DIGITAL PHOTOGRAMMETRIC MAPPING AT THE NATIONAL LAND SURVEY OF SWEDEN

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Abstract

At the National Land Survey of Sweden digital methods for map compilation has been used for more than ten years. During that time a system for handling map data in digital form has been developed and taken into production.

The software package of the mapping system contains a data base system for storing digital map data and application programs. The application programs handle input data from various measuring devices, create output for numerical and graphical display as well as orthophoto production, and finally make it possible to manipulate data in the map data base both interactively and in batch mode.

The map data base system has been used in production of various kinds of map products at different scales. As an example it can be mentioned that about 10 million elevation points are stored in a terrain elevation data base for the orthophoto production. The map data base has also been used for large scale mapping from photogrammetric measurements. An investigation shows that digital methods are economically well justified compared to analog methods for large scale photogrammetric mapping of planimetric details.

DIGITAL PHOTOGRAMMETRIC MAPPING AT THE NATIONAL LAND SURVEY OF SWEDEN

Introduction

Digital mapping is used at LMV, the National Land Survey of Sweden, for map production in a relatively large extent. For more than ten years flat-bed plotters have been employed for producing layers for the official maps i.e frames, grids and map symbols, and their use has gradually increased to include other details such as real estate boundaries for the Economic map (1:10 000), texts and real estate annotations.

Digital methods has also been used for large scale mapping, at scales of 1:5 000 or larger. Thus legal maps and real estate maps have been in production using automatic drafting for more than ten years and about five years ago the development of a production system for digital photogrammetric urban mapping was started.

Software aspects

The first generation of computer programs written at LMV for digital mapping were designed to solve a specific problem with a specific combination of devices for data capture and display. The map data was not stored in a general concept. This meant that it became both difficult and cumbersome to use data captured for other purposes. With time it became clear that the further use of digital methods for mapping demanded co-ordination of the software development and that the software should make it possible to meet the following requirements:

The establishment of a uniform system for storing and retrieving map data. Storage of map data in a specified reference co-ordinate system, generally the National co-ordinate system.
It must be possible to define a stored map detail according to its property using a feature code. Feature coding must be simple. The system must permit the use of menues or alfa-numeric codes. If numerical codes are to be used, the number of digits must be restricted to three.
Stored map data must be independent of the limits of the digitised map sheet or the measured stereo model. It must be possible to retrieve all the map data belonging to a specific working area for simultanous computations.
It must be simple to change mapping scale, sheet format, number of features and use different styles of presentation for the graphical display.
It must be possible to add and revise map data, firstly by measuring devices such as digitisers, secondly by using graphic screens.

The system specifications led to the conclusion that map data should be stored in a map data base. The management of the map data base, the storing and retrieving of data, is carried out with the use of a separate software package called MAPSOF, map data base software. The application programs which can be divided into the three major categories, data capture, display and maintenance, work against the map data base and MAPSOF as shown in Figure 1.
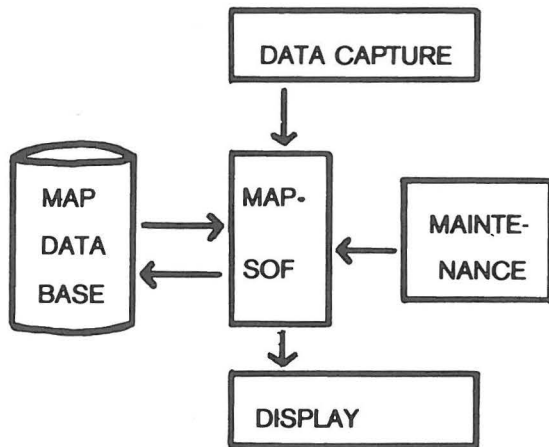
Figure 1. Software system for digital mapping.

Application software

Data capture: digital map data from geodetic measurements, digitisers and stereo plotters is handled. Before storing in the map data base, the measurements have to be checked as fas as possible concerning gross errors, wrong feature codes etc. The software package also contains routines for transformation to the reference co-ordinate system, geometrical correction i.e squaring of house corners, filtering and curve fitting.

Display: data stored in the map data base is transformed for graphic or alphanumeric display. This package contains a set of drivers for display on graphic screen, drumplotter, flatbed plotter, photosetting and ortho-photo projector.

Maintenance: this set of programs performs revision of the map data base, edge-matching and positioning of textstrings to avoid collision with planimetric details.

Map data base

The map data base is stored on discs and consists of different map files. Each file contains measurements from one stereo model or a digitised map sheet etc. The data in a map file is stored in different types of items depending on what kind of map detail that is stored. Each item contains only one detail i.e a point, a polygon, an annotation etc. Storing and retrieving is carried out item by item. Map data is stored in the same order as the measurements are made. Data can be retrieved in the same order by reading sequentially. Map data can also be retrieved by direct access using the keys "position", "feature", "number" and "marking".

The key "position" is given by a co-ordinate. This co-ordinate defines a square in the reference co-ordinate system. When using direct access by "position" one gets all map details which lie within that square.The key "feature" is the feature code and the key "number" is a point number or a line number etc. The use of the key "marking" varies depending on applications. Normally it is used to mark faulty items. Thus it is possible to get direct access to all items that have to be corrected.

The computer time required to retrieve an item by direct access varies between 5 to 50 msec, the average time is about 15 msec, which means that one can retrieve about 60 items per second.

Hardware

The development of a system for digital mapping had to be based on the hardware that already was available at LMV: a PRIME 400 computer, a large number of stereoplotters of different makes, several digitisers and Kongsberg flatbed plotters etc.

The PRIME 400 has a virtual memory and 16-bits wordlength. It has been up-graded about every second year and at the present time the configuration of the PRIME is:

A central unit with a core memory of 1024 kbytes.
Three disc units with a total capacity of 700 Mb.
Two magnetic tape units.
Forty terminal lines.

Data capture

Digitisers and stereoplotters work off-line. Data is mainly stored on cartridge tapes and,in some cases, floppy discs.

A total of six stereo plotters are available for digital mapping. Three of the plotters can be used for digital mapping of planimetric details and are equipped with desktop computers as shown in Figure 2. The graphic screen of the computer is used for verification of what has been plotted. The desk computer is also used for computer-assisted relative and absolute orientation. The other three stereoplotters are mainly used for capture of elevation data for ortho photo production. For this work there is no need for graphic verification and, therefore, the desktop computer used is rather simple. Data is recorded on cartridge tape recorders.

The seven digitisers which can be used for digital mapping are of diffe-rent makes. In principle they are equipped in the same way as the last mentioned stereo plotters,that is, with a small desk top computer and cartridge tape recorders.

Display

In April 1980 the fourth Kongsberg flatbed plotter will be installed at LMV. The plotters are used both for verification plots and final drawings using ink or engraving. One plotter is also equipped with a photohead which is mainly used for exposing map symbols. Two Kongsberg plotters will be working on-line to the PRIME 400, but they can also be used with paper tapes as input. Experiences from digital mapping have shown that there is a great need for verification plots on paper throughout the mapping pro-cess. Therefore, a drum plotter will, in the near future, be connected on-line to the PRIME computer. It is intended that this plotter will work unattended at night and deliver check plots for the next day work.

LMV has two photo setting units which are used for setting texts on light sensitive materials. It is possible to guide the setting of texts using co-ordinates which means that the texts can be placed on the map in the

required positions. The positions of the texts are normally obtained from digitising.

Figure 2. Photogrammetric digital mapping.
            (1) Registration unit. (2) Desktop computer. (3) Keybord.

The digital mapping system also includes a Wild Avioplan OR1 orthophoto projector. Input to the Avioplan is in the form of magnetic tapes.

Maintenance

The use of a map data base for storing digital map data provides the base for interactive maintenance of captured map data. The interactive editing of the map data base is performed on graphic screens and is made directly in the map data base. For this purpose the desktop computers with graphic screens can also be used. Data capture for editing can also be carried out using digitisers or stereo plotters. The editing of the map data base is, in this case, performed by batch-mode computing. The production system for editing and revision which is used at LMV is illustrated in Figure 3.

As shown in Figure 3 data can be captured using different types of instruments. After checking and refinement, data is stored in a map data base. Somewhat simplified verification plots usually one for each sheet are then produced. The plots are examined and remeasured. The map data base is corrected and new verification plots are produced. Normally one has to go through this procedure one to three times before the map data base is correct and the final drawing can be done.

DATA CAPTURE

| Stereo | Dig | Geo |

COMPLE-TION AND CORREC-TION | Stereo / Dig / Geo

MAP DATA BASE

Gra-phic screen | CHECK-ING AND EDIT-ING

EXAMI-NATION

Flatbed,drumplotter
VERIFICATION PLOTTING
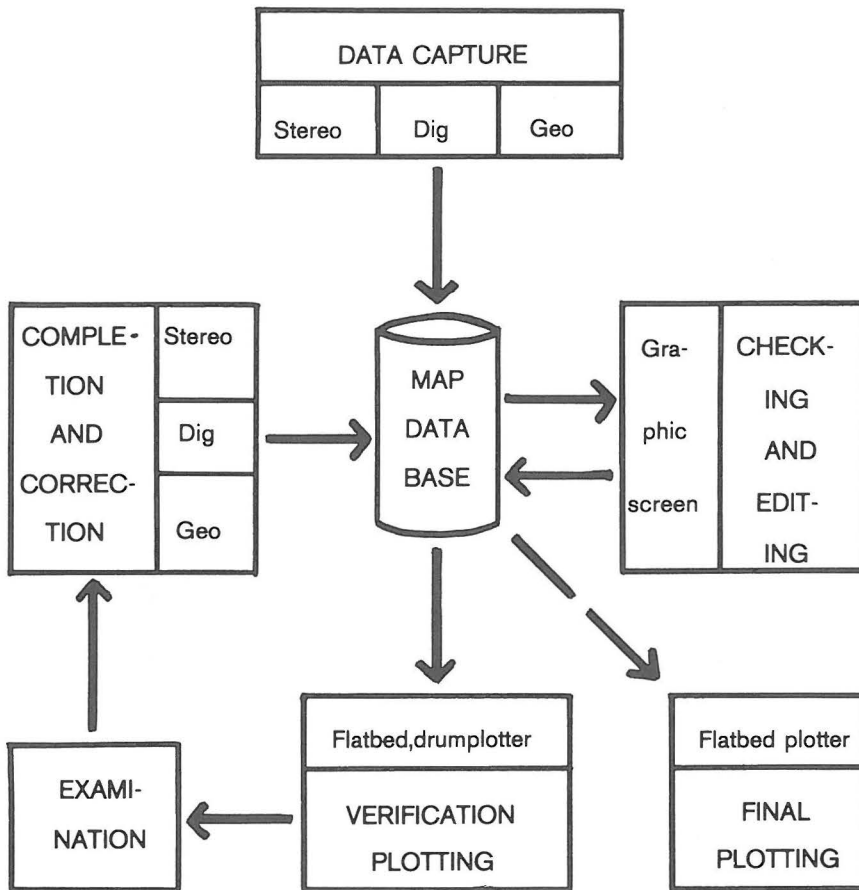
Flatbed plotter
FINAL PLOTTING

Figure 3. Digital mapping. Production system.

The main part of the editing is made either using software applications or by measuring in digitisers or stereo plotters. The interactive work on graphic screens is limited to the final editing of minor errors. The reasons why interactive editing is kept to a minimum are:

Computer capacity is limited and interactive work is very computer time-consuming. Computing in batch mode allows a much better use of the computer capacity as the computer can be used at night.
Graphic screens are rather expensive, especially as a screen has to have a large area to permit good working conditions.
Users are used to, and prefer to work with maps drawn on paper.

Some applications of digital mapping

Map data bases have been used for map production at LMV for some years. Still, however, experimental production dominates but the new techniques are gradually being introduced into every-day production for various applications.

Small-scale mapping

Digital mapping has been applied, among other things, in the following map series:

The General Map at a scale of 1:500 000 for drawing of boundaries, roads, railroads, map symbols and setting of text.

The General Map at a scale of 1:250 000 for setting of text.

The Topographic Map at a scale of 1:50 000 for producing map symbols.

The Economic Map at a scale of 1:10 000 for drawing of real estate boundaries, setting of real estate annotations, drawing of contour lines produced from the terrain elevation data bank and for map symbols.

Terrain elevation data bank

As the Avioplan orthophoto projector was phased into production in 1978 the establishment of a terrain elevation data bank was begun. The elevation data is stored in grids, normally with a size of 50 x 50 m. Up to the present time the data bank contains about 10 million elevation points and it is planned that it will cover the whole area of Sweden within the next 10 years, (1), (2).

Large scale mapping

Since 1978 digital photogrammetric mapping methods have been used to produce urban maps at scales of 1:400 to 1:2 000. The use of digital methods has been concentrated on the planimetric details from photogrammetric measurements, real estate boundaries and text. Figure 4 shows an example of an urban map produced from a map data base. The data of this map data base has been obtained from the following measurements and working steps:

Aerial triangulation including computation of control points, utilities and installations.
Digital photogrammetric capture of planimetric details.
Photogrammetric remeasurement and updating of the map data base.
Field check and updating of the map data base.
Real estate boundaries obtained by digitising.
Real estate annotations, street names and addresses obtained by digitising.
Interpretation of town planning area limits.

In most cases the digital mapping of urban maps has been carried out using stereo plotters. In some cases, however, old urban maps have been remeasured using digitisers. In both cases the technique is essentially the same and the time used for data capture and computation is of the same order.

Profitability

The advantages of digital mapping are, in some cases, quite clear. Applications which demand a small amount of measurement and a large amount of computation and drafting i.e reference grids and map symbols are clearly economically viable. In other cases the viability is less certain and
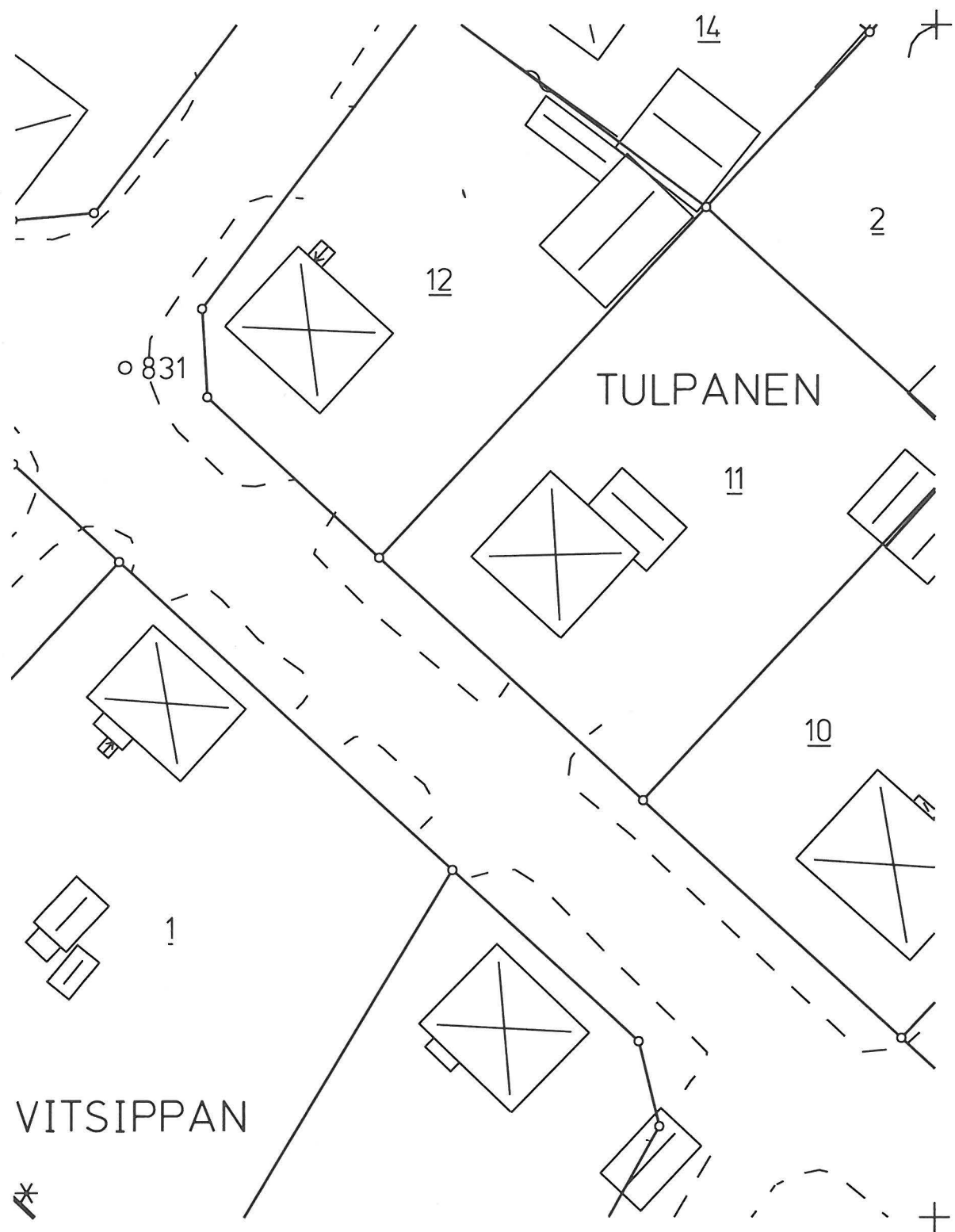
Figure 4. Urban Map, scale 1:500.

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difficult to predict. In many cases it is necessary to use both conventional and digital methods and make a comparative investigation of the production costs.

Such an investigation of production costs for urban maps has recently been carried out at LMV. This comparison comprises the production of the planimetric layer for urban maps at scales of 1:400 and 1:500 from photogrammetric plotting using both conventional and digital methods for three different areas, Kiruna, Märsta and Vänersborg. A total of eight map sheets were produced using conventional methods and fourteen map sheets using digital methods. The complexity of the mapped areas varies from easy in Kiruna to difficult in Vänersborg. In Table 1 some technical data for the three different areas is summarised.

Table 1. Comparison between conventional plotting and digital mapping.

Technical data	Area		
	Kiruna	Märsta	Vänersborg
Scale	1:500	1:500	1:400
Sheet format, m^2	0.5x0.5	0.5x0.8	0.6x0.8
Degree of complexity	easy	relatively complex	complex
Number of registrations per hectare	215	280	615

The time study covers the production of a fair-drawn planimetric layer. Using conventional methods this includes a photogrammetric plotting of the pencil plot and fair drawing by hand. Using digital methods the corresponding working steps are: photogrammetric data capture, computation, checking, editing and plotting. The time required in hours is shown in Table 2.

Table 2. Comparison between conventional plotting and digital mapping, required time.

Working steps	Kiruna	Märsta	Vänersborg
Conventional plotting	12.5 hectares	20 hectares	30.7 hectares
Stereo plotting	10 h	40 h	63 h
Fair drawing	9 h	32 h	49 h
Digital mapping	50 hectares	20 hectares	30.7 hectares
Data capture	33.5 h	12.5 h	64.5 h
Check, editing	14.5 h	9.7 h	6.6 h
Flatbed plotting	6 h	3 h	9 h
Computer, CPU	1160 sec	610 sec	1340 sec

Based on the number of hours shown in Table 2 the following costs can be calculated. The costs are expressed in Swedish kronor per hectare (2.5 acres).

	Kiruna	Märsta	Vänersborg
Conventional mapping	223	536	545
Digital mapping	246	274	605

The investigation is, naturally, too limited to draw definite conclusions as to whether one method is more profitable than the other. The figures indicate, however, that digital methods are reasonably competitive for large scale photogrammetric mapping.

The share of hardware costs is about 7 % and 30 % respectively for digital and conventional methods in our investigation. As personal costs tend to increase faster than hardware costs, the trend will certainly be in favour of digital methods. Working methods and software can certainly also be improved to make digital methods more competitive. Corresponding improvements cannot be predicted for conventional mapping.

Other advantages

Digital mapping also offers a number of other advantages. Digital, point by point, measuring gives a higher accuracy than conventional mapping. Access to the computer also makes it possible to correct captured data for systematic errors which improves the accuracy. Theoretically, this improvement in the accuracy could be used to increase the flying altitude for aerial photography with a reduction in production costs.

Another significant advantage of the map data base is that it can be used to produce other maps at different scales and for different purposes at a relatively small cost. For example, the map data base which has been used to produce the urban map shown in Figure 4 has also been used to produce a real estate map at the scale of 1:2 000, a street map at the scale of 1:2 000 and a sewerage net work map at the scale of 1:500. See Figures 5-7.

References

1.   L. Ottoson: Establishment of a High Density Terrain Elevation Data Base in Sweden, ICA, July 1978.

2.   L. Ottoson: Ortho Photo Mapping in Sweden, 2nd UN cartographic conference, Mexico City, Sept 1979.
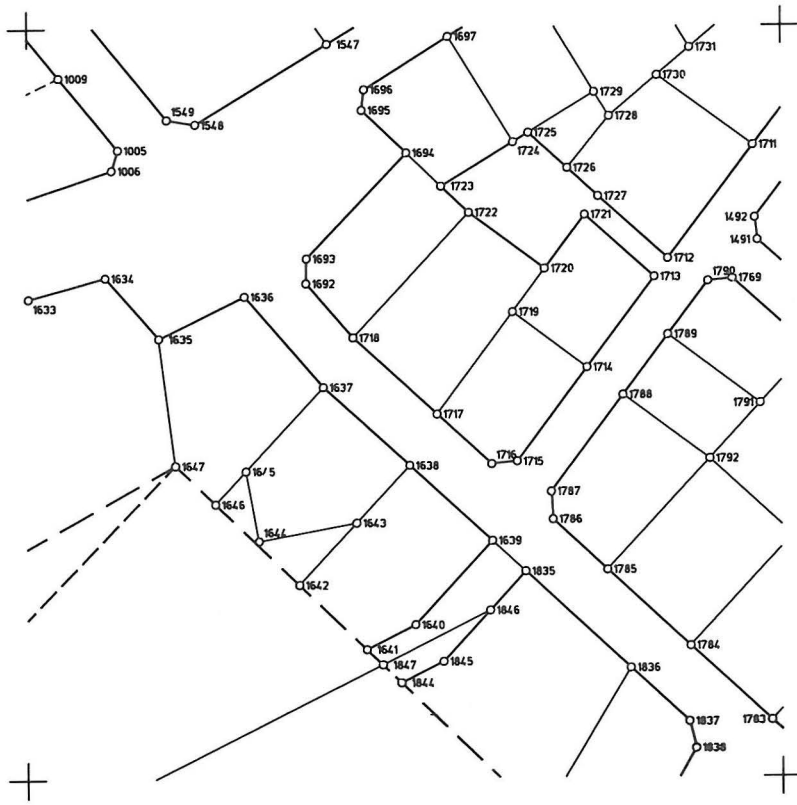
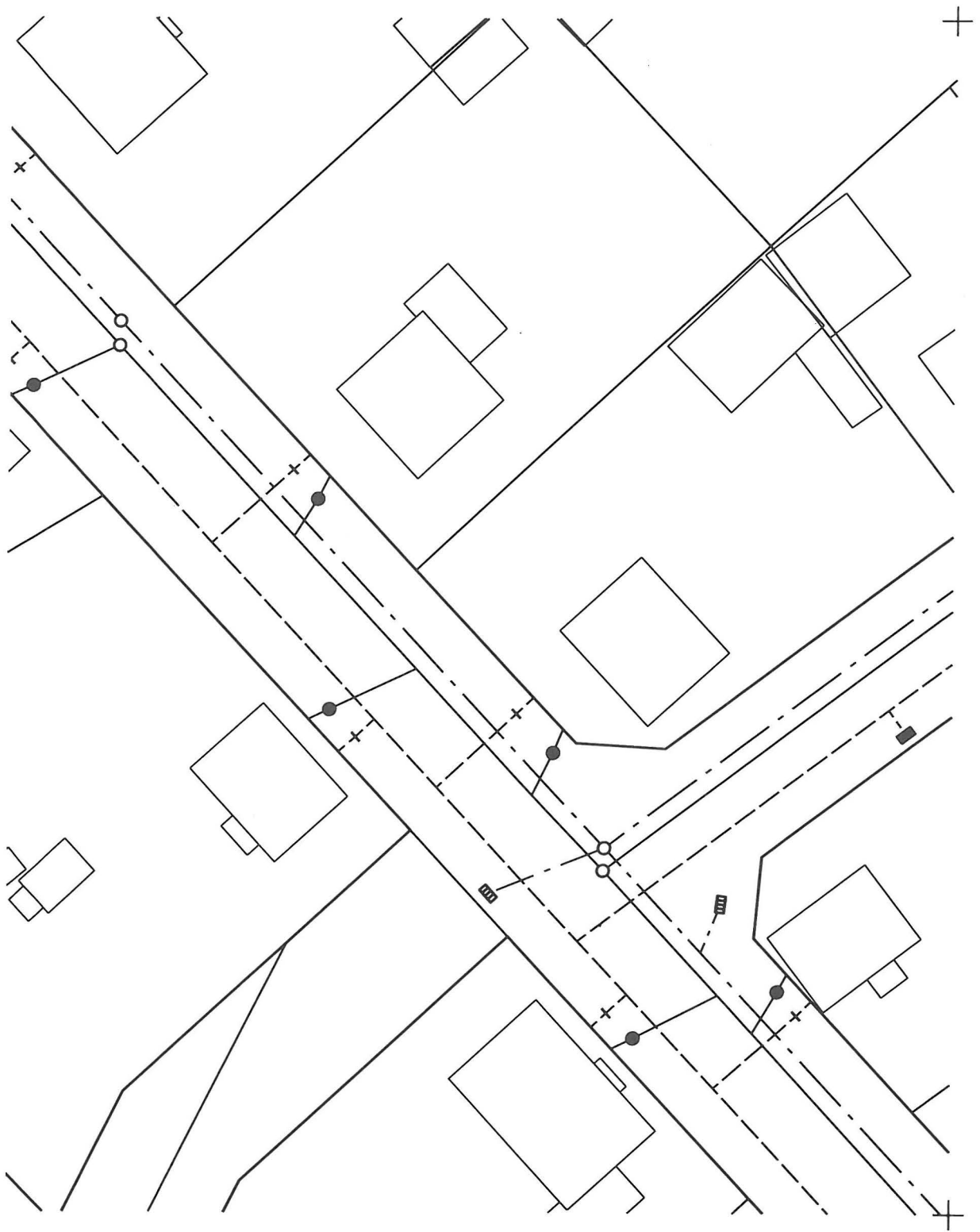Figure 5. Real Estate Map, scale 1:2 000.

Figure 6. Street Map, scale 1:2 000.

Figure 7. Sewerage Network Map, scale 1:500.