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EUROPEAN ORGANISATION FOR EXPERIMENTAL PHOTOGRAMMETRIC RESEARCH

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N° 14

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Test of Digitising Methods

Commission D
Photogrammetrie and Cartography

(with 38 Figures and 18 Tables)

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Foreword

This project is the first of its kind by OEEPE to investigate digitising methods which are increasingly being adopted in cartographic work. The project was intended primarily to test methods in use in production agencies; and for Commission D to gain experience of this type of production procedure, many aspects of which are also of importance to photogrammetric procedures.

The state of the art in digital photogrammetry and cartography is advancing rapidly, and it has therefore been important that the project and this report be completed as expeditiously as possible. I am most grateful to all the participants for adhering to our timetable, for the quality of their work and the very detailed reports they submitted. I am also most grateful to Mr. *W. P. Smith*, Director General, for the support of the Ordnance Survey in organising this project, and to Mr. *Wesley*, Mr. *Faulkner*, Mr. *Harris* and other members of his staff who have contributed so much of their time in bringing it to a successful conclusion.

14 September 1984

C. N. Thompson
President
Commission D

COMMISSION D — Photogrammetry and Cartography

Test of Digitising Methods

SUMMARY: This report describes and assesses the result of phase one of an OEEPE Commission D project to evaluate alternative methods of digitising existing maps, using equipment available in 1982.

Extracts of 1 : 2500 and 1 : 10 000 scale Ordnance Survey (GB) maps were digitised for the project using a mix of four broad bands of technology as follows:

- "Blind digitising" — manual digitising without on-line computer graphics facilities.
- "Interactive digitising" — manual digitising with on-line computer graphics processing and edit.
- "Semi-automatic line following with interaction" — line following digitising with on-line computer processing and computer graphics processing and edit.
- "Scanning, vectorising with interaction" — raster digitising with computer processed vectorisation and computer graphics processing and edit.

Eleven organisations, including national mapping agencies, universities and private companies, participated in one or more of the digitising options.

The project provided a valuable comparison of cartographic digitising technology and methods available in 1982. Overall the project has confirmed that the digitising equipment and software used by the participants is capable of capturing map information in digital form and of subsequently plotting an acceptable cartographic output. Manual digitising was a well established and proven method, whilst automated methods were relatively new and suffered some limitations which reflected the state of the art at the time of the project.

1 Project Overview

1.1 Background

1.1.1 In 1981 Commission D, OEEPE started discussions on a project to evaluate alternative methods of digitising existing maps. A simple project to gain experience in digital technology was deemed an essential first step before embarking on more sophisticated photogrammetric applications. The project agreed was to consist of two phases with the following objectives:

Phase One — assessment of digitising methods, and the graphic plots produced from the digital data.

Phase Two — assessment of the digital data, including an evaluation of data structures and formats adopted by participating centres.

1.1.2 This report marks the completion of Phase One of the project. At the Commission D meeting in November 1983 it was agreed that Phase Two was more appropriate to specialist investigation, perhaps as a university research project. The data is available from the Ordnance Survey, Southampton, England.

1.2 Scope of Project

1.2.1 The Phase One of the project was designed to provide an evaluation of the currently available (1982) equipment and methods for cartographic digital data capture using the following four broad bands of technology:

Blind digitising
Interactive digitising
Line following digitising
Scanning (raster) digitising and vectorising

A general description of the type of equipment used is given at Appendix C.

1.2.2 The map extracts used for the project were Ordnance Survey maps, and three options for digitising were offered as follows:

1 : 2500 planimetry
1 : 10 000 planimetry
1 : 10 000 contours (same map extract as 1 : 10 000 planimetry)

1.2.3 Eleven agencies participated in the trial including six national mapping agencies, one private survey and mapping company, one university and three manufacturers. No agency participated in all options, but for most options there was more than one participant. Three agencies participated in each Blind digitising option and the scanning and vectorising options for 1 : 10 000 planimetry and contours.

1.2.4 Digitising of map extracts was undertaken between August and December 1982, with assessment of results and draft report completed by June 1983. Commission D considered the draft report at their meeting in November 1983. A further draft was circulated in February 1984 with a view to producing a final draft in April 1984.

1.3 Results

This report is a collation of the material provided by the participants. Some effort has been made to assess accuracy, cartographic quality and comparative times but it was recognised at the outset that there were a number of limiting factors that would make comprehensive comparisons difficult. These include:

- Only the Ordnance Survey was familiar with the specification of the map extracts.
- Participants experience of equipment and methods varied considerably.
- The grade, expertise and experience of operators varied considerably.
- Procedures for recording times of the operations involved varied.

1.4 Summary of Conclusions

This project provides a valuable comparison of cartographic digitising technology and methods available in 1982. It is clear that manual digitising was well established and proven, whilst automated digitising systems were relatively new and suffered some limitations which reflected the state of the art at the time of the project. Many have since been improved. The main conclusions are summarised below.

1.4.1 The project has confirmed that the equipment and software used by all the participants is capable of capturing map information in digital form and of subsequently plotting an acceptable cartographic output. (9.1.2.)

1.4.2 A comparison of the times taken by participants to carry out individual operations provides some indication of the relative merits of the equipment and methods used. (9.1.3)

1.4.3 There is a significant difference in the proportion of time spent on preparation/digitising and processing/edit between the different types of digitising. (9.1.4)

1.4.4 There was a significant level of consistency in the accuracy achieved by all participants throughout the trial, and an acceptable standard of accuracy was achieved in all cases in the production of cartographic plots. (9.2.1)

1.4.5 A variety of set up procedures and transformation algorithms were used by participants for manual and semi-automatic digitising, but have had little apparent effect on the accuracy achieved. (9.2.3)

1.4.6 The cross hair cursor is in general considered preferable for manual digitising from a positive base and all participants expressed a preference for backlighting for digitising tables. (9.2.4)

1.4.7 For manual digitising the use of an enlarged base document had no significant effect on the accuracy of the final plots produced. (9.2.4)

1.4.8 The scanning systems achieved a marginally better overall accuracy than the line following system, but the scan resolution in both cases is a critical factor. (9.2.5)

1.4.9 Most participants produced an acceptable cartographic plot. For edit purposes features can be plotted by feature numbers, colour code or as layered plots. (9.5.3)

1.4.10 The squaring and alignment of buildings caused some difficulties for participants using manual digitising methods, particularly at 1 : 2500 scale. (9.3.2)

1.4.11 In general all participants achieved a satisfactory result with curvilinear detail. (9.3.3)

1.4.12 To produce an acceptable cartographic product from the automated digitising systems required extensive interactive editing. (9.3.2)

1.4.13 For manual digitising satisfactory results were achieved with both point and stream digitising, but considerable experience is required to maintain key in the stream mode. One participant used a groove following technique which offers considerable potential for digitising contours. (9.3.4)

1.4.14 If digitising is to be undertaken at a variety of scales there is little to be gained using interactive rather than blind digitising methods. (9.4.2)

1.4.15 With one possible exception, automated digitising methods have proved to be at least twice as quick as manual methods of digitising for planimetry, and for contours of the order of 7 times faster. (9.4.3)

1.4.16 There is further evidence that these systems are better suited to digitising maps with simple line work and coding and less suited to digitising dense urban large scale plans, though this may change as the technology develops. (9.4.3)

1.4.17 It is clear that automated scanning and vectorising systems use significant amounts of CPU time for processing — between 0.2 and 4 hours for these trials. (9.4.5)

1.4.18 The price of equipment varies very considerably with a manual workstation costing less than 25% that of an automated or semi-automated systems. (9.6.1)

1.4.19 It was agreed by all participants that prospective purchasers should ask manufacturers to carry out "Benchmark" trials. (9.6.2)

1.4.20 Purchasers should be prepared to pay for such trials and should insist on overseeing the trials when they are carried out. (9.6.2)

2 Introduction

2.1 Background to Project

2.1.1 This report describes and accesses the result of Phase One of a OEEPE Commission D project to evaluate alternative methods of digitising existing maps. The project was agreed at the Commission D Meeting in Hønefoss, Norway in January 1982, and initiated by Commission D Paper 1/82 dated 23 February 1982 (see Appendix A). Although originally conceived as a project to be undertaken by member agencies of Commission D, this was changed at the 61st Meeting of the Steering Committee to allow participation by other agencies including private survey and mapping companies, universities and manufacturers. Eleven agencies eventually participated in Phase One of the project.

2.1.2 The overall project was seen to consist of two phases:

Phase one encompassed the assessment of digitising methods and the graphic plot produced from the digital data.

Phase two would be an assessment of the digital data, including an evaluation of data structures and formats adopted by participating centres.

2.2 Scope of Project — Phase One

2.2.1 Phase One of the project was designed to provide reliable information on methods of digitising and equipment, as well as times for preparation, digitising, data processing, edit and plotting using relatively simple map extracts at 1 : 2500 and 1 : 10 000 scales as the cartographic base document for digitising. It was intended also to provide experience in undertaking projects involving digital technology, and as a first step towards investigating more sophisticated cartographic and photogrammetric digital methods and systems. If possible cost models reflecting grades of staff used, equipment type and cost, material cost and time taken for the various relevant functions were to be developed. In the time available it has not been possible to develop these cost

models. However the report contains much of the information to enable an agency to determine a cost model for their own organisation taking account of the particular purpose for which they wish to install a digitising system, and the method of costing in use by the agency.

2.2.2 The Phase One project was designed to provide an evaluation of the currently available (1982) equipment and methods for cartographic digital data capture. Four broad bands of technology were considered:

- "Blind digitising" — manual digitising without on-line computer graphics facilities.
- "Interactive digitising" — manual digitising with on-line computer graphics processing and edit.
- "Semi-automatic line following with interaction" — line following digitising with on-line computer processing and computer graphics processing and edit.
- "Scanning, vectorising with interaction" — raster digitising with computer processed vectorisation and computer graphics processing and edit.

Each participant was supplied with a transparent film positive of the map extract(s) they elected to digitise. For the 1 : 10 000 (planimetric) extract an overlay showing vegetation areas was also supplied. With the material each participant also received a copy of paper 2/82 (App B) giving the data required, a feature code list and the request for a narrative report on the procedures used.

2.3 Participation

2.3.1 Participation was sought from all Commission D members and it was agreed that other centres would be invited to take part. In all eleven organisations took part. The participants are shown at Table 2.1.

Table 2.1 — Participants in digitising project

Clyde Surveys Ltd. (CLYDE)
Reform Road
Maidenhead
Berkshire SL6 8BU
ENGLAND

Istituto Geografico Militare (IGMI)
Via Cesare Battista 8—10
I—50122 Firenze
ITALY

Laser Scan Laboratories Ltd. (LASERSCAN)
Cambridge Science Park
Milton Road
Cambridge CB4 4BH
ENGLAND

National Board of Survey (NBS)
PL 84
SF—00521 Helsinki 52
FINLAND

National Land Survey (NLS)
S—80112 Gävle
SWEDEN

North East London Polytechnic (NELP)
Department of Land Surveying
Faculty of Engineering
Longbridge Road
Dagenham Essex RM8 2AS
ENGLAND

Norges Geografiske Oppmaling (NGO)
N—3500 Hønefoss
NORWAY

Ordnance Survey (OS)
Romsey Road
Maybush
Southampton S09 4DH
ENGLAND

Scitex Corporation Ltd. (SCITEX)
Industrial Park
POB 330
Herzlia B 46 103
ISRAEL

SysScan (SYSSCAN)
PO Box 131
N—3601 Kongsberg
NORWAY

Topografische Dienst (TDN)
2611 Ax Delft
Westvest 9
NETHERLANDS

2.3.2 Table 2.2 is a summary of the digitising methods participants used and the map extracts participants undertook to digitise.

Table 2.2 — Summary of participants, digitising method and map extracts

Digitising Methods	Scales		
	1 : 2500	1 : 10 000	
	Planimetry		Contours
Blind Digitising	CLYDE,NLS, OS,NELP	NBS,OS,TDN	NBS,OS,TDN
Interactive Digitising	OS	TDN	TDN
Semi-Automatic Line Following with Interaction	OS	LASERSCAN OS	LASERSCAN OS
Scanning, Vectorising with Interaction	SCITEX	NGO,SCITEX SYSSCAN	IGMI NGO,SCITEX SYSSCAN

2.4 Digitising Equipment

2.4.1 The equipment used by participants for each of the options is given in Chapters 3,4 and 5 for the blind and interactive digitising, line following digitising and scanning and vectorising digitising options respectively. A summary of the general types of equipment used is given below, and a more detailed description of some of the major equipments is given in Appendix C.

2.4.2 For blind and interactive digitising the basic equipment used is a digitising table using a cursor to record x and y table co-ordinates, which are subsequently transformed to give map co-ordinate values. In most cases the digitising tables used had back lighting. Attributes, or feature codes, can be entered through a keyboard, or by use of a "menu" mounted on the digitising table. Text can either be entered offline with the position of the text recorded on the digitising table, or with interactive systems through a keyboard with the text positioned through use of the graphics screen.

2.4.3 The only line following digitiser used was the Laserscan Fastrak Digitiser, which through the use of lasers enable lines to be followed automatically — although a significant amount of operator intervention is required for all but the simplest linework. During digitising co-ordinates are recorded continuously with subsequent online processing used to filter unwanted data. Attributes, or feature codes, can be entered during digitising. The equipment can also be used for interactive edit although this function is now normally done as a separate operation using cheaper interactive graphics edit equipment (see 2.4.5).

2.4.4 Scanning, or raster digitising involves a two part process. The actual scanning or digitising is achieved driving a sensor, which records grey levels of segments (or "pixels"), across the document in one direction. The resolution, or width, of each scan is normally between 25 μm and 200 μm (depending on the accuracy required and time/cost of digitising). Successive scans enable the whole document to be digitised, and the data recorded will be a matrix of the grey scale values and co-ordinates of each pixel. Filtering routines enable redundant data to be removed.

Vectorising involves processing the data to convert it to a vector format, similar to that achieved by manual or automatic line following digitising techniques. The algorithms and software to achieve vectorisation are still the subject of much development work, and at present involves substantial computer processing time. Feature codes, and normally text, are added as part of the editing operation.

2.4.5 Most digitising systems now use interactive computer graphics facilities to correct errors made during digitising, and input additional information such as feature codes and text if this is not done during initial digitising. Edit systems normally comprise a vector graphics display, a digitising table or tablet, keyboard and on-line computer. Increasingly colour raster displays are also being incorporated, and most systems require the use of fast plotters for the production of single or multi-colour edit plots.

2.4.6 Final cartographic output is ideally by a high precision plotter. High quality and accurate plots are normally obtained using expensive flatbed plotters either using lighthead projectors exposing on to film, or by scribing.

2.5 Digitising Methodology

2.5.1 A brief description of the methods used by each participant for the options they undertook for blind and interactive digitising, semi-automatic digitising and scanning and vectorising digitising are given in Chapter 3,4 and 5 respectively, under the following main categories:

Preparation
Digitising
Processing
Editing

Times for each operation, and sub-operation, have also been reported under these main categories.

2.5.2 Methods of plotting are not described in Chapters 3,4 and 5 as the choice or availability of plotters used are largely independent of the method of digitising. However times for the production of edit plots are included as a sub-operation of editing.

2.6 Results

2.6.1 Summaries of preparation, digitising, editing and plot times are given in Chapter 6 for each of the three map extracts (1 : 2500 planimetry, 1 : 10 000 planimetry and 1 : 10 000 contours) used in the project. Additional details and times for production of final plots and a statistical analysis of accuracy of the plots is also given.

2.6.2 Discussion of the results of the digitising of 1 : 2500 and 1 : 10 000 planimetry is given at Chapter 7, and of the digitising of 1 : 10 000 contours at Chapter 8.

2.6.3 Conclusions of Phase One of the project are given in Chapter 9. Overall this report is a collation of the material provided by participants, and although effort has been made to assess accuracy, cartographic quality and comparative times, it was recognised at the outset that there were a number of limiting factors that would make comprehensive comparisons difficult. These include:

Only OS was familiar with the specification of the map samples.

Participants experience of equipment and methods varied considerably.

Grade, expertise and experience of operators varied considerably.

Procedures for recording times of the operations involved varied.

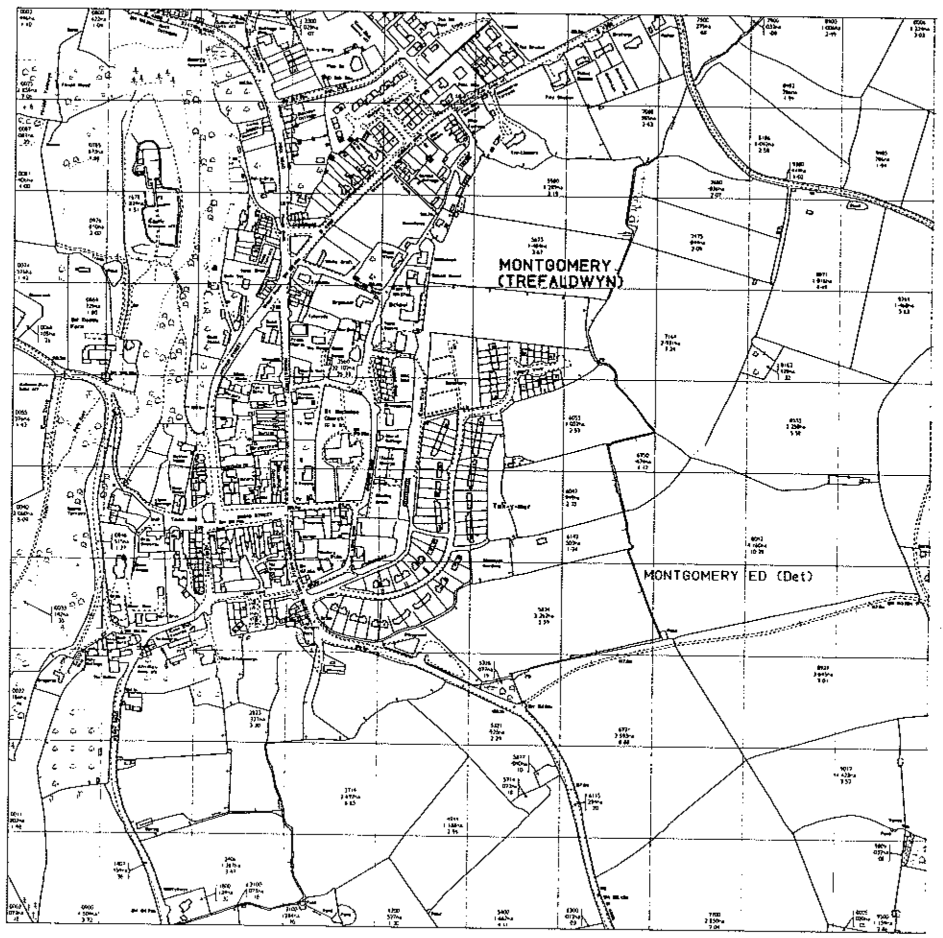
2.7 Project Phase Two

Phase Two of the project was discussed at the Commission D meeting in November 1983 and it was agreed that the data would provide material for a worthwhile research or university project. It was agreed that data tapes would be held by Ordnance Survey and supplied to interested parties after prior agreement from the participants concerned.

MAP A

OEEPE DIGITAL MAPPING PROGRAMME

SCALE 1 2500

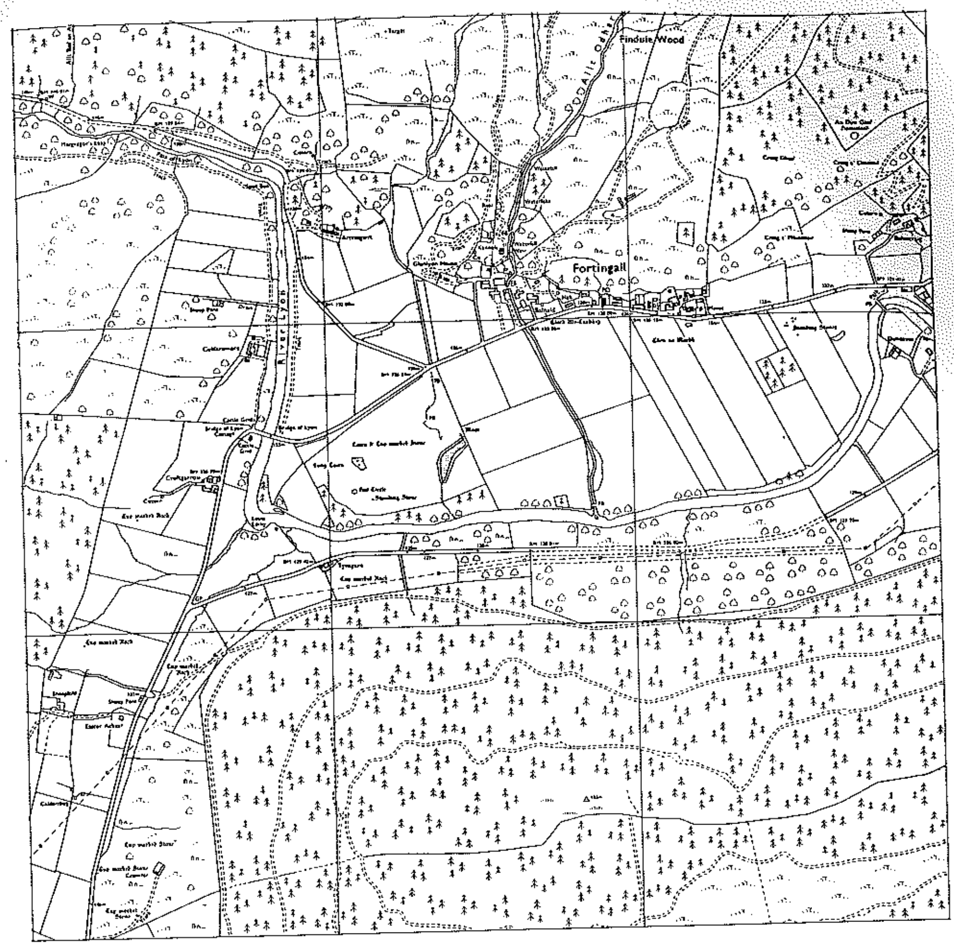


Reproduced at 1 : 10 000 scale

Figure 2.1 — 1 : 2500 planimetry extract

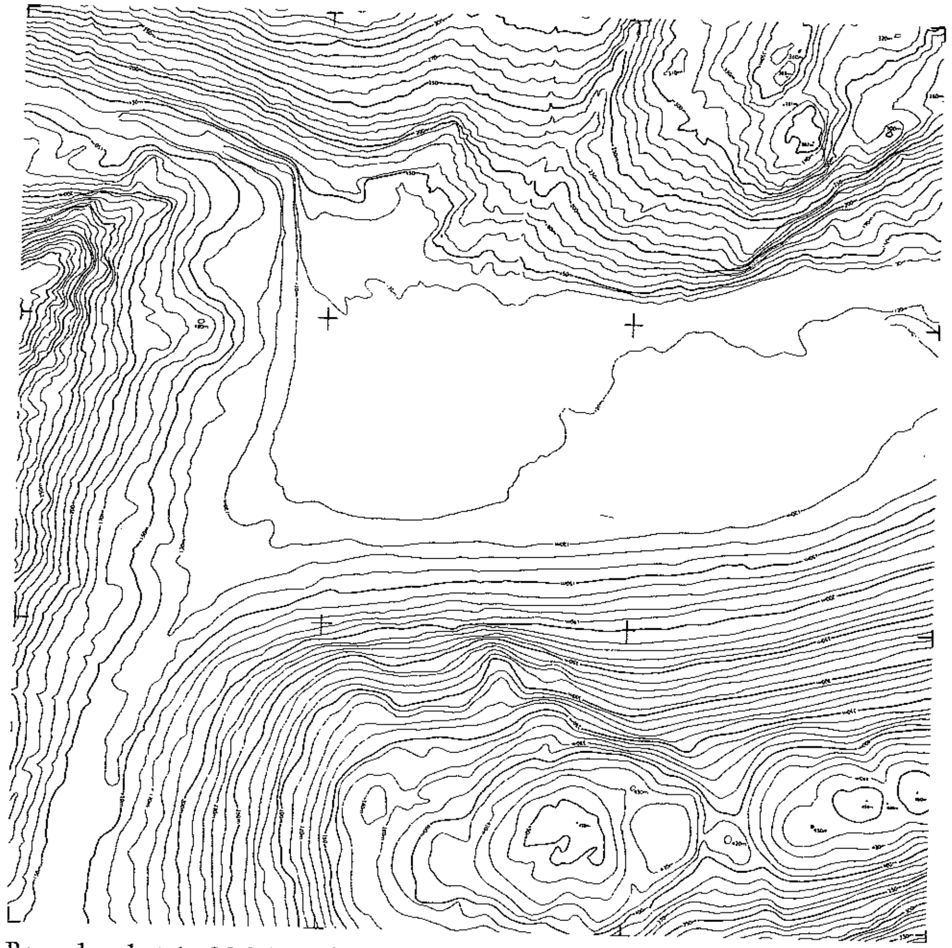
MAP B

SCALE 1 10000



Reproduced at 1 : 30 250 scale

Figure 2.2 — 1 : 10 000 planimetry extract



Reproduced at 1 : 30 250 scale

Figure 2.3 — 1 : 10 000 contour extract

3 Blind and Interactive Digitising

3.1 *Equipment Used*

The equipment used by each participant is given below:

CLYDE

Altek AC 734 2D Digitising table + display
HP 1000F series computer
Kongsberg GT 5000 flatbed plotter

NBS

Altek Datatab AC90C Digitising table
HP 3000/11 computer
Calcomp 960 belt drive plotter (proofs)
Kongsberg 1216/DC300 plotter (scribing)

NLS

Altek digitising table
Prime computer
Benson and HP 7580A drumplotters (proofs)
Kongsberg flatbed plotter

OS

Ferranti Freescan digitising tables (blind)
ICL 1906S computer
Laserscan Interactive Editing Station (LITES)
VAX 11/780 computer
Xynetics 1050 and 1100 flatbed plotters (edit plots)
Ferranti Master Plotter EP 330

TDN

Gradicon digitising tables (blind)
Intergraph interactive digitising system
PDP 11/70 computer
Contraves C 1700 flatbed plotter

NELP

Calcomp 9000 digitising table with 12 button cursor
North Star Horizon micro computer
Zeta plotter

3.2 *Preparation*

Most centres produced a photographic copy of the original map extract to suit their methods. This work does not fall under the heading of preparation as intended in this report but rather a pre-flowline task. Therefore costs and times incurred have not been included in the following report on preparation.

3.2.1 Preparation for Blind Digitising (1 : 2500)

CLYDE spent some time listed under computing developing new macros to match those on the extract supplied. This time is not included in this report. Of the three centres attempting this option, CLYDE was the only one to prefer to leave all decisions to the operator and produce no aid. An enlarged film positive was produced at 1 : 1250 scale to aid accuracy during digitising.

NLS found extra work was required in preparing for digitising and creating new macro symbols for their plotter due to the differences between Swedish maps and the UK map. The times incurred on this task have not been included in their times for preparation. Unfortunately, no details of the preparatory work was forthcoming from NLS.

Times: detail 5 hrs, text 4 hrs

OS prepared a negative at 1 : 2500 scale, although their normal production procedure is to use a 3 : 5 enlargement at 1 : 1500 scale. The feature codes used at OS are more extensive than the codes allowed for this project, therefore substitute codes had to be selected for certain features. The times taken for this task are not included in the preparation times supplied. A diazo copy of the extract was colour coded to aid coding decisions during digitising and text lines were given anticipated feature serial numbers. Decisions were made on text size, style, category, and position of the digitised point in relation to the text block before being added to text input offline forms.

Times: detail 4 hrs, text 8 hrs

NELP had no previous experience of digitising but had previously plotted from OS 1 : 1250 and 1 : 2500 digital data. Software development and digitising was treated as a research project which was divided into three stages so that work could be shared. One person digitised names and symbols, another line features and a third buildings. Names were entered via the North Star key board and a listing produced to check spellings and completeness. The file was then relisted on a VDU and each name was again checked individually and a classification and type size added prior to positioning. There was no preparation for the detail.

Times: detail 0 hrs, text 5 hrs

3.2.2 Preparation for Blind Digitising (1 : 10 000)

NBS performed no preparatory task apart from producing an enlarged positive copy of the extract at 1 : 6666 scale, at which it more closely resembled a Finnish basic scale map (1 : 10 000/1 : 20 000).

The OS preparation for the 1 : 10 000 was much the same as for the 1 : 2500 map, but the complete map from which the extract was prepared was available to the digitising section. Therefore a negative was made of this map to enable a 36 point set up procedure to be used. Again convention was broken in preparing a digitising negative at scale rather than a 3 : 5 enlargement.

Times: detail 9 hrs, text 2.5 hrs

A graduate TDN Staff member made a model to "facilitate" the digitising. This would normally have been prepared by a cartographer (senior draughtsman), but the procedure was changed due to the different type of map involved. Software was adapted to incorporate the British symbols and codes. Times given for preparation were headed general preparation and preparation of models, therefore it is assumed the work on the software is labelled general preparation and so ignored.

Time: preparation of models 4 hrs

3.2.3 Preparation for Blind Digitising (Contours)

In practice the only preparation considered necessary by the OS draughtsman was to decide upon type style and size to produce a facsimile of the original and to transfer that information to computer input forms.

Time: 3 hrs

The only preparation carried out by NBS was to produce an enlarged negative etched peelcoat copy of the original at 1 : 6666 scale.

TDN carried out no preparatory work.

3.2.4 Preparation for Interactive Digitising (1 : 2500)

OS were the only centre to participate in this option. Although interactive work stations are used in the production area for editing, this trial was carried out in a research and development environment by a higher grade draughtsman. The extract was enlarged to a 1 : 1500 negative for digitising purposes but the only aid prepared was one decisions such as size and position.

Time: 0.5 hrs

3.2.5 Preparation for Interactive Digitising (1 : 10 000)

TDN were the only centre to participate in this option and there was no difference in their preparation for this than for the blind digitising (3.2.2).

Time: 4 hrs

3.2.6 Preparation for Interactive Digitising (Contours)

TDN were the only centre to participate in this option and required no preparation.

Table 3.1 — Summary of preparation times (hours) for blind and interactive digitising

	Blind			Interactive		
	1 : 2500	1 : 10 000 Planimetry	1 : 10 000 Contours	1 : 2500	1 : 10 000 Planimetry	1 : 10 000 Contours
*) CLYDE	0	—	—	—	—	—
*) NBS	—	0	0	—	—	—
NLS	9(4)		—	—	—	—
OS	12(8)	11.5(2.5)	3(3)	0.5(0.5)	—	—
*) TDN	—	4	0	—	4	0
NELP	5(5)	—	—	—	—	—

*) No text

Figures in brackets represent time preparing text included in total time given.

Table 3.2 — Summary of source documents used

	Source	Scale	Illumination	Digitising Methods
CLYDE	POS	Enlarged (X2)	Backlit	"Semi-Blind"
NLS	POS	At Scale	?	Blind
NBS	POS	Enlarged (X3/2)	Backlit	Blind
OS	NEG	At Scale	Not Backlit	Blind
TDN	POS	At Scale	Backlit	Blind
NELP	POS	At Scale	Not Backlit	Blind
OS	NEG	Englarged (X5/3)	Not Backlit	Interactive
TDN	POS	At Scale	Backlit	Interactive

3.3 Digitising

3.3.1 Blind Digitising (1 : 2500)

CLYDE term their system "semi-blind" as their Altek digitising table is on-line to an HP 1000 computer allowing each table to have a display terminal upon which the Eastings and Northings of points digitised are output. Through this system they possess the ability to input commands such as recall points, join lines, etc., but at this time cannot collect text. The map was digitised at 1 : 1250 scale with set-up achieved by digitising the position of the menu and the four sheet corner points. The computer calculates an affine transformation on the table coordinates to Eastings and Northings and outputs the residuals to the display terminal. The system used is part of a photogrammetric rather than cartographic workstation which explains the high digitising time.

Time: 61.5 hrs

NLS have twelve tables of different makes available for digital mapping, but essentially are equipped in the same way, ie, with a small desk top computer and a cartridge tape recorder. No set-up details have been supplied and no curve fitting routine was used during digitising, which will be discussed further in the results chapter.

Time: detail 39 hrs, text 10 hrs

The OS undertook this option digitising at 1 : 2500 scale rather than the usual 3 : 5 enlargement. A nine point set-up was employed comprised of four rounds of observations of the corner points, midpoints of the neat line, and the centre point. The position of the menu was also indicated prior to setting up the map. The vegetation was symbolised by a dot symbol as all ornamentation is normally applied by waxed transparencies to the data positive. The curve fitting routine was rarely used during digitising and will be discussed further in the results chapter.

Time: detail 22.5 hrs, text 1.5 hrs

NELP digitised directly from the 1 : 2500 document at scale. Set up was achieved using an affine transformation based on digitised sheet corners. Text and symbols were added and where necessary oriented. Feature codes were input via cursor button rather than through a menu. Multiple feature coding was attempted for buildings. Three inexperienced operators carried out digitising using point mode. Lack of back lighting and an enlarged base document were noted as problems when digitising.

Time: detail 18.0 hrs, text 2.7 hrs

3.3.2 Blind Digitising (1 : 10 000)

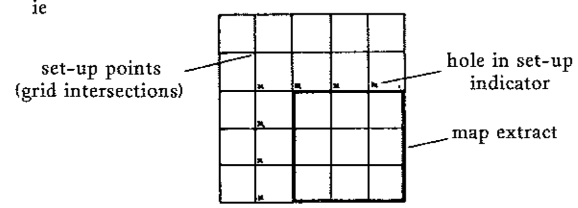
No centre attempting this option digitised the vegetation in the southern portion by area.

The set-up employed by NBS made use of the sheet corner points of the 1 : 6666 scale negative. No bench marks or electricity pylons were digitised and no text was attempted. NBS do not produce text using their plotter for two reasons — too great a variety of type styles are used, and the quality of text produced by scribing or light spot projector is not considered good enough. The roads and tracks have been represented by standard width double lines as is the symbolisation of these features on the Finnish basic scale maps. NBS also stated that buildings were "a little simplified"; but only one example of this could be found.

Time: 5.7 hrs

As the complete grid was contained on the 1 : 10 000 scale negative prepared at 3.2.2 by OS, a "16 point set up" procedure was employed in a 36 point routine.

ie



Following pointings to establish the table position of the menu the map was set-up using a full 36 point routine followed by a "hole in set-up" indicator on the menu and a point digitised in the south west corner of each grid square adjacent to the map extract. This ensures detail is clipped at the extract edge and allows on this extract a 16 point set-up. During digitising a curve fitting routine was used in which a minimum of 3 points are required along a single curve. A spline function is calculated during processing to which a number of points are added by the computer. As with the 1 : 2500 digitising all vegetation has been symbolised by a dot symbol.

Time: 20 hrs

As TDN's Gradicon digitising table was out of order the digitising was done at Rijkswaterstaat at The Hague on their Gradicon table. Times and procedures have been supplied as if the work had been done at TDN. Observations to the four sheet corner points were used to set up the extract. No facilities are available to reproduce text digitally as TDN feel text can be reproduced more economically by traditional photosetting.

Time: 9.4 hrs

3.3.3 Blind Digitising (Contours)

NBS used a stream facility employing a cursor containing a pen which is used to follow the track in the etched peelcoat prepared at 3.2.3. The set-up uses the four sheet corner points as when digitising the planimetry. The height value of each contour is recorded through a keyboard before the contour is digitised using, on this project, a recording speed of 15 points/second.

Time: 1.2 hrs

OS attempted digitising on a modular table both in point mode and in stream mode. The 16 point set up described in 3.3.2 was used in each case. No differentiation was recorded between different contour lines, apart from coding "normal" contours and "accentuated" contours. The stream digitising was recording 8 points/second. This mode of digitising is not normally used at OS and difficulties arose mainly due to the cursor having to slide over the negative offering no useful "drag" and the operator's inexperience in this technique.

Times: point 16 hrs, stream 15 hrs

TDN set up the contour extract in the same manner as at 3.3.2. Digitising was performed in the point mode.

Time: 10.6 hrs

3.3.4 Interactive Digitising (1 : 2500)

Using the 1 : 1500 scale negative prepared at 3.2.4 OS performed a normal nine point set-up on the LITES equipment requiring just one round of observations. On completion of transformation the residual values are displayed on the control screen allowing the option of redigitising one or more of the set-up points. The map was digitised by the most experienced LITES operator within the OS and therefore a certain amount of checking and a great deal of editing was carried out during digitising. Much of the editing was to ensure buildings were square, alignments satisfactory, etc. On completion of the detail the vegetation was added, symbolised by point symbols, and text was added via the keyboard, controlling the position and orientation of text by the bit pad cursor and graphic screen.

Times: detail 22.5 hrs
text and vegetation 5 hrs

3.3.5 Interactive Digitising (1 : 10 000)

TDN's Intergraph system set up the extract by digitising one point for the origin, the south west and north east corner points for scale, and the south west and south east corner points for orientation. Finally, the digitised corner points were compared with their theoretical values (0.0 and 3.0 km), the residuals were found to be less than 0.1 mm. No text was produced for the reason given at 3.3.2. The large amount of extra time required to digitise this option compared to the blind digitising was explained by TDN to be due to:

1. The Gradicon cursor being better to work with than the Altek.
2. Editing being carried out as the extract was digitised.
3. Lack of experience in editing techniques.

Time: 16.7 hrs

3.3.6 Interactive Digitising (Contours)

TDN set up the contours in the same manner as at 3.3.5. Digitising was performed in the point mode. The extra time taken compared with the blind digitising is also explained at 3.3.5.

Time: 15 hrs

Table 3.3 — Summary of blind and interactive digitising times (hrs) excluding text

	Blind			Interactive		
	1 : 2500	1 : 10 000 Planimetry	1 : 10 000 Contours	1 : 2500	1 : 10 000 Planimetry	1 : 10 000 Contours
*) CLYDE	61.5	—	—	—	—	—
*) NBS	—	5.7	1.2(S)	—	—	—
NLS	39	—	—	—	—	—
OS	22.5	20	15(S) 16(P)	27.5	—	—
*) TDN	—	9.4	10.6(P)	—	16.7	15(P)
NELP	18.0	—	—	—	—	—

*) No text attempted
P — Point mode
S — Stream mode

3.4 Processing

3.4.1 Processing Blind Digitising

CLYDE run two programs at processing stage. The first modifies the data by squaring buildings and joining lines and points. The second, accessing the modified data, applies a curve fitting technique, produces parallels where required, adds commands to produce standard symbols, and finally produces a magnetic tape to drive the plotter.

NBS process their data in batch mode and includes an affine coordinate transformation, curve fitting by average tangent method, and what NBS term "aesthetic corrections" such as line filtering and squaring of buildings. To check contour heights input during digitising a logical check program is included in the processing. The data is scanned in lines in a north-south direction, as contours are read the height values given are not allowed to deviate from the previous value by more than the contour interval. If the deviation is larger, then an error flag is recorded on the proof plot.

Times: planimetry 612 cpu secs, contours 597 cpu secs
plus 0.5 hrs for preparation of computing

Batch mode processing at NLS contains routines for transformation to the reference coordinate system, line filtering, curve fitting, and geometrical corrections such as squaring of buildings. The data is transformed in format for graphic or alphanumeric display. A set of "maintenance" programs is used for the revision of the data, edge matching, and positioning of text strings.

Time: 760 cpu secs

Within the OS blind digitising flowline all processing is worked in batch mode when the ICL computer prepares data for future use. A piecewise affine transformation is calculated, feature codes are applied to individual features, commands such as curve fitting by means of a spline function and building squaring, producing a plotting tape for the Master Plotter or the Xynetics plotter are all part of the processing procedure.

TDN's processing includes an overdetermined similarity transformation (conformal linear transformation to 4 points). Curve fitting for contours is by means of a spline function, the coefficients of which are determined by the coordinates of seven points. This spline function was not used for planimetry.

NELP digitising was carried out with the tablet linked to the North Star Horizon micro computer with software written in BASIC. Programs and data were stored on 5 1/2" diskettes. Data was subsequently transferred to a Prime 550 for additional editing. Editing refinements like squaring and curve fitting algorithms were not available.

3.4.2 Processing Interactive Digitising

Processing of interactive work is, of course, essentially carried out during digitising or editing.

The OS data processed interactively on the LITES equipment are held in ascending geographical order from the SW corner of the map, therefore to transfer the data to the Master Plotter or data bank the data must be re-sorted into feature serial number order. This is achieved on completion of the digitising by the draughtsman typing a simple

command. Further commands can be given at this stage such as to clip the data at the sheet edge, supply a feature listing, or to order a Xynetics plot.

TDN's Intergraph system has the added ability to combine, for plotting purposes, parts of a long feature split during coding. Therefore a long line of pecks, broken into strings of separate features, will be plotted as one continuous line ensuring all pecks and gaps are the same length with the exception of the last.

3.5 Editing

3.5.1 Blind Editing (1 : 2500)

For checking purposes CLYDE produce a ballpoint plot on their Kongsberg Plotter. This plot contains no feature numbers, if many edits are required then a second ballpoint plot containing feature numbers is produced to aid editing. The feature numbers can be used via the keyboard for deletions while additions are made by digitising. This process is repeated until the data is considered acceptable. Although seemingly tedious, this system is felt to be viable at CLYDE due to the large proportion of plotting time spent writing feature numbers added to the fact, that often only small areas of the map need be plotted with feature numbers. Two edit runs were required, needing a total of 3 plots.

Time: proof production 6.5 hrs
edit 6.5 hrs

NLS produce simplified plots on their Benson and HP 7580A drumplotters for examination and edit purposes. Editing is performed using software facilities or by digitising. A new edit plot is produced for verification of the edits. This procedure is continued until the data is ready for final plotting. Interactive editing is available on graphic screens but is limited to the final editing of minor errors. No indication that interactive editing has been employed in this project has been given.

Time: 10 hrs

At the OS a four colour ballpoint plot on paper is produced by a Xynetics flatbed plotter, for examination of the initial digitising. Each feature is uniquely numbered in digitised order. Edits are attended to via offline forms keyed onto magnetic tape, and/or digitising, for which further plots are required for verification. This edit cycle is repeated until the data is correct for databanking. This option required two correction runs.

Time: check 5 hrs
edit 2.5 hrs
edit plot 0.7 hrs

NELP developed separate systems for editing text and line detail. For text, after positioning as described in para 3.2.1 and 3.3.1 additional editing time was required for parallelism and left adjustment. To edit line detail the data file was transferred to the Prime 550 where it was edited to remove points already flagged as being in error. A plot was then produced and checked by visual overlay for errors. Errors were marked up and each feature displayed on a Tektronix 4010 display tube where it was checked and accepted or rejected. A second edit plot was then produced and checked before producing a final plot.

Time: detail 1 hr, text 1 hr

3.5.2 Blind Editing (1 : 10 000 Planimetry and Contours)

A Calcomp 960 belt-drive plotter produces a ballpoint plot on Ozatex for edit purposes for NBS. On completion of examination the plot is transferred to the digitising table where commands can be selected from the menu for deleting, changing code, moving, or adding data. Further plots can be produced but are seldom needed as a certain number of deficiencies can be tolerated and corrected on the master scribe. For this project two edit proofs were made for the 1 : 10 000 planimetry but no corrections were found to be necessary for the contours.

Times: proof production — planimetry 2 × 13 mins,
— contours 14 mins
planimetry — check 0.5 hrs, correct 0.7 hrs
contours — check 0.2 hrs

The edit sequence at OS is briefly explained at 3.5.1. The planimetry required just one correction run while the contours (stream mode) required two and the contours (point mode) required only an offline form to be written to delete a double digitised line. The difference in edit times for the two contour methods are a vivid indication of the operator's relative experience of the two techniques.

Times: planimetry — check 3 hrs, edit 5.7 hrs
contours (point) — check 2 hrs, edit 0.2 hrs
contours (stream) — check 2 hrs, edit 9 hrs
edit plot production 0.5 hrs planimetry
0.7 hrs contours

Although software exists at TDN to edit on their Gradicon digitiser the data captured at Rijkswaterstaat was not suited to TDN's procedures and was therefore edited interactively on the Intergraph system.

3.5.3 Interactive Editing (1 : 2500)

No check plot was supplied nor any editing carried out by OS due to other commitments within the research and development area. This was acceptable for this project due to the experience of the digitising draughtsman and the amount of editing carried out by him during the initial digitising.

3.5.4 Interactive Editing (1 : 10 000 and Contours)

TDN, the only participant in this option, also edited interactively the data collected by blind digitising. Four ballpoint paper plots are produced on the Contraves C 1700 in different colours for checking purposes. Each plot is examined against the original and marked for editing. The planimetry collected interactively required just one set of check plots before producing a scribed plot, while that collected through blind digitising required a second set of three plots for further editing. The scribes were checked and the few errors remaining were digitised but corrected manually on the scribes. The contours digitised interactively again required only one correction run while those digitised blind required two. The contour scribe resulting from the blind digitising was checked and corrected in the same manner as the planimetry. That resulting from the interactive digitising was not corrected manually, but spot heights were found to be missing so were digitised and scribed by the plotter onto the existing scribe. The times for production of checkplots, checking, editing and manual correction of the scribe for the blind and interactive digitising methods used by TDN are given in Table 3.5. A summary of blind and interactive editing times for all options is given in Table 3.4.

Table 3.4 — Summary of blind and interactive editing times (hrs)

Method	Scale	Organisation	Produce Edit Plot	Checking	Editing	Total	Remarks
Blind	1 : 2500	CLYDE	6.5		6.5	13.0	All times in hours
Blind	1 : 2500	NLS				10.0	
Blind	1 : 2500	OS	0.7	5.0	2.5	8.2	
Blind	1 : 2500	NELP			2.0	2.0	
Interactive	1 : 2500	OS				0.0	
Blind	1 : 10 000 Planimetry	NBS	2 × 0.2	0.5	0.7	1.6	
Blind	Planimetry	OS	0.5	3.0	5.7	9.2	
Interactive	Planimetry	TDN	12.4	3.0	4.8	20.2	From blind digitising
Interactive	Planimetry	TDN	6.2	0.8	2.4	9.4	From interactive digitising
Blind	1 : 10 000 Contours	NBS	0.2	0.3	0	0.5	Stream Mode
Blind	Contours	OS	0.7	2.0	0.2	2.9	Point Mode
Blind	Contours	OS	0.7	2.0	9.0	11.7	Stream Mode
Interactive	Contours	TDN	2.6	2.1	3.0	7.7	Point Mode — from blind digitising
Interactive	Contours	TDN	2.5	0.8	1.8	5.1	Point Mode — from interactive digitising

Table 3.5 — Comparison of editing times for blind and interactive initial digitising

Times		Blind	Interactive
Planimetry —	production of checkplots	12.43 hrs	6.18 hrs
	checking	3.00 hrs	0.83 hrs
	editing	4.76 hrs	2.42 hrs
	checking and manual correction of scribe	0.75 hrs	3.50 hrs
Contours —	production of checkplots	2.58 hrs	2.50 hrs *)
	checking	2.08 hrs	0.83 hrs
	editing	2.95 hrs	1.75 hrs
	checking and manual correction of scribe	1.58 hrs	0.33 hrs

*) Only one plot but plotted at lower speed.

4 Semi-Automatic Line Following with Interaction

4.1 Equipment Used

LASERSCAN

Laserscan Fastrak Digitiser
Laserscan Interactive Editing Station (LITES)
VAX 11/780 computer
Integral Plotter

OS

Laserscan Fastrak Digitiser
Laserscan Interactive Editing Station (LITES)
VAX 11/780 computer
Xynetics 1050 and 1100 flatbed plotters (edit plot)
Ferranti Master Plotter EP 330

4.2 Preparation (1 : 2500 and 1 : 10 000 Planimetry)

4.2.1 LASERSCAN's only preparation was to produce 105 mm negatives of the original (1 : 10 000) and a calibration grid.

4.2.2 OS prepared only 105 mm negatives (working area 68 × 68 mm) of the originals (1 : 2500 and 1 : 10 000).

4.3 Digitising (1 : 2500 and 1 : 10 000 Planimetry)

4.3.1 LASERSCAN calibrated the Fastrak by digitising the grid intersections of the calibration grid and then set up the map by digitising its four corner points. Point filtering parameters suitable for the types of detail concerned were set for operation during digitising. No curve fitting techniques were used, but LASERSCAN state they are available if required, and no attempt was made to digitise text, vegetation, or symbols at this stage. Double pecked lines where thought to be parallel by LASERSCAN were digitised on one side only with the other being generated at editing stage. Although not fully developed, a junction recognition program was used to improve the depiction of intersections. LASERSCAN claim that the digitising time could have been halved with more experience of this type of detail and the use of future software enhancements. The bureau's senior operator with 3 years experience was employed on this project.

Time: 1 : 10 000 calibration 0.1 hrs
digitising 7.5 hrs

4.3.2 OS calibrated the Fastrak and set up the maps using the grid intersections contained on the maps. Any future set up of the maps then only required the four corner points to be digitised. The same parameters were selected to deal with the varying types of detail for both planimetry sheets. No text or vegetation symbols were digitised at this stage. The complexity of the detail caused problems in that the short line lengths of the fences and buildings in built up areas required a considerable amount of operator intervention. The operator used was, at the time, the only operator trained at OS and has 2 years experience.

Times:		calibration and set-up	digitising
	1 : 2500	0.5 hrs	13 hrs
	1 : 10 000	0.5 hrs	6 hrs

4.4 Processing (1 : 2500 and 1 : 10 000 Planimetry)

Processing for both LASERSCAN and OS are very similar. The algorithms calculated at calibration and set-up stage are worked against the filtered data points to perform a transformation of the data. Squaring of buildings flagged during digitising is also carried out at this stage.

Times: LASERSCAN none indicated
OS 0.2 hrs for each map

4.5 Editing (1 : 2500 and 1 : 10 000 Planimetry)

4.5.1 LASERSCAN's checkplot was produced by the Fastrak's own laser plotter, plotting on a 105 mm diazo material which was enlarged photographically to full size and checked. The data were edited on the Laser-Scan Interactive Editing Station (LITES), with some symbols added at this stage. LASERSCAN feel digitising in some of the more complex areas should not have been attempted automatically but that this sort of data should have been captured manually prior to Fastrak capturing the bulk of the detail.

Times: 1 : 10 000
plotting and enlargement
of checkplot 0.2 hrs
check 0.5 hrs
edit 2 hrs

4.5.2 OS produced a four colour paper check plot on the Xynetics for each of the maps. These were checked and edited by a draughtsman on LITES. Due to the problems that densely built-up areas, especially, pose for the Fastrak it was found to be more practical in many cases to delete areas and redigitise rather than to proceed with normal interactive edit routines. Symbols were added at this stage but no vegetation symbols were added to the 1 : 10 000 and no text to the 1 : 2500.

Times:			
	1 : 2500	check	5.2 hrs
		edit	25.5 hrs
		check plot	0.7 hrs
	1 : 10 000	check	1.5 hrs
		edit	6.7 hrs
		add text	1.7 hrs
		check plot	0.5 hrs

4.6 Preparation (Contours)

The preparation for this option was the same as at 4.2.

4.7 Digitising (Contours)

4.7.1 LASERSCAN calibrated the Fastrak as at 4.3.1 and digitised the contours, height tagging each one prior to digitising, although no text was produced. LASERSCAN feel this sort of detail is ideal for the Fastrak.

Times: calibration 0.1 mins
digitising 1.5 hrs

4.7.2 OS calibrated the Fastrak as at 4.3.2 setting parameters for fast line following with no junctions and filtering to give an accurate depiction of the curvilinear detail. Each contour was labelled prior to digitising which required very little operator intervention.

Times: calibration and set up 0.5 hrs
digitising 1.5 hrs

4.8 Processing (Contours)

Processing of the contour data was the same as at 4.4.

4.9 Editing (Contours)

4.9.1 LASERSCAN produced a checkplot as at 4.5.1 and also ran software to produce and plot a Digital Terrain Model (DTM). It can be seen at Figure 4.1 how a coding error was detected using this model corrected on the Fastrak. Figure 4.2 shows the DTM of the corrected contour data.

Times: production of checkplot 0.3 hrs
and DTM
check 0.2 hrs
edit 0.1 hrs

4.9.2 OS required no editing but used the Fastrak's own editing software to capture the text.

Time: 1.5 hrs
check plot 0.7 hrs

Table 4.1 — Summary of semi-automatic production times

	1 : 2500	1 : 10 000 Planimetry	1 : 10 000 Contours
OS			
Preparation	—	—	—
Digitising			
cal + set up	0.5 hrs	0.5 hrs	0.5 hrs
digitising	13.0 hrs	6.0 hrs	1.5 hrs
Processing	0.3 hrs	0.3 hrs	0.3 hrs
Editing			
plot	0.7 hrs	0.5 hrs	0.7 hrs
check	5.4 hrs	1.5 hrs	—
edit	25.5 hrs	6.7 hrs	—
text	—	1.7 hrs	1.5 hrs
Total	45.4 hrs	17.2 hrs	4.5 hrs
LASERSCAN			
Preparation	—	—	—
Digitising			
cal	—	0.1 hrs	0.1 hrs
digitising	—	7.5 hrs	1.5 hrs
Processing	—	0.3 hrs	0.3 hrs
Editing			
plot	—	0.2 hrs	0.3 hrs
check	—	0.5 hrs	0.2 hrs
edit	—	2.0 hrs	0.1 hrs
Total	—	10.6 hrs	2.5 hrs

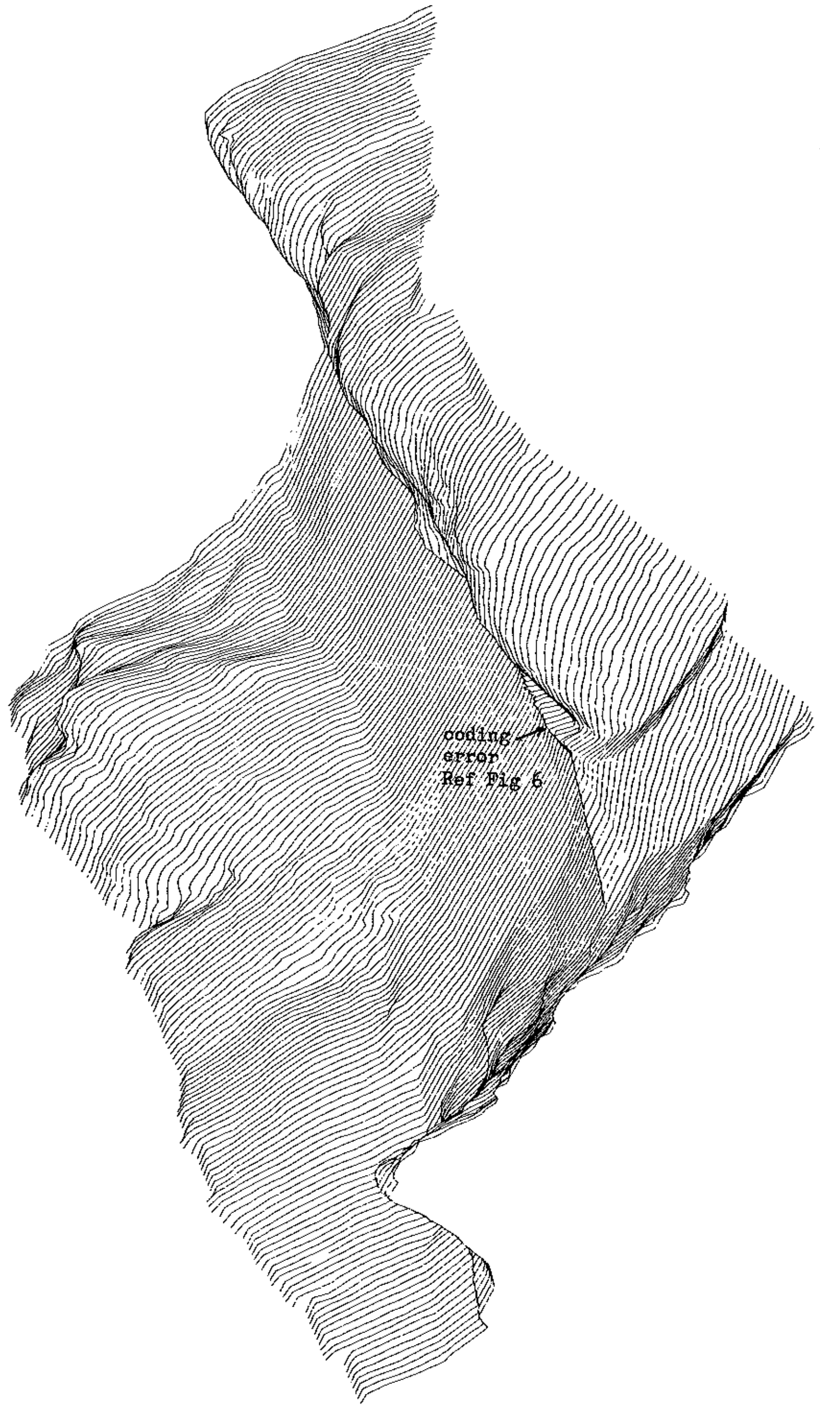


Figure 4.1 — LASERSCAN digital terrain model for checking contours

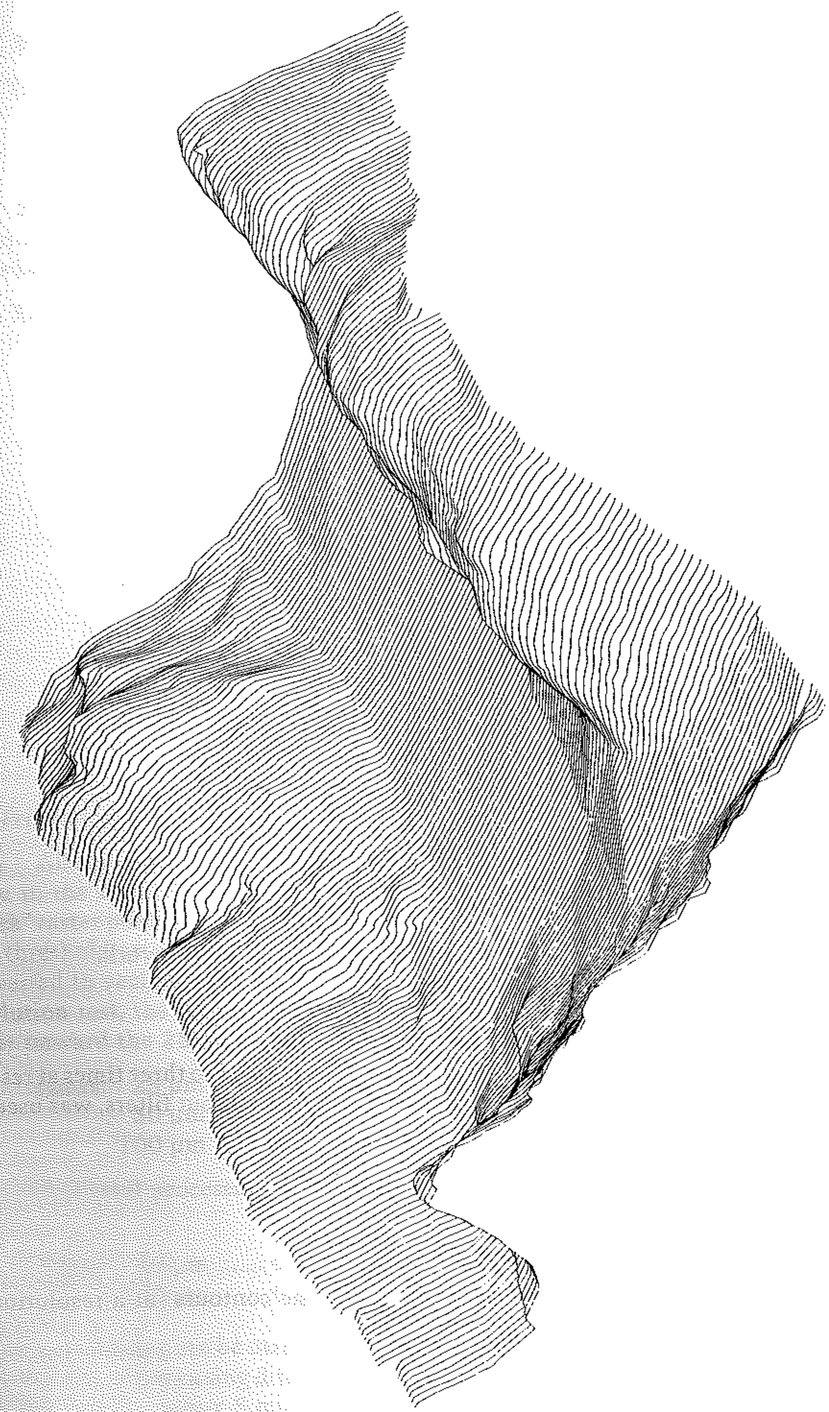


Figure 4.2 — LASERSCAN digital terrain model for checking contours

5 Scanning, Vectorising with Interaction

5.1 Equipment Used

IGMI
Kartoscan — MBB
VAX 11/750 computer
Graphic 7 interactive terminal
Kongsberg GT 5000 plotter

NGO
SysScan System comprising:
Kartoscan raster scanner
VAX/VMS V 2.5 computer
Graphic 7 interactive terminal
Kongsberg 12/6 plotter

SCITEX
Response — 280 digitising system comprising:
Scitex Super-Scanner and colour edit station
HP 21 MXE computers
Scitex ELP-II Laser plotter

SYSSCAN
Kartoscan raster scanner
VAX/VMS V 2.5 computer
Graphic 7 interactive terminal
Kongsberg 5000 plotter

5.2 Preparation

None of the participants of this option required any preparatory work.

5.3 Data Capture

5.3.1 IGMI chose to scan only the 1 : 10 000 contours, but did so three times at resolutions of 100 µm, 50 µm, and 25 µm. Incident white light, without filters, was used for scanning.

Times: 100 µm .... 0.4 hrs
50 µm .... 1.2 hrs
25 µm .... 3.4 hrs

5.3.2 NGO scanned the 1 : 10 000 planimetry and the contours at a resolution of 50 µm. Transmitted light was used for scanning.

Times: planimetry .... 0.3 hrs
contours .... 0.3 hrs

5.3.3 SCITEX scanned all three map extracts at a chosen resolution of 50 µm.

Times: 1 : 2500 .... 0.8 hrs
1 : 10 000 planimetry ...... 0.8 hrs
1 : 10 000 contours .... 0.7 hrs

5.3.4 SYSSCAN scanned the 1 : 10 000 planimetry and the contours. The planimetry was captured at a resolution of 25 µm and the contours at 50 µm. Transmitted light was used when scanning.

Times: planimetry .... 1 hr
contours .... 0.3 hrs

Table 5.1 — Summary of scan times (hrs)

	1 : 2500	1 : 10 000 Planimetry	1 : 10 000 Contours
IGMI	—	—	0.4 (100 µm) 1.2 (50 µm) 3.4 (25 µm)
NGO	—	0.3 (50 µm)	0.3 (50 µm)
SCITEX	0.8 (50 µm)	0.8 (50 µm)	0.7 (50 µm)
SYSSCAN	—	1.0 (25 µm)	0.3 (50 µm)

5.4 Processing

5.4.1 All raster points collected by IGMI are output on magnetic tape with a grey tone value in the range 0—127 where "O" represents a "white" raster point and "127" a "black" raster point. A threshold value is set below which all information is filtered out. The threshold set for this project was 70. Having filtered the data the remainder are converted to vectors. Because of the excessive amount of data acquired in the 25 µm resolution test, the times given for processing relate to only one tape and from this point onward the 25 µm test takes no further part.

Times: 25 µm .... 2.3 hrs (1 of 6 tapes)
50 µm .... 2 hrs
100 µm .... 0.7 hrs

Some additional processing was carried out on the vectorised data to eliminate noise lines.

Times: 50 µm .... 0.5 hrs
100 µm .... 0.3 hrs

Further processing can be carried out after editing by generalisation programs. This was done for this project using different parameters and plotted on paper. The time involved for each plot is approx 5 mins.

5.4.2 At NGO the rasterised data was processed through one of two vectorising programs. One, primarily for line maps and used for the contours, comprises four logical steps:

1. generation of a binary picture;
2. building of a distance function in the raster pattern;
3. skeletonisation;
4. line tracing and generation of node information.

The second was used for the planimetry extract and is designed for use on maps with a mixture of lines and areas. The program will automatically distinguish between lines and areas based on line width. If the line width exceeds a user definable parameter, it will be processed as an area. A "post-processing" program is used for node correction and the removal of noise lines.

Times: 1 : 10 000 contours .... 1.5 hrs
1 : 10 000 planimetry .... 5.0 hrs (includes 2.7 hrs to generate a file to be handled by the interactive editing system)

5.4.3 By establishing a table of parameters according to number of pixels, SCITEX can separate data such as text and building fill stipple from the data requiring digitising, holding the data in another layer. Dirt-points, in the same manner, given parameters of, say, 1–3 pixels are changed to the surrounding. This aspect of processing is Automatic Retouching and Feature Classification by Area. To begin vectorisation it is necessary to establish the centre line of pixels (skeletonisation) at which stage they are converted to chains of vectors. Noise lines are automatically removed during this process which is completed by a line smoothing technique.

Times	1 : 2500	1 : 10 000 plani	1 : 10 000 contours
Auto Retouch	4 mins	4 mins	3 mins
Skeletonisation	4 mins	4 mins	4 mins
Vectorisation (tolerance of 0.07 mm)	10 mins	10 mins	10 mins
	18 mins (0.3 hrs)	18 mins (0.3 hrs)	17 mins (0.3 hrs)

5.4.4 SYSSCAN provided no information but as NGO use a SysScan system we can assume the processing to be very similar.

Times: 1 : 10 000 contours 0.5 hrs
1 : 10 000 planimetry 4.1 hrs

Table 5.2 — Summary of processing times (hrs)

	1 : 2500	1 : 10 000 Planimetry	1 : 10 000 Contours
IGMI	—	—	2.0 (50 μm) 0.7 (100 μm)
NGO	—	5.0 (50 μm)	1.5 (50 μm)
SCITEX	0.3 (50 μm)	0.3 (50 μm)	0.3 (50 μm)
SYSSCAN	—	4.1 (25 μm)	0.5 (50 μm)

5.5 Editing

5.5.1 IGMI interactively edited the contour data to remove any spikes or noise lines remaining. The contours were then given height values which were used in a small program to sort the data into a hierarchic structure.

Times:	clean	labelling	sorting
50 μm	3 hrs	3 hrs	0.3 hrs
100 μm	1.5 hrs	1.3 hrs	0.1 hrs

5.5.2 NGO interactively connected gaps in the contours where text had been positioned and at this stage, also, height tagged them. The planimetry was edited interactively and the data coded to form a logical hierarchy. Because a program which would have squared building corners was not run, new outlines for all buildings were defined to remove the rounded corners.

Times: contours 2 hrs
planimetry 22 hrs

5.5.3 SCITEX carried out no editing on either of the planimetry sheets, however, minor corrections were carried out on the contours.

Times: automatic connection of small gaps 0.1 hrs
interactive connection of larger gaps 0.6 hrs

5.5.4 No details on editing were forthcoming from SYSSCAN.

Times: contours 1 hr
planimetry 13 hrs

Table 5.3 — Summary of editing times (hrs)

	1 :2500	1 : 10 000 Planimetry	1 : 10 000 Contours
IGMI	—	—	6.3 (50 μm) 2.8 (100 μm)
NGO	—	22 (50 μm)	2 (50 μm)
SCITEX	0 (50 μm)	0 (50 μm)	0.6 (50 μm)
SYSSCAN	—	13 (25 μm)	1 (50 μm)

6 Summary of Results

6.1 Summary of Digitising Times — Planimetry

The times reported in Sections 3, 4 and 5 for preparation, digitising, processing, editing and plotting of planimetry are summarised in Table 6.1. It should be noted the times shown exclude computer processing time, and times for producing text and edit plots which are given in Table 3.4. Times for the preparation and digitising of text, computer processing times for scanning and the resolution used for scanning are shown in the Remarks column. Times include the work of all grades of staff.

6.2 Summary of Digitising Times — Contours

The times reported in Sections 3, 4 and 5 for preparation, digitising, processing, editing and plotting of contours are similarly summarised in Table 6.2.

6.3 Summary of Plotting Equipment and Times

As the times for plotting varied considerably depending on the type and age of plotter further details of the type of plotters used and plotting times are given in Tables 6.3.1, 6.3.2 and 6.3.3 for plotting of 1 : 2500 planimetry, 1 : 10 000 planimetry and 1 :10 000 contours respectively.

Table 6.1 — Summary of overall times (hours) — planimetry

Method	Scale	Organisation	Preparation	Digitising	Editing	Plot	Total	Remarks Text = Prep + Digitising
Blind Manual	1 : 2500	CLYDE	0	61.5	6.5	7.0	75.0	Stereocompiler, No text
		NLS	5.0	39.0	10.0	3.0	57.0	Text 14.0
		NELP	0	18.0	2.5		20.5	Text 7.7
		OS	4.0	22.5	7.5	4.0	38.0	Text 9.5
Interactive Manual		OS	0	22.5	0	4.0	26.5	Text 5.5
Semi-Automatic Line Following		OS	0	13.5	30.75	4.0	48.25	No text
Scanning		SCITEX	0	0.8	0	0.2	1.0	50 μm Resolution Required Editing
Blind Manual	1 : 10 000	NBS	0	5.7	1.3	0.7	7.7	No text
		OS	9	20.0	8.8	3.0	37.8	Text 2.5
		TDN	4	9.4	7.8	12.8	34.0	+ 0.8 Checking Scribe
Interactive		TDN	4	16.7	3.2	13.0	36.9	+ 3.5 Checking Scribe
Semi-Automatic Line Following		LASERSCAN	0	7.6	2.5	0.1	10.2	
		OS	0	6.5	8.2	0.1	14.8	Text 1.8
Scanning		NGO	0	0.2	22.0*)	1.5	23.7	*) Includes text 50 μm Resolution + 5 hrs Processing
		SYSSCAN	0	0.8	0	0.2	1.0	50 μm Resolution + 4.1 hrs Processing No text
		SCITEX	0	1.0	13.0*)	0.7	14.7	25 μm Resolution *) Includes text

Table 6.2 — Summary of overall times (hours) — contours

Method	Scale	Organisation	Preparation	Digitising	Editing	Plot	Total	Remarks Text = Prep + Digitising
Blind Manual	1 : 10 000	NBS	0	1.2*)	0.2	0.4	1.8	Stream Mode *) "Groovy" Digitising
		OS	0	15.0	11.0	5.0	31.0	Stream. Text 3.0 hrs
		OS	0	16.0	2.2	5.0	23.2	Point. Text 3.0 hrs
		TDN	0	10.6	5.0	2.5	18.1	Point Mode Checking/Editing Scribe + 1.58 hrs
Interactive Manual	1 : 10 000	TDN	0	15.0	2.6	2.8	20.4	Point Mode Checking/Editing Scribe + 0.3 hrs
Semi-Automatic Line Following	1 : 10 000	LASERSCAN	0	1.6	0.2	0.1	1.9	
		OS	0	2.0	1.5	5.0	8.5	Edit includes adding text
Scanning	1 : 10 000	IGMI	0	0.4	2.8	1.0	4.2	100 µm Resolution
		NGO	0	0.2	2.0	0.3	2.5	50 µm Resolution
		SYSSCAN	0	0.2	1.0	0.2	1.4	50 µm Resolution
		SCITEX	0	0.7	0.6	0.2	1.5	50 µm Resolution

Table 6.3.1 — Plotting of 1 : 2500 map extract

	Plotter	Method	Time Hrs	Remarks
CLYDE	Kongsberg GT 5000	Scribe	7	No text
NLS	Kongsberg	Scribe	3.0	A peelcoat for building stipple was also cut on this plotter — extra time 2 hrs
OS	Ferranti Master Plotter EP 330	Light spot Projector	4	Estimated time for all 1 : 2500 options attempted
SCITEX	Scitex ELP-11	Laser	0.2	No text Time includes vector to raster conversion

For edit plot times see Table 3.4

Table 6.3.2 — Plotting of 1 : 10 000 planimetry extract

	Plotter	Method	Time Hrs	Remarks
LASERSCAN	Fastrak	Laser	0.1	No text. Enlargement time 5 mins
NBS	Kongsberg DC 300/1216	Scribe	0.7	No text
NGO	Kongsberg DT 1216	Ballpoint (plastic)	1.5	Time includes 1 hr plotting vegetation
OS	Ferranti Master Plotter EP 300	Light spot Projector	3	Estimated time
OS	Fastrak	Laser	0.1	Approx 20 mins is required for photographic enlargement
SCITEX	Scitex ELP-11	Laser	0.2	No text. Time includes vector to raster conversion
SYSSCAN	Kongsberg GT 5000	Scribe	0.7	
TDN	Contraves C 1700	Scribe	12.8 13.0	Blind digitising option Inter digitising option

Table 6.3.3 — Plotting of 1 : 10 000 contours extract

	Plotter	Method	Time Hrs	Remarks
*) IGMI	Kongsberg GT 5000	Light Spot Projector Ballpoint (paper)	1 2 × 0.25	No text **)
LASERSCAN	Fastrak	Laser	0.1	No text. Enlargement time 5 mins
NBS	Kongsberg DC 300/1216	Scribe	0.4	No text
NGO	Kongsberg DT 1216	Ballpoint (plastic)	0.3	
OS	Ferranti Master Plotter EP 330	Light spot Projector	5	Estimated time for point and stream mode and line following option
SCITEX	Scitex ELP-11	Laser	0.2	No text Time includes vector to raster conversion
SYSSCAN	Kongsberg GT 5000	Scribe	0.2	No text
TDN	Contraves C 1700	Scribe	2.5 2.8	Blind digin option Inter digin option

*) IGMI plotted only the 100 μm test
**) 2 ballpoint paper plots were produced using different parameters for the line smoothing program

6.4 Accuracy

6.4.1 Introduction

In performing a brief analysis of the final graphic as an end product the main considerations were accuracy and quality. Further consideration was given to the handling of data such as text and vegetation.

Quality must include, as well as an overall visual attribute that would add weight to the degree of confidence held in the graphic by the user, certain aspects of the data such as curves, squareness of buildings, and alignments (fit of detail to detail).

To check accuracy it is fairly simple and quick to overlay the original and check each graphic visually, and this was done. However, to give a further indication of the accuracy of each graphic, 30 identifiable points of detail were selected on each of the map extracts and, using a coordinatograph, these points were measured on each graphic for computer analysis. The 30 selected points were roughly representative of the percentage of feature types to the whole. Included were 6 points such as shallow "Y" junctions or broad "V"s to give a truer cross-section of points rather than all easily definable points.

It is accepted that:

1. Different agencies require differing standards of accuracy and quality to suit their needs.
2. Graphic images would normally be improved upon, at least aesthetically, before final production.
3. Participating manufacturers may not, as yet, have a great deal of experience in the world of digital cartographic production.

It is also recognised that OS had a distinct advantage in that they would immediately recognise and understand the specifications of a map of a native landscape.

6.4.2 Statistical Analysis

The standard error (σ) indicates the extent of random error present. To provide an indication of overall accuracy it is common practice to use the root mean square error (RMSE), while the RMSE (r) is a square law combination of σ and systematic error (S) so that

$$r^2 = \sigma^2 + S^2.$$

However, one would expect to find an insignificant systematic error and because of the scale changes that would occur on the graphics due to expansion/contraction and systematic error introduced by the coordinatograph the program removed systematic error by means of a block shift, rotation, and scale change. The result is a least squares residual fit at the 30 common points of the original map extract and the analysed graphic so that the standard error (σ) is directly determined. The method of analysis has not allowed the systematic errors to be quantified, although visual inspection in some cases suggests systematic errors arising from loss of origin and other reasons.

Any vector error $2 \times \sigma$ was checked on the graphic and often found to have an explanation to justify removing it and re-testing. Any error greater than $3 \times \sigma$ was automatically rejected from the analysis.

The statistics derived are displayed in histogram form showing:

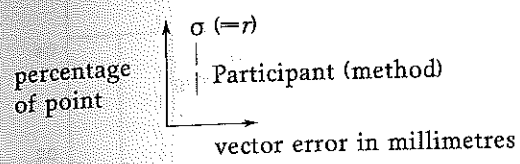
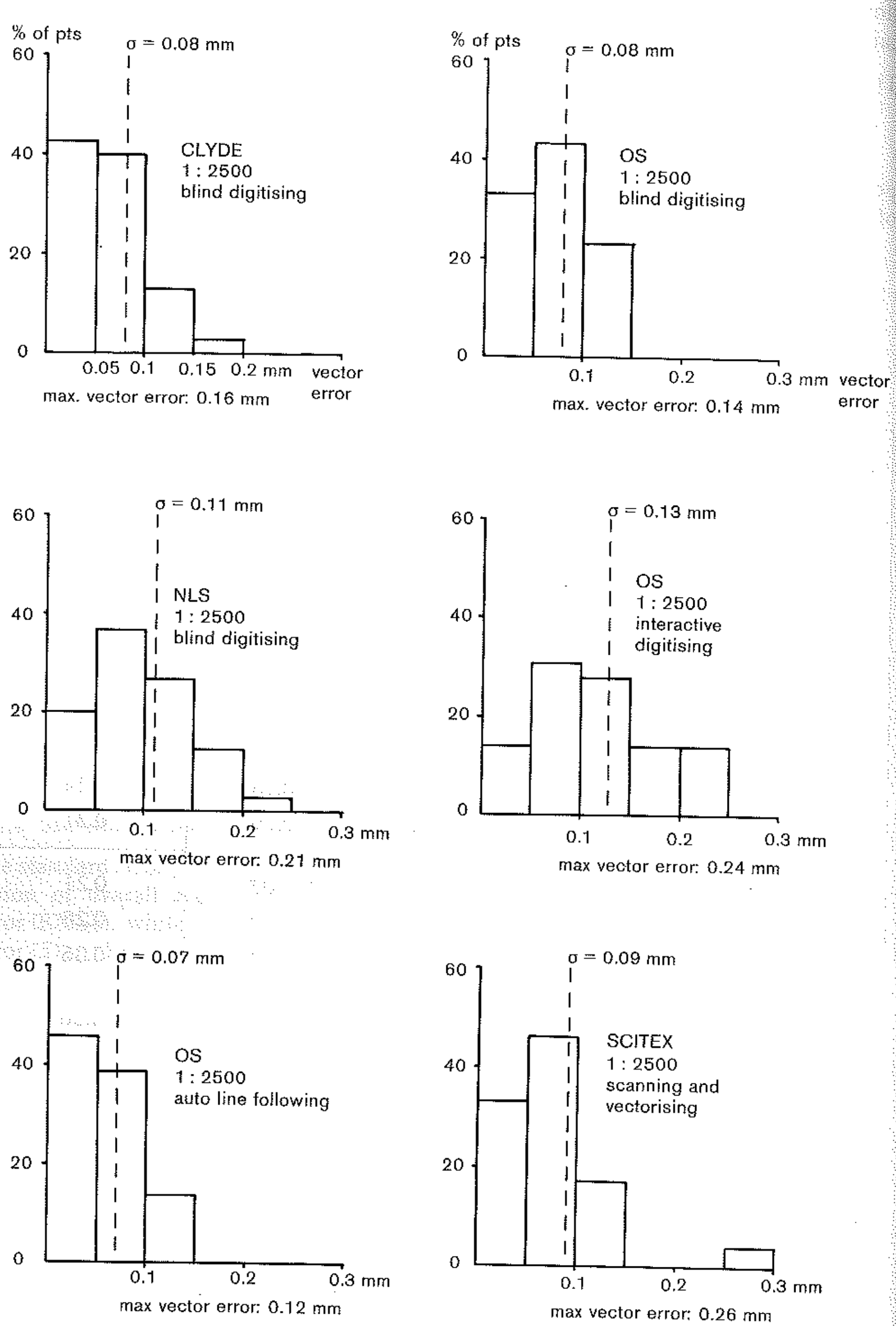


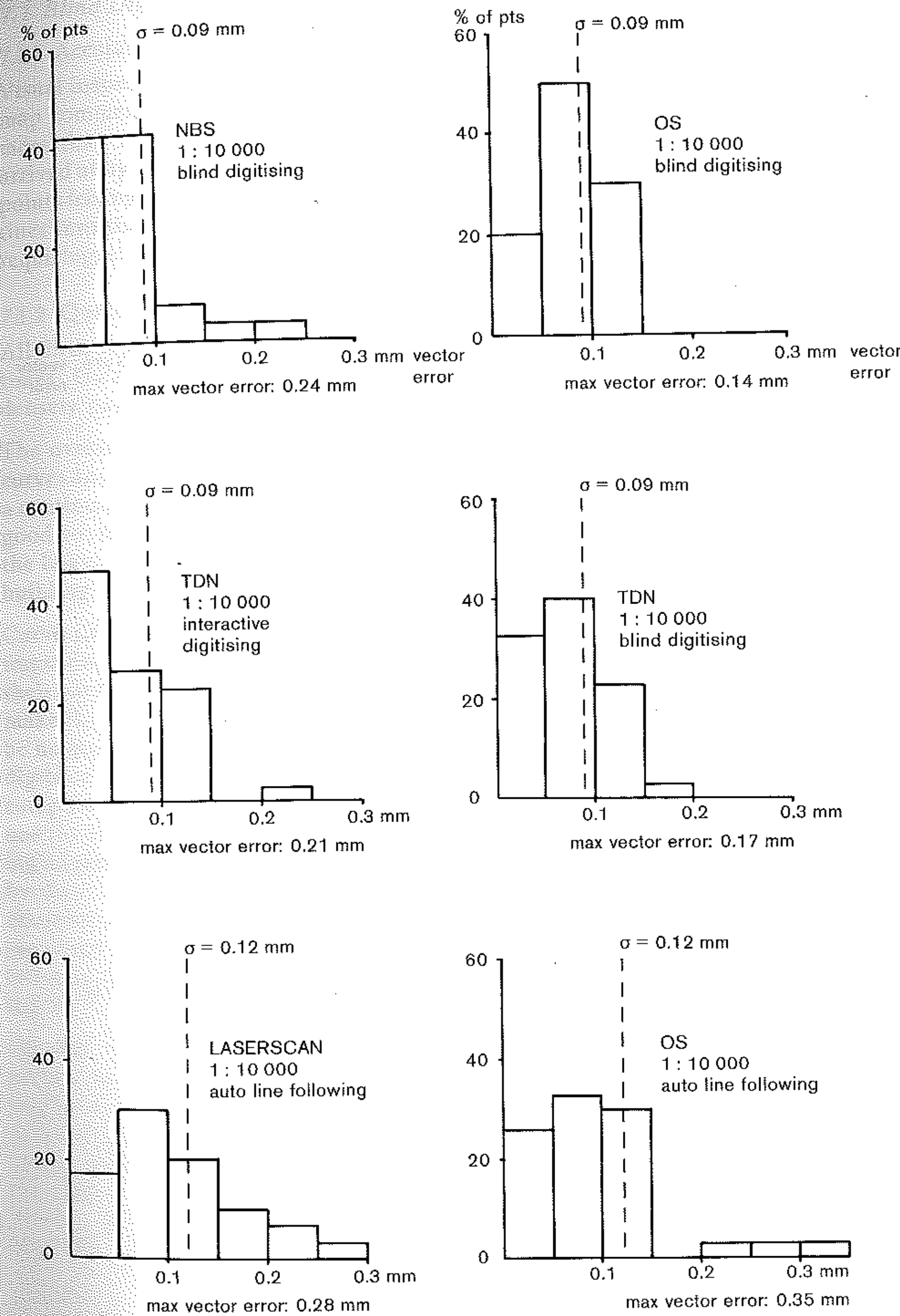
Table 6.4.1 — Summary of statistical accuracy results

Method	Particpant	Scale	Standard Error (mm)	Maximum Vector Error (mm)
Blind	CLYDE	1 : 2500	0.08	0.16
Blind	OS	1 : 2500	0.08	0.14
Blind	NLS	1 : 2500	0.11	0.21
Blind	NBS	1 : 10 000	0.09	0.24
Blind	OS	1 : 10 000	0.09	0.14
Blind	TDN	1 : 10 000	0.09	0.17
Interactive	OS	1 : 2500	0.13	0.24
Interactive	TDN	1 : 10 000	0.09	0.21
Semi-Automatic Line Following	OS	1 : 2500	0.07	0.21
	LASERSCAN	1 : 10 000	0.12	0.28
	OS	1 : 10 000	0.12	0.35
Scanning	SCITEX	1 : 2500	0.09	0.26
	NGO	1 : 10 000	0.09	0.26
	SCITEX	1 : 10 000	0.09	0.19
	SYSSCAN	1 : 10 000	0.06	0.14

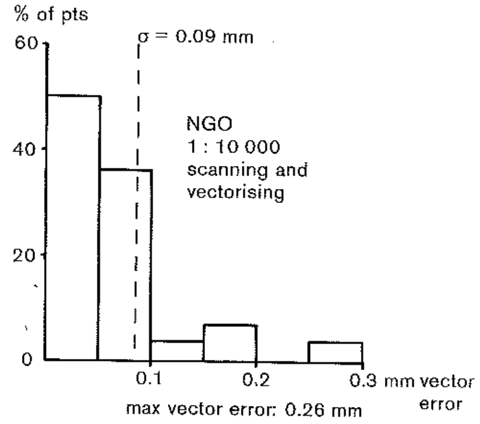
Table 6.4.2 — Distribution of errors

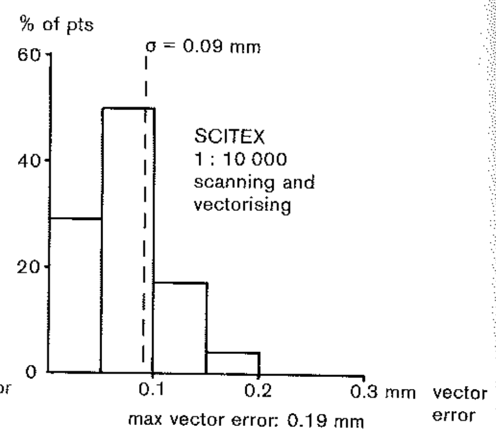


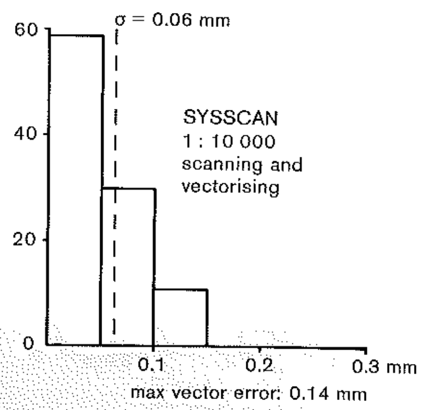
continued Table 6.4.2 — Distribution of errors



continued Table 6.4.2 — Distribution of errors







7 Discussion of Planimetric Results

7.1 *Blind Digitising 1 : 2500*

7.1.1 Accuracy

Visual inspection by overlay showed that OS and NLS were fairly consistent over the map commensurate with their calculated standard error. CLYDE drifted off key by more than a line width on several occasions, contradicting the low standard error arrived at by computer analysis. The reason appeared mainly to be gross errors such as points (changes of direction) being missed or too few points selected during curve routines resulting in over generalisation. This occurred most often in the more open area requiring less of the draughtsman's concentration, possibly leading to pointing errors!

7.1.2 Quality

All three participants appeared to have some difficulty in producing square buildings at times. Isolated buildings caused least problems whilst the worst examples are in densely packed terraces containing a number of small juts.

The overall quality produced by CLYDE was quite neat, reinforced by very smooth curves and alignments (e.g. fence — side of building, although two features they appear a continuous straight line on graphic) which are, in the main, good. The line quality is good but there are tell-tale signs of the final plot being scribed, such as small breaks in the linework, often at junctions. A second indication is the start and finish points of a building very often being clearly identified.

Curve fitting and a better digitising technique to improve alignments would have improved the overall quality of the NLS submission. NLS made it clear they did not use their curve facility as no curves could be found on the extract supplied and wished to make their submission as close as possible to the original. The reason there appears to be no curves on the extract is as explained in the next paragraph. NLS appear to have digitised the outlines of buildings or groups of buildings, whatever the complexity, complete, digitising any internal walls as separate entities. Internal walls often continue the alignment of an outside wall, therefore, by digitising in this manner the resulting alignments are very poor. However, NLS cut a house fill mask on their plotter and by digitising outlines complete and distinct from internal walls, may be seeking to minimise work on the mask by filtering out the internal walls together with the rest of the unrequired data. The line quality is quite good but, again, tell-tale signs of the plot being scribed, here there are marks at the end of lines (most easily seen on pecks) forming at "T".

OS could have improved the overall quality of their submission by adhering to their normal convention of digitising at an enlarged scale and by better use of the curve fitting facility which was rarely used. A problem, highlighted by this project, is that some draughtsmen are very reluctant to use the curve routine, especially on long sinuous features, as they feel they can achieve a better result without it. Unfortunately, even when the curve routine is used correctly, the output from the plotter is a little angular when viewed closely suggesting the reason why the reluctance to use the curve routine has, largely, gone unnoticed. Poor curves on the graphics appear to be a function of:

a) too many points digitised along curve. This is a question of experience to achieve the correct balance. Too few points, of course, would result in generalisation of the curve; and/or

b) acceleration/deceleration of the plotter resulting in overexposure of each end of the line segments, accentuating changes of direction.

Apart from this factor the line quality produced is very good and alignments of detail are, in the main, satisfactory.

7.1.3 Text

CLYDE produced no text as they, as yet, do not prossess the facility to capture it. NLS produced text scribed by their Kongsberg while OS produced text written by the Ferranti's lightspot projector. Although a few errors still exist, mainly on the OS submission, the positioning and orientation of text on both samples indicates this has caused no problems for either participant. OS have not broken linework for text as it is house policy not to break data during digitising but to correct this on the positive as part of the aesthetic corrections in a normal flowline. Neither participant were able to produce the Lutheran style text denoting antiquities by digital means. The quality of the scribed text does not match that of the text written by the photohead, although this could be criticised for being on the heavy side.

7.1.4 Symbols

NLS produced new symbols to match all those on the supplied original, including vegetation. Building stipple was also added, the mask being cut by the Kongsberg plotter. CLYDE produced vegetation symbols and most other map symbols very similar to the original but chose not to show the area symbols (braces and town band symbols). The OS symbols were "flashed" down by the plotter, but those symbols normally applied by waxed stripfilm were substituted by short lines (for area symbols) or dots (for vegetation) indicating position. No participant appeared to have any problem in the positioning or orientation of symbols.

7.1.5 NELP did not provide a final plot for evaluation but did provide the following comments in their report:

a) The geometry of buildings was generally poor — no squaring algorithm used.

b) The use of multiple feature codes (building/road, building/boundary etc.) introduced problems of interpretation and ambiguity from the base map particularly dense urban areas.

c) Curve fitting algorithms were not used.

7.2 Interactive Digitising 1 : 2500

Only OS participated in this option.

7.2.1 Accuracy

Quite a lot of detail is off key on the eastern half of the sheet by as much as 2—3 line widths. As the error is consistently in the same direction it appears there has been a loss

of origin during digitising. It would certainly have been noticed had a check plot been produced and examined in the normal manner.

7.2.2 Quality

Curves appear acceptable but, on closer inspection, can be seen to be rather angular due to the factors explained at 7.1.2. The line quality is good and alignments, also, are generally good, but while isolated and simple shaped buildings have been squared well, complicated shapes found in some of the congested terraced blocks have caused problems. The overall appearance of the graphic would have been improved further had the data progressed through a check and edit sequence. However, there is the real danger of overkill in editing interactively due to the ability of enlarging very small areas of the map by a high degree of magnitude onto the graphic screen.

7.2.3 Text

The addition of text caused no problems adding it via the keyboard. The positioning and orientation is simpler and more sure of success than on blind digitising having the facility to move around and deposit text on the graphic screen relative to any features. House policy was adhered to in that no detail was broken for text on the file.

7.2.4 Symbols

The positioning and orientation of symbols has caused no problems. A dot has substituted for a group of vegetation symbols rather than each individual symbol.

7.3 Semi-Automatic Line Following 1 : 2500

Only OS participated in this option.

7.3.1 Accuracy

A very good fit of detail to detail was achieved on the visual overlay.

7.3.2 Quality

No curve routine was invoked but parameters set should ensure smooth looking curves. On this plot the tighter the curve the smoother it tends to be, although this effect could be partly due to the acceleration/deceleration of the slow Master Plotter. Buildings are generally squared well and alignments good, but considerable interactive editing took place resulting in a graphic bearing little resemblance to the Fastrak output. It could be argued, for some purposes, the data was over-edited, therefore an extract of the unedited data is included, produced on the Fastrak's plotter and enlarged photographically.

7.3.3 Text

No text was added.

7.3.4 Symbols

Vegetation has been symbolised by a dot substituting for a group of vegetation symbols rather than individual symbols. No symbols requiring orientation have been added but no reasons given why, as this could easily have been achieved at editing stage on LITES.

7.4 Scanning and Vectorisation 1 : 2500

SCITEX were the only participants in this option. It is, therefore, convenient to consider the SCITEX 1 : 10 000 submission at the same time as, it can be seen, the following points apply to both. Recently SCITEX participated in an OS bench mark trial presenting very different results to this OEEPE trial. In that bench mark trial processing was more controlled and interactive editing also featured.

7.4.1 Accuracy

To measure the selected points for the statistical analysis, the coordinatograph's operators very often had to extend the line of building sides to overcome the problem of rounded corners. This, of course, throws doubt on the results of the analysis, but were the best that could be obtained under the circumstances. A visual check of the graphics give the impression that had the maps been completed to a satisfactory conclusion the accuracy would have caused no problems.

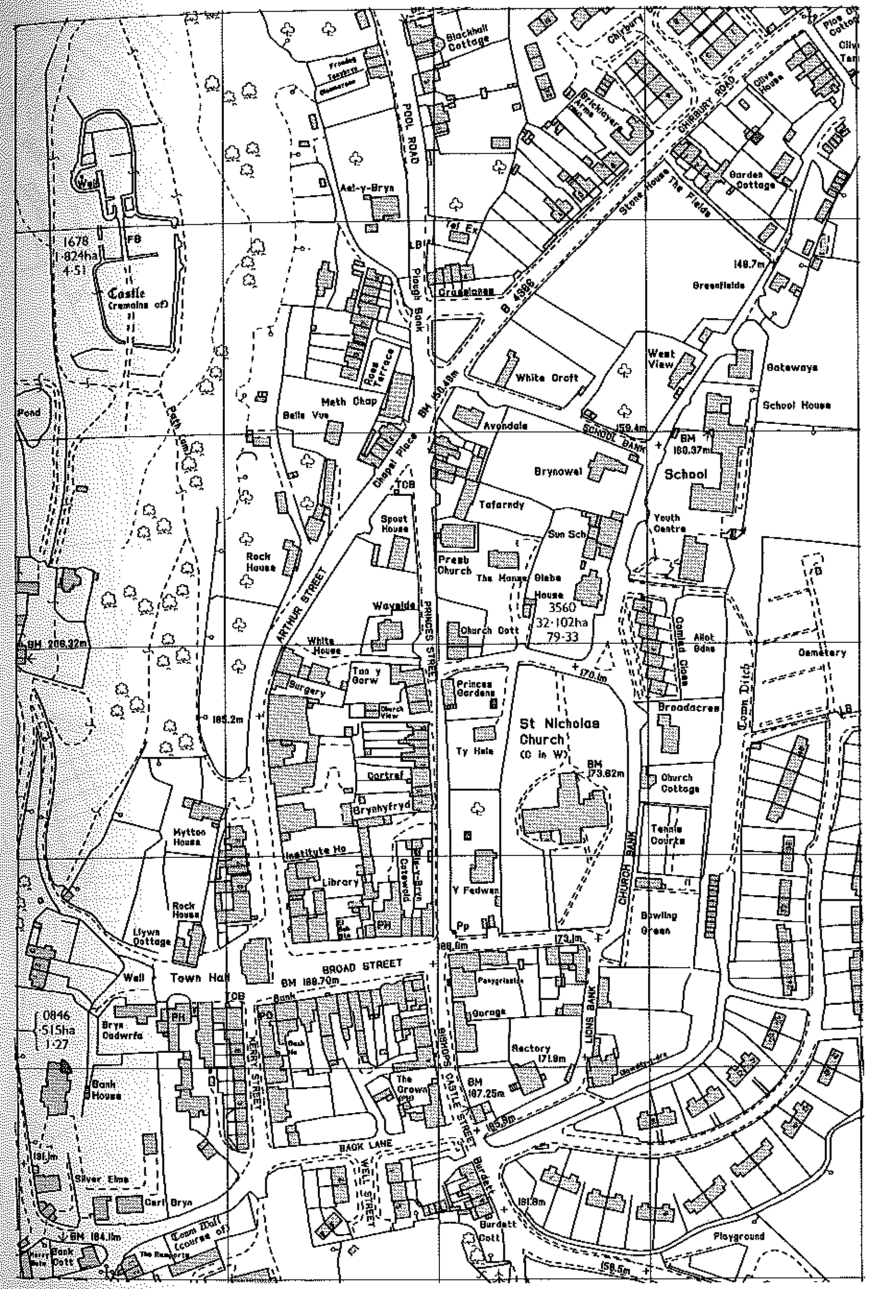
7.4.2 Quality

Very little can be said of the quality of the graphics in their unfinished state. No interactive editing was attempted, of which a considerable amount would be required to produce usable graphics. No pecked lines were captured, while some quite large lengths of detail and small buildings are missing presumably due to the "fairly large segment" SCITEX state was specified for noise removal during processing. Setting new parameters would, no doubt, have improved the data resulting at this stage. However, these graphics do indicate the degree of editing required by all automatic digitisers for most cartographic purposes. Most unwanted detail such as text and stipple has been successfuly removed at processing stage but, where touching required detail, has either been plotted or has effected short changes of direction in the linework. Most other problems resulting from the effects of skeletonisation and vectorisation, such as at junctions and line intersections, are clearly identifiable. Without criticising the values of raster plotters, there is no doubt the use of one for these graphics has contributed to the poor appearance.

7.4.3 Text and Symbols

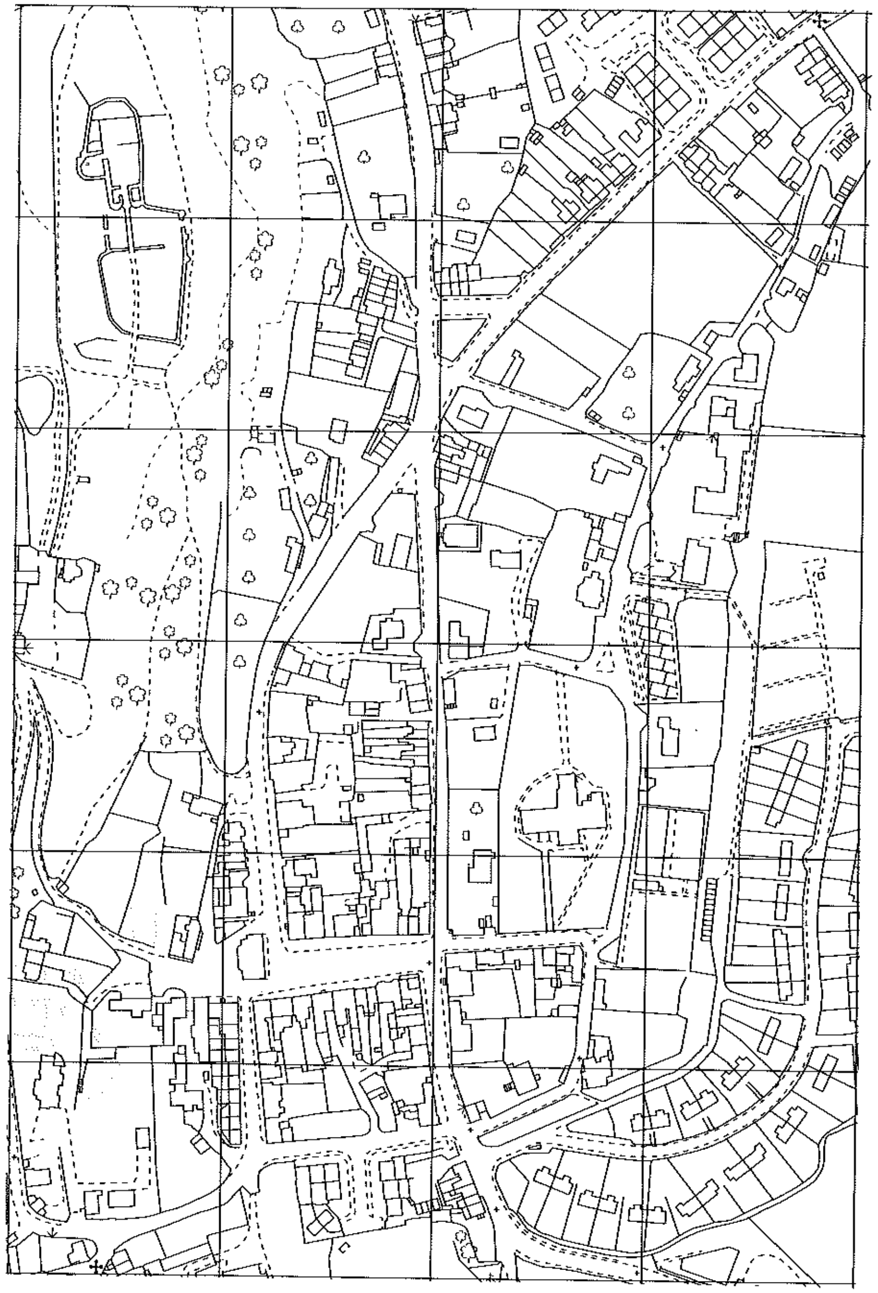
None have been intentionally captured.

7.4.4 Due to tight schedules SCITEX claim to have had little time to spare to plan optimum procedures for the OEEPE project. SCITEX also assumed the results for the OS bench mark would be considered in the OEEPE report although it was made clear the two are entirely independent of each other.



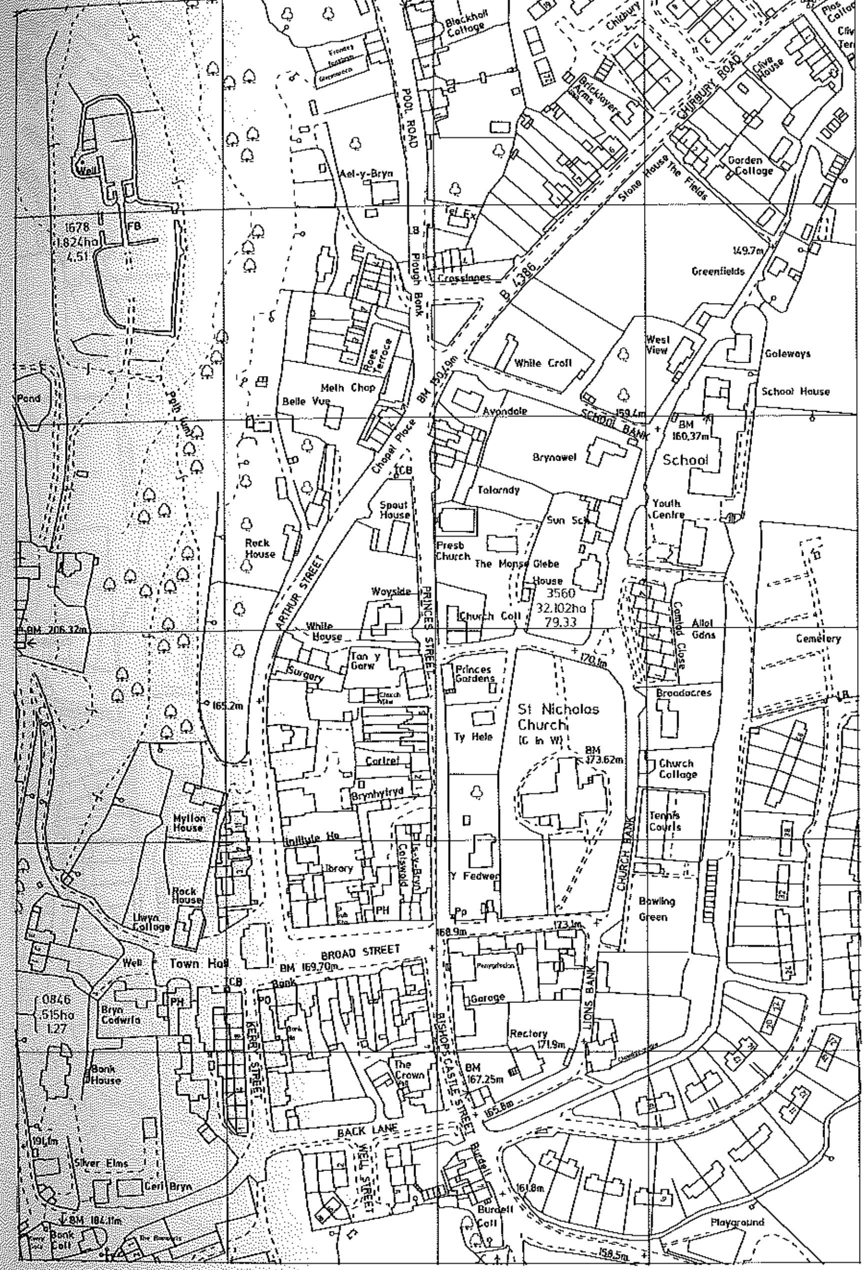
Reproduced at 1 : 4300 scale

Figure 7.1 — 1 : 2500 original (extract)



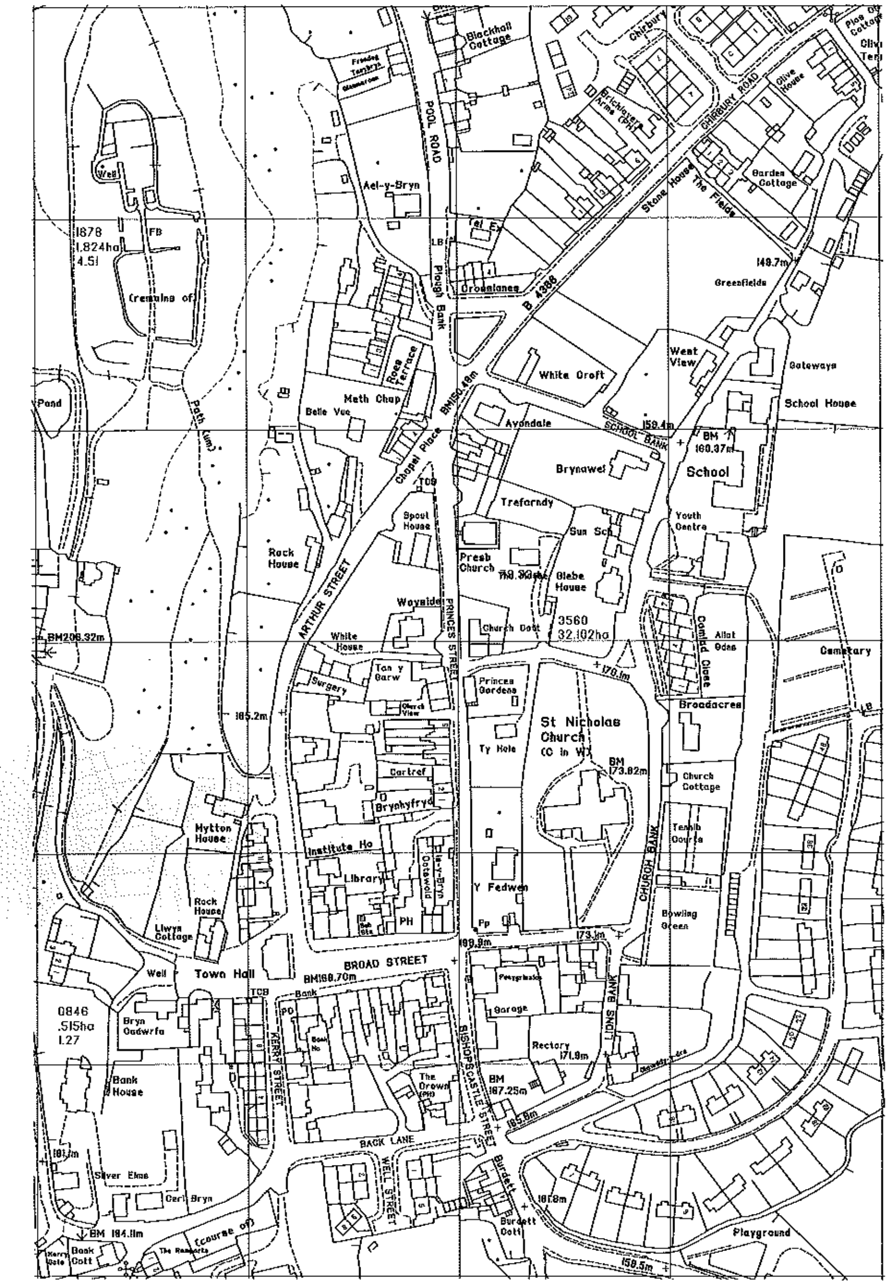
Reproduced at 1 : 4300 scale

Figure 7.2 — 1 : 2500 CLYDE blind digitising



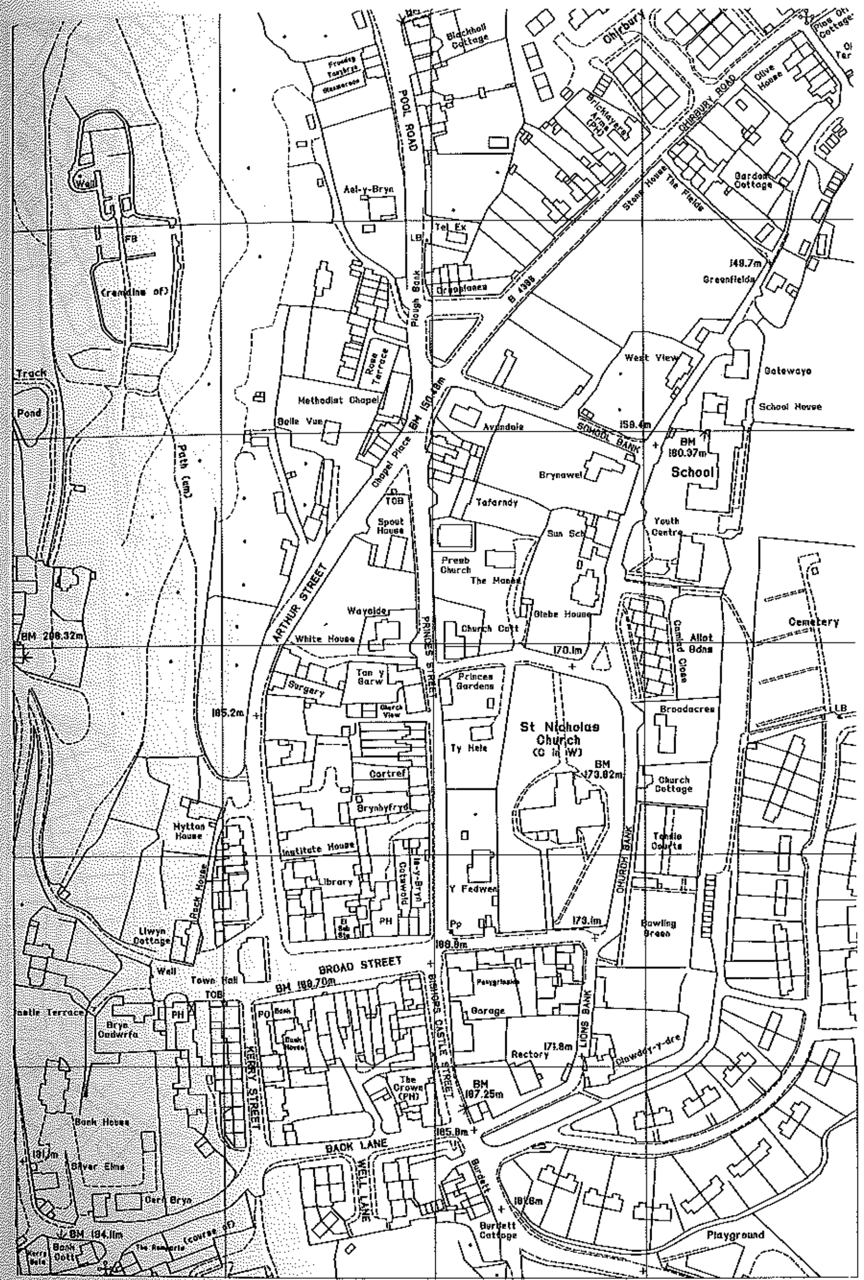
Reproduced at 1 : 4300 scale

Figure 7.3 — 1 : 2500 NLS blind digitising



Reproduced at 1 : 4300 scale

Figure 7.4 — 1 : 2500 OS blind digitising

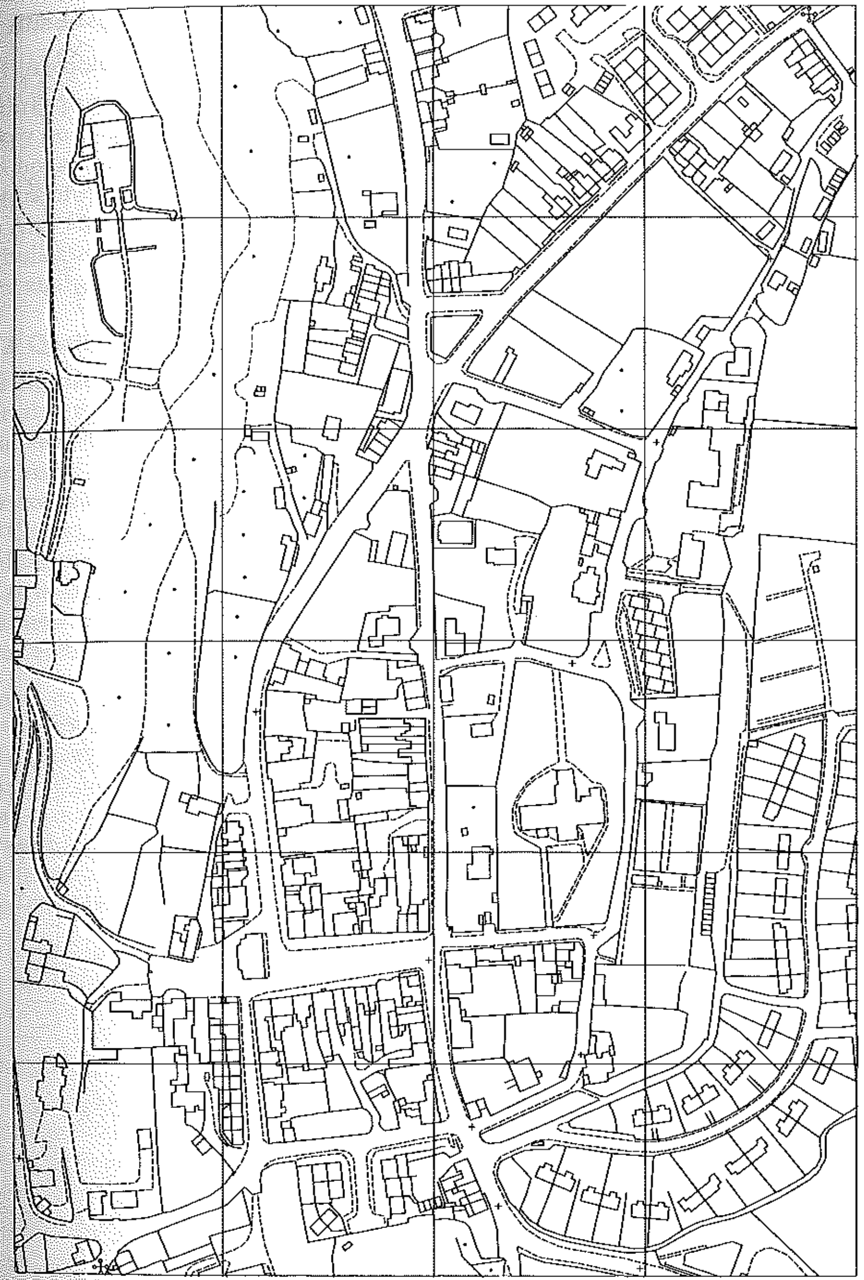


Reproduced at 1 : 4300 scale

Figure 7.5 — 1 : 2500 OS interactive digitising

Reproduced at 1 : 4300 scale

Figure 7.6 — 1 : 2500 OS automatic line following (unedited)



Reproduced at 1 : 4300 scale

Figure 7.7 — 1 : 2500 OS automatic line following

Reproduced at 1 : 4300 scale

Figure 7.8 — 1 : 2500 SCITEX scanning and vectorising

7.5 Blind Digitising 1 : 10 000

7.5.1 Accuracy

All three participants, NBS, OS, and TDN, produced graphics with very little linework off key on a visual check. The only aspect to affect accuracy to any great degree is the NBS house policy to symbolise roads and tracks by a standard width double line. A mixture of specifications has meant buildings that were marking the road edge now do not. Also fences haven't always been extended to make up the shortfall caused by the symbolisation. Any points of detail affected by this have been removed from the computer analysis.

7.5.2 Quality

NBS digitised the extract in by far the quickest time but the graphic reflects the speed to a certain extent displaying generally poor alignments and only a few attempts to tidy up detail following the road symbolisation. Buildings are squared well but lose some of their visual impact due to the sides distinctly wavering. This apparent plotter fault is very noticeable on buildings and the Finnish symbol for coniferous trees, an inverted "V". Curves produced are good, as is the line quality, but for a slight wobble occasionally which must also prove to be due to the plotter, rather than misuse of the curve facility, as it has occurred on one occasion on just one side of the symbolised double line road network. Pecks in double rows are twice the length of pecks in single rows resulting in some loss of clarity in built up areas.

Overall quality of the OS submission is quite good although on close inspection the curves lack any smooth sinuosity probably due to the reasons given at 7.1.2 that too many points were digitised coupled with "angular" appearance of curves drawn by the Master Plotter. The line quality is good although a much lighter line gauge all round than those on the extract with the exception of road fences which appear much closer to the original. Generally, buildings have been squared well and alignments are good. Peck lengths and gaps, though, appear too large making it difficult at times to interpret short pieces of pecked detail in built up areas.

The overall appearance of the TDN submission is good but on inspection it can be seen that alignments are very often poor and buildings are generally lacking squareness. TDN stated that a squaring algorithm is available but was not used to avoid distorting the accuracy test. The digitised start/end points of buildings at times require touching, probably due to the plotter not being programmed to provide the small overshoot required on scribing to present a completed building corner. The line quality produced is quite good along straight lines but deteriorates rapidly on changes of direction. This results in a very poor curve output as each change in direction of the line segments is very visibly accentuated. Dot symbols haven't been handled by the plotter very well and, therefore, have been manually touched on the scribe.

7.5.3 Text

NBS and TDN produced no text for reasons explained at 3.3.2. OS produced the text with no difficulty as far as positioning and orientation is concerned. However, they were unable to produce Lutheran type style by digital means and therefore substituted it by Univers style.

7.5.4 Symbols

No participant was able to produce vegetation by establishing an area within which it should appear, as was requested for the southern sector. TDN produced vegetation in this sector but it was obviously digitised as point symbols due to the fact that each symbol has been plotted in the same position as appears on the original extract. Because of the extra effort in producing symbols matching the extract, TDN were able to produce a very good near replica of the extract. NBS produced all symbols as would appear on their native maps with the exception of electricity pylons, which they left off, and bench marks, also left off being unknown in Finland. Important buildings, also, were unaccentuated. The OS substituted dots for vegetation symbols, all of which would normally be applied as waxed stripfilm to the positive.

7.6 Interactive Digitising 1 : 10 000

Only TDN participated in this option.

7.6.1 Accuracy

Very little linework was found to be off key.

7.6.2 Quality

As with their blind digitising submission the overall appearance is good but, although an improvement on the blind digitising, some of the alignments and squaring of buildings could be improved further. The same problem with building start/end points has occurred on this option but have been touched on the scribe. Dot symbols have also required a manual improvement on the scribe. The line quality is not very good over the whole sheet rather than only on changes of direction, as with the blind digitising, therefore curves appear smoother. Breaks in linework occurring at junctions indicate the use of a scribed plot.

7.6.3 Text and Symbols

All that applies to the blind digitising submission equally applies to this.

7.7 Semi-Automatic Line Following 1 : 10 000

7.7.1 Accuracy

Both the LASERSCAN and the OS submissions proved very good on a visual check. The only aspect working against accuracy of the LASERSCAN graphic is that curves are represented by long straight line segments resulting in some minor curves being lost completely.

7.7.2 Quality

Both LASERSCAN and OS produced their submitted graphics by using the Fastrak's plotter and photographically enlarging to scale from the resultant A6 negative. The line quality is poor, giving the impression when magnified of never quite being in focus. The image varies from very dark to very light, particularly on the OS attempt.

Alignments produced by LASERSCAN are good as is the squaring of buildings, however, some buildings have been rotated, probably during the squaring routine. Important buildings have not been accentuated and curves, as mentioned at 7.6.1, are poorly represented due to inappropriate parameters selected. An extract of the unedited LASERSCAN data is included.

On the OS graphic buildings are squared well and alignments are good, but as with the 1 : 2500, considerable interactive editing took place on this sort of detail. Important buildings are not accentuated and it is not until viewed quite closely, that the line segments can be traced around "curves". The western side of the moat still shows line wobble where the line following was diverted by stipple dots touching the outline.

7.7.3 Text

LASERSCAN produced no text while OS added text at editing stage on LITES appearing to have encountered no problems.

7.7.4 Symbols

LASERSCAN plotted only electricity pylon symbols, the majority oriented correctly. OS produced point symbols and oriented symbols with no apparent problems but no vegetation has been symbolised.

7.8 Scanning and Vectorisation 1 : 10 000

There was great concern on receipt of the SYSSCAN submission being delivered at OS rolled in paper without the protection of a cardboard or plastic tube. Needless to say the plots were creased. To make the best of it contact positives were made in a vacuum frame. SCITEX also participated in this option but the comments regarding their submission are at 7.4.

7.8.1 Accuracy

When given a visual check by overlaying the original extract both the NGO and the SYSSCAN positives appeared an extremely good fit of detail to detail. Several misplaced features on the NGO graphic have been explained in their narrative reports as being attributable to a fault in the interactive display. Any of these points affecting the computer analysis have been removed from the computer data.

7.8.2 Quality

NGO feel their final result could have been improved had they had time to experiment with editing and plot preparation. Their system has been mainly used for the production of a Digital Terrain Model and the programs used for structuring and editing of cartographic data has not yet been used in regular production, therefore several problems were encountered during digitising of the planimetry. There are some jumps left in the linework so characteristic of skeletonised data where captured detail had been touching, or nearly touching, unwanted data such as stipple and the grid lines. Some large pieces of detail are unaccountably missing, but curves have been produced satisfactorily as has the capture and output of pecked lines. Buildings appear squared well at editing stage but there was no distinction made for important buildings, in fact these caused NGO a problem in that their line widths on the original extract are close to the maximum line width set for lines, therefore they can, and were, processed as areas having an inner and an outer line. No comment can be made of the line quality as the final output was by ballpoint pen.

On the SYSSCAN graphic, buildings look square but curves vary from being very angular to good. Important buildings have not been accentuated while pecks have been captured satisfactorily but output, apart from one incident, as solid lines. There are often small breaks in the linework where the grid lines would have been positioned. Probably small jumps, as mentioned for NGO, have been removed during interactive editing without joining the hanging ends. Unfortunately, line quality is very poor making the graphic appear very messy.

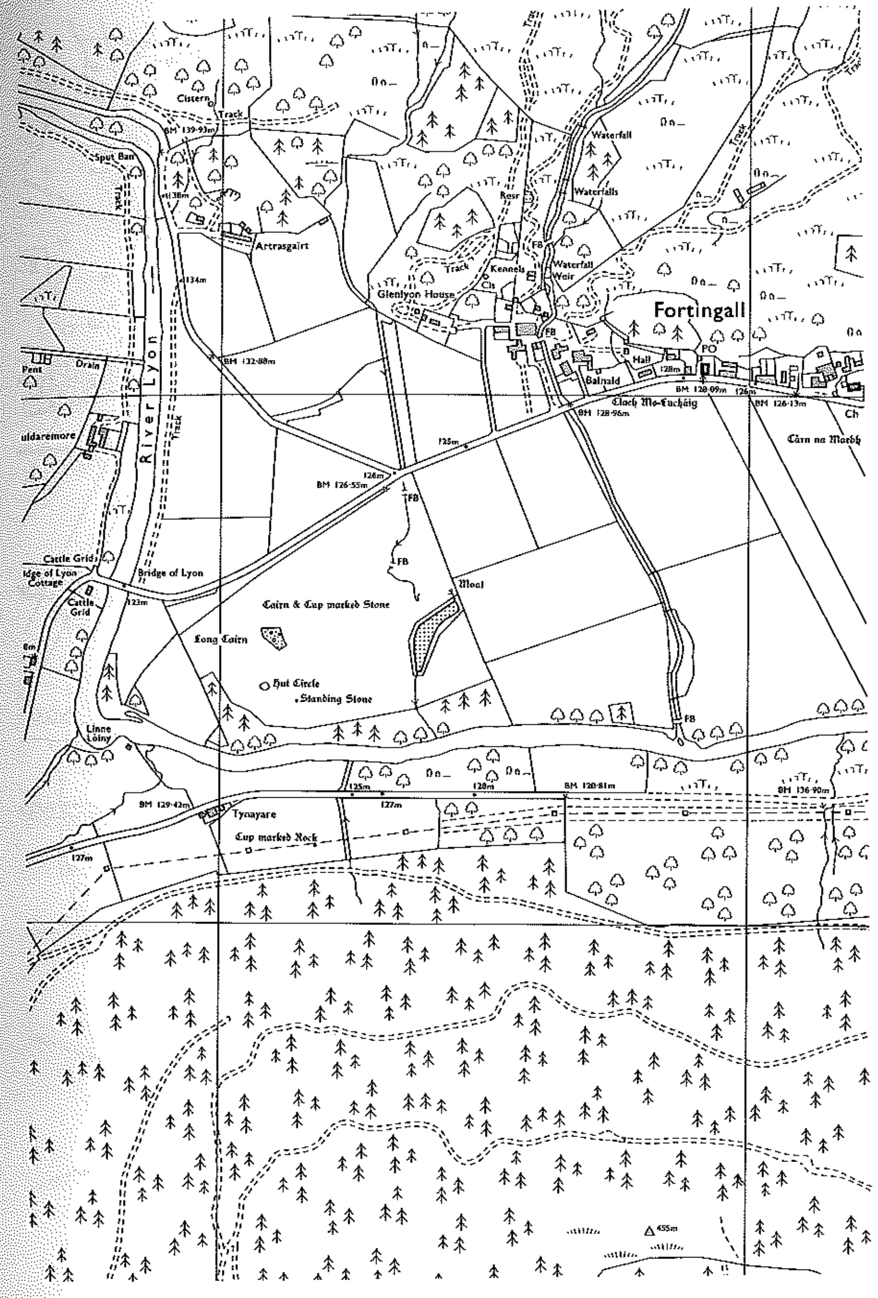
7.8.3 Text

All text produced by NGO is upper case and of the same size. NGO stated they could have produced varying text sizes by breaking it down into different logical blocks within the hierarchy. The text produced by SYSSCAN is as produced by NGO with the exception that it is of a less condensed style therefore requiring more room. SYSSCAN left off some text in areas of denser detail. Both participants were able to orientate text but positioned it with the text line's south west corner approximately coincident with that of the extract's and no regard to the additional text length involved. Hence the frequent overwriting of named features.

7.8.4 Symbols

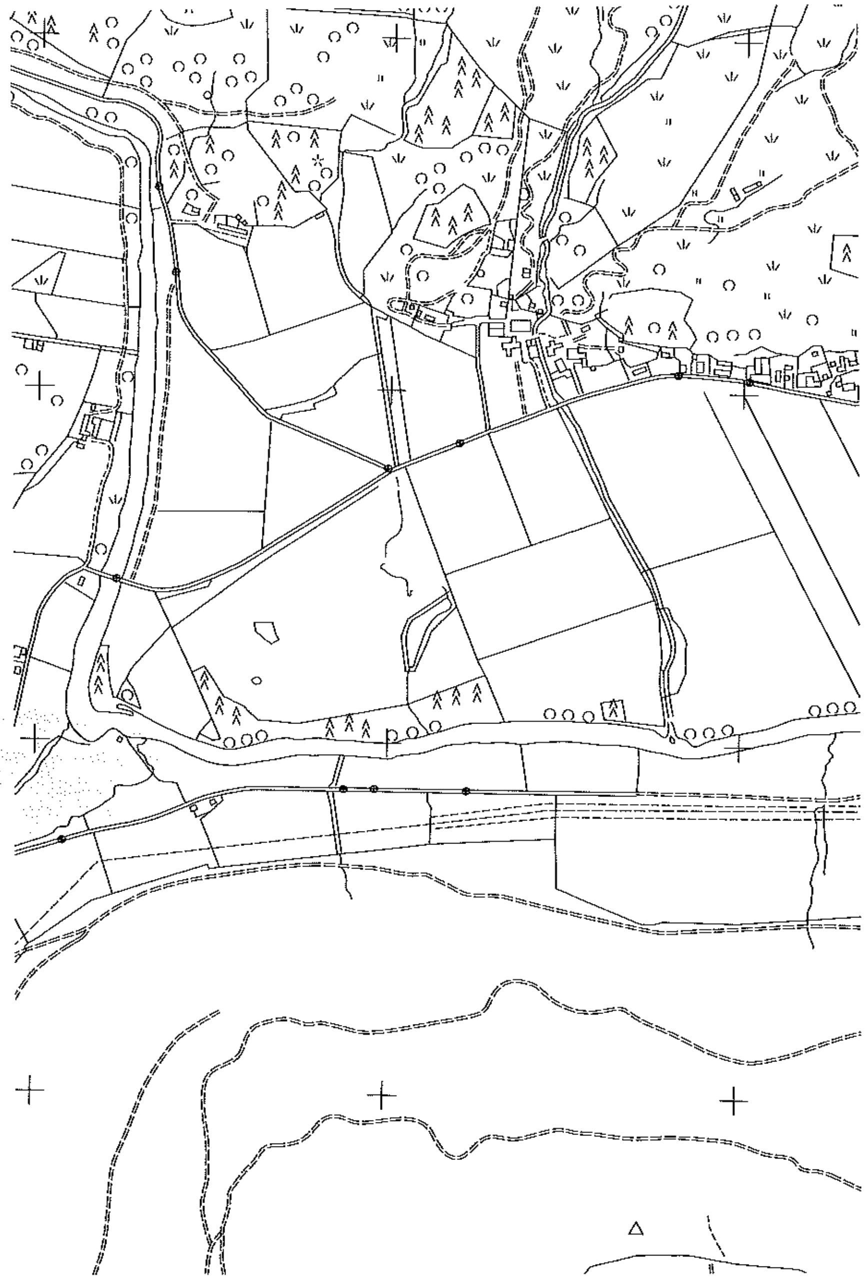
Although not mentioned in the reports, by inspection it appears neither participants were able to digitise vegetation in the southern sector by area. All symbols shown by NGO are of Norwegian origin. NGO were also unable to digitise each vegetation symbol as a point symbol as 3 to 7 symbols are allocated to one pointing in the plot library. Secondly, the interactive display has a different library to the plotting program, therefore the operator cannot see how the vegetation will appear on the final plot. Hence the great deal of overlapping and extending into unvegetated areas. Bench Marks (BM) and direction of flow arrows share a common symbol and each are orientated correctly. However, the positioning of the BMs are incorrect in that every symbol overshoots the correct planimetric position of the BM marked by the point of the arrow on the extract.

SYSSCAN produced vegetation symbols very similar to those on the extract but all were shifted to the north by some 2—3 mm and some large areas of vegetation were missing altogether. Of the other map symbols only some dot symbols have been reproduced, these by small squares. Most of the spot heights have been digitised but can be anything up to 1 mm out of position.



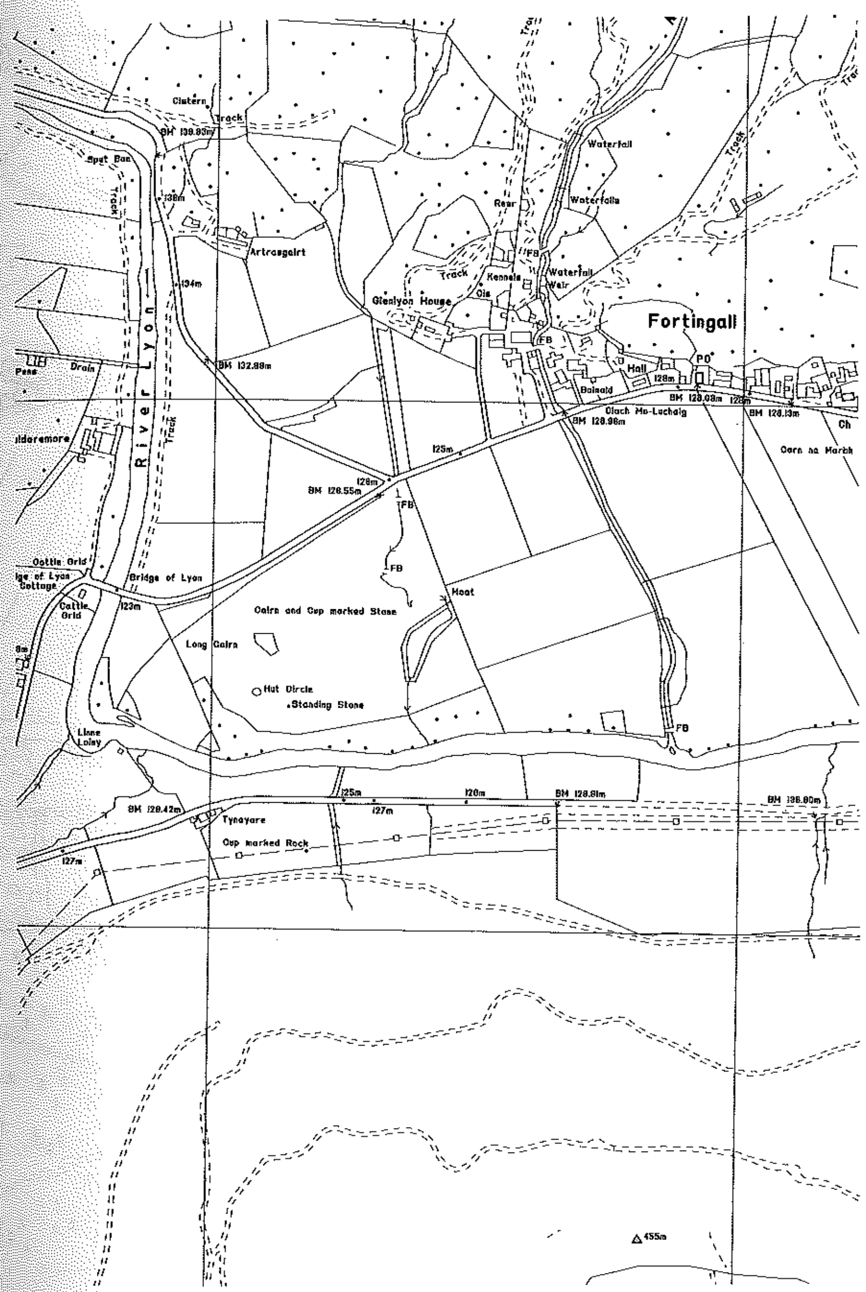
Reproduced at 1 : 17 100 scale

Figure 7.9 — 1 : 10 000 original (extract)



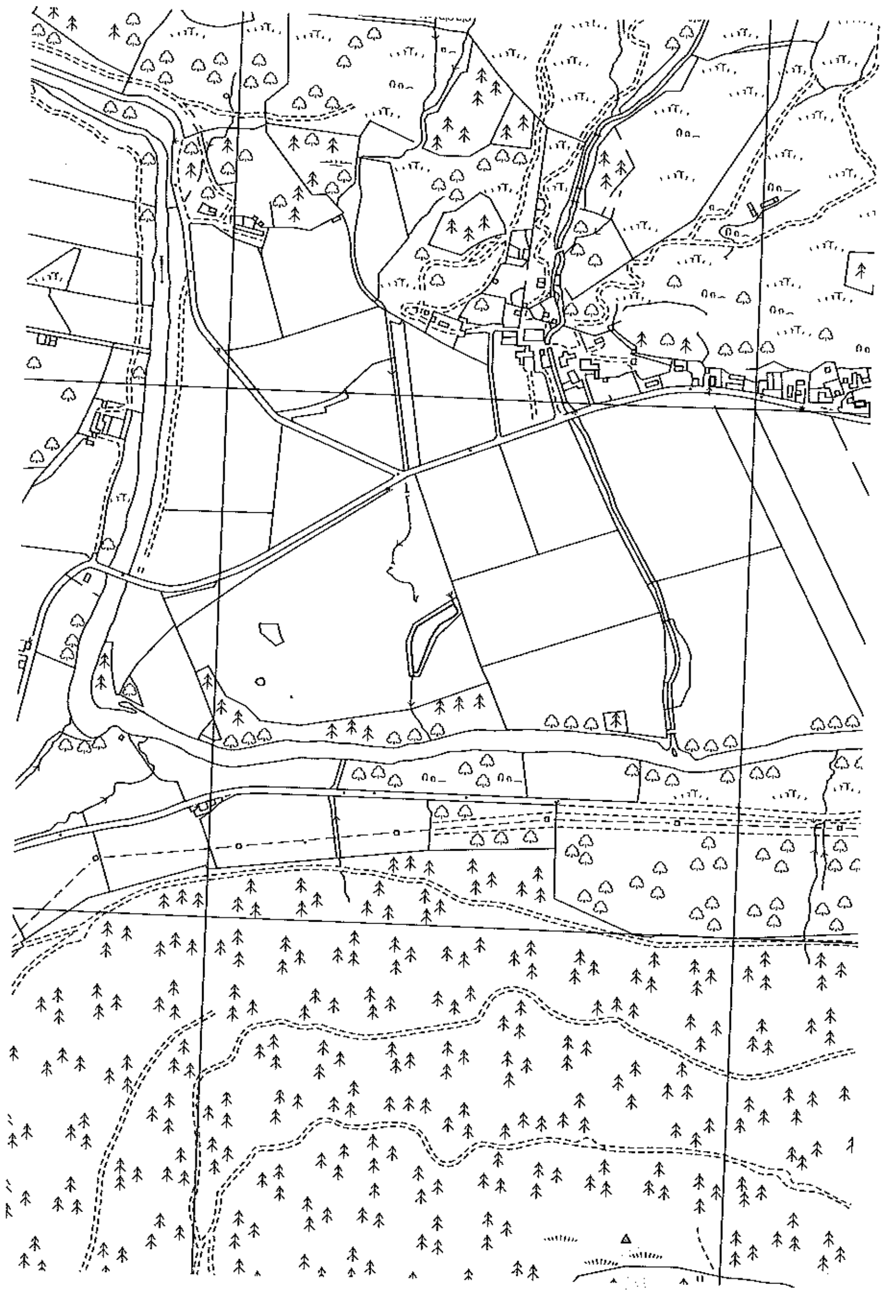
Reproduced at 1 : 17 100 scale

Figure 7.10 — 1 : 10 000 NBS blind digitising



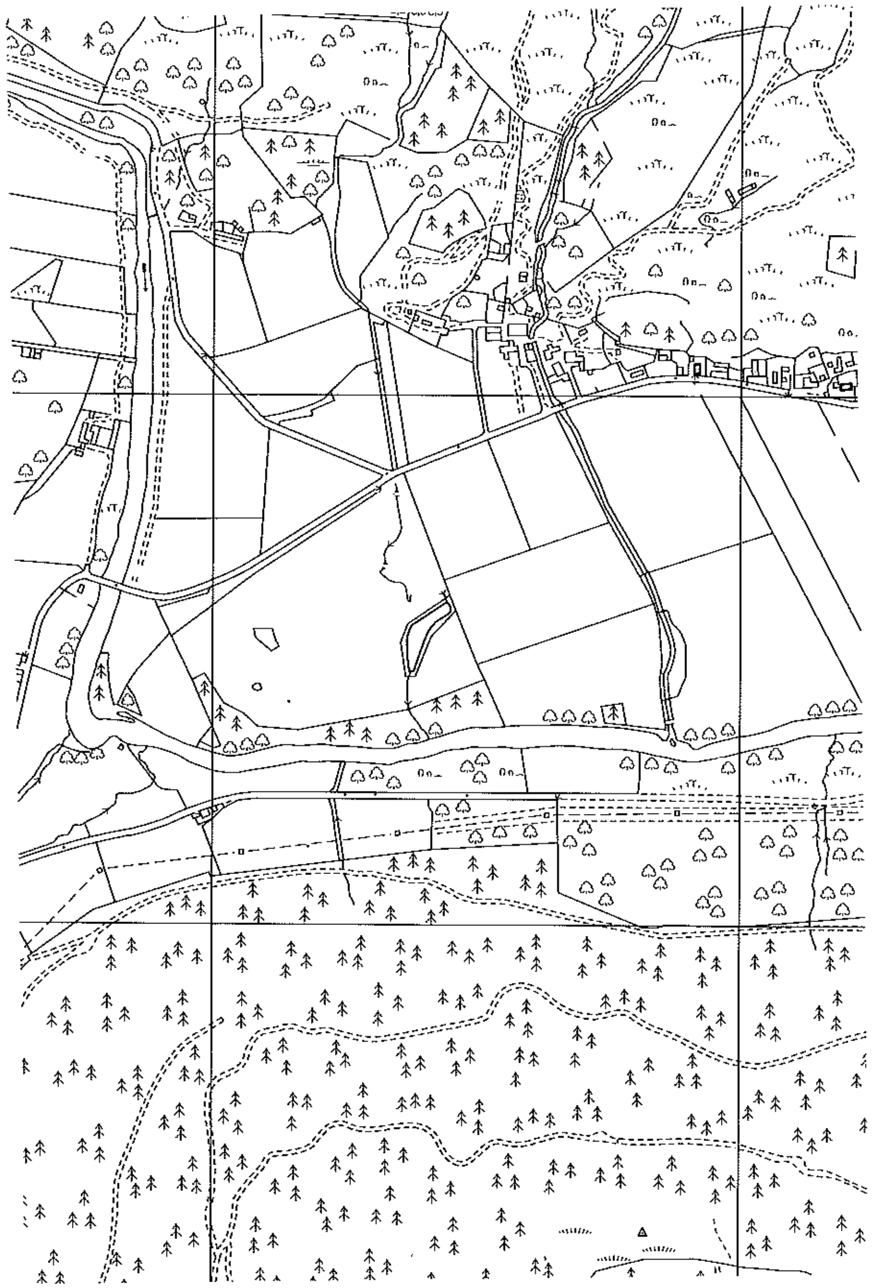
Reproduced at 1 : 17 100 scale

Figure 7.11 — 1 : 10 000 OS blind digitising



Reproduced at 1 : 17 100 scale

Figure 7.12 — 1 : 10 000 TDN blind digitising

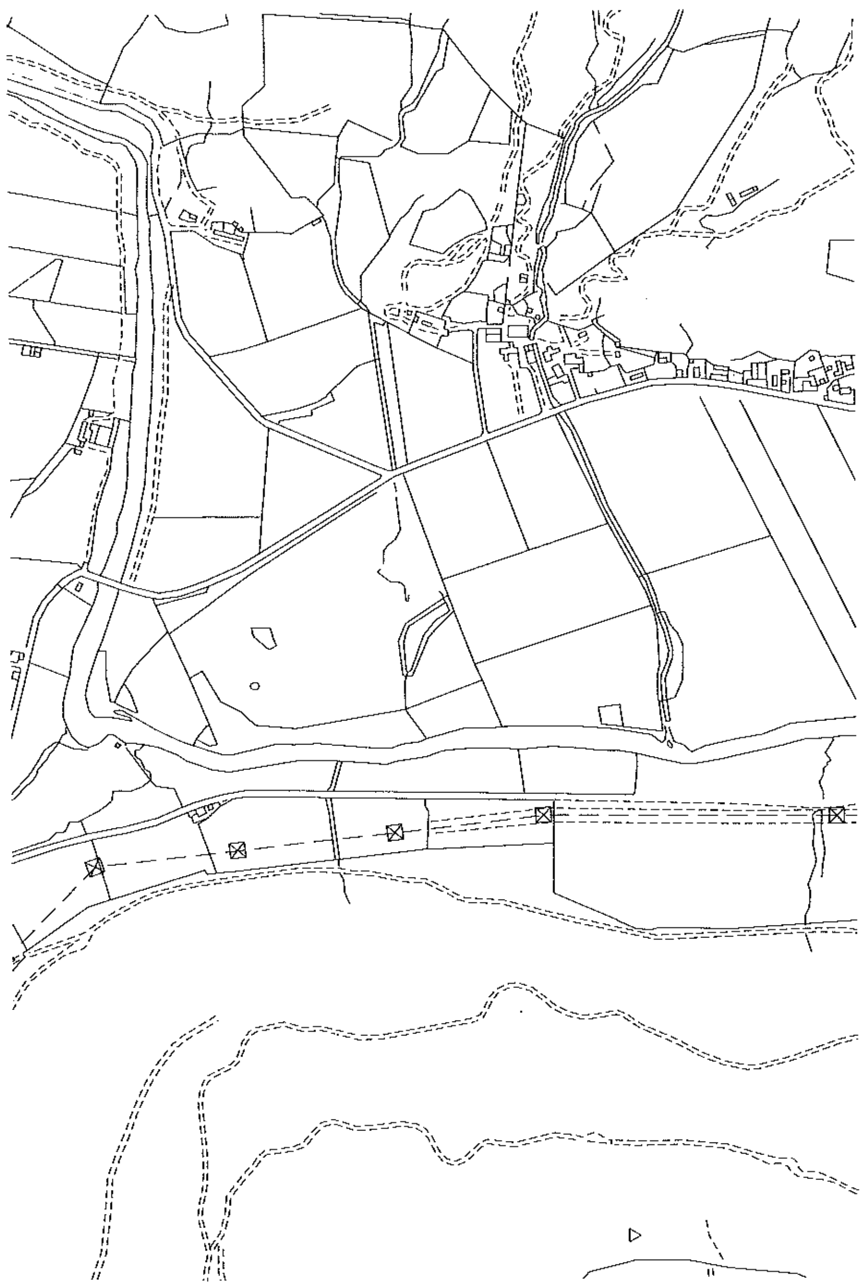


Reproduced at 1 : 17 100 scale

Figure 7.13 — 1 : 10 000 TDN interactive digitising

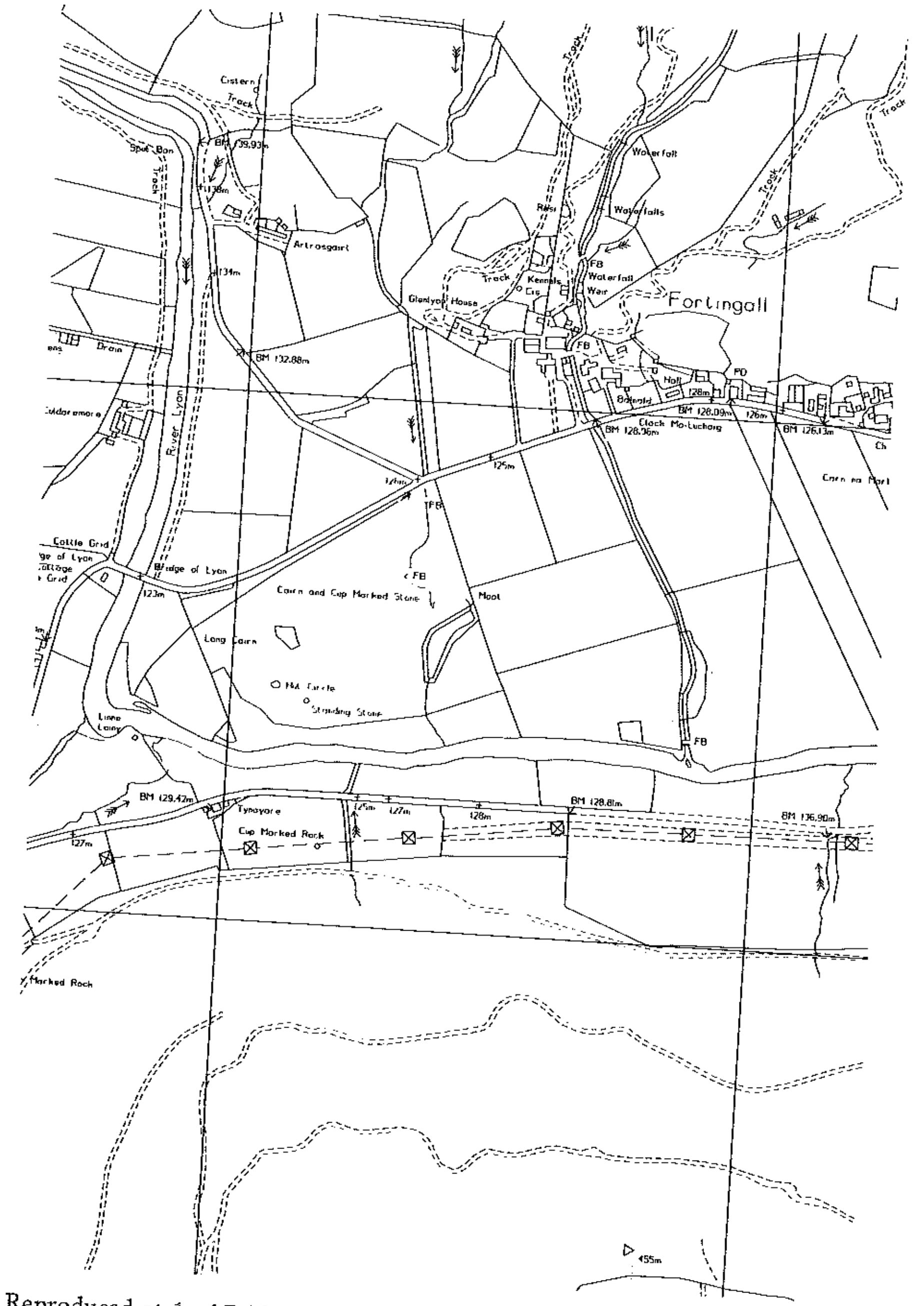
Reproduced at 1 : 17 100 scale

Figure 7.14 — 1 : 10 000 LASERSCAN automatic line following (unedited)



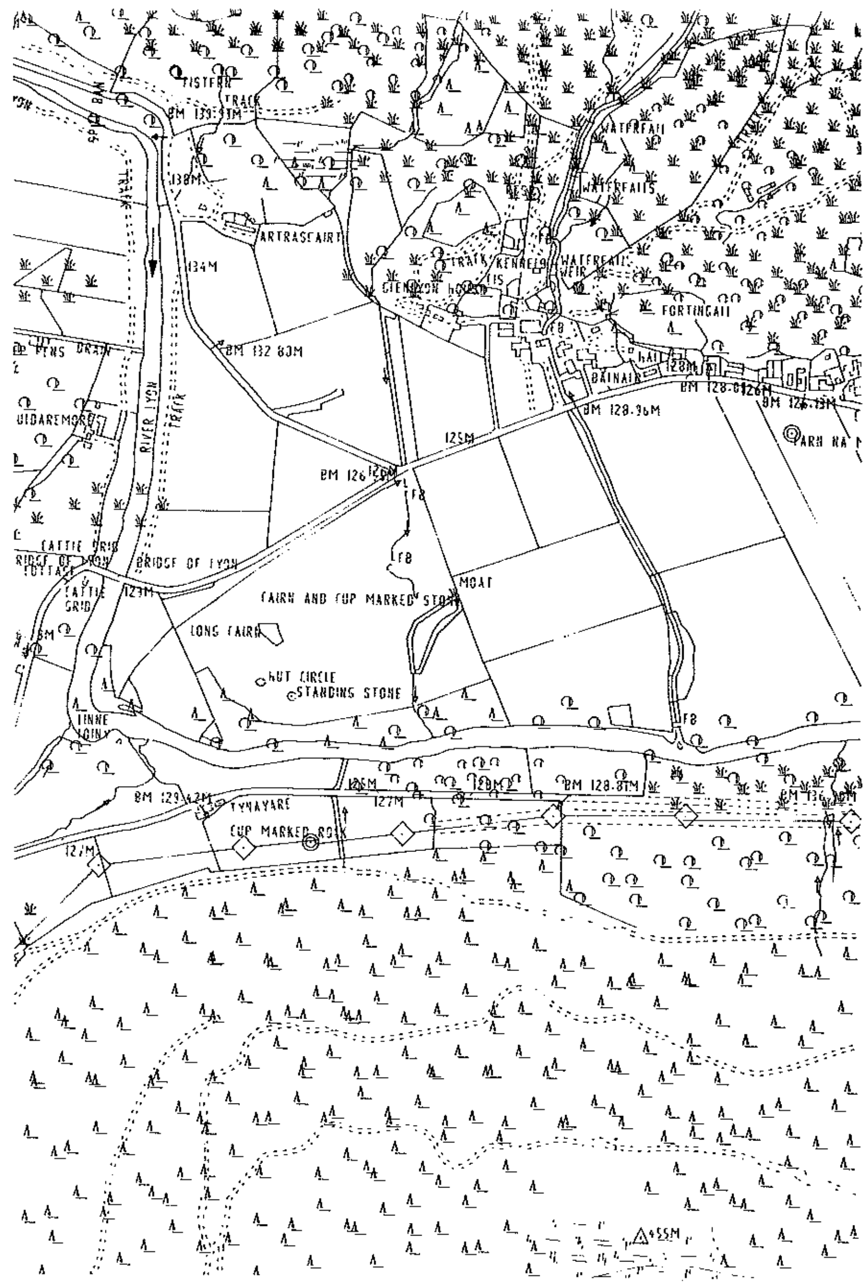
Reproduced at 1 : 17 100 scale

Figure 7.15 — 1 : 10 000 LASERSCAN automatic line following



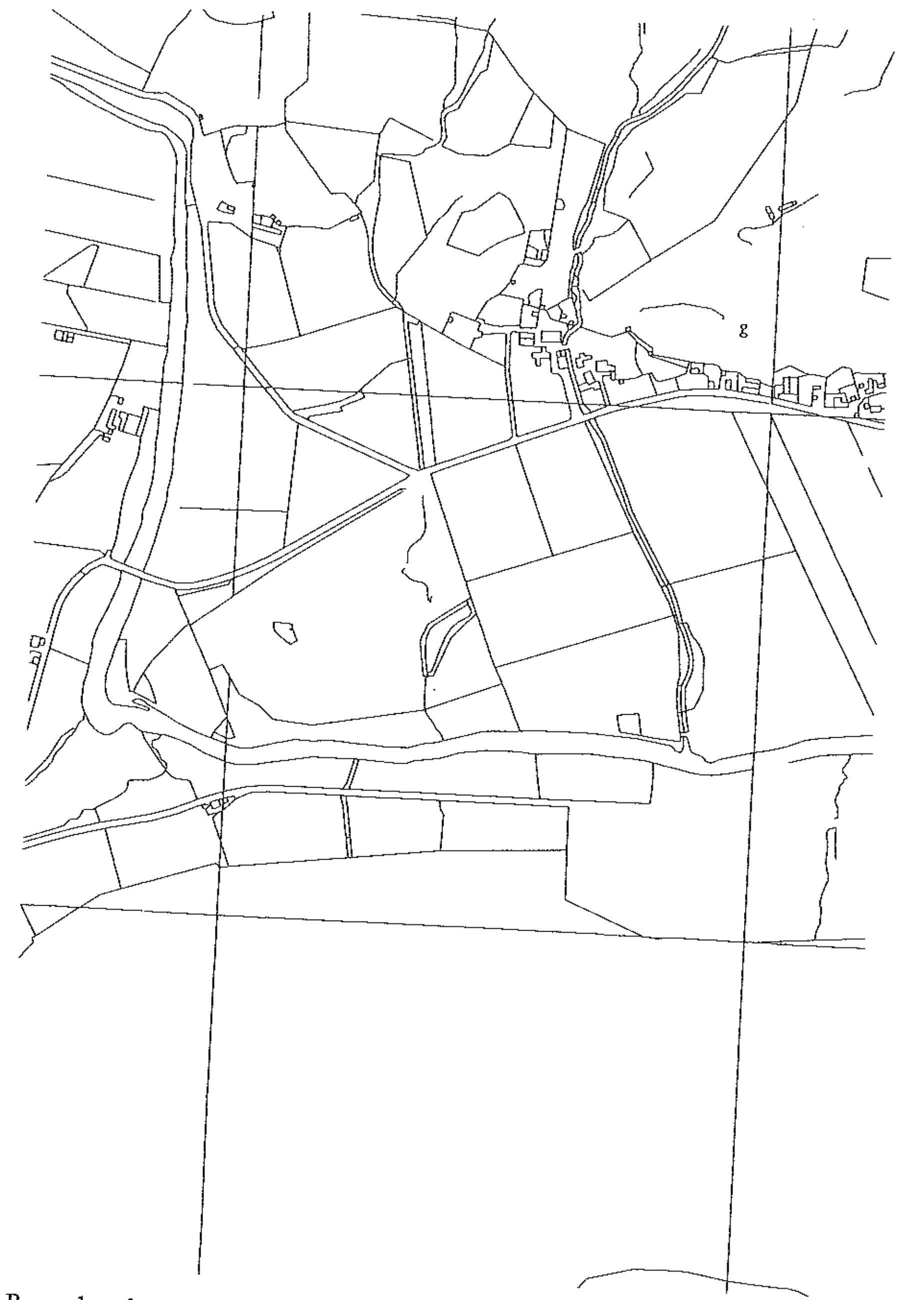
Reproduced at 1 : 17 100 scale

Figure 7.16 — 1 : 10 000 OS automatic line following



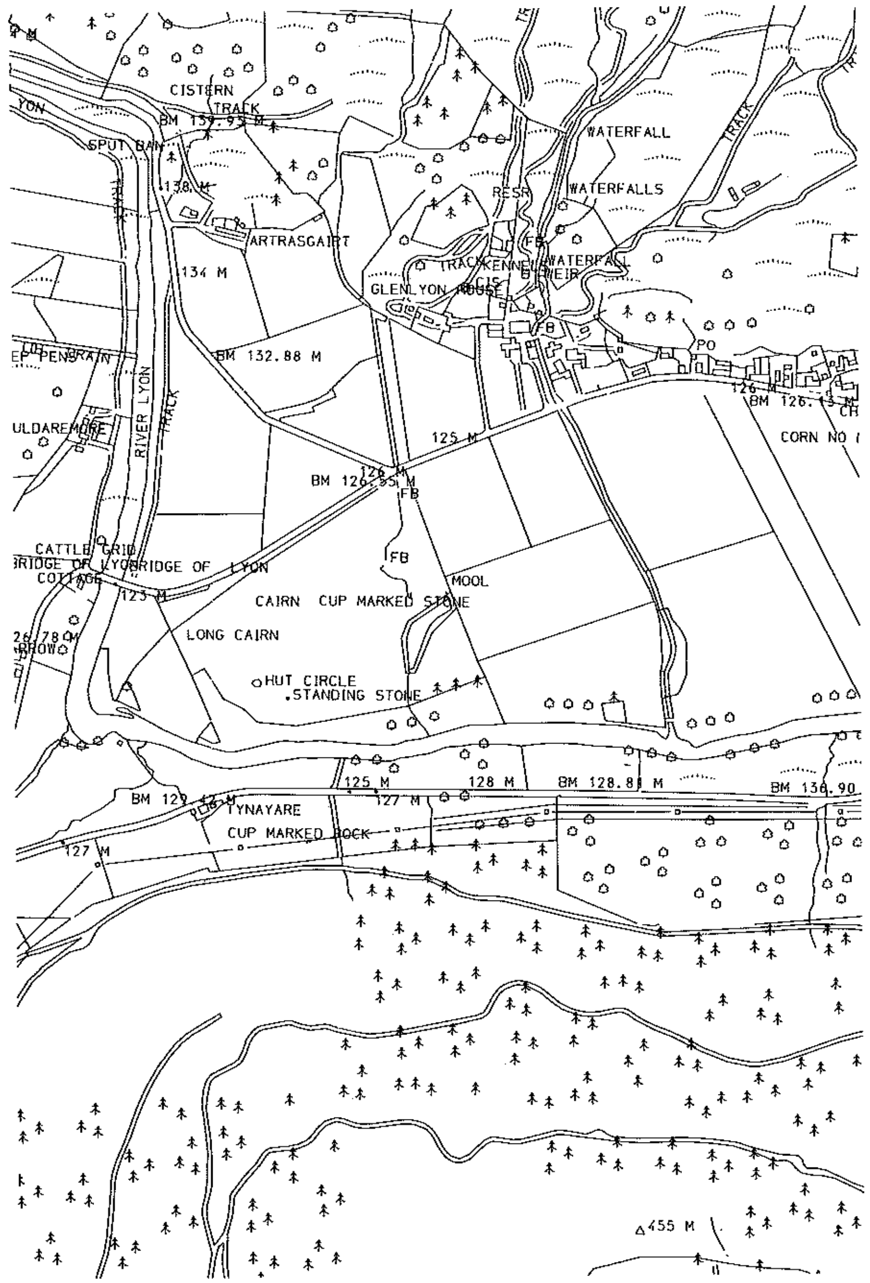
Reproduced at 1 : 17 100 scale

Figure 7.17 — 1 : 10 000 NGO scanning and vectorising



Reproduced at 1 : 17 100 scale

Figure 7.18 — 1 : 10 000 SCITEX scanning and vectorising



Reproduced at 1 : 17 100 scale

Figure 7.19 — 1 : 10 000 SYSSCAN scanning and vectorising

8 Discussion of Contour Results

8.1 Introduction

The contour graphics were checked by a visual overlay only, considering the following attributes:

- usual cartographic desire for smooth curvilinear contour lines, although it is recognised that not everybody may think this is important
- key. Bearing in mind tolerance is often 1/2 contour interval
- line quality
- accentuation of the × 50 m contours
- any other form of coding
- text
- spot heights.

8.2 Blind Digitising

NBS, using the s t r e a m m o d e, produced a contour graphic very pleasing to the eye. Unfortunately there appears to be a loss of origin over almost the whole sheet, but when fitted detail to detail, the key is mostly good. However, the speed of digitising has resulted in some generalisation, quite heavy in places. No text has been produced for reasons at 3.3.2 and gaps in linework for text have been joined by continuing the contour's general curve. Each contour has been labelled at digitising stage, but as the Finnish basic scale map has a contour interval of 5 m with accentuated contours every 20 m, every other contour has been accentuated on this 10 m contour interval graphic. The line quality produced is good and spot height symbols have been captured satisfactorily.

The OS first attempted this option in s t r e a m m o d e producing a graphic in which the contours meander around the key without drifting off by more than about 1/2 mm. The result is also somewhat angular where the operator, inexperienced in this mode, has "jerked" the cursor back on key. The contours have been correctly accentuated and the line quality is very good although produced at the width appearing on the extract. Spot heights and text have been produced well.

Because of the lack of experience of stream digitising at OS, the contour test was attempted using p o i n t m o d e . The overall result is quite pleasing but on closer inspection the curves are again disappointing due to too many points digitised and the overexposure effect mentioned at 7.1.2. Apart from this effect the line quality is good as is the production of spot heights and text. The contours are correctly accentuated although, as with the stream output, are drawn at the width appearing on the extract. Although off key frequently, the lines are always well within tolerance.

TDN, digitising in p o i n t m o d e, produced a graphic very near an exact copy of the original. The correct contours were accentuated whilst the curvilinearity and key were both very good. Spot height symbols were produced but no text for reasons stated at 3.3.2, the breaks in the contours for text being left. Line guages were as they appeared on the extract but the lines themselves were a little ragged at the edges.

8.3 Interactive Digitising

All that was said in the previous paragraph equally applies to TDN's attempt at interactively digitising the contours in p o i n t m o d e . The only difference is the occurrence of small angular jumps off key now and again spoiling the curvilinearity a little in the immediate area. However, still a very good graphic resulted.

8.4 Semi-Automatic Line Following

As with the 1 : 10 000 planimetry LASERSCAN produced their plot on the Fastrak's plotter with very much the same result. The line quality is very fuzzy on magnification, appearing never to come into focus, and the image varies from being very light to very dark. The key is very good but "curves" are very angular although improve on the tighter curves. No contours have been accentuated but spot height symbols have been produced. No text has been attempted and where the gaps have been joined the contour has merely been linked by one straight line.

The overall impression of the OS submission is one of acceptable curvilinearity, it is only on closer inspection that the straight line segments are clearly seen. The line quality produced by the Master Plotter is good as is the key but there are some small jags in the contour lines. The correct contours have been accentuated and text added but no spot height symbols have been produced.

8.5 Scanning and Vectorisation

IGMI produced a final graphic in which the curvilinearity is very good apart from very short sections of line "wobble" mainly in close proximity to a sharp curve. These however, are only just noticeable with the naked eye. The key is generally acceptable but the generalisation program employed has, in parts, smoothed out the line so much as to produce a different shape to the land form, even on the more steep slopes thus pulling the contour off key by more than 1/2 contour interval. The contours are correctly accentuated and the line quality is very good but no spot height symbols or text have been produced, even though the contours had been labelled at editing stage. Good cartographic practice has been shown by joining the gaps left for text by continuing the contour's general curve. Two paper biro plots of the data were also produced with, generally, even more generalisation taking place, although in some places shapes are closer to the original than the film plot.

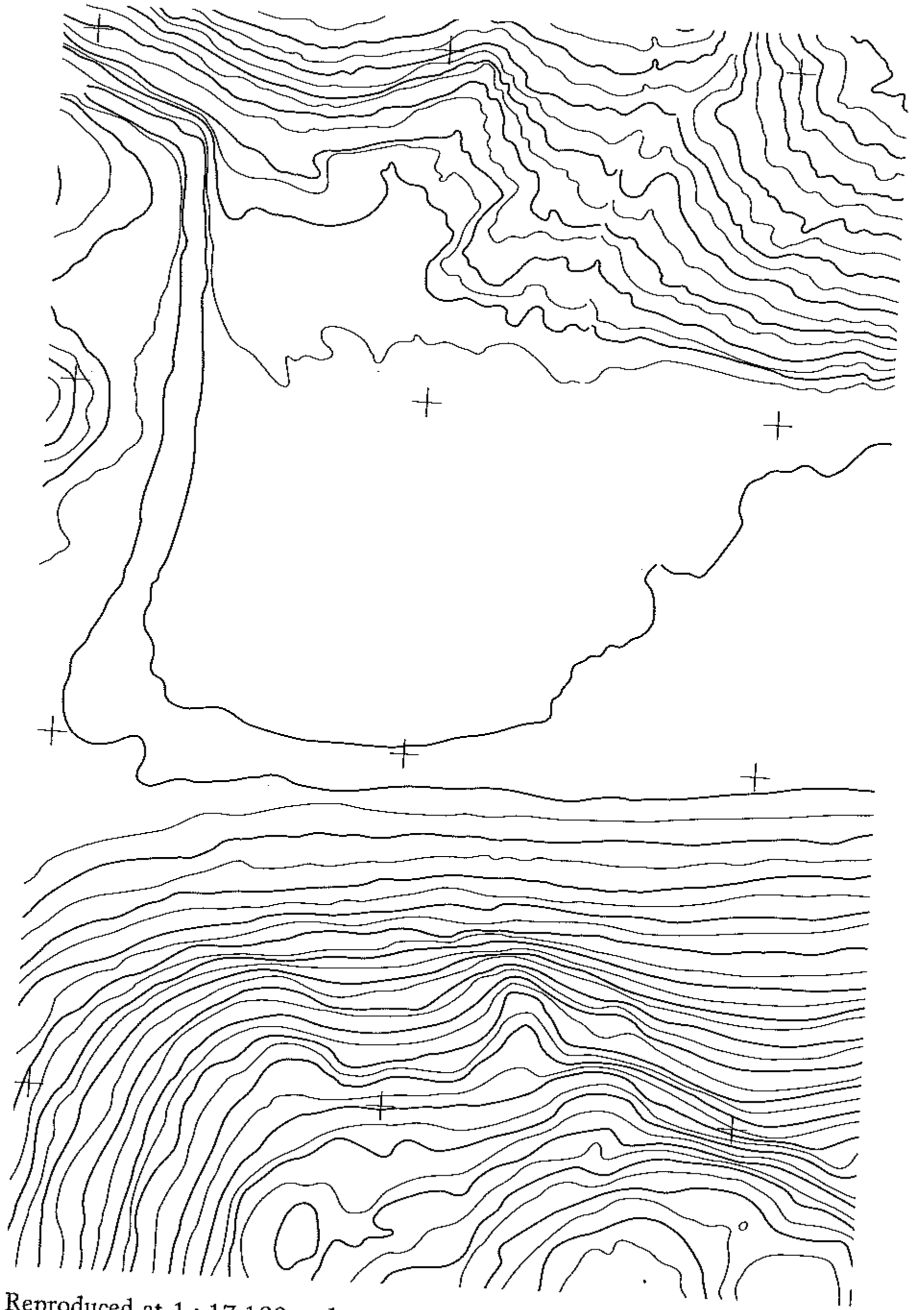
NGO produced a 2 colour ballpoint plot on film of their vectorised data and although the key is excellent the "curves" appear a little angular. Only the 100 m contours have been accentuated, by plotting in a different colour. No text has been produced and the gaps have been joined interactively, but no account has been taken of the curve, merely linked by a straight line. No spot height symbols have been produced due to the ABS program used for vectorising reducing dots to single points which are lost on later conversion.

SCITEX plotted their data using a raster plotter resulting in the segmented contours observed on close inspection. The key is very good but there is a shortfall of contours along the west and east edges and some short lines have been missed altogether, presumably for the same reason given for planimetry — that a fairly large segment was specified during noise removal. No contours have been accentuated and no spot height symbols or text produced. Gaps for both double water and text have been joined by straight lines.

As with the 1 : 10 000 planimetry the SYSSCAN graphic arrived badly creased due to poor packaging, a contact positive was made to try to rectify the situation to some degree. The key is very good but the linework is very angular appearing too clearly as a series of straight lines, and the line quality produced is poor. No contours have been accentuated and no text or spot height symbols produced. Gaps in the contours have been joined simply by linking the two ends by a straight line.

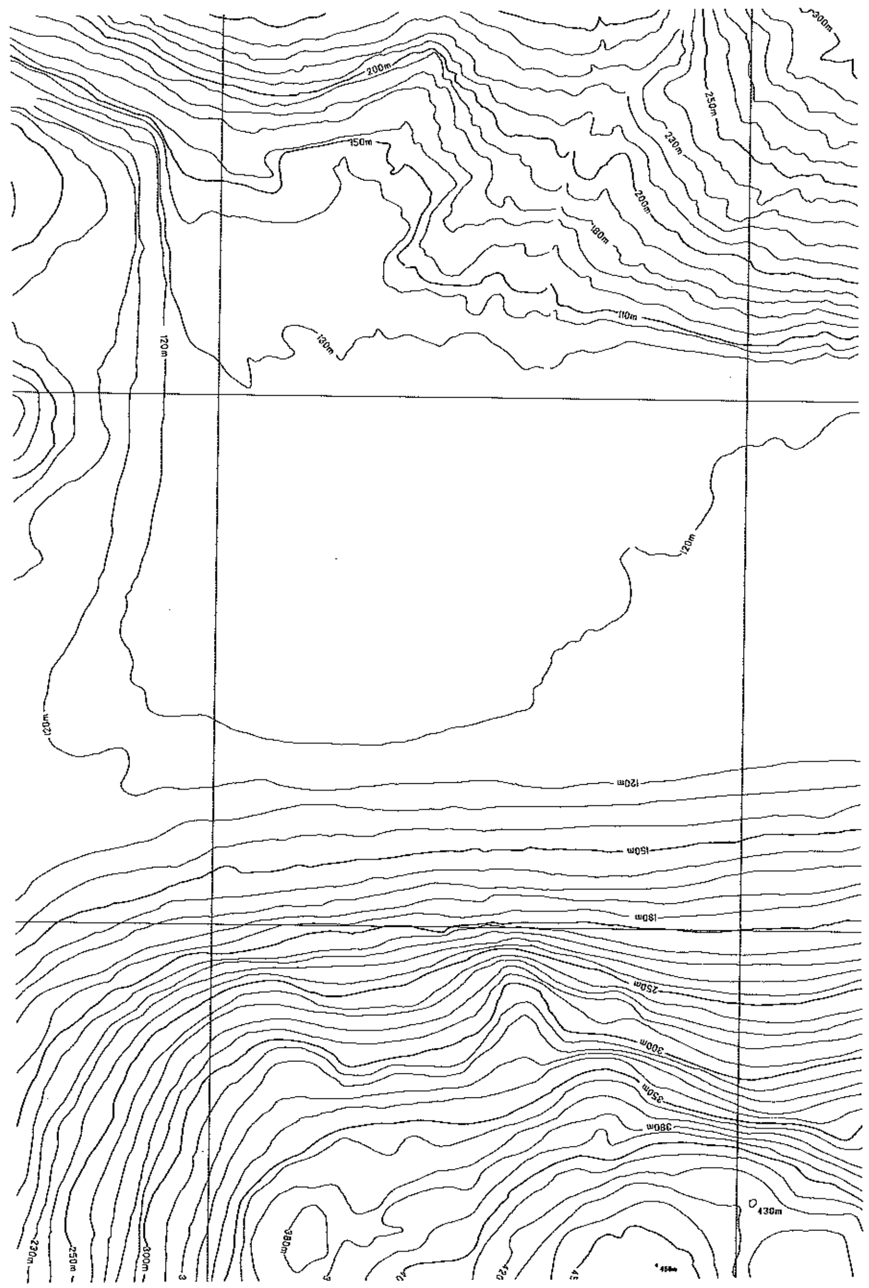
Reproduced at 1 : 17 100 scale

Figure 8.1 — 1 : 10 000 contour original (extract)



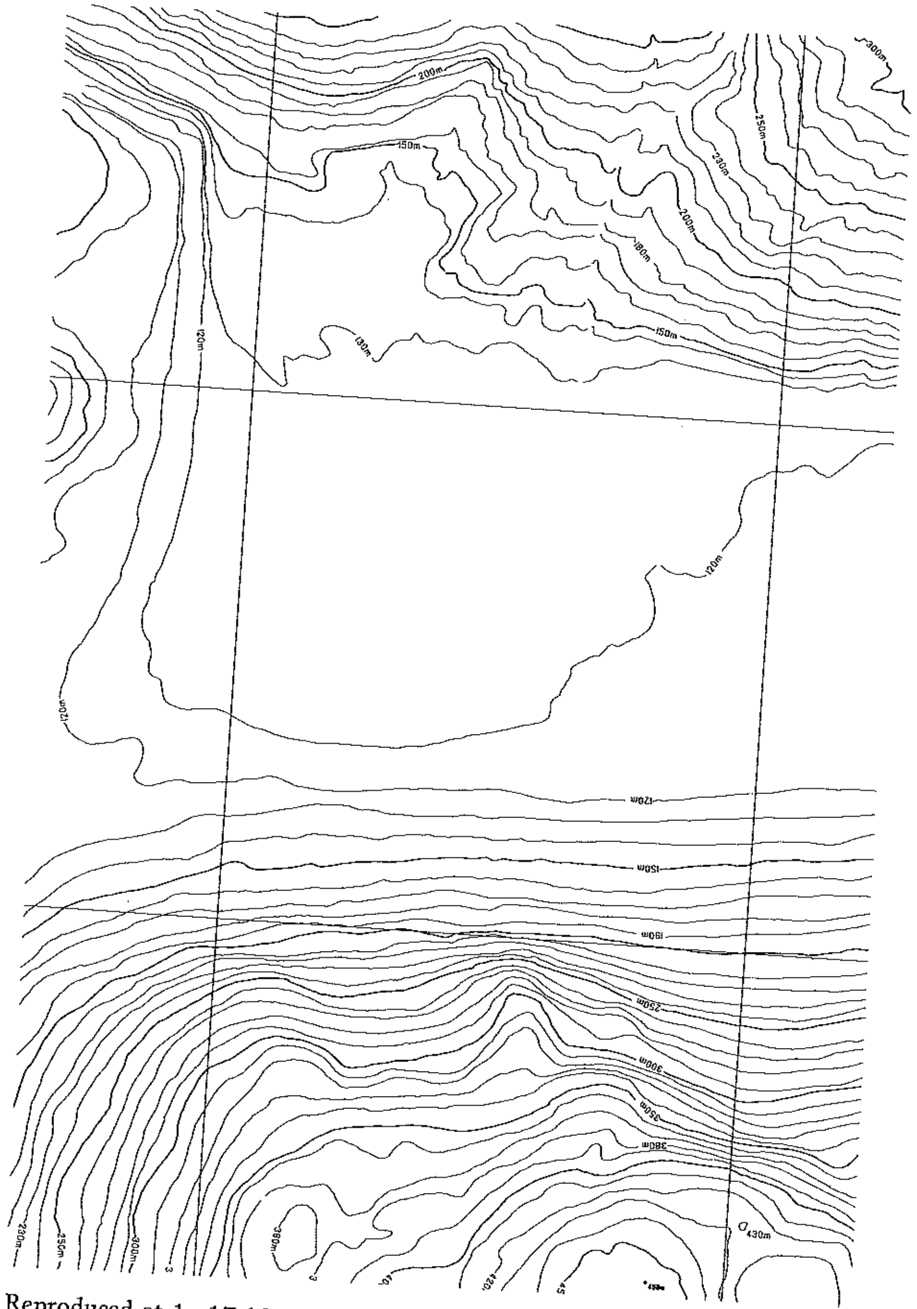
Reproduced at 1 : 17 100 scale

Figure 8.2 — Contours NBS blind digitising



Reproduced at 1 : 17 100 scale

Figure 8.3 — Contours OS blind digitising (point mode)

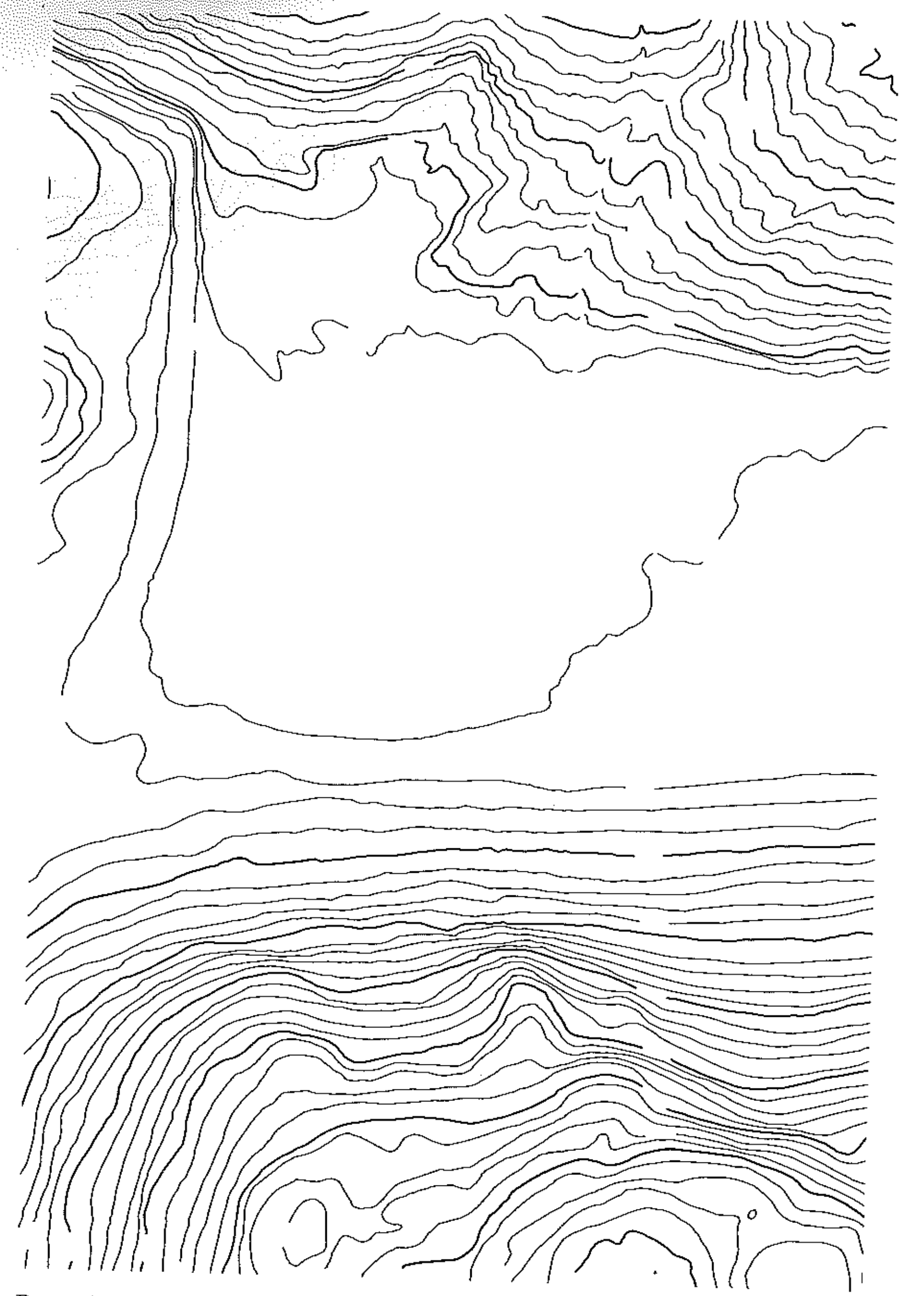


Reproduced at 1 : 17 100 scale

Figure 8.4 — Contours OS blind digitising (stream mode)

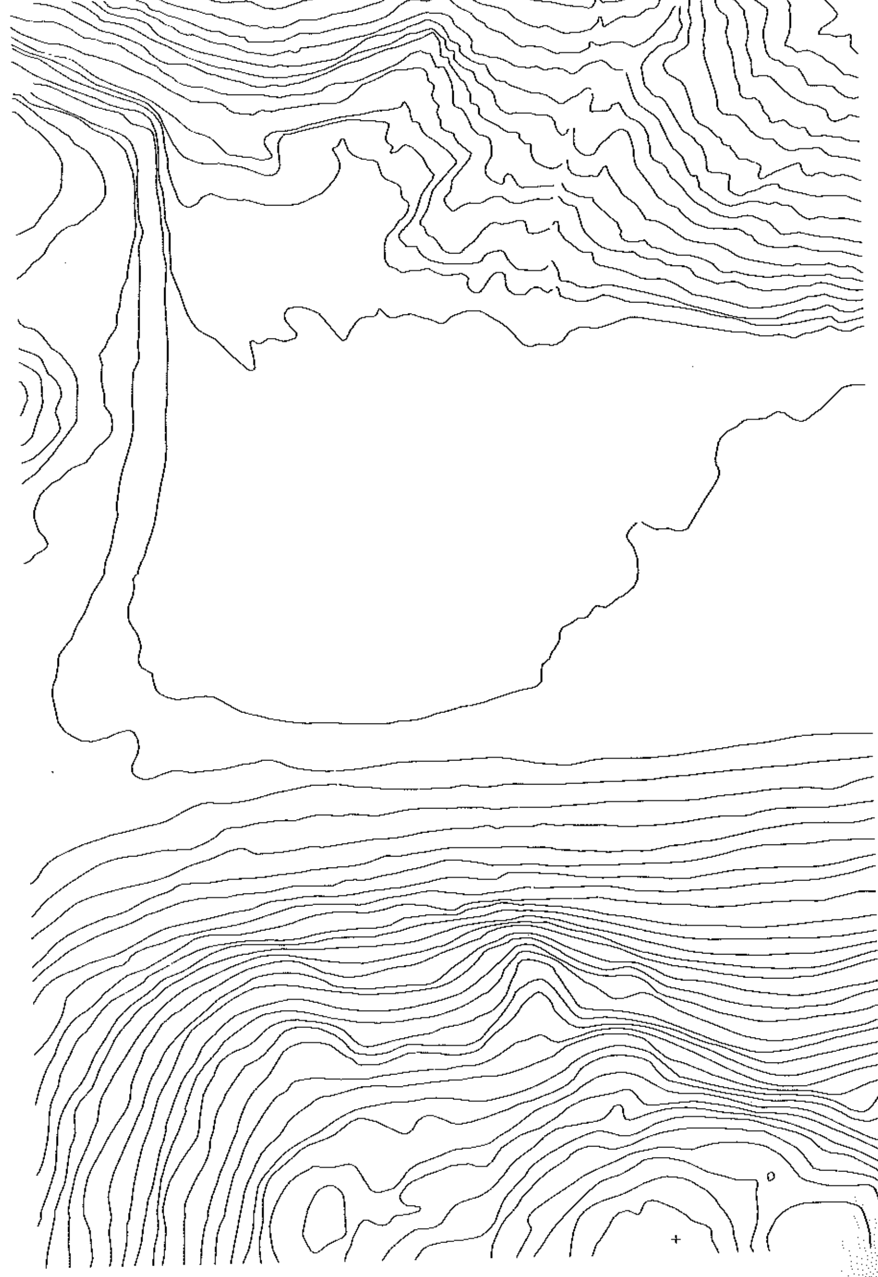
Reproduced at 1 : 17 100 scale

Figure 8.5 — Contours TDN blind digitising



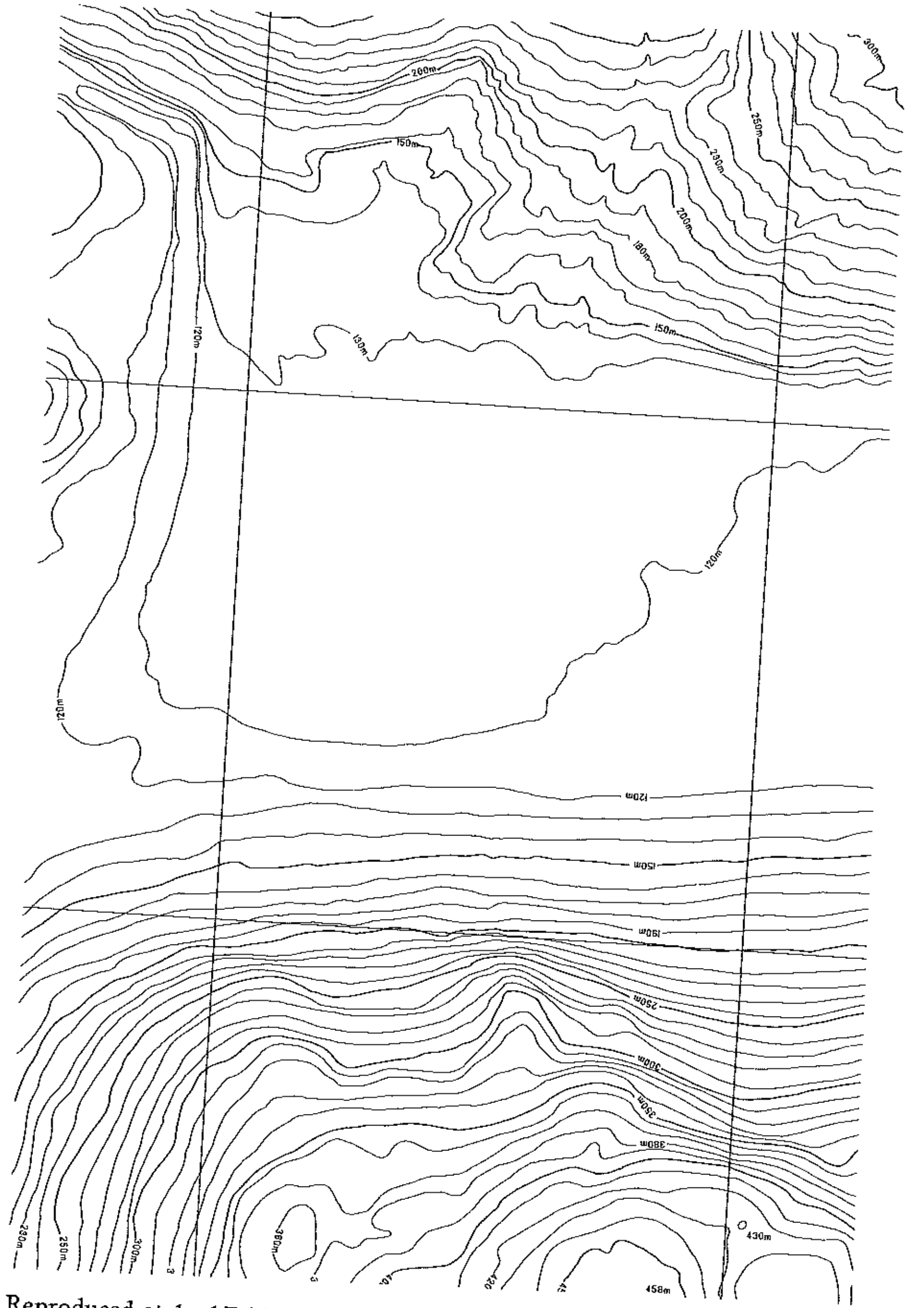
Reproduced at 1 : 17 100 scale

Figure 8.6 — Contours TDN interactive digitising



Reproduced at 1 : 17 100 scale

Figure 8.7 — Contours LASERSCAN automatic line following

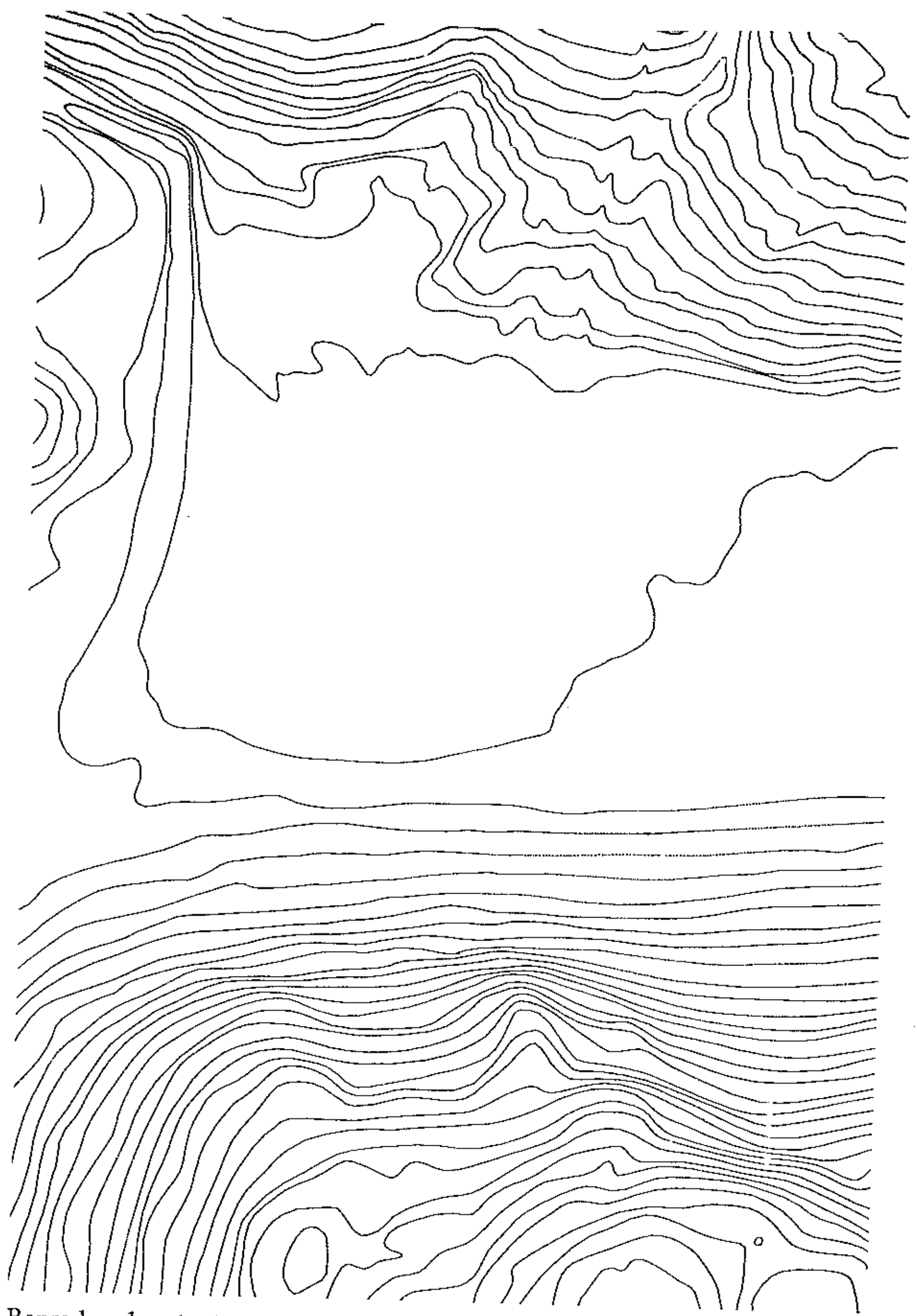


Reproduced at 1 : 17 100 scale

Figure 8.8 — Contours OS automatic line following

Reproduced at 1 : 17 100 scale

Figure 8.9 — Contours IGMI scanning and vectorising

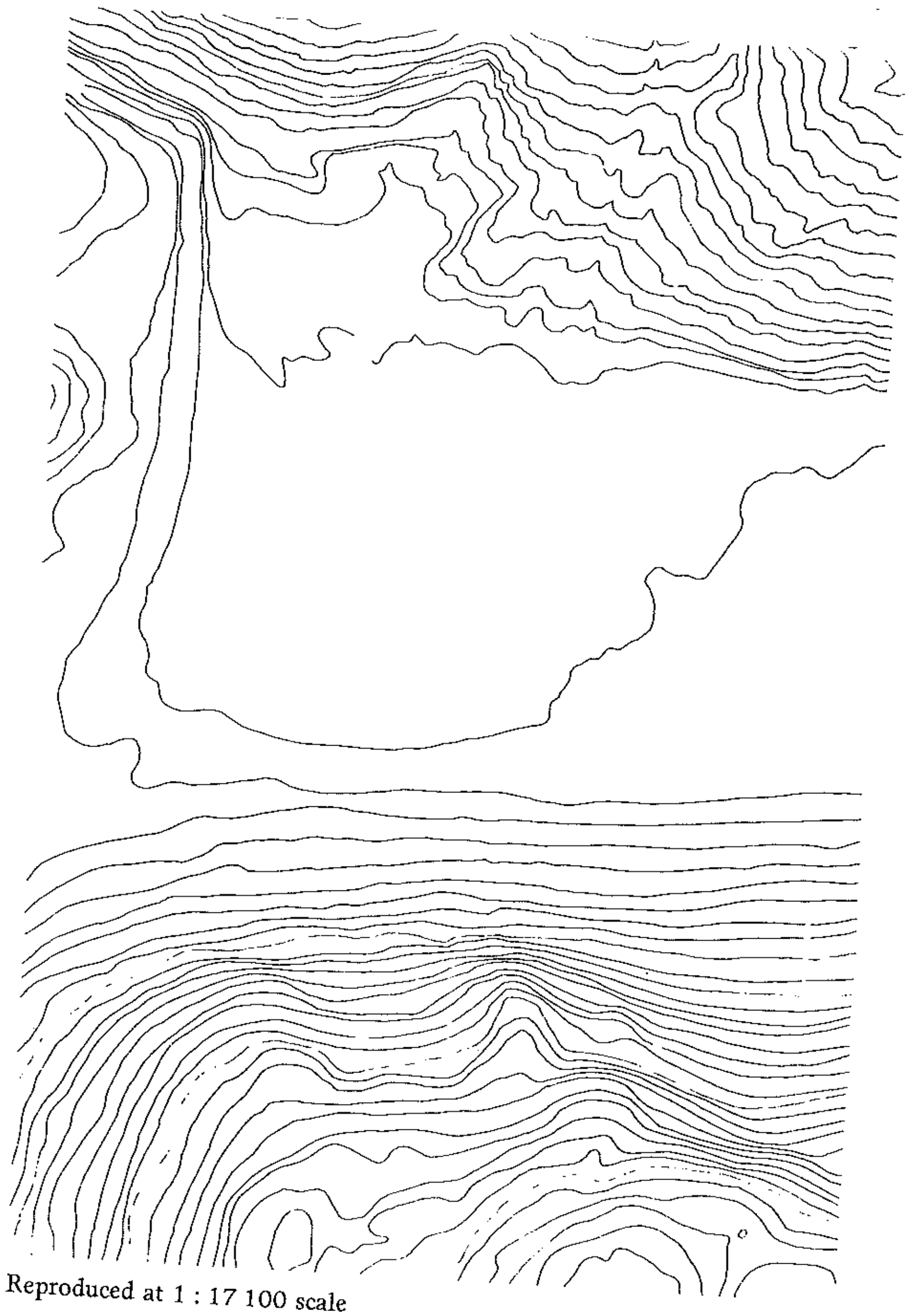


Reproduced at 1 : 17 100 scale

Figure 8.10 — Contours IGMI scanning and vectorising (ballpoint paper plot 1)

Reproduced at 1 : 17 100 scale

Figure 8.11 — Contours IGMI scanning and vectorising (ballpoint paper plot 2)

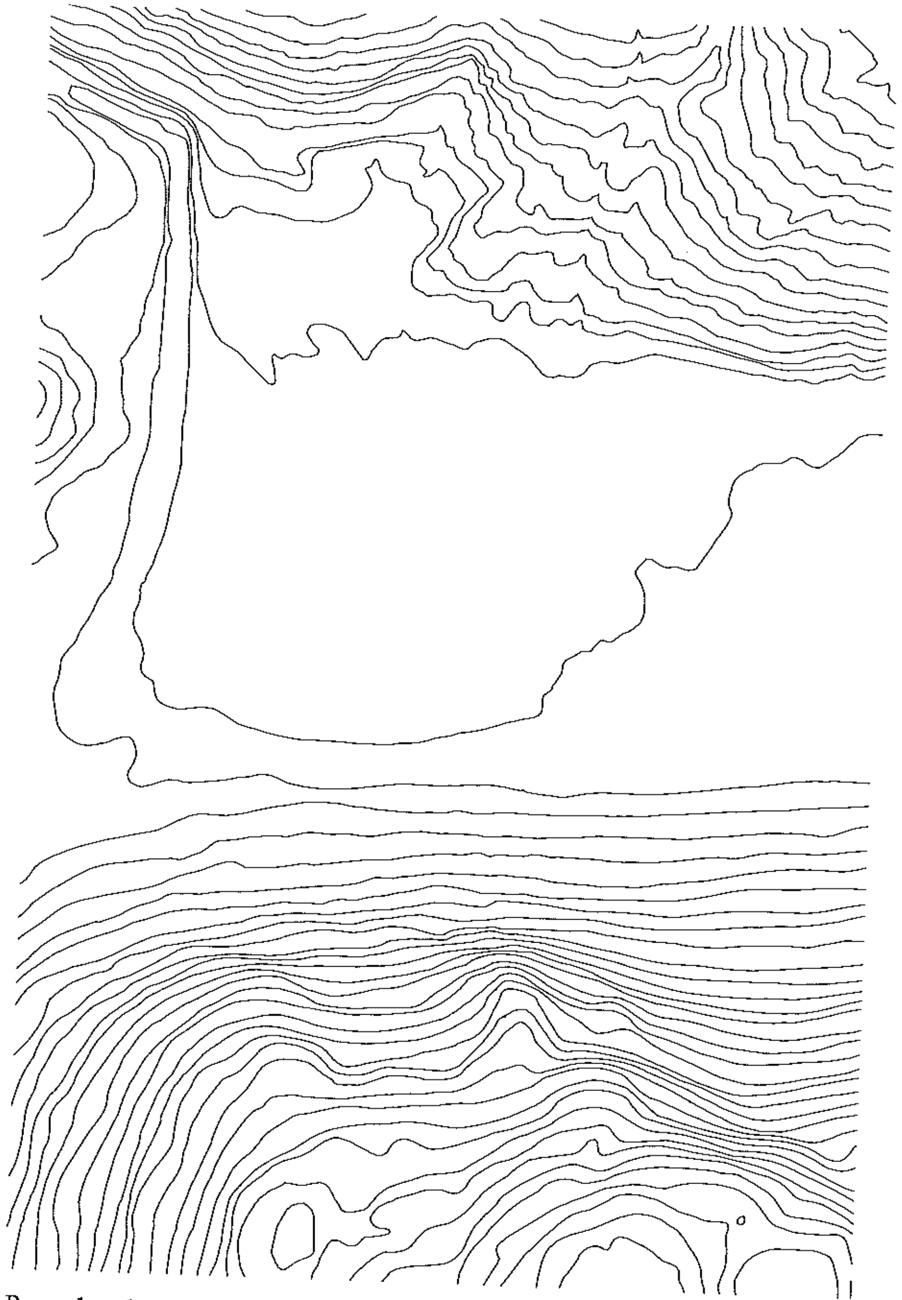


Reproduced at 1 : 17 100 scale

Figure 8.12 — Contours NGO scanning and vectorising

Reproduced at 1 : 17 100 scale

Figure 8.13 — Contours SCITEX scanning and vectorising



Reproduced at 1 : 17 100 scale

Figure 8.14 — Contours SYSSCAN scanning and vectorising

9 Conclusions

9.1 General

9.1.1 This project provides a valuable "snapshot" of the cartographic digitising technology which was available in 1982. It is clear that manual digitising was well established and proven whilst automated systems were new and suffered some limitations which reflected the state of the art at the time of the trial. Many have since been improved.

9.1.2 Even though the majority of participants were unfamiliar with the specification and content of the map extracts used, the trial has confirmed that the equipment and software used by all participants is capable of capturing map information in digital form and of subsequently plotting an acceptable cartographic output. Some additional development would, in many cases, have been needed to exactly replicate the symbols and text used by Ordnance Survey. In most cases this could be achieved relatively easily, but at additional cost and time to this project.

9.1.3 A comparison of the times taken by participants to carry out individual operations provides some indication of the relative merits of the equipment and methods used, but the experience of staff and organisations with equipment and digitising methods varied greatly and is also reflected in the results.

9.1.4 There is a significant difference in the proportion of time spent on preparation/digitising and processing/edit between the different types of digitising. In general, for manual digitising preparation/digitising time is highest with processing/edit times reflecting the system and method used. For scanning systems the processing/edit time constitutes the major proportion of time compared with a short digitising time; semi-automatic line following requires relatively long digitising time but short processing edit time. Plotting times very much reflect the type and vintage of plotter used.

9.2 Accuracy

9.2.1 Table 6.4.1 shows that there was a remarkable level of consistency in the accuracy achieved by all participants throughout the trial. The range of standard error (σ) for vectors from a sample of thirty points of detail for all participants was between 0.06 mm to 0.13 mm at map scale. The range of maximum vector errors was between 0.12 mm and 0.35 mm compared to the original map extract. Since the average line width was 0.2 mm, and the resolution of digitising equipment was typically 0.025 mm or 0.05 mm, an acceptable standard of accuracy was achieved in all cases in the production of cartographic plots.

9.2.2 Accuracy checks by overlay and visual inspection for fit indicated that manual methods of digitising are more susceptible to loss of key and loss of origin than automatic methods. In all cases LASERSCAN, SCITEX and SYSSCAN semi-automatic and automatic digitising achieved visually accurate results (7.5, 7.6.1 and 8.5) though the resolution of the scan is critical if degradation is to be avoided. Using manual methods there were a number of examples of loss of key and origin (7.3 and 7.4).

9.2.3 A variety of set up procedures and transformation algorithms were used by participants for manual and semi-automatic digitising. The majority (CLYDE, NLS, NBS and TDN) used a four point set up to sheet corners with some form of affine transformation. OS used nine and sixteen point set ups to grid intersections and a grid square by grid square transformation. LASERSCAN used a four point set up to sheet corners but have the facility to include internal grid intersections if required. The results in Table 6.4.1 and the visual accuracy tests indicate that the set up procedure used had little apparent effect on the accuracy achieved.

9.2.4 Table 3.2 shows that OS was the only participant to use a negative as a base document for manual digitising. All others used a positive. OS used a "Bulls eye" type cursor which has proved preferable to a cross hair cursor when working with a negative.

The cross hair cursor is in general preferable when digitising from a positive base but participants using a positive base did not record which type of cursor they used and hence guidance is not available from this trial.

All participants with the exception of NELP, used a digitising table with backlighting. NELP stated that they would also have preferred to use backlighting, but had only just received their first set of cartographic digitising equipment.

Three of the eight participants who manually digitised planimetric detail used an enlarged base document. The remaining five digitised at scale. Enlargement factors of between 5 : 3 and 2 : 1 were used by CLYDE, NBS and OS.

From this limited trial there is no evidence to indicate that for manual digitising the use of an enlarged base document has any significant effect on the accuracy of the plots produced, or that the use of a positive or negative digitising document has particular advantage in ease of digitising.

9.2.5 The LASERSCAN Fastrak semi-automatic system used by LASERSCAN and OS uses a 105 mm negative as a base for digitising. The SCITEX and Kartoscan scanning systems used by SCITEX, IGMI, NGO and SYSSCAN all scanned the original positive document provided. IGMI used incident light with a mirror like plastic plate behind the document, as in the usual work procedures. NGO and SYSSCAN used transmitted light as recommended by the manufacturers. The scanning systems achieved a marginally better overall accuracy than the semi-automatic method but as already stated the scan resolution in both cases is a critical factor and there is a trade off between speed of scanning and quality.

9.2.6 The results from Phase One have shown that in all cases participants achieved an accuracy of coding sufficient to produce a satisfactory cartographic product. The analysis of data proposed in Phase Two will provide an evaluation of the accuracy of coding for database purposes.

9.3 *Cartographic Quality*

9.3.1 Most participants produced an acceptable plot, though not all could show symbols, due to a lack of familiarity with the specification.

9.3.2 The squaring and alignment of buildings caused some difficulties for participants using manual digitising methods, particularly at 1 : 2500 scale. In general, isolated buildings were squared well but densely packed terraces with a number of small projections caused problems (Ref. 7.3.2 and 7.4.2). The results at 1 : 10 000 were in general more acceptable.

The final product from the semi-automatic system used by LASERSCAN and OS showed that buildings were in general squared well. However, in the case of OS this was achieved only as a result of considerable interactive editing (Ref. 7.5.2).

The output from scanning systems used by NGO and SYSSCAN showed that buildings had been squared well at the edit stage (Ref. 7.6). SCITEX did not carry out any interactive editing and this is reflected in the quality of the plot. This clearly illustrates the amount of interactive editing required to produce an acceptable cartographic product from raster digitising systems.

9.3.3 In general all participants achieved a satisfactory result with curvilinear detail. There was a reluctance to use curve fitting algorithms for manual digitising, with draughtsmen preferring to select sufficient points to define a smooth curve in straight line mode. Inexperience often resulted in angular looking curves because too many or too few points were selected. This problem was sometimes exacerbated by plotter acceleration and deceleration at digitised points which tended to highlight changes of direction (Ref. para 7.3.2).

9.3.4 For manual digitising of contours two participants used point mode and two stream mode. The trials confirmed that satisfactory results could be achieved with either method but that considerable experience is required to maintain key in the stream mode. NBS were the only participant to use a groove following technique for stream digitising. This technique required a significantly shorter digitising time and one comparable with semi-automatic line following and scanning digitising and appears to offer considerable potential for digitising contours. (See para 9.4.4).

9.3.5 Those participants who showed text and symbols had no problems with either orientation or positioning. Interactive systems obviously offered more flexibility than blind systems.

9.4 *Production Times*

9.4.1 Tables 6.1 and 6.2 summarise the times taken by participants for each operation. Any comparison of these results are only valid for the map extracts and scales used during the trial. They are also influenced by the relative experience and skills of operators, which goes some way to explaining the wide spread of results particularly for manual digitising. However, given these qualifications the results do provide an indication of the relative outputs obtainable from alternative systems.

9.4.2 From the 1 : 2500 trial where OS participated in Blind, Interactive and Semi-automated line following tests, the resultant times for the whole process indicate that for one organisation, manual interactive digitising and editing is quicker than blind digitising; which is in turn quicker than semi-automated line following.

The comparison with semi-automated line following suggests some limitations on the OS systems or methods. If account is taken of the comparison between OS and LASERSCAN at 1 : 10 000 scale digitising, the proportion of edit time to digitising time is 4 : 3 for OS and 1 : 3 for LASERSCAN ie a difference of 4 times.

At 1 : 10 000 for both planimetry and contours the results from TDN who participated in both blind and interactive tests shows that the times for manual interactive and blind digitising methods were very similar.

These results indicate that if equipment is purchased for digitising at a variety of scales, there is little to be gained by using interactive rather than blind methods for initial digitising. If the majority of work is at large scale or in a dense urban environment, interactive digitising may offer advantages in output commensurate with the increase in equipment cost.

9.4.3 In almost all cases (with the exception of OS semi-automated 1 : 2500 scale) automated and semi-automated methods have proved to be at least twice as quick as manual methods of digitising for planimetry. For contours this difference is of the order of 700 %. There is further evidence to indicate that semi-automated and automated equipment is better suited to digitising maps with simple line work and coding and less suited to digitising dense urban large scale plans, though this may change as technology develops.

9.4.4 The results from the NBS work for both 1 : 10 000 planimetry and contours are of interest because in both cases they were very significantly quicker than other participants. This is in part due to faster plotter times, which may reflect operator rather than plotter time, but in fact all operations are significantly quicker than other participants. For contouring as discussed in 9.3.4 NBS were the only participant to use a groove following technique for stream digitising. This achieved cartographically pleasing results in a time which was comparable with those achieved by much more expensive scanning systems. This result is particularly significant for organisations who are planning to undertake large amounts of contour digitising.

9.4.5 It is clear that automated scanning and vectorising systems use significant amounts of CPU time for processing (between 0.2 and 4 hours for these trials). However, manual methods also involve either a dedicated workstation processor or core time on a main frame. These times have not been quantified during these trials but should not be ignored.

9.5 Plotting

9.5.1 The results in Table 3.4 indicate the significance of edit plotting times. CLYDE and TDN in particular, used expensive, high accuracy plotter for a considerable time (up to 12 hours) to produce edit plots. The quality of output required for editing purposes should be carefully considered. High speed and relatively cheap plotters offer many advantages for the production of edit plots, such as versatility and time, but the final choice is likely to depend on the overall loading and utilisation of plotters for both edit and final plots.

9.5.2 For edit purposes features can be separated either by use of different feature numbers, colour codes or layered plots. A combination of feature numbers and colour coding offers significant advantages in that features can be readily identified from one plot or screen display.

9.5.3 For final plots accuracy and quality become overriding requirements. At present Flat Bed Plotters employing either a light head projector (OS and IGMI) or a scriber (TDN, CLYDE, NBS and NLS) can produce high quality reproduction material on film or scribecoat respectively. Such systems are slow and expensive. The trial has shown that laser plotters developed by LASERSCAN and SCITEX provide potential for producing high quality plots very rapidly (0.1–0.2 hours).

9.6 Methodology

9.6.1 The equipment used by all participants has proved itself to be satisfactory for digitising and coding topographic map detail. The price of equipment varies very considerably with a manual workstation costing less than 25 % of an automated or semi-automated system. The trial has shown that the throughput of automated systems are significantly greater than manual ones, though this is dependent on the level of feature coding and density of detail to be digitised. Any organisation which is contemplating the purchase of equipment must consider: the total volume of digitising to be carried out; the nature of the topography and the level of feature coding to be digitised. It is important too to remember that state of the art technology inevitably requires greater maintenance than tried and tested equipment, and the availability and response time of maintenance support is also an important factor.

9.6.2 It was agreed by all participants that prospective purchasers should ask manufacturers to carry out "Benchmark" trials. Purchasers should be prepared to pay for such trials and should insist on being present when they are carried out.

Appendix A

To All Members of Commission D, OEEPE **Paper 1/82**

Proposals for New Programmes for Participation by Commission D Members

1. The report of OEEPE Commission D for June—November 1981 contained proposals for new programmes to be undertaken by Commission D. Paragraph 5c 2 of the report suggested the establishment of a simple digitising project designed to assess the different methods of digitising existing mapping. It is to this proposed project that this communication is addressed. The primary objective of the trial is to compare digitising methods.

2. Members are asked to respond to this communication indicating their willingness to participate in the proposed programme. A questionnaire is attached as Appendix A and replies to this should be received here by **10 April 1982**. It is hoped to finalise arrangements for the programme at the Commission D meeting in Oslo in June 1982.

3. Also enclosed with this letter is a sheet containing 2 map extracts which will be used for the programme. The extracts are at 1 : 2500 and 1 : 10 000 scales. For those members willing to participate, stable based positives will be provided as working documents and the planimetric and contour elements at 1 : 10 000 scale will be provided separately. Having indicated their willingness and ability to take part in the programme, members will need to base the investigation on digitising equipment available in their own institutions. The possible range of equipment envisaged is:

3.1 Manual Digitising

3.1.1 Blind Digitising

3.1.2 Interactive Digitising

3.2 Semi-Automatic Line Following Digitising with Interactive Facilities

3.3 Scanning Digitising with Vectorising Software and Interactive Edit Facilities

4. Phase One of the project was designed to provide reliable data on times and manpower required for digitising, processing, editing and plotting simple map extracts as well as for data-banking of the data on magnetic tape or other suitable medium. The project was to provide data derived from the procedures available in a number of mapping departments and agencies to produce cost models reflecting grades of staff used, equipment type and cost, material cost and the time taken for the various relevant functions.

5. Also attached at Appendix B is a list of feature codes or attributes that should be used during digitising in this programme. Members participating in the programme will undoubtedly discover that facilities or methodology available to them within their institution or agency will necessitate some variation in practice. This is obviously acceptable but any such variation should be noted and reported as it may well have an influence on interpretation or evaluation of data derived from the programme. To increase the value of the programme to all members a descriptive report would be required from each participant in addition to the data referred to in paragraph 4 (above).

Please complete the questionnaire at Appendix A and return as shown by 30 April 1982.

Brigadier *C. N. Thompson*
Chairman Commission D
OEEPE

23 February 1982

Copy to Secretary General OEEPE

Questionnaire to be completed for the OEEPE Commission D Digitising Programme

To be returned to the Chairman of Commission D by 10 April 1982

Brigadier *C. N. Thompson*
Ordnance Survey
Romsey Road
Maybush
Southampton S09 4DH
ENGLAND

1. Name of Agency or Department and name of contact. ....

2. Do you wish to participate in the programme proposed in the circular of 22 Feb. 1982 ? yes / no*)

3. If yes, at which scale/scales do you wish to take part ?
   1 : 2500 yes / no*)
   1 : 10 000 yes / no*)

4. With reference to paragraph 3 of the circular, which methods do you propose to use ?

Method	1 : 2500	1 : 10 000
3.1.1		
3.1.2		
3.2		
3.3		

(Please tick appropriate box)

5. Do you consider the feature or attribute code list suitable ? yes / no*)
   Comment ....

6. The programme is to be based on the use of at scale positives on a stable medium which will be supplied to participants. If a different medium is required please give details ? ....

7. Please provide any comment or proposals on the programme. ....

   (Please continue on a separate sheet if necessary)

*) Delete as appropriate

Paper 2/82

Background Paper for OEEPE Commission D Digitising Programme

1 Introduction

1.1 Paper 1/82 dated 23 February 1982 was circulated at first to all members of Commission D. Attached to this paper as appendices was a questionnaire inviting participation in the proposed programme, a list of feature or attribute codes to be used during digitising and the two map extracts:

Map A 1 : 2500 scale planimetric map.

Map B 1 : 10 000 scale map with planimetry and contours presented as separate components.

1.2 Paper 1/82 suggested four possible digitising methodologies that participants could consider using and it also outlined the main objectives of such a programme.

1.3 The proposed programme was accepted as a suitable project for OEEPE and Commission D by the OEEPE Steering Committee with the principal objectives being to learn about the organisation and management of such programmes as well as to derive information on this particular subject matter. The programme was discussed at some length at the Commission D meeting at Hønefoss, Norway in June 1982.

1.4 Participation has subsequently been invited from any other centres not represented on Commission D and from equipment manufacturers.

2 The Programme

2.1 This will be conducted in two phases –

2.1.1 Phase One will conclude with the production of graphic images or plots from the digitised map extracts.

2.1.2 Phase Two will be oriented more towards consideration of the digital data as an end product looking at such matters as data structure, formats etc.

However it is appreciated that some centres, where the philosophy is one of automating cartography rather than the production of digital data, may not proceed beyond Phase One.

2.2 The following table is a summary of positive responses received to date from participating centres. Further positive reponses may be received when this further notice is circulated.

Digitising Method	Scales		
	1 : 2500	1 : 10 000	
		Planimetry	Contours
3.1.1 Blind Digitising	OS (UK), Sweden North East London Polytechnic (NELP) UK	OS (UK) Finland Netherlands	OS (UK) Finland Netherlands

Digitising Method	Scales		
	1 : 2500	1 : 10 000	
		Planimetry	Contours
3.1.2 Interactive Digitising	OS (UK)	OS (UK) Netherlands Finland France	OS (UK) Netherlands Finland
3.2 Semi-Automatic Line Following with Interaction	OS (UK)	OS (UK)	OS (UK)
3.3 Scanning, Vectorising with Interaction		Norway	Norway IGMI (Italy) France

3 Schedule for the Programme

3.1 The schedule for Phase One was accepted in the Norway Commission D meeting as follows –

End July 1982	– supply of map extracts and additional briefing material
30 November 1982	– completion of work in participating centres with production of plots and narrative reports etc.
June 1983	– assessment of data and results and completion of a report for consideration by Commission D.

4 Project Management

4.1 Mr. *Peter Wesley* (Ordnance Survey) will act as technical coordinator for the programme. Technical enquiries arising from the conduct of the programme in participating centres should be addressed as follows –

Mr. *Peter Wesley*
Manager Development Branch
C402A
Ordnance Survey
Romsey Road
Maybush
Southampton S09 4DH
ENGLAND

Telephone: 0703 775555 Ext 788

Telex: 477843

5 General Information

5.1 Several of the participants have raised the question of likely difficulties that may be encountered arising from the use of digitising procedures developed in centres which are now to be employed on maps from an "alien" environment. The force of this point is well understood and as general guidance the output or plots from Phase One should as near represent the map extracts provided as is possible. The programme, it is hoped, will illustrate the way in which methodologies developed in different centres are able to reproduce the map extracts.

5.2 Problems and difficulties identified, arising from this source or indeed from any other source should be reported in the narrative report from each participant. Such a report is seen as an important element of the programme.

6 Data to be Collected from the Programme

6.1 Data on production times and costs for the programme conducted in each participating centre is to be based on the following classification –

Operations	In relation to:
a) preparation/pre-edit	i) personnel by time and grade (e.g. engineer, technician etc.)
b) digitising	ii) equipment by time and cost*)
c) processing	iii) processing time
d) editing	iv) materials etc.
e) plotting	

*) where possible to include capital cost and maintenance etc.

6.2 Concern was expressed at the Commission D meeting in Hønefoss with regard to the danger in cost comparisons between different methods and centres. This danger is recognised but it was felt that without the information shown in 6.1 (above) the programme would only prove to be of limited value.

6.3 It is also recognised that those centres that are developing a methodology with the prime objective of producing digital data (in some structured and accessible form) will almost certainly have higher costs than an organisation simply developing automated cartographic methods.

7 Map Extracts

7.1 Film positives on a transparent medium are provided with this paper for those participants that made a positive reponse to paper 1/82.

7.2 For the 1 : 2500 experiment (Map A) an extract of the planimetry is provided.

7.3 For the 1 : 10 000 experiment (Map B) the extract consists of the planimetry and contours separated and punch-registered. The 1 : 10 000 extract also has an overlay which is connected with the digitising procedure for vegetation symbols (see 8.2). Those centres electing to tackle only the contour aspect of Map B have been provided with the contour extract only.

8 Digitising

8.1 At the Commission D meeting it was agreed that all slope and rock depiction symbols would be removed from the extracts. This has been completed.

8.2 With regard to vegetation symbols, on the 1 : 2500 scale extract (Map A) each symbol should be digitised as a point symbol. On the 1 : 10 000 extract (Map B) the overlay explains the digitising procedure to be adopted. In the northern portion of the extract each vegetation symbol should be digitised as a point symbol whilst in the southern portion the vegetation may be digitised as area or polygon symbols.

8.3 Those centres with curve fitting routines for the digitising and plotting of curvilinear lines should use them and the routine should be explained in the narrative report.

8.4 The production of text (e.g. orientation and point size) may prove to be a problem in some centres. Again, as general advice, centres should attempt to produce a replica of the original map extract and utilise their narrative report to describe the method used and the problems encountered.

8.5 There is a distinction for buildings between important buildings (shown by a heavier gauge) and other buildings and these are reflected by separate feature or attribute codes.

8.6 Feature codes for "objects shown by a circle" or "object shown by a dot" may be used as locating points where a suitable feature code cannot be found.

8.7 "Vegetation pecks" should be used where vegetation is to be shown by are symbols on Map B.

9 Aspects of Digital Data

9.1 Centres participating in the programme may wish to consider at an early stage questions of data format etc. Clearly if Ordnance Survey, as the pilot centre, is to assess and report on this aspect of the programme (Phase Two) some thought should be given

to the question of exchange formats, structure etc. Attached as an annex is a copy of Prof. *L. van Zuylen's* paper published in ITC Journal 1980–81 which the Commission D meeting felt would be useful to participants.

9.2 Ordnance Survey has developed facilities that enables almost any data to be "unscrambled" but the following broad guidelines will minimise the effort involved.

9.2.1 Centres should supply a listing with coordinates and attribute or feature codes for the complete data set.

9.2.2 A 9 track tape should be supplied (industry compatible) with reel size up to 800 metres.

9.2.3 Physical characteristics as follows

- formatting – either phase-encoded 1600 characters/inch or NRZI 800 characters/inch
- maximum block size – 4095 characters (variable in any one data set)

9.2.4 Content characteristics as follows

- header information – any acceptable as long as it is described
- tape marks (file marks) – any are acceptable if they conform to accepted standards.

9.2.5 Character representation in ASCII or EBCDIC preferred but ISO (6 bit packed) can be read. We could also accept data in binary if this were necessary and we would decode it. Hopefully binary not necessary.

9.2.6 A listing of a few blocks to show us what the tape looks like would be helpful in any case.

10 Feature or Attribute Codes

10.1 An amended list is attached as an annex to this paper. To assist participants a legend for the two map models is also attached to this annex.

11 Narrative Report

11.1 The value of a narrative report from each participating centre cannot be overestimated. The report should describe the equipment, methods and software employed in the programme and attempt to illustrate difficulties and problems that participants encountered.

11.2 It is hoped that reports will for example describe the "set-up" procedures employed for digitising e.g. the number of grid intersections observed, the number of pointings employed and the nature of any transformation used etc., etc. The value of the report will be increased by accurate descriptions of the type of staff used and whether the programme is conducted in an R & D or production environment.

Peter W. Wesley

26 July 1982

Feature or Attribute Code List for the OEEPE Commission D Digitising Programme

Scale	Description	Feature Code
Scale 1 : 2500		
	Building important/major	1
	Building other/minor	2
	Road carriageway (pecked line) /road pecks	3
	Path	4
	Bench Mark	5
	Trig pillar/point/station	6
	Name/number position	7
	Road fence or wall	8
	Vegetation pecks	9
	Ground surface feature limits	10
	Telephone call box	11
	Step treads	12
	Antiquity symbol	13
	Objects shown by a dot	14
	Bank of lake or pond	15
	Single stream or river	16
	Flow arrow	17
	Bar of culvert	18
	Track	19
	Object shown by circle	20
	Road pecks (pavement or sidewalk)	21
Scale 1 : 10 000		
	All the above plus	
	Electricity transmission line	22
	Electricity pylon	23
	Bank of double stream or river	24

Appendix C

Glossary of Terms

1 Data Capture — The recording of graphical and other detail in computer compatible form.

2 Digitising — The pointing at and recording of x,y coordinates of detail relative to a local origin using a **Digitising Tablet.**

2.1 Digitising Tablet — A device for precisely measuring and recording the relative x,y positions of graphical data drawn on a material fixed to its surface. Coordinate reading and recording is achieved electronically by the interaction of a cursor with an electronically sensitive grid within the surface of the tablet.

2.2 Blind Digitising — The act of digitising without recourse to an on-line graphics device to show detail already captured.

2.3 Interactive Digitising — The act of digitising using an on-line system on which detail is processed and graphically portrayed as it is digitised.

2.4 Semi-Automatic Line Following — A computer driven device which employs a laser "cursor" to automatically follow any line on which it is set.

2.5 Scanner — A computer driven device for recording graphical information in computer compatible form by passing a recording head systematically over a document in narrow bands in the x or y direction.

3 Edit — The enhancement of digital data after initial capture by correction, addition or deletion.

3.1 Blind Edit — Editing, usually offline, without recourse to a graphics display to show work in progress.

3.2 Interactive Edit — Editing, on-line, with the aid of a graphics device to show work in progress.

4 Plotters — Computer driven devices for drawing data held in digital form.

4.1 Flatbed Plotter — A high accuracy plotter which draws on material held horizontally on a fixed flat surface or "bed". The drawing device is supported on a gantry above the "bed". Movement of the gantry provides x motion and movement along the gantry provides y motion.

4.2 Drum Plotter — A plotter which draws on a material held on a moving or rotating drum. Pen movement is in the x direction along a gantry, y movement is achieved by rotating the drum which in turn moves the film or paper which is attached to it by sprockets.

4.3 Belt Driven Plotter — Similar to a drum plotter but the drum is replaced by a moving belt.

LIST OF THE OEEPE PUBLICATIONS

State — November 1984

A. Official publications

1 *Trombetti, C.:* „Activité de la Commission A de l'OEEPE de 1960 à 1964" — *Cunietti, M.:* „Activité de la Commission B de l'OEEPE pendant la période septembre 1960—janvier 1964" — *Förstner, R.:* „Rapport sur les travaux et les résultats de la Commission C de l'OEEPE (1960—1964)" — *Neumaier, K.:* „Rapport de la Commission E pour Lisbonne" — *Weele, A.J. v. d.:* „Report of Commission F." — Frankfurt a. M. 1964, 50 pages with 7 tables and 9 annexes.

2 *Neumaier, K.:* „Essais d'interprétation de »Bedford« et de »Waterbury«. Rapport commun établi par les Centres de la Commission E de l'OEEPE ayant participé aux tests" — „The Interpretation Tests of »Bedford« and »Waterbury«. Common Report Established by all Participating Centres of Commission E of OEEPE" — „Essais de restitution »Bloc Suisse«. Rapport commun établi par les Centres de la Commission E de l'OEEPE ayant participé aux tests" — „Test »Schweizer Block«. Joint Report of all Centres of Commission E of OEEPE." — Frankfurt a. M. 1966, 60 pages with 44 annexes.

3 *Cunietti, M.:* „Emploi des blocs de bandes pour la cartographie à grande échelle — Résultats des recherches expérimentales organisées par la Commission B de l'O.E.E.P.E. au cours de la période 1959—1966" — „Use of Strips Connected to Blocks for Large Scale Mapping — Results of Experimental Research Organized by Commission B of the O.E.E.P.E. from 1959 through 1966." — Frankfurt a. M. 1968, 157 pages with 50 figures and 24 tables.

4 *Förstner, R.:* „Sur la précision de mesures photogrammétriques de coordonnées en terrain montagneux. Rapport sur les résultats de l'essai de Reichenbach de la Commission C de l'OEEPE" — „The Accuracy of Photogrammetric Co-ordinate Measurements in Mountainous Terrain. Report on the Results of the Reichenbach Test Commission C of the OEEPE." — Frankfurt a. M. 1968, Part I: 145 pages with 9 figures; Part II: 23 pages with 65 tables.

5 *Trombetti, C.:* „Les recherches expérimentales exécutées sur de longues bandes par la Commission A de l'OEEPE." — Frankfurt a. M. 1972, 41 pages with 1 figure, 2 tables, 96 annexes and 19 plates.

6 *Neumaier, K.:* „Essai d'interprétation. Rapports des Centres de la Commission E de l'OEEPE." — Frankfurt a. M. 1972, 38 pages with 12 tables and 5 annexes.

7 *Wiser, P.:* „Etude expérimentale de l'aérotriangulation semi-analytique. Rapport sur l'essai »Gramastetten«." — Frankfurt a. M. 1972, 36 pages with 6 figures and 8 tables.

8 „Proceedings of the OEEPE Symposium on Experimental Research on Accuracy of Aerial Triangulation (Results of Oberschwaben Tests)"
Ackermann, F.: „On Statistical Investigation into the Accuracy of Aerial Triangulation. The Test Project Oberschwaben" — „Recherches statistiques sur la précision de l'aérotriangulation. Le champ d'essai Oberschwaben" — *Belzner, H.:* „The Planning. Establishing and Flying of the Test Field Oberschwaben" — *Stark, E.:* Testblock Oberschwaben, Programme I. Results of Strip Adjustments" — *Ackermann, F.:* „Testblock Oberschwaben, Program I. Results of Block-Adjustment by Independent Models" — *Ebner, H.:* Comparison of Different Methods of Block Adjustment" — *Wiser, P.:* „Propositions pour le traitement des erreurs non-accidentelles" — *Camps, F.:* „Résultats obtenus dans le cadre du project Oberschwaben 2A" — *Cunietti, M.; Vanossi, A.:* „Etude statistique expérimentale des erreurs d'enchaînement des photogrammes" — *Kupfer, G.:* „Image Geometry as Obtained from Rheidt Test Area Photography" — *Förstner, R.:* „The Signal-Field of Baustetten. A Short Report" — *Visser, J.; Leberl, F.; Kure, J.:* „OEEPE Oberschwaben Reseau Investigations" — *Bauer, H.:* „Compensation of Systematic Errors by Analytical Block Adjustment with Common Image Deformation Parameters." — Frankfurt a. M. 1973, 350 pages with 119 figures, 68 tables and 1 annex.

9 *Beck, W.:* „The Production of Topographic Maps at 1 : 10,000 by Photogrammetric Methods. — With statistical evaluations, reproductions, style sheet and sample fragments by Landesvermessungsamt Baden-Württemberg, Stuttgart." — Frankfurt a. M. 1976, 89 pages with 10 figures, 20 tables and 20 annexes.

10 „Résultats complémentaires de l'essai d'«Oberriet» de la Commission C de l'OEEPE — Further Results of the Photogrammetric Tests of «Oberriet» of the Commission C of the OEEPE"
Härry, H.: „Mesure de points de terrain non signalisés dans le champ d'essai d'«Oberriet» — Measurements of Non-Signalized Points in the Test Field «Oberriet» (Abstract)" — *Stickler, A.; Waldhäusl, P.:* „Restitution graphique des points et des lignes non signalisés et leur comparaison avec des résultats de mesures sur le terrain dans le champ d'essai d'«Oberriet» — Graphical Plotting of Non-Signalized Points and Lines, and Comparison with Terrestrial Surveys in the Test Field «Oberriet»" — *Förstner, R.:* „Résultats complémentaires des transformations de coordonnées de l'essai d'«Oberriet» de la Commission C de l'OEEPE — Further Results from Co-ordinate Transformations of the Test «Oberriet» of Commission C of the OEEPE" — *Schürer, K.:* „Comparaison des distances d'«Oberriet» — Comparison of Distances of «Oberriet» (Abstract)." — Frankfurt a. M. 1975, 158 pages with 22 figures and 26 tables.

11 „25 années de l'OEEPE"
Verlaine, R.: „25 années d'activité de l'OEEPE" — „25 Years of OEEPE (Summary)" — *Baarda, W.:* „Mathematical Models." — Frankfurt a. M. 1979, 104 pages with 22 figures.

12 *Spiess, E.:* „Revision of 1:25,000 Topographic Maps by Photogrammetric Methods" (in preparation).

13 *Timmerman, J.; Roos, P. A.; Schürer, K.; Förstner, R.:* On the Accuracy of Photogrammetric Measurements of Buildings — Report on the Results of the Test "Dordrecht", Carried out by Commission C of the OEEPE. — Frankfurt a. M. 1982, 144 pages with 14 figures and 36 tables.

B. Special publications

- Special Publications O.E.E.P.E. – Number I

  Solaini, L.; Trombetti, C.: Relation sur les travaux préliminaires de la Commission A (Triangulation aérienne aux petites et aux moyennes échelles) de l'Organisation Européenne d'Etudes Photogrammétriques Expérimentales (O.E.E.P.E.). I^{ère} Partie: Programme et organisation du travail. – *Solaini, L.; Belfiore, P.:* Travaux préliminaires de la Commission B de l'Organisation Européenne d'Etudes Photogrammétriques Expérimentales (O.E.E.P.E.) (Triangulations aériennes aux grandes échelles). – *Solaini, L.; Trombetti, C.; Belfiore, P.:* Rapport sur les travaux expérimentaux de triangulation aérienne exécutés par l'Organisation Européenne d'Etudes Photogrammétriques Expérimentales (Commission A et B). – *Lehmann, G.:* Compte rendu des travaux de la Commission C de l'O.E.E.P.E. effectués jusqu'à présent. – *Gotthardt, E.:* O.E.E.P.E. Commission C. Compte-rendu de la restitution à la Technischen Hochschule, Stuttgart, des vols d'essai du groupe I du terrain d'Oberriet. – *Brucklacher, W.:* Compte-rendu du centre «Zeiss-Aerotopograph» sur les restitutions pour la Commission C de l'O.E.E.P.E. (Restitution de la bande de vol, groupe I, vol. No. 5). – *Förstner, R.:* O.E.E.P.E. Commission C. Rapport sur la restitution effectuée dans l'Institut für Angewandte Geodäsie, Francfort sur le Main. Terrain d'essai d'Oberriet les vols No. 1 et 3 (groupe I). – I.T.C., Delft: Commission C, O.E.E.P.E. Déroulement chronologique des observations. – Photogrammetria XII (1955–1956) 3, Amsterdam 1956, pp. 79–199 with 12 figures and 11 tables.

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  Solaini, L.; Trombetti, C.: Relations sur les travaux préliminaires de la Commission A (Triangulation aérienne aux petites et aux moyennes échelles) de l'Organisation Européenne d'Etudes Photogrammétriques Expérimentales (O.E.E.P.E.). 2^{e} partie. Prises de vues et points de contrôle. – *Gotthardt, E.:* Rapport sur les premiers résultats de l'essai d'«Oberriet» de la Commission C de l'O.E.E.P.E. – Photogrammetria XV (1958–1959) 3, Amsterdam 1959, pp. 77–148 with 15 figures and 12 tables.

- *Trombetti, C.:* Travaux de prises de vues et préparation sur le terrain effectuées dans le 1958 sur le nouveau polygone italien pour la Commission A de l'OEEPE. – Florence 1959, 16 pages with 109 tables.

- *Trombetti, C.; Fondelli, M.:* Aérotriangulation analogique solaire. – Firence 1961, 111 pages, with 14 figures and 43 tables.

- Publications spéciales de l'O.E.E.P.E. – Numéro III

  Solaini, L.; Trombetti, C.: Rapport sur les résultats des travaux d'enchaînement et de compensation exécutés pour la Commission A de l'O. E. E. P. E. jusqu'au mois de Janvier 1960. Tome 1: Tableaux et texte. Tome 2: Atlas. – Photogrammetria XVII (1960–1961) 4, Amsterdam 1961, pp. 119–326 with 69 figures and 18 tables.

- „OEEPE – Sonderveröffentlichung Nr. 1"

  Gigas, E.: „Beitrag zur Geschichte der Europäischen Organisation für photogrammetrische experimentelle Untersuchungen" – *N. N.:* „Vereinbarung über die Gründung einer Europäischen Organisation für photogrammetrische experimentelle Untersuchungen" – „Zusatzprotokoll" – *Gigas, E.:* „Der Sechserausschuß" – *Brucklacher, W.:* „Kurzbericht über die Arbeiten in der Kommission A der OEEPE" – *Cunietti, M.:* „Kurzbericht des Präsidenten der Kommission B über die gegenwärtigen Versuche und Untersuchungen" – *Förstner, R.:* „Kurzbericht über die Arbeiten in der Kommission B der OEEPE" – „Kurzbericht über die Arbeiten in der Kommission C der OEEPE" – *Belzner, H.:* „Kurzbericht über die Arbeiten in der Kommission E der OEEPE" – *Schwidefsky, K.:* „Kurzbericht über die Arbeiten in der Kommission F der OEEPE" – *Meier, H.-K.:* „Kurzbericht über die Tätigkeit der Untergruppe „Numerische Verfahren" in der Kommission F der OEEPE" – *Belzner, H.:* „Versuchsfelder für internationale Versuchs- und Forschungsarbeiten." – Nachr. Kt.- u. Vermesss.-wes., R. V, Nr. 2, Frankfurt a. M. 1962, 41 pages with 3 tables and 7 annexes.

- *Rinner, K.:* Analytisch-photogrammetrische Triangulation eines Teststreifens der OEEPE. – Österr. Z. Vermess.-wes., OEEPE-Sonderveröff. Nr. 1, Wien 1962, 31 pages.

- *Neumaier, K.; Kasper, H.:* Untersuchungen zur Aerotriangulation von Überweitwinkelaufnahmen. – Österr. Z. Vermess.-wes., OEEPE-Sonderveröff. Nr. 2, Wien 1965, 4 pages with 4 annexes.

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- „OEEPE — Sonderveröffentlichung Nr. 5"

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  Weitere Ergebnisse des Meßversuchs „Oberriet" der Kommission C der OEEPE. *Härry, H.:* „Messungen an nicht signalisierten Geländepunkten im Versuchsfeld «Oberriet»" — *Stickler, A.; Waldhäusl, P.:* „Graphische Auswertung nicht signalisierter Punkte und Linien und deren Vergleich mit Feldmessungsergebnissen im Versuchsfeld «Oberriet»" — *Förstner, R.:* „Weitere Ergebnisse aus Koordinatentransformationen des Versuchs «Oberriet» der Kommission C der OEEPE" — *Schürer, K.:* „Streckenvergleich «Oberriet»." — Nachr. Kt.- u. Vermess.-wes., Sonderhefte, Frankfurt a. M. 1975, 116 pages with 22 figures and 26 tables.

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