INSTITUTE of HYDROLOGY

A27 WESTHAMPNETT BY-PASS, CHICHESTER.

HYDROGEOLOGICAL STUDY.

Water Level Control Measures.

INSTITUTE of HYDROLOGY

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Institute of Hydrology,
Wallingford.

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1. INTRODUCTION

A hydrogeological study undertaken by the Institute of Hydrology in October 1989 on the potential hydrological impact of the proposed A27 Westhampnett By-pass, indicated that water levels in Church Farm Pit (Westhampnett Water Park) are likely to rise as a result of the proposed construction of an embankment for the dual carriageway along the southern edge of this pit.

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.

Following a meeting with the Consultants on 21 November 1989 to discuss the implications of the conclusions from the hydrogeological study, the Institute of Hydrology were requested to examine the use of a soakaway connected to the Church Farm Pit as a means of preventing the potential impact on water levels resulting from the roadline.

2. SOAKAWAYS AS A PREVENTATIVE MEASURE

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.

The Southern Water Authority and its predecessor have been examining the problem of rising water levels in the area east of Chichester for more than 20 years, in particular to protect installations constructed on former working levels within the Church Farm Pit and in the Sopwyke North Pit immediately to the south. The rise in regional water levels is thought to be due mainly to the effects of gravel extraction and subsequent infilling, although the problem has been exacerbated by a period of higher rainfall over the past few years compared to the early 1970's.

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. It is understood that this method of controlling water levels has been used recently to dispose of water from the Shopwyke pits.

By utilising aquifer storage, soakaways can offer an attractive alternative to pumping directly to water courses or into adjacent pits (particularly as pumping is usually required when surface flows and pit water levels are high) and provide a means of "short-circuiting" the barriers to groundwater flow caused by the sealing and infilling of gravel pits.

However, the use of soakaways to control pit water levels also has some disadvantages:

- 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 actually benefit by including a soakaway 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.

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, although it may aggravate the rise in water levels in Church Farm Pit).

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.

2.3 Ground Conditions

Several trial pits and two boreholes have been drilled in the area of the soakaway. These include TPA 11 and 12, TPC 3 and 4, and BH 5 and 6.

BH 5 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. TPA 11 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 BH 5. 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 TP12 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.

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 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 loss in 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, as well as 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.

3. ACCEPTANCE RATE

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.

Using $n = L/\sqrt{(4Tt/S)} = 20/\sqrt{(4x1500x0.33/0.15)} = 0.17$

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:

$h = (hS/Wt)Wt/S = 0.05x7.5x0.33/0.15 = 0.82m$

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 0.8 days before the water level rose by 2m.

Conversely 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%.

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.

4. CONCLUSIONS AND RECOMMENDATIONS

1. This 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.

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.

The **Terrestrial and Freshwater Sciences** Directorate of the Natural Environment Research Council brings together an exceptionally wide range of appropriate disciplines (chemistry, biology, engineering, physics, geology, geography, mathematics and computer sciences) comprising one of the world's largest bodies of established environmental expertise. A staff of 550, largely graduate and professional, from four Institutes at eleven laboratories and field stations and two University units provide the specialised knowledge and experience to meet national and international needs in three major areas:

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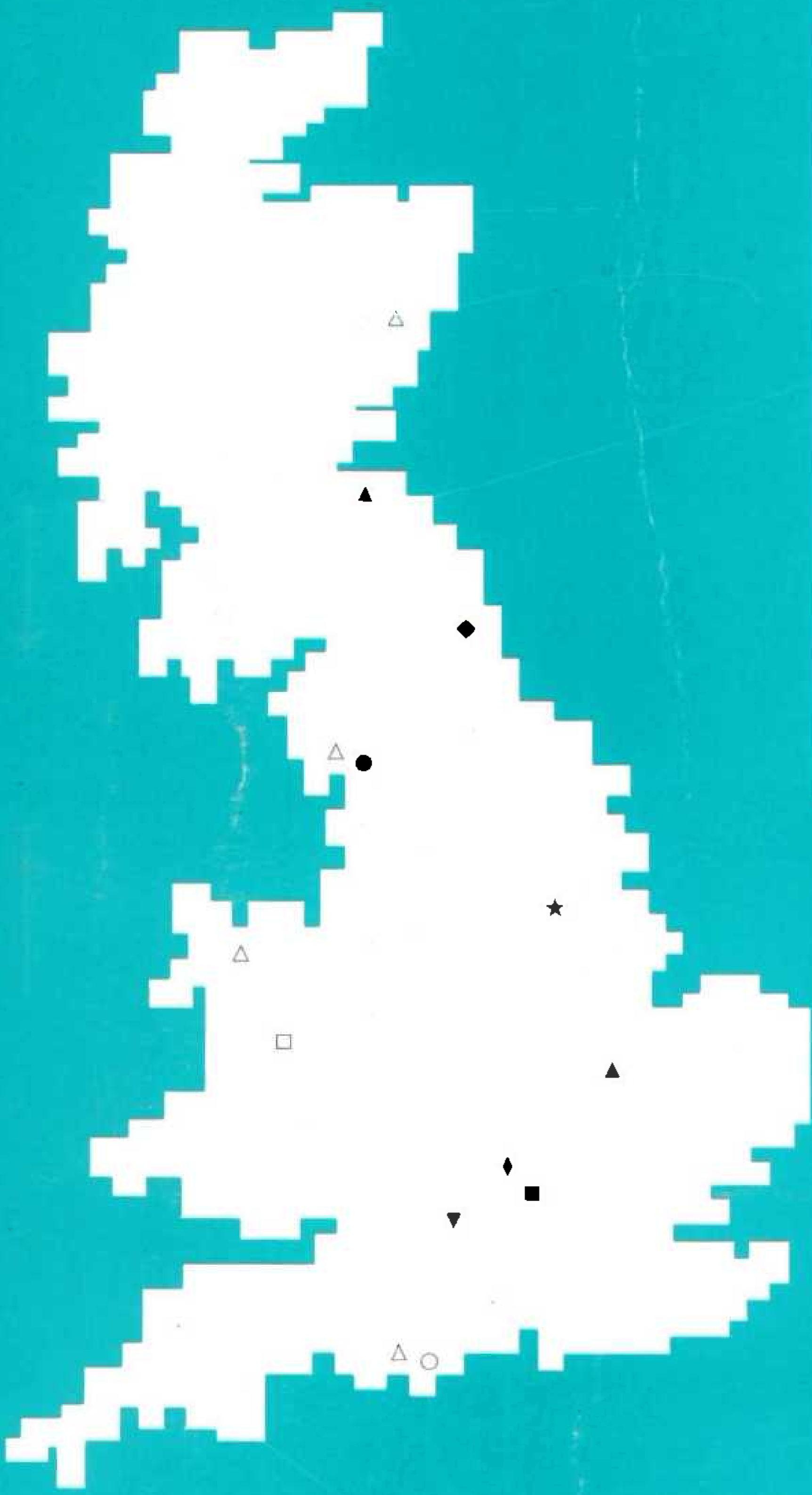

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