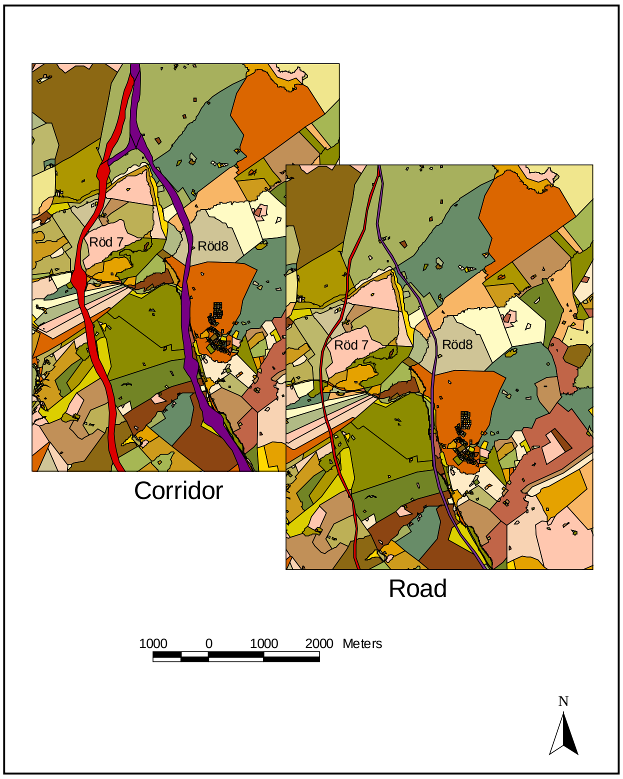
Lunds Universitets Naturgeografiska Institution

Seminarieuppsatser Nr. 62

GIS as a Tool for Environmental Impact Assessment
A case study of EIA implementation for the road building project in Strömstad, Sweden



Marianna Moskvitina

Department of Physical Geography,
Lund University
Sölvegatan 13, S-221 00 Lund,
Sweden

1999

ACKNOWLEDGEMENTS

I would like to express my gratitude to all contributing to the work on this thesis with their help, support and advice, special thanks should be given to Leif Edenheim, Per Berntsen, Mats Söderberg, and Anders Forsberg.

Warm thanks for help and guidance are to my supervisor, Ph.D. Petter Pilesjö, and colleague, Daniel Nilsson.

TABLE OF CONTENTS

ABSTRACT

To create an environmentally friendly road transport system is one of the main policy goals of the Swedish National Road Administration (Vägverket). In order to achieve this goal Environmental Impact Assessment (EIA) has been introduced at all levels of road planning process at Vägverket. The role of EIA is to provide decision-makers with information about the possible consequences of a planned facility. During EIA a lot of data, mostly of geographical nature, is gathered, stored, analysed and presented. Quality of data and information produced of it defines in large extent thoroughness and objectivity of EIA.

Geographical information system (GIS) provides an efficient technique for managing geographical information. Using GIS in road planning may significantly improve the result of EIA. The main objectives of this thesis are:

- To introduce the concept of GIS as a tool for documenting, control, and modeling of conceivable environmental impacts that can be caused by construction of the transport corridor.
- To test a practical application of GIS-technique for the purposes of EIA.

After giving a brief description of the road planning procedure at Vägverket and explaining which functions EIA has at each stage of the road planning process, the thesis introduces the concept of GIS. In order to study the potential of GIS for improving the planning process at Vägverket several problems simulating real situations were solved using GIS-programs ArcView and ARC/INFO. The problems are presented in the form of five analyses. A part of the road ”E6” between the towns Vik and Hogdal was chosen as a study area.

The traffic situation at this part of ”E6” does not satisfy the main goals of the international transport policy and, therefore, an improvement and reconstruction is needed. Several road corridors were proposed as an improvement measure during the planning stage. For Vägverket to be able to choose the best alternative a detailed EIA was needed.

The alternative road corridors proposed during the planning process were used in this thesis for a comparative study applying GIS-technique. The study does not have an intention to propose the best corridor but uses the road corridors as examples to demonstrate the potential of GIS when making comparative assessment, or solving other problems.

After having evaluated the potential and obstacles of GIS application in EIA it can be concluded that GIS is an advanced information technology that can offer EIA a great deal of flexibility and efficiency in the work with spatial data. As for the obstacles that slow down the implementation of GIS, most of them are of temporary character and will be eliminated in the future.

1. INTRODUCTION

1.1 Background

Creating a single market is one of the main goals of the European Union (EU). During the last ten years tremendous efforts were made to break down the barriers between the Member States to bring them together. In these terms, free movement of people and free circulation of goods is one of the important preconditions on the way towards the integrated Europe.

The aim of the EU's transport policy is to achieve an integrated Trans-European transport network which would respond to peoples' demands for a cleaner environment and safer, reliable mobility (The EU's transport policy). Membership of Sweden in the European Union demands compliance with so called "common" policies and regulations. For the Swedish transport system to be up to the task improvements and adjustments to the common regulations are to be made. It means there is a need for a thorough evaluation of an existing transport systems with a special attention to such aspects as safety, efficiency, and impact on the environment.

In 1997 the Swedish National Road Administration – Vägverket initiated a project "Infrastructures and transport systems on the link Oslo – Göteborg with geographical focusing on the part Svinesund – Göteborg" (Infrastrukturer och transportsystem på länken Oslo – Göteborg med geografisk fokusering på delen Svinesund – Göteborg). The general idea of this project was to find the way to optimize the process of road planning by taking into consideration the influence of different factors and parameters as well as the possible changes in public values in the future. The project was supposed to cover the following five aspects of the transport policy: availability, efficiency, safety, environmental issues, and regional balance. The project was divided into several subprojects and performed in cooperation between four institutes and universities in Sweden: Lund University, Lund Institute of Technology, Chalmers University of Technology, and School of Economics and Commercial Law, Göteborg University.

Lund University, GIS Center, where this thesis work was done, was responsible for the subproject under the title "Geographical information systems and remote sensing for environmental control" (GIS och fjärranalys för miljöövervakning). The subproject aimed to develop the application of (GIS) for managing transportation infrastructure and landscape information with focusing on environmental issues. The work on the subproject and results from it were integrated into this thesis work which became a completion of the Master level courses in GIS and Remote Sensing.

1.2 Aim

Transport system as many other human activities has negative impacts on the environment and public health. To be able to reduce these impacts, all possible negative effects from the transport system activity should be considered and assessed at an early stage. Therefore Environmental Impact Assessment (EIA) is an essential part of any road planning project at Vägverket. Since EIA provides the basic data for decision-making its thoroughness and objectivity is an important matter. To perform an accurate and thorough assessment a lot of information about the studying object or area must be gathered and analysed. The most of information necessary for EIA is of geographical nature, which means that it has geographical coordinates.

Geographical Information Systems (GIS) is an advanced technique for managing geographical information. It can be an effective tool for storing, analysing and processing geographical data. The application of this technique for EIA and its potential benefit to the work of Vägverket have not been studied adequately yet.

The aim of the thesis is:

- To introduce the concept of GIS as a tool for documenting, control, and modeling of conceivable environmental impacts that can be caused by the construction of the transport corridor.
- To test the practical application of the concept using Strömstad commune as a case study.
- To present the implementation of the concept in GIS-software ArcView and Arc/Info.
- To show the potential of GIS and the possibilities to improve EIA by applying GIS in the road planning

1.3 Scope and limitations

The practical application of the concept in the thesis is limited to five analyses. The choice and the content of analyses were defined under the supervision of Dr. Petter Pilesjö, who was in charge for the subproject "Geographical information systems and remote sensing for environmental control". All analyses are of demonstrative character and do not have a practical application in the work of Vägverket. Since no precision criteria were set up, no accuracy evaluation was made.

All analyses in the thesis are performed by applying GIS-method. It would be, perhaps, interesting to compare the results if analyses were done by both GIS- and conventional methods as well. Unfortunately, such comparison is not possible, since the project did not intend to carry out the analyses by alternative methods.

2. ROAD PLANNING PROCESS AT VÄGVERKET

Vägverket (the Swedish National Road Administration) is a government authority that is in charge for the road management planning in Sweden. Any road planning activity at Vägverket usually initiates by a need or a problem. For instance, a bad visibility on one section of the road can be a reason for the increased number of traffic accidents. Such situation definitely needs an improvement.

When a problem, or a need for improvement has been stated Vägverket gets an incentive to start a road planning project. The purpose of the road planning is to elaborate a solution or a measure that could improve the situation or satisfy the need. The measure can mean an improvement of an existing road network, or building a new one, or creating a new type of communication, for example, boat communication, or rail way communication. If the chosen measure implies a building of a new road, then the task of the road planning is to work out a road profile that would optimally serve the needs and be the best possible solution from technical, economical and environmental point of view. Very often, the process of road planning is based on the choice from several alternatives: first, the choice of a road corridor and later, a road profile. In order to make an optimal choice, consequences of different alternatives are compared with each other and with zero-alternative (the situation if nothing is changed).

The entire process of road management from planning stage to construction and operation of the road can be generally divided into two levels: system level and project level.

The system level is the highest level of the road management planning at Vägverket and it functions as a level of strategic planning. At this level Vägverket makes an overall assessment of the transport system and works out goals and strategies regarding the further development of the transport system on the national and regional scope; in large extent, the strategic planning at Vägverket is defined by the transport policies and directives issued by the Swedish Government, many of which are directed towards creating the environmentally friendly transport system (Vägverket 1999).

At the stage of the strategic planning Vägverket studies the present state of the road transport system, gathers the information about road-users' needs and demands, and analyses the role of the road transport system in the society in the future. Based on these results Vägverket points out on what should be done in order to improve the transport system regarding such issues as availability, efficiency, safety, environmental issues, and regional balance. If there is a need for improvement Vägverket initiates a project. Planning and design of an individual road project take place at the project level. It is important that planning and design of an individual road project is done in concord with an overall strategy.

After the need for improvement has been singled out the process of road planning goes to the second stage – the project level. At this level Vägverket work out technical solutions on how to satisfy the need: which measures are needed and where and how they should be applied, for example, where and how the roads should be built. The project level includes the following steps (Figure 1):

- Initial study,
- Feasibility study,
- Road design,
- Execution,
- Follow up.

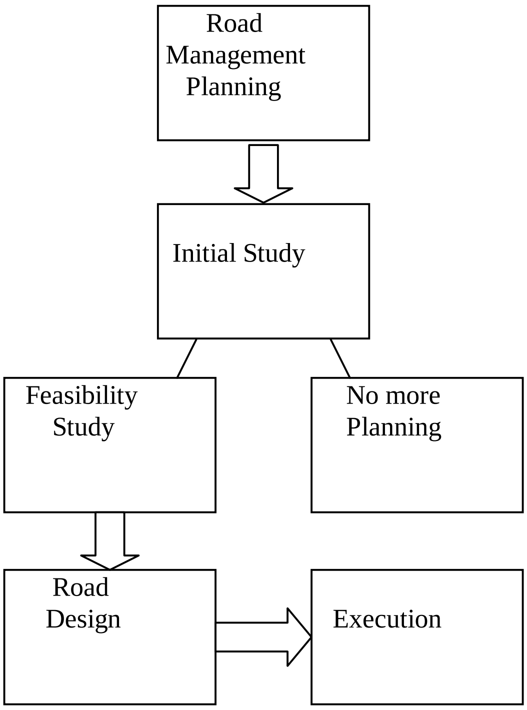


Figure 1. Different stages of the road planning process.

According to the procedure at Vägverket, all road planning activities at the project level begin with initial study. During this step the ground for the continuation of the project is prepared.

The initial study is an inventory stage in the whole planning process and its purpose is to analyse the problem and present the alternative measures (alternative corridors) that can be taken to solve the problem. It is important that all possible conflicts that can be caused by a proposed measure, for example building a new road, are taken into consideration. It is also important that all actors that some how will be engaged in the conflict are fully aware of the problem and of measures to be taken. To delimit a working area, to gather all data necessary for the further work, to define the start point and the purpose of the project are also tasks of the initial study. In general outline, the initial study prepares the ground for decision-making, on the basis of which Vägverket evaluates the problem and decide on the relevance of the proposed solutions. If the proposal has been adopted, the project continues at the next stage.

The initial study makes the ground for the next step – the feasibility study. At the feasibility study all data and information gathered during the initial study is being elaborated and completed. All materials are then compiled together to perform an overall assessment. The overall assessment includes technical and economic prerequisites for different solutions and environmental impact assessment of the alternative corridors. By comparing consequences of different alternatives proposed in the initial study, including zero-alternative, a final road corridor is suggested. At the same time the first decision on the road technical standards is being taken, for example, for which speed category the road should be designed and which level of priority it will get (national, regional, etc.) All national, environmental and public interests that can be affected by the construction of the road should be revealed and clearly stated at this stage. Before the planning process goes to the next stage, Väverket presents the results of the feasibility study for the open discussion with county- and local administrative boards. Public opinion is also taken in consideration. When the choice of the road corridor is finally approved the planning process goes further to the stage of road design.

One of the main purposes of the road design is to make a location of the road profile within the road corridor chosen during the feasibility study. Besides this, the road design should provide the information on which land will be required for the road building and upholding. In order to make a choice of the final road profile, several road lines are drawn within the corridor, analysed, and the consequences of different alternatives are presented. After having done a preliminary assessment, Vägverket holds the discussion with the involved authorities and landowners whose land may be required for the road construction, to consider their points of view. The final road profile is then presented in the detailed study where the consequences of the road exploitation (cost, safety, accessibility etc.) and its technical characteristics are worked out and described. Planned protection measures for the expected environmental impacts should be presented as well. When the road design is done, it should get an approval of county administrative board and Vägverket's head office.

Execution is the last stage in the road management planning process before the construction and operation of the road. During this stage the final information and materials that are necessary to carry out the building of the road are prepared. These materials usually include:

- project description,
- function, standard and quality requirements,
- landscape information,
- building information,
- technical description,
- measures of environmental protection.

3. ENVIRONMENTAL IMPACT ASSESSMENT

The transport policy established by the Swedish Government has put more weight on Vägverket's responsibility for the environmentally friendly operation of the road transport sector. It requires that Vägverket's activity should contribute to preservation, protection and improvement of the environment, protection of public health and the conservation of natural resources (Vägverket 1998). In order to reach these requirements Vägverket has to integrate Environmental Impact Assessment in the process of road planning.

3.1 EIA and its role in road planning

Environmental Impact Assessment (EIA) comprises the analyses and assessment of the impacts from a planned facility, activity, or measure on the environment, public health and the conservation of natural resources (Vägverket 1995). EIA functions both as a procedure within a project or planning process, and as a document which constitutes a basis for decision-making.

The general role of EIA in Sweden is to support the strategy of sustainable development regarding such issues as environment, health, and natural resources[1]. It means that these issues should get a proper attention in the process of decision making. This can be reached by improving the quality of information that forms the basis for decision-making; in other words, the basis for decision-making should be more comprehensive. Thus, the aim of EIA is to contribute to the decision-making and provide decision-makers with knowledge about the conceivable effects from a project or any other activity on the environment, people's health and natural resources.

By performing an overall environmental assessment for the project, EIA works as a tool which helps to evaluate how well the project fulfills the requirements on endurance with respect for the environment, and how well the project corresponds to laws and land-use planning when it concerns environmental issues, public health and utilization of the natural resources (Boverket 1997). Introduced at an early stage of the planning process, EIA provides that the knowledge about the risk for the environment from planning facility and its operation is obtained adequately and continuously.

By showing the potential danger or impacts from the project, EIA promotes the generation of the alternative solutions. By describing the impacts of the various alternatives and comparing them with a “do nothing alternative” (the situation when the project is not implemented), it is possible to make the choice of the final road corridor and later, final road profile more objective. This also means that the solutions can be designed in such ways that negative impacts are limited and positive

[1] It might be relevant to underline that EIA comprises not only environmental/ecological impacts but equally covers social and national economic impacts. Further the word ”impacts” will imply all the impacts mentioned above.

qualities provided (Vägverket 1995). In this way, the possible mistakes can be avoided and high costs for improvement measures can be much lower.
The results of analyses and assessments carried out during EIA are exhibited in public and presented in basis for decision.

3.2 EIA at different stages of road planning

EIA can be done at all stages of road planning. Depending on the planning stage and the type of decision that is to be made, EIA can have different tasks and focuses on different issues.

3.2.1 EIA at system level

At system level EIA provides an impact assessment for the entire road and transport system and concentrates on impacts that are important in achievement of long-term environmental goals. It evaluates how the project and proposed road measures correspond with national and regional environmental goals and takes up questions that are of importance to the environmental adaptation of the entire road transport system, including co-ordination with other types of transport (Vägverket 1995). Finally, EIA makes an overall assessment of the whole project and contribute to the decision weather or not the project is feasible from the environmental point of view.

At this stage it is being determined which direction is to be taken in the EIA work, which types of impacts should be included, and which aspects in EIA should get the first and the second priority.

Among other aspects, EIA gives an overall assessment of the following consequences:

- communication interests come into conflict with other public interests; what impacts (for example, water and air pollution, deterioration of living condition) are expected for those who live in the area affected by the road planning,
- risk of creating conflict with strong preservation and recreation interests,
- the effect on the land-use structure and land-use planning,
- the impact from the implementation of the project on non-renewable natural resources.

3.2.2 EIA at project level

At the project level, EIA provides input data for the decisions on where a possible new corridor can be located, how sections of the road should be designed with a minimum impact for the environment and which environmental measures have to be taken. At the project level EIA is included in all stages of road planning.

In the initial study the role of EIA is to give a general assessment of what the potential impacts from alternative solutions are and to assist in selecting those solutions that will be submitted for consideration in the next stage. EIA is also needed to define the possibilities and limitations of the project regarding its environmental adaptation, so it would be possible to set up the priorities and specify which environmental aspects are of most importance. EIA makes an evaluation on how the project from environmental point of view concurs with the direction and the goals of the strategic planning. At the same time EIA-work in further stages gets scopes and direction.

In the feasibility study EIA contributes to the comparison of alternative corridors and serves as a basis for weighing up which alternative should later be a subject of detailed design (Vägverket 1995). The comparison is made on the basis of information about impacts from different alternatives with technical and economic evaluation of protection measures that are needed in each case. EIA is also important when considering the public interests in decision-making.

In the road design EIA is necessary while making the choice of the road profile. It provides a detailed study of the impact assessment from construction and operation of the finally chosen road profile and indicates the needs for the environmental adaptation and protection measures. At this stage the work of EIA ends up and EIA-report is sent for the review to the County Administrative Board.

4. GEOGRAPHIC INFORMATION SYSTEM AS A TOOL FOR EIA

4.1 Geographic information system (GIS)

According to Bruce E. Devis (1996), the author of the book ”GIS: A Visual Approach”, ”the world is entering the ”post-industrial Information Age” - a time when information is becoming a major product of, and foundation for, progress. Increasing emphasis on data management is apparent and necessary. As the world moves into the Information Age, the major ”currency” is becoming meaningful data”.

By being a tool for managing geographical information, GIS plays an important role in the Information Age. GIS stands for geographic information system and, in general, means the system that manages geographical (spatial) data and information by means of computer technology and support infrastructure. GIS is a multilateral area that can be equally presented as technology (a system of hardware, software, and associated equipment), methodology (approach to managing and analysing spatial and associated nonspatial data), new profession, and business (selling hardware, software, data, and services) (Devis 1996).

In this thesis GIS is addressed and discussed as a method which gives its user the power of working with spatial information in terms of its integration, presentation, visualization, and producing new information.

4.2 Why EIA needs GIS

As a rule, EIA is applied for physical objects or facilities that can be located on the ground and, hence, can be described by geographical coordinates. In order to perform EIA a lot of information about the studying objects and facilities should be collected and analysed. Most of such information has geographical references, i. e., can be connected to a certain point (object, facility) on the ground. The need to process a lot of spatial data and information quickly and effectively makes the adoption of GIS for the needs of EIA almost inevitable. Accepting GIS as means of using spatial data can have many advantages over traditional methods, when making use of spatial data. Below there are given several examples on how EIA can be improved by using GIS.

Spatial data used in EIA is coming from different sources, in different forms (both digital and analog) and in different formats (when it is digital). This creates problems when working with a large amount of data, especially when it should be integrated or compared. Another problem is storage of data; since there are a lot of people working with the same data, it should be well organized, quickly accessible and easy to exchange. Besides this, more and more digital data are being used, which creates a need of a computer system that can accept, convert and manage large amounts of digital data.

GIS has a capacity to meet these needs in terms of following: it can provide a very flexible system for gathering data from many sources in a variety of formats. Moreover, it has a capability to transform analog data into digital form. GIS can easily integrate in one system several data types, such as maps, images, digital products, Global Positioning System (GPS) data, text and tabular data. These and other types of data are combined and integrated into GIS in the form of a database, a program or system that provides an effective storage and management of data. Database allows to keep track of data and to hold it conveniently for use (Devis 1996).

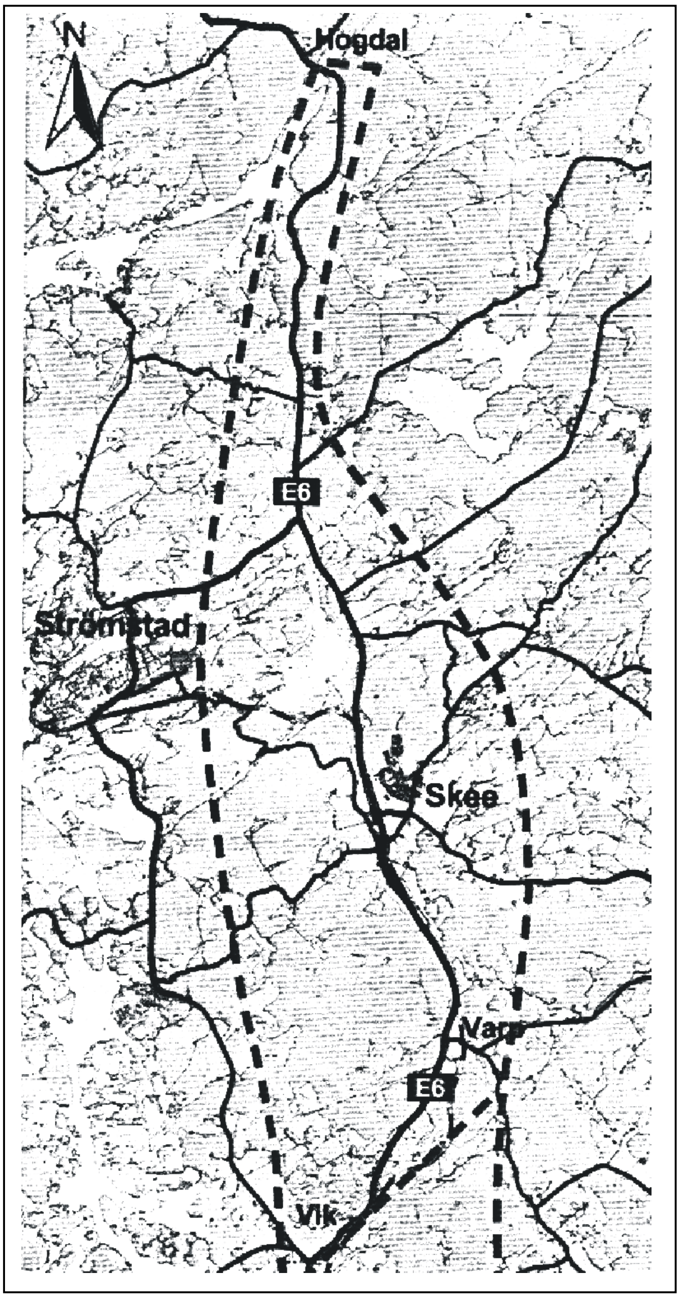
While working with data a lot of technical problems can appear, for example, to be able to use geographical data in different scales, or to set geographical boundaries for the area of study, or to adjust data to a particular task. GIS technology offers many tools for manipulating spatial data, among others is a possibility to store data in different thematic layers which gives a user the power to combine different information layers according to the need. When operating with GIS functions the user can very easy define the locations of spatial features and make measurements of different types of spatial parameters, such as distance, perimeter, area and size.

It is a fact that geographical data are expensive. GIS allows to make use of data more efficiently by offering possibilities to manipulate data to produce new information. This information can be added to the database as well. Among various tasks of EIA is to be able to give forecasts of possible consequences that the project can have on the environment. In this case, GIS can provide its user with numerous tools for analysing geographical data and revealing trends and patterns when making different scenarios.

When the results of EIA are presented for public and authorities, they should be in short but informative form instead of bulky reports. GIS technology gives good outcomes when used to visualize information. Possibility to display information in form of maps in combination with graphs, tables and texts has proved to be the most efficient way to present geographical information.

5. STUDY AREA

The practical application of the GIS-method was tested in the subproject ”GIS and remote sensing for environmental control” which was linked to the feasibility study of the planning project[2] at Vägverket. The project comprised the rebuilding of the part of the road ”E6” in Strömstad commune. During the feasibility study several alternative road corridors were worked out as improvement measures. The essential part of the feasibility study included the assessment of the impacts and consequences of the planned corridors.



[2] This project was mentioned in the part ” Introduction” under the title ”Infrastructure and transport systems on the link Oslo - Göteborg with geographical focusing on the part Svinesund - Göteborg”

Figure 2. Study area. The part of the road "E6" between Vik and Hogdal

5.1 Present situation

Road ”E6” is a part of Trans-European transport network and has an international importance as a link between European capitals and other large transport centers. On the national scale road ”E6” functions as a north-south transport link along Sweden's west coast and gathers the traffic from central and eastern parts of Sweden. The road ”E6” plays also an important role for the regional and local traffic between different towns and communes in Bohus County (Bohuslän), for example, Uddevalla, Munkedal, Tanumshede and Strömstad. It is quite significant for the tourist traffic during the summer time.

The growing economic development in the region and the strong connection between Norway and Sweden have caused an extra traffic load especially on the part of the road ”E6” between Svinesund and Strömstad, that lies closer to the Swedish-Norwegian border. The attractiveness of the Bohus county for the tourists also adds to the traffic situation: traffic during the summer time is twice as large as during the winter. As a result, passability on ”E6” can be very low depending on the day time and season. On the road section Vik – Hogdal (Figure 2) the lack of alternative roads causes the mix of the passing-by and local traffic and high-speed and low-speed traffic. In many parts E6 is the only road alternative for unprotected road-users: passengers, bicyclists and those waiting the buss. There is often a substantial extension of waiting time for vehicles turning to and from ”E6”.

At present, the road ”E6” on the section Vik- Hogdal does not fulfill the goals of the transport policy[3]. The function of the road has revealed essential problems. Thus, the whole section has a high rate of accidents and its narrowness in many parts does not allow overtaking. An initial study showed that cross-roads are lying too close to each other, ditches are deep with steep slopes, and there is a lack of broad safe zones and a hinder fence for game. The passable capacity of the road is low with long traffic queues as a consequence. The problematic situation on the road ”E6” results in a high rate of accidents (much higher than on the roads of corresponding standards in Sweden), especially with mortal outcome, and progressing deterioration of the environment (Förstudie 1997).

The present situation on the road ”E6” indicates that there is a need for improvement. The improvement measures suggested during the feasibility study implied the rebuilding of the existing road into four-lane road with median. Therefore, several road corridors have been proposed for the further evaluation, during which technical, economical and environmental aspects were evaluated for each corridor. For the section Vik - Hogdal two alternative corridors - Röd 7 and Röd 8 - were chosen as final alternatives while the rest were rejected.

[3] In order to reach sustainable development the Swedish Government has included the following goals in the transport policy: accessible transport system, high transport quality, safe traffic, good environment, and positive regional development.

5.2 The choice of analyses

The objective of the subproject was to demonstrate the potential of GIS application for improving environmental impact assessment in the road management planning. For this purpose the number of analyses were devised. All analyses are designed in such a way that they cover the most actual aspects of road management planning. The analyses simulate scenarios similar to those, usually investigated in the feasibility study and are made up as a comparative assessment of two alternatives (Röd 7 and Röd 8).

The following analyses were designed and carried out:

5.2.1 Analysis 1. - Points/areas of conflict

Problem presentation
Among the major tasks of EIA during the feasibility study is to define and describe the areas of conflicts, i. e., areas where the road will cross natural, residential, or cultural environments and places that are classified as national or public interests. In order to be able to analyse the consequences of the road construction it is necessary to know how much of land or water areas will be claimed for the construction of the road and how the landscape and people will be affected. Claiming of land may result in removal of houses, buildings, ancient remains, etc. As an example there can be taken a very common but, at the same time, very sensitive issue, such as an agreement with owners whose land and property will be claimed for the construction. To be able to assess the caused damage, and, thus, the compensation that all affected people have a right for, it is important to know which estates will be intersected with the road, how many people will be affected in each estate and what value the estates have.

Task
A new road is being planned. Which estates will be in the area of conflict? How many people will be affected? How will be the borders of the estates changed?

5.2.2 Analysis 2. - Transportation of dangerous goods

Problem presentation

Transportation of dangerous goods has increased tremendously during the last years and is expected to grow in the nearest future. Vägverket is responsible to provide such a road network where the number of accidents would be as low as possible and the consequences of the accidents that may occur will be limited (Vägverkets underlagsmaterial för tillämpning av PBL och NRL 1997).

In order to make the transportation of dangerous goods as safe as possible, risk analyses should be performed during planning and location of new roads. Risk analyses imply ”what if ” scenarios where the potential risk of possible accidents is studied. The task of this analysis is to demonstrate the application of the GIS-method in risk analysis, where it is needed to find out what is lying in the zone of risk.

Task
During the transportation of dangerous goods an accident took place in the certain point of the road. The risk area around the point of accident is X meters. How many people and estates are lying in the zone of risk? Perform the same analysis for the whole study area, assuming that each point can be a potential center of accident.

5.2.3 Analysis 3. - Encroachment into natural environment

Problem presentation
Another important matter that is studied during EIA is the content of the road corridor or road zone. In order to evaluate the impact of different alternatives, the decision-maker needs to know the type and value of the environment inside the corridor or road zone that will disappear during the construction. In case the road is crossing the natural environment, it is necessary to make an overall but comprehensive assessment of how the different types of land use, for example forest, or agricultural area, will be changed.

This analysis is going to show how the GIS-method can be used to produce the data on land use distribution inside the road corridor and to demonstrate, as an example, which of road corridors has less impact on valuable agricultural land.

Task
The construction of a road facility leads to the claiming of land and water areas. In order to study the change of natural environment, the distribution of land use classes inside alternative road corridors should be found out. Which of the alternative corridors has less impact on valuable agricultural land.

5.2.4 Analysis 4. - Transportation of dangerous goods

Problem presentation
The same as for analysis 2.

Task
During the transportation of dangerous goods an accident took place in the certain point of the road. The risk zone around the point of accident is X meters. How much area inside the zone of risk is agricultural land? Perform the same analysis for the whole study area, assuming that each point can be a potential center of accident.

5.2.5 Analysis 5. - Hydrological impact

Problem presentation

Roads function as barriers for water streams and can have negative effects on surface and ground water movement. Moreover, roads can have an impact on water streams and rivers in form of pollution from cars petroleum products and from transportation of polluting goods.

To know how the road can endanger the landscape hydrology is important information when locating roads. In order to eliminate negative effects and minimize the disruption of water movement, the watersheds that are lying inside the road influence zone must be studied. This analysis tests the application of the GIS-method for demarcation of watersheds within the area of road influence and shows the potential of GIS-method for assessing the hydrological impact.

Task

During the transportation of dangerous goods an accident can take place in any point of a road. In which direction can polluted discharge be transported by surface water? How many water wells are under the risk to be polluted?

6. MATERIALS

6.1 Database building and data processing

6.1.1 Data used

In order to perform the analyses using the GIS-method many types of data were needed. The GIS database was built from a variety of sources, such as digital data, analog data, tabular data and typed-in data. GIS database consisted of both spatial and non-spatial data.

Spatial database
The spatial database included the following data:

Data content	Form of data	Format
Elevation data	**Raster**	**IDRISI**
Soil type data	**Vector**	**shape**
Well archives data	**Vector**	**shape**
Real estates data	**Vector**	**shape**
Road data	**Vector**	**shape**
Topographic map (Ekonomiska kartan)	**Vector**	**shape**

Non-spatial database
Non-spatial database included tabular data, such as population data and real estates data.

Other sources of data included the description of the study area and reports from the initial and feasibility studies.

6.1.2 File conversion

Since ARC/INFO was chosen as basic software for performing the analyses, all digital data had to be converted to ARC/INFO format.

The main problem while converting shape files into ARC/INFO coverages was that only the files containing feature types ”point” and ”line” could be converted directly. For the files containing feature type ”polygon” the direct conversion was not applicable. It proved to be that the files containing polygon features converted in a usual way turned into line coverages and had their attribute information lost. To eliminate this problem the files containing polygon features had to be converted in several steps, using a ”subclass” function. In this case, the polygons were, first converted into regions while their attribute information (the relationship between regions and polygons) was temporarily stored in the region subclass cross-reference file. The regions were then converted into polygons. The process of creation the polygon coverages was finished by joining the attribute information stored in the region subclass file with the attribute data table of the new polygons.

Files containing elevation data in IDRISI format were converted into ARC/INFO GRID format using a program ”Arcidr” made by P. Pilesjö. The program allowed to change format of a raster file from IDRISI into ARC/INFO GRID ASCII.

6.1.3 Digitizing

The summary of the feasibility study ”Väg E6, Rabbalshede - Hogdal” used in this thesis (Vägutredning 1998) contained an analog map with corridors (Röd 1 - Röd 8) presented as different improvement solutions. Since the corridors were needed for performing the analyses, they had to be in the GIS database in digital form.

By manual digitizing all corridors on the section Rabbalsshede - Hogdal were entered into the GIS database. Manual digitizing produced digital data in vector form (polygons). Each corridor was saved as a separate polygon. The polygons were automatically assigned a sequence identification number (ID). Attribute information (corridor names) was attached later. Since digitizing was performed in ArcView the corridors converted into digital form acquired ArcView shape format and had to be converted into ARC/INFO polygon coverages.

After digitizing a lot of editing was done to correct the problems typical for manual digitizing, for example, undershoots, overshoots, double lines, incorrect polygons and so on.

6.1.4 Data limitation

The GIS database was built of different types of data from different sources. Despite of an attempt to collect the data covering the same geographical area, different data layers did not coincide exactly with each other and often covered much larger area than needed. It was decided to decrease the amount of data and to limit the geographical scope of the study to the area with the following coordinates[4]:

X min: 1235000
X max: 1245000
Y min: 6540000
Y max: 6550000

[4] The coordinates are given in meters RN. RN (Rikets Nät) is the Swedish map grid net, 2,5 gon W, with the average meridian 15°48’29.8’’ E of Greenwich.

In order to limit all the data to the same geographical area a polygon master coverage with the above mentioned coordinates was created in ARC/INFO. This master coverage was intersected with all other coverages in the ARC/INFO database.

6.2 Software used

The software used in this study included:

- ARC/INFO NT
- ArcView (ESRI, 1996)
- IDRISI
- Microsoft Excel
- Microsoft Access
- Microsoft Word
- CorelDraw 6
- Arcidr
- Programs in Avenue and Fortran

7. METHODS

7.1 Analysis 1. - Points/areas of conflict

The GIS relational database gives a possibility, by making ”queries”, to select out of the whole database only the information meeting the certain conditions. In other words, out of an enormous quantity of collective data (data in its raw, uninterpreted form) the information (meaning or significance of collective data) is produced. By linking the relational database to graphics, the results of the query can be shown on a map. Thus, the produced information can be presented visually, in easy to understand demonstrative form.

The analysis was performed using the program Arc/View and was done for both road corridors and road lines Röd 7 and Röd 8. In Arc/View the vector data were divided into the following themes:

- Theme 1 - contained polygons ”Real estates” and different types of attribute data (number of people in each estate, estates area, estates assesses value, and so on)
- Theme 2 - contained road corridor Röd 7
- Theme 3 - contained road corridor Röd 8
- Theme 4 - contained road line Röd 7
- Theme 5 - contained road line Röd 8

Theme 1 and Theme 2 were activated in the View-menu to find out which estates are intersected by the corridor. The Query-function was used to select all the estates that were lying inside the road corridor. Selected features were saved as a new theme.

The new theme was activated in the View-menu, to be able to open its attribute table. When the attribute table was opened it became possible, by activating certain ”fields” in the attribute table and using function ”Statistics”, to get the necessary information to answer the questions of the task. The same operation was repeated for all themes containing alternative road corridors and lines.

7.2 Analysis 2. - Transportation of dangerous goods

This analysis was based on the overlay operation. The principle of GIS overlay comprises the merging of different coverages to produce a multiple-theme coverage containing new information. The analysis was performed using the program ARC/INFO.

To be able to calculate the number of estates and people that were affected by the accident, a zone of risk had to be singled out of the polygon coverage containing the real estate data; this coverage contained in its attribute data table the data on population, estates assessed value and estates area. For this purpose a polygon master coverage was created. Since the risk zone was an area of a certain radius around the center of accident, the option ”Circle” was chosen when creating the master coverage.

X- and Y coordinates were typed in to define the center of the circle and a radius of 500 meters was chosen.

An overlay was performed between the master coverage ”Circle” and the coverage ”Real estate” and the option ”Intersect” was used. The overlay operation produced a new polygon coverage containing only those estates that happened to be within the risk zone. The remaining area lying outside the risk zone was omitted.

The following fields: population, real estates, and estates assessed value were activated in the attribute table of the new polygon coverage. By using function ”Statistics”, the information necessary to answer the questions of the task was obtained.

It was decided to make this analysis for all the points within the area of study with 250 meters interval, assuming hypothetically that each point could be a potential center of accident. For this purpose a program in Avenue was written, which allowed repeating the same analysis until the whole study area was covered. Another program written in Fortran allowed to sum up the result and present it in the form of a raster image.

7.3 Analysis 3. - Encroachment in land use distribution

This analysis was performed using both overlay and relation database techniques described above. Both ARC/INFO and ArcView programs were used to make the analysis.

An overlay (option ”Intersect”) was done between polygon coverage ”Land use” and polygon coverages ”Corridor Röd 7” and ”Corridor Röd 8”. The option ”Intersect” allowed to create new polygon coverages where the content was limited to satisfy the task. The new polygon coverages contained the road corridors Röd 7 and Röd 8 and only those land use classes that were inside of each corridor. The land use area lying outside the corridors was omitted. Both coverages were then imported into ArcView.

In ArcView the function ”Query” was used to create a circle diagram which would show the distribution of the land use classes inside the corridors.

8.4 Analysis 4. - Transportation of dangerous goods

The method is the same as for Analysis 2. The principle difference is that instead of polygon coverage containing real estates data, the polygon coverage containing land use classes was used.

7.5 Analysis 5. - Hydrological impact

This analysis was performed using ARC/INFO program. First of all, Digital Elevation Model (DEM) used as input had to be compensated for mistakes in the elevation data. A GRID hydrologic function was used to fill depressions and level peaks in a continuous grid and, thus, to remove small imperfections of data.

The next step was to determine from the elevation grid the direction of flow in the study area. This was done with ”Flowdirection” function in ARC/INFO, which created a grid of flow direction from each cell to its steepest downslope neighbor. The result showed the direction of flow for each cell in the raster grid.

Finally, watersheds could be determined. To create watersheds, the flow direction was needed as input data. Besides this, one more grid was needed that would contain the cells above which the contributing area, or catchment, could be determined. To find these cells, the accumulation of the flow had to be calculated.

The flow accumulation was calculated; it represented the amount of rain that would flow through each cell, assuming that all rain became runoff and there was no interception, evapotranspiration, or loss to ground water. In other words, there was created a grid of accumulated flow to each cell, by accumulating the weight for all cells that flow into each downslope cell. Out of this grid the cells that would be the outlets for the watershed could be selected. These cells were defined as having the lowest elevation and the highest accumulation values. The coordinates of the selected cells were identified. Using this final grid containing cells with the highest accumulation values as input, grid of watersheds was created.

The result of this analysis - watersheds and flow direction - was placed in Layout in ArcView in combination with other themes: wells and road corridors Röd 7 and Röd 8.

8. RESULTS

8.1 Analysis 1. - Points/areas of conflict

The analysis presents GIS-solution of defining the area of conflict between the road and the immediate environment. The analysis is done for each alternative (Röd 7 and Röd 8), both for road corridors and road lines within the corridors (Figure 3). The alternatives Röd 7 and Röd 8 are crossing the area that can be classified as residential and natural environment. The results (Figures 4-7) show which estates will be affected by the intersection, how the borders of the estates will be split up by the road, and how many people will be affected in case of each alternative. The results also present the assessed value of the estates, which allows to compare the cost of alternative solutions. The analysis demonstrates how the large amount of data can be presented in compact, visualized form that makes the comparison and evaluation of data much easier both for public, and those taking the decision.

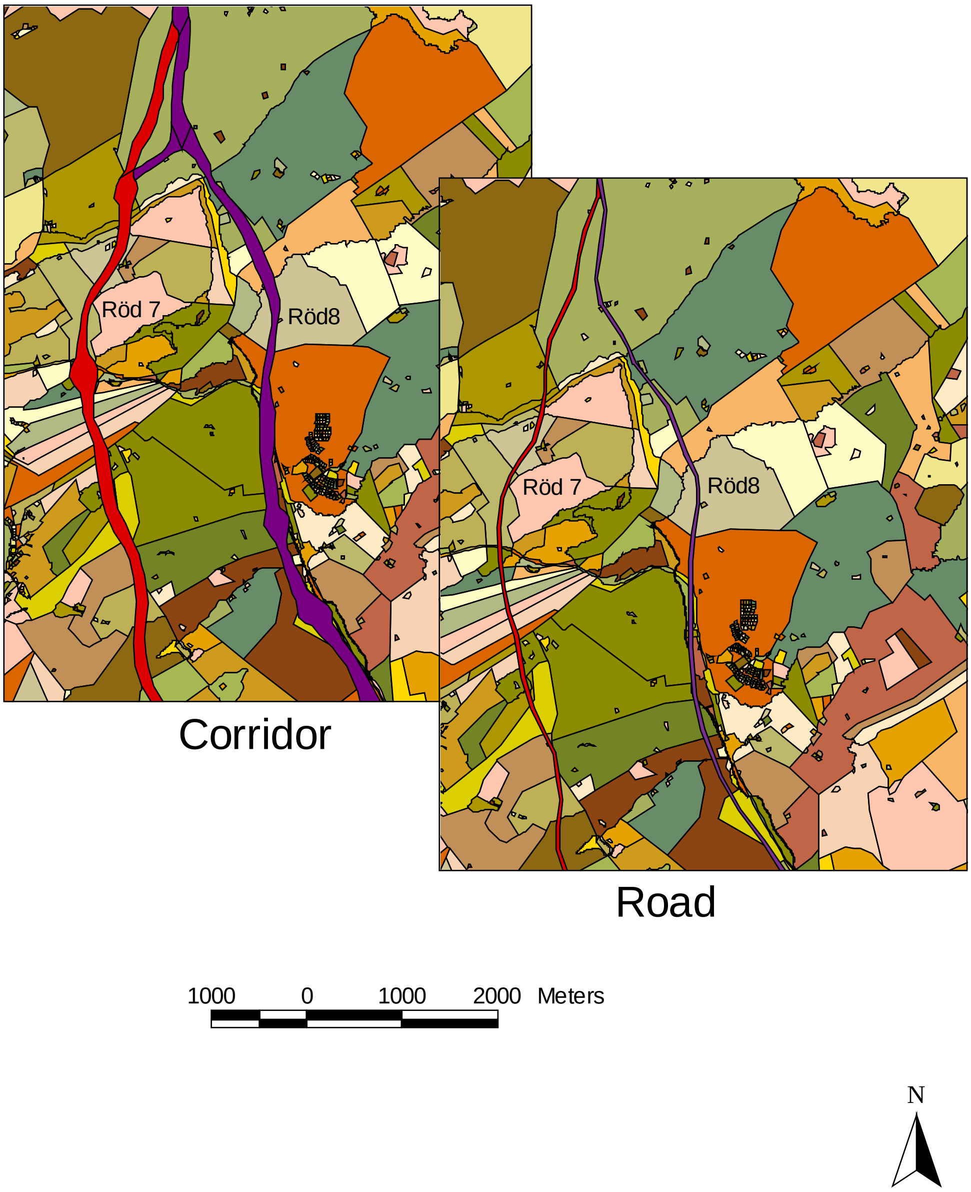
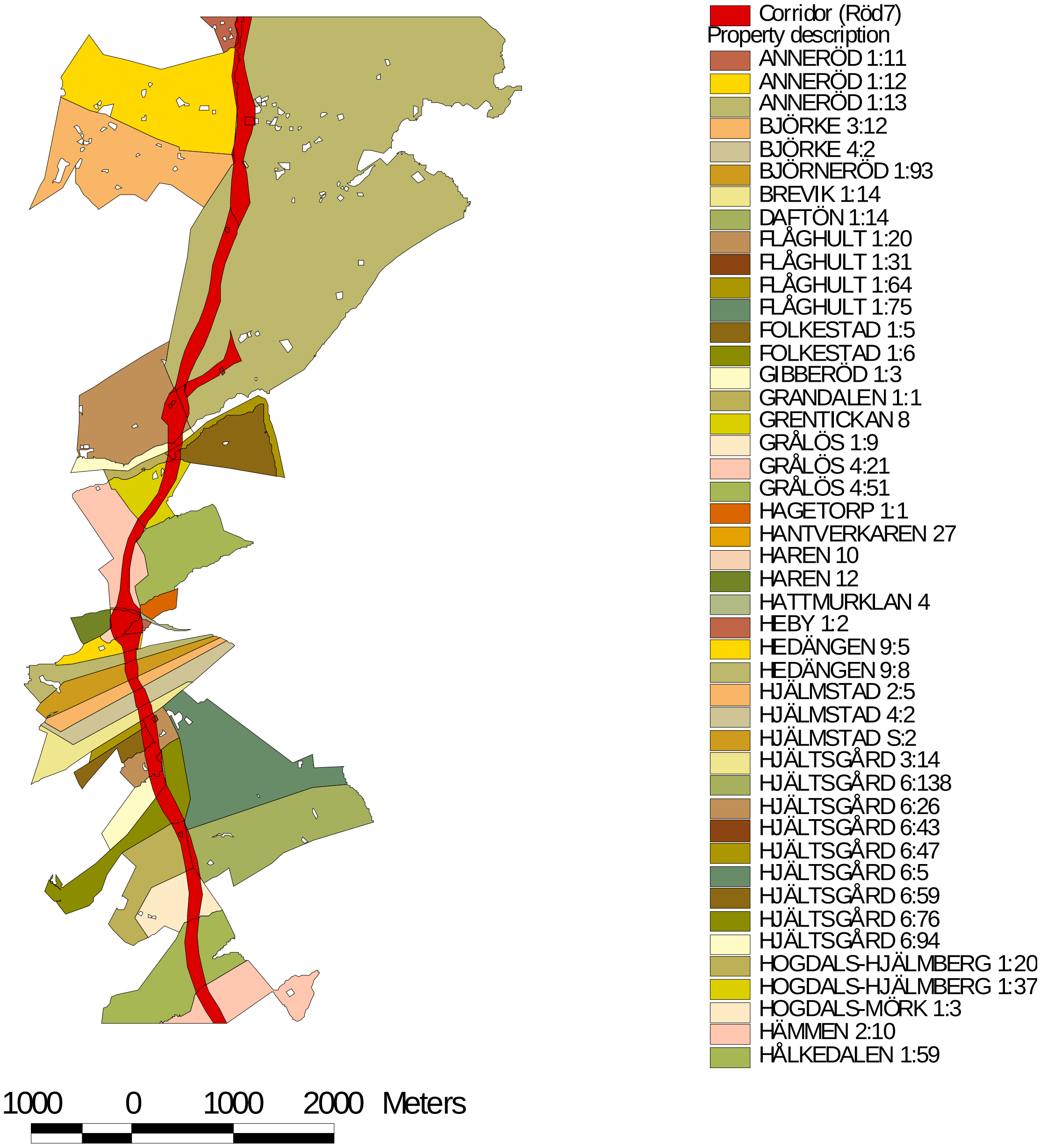


Figure 3. Two alternative road corridors and road profiles (Röd 7 and Röd 8) laid over the real estate data.



Number of people	73
Number of properties	45
Assessed value (thousands SEK)	17,872

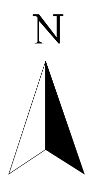
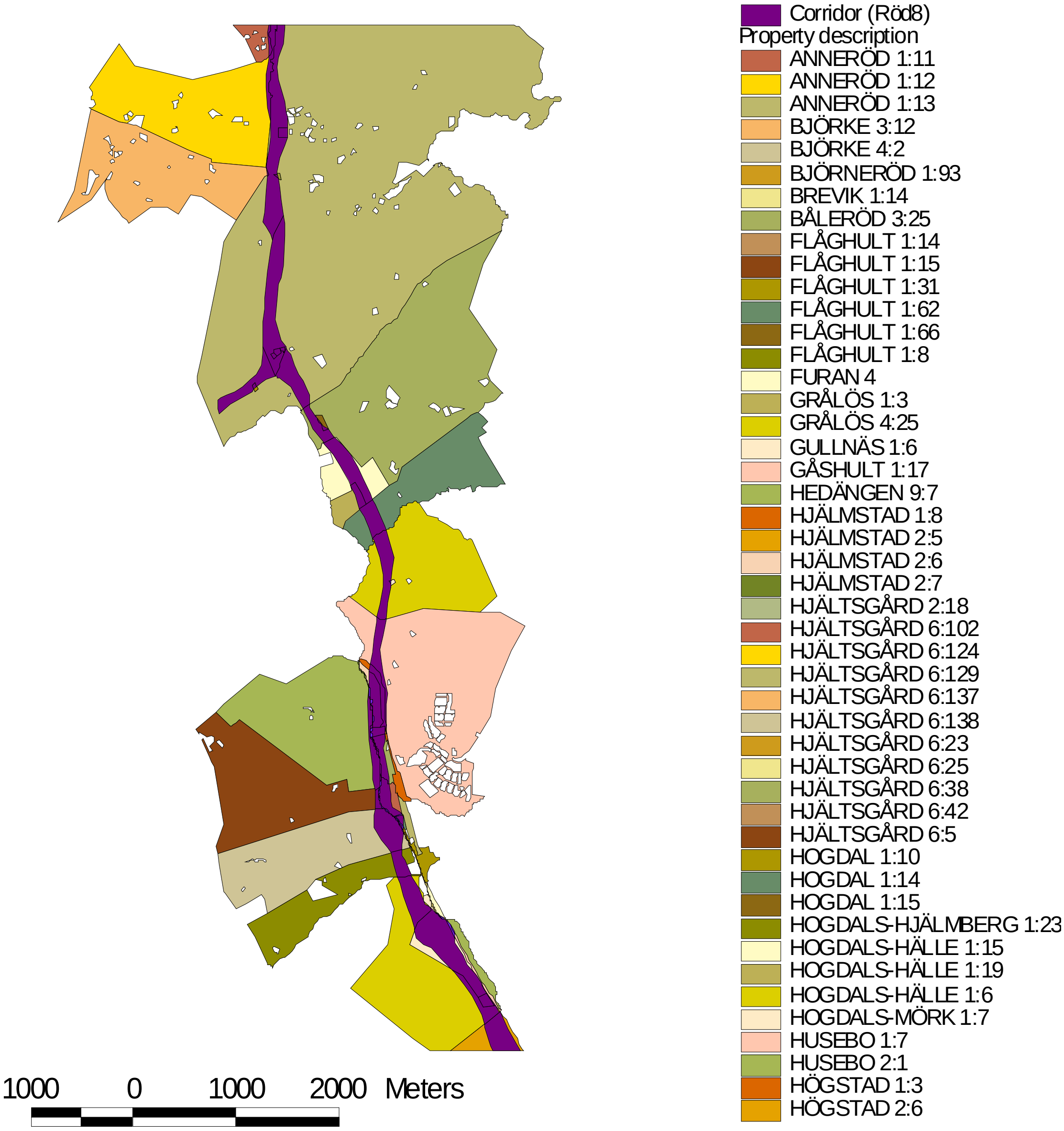


Figure 4. The number of affected people, estates, and estates assessed value in the ”area of conflict” for the road corridor Röd 7.



Number of people	96
Number of properties	48
Assessed value (thousands SEK)	21,787

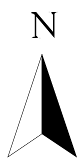
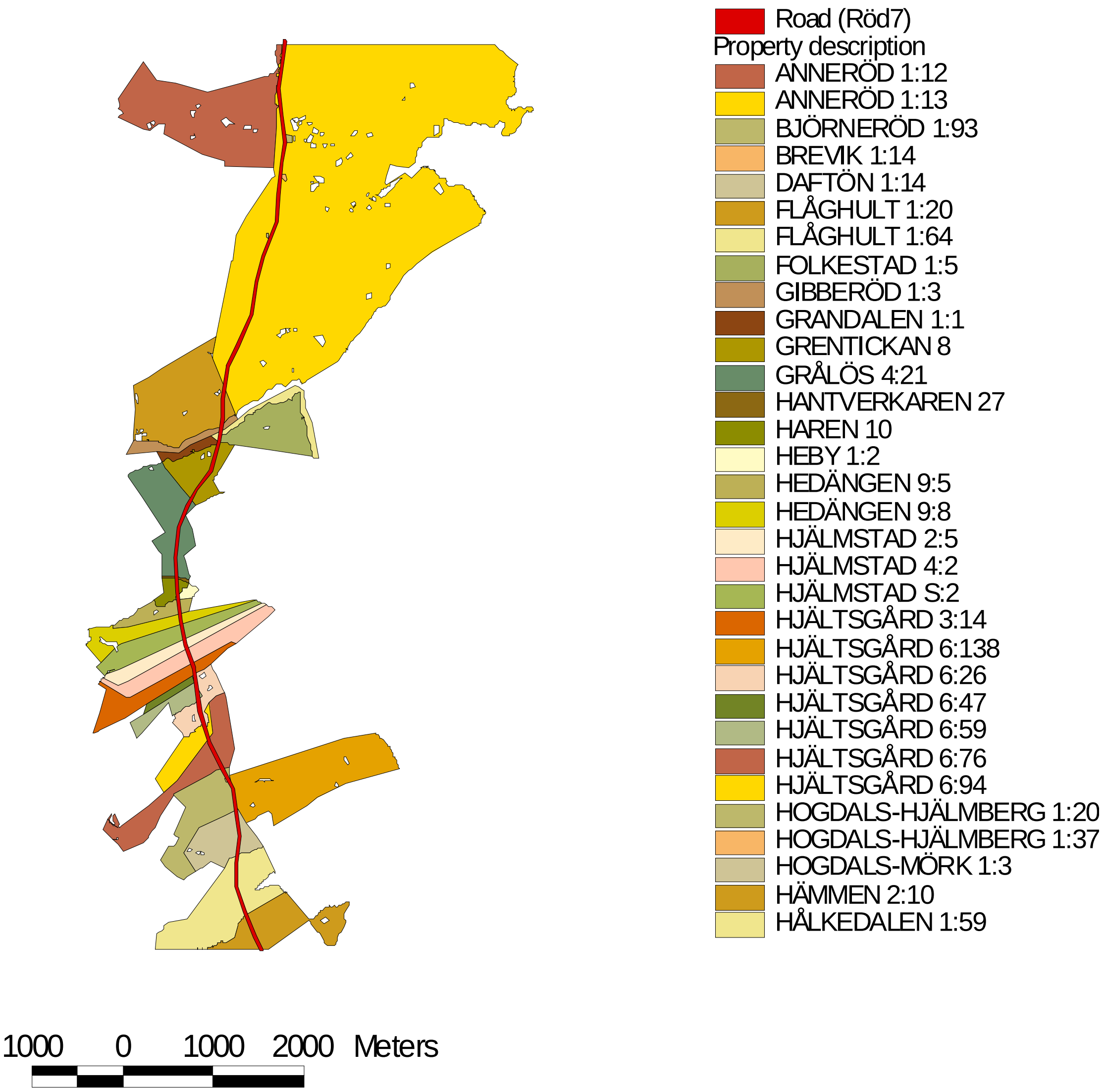


Figure 5. The number of affected people, estates, and estates assessed value in the ”area of conflict” for the road corridor Röd 8.



Number of people	55
Number of properties	32
Assessed value (thousands SEK)	13,466

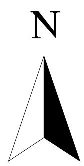
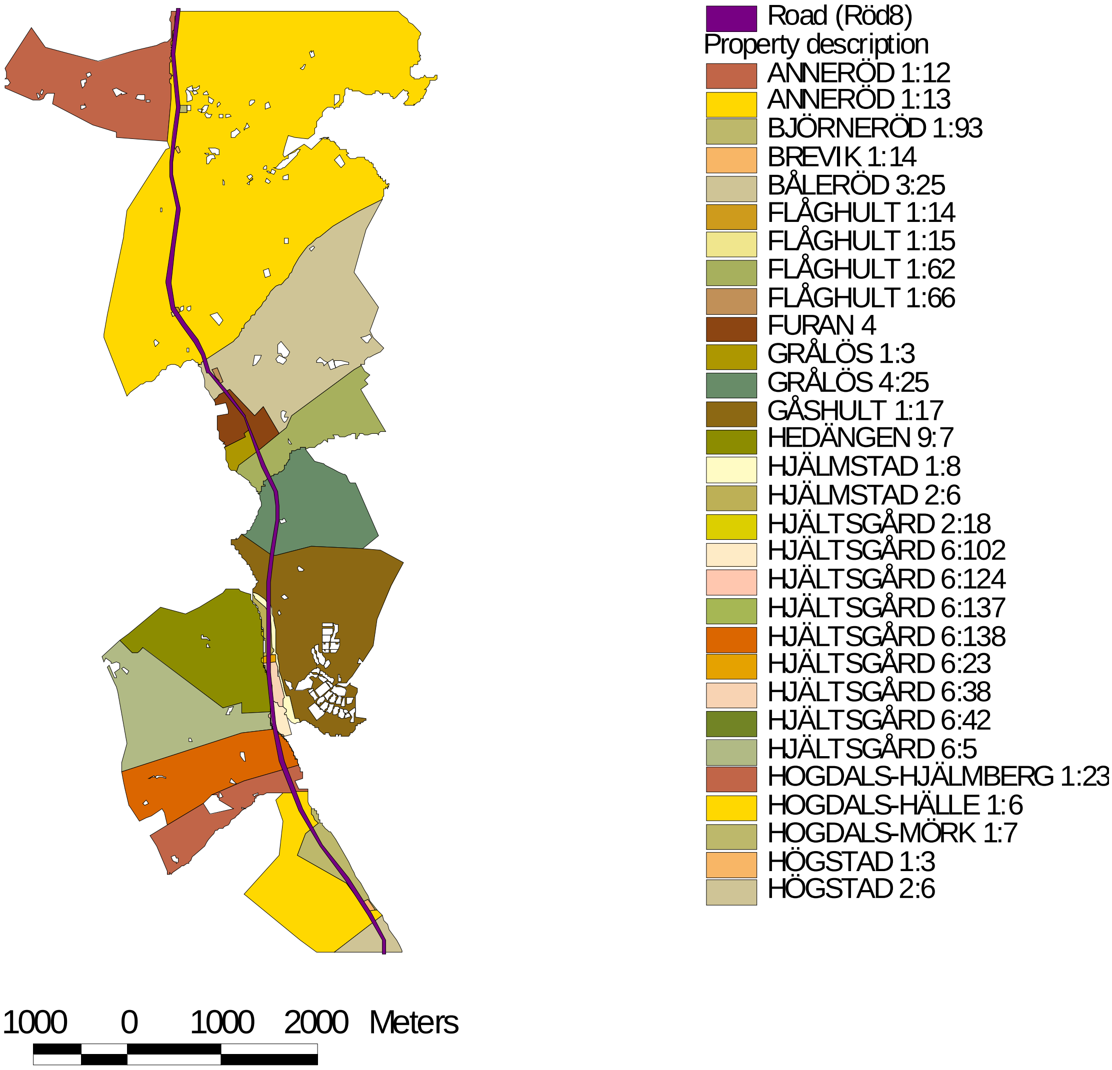


Figure 6. The number of affected people, estates, and estates assessed value in the ”area of conflict” for the road Röd 7.



Number of people	57
Number of properties	31
Assessed value (thousands SEK)	11,344

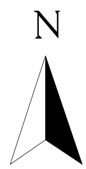


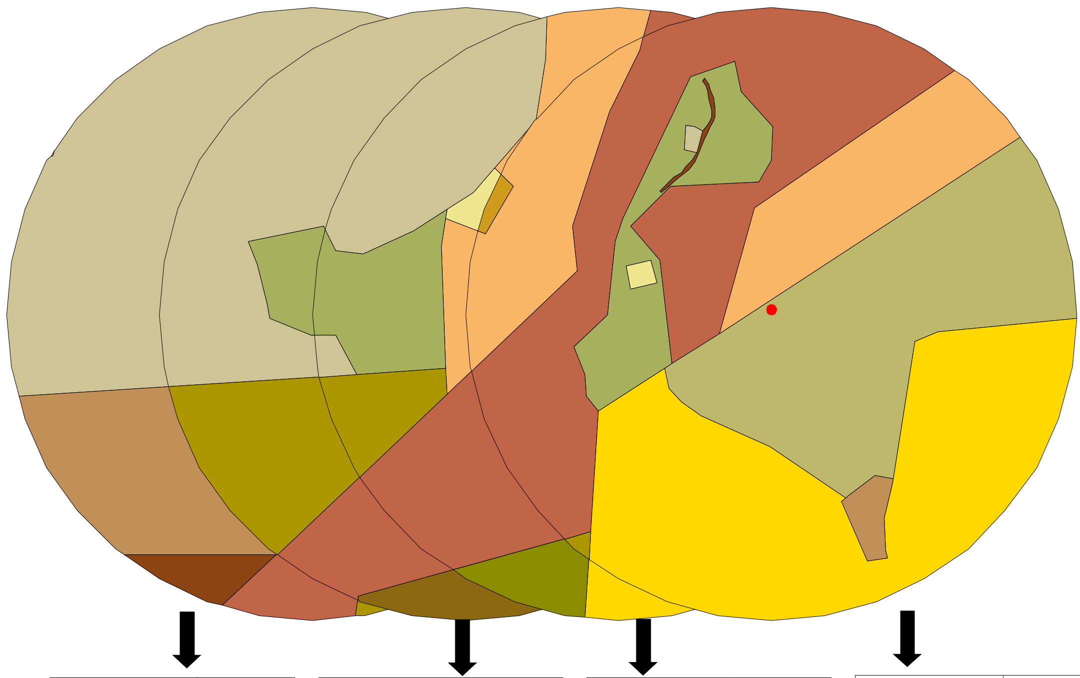
Figure 7. The number of affected people, estates, and estates assessed value in the ”area of conflict” for the road Röd 8.

8.2 Analysis 2. - Transportation of dangerous goods

The analysis demonstrates a GIS-solution of finding and describing all objects falling inside the zone of risk around the simulated point of accident[5]. Using real estates and population data as an input data the GIS-method allowed to determine all objects inside the area of risk and to calculate the exact number of people, estates and estates assessed value (Figure 8). The analysis was complicated by assuming that all points within the area of study can be the points of potential accidents[6]. The same analysis was performed for all points within the study area. The zone of risk around the simulated accidents had a radius of 500 meters. The distance of 250 meters was chosen between the points of accident.

The result was obtained in the form of a raster image where each cell represents the number of affected people if an accident would happen in this particular cell (Figure 9), and the assessed value of the affected estates (Figure 10). Thus, it became possible to assess the sensitivity of the whole area regarding population and estate value. Such assessment can be useful when locating the road, to minimize the consequences and avoid high cost of compensation if an accident happens in a very populated area or area with estates of high value.

[5] Several points were chosen randomly along one of the road corridors.
[6] It was assumed that the road corridors Röd 7 and Röd 8 had not been planned yet.



	Zone 1	Zone 2	Zone 3	Zone 4
Number of people	8	13	14	14
Number of estates	11	13	14	11
Assessed value (thousands SEK)	2317	5311	5305	4840

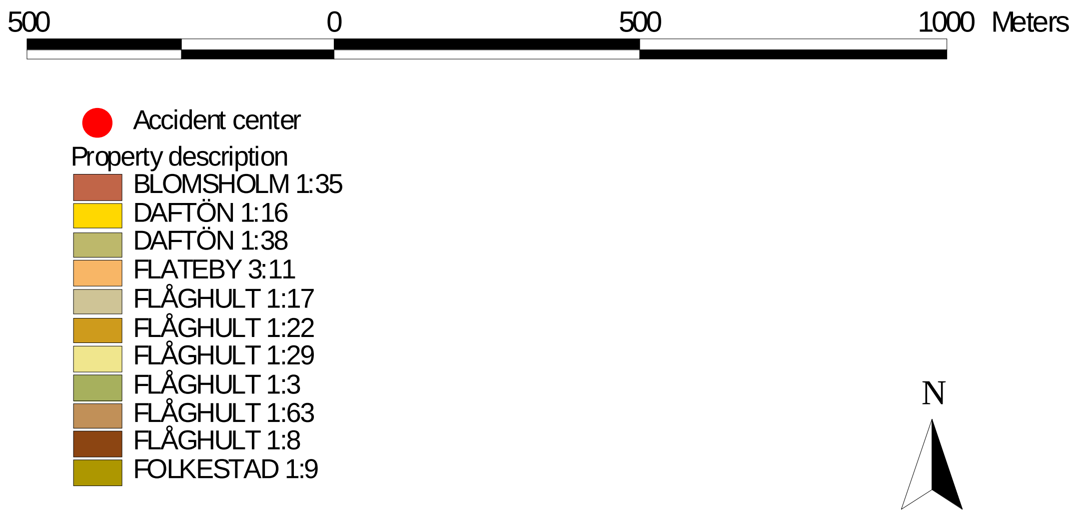


Figure 8. The number of affected people, estates, and estates assessed value within the risk zone. The zone of risk around the simulated accident has a radius of 500 meters.

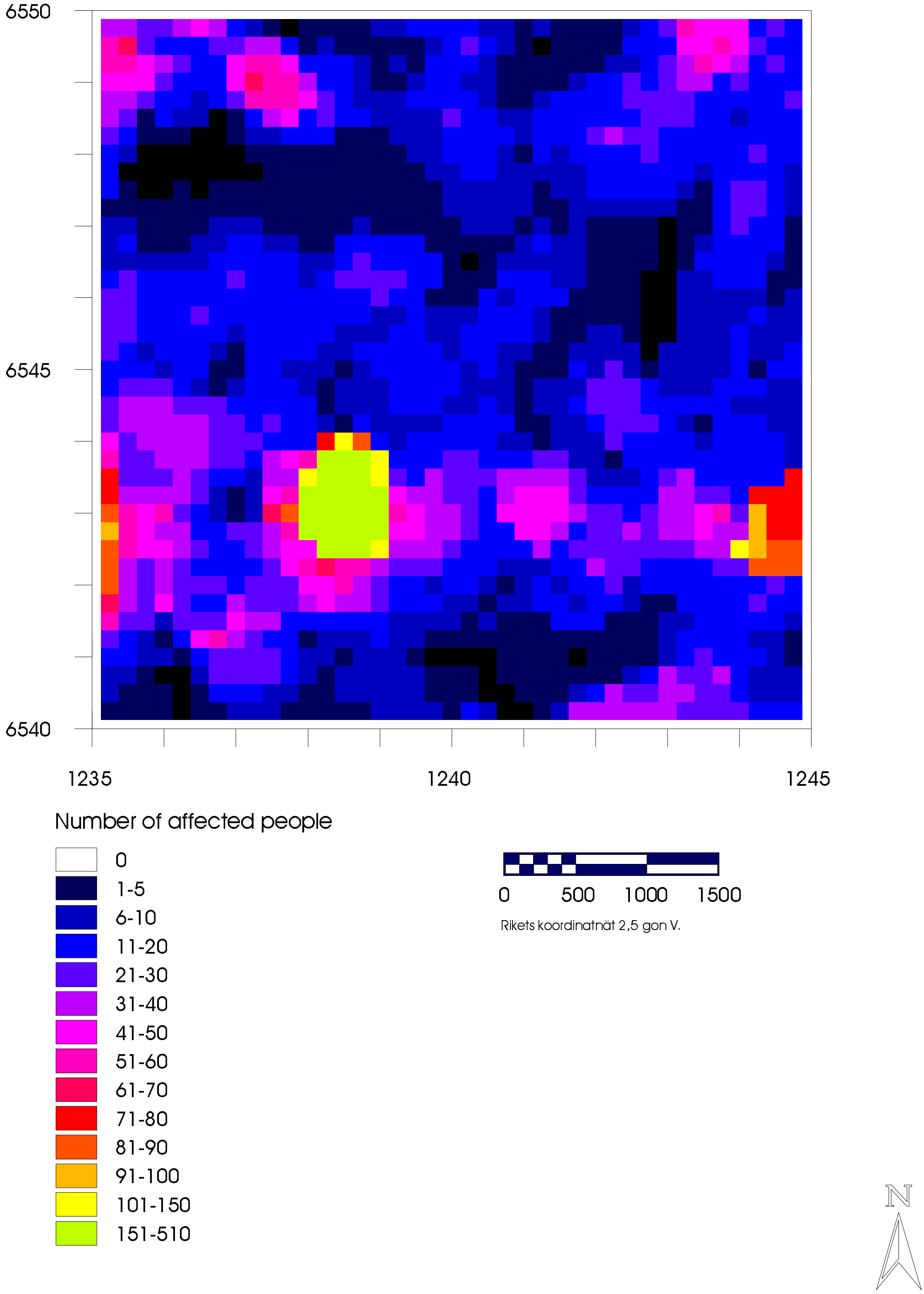


Figure 9. The number of people within the risk zone calculated for each point within the study area. The zone of risk around the simulated accident has a radius of 500 meters. The distance between the points of accident is 250 meters.

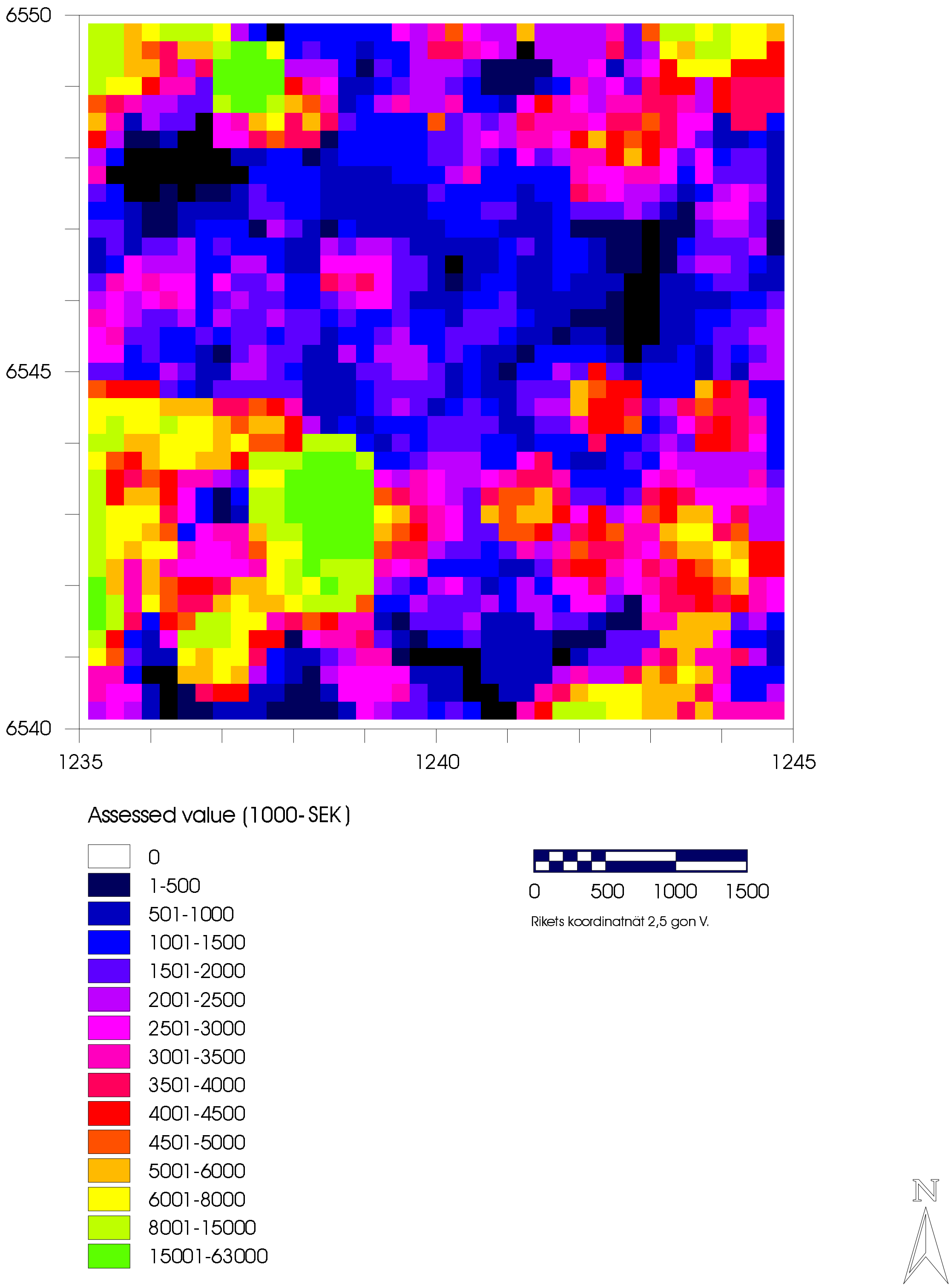


Figure 10. Assessed value of the estates within the risk zone calculated for each point inside the study area. The zone of risk around the simulated accident has a radius of 500 meters. The distance between the points of accident is 250 meters.

8.3 Analysis 3. - Encroachment in land use distribution

The result presents the distribution of land use classes within the alternative corridors Röd 7 and Röd 8 (Figure 11). The GIS-method allows to present land use distribution both as a map and as a data table. The combination of map and table is necessary in this case, since it is difficult to evaluate the result using only a simple map. According to the table data, Röd 7 contains much more forest than agricultural land comparing with land use distribution in Röd 8. This data can be necessary when making the choice between two alternatives.

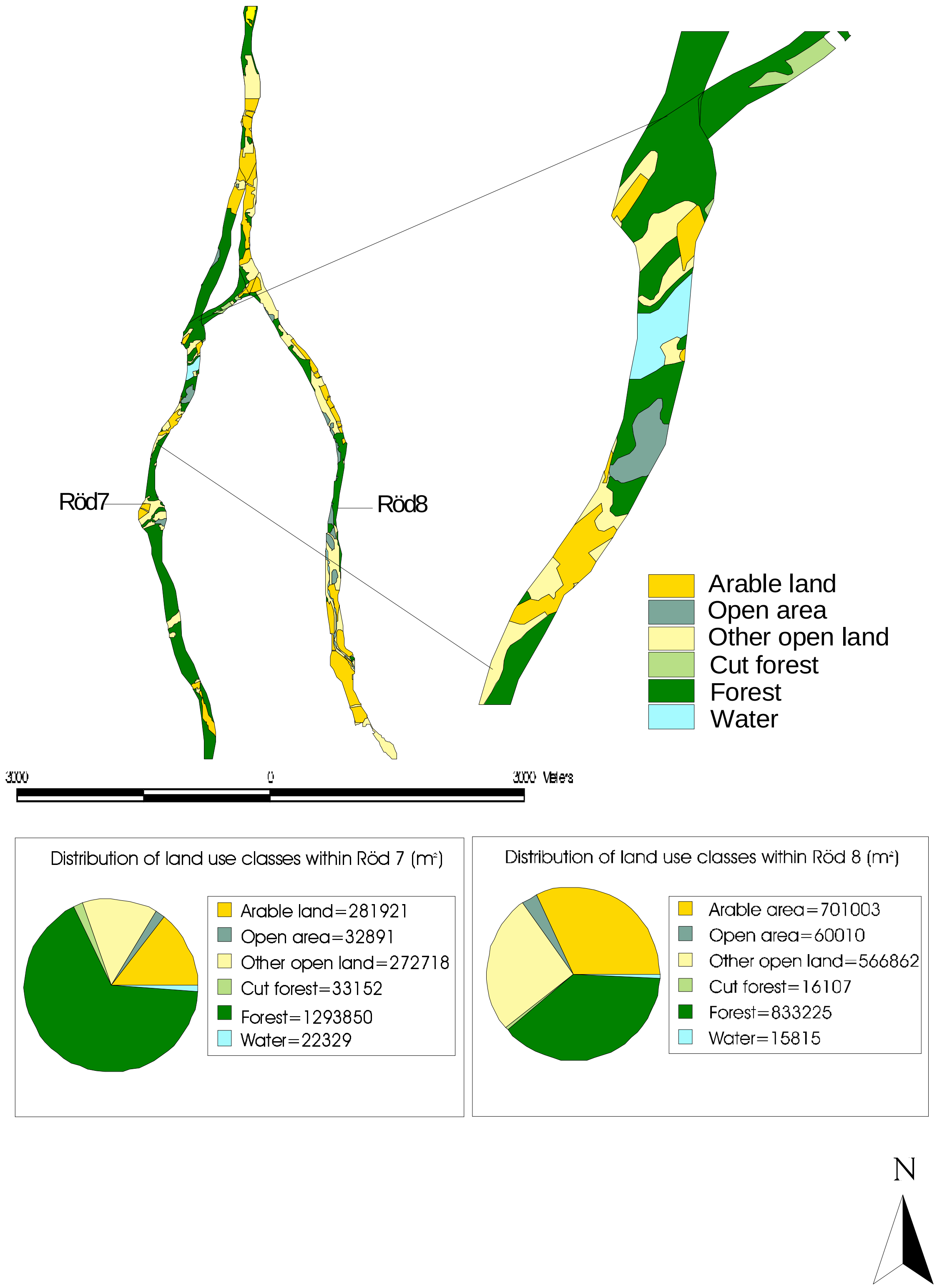


Figure 11. Distribution of different land use classes within the alternative corridors Röd 7 and Röd 8.

8.4 Analysis 4. - Transportation of dangerous goods

The analysis shows the distribution of land use classes within the risk zone (Figure 12). The result is very similar to the result of analysis 2, though in this case land use data was used as an input data for the analysis. More complicated analysis was performed for the whole area of study (Figure 13) which allowed to define the sensitivity of the area regarding valuable agricultural land. Locating the road in a less sensitive area can prevent high costs and damage of the valuable agricultural land.

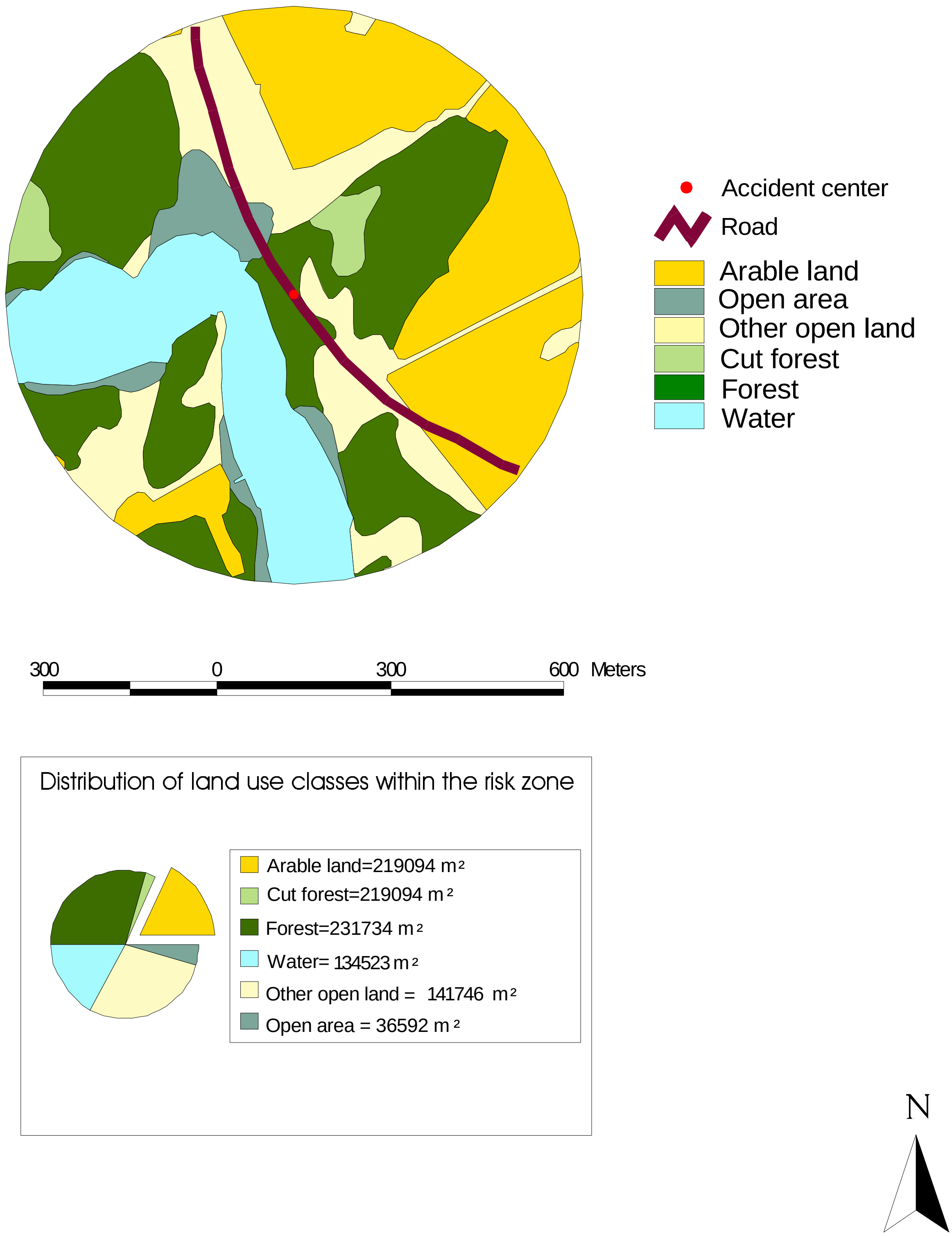


Figure 12. Distribution of different land use classes within the risk zone. The zone of risk around the simulated accident has a radius of 500 meters.

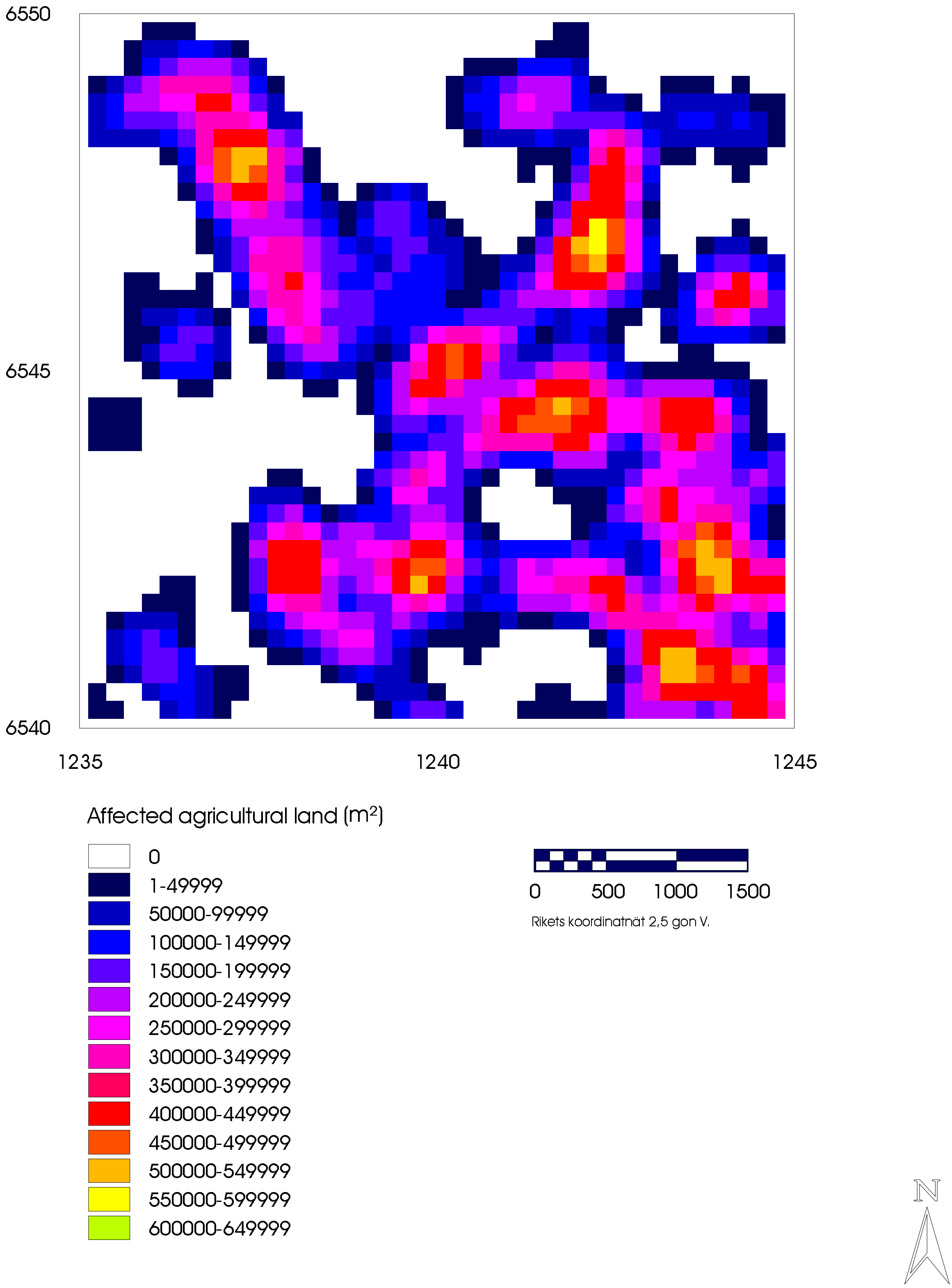


Figure 13. Area of affected agricultural land within the risk zone calculated for each point inside the study area. The zone of risk around the simulated accident has a radius of 500 meters. The distance between the points of accident is 250 meters.

8.5 Analysis 5. - Hydrological impact

The analysis presents the result of determining the contributing area above a set of cells in a grid. The study area is divided into several watersheds, where the flow direction is shown with black arrows (Figure 14). Flow direction can be used as information on where the polluted discharge can be transported in case of an accident. Depending on where the road is crossing the watershed, it is possible to say if the road construction would lead to the disruption of the water movement in the landscape. It is also possible to estimate which part of the water basin is under the damage of being polluted by road operation, or an accident. The flow direction can also be used to define which water wells are lying in the road influence zone, or if there is a risk for contamination in case of an accident. According to the result (Figure 15) none of the alternative roads mean any threat for the wells. However, a thorough hydrological study is needed to make a certain conclusion. The method can be used in EIA for an overall assessment or for producing basis for the further studying.

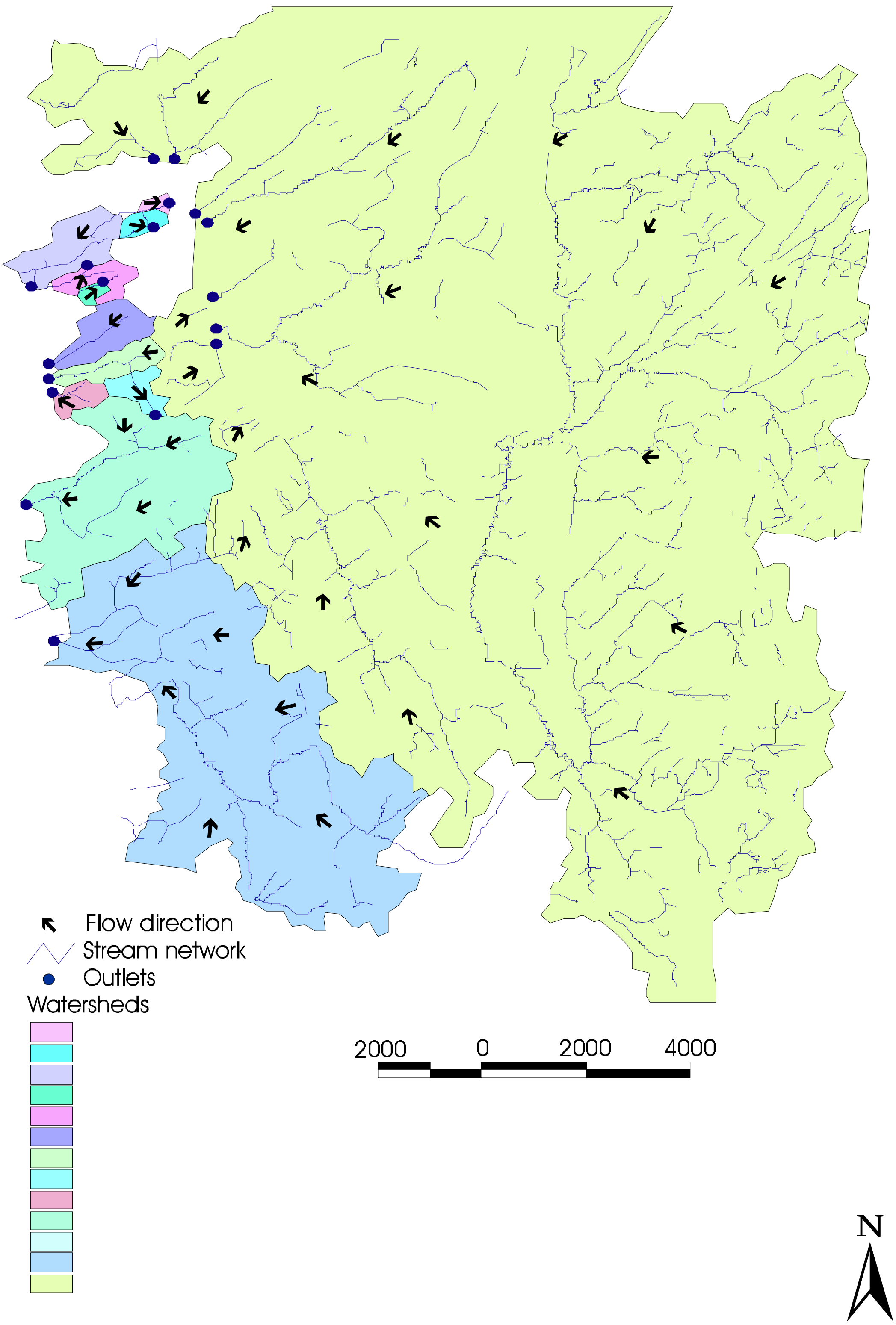


Figure 14. Watersheds and flow direction of the surface water in the study area.

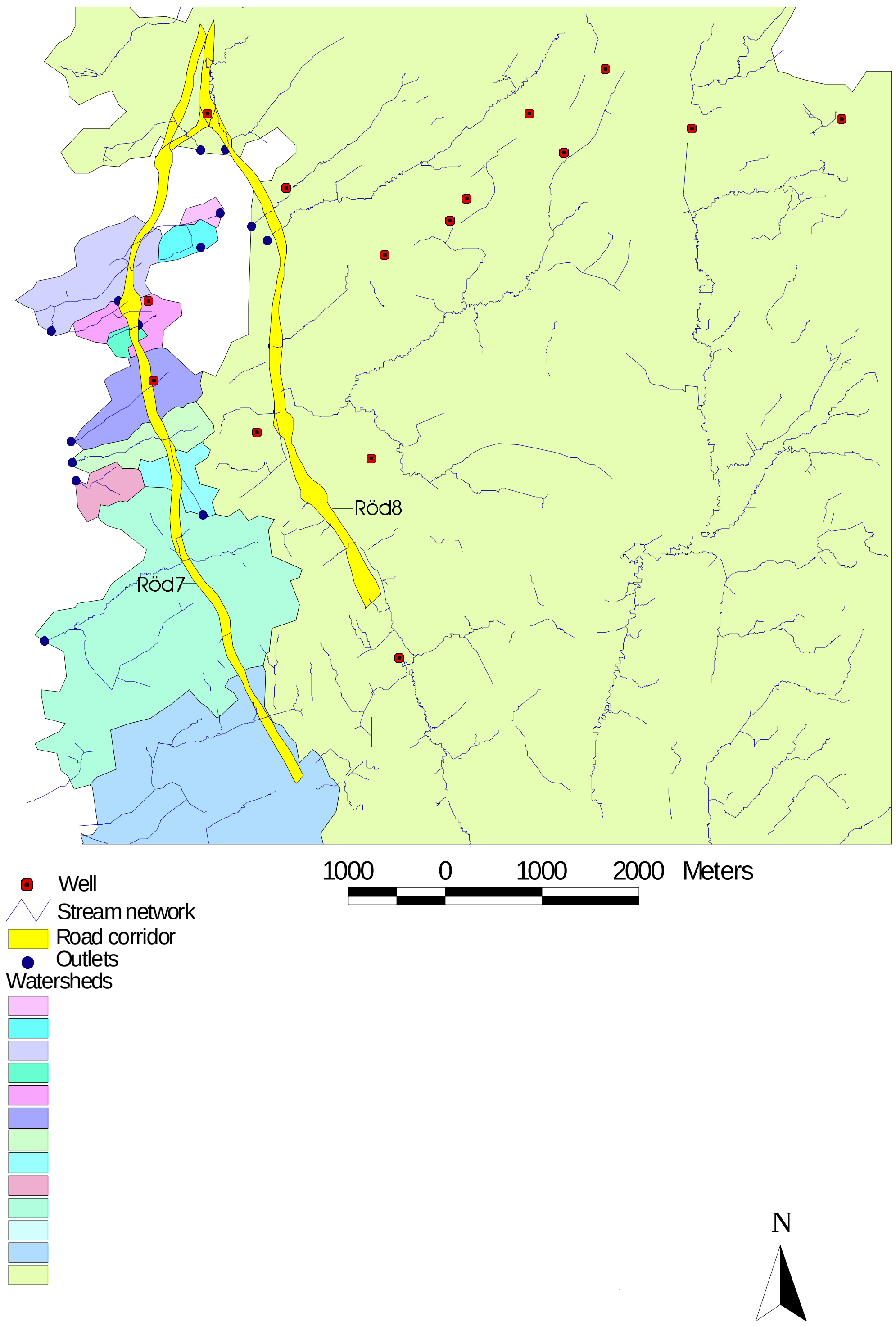


Figure 15. Watersheds within the study area in combination with water wells and alternative corridors Röd 7 and Röd 8.

9. DISCUSSION

GIS is a rapidly growing field that has in most cases proven to be the accepted and standard means of using spatial data. The use of spatial data is growing very rapidly and the adoption of GIS by diverse fields and professions is inevitable (Devis 1996). Quite often it is not a question any longer, if GIS should be used or not, it is just the matter of time, when GIS will be applied. In this situation it is necessary to be well prepared for adopting the new technique. Introduction of a new technique or method is very often uneasy and painful process; it demands time, resources, knowledge and so on. By being aware of potential and problems of the technique it can be much easier to establish well functioning application of GIS. Therefore, the scope of this study is to present the possibilities for improving EIA performance by using GIS, as well as to show the obstacles and difficulties of its application.

19.1 Advantage of using GIS-method for performing EIA

The goal of the study was achieved. The study showed that GIS is applicable for managing and analysing spatial data for EIA purposes. It demonstrated how EIA's tasks could be solved by GIS-methods. The methods developed in the study allowed to solve all the tasks successfully. However, it is hard to say how good the results are, because no comparison with traditional methods was done. It should be mentioned, that there is always an opportunity to improve the method or to use better input data, which will improve the result. Though the methods are developed for the particular analyses, they can be used for the similar analyses as well. Any kind of adjustments can be easily done.

The GIS-application showed that the system could accept and manage different types of spatial data both in digital and analog form. The output of the result could be obtained in the form of maps accompanied by statistics in the form of tabular data. All results were in digital form and could be easily stored inside the system, could be output directly to disks or a network, or used as an input to another GIS.

GIS provided functions that made the performance of the analyses much quicker and easier. It was possible to measure automatically the distance, perimeter, and area and to determine very quickly the location of spatial features (this function was mostly used in the analysis ”Hydrological impact”, where the pour points for the watersheds had to be selected). The GIS database function has proved to be a powerful tool not only for data storage but for extraction as well. The tasks of analyses 1 and 3, that involved the coordination of multiple data sets, were easily handled by the GIS relational database, using ”queries” for data extraction.

Another strong side of the GIS that was revealed during the study is a link between a relational database and graphics: the results of the relational queries could be shown on the graphics, as well as graphics selection could be displayed in the database. For example, by pointing to a specific feature on the displayed theme or coverage it was possible to get all the information about this particular feature displayed in the database, or by selecting a field in the attribute table as it was possible to reduce the graphic presentation to the essential theme. This offered a great deal of flexibility in the work with spatial data, while solving the tasks.

The GIS-method permitted to perform advanced analyses such as spatial modeling. In the analyses 2 and 4 several spatial models that presented different ”what-if” scenarios were built. These ”what-if” models allowed to evaluate the sensitivity of the whole area with respect to different parameters. Being generalized presentation of the reality, the GIS models appeared to be useful tools in prognosticating of what could happen under various conditions.

19.2 Obstacles that appeared during the study

The main difficulties that appeared during the study were mostly connected to the data and not to the technique. The most time-consuming part of the study fell on data acquisition and database building. Not all desired data were available at the market and it took a great deal of time to receive the data that were available. Not all the data were available in digital form, which acquired additional work of manual digitizing.

The most serious problem that came up during the analyses was that some of the data were of low quality or contained errors. For example, the input data in analysis 5 contained errors that affected negatively the results. Overlay between water streams and watersheds revealed that some of the streams do not coincide with the watersheds to where they belong (Figure 16). However, it is not possible to say which of the data contains imperfections.

Another obstacle was a lack of data standards; since data sets were obtained from different sources, they were in different formats and had to be converted to the same format. Here, GIS-technique revealed its, probably, the weakest point: it is not flexible enough, while converting data from one format to another.

The GIS-technique used in this study demanded a high level of competence and good knowledge of software. Different types of software had certain limitations, which in some cases made it impossible to perform the analyses using only one program. The switching between the programs was complicated by the fact that different types of software very often do not accept the same formats and, therefore, a lot of conversion was needed, which in some cases could be very bulky and time-consuming.

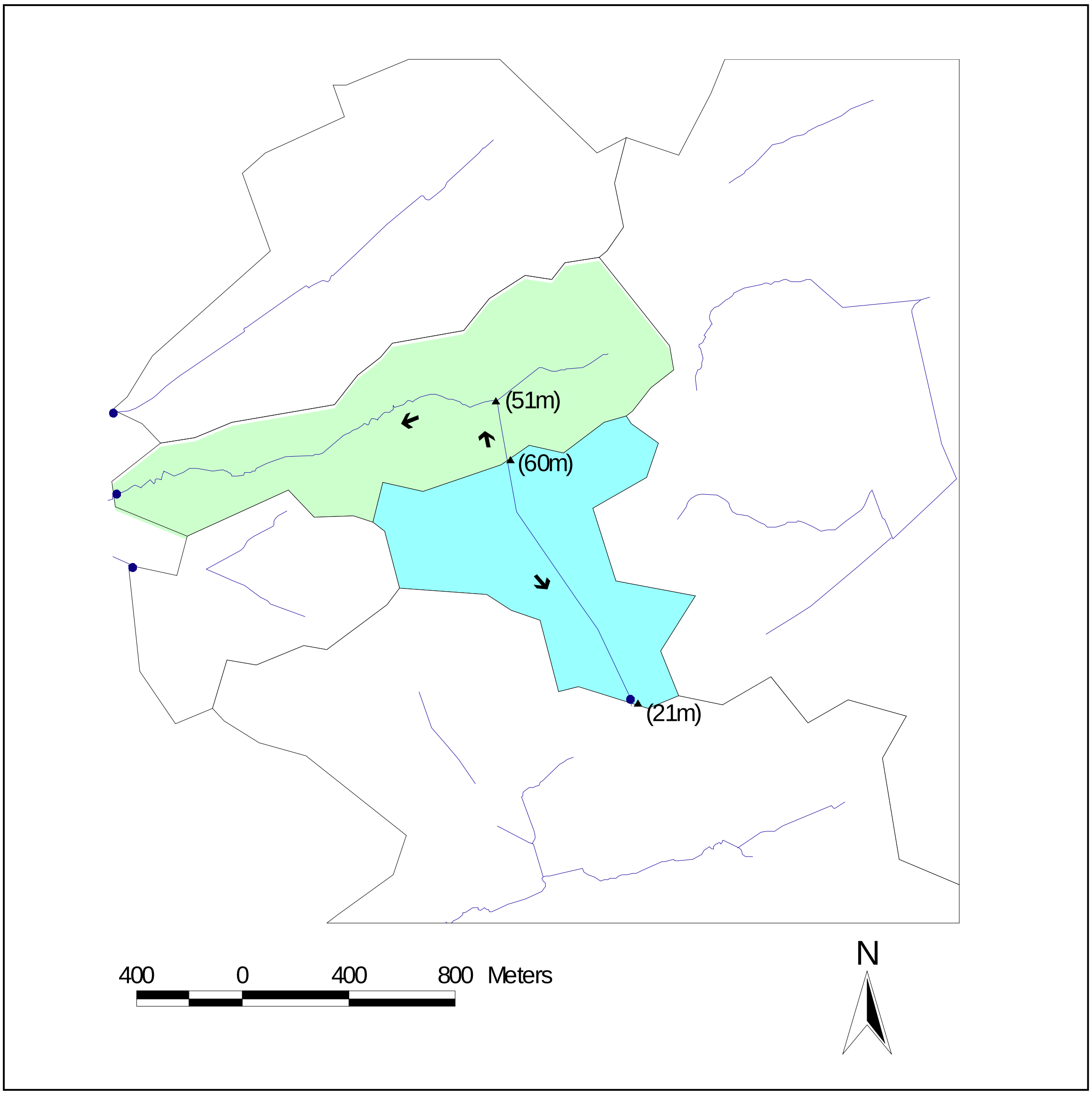


Figure 16. Contradictory results are caused by errors either in elevation or in hydrological data.

10. CONCLUDING REMARKS

Perhaps, the main advantage that the GIS-technique can offer to EIA is a high efficiency of working with spatial data. Traditional methods that comprises a lot of manual and time-consuming work, such as map drawing and writing, cannot compete with computers which become more and more affordable, more easy to use, and more inevitable. New tools that GIS can provide to EIA include: ”computer disks that hold tremendous amounts of data, the digitizer table that converts paper maps into digital data, the electronic plotter that produces maps with very fine detail and in a much shorter time than what once was hand-rendered art” (Devis 1996). Besides this, GIS is a leading technology in visualization of geographical data. It can offer EIA a convenient and effective way to communicate complex information (Devis 1996).

Efficiency in working with information is a key for a successful decision-making. The right information at the right time to a very large extent defines the objectivity of the decision. GIS provides a quick and easy access to any information within the system and allows spreading the information in no time to everybody who needs it. The fast updating of information means that the latest information is always available. This saves time, resources, and improves the quality of the decision (Slutrapport för Pilot-GIS-projektet 1997).

As a rule, EIA is a cooperative work of a large group of people, specialists in different fields, that are making environmental impact assessment in their own areas. Finally, the results of different working groups are to be compiled in a joint report. By providing a common database, standardized and easy to access, GIS is a system that can unite specialists working in different sectors, making their results presentable for each other and in easy form to exchange.

The analyses of spatial data are an essential part of EIA. Such analyses often comprise the study of the relationships and patterns in data. Not all spatial relationships can be seen with the eye. In order to reveal the complexity of spatial patterns and relationships, a lot of data should be processed. GIS provides technique for performing different types of geographical analyses, from the most basic to highly advanced.

However, there are certain difficulties and obstacles that slow down the implementation of GIS. Among the most serious obstacles the following can be pointed out:

- Though there is a rapidly growing market, the prices on hard- and software are still very high. Digital data are very expensive as well.

- GIS-technique is quite advanced, to be able to use GIS special training is needed. The most common obstacle is a lack of fundamental competence.

- Difficulties in obtaining digital data. Not all data are available in digital form. It can take a long time both to find data and to get it in your own system.

- Some times data quality is uncertain.

- The lack of standards is a hindrance for data acquisition and data exchange.

The most obstacles mentioned above are of temporary character and can be explained by the fact that GIS is relatively “young” area. There is a high degree of confidence that the most difficulties will be eliminated with the further development of the GIS technology. There are improvements that are happening all the time: more and more data has been available in digital form, hardware is getting more powerful, software is more advanced and at the same time more easy to use, standardization is a big issue that has been discussed a lot during the last years. The quick development of Information Age promotes the continuous improvement and acceptance of GIS which according to Bruce E. Device (1996) is one of the most important new information technologies to arrive in recent years.

11. REFFERENCES

Boverket (1997), *Boken om MKB*, ISBN: 91-7147-300-9.

Davis, Bruce E. (1996), *Geographic Information Systems: a visual approach,* first edition, OnWord Press.

Förstudie (1997), *Väg E6, Rabbalshede- Hogdal*, Vägverket

Naturvårdsverket (1994), *Miljökonsekvensbeskrivningar inom trafiksektorn*, ISBN 91-620-4334-X.

Slutrapport för PilotGIS-projektet (1997), *Geografiska information system för fysisk planering.*

Staffan Westerlund (1992), *Grunderna i plan- och marklagstiftningar,* Naturskyddsföreningen, ISBN 91-558-3691-7.

The Union's Policies (1999), *The European Union's Transport Policy*, http://europa.eu.int/en/eupol/trans.html.

Vägutredning (1998), *Väg E6 delen Vik-Hogdal,* Vägverket.

Vägverket (1995), *Environmental Impact Assessment for Roads, Manual,* Borlänge, 1995:30 E.

Vägverket (1998), *Miljörapport*, Publikation nr 1998:19

Vägverkets underlagsmaterial för tillämpning av PBL och NRL (1997), *2.2 Strategisk Planering av Vägtransportsystem,* Vägverket, Publikation nr 1997:5.

Vägverkets underlagsmaterial för tillämpning av PBL och NRL (1997), *2.3 Vägplanering och vägprojektering,* Vägverket, Publikation nr 997:6.

Vägverkets underlagsmaterial för tillämpning av PBL och NRL (1997), *4.2 Markanvändning,* Vägverket, Publikation nr 1997:9.

Vägverkets underlagsmaterial för tillämpning av PBL och NRL (1997), *4.3 Farligt Gods,* Vägverket, Publikation nr 1997:10.

Vägverket, Banverket (1996), *Bedömning av ekologiska effekter av vägar och järnvägar.*

Vägverket (1999), *Detta är vägverket, Vägverkets mål,* http://www.vv.se/vagverk/vv-maal.htm

Lunds Universitets Naturgeografiska institution. Seminarieuppsatser. Uppsatserna finns tillgängliga på Naturgeografiska institutionens bibliotek, Sölvegatan 13, 223 62 LUND.

The reports are available at the Geo-Library, Department of Physical Geography, University of Lund, Sölvegatan 13, S-223 62 Lund, Sweden.

1. Pilesjö, P. (1985): Metoder för morfometrisk analys av kustområden.
2. Ahlström, K. & Bergman, A. (1986): Kartering av erosionskänsliga områden i Ringsjöbygden.
3. Huseid, A. (1986): Stormfällning och dess orsakssamband, Söderåsen, Skåne.
4. Sandstedt, P. & Wällstedt, B. (1986): Krankesjön under ytan - en naturgeografisk beskrivning.
5. Johansson, K. (1986): En lokalklimatisk temperaturstudie på Kungsmarken, öster om Lund.
6. Estgren, C. (1987): Isälvsstråket Djurfälla-Flädermo, norr om Motala.
7. Lindgren, E. & Runnström, M. (1987): En objektiv metod för att bestämma läplanteringars läverkan.
8. Hansson, R. (1987): Studie av frekvensstyrd filtringsmetod för att segmentera satellitbilder, med försök på Landsat TM-data över ett skogsområde i S. Norrland.
9. Matthiesen, N. & Snäll, M. (1988): Temperatur och himmelsexponering i gator: Resultat av mätningar i Malmö.

10A. Nilsson, S. (1988): Veberöd. En beskrivning av samhällets och bygdens utbyggnad och utveckling från början av 1800-talet till vår tid.

10B. Nilson, G., 1988: Isförhållande i södra Öresund.

11. Tunving, E. (1989): Översvämning i Murciaprovinsen, sydöstra Spanien, november 1987.
12. Glave, S. (1989): Termiska studier i Malmö med värmebilder och konventionell mätutrustning.
13. Mjölbo, Y. (1989): Landskapsförändringen - hur skall den övervakas?
14. Finnander, M-L. (1989): Vädrets betydelse för snöavsmältningen i Tarfaladalen.
15. Ardö, J. (1989): Samband mellan Landsat TM-data och skogliga beståndsdata på avdelningsnivå.
16. Mikaelsson, E. (1989): Byskeälvens dalgång inom Västerbottens län. Geomorfologisk karta, beskrivning och naturvärdesbedömning.
17. Nhilen, C. (1990): Bilavgaser i gatumiljö och deras beroende av vädret. Litteraturstudier och mätning med DOAS vid motortrafikled i Umeå.
18. Brasjö, C. (1990): Geometrisk korrektion av NOAA AVHRR-data.
19. Erlandsson, R. (1991): Vägbanetemperaturer i Lund.
20. Arheimer, B. (1991): Näringsläckage från åkermark inom Brååns dräneringsområde. Lokalisering och åtgärdsförslag.
21. Andersson, G. (1991): En studie av transversalmoräner i västra Småland.

22A. Skillius, Å., (1991): Water havesting in Bakul, Senegal.

22B. Persson, P. (1991): Satellitdata för övervakning av höstsådda rapsfält i Skåne.

23. Michelson, D. (1991): Land Use Mapping of theThat Luang - Salakham Wetland, Lao PDR, Using Landsat TM-Data.
24. Malmberg, U. (1991): En jämförelse mellan SPOT- och Landsatdata för vegetationsklassning i Småland.
25. Mossberg, M. & Pettersson, G. (1991): A Study of Infiltration Capacity in a Semiarid Environment, Mberengwa District, Zimbabwe.
26. Theander, T. (1992): Avfallsupplag i Malmöhus län. Dränering och miljöpåverkan.
27. Osaengius, S. (1992): Stranderosion vid Löderups strandbad.
28. Olsson, K. (1992): Sea Ice Dynamics in Time and Space. Based on upward looking sonar, satellite images and a time series of digital ice charts.
29. Larsson, K. (1993): Gully Erosion from Road Drainage in the Kenyan Highlands. A Study of Aerial Photo Interpreted Factors.
30. Richardson, C. (1993): Nischbildningsprocesser - en fältstudie vid Passglaciären, Kebnekaise.
31. Martinsson, L. (1994): Detection of Forest Change in Sumava Mountains, Czech Republic Using Remotely Sensed Data.
32. Klintenberg, P. (1995): The Vegetation Distribution in the Kärkevagge Valley.
33. Hese, S. (1995): Forest Damage Assessment in the Black Triangle area using Landsat TM, MSS and Forest Inventory data.

34. Josefsson, T. och Mårtensson, I. (1995). A vegetation map and a Digital Elevation Model over the Kapp Linné area, Svalbard -with analyses of the vertical and horizontal distribution of the vegetation
35. Brogaard, S och Falkenström, H. (1995). Assessing salinization, sand encroachment and expanding urban areas in the Nile Valley using Landsat MSS data.
36. Krantz, M. (1996): GIS som hjälpmedel vid växtskyddsrådgivning.
37. Lindegård, P. (1996). VINTERKLIMAT OCH VÅRBAKSLAG. Lufttemperatur och kådflödessjuka hos gran i södra Sverige.
38. Bremborg, P. (1996). Desertification mapping of Horqin Sandy Land, Inner Mongolia, by means of remote sensing.
39. Hellberg, J. (1996). Förändringsstudie av jordbrukslandskapet på Söderslätt 1938-1985.
40. Achberger, C. (1996): Quality and representability of mobile measurements for local climatological research.
41. Olsson, M. (1996): Extrema lufttryck i Europa och Skandinavien 1881-1995
42. Sundberg, D. (1997): En GIS-tillämpad studie av vattenerosion i sydsvensk jordbruksmark.
43. Liljeberg, M. (1997): Klassning och statistisk separabilitetsanalys av marktäckningsklasser i Halland, analys av multivariata data Landsat TM och ERS-1 SAR.
44. Roos, E. (1997): Temperature Variations and Landscape Heterogeneity in two Swedish Agricultural Areas. An application of mobile measurements.
45. Arvidsson, P. (1997): Regional fördelning av skogsskador i förhållande till mängd SO_2 under vegetationsperioden i norra Tjeckien.
46. Akselsson, C. (1997): Kritisk belastning av aciditet för skogsmark i norra Tjeckien.
47. Carlsson, G. (1997): Turbulens och supraglacial meandring.
48. Jönsson, C. (1998): Multitemporala vegetationsstudier i nordöstra Kenya med AVHRR NDVI
49. Kolmert, S. (1998): Evaluation of a conceptual semi-distributed hydrological model – A case study of Hörbyån.
50. Persson, A. (1998): Kartering av markanvändning med meteorologisk satellitdata för förbättring av en atmosfärisk spridningsmodell.
51. Andersson, U. och Nilsson, D. (1998): Distributed hydrological modelling in a GIS perspective – an evaluation of the MIKE SHE model.
52. Andersson, K. och Carlstedt, J. (1998): Different GIS and remote sensing techniques for detection of changes in vegetation cover - A study in the Nam Ngum and Nam Lik catchment areas in the Lao PDR.
53. Andersson, J., (1999): Användning av global satllitdata för uppskattning av spannmålsproduktion i västafrikanska Sahel.
54. Flodmark, A.E., (1999): Urban Geographic Information Systems, The City of Berkeley Pilot GIS
55. Tagesson, I., och Wramneby, A., (1999): Kväveläckage inom Tolångaåns dräneringsområde – modellering och åtgärdssimulering.
56. Almkvist, E., (1999): Högfrekventa tryckvariationer under de senaste århundradena.
57. Alstorp, P., och Johansson, T., (1999): Översiktlig buller- och luftföroreningsinventering i Burlövs Kommun år 1994 med hjälp av geografiska informationssystem – möjligheter och begränsningar.
58. Mattsson, F., (1999): Analys av molnklotter med IRST-data inom det termala infraröda våglängdsområdet
59. Hallgren, L., och Johansson, A., (1999): Analysing land cover changes in the Caprivi Strip, Namibia, using Landsat TM and Spot XS imagery.
60. Granhäll, T., (1999): Aerosolers dygnsvariationer och långväga transporter.
61. Kjellander, C., (1999): Variations in the energy budget above growing wheat and barley, Ilstorp 1998 - a gradient-profile approach
62. Moskvitina, M., (1999):GIS as a Tool for Environmental Impact Assessment – A case study of EIA implementation for the road building project in Strömstad, Sweden.