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# Computerised delimitation of urban settlements

A method based on the use of administrative registers and digital maps

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## A method based on the use of administrative registers and digital maps

**Abstract:**
A method for delimitation of urban settlement boundaries has been developed and implemented in the statistical portfolio of Statistics Norway. The method is based on the use of geographical information systems (GIS) and administrative registers, and makes it possible in a cost efficient way to follow the dynamic development of the urban settlement growth.

**Keywords:** Land use, urban settlements, GIS analyses, method development

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# Summary

The purpose of this document is to make available an English documentation of the work concerning development of a register-based method for delimitation of urban settlements in Norway.

Statistics Norway introduced the term «urban settlement» as a regional unit in connection with the Population and Housing Census 1960. However, due to subjective and decentralised work with delimitation of urban areas, it has up to now been difficult to produce statistics for the spatial growth of the settlements. Due to improved data-sources and raising awareness of the importance of the urban areas, it was initiated a pilot project in 1996 with the objective to improve the statistical information in this field.

The method developed during 1996 to 1998 makes it possible, in a cost-efficient and objective way, to produce urban settlements boundaries based on administrative registers. A very important spin-off for this project was that population and building information, geographically distributed with co-ordinates, became available for statistical purposes.

The method and the derived boundaries for urban settlements was officially approved and implemented in the portfolio of Statistics Norway onwards from January 1999. Statistics will be updated annually.

This report is the first out of three planned to be published 1999-2000 due to the project "Land Use Statistics for Urban Settlements" conducted by Statistics Norway. The project is partially funded by Eurostat. Altogether these three publications will cover the work with delimitation of urban settlements, development of land use statistics and a pilot project on the linkage between physical land use and economic parameters.

# 1. Background and objectives

Approximately 75 percent of the Norwegian population was living in urban settlements in 1998, and thus the use of land in urban settlements concerns the environment of a major part of the population. Furthermore, urban areas are characterised by high economic activity due to concentration of trade, service and industry. Urban settlements is therefore regarded as an important statistical regional unit for environmental, economic and demographic studies and research.

Statistics Norway introduced the term «Urban Settlement» as a statistical unit for the first time in connection with the Population and Housing Census 1960. Since then the work with delimitation of urban areas has been conducted every ten years in connection with population and housing censuses in Norway.

Since 1980 the definition has not changed, but due to manual and subjective work with delimitation done by different local administrations, it has been difficult to follow the change over time of physical distribution and growth of urban settlement in terms of areas.

Statistics Norway has during 1997 and 1998 developed and documented a method for automatic and computerised delimitation of urban settlement. The method is based on the use of continuously updated administrative registers on buildings and population. The method developed ensures that the dynamic boundaries of urban settlements can be objectively delimited in a cost-efficient way.

The method and the derived boundaries of urban settlements are onwards from 1999 implemented in the portfolio of Statistics Norway's standards. Annual statistics on population, total area of settlements as well as geographical distribution of settlements will be produced.

The overall objective with work on urban statistics is to develop sustainable indicators for urbanisation - hereunder; indicators for measuring more efficient use of urban areas, amount and direction of changes in land use, centre and periphery characteristics, economic development, environmental sustainability and indicators for transportation requirements.

The objective with this report is to make available an English version of the documentation of work done in Statistics Norway in order to develop and implement a method for computerised delimitation of urban settlements based on administrative registers and digital maps.

# 2. Terms and definitions

An urban settlement is, compared to a municipality or a basic statistical unit, a rather dynamic regional unit. The boundaries change continuously according to construction activity and changes in resident population.

Compared to the recommendations given by ECE (UN/ECE, 1998) and the common Nordic definition from 1960, the most important difference to the Norwegian definition of urban settlements is found in the criteria of distance between buildings; in the Nordic definition and in the ECE recommendations this criteria is set to up to a maximum of 200 metres between buildings. However, the Norwegian definition opens for some flexibility for accepting distances more than 50 metres, and thus the intention of the definition is regarded as being very close or equal to the international recommendations.

The Statistics Norway official definition of the term urban settlement (SSB, 1998) is as follows:

> 1. A hub of buildings shall be registered as an urban settlement if it is inhabited by at least 200 persons (60 - 70 dwellings).
>
> 2. The distance between the buildings shall normally not exceed 50 metres. Distances more than 50 metres are allowed in areas that can not or should not be build-up. This can f.ex. be green-parks, facilities for sports, industrial areas and natural barriers such as rivers or arable land. Smaller hubs of buildings that naturally belong to the urban settlement should be included if situated in a distance up to 400 metres from the main urban settlement.
>
> Urban settlements are geographical areas with dynamic boundaries. Thus number of urban settlements and their boundaries will change over time, depending on construction activity and changes of resident population.
>
> (Unofficial translation 1999)

Compared to many other countries in the ECE region, the Norwegian pattern of distribution of urban areas may deviate. It is often gradual transitions from intensively used urban areas to rural areas with scattered farms and other buildings. Also the Norwegian topography with bands of urban areas concentrated along fjords and in narrow valleys calls for national adjustments of the international recommendations. To establish up to 200 meters between houses in urban settlements as an absolute criteria, will give as a result that many urban settlements will cover a too large proportion of land according to common sense and traditional understanding of the term. However, due to the flexible character of the method developed, it is possible to adjust the parameters and perform several alternative delimitation of urban settlements in order to further increase comparability with international statistics.

# 3.Operationalisation of the definition - selection of criteria

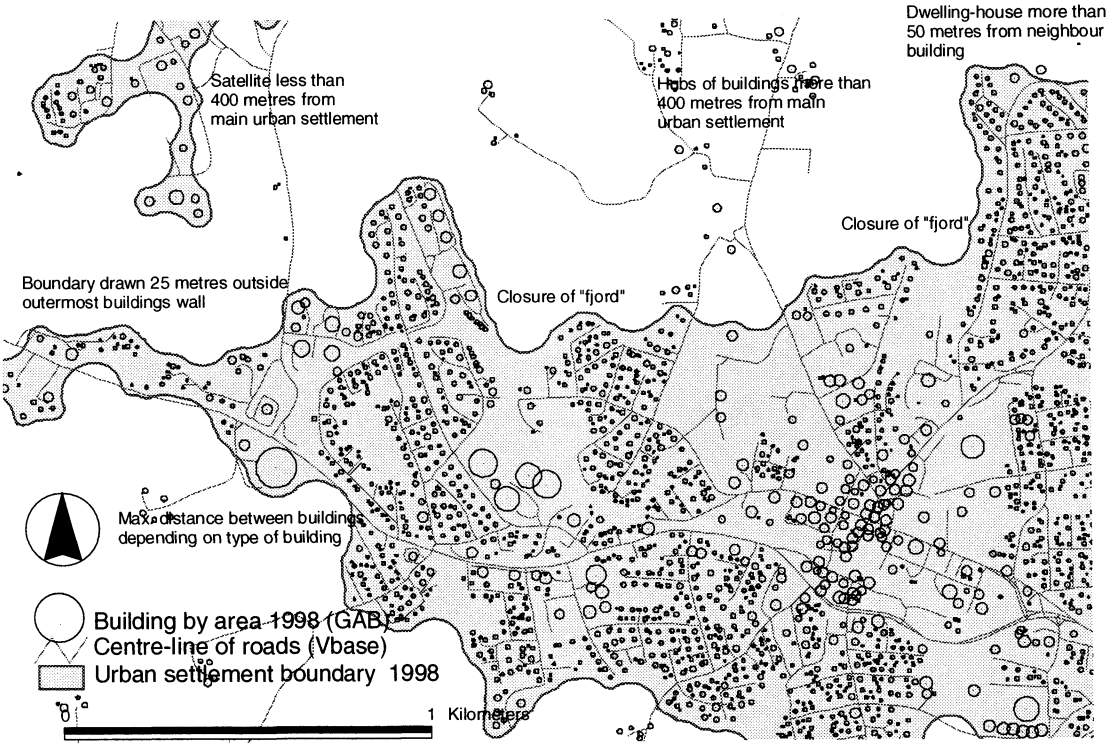
The definition of urban settlement is primarily created with the objective for use in demographic statistics and analyses in order to trace concentrations of population. The definition is thus not very precise when the objective is accurately to define the boundaries and land related to the concentration of population. The wording of the definition comprises several terms of which the meaning has to be specified before an automatic routine for aggregation of boundaries can be programmed.

Work on developing a methodology and testing out criteria have been conducted in 1997 and 1998 by Statistics Norway. After a broad external hearing and thorough discussions in the project's reference group, the following additional operational criteria were agreed to be used for automatic delimitation of urban settlements:

- For a specified selection of building-types (building-blocks, industrial buildings, shopping-centres, office-buildings, store houses, hospitals, educational- and official administrative buildings) the general rule of maximum allowed distance between buildings is increased from 50 to 200 metres.

- The distance between the outermost building in the urban settlement and the settlement boundary shall be 25 metres measured from the building's wall.
- Urban settlements situated up to 400 metres apart shall be merged and counted as one settlement.
- Smaller hubs of buildings («satellites») with at least 5 dwelling-houses, industrial-buildings or other building as specified above, should be counted as belonging to the adjacent urban settlement as long as the hub is situated not more than 400 metres from the main urban settlement.
- Cottages and huts in the peripheral areas of an urban settlement should not be included
- The settlement boundaries shall be generalised and smoothed so that enclaves of land occurring due to irregular forms of the urban settlement boundaries («fjords») should be enclosed into the urban settlement area. This applies as long as the distance between neighbouring buildings on both sides of the «fjord outlet» does not exceed 200 metres.
- To secure continuity, especially for smaller urban settlements with longer tradition, special routines must be performed before such an urban settlement is reclassified as rural.
- The coastline will form the boundaries of urban settlements towards the sea.
- The area of rivers and freshwater is normally included in the urban settlement areas.
- Manual adjustments of automatically aggregated urban settlements can be done in exceptional cases, but then with thorough documentation. Such adjustments occur f.exe. when large and typical rural areas is enclosed in the urban settlements. As a guideline such areas should be excluded manually if they exceed 1 km$^2$ of land.

**Figure 1. Examples on how the agreed operational set of criteria influence on the urban settlement boundary**



# 4.Available data sources

Delimitation of urban settlements is based on data concerning distribution of buildings and resident population. This information can be found in The Official Register for Buildings, Addresses and Ground-properties (GAB) and in The Central Population Register (CPR). Both these registers are continuously updated so that the dynamic development of the urban settlement boundaries can be reflected.

Digital maps in scale 1: 50 000 is used to distinguish between land- and water areas as well as to exclude salt water from urban settlement areas.

Satellite images have been tested both for delimitation and for aggregating land cover statistics for urban areas. The conclusion so far is that this source can be regarded as complementary and may turn out to be useful to adjust the register-based aggregated boundaries. There is however not available a full cover of satellite images in Norway at the present.

***The official register for Buildings, Addresses and Ground-properties (GAB)***
GAB consists of three mutually linked registers where the A- and G-part comprise all addresses and ground-properties. The B-part comprises information of all buildings larger than 15 $m^2$ including co-ordinates. The register is under the responsibility of The Norwegian Mapping Authority.

The following parameters are extracted from GAB:
- Building number
- Estimated ground surface of building
- Date for building taken into use
- Type of building ( class 0-99)
- Different geo-referencing identifiers including co-ordinates (municipality, basic statistical unit, street-address, ground property address etc.)

The GAB information concerning ground surface for older buildings (built before 1983) is not completely filled in. Thus it has been necessary to do imputation for missing values for each building type.

***The Central Population Register (CPR)***
CPR is The Official Central Population Register and is under the responsibility of the Norwegian Tax Authority. The following parameters are extracted from this register:

- Number of persons resident on the actual address
- Different geo-referencing identifiers matching the data from the GAB register

***Digital data from maps***
The Norwegian Mapping Authority delivers digital vector data on coastline, rivers and lakes in scale 1:50 000 and 1: 250 000. Until full national-wide coverage of 1: 50 000 scale data is available, the smaller scale will have to be used for some areas.

# 5. Method

Computerised and automatic delimitation of urban areas is done in two separate steps. Firstly number of residents is geographically distributed to co-ordinates of addresses or buildings. Secondly a geographical information system (GIS) is used to aggregate polygons of urban settlements due to the agreed set of criteria. Thorough technical documentation can be found in SSB Notater 1999.

***Linking information of resident population with building-attributes and co-ordinates***
The merging of population from CPR and co-ordinates from GAB is done in several steps:

1. Based on A-part of GAB: Match on numeric addresses (municipality-code*groundproperty-number or street number*parcel-number or the entrance-number's first level )
2. Based on G-part of GAB: Matching another numeric address on the same ground-property number
3. Based on B-part of GAB: Matching population to building co-ordinates due to address
4. By use of GIS: Simple allocation of unmatched rest population per municipality and groundproperty-number, to the residential-buildings with no resident population attached in the first three steps

The amount of match between population and addresses is depending on the status and quality of registration-work for the GAB register done by the municipalities. Also the quality of the address part of CPR is crucial for a successful operation. The rest group of unmatched population is for most of the 435 Norwegian municipalities less than 2.5 percent of the municipality's total resident population, which is regarded as an acceptable accuracy for delimitation of urban areas.

The final product of the process of matching population and addresses and thus adding co-ordinates is two data-files:

1. A data-file with addresses, co-ordinates and resident population
2. A data-file with attributes concerning buildings and building co-ordinates

***Aggregation of urban settlement area***
Firstly the data-file with building attributes and co-ordinates is loaded into a GIS (ARC/INFO). In each centre-point of buildings a circle proportional with the ground-surface of the building is constructed. Outside each circle representing the ground-surface of the building, a buffer with distance 25 or 100 metres (depending on type of building) is added. Thereafter larger polygons are aggregated based on merging of adjacent building-buffers.

When the larger polygons are made/merged, the resident population within each polygon is calculated. If at least 200 residential persons is found, the polygon fulfils the requirements for being an urban settlement. Polygons that are registered as urban settlements and situated up to 400 metres apart, are merged to one polygon/urban settlement. The area and population of small hubs of buildings (satellites) situated up to 400 metres from the main urban settlement are coded as belonging to the main urban settlement, but not physically attached to it (see figure 1).

***Possible further improvement of the method***
The method for automatic computerised delimitation of urban settlements is adopted and implemented as the Statistics Norway official method onwards from 1999.

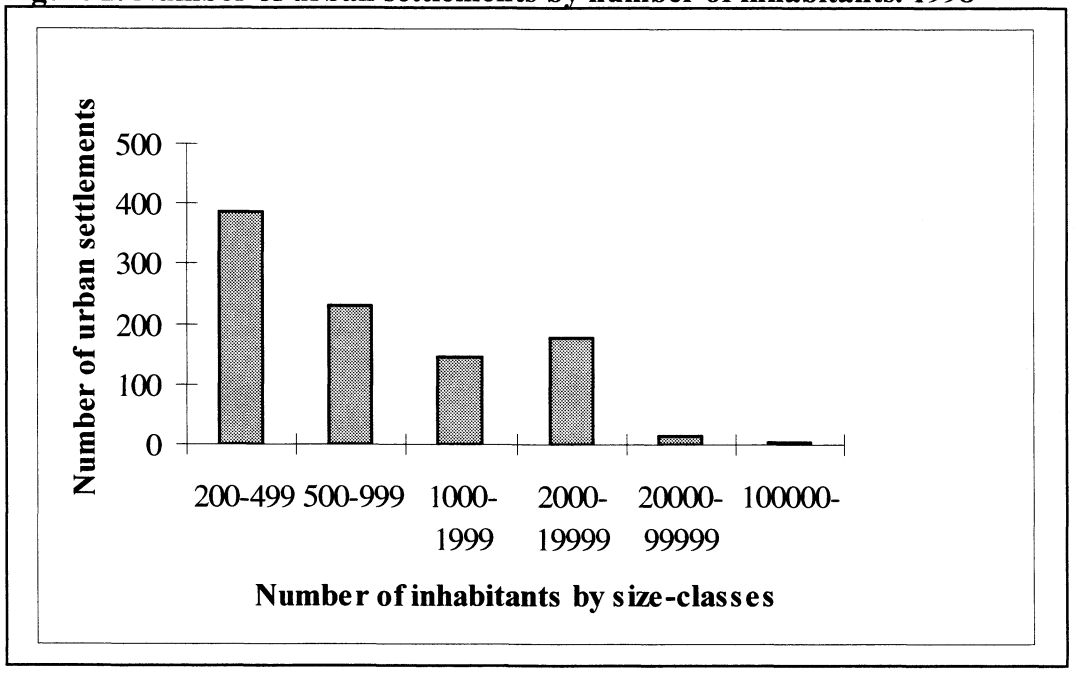
Compared with earlier manual work on delimitation and with the actual purpose of this statistical regional unit, the method yields results of sufficiently high quality. However there are future potentials for further improvement both concerning better matching of population and buildings co-ordinates, as well as for improvement of the process of delimitation. The latter by taking advantage of the now complete database of digital network of roads - Vbase, other administrative register as well as by using satellite images. These additional sources will make it possible also to calculate in the physically sealed areas without buildings on it, such as runways at airports, parking-lots and the often large sealed areas surrounding industrial buildings. Also "green areas" with typical urban functions such as parks, athletic fields etc. in the periphery of the urban areas can then better be integrated.

# 6. Results

For the year 1998, a total of 952 urban settlements with at least 200 inhabitants were delimited by use of the method. The total area of urban settlements was 2 026,1 $km^2$ or 0.7 percent of the total Norwegian mainland area. A total of 3 279 195 inhabitants, or 74,2 percent of the Norwegian resident population were living in urban settlements. For increasing the information-value of the statistics yielded, an overlay with the digital road-database was made, as well as that ground-surface of all buildings and ground-surface under dwelling-buildings were calculated.

The capital Oslo with 754 552 inhabitants pr. 1998 is the biggest urban settlement in Norway measured both by area and by number of inhabitants. However, most of the Norwegian urban settlements are small, and only 8 out of the 952 urban settlements had more than 50 000 inhabitants pr. 1998 (figure 2).

**Figure 2. Number of urban settlements by number of inhabitants. 1998**



Results valid for 1998 concerning the 5 major Norwegian urban settlements are listed in the table (table 1) and illustrated in the attached maps. Also a map showing the distribution of all urban settlements with more than 5 000 inhabitants is annexed. Thorough documentation of results from 1998 can be found in a Statistics Norway report (SSB 1999b). Some discussions and results are also annually published in the booklet Natural Resources and the Environment 1999 (SSB 1999a)

**Table 1. Area, population and land cover of the five largest Norwegian urban settlements 1998**

| Name of urban settlement | Total urban settlement area $km^2$ | Population | Area of roads $km^2$ | Total ground surface of buildings 1000 $m^2$ | Of which ground surface of dwellings 1000 $m^2$ |
|---|---|---|---|---|---|
| Oslo | 259.5 | 754 552 | 32.9 | 32 400 | 15 039 |
| Bergen | 79.3 | 197 573 | 14.3 | 7 015 | 4 323 |
| Stavanger/Sandnes | 59.6 | 143 857 | 9.5 | 7 768 | 3 700 |
| Trondheim | 56.1 | 137 108 | 6.7 | 5 258 | 2 853 |
| Fredrikstad/Sarpsborg | 61.6 | 91 442 | 9.1 | 5 860 | 2 801 |

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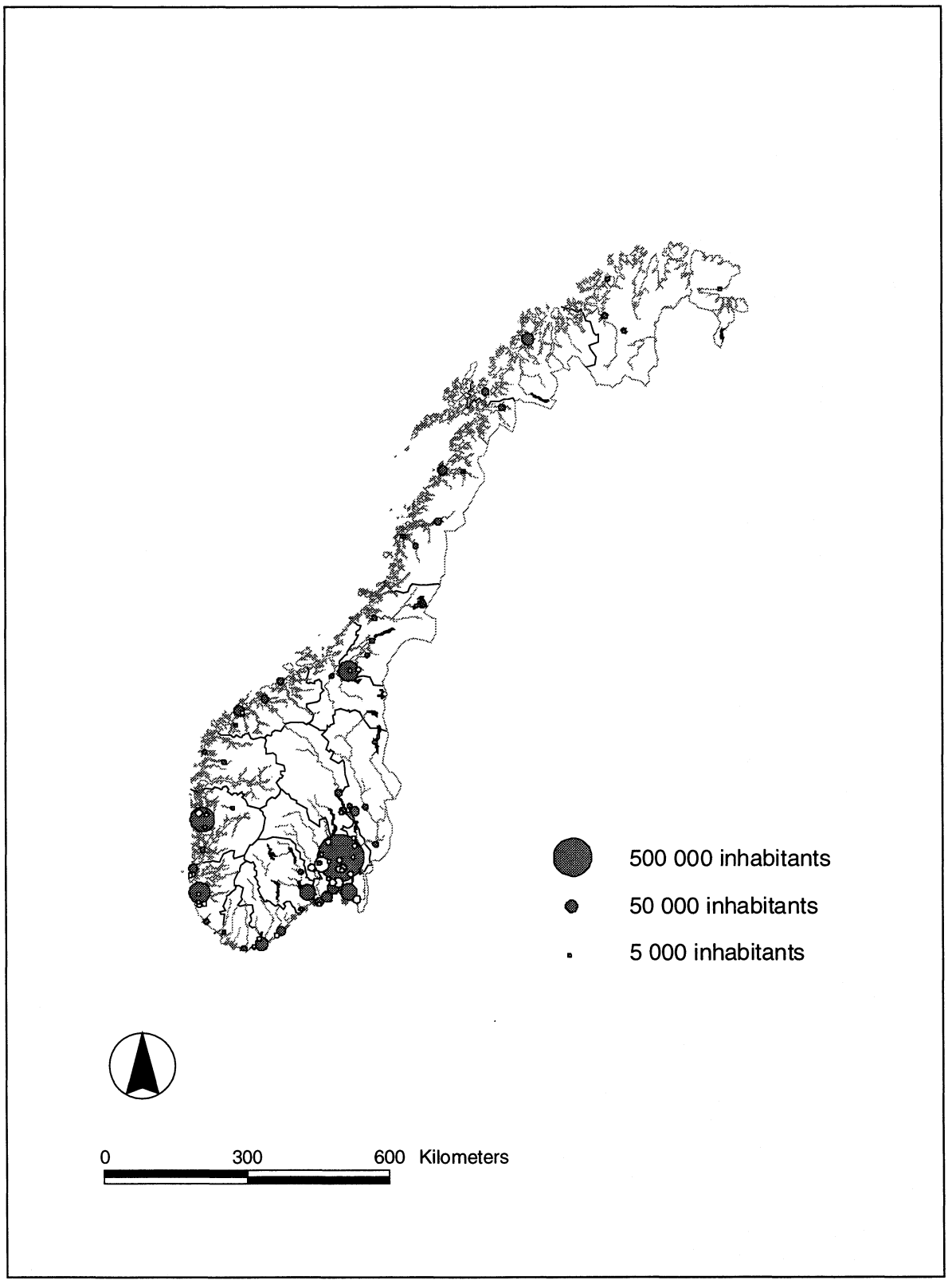
**SSB 1998:** Regionale standarder. Notater 98/25. Statistisk sentralbyrå 1998
**SSB 1999a** Natural Resources and the Environment. Statistics Norway 1999
**SSB 1999b:** Tettstedsavgrensing og arealdekke innen tettsteder. Metode og resultater. Rapporter. Statistisk sentralbyrå 1999
**Notater 1999:** Tettstedsavgrensing 1998. Teknisk dokumentasjon av nye rutiner. Notater 99/4. Statistisk sentralbyrå

# Urban settlements with at least 5 000 inhabitants. 1998




Source: Statistics Norway, 01.11.1999
Basic map data: The Norwegian Mapping Authority

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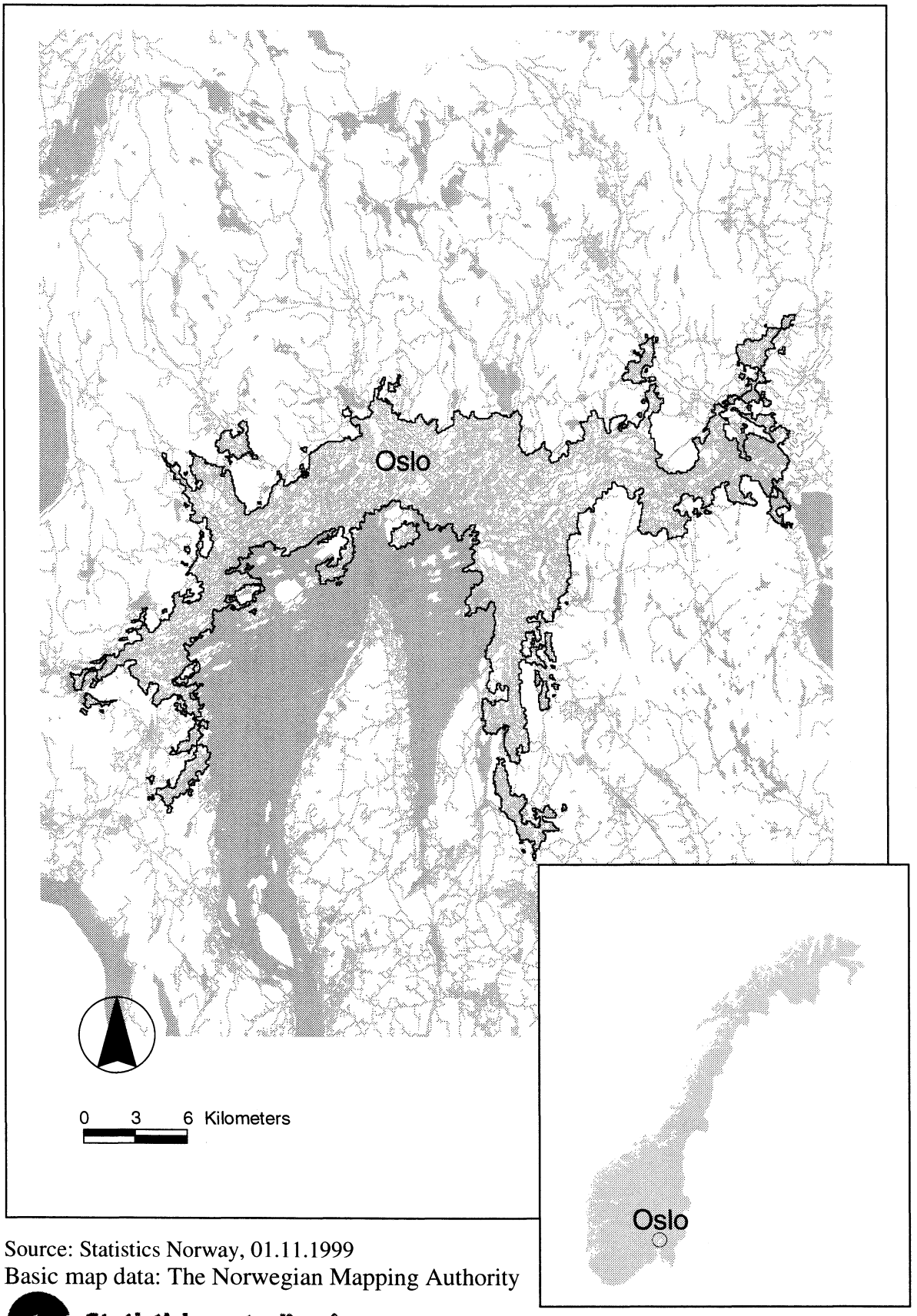
# The urban settlement of Oslo. 1998




Source: Statistics Norway, 01.11.1999
Basic map data: The Norwegian Mapping Authority

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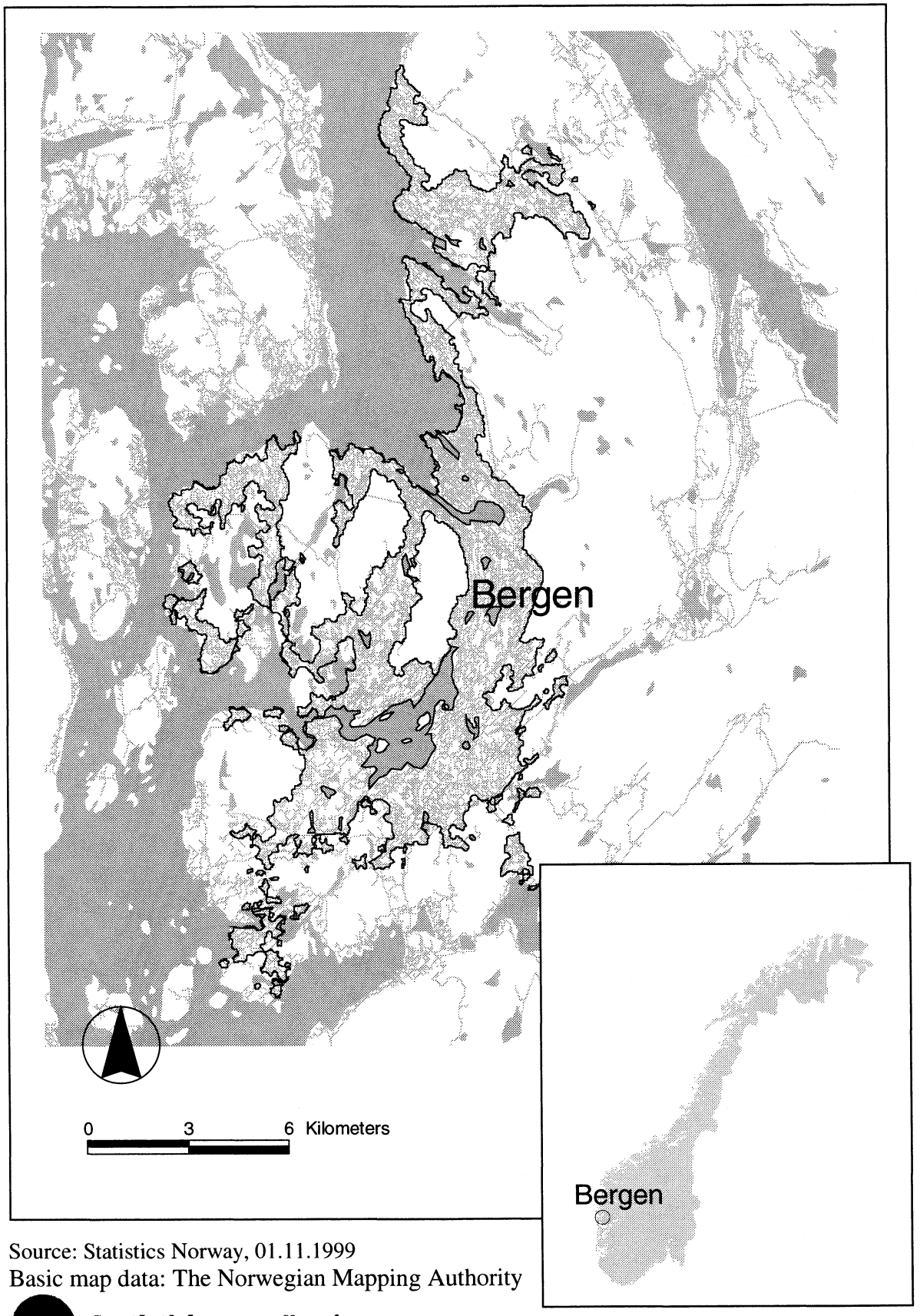
# The urban settlement of Bergen. 1998




Source: Statistics Norway, 01.11.1999
Basic map data: The Norwegian Mapping Authority

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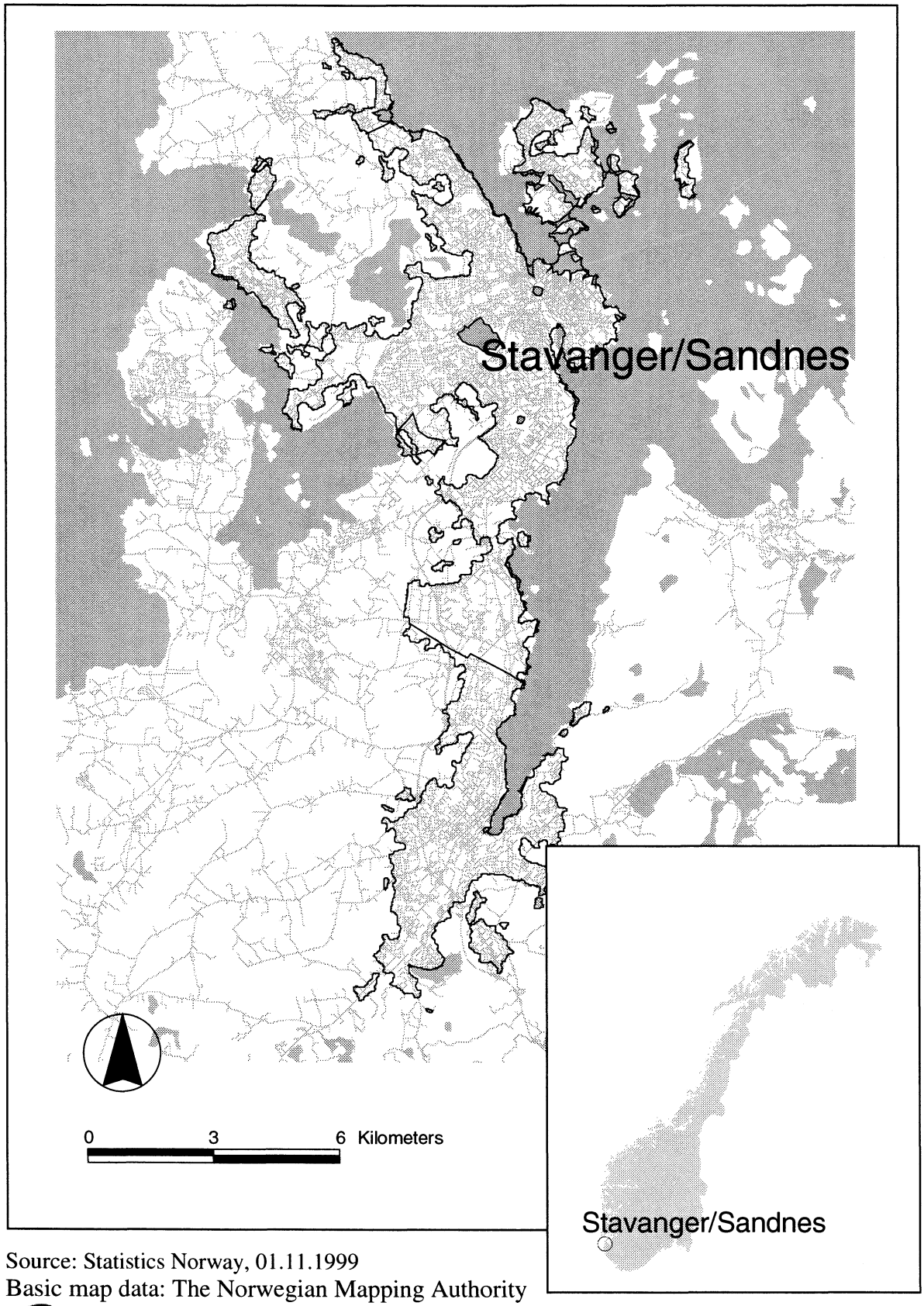
# The urban settlement of Stavanger/Sandnes. 1998




Source: Statistics Norway, 01.11.1999
Basic map data: The Norwegian Mapping Authority

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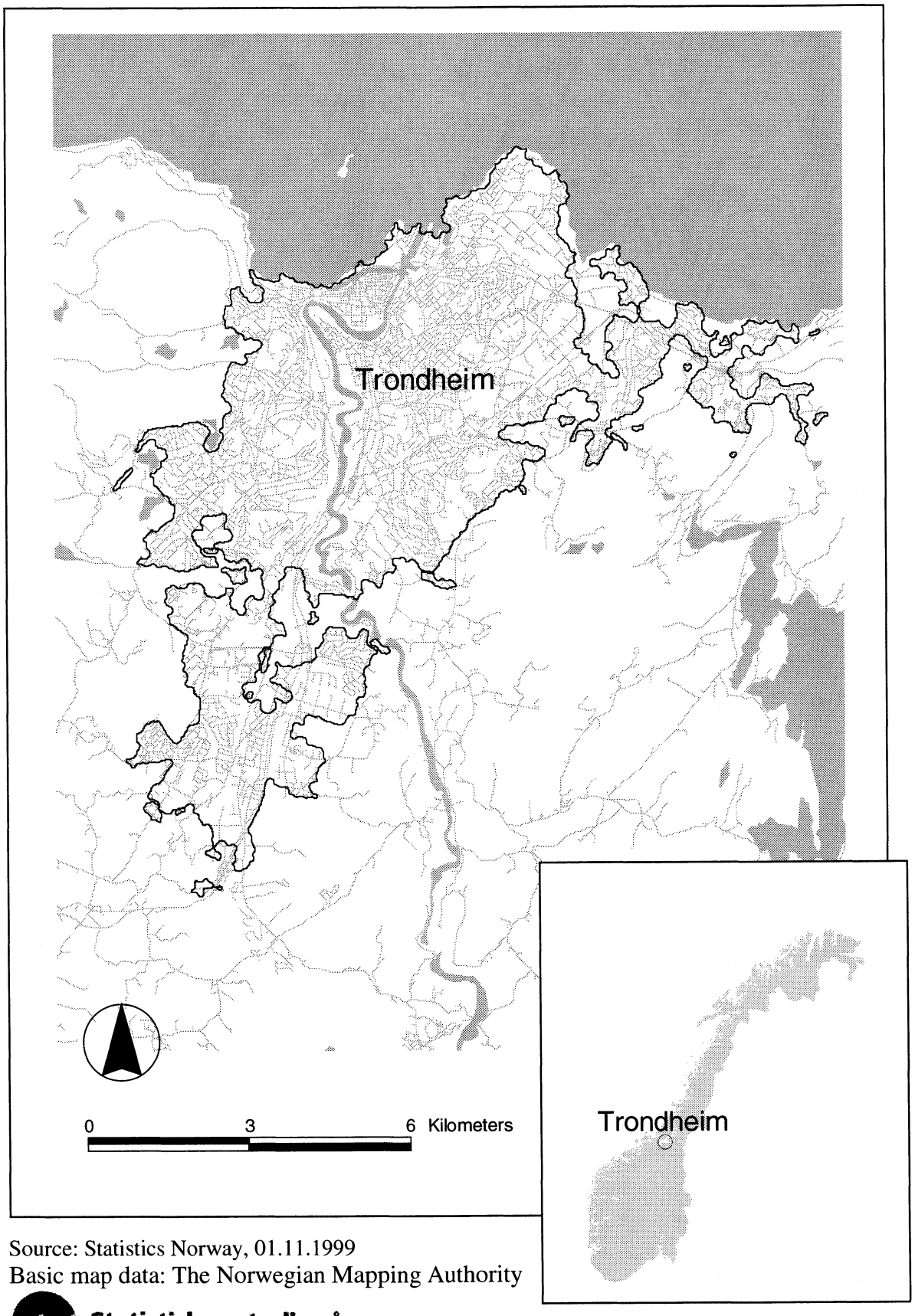
# The urban settlement of Trondheim. 1998




Source: Statistics Norway, 01.11.1999
Basic map data: The Norwegian Mapping Authority

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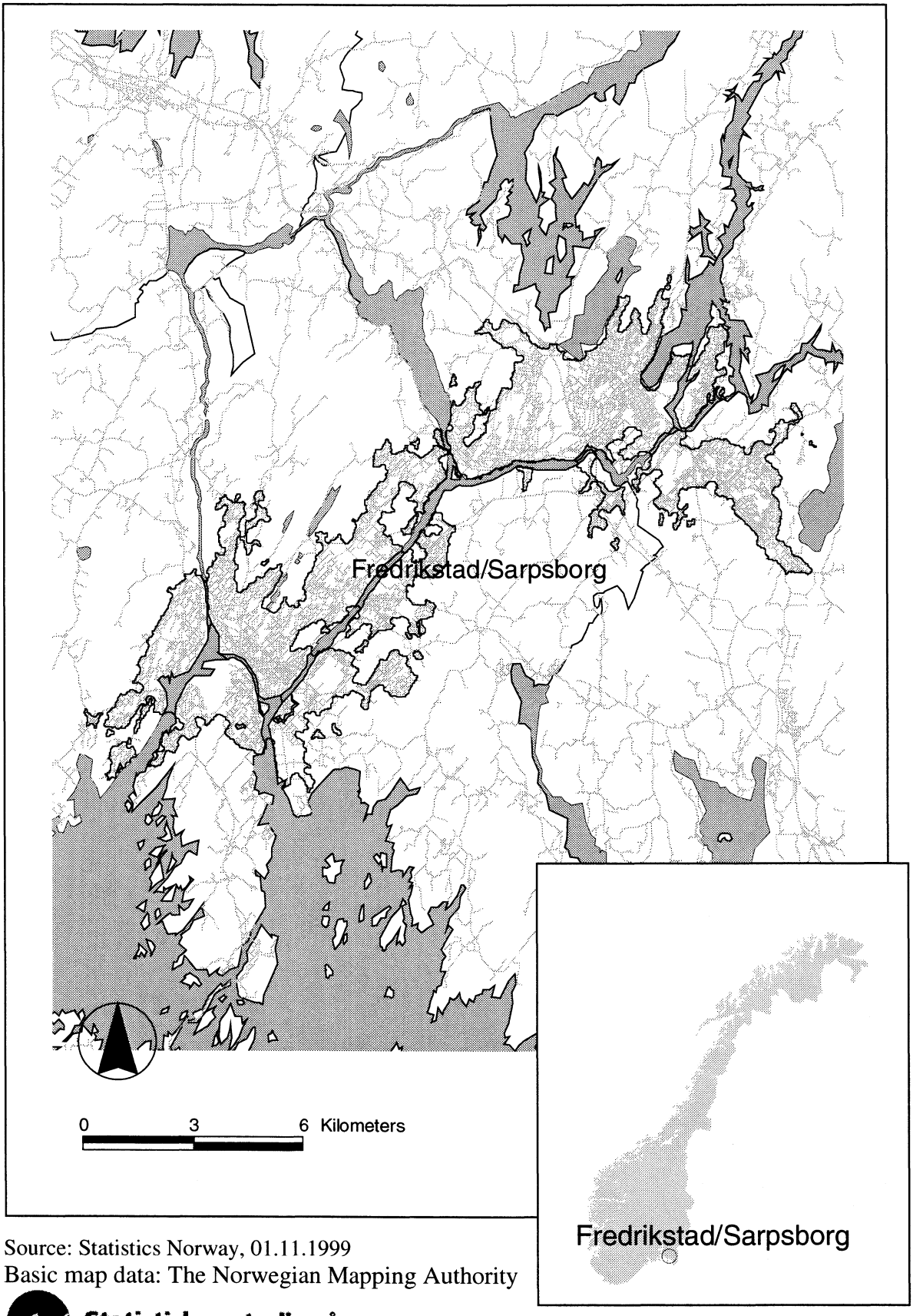
# The urban settlement of Fredrikstad/Sarpsborg. 1998




Source: Statistics Norway, 01.11.1999
Basic map data: The Norwegian Mapping Authority

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