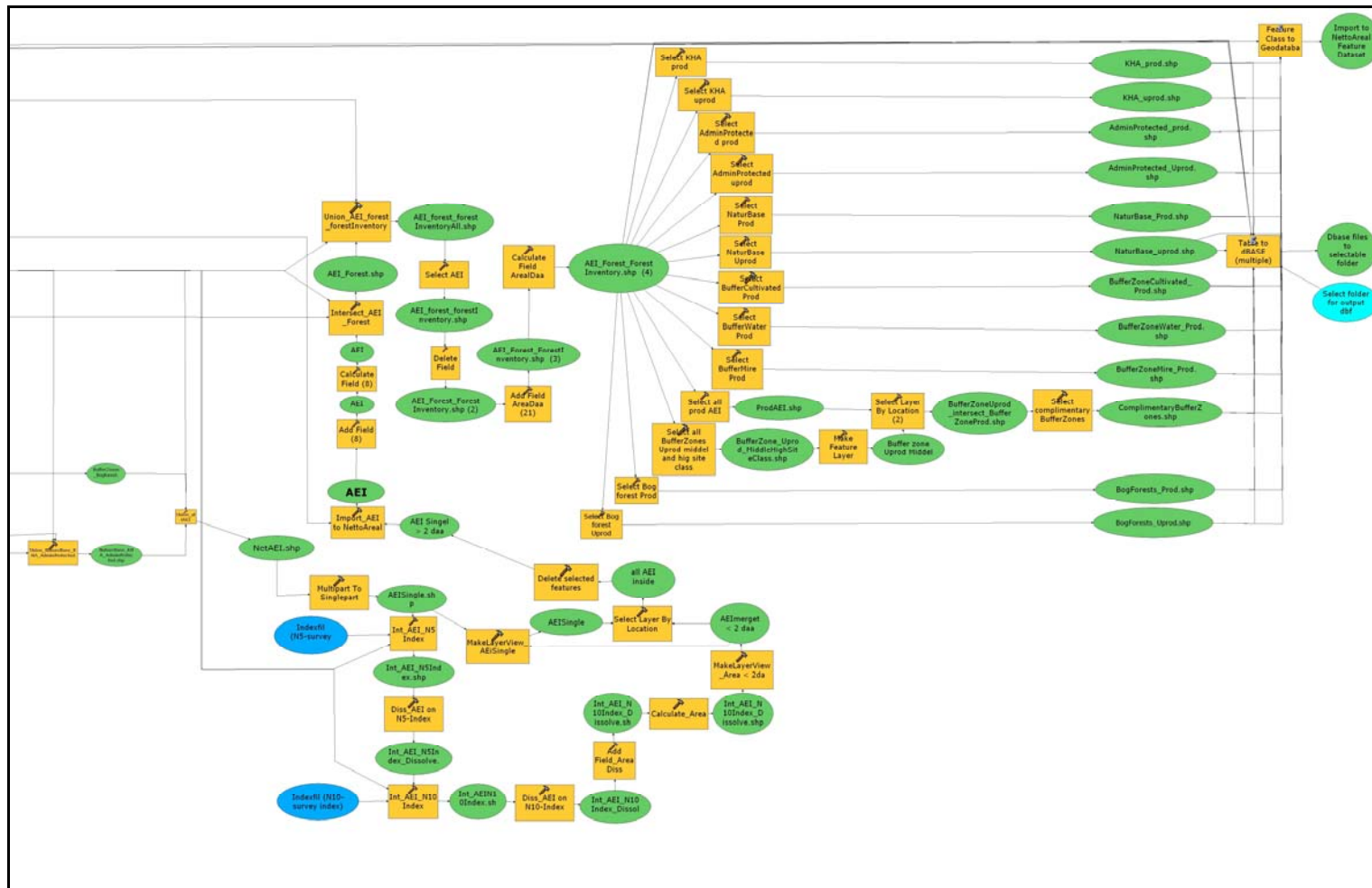
Workflow model part 2: Larger extend showing the second part of the workflow mode. Includes deleting unmanageable polygons and result presentations selections