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INITIAL HYDROLOGICAL APPRAISAL

CRANSLEY LODGE, KETTERING

for

STOCK LAND AND ESTATES LTD

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INITIAL HYDROLOGICAL APPRAISAL

CRANSLEY LODGE, KETTERING

SUMMARY

This initial appraisal outlines the progress of studies being undertaken by the INSTITUTE OF HYDROLOGY to assess the hydrological impact of the proposed Cransley Lodge village development upon the Birch Spinney - Mawsley Marsh Site of Special Scientific Interest. Following a preliminary hydrological assessment in December 1990, a monitoring network was designed and installed during March - April 1991.

A normal fault striking approximately 40° E through Birch Spinney has downthrown Northampton Sand to the north against Upper Lias clays to the south. The important perennial springs within Birch Spinney appear to be located along this barrier to regional southeastward groundwater flow.

The area to the south of this fault consists of three distinct hydrological zones of differing runoff, infiltration and groundwater characteristics. The hydrological impact of the proposed village development should therefore be considered in terms of these three distinct zones, which are as follows:

1. Lias Clay Zone: To the southwest of BH5 a thick cover of Boulder Clay rests directly upon Upper Lias clay. In this zone infiltration rates are extremely low and hence very little groundwater from this area would reach the SSSI. Surface flow from direct runoff dominates the hydrological regime in this zone.

2. Lower Estuarine Series Zone: Infiltration rates are relatively high in the zone to the east of BH4 where thin Boulder Clay partly overlies the fine sands of the Lower Estuarine Series. A southeast dipping clay aquiclude at the base of the Lower Estuarine Series restricts groundwater flow towards the SSSI.

3. Northampton Sand Zone: In the area between BH4 and BH5 infiltration rates are very low in areas directly underlain by Boulder Clay. Along the margins of the Boulder Clay runoff infiltrates into the Northampton Sand where groundwater flow is primarily towards the SSSI.

Initial results suggest that the proposed 350 unit village development is unlikely to significantly affect the volume or quality of groundwater entering the SSSI. The primary impact of the proposed village development will be upon surface runoff.

Preliminary indications are that the probable volume of runoff affected could be ameliorated by established engineering practices.

CHAPTER 1

INTRODUCTION

The INSTITUTE OF HYDROLOGY has been commissioned by STOCK LAND & ESTATES LTD to undertake a hydrological assessment of the Cransley Lodge area near Kettering, Northamptonshire.

The object of this study is to characterise the existing hydrological regime, and in particular the relationship between surface and groundwater flow in this area. This study will quantifying the hydrological impact of a proposed village development on the Birch Spinney - Mawsley Marsh wetland SSSI. These results will form part of a larger multidisciplinary assessment of the wider implications of the proposed village development.

The following is an initial appraisal of the progress of the work undertaken to date, and preliminary interpretation of these results.

CHAPTER 2

MONITORING NETWORK

In order to characterise the local hydrological regime prior to assessing the possible impact of the proposed village development a monitoring network was established. The network was designed to provide a the necessary hydrogeological framework against which the seasonal variations in rainfall, infiltration, runoff and surface flows could be assessed. In particular, the network was to enable quantification of the volume and chemistry of any waters which may be affected by the proposed village and the relative importance of these waters to the maintainance of the Birch Spinney - Mawsley Marsh wetland SSSI. To achieve this the following network has been established. The location of the network installations is shown in Figure 2.

RAINFALL: A 0.5mm tipping bucket raingauge linked to an digital datalogger recording the number of tips per minute. The lip of the raingauge is approximately 30cm above ground level which is at an elevation of m.O.D..

SOIL MOISTURE: A neutron probe access tube was installed approximately 8m north of BH6. The tube was sunk to 1.95m below ground level in Boulder Clay.

GROUNDWATER: Six boreholes were drilled through the Jurassic sands and into the underlying Lias clay. The holes were geologically logged during drilling and screened HPVC tubing installed. A seventh borehole was drilled to monitor water levels within the Boulder Clay.

In excess of ten piezometers have been installed and geological logs have been prepared for these and other hand auger holes drilled at various sites around the study area.

Boreholes and piezometers have been manually dipped on a monthly basis, while a multi-channel datalogger recording at 8 hourly intervals has been installed at BH6 and BH7.

SURFACE FLOW: V-notch gauges with chart recorders have been installed on two intermittent streams, with a third chart recorder monitoring stage levels through the railway tunnel at the eastern edge of the SSSI. A pressure transducer and datalogger are monitoring stage levels over the hydraulic ram weir.

CHAPTER 3

GEOLOGY

3.1 STRATIGRAPHY

The Cransley Lodge area is underlain by a sequence of Pleistocene fluvio-glacial clays which partially cover Jurassic sandstones and Lias clay. The stratigraphic sequence is summarised in Table 1.

Table 1 Stratigraphic Sequence

		Thickness (m)
RECENT	Alluvium	0- 1
	Peat	0- 2
PLEISTOCENE	Boulder Clay	0-12
	Gravel	0- 4?
JURASSIC	Upper Estuarine Series	0- 5
	Northampton Sand	0- 7
	Upper Lias Clay	>6

Areas of higher topographic relief are capped by Boulder Clay while the valleys have incising through these sediments into the underlying Jurassic sequence.

3.1.1 Boulder Clay

The Boulder Clay is predominantly dark grey to black, heavy impermeable clay with variable amounts of clastic material. These clastics are usually matrix supported and are more common towards the base of the section. In some locations the clastics have sufficient continuity to be mapped as a separate basal gravel unit. Limestone and chert fragments predominate throughout the section, while the basal portions have a greater proportion of ironstone or clay clasts derived from the underlying Jurassic sequence.

The Boulder Clay was deposited on an irregular Pleistocene erosion surface as shown in Figure 10. During the Pleistocene a valley existed approximately coincident with the location of the present valley.

The data presented in Figure 10 also suggests that there was a northeast trending Pleistocene age topographic high between BH6 and BH5. This ridge forms and important hydrological barrier where the

Pleistocene lies directly upon the Upper Lias.

The two aquifers in BH6 are the only 'marker beds' to have been identified within the Boulder Clay. The absence of the lower sandy clay aquifer and the thickening of the upper silty aquifer at the BH7 site would suggest that these units may be small, discontinuous channel fill deposits. It is probable that other lenses of this type will occur elsewhere in the area.

The relative elevation of the upper clayey siltstone aquifer in boreholes BH6 and BH7 indicates a general westerly dip. This suggests approximate conformity with the dip of the basal contact of the Boulder Clay, in which case the dip would be to the south west. The inferred outrop trace and hence principal source of recharge to these two aquifers within the Boulder Clay is shown in Figure 11.

3.1.2 Lower Estuarine Series

The Lower Estuarine Series in the Cransley Lodge area consists of intercalated fine yellowish white sands, siltones and occasional clay lenses. The base of the Series is marked by a persistent 25-30cm thick dense dark grey clay horizon.

The outcrop trace of the basal clay is shown in Figure 12 as is the elevation to the top of this horizon. In the fault block to the south of Cransley Brook this unit is thought to dip at approximately 0.6 degrees to the north north east.

In the Kettering district the Lower Estuarine Series can be up to 7.6m thick. Over most of the Cransley Lodge area only the lower part of the Series is preserved, however it does reach a maximum thickness of approximately 7.0m between BH3 and BH4. as Pleistocene erosion has removed all of the Lower Estuarine Series in the area south west of KDC1, BH5, and BH6 as shown in Figures 9 and 13.

3.1.3 Northampton Sand

The Northampton Sand consists of orange brown, medium to coarse grained quartz sand with lesser sandy silts. Ironstone is developed mostly in the basal portions of the unit and thin limestone bands occur through the section. Where the ironstone has been encountered at Cransley Lodge it is always oxidised and consists of irregular veins of iron oxides filling joints, fractures and bedding planes.

To the south of Cransley Brook the Northampton Sand/Upper Lias contact dips gently to the north east as seen in Figure 14. To the north of the brook this contact has been rotated by faulting into a south easterly direction. On a more detailed scale, as shown on several of the cross sectional figures there are local reversals to the regional dip of these two blocks.

Complete sections of Northampton Sand have been encountered in BH's 2-4 while reduced sections have been encountered in BH5, BH6, and KBC1. Changes in the thickness of the unit due to original depositional conditions are apparent in boreholes BH2, 3, and 4, although there is insufficient data to show particular trends.

Recent erosion along Cransley Brook has removed much of the Northampton Sand, while Pleistocene erosion has resulted in rapid thinning of the unit to the south and west of BH5.

3.1.4 Upper Lias

The Upper Lias consists of bluish grey mudstones which become pale brownish grey when weathered. A deep borehole (SP77/10) at Harringdon Dale near Orton (794 791) intersected 11.6m of Upper Lias Clay above a 2.4m thick oolite bed marking the top of the Middle Lias. Borehole BH6 finished in silty clay beneath 3.7m of slightly weathered Upper Lias clay.

3.2 STRUCTURAL GEOLOGY

On a regional scale the Jurassic sequence dips to the south east at approximately 2-3 degrees. The base of Northampton Sand/ Lias contact as shown in Figure 15 is quite irregular and suggests that the local structural setting is complex. This complexity may be as a result of block faulting, and/or local arching of the Lias beneath the axis of the valley.

A fault has been inferred to separate KBC1 and BH2 in the north from BH5 in the south.

CHAPTER 4

HYDROGEOLOGY

4.1 BOULDER CLAY

Both aquifers encountered within the Boulder Clay in BH7 and BH7 are confined. The limited amount of data available indicates that water levels in the lower more permeable aquifer fluctuate over a greater range. It appears unlikely that these two aquifers are not in hydraulic continuity with each other or the underlying aquifer of very thin Jurassic sands.

A falling head test on the upper silty aquifer encountered in BH7 indicated a permeability of 0.037 m/d. This value is consistent with the lithology of the material recovered from the borehole. There is insufficient data to allow determination of the hydraulic gradient or direction of groundwater flow.

It is probable that groundwater flow within the Boulder Clay aquifers is towards the southwest. Groundwater flow within the very near surface environment will be controlled by local topographic influences.

Soil moisture data are incomplete at this time with a requirement for summer soil moisture deficits being required.

The absence of groundwater in borehole BH5, and the very slow entry of water into BH4 suggests very low infiltration rates through the Boulder Clay. The Boulder Clay can be considered as a virtually impermeable aquiclude where it caps the Jurassic sands.

4.2 PLEISTOCENE GRAVEL

There is very little data available on the gravel unit at the base of the Pleistocene sequence. Where this unit has been intersected clasts of limestone, chert and ironstone have been supported in a heavy clay matrix and as a result the unit is regarded as having the aquifer characteristics of typical Boulder Clay.

4.3 LOWER ESTUARINE SERIES

The fine sands of the Lower Estuarine Series have only been encountered in drilling south of Cransley Brook. The clay horizon at the base of the Lower Estuarine Series was encountered in BH2 indicating that the Series is present to the north of the Brook.

The basal clay layer forms an aquiclude between the Lower Estuarine Series and the underlying Northampton Sands. A perched water table occurs above this aquiclude.

The limited data available suggests that the saturated thickness of the Lower Estuarine Series appears to be quite variable, as seen in Figure 6. This would be consistent with a very small area of recharge occurring predominantly along the margins of the overlying Boulder Clay. Groundwater is observed seeping from springs high on the southern banks of Cransley Brook that are coincident with the outcrop trace of the basal clay aquiclude.

Although there is only limited data available it can be expected that groundwater flow within the Lower Estuarine Series will undergo a marked seasonal variation. During the winter months flow directions will be strongly controlled by the steep gradients that will develop between the line of recharge at the edge of the Boulder Clay and the northern edge of the basal aquiclude. During this period groundwater flow will be in a more northwesterly direction.

Recharge of the Lower Estuarine Series by runoff from three Boulder Clay will be focussed at points where local drainage depressions cross the outcrop boundary of the Boulder Clay. two such focal points of recharge are shown on Figure 16.

In the summer months, the absence of a recharge mound beneath the margin of the Boulder Clay will result in the direction of flow being influenced to a greater extent by the dip of the aquifer. During these periods flow is expected to take on a more northeasterly direction.

The high silt content of a bulk sample of Lower Estuarine Series resulted in permeameter tests giving inconclusive permeability readings with a specific yield of 14.6%. Similarly grain size analysis techniques for determining permeability are considered to be inappropriate for such silty material.

Falling head tests on the Lower Estuarine Series have as yet to be completed.

4.4 NORTHAMPTON SAND

The Northampton Sand has been encountered in boreholes to the north and south of Cransley Brook. To the north of Birch Spinney a block including KDC1 and BH2 appears to have been downthrown relative to areas to the east (BH1) and south (BH5). This structural feature results in large differences in saturated thickness of Northampton Sand as shown in Figures 6 & 12.

While the geometry of the Northampton Sand to the south of Cransley Brook is more regular, there are also rapid lateral changes in saturated thickness. As the Northampton Sand/Lias contact dips to the south east the regional groundwater flow may also be expected to be in this direction.

The Northampton Sand has been removed by Pleistocene erosion to the west of BH5 effectively eliminating any recharge from this direction, while the aquiclude at the base of the Lower Estuarine Series prevents recharge by infiltration from above. This geometry accounts for the absence of groundwater in BH5 and the very narrow saturated thickness in BH4. The geometry of the saturated section of the Northampton Sand to the south of Cransley Brook suggests that recharge is primarily from the Brook. The Northampton Sands will also be recharged from springs at the base of the Lower Estuarine Series above the southern bank of Cransley Brook.

The hydraulic gradient between BH3 and BH4 is approximately 0.0045. There is insufficient data at the time of writing to calculate the hydraulic gradient in the predominant direction of flow to the south east. The gradient is expected to steepen closer to Cransley Brook. The hydraulic gradient between BH4 and BH6 is 0.015 although it is by no means certain that there is hydraulic connection between these two areas.

Borehole BH1 is sited within a small remnant of Northampton Sand left after mining of the surrounding material to the north, east and west of Mawsley Lodge. The very narrow saturated thickness is thought to reflect the reduced recharge due to mining, and the effects of dewatering by land drains.

Permeameter tests on a bulk sample of the Northampton Sand returned inconclusive results for permeability and a specific yield of 15.8%. An input test on the Northampton Sand in BH2 returned values for permeability of 0.016 m/d.

4.5 UPPER LIAS

The Upper Lias is the regional basal aquiclude to the Jurassic sand sequence. The Upper Lias where faulted against the Northampton Sand to the south of KBC1 and BH2 forms a barrier to the southerly flow of groundwater within the sands. This barrier of up-thrown Lias has probably been instrumental in the focussing of spring flow towards the western edge of Birch Spinney.

A ridge of Upper Lias clay is thought to have existed during the Pleistocene between BH6 and KBC1, as shown in Figure 11. In those places where there is a thin lens of clastic material at the Pleistocene/Lias unconformity, such as in BH6, this ridge exercises an important control upon groundwater flow. To the north of the ridge groundwater is directed northwards to the SSSI, while to the south flow is directed to the south.

Within the central portions of the SSSI Cransley Brook cuts through a thin alluvial cover resting directly upon the Upper Lias. In these areas there is a restricted capacity for the stream to directly recharge the Northampton Sand to the south.

CHAPTER 5

HYDROLOGY

The principal hydrological feature of the site is Cransley Brook, a perennial stream fed by groundwaters derived from the Jurassic sandstone aquifers of the area. The continuity of groundwater flow from springs at the western edge of Birch Spinney and from seepages along the banks of Cransley Brook have been critical factors in the maintainance of the existing wetland ecosystem.

The countryside surrounding the Birch Spinney-Mawsley Marsh SSSI consists of predominantly impermeable Boulder Clay capping Jurassic sands. The impermeable nature of the Boulder Clay results in low infiltration rates and flashy runoff response. Infiltration is expected to be far higher in those areas directly underlain by Jurassic sands.

The long term average annual rainfall for the Kettering area is approximately 635mm., with runoff from Boulder Clay areas expected to be approximately 50% or 317mm per annum. As yet there is insufficient local data available to allow calculation of site specific rainfall/runoff relationships for the Cransley Lodge area.

5.1 APRIL 29TH - MAY 2ND RAINFALL EVENT

A period of unusually high rainfall occurred throughout southern England between April 29th and May 2nd, 1991. This event occurred after an extended dry period and produced surface flow at the four flow gauging stations at Cransley Lodge. The response at these stations to the rainfall event is shown in Figures 18-21. The broad characteristics of the different catchments are apparent from these hydrographs, although there is insufficient data available at the time of writing to allow detailed analysis of these results.

The approximate peak flows recorded for this event have been compared to baseflows in Table 2. The inconsistencies apparent in this data set will be reduced with better calibration of the stage recorders.

5.2 IMPACT OF MINING ACTIVITIES

The hydrology of the Birch Spinney-Mawsley Marsh SSSI has been considerably modified as a result of mining during the 1940's and 1950's. Catchment areas to the north of Mawsley Lodge have been increased in size and had their drainage channels significantly altered. These changes have increased the total volume of water entering the SSSI, while channelling this increased flow to very localised sites. The presence of land drains below these mined areas result in rapid dewatering and lowering of groundwater levels. This has effectively eliminated any baseflow from the stream to the west of Mawsley Lodge and reduces the volume of groundwater seeping out along the valley banks during the summer months.

Table 2. Approximate Peak Flows April 29th - May 2nd Rainfall Event

	Gauging Station	Baseflow (l/s)	Peak Flow (l/s)
Outflow	Railway Bridge (S4)	47*	820
Inflow	Hydraulic Ram (S1)	3#(18%)	290 (36%)
	Village Stream (S2)	0	370 (5%)
	Mawsley Lodge (S3)	0	200 (25%)
	Other :	(43)	(290)
	- Western Land Drain	(1)	
	- Eastern Land Drain	(1)	
	- Northern Groundwater		
	- Southern Groundwater		

* Estimated using SENSA-RC2 Water Velocity Meter
# Estimated using measuring bucket

5.3 HYDROCHEMISTRY

Eight water samples have been collected and submitted for analysis. The results obtained will be used to establish :

1) A chemical signature for the wtaer derived from the different aquifers and surface water sources.

2) The seasonal variation in chemistry of these different sources.

3) Background chemical levels against which future possible urban effects can be compared.

A database of regional hydrochemical analyses is being prepared for comparitive purposes. Information collected to date is presented in Table 3.

5.4 HYDROLOGICAL ZONES

Based upon the geometry of the aquifers described above three hydrological "Zones" have been defined in the area to the south of the SSSI as shown in Figure 22. These three zones have markedly differing runoff, infiltration and groundwater characteristics. The hydrological impact of the proposed village development will therefore be considered in terms of these three distinct zones, which are as follows:

The "Lias Clay Zone" in the west is characterised by thick Boulder Clay resting directly upon Upper Lias clay. This zones corresponds approximately with the site of the proposed 350 unit village development. The combination of low infiltration rates though the clays, and thin or absent Jurassic aquifers result in very little groundwater from this zone reaching the SSSI.

The "Lower Estuarine Zone" in the east is characterised by Boulder Clay partially covering Lower Estuarine Series sands. A south east dipping clay aquiclude at the base of the Lower Estuarine Series restricts the northward movement of groundwater towards the SSSI.

In the intervening "Northampton Sand Zone" the high runoff from the Boulder Clay infiltrates through permeable sandy soils above the Northampton Sands. Groundwater flow in this aquifer is primarily towards the SSSI to the north.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

The preliminary results of the hydrological study of the Cransley Lodge area suggest the following:

1. The important perennial springs at the western edge of Birch Spinney occur in an area where the regional southeastward groundwater flow through Jurassic sands meets an impermeable fault barrier.

2. Three hydrological "Zones" have been defined in the area to the south of the SSSI.

   2.1 The "Lias Clay Zone" in the west is characterised by thick Boulder Clay resting directly upon Upper Lias clay. This zones corresponds approximately with the site of the proposed 350 unit village development. The combination of low infiltration rates though the clays, and thin or absent Jurassic aquifers result in very little groundwater from this zone reaching the SSSI.

   2.2 The "Lower Estuarine Zone" in the east is characterised by Boulder Clay partially covering Lower Estuarine Series sands. A south east dipping clay aquiclude at the base of the Lower Estuarine Series restricts the northward movement of groundwater towards the SSSI.

   2.3 In the intervening "Northampton Sand Zone" the high runoff from the Boulder Clay infiltrates through permeable sandy soils above the Northampton Sands. Groundwater flow in this aquifer is primarily towards the SSSI to the north.

3. Quantitative rainfall, infiltration, runoff and groundwater level data has been collected between March and June 1991. This data set includes one significant rainfall event which has enabled a preliminary evaluation to be made of catchment characteristics.

4. Initial results suggest that the proposed 350 unit village development, being sited within the "Lias Clay Zone", is unlikely to have a major impact upon the volume or quality of groundwater entering the SSSI. The primary impact of the proposed village development will be upon surface runoff. Preliminary indications are that the probable impact of the site upon surface runoff could be ameliorated by established engineering practices.

5. There is a greater possibility of runoff from any development in the "Northampton Sand Zone" entering the SSSI via the Northamton Sand aquifer. The impact of the limited volume of water that may be affected by development could be reduced by the positioning of the village and remedial engineering works.

6. The existing network will continue to be monitored and catchment characteristics defined over a range of seasonal conditions.

7. Certain important aspects of the hydrological regime at Cransley Lodge require clarification. Additional studies over the coming months will be directed towards resolving these matters.
This work will include:

6.1 Improving the calibration of the surface flow gauges prior to monitoring winter flow conditions.

6.2 Improving the monitoring of flow from, and influence of land drains beneath the restored mining areas.

6.3 Collecting water samples during the summer period for hydrochemical analysis.

6.4 Installing an additional soil moisture probe site within the "Northampton Sand Zone".

6.5 Obtaining additional data on the Jurassic sands including the dip of basal aquicludes, the hydraulic gradient and permeability/storativity characteristics.

6.6 Defining the geographical limits and thickness of Jurassic sand cover in the "Lias Clay Zone".

6.7 Locating any fault boundaries which may be controlling groundwater flow.

6.8 Obtaining additional data on the location, geometry and characteristics of any aquifers within the Boulder Clay.

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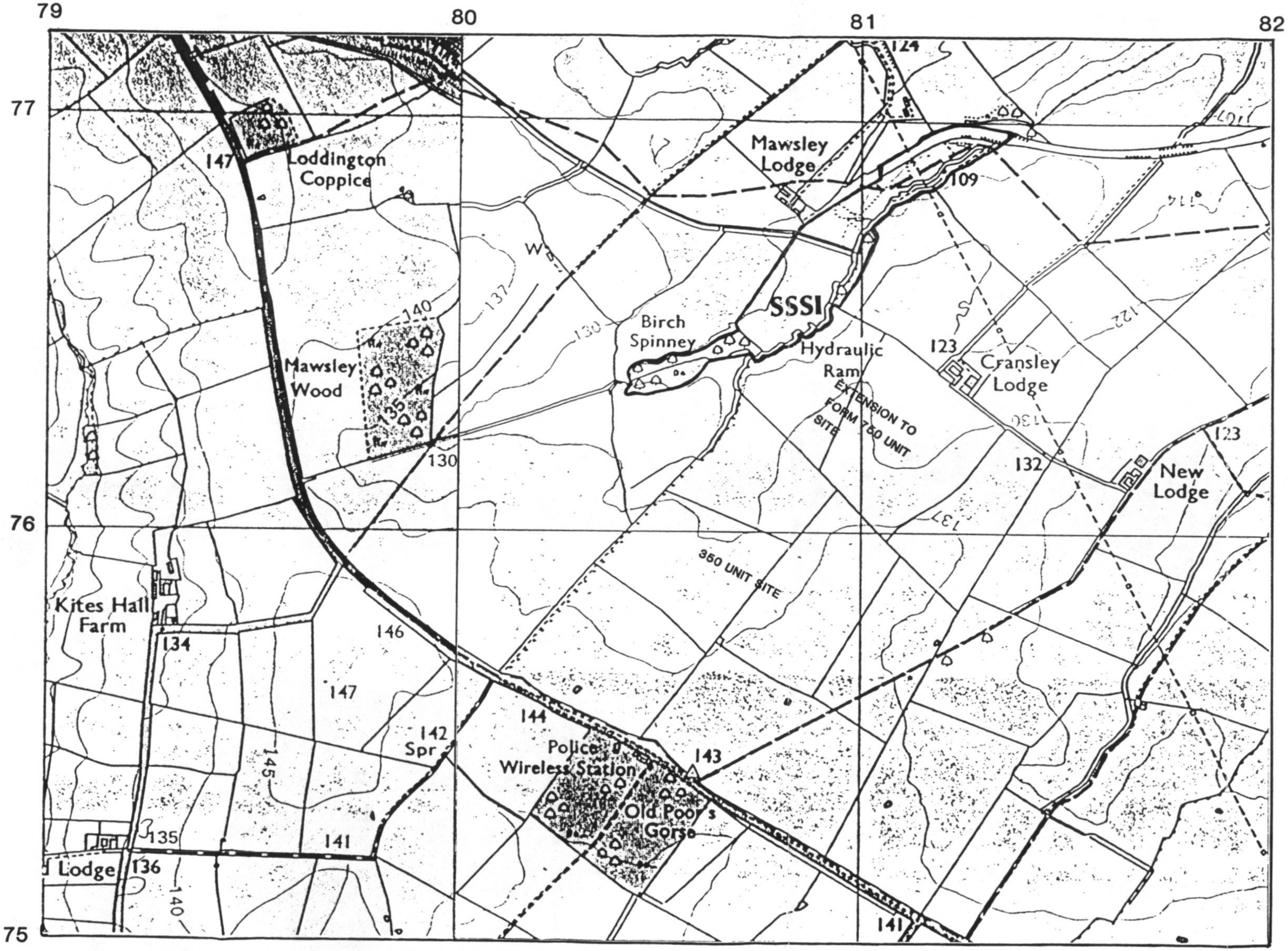

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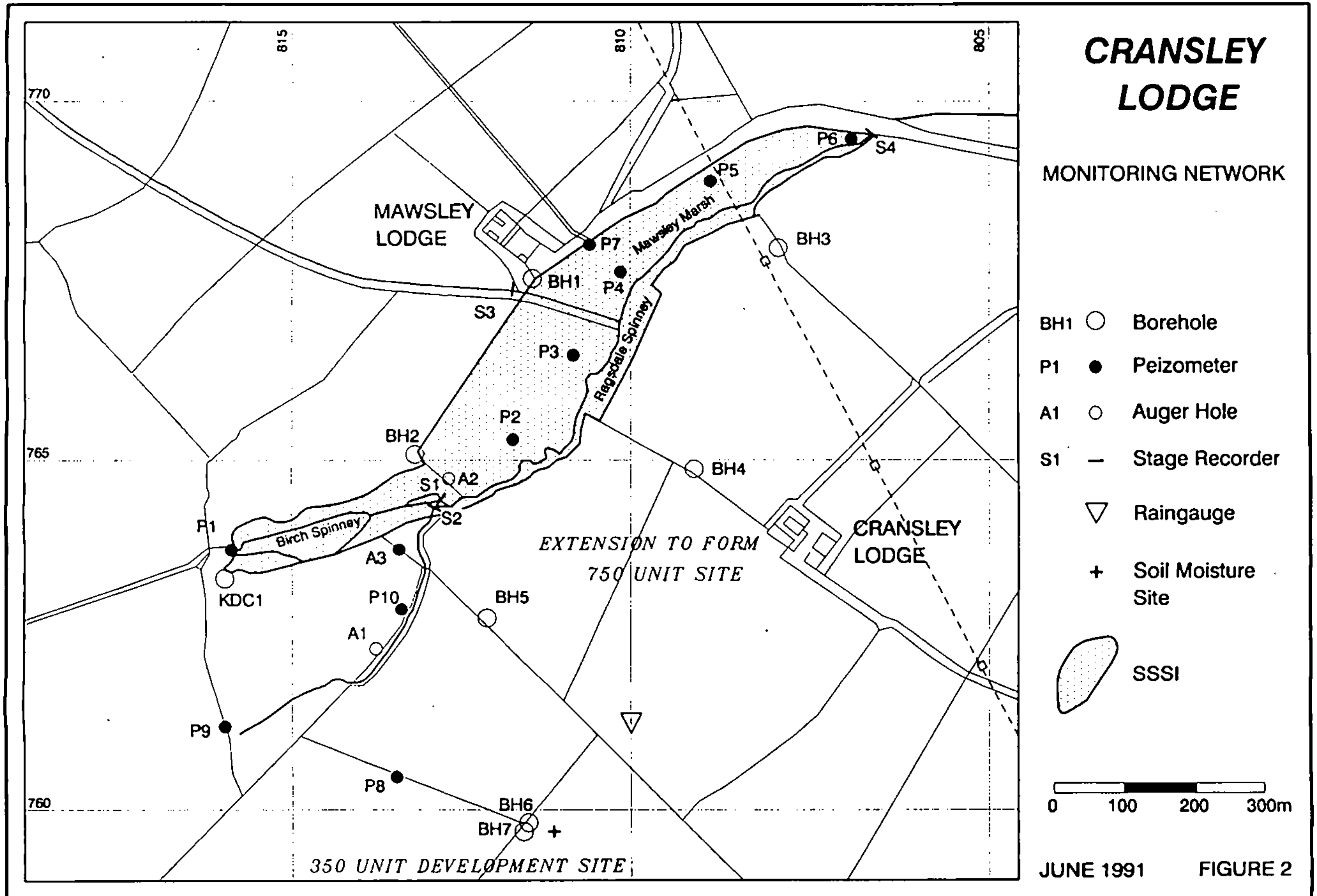
BASEPLAN FROM O.S. 67/77,87/97

KETTERING

LOCATION PLAN

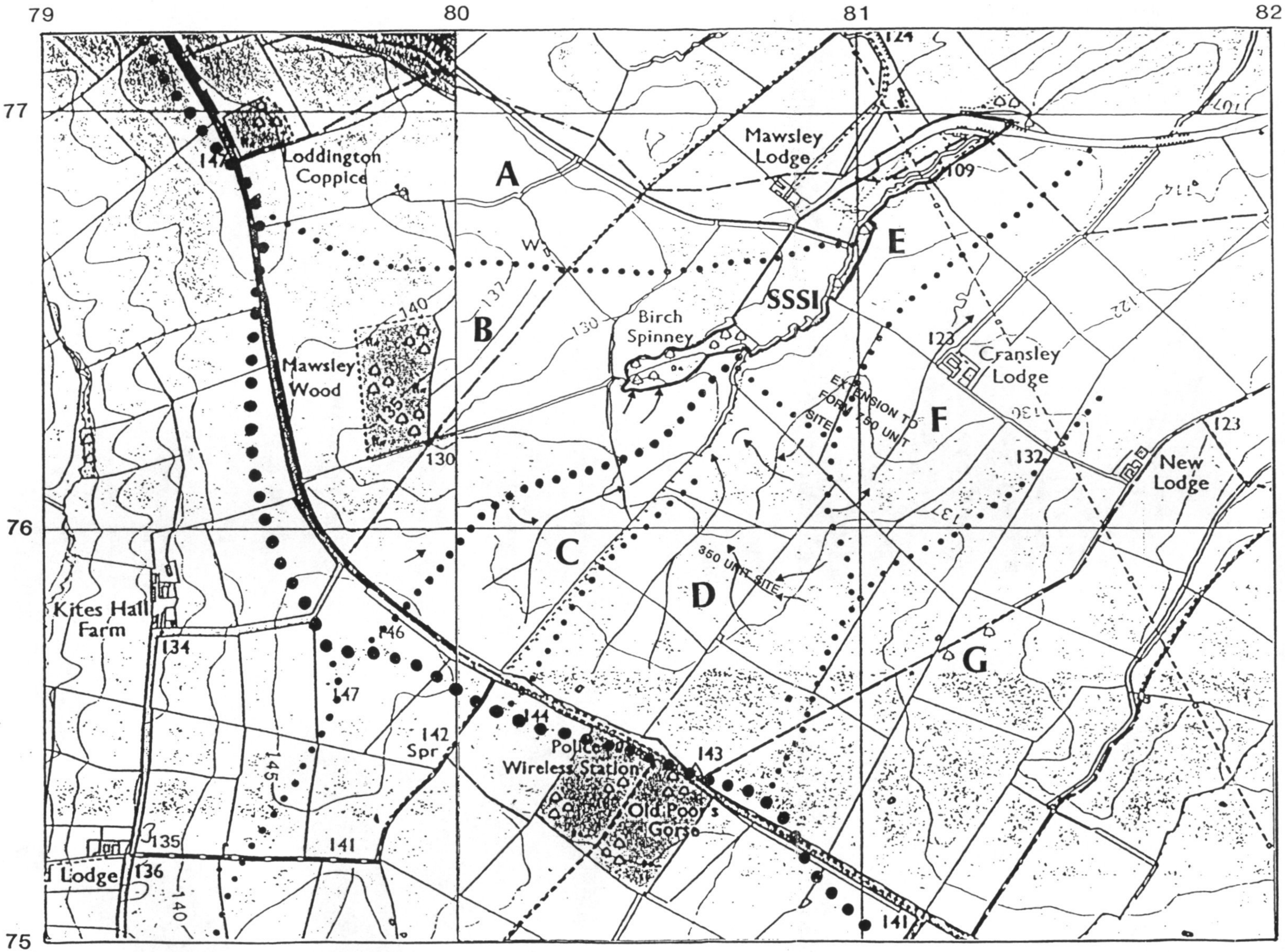
FIG. 1

PRELIMINARY



JUNE 1991 FIGURE 2

INSTITUTE OF HYDROLOGY



KETTERING

SURFACE DRAINAGE

FIG. 3

STREAMS

CATCHMENT BOUNDARY

SCALE 1:10000

BASEPLAN FROM O.S. 67/77,87/97

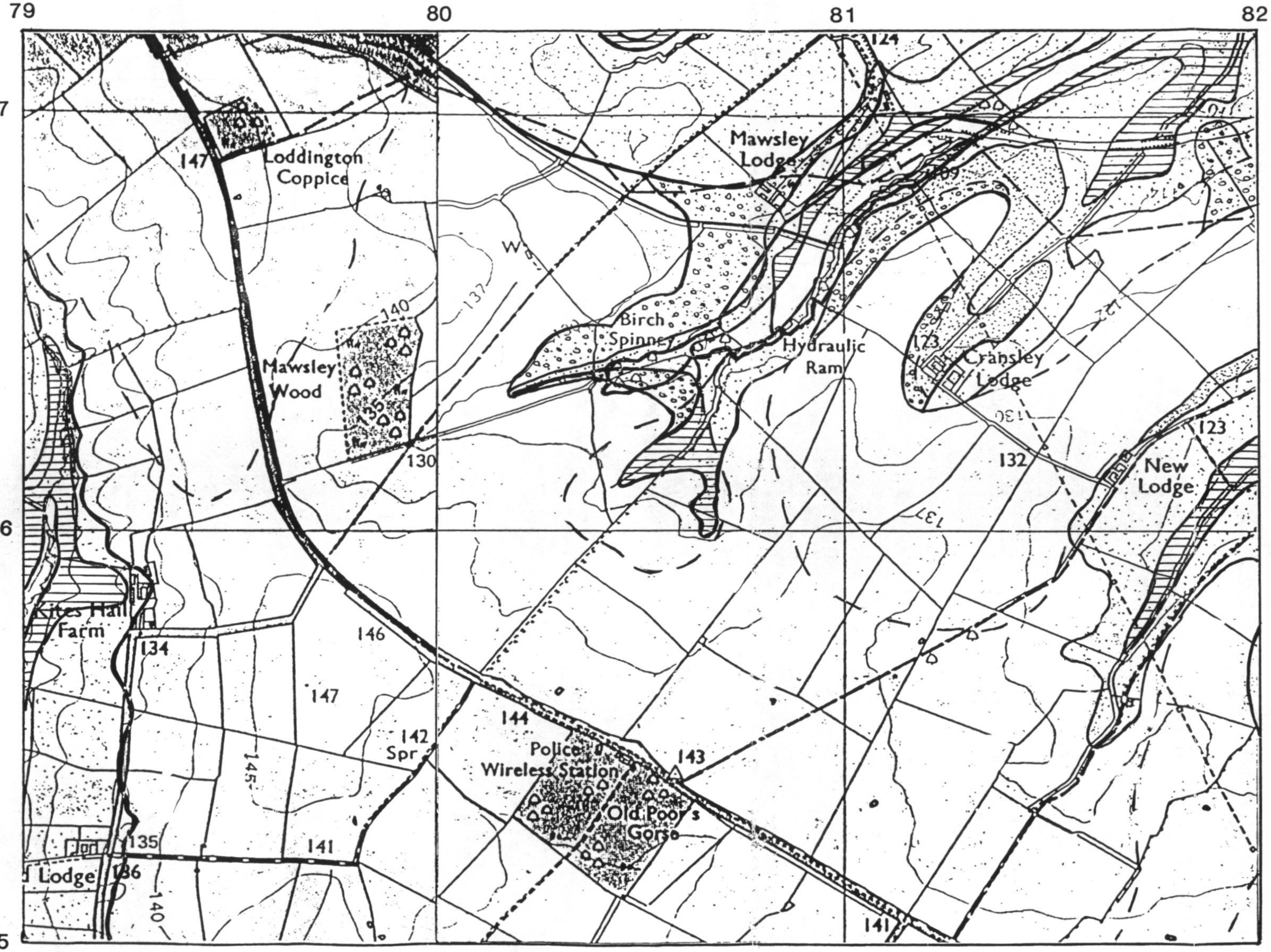
PRELIMINARY

INSTITUTE OF HYDROLOGY

KETTERING

HYDROGEOLOGY

FIG. 4



PLEISTOCENE

BOULDER CLAY

SAND & GRAVEL

JURASSIC

LOWER ESTUARINE

NORTHAMPTON SAND

UPPER LIAS

SCALE 1:10000

BASEPLAN FROM O.S. 67/77,87/97

PRELIMINARY

CRANSLEY LODGE

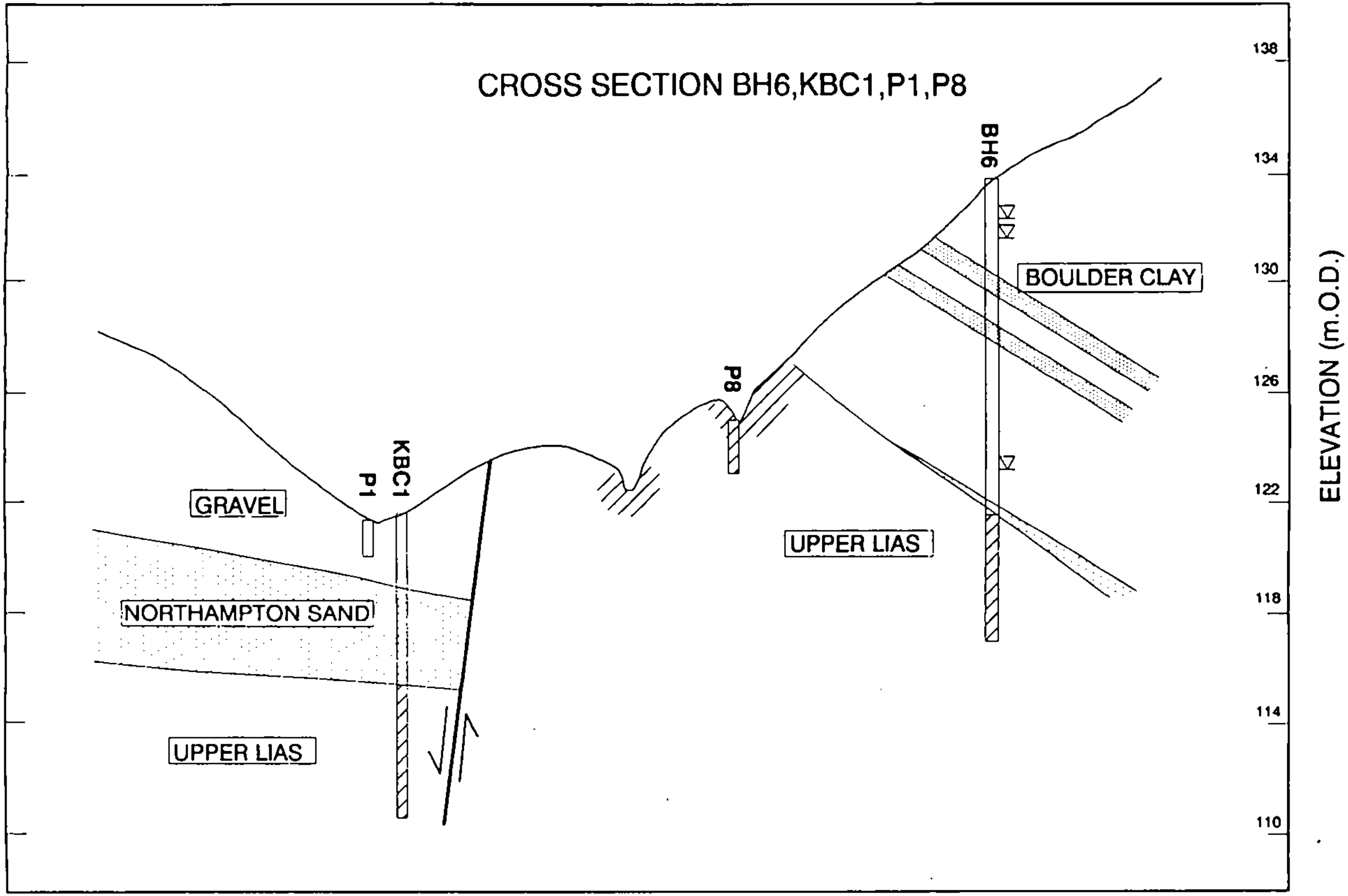


FIGURE 5

CRANSLEY LODGE

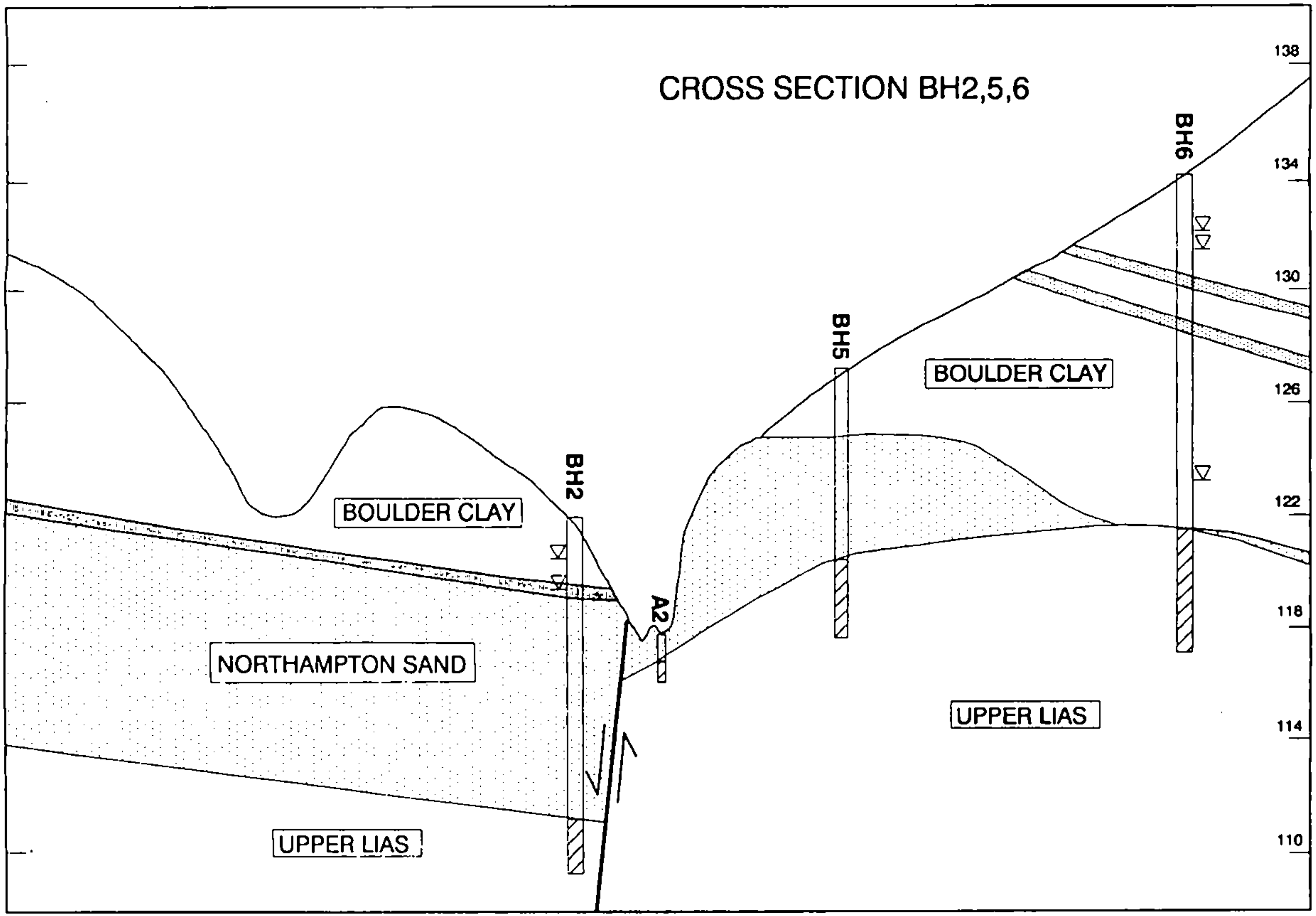


FIGURE 6

CRANSLEY LODGE

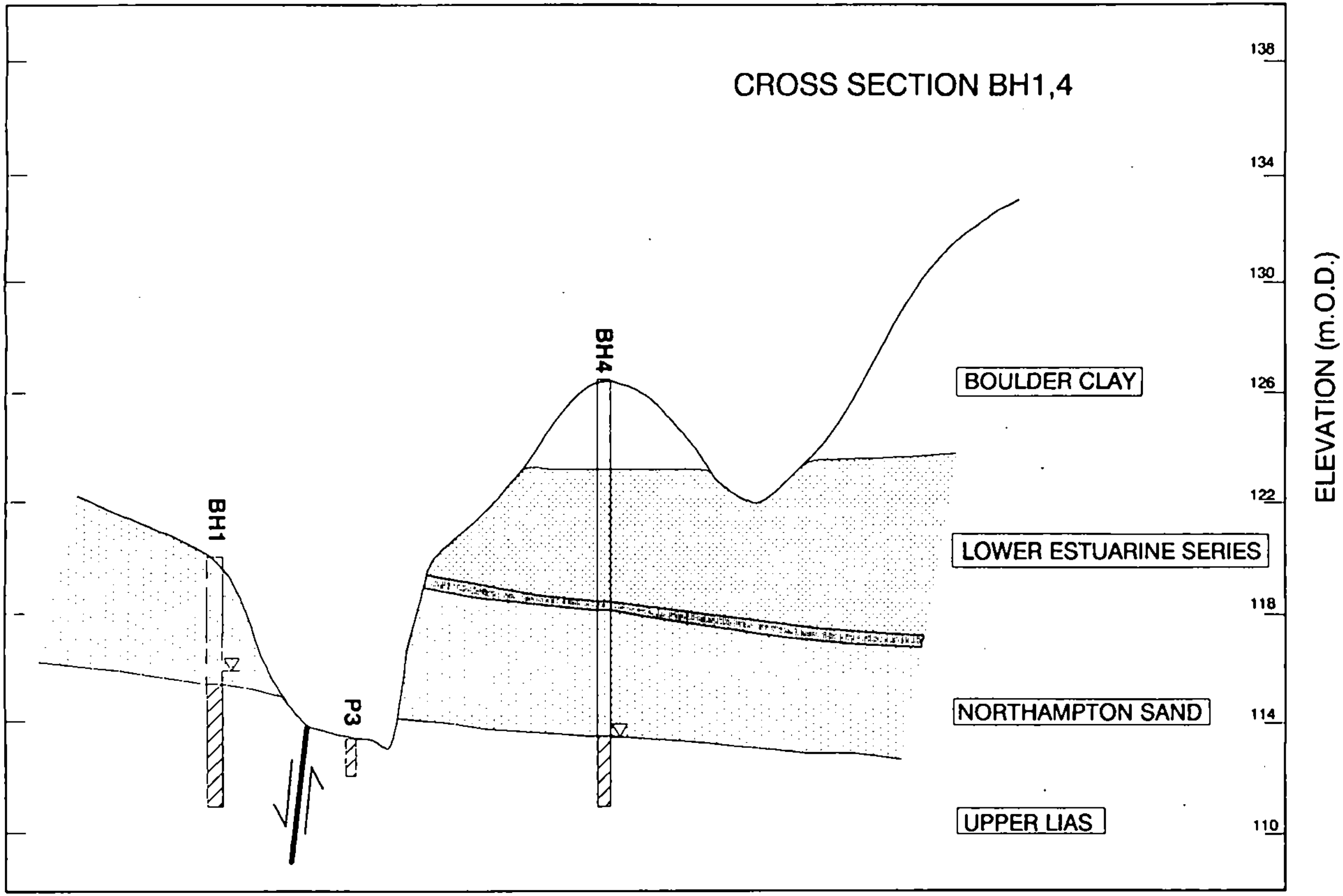


FIGURE 7

CRANSLEY LODGE

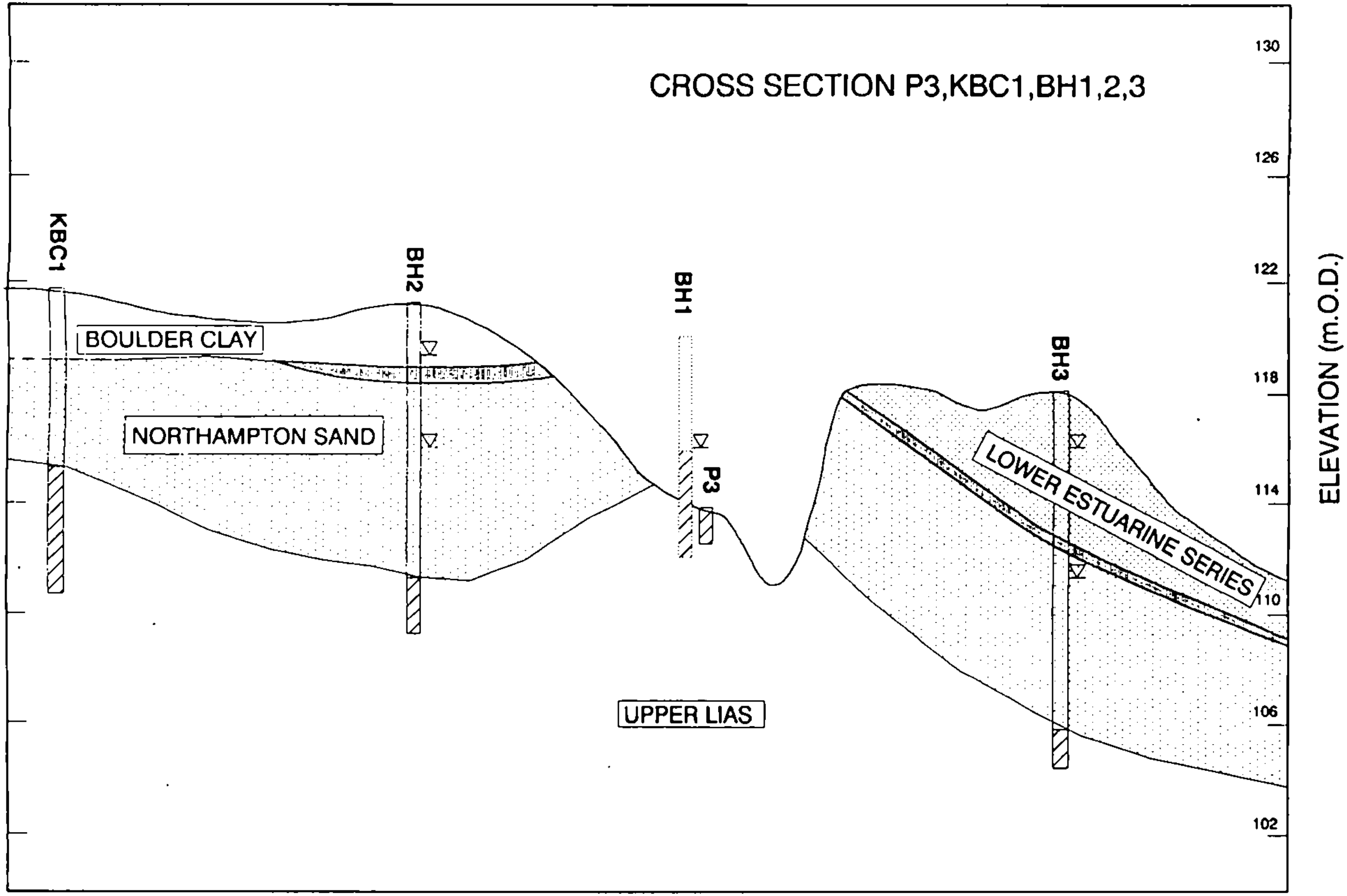


FIGURE 8

CRANSLEY LODGE

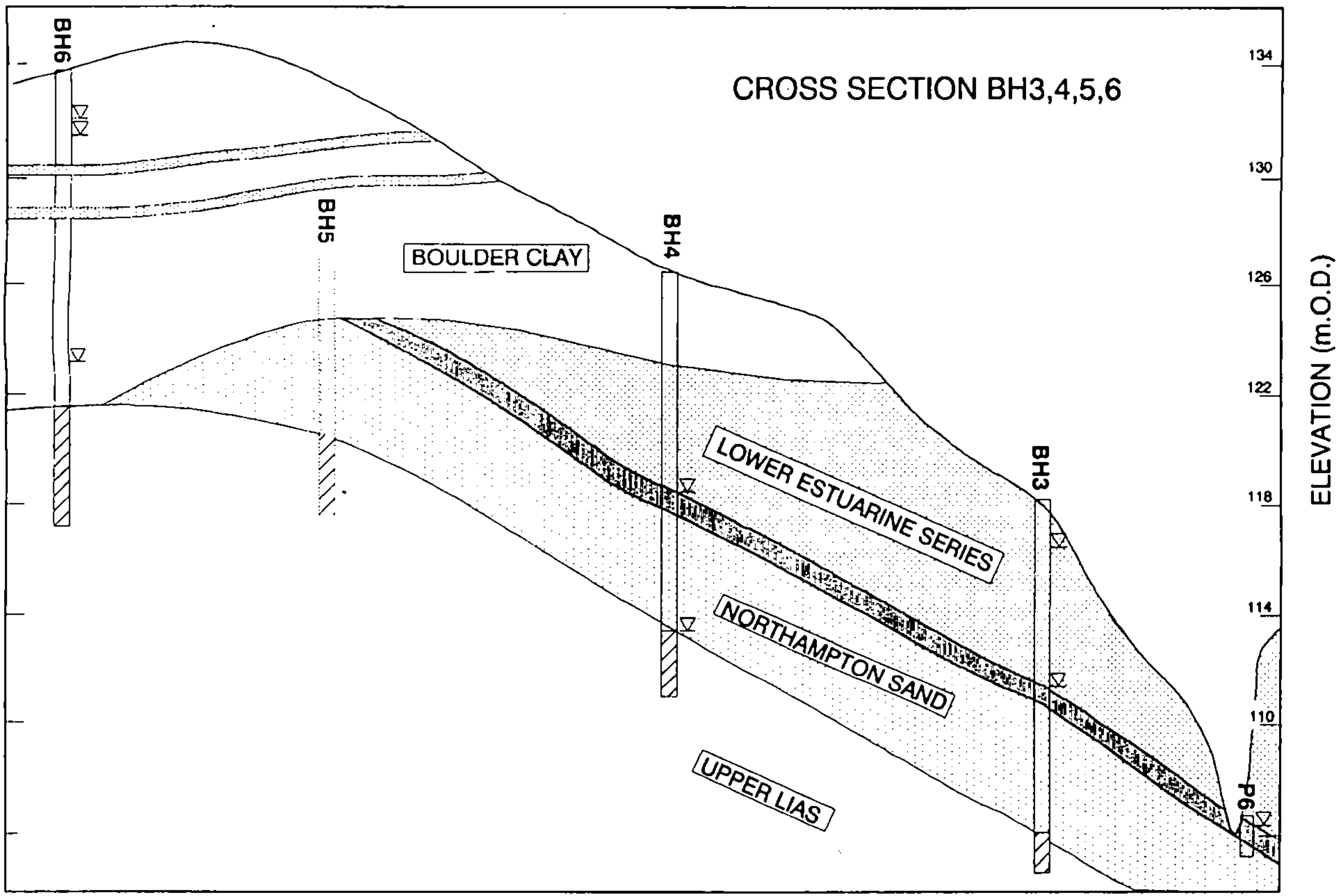
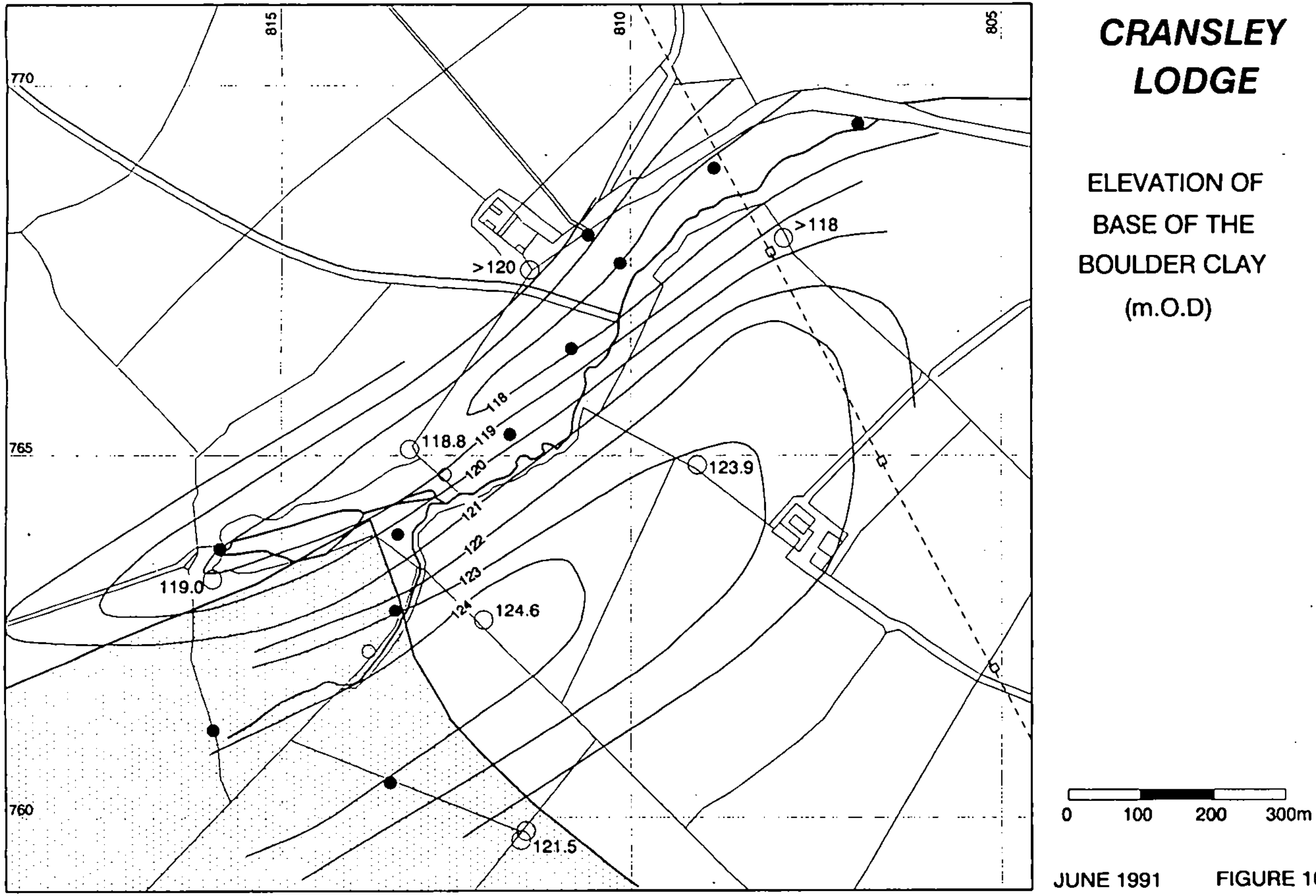


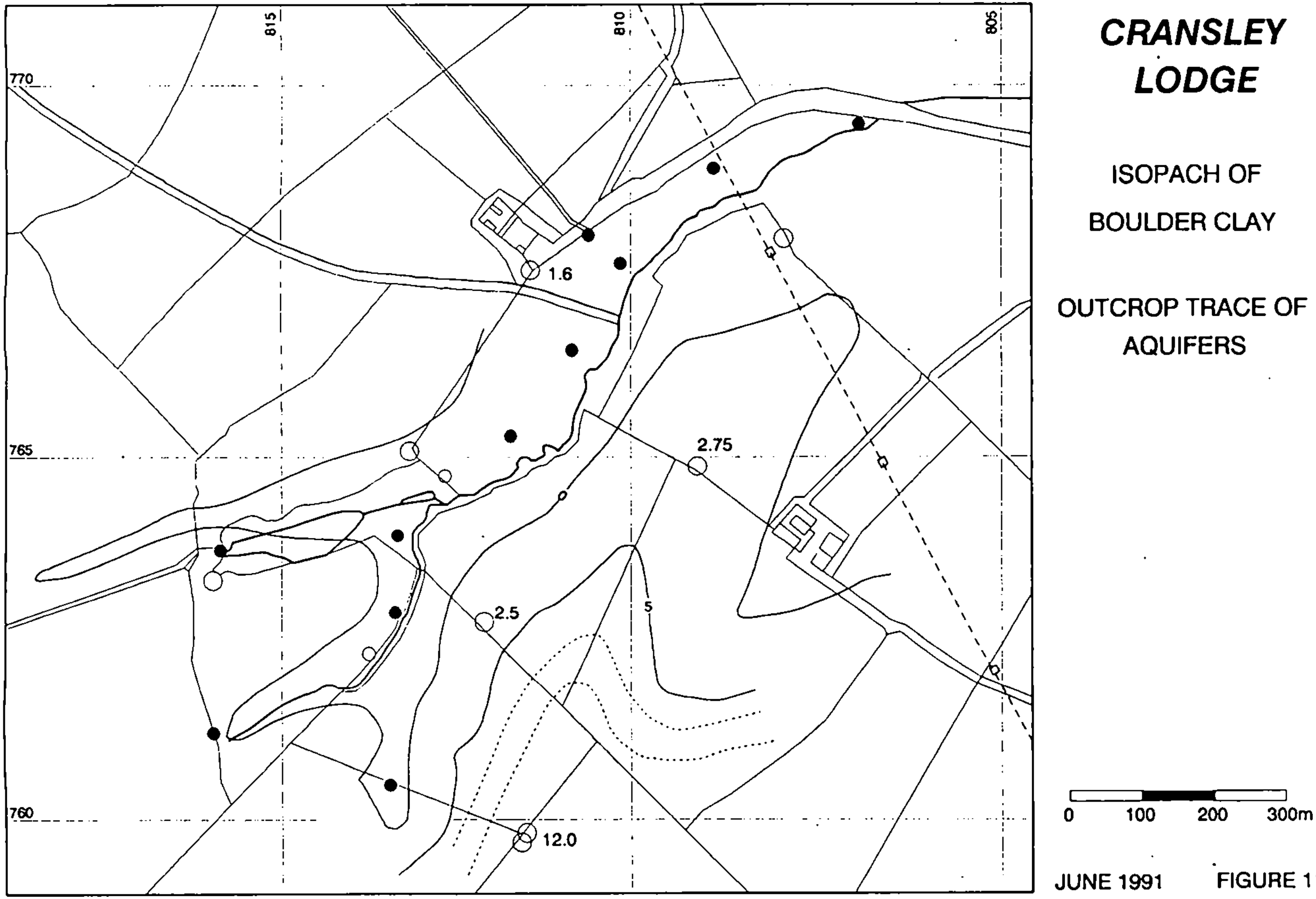
FIGURE 9

CRANSLEY LODGE

ELEVATION OF BASE OF THE BOULDER CLAY (m.O.D)



JUNE 1991 FIGURE 10



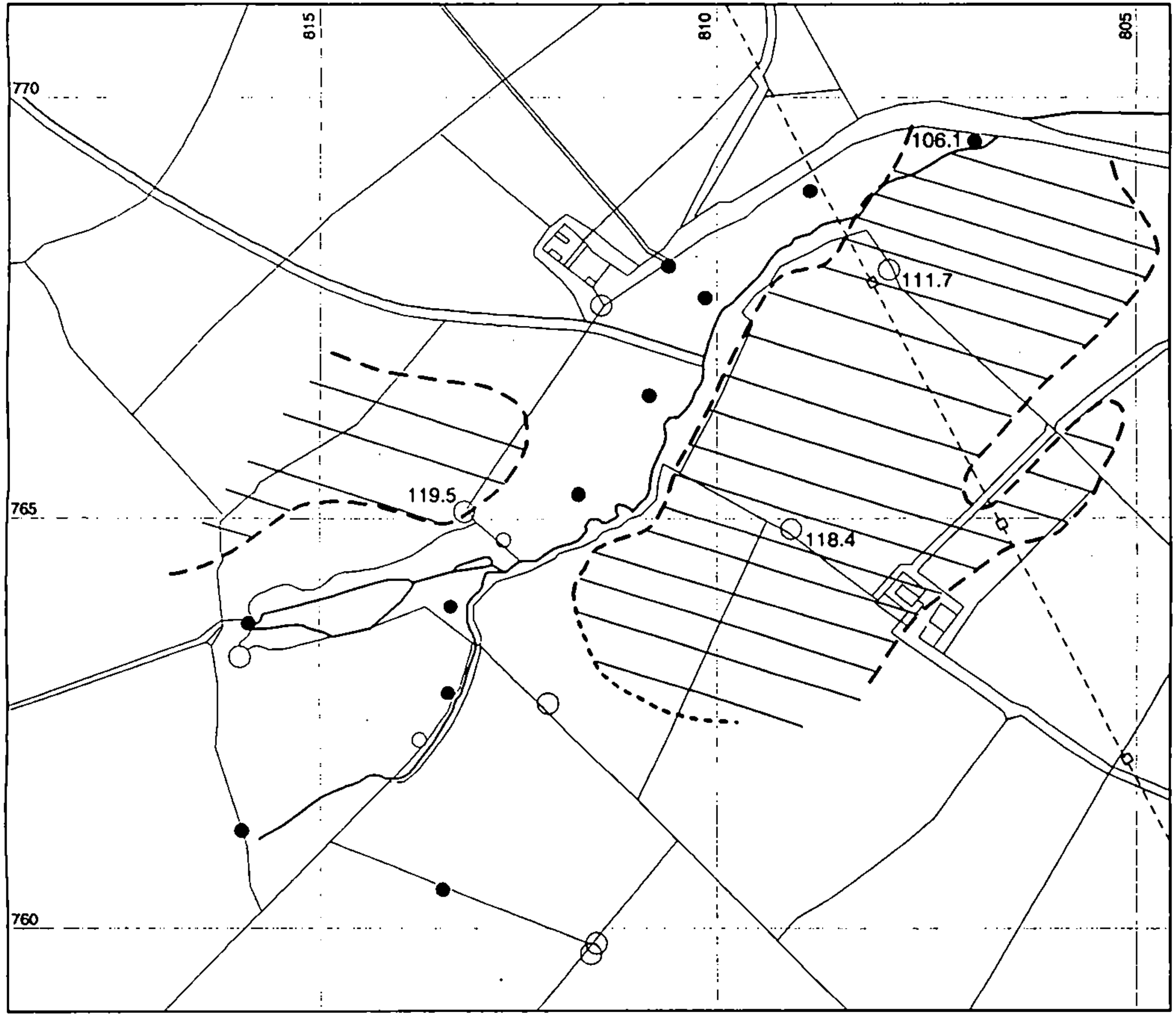
CRANSLEY LODGE

ISOPACH OF

BOULDER CLAY

OUTCROP TRACE OF AQUIFERS

JUNE 1991 FIGURE 11



CRANSLEY LODGE

ELEVATION OF BASE OF THE LOWER ESTAURINE SERIES m.O.D

(TOP OF CLAY AQUICLUDE)

0 100 200 300m

JUNE 1991

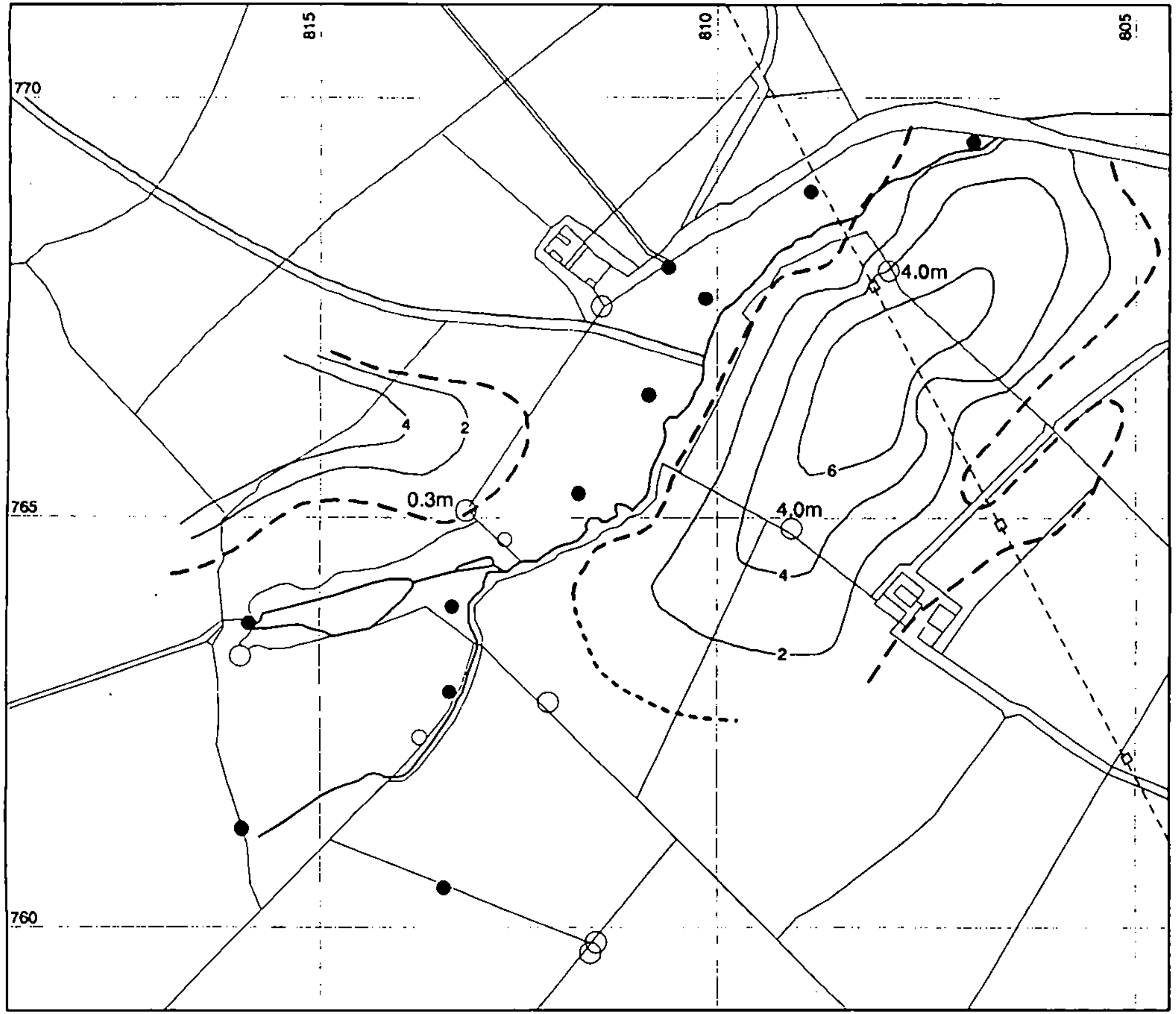
FIGURE 12

CRANSLEY LODGE

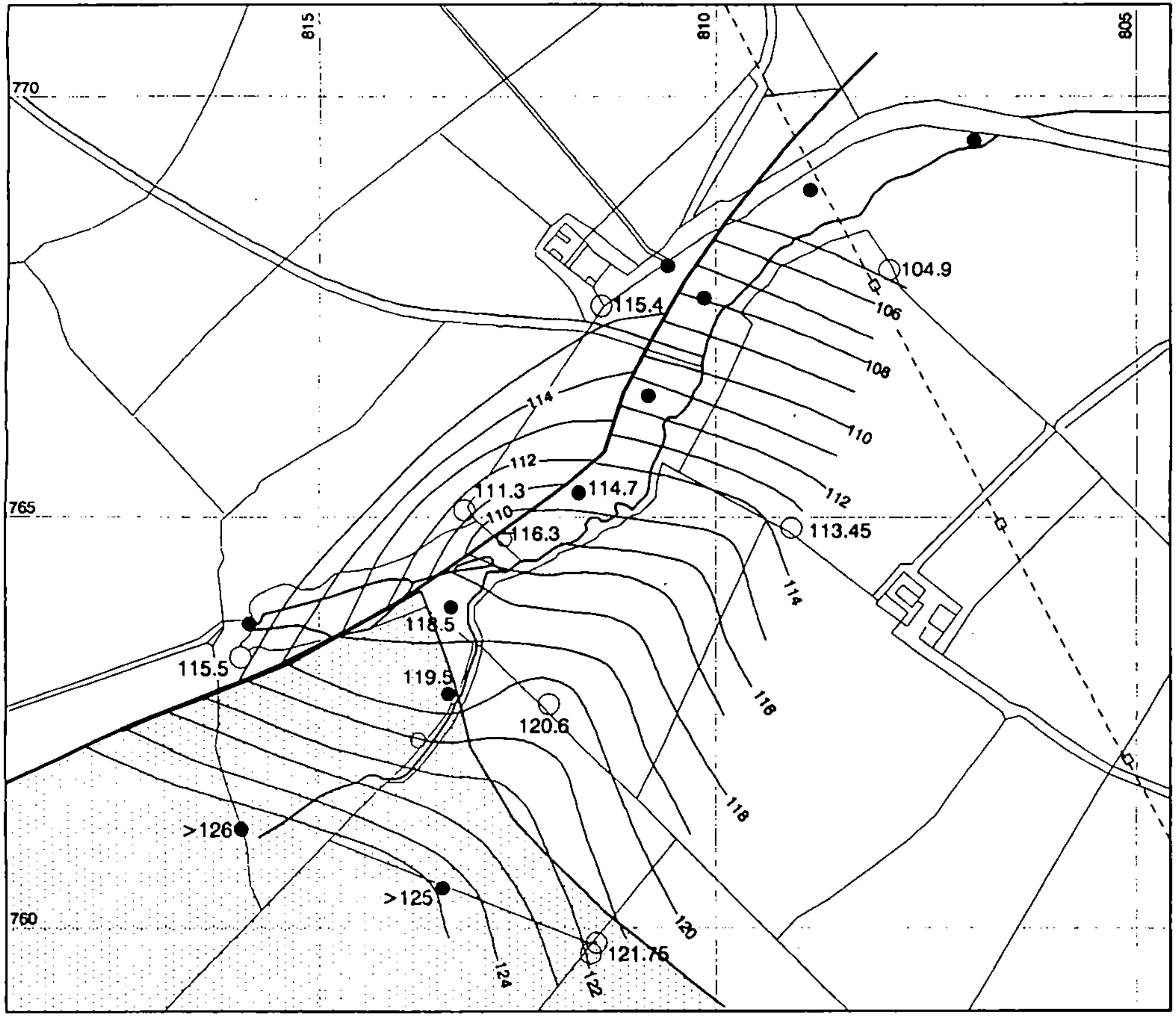
ISOPACH

OF THE LOWER

ESTAURINE SERIES



JUNE 1991 FIGURE 13



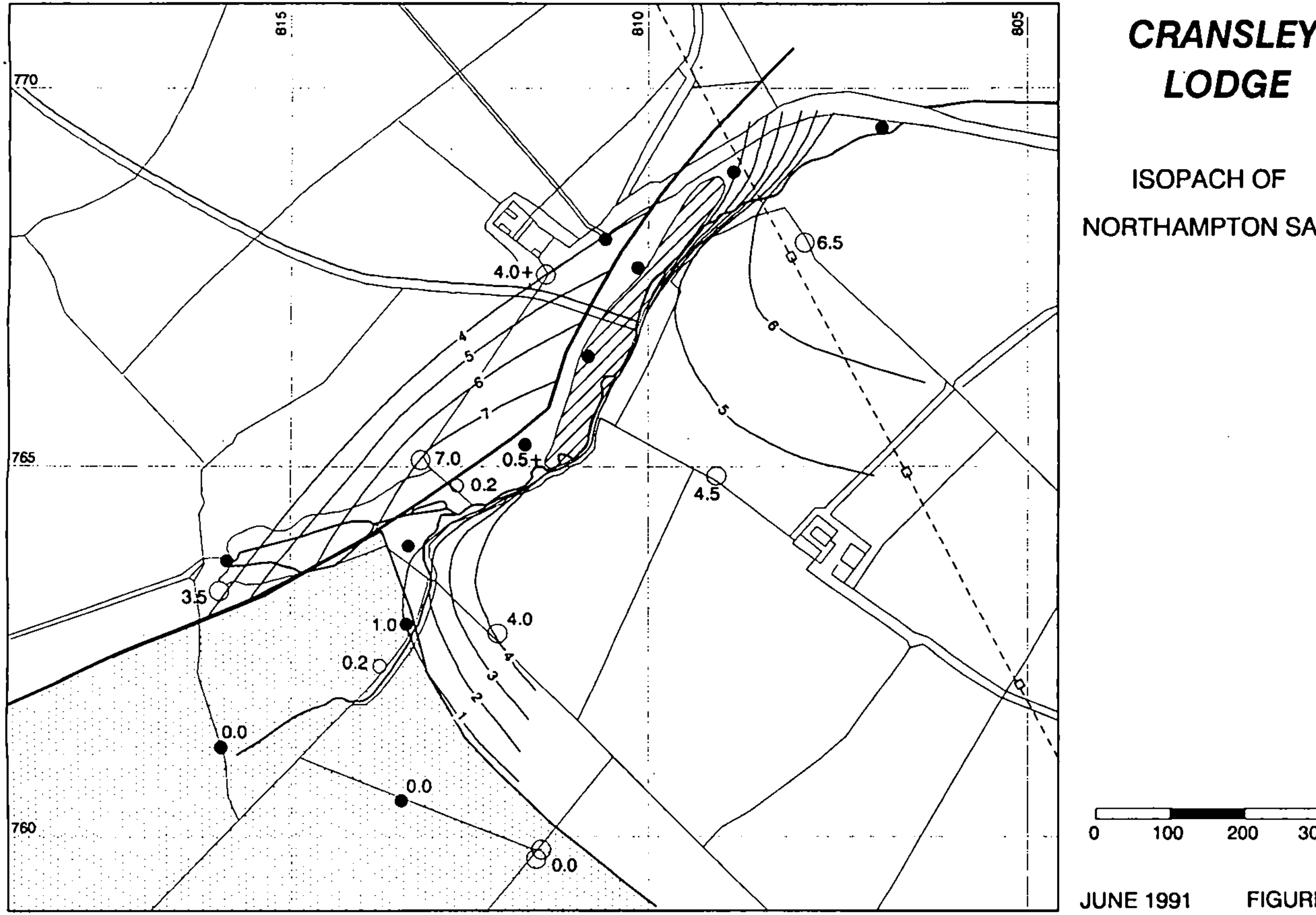
CRANSLEY LODGE

ELEVATION OF BASE OF THE NORTHAMPTON SAND (m.O.D)

0 100 200 300m

JUNE 1991

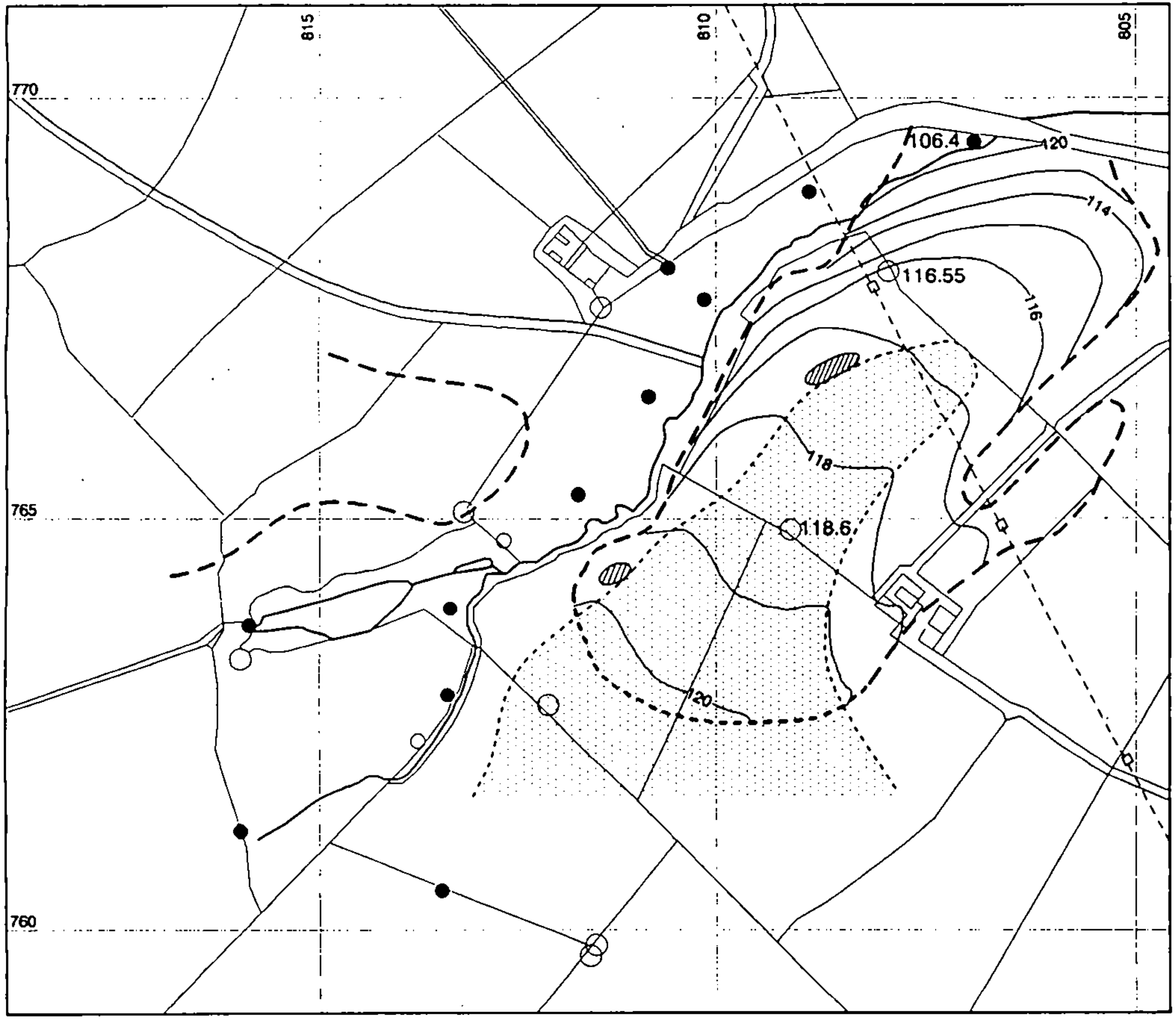
FIGURE 14



CRANSLEY LODGE

ISOPACH OF
NORTHAMPTON SAND

JUNE 1991 FIGURE 15



CRANSLEY LODGE

WATER LEVEL CONTOUR PLAN

THE LOWER ESTAURINE SERIES

m.O.D

OUTCROP TRACE OF BASAL CLAY AQUICLUDE

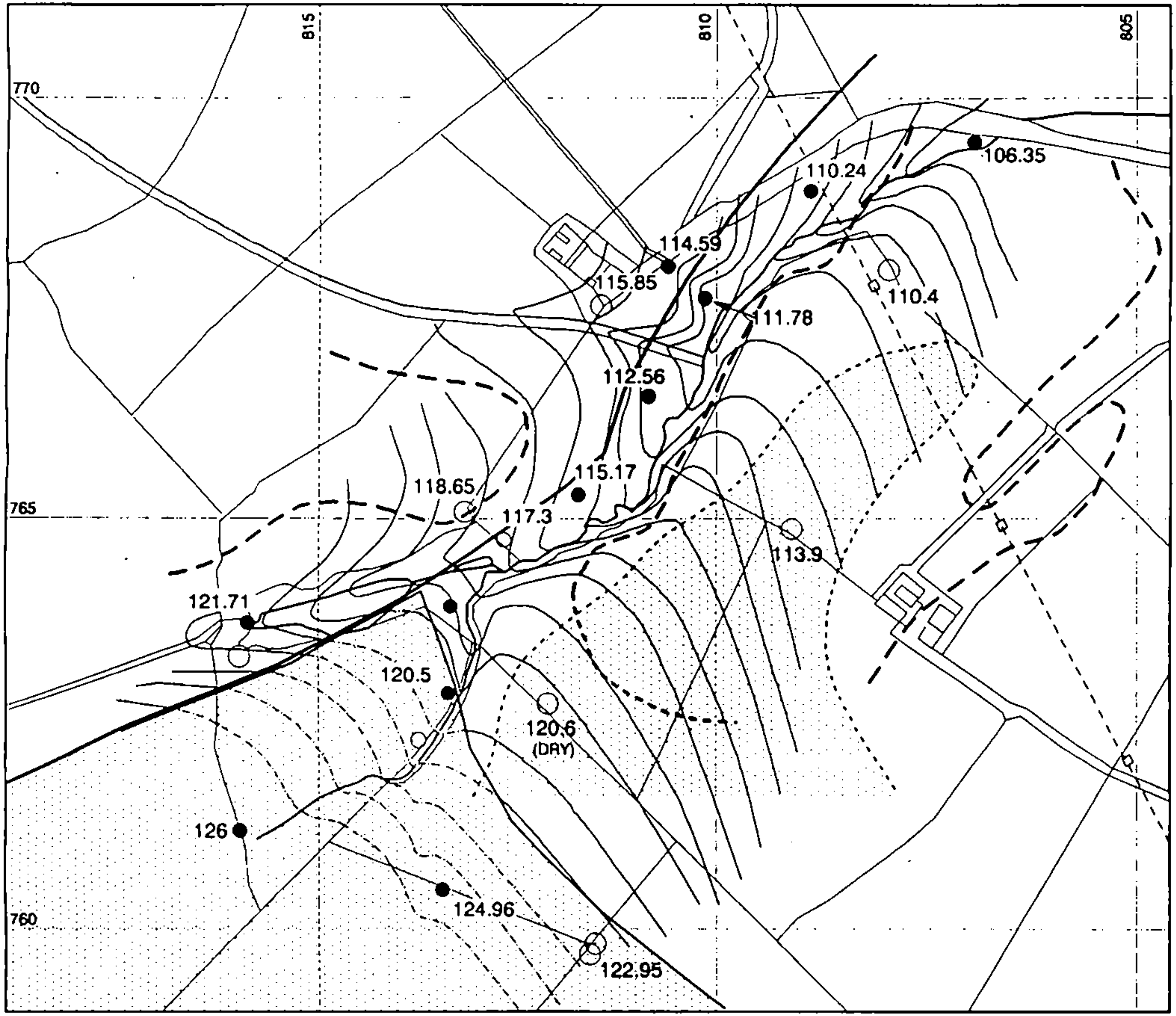
BOULDER CLAY

AREAS OF FOCUSSED RECHARGE

0 100 200 300m

JUNE 1991

FIGURE 16



CRANSLEY LODGE

WATER LEVEL CONTOUR PLAN NORTHAMPTON SAND m.O.D

OUTCROP TRACE OF BASAL CLAY AQUICLUDE

BOULDER CLAY

0 100 200 300m

JUNE 1991

FIGURE 17

FLOW AT CRANSLEY LODGE - GAUGING STATION S1

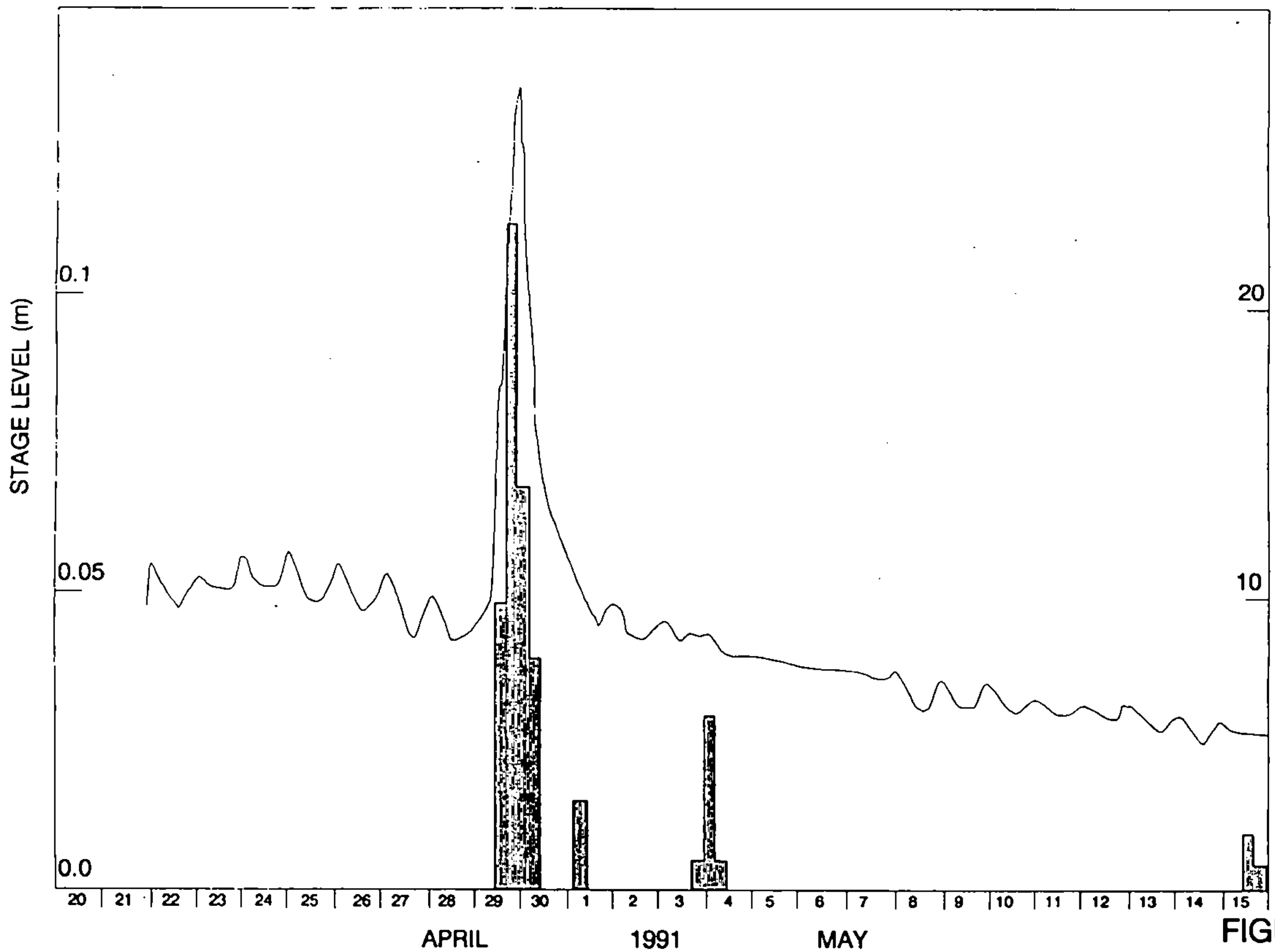


FIGURE 18

FLOW AT VILLAGE STREAM - GAUGING STATION S2

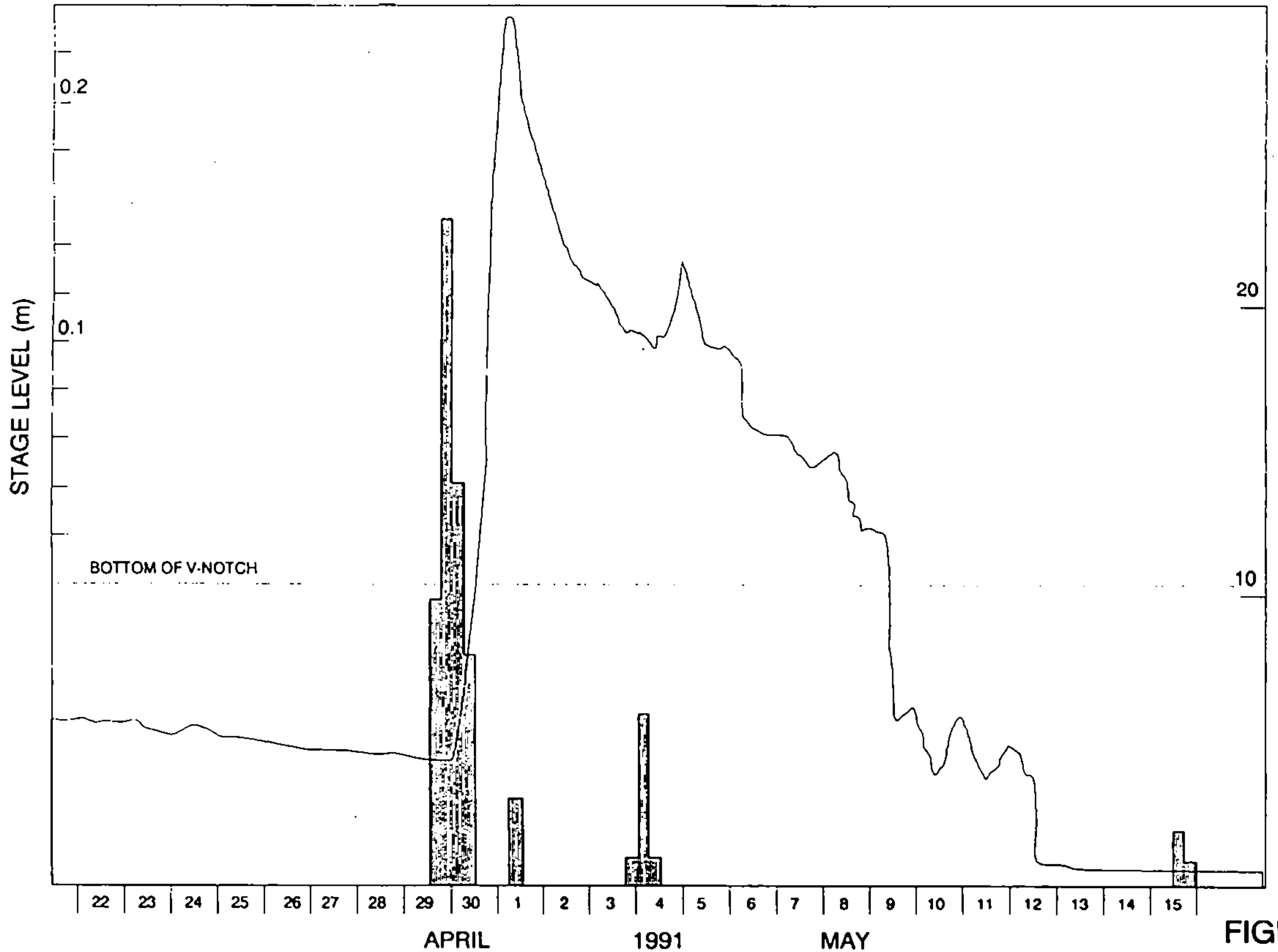


FIGURE 19

FLOW AT MAWSLEY LODGE - GAUGING STATION S3

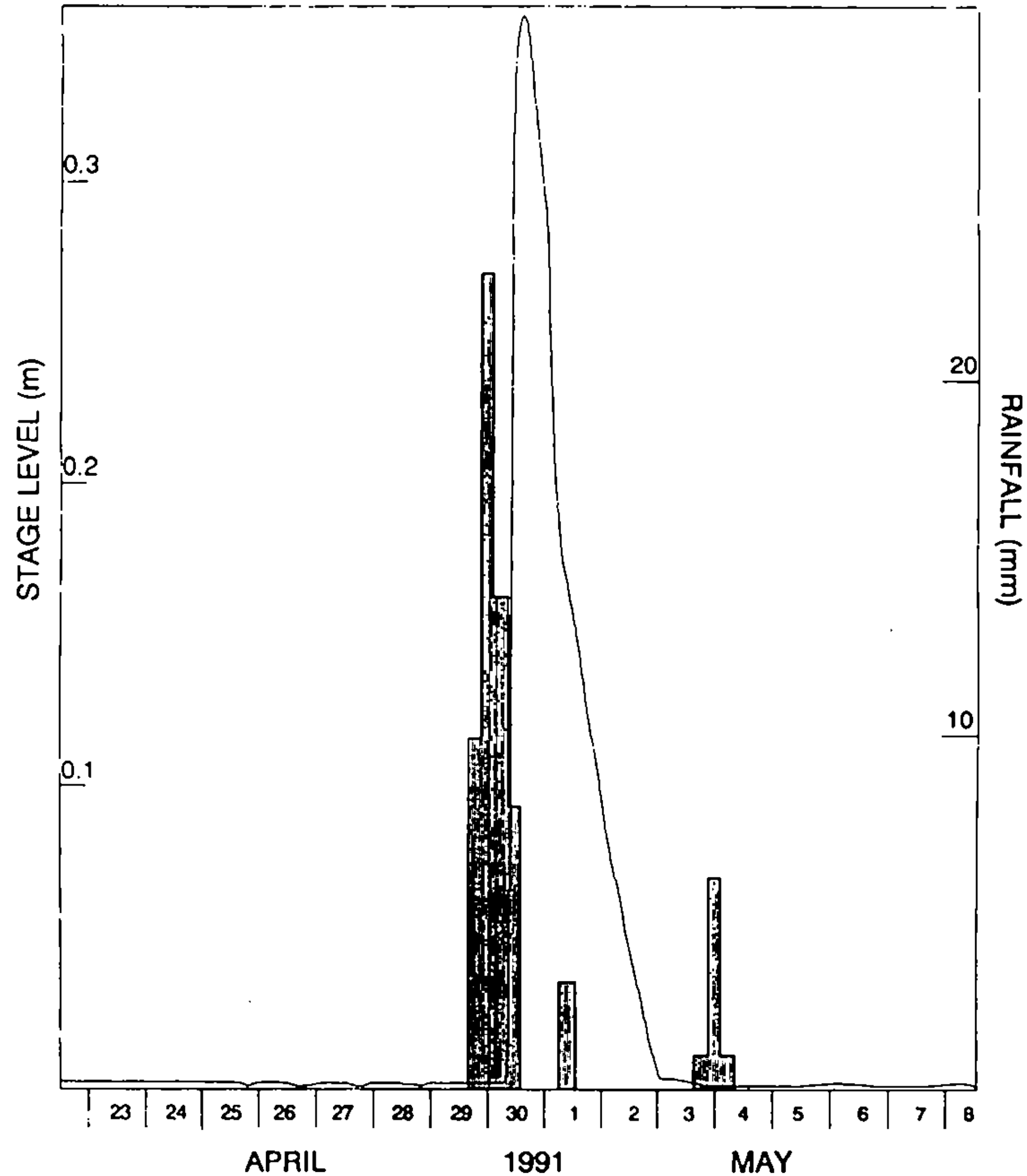


FIGURE 20

FLOW AT RAILWAY BRIDGE - GAUGING STATION S4

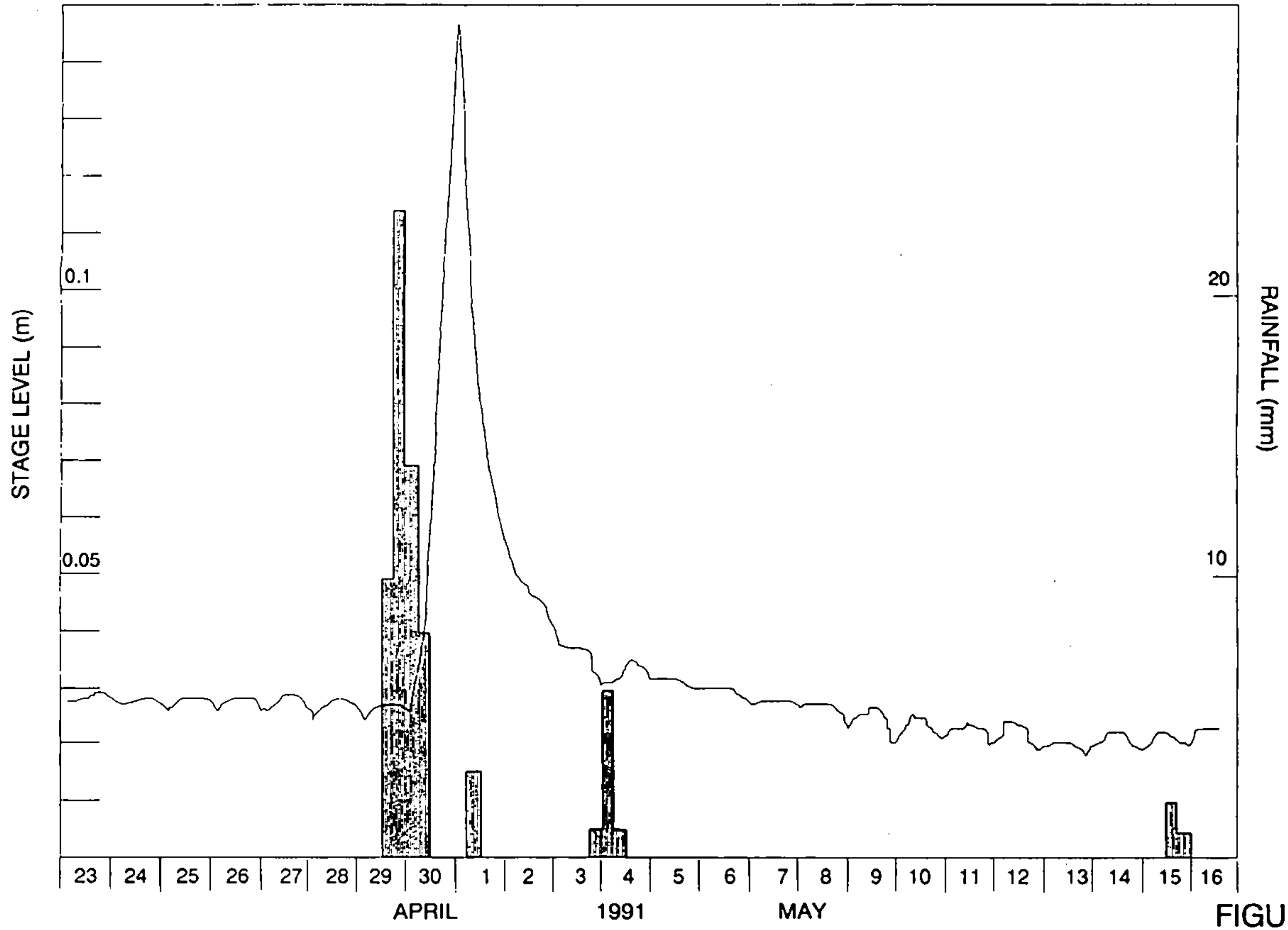
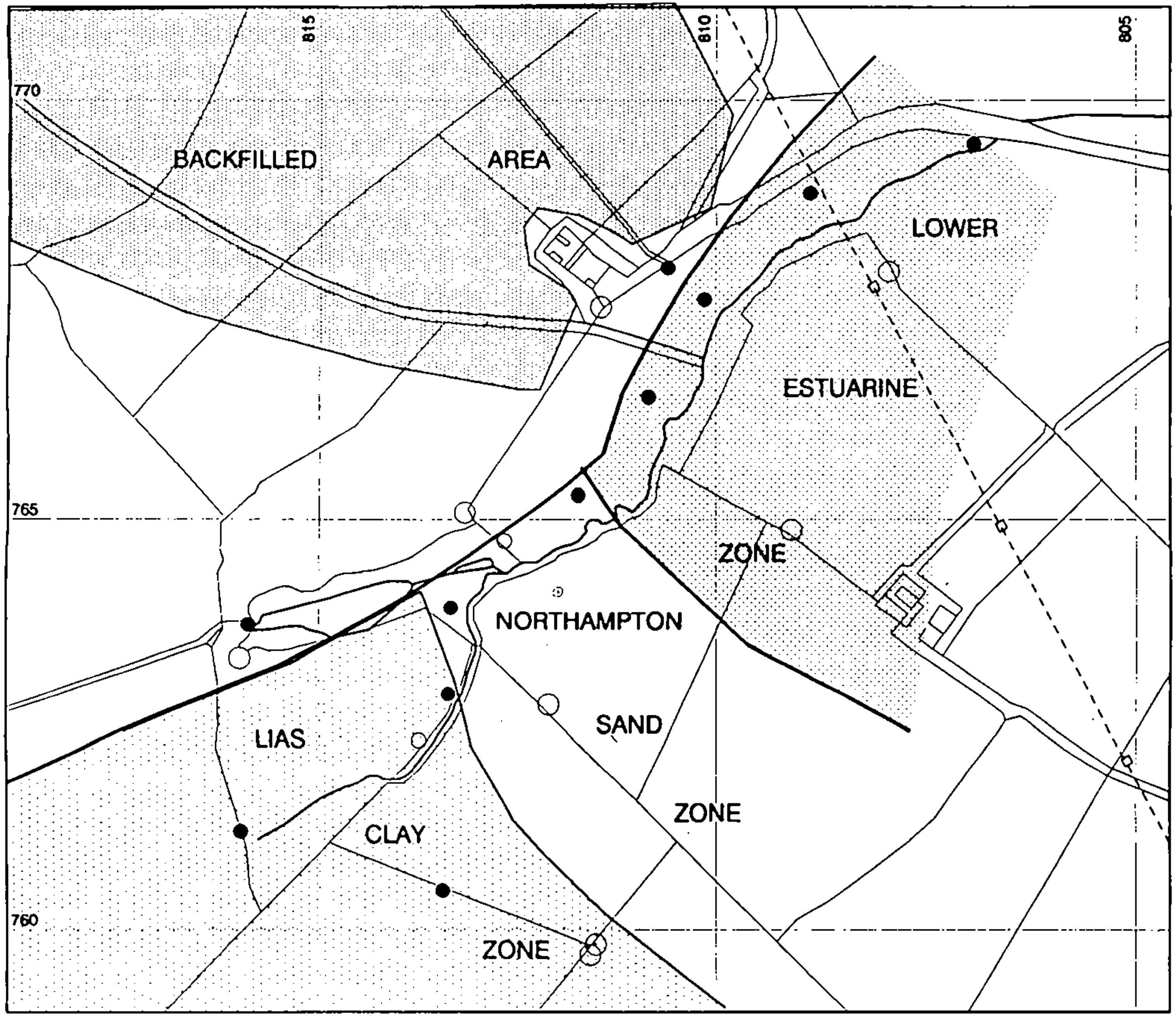


FIGURE 21



CRANSLEY LODGE

HYDROLOGICAL ZONES

0 100 200 300m

JUNE 1991

FIGURE 22

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