INSTITUTE of HYDROLOGY

WESTHAMPNETT BY-PASS, CHICHESTER.

HYDROGEOLOGICAL STUDY

Final Report

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A27 WESTHAMPNETT BY-PASS, CHICHESTER.

HYDROGEOLOGICAL STUDY

Final Report

Institute of Hydrology,
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SUMMARY

A study of the hydrological conditions along the western part of the proposed Westhampnett By-Pass north-east of Chichester indicates that the period of more average rainfall since 1976/7 has been an important contributing factor to the rise in pit water levels in the area. The future water level situation is therefore rather unpredictable.

An impermeable embankment along the northern side of the causeway separating the Church Farm Pit (Westhampnett Water Park) from Shopwyke North Pit is likely to cause a rise in water levels in Church Farm Pit due to a reduction in pit storage and by reducing the rate of seepage losses. This will increase the frequency and duration of flooding in the vehicle park area in the northwestern part of this pit and could even result in overtopping in the southeastern and southwestern corners of the pit.

A permeable embankment could also increase water levels by reducing pit storage but, provided the seal along and adjacent to the southern bank is undisturbed, is unlikely to cause a rise in water levels in Shopwyke North Pit.

Any temporary dewatering for the construction of the embankment is unlikely to draw leachate from the adjacent infilled pits.

A preliminary assessment of the use of soakaways as a control measure indicates that the soakaway trench proposed for the disposal of run-off from the road could be used to remove the volume of water resulting from the loss of pit storage caused by a permeable embankment, provided the discharge is limited to this amount.

A more detailed hydrogeological study is advisable and this should include water level monitoring, numerical model studies, a survey of groundwater quality in the causeway area, and more information on the permeabilities of the gravel deposits in the area of the soakaway trench.

WESTHAMPNETT BY-PASS, CHICHESTER
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Chapter 1

BACKGROUND INFORMATION

1.1 INTRODUCTION

This study of the hydrogeological conditions of the western part of the proposed route of the Westhampnett By-Pass has been undertaken by the Institute of Hydrology (IH), a component organisation of the Natural Environment Research Council. It was carried out as sub-consultants to Gifford Graham and Partners, who are the Consulting Engineers to the client, the Department of Transport, South East Regional Office (Dorking).

1.2 GENERAL

It is proposed to build a new dual carriageway to by-pass Westhampnett village some 4km north-east of Chichester as part of a road improvement scheme for the A27.

The proposed route of the new road is shown in Figure 1.1. At its western end it will include a link road joining the existing Sainsbury roundabout on the A285 to a new roundabout junction on the A27 East Chichester By-Pass. From this junction the route will pass north-east along the southern edge of Westhampnett Water Park (or Church Farm Pit) then along Dairy Lane and across arable land south of Maudlin to join the existing A27 some 3km east of Westhampnett.

The proposed route follows a causeway some 650m in length which separates Westhampnett Water Park, an open water filled gravel pit, from Shopwyke North Pit, a worked out pit now used for gravel washing. It is proposed to build an embankment along the northern side of this causeway to accommodate the road. This embankment will intrude some 30 to 50m into Church Farm Pit.

There is a perception amongst local interests that the infilling of gravel pits in the general area crossed by the western part of the new roadline has caused a rise in water levels in the open pits. The rise in water levels has increased the risk of flooding of buildings and installations situated on the northern side of Church Farm Pit and in the Shopwyke North Pit. Objections have been made to the Draft Orders published in April 1989 under the Highways Act on the grounds that the proposed embankment will further exacerbate the flood risk.

Possible objections concerning the potential impact of the proposed roadline on the hydrology of the area can be summarised as follows:

- whether the embankment along the causeway, either during its construction or more permanently, will cause a rise in water levels in Church Farm Pit and increase the risk of flooding in the north-west corner of this pit.

- whether any rise in water levels in Church Farm Pit that might result from the embankment will give rise to flooding problems in Shopwyke North Pit.

- whether the embankment will increase the degree of hydraulic connection between the two pits causing a rise in water levels in Shopwyke North Pit.

In addition, the proposed design of the roadline may need to be modified to prevent or reduce any potential impact on the local hydrology and to assist the Southern Water Authority (SWA) to alleviate flood risks.

The hydrogeological conditions in the area are complex, and before the potential impact of the new road construction on water levels in the gravel pits can be ascertained, the changes in the groundwater regime resulting from gravel extraction and site restoration in the Westhampnett area need to be examined more fully.

1.3 SOURCES OF INFORMATION

The study has not included any new field investigations and has been based on existing information only. A list of references is given at the end of this report.

The main sources of information were as follows:

- Information on the ground conditions along the route of the proposed roadline was obtained from geotechnical reports prepared by Thyssen Ltd and Frank Graham Geotechnical.

- A series of reports on the gravel pits in the Chichester area was provided the Southern Regional Office of the National Rivers Authority.

- The geology of the area is described in Report 138 on the Chichester and Bognor Regis area (Sheets SU80 and 90) prepared by the Industrial Minerals Assessment Unit (IMAU) of the British Geological Survey.

- The general hydrogeology of the region is described in a recent report prepared by Southern Water Authority.

- Hydrometeorological data were obtained from the Meteorological Office and from the National Surface Water Archive and National Borehole Archive held at Wallingford.

It is understood that Ready Mixed Concrete (RMC) Ltd has carried out a study of the flooding problems in the Church Farm Pit. Records of the mineral investigations for the gravel pits in the area, which could provide additional historical groundwater level data and borehole logs, may also be available from the owners of the gravel pits. However, at the request of the Consulting Engineers, no approach was made to obtain additional information from local companies or organisations who might be involved as objectors to the proposed roadline.

1.4 GRAVEL PITS

Gravel has been extracted in the area north-east of Chichester for some considerable time, although the pits are now worked out and most have been infilled. Recently, an application was submitted by Tarmac Ltd, the present owners of the Shopwyke North Pit, to renew their planning permission to extract sand and gravel from the area of land between this pit and Coach Lane (Figure 3.1) in the event of an industrial dispute affecting the import of gravel from other sources.

The distribution of gravel pits is shown in Figure 1.1. Those pits within the immediate area of the roadline have a total area of about 1 km2 (Table 1.1). These are described briefly below.

Pits west of Eastern By-Pass. The Pound Farm Pits between the River Lavant and Westhampnett Mill, the pit at Sainsburys, and the Portfield Pit further south towards the railway line appear to be older pits and are all now infilled, although the Sainsbury Pit was not infilled until the early 1980's.

Coach Lane Pit (SWA Pit 2). This pit east of Coach Lane was formerly owned by Hall and Company and was partly infilled with domestic and other waste by the Chichester District Council starting in 1975. Further infilling is presently taking place.

Church Farm Pit (SWA Pit 1, Westhampnett Water Park). This pit was also owned by Hall and Co but subsequently taken over by Ready Mixed Concrete (RMC) Ltd. It was worked dry by dewatering with the western half of the site being worked first. It was reported that the main excavation began in 1967.

This pit is the only water-filled pit remaining in the area and is currently used for water sports. The Chichester District Council depot is located on the northern side of the pit adjacent to the A27. A waste Pulverisation Plant, which was constructed in 1974 between the depot and the lake on a former working level at an elevation of about 14.5m OD, ceased operations in about 1983/4.

In 1979 a vehicle parking area and two warehouses (leased by Booker McConnell) were built on a former low lying, water logged area acquired by National Provident Institution in the north western corner of the pit. This was raised by infilling to an elevation of about 15.9m OD.

Shopwyke North Pit (SWA Pit 3). This pit, together with other pits to the south, was originally worked by Heavers Ltd. It was subsequently taken over by Francis Parker Ltd and is now owned by Tarmac Ltd.

The pit has been used for some years for screening and washing gravel brought in by rail from pits at Lavant. About 14000 m3/d of water is required for this purpose and is obtained by recycling from the Shopwyke South-East Pit.

Fines from the washing process are discharged into the eastern part of the pit. A bund separates the northern and southern parts of the silt pond and a new north-south bund has been built to separate the northeastern corner. The southern lagoon has now been largely infilled with silt. The northeastern part has a silt surface level of about 12.5m OD.

Various industrial buildings and plant are located in the western part of this pit at elevations of about 13.5 to 14.5m OD, which would appear to be either a former working surface or infilled and raised land with a surface level now about 2.5m lower than the original ground surface.

It is reported that the Shopwyke North Pit was worked wet from floating barges and that a seal was emplaced around the edges to maintain water levels for this purpose. The causeway separating the Church Farm and Shopwyke North Pits appears to be undisturbed Head and Fan gravels.

1.5 GEOLOGY

The geological succession is given in Table 1.2 and the geology of the area is shown in Figure 1.1 (from IMAU 1983).

The drift sequence unconformably overlies an eroded, gently dipping surface of sedimentary rocks. The dip slope of the Upper Chalk of the South Downs occurs about 3km north of the site. The Upper Chalk is also exposed in the Boxgrove-East Hampnett area about 1km north east of the roadline.

The Upper Chalk together with the London Clay and Woolwich and Reading Beds form the southerly dipping, northern limb of a synclinal structure having an east-west axis passing through Chichester (Chichester Syncline).

Raised cliff-lines, which trend east-west, occur at the foot of the South Downs and through Westhampnett. The lower cliff-line separates the older (older) raised beach deposits to the north from the younger (lower) raised beach deposits to the south.

The hydrogeological conditions associated with the unconsolidated sequence of deposits are those of most importance to the potential impact of the proposed roadline on the local hydrology.

These deposits can be considered to form a single aquifer system in overall hydraulic continuity but with varying aquifer characteristics. The Tertiary sediments can be considered as an impermeable base to this sequence.

1.5.1 Drift Deposits

Different nomenclatures have been used in earlier reports for the sequence of drift deposits. As these deposits show broadly similar lithologies, the stratigraphic identification of different parts of the sequence based on lithostratigraphy is often difficult.

The equivalent stratigraphic names used by the roadline geotechnical survey by Thyssen and in the geological report by IMAU are as follows:

Thyssen	IMAU
Valley Gravels	Fan Gravels and Head (or Coombe) Gravels
Marine Gravels	Lower Raised Beach Deposits

A brief description of the geological sequence is given below.

Brickearth. The brickearth deposits are the most widespread drift deposit. They have a very uniform thickness of about 1 to 2m and are generally non-calcareous, structureless, yellow brown clayey silts with little sand or coarser material.

These deposits have been removed over the area of the gravel workings as "overburden", which in combination with the clayey raised beach deposits have been used to seal the edges of the gravel pits.

Head (Coombe) Deposits. These are widespread and increase in thickness northwards. South of the lower cliff-line they are less continuous and up to 4m thick.

The head deposits are very variable but consist mainly of coarse, angular flint gravels in a clay matrix. The average fines content is about 25% with an average of about 55% fine to coarse gravel. The general sequence consists of two layers of clayey gravel separated by a silt layer and a basal laminated silt.

Fan Gravels. The fan gravels are of fluvial origin and are recorded as being about 10m thick at Westhampnett Mill . They have an outcrop of about 200 to 300m wide along upper part of the River Lavant but this broadens into a fan with a radius of some 3km extending beneath much of Chichester. The area of gravel pits largely coincides with the eastern edge of the fan gravels (see Figure 1.1).

The composition of the fan gravels is very variable, ranging from almost solely gravels to very clayey gravels with nearly 25% fines content. The average composition is about 10 to 15% fines and about 60% gravel.

Lower Raised Beach Deposits. These deposits are thickest over the Tertiary subcrop where they are mainly concealed beneath head gravels. They are usually only 1 to 2m thick (maximum thickness east of Chichester is about 4.5m) and consist of yellow to yellow brown, bedded sands, sandy gravels and loams with occasional lenses of clayey material. The fines content averages about 20% and the gravel content about 15%.

Upper Raised Beach Deposits. These deposits are generally obscured by head deposits and occur north of the lower cliff-line above elevations of about 20m OD. They are usually about 2m thick and consist of olive brown to medium brown fine silty sand containing an average of about 25% fines (mainly silt) and about 10% gravel.

Raised Storm Beach Deposits. These occur as a series of outcrops forming a hummocky ridge about 1 km wide just north of the line of the A27 east of Westhampnett where they directly overlie bedrock. They are up to 7m thick and consist mainly of clean sandy gravel but also include very clayey gravels to sandy silts. The average fines content is about 15% (mainly silt) and average gravel content is about 40 to 45%.

Made Ground (including Fill and Industrial Waste). Extensive areas of the shallower drift and overburden have been replaced to depths of up to several metres by variable material as a result of the sealing, infilling of gravel pits and road construction or other activities. The made ground is often red-brown, soft to firm silty and sandy clay with fine to coarse gravel.

1.5.2 Tertiary and Cretaceous Sediments

London Clay. The London Clay consists of bluish to dark grey usually laminated clay containing sandy seams and shelly sandstones. The surface weathers to a grey brown colour.

Woolwich and Reading Beds. These sediments underlie the London Clay but subcrop along the base of the younger shoreline at Westhampnett. They are usually dark grey clays with red or green mottling and weather to an orange brown colour. The basal bed consists of dark grey sands and loams.

Upper Chalk. The Upper Chalk outcrops north and north-east of the roadline and underlies the Tertiary sequence beneath the roadline.

1.6 INFORMATION ON AQUIFER PROPERTIES AND HYDROLOGY

1.6.1 Aquifer Properties

Information on the hydraulic properties of the drift deposits and made ground is available from a pumping test and input tests carried out by SWA at the Pulverisation Plant and from input tests undertaken during the roadline investigations.

Two pumping tests at different rates were undertaken by SWA in 1975 on a well at the disused Pulverisation Plant for the design of a dewatering scheme to prevent flooding of the plant. The test site included 15 piezometers arranged on three arrays at distances of up to 30m in a north, south-west and south-east direction. The full data for this test are not available but some information is contained in the test report of May 1977 .

Several values of transmissivity (T) were derived by SWA using the steady-state Thiem equation for the piezometers on the northern array, which was considered to be the most representative of the aquifer conditions. A T value of 250 m2/d was selected as the most representative.

However, the distance drawdown data for the northern array have been reanalysed using the Jacob equation. A T value of 650 m2d and a specific yield (Sy) value of 3.5% were obtained based on the data from the piezometers at 5, 10 and 20m and assuming the data are for an elapsed time of 300 minutes. The average saturated thickness of the gravels at this location was 3.5m indicating an average hydraulic conductivity (K) of 185 m/d.

Falling head permeability tests were undertaken on the gravels, clays and made ground encountered in five boreholes drilled at the Pulverisation Plant pumping test site. Falling head and constant head permeability tests were also made on the gravel deposits encountered in the roadline investigation boreholes BH1, BH2, and BH5. The results of these tests are given in Table 1.3.

The permeability tests at the Pulverisation Plant indicated the following broad range of values:

Made Ground		(2 results) 2 m/d
Clay	(3 ")	0.1 to 3 m/d
Fan Gravels	(3 ")	0.3 to 30 m/d
Beach Gravels	(5 ")	0.1 to 10 m/d

The values obtained for the clays are high whilst those for the gravels seem rather low, although there is usually a high fines content in the gravel sequence. The permeability values for the gravels are an order of magnitude less than the permeability value derived from the pumping test at the same site, which is likely to be more reliable.

The permeabilities obtained from the site investigation boreholes suggest generally low permeabilities for the waste fill ranging from about 0.1 to 1.0m/d, although one test gave a value of about 120m/d. The lower values have a similar range to those obtained for the clays. The permeability values for the valley gravels are very similar to that obtained from the pumping test.

1.6.2 Rainfall

Rainfall records are available from several locations in the general area (see Figure 1.1). The nearest locations are Tangmere (SU 913 067), from 1974, Portfield Depot (SU 878 051), from 1941 to 1976, and Chichester Ambulance Station (SU 863 064), from 1977.

A long term record dating from 1898 is also available at Bognor (SZ 934 989). The annual average rainfall at this station for 1941 to 1970 is only 6% less than that recorded at Chichester over the same period. It can therefore be used to show longer term variations in rainfall and, since the pattern of monthly rainfall is also similar, to infill gaps in the rainfall record for Chichester.

The long term average annual rainfall at Portfield and Chichester Ambulance

Station are very similar, 787 and 780 mm respectively, and can be treated as a single record. For this study we have combined the records from Portfield and Chichester Ambulance Station, which are situated just to the south-west of the area, to examine the variation in annual rainfall for the period 1966 to 1988. This period includes the earliest records of pit water level fluctuations which date from 1969/70. The annual total rainfall since 1966 is shown in Figure 1.2. (A 3-year moving mean of total annual rainfall is included in Figure 2.3).

The annual rainfall between 1966 and 1968 was more than average. This was followed by a prolonged period of much lower than average rainfall from 1969 to 1973. The rainfall in 1974 was significantly higher than average but was followed by another dry spell in 1975 and 1976. Since 1976, the pattern has been more varied with 1978, 1983, 1985 and 1988 being significantly drier than average, whilst 1977, 1979, 1981, 1982, 1984, and 1986 had more than the average rainfall.

Copy.

Figure 1.3 shows the total winter rainfall, that is the rainfall over the period from September to April (inclusive), compared to the average total rainfall for the same months from 1965/66 to 1987/88. Whilst this shows a similar pattern to the annual variation, there are several important differences. For example, despite the higher than average winter rainfall in 1974/5 and 1987/88, both 1975 and 1988 were dry years overall. Winters having exceptionally high rainfall are 1965/6, 1974/5, 1982/3 and 1987/8. Those with dry winters are 1969/70, 1971/2 to 1975/6 and 1985/6.

1.6.3 River Lavant

The River Lavant is the main source of recharge in this area. It is an ephemeral stream fed by Chalk springs on the dip slope of the South Downs and is the largest such stream in the Chichester area.

The river enters the Westhampnett area from the north-west, passing through the old Pound Farm gravel pit area west of Sainsburys before turning south-west towards Chichester along the Westhampnett road (A285).

The flow just upstream of Westhampnett Mill is diverted into two channels (Mill Stream) which join together below the mill to follow a culvert along the Westhampnett road before rejoining the main channel.

At its closest point the Mill Stream is only 100m from the northwest corner of the Church Farm Pit. The bed of the Mill Stream culvert is unlined and about 1.5m below ground level, or about 17m OD. The bed is therefore about 1m above the level of the vehicle park in the northwest corner of Church Farm Pit and some 1.5 to 2m higher than the present maximum water level in this pit. A hydraulic gradient exists therefore from the river towards Church Farm Pit.

Flows of the R. Lavant have been measured at Graylingwell (topographic catchment area 85 km2), which is situated about 750m upstream of Westhampnett Mill.

Flow may occur on the R. Lavant between September and July, but usually the first major flow occurs in November or December with significant flows continuing through to April. However, whilst periods of sustained flow have been recorded lasting two years (1967/69) there are also long periods when the river is dry, such as in 1972/73 and 1975/6 when there was no flow for 1.5 years.

The flow volume and regime of the R. Lavant are related to groundwater levels in the Chalk. Although the flow is derived mainly from groundwater, high flows of short duration also occur producing a "flashy" response. The maximum mean monthly flow recorded is 2.61 cumecs (February 1988).

A hydrograph of mean monthly flow is shown in Figure 1.4. The duration of flows exceeding certain values is shown in Figures 1.5 and 1.6.

A flow frequency plot is shown in Figure 1.7. This was obtained using the annual maximum mean monthly flow over the period for each year that flow occured (15 years in the available 17 year record). These flows were ranked (r) and the probability, P(x) of an annual maximum equalling or exceeding a given mean flow (x) was determined as a Weibull distribution according to the formula:

$$P(x) = r/(n+1), \text{ where } n=15$$

The probability, f(x), of the mean monthly flow being less than a given mean flow was then plotted against the maximum mean monthly flow. The return periods, T(x), where $T(x) = 1/(1-f(x))$, are also shown in Figure 1.7.

This analysis, which excludes months of no flow, indicates that the mean monthly flow provided flow occurs will on average equal or exceed 1.15 cumecs every other year (return period 2 years). A flow of 1 cumec will occur in 4 years out of 5 (return period about 1.6 years) in those years when flow occurs.

1.6.4 Groundwater Levels

Water levels have been measured in Church Farm Pit (SWA pit 1) for occasional periods since 1969 (a stage board is still present in the north-west corner) and monitoring data for other local pits are also available. However, a long term uninterrupted record has not been maintained and the available records are influenced by pumping.

Whilst there has been no corresponding long term monitoring of boreholes tapping the gravel aquifer in this area, it is understood that the SWA have begun recently to monitor water levels in a shallow piezometer close to the Shopwyke Depot on the south side of Shopwyke North Pit. x wrong

Pit water levels have been monitored by SWA from November 1969 to July 1970, November 1974 to August 1975, and January to July 1983. The 1969/70 records include Church Farm Pit (Pit 1) the Sainsbury Pit and Pound Farm Pit, the two latter pits having apparently been open at this time. The 1974/5 records include Church Farm Pit, Coach Lane Pit (Pit 2), and Shopwyke North Pit (Pit 3) and other pits further south (Pits 4 to 7). The 1983 record only includes Church Farm Pit. A general record of pumping from Church

Farm Pit was also kept during the 1974/5 and 1983 monitoring periods.

Other occasional measurements of pit water levels have been obtained from maps and the roadline investigations and have also been used to assist in establishing the changes in pit water levels described in Chapter 2.

Water levels were monitored by SWA between June and August 1975 at four boreholes situated around the Church Farm Pit in association with a pumping test from 24 to 31/7/75. The water levels in these boreholes fluctuated by about 0.2m during the period between the end of pumping from the pit and prior to the test. The following water levels were recorded on the 20/7/75:

Borehole	Water Level Elevation (mOD)
1	13.55
2	13.58
3	13.25
4	13.65
Pit water level	13.30

In April 1976 water level elevations averaging about 11m OD were observed in five boreholes drilled by SWA at the Pulverisation Plant. The pit water level was 11.7m in February 1976.

Some limited monitoring of groundwater levels has been carried out since November 1986 in several boreholes drilled for the roadline investigations. These are given in Table 1.4.

Chapter 2

CHANGES IN GROUNDWATER LEVELS

2.1 INTRODUCTION

The potential impact of the roadline on pit water levels needs to take into consideration whether the rise in pit water levels that has occured during the past 20 years has become a permanent feature and will continue to rise. This will depend on the extent to which the present situation is due to natural variations in recharge and/or a reduction in the rate of groundwater flow out of the area due to the gravel operations.

The Southern Water Authority has become increasingly concerned about the rise in groundwater levels in the area east of Chichester. They consider that this rise is due to the removal of the upper part of the gravel sequence during the gravel excavations, sealing of the pit perimeters and subsequent infilling of the pits.

The natural pattern of groundwater flow is usually altered by gravel operations. Often this causes a fall in water levels on the upstream side of a pit but a rise in water levels on the downstream side when the pit is unsealed. Excessive sealing on the downstream bank, however, will tend to raise water levels on the upstream side and result in a steep gradient with lowered water levels on the downstream side causing a net rise in the pit water levels. The extent and magnitude of the impact of gravel operations on the local hydrological regime, however, often depends on a wide variety of factors. These include the pit size, shape, depth, orientation to groundwater flow, effectiveness of the sealing of the bed or edges, and whether the pit is left water filled or infilled. Where left open they can provide additional storage in the system but increase losses by evaporation. Shorter term effects include dewatering of the pit to assist excavation or the direct transfer of water between different pits.

The aquifer response to such changes is often complex and gradual but has seldom been studied in detail. It may often prove difficult to distinguish the effects of extraction and infilling from the response of the aquifer system to natural hydrological events without a sufficient period of monitoring prior to extraction.

If the rise in water level is due only to the infilling of the nearby pits, then the situation could be approaching or have even reached a new steady state condition, although this could be disturbed by the proposed extraction of gravel to the south-east of Church Farm Pit. However, if the water level changes are due solely to natural variations in recharge, then the future situation is more unpredictable.

The direction of groundwater flow in this area is broadly from north-west to south-east, but since each pit will have different conditions of sealing and therefore continuity with the aquifer, the local pattern and rate of groundwater flow will be rather complex and variable.

After removal of the upper part of the gravel sequence and the subsequent sealing and infilling of the pits, the groundwater flow would become restricted to the remaining "corridors" of more permeable, unworked Fan and Head deposits. However, the present water table configuration cannot be determined from the limited water level information with any reliability.

2.2 HISTORY OF FLOODING PROBLEMS

The water levels in Church Farm Pit and Shopwyke North Pit are of particular concern since both contain buildings and other installations on raised or former pit working levels which are at risk from a rise in water levels.

After the very wet conditions of September and November 1975 the water level of Church Farm Pit reached 13.93m OD, which presented a risk of flooding of the electrical installations of the Pulverisation Plant. Water levels were maintained at a safe level by pumping to the River Lavant. This was required until July 1975. Pumping was also necessary during the winter of 1976/7. Subsequently, a dewatering scheme was installed in 1978 at the Pulverisation Plant and used as required until the plant ceased operations in 1983/4.

The high rainfall in October to December 1982 resulted in the flooding of the vehicle park adjacent to one of the warehouses in the northwest corner of Church Farm Pit. As a temporary solution permission was obtained from the owners of Shopwyke North Pit to pump water into their pit. However, this led to the risk of flooding of installations in the Shopwyke North Pit. An overflow drain in the southwest corner of Church Farm Pit which connects the two pits was blocked off by Tarmac Ltd to prevent such flooding. This appears to have been carried out during the period of high water levels in May 1987.

Springs are reported to break-out along the side of the gravel pit adjacent to the vehicle park under conditions of high rainfall or high flows in the R. Lavant. Flooding was reported in the vehicle park area in April/May 1987 when the pit water level reached almost 15.5m OD. It is understood that pumping from the drainage system in the vehicle park has taken place on subsequent occasions. The flooding situation in the north-west part of Church Farm Pit has probably been aggravated by several other factors. These are discussed in Chapter 3.

The SWA (and its predecessor, the Sussex River Authority) has been investigating the flooding problems in this area for more than 20 years. During this period several groundwater studies have been undertaken to provide short term flood alleviation measures and to consider longer term solutions to the problem of flooding.

Measures proposed by the pit owners have included pumping directly to the R.Lavant or pumping to the southern pits to utilise their storage and interconnecting these southern pits so that water could be transferred eventually into Forebridge Rife. However, these proposals have not been accepted by the SWA as they would be likely to increase the risk of flooding in other areas, such as in Chichester itself or the Merston area.

More recently, SWA has proposed that a longer term solution may be possible by transferring excess water from the pits into soakaways situated in the unworked gravel to the southeast of Church Farm Pit . This means of control has worked successfully for the Shopwyke South-East Pit. A permanent lowering of the water level in Church Farm Pit by this control measure would create some additional storage capacity to accommodate exceptionally wet conditions.

It is understood that the proposed roadline could include a culvert to allow water to be transferred from Church Farm Pit to soakaways south of the roadline, but further studies are required to ensure that there is no detrimental effect on water levels further south. However, the recent application to extract gravel from the area immediately south-east of Church Farm Pit may affect the use of soakaways to control water levels in Church Farm Pit.

2.3 RECORD OF HISTORICAL CHANGES IN PIT WATER LEVELS

The pit water level records were obtained mainly during periods with unusual hydrological events and are discussed in more detail below in relation to the rainfall and flow records; firstly, for those years with frequent monitoring and, secondly, for the more recent years when only infrequent measurements were made. No data are available for 1971 to 1974, 1977 to 1982, and 1984 and 1985.

2.3.1 Data Prior to 1986

The winters preceding 1969/70 had a total rainfall slightly more than average but the winter of 1969/70 was only 83% of the average. No flow records are available for this particular period but it is likely that flows would have been lower than normal during the winter of 1969.

In 1969/70 the water levels in Church Farm Pit varied from about 9.5 to 11m OD following a winter of below average rainfall. These were about 3m lower than those observed in 1974/5 and about 4.5m lower than during the 1980's. The seasonal rise in water level in January 1970 was similar to that recorded in later years despite the low rainfall, which suggests that the R. Lavant is the main source of recharge.

Lavant didn't flow until Feb'

The water level decline during 1970 was much steeper than either 1975 or 1983, when pumping was also taking place. This could indicate that there was a better degree of hydraulic connection throughout the area at this time. However, the period of high flows was more prolonged in these years and this would affect the subsequent rate of recession.

The following minimum and maximum water levels were recorded in 1969/70 in Church Farm Pit, the Sainsbury Pit and Pound Farm Pit:

	Minimum (Dec 1969)	Maximum (March 1970)
Church Farm Pit	9.5	11.0
Sainsbury Pit	11.5	13.0
Pound Farm Pit	13.8	17.0 (estimated)

The maximum level in Pound Farm Pit is similar to the elevation of the bed of the Mill Stream/River Lavant in this area and therefore it would seem unlikely that levels can have risen to the same extent as Church Farm Pit since 1970. However, the water level in borehole BH1, which is installed in the infill material in the Sainsbury Pit, has varied from 12.94m OD in September 1987 to 16.21m OD in May 1988, an increase in the minimum water level of about 1.5m.

It is possible that the early water level data may include the effects of dewatering of the Church Farm Pit at about this time, since the water level in 1970 was only about 1m above the bed of the pit. Unfortunately, there are no pit water level or groundwater level data relating to the period of higher rainfall in the mid-1960's, although this may be available from the pit owners. However, the water level in May 1988 at borehole BH1 was 1.3m higher than the water level in Church Farm Pit, which would indicate a hydraulic gradient towards Church Farm Pit. This would suggest that dewatering was not significantly affecting the early data.

If water levels in Church Farm Pit were naturally as low as those recorded in 1970, then groundwater flow would have occured mainly in the more clayey Beach (Marine) Gravels underlying the more permeable Head (Valley) Gravels, which are those usually removed by the gravel operations. The infilling of the gravel pits would have less impact on flow through the aquifer if the water table does occur naturally within the Marine Gravels. However, if water levels are now higher because of the more average rainfall conditions since the 1970's, then the removal of the Head Gravels and their replacement by less permeable material would restrict the flow of the additional recharge through the area.

Whether these pits were unsealed at this time is uncertain (the pit water level records suggest that these were in connection with the aquifer) but if this was the case then recharge from the Lavant would have been able to pass more freely through the area and the open pits would have provided additional storage.

The winter of 1974/5 was extremely wet, although the early 1970's were generally much drier than average. The wet period began in August/September 1974 but flow on the R.Lavant did not begin until November 1974 when there was a large initial flow of 1.35 cumecs. This was followed by continued high flows ranging from 0.9 to 1.74 cumecs until March 1975.

The water level record for Pit 1 for 1974/5 began in November 1974 when a water level of about 11.5m was observed, or about 2m higher than the minimum in 1969. The water level then rose rapidly during November 1974 by about 3m to 14.4m OD and remained in the range of about 14.0 to 14.4 until the end of May 1975. The high water levels at this time presented a risk of flooding to the Pulverisation Plant and were stabilised by pumping from the pit until July 1975. Hence the maximum water level may not be as high as might have otherwise occurred since high flows on the R. Lavant continued until March/April 1975. Pumping during June 1975 caused water levels to fall from 14.0m to 13.4m OD recovering slightly to 13.5m OD at the time of a pumping test on 24 July 1975.

By 13 February 1976 water levels had fallen to 11.7m OD following the dry winter of 1975/6 when there was no flow on the R.Lavant. This water level is still about 2m higher than the minimum recorded in 1969 but about 2.7m lower than that after the wet winter of 1974/5. It is likely that water levels continued to decline throughout the winter and exceptionally dry summer of 1976 as there was no flow on the R.Lavant during this period. There are no records of pit water levels during this period and consequently it is not known whether water levels returned to the low levels of 1969/70. However, further pumping was required during the winter of 1976/7 suggesting water levels must have risen by some 3m or more during that winter.

The winter of 1982/3 was very wet (124% of average). Flow began on the R.Lavant in November 1983, although high flows did not begin until December 1983 and continued at levels of 1.1 to 1.4 cumecs from December 1983 to February 1984 inclusive.

The water level record for 1983 began in early January with a recorded level of 15.1m OD declining to 14.8m OD in May 1983. Pumping was known to be taking place throughout this period to control water levels and therefore the maximum water level is probably lower than would have taken place without this pumping. However, the levels in 1983 are consistently higher than those in 1974/5 by about 0.7m.

Water levels remained high during the spring of both 1975 and 1983 rather than showing the steep recession recorded in 1969/70. This may be due to the prolonged period of high flows on the R.Lavant in these two years. The decline in water level appears to accelerate when flow ceases on the R. Lavant.

2.3.2 Period from 1986

Figure 2.1 shows an interpretation of the changes in pit water levels from 1986 to 1988 based on the few point measurements available and taking account of the variation in river flows.

January 1986 was the first month of the winter of 1985/6 when there was significant rainfall and flow on the R.Lavant (0.55 cumecs). Flow reached 0.84 cumecs in February before receding until flow ceased in August 1986. The water level in January is thought to be close to the peak for that winter but would not have presented a risk to the vehicle park and, consequently, it is unlikely that any pumping was required to protect the installations in Church Farm Pit.

There was significant rainfall in November and December 1986 (117 and 112 mm respectively) and flow began on the Lavant in December (0.32 cumecs) increasing to 0.9 cumecs in January 1987. Water levels in BH3 near the southwestern corner of the pit reached 14.5m OD in February 1987, which suggests that a significant and rapid rise of 1.3m occured during January.

Flows decreased to 0.57 and 0.34 cumecs in February and March before increasing in April due to exceptional rainfall in March and April (87 and 71mm respectively). This produced another rise in water levels to about 15.5m OD in May 1987, which is thought to be the highest water level recorded. At this time steps were taken to protect the installations in the northwest corner of the pit, which may have supressed the maximum water level. This unusual combination of a double peak in the flow of the Lavant contributed to the high water levels. After May 1987 river flow dropped rapidly and pit water levels also declined at a faster rate to a level slightly higher than 1986.

Flow on the R. Lavant commenced again in November 1987 after high rainfall in October (213mm). There are no flow records for December 1987, although there was a low rainfall this month of 34mm. Exceptionally heavy rainfall occured in January 1988 (165mm) when there was also significant flow on the Lavant (0.94 cumecs) resulting in a rapid rise in pit water levels. High flows continued through February and March, with the highest flow on record occuring in February (2.61 cumecs). However, it is not thought that pit water levels rose much higher than the level of 15.2m OD recorded in February, although this high level was sustained for several months before declining after flow on the Lavant receded in April 1988.

The dry winter and summer of 1989 will have resulted in low water levels, possibly close to those of 1976. A visual estimate made in late August was about 12 to 12.5m OD.

2.4 RELATIONSHIP BETWEEN PIT WATER LEVELS AND RECHARGE

The approximate maximum and minimum water level elevations observed or inferred for Church Farm Pit are as follows:

	Maximum	Minimum
1969/70	11.0	9.5
1974/5	14.5	-
1975/6	11.7	-
1982/3	15.0	14.0
1985/6	14.3	13.0
1986/7	15.5	13.2
1987/8	15.2	-

These indicate that water levels have risen by some 4m since 1969. In the past few years the seasonal change has generally varied from 13 to 15 m OD. The seasonal rise in water levels, however, has not changed substantially.

The peak water levels from 1975 to 1983/4 were controlled by pumping to avoid the flooding of installations either from the pit itself or from 1978 from the dewatering scheme at the Pulverisation Plant (the rate of pumping from the pit during 1975 was reported to be about 10000 m3/d). Since 1983/4 the only pumping believed to take place from Church Farm Pit has been that to reduce flooding in the warehouse area in the northwest corner, but it is not thought that this has been on the same scale as that to protect the Pulverisation Plant area.

SWA have attempted to relate maximum pit water levels with winter rainfall, as shown in Figure 2.2. This was based only on data for 1970, 1971 and 1975 but suggested a tentative correlation between pit water levels and winter rainfall. (This of course may only be an indirect correlation as the main source of recharge is the Lavant, the flow of which is related to water levels in the Chalk aquifer).

The additional water level data for 1983 and the interpolated maximum water levels for 1986 to 1988 have also been plotted in Figure 2.2. These do not show the same correlation as the earlier records and are all higher for the same winter rainfall. This suggests that water levels have risen sometime between 1975 and 1983 and that the system now responds in a different way.

However, it is not possible to relate water level elevation to annual rainfall or river flows as the water level elevation in a particular year will depend on the cumulative effects of recharge during the preceding years and, furthermore, the maximum water levels have been influenced by pumping.

The seasonal rise in pit water level does not appear to be significantly greater than in the past, ie it is the minimum water level that has risen. Hence, the maximum water level elevation in a particular year does not depend solely on the amount of rainfall (or flows on the Lavant) during the previous winter but also on the net gain to aquifer storage from previous years.

The rise in water level each year should show a relationship with the flows of the R.Lavant. However, this correlation cannot be established as the maximum water levels are influenced by pumping and there is insufficient information on the minimum annual water levels.

Figure 2.3 compares the water levels in Church Farm Pit and Shopwyke North Pit with river flow of the R. Lavant, winter rainfall and the variation in annual rainfall over the period 1968 to 1988.

There is an overall similarity between the trend in annual rainfall and the change in pit water levels. The water level elevation in Church Farm Pit over the past five years has shown a seasonal variation from 13m to about 15.5m OD. These levels may reflect the more average rainfall conditions since 1976/7, during which there has been a regular annual flow on the Lavant. The minimum water level was about 1.5m lower in the early 1970's, when rainfall was generally below average and when there was no flow on the Lavant during 1972/3 and 1975/6. The low water levels in 1969/70, which ranged from 9.5 to 11.5m, seem abnormal given the preceding period of generally average rainfall and this may be due to dewatering.

However, the apparent rise in the minimum water level between 1970 and 1975 and sometime between 1976 and 1983 may be due to the infilling of pits adjacent to Church Farm Pit. The overall impression is that water levels are now higher than would have been the case with the average rainfall conditions in the late 1960's. However, it is not possible with the information available to distinguish the effects of infilling of local pits during the 1970's and early 1980's and the reduction in pumping since the mid-1980's from the gain in aquifer storage resulting from the more average rainfall in recent years.

Whilst it has not been possible to establish a reliable relationship between water level fluctuations or water level elevations and recharge from the R.Lavant or rainfall, the following general observations can be made from the available information:

- recharge from the River Lavant is of more importance than direct rainfall. The decline in water levels each year is controlled by seepage and evaporation, which will occur at a relatively continuous and constant rate.

- the first major flow of the River Lavant (usually about 1 cumec) initiates recharge and causes the greatest rise in the water level of the pit. The magnitude of this rise depends on the preceding summer water level: a larger rise occurs when water levels are low due to the greater available aquifer storage, such as in 1974/5.

- a continued period of high flows prolongs the period of high water levels and can result in a net gain in storage. This has been an important factor in the general rise in water levels since 1976/7 and implies that the distribution *of rainfall during the winter and spring may be as important as the total* quantity of rainfall.

- if the average rainfall conditions that have occured during recent years (except for 1989) continue then water levels should also continue to rise, although the maximum level will now be determined by other factors, such as the elevation of the edge of the pit.

- water levels will decline if there is a low flow or short period of high flows succeeded by a period of little or no flow. This appears to be the situation in 1989 when water levels have fallen to about 12.5m OD, which is only about 1m higher than in 1975/6. This, however, is exceptional but could also suggest that the gravel operations have caused a rise in minimum water levels of about 1 to 1.5m since 1975.

- the additional storage available following several dry years reduces the risk of flooding from a wet winter, even though there may be a large seasonal rise in water level. Conversely, a relatively high water level still remaining after a previously wet winter or several years with average rainfall could still pose a risk of flooding with a relatively low rainfall during the succeeding winter and a corresponding relatively small rise in the seasonal water level. This could have become more significant with the reduction in pumping from the pit since about 1983/4, when the Pulverisation Plant ceased operations.

- since peak water levels in the past have been controlled by pumping, it is likely that these could reach higher elevations during a wet year without some form of control.

The water level information for November 1974 was used to estimate the recharge contribution from the River Lavant. The area of Church Farm Pit is about 21 ha. A change in water level of one metre therefore represents about 210000 m3. The water level rise during November 1974 was 2.7m or about 0.1m/d, when the river flow was 116000 m3/d. A water level rise of 0.1m represents a gain of 21000 m3/d (or about 0.6 Mm3 during the month), which is about 18% of the flow of the Lavant.

The data for 1975/6 have been used to estimate the rate of outflow from the Church Farm Pit. The water level declined by 1.9m from about 13.6m OD on 23 July 1975 (at the end of pumping but just prior to a one week pumping test at the Pulverisation Plant) to 11.7m OD in February 1976 during which no significant pumping or recharge took place, although groundwater inflow would still be occuring. This decline in water level indicates a recession of about 0.27 m/month (or 9 mm/d), due mainly to seepage, which is equivalent to a loss of about 2000 m3/d. Losses from the Church Farm Pit will be largely controlled by the efficiency of the clayey material placed around the eastern, southern and western boundaries of the pit, which have a total length of about 1320m. The causeway has a length of about 650m and, hence, perhaps 1000 m3/d is lost through this southern boundary.

The rapid rise in pit water levels each year in response to the first major flows on the R.Lavant suggests that groundwater enters the Church Farm Pit through the Valley Gravels, mainly in the northwestern area. The rate of outflow is much slower than the rate of inflow as the water can only escape through the less permeable materials lining the edges and base of this pit and by evaporation. The difference in water levels between this pit and the Shopwyke Pit, especially during the recharge period, is further evidence of the low permeability of these materials, especially of those lining the northern side of the causeway where most outflow would tend to take place.

The proposed roadline will not affect the inflow of water into Church Farm Pit as this is derived from the north-west and north. Consequently any hydrological impact from the western part of the proposed roadline will be on the pit storage or on the rate of outflow from the pit and any impact would be greater during the period of recharge than during the period of recession.

An exceptionally wet year with sustained high flows on the R.Lavant could result in a further rise in water levels. This presents a serious risk of flooding of the installations, particularly to those in Church Farm Pit but also to the installations in Shopwyke North Pit.

In order to reduce the risk of flooding of the vehicle park area in the northwestern part of Church Farm Pit, water levels should not exceed the outlet level of the drains serving this area. This level, which is understood to be about 15m OD, has already been reached on several occasions (January 1984, May 1987, and February 1988).

In addition, water level elevations exceeding 14.1m OD could also affect the Chichester District Council waste disposal area situated on the central northern side of the pit. As water levels currently range from about 13 to 15m OD, this area is at risk from flooding in most years.

The ground surface in the Shopwyke North Pit adjacent to the causeway varies from about 12 to 14m. This is generally lower than the present range of water level fluctations in Church Farm Pit. The installations in this pit would be affected by a water level of about 13.0 to 13.5m OD.

If water levels exceed about 15.9m OD, flooding of the road entrance leading from the A27 Eastern By-Pass to the vehicle park could occur and if they exceed about 16.1m OD water levels would overtop the southeastern corner of Church Farm Pit (with the present ground level). The culvert in the south-eastern corner would have protected the road entrance since water could escape directly into Shopwyke North Pit. However, this is no longer the case as this culvert was blocked off in 1987.

2.5 WATER LEVELS IN SHOPWYKE NORTH PIT

The water level data available for the Shopwyke North Pit are very limited. Water levels were monitored in 1974/5 and there are a few occasional measurements for 1985 and 1986.

The available data are plotted in Figure 2.2. The data indicate that water levels have also risen in the Shopwyke North Pit but are always lower than in the Church Farm Pit. The rise in minimum water level between 1975 and 1986 appears to be about 1m, which is similar to that of the Church Farm Pit over the same period. In December 1986 the difference in minimum water level between the two pits was only 0.7m.

During wet years, such as the winter of 1974/5, the difference in water level between Church Farm Pit and Shopwyke North Pit increases to about 1.5m but during dry periods the water level difference is more typically about 0.5m. The peak water level in the Shopwyke North Pit in 1975 occured about 1 month later than in the Church Farm Pit, although the pattern and magnitude of the water level fluctuation in each pit was broadly similar.

The hydraulic gradient across the causeway separating the two pits varies from 0.02 to 0.06 during low to high water level conditions. These steep gradients suggests that the hydraulic connection between the two pits is limited.

The silt washings and infill in the Shopwyke North Pit, which are present above an elevation of about 6m OD, are likely to form an additional barrier to the connection between the two pits.

Chapter 3

EFFECTS OF ROADLINE PROPOSALS

3.1 INTRODUCTION

The causeway separating Church Farm Pit from the Shopwyke North Pit will be widened by constructing an embankment on its northern side to accommodate the width of the carriageway. The causeway itself will not be altered by the road construction, except for the compaction of soft areas. The elevation of the road surface will be similar to the present surface of the causeway, which varies from about 16 to 17.5m OD.

The road embankment will be 8m high and extend 35 to 50m out into the pit from the northern side of the causeway. It is proposed to remove the silt layer on the bed of the pit below the embankment by suction dredging and also to remove all or part of the underlying soft/loose clayey gravels or gravelly clays. This will affect an area of some 30000m2, or 14% of the area of the pit.

The construction will take place in two stages: the first up to water level and the second above the water surface when pore pressures have dissipated in the soft/loose material (estimated to require 10 to 15 weeks).

A toe bund of coarse granular rockfill, or possibly fabric bags filled with granular material or concrete, will be placed first and then the zone between this bund and the causeway will be infilled with granular material, such as sand or gravel. However, consideration has also been given to dry construction using a temporary bund or sheet piling and subsequent dewatering. This may be more economic since this would allow the emplacement of trafficable fill, which will be more economic but less permeable than a granular fill.

The final design of the embankment has yet to be decided but its potential impact on pit water levels will depend largely on the reduction in pit storage and its effect on the rate of seepage through the causeway. In addition, dewatering of the embankment zone may be required as a temporary measure to assist construction and this might cause leachates from the adjacent infilled pits to enter this zone.

3.2 GROUND CONDITIONS IN THE CAUSEWAY AREA

The area of the causeway has been investigated in some detail (Figure 3.1). Six trial pits (TPA 3 to TPA8), seven shallow inspection trial pits (TPB1 to TPA 7), one borehole (BH4) and four overwater boreholes (BHW1 to BHW4) were carried out to investigate the causeway itself. In addition, probes were used to investigate the thickness of the soft deposits on the floor of Church Farm Pit to the north of the causeway and of the silt deposits in the northeastern corner of Shopwyke North Pit.

The connection between Church Farm Pit and Shopwyke North Pit may have been reduced by the infill and accumulation of silt deposits in the Shopwyke North Pit. Most of the silt deposits were accumulated in the southern part of the pit, but sometime after 1975 were also deposited in the northeastern area of the pit adjacent to the causeway. These low permeability materials would have a gradual effect on raising water levels in Church Farm Pit depending on the efficiency of the clay battering on the northern side of the causeway.

An additional factor that could influence the rate of seepage from (and into) the Church Farm Pit is the layer of soft deposits formed by physical and biochemical processes on the original floor of the pit after flooding, which also tend to clog any coarser deposits. This would also have a gradual effect on raising water levels. However, this layer rests mainly on clayey gravels and on made ground which also have a low permeability.

The deposits on the floor of the Church Farm Pit are described as very soft, light yellow brown, slightly sandy clayey silt with some gravel. These have probably accumulated by natural physical and biochemical processes. They are generally about 0.5m in thickness but vary from 0.2 to 0.8m thick. The thickness of the soft deposits is shown in Figures 3.1.

Sections across the causeway based on the geotechnical survey are shown in Figures 3.2 a-d. These indicate:

- the causeway has a steeply dipping southern face whilst the northern face has a shallower slope, which could be related to the different ways in which the two pits were worked.

- the causeway itself consists of natural ground of Fan or Coombe deposits (Valley Gravels) with a thin but variable layer of made ground along the northern face, which may be absent at the eastern end of the causeway. These deposits are present between about 9m OD and the original ground surface along the causeway but have been removed on either side.

- infill materials and silt deposits with a base at about 6m OD are present adjacent to the southern face of the causeway.

- the deposits occuring between the soft silt layer and the top of the London Clay vary from soft silty clay with flint gravel to coarse gravel in a soft silty clay matrix and appear to be made ground and debris remaining from the gravel operations and unworked Lower Raised Beach (or Marine) deposits. These extend beneath the causeway and are about 3m thick (3m to 6m OD).

- the top of the London Clay is a fairly steep southwestward dipping surface with an elevation of about 3 to 6m OD beneath the causeway. This extends northwards beneath Church Farm Pit to the area of the Pulverisation Plant where boreholes show the thickness to be about 1m. The London Clay forms an impermeable base to the overlying deposits.

3.3 NORTHWESTERN AREA

The northwestern corner of Church Farm Pit would not appear to be sealed. The pit dewatering pumps were situated in this corner and a pumping test at the Pulverisation Plant indicated flow from the north-west. The former pits to the west at Sainsburys and Pound Farm have been sealed and infilled with waste of low permeability. Aerial photographs indicate that the Sainsbury Pit was infilled during the early 1980's. As a result, a greater proportion of the recharge derived from the R.Lavant and the Mill Stream which previously flowed southwards would now tend to flow southeast towards the northwest corner of Church Farm Pit. A section across the Church Farm Pit is shown in Figure 3.3.

The cessation of pumping from the pit and the dewatering scheme at the Pulverisation Plant by the Chichester District Council in about 1983/4 would have also increased the risk of flooding of the vehicle park and warehouses in the northwestern part of Church Farm Pit. Other contributing factors include:

Infill material was used to raise the level in the northwest corner to construct the vehicle parking area, which has an elevation of about 15.9m. This would tend to raise water levels between the northwestern corner of the pit and the Mill Stream. (Design sketches for the parking area suggest that an 8m thick sequence of clay and pulverised waste were used for the infill to raise the original pit level from about 8m OD to the present level, although it is uncertain as to whether this design was implemented as other information suggests that the earlier level was about 13.5m).

The drainage gullies installed beneath the vehicle park have an outlet to the pit at an elevation of about 15m, or some 2m above the average pit water level adopted by the designers of the vehicle park and warehouse area of 12.8m OD. When water levels in the pit reach more than 15m OD these gullies are not able to drain the vehicle park of the additional run-off entering from springs which emerge from the adjacent bank at periods of high recharge.

Additional recharge to this particular area during wet periods could also be derived from a gulley and soakaway costructed on the north side of the A27 roundabout in about 1981/2 to reduce flooding of the A27 near the Chichester Motel. However, the additional recharge contributed by this soakaway would probably be limited.

3.4 EFFECT OF EMBANKMENT ON PIT STORAGE

The volume of storage within Church Farm Pit will be reduced by the embankment and this could cause a rise in water levels depending on the porosity of the material used to construct the embankment and whether the rise in head is ameliorated by an increase in seepage rates. The following estimates compare the loss in pit storage from impermeable and permeable fill materials.

The total volume of water in the Church Farm Pit, assuming an average bed level of 8.5m OD, ranges from 0.95 Mm3 to 1.36 Mm3 for water level elevations of 13 and 15m OD, respectively. (This assumes a constant area for the pit of 21.5 ha for both water level elevations. Although the area of the water surface will vary with water level, this assumption is reasonably valid given the relatively steep sides of the pit and other uncertainties such as the variation in the depth of the pit).

The volume of the embankment above the present bed (which has an average elevation of 9.3m OD at the toe of the embankment) with a water level of 13m OD is about 60000 m3 and with a water level of 15m OD is about 88000 m3. Both water level conditions represent a reduction of about 6% in the total storage in the pit for an impermeable embankment. For a permeable embankment with an assumed porosity of 30%, the loss in storage would be about 4%.

These estimates can only be very approximate, but indicate that the increase in water level due to placing an impermeable embankment would be about 0.3 to 0.4m and for a permeable embankment about 0.2 to 0.3m.

Groundwater enters the pit at a rate some 10 times faster than the rate of outflow when significant flow begins on the R.Lavant. Since this causes a rapid rise in water levels of usually 1.5 to 2.5m, the increase in head resulting from the loss in pit storage will not be offset significantly by any increase in the rate of seepage. As the rate of seepage will not be significantly increased during the time of peak water levels, the effect of the embankment would be greatest during this initial period of water level rise each year. The net result will be to increase both the duration and frequency of flooding in the northwestern area.

Evaporation losses would be decreased by the area of the embankment above the water line. Assuming this to be about 10m wide, the loss in area would be about 6500m2 or about 3% of the surface area of the pit. This would not have a significant impact on water levels.

3.5 EFFECT OF EMBANKMENT ON SEEPAGE

Seepage from Church Farm Pit is most likely to take place along the southern and eastern edges, as groundwater flow occurs predominantly in a southeasterly direction. Unworked gravels also occur adjacent to the southeastern edge and the trial pits suggest that the clay battering may be thin or even absent in this area.

The rate of seepage will be determined by the water level in the pit and the permeability of the silt layer on the lake bed, the made ground and gravelly clays or clayey gravels and Marine Gravels underlying this layer, the battering placed against the edges of the pit and the Valley Gravels (where the sealing is absent).

With the relatively recent rise in water level, the silt layer on the bed of the gravel pit is likely to be thin on the sides of the causeway above an elevation of about 12m OD. The efficiency of the sealing material above this elevation will now be influencing the rate of seepage.

The clay battering around the perimeter of the pit is likely to show a wide variation in continuity, permeability and thickness. Clayey material was encountered between elevations of 13 to 15m OD in the trial pits dug along the northern slope of the causeway (see Figures 3.2a-d). However, the trial pits indicated that such material may be absent in the southeastern corner of the gravel pit allowing direct contact along a length of some 100m between the water in the pit and the Valley Gravels which extend to the southeast.

Tarmac Ltd have applied for planning permission to extract the gravel from the area adjacent to the southeastern corner. As yet the manner in which the pit will be worked is not known, but it is likely that a seal will be placed against the new face adjacent to Church Farm Pit. This could reduce or even prevent any outflow from Church Farm Pit that takes place from this southeastern corner.

The use of impermeable material to form the embankment will have a similar effect, since this will also effectively seal the southeastern corner. However, if permeable material is used for the embankment water will still be able to move out of this corner of the pit and water levels would not be affected.

Removal of the silt layer and of the soft/loose deposits and their replacement by permeable fill material would increase losses from the pit where these are not underlain by made ground of low permeability along the causeway. However, if the made ground forms a continuous layer along the sides of the causeway to elevations of 16m OD and is not disturbed by the construction of the embankment, then a permeable embankment and removal of the silt layer will not effect the amount of seepage in the causeway area.

The removal of the silt and soft deposits will expose the Marine Gravels, which despite their variable and clayey nature, are likely to have a higher permeability than the silts and made ground. The use of permeable fill would then increase the rate of seepage. An impermeable fill is likely to have less effect on the rate of seepage as this would merely replace the silts and made ground, which are considered to have a low permeability.

Compaction of the loose/soft deposits underlying the silt layer would reduce their permeability and decrease the rate of seepage. Removal of the silt layer and its replacement whether by permeable or impermeable fill material would then have little effect on seepage; the compaction of the soft sediments would be more important.

If seepage takes place preferentially in the southeastern corner, then the compaction of the loose/soft deposits or the use of impermeable fill could cause a significant rise in water levels as the water level recession would take place at a slower rate. This would cause the minimum water level to be higher prior to the next recharge event than would otherwise be the case. When recharge next occured, the subsequent peak water level would be higher for the same amount of recharge. This would be repeated each year leading to a gradual rise in water levels. It is probably this process occuring on a more regional scale that has led to the general rise in water levels.

The effect of this on water levels is difficult to quantify from the available data. But, for example, if outflow ceased along the southern boundary this could reduce the outflow by 50%. Assuming an annual fluctuation of 2m, then the minimum water level could then rise by as much as 1m per year. With the present minimum water level being about 13m (excluding the exceptionally low conditions in 1989), then after only one year the peak water level could actually reach ground level in the southeastern corner and at the road entrance from the Eastern By-pass and would have an almost immediate impact on the installations located in Church Farm Pit.

However, the actual rise in water level will depend on a number of other variables, such as the year to year variation in recharge and head conditions or the proportion of the seepage which currently takes place along the southern boundary and, in particular, from the southeastern corner of the pit.

3.6 EFFECT ON WATER LEVELS IN SHOPWYKE NORTH PIT

The available record is rather limited but water levels do not appear to have risen in Shopwyke North Pit to quite the same extent as in Church Farm Pit. Nonetheless, the minimum water level seems to have risen by about 1m between 1976 and 1986 and is now at an elevation of about 12.5m OD. There are a number of installations and buildings in the western part of this pit which would be at risk from a further rise in water level of only 0.5 to 1m.

The clay battering along the northern side of the causeway and the thick silt and infill deposits bordering the southern side of the causeway appear to provide an effective barrier to the subsurface movement of water from Church Farm Pit into Shopwyke North Pit.

Four trial pits (TPB6 to TPB9) were excavated to depths ranging from 1.3 to 4.2m (about 14m OD) along the southern side of the causeway . These showed the presence of clays up to about 1m thick (above an elevation of 15m OD in the western part and above 16m in the eastern part of the causeway) which are underlain by clayey gravels (Valley Gravels). The gravels would have a reduced permeability due to their clay content.

Water seepages occured in the two deeper trial pits, at about 14.4m OD in TPB7 and at about 13.5m OD in TPB9. These would seem to be just above the surface of the infill and silt deposits along the northern edge of Shopwyke North Pit. The water levels at the time of the roadline investigations were about 13.2 and 12.5m in Church Farm Pit and Shopwyke North Pit respectively. (Presumably the gravel pit water levels were slightly higher at the time the trial pits were excavated.).

The hydraulic connection between the two gravel pits would only be increased if both the silt layer and clay battering were removed and replaced by a permeable embankment. Although the silt layer will be removed below the embankment, provided the clay battering is not disturbed and extends up the full face of the causeway, a permeable embankment would not increase the hydraulic connection between the pits.

An impermeable embankment, together with any compaction of the soft/loose layer, would reduce the hydraulic connection between the pits. With a reduction in seepage losses from the southern boundary of Church Farm Pit, more water will tend to move through the eastern side of the pit.

Overall, it would seem unlikely that the proposed roadline will result in an increase in water levels in Shopwyke North Pit. Any changes within this pit will be dominated by the more regional effects of the gravel workings and infilling and by natural variations in the amount of recharge.

3.7 EFFECTS OF TEMPORARY DEWATERING ON WATER QUALITY

A temporary bund and dewatering of the embankment area may be used to assist the construction of the embankment, which has raised the possibility that the dewatering may induce the movement of leachates from the two areas of waste fill beneath the Sainsbury link and Coach Road Pit.

Two samples of waste material were collected in August 1983 from boreholes drilled in Coach Lane Pit. Chemical tests were also carried out in 1987 on samples of natural ground from trial pits TPC1 and TPC4 to assess the possible spread of contaminants from Coach Lane Pit. The samples were analysed for the prescence and concentration of selected potential contaminants.

The results of the chemical tests indicated that in general the fill is uncontaminated in the Sainsbury Pit. This would also appear to be the general case in Coach Road Pit, except for very high levels of cadmium and slight contamination with zinc, nickel and toluene. However, this assessment applies to safety aspects and land use. Further details are given in the Interpretative Geotechnical Report of 1987.

The natural samples from the gravels in the trial pits on the southern edge of the Coach Road Pit showed the prescence of chromium (5.8 mg/l) and lead (1.5 mg/l), copper (1.2 mg/l) and nickel (0.8 to 1.5 mg/l). These samples were taken within a few metres of the refuse material and downdip of the waste tip. The low concentrations and abscence of other toxic chemicals indicate that the contamination is confined to the pit itself.

A water sample was taken from a borehole near the centre of the pit (borehole 1) in 1983 had a sulphate concentration of 130 mg/l and a pH of 7.5. Besides this analysis, we understand that no other chemical analyses of groundwater have been undertaken in the area.

Six boreholes were drilled in Coach Farm Pit in 1983. These indicated water levels varying from 14.1 to 17.0m OD and groundwater flow in a southeasterly direction away from Church Farm Pit. The water level is similar to the Church Farm Pit and suggests a continuity between the two pits. The presence of a gradient across Coach Lane Pit also indicates an imperfect seal around the pit.

Dewatering of the area of the embankment would potentially alter the local pattern of groundwater flow and draw groundwater from beneath the embankment and from the western and eastern ends of the embankment. However, the hydraulic continuity in these areas is affected firstly by the silt and clay battering along the bed and sides of Church Farm Pit and, secondly, the seal placed around Sainsbury and Coach Road Pits. This would tend to suggest that any groundwater moving into the dewatered zone of Church Farm

Pit would be derived preferentially from the unworked gravels separating the pits with a limited drawdown in the adjacent infilled pits.

It is most unlikely that the groundwater underlying Coach Road will be contaminated since this is fed from Church Road Pit, although the gravels underlying the Eastern By-Pass are downdip of Sainsbury Pit and could possibly be contaminated. The risk is therefore slightly greater at the western end of the dewatered zone. However, the direct risk of any contaminated water moving from these pits would seem to be slight.

The other potential source of contamination depends on the degree of hydraulic continuity through the southeastern corner of Church Farm Pit. Dewatering could reverse the direction of groundwater flow in this area and possibly draw groundwater from the gravels south of Coach Lane Pit. The effects would depend on whether the groundwater is contaminated in this area, on the pumping rate and duration of the dewatering, and the extent of the hydraulic connection.

It would be prudent to investigate the groundwater quality in the areas adjacent to the infilled pits, to monitor any inflow to the dewatered zone during the excavation, and ensure proper attention to the Health and Safety regulations.

An additional risk to be considered would be whether the water quality in Church Farm Pit would be affected from any contaminated groundwater left in the dewatered zone after completing the dewatering operations.

However, although it is recommended that water samples are collected to establish the presence and concentration of toxic chemicals in the groundwater, the risk of toxic chemicals entering the dewatered zone and therefore possibly also affecting the quality of the water in Church Farm Pit would seem to be slight.

Chapter 4

WATER LEVEL CONTROL MEASURES

4.1 INTRODUCTION

At present there is no satisfactory way of economically disposing of water from Church Farm Pit without causing potentially adverse effects on the River Lavant, the flow in local drains or pits to the south. The vehicle parking area in the northwestern corner of the pit is at particular risk from flooding. Whilst the predicted increase in water levels from the construction of a permeable embankment is small, about 0.2 to 0.3m, water levels in recent years have reached critical levels such that flooding of this area could occur more frequently or for longer periods as a result of the proposed roadline.

In this chapter the use of a soakaway connected to the Church Farm Pit is examined as a means of preventing a potential rise in water levels resulting from the roadline.

4.2 SOAKAWAYS AS A PREVENTATIVE MEASURE

4.2.1 General

In the case of the Church Farm Pit, there are practical problems of transferring water across roadlines or south into Shopwyke North Pit where there are low level installations. The volumes of water involved can also be relatively large: the natural rate of inflow to Church Farm Pit from recharge derived from the River Lavant has been estimated as 21000 m^3/d and pumps have been operated in the past at rates of 10000 m^3/d to stabilise water levels and prevent flooding. Such flows would exceed the capacity of local minor water courses, such as that along the eastern edge of Church Farm Pit, and could result in flooding downstream.

Recently, the National Rivers Authority (NRA) have begun to consider the transfer of excess water from open pits by pumping or gravity drainage to soakaways located in adjacent areas of unworked gravels. By utilising aquifer storage, soakaways can offer an attractive alternative to pumping directly to water courses or into adjacent pits and provide a means of "short-circuiting" the barriers to groundwater flow caused by the sealing and infilling of gravel pits.

However, there are some disadvantages in using soakaways to control pit water levels:

- they are less flexible in terms of water level control if only gravity drainage is used
- they may cause an unacceptable rise in groundwater levels elsewhere, which may indirectly give rise to higher surface water flows in local watercourses or even groundwater flooding

- the depth to water level and the aquifer properties of the gravels must be suitable to accept the additional recharge and any overlying clays should be thin if trenches are used
- the rate of acceptance often decreases with time due to clogging from fine material or algal growth and may require occasional cleaning
- they could be affected by or prevent future gravel extraction in the immediate area or downgradient of the soakaway
- the transfer of water from one drainage system to another is also considered undesirable by SWA
- they may result in pollution of the aquifer.

The use, location and design of soakaways therefore needs to be carefully planned at both the local and more regional scale. These aspects could be investigated in advance by the application of groundwater models.

The owners of the installations in Church Farm Pit could also benefit if a soakaway is included in the roadline proposals to dispose of water from this pit. However, this preliminary appraisal has concentrated mainly on the use of a soakaway to prevent an unacceptable rise in water levels in Church Farm Pit resulting from the roadline construction.

4.2.2 Soakaway Trench

The preliminary design of the new by-pass includes a soakaway trench on the southern side of the road some 400m east of Church Farm Pit between about chainages 1100m and 1250m. This will be used to dispose of run-off from the road surface between the Tarmac and Maudlin roundabouts. The use of this soakaway to assist in controlling water levels in Church Farm Pit has been considered in this report.

The preliminary design of the run-off trench is based on a rainfall intensity of 21.8 mm/h for one hour and a road surface area of 6.7 ha. The trench will be trapezoidal in section with a depth of 2m, a width of 7.5m at the top and 3.5m at the base, and a length of 133m. The trench will be open and have a volume of about 1500m^3. It will be situated in a low topographic area near the southeastern corner of the infilled Dairy Lane (Coach Road) Pit. The top of the trench will be at about 14.5m OD and the base at 12.5m OD.

The ground level at the site of the soakaway trench is lower than the highest recorded water levels in Church Farm Pit, which could allow gravity drainage to the soakaway. The gravel deposits have not been worked in or to the south of this particular area (whilst there is an application to extract gravel from the area immediately south-east of this pit as far as Coach Road, this will not affect the area of the proposed soakaway.)

The use and design of the soakaway trench needs to take into account the following main factors, which are considered in more detail below:

- the thickness of surface clays
- the elevations of the intake and soakaway
- the rate of inflow into the pit and future water levels
- the capacity of the pipe
- the dimensions of the soakaway

- the acceptance rate of the gravels.

The more regional aspects have not been examined at this design stage.

4.2.3 Ground Conditions

Several trial pits and two boreholes have been drilled in the area of the soakaway. These include TPA11 and 12, TPC3 and 4, and BH5 and 6.
BH5 was drilled to a depth of 10m (6.16m OD). This encountered sandy to very silty clay to 3.0m (13.16m OD) and Valley Gravels from 3 to at least 10m. TPA11 and 12, which are at or close to the site of the soakaway, recorded clay to 1.3 and 0.3m depth overlying Valley Gravels to 2.4 and 3.3m, and Marine Gravels to the pit depths of 3.5 and 3.8m. The borehole logs suggest that the London Clay occurs at an elevation of about 5m OD beneath the road line adjacent to the Dairy Lane Pit.

The presence of Marine Gravels, which are usually more clayey, at shallow depth recorded in the trial pits contrasts with the thick sequence of Valley Gravels recorded at the boreholes. It is possible that a buried valley cut into the Marine Gravels passes south or south-east through BH5. If so, this would provide a distinct advantage for a soakaway in this area. However, the sequence at either the boreholes or the trial pits may have been identified incorrectly.

In the area of TPA12 a trench 2m deep will be in contact with the Valley Gravels, which occur to a depth of 3.3m (or more if the Marine Gravels have been identified incorrectly). The surface clays increase in thickness further west until at BH5 they exceed the planned depth of the soakaway.

Water levels show an annual fluctuation of about 1 to 2m and the saturated thickness of gravels above the London Clay is about 7 to 8m. The borehole data for the Dairy Lane Pit indicate a hydraulic gradient of about 1:200 in a southeasterly direction.

The water level data for the soakaway area provide differing values for the depth to water in this area. The monitoring data from BH5 and BH6 suggest that the maximum water level in the soakaway area is about 13.5m OD (2.3 to 3.3m bgl), which is consistent with water level data from the boreholes drilled in Dairy Lane Pit. Water was struck at 11.4m OD (3.3m bgl) at TPA12 in November 1986, when perhaps water levels were close to their seasonal low.

The thickness of the unsaturated zone below the likely pipe entry level in the soakaway is small and restricts the amount of available aquifer storage. This will need to be offset by a high transmissivity to ensure that the soakaway can cope with the likely inflows.

Permeability tests have been carried out at depths of 1.5 and 3.0m at BH5 within the surface clay deposits. Despite the clayey sequence, falling head tests could not be performed due to the high acceptance rate and constant head tests were used with an assumed head of 0.1m. A volume of 1.125 m^3 was accepted in about 2.5 minutes (0.073 m^3/s). The tests at both depths gave a permeability value of 15500 m/d, which is so exceptionally high for the sequence that the test results must be considered as doubtful, even though the acceptance rate was high.

In contrast, pumping tests at the Pulverisation Plant site gave a permeability value of 180 m/d. This is much more consistent with sand and gravel deposits, which typically have permeabilities of between 10 and 300 m/d. This would suggest a transmissivity of about 1500 m^2/d for the aquifer thickness at BH5 and a natural groundwater flow of about 1000 m^3/d over a width of 130m (the length of the soakaway trench) with a gradient of 1:200.

The contrasting permeabilities derived from the constant head tests and the available pumping test results suggest that further tests should be undertaken to check the results of the constant head tests.

4.2.4 Volume and Discharge Rate

A permeable embankment will reduce the pit storage by about 45000 to 65000m^3 for the present seasonal range in water levels of about 13 to 15m OD, respectively. Whilst this represents a loss in total storage of only 4%, the embankment could increase the rate of water level rise by 10 to 15% (assuming an annual rise of 2m) and increase the seasonal maximum water level elevation by 0.2 to 0.3m. The rate at which water needs to be removed to avoid this increase is at least about 2000 to 3000 m^3/d.

Without some form of control on the pipe intake leading to the soakaway, more water will be removed than would be required to offset the effects of an embankment. This, however, would benefit local interests.

The critical elevation for water level control will depend on a variety of factors, such as the elevation of the drains and vehicle park apron in the north-west area or to meet the needs of local users of the water park. Discussions with local interests are required to determine an acceptable water level. However, direct flooding of the car park area could occur if water levels exceed about 15m OD and this elevation has been adopted for this preliminary assessment. No discharge would take place (unless pumped) when water levels are less than 15m OD but a lower elevation may be desirable for other reasons and, in addition, no account is taken of any future regional rise in water levels.

Water levels will rise more quickly than in the past due to the reduction in pit storage volume. The rate at which water would have to be removed once the elevation of the intake is reached would have to be greater to maintain water levels at this elevation. Without a form of control the discharge rate would depend mainly on the pipeline capacity.

When the water level reaches the intake level, water would be continuously discharged to the soakaway unless the rate of discharge is controlled. If uncontrolled, the discharge could then exceed the acceptance rate of the soakaway and cause flooding in the soakaway area as the ground level at the soakaway is about 14.5m.

The highest water level observed was about 15.5m in May 1987. This represents a volume of about 105000 m^3 above an elevation of 15m OD. Pit water level records indicate that the initial rise in water level at the start of the winter takes place at about 0.1 m/d, or 21000 m^3/d. Hence, without a controlled discharge, this volume of inflow becomes more important than the increase in the volume caused by the roadline if water levels are to be prevented from exceeding the critical level. As there would be no effect of the pipeline until an elevation of 15m was reached, the discharge required would also have to remove a further 3000 m^3/d to prevent a rise to 15.8m OD, which is also about the lowest ground elevation of the sides of the pit.

A correspondingly greater volume would be removed with an intake set at a lower elevation than 15m OD, although a constraint would be the discharge level into the soakaway. The minimum intake elevation would be about 13.5m OD.

Since an uncontrolled, gravity-fed scheme would remove a greater quantity of water than is required to prevent the additional rise in water level caused by the embankment and even lead to flooding in the area of the soakaway, a means of controlling the discharge would need to be installed to ameliorate only the effects of the embankment. Whilst a sluice gate or other means of discharge control could be incorporated, there may be some practical difficulties in operating the control device over a long period. An automatic method of control could be a way of overcoming such difficulties.

The volume of water to be removed and whether this should be a controlled amount needs to be examined in more detail as this involves local interests, more regional considerations, and the design of the soakaway itself.

For preliminary design purposes, the ability of the proposed run-off soakaway to accept three alternative discharge rates has been examined:

(a) a rate of 3000 m^3/d, related to the potential impact of the roadline only

(b) a rate of 10000 m^3/d, being the rate of pumping that is believed to have been required to stabilise water levels in the past (probably after the first, main rise in water levels has taken place)

(c) a rate of 25000 m^3/d, being that needed to reduce the rate of water level rise during the initial, main recharge event if water levels during this time rise above 15m OD and to offset the effects of the roadline. / ?

The discharge level at the soakaway for run-off from the road can be set close to ground level allowing the full storage capacity of the soakaway to be used. However, the outlet level of the pipe from the pit would have to be set at least 0.5m bgl, or about 14m OD, to provide a sufficient gradient for the pipe. This reduces the effective storage volume for controlling water levels to 1000 m^3 and reduces the total infiltration area of the soakaway trench for pit water level control to about 900m^2.

Discharge from the pit and run-off from the road surface into the soakaway are likely to occur at the same time. For example, a pit water discharge of 3000 m^3/d would, without a similar rate of infiltration, utilise the soakaway storage below the pipe outlet within 8 hours and reduce the ability to accept run-off from the road to a volume of 500m^3, or only 20 minutes. Similarly, if run-off has utilised the soakaway storage prior to water levels reaching the intake elevation then flooding of the soakaway could occur or prevent the control of pit water levels.

It is not possible at this stage to examine the various combinations of run-off and flows from the pit in relation to the soakaway design or whether it may be desirable to use separate soakaways. This would need to be considered at a more detailed design stage and will require more detailed information than is presently available on aspects such as rainfall intensity and return periods, pit water level changes in response to rainfall and river recharge, and the aquifer conditions.

As a preliminary estimate for design purposes, it has been assumed that the intake would be at an elevation of 15m OD in the southeastern corner of the Church Farm Pit. The distance to the western end of the planned soakaway would be about 375m and the head difference would be about 1m. A water level of 12m OD, or 2.5m bgl, has been assumed: this is only about 0.5m below the base of the soakaway.

4.3 ACCEPTANCE RATE

4.3.1 Discharge rate of 3000 m^3/d

A pipe diameter of 9 inches would be required to remove the minimum quantity of pit water of 3000 m^3/d (125 m^3/h) necessary to offset the emplacement of a permeable embankment with a head difference of 1m. The pipe velocity would be about 0.75m/s. Without infiltration the soakaway could accommodate 8 hours of flow from the pit at this rate.

In the following calculations a square basin with sides of 20m has been used for simplicity to examine the ability of the soakaway to accept an inflow rate of 3000 m^3/d, or 7.5m/d infiltration rate, assuming a T of 1500 m^2d, a specific yield of 0.15 and a retention time of 8 hours, or 0.33 days.

$$\text{Using } n = L/\sqrt{(4Tt/S)} = 20/\sqrt{(4 \times 1500 \times 0.33/0.15)} = 0.17$$

The head increase at the edge of the basin x/L = 0.5 and from plots of x/L against hS/Wt for values of n, then hS/Wt = 0.05 and the head increase at x/L is:

$$h = (hS/Wt)Wt/S = 0.05 \times 7.5 \times 0.33/0.15 = 0.82\text{m}$$

With these conditions the water level elevation below the edge of the basin would be 12.8m, or 0.3m above the base of the soakaway. The difference between the pipe inlet level and the rest water level is 2m. This indicates that the maximum acceptance rate using the above equations would be 18.2 m/d, or 7300 m^3/d and that with an input rate of 7.5m/d it would take about 20 hours before the water level rose by 2m.

If the water table is to be kept lower than the base of the basin, then the rise in water level would need to be limited to 0.5m with an assumed water table elevation of 12.0m OD. In this case the acceptance rate would have to be reduced to 4.5m/d, or 1800 m^3/d. The shallow water levels limit the use of soakaways by restricting the amount of available storage. This has to be offset by a high transmissivity.

These estimates are based on the permeability value derived from the pumping test at the Pulverisation Plant, which, whilst consistent with the type of deposits, is considerably less than the permeability values obtained from the constant head tests. The total infiltration area of the proposed soakaway trench is also about 900m^2 compared to the area of 400m^2 used in the above calculations, which represents only the floor area of the soakaway. Hence, even with rather conservative values, the proposed soakaway trench should be capable of removing the rise in water level resulting from the embankment construction. The rate of acceptance would, however, decrease with time due to clogging, perhaps by as much as 50%.

4.3.2 Discharge Rates of 10000 and 25000 m^3/d

A pipeline diameter of 12 inches could accommodate a flow of 10000 m^3/d with a head difference of 1m. The pipe velocity would be about 1m/s. However, unless the permeabilities are really as high as indicated from the constant head tests, the above estimates indicate that the acceptance rate of the proposed soakaway would not be capable of removing this discharge rate.

The diameter of the pipeline required to remove 25000 m^3/d would be excessive and the acceptance rate of the proposed soakaway would not be sufficient to cope with this high discharge rate.

The storage volume of the soakaway would be fully utilised within 2.5 hours at 10000 m^3/d and within 1 hour at 25000 m^3/d. The inflow may also take place when run-off is occuring into the soakaway from the road itself.

Consequently, the size of the soakaway would have to be considerably increased to accommodate these discharge rates. The area of high permeabilities was considered from the results of the roadline investigations to be limited to the south side of the roadline between chainages 700m and 1400m. Even so, the surface clays extend to depths of 2 to 3m in part of this area which would reduce the availability of sites for a soakaway trench.

However, given the doubts concerning the permeabilty estimates in particular, it would be advisable to undertake further investigations before more detailed designs can be examined.

Chapter 5

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

The hydrological conditions in the western part of the proposed roadline are rather complex having been disturbed by the gravel workings and subsequent infilling of the disused pits. This situation requires more detailed information than is presently available to achieve a full appraisal of the hydrogeological conditions and the potential impact of the proposed roadline: at this stage it has only been possible to discuss the impact in general terms. Nevertheless, it has been possible to draw some tentative conclusions from this review of the available data.

A. General

1. The potential impact is limited to the western part of the roadline. It will not affect the regional rise in water levels nor the inflow into Church Farm Pit.

2. There has been a rise in groundwater levels in recent years, by perhaps as much as 4m since 1969/70. This may be largely due to the more average rainfall conditions since 1976/7 compared to the preceding below average rainfall conditions of the early 1970's.

3. This natural variation in the hydrological conditions has been superimposed upon the effects of the sealing and infilling of gravel pits in the area which have restricted the movement of groundwater through the aquifer.

4. An important control is the recharge from the River Lavant, in particular the duration of significant flows, which in turn is controlled by the variation in infiltration into the Chalk aquifer. Since the natural variation in the amount of recharge is an important control, future water levels cannot be predicted with any certainty. It will also be difficult to distinguish the natural variations in water level from any water level rise resulting from the roadline or other developments in the general area.

5. Pit water levels presently range from about 13 to 15m OD. This represents an inflow to the pit of about 21000 m3/d and an outflow of about 2000 m3/d. Inflow takes place predominantly from the north-west and, whilst seepage probably takes place along the south-western, southern and south-eastern edges of the pit, most outflow is thought to occur in the south-eastern corner.

6. In the past the peak water levels have been controlled by pumping, which now takes place on only a reduced scale. Ultimately, water levels would be constrained to a level of about 16m OD by the edges of the pit, by the reduction in the storage volume of the aquifer to accept further recharge, and by the bed level of the R. Lavant.

7. When water levels exceed about 15m OD water tends to back-up in the drains serving the vehicle park in the northwestern corner of the pit. This prevents the groundwater which emerges from the adjacent face from the north-west to drain from the area. The situation in this area has been aggravated by the material used to raise the original ground level.

B. Impact of the Proposed Roadline

1. An impermeable or permeable embankment is likely to decrease the available storage in Church Farm Pit and cause a rise in peak water levels by up to about 20 to 40cm.

2. Removal of the silt layer and the construction of a permeable embankment is unlikely to increase the rate of seepage if the soft/loose deposits are compacted and if the clay battering along the causeway is not disturbed.

3. An impermeable embankment could reduce the seepage by 50% and potentially cause a water level rise of up to 1m/y depending on the variation in recharge, increase in losses along other parts of the perimeter due to the increase in head, and what proportion of losses currently take place in the southeastern corner.

4. A rise in water levels in Shopwyke North Pit is unlikely to occur from the proposed roadline.

5. It is considered unlikely that leachate will be drawn from the adjacent infilled pits during any temporary dewatering.

6. The application to extract gravel from the area bordering the southeastern corner of the pit could reduce outflow from the pit. The effects of this extraction on water levels within the pit will be difficult to distinguish from any water level rise resulting from the roadline.

7. The potential rise in water level due to the embankment could increase the risk and duration of flooding in the northwestern corner.

C. Soakaway as a Control Measure

1. A preliminary assessment suggests that one or more soakaways could be used to prevent or ameliorate the potential impact of the proposed roadline on water levels in Church Farm Pit.

2. Existing site information indicates that, subject to more detailed design, the soakaway trench proposed for the disposal of run-off from the road could be used to remove the volume of water resulting from the loss in storage caused by a permeable embankment. This will require a control on the intake, otherwise a much greater volume of water will be removed than would be necessary simply to overcome the additional rise in water levels caused by the roadline and the soakaway trench would be unable to cope with this additional discharge.

3. The use of soakaways to control pit water levels in excess of that required to offset the impact of the proposed roadline would benefit local interests but needs to be examined in a more regional planning context, for which numerical models would be appropriate. However, to undertake a more detailed appraisal of the ability of the aquifer to accept higher flows or to prepare alternative soakaway designs requires further information on the permeabilities of the gravel deposits, water levels in the area of the proposed soakaway and on rainfall and pit water level changes.

RECOMMENDATIONS

The following recommendations are suggested:

* A more detailed groundwater investigation is required throughout the general area. This should be supported by a programme of regular and routine monitoring of pit and borehole water levels. Due to the complexity of the area the new information should be used to establish and calibrate a numerical model of the area to examine and quantify:

- variations in pit water level due to hydrological extremes

- impact of sealing and infilling of gravel pits

- water level response to the combined effects of the proposed roadline and the new gravel extraction

- water level control measures.

Such a model will provide a better understanding of the processes governing water level fluctuations in the area.

* At present it would appear that the embankment is likely to have an effect on water levels in Church Farm Pit. The proposed design of the roadline need not necessarily be altered if water level control measures could be implemented. Consideration should be therefore be given to incorporating a culvert or other suitable means of allowing water to be transferred from Church Farm Pit to soakaways located in the area of unworked gravel south-east of this pit. This will require further study in conjunction with the Southern Water Authority due to the potential impact on water levels further south and with local interests to determine the elevation at which water levels should be stabilised within the pit.

* A survey of groundwater quality around the causeway area should be undertaken to show whether toxic chemicals are present.

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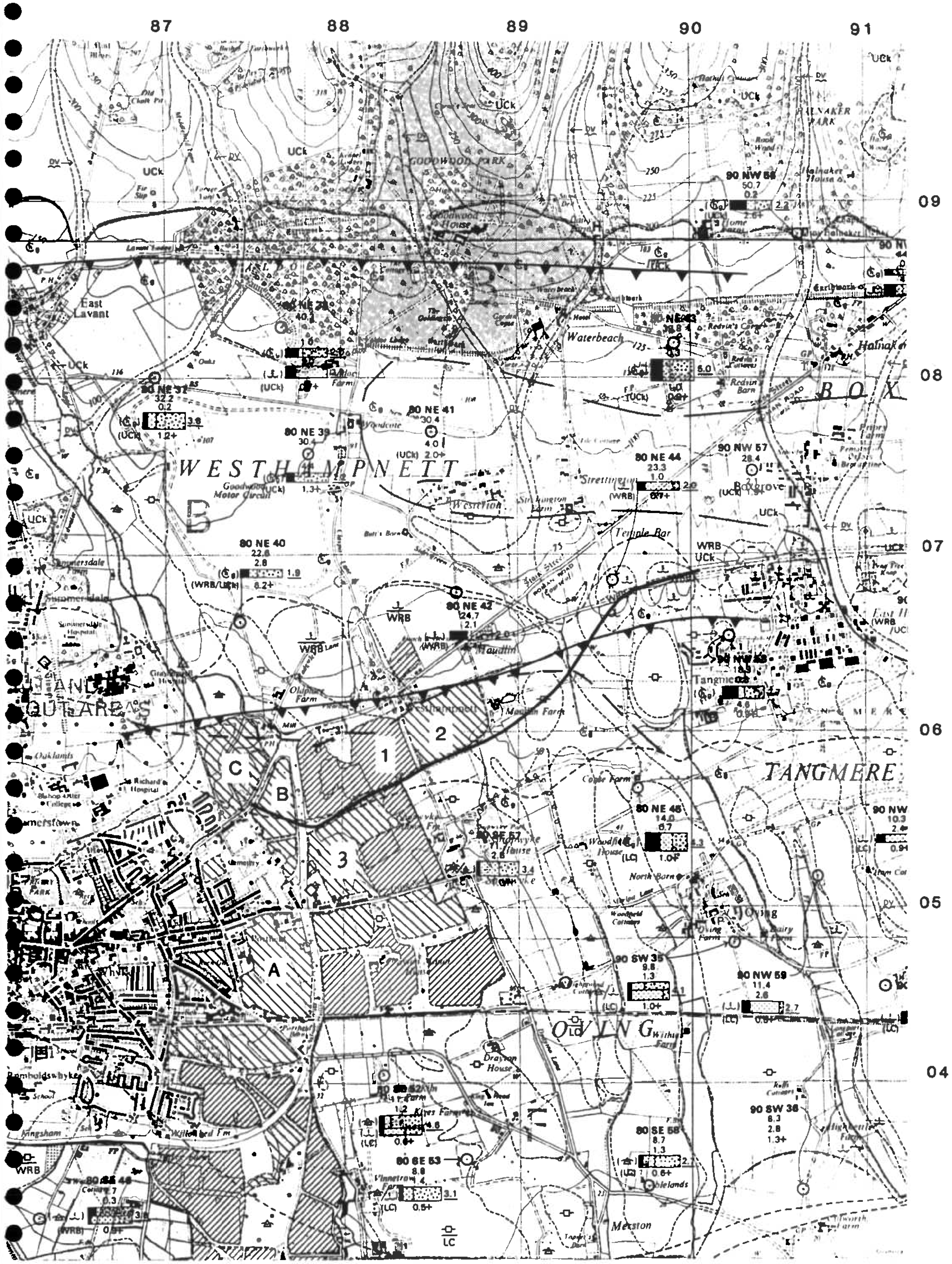
Study Area and Geology

Scale 1:25000



DRIFT

- Alluvium - clay, silt, sand and some gravel
- Brickearth - yellow brown silt, pebbly in parts
- Head, undifferentiated - flinty, clayey loam and reworked Brickearth
- Head Gravel - angular flint gravel in brown clay matrix
- Raised Storm Beach Deposits - topographic mounds of sand and gravel
- Raised Beach Deposits (Younger) - widespread, fossiliferous sand and gravel
- Raised Beach Deposits (Older) - patches of fossiliferous, intertidal sand and gravel

SOLID

- LC — London Clay - blue-grey clays, weathering brown
- WRB — Woolwich and Reading Beds - silty clays, mottled reddish brown and grey with chalk and flint clasts
- UCk — Upper Chalk - white, microporous limestone, deeply weathered at top, with nodular and tabular flints

- Made Ground
- Worked-out ground, sand and gravel

BOUNDARY LINES

- Geological boundary, Drift
- Geological boundary, Solid
- Chalk outcrop
- Proposed By-Pass
- Revised boundary of London Clay subcrop
- Cliff line lower raised beach
- Cliff line upper raised beach
- Meteorological Station
- River Gauge
- I.M.A.U. boreholes

1 Church Farm Pit (Westhampnett Water Park)
2 Coach Lane Pit
3 Shopwyke North Pit
A Portfield Pit
B Sainsbury Pit
C Pound Farm Pit

Figure 1.1

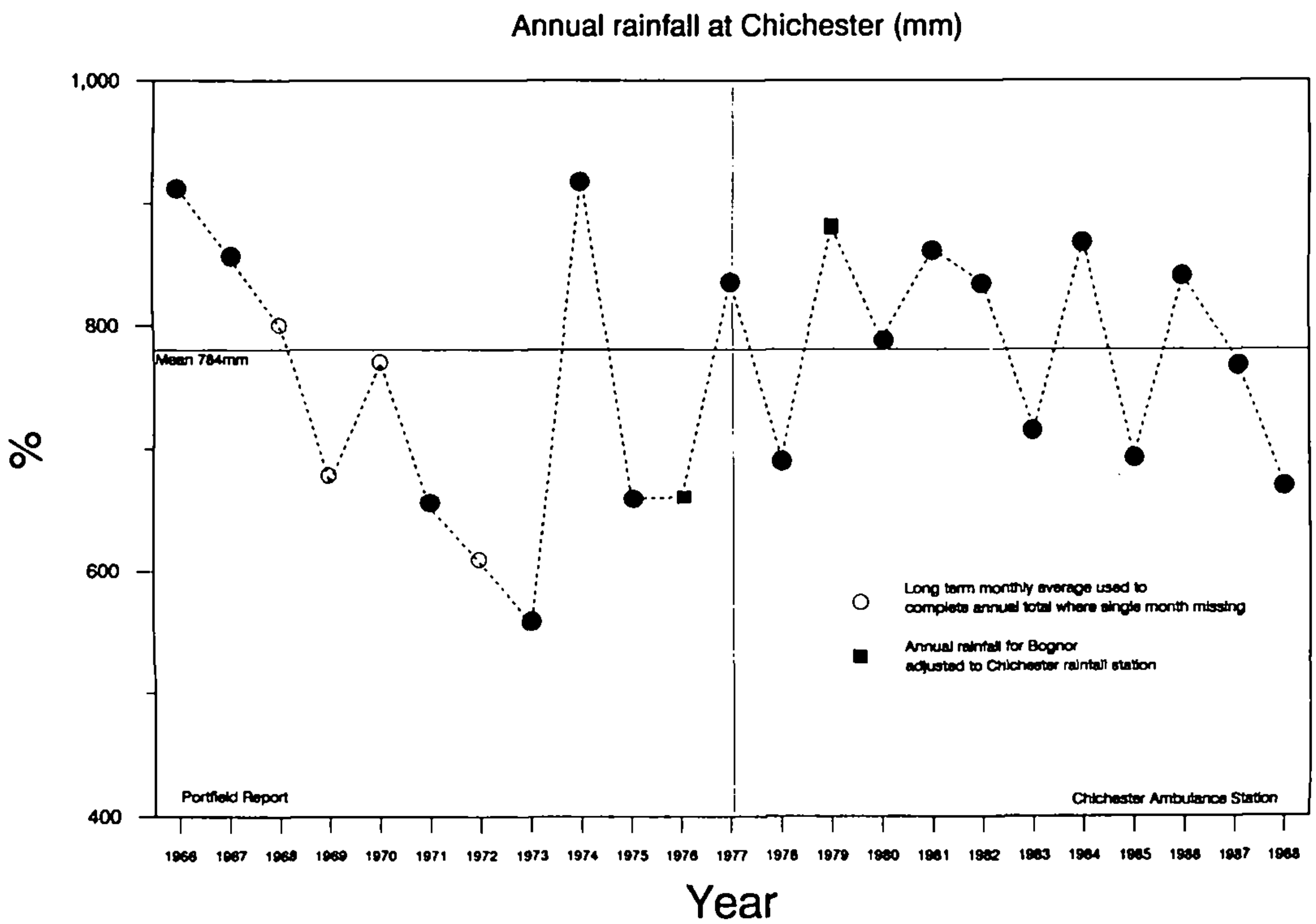

Annual rainfall at Chichester (mm)
1,000
800
600
400
%
Mean 784mm
Portfield Report
Chichester Ambulance Station
Long term monthly average used to complete annual total where single month missing
Annual rainfall for Bognor adjusted to Chichester rainfall station
1966
1967
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
Year

Figure 1.2

Departure in Annual Rainfall from Long Term Average at Chichester (mm)

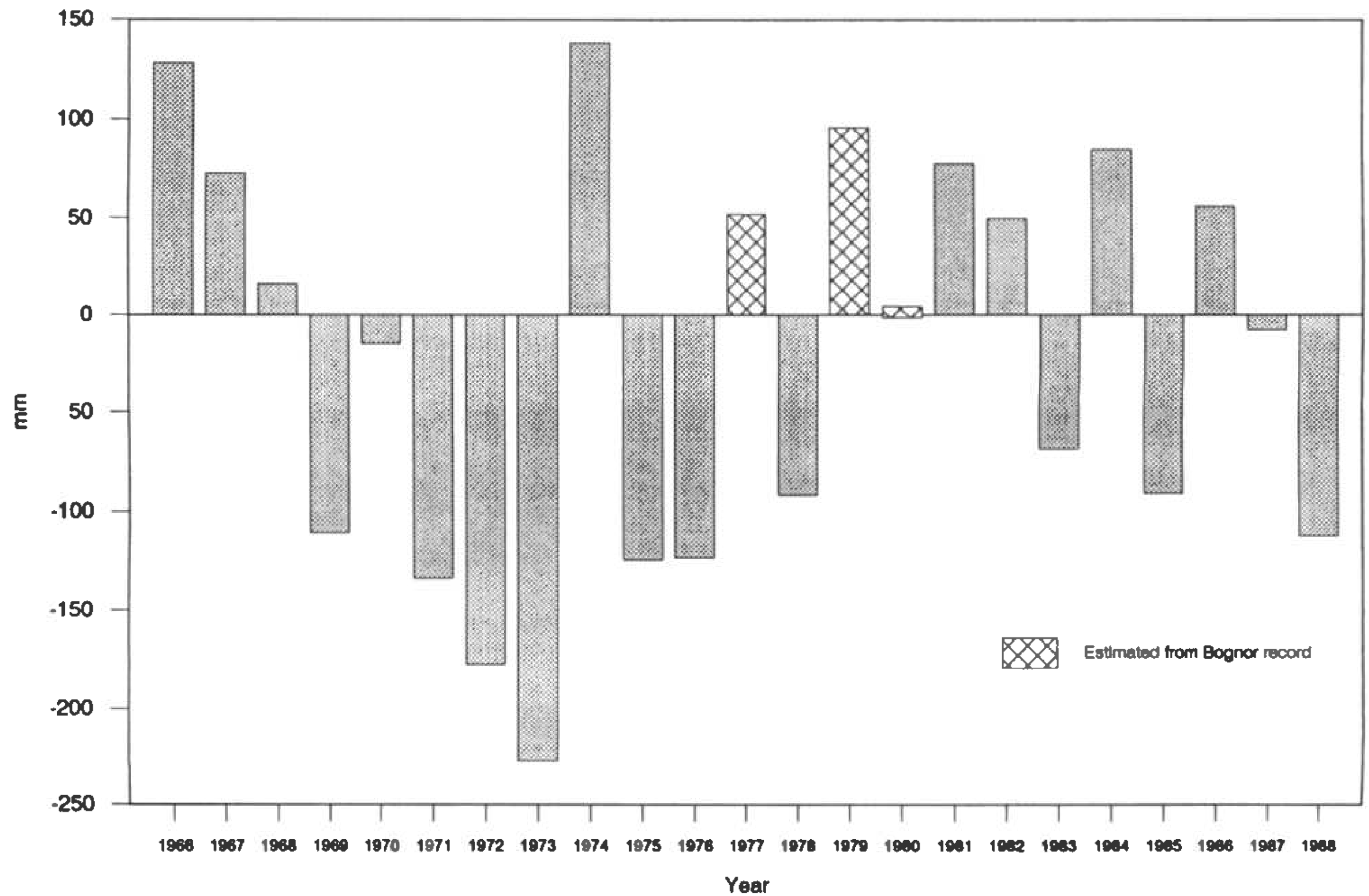


Figure 1.3

R.Lavant at Graylingwell
Average Mean Monthly flow (cumecs)

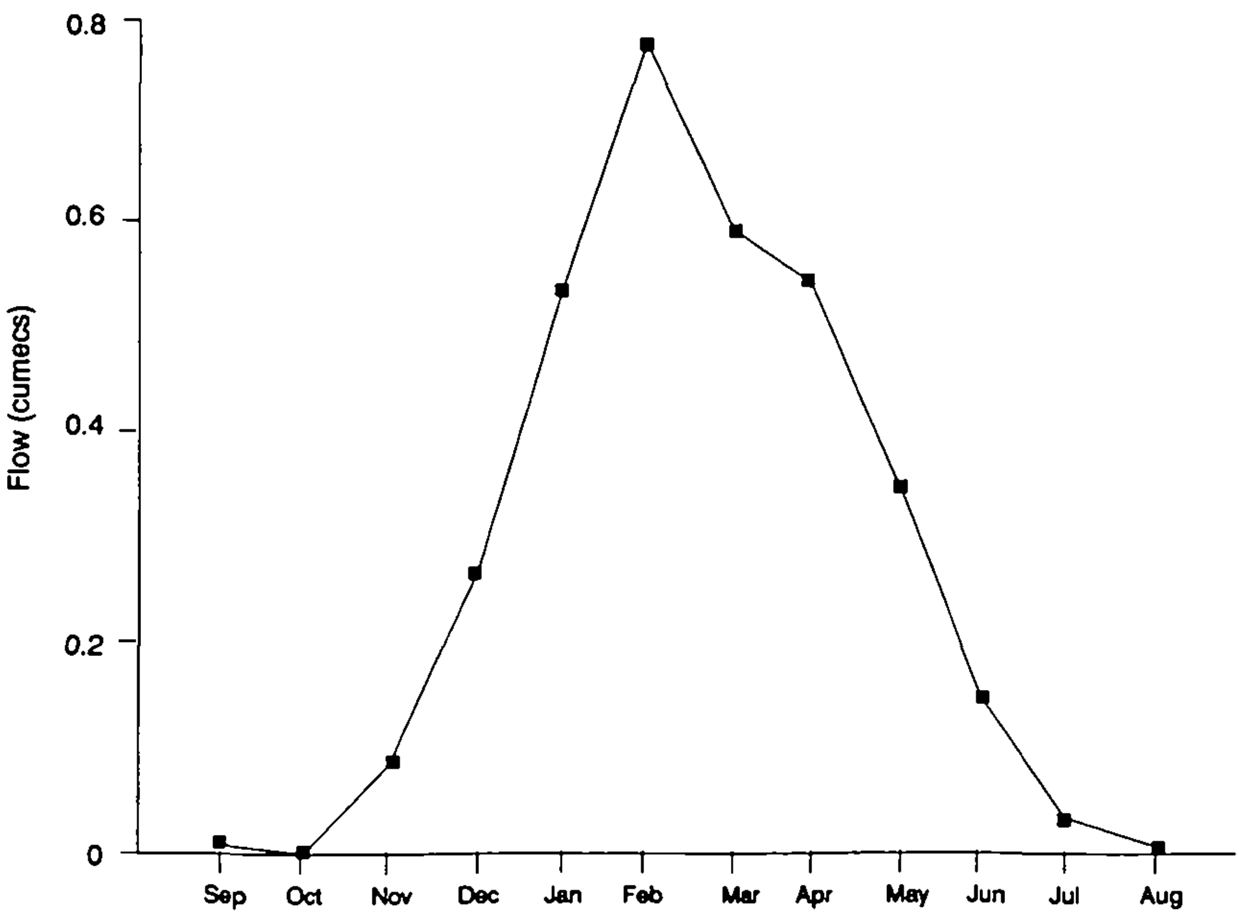


Figure 1.4

Flow Duration Curve: R.Lavant at Graylingwell

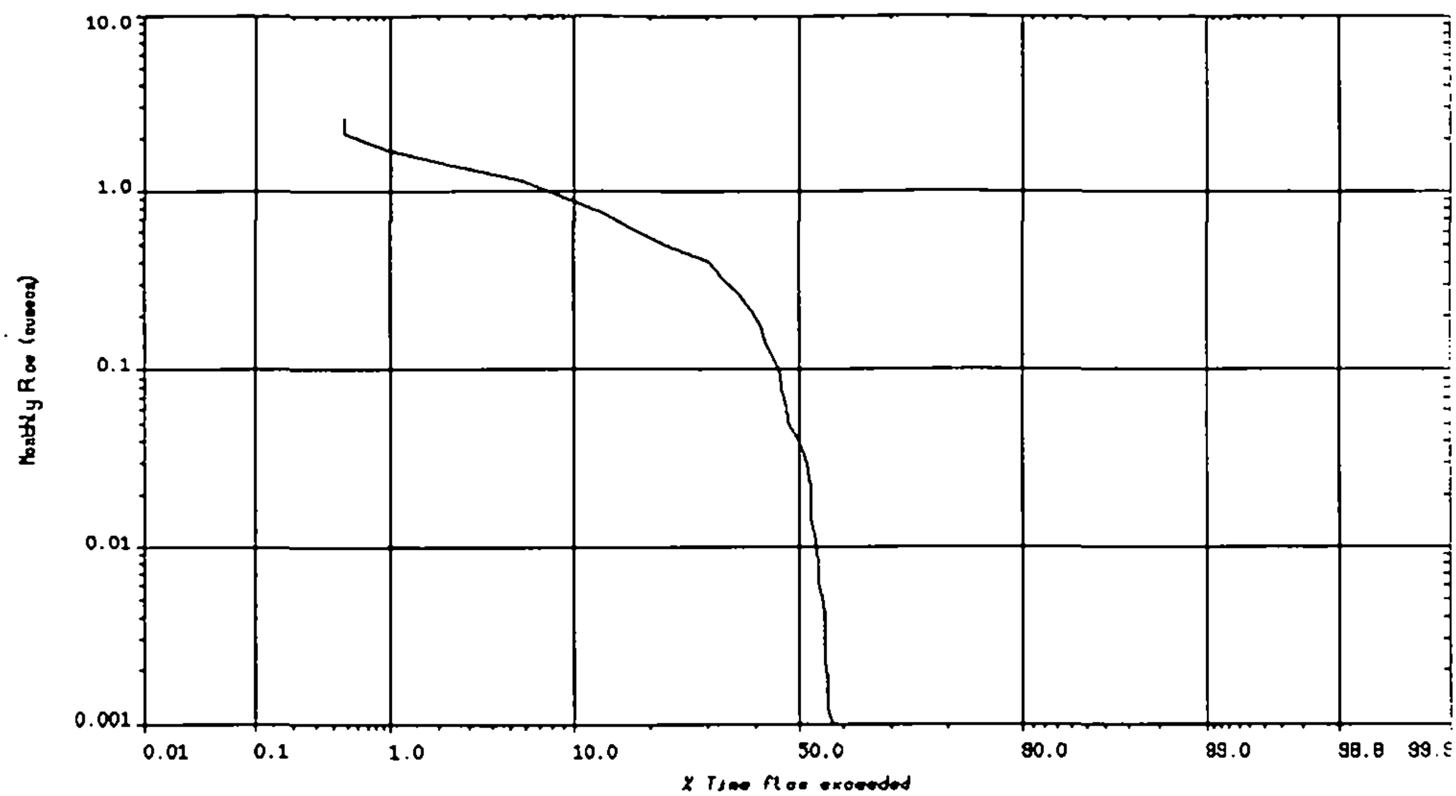


Figure 1.5

Duration of continuous flow of >0.5 cumecs
R.Lavant at Graylingwell

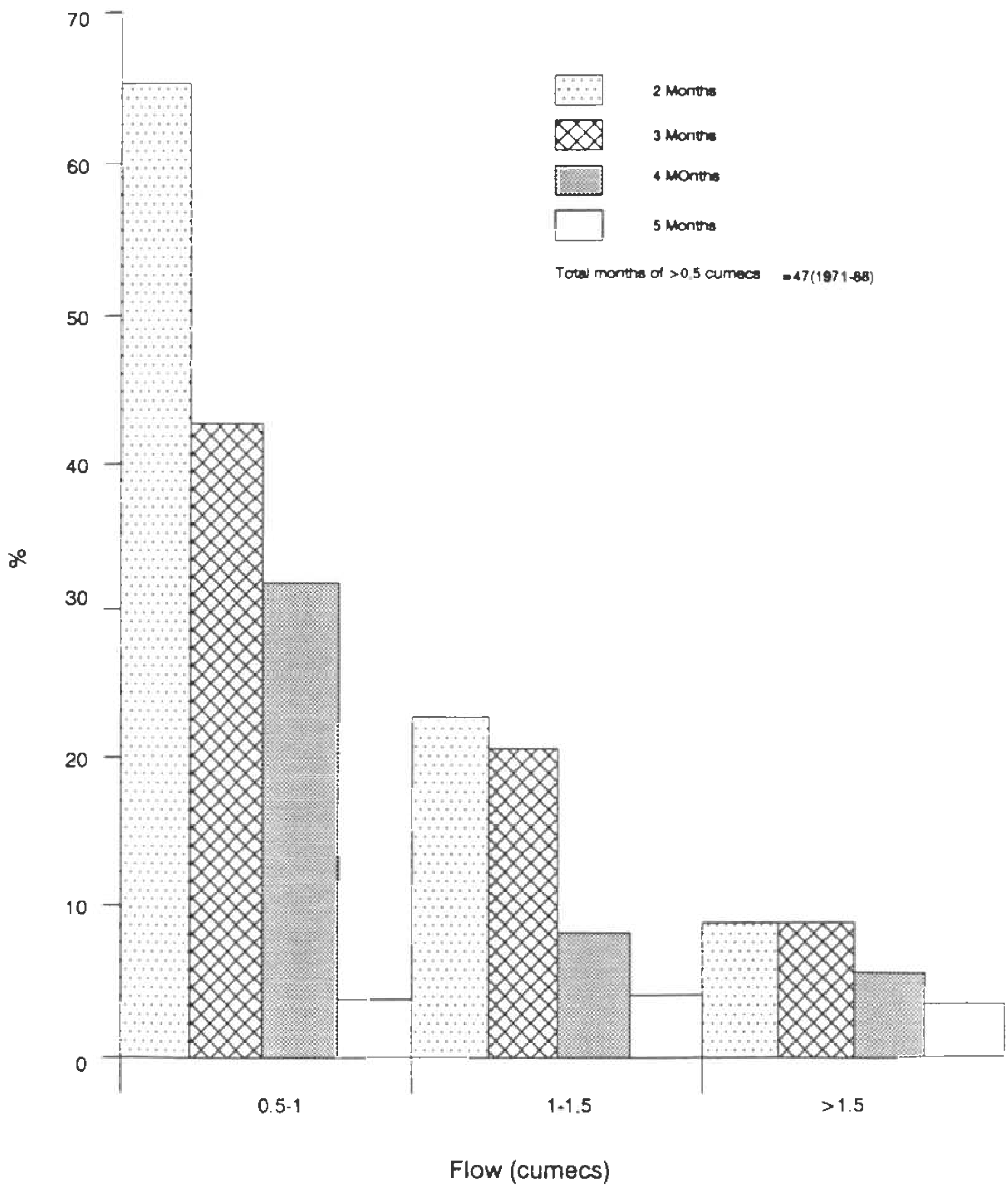
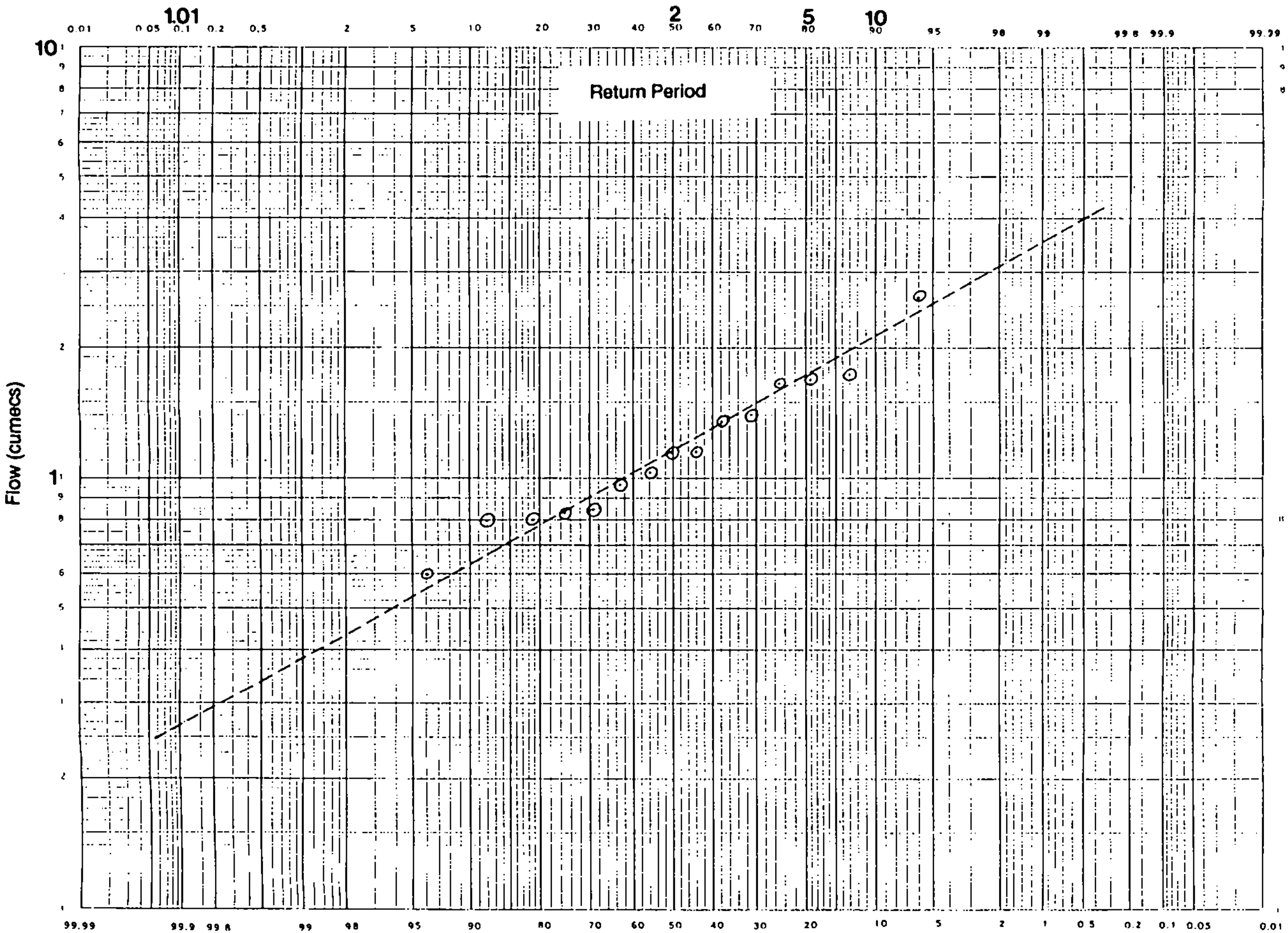


Figure 1.6

Flow Frequency Diagram for R.Lavant at Graylingwell



Interpolated Pit Water Levels,1986-88

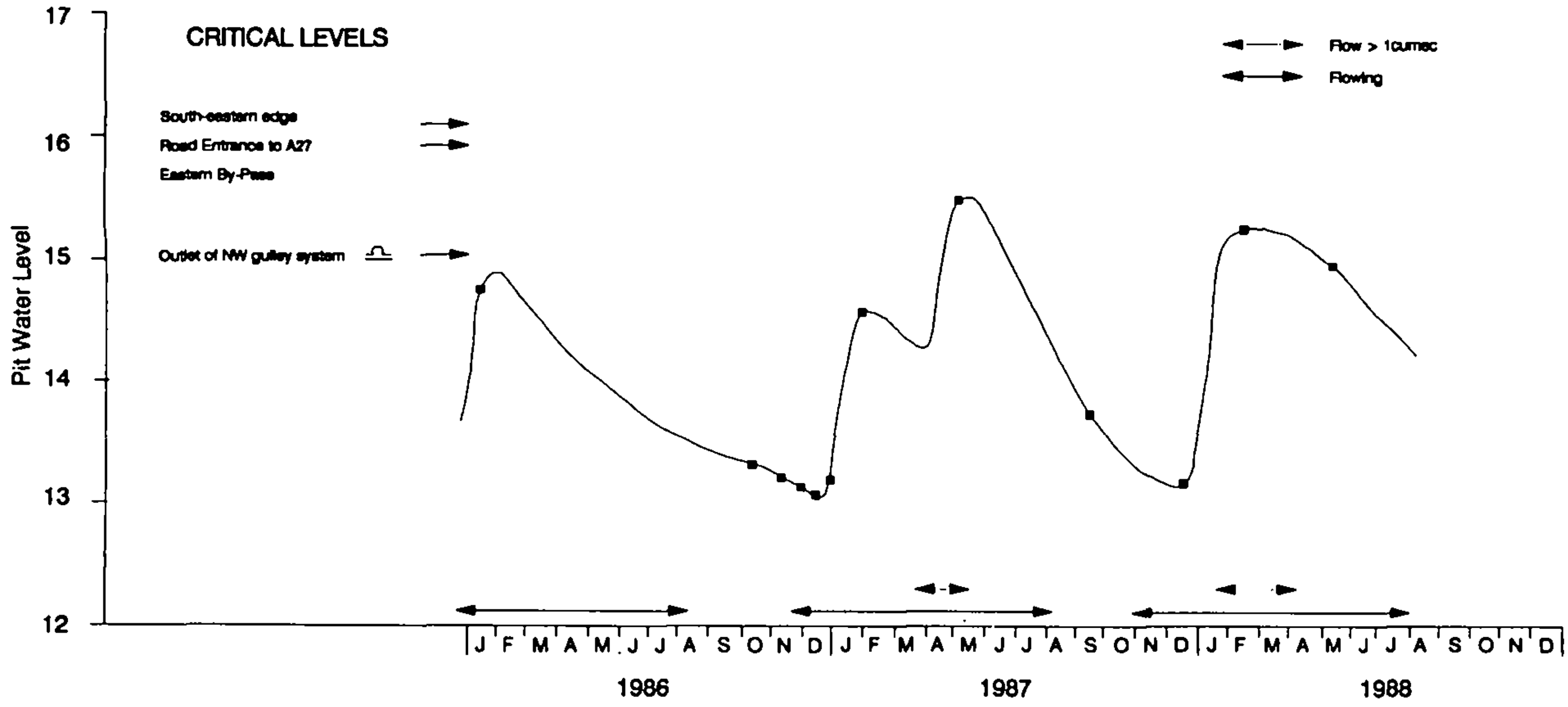


Figure 2.1

Pit Water Levels and Total Winter Rainfall

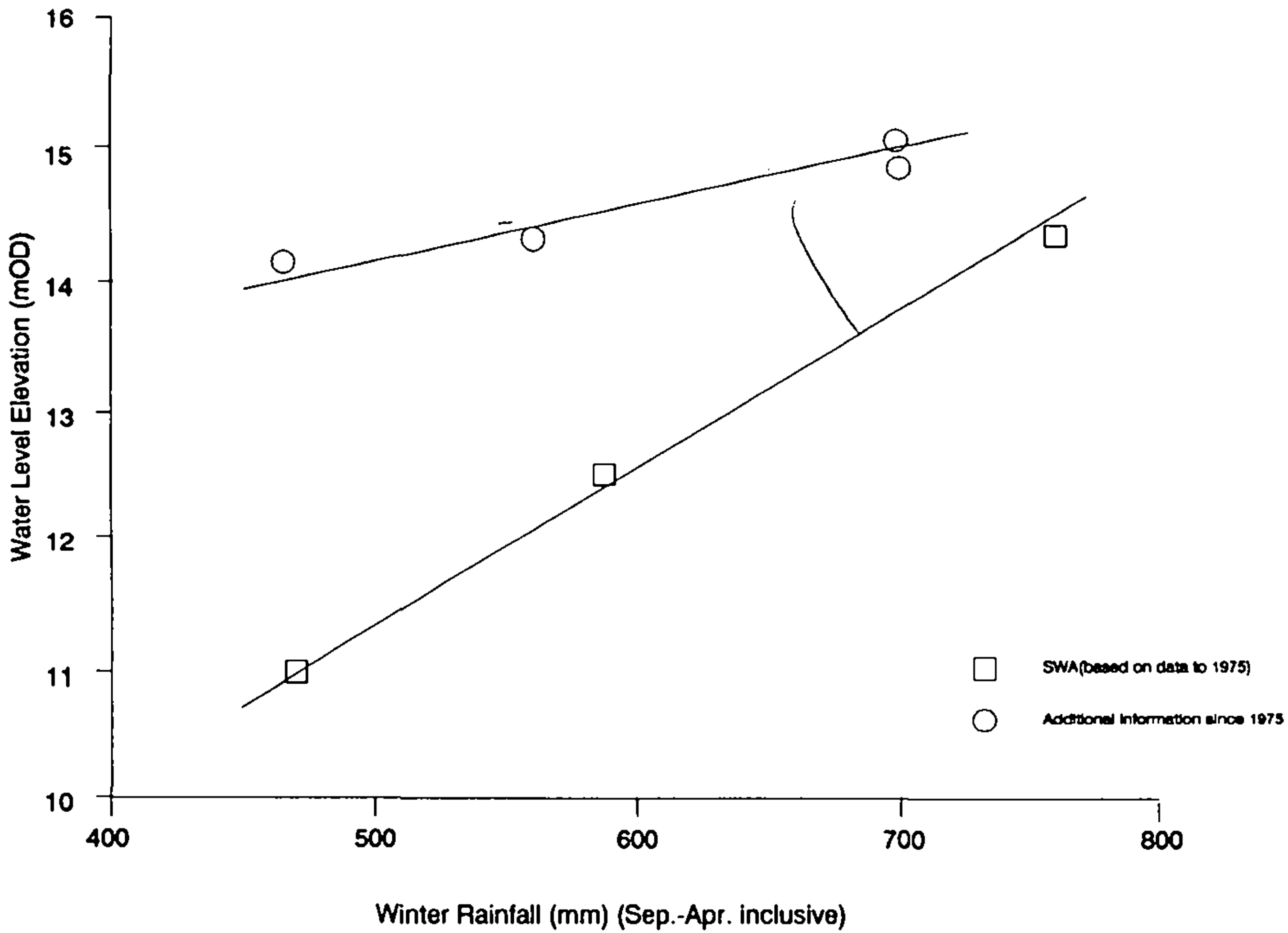


Figure 2.2

Pit Water Levels, R.Lavant flow and Winter Rainfall 1968 - 1988

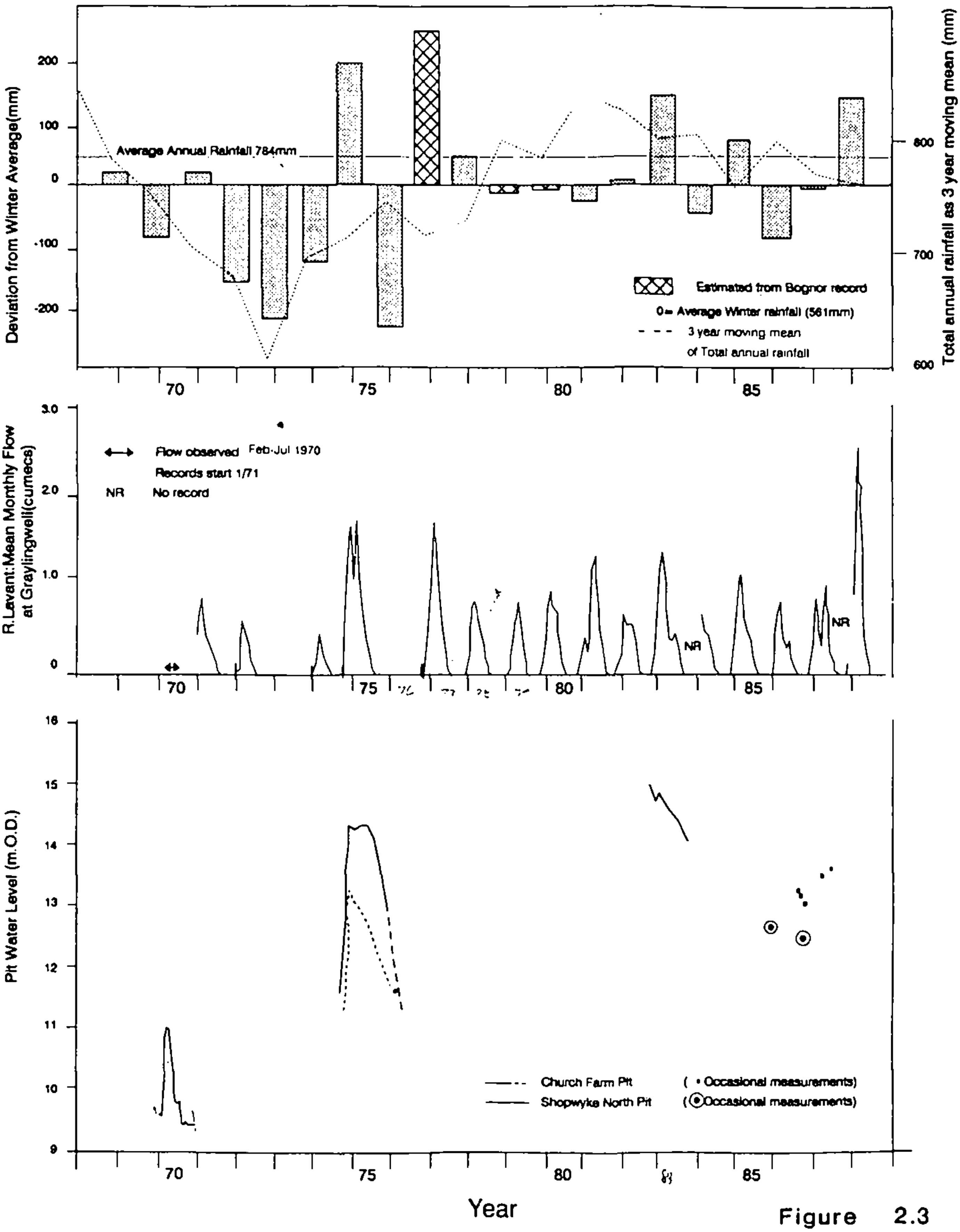


Figure 2.3

Scale 1 2500

⊕	SWA Investigation Boreholes (1975?)
+	SWA Investigation Boreholes (1976)
W O	Well
△	Staff Gauge (approx)
(a)	Section Line (see Figs.3.2a-d and 3.3)
0 5	Thickness of Soft Deposits (m)
→	Probable Direction of Groundwater Flow

KEY

A1	TRIAL PIT TYPE A
B1	TRIAL PIT TYPE B
C1	TRIAL PIT TYPE C
BH1	BOREHOLE OVER LAND
BHW1	BOREHOLE OVER WATER
• PA1	PROBE TYPE A
• PB1	PROBE TYPE B
100	PROPOSED CENTRELINE AND CHAINAGE

Figure 3.1

A27 WESTHAMPNETT BYPASS.

WESTERN SECTION

Based on Drawing 5204/1/101 Gifford Graham & Partners Apr 1986

Section N-S of Causeway at Chainage 200m

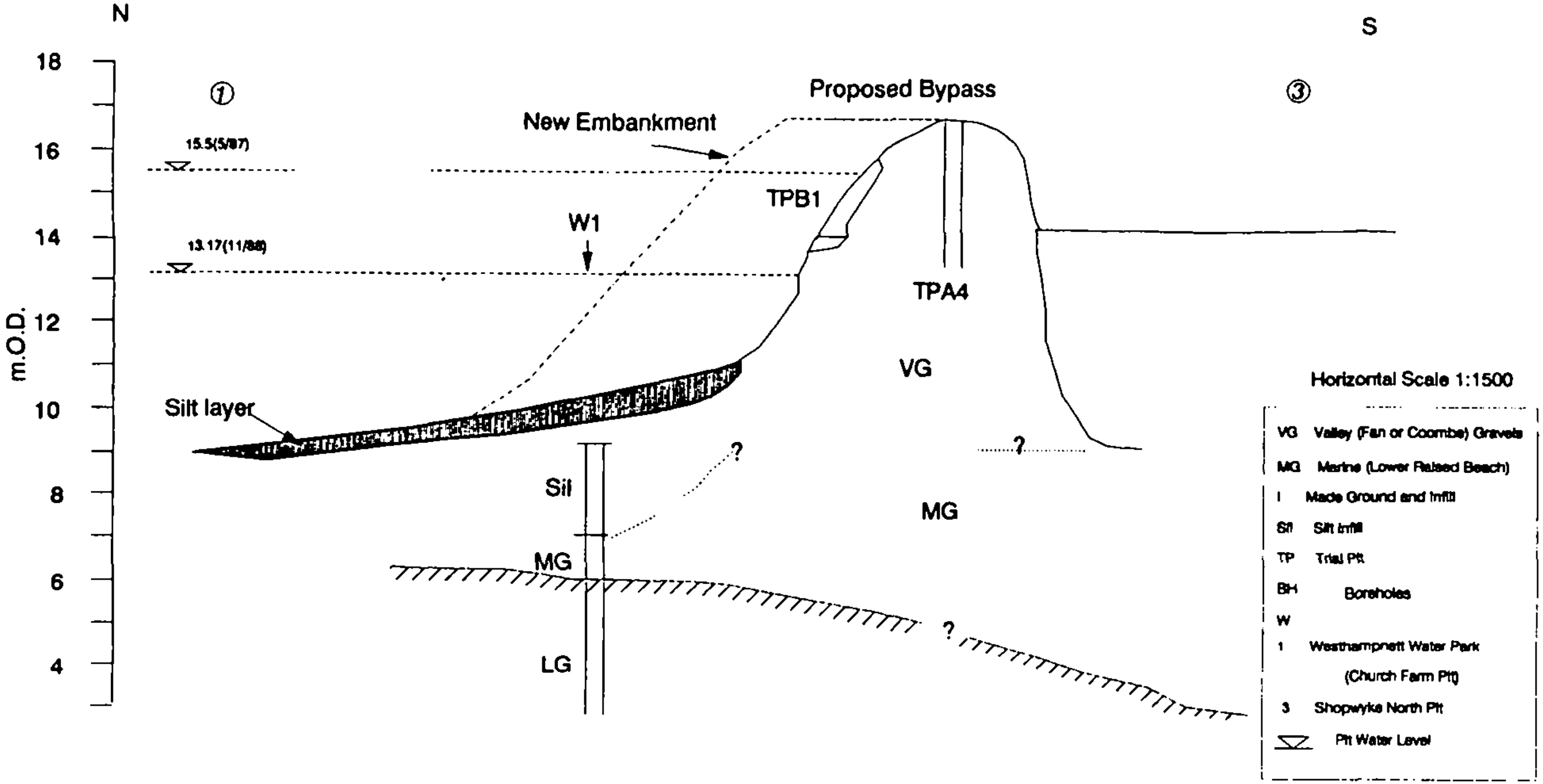
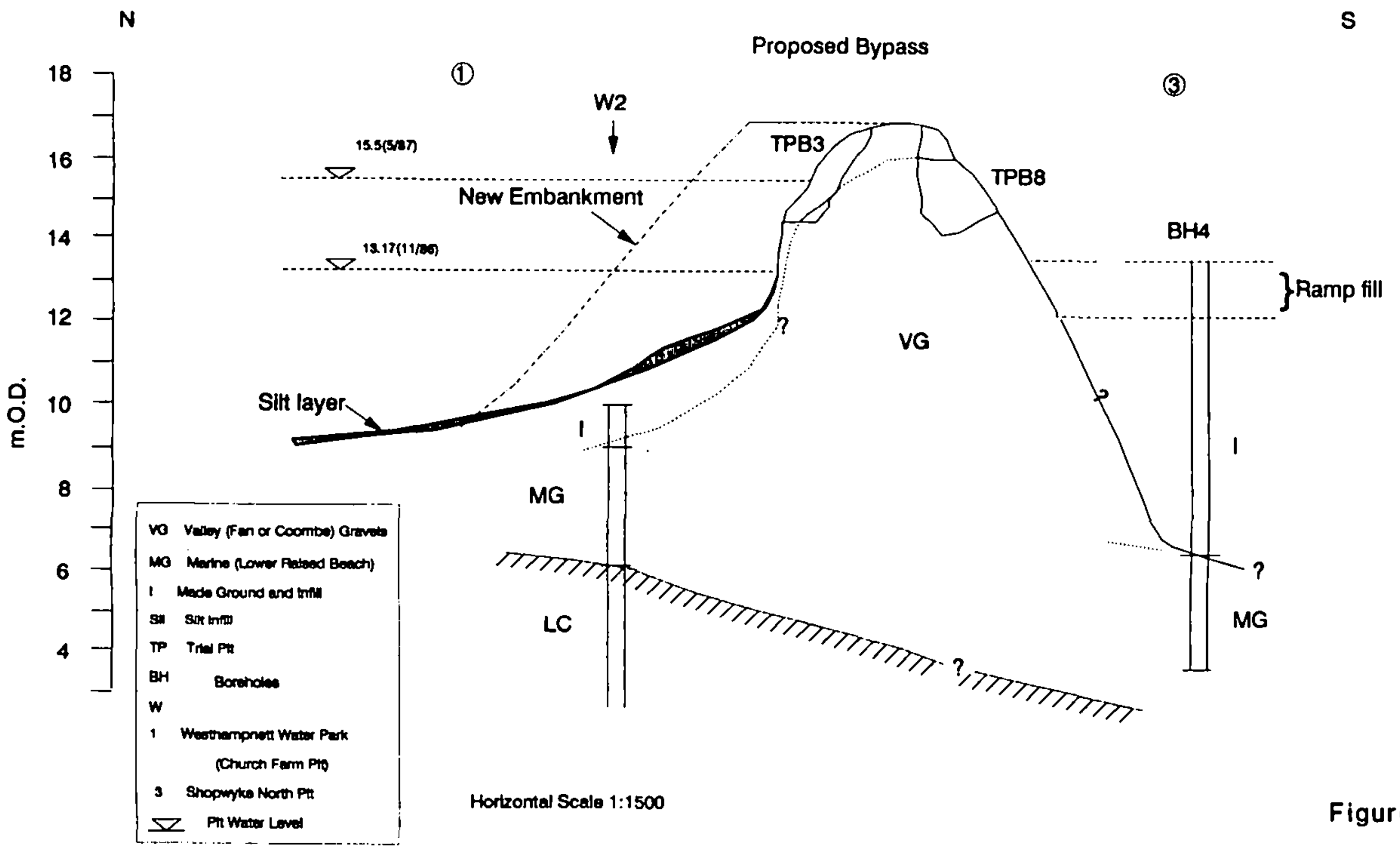


Figure 3.2a

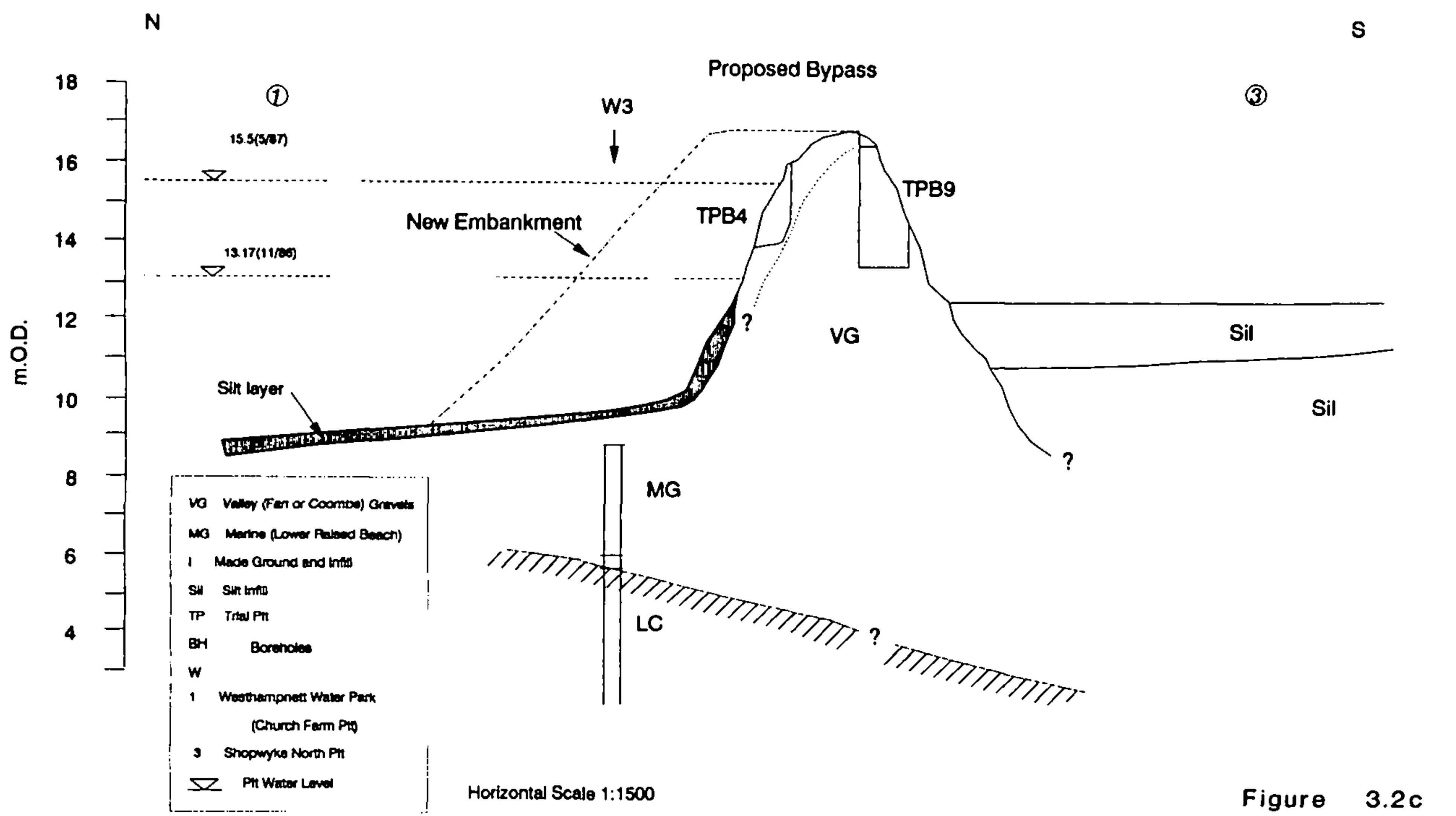
Section N-S of Causeway at Chainage 400m



Horizontal Scale 1:1500

Figure 3.2b

Section N-S of Causeway at Chainage 540m



Horizontal Scale 1:1500

Figure 3.2c

Section N-S of Causeway at Chainage 710m

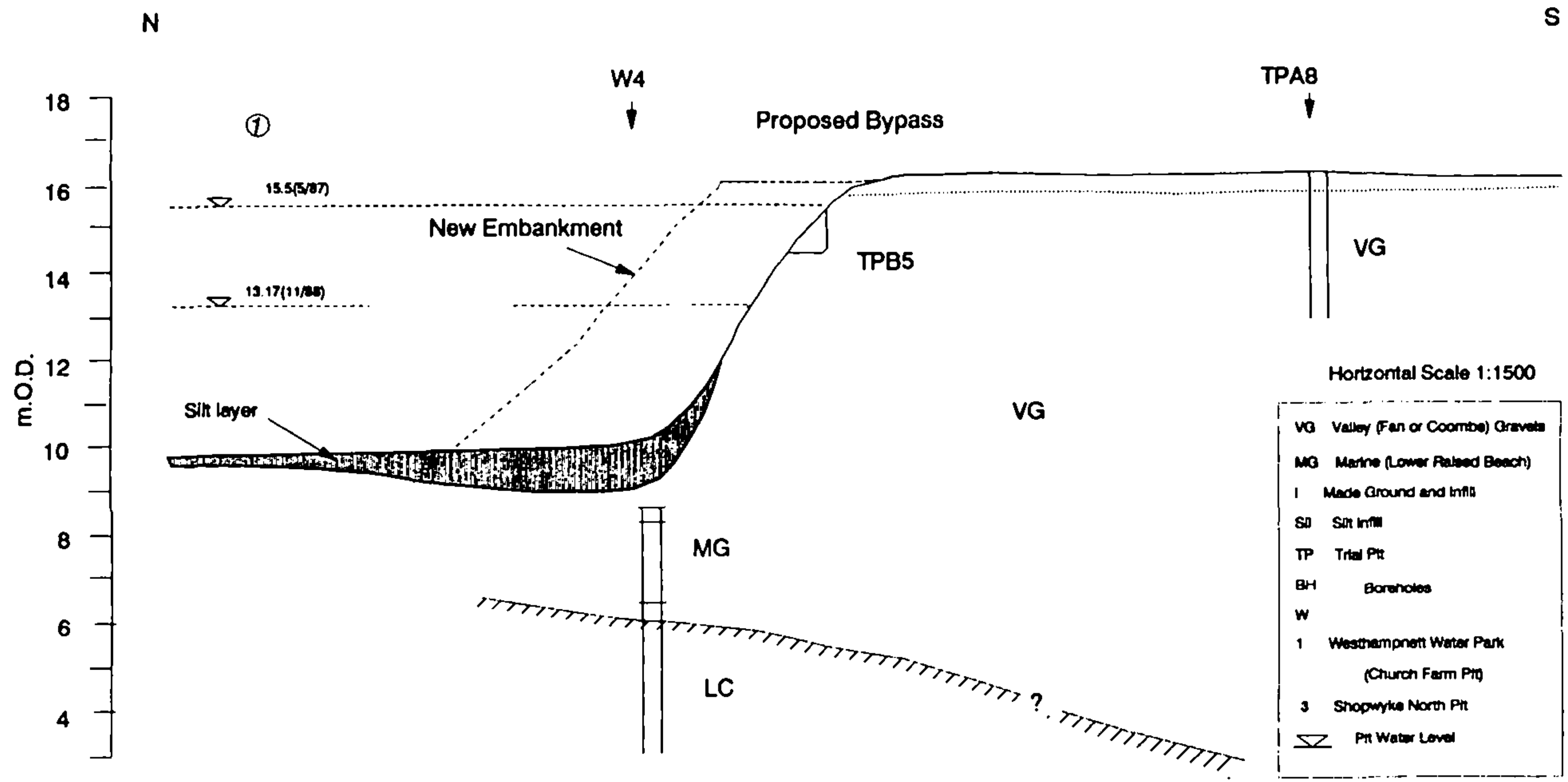


Figure 3.2d

Section across Church Farm Pit

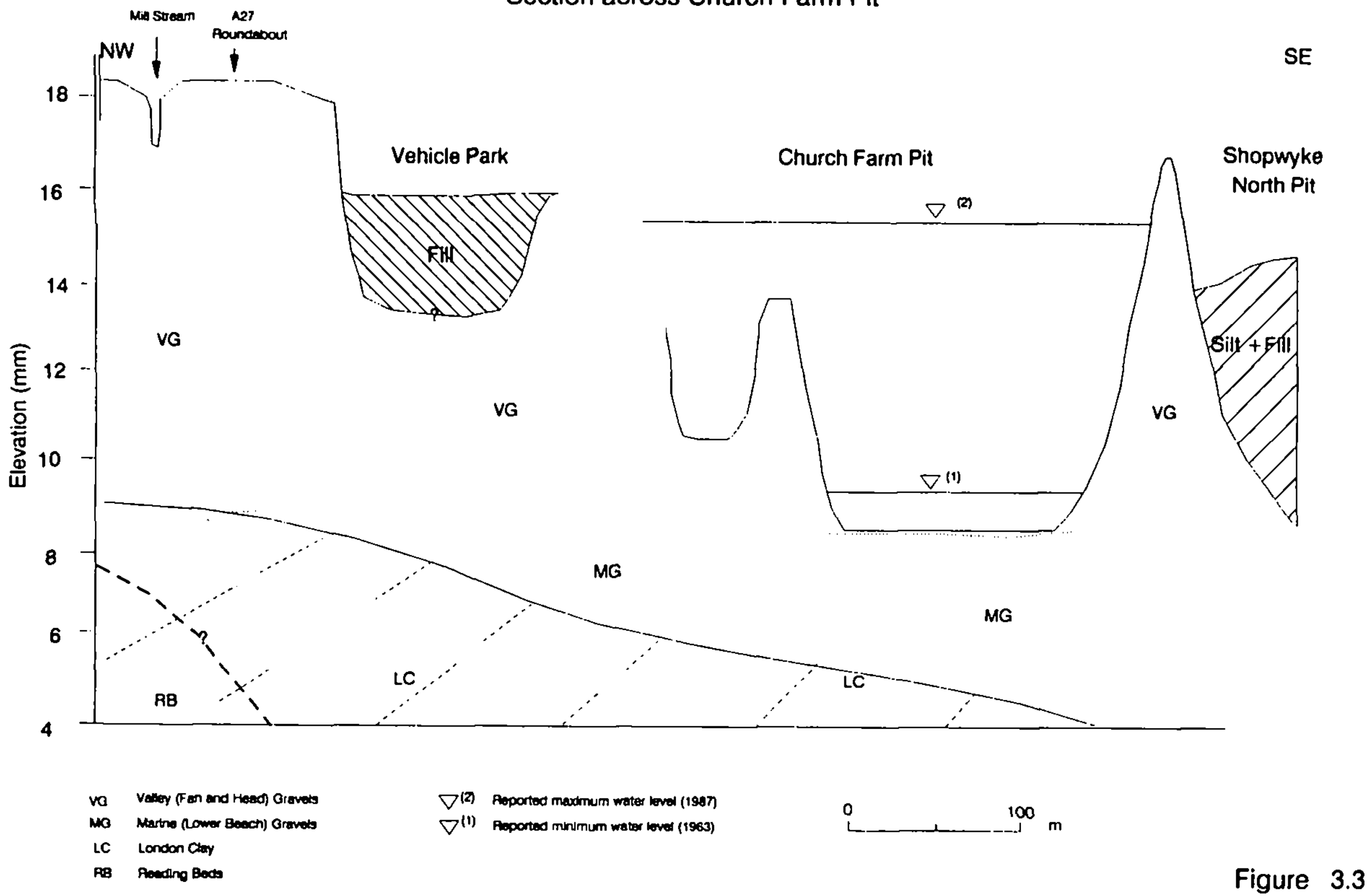


Figure 3.3

The demand for long-term scientific capabilities concerning the resources of the land and its freshwaters is rising sharply as the power of man to change his environment is growing, and with it the scale of his impact. Comprehensive research facilities (laboratories, field studies, computer modelling, instrumentation, remote sensing) are needed to provide solutions to the challenging problems of the modern world in its concern for appropriate and sympathetic management of the fragile systems of the land's surface.

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★

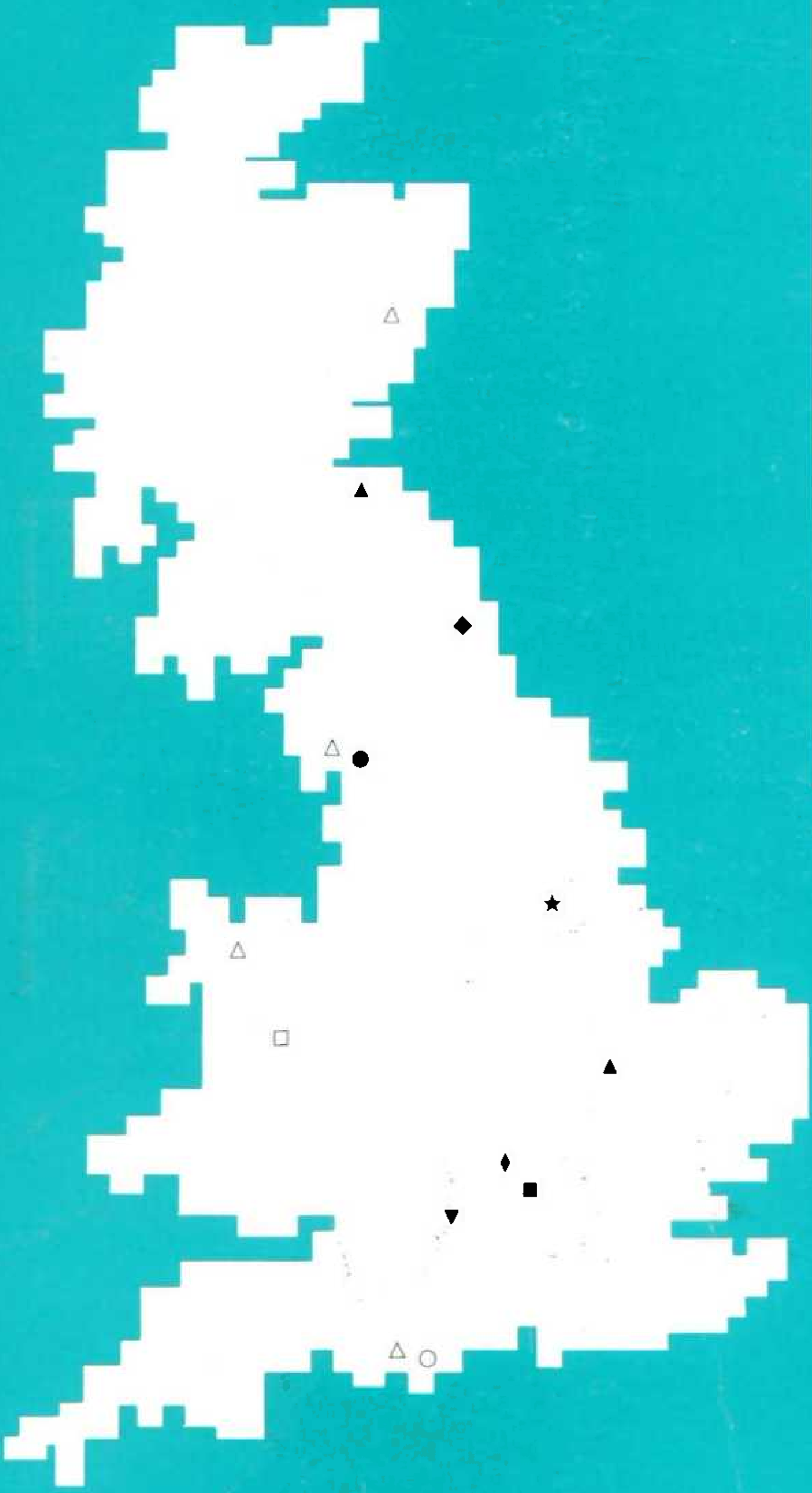
Land Use and Natural Resources

★

Environmental Quality and Pollution

★

Ecology and Conservation



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