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Technical Note

A computer program for ground investigation data storage, manipulation and presentation

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Abstract

The development of a geotechnical data handling, storage and presentation program is described. The system has demonstrated its capability on a major ground investigation contract and is currently being further developed to enhance its capabilities. Use of the system will reduce the time spent by relatively expensive engineering staff on routine plotting tasks and allow them to use large data sets more fully prior to selection of design parameters.

Introduction

On major ground investigations a great deal of engineering staff time is spent collating and analysing large data sets. The geotechnical engineer or engineering geologist can reduce the man-hours spent on this task while enhancing the process by using suitably developed software to store, manipulate and present data. Such a system would encompass borehole and trial pit records, laboratory test data, location plans, cross sections and '*X–Y*' plots become an easily accessible databank of projects, material parameters and other historical information.

Development history

In 1989 a review of the existing geotechnical data storage and handling packages available was carried out. Their capabilities and state of development were assessed and a decision made to enhance the GEOtechnical DAtabase SYstem (GEODASY) produced by G D Systems Ltd (GDS). In November 1989 GDS were asked to customize GEODASY to a specification prepared by W S Atkins Consultants Ltd (WSAC).

During November 1989 and April 1990 input and checking routines were developed together with factual report quality output formats. By April 1990 the system was sufficiently well developed to use on a major ground investigation contract. The Department of Transport was interested in such a system, where the ground investigation data could be compiled on computer at an early stage of a project and used for both factual and interpretative reporting. The usage of the program was therefore written into the contract documents of a major ground investigation valued at several hundred thousand pounds.

Extensive use of the program between April and August 1990 in the field provided valuable feedback leading to minor amendments. The program is now in the final testing of further interpretative and manipulative routines in readiness for use on the analysis work of the above mentioned project and other similar jobs.

System description

The relational database 'REVELATION' was used to provide the fundamental collection, storage, interrogation and retrieval facilities for the system. A variable length field structure allows the storage commitment to be governed largely by the amount of data entered. This gives a compact and very space efficient form. Data within the system can be interrogated by the development system's own query language to provide simple listings. More rigorous extractions can be achieved by purpose written routines using the development language. Alternatively, data can be exported as an ASCII file suitable to be read by any IBM compatible computer using either PC-DOS or MS-DOS operating systems (see system flow diagram, Fig. 1).

The system develops the proposal that transcription errors can be eliminated by fully integrating the production of the borehole record with the input procedure for the database (Howland 1989). The advantage to the contractor is that the report quality borehole records and tabulated information is entered by the use of the familiar QWERTY keyboard and no re-typing of the data is needed before the information can be passed to the database. No further work is therefore required of the contractor than would have

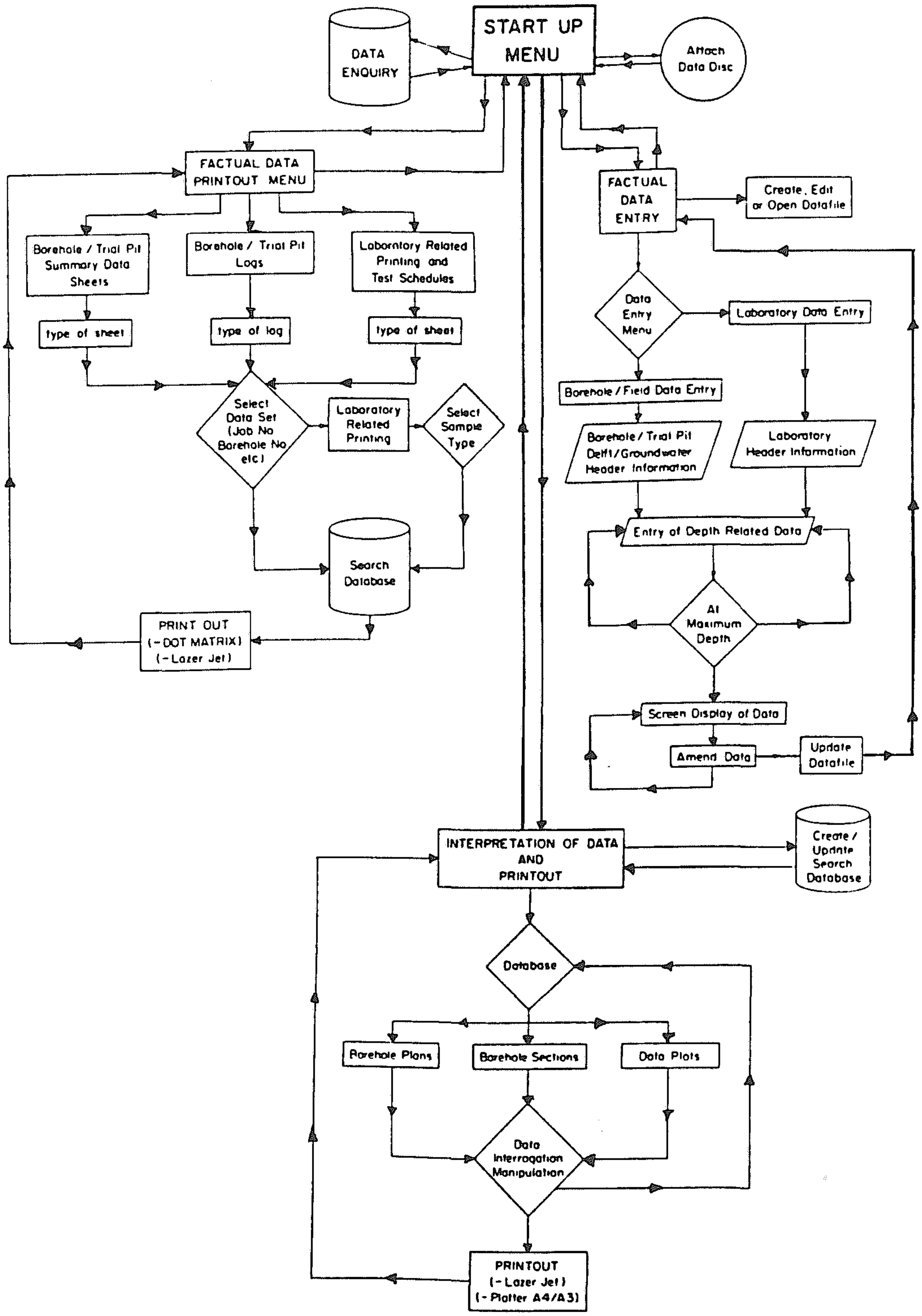


FIG. 1. Flow diagram of GEOtechnical DAtabase SYstem (GEODASY).

```
                    GEODASY - Start Up Menu                  SYSPROG
                     15:55:59  24 JUL 1992

              1. ATTACH Data Disk in Disk Drive.
              2. Data Entry. (Field and Laboratory)
              3. Data Enquiries.
              4. Data Printouts.
              5. Data Plots.

              6. Utilities and Housekeeping.
              7. Log Off.
```

```
                    GEODASY - Data Entry Menu                SYSPROG
                     15:56:31  24 JUL 1992

                 1. Field Data Entry.
                 2. Laboratory Data Entry.
```

```
                 GEODASY - Field Data Entry Menu             SYSPROG
                     15:56:44  24 JUL 1992

     1. Enter Borehole Header Data.
     2. Enter Test & Sample Details.
     3. Enter DETAILED SPT test results
     4. Enter Progress Details.
     5. Enter Stratum Details.
     6. Enter Chiselling, Excavation and Other Details.
     7. Enter Instrumentation Details and Readings.
     8. Enter General Remarks
     9. Enter Water Details.
    10. Steps 1 to 9, as above (Linked in step).
    11. Enter Additional Rotary Data.
               i)   Rotary Header Data.
               ii)  Rotary Core Properties.
               iii) Rotary Field Records.
    12. Enter Groundwater Level Observations.
```

```
                  GEODASY - Lab Data Entry Menu              SYSPROG
                     15:56:55  24 JUL 1992

   1. Enter Sample HEADER Details
   2. Enter Detailed Sample Descriptions.
   3. Enter Laboratory Test Results - Soil
   4. Enter Laboratory Test Results - Rock
   5. Enter Specialist Chemical Test Results - Soil
   6. Enter Specialist Chemical Test Results - Groundwater
   7. Enter Particle Size Distribution Data.
   8. Enter Point Load Test Results.
   9. Enter Landfill Gas Data.
```

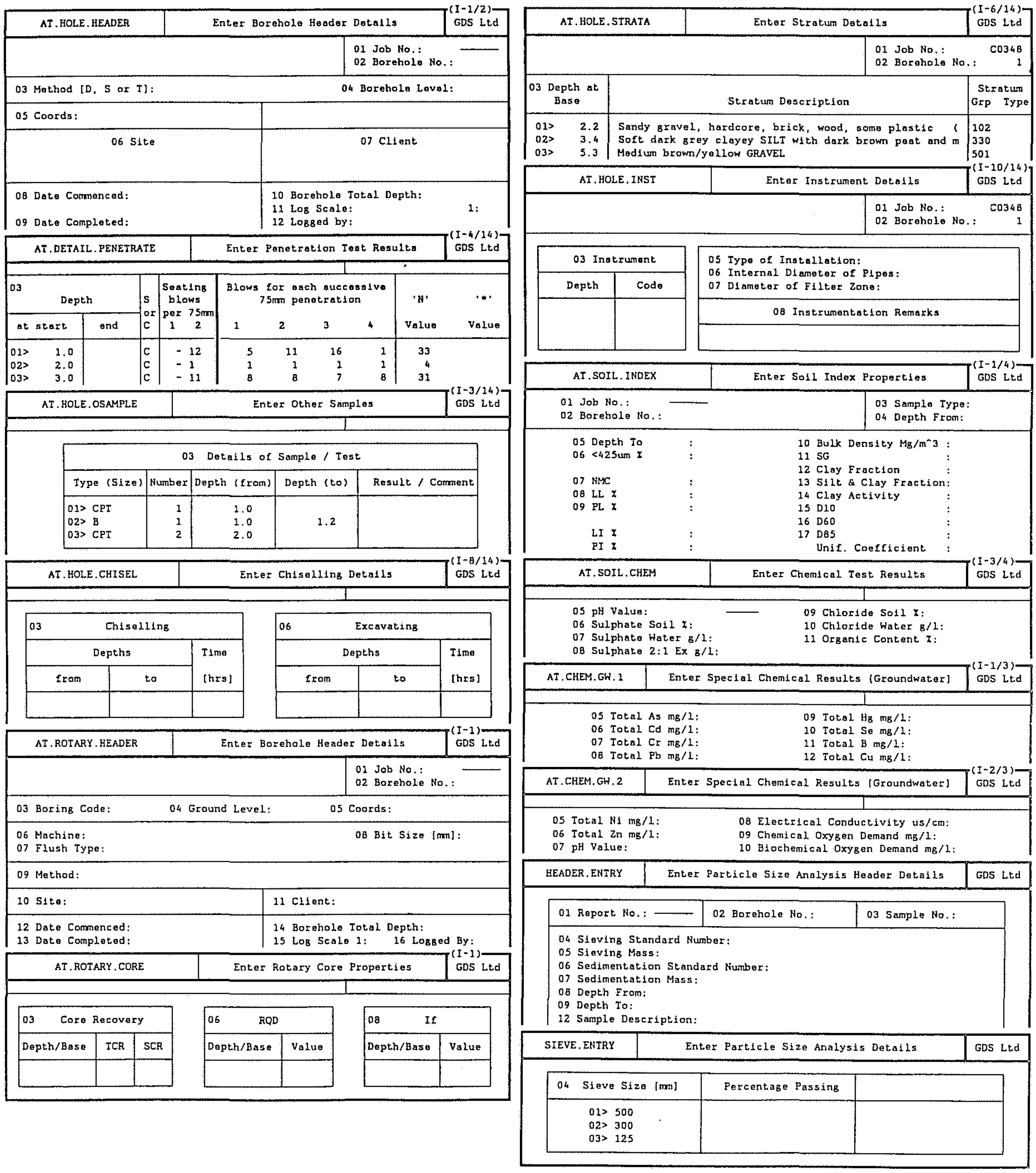
```
                    GEODASY - Print Menu                     SYSPROG
                     15:57:13  24 JUL 1992

       1. 'Download Fonts to the Laser Printer'
       2. Borehole Related Printing [ Summary Sheets ]
       3. Borehole Related Printing [ Logs ].
       4. Laboratory Related Printing.
       5. Summary Sheets.
```

```
               GEODASY - Field Data Prints [Logs]            SYSPROG
                     15:57:28  24 JUL 1992

        1. Print Shell & Auger Log.
        2. Print Delft Log.
        3. Print Trial Pit Log.
        4. Print Rotary Borehole Log.
        5. Print a Standpipe/Piezometer Log.
        6. Print Groundwater Level Observation Summary Sheet.
```

FIG. 2. Menu screens.



AT.HOLE.HEADER | Enter Borehole Header Details | (I-1/2) GDS Ltd

01 Job No.: ———
02 Borehole No.:
03 Method [D, S or T]: 04 Borehole Level:
05 Coords:
06 Site | 07 Client
08 Date Commenced: | 10 Borehole Total Depth:
| 11 Log Scale: 1:
09 Date Completed: | 12 Logged by:

AT.DETAIL.PENETRATE | Enter Penetration Test Results | (I-4/14) GDS Ltd

03 Depth at start	end	S or C	Seating blows per 75mm 1	2	Blows for each successive 75mm penetration 1	2	3	4	'N' Value	'*' Value
01> 1.0		C	-	12	5	11	16	1	33	
02> 2.0		C	-	1	1	1	1	1	4	
03> 3.0		C	-	11	8	8	7	8	31	

AT.HOLE.OSAMPLE | Enter Other Samples | (I-3/14) GDS Ltd

03 Details of Sample / Test

Type (Size)	Number	Depth (from)	Depth (to)	Result / Comment
01> CPT	1	1.0		
02> B	1	1.0	1.2	
03> CPT	2	2.0		

AT.HOLE.CHISEL | Enter Chiselling Details | (I-8/14) GDS Ltd

03 Chiselling Depths from	to	Time [hrs]	06 Excavating Depths from	to	Time [hrs]

AT.ROTARY.HEADER | Enter Borehole Header Details | (I-1) GDS Ltd

01 Job No.: ———
02 Borehole No.:
03 Boring Code: 04 Ground Level: 05 Coords:
06 Machine: 08 Bit Size [mm]:
07 Flush Type:
09 Method:
10 Site: | 11 Client:
12 Date Commenced: | 14 Borehole Total Depth:
13 Date Completed: | 15 Log Scale 1: 16 Logged By:

AT.ROTARY.CORE | Enter Rotary Core Properties | (I-1) GDS Ltd

03 Core Recovery Depth/Base	TCR	SCR

06 RQD Depth/Base	Value

08 If Depth/Base	Value

AT.HOLE.STRATA | Enter Stratum Details | (I-6/14) GDS Ltd

01 Job No.: C0348
02 Borehole No.: 1

03 Depth at Base	Stratum Description	Stratum Grp	Type
01> 2.2	Sandy gravel, hardcore, brick, wood, some plastic (	102	
02> 3.4	Soft dark grey clayey SILT with dark brown peat and m	330	
03> 5.3	Medium brown/yellow GRAVEL	501	

AT.HOLE.INST | Enter Instrument Details | (I-10/14) GDS Ltd

01 Job No.: C0348
02 Borehole No.: 1

03 Instrument Depth	Code

05 Type of Installation:
06 Internal Diameter of Pipes:
07 Diameter of Filter Zone:
08 Instrumentation Remarks

AT.SOIL.INDEX | Enter Soil Index Properties | (I-1/4) GDS Ltd

01 Job No.: ——— | 03 Sample Type:
02 Borehole No.: | 04 Depth From:

05 Depth To : | 10 Bulk Density Mg/m^3 :
06 <425um % : | 11 SG :
| 12 Clay Fraction :
07 NMC : | 13 Silt & Clay Fraction:
08 LL % : | 14 Clay Activity :
09 PL % : | 15 D10 :
| 16 D60 :
LI % : | 17 D85 :
PI % : | Unif. Coefficient :

AT.SOIL.CHEM | Enter Chemical Test Results | (I-3/4) GDS Ltd

05 pH Value: ——— | 09 Chloride Soil %:
06 Sulphate Soil %: | 10 Chloride Water g/l:
07 Sulphate Water g/l: | 11 Organic Content %:
08 Sulphate 2:1 Ex g/l:

AT.CHEM.GW.1 | Enter Special Chemical Results [Groundwater] | (I-1/3) GDS Ltd

05 Total As mg/l: | 09 Total Hg mg/l:
06 Total Cd mg/l: | 10 Total Se mg/l:
07 Total Cr mg/l: | 11 Total B mg/l:
08 Total Pb mg/l: | 12 Total Cu mg/l:

AT.CHEM.GW.2 | Enter Special Chemical Results [Groundwater] | (I-2/3) GDS Ltd

05 Total Ni mg/l: | 08 Electrical Conductivity us/cm:
06 Total Zn mg/l: | 09 Chemical Oxygen Demand mg/l:
07 pH Value: | 10 Biochemical Oxygen Demand mg/l:

HEADER.ENTRY | Enter Particle Size Analysis Header Details | GDS Ltd

01 Report No.: ——— | 02 Borehole No.: | 03 Sample No.:
04 Sieving Standard Number:
05 Sieving Mass:
06 Sedimentation Standard Number:
07 Sedimentation Mass:
08 Depth From:
09 Depth To:
12 Sample Description:

SIEVE.ENTRY | Enter Particle Size Analysis Details | GDS Ltd

04 Sieve Size [mm]	Percentage Passing	
01> 500		
02> 300		
03> 125		

FIG. 3. Field and laboratory data entry screens.

been necessary had he typed the logs in the traditional way. This together with the efficiency of flow and the use of the data to the engineer should mean that adoption of the system should not impose an additional cost overhead on the site investigation.

The data may be stored on standard IBM-PC or compatible $5\frac{1}{4}$ or $3\frac{1}{2}$-inch floppy disks or indirectly onto an internal hard disk. The system was designed initially to write the data to floppy disks to allow easy amendment and editing before adding to the main

```
GEODASY - Laboratory Data Prints                    SYSPROG
15:58:23  24 JUL 1992

1. Laboratory Testing Schedule. (Samples listed)
2. Summary of Laboratory Test Results.
3. Summary of Specialist Chemical Results.
4. Detailed Description of Split Samples.
5. Particle Size Distribution Graph.
6. Point Load Test Results Sheet.
7. Landfill Gas Results Sheet.
```

```
GEODASY - Data Plotting Menu                        SYSPROG
15:58:46  24 JUL 1992

1. Update Plotting Database.
2. Borehole Plans.
3. Borehole Sections.
4. Data Plots.
5. Data Export
```

Data Manipulation and Plotting				
01 Plot Reference: SPT 02 Re-Extract Data Y/N : Yes				03 Bot Grid reference ... 04 Top Grid reference ...
05 Sub Group				06 Plot Type (see Insert)
01> B	02> K	03> S		07 Plot Size A4/A3 : ...
X Parameter: SPT				Y Parameter: Depth
08 Item 09 Min 10 Max 11 Step 1 0 250 25 12 Scale : LIN				13 Item 14 Min 15 Max 16 Step 15 0 25 50 17 Scale : LIN
18 X-Title : S.P.T. 19 Y-Title : Depth 20 Plot Title : S.P.T. vs Depth. 21 Project : 22 Job Number :				23 Date : 04/Jul/91

Graphs Avaliable ..	
S	Scattergram
H	Histogram
C	Cumulative Freq'
A	A-Line
P	p' vs q'
N	NMC-PL-LL
G	Grading Chart
T	Time

Select a Parameter For The X-axis

1 SPT
2 Bulk Density
3 Moisture Content
4 Undrained Shear Strength
5 Unconfined Compressive Strength
6 Liquid Limit
7 Plasticity Index
8 Liquidity Index
9 Plastic Limit
10 Point Load Axial
11 Point Load Diametral
12 Permeability
13 Population
14 Point Load Anistropy
15 Depth
16 Reduced Level
17 Rock Quality Designation
18 Solid Core Recovery
19 Total Core Recovery
20 Fracture Index
21 Population
22 Moisture Content / Plastic Limit
23 Moisture Content / Liquid Limit

Select a Parameter For The X-axis

24 p'
25 q'
26 Clay Fraction (%)
27 Silt and Clay Fraction
28 Clay Activity
29 Uniformity Coefficient
30 PL/NMC/LL
31 Depth below strata
32 User Defined Value
33 Partical Size (mm)
34 Percentage Passing
35 Piezometer Date Read
36 Methane concentration - initial
37 Methane concentration - constant
38 Carbon dioxide - initial
39 Carbon dioxide - constant
40 Oxygen - initial
41 Oxygen - constant
42 Gas emission rates - velocity
43 Gas emission rates - flow rate
44 Time
45 Depth above strata

FIG. 4. Data manipulation and plotting screens.

Borehole No.	3122
Sheet	1 of 4
Methods	Cable tool boring, 150mm dia G.L to 12.30m. Rotary coring 92mm dia. from 12.30m to 32.00m, using air/mist flush and mylar.
Dates	02/03/90 - 12/03/90
Job No.	7625
Coordinates	359185 E 186398 N
Site	
Ground Level	6.37 mOD
Client	

Depth m	Sample/Test	Field Records	Level mOD	Depth m (Thick)	Description	Legend
			6.17	(0.20) 0.20	TOPSOIL	
0.50	W 1				Soft and firm brown and grey mottled CLAY with frequent subvertical root holes. (ESTUARINE ALLUVIUM)	
				(1.55)		
1.20 - 1.50	P 2					
			4.62	1.75	Grey silty fine SAND interlaminated with soft grey very silty CLAY. (ESTUARINE ALLUVIUM)	
2.00 - 2.35	P 3					
3.00 - 3.55	P 4					
				(4.75)		
4.50 - 5.50	P 5					
5.70	D 6					
6.00 - 7.00	P 7					
			-0.13	6.50	Firm to spongy dark brown PEAT with wood and plant remains interlaminated with soft grey fine sandy SILT. (ESTUARINE ALLUVIUM)	
7.30	D 8					
7.50 - 8.20	P 9					
				(2.10)		
			-2.23	8.60	Probably soft reddish brown very silty sandy CLAY with a little to some subangular to subrounded fine to medium gravel. (Probable HEAD DEPOSITS)	
8.70	D 10					
9.00 - 9.45	U 11 (100 BLOWS)		-2.63	(0.40) 9.00	Firm red brown calcareous very silty CLAY with many fine to medium gravel sized lithorelicts and occasional upto medium gravel sized light grey pockets of calcareous silt. Occasional black rootlets. (KEUPER MARL GRADE III) At 9.00m, very	
9.50	D 12					
9.60 - 10.05	SPT N(27)	2,3/5,5,7,10				
9.60 - 10.05	D 13			(1.50)		

Remarks
1. Inspection pit to 1.20m.
2. Water strike in inspection pit at 0.50m.
3. Water added from 2.00 to 8.60m.

Scale 1:50 Logged by GW

See key sheet for symbols and abbreviations 081090/1017

Borehole No.	3122
Sheet	2 of 4
Methods	Cable tool boring, 150mm dia G.L to 12.30m. Rotary coring 92mm dia. from 12.30m to 32.00m, using air/mist flush and mylar.
Dates	02/03/90 - 12/03/90
Job No.	7625
Coordinates	359185 E 186398 N
Site	
Ground Level	6.37 mOD
Client	

Depth m	Sample/Test	TCR	SCR	RQD	If	Field Records	Level mOD	Depth m (Thick)	Description	Legend
10.10	W 20 (LARGE)								closely spaced subv discontinuities infilled upto 10mm with soft grey fine sandy organic silt.	
10.40	D 14						-4.13	10.50	Recovered as angular medium to coarse gravel sized fragments of red brown slightly weathered calcareous MUDSTONE, weak to moderately weak. (KEUPER MARL Probable GRADE II/III)	
10.60 - 11.10	SPT N(29)					3,5/6,6,8,9				
10.60 - 11.05	B 15									
								(1.93)		
11.40	D 16									
11.60 - 11.89	SPT N(79*)					8,19/29,50 for 60mm,,				
11.60 - 12.05	D 17									
11.60 - 12.10	B 18									
12.30 - 12.43	SPT N(67*)					17,50/,,,				
12.30 - 12.43	D 19						-6.06	12.43	Red brown fine grained slightly weathered calcareous very silty SANDSTONE moderately weak to moderately strong with very closely spaced subhorizontal joints stained black. (KEUPER SANDSTONE)	
13.00						Coring started at 12.30m				
13.30		80	20	13						
					60			(1.77)		
14.20		92	21	8			-7.83	14.20	Red brown slightly weathered calcareous very silty MUDSTONE, very weak with extremely to very closely spaced 60 to 70 deg joints stained black. (KEUPER MARL GRADE II) Thin sandstone band	
								(1.50)		
					NI					
15.30						SPT: 50 for 62mm D20				
							-9.330	15.70	Red brown fine grained slightly weathered calcareous very silty SANDSTONE modertately weak to moderately strong, with very closely spaced subhorizontal to 60 deg planar joints stained black. (KEUPER MARL GRADE II) Greenish grey mottling. Thin mudstone band. Locally fine to medium gravel size cavities	
15.90					80					
16.30		82	10	0				(1.80)		
17.50						SPT: 47,50 for 47mm D21	-11.13	17.50	Recovered as sand and gravel size fragments of red brown slightly weathered very silty MUDSTONE very weak, in parts with a little red brown clay. (KEUPER MARL GRADE II)	
					NI			(1.70)		
		83	2	0						
19.20							-12.83	19.20	Recovered as red brown very silty CLAY with many lithorelicts and closely to medium spaced very thin mudstone beds. (KEUPER MARL GRADE II/III)	
					5			(1.30)		

Remarks
4. Water added from 10.60 to 12.30m.
5. Chiselling, 11.60 to 12.30m, 2 hrs.
6. After completing core run to 15.30m water rose to 0.30m above ground level in 30 secs. No further

Scale 1:50 Logged by GW

See key sheet for symbols and abbreviations 081090/1018

FIG. 5. Specimen report.

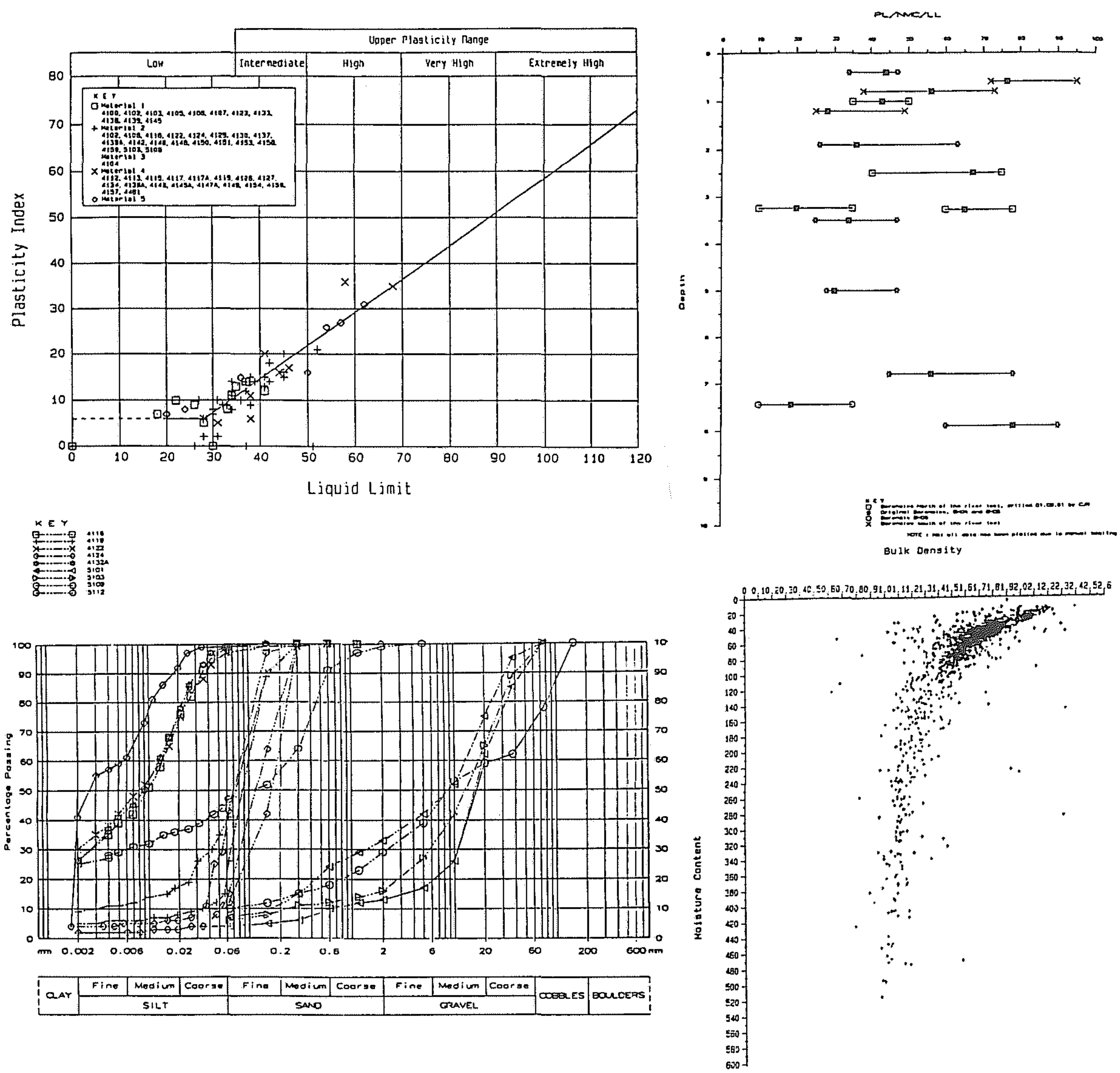


FIG. 6. Data manipulation example sheets.

database stored on a larger medium or hard disk. The initial use of floppy disks also allows independent back-up disks to be maintained for data security. Due to the efficiency of data storage, the system will store a twenty metre borehole record with extensive laboratory data in approximately 1.2 kilobytes of magnetic storage area. This would allow up to 33 000 boreholes and associated laboratory testing to be stored on a 40 megabyte hard disk using the appropriate operating software.

Program usage

The input format for the system has been developed as an interlinked sequence of user friendly entry menus, as illustrated in Figs 2–4.

The database system has been developed as two distinct packages in order to provide a partial data collection, printing and editing system for use on-site by a ground investigation contractor and the more

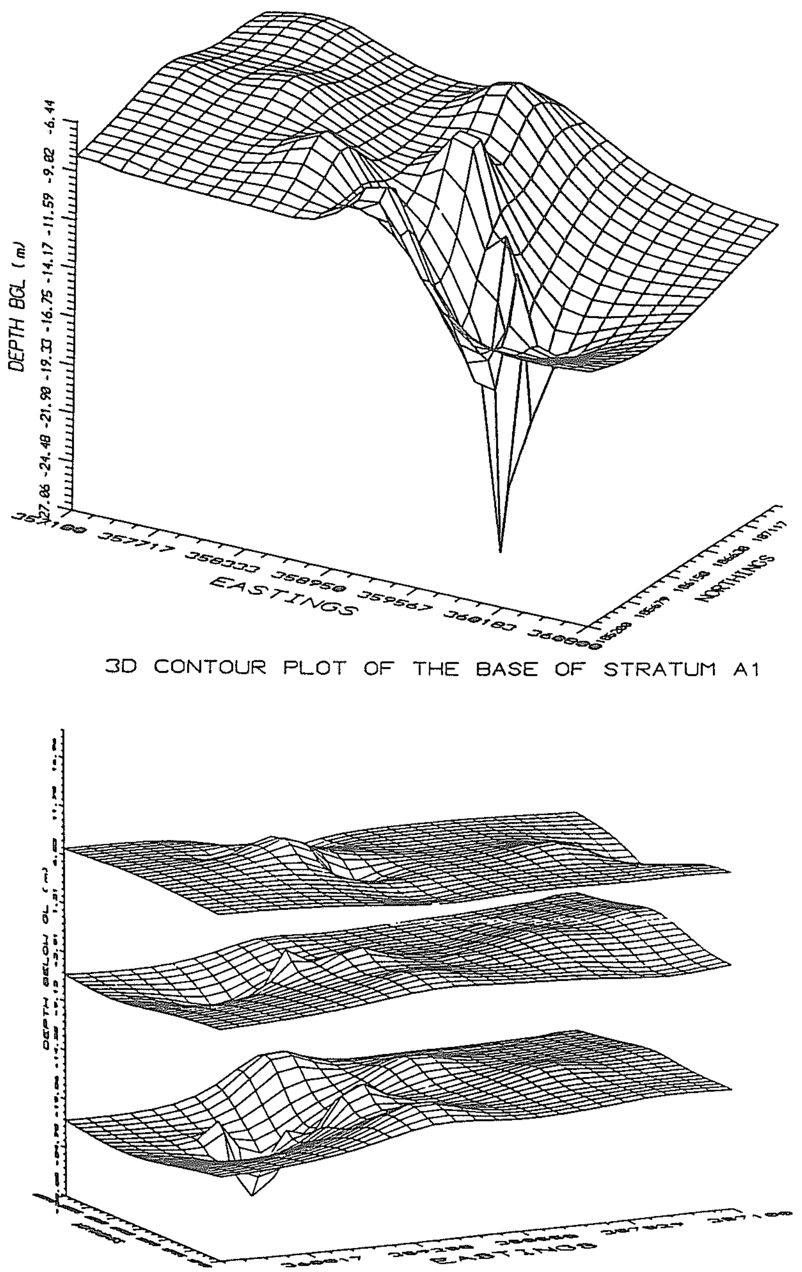


FIG. 7. 3D surface plotting using database parameters.

extensive data entry, editing, interrogation, manipulation and high-quality printouts by the head office.

The on-site data collection and editing package has now been extensively tested and used by the contractor working on the ground investigation referred to above. This included 160 cable percussion boreholes, of which 150 were extended by rotary drilling, 22 Delft continuous sampling holes and 200 trial pits. Extensive in situ testing was carried out together with laboratory testing including index tests, strength tests, consolidation tests and specialist chemical and effective stress tests. The contractor has successfully used the system both on site and in his head office and laboratory in the production of his factual report (see Figs 5 & 6).

The system is now in the final stages of development and testing, with project data successfully installed to form part of the national database. The system is capable of editing, interrogating, manipulating and interpreting the results of any data field or data set within the database, using a 'user-defined' alpha numeric flagging identifier, entered as part of the strata description. The manipulated data may be presented on site plans, cross sections, 'X–Y' graphical plots, plasticity charts, particle size distribution envelopes, piezometer data and landfill gas emissions versus time plots.

Histograms and cumulative frequency plots are also obtainable together with statistical analyses of any selected data set. The system will allow the exporting of information in the form of a continuous ASCII data file, which may then be manipulated by other standard statistical packages such as Lotus 1–2–3 or Modistat, or by existing 3D surface plotting techniques or draughting packages (see Fig. 7).

Typical 'X–Y' plots of parameter versus depth include standard penetration test (N-Value), undrained shear strength, index properties or any laboratory test parameters for soils, rocks or specialist chemical test results either within the database or entered as a special field.

Manipulation of the data prior to plotting may include any number of 'cross-field' calculations supporting all standard mathematical functions as well as the option of using an additional constant value if required. The scaling of the plots may be either automatic (linear/logarithmic) or by manual entry. In the case of the latter, a quality control note will be added to the final printout when the plot only contains part of the original data set within the database.

The output from the database system is designed for direct inclusion into a geotechnical, interpretative or design report using either a HP laser-jet or HP plotter.

Conclusion and future developments

The use of computers in the field of geotechnical engineering is now widely accepted as a means of increasing productivity. The geotechnical database system described in this paper has been designed to provide a system for field entry and head office manipulation of data. Data manipulation is a very time-consuming task on any large-scale investigation and, with a computerized database for storage and retrieval of data, a substantial reduction in man-hours may be achieved. The speed of manipulation also allows the engineer to consider more data correlations within the project time.

Although the system does require some training, after familiarization a complete borehole of between 20 m and 30 m may be entered in approximately 25 to 30 minutes. On-site entry of data may result in considerable time savings in the checking and minor alterations of logs as well as with the laboratory test data. The geotechnical reporting is also made considerably more efficient while time is reduced in producing report quality printouts.

The main advantages for this approach to a geotechnical database lie in the compatibility of the system with small portable computers, the high-quality printouts, the ease and efficient searching and sorting of data and the additional interpretation and manipulation of data at the design work stage which can be performed. The system will also export any or all the database records to another computer or software package in the form of a suitable ASCII file.

Future advances in the system are likely to be in the development of the head office package to work on a networking system.

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