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CASE STUDY OF THE DEWATERING OF A MAJOR EXCAVATION IN A GLACIAL AQUIFER

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SUBMITTED IN FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

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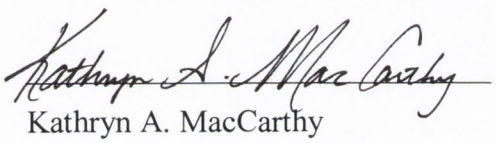
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SUMMARY

This thesis presents the findings of a case study of dewatering a major staged 3.5 km excavation in a heterogeneous, unconsolidated aquifer, the Mid-Kildare Aquifer. The objectives were to compile all the information available on the hydrogeological properties of the aquifer and on the dewatering project, and to analyse this information to compare the parameters predicted from the ground investigation with those back-analysed from the recorded aquifer response using traditional methods. This information was used to develop a conceptual model of the 200 km^2 Mid-Kildare Aquifer and finite-element numerical models of increasing complexity until both the seasonal groundwater level variation of the aquifer, which is generally about 2 m, and the dewatering were adequately represented. The finite-element numerical model was used to assess the influence of time varying recharge and the construction sequence on the dewatering exercise.

The data gathered during the ground investigation prior to construction of the Kildare Town Bypass included pump tests, variable head tests (VHT), and particle size distribution analyses (PSD). The analysis of the pump tests determined that the gravels that predominantly comprise the aquifer had a hydraulic conductivity varying from 10^{-5} m/s to 10^{-4} m/s, generally increasing from west to east along the excavation. The VHT and PSD tests were found to be unreliable, as the former underestimated while the latter overestimated the hydraulic conductivity. The underestimation of the VHTs could not readily be explained, however, the overestimation of PSDs could be attributed to a possible loss of fines during sampling.

Traditional methods, when back-analysed, gave a good estimation of the hydraulic conductivity values for the main excavation (when it was opened from Ch. 69+00 to 74+00) ($5.3x10^{-5}$ - $3.1x10^{-4}$ m/s) and at the Tully Bridge site ($1.2x10^{-4}$ - $3.1x10^{-4}$ m/s). These results are similar to the estimates of hydraulic conductivity obtained through the pump tests.

A three-dimensional conceptual model of the aquifer incorporating bedrock geology and glacial and recent geological maps; and depth to bedrock data from the Geological Survey of Ireland, data from the ground investigation for the Kildare Town Bypass along

with a digital terrain model of the topography from the Ordnance Survey of Ireland was used as the basis for the numerical model. The outflows to rivers and seepage areas (River Liffey, Tully Stream and Pollardstown Fen) and the flows into the aquifer from recharge were also incorporated. The numerical modelling was calibrated against the seasonal groundwater level variations observed in regional monitoring boreholes and boreholes along the excavation of the Kildare Town Bypass over a period from 1998 to 2006. Assuming a vertical/horizontal anisotropy of 1/10, it was necessary to vary the horizontal hydraulic conductivity in the gravels in the model from 10^{-5} m/s to 10^{-3} m/s, in order to obtain a good correlation with the groundwater levels and response. The numerical model established that two and a half years after dewatering, December 2006, most of the groundwater levels in the monitoring boreholes were between 0.1 m and 0.4 m lower than they would have been without dewatering. The amount of drawdown observed in the monitoring boreholes was a function of both the distance from the site of dewatering and the sediments in which they were located. The numerical model had a good correlation with the measured groundwater levels and estimated baseflow into the river, streams, and fen.

The numerical model established that recharge and hydraulic conductivity were the parameters which had the greatest effect on groundwater levels and response and that a complex model can be used to examine dewatering on a regional scale. Limitations encountered during the modelling included a numerical instability and potential inaccuracies with estimates of recharge. The numerical instability caused spikes within the total fluxes but did not affect the convergence of the model, the modelled groundwater levels or the discharges from the aquifer into the rivers and streams.

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Glacial sediments deposited by the last ice age cover much of the land mass in the northern latitudes of the northern hemisphere. These deposits overlie the bedrock in much of Ireland and thus are important reservoirs of groundwater and are commonly used, moved, and removed for infrastructure projects. In Ireland, when a cutting is formed in glacial sediments it may intersect with the groundwater table making it necessary to dewater the cutting to allow the construction to proceed. The wide range of properties exhibited by glacial sediments, ranging from fine, over-consolidated, basal tills to clean, coarse glaciofluvial sands and gravels, makes it difficult to predict the range of flows which may occur when dewatering these sediments. This thesis examines the Mid-Kildare Aquifer, which is the largest glacial aquifer in Ireland, and the effect of a major dewatering project on this aquifer. It will address, through the analysis of tests conducted during the site investigation, by the back-analysis of data collected during dewatering, and by finite-element modelling, the groundwater response of the Mid-Kildare Aquifer and characterise the effects of aquifer heterogeneities on groundwater flow. The results of this study will expand the understanding of groundwater response and should aid in planning future major dewatering projects.

1.2 BACKGROUND

Kildare County Council proposed the construction of the Kildare Bypass to help relieve traffic congestion caused by the National Primary Road (N7) running through the centre of Kildare town. The N7 is part of the national route linking Dublin to Limerick and Cork and is located approximately 50 km southwest of Dublin (Figure 1.1). The road, which bypasses Kildare town to the south, contains a 4.5 km section that was cut up to 7 m below ground level of which 3.5 km intersected the water table and required dewatering (Farrell and Coppinger, 2004). To reduce the long-term effects on the water table, a groundwater control system was installed beneath the road surface to allow the groundwater levels to return to 1.75 m above the road surface after completion of the road (Farrell and Coppinger, 2004).

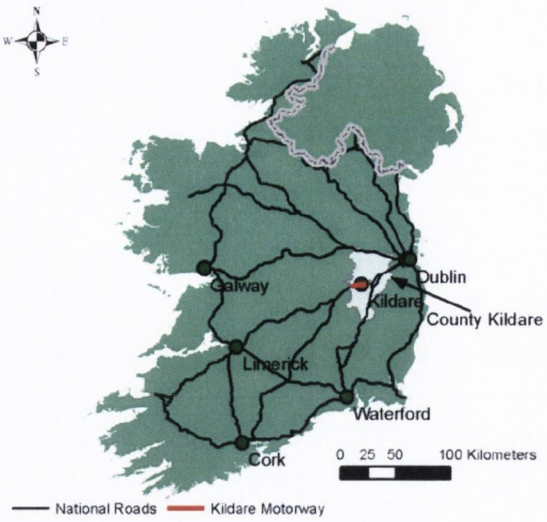


Figure 1.1: Location of Kildare Town Bypass in Ireland

The bypass was located 5 km away from Pollardstown Fen, a Special Area of Conservation, which necessitated an extensive groundwater monitoring programme to assess the effects of dewatering on the Fen. This provided a wealth of data which could be analysed to further the understanding of the groundwater response to dewatering in highly variable glacial aquifers. The data collected for the preliminary assessment of the aquifer before construction, from the construction period and post-construction period were analysed and will be used to develop an in-depth picture of the groundwater response to dewatering.

Much work has been conducted in an attempt to characterise various aspects of the Mid-Kildare Aquifer. The Geological Survey of Ireland (GSI) has produced maps of the bedrock, glacial and recent deposits. Geotechnical firms conducted site investigations including particle size distribution analyses, rising and falling head tests, and large-scale pumping tests. Boreholes were drilled to assess the depth to bedrock, the variation of the sediments with depth, and to monitor the groundwater levels. Flow rates were monitored in streams and rivers and rates of flow were measured from the pumps dewatering the cutting. Rainfall, potential evapotranspiration, and soil moisture deficit data were collected and calculated. These large collections of data from different sources, along with a digital terrain model (DTM) of the topography with a horizontal resolution of 50 and 10 m and a vertical accuracy to 25 cm from the Ordnance Survey of Ireland (OSI), make the Mid-Kildare Aquifer a suitable location for a case study.

In this thesis, these sources of data will be combined with complementary data, such as the maps obtained from the GSI, the borehole logs and photos of the exposed sediments during the cutting, to assess the variation and limitations of each source of data. The OSI DTM data and the GSI depth to bedrock data were combined to form a realistic three-dimensional model of the aquifer. The geological and geotechnical data on hydraulic conductivity were analysed, compared, and correlated to develop a three-dimensional model of the variation in permeability throughout the aquifer. The three-dimensional model was correlated to groundwater levels to assess its accuracy. The aquifer was modelled using a finite-element technique. The groundwater response of the aquifer to the dewatering is modelled to assess its effect on the aquifer.

The Mid-Kildare Aquifer extends from Naas in the southeast to Nurney in the southwest to the Chair Hills in the northwest to Kilcullen in the southeast covering approximately 200 km^2 (Figure 1.2). Understanding the setting in which the sediments were deposited is critical to understanding the groundwater response. Glacial sediments can be deposited from the base of the glacier (basal till), from the glacier melting away (ablation till), or from melt water running off of the glacier (outwash or glaciofluvial deposits). Both basal till and ablation till are unsorted and contain whatever material the glacier eroded as it advanced and retreated. Outwash or glaciofluvial deposits are sorted by the running water and generally contain sand and gravel deposits which are very permeable and can be very good aquifers as well as an economically important aggregate resource. Glacial deposits generally occur interlayered together as the glacier went through periods of advance and retreat. This creates the complex stratification that is found today in the area around Kildare. In glacial aquifers the hydraulic conductivity is dependent on the presence of sand and gravel layers. These tend to be highly variable, discontinuous and often interrupted by low permeability clay lenses. To develop an accurate three-dimensional conceptual model of the hydraulic conductivity in the aquifer these data were correlated to the glacial and recent geology, in an attempt to identify the hydraulic conductivity for specific units. To establish the accuracy and validity of this method, the calculated hydraulic conductivity was compared with those estimated from the flow measured from the dewatering during excavation for the construction.

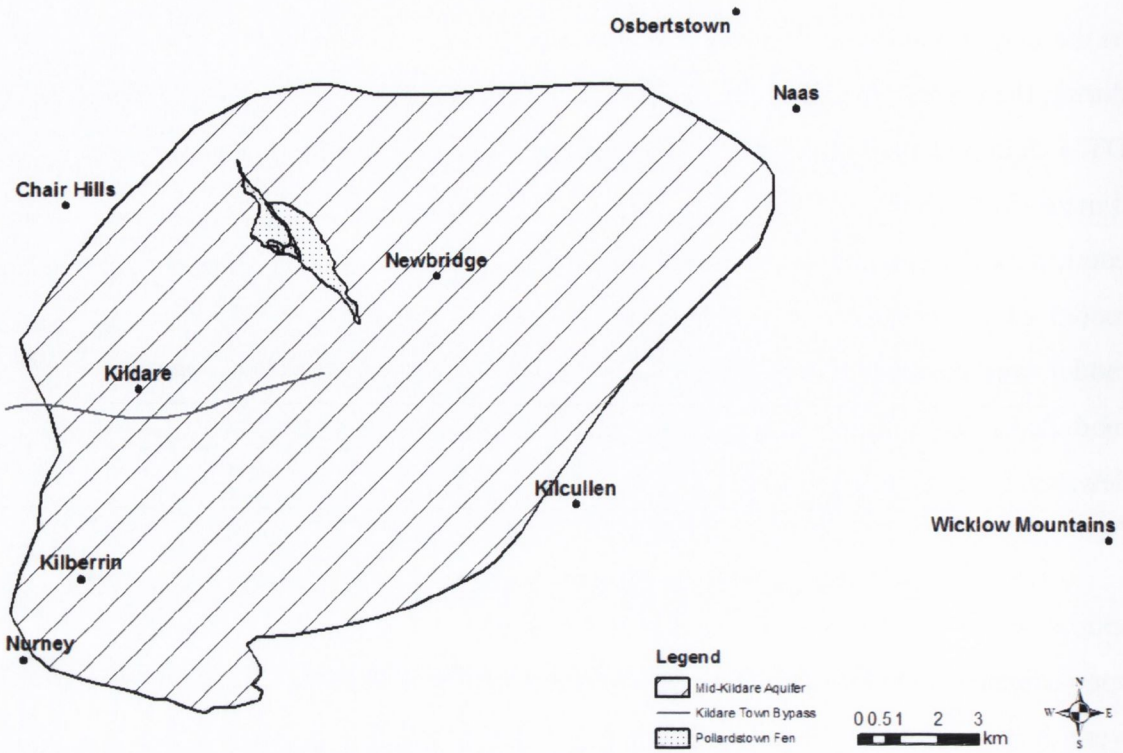


Figure 1.2: Location of the Mid-Kildare Aquifer and surrounding towns.

1.3 SCOPE AND OBJECTIVES OF THE STUDY

The objectives of this thesis were to compile all the information available on the hydrogeological properties of the aquifer and on the dewatering project, to analyse this information and to compare the parameters predicted from the ground investigation with those back-analysed from the recorded aquifer response using traditional methods, and to further the understanding of the groundwater response and the effect of construction dewatering on a heterogeneous unconsolidated aquifer. The case study of the Mid-Kildare Aquifer was selected to study the effect of dewatering on a glacial aquifer as a large quantity of data were collected as part of the Kildare Town Bypass project which required dewatering along a 3.5 km cutting. Additional monitoring boreholes were installed to record groundwater levels by a Monitoring Committee which was established to make recommendations on methods of mitigating the effects of dewatering.

The main objectives were achieved by compiling and analysing the available data and using these data to develop a conceptual model of the Mid-Kildare Aquifer and the dewatering for the Kildare Town Bypass. The methods used in the ground investigation of the Mid-Kildare Aquifer to obtain aquifer properties were assessed with particular attention to the conflicting results from the site investigation, as commonly occurs in

heterogeneous unconsolidated sediments. The reanalysed and compiled data were used to construct a finite-element model of the aquifer and the dewatering process. This model was subsequently compared to the groundwater levels measured in the monitoring boreholes and the groundwater patterns observed in the Mid-Kildare Aquifer to assess the accuracy and usefulness of the model in determining aquifer response to dewatering. The objectives include re-evaluations of current approaches to the design of dewatering systems with a view to highlighting the most important parameters to obtain when modelling an aquifer and dewatering and the best methods of obtaining these parameters. It is hoped that through these recommendations, future schemes can be developed to better target site investigations.

The objectives of this thesis will be achieved through:

1) Compiling the geotechnical and geological data, including the Monitoring Committee data on groundwater levels in monitoring boreholes.
2) Compiling data on dewatering.
3) Interpreting the geology in the area of the Mid-Kildare Aquifer.
4) Critically assessing the hydrogeological parameters from the pre-construction information.
5) Documenting the groundwater response to the excavation.
6) Making an assessment of the hydrogeological parameters for recorded response using a simple model.
7) Developing a conceptual hydrogeological model of the Mid-Kildare Aquifer.
8) Conducting finite-element analysis and calibrating the aquifer parameters.
9) Developing a method of modelling a staged dewatering excavation.
10) Carrying out verification studies.
11) Developing a groundwater model of an excavation correlating measured data from before, during and after excavation.

The novel aspects of this project which will contribute to the general knowledge of the area are:

1) The development of a three-dimensional model of the Mid-Kildare Aquifer by combining a digital terrain model, depth to bedrock data, bedrock, and glacial and recent geology maps.

2) Assessment of the validity of applying the traditional techniques of estimating the dewatering requirements which were developed for homogeneous, isotropic sediments in heterogeneous, anisotropic sediments.
3) The dewatering model which looks at effects over the entire aquifer rather than simply local cone of depression and following the drawdown through time.
4) The critical assessment of the benefits and drawbacks of using finite-element modelling to investigate the effects of dewatering in heterogeneous glacial aquifers.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Glacial aquifers provide a challenging environment to assess hydrogeological properties due to the wide range of possible characteristics. The glacial aquifer, which was dewatered as the case study of this thesis, broadly consists of glacial outwash deposits which are, in some places, overlain by glacial till. A till is defined as a collective term for the group of sediments laid down by the direct action of glacial ice without the intervention of water. Glacial outwash consists of stratified sands and gravels deposited by melt water at or near the margins of a glacier. Thus, the literature review focuses on both of these types of sediments. The review of the published literature pertaining to the Mid-Kildare Aquifer can be found in the first part of Chapter 3. Many studies have focused solely on the formation or on the effect of the method of deposition and subsequent weathering on the aquifer properties and some of these are reviewed. Studies on the methods of determining groundwater properties such as hydraulic conductivity in unconsolidated soils (overburden) will also be reviewed. The hydraulic conductivity is the parameter which relates the rate at which water can move through a permeable medium in relation to the hydraulic gradient. It is also known as the coefficient of permeability but differs from the intrinsic permeability. The intrinsic permeability of a porous medium is independent of the properties of the fluid involved and is a characteristic of the porous medium alone (Misstear *et al.*, 2006). The generic term, permeability, is used in this thesis to refer to the hydraulic conductivity. These studies outline the benefits and limitations of each testing method and the best approach to analysing the data to determine the hydraulic properties of glacial aquifers. Dewatering projects elsewhere and the methods used to dewater and monitor the groundwater response with respect to dewatering will be examined.

The literature review is subdivided into the following areas which are relevant to different facets of this study:

1) The hydrogeology of glacial aquifers.
2) The field assessment of hydrogeological parameters.
3) A review of groundwater modelling of glacial aquifers.
4) A review of dewatering projects in unconsolidated sediments (overburden).
5) A brief review of groundwater response.

2.2 *HYDROGEOLOGY OF GLACIAL AQUIFERS*

Several studies have been conducted to assess the heterogeneity of glacial aquifers which provide insights into techniques which could be incorporated into site investigations. These studies have been conducted primarily by glaciologists and geophysicists therefore the terminology used in this section reflects the language in the papers themselves, which in some cases, may differ from that used by geotechnical engineers. The review of the hydrogeology of glacial aquifers contains an examination of the methods used to characterise glacial environments and the variation that exists in the published hydraulic conductivities for similarly classified sediments.

Heinz and Aigner (2003) conducted an extensive study of all scales of heterogeneity within glaciofluvial deposits of the Rhine glacier area in southwest Germany. The Rhine glacier was a typical Alpine ice lobe that accumulated in the upper reaches of the Alps and advanced to the north through high-relief mountain valleys before spreading out into the Alpine foreland during several climate cycles of the Pleistocene. A systematic hierarchical analysis of the Quaternary gravel deposits was conducted covering the different spatial and temporal scales in order to deduce the sedimentary processes of their formation at each level. As the various scales of heterogeneity affect and control the subsurface permeability distribution, their impact on aquifer characterization was highlighted and qualitative data on geometries and hydraulic properties of various gravel units were presented (Heinz and Aigner, 2003).

The study defined and classified the glaciofluvial sediment heterogeneity into six scales whereby each scale could be translated into a defined hydrostratigraphic unit. The scales varied from: 1) particles and pores, 2) strata, 3) depositional elements 4) facies bodies 4) genetic sequences 6) entire basin fill. Heinz and Aigner (2003) report a very large range in hydraulic conductivity with the alternating gravels varying over eight orders of magnitude (10^0 m/s for open-work gravels (very little fines content) to 10^{-7} m/s for massive and matrix-rich (silty) gravels), however they do not indicate the techniques used to obtain the hydraulic conductivity. This study concluded that a combination and integration of different methods (sedimentological, geophysical, geochemical, and morphostratigraphical) is necessary for the recognition and detection of sedimentary units and all scales of heterogeneity exert a profound influence on the hydrostratigraphic behaviour of strata (Heinz and Aigner, 2003).

Geophysical techniques such as seismic reflection, seismic refraction, ground penetrating radar and resistivity, have been used with success to define aquifer parameters (e.g. Birkelo, *et al.*, 1987; Miller, *et al.*, 1989; Bruno and Godio, 1997; Karaman and Carpenter, 1997; Gburek, *et al.*, 1999; Francese, *et al.*, 2005). High-resolution seismic reflection profiling has been widely developed and applied in many different locations to assist in the investigation of groundwater resources (e.g. Birkelo, *et al.*, 1987; Miller, *et al.*, 1989; Bruno and Godio, 1997; Francese, *et al.*, 2005). Francese *et al.* (2005) examined the effectiveness of seismic reflection techniques in a mixture of natural sediments and deposits related to excavation activity in an urban setting which restricted the type and size of seismic source that could be applied. The seismic waves were useful in identifying low permeability structures up to a depth of approximately 150 m. Seismic refraction surveys have also been widely used to identify fractures, to determine the lateral and vertical extent of aquifers, depths of gravels over more dense bedrock, and depth to the water table (Karaman and Carpenter, 1997; Gburek, *et al.*, 1999). Resistivity data has been found to be useful in estimating lithology and hydraulic conductivity Ponzini *et al.*, 1984, (Bowling *et al.*, 2005). Bowling *et al.* (2005) examined the effectiveness of electrical resistivity surveys and ground penetrating radar (GPR) in a fluvial environment with particle sizes ranging from gravel to clay. The GPR was able to penetrate to a depth of 14.7 m while the resistivity survey penetrated to a depth of 15.0 m which was the approximate depth to the aquitard bounding the unconfined aquifer. The GPR was useful in determining the structure of the sediments and identifying the strata within the depth of penetration and can also be used to determine the location of the groundwater table. The resistivity survey was useful in identifying disturbed sediments. High-resistivities were associated with gravels, moderate resistivities with sands, and low-resistivities with clays. In this study, the water table coincided with the top of the gravel layer masking its signature within the resistivity survey. The water level was known from boreholes drilled within the study area.

Several studies have been published on the hydraulic conductivity values of glacial tills (Frink *et al.*, 1997; Shaw and Hendry, 1998; Salem, 2001; Leroueil *et al.*, 2002; Farrell *et al.* 2003; Swartz *et al.*, 2003). Hydraulic conductivity of glacial tills depends on the clay content, mode of deposition, and degree of weathering (Salem, 2001; Swartz *et al.*, 2003). Ablation till is deposited as the glacier melts and is typically slightly water sorted making it more permeable than basal till which is laid down beneath the ice. Frink *et al.* (1997) conducted rising head tests to determine the hydraulic conductivity of tills and glacial

outwash sediments from southwestern Ohio and the effect of weathering on the tills and outwash (Table 2-1). This study shows the wide range in hydraulic conductivity found even within very similar sediments and indicates the need for the consistent use of soil classifications so that studies can be compared to each other, since Frink *et al.* (1997) find a very low hydraulic conductivity for gravels. Frink *et al.* (1997) mention the difficulty involved in classifying some of the sediments as they grade from one to another and are in close proximity to each other.

Table 2-1: Estimations of hydraulic conductivity from rising and falling head tests from Frink *et al.*, (1997).

AUTHOR	UNIT TESTED	TESTING METHOD	HYDRAULIC CONDUCTIVITY
Frink *et al.* (1997)	clay	Rising and falling tests	1.9×10^{-8} m/s (fresh) to 3.6×10^{-7} m/s (weathered)
	silt	Rising and falling tests	8.8×10^{-7} m/s (fresh) to 9.9×10^{-7} m/s (weathered)
	sand	Rising and falling tests	8.0×10^{-6} m/s (fresh) to 1.7×10^{-5} m/s (weathered)
	gravel	Rising and falling tests	4.3×10^{-5} m/s (fresh) to 3.1×10^{-4} m/s (weathered)

Shaw and Hendry (1998) tested a clay-rich till in southern Saskatchewan using both field and laboratory methods (Table 2-1). The till layer consisted of an upper 3 - 4 m of oxidized and fractured weathered till underlain by 76 - 77 m of unweathered till. The particle size distributions for this till were uniform with depth indicating a relativity homogeneous till which was confirmed by the laboratory hydraulic conductivity tests which yielded consistent results with depth. The close agreement among the results suggests that transient (consolidation testing), quasi-steady-state (falling-head testing), and steady-state (constant-head testing) techniques were equally effective in determining the hydraulic conductivity of the matrix. The authors explained the relatively higher hydraulic conductivity found in the oxidized till as the result of hydraulically continuous fractures and the higher values measured at 15.7 m were attributed to the presence of sand streaks which were observed in core samples collected between 12.5 and 14 m (Shaw and Hendry, 1998).

Table 2-2: Estimations of hydraulic conductivity from Shaw and Hendry (1998).

AUTHOR	UNIT TESTED	TESTING METHOD	HYDRAULIC CONDUCTIVITY
Shaw and Hendry (1998)	clay-rich till	consolidation tests	3.2×10^{-11} m/s
	clay-rich till	falling-head tests (lab)	1.3×10^{-11} m/s
	clay-rich till	constant-head tests	2.3×10^{-11} m/s
	oxidized till	rising-head tests (field)	6.5×10^{-9} to 1.3×10^{-8} m/s
	Unoxidized till	rising-head tests (field)	1.1×10^{-8} m/s at 8.4 m 4.5×10^{-10} m/s from 8.4 to 15.7 m 5.8×10^{-11} m/s at 28.9 m 2.4×10^{-11} to 8.4×10^{-11} m/s from 29 to 80 m

Leroueil *et al.* (2002) tested glacial tills from northern Québec and found the hydraulic conductivity to be extremely sensitive to fines content varying up to four orders of magnitude. The hydraulic conductivity obtained with homogeneous fabric was found to vary with the clay-size particle fraction, typically decreasing by one order of magnitude when the clay-size particle fraction increases by 2.5%.

Farrell *et al.* (2003) conducted laboratory hydraulic conductivity tests on undisturbed and compacted samples of well graded Irish tills. The hydraulic conductivity values were obtained from triaxial tests on 100 mm diameter by 100 mm high specimens and found the hydraulic conductivity of the undisturbed to be between 10^{-9} and 10^{-10} m/s for void ratio less than 0.45. The hydraulic conductivity of the compacted samples had similar values between 10^{-9} and 10^{-10} m/s, apart from three specimens which had values between 10^{-7} to 10^{-9} m/s. The specimens with the higher hydraulic conductivities were compacted dry as opposed to wet of optimum. This study highlights the effect of soil structure, which influences the porosity and anisotropy of the soil, on the hydraulic conductivity of compacted tills.

Fewer studies have been conducted on coarse-grained glacial sediments. Salem (2001), Gierczak *et al.* (2006), and Levy *et al.* (2007) examined the hydraulic conductivity of glaciofluvial and outwash deposits using a variety of techniques. Salem (2001) used the Kozeny-Carman equation to calculate the hydraulic conductivity for glacial outwash sediments collected from the Segeberger forest, northern Germany. The proportion of clays and silts ($\leq$63 μm) in these sediments were less than 1.5% causing the hydraulic conductivity to be relatively high, ranging from 4.0×10^{-6} to 3.4×10^{-2} m/s. Salem (2001) found the hydraulic conductivity obtained from grain size to correlate well those obtained experimentally from pump tests and laboratory measurements.

Gierczak *et al.* (2006) measured the hydraulic conductivity using a variety of field and laboratory techniques in complex, discontinuous and interstratified silt, sand and gravel units of glaciofluvial origin located in Baden, Ontario. The hydraulic conductivity obtained from grain size (2 samples), permeameter testing performed on core samples, a borehole flowmeter test (using a tracer), and pumping tests (2 locations) are shown in Table 2-3. These tests highlight the effect of scale on heterogeneous aquifers as the hydraulic conductivity varies over two orders of magnitude within the test interval.

Table 2-3: Estimations of hydraulic conductivity from Gierczak *et al.* (2006).

AUTHOR	UNIT TESTED	TESTING METHOD	HYDRAULIC CONDUCTIVITY
Gierczak *et al.* (2006)	interstratified silt, sand and gravel	grain size (2 tests)	1.92×10^{-4} m/s and 9.41×10^{-4} m/s
		permeameter	6.22×10^{-5} m/s
		flowmeter	1.29×10^{-3} m/s
		pump tests (2 tests)	5.27×10^{-4} m/s and 5.94×10^{-4} m/s

Levy *et al.* (2007) investigated the physical properties of glacial outwash collected from southwestern Ohio with a view to determining the transport of *E. Coli*. The examined samples (3.05 m long with a 10 cm diameter) had a gravel content ranging from 19 - 80% averaging 43% and a sand content ranging from 11 - 75% averaging 52%. The rest of the samples were composed of silts and/or clays. The porosity of the samples in the laboratory ranged from 0.18 to 0.30 with an average of 0.24 and the hydraulic conductivity was estimated using a constant head permeameter and was found to be in the range of 5.3×10^{-6} m/s to 6.2×10^{-4} m/s with an average of 7.0×10^{-5} m/s.

Glacial aquifers are often heterogeneous and thus behave differently under pumping than their homogeneous counterparts (Gierczack *et al.*, 2006). Gierczack *et al.* (2006) studied pump tests in a heterogeneous glacial aquifer in Baden, Ontario and found that because water is transmitted most quickly through the units with the highest hydraulic conductivity, if multilevel monitors are installed across layers of relatively low and high hydraulic conductivity then the greatest early time drawdowns will occur in the most permeable units while the lowest early time drawdowns will occur in the least permeable units. If the heterogeneous units comprise discontinuous lenses, vertical flow from low permeability strata to higher permeability strata will maintain non-vertical equipotentials indefinitely, leading to a steady-state drawdown profile that resembles the early-time drawdown profile. Gierczack *et al.* (2006) concluded that the highest drawdowns will be

observed in the most permeable units which cause the pattern of drawdowns to be exactly the inverse of that expected assuming homogeneity and fully screened wells.

2.3 ASSESSMENT OF HYDROGEOLOGICAL PARAMETERS

Field assessment is an integral part of any characterisation of hydrogeological parameters of an aquifer. The hydraulic conductivity and storativity are the hydrogeological parameters which are considered in this section. The hydraulic conductivity can be estimated using laboratory (particle size distribution analyses) and field methods (variable head and pumping tests) while the storativity is generally estimated from pumping tests. The flow of water through the saturated zone of an aquifer can be represented by the Darcy equation where Q is the groundwater flow rate, A is the cross-sectional area of flow, K is the hydraulic conductivity, and i is the hydraulic gradient (Misstear *et al.*, 2006). The negative denotes that flow takes place in the direction of negative (decreasing) hydraulic gradient.

$$Q = -AKi \qquad \textbf{Eq. 2-1}$$

The storativity is the volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head (Fetter, 2001). The storativity in a confined aquifer is referred to as specific storage which is the volume of water that a unit volume of aquifer releases from storage under a unit decline in hydraulic head (Kruseman and de Ridder, 2000). In an unconfined aquifer the storativity is referred to as the specific yield which is the volume of water that an unconfined aquifer releases from storage per unit surface area of aquifer per unit decline in watertable (Kruseman and de Ridder, 2000). The storativity, S, of a confined aquifer is given by the product of the specific storage, S_S, and the aquifer thickness, b, and is dimensionless. It can also be defined in terms of ΔQ, the amount of water released to or from storage, A, the area from which the volume of water is released per unit change in head, Δh, and the change in head (Misstear *et al.*, 2006).

$$S = \frac{\Delta Q}{A\Delta h} = S_S b \qquad \textbf{Eq. 2-2}$$

2.3.1 HYDRAULIC CONDUCTIVITY

Hydraulic conductivity may be determined by collecting samples in the field and then analysing them in a laboratory (e.g. particle size distribution analyses), or *in-situ* by variable head tests or pumping tests. Variable head tests are the least expensive *in-situ* testing method; however, these tests are small in scale and are limited to providing values of hydraulic conductivity representative of only a small volume of ground in the immediate vicinity of the test. Pumping tests are generally larger in scale and duration compared with variable head tests and, therefore, are more expensive, but can provide measurements of aquifer transmissivity and storativity that are representative of a large volume of the aquifer.

The value of hydraulic conductivity can be dependent on the testing method used especially if the testing methods sample different amounts of soil. Benson *et al.* (1997) investigated this using four test beds, which were constructed with soil composed of 1% gravel and 85% fines (including 42% clay) from the same source using the same specifications. Three of the test beds were 46 m long, 8 m wide and 0.9 m thick and the fourth bed had the same dimensions as the others except that it was 22 m wide. Four methods were used to assess hydraulic conductivity: (1) sealed double-ring infiltrometers (SDRI); (2) two-stage borehole permeameters; (3) laboratory hydraulic conductivity tests on large block specimens; and (4) laboratory hydraulic conductivity tests on small specimens collected in thin-wall sampling tubes. The two-stage borehole permeameter test is also known as the Boutwell Permeameter and consists of two falling head tests where the geometry of the borehole is changed between the first and second test (Daniel, 1989). Benson *et al.* (1997) used a cased borehole as the first geometry which was subsequently extended with the extended section left uncased for the second geometry. Two of the test beds were constructed in such a way as to produce macroscopic defects. The large scale field tests provided similar hydraulic conductivities (10^{-9} m/s) regardless of defects, however, the small scale field tests were an order of magnitude lower (10^{-10} m/s) in the samples with the macroscopic defects than in the homogeneous samples. This indicates that the small specimens were too small to adequately represent the network of pores controlling the field-scale hydraulic conductivity.

2.3.1.1 PARTICLE SIZE DISTRIBUTION ANALYSES

Particle size distribution analyses are an inexpensive method of estimating hydraulic conductivity, however, the accuracy of the results obtained varies widely with the method chosen to do the estimation. Most of the methods are designed to be used with either fine- or coarse-grained soils. Estimates of hydraulic conductivity from particle size distribution data are useful because the data are routinely collected to measure textural and structural soil properties. Caution must be used with the results of particle size distribution analyses as they are collected in the field and transported to a laboratory. This may cause the structure of the sample to be disturbed losing the original structure of the sample causing fines or coarse material to be lost affecting the resulting estimates of hydraulic conductivity.

Several empirical formulae have been developed to relate the particle size distribution of a soil to its hydraulic conductivity. The Hazen method (Hazen, 1911; Fetter, 2001) is the simplest of the methods using the particle size distribution of the soil to obtain an estimate of the hydraulic conductivity. Hazen's approximation of hydraulic conductivity was originally for clean sands; however, it has been applied to soils ranging from fine sands to gravel. Many of the other methods of assessing hydraulic conductivities from particle size distribution analyses involve variations or refinements of the basic Hazen method. The variations generally try to better predict the hydraulic conductivity for a wider range of grain sizes. The other methods range in complexity from changing the constant that is multiplied by the effective grain size to the introduction of multivariate regression analysis to account for the whole spectrum of the grain-size distribution (Boadu, 2000). The methods which incorporate more robust variables than Hazen's effective grain-size are generally recommended but the Hazen formulation still enjoys widespread use due to its simplicity (Carrier, 2003).

The Hazen (1911) method consists of a simple formula which relates the hydraulic conductivity, K, to the effective grain size in mm, D_{10}, (the grain size diameter at which 10% by weight of the soil particles are finer) and a coefficient, C, related to the type of soil being tested (e.g. medium sand, well sorted C = 0.08 to 0.12 (Fetter, 2001)):

$$K = CD_{10}^2 \qquad \textbf{(m/s)} \qquad \textbf{Eq. 2-3}$$

The Pavchich method (Vuković and Soro, 1992; Kasenow, 2002), expressed solely on the basis of effective grain size diameter, is given below. This method is intended for use with fine-grained samples and is based on results from over 300 laboratory experiments. It follows the same basic formula as Hazen but uses D_{17} as the effective grain size in mm.

$$K = 0.35x10^{-2} D_{17}^2 \quad \textbf{(m/s)} \qquad \textbf{Eq. 2-4}$$

The Harlemann (Chin, 1999) formulae were devised though laboratory experiments and were found to give a reasonable estimate of hydraulic conductivity for coarse-grained soils.

$$K = 0.750x10^{-3} D_{10}^2 \quad \textbf{(m/s)} \quad \text{Harlemann} \qquad \textbf{Eq. 2-5}$$

Kozeny (1927) and Carman (1938; 1956) developed a formula that took more soil parameters into account. The Kozeny-Carman formula is based on the unit weight of the permeant, γ, the viscosity of permeant, μ, the Kozeny-Carman empirical coefficient, $C_{K\text{-}C}$, the specific surface area per unit volume of particles (1/cm), S_0, and the void ratio, e (Carrier, 2003).

$$K = (\gamma/\mu)(1/C_{K-C})(1/S_0^2)[e^3/(1+e)] \quad \textbf{(m/s)} \qquad \textbf{Eq. 2-6}$$

This formula can be simplified for use when the permeant is water at 20°C. Then $\gamma/\mu = 9.93x10^4$ 1/cm s and $C_{K\text{-}C}$ is taken to be equal to 5 (Carrier, 2003). Thus Eq. 2-7 becomes:

$$K = 1.99x10^4 (1/S_0^2)[e^3/(1+e)] \quad \textbf{(m/s)} \qquad \textbf{Eq. 2-7}$$

Bear (1972) simplified the Kozeny-Carman formula to only take into account the porosity, n, and mean particle size of the soil, D_M in mm.

$$K = 9.79\left(\frac{n^3}{(1-n)^2}\right)\frac{D_M}{180} \quad \textbf{(m/s)} \qquad \textbf{Eq. 2-8}$$

Mbonimpa *et al.* (2002) adjusted the Kozeny-Carman formula to take into consideration more geotechnical parameters of the soil. These include a dimensionless constant, C_G, which is equal to the product of C_e (material parameter used in the void ratio function) and C_d (material parameter used in the effective diameter function) which is

equal to $1/\alpha$ where α is the shape factor and equal to 0.1 which Mbonimpa *et al.* (2002) based on a large number of test results; the unit weight of water, γ_w, which equals 9.81 kN/m^3 at 20°C; the dynamic viscosity, μ_w, which equals 10^{-3} Pa.s at 20°C; the void ratio, e, which Mbonimpa *et al.* (2002) found to equal 0.312 (calculated as an average from the consolidation test calculations - one anomalous value not used); a parameter introduced in the void ratio function to take into account the effect of tortuosity, x, which equalled 2 and was not dependent on type of material tested; the uniformity coefficient, C_U, which is equal to D_{60}/D_{10}, where D_{10} is equal to the effective diameter, corresponding to 10% passing on the cumulative grain size distribution curve and D_{60} which is equal to the diameter corresponding to 60% passing on the cumulative grain-size distribution curve in mm. This formula was developed to work for all granular soils with permeabilities in the range of 10^{-10} to 10^{+0} m/s.

$$K = C_G \frac{\gamma_w}{\mu_w} \frac{e^{3+x}}{1+e} C_u^{1/3} D_{10}^2 \qquad \textbf{(m/s)} \qquad \textbf{Eq. 2-9}$$

The Geological Survey of Ireland identified tills in Ireland on the basis of their till lithology. Swartz *et al.* (2003) determined that mapping based on stone lithology was not useful in terms of classifying the permeability of the tills, as tills that had been classessed has having a moderate permeability using stone lithology were found to have nearly identical grain size distributions as those classessed as having a low permeability. This is the result of the permeability of tills being more closely related to the till matrix rather than the dominant type of clast. Swartz *et al.* (2003) found that the most successful method of determining permeabilities was to use a holistic approach using data from a wide variety of sources. Other authors have attempted to link hydraulic conductivity to void ratios, soil structure and moisture content (Farrell *et al.*, 2003).

2.3.1.2 VARIABLE HEAD TESTS

The determination of hydraulic conductivity in the field using boreholes is dependent on creating a hydraulic pressure in a borehole which is different from that of the surrounding soil. Variable head tests (VHT) are conducted by either filling a borehole with water for a falling head test or by pumping out water for a rising head test. The head of the borehole is then allowed to equalize with that in the ground, the head being measured at intervals of time from the commencement of the test. In some cases, the borehole may be extended beyond the bottom of the casing, thus increasing the surface

through which water can flow. Variable head tests can take days to equilibrate in fine clays or can be nearly instantaneous in coarse gravels. These tests assume that the soil is not significantly changed by the drilling of the borehole, the effect of soil compressibility is negligible, and that the natural groundwater level is known and does not change during the time of the test. Variable head tests are limited in the volume of soil tested and so are more suited to homogeneous sediments as they do not test a large enough area to account for most heterogeneity (Hiscock, 2005). They are not suitable for soils with extremely high hydraulic conductivity ($>10^{-3}$ m/s) as the flow rates may be large and the head losses entering or exiting the borehole may be too fast to measure. Nor are they suitable for sediments with extremely low hydraulic conductivity ($<10^{-8}$ m/s) as the flow rate is very slow and the head loss may be too small to measure (British Standards Institution, 2003).

Hvorslev (1951) assumed that the time lag is the only measurable effect and that all others are negligible. The time lag is the time required for water to flow to or from the borehole until a desired degree of pressure equalization is attained. In order to reduce time lag and increase the sensitivity of the installation to rapid pressure changes, the volume of flow required for pressure equalization should be reduced to a minimum, and the intake area should be as large as possible (Hvorslev, 1951). The time lag is assumed to be the only source of error which produces a measurable effect which can be corrected for and is sometimes referred to as the basic time lag.

Hvorslev (1951) defined the hydraulic conductivity, K, in terms of the cross-sectional area of the borehole, A, the intake factor, F, the variable head measured, H_1, at time at the start of the test, t_1, and the variable head, H_2, measured at later time during the test, t_2. The intake factor is determined by the borehole geometry (e.g. the relationship between the diameter of the borehole and the length of the screened section) in which the variable head test is conducted.

$$K = \frac{A}{F(t_2 - t_1)} \log_e \frac{H_1}{H_2} \qquad \textbf{Eq. 2-10}$$

This equation can be simplified for the case where $\log_e H_1/H_2$ equals 1 to produce Eq. 2-11. Eq. 2-10 can be rearranged to determine the time lag, T (equivalent to $t_2 - t_1$ in Eq. 2-10):

$$T = \frac{V}{q} = \frac{AH}{FKH} = \frac{A}{FK} \qquad \textbf{Eq. 2-11}$$

Hvorslev's (1951) formula is derived on the assumption that the soil stratum in which the borehole is placed is isotropic, of infinite thickness and that artesian conditions prevail, or that the inflow or outflow is so small that it does not cause any appreciable change in the groundwater level or pressure. It is also assumed that the hydraulic conductivity of the soil is uniform throughout the stratum. The assumptions, on which the formulae are based, are seldom fully satisfied under practical conditions. Often the horizontal hydraulic conductivity of the soil strata is larger than the vertical hydraulic conductivity (Fetter, 2001). The soil strata are never infinite in extent and are rarely uniform in character. Hvorslev (1951) attempts to correct his formulae for anisotropy and cautions that the formula gives a reasonable estimate rather than an exact result.

Variable head tests can be difficult to analyse in highly permeable sediments such as gravels because of the rapid response rate to the addition or removal of water. Butler *et al.* (2003) proposed that variable head tests in highly permeable aquifers should be initiated very rapidly relative to the formation response to ensure that details of the test initiation process can be justifiably ignored in the analysis. A series of tests should be performed at each well using a range of initial displacements to demonstrate that any dependence on the initial displacement of the water can be assumed negligible. The pressure transducer in the water column should be placed close to the static level (<0.5 m), so that type curves do not have to be corrected for water-column acceleration. Butler *et al.* (2003) found that when these guidelines were followed and proper analysis techniques were used the error in the hydraulic conductivity values was greatly reduced.

2.3.1.2.1 Methods for Unsteady-state Flow in Confined Aquifers

Cooper *et al.* (1967) present a method that uses a family of type curves and a graphical solution technique to determine the transmissivity of a confined aquifer in which a fully penetrating well undergoes an instantaneous change in water level. This method is based on V, a volume of water instantaneously withdrawn from or injected into a well of finite diameter, r_c, the radius of the unscreened part of the well where the head is rising, which causes an instantaneous change in the hydraulic head, h_o, of the well (Eq. 2-12) (Kruseman and de Ridder, 2000).

$$h_o = \frac{V}{\pi r_c^2} \qquad \textbf{Eq. 2-12}$$

After this change, the head will gradually return to its initial head. Cooper *et al.*, (1967) derived Eq. 2-13 for a fully penetrating large-diameter well tapping a confined aquifer. The standard methods of analysis assume that storage in the well is negligible, which is not true for large-diameter wells. In Eq. 2-13 the function F(α, β) represents the correction for storage in the well. This equation uses the change in water level in the casing due to injection at time t = 0, h_0; the height of water in well above equilibrium at t > 0, h_t; the aquifer storativity, S; the hydraulic conductivity, K; the aquifer thickness, D; the aquifer transmissivity, $T = KD$; the well radius, r_w; the radius of the well casing, r_c; zero-order Bessel functions, $J_0(u)$, $Y_0(u)$; and first-order Bessel functions, $J_1(u)$, $Y_1(u)$.

$$\frac{h_t}{h_o} = F(\alpha,\beta) = \frac{8\alpha}{\pi^2}\int_0^\infty \frac{\exp\left(-\beta u^2/\alpha\right)}{u f(u,\alpha)}du \qquad \textbf{Eq. 2-13}$$

$$\alpha = S\frac{r_w^2}{r_c^2}$$

$$\beta = \frac{Tt}{r_c^2}$$

$$f(u,\alpha) = \left[uJ_0(u) - 2\alpha J_1(u)\right]^2 + \left[uY_o(u) - 2\alpha Y_1(u)\right]^2$$

The Cooper-curve fitting method can be used if the following assumptions are satisfied (Kruseman and de Ridder, 2000):

1) The aquifer is confined and has an apparently infinite aerial extent.
2) The aquifer is homogeneous, isotropic, and of uniform thickness over the area influenced by the test.
3) Prior to the test, the piezometric surface is (nearly) horizontal over the area that will be influenced by the test.
4) The head in the well is changed instantaneously at time t_o=0.
5) The flow to or from the well is in an unsteady-state.
6) The rate at which the water flows from the well into the aquifer or vice versa is equal to the rate at which the volume of water stored in the well changes as the head in the water falls or rises.

7) The inertia of the water column in the well and the non-linear well losses are negligible.
8) The well penetrates the entire aquifer.
9) The well diameter is finite; hence storage in the well cannot be neglected.

2.3.1.2.2 METHODS FOR STEADY-STATE FLOW IN UNCONFINED AQUIFERS

The Bouwer and Rice (1976) method can be used to estimate the hydraulic conductivity around a partially or fully penetrating well in an unconfined aquifer by measuring the rise or fall of the water level in the well, initially at equilibrium conditions, and then after a volume of water is quickly removed or injected. The method is based on the Thiem (1906) equation and assumes that the aquifer is bounded below by an aquiclude and is homogeneous, isotropic, incompressible, of uniform thickness and of infinite radial extent (Frink *et al.*, 1997). This equation uses r_c, the radius of the unscreened part of the well where the head is rising, r_w, the horizontal distance from the well centre to undisturbed aquifer, R_e, the effective radial distance over which the difference in head, h_o, is dissipated in the flow system of the aquifer, d, the length of the well screen or open section of the well, h_t, the head in the well at time $t > t_o$, and h_o, the head in the well at $t_o = 0$, to calculate the hydraulic conductivity, K.

$$K = \frac{r_c^2 \ln(R_e/r_w)}{2d} \frac{1}{t} \ln \frac{h_o}{h_t} \qquad \textbf{Eq. 2-14}$$

The Bouwer-Rice method can be used if the following assumptions are satisfied (Kruseman and de Ridder, 2000):

1) The aquifer is unconfined and has an apparent infinite aerial extent.
2) The aquifer is homogeneous, isotropic, and of uniform thickness over the area influenced by the test.
3) Prior to the test, the water table is (nearly) horizontal over the area that will be influenced by the test.
4) The head in the well is lowered instantaneously at time $t_o=0$; the drawdown in the watertable around the well is negligible; there is no flow above the watertable.
5) The inertia of the water column in the well and the linear and non-linear well losses are negligible.
6) The well either partially or fully penetrates the saturated thickness of the aquifer.

7) The well diameter is finite; hence storage in the well cannot be neglected;

8) The flow to the well is in a steady state.

Frink *et al.*, (1997) analysed the same test using the Cooper *et al.* (1967) method and the Bouwer and Rice (1976) method and found that the hydraulic conductivity values tended to underestimate the Cooper *et al.* (1967) results. Although the Bouwer and Rice (1976) method was originally developed for rising water levels in an unconfined aquifer, the estimated hydraulic conductivity for a confined aquifer will be of the same order of magnitude as that calculated with the procedure of Cooper *et al.* (1967) if the top of the screen is some distance below the upper confining layer (Bouwer, 1989; Frink *et al.*, 1997). The Cooper *et al.* (1967) method was used to calculate the hydraulic conductivity of a large diameter well in a confined aquifer (taking into account well storage) while the Bouwer and Rice (1976) method was used to calculate the hydraulic conductivity in a confined aquifer and can be adapted to account for partially penetrating wells (ignores well storage). Frink *et al.* (1997) found that in confined aquifers containing stratification or interbeds of lower permeable materials, as is common in glacial aquifers, there was less agreement between the Cooper *et al.* (1967) method and the Bouwer and Rice (1976) values. Mace (1999), when comparing the results of Hvorslev (1951), Bouwer and Rice (1976) and Cooper *et al.* (1967) on the same variable head tests in large diameter wells, found that the Hvorselv and Bouwer and Rice (1976) methods tended to be one order of magnitude lower than the Cooper *et al.* (1967) method. He hypothesised that this was a result of the Cooper *et al.* (1967) method taking into account the effects of storage in the aquifer.

2.3.1.3 Aquifer Pump Tests

Pump tests are conducted by pumping water from a well with several observation wells nearby and by monitoring the drawdown (Kruseman and de Ridder, 2000). The pumped well with its lower water level creates a localized hydraulic gradient which causes water to flow to the well from the surrounding aquifer. In order to analyse a pumping test, the following properties must be known:

1) The aquifer thickness.

2) The discharge from the well.

3) The location and distance of the pumping well and observation wells.

4) The initial groundwater levels in the pumping well and observation wells.
5) The well design including the intake interval and whether the well is partially or fully penetrating.

Pump tests often must last several days in order for the groundwater response to be measured fully. During the pump test the drawdown with time is monitored and recorded in the pumping and observation wells until a quasi- or actual equilibrium condition is reached (British Standards Institution, 2003). This occurs when the rate of recharge in the borehole catchment balances the rate of abstraction. The recovery phase occurs after the pump has been switched off causing the groundwater level to recover to the static water level following a drawdown versus time curve that is approximately the inverse of the drawdown curve (Misstear *et al.*, 2006).

The standard method of conducting a pump test can be found in the British Standards (BS ISO 14686:2003). The standard configuration consists of pumping at a steady rate from a well and observing the groundwater response at some distance away from the pumped well in observation wells (British Standards Institution, 2003). Various mathematical and curve-matching techniques have been developed to analyse pump test data (Thiem, 1906; Hantush-Jacob, 1955; Walton, 1962; Streltsova, 1974; Neuman, 1975).

2.3.1.3.1 Confined Aquifers

The following methods are considered for confined aquifers under steady-state conditions (Thiem) and under unsteady-state conditions (Theis and Jacob). These methods assume that (Kruseman and de Ridder, 2000):

1) The aquifer is confined.
2) The aquifer has a seemingly infinite aerial extent.
3) The aquifer is homogeneous, isotropic and of uniform thickness over the area influenced by the test.
4) Prior to pumping, the piezometric surface is horizontal (or nearly so) over the area that will be influenced by the test.
5) The aquifer is pumped at a constant discharge rate.
6) The well penetrates the entire thickness of the aquifer and thus receives water by horizontal flow.

Thiem (1906) showed that the well discharge, Q, can be expressed in terms of hydraulic conductivity, K, aquifer thickness, D, the respective distances of the observation wells from the well, r_1 and r_2, and the respective steady-state heads in the observation wells, h_1 and h_2 (Kruseman and de Ridder, 2000) (Table 2-4 Eq. 2-15). The well formula is based on the assumptions listed above and the flow to the well is in steady-state.

The Theis (1935) method is used to calculate the transmissivity or hydraulic conductivity and storativity for unsteady-state flow from pumping tests and introduces the well function or Theis well function, $W(u)$, and storativity, S_A. The Theis (1935) equation was derived from the analogy between the flow of groundwater and the conduction of heat (Kruseman and de Ridder, 2000) (Table 2-4 Eq. 2-16). The Theis curve fitting method is based on the assumptions listed at the beginning of this section and that the flow to the well is in unsteady-state, i.e. the drawdown differences with time are not negligible, nor is the hydraulic gradient constant with time, and that well storage is infinitesimal.

The Jacob (Cooper and Jacob, 1946) method is used to calculate the transmissivity or hydraulic conductivity for unsteady-state flow from pumping tests and uses a semi-log plot of drawdown versus log time. If drawdown observations at a short distance from the well are used, the plot of drawdown versus log time forms a straight line (Kruseman and de Ridder, 2000). From this plot the value for Δs can be obtained (Table 2-4 Eq. 2-17). The Jacob method is based on the assumptions listed at the beginning of this section and that the flow to the well is in unsteady-state, i.e. the drawdown differences with time are not negligible, nor is the hydraulic gradient constant with time, and the values of u are small ($u < 0.01$), i.e. r is small and t is sufficiently large (Kruseman and de Ridder, 2000).

Table 2-4: Summary of formulae for pump test analysis methods.

METHOD	APPLICATIONS	FORMULA
Thiem (1906)	Confined Aquifers, Steady-state flow	$KD = \frac{Q}{2\pi} * \frac{\ln\left(r_2/r_1\right)}{(h_2 - h_1)}$ **Eq. 2-15**
Theis(1935)	Confined Aquifers, Unsteady-state flow	$KD = \frac{Q}{4\pi S_A} W(u)$ **Eq. 2-16**
Jacob (Cooper and Jacob, 1946)	Confined Aquifers, Unsteady-state flow	$KD = \frac{2.30Q}{4\pi\Delta s}$ **Eq. 2-17**

2.3.1.3.2 LEAKY AQUIFERS

Aquifers that are not totally isolated from vertical recharge are known as leaky or semi-confined aquifers. The main assumptions for pump tests in leaky aquifers are as follows (Kruseman and de Ridder, 2000):

1) The aquifer is leaky.
2) The aquifer and aquitard have a seemingly infinite aerial extent.
3) The aquifer and aquitard are homogeneous, isotropic, and of uniform thickness over the area influenced by the test.
4) Prior to pumping, the piezometric surface and the watertable are horizontal over the area that will be influenced by the test.
5) The aquifer is pumped at a constant discharge rate.
6) The well penetrates the entire thickness of the aquifer and thus receives water by horizontal flow.
7) The flow in the aquitard is vertical.
8) The drawdown in the unpumped aquifer (or in the aquitard, if there is no unpumped aquifer) is negligible.

The Hantush-Jacob method (1955) is used to analyse steady-state flow into a partially penetrating well in a leaky aquifer. The steady-state drawdown, s_m, in a borehole at a distance, r, from the well can be calculated using the discharge of the well, Q, the hydraulic conductivity, K, and the aquifer thickness, D (Table 2-5 Eq. 2-18). A plot of s_m against r on semi-log paper, with r on the logarithmic scale, will show a straight-line relationship in the range where r/L is small. The extended straight-line portion of the curve intercepts the r axis where the drawdown is zero. L is the leakage factor and is derived from $\sqrt{KDc}$. At the point of interception, $s_m = 0$ and $r = r_o$ and thus the equation can be further reduced to calculate the hydraulic resistance of the aquitard, $c = D'/K'$. D' is the saturated thickness of the aquitard and K' is the hydraulic conductivity of the aquitard (Table 2-5 Eq. 2-19).

The Hantush-Jacob (1955) method is valid as long as the assumptions for a leaky aquifer listed above are satisfied and the conditions below are satisfied:

1) The flow to the well is in a steady state.

2) L > 3D.

3) r/L ≤ 0.05.

Walton (1962) developed a method of solution for pumping tests based on Hantush-Jacob (1955) in leaky-confined aquifers with unsteady-state flow. Walton's method assumes the effects of aquitard storage to be negligible. The drawdown due to pumping in a leaky aquifer is described in terms of drawdown, s, in a borehole at a distance, r, from the well, the discharge of the well, Q, the leakage factor, $L = \sqrt{KDc}$, the saturated thickness of the aquifer, D, the hydraulic conductivity, K, the time since pumping started, t, the storativity of the aquifer, S, and the well function, $W(u)$ (Table 2-5 Eq. 2-20 and 2-21).

The Walton (1962) method has the same form as the Theis method, and approaches the Theis method for large values of L (the aquifer is confined – very little leakage through the aquitard). Walton (1962) developed a modification of the Theis (1935) curve-fitting method using a type curve for each value of r/L.

Walton's (1962) method is valid as long as the assumptions above for a leaky aquifer are satisfied and conditions below are satisfied (Kruseman and de Ridder, 2000):

1) The aquitard is incompressible, i.e. the changes in aquitard storage are negligible.

2) The flow to the well is in an unsteady-state.

Table 2-5: Summary of methods to analyse pump tests in leaky aquifers.

METHOD	APPLICATIONS	FORMULA
Hantush-Jacob (1955)	Leaky Aquifers, Steady-state flow	$\Delta s_m = \frac{2.30Q}{2\pi KD}$ **Eq. 2-18** $0 = \frac{2.30Q}{2\pi KD}\left(\log 1.12\frac{L}{r_o}\right) = c = \frac{(r_o/1.12)^2}{KD}$ **Eq. 2-19**
Walton (1962)	Leaky Aquifers, Unsteady-state flow	$s = \frac{Q}{4\pi KD}W\left(u, r/L\right)$ **Eq. 2-20** $u = \frac{r^2 S}{4KDt}$ **Eq. 2-21**

2.3.1.3.3 UNCONFINED AQUIFERS

Pumping in unconfined aquifers causes a dewatering of the aquifer forming a cone of depression in the watertable. As pumping continues, the cone expands and deepens, and the flow towards the well has vertical as well as horizontal components. To analyse a pump test in an unconfined aquifer the assumption is made that flow into the pumped well

is radial and the Dupuit (1863) assumptions are satisfied. The Dupuit (1863) assumptions are that the velocity of flow is proportional to the tangent of the hydraulic gradient, instead of the sine as it is in reality and that the flow is horizontal and uniform everywhere in a vertical section through the axis of the well (Kruseman and de Ridder, 2000). The following methods are based on the assumptions below (Kruseman and de Ridder, 2000).

1) The aquifer is unconfined.
2) The aquifer has a seemingly infinite aerial extent.
3) The aquifer is homogeneous and of uniform thickness over the area influenced by the test.
4) Prior to pumping, the watertable is horizontal over the area that will be influenced by the test.
5) The aquifer is pumped at a constant discharge rate.
6) The well penetrates the entire aquifer and thus receives water from the entire saturated thickness of the aquifer.

The Thiem-Dupuit Method (Kruseman and de Ridder, 2000) was developed for pumping tests performed in unconfined-aquifers under steady-state conditions. This equation uses H which is the thickness of the water bearing strata at the radial distance, R_o, from the centre of the well; h_o is the thickness of the water bearing strata at the edge of an excavation, of radius r_o; the total pumping rate is Q; and the average hydraulic conductivity is K (Table 2-6 Eq. 2-22). R_o is a theoretical concept and occurs at the point where drawdown is considered to be negligible and does not really exist. Since this method is not very sensitive to the value of R_o it is a practical and useful method to estimate flow. When using Eq. 2-22 generally all values are known except for the radius of influence, R_o (Table 2-6 Eq. 2-22).

This method is valid as long as the assumptions above for an unconfined aquifer are satisfied and conditions below are satisfied:

1) The aquifer is isotropic.
2) The flow to the well is in steady-state.
3) The Dupuit assumptions are satisfied.

The Neuman Method (1975) was developed for pumping tests performed in unconfined aquifers with fully penetrating wells with unsteady flow. Neuman (1975)

treats the aquifer as a compressible system and the watertable as a moving material boundary (Kruseman and de Ridder, 2000). The delayed watertable response is simulated by treating the elastic storativity, S_A, and the specific yield, S_Y, as constants. The Neuman (1975) curve consists of a steep segment at early time, a flat segment at an intermediate time, and a somewhat steeper curve at late time (Kruseman and de Ridder, 2000).

Neuman (1975) determined the drawdown, s, in terms of the discharge of the well, Q, the hydraulic conductivity, K, the saturated thickness of the aquifer, D, the unconfined well function, $W(u_A, u_B, \beta)$ (Table 2-6 Eq. 2-23). The horizontal hydraulic conductivity is determined by: $K_h = T/D$ and the value of the vertical hydraulic conductivity is determined from: $K_v = \beta D^2 K_h / r^2$ (Table 2-6 Eq. 2-23).

The Neuman (1975) method assumes the following in addition to the assumptions listed at the beginning of this section (Kruseman and de Ridder, 2000):

1) The aquifer is isotropic or anisotropic.
2) Flow to the well is in an unsteady-state.
3) The influence of the unsaturated zone upon the drawdown in the aquifer is negligible.
4) SY/SA > 10.
5) An observation well screened over its entire length penetrates the full thickness of the aquifer.
6) The diameters of the pumped and observation wells are small, so well storage is negligible.

The Streltsova (1974) curve-fitting method is used to determine the hydraulic conductivity for partially penetrating wells in unconfined anisotropic aquifers with unsteady-state flow. Streltsova (1974) developed two equations, one to describe the early-time drawdown behaviour and one to describe the late-time drawdown behaviour modified from the Dagan (1967) method. The early time drawdown, s, is described in terms of the discharge from the pumped well, Q, the horizontal hydraulic conductivity, K_h, the thickness of the aquifer, D, the depth from original water table to bottom of pumped well, b_1, the depth from original water table to bottom of observation well, b_2, the storativity of the aquifer, S_A, the specific yield of the aquifer, S_Y, the distance from the pumped well to

the observation well, r, the vertical hydraulic conductivity, K_v, and time, t (Table 2-6 Eq. 2-24 and 2-25).

The Streltsova (1974) curve-fitting method is valid under the following assumptions (Kruseman and de Ridder, 2000):

1) The diameter of the well is small, i.e. the storage in the well can be neglected.
2) The aquifer is homogeneous, anisotropic, and of uniform thickness over the area influenced by the pump test.
3) The well does not penetrate the entire thickness of the aquifer.
4) The aquifer is unconfined and shows a delayed water table response.
5) The flow to the well is in an unsteady-state.
6) $S_Y/S_A > 10$.

Table 2-6: Summary of methods to analyse pump tests in leaky aquifers.

METHOD	APPLICATIONS	FORMULA
Thiem-Dupuit Method (Kruseman and de Ridder, 2000)	Unconfined Aquifers, Steady-state flow	$Q = \frac{\pi K\left(H^2 - h_o^2\right)}{\ln\left(R_o / r_o\right)}$ **Eq. 2-22**
Neuman (1975)	Unconfined Aquifers, Unsteady-state flow	$s = \frac{Q}{4\pi KD} W\left(u_A, u_B, \beta\right)$ **Eq. 2-23** $u_A = r^2 S / 4Tt$ (Type A curve for early time) $u_B = r^2 S_y / 4Tt$ (Type B curve for late time) $\beta = r^2 K_v / D^2 K_h$
Streltsova (1974)	Unconfined Anisotropic Aquifers, Unsteady-state flow	$s = \frac{Q}{4\pi K_h D(b_1 / D)} W(u_A, \beta, b_1 / D, b_2 / D)$ **Eq. 2-24** where $u_A = \frac{r^2 S_A}{4K_h Dt}$ $\beta = \left(\frac{r^2}{D^2}\right)\frac{K_v}{K_h}$ Late-time drawdown behaviour is described by a modification of the Dagan solution (Kruseman and de Ridder, 2000; Dagan, 1967): $s = \frac{Q}{4\pi K_h D\left(b_1 / D\right)} W\left(u_B, \beta, b_1/D, b_2/D\right)$ **Eq. 2-25** where $u_B = \frac{r^2 S_Y}{4K_h Dt}$

2.3.1.3.4 Recovery Tests

After a pumping test has been completed the recovery in the well can be analysed as an additional test. The Theis (1935) recovery solution was originally intended for confined aquifers, however, if additional limiting conditions are satisfied the Theis recovery solution method can be applied to leaky and unconfined aquifers and aquifers with partially penetrating wells. The Theis Recovery Solution makes the same assumptions as the Theis method in Section 2.3.1.3.1.

The Theis (1935) formula for residual drawdown, s', after pumping has ceased can be calculated if the distance from well to borehole, r, the transmissivity of the aquifer, T, the storativity values during pumping and recovery respectively, S and S', and elapsed times from the start and ending of pumping respectively, t and t' are known.

$$s' = \frac{Q}{4\pi T} W(u) - W(u') \qquad \textbf{Eq. 2-26}$$

where:

$$u = \frac{r^2 S}{4Tt} \qquad \textbf{Eq. 2-27}$$

$$u' = \frac{r^2 S'}{4Tt'} \qquad \textbf{Eq. 2-28}$$

Using the approximate well function, $W(u)$, this equation becomes:

$$s' = \frac{Q}{4\pi T}\left(\ln\frac{4Tt}{r^2 S} - \ln\frac{4Tt'}{r^2 S'}\right) \qquad \textbf{Eq. 2-29}$$

When S and S' are constant and equal and T is constant, this equation reduces to:

$$s' = \frac{2.3Q}{4\pi T}\log\left(\frac{t}{t'}\right) \qquad \textbf{Eq. 2-30}$$

2.3.2 Storativity

Storativity is measured in the field as part of a pump test which also measures the hydraulic conductivity (Freeze and Cherry, 1979). The storativity is dependent on the type of aquifer (e.g. gravel versus limestone) as well as the aquifer condition (confined - specific storage or unconfined - specific yield). To derive a storativity value from a pumping test the analysis of time-variant (or nonsteady-state) drawdown data from one or more observation wells is required (Misstear *et al.*, 2006). In confined aquifers, the

storativity typically ranges in value from 0.005 to 0.00005 (Freeze and Cherry, 1979). The storativity, S, for a confined aquifer is calculated using the density, ρ, the acceleration due to gravity, g, the saturated thickness of the aquifer, D, the compressibility of the material, α, the compressibility of water, β, the porosity of the aquifer, n, and the specific storage, S_s (Eq. 2-31) (Kruseman and de Ridder, 2000):

$$S = \rho g D(\alpha + n\beta) = S_s D \qquad \textbf{Eq. 2-31}$$

The storativity of unconfined aquifers is known as the specific yield, S_Y, and is equal to the porosity, n, minus the specific retention, S_r (Eq. 2-32) (Misstear *et al.*, 2006).

$$S_Y = n - S_r \qquad \textbf{Eq. 2-32}$$

The specific yield of unconfined aquifers is typically in the range of 0.01 to 0.30 (Freeze and Cherry, 1979). The specific retention is the water which is unable to drain and is retained in the pores (Misstear *et al.*, 2006). The specific yield can be measured through the analysis of pump tests (e.g. Streltsova (1974) or Neuman (1975) methods). Specific yield can also be estimated using the correlation between hydraulic conductivity and specific yield (Figure 2.1) (Kasenov, 2006). The method is based on approximately 2000 laboratory tests on undisturbed samples of all soil types. This method is appropriate when the sediment size is no greater than coarse-grained sand with a hydraulic conductivity no greater than 7.0×10^{-4} m/s (Kasenov, 2006).

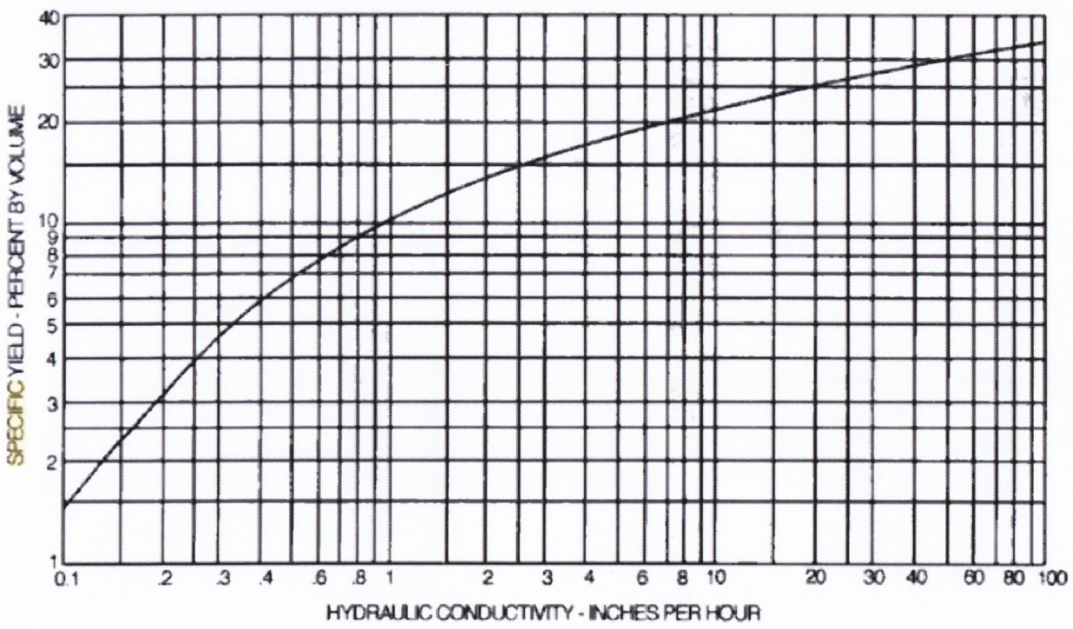


Figure 2.1: Graph that can be used to estimate specific yield for an unconfined aquifer.

Heidari and Moench (1997) reviewed storativity (specific yield) values obtained using curve matching techniques using the Neuman method (1974) for partially penetrating wells against those obtained using a nonlinear least squares (NLS) method for the pump tests in three unconfined aquifers. The estimations of storativity were found to be similar regardless of the method used. The storativity obtained was equal to 0.24 (curve-matching) and 0.234 (NLS) for a sand aquifer in Borden, Ontario, 0.24 (curve-matching) and 0.183 (NLS) for a sand and gravel aquifer in Cape Cod, Massachusetts, and 0.19 (curve-matching) and 0.183 (NLS) for a sand and gravel aquifer in Saint Pardon de Conques, France.

2.4 GROUNDWATER MODELLING

Numerical modelling for groundwater is a recent development in hydrogeology that has advanced significantly due to increased computing abilities. Groundwater numerical modelling is based on the fundamental principle of the continuity of fluid mass (Frind, 2003). The continuum which represents the aquifer and its boundary conditions are broken up into discrete cells or elements. This means that for each element/cell in the model, the fluid mass into the cell minus the fluid mass out of the cell equals the change in the fluid mass stored in that cell (Frind, 2003). A computer program solves a set of algebraic equations generated by approximating partial differential equations (governing equation, boundary conditions, and initial conditions) that form the mathematical model. Approximating techniques such as the finite difference and finite element methods operate on the mathematical model and change it into a form that can be solved by a computer (Anderson and Woessner, 1992). Groundwater modelling is often the only practical way to gain an understanding of the many complex processes that take place in the subsurface environment and where water plays a role (Frind, 2003). Although it is an approximation and simplification of the natural system, it is a useful tool to visualise groundwater flow and to assess the systems sensitivity to change.

Numerical modelling can be used to validate the analytical methods commonly used to measure hydraulic conductivity. This is often done when testing does not match the ideal results predicted by the traditional analytical methods. One example of this is the study by Chapuis and Chenaf (2002) where they conducted variable head tests in a large soil tank and compared the results with those from numerical modelling. The experimental results indicated that the variable head test results did not depend on the storativity of the

aquifer as is taken into account by the Cooper *et al.* (1967) method. This was proven mathematically, physically, and through numerical analyses by Chapuis (1998). The mathematical review showed that the adapted heat conduction problem did not correspond to a variable head test. The physical examination of material deformation showed that the influence of storativity does not exceed 1% of the initial water removed/added for the most compressible materials and thus is almost impossible to detect its influence in test results. Chapuis and Chenaf (2002) confirmed the negligible influence of storativity through numerical modelling of a variable head test. Another example is the numerical modelling of rising-head tests after lowering the water level down to the screen (Chapuis, 2005). Although ideally when conducting a rising head test the water level should not be lowered to the screen in practice this sometimes happens. It had been previously theorised that when the screen and filter pack are dewatered to start a rising head test the groundwater inflow must first fill the drained portions of the filter pack and screen before filling the pipe. It was believed that this caused the curved semi-log plot and the numerical modelling confirmed this to be the case.

Numerical modelling can be used to reproduce the overall observed hydraulic behaviour and to permit effective visualisation of aquifer responses under different conditions. Flemming and Clark (2000) constructed a one-dimensional model with three layers representing ice, the aquifer, and bedrock. Within the ice layer there was an open conduit through which water could flow freely. The modelling helped the authors to visualize the change in head with time around the conduit and the hydrogeological factors which are important in determining the amount of groundwater flow.

Numerical analysis has been used to consider the scale effect in hydraulic conductivity. It is commonly observed that measured values of hydraulic conductivity increases with the scale of testing (Benson *et al.*, 1997; Rovey, 1998; Shaw and Hendry, 1998; Gierczak, *et al.,* 2006). However, the reason for this so-called scale effect is not clear. The two main possibilities are that high-conductivity heterogeneities are more effective in raising the hydraulic conductivity over a regional scale rather than over a local scale (Rovey, 1998). Alternatively, effects inherent to the testing method could be responsible such as borehole and storage effects. Numerical modelling can provide an avenue to explore this type of problem as testing method effects can be completely eliminated if the models include an adequate representation of the factors responsible (e.g.

macropores, fractures, heterogeneity, etc). Rovey (1998) conducted numerical modelling to investigate this problem. Several important features of the field data were reproduced with the model simulations such as the mean hydraulic conductivity increasing with scale at small radii and the mean conductivity eventually becoming constant as measurements reach and exceed the scale of a statistically homogeneous medium. The field data were found to fit linear functions over the distances measured while the simulated results were non-linear. This indicated that the scale effect may be the result of a combination of a real dependency on scale as well as test bias. In small scale tests, only those nodes on or directly adjacent to "fractures" have hydraulic conductivities greater than the regional average (Rovey, 1998). This means that randomly located small-scale tests would be expected to give mean values lower than the regional because most of the test locations are not located near "fractures". As the test area expands it becomes more and more likely that a randomly located test will be influenced by "fractures" which accounts for the levelling off effect after a certain scale is reached. A greater heterogeneity in the soils caused the scale of increase in hydraulic conductivity to be larger. It seems, therefore, that hydraulic conductivity, as measured by radial flow, should increase with scale in all media as long as high-conductivity heterogeneities have distinct trends with long correlation scales (Rovey, 1998).

2.4.1 Finite-Difference Techniques

Finite-difference methods compute a value for the head at the node, which also is the average head for the cell that surrounds the node, with no assumptions made about the form of the variation of head from one node to the next (Anderson and Woessner, 1992). Finite-difference programs tend to be easier to use and are more widely used than finite-element programs. There are many finite-difference software packages commercially available for modelling groundwater flow. The software MODFLOW will be considered below as it is commonly used in industry.

MODFLOW is a modular, three-dimensional, finite difference, groundwater flow model first developed by McDonald and Harbaugh (1988) at the USGS in 1983. The basic groundwater flow equation that MODFLOW solves in a three-dimensional porous medium is as follows:

$$\underbrace{\frac{\partial}{\partial x}\left(K_{xx}\frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial y}\left(K_{yy}\frac{\partial h}{\partial y}\right)+\frac{\partial}{\partial z}\left(K_{zz}\frac{\partial h}{\partial z}\right)}_{\text{Groundwater flux in 3D}}+\underbrace{W}_{\text{Sources \& Sinks}}=\underbrace{S_s\frac{\partial h}{\partial t}}_{\text{Change in Storage}} \qquad \textbf{Eq. 2-33}$$

In MODFLOW, the model domain is divided into rows, columns and layers of cells. Each cell is an elemental control volume (McDonald and Harbaugh, 1988) (Figure 2.2).

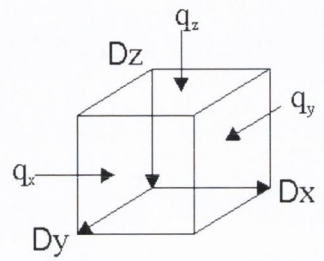


Figure 2.2: Elemental control volume

To solve for the above equation the model substitutes a finite difference, Δx, for the infinitesimal difference, ∂x (McDonald and Harbaugh, 1988) (Figure 2.3). This changes the previous equation to:

$$\frac{\partial}{\partial x}\left(K_{xx}\frac{\partial h}{\partial x}\right)=\frac{1}{\Delta x}\left[\left(K_{xx}\frac{\partial h}{\Delta x}\right)_{j+1/2}-\left(K_{xx}\frac{\partial h}{\Delta x}\right)_{j-1/2}\right]=\frac{1}{\Delta x}\left(K\frac{(h_3-h_2)}{\Delta x}-K\frac{(h_2-h_1)}{\Delta x}\right) \qquad \textbf{Eq. 2-34}$$

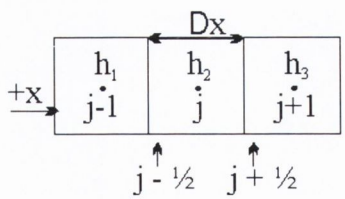


Figure 2.3: Cell calculation for finite-difference equations

By solving this equation for each individual cell over the entire model the flow of groundwater is modelled (McDonald and Harbaugh, 1988). The MODFLOW software consists of a variety of modules or packages each having a different function giving the program its versatility and functionality. It uses a grid, which in plan view consists of columns and rows forming squares or rectangles (Figure 2.4). The layer surfaces can have x, y, z co-ordinates inputted to reflect the topography of the surfaces. In MODFLOW, as

in all finite-difference modelling software, the calculation points are at the centre of the cell (McDonald and Harbaugh, 1988).

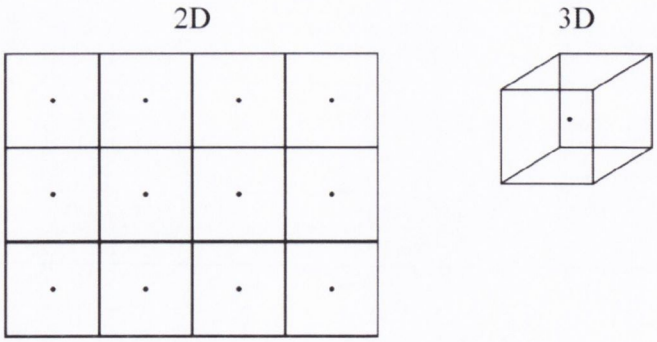


Figure 2.4: Two- and three-dimensional layout for finite-difference modelling

2.4.2 FINITE-ELEMENT TECHNIQUES

Finite-element methods differ from finite-difference methods by precisely defining the variation of head within an element by means of interpolation functions (Anderson and Woessner, 1992). Finite-elements are better able to approximate irregularly shaped boundaries than standard finite-differences and it is easier to adjust the size of individual elements as well as the location of boundaries with the finite-element method. There are several finite-element software packages which are commercially available to model groundwater flow and in the following section FEFLOW will be considered as a representative finite-element package.

FEFLOW is a finite-element simulation system for two or three-dimensional, transient or steady state, fluid density groundwater systems first designed in 1979 by WASY – Institute for Water Resources Planning and Systems Research, Ltd. The shape of the grids/meshes created for the model domain are different in finite-difference and finite-element modelling software (Frind, 2003). In finite-difference software, the grids are composed of rows and columns forming rectangles as shown in Figure 2.4. The model domain in finite-element modelling is divided into triangular shaped elements forming the mesh, which can contain one-, two-, and three-dimensional elements all within the same grid/mesh (Frind, 2003) (Figure 2.5). The calculation point is at the corners of the elements, which allows for a far greater variety of shapes that the elements can have since they are not restricted to just being boxes as with the finite-difference grid (Frind, 2003).

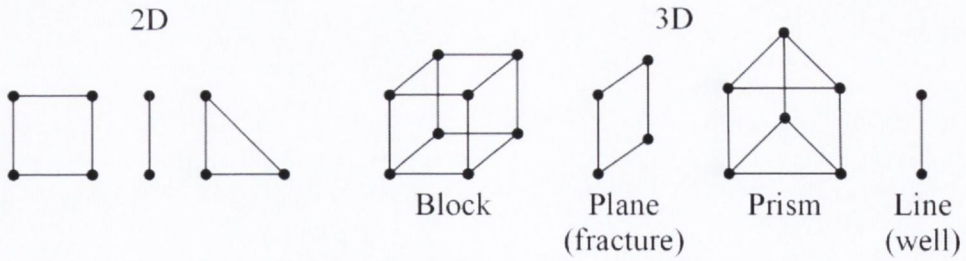


Figure 2.5: Two- and three-dimensional elements used in finite-element modelling

Solving the continuity equation is far more complex using finite-elements (Fetter, 2001). The same continuity equation for groundwater is used as the starting point but the infinitesimal difference, ∂x, is not approximated by the finite difference Δx (Diersch, 2002).

$$\frac{\partial}{\partial x}\left(K_{xx}\frac{\partial u}{\partial x}\right)+\frac{\partial}{\partial y}\left(K_{yy}\frac{\partial u}{\partial y}\right)+\frac{\partial}{\partial z}\left(K_{zz}\frac{\partial u}{\partial z}\right)+\frac{Q_w}{\Delta V}\delta(x_i-x_w)=S_s\frac{\partial u}{\partial t} \qquad \textbf{Eq. 2-35}$$

In this case, the unknown function, u, is approximated by piecewise linear functions used as a trial solution where, w_j, is the basis function.

$$u(x,t)\approx\hat{u}(x,t)=\sum_{j=1}^{n}u_j w_j(x) \qquad \textbf{Eq. 2-36}$$

The trial solution is then substituted into the partial differential equation (for a homogeneous, isotropic case).

$$K\frac{\partial^2\hat{u}}{\partial x^2}-S_s\frac{\hat{u}-u^{t-\Delta t}}{\Delta t}=R(x,t)\neq 0 \qquad \textbf{Eq. 2-37}$$

The equation becomes even more complex for the heterogeneous, anisotropic case. The residual, R, is then minimized globally where i = 1, …, n, w_i = weighting functions, and n = number of nodes.

$$\int_A R(x,t)w_i(x)\partial x=0 \qquad \textbf{Eq. 2-38}$$

The function is integrated element-wise and yields n linear equations that can be solved for u. FEFLOW uses a special variant of weighted residuals known as the Galerkin Method, in which the weighted functions, W_i, are chosen to be identical to the basis functions, w_j (Diersch, 2002; Frind, 2003). This simplifies the functions so to speed up the

computations. The system of equations is organized in a matrix where A is the coefficient matrix, u is the head vector, F is the flux vector:

$$[A]\{u\} = \{F\} \qquad \textbf{Eq. 2-39}$$

The matrix is assembled for each element, and then combined into a global matrix A (Frind, 2003). Mixed element types are permitted within the matrix. The finite-element solution has the following basic characteristics. The nodal heads are continuous; however, the fluxes across the element sides are generally discontinuous. The matrix contributions at each node are summed rather than calculated as a harmonic mean as with the finite-difference solution. The harmonic mean is defined by $HarmonicMean = \frac{n}{1/a_1 + 1/a_2 + \ldots + 1/a_n}$ and is usually used to determine average velocities. The finite-element solution is identical to the finite-difference solution for a one-dimensional homogeneous isotropic material. The solutions differ in two- and three-dimensional, heterogeneous, anisotropic materials due to the differences in the way the groundwater continuity equation is solved (Frind, 2003).

2.5 *DEWATERING*

This section reviews the literature on the methods available to dewatering of an excavation and examines some case studies of dewatering. There is very little literature on dewatering in heterogeneous coarse-grained sediments such as those in the Mid-Kildare Aquifer. The studies below are presented in chronological order and present other major dewatering projects and any problems that were encountered as part of the dewatering project.

2.5.1 TRADITIONAL METHODS OF ESTIMATING DEWATERING

Cedergren (1968) considered three methods of estimating seepage rates in an excavation below the water table. The first method uses a modified Thiem equation where the excavation is treated as a large circular well. The assumptions for the Thiem method can be found in Section 2.3.1.3. This method works best if the excavation is nearly square and therefore can be approximated by a circular hole. If the seepage is primarily within a confined aquifer then the Thiem equation may be used (Eq. 2-15) whereas the Thiem-Dupuit equation (Eq. 2-22) may be used for unconfined aquifers. These methods assume

that the excavation dewatering is in steady-state and although this is not strictly true an estimation of the flows into the excavation may be made.

The concept of the radius of influence, R_o, is used to represent the distance from the excavation where the drawdown is essentially zero (Cedergren, 1968; Somerville, 1986). Empirical relationships have been developed which relate the radius of influence (m), R_o, to the drawdown, h, hydraulic conductivity (m/s), K, and a constant, C.

$$R_o \approx Ch\sqrt{K} \qquad \textbf{(m)} \qquad \textbf{Eq. 2-40}$$

The constant, C, is generally taken as 3000 for radial flow to pumped wells and between 1500 and 2000 for line flow to trenches or a line of well points (Somerville, 1986). Although R_o is does not really exist it is a practical and useful method to determine the estimated flow into an excavation, which is not very sensitive to the value of R_o.

The second method of estimating the dewatering requirements of an excavation that Cedergren (1968) proposed is a modification of Darcy's Law whereby an average hydraulic gradient is used along a distance which represents an inflow boundary. The total rate (Q) entering an excavation can be estimated from:

$$Q = qL \qquad \textbf{Eq. 2-41}$$

Where q is the seepage quantity per metre and is equal to AKi (per unit length). A, the area through which the water flows, is equal to Lh_a where, L, equal to $2\pi r_a$ for a circular excavation, is the length of that boundary. In this simplification h_a, the thickness of the water bearing unit at r_a, is equal to $(H+h_o)/2$. The mean radial distance (r_a) is equal to $r_a = r_o + (R_o - r_o)/2$. The hydraulic gradient, i, at a radial distance (r_a) can be approximated at $(H-h_o)/(R_o-r_o)$. The total flow through the seepage area at the circumference of r_a is $Q = iKA = Kh_aL(H-h_o)/(R_o-r_o)$.

The third method suggested by Cedergren (1968) to estimate the amount of seepage into an excavation is to use flow nets. Flow nets are a graphic method of solving the Laplace equation which is applicable to the continuity of flow when using Darcy's Law. For a homogeneous isotropic soil, flow nets form curvilinear squares with the equipotential lines forming right angles to the flow lines. This graphical method of analysing flows can be applied for both horizontal and vertical flow.

Mansur and Kaufman (1958; Somerville, 1986) proposed the following method for estimating the flow when dewatering a long narrow trench in an unconfined aquifer. This method envisages the trench as a row of single well points and assumes that the trench only partially penetrates the saturated sediments. The flow (Q) into the trench is estimated using the height of the static water table (H), the height of the water table in the wells (h_o), the hydraulic conductivity of the soil (K), the length of the trench (x), the distance to line source, taken as equal to the radius of influence (R_o) (Eq. 2-42).

$$Q = \left[\left(0.73 + 0.27 \frac{(H - h_o)}{H} \right) \frac{Kx}{2R_o} \left(H^2 - h_o^2 \right) \right] \qquad \textbf{Eq. 2-42}$$

2.5.2 Case Studies of Dewatering Projects

Construction dewatering systems often use the "observational method" as applied to soil mechanics by K. Terzaghi (1961) and set out by R.B. Peck in the Ninth Rankine Lecture (Peck, 1969). This method is based on developing a working hypothesis of anticipated behaviour under probable conditions. The designs of dewatering systems are then refined depending on the actual behaviour during dewatering (Peck, 1969). This process is often necessary as it is nearly impossible to know the exact ground conditions and, therefore, unexpected complications often arise. If flexibility to accommodate these unexpected complications is built into the design then no disruption in construction is needed saving both time and money.

Powrie and Preene (1994) examined construction dewatering in fine soils where dewatering was conducted not only to keep the excavation from flooding but also to maintain the stability of the sides and the base. The pore-water pressures associated with seepage result in low effective stresses in the soil zone around and below the excavation. This reduces the ability of the soil to withstand shear, potentially leading to failure of the excavation slopes and development of quick conditions in the base of the excavation.

Sargent *et al.* (1998) reviewed the design and performance of a dewatering system used for construction at a wastewater treatment facility located on Annacis Island in Delta, British Columbia, Canada which required an open-cut excavation lowering the water table by 10 m over a 32 m x 22 m area. The observational method was used at this site, which consisted of three steps. Firstly, the data were gathered and assessed which consisted of using available data to identify the most probable conditions and the possible unfavourable

deviations from these conditions. The second step was to design a dewatering system which was recommended based on a "working hypothesis of behaviour" anticipated under the most probable conditions. The dewatering system was designed to be flexible so it could be adapted for varying ground conditions. The third step was to establish a testing and monitoring protocol to identify deviations in the observed behaviour from that predicted from the working hypothesis. By comparing observed flow rates and drawdowns with design estimated values Sargent *et al.* (1998) were able to refine the dewatering design and improve their knowledge of the ground properties.

The wastewater treatment plant was to be built on alluvial deposits consisting of silt interlayers in a sand aquifer unit (Sargent *et al.*, 1998). This unit had a hydraulic conductivity of around 6.9×10^{-4} m/s. The dewatering design consisted of deep wells which had proved previously successful on the site. The hydrostratigraphy of the site was assessed using pre-existing grain-size analysis. A shallow silt layer was identified which is relevant to establish the hydraulic response of the aquifer to pumping. The aquifer would be confined where the silt layer is present and the water table is above the base of the silt, but unconfined where the silt layer is removed for construction or where the water table has been lowered below the base of the silt. The hydrogeology of the site was assessed through a large-scale pumping test to determine the hydraulic conductivity. The hydraulic conductivity was found to vary between 4.6×10^{-4} - 8.1×10^{-4} m/s. Two static cone penetration tests (CPT) were preformed in the study area to study the subsurface conditions relevant to the conceptual design working hypothesis. These tests identified a 1 m thick silt interlayer at 26 m below the ground surface. This silt interlayer would reduce the vertical hydraulic conductivity, thus reducing the total extraction rates. The sand was also found to fine upwards which would further reduce the dewatering requirements. Sargent *et al.* (1998) then conducted numerical modelling to assess the impact of the following factors on the performance of the dewatering system: the uncertainty in the hydraulic conductivity; well yields; possible presence of silt interlayers; variation in river stages and tidal effects on river levels; variation in extraction rates at other dewatering systems on site; uncertain storage properties; and long-term system component deterioration. Their numerical modelling sensitivity testing suggested that seven pumping wells, each yielding 44 l/s could achieve the target drawdowns if the hydraulic conductivity was 6.9×10^{-4} m/s. The numerical model used to investigate the effects of a thin silt layer found that the

reduction of the system pumping requirements was highly dependent on the spatial extent of the silt layer (Sargent *et al.*, 1998).

Well capacities are difficult to predict because they depend on construction techniques and formation properties close to the well (Sergant *et al.*, 1998). Dewatering systems using deep wells may fail for the following reasons: flows from the ground being unexpectedly high or low; well-aquifer connection problems (e.g. the well fails to connect with the permeable zones); long-term performance deterioration (e.g. iron encrustation); and unacceptable off-site effects (e.g. settlement) (Roberts and Preene, 1994).

The rate of groundwater extraction for the system can be estimated directly from field data using the method of proportions (Sargent *et al.* 1998). This approach provides a quick and independent estimate of flow rates without the use of complicated models. This method is based on the premise that the rate of groundwater extraction is linearly proportional to drawdown in an ideal confined aquifer and to H^2 - h^2 in an ideal unconfined aquifer. Therefore, the estimated system flow to achieve target drawdown, Q_S, can be determined using the method of proportions if the target system drawdown, δ_S, the pumping test drawdown, δ_{PT}, the flow rate measured in pumping test, Q_{PT}, is known (Eq. 2-43).

$$Q_S = Q_{PT} \frac{\delta_S}{\delta_{PT}} \qquad \textbf{Eq. 2-43}$$

Mansur and Durrett (2002) conducted a review of a dewatering project for a cofferdam at the Olmsted Locks in the Ohio River, Kentucky, USA. The excavation, 365 m x 670 m, was one of the longest and deepest in a river in the United States. The excavation was into alluvial deposits consisting of 12 - 15 m of stratified silts, very fine sand and clay underlain by a fissured clay stratum. The excavation required dewatering of 1.5 m below the river stage. The pre-excavation site investigation consisted of estimating the hydraulic conductivity from grain-size distribution samples conducted at another lock along the river which gave a hydraulic conductivity of 1.3×10^{-3} m/s for the alluvial sands. A pumping test was conducted in the upper layer within the stratified deposits.

As most pumping test analyses assume the formation is homogeneous, isotropic, and the flow to the well is either artesian or by gravity, this presents a problem when the soil is heterogeneous, anisotropic and flow to the well is from seepage from a river. Mansur and

Durret (2002) worked around this problem by using an average drawdown curve developed from the piezometric data, the average pumping rate, the average thickness of the upper strata, and the average thickness of the sand seam within the upper strata. They assumed artesian flow which gave a hydraulic conductivity of $1.5x10^{-5}$ m/s for the entire strata and $2.6x10^{-5}$ m/s for the sand seam. This dewatering project was further complicated by the lower strata having a very high artesian head. As part of the dewatering project, the head had to be lowered using deep wells to control the differential heads.

The design of the dewatering system was based on the following assumptions and parameters: that the dewatering wells fully penetrate the water bearing seams; that the flow in the water bearing seams is artesian; that the Ohio River and alluvial sand formation produce a constant source of seepage; that the thickness and hydraulic conductivity of the water bearing strata are constant throughout the zone of influence; that the sheet pile coffer cells are essentially water tight and cut off seepage immediately beneath the bottom of the coffer cells; and that all seepage flowing into the dewatering system is through the clay which generally overlies the sand seam.

Mansur and Durrett (2002) used flow nets to analyse the dewatering system which resulted in a well spacing of 20 m (Figure 2.6). This was reduced to 15 m in practice to account for the heterogeneity in the soils. The coffer cells were spaced on about 12 m centres along the cofferdam and a dewatering well was installed in each of the coffer cells and arc cells. Along the Illinois bank a well spacing of 25 m was selected because less concentrated flow was expected and there was less risk of piping into the excavation compared to that beneath the cells in open water. The dewatering system was found to be effective with pumping rates required to lower the water level in the coffer cells being close to the estimated amounts and well within the pumping capacity. However, a few unexpected complications arose during dewatering. It was assumed that the larger coffer cells would leak more than the connecting arc, thus the pumps in the arc wells were somewhat smaller than those in the cell wells due to the lower estimated in-flows.

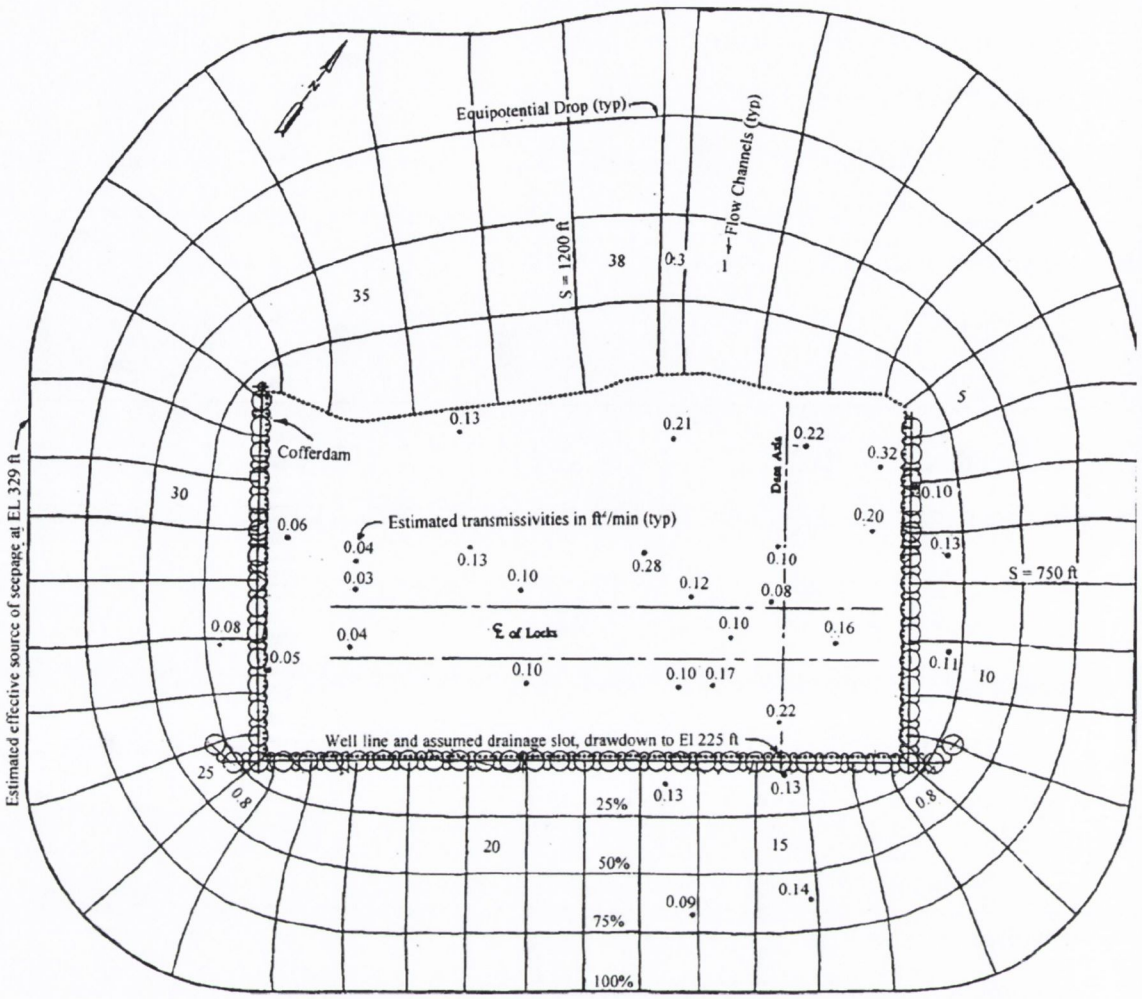


Figure 2.6: Plan flow net and transmissivities for the dewatering system (Mansur and Durrett, 2002).

Following the initial pump test, it was found that the opposite was true. This observation was attributed to the fact that the arcs do not develop the hoop stresses that circular cells do, and therefore the inter locks did not tighten up as much, and cut off seepage as effectively, as in the circular cells (Mansur and Durrett, 2002). Over the long term seepage decreased which was attributed to the rusting of the sheets, clogging of interlocks, subsidence and densification of cell fill, and deflections in the cells, along with increasing interlock tensioning. The dewatering system for the cofferdam and Olmstead Locks was effective with most of the design assumptions valid. The system was flexible enough to cope with the problems encountered during dewatering (Mansur and Durrett, 2002).

Tokgoz *et al.* (2002) investigated the optimal dewatering system design for a trench type excavation (3000 m in length) in Aksaray, Turkey. The construction of a collector line required the groundwater level to be lowered by 4 m along the entire 3000 m length.

The hydraulic conductivity was found to vary between 1-2 m/d in the southern part of the excavation to 20-40 m/d in the northern part. Two dewatering systems were designed: one to minimize the total amount pumped and the other to minimize total amount pumped plus the completion cost of the pumping wells. Numerical modelling was used to assess the systems consisting of: two steady-state models (one minimizing total pumpage and the other minimizing total pumpage plus costs) and two transient-state models (one minimizing total pumpage and the other minimizing total pumpage plus costs).

The steady-state model which minimized total pumpage resulted in 54 wells, 16.5 million m^3 of total pumpage and a construction time of 7.5 years. The steady-state model which minimized costs as well as total pumpage resulted in 15 wells, 21.2 million m^3 of total pumpage and a construction time of 8 years. The transient-state model which only minimized total pumpage resulted in 99 wells, total pumpage of 4.0 million m^3, and 3.75 years to construct it. The transient state model which reduced total cost as well as total pumpage resulted in 79 wells, 4.0 million m^3 of total pumpage and 3.75 years of construction. The results show that although the steady-state models yield the least number of wells compared with the transient models the completion time of construction is almost doubled and the total volume of water pumped is four to five time greater. Both transient models yield the same volume of water pumped over the same pumping period to complete construction, however, the model which minimized costs did it with a 20% reduction in the number of wells required. This study highlights the importance of using transient-state modelling and factoring costs into a model to achieve optimal results for a dewatering scheme (Tokgoz *et al.*, 2002).

Long *et al.* (in press) described the ground conditions, soil characteristics and difficulties encountered in constructing excavations in glaciofluvial gravels in Cork city, Ireland which required dewatering. This study was primarily concerned with reviewing the local conditions which result in dewatering being required when basements are constructed. This study, like many dewatering studies, was not concerned with monitoring the effect of dewatering on the regional groundwater table and modelling the regional groundwater response to the dewatering. It was concerned only with the local effects of the settlement of nearby buildings and the use of sheet piles to reduce flow into an excavation and thereby reduce the amount of water needed to be removed (Long *et al.*, in press).

Pickels *et al.* (2003) studied the effect of dewatering of a 20 m deep excavation in Hong Kong within previously and recently reclaimed land for the construction of an underground railway station and access tunnels. Like many dewatering publications, the groundwater levels were only monitored during construction so little is reported as to the historic groundwater fluctuations in response to natural changes such as recharge and, in the Hong Kong case, tidal fluctuations. The groundwater levels ceased to be measured after completion of the railway station and access tunnels thereby not recording what, if any, permanent effects the dewatering and construction of the structure had on the groundwater levels. The boreholes were located 5 m outside the diaphragm walls and so only local effects were measured and up to 10 m of drawdown were recorded at the boreholes (Pickels *et al.*, 2003).

2.6 GROUNDWATER RESPONSE

The response of groundwater to inflows, such as recharge, or outflows, such as dewatering, is often characterised using numerical modelling. The numerical models are run with a range of values for parameters such as hydraulic conductivity and storativity and running them with varying inflows or outflows such as recharge or pumping rates to determine the effect on the groundwater levels.

Erskine and Papaioannou (1997) examined the groundwater response rate in the assessment of groundwater resources. It is important to know how much water can be abstracted from an aquifer without causing ecological damage or depleting the aquifer for future use. They looked specifically at defining maximum permissible abstraction (MPA) and minimum flow requirement (MFR) for rivers in the study area. The minimum flow requirement was defined as the flow below which the river flow must never fall or unacceptable consequences are expected to occur such as ecological problems, derogation of existing rights, inadequate dilution of discharge, etc. Erskine and Papaioannou (1997) defined a quantity known as the aquifer response rate, α, using the aquifer transmissivity, T, the aquifer storage coefficient, S, and the length representing the distance from river to groundwater divide, L:

$$\alpha = \frac{T}{\left(SL^2\right)} \qquad \textbf{Eq. 2-44}$$

The aquifer response rate has been proven to be valid for an idealized aquifer; however, transferring this parameter to the unconfined aquifer situation is not valid because T is not constant in the unconfined configuration (Erskine and Papaioannou, 1997).

Erskine and Papaioannou (1997) devised a simple numerical model to investigate the behaviour of an idealised aquifer under more variable recharge conditions and under true unconfined conditions. The model consisted of a one-dimensional unconfined aquifer in section with a river forming the boundary at one end and a groundwater divide at the other end. The model was run as steady-state, quasi-steady-state, and transient state. The steady-state run was used to verify the model against the analytical solution and the results were in close agreement. The quasi-steady-state runs were transient runs using a monthly time-step where the recharge was set to an annual cycle. After a few years the flow to the river becomes cyclical about a constant value. Within the Erskine and Papaioannou (1997) model, the minimum flows to the river became smaller as K was increased, S was decreased, the aquifer length (L) was decreased and the thickness of saturated aquifer at the river was increased. The transient state run varied the rainfall each year so that both the total amount of recharge was varied and the amount of recharge at one time was varied. The variability of the real annual recharge was found to cause lower minimum flows than those predicted from the quasi-steady-state model (Erskine and Papaioannou, 1997). This is caused by the inherent variability in each individual year. This paper demonstrates the importance of considering the natural variation in recharge when trying to predict the groundwater response.

Myrabø (1997) examined run-off processes under Norwegian till conditions giving emphasis on the temporal and spatial scale of the processes. An attempt was made to include the variation in the soil moisture content in the models. The study area was located in Bærum, 10 km west of Oslo. The soils consisted mostly of till with a few bogs in the area. Parameters such as temperature, flow rates in a stream within the catchment, precipitation, snow melt, hydrostatic pressure, soil suction, and groundwater levels were carefully measured to obtain simultaneous observations to develop a picture of the groundwater response. The most commonly used methods for estimation of the saturated (or response) area are: mapping of the saturated areas in the catchment; direct measurements of groundwater and vadose water variations; and use of the vegetation as an

indicator of moisture conditions. A first approximation of a possible response area and its possible variation can be deduced from a digital terrain model (DTM). When using a DTM in a levelled catchment to estimate a potential spatial distribution of moisture, an idea about the actual extension of the response area may be obtained by continuous recording of soil moisture and groundwater levels in a few strategic locations (Myrabø, 1997).

Catchment discharges can often be simulated adequately by a range of hydrological models. It is doubtful that these models fully represent the complex three-dimensional spatially heterogeneous and time varying system that is a real catchment. However, the results from Myrabø (1997) suggest that it may be possible to model conceptually the complex moisture distribution and variation in time and space, which continuously control the different runoff processes in a catchment. The most important contribution to runoff, particularly to storm flow, comes from saturated overland flow and flow in the root zone (in macropores) (Myrabø, 1997). To understand the runoff processes and simulate the catchment response to a precipitation event, it is of vital importance to get a clear idea about the soil moisture and its changing patterns. The potential patterns can be obtained using a DTM, then verified by a field survey and groundwater measurements. Continuous recording of the groundwater level and/or discharge may make it possible to estimate the distribution of the response area in a catchment at any time (Myrabø, 1997).

CHAPTER 3

GEOLOGY AND HYDROLOGY OF THE STUDY AREA

3.1 INTRODUCTION

As part of the preliminary ground investigation for the construction of the Kildare Town Bypass, particle size distribution analyses, variable head tests, pump tests were performed and a number of boreholes were drilled. The ground investigation and groundwater monitoring for this project were especially detailed as an ecologically sensitive and an officially protected area, Pollardstown Fen, (National Nature Reserve and Special Area of Conservation) is located 5 km to the northeast of the motorway. This area contains two priority habitats (petrifying springs and saw sedge fen), as well as at least 7 species (*Drepanocladus vernicosus* - a moss; *Euphrydryas aurina* - the Marsh Fritilary butterfly; *Vertigo geyeri*, *Vertigo moulinsiana, and Vertigo angustior* - snails; *Lutra lutra* - the otter; and *Lampetra planeri* - the lamprey), which are protected under law (Irish Peatland Conservation Council, 1999). Because of the sensitivity of this area, a Monitoring Committee was established to assess the data collected on the Mid-Kildare Aquifer and to assess any potential influence the dewatering might have on Pollardstown Fen (Figure 3.1). This meant that a comprehensive groundwater monitoring programme was put in place and the Monitoring Committee reviewed the data collected during the ground investigation to characterise the groundwater response before, during and after construction. These data together with the groundwater levels and discharges collected for the construction of the road form the basis of this unique case study of a major dewatering project.

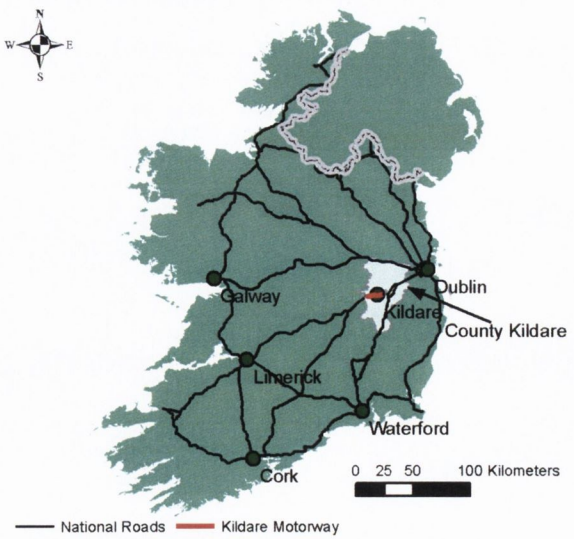


Figure 3.1: Location of the Kildare Town Bypass, shown in red, in Ireland

This chapter is divided into several sections. The literature published on the geological and hydrogeological properties of the Mid-Kildare Aquifer is assessed and the testing methods and data collected for the Monitoring Committee are analysed. The bedrock, glacial and recent geology is reviewed to gain an understanding of the environment in which the Mid-Kildare Aquifer is hosted. The pattern of groundwater flow is influenced by both the bedrock geology (Section 3.2) and the unconsolidated sediments overlying the bedrock (i.e. overburden) (Section 3.3) (Fetter, 2001). The hydrogeology, including the inflows and outflows of the aquifer and the groundwater heads and gradients, is presented. The field assessment of the hydrogeological parameters includes a review of the tests conducted as part of the initial ground investigation for the Kildare Town Bypass and, in some cases, the data are analysed. This chapter aims to outline the important features of the aquifer which will be used to develop the conceptual model of the Mid-Kildare Aquifer in Chapter 5.

3.2 BEDROCK GEOLOGY

The broad plains of County Kildare have evolved slowly through erosion, particularly by dissolution, of the Carboniferous Limestone (Conry *et al.*, 1970). The bedrock formations in the area include: the Boston Hill Formation consisting of muddy limestone with subordinate shale, commonly dolomitised; the Rickardstown Formation dominated by dark grey limestones which are commonly cherty, and partly dolomitised; and the Milford Formation characterised by variable dark grey limestones (McConnell, 2004a and 2004b) (Figure 3.2). Older more resistant rocks form the boundaries of the aquifer. The Silurian Carrighill Formation which is predominantly composed of greywacke siltstones and shales forms the southeast boundary of the trough while the northwest is bound by the low ridge of the Chair Hills (Dunmurry Hill, Grange Hill, the Chair of Kildare, and the Hill of Allen). The Chair Hills are composed of Lower Paleozoic rocks including the Dunmurry Formation (sandstone and shale), Rahilla Formation (mudstones), Guidenstown Formation (shales), Kildare Limestone Formation (limestones and mudstones), Grange Hill Formation (siltstone and shale), Allen Andesite (andesite and basalt), Grange Cottage Formation (sandstones and siltstones), and Conlanstown Formation (shales and siltstones). Towards the northwest of the trough, between the limestones of the trough and the elevated rocks of the Chair Hills, are Carboniferous sandstones and shales such as: the Feighcullen Formation consisting of variable

limestones; the Cloghan Sandstone Formation dominated by light grey thick bedded sandstones with subordinate limestones and shale; Ferbane Mudstone Formation characterised by shale and sandstone; and Old Red Sandstone comprised of conglomerate, sandstone and siltstone.

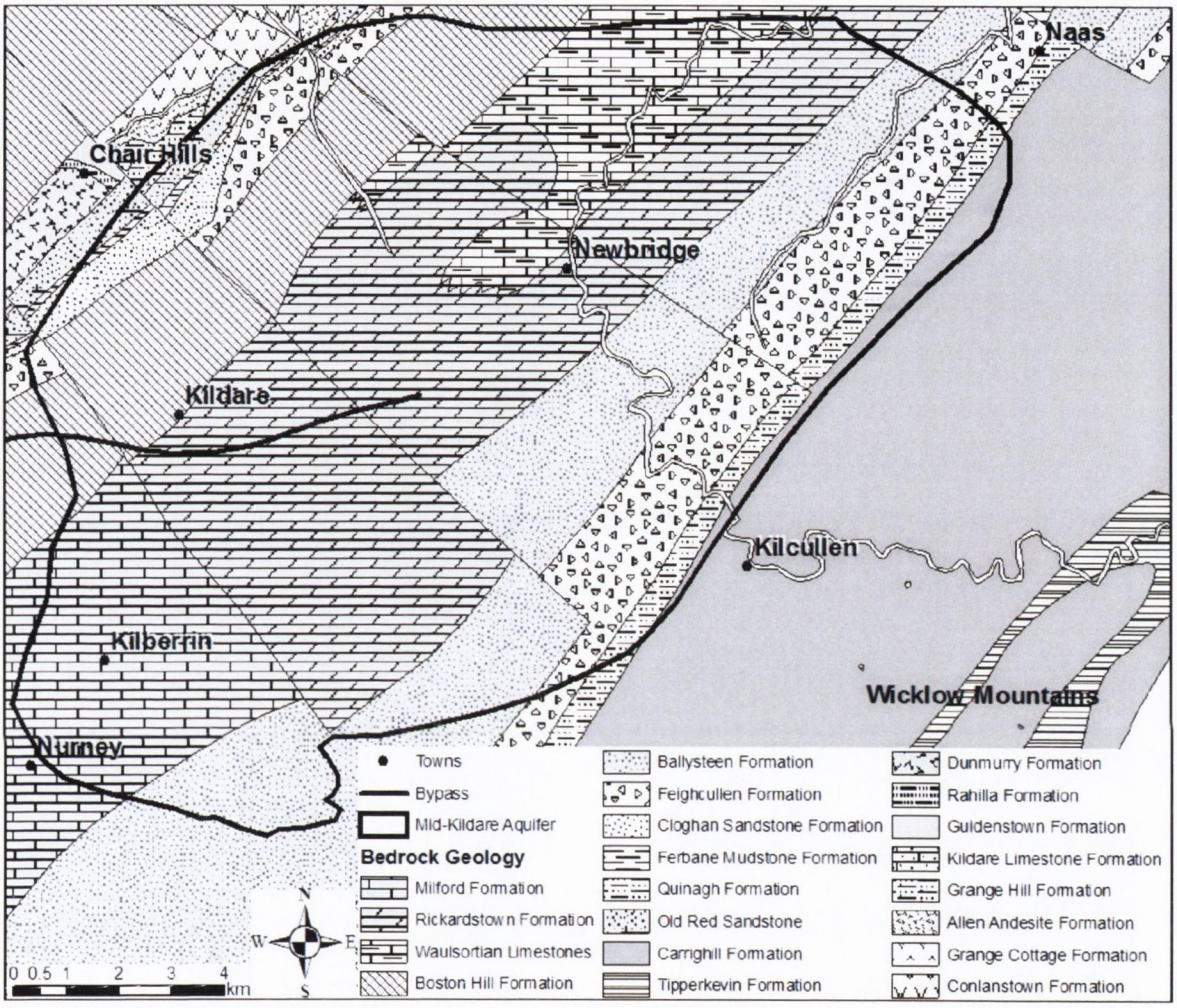


Figure 3.2: Bedrock geology in the region of the Mid-Kildare Aquifer (McConnell, 2004a and 2004b). The location of the Kildare Town Bypass is indicated by the black line south of Kildare Town.

Bedrock aquifers, in Ireland, primarily have secondary hydraulic conductivity controlled by fractures, karstification, and dolomitisation rather than having pore-space hydraulic conductivity (Geological Survey of Ireland, 2004a). The bedrock in the area of the Mid-Kildare Aquifer has been identified by the Geological Survey of Ireland (GSI) as a "Regionally Important Aquifer - Karstified" to the east of Kildare Town and as a "Locally Important Aquifer - Karstified" to the west of Kildare Town. The GSI defines a regionally important aquifer as an aquifer which is sufficiently productive to be able to yield enough water to boreholes or springs to supply major regional groundwater schemes. A locally important aquifer is defined by the GSI as an aquifer which is moderately productive, i.e.

capable of yielding enough water to boreholes or springs to supply villages, small towns or factories. The regionally important bedrock aquifer is associated with the Dinantian Pure Bedded Limestones of the Rickardstown Formation and the locally important bedrock aquifer is associated with the Dinantian Lower Impure Limestones of the Boston Hill Formation (Geological Survey of Ireland, 2007). There are also several regionally important faults running through the area, which may further increase secondary permeability. Therefore, the limestone bedrock may host a secondary aquifer in the area of the Kildare Town Bypass.

3.3 GLACIAL AND RECENT GEOLOGY

The bedrock trough between the Leinster Massif and the Chair Hills is covered by a thick layer of glacial sediments as a result of last glacial period, known as the Midlandian in Ireland, that lasted between 73 000 and 20 000 years ago (Woodcock and Strachan, 2000). During this time the glaciers in Ireland advanced and retreated many times eroding, depositing, and reworking sediments. A warming trend has continued since 20 000 years ago and many of the glacial sediments deposited in Ireland come from the period from approximately 17 000 to 14 000 years ago when the glaciers were retreating for the last time (McCabe and Clark, 2003). A mixture of sediments were deposited in County Kildare, including a high proportion of sand and gravel, up to 70 m thick in some places (Wright, 1988). The depth to bedrock ranges from exposed bedrock at the surface in the Chair Hills to approximately 70 m near the village of Brackagh in the northwest of the county. The Mid-Kildare Aquifer consists of layer of glacial deposits ranging from 7 m to 63 m, with the majority having depths to bedrock between 20 – 40 m.

The Mid-Kildare Aquifer is a very large sand and gravel body with an area of approximately 200 km^2 (Wright, 1988). A thick mantle of glacial tills and outwash sand and gravel drapes the bedrock almost everywhere, thinning only as bedrock emerges as hills or where rivers have recently eroded the till (Glanville, 1997a). The area around Pollardstown Fen, in a typical vertical sequence, consists of fine sands, overlain by gravels, overlain by a gravely diamicton (Glanville, 1997a). Diamicton is an unsorted deposit with no genetic implications, synonymous with till; however, till implies that the sediment was deposited through glacial action. Pollardstown Fen consists of layers of peat and marl underlain by clay deposits (Daly, 1981). The fen was formed as a proglacial lake in a depression which then became in-filled with marl as a result of alkaline water and peat as

vegetation decayed. The area around Ballysax (in the southeast of the Mid-Kildare Aquifer) has many eskers (Glanville, 1997a). A typical sequence in this area consists of cross-bedded gravel overlain by matrix supported (sand) gravel.

Ice-marginal glacial deposits, which are formed at the edges of a glacier typified by sediments being deposited by gravitational processes and/or glaciofluvial processes, dominate the Mid-Kildare region (Glanville, 1997b). They are typically complex and variable, being very sensitive to sediment supply, subglacial topography, ice margin fluctuations, and climatic changes. The dominance of gravitational or glaciofluvial processes depends on the glacier, according to the availability of debris and melt water, and whether the glacier is in a period of retreat or advance. The most common gravitational processes are debris flows, rolling and sliding, and deposition from flowing water (Benn and Evans, 1998). Substantial amounts of glacial sediments can be reworked by braided or meandering meltwater streams flowing from the margins of the glacier known as glaciofluvial processes. Glanville (1997a; 1997b; 2003) suggests that the ice mass covering Co. Kildare separated into three lobes each of which retreated to its own centre. The three lobes are known as: the Irish Sea Ice (retreated towards the north and northeast); the Northern Dome Ice (retreated towards the northwest); and the Midland Dome Ice (retreated towards the west) (Figure 3.3). In the context of this model the Mid-Kildare Aquifer would have been situated in the ice-marginal area between the northern and western lobes as they decayed.

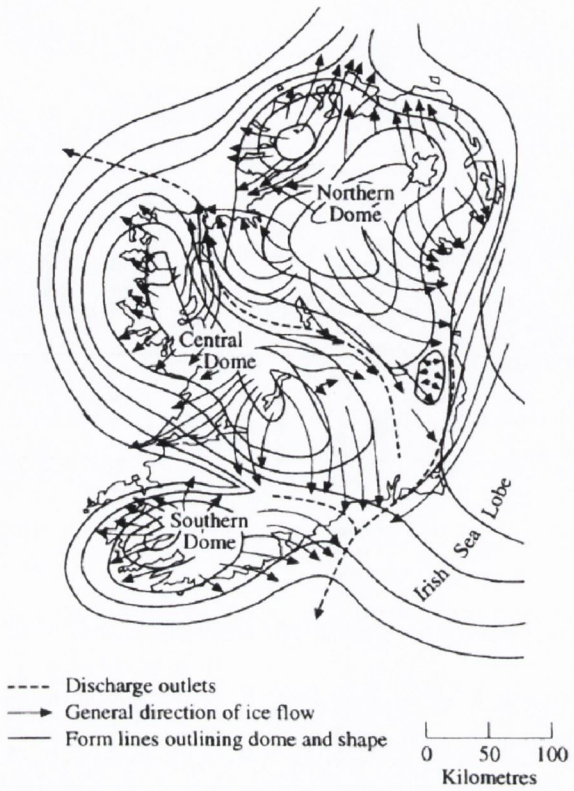


Figure 3.3: Schematic diagram of multiple ice domes at the maximum of the last glaciation in Ireland (from Warren and Ashley, 1994; Glanville, 1997a).

The GSI undertook extensive Quaternary mapping of the Kildare area in 1995 and 1996 (Figure 3.4) (Glanville, 2000). The Quaternary mapping represents the surface deposits rather than those at depth and the aquifer boundary shown on Figure 3.4 is based on that defined by Wright (1998) on the basis of the saturated thickness of the sand and gravel deposits. Limestone-dominated tills were mapped in the western part of the Mid-Kildare Aquifer and outwash gravels were mapped in the central part of the Mid-Kildare Aquifer. Outwash deposits are generally coarse-grained stratified glaciofluvial sediments which are highly permeable and are very good aquifers (Fetter, 2001). The limestone-dominated tills extend to the north while the outwash gravels continue to the east as the Curragh plain. The gravels and sands are interpreted as proglacial ice-marginal outwash and the overlying tills are interpreted as re-advance tills which reworked the previously deposited outwash gravels. A more compact till is also present in lower lying areas and is a dark grey silty limestone dominated till and may represent a basal till and is mapped as till with gravel (Glanville, 2003). Basal till is generally characterised by overconsolidated unsorted sediments that were deposited on the bedrock surface by an advancing glacier and often form aquicludes as they generally have low hydraulic conductivity.

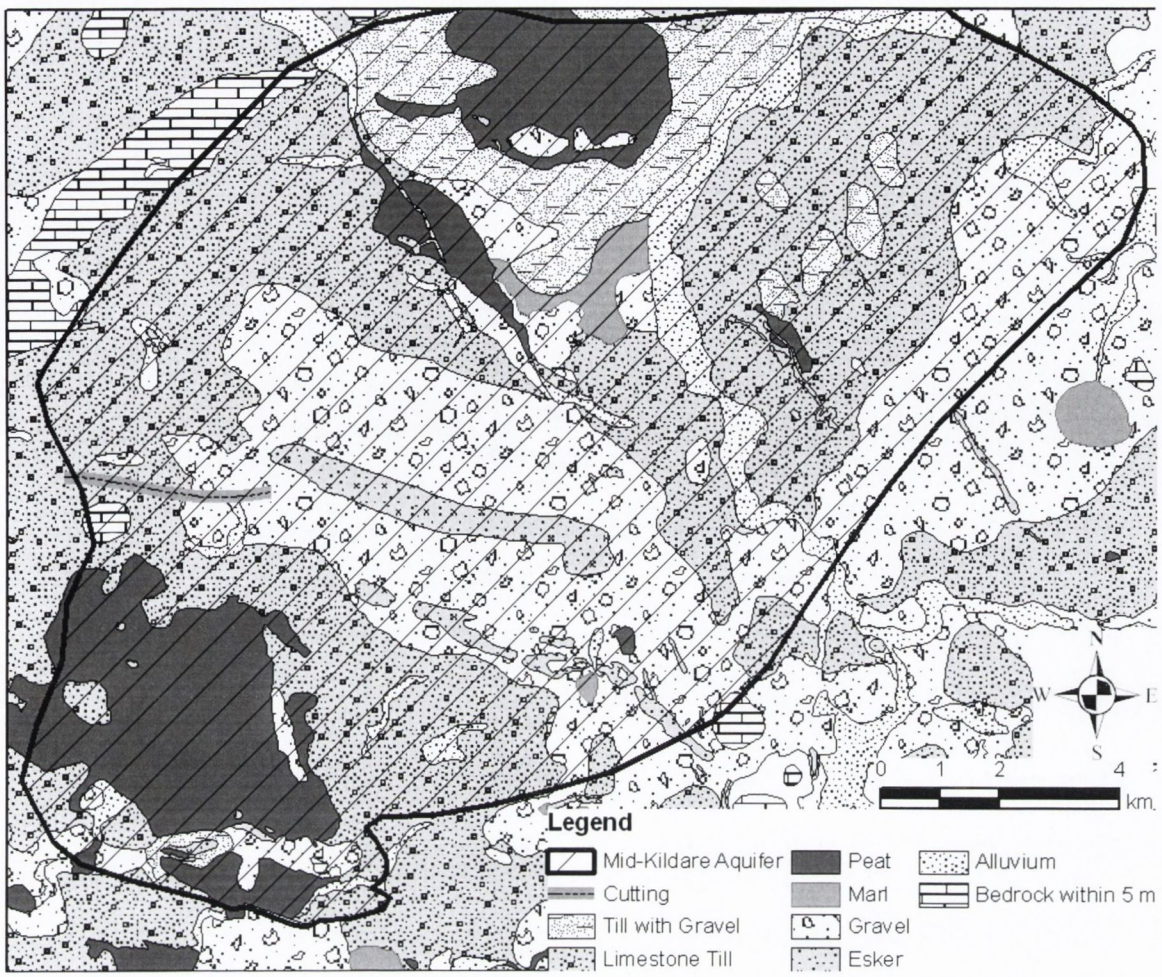


Figure 3.4: Surface quaternary and recent geology within the Mid-Kildare Aquifer in the study area (modified from Glanville, 2000), extent of aquifer defined by Wright (1988).

Glanville (2003) assessed the glacial sediment during construction of the groundwater control system when they were exposed from the road cutting. Four facies were identified each with distinct depositional environments: 1) glaciofluvial sands and gravels; 2) brown silty to sandy till; 3) compact stiff grey clayey tills; and 4) laminated silts and clays.

Glanville (2003) proposed two processes which deposited the sediments of the Mid-Kildare Aquifer: 1) subglacial and proglacial glaciofluvial outwash (sands and gravels); and 2) subglacial and ice marginal deposition (till). The glaciofluvial deposits occupy what was the topographically high ground along the length of the Aquifer. This environment was highly dynamic with varying flow directions and sediment changes in very short distances. The brown sandy till facies is interpreted as a flow till or reworked gravel deposit. This facies would be expected to have a higher hydraulic conductivity than a basal till as it would not be over-consolidated and may show some winnowing of fines

from melt water. The laminated silts and clays are interpreted as ice marginal pond fill from either decaying ice margins or dead ice blocks. These would be expected to have a low hydraulic conductivity with a larger horizontal hydraulic conductivity than vertical as the layers produce preferential flow paths for groundwater flow. Reworked tills or flow tills overlie these ponded areas and are interpreted as being deposited during a period of ice re-advance.

The glaciofluvial sands and gravels are found predominantly in the western edge of the aquifer and were separated laterally by topographically low areas in which laminated silts and clays were found (Glanville, 2003). The vertical sequence generally consists of 2 – 3 m of till overlying well-sorted, bedded, fine sands and gravels. The overlying till contains frequent inclusions of sands and fine gravels commonly up to 20 cm across. Within these inclusions, traces of original depositional structures were occasionally observed. The contact between the till and the sands and gravels are poorly defined and occasionally unconformable (Glanville, 2003).

The glaciofluvial gravel sediments are interpreted by Glanville (2003) as being the result of several depositional environments. The gravel deposits towards the west are interpreted as subaqueous fan deposits, deposited directly from the ice margins into standing or low velocity water. Typically outwash sediments occur just south of Kildare Town which fine upwards from gravels to sands to silts that are overlain by reworked till. This is interpreted as an outwash plain deposited in a slowly flowing aqueous environment. This was also observed in the eastern section close to the Curragh plain.

The compact grey tills were found predominantly to the east of Kildare Town. They were interpreted by Glanville (2003) as basal till and could be remnants of earlier depositional processes. The underlying gravels formed a marked distinction in the lateral variation between facies assemblages along the length of the excavated sections; to the west outwash and fan deposits and to the east further outwash gravels. The stratigraphy generally consists of a 4 – 6 m layer of till overlying a 0.4 – 1.0 m layer of silty clay or silty sand which overlies laminated silt deposits or well sorted gravel (outwash and fan) deposits.

Laminated silts and clays underlying silty sandy tills and overlying sands and gravels were found in topographically low areas near the surface, and generally had the U-shape of

a channel in cross-section (Glanville, 2003). The gravels tend to be less well sorted than the ones previously described. They appear to have a limited aerial extent, as they commonly did not continue across the northern and southern sides of the excavation.

3.3.1 Analysis of glacial and recent geology near the Kildare Town Bypass

The data from the ground investigation for the bypass, which included boreholes, drill holes, particle size distribution analyses, variable head tests, and pump tests, were used in the analysis of the geology and hydrogeology of the Mid-Kildare Aquifer. The borehole data, obtained using cable percussion boreholes or drill holes, collected by Irish Geotechnical Services (1993) were used to create a geological profile along the length of the excavated area for the bypass from Ch. 69+00 to Ch. 124+00 a distance of 5.5 km (Figure 3.5). In the area of the Kildare Town Bypass, the till and the glaciofluvial outwash layers have a complex stratigraphy with occasional lenses of higher or lower permeability sediments. The CLAY and SILT deposits in the profile correspond to the till and the SAND and GRAVEL correspond to the glacial outwash mapped by the GSI. The profile (Figure 3.5) shows that the CLAY and SILT deposits range from being non-existent to 15 m thick. In general, it is thicker towards the west (lower chainages) and thins towards the east (higher chainages). The SAND or GRAVEL, (shown in Figure 3.5) interpreted as glaciofluvial/outwash deposits, underlie till deposits where present. The division between the two units can be sharp or gradational and laterally discontinuous (Figure 3.6). The SAND and GRAVEL deposits generally become thicker towards the east (higher chainages) and are thicker at areas of higher topography. It is difficult to assess the true thickness of this layer as many of the boreholes were not fully penetrating. However, the glaciofluvial/outwash layer is in excess of 10 m in areas towards the centre and east of the road length (Ch. 72+00-76+00, 86+00, 113+00-124+00). In the areas where boreholes were taken to a sufficient depth (Ch. 75+00, 76+00 86+00), the SAND and GRAVEL (glaciofluvial outwash) layer was continuous to bedrock. In the area of the excavation for the bypass, the glaciofluvial outwash layer is generally at least 5 – 10 m thick. The typical thickness of the CLAY and SILT in the area around the Mid-Kildare Bypass, is around 3 m, at its thickest point it is 11 m (Ch. 81+00) and at its thinnest point it is non-existent (Ch. 79+00, 92+00-93+00, and 105+00-106+00). The entire section has a layer of topsoil between 0.1 – 0.5 m thick.

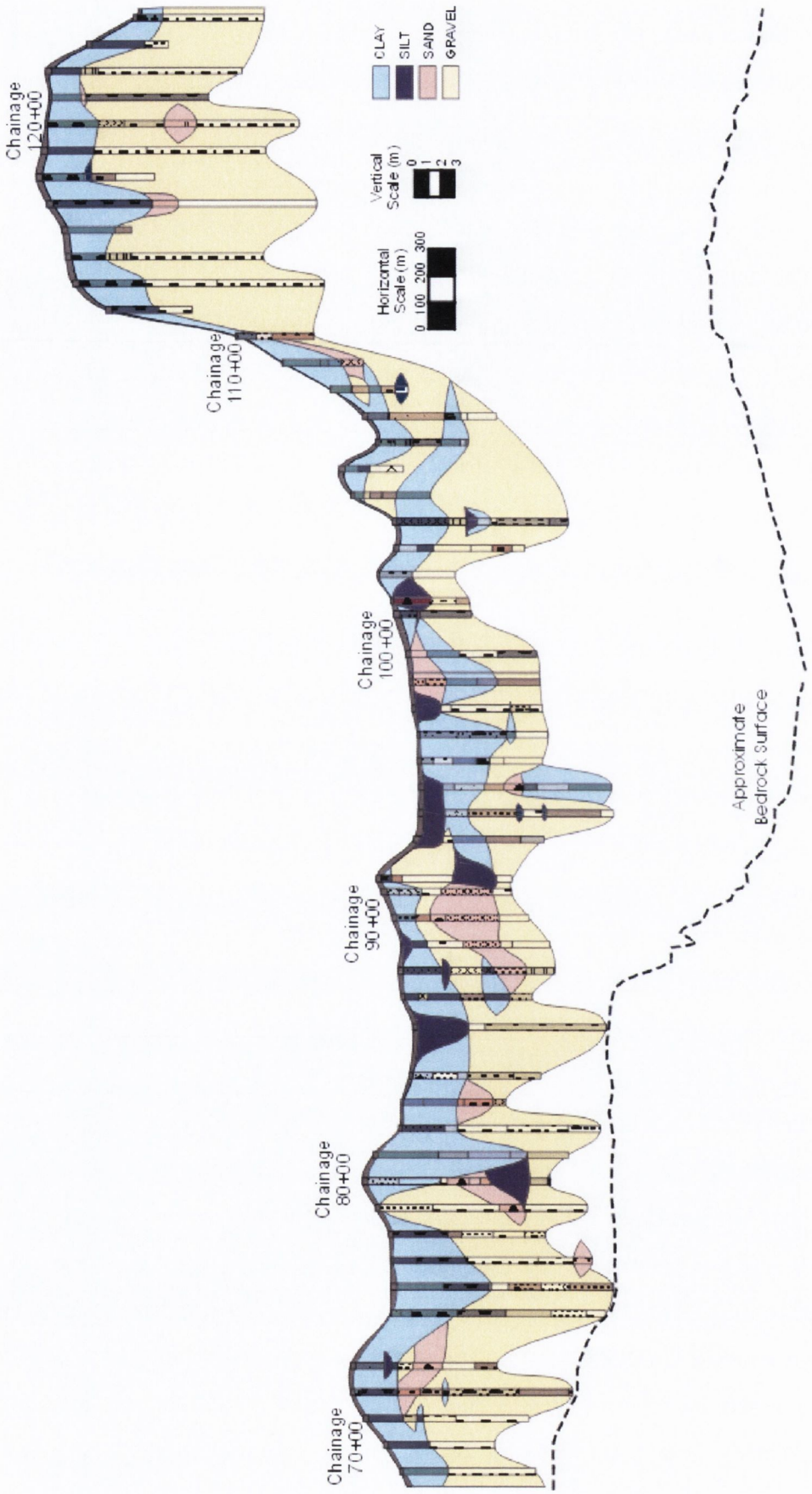


Figure 3.5: Geological profile of the section which was excavated for the construction of the bypass.

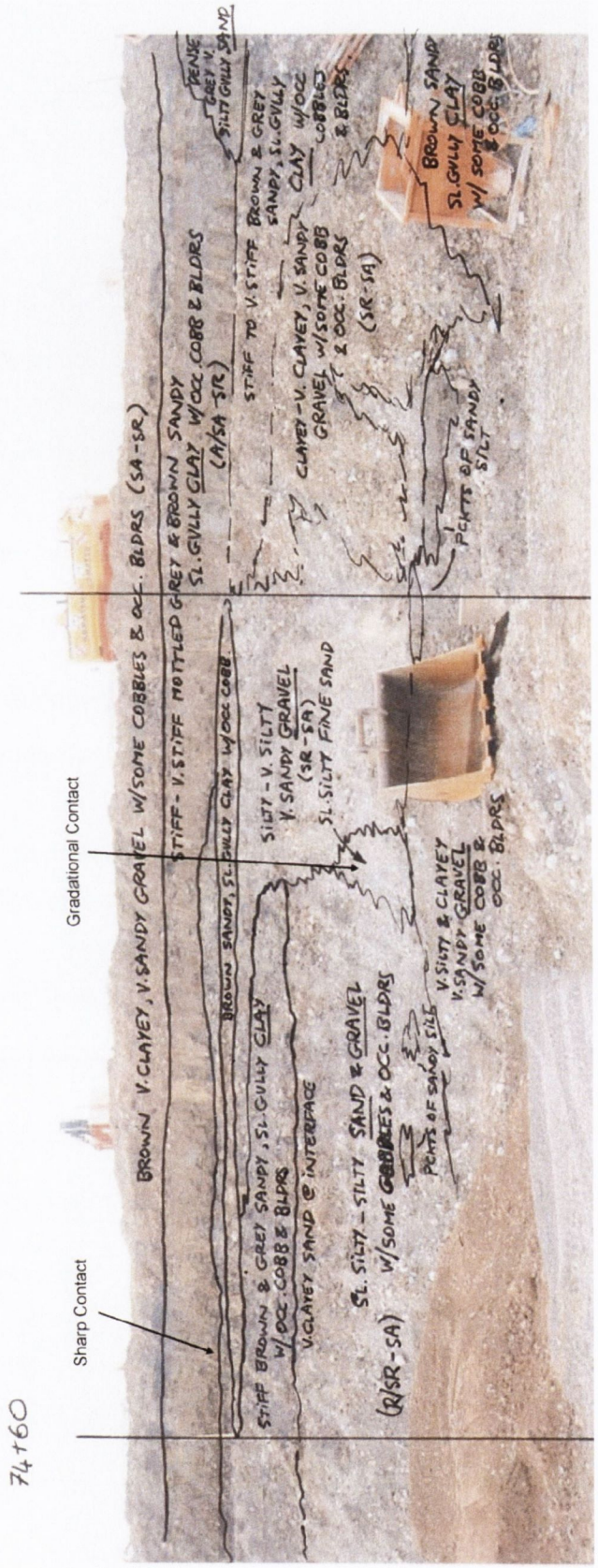


Figure 3.6: Section through the Mid-Kildare Aquifer exposed during construction from Ch. 74+30-74+60. This shows the sharp and gradational contacts between units, the lateral discontinuity of units, and the lenses or pockets of sandy SILT within the SAND and GRAVEL units (photo from AGL Consulting).

3.4 HYDROGEOLOGY

The Mid-Kildare Aquifer has been classed by the GSI as a regionally important sand and gravel aquifer, which is defined as an aquifer capable of having a large number of "excellent" wells defined as yielding in excess of 5 l/s (Geological Survey of Ireland, 2004a). The boundaries of the aquifer are well defined to the southeast by the Leinster Massif and to the northwest by the Chair Hills, and less clearly defined to the northeast and southwest. In these areas, Wright (1988) defined the aquifer by the existence of at least 5 m of saturated sand or gravel. Using this criterion, the aquifer has an area of approximately 200 km^2. It has an ovoid shape with a maximum length of 21 km and a maximum width of 13 km, and extends from near Naas in the northeast to Nurney in the south and from Kildare town in the west to Kilcullen in the east (Figures 3.7 and 3.8) (Wright, 1988). The overburden in County Kildare is fairly thin to the east and thickens westwards (Cussen and Wolfe, 1992). The seasonal variation in the groundwater level within the aquifer is in the order of 1.25 – 2.50 m with the lowest levels around October and the highest around February (Hayes *et al.*, 2001). The annual variation is typical of sand and gravel aquifers, suggesting high permeabilities and/or high storage capabilities (Hayes *et al.*, 2001). The tills impede the flow of recharge to the aquifer because the hydraulic conductivity of the till is thought to be moderate to low (Geological Survey of Ireland, 2004b). From field and laboratory testing of tills in Ireland, Swartz *et al.* (2003) suggest that the 'boundary between low and moderate permeability subsoils appears to be in the region of 10^{-9} m/s using falling head tests' (Fitzsimons and Misstear, 2006). The Mid-Kildare Aquifer has intergranular primary porosity (Geological Survey of Ireland, 2004c). The groundwater flow velocity is considered to be 1 m/day towards the northwest and north (Pollardstown Fen) and the groundwater gradient is estimated to be 0.002 (Geological Survey of Ireland, 2004c).

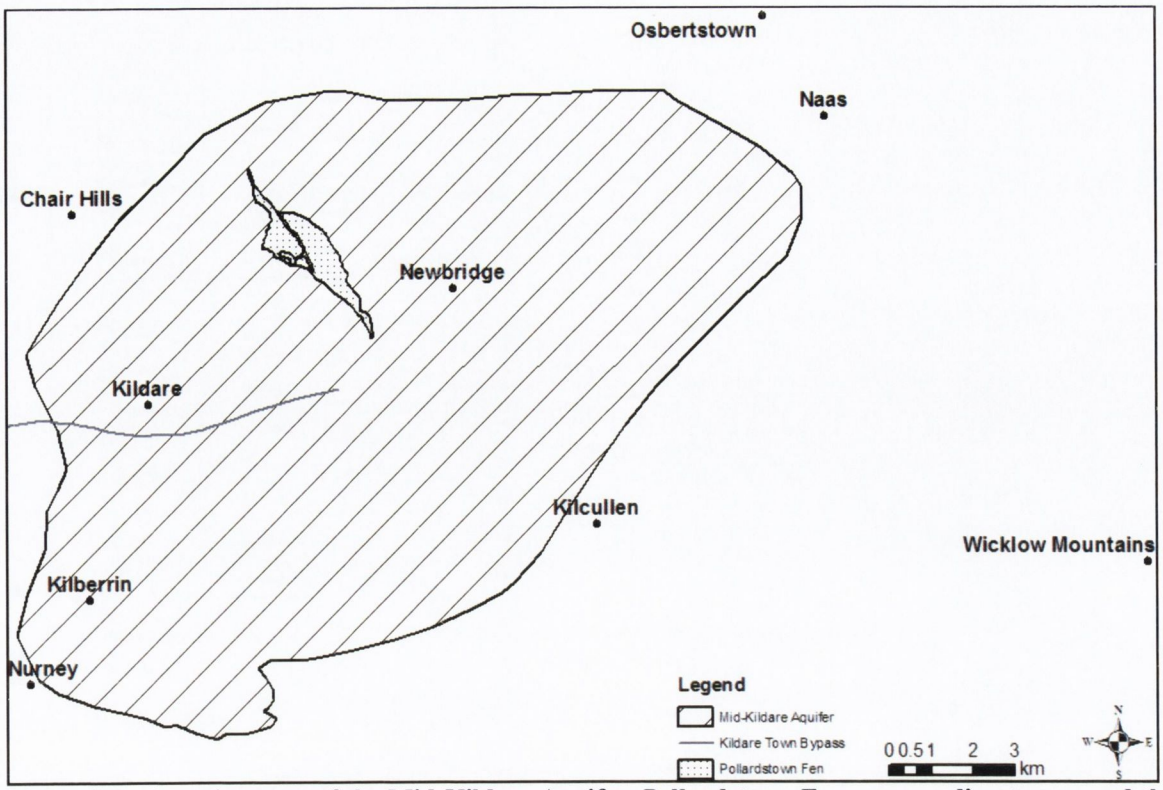


Figure 3.7: Location map of the Mid-Kildare Aquifer, Pollardstown Fen, surrounding towns, and the Kildare Town Bypass.

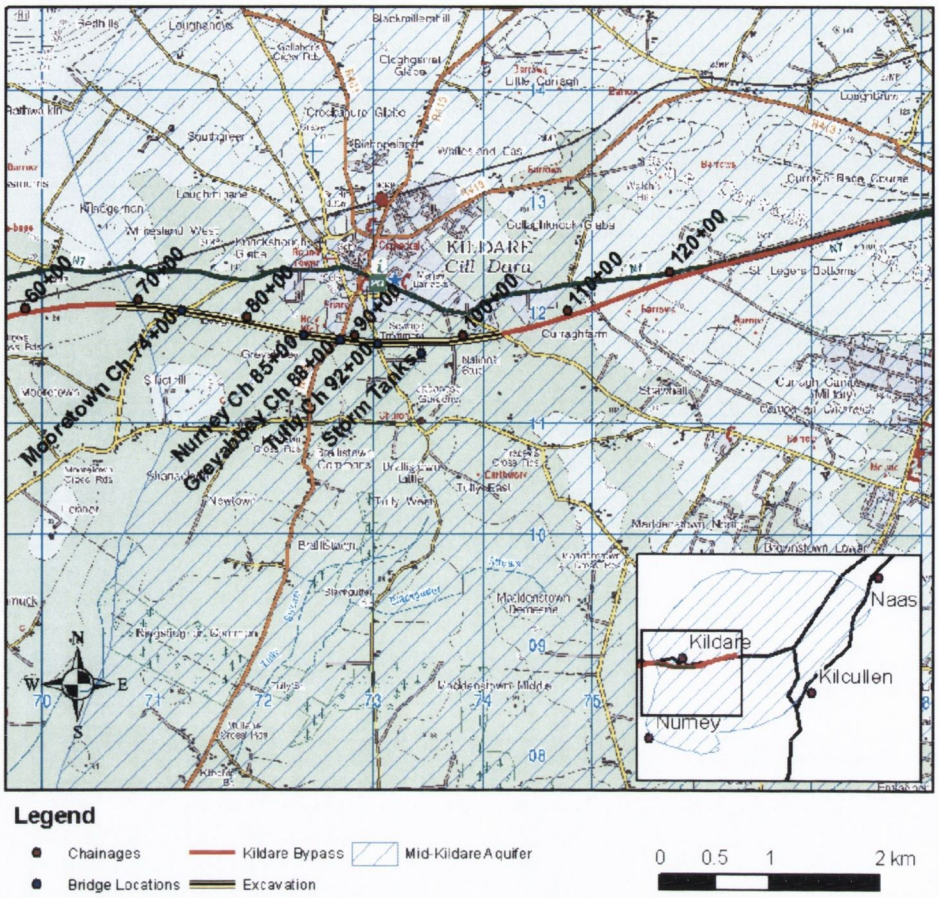


Figure 3.8: Location of the Mid-Kildare Aquifer as defined by Wright (1988) and Kildare Bypass where the watertable was intersected. Chainages are shown along the length of the motorway and will be used to refer to locations along the motorway throughout the thesis.

Information of the hydrogeology of the Mid-Kildare Aquifer was available from several sources including the GSI, the initial ground investigation reports, published articles, and Farrell and Devine (2006). Many authors have estimated the hydraulic properties of the Mid-Kildare Aquifer (Daly, 1981; Cussen and Wolfe, 1992; K.T. Cullen & Co. Ltd., 1993; Hayes *et al.*, 2001; White Young Green 2003). Daly (1981) determined his estimates of the hydraulic conductivity from short pumping tests carried out on three boreholes within the gravels underlying the Pollardstown Fen peat and marl deposits. Cussen and Wolfe (1992) do not indicate the unit for which the hydraulic conductivity is being estimated or the methods used to obtain their estimates, or if the estimates are based on work conducted by themselves or previously reported values. Hayes *et al.* (2001) estimated the hydraulic conductivity of Mid-Kildare Aquifer from pumping tests. K.T. Cullen & Co. Ltd. (1993) conducted their pump tests as part of the ground investigation for the Kildare Town Bypass project. These pump tests were used to develop a finite-difference model (known as the Kildare Aquifer Model - KAM) of the Mid-Kildare

Aquifer. The KAM model, which was commissioned by the Monitoring Committee to study the effects of the dewatering on the aquifer, was developed by Entec UK Ltd. under the guidance of K.R. Rushton. In this model, the gravel properties in the northwest were modified from the pump test results to achieve better correlation between KAM and the observed water levels in the aquifer. A summary of the hydraulic conductivity, transmissivity, specific yield, specific storage, and porosity estimations from Daly (1981), Cussen and Wolfe (1992), K.T. Cullen & Co. Ltd. (1993), Hayes *et al.* (2001) and the KAM model values (White Young Green Environmental, 2003) can be found in Table 3-1.

Table 3-1: Summary of horizontal hydraulic conductivity (K_x, K_y), vertical hydraulic conductivity (K_z), transmissivity (T), specific yield (S_y), specific storage (S_s), and porosity (n) as estimated by Daly (1981), Cussen and Wolfe (1992) , K.T. Cullen & Co. Ltd. (1993), Hayes *et al.* (2001) and White Young Green Environmental (2003).

		METHOD	K_X, K_Y (m/s)	K_Z (m/s)	T (m^2/s)	S_Y	S_S (m^{-1})	n
Daly (1981)	Gravels	Pumping Tests	$2x10^{-3}$					
	Clayey gravels		$1x10^{-5}$ - $1x10^{-6}$					
	Lacustrine clays		$1x10^{-8}$					
Cussen & Wolfe (1992)		Not stated	$2x10^{-4}$ - $2x10^{-3}$		$2x10^{-3}$ - $6x10^{-3}$	0.07-0.15		45 %
K.T. Cullen & Co. Ltd. (1993)	Gravels	Three pump tests at Sewage Treatment Works, Frenchfurze Road, and Greyabbey Road	STW $5x10^{-4}$ FF $1x10^{-3}$ GA $3x10^{-4}$					
Hayes *et al.* (2001)		Pumping Tests	$4x10^{-4}$					30-40 %
KAM model values (White Young Green, 2003)	Till	Values adjusted from pumping tests to improve correlation	$3x10^{-5}$	$1x10^{-6}$		0.13	0.0001	
	Gravel		$1x10^{-3}$	$5x10^{-5}$		0.13	0.0001	
	Gravel NW		$3x10^{-4}$	$5x10^{-5}$		0.07	0.0001	

3.4.1 FIELD ASSESSMENT OF HYDROGEOLOGICAL PARAMETERS

The data from the ground investigation were collated and additional sources of data were obtained from published articles and reports to enhance the assessment of the hydrogeology of the Mid-Kildare Aquifer. Some data, such as the topography, were obtained from a single source (e.g. Ordnance Survey of Ireland). Other data including the

depth to bedrock and hydraulic head data had to be combined from a variety of sources. The hydraulic conductivity and storativity were reanalysed from data obtained from the initial ground investigation.

3.4.2 Depth to Bedrock and Topography

Depth to bedrock data with respect to ground level was obtained from borehole data available from the GSI as well as from the ground investigation for the Kildare Town Bypass. Only the boreholes which cored the bedrock were used to define the depth to bedrock. The rock levels were related to the Ordnance Datum (Malin Head) by subtracting the depth to bedrock given in borehole logs from the ground elevation obtained from the Ordnance Survey of Ireland (OSI) which is referenced to the Malin Head datum or by converting the ground levels of the boreholes given in the IGSL report from the Poolbeg datum to the Malin Head datum by subtracting 2.7 m. The Poolbeg reference datum was used in the ground investigation for the Kildare Town Bypass and in all the Monitoring Committee analyses and reports but has been converted to Malin Head in this thesis.

A total of 337 data points (obtained from borehole data from the GSI and coring logs from the ground investigation) were used to contour the bedrock elevation (Figure 3.9) using ArcGIS software which interpolated the data using the natural neighbours method of interpolation. Natural neighbours is a deterministic interpolation method which means that values are assigned based on surrounding measured values and on a specified mathematical formula that determines the smoothness of the resulting surface (Sibson, 1980; Sibson, 1981) . Several interpolation methods were tried including inverse distance weighted and kriging but natural neighbours produced a surface which produced the least amount of "bull's eyes" and the most natural looking contours and thus is considered to be a good approximation the actual surface based on the current available data. The contour pattern is necessarily influenced by the density of information which causes greater uncertainty where this is low.

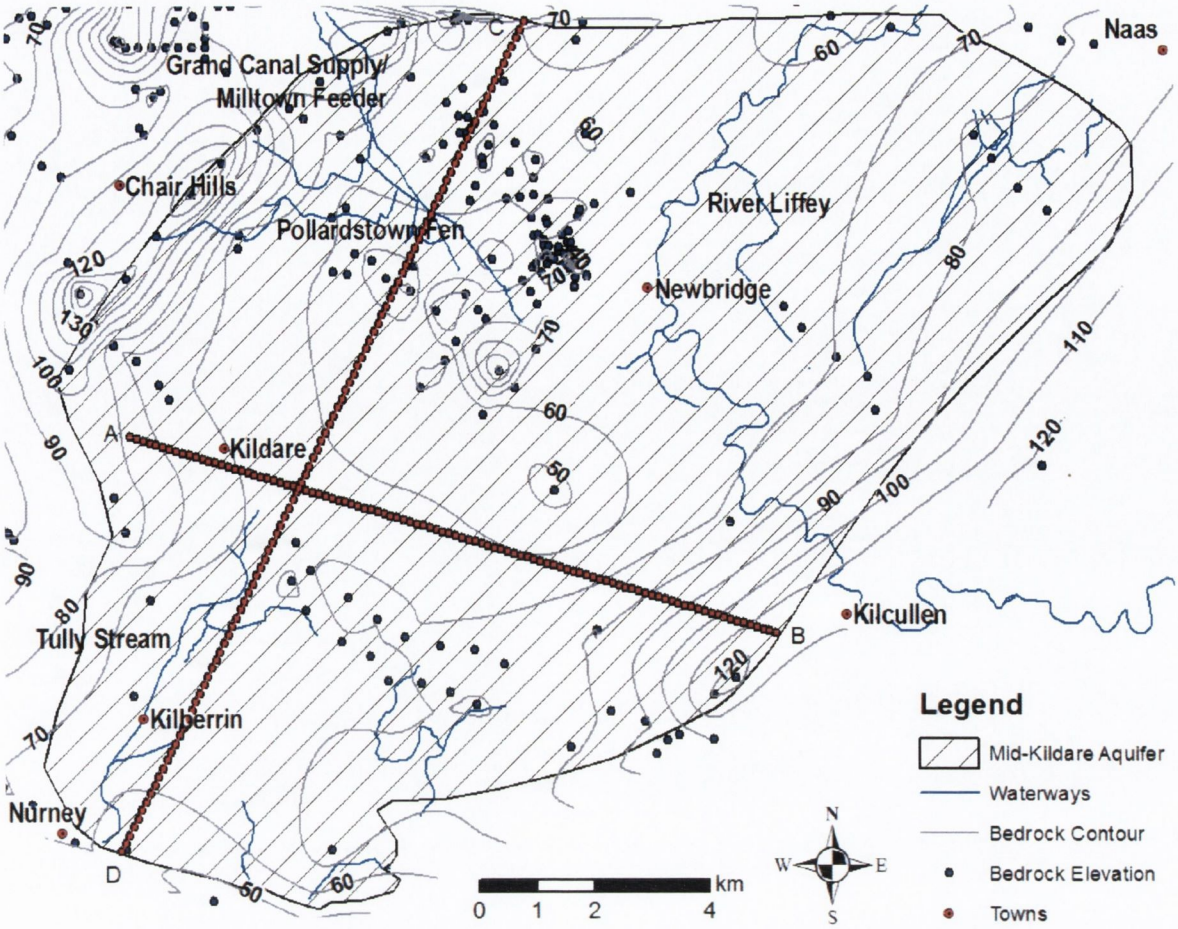


Figure 3.9: Map showing the elevation of the bedrock underneath the Mid-Kildare Aquifer and locations of the profiles AB and CD taken through the aquifer.

The topography data were obtained from the OSI and had a data spacing of 50 m (OSI, 2002). These data were interpolated using the natural neighbours method and a contour map of the topography was made (Figure 3.10). Two profiles through the study area AB (Figure 3.11) and CD (Figure 3.12) were constructed from this information.

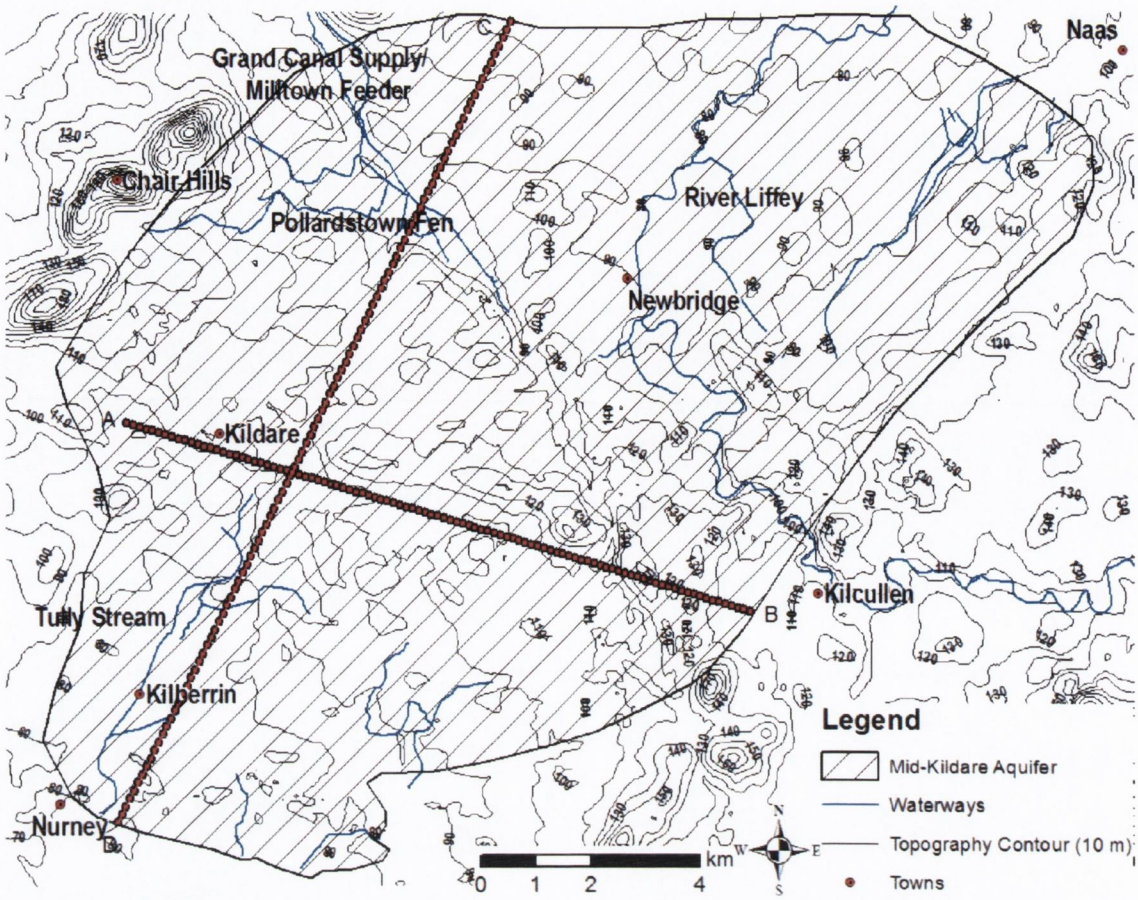


Figure 3.10: Topographic contours in 10 m intervals in the area of the Mid-Kildare Aquifer. The contour levels are metres above sea level (mASL) (Malin Head datum).

The topographic and the bedrock profile are shown together in Figures 3.11 and 3.12 so that the aquifer shape and thickness of the overburden could be visualized. The interface between the upper till layer and the lower sand and gravel layer could not be added to these profiles as the data were only collected at the bypass and so they could not be gridded for the entire aquifer.

The base of the aquifer forms a trough-like depression in the northwest to the southeast profile, AB, as shown in Figure 3.11. The northeast to the southwest profile, CD, shows the bedrock is undulating and varies by approximately 20 m in elevation, see Figure 3.12.

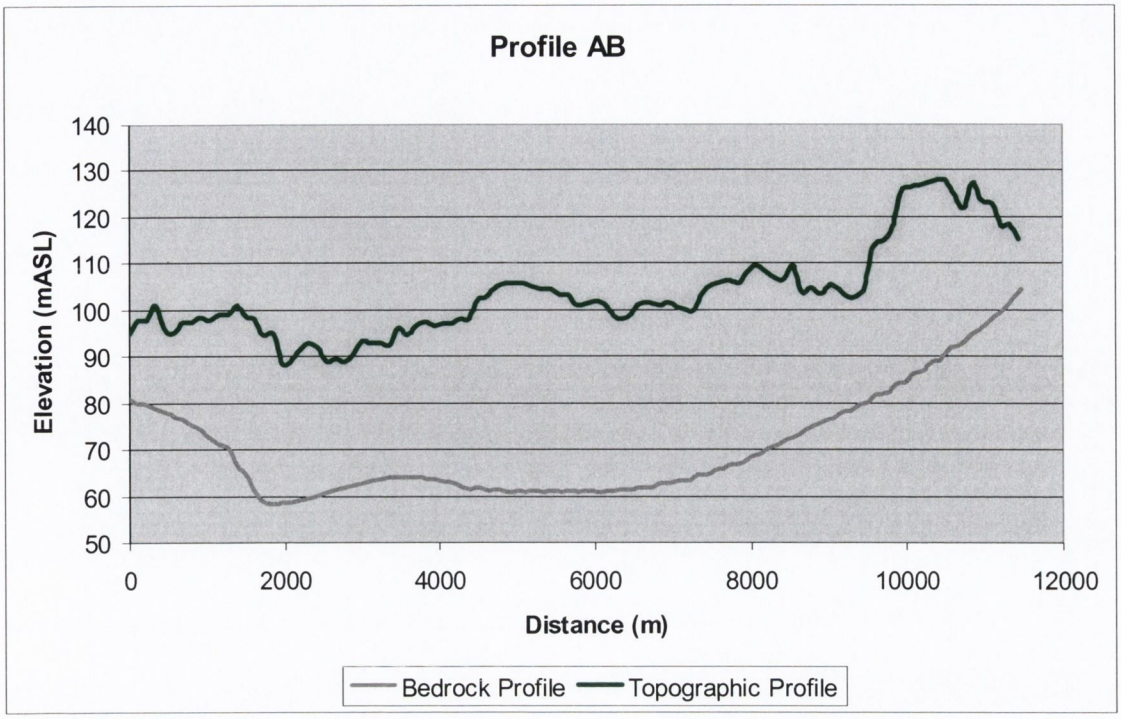


Figure 3.11: Bedrock and topographic profile from AB as seen in Figures 3.8 and 3.9. The bedrock along this area forms a trough like depression. Topography and bedrock elevations are in metres above sea level.

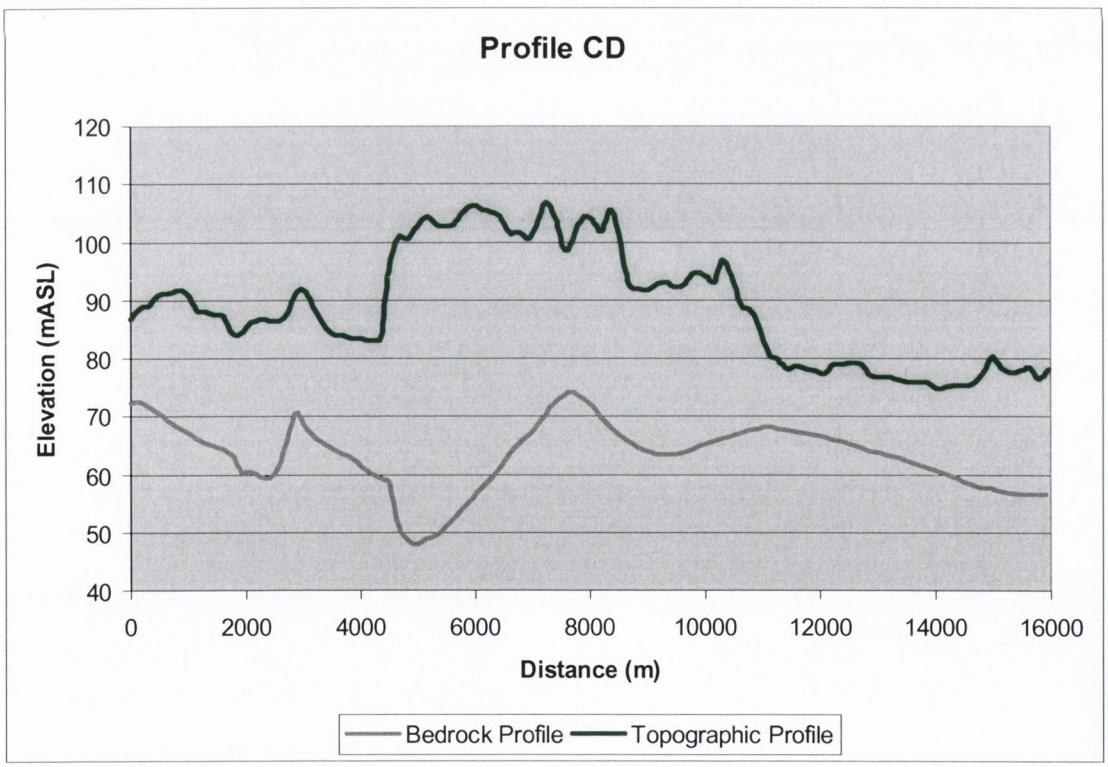


Figure 3.12: Bedrock and topographic profile from CD as seen in Figure 3.8 and 3.9. The bedrock along this area forms a gently undulating surface. Topography and bedrock elevations are in metres above sea level. The steep gradient around 4500 m is near the southwestern margin of Pollardstown Fen.

The high topographic and bedrock elevation found towards 12000 m on Profile AB is the start of the foothills of the Wicklow Mountains which are formed from hard resistant rocks such as granite, sandstone, and shale which were not eroded by glacial activity and thus the bedrock is nearly at the surface which is consistent with Wright (1988) (Figure 3.11). The topographic rise near the centre of profile CD is where the ground rises in the centre of the aquifer just southwest of Pollardstown Fen. These profiles show that the aquifer boundaries are well defined along AB where the Chair Hills rise to the northwest and the Wicklow Mountains rise to the southeast, however the aquifer limits are poorly defined along CD where there is no thinning of the overburden (Figure 3.12).

Both the topography and the bedrock surface are hummocky which results in varying thicknesses of Quaternary and recent deposits. In the area around the Kildare Town Bypass, it consists of two basic units: an underlying sand and gravel outwash plain and an overlying clay and silt till unit. Elsewhere the upper till unit may be absent and the sand and gravel outwash plain may be exposed at the surface or other Quaternary or recent deposits may be in its place such as alluvium, eskers or peat. The thickness of the glacial deposits ranges from 5 to 63 m, with the average thickness, obtained from boreholes which extended through the entire aquifer thickness, being between 20 and 40 m.

3.4.3 Groundwater Levels and Flow Patterns

The groundwater levels, flow patterns, and variation were assessed to determine the hydrogeology of the Mid-Kildare Aquifer. The groundwater level data were obtained from the Monitoring Committee (boreholes prefixed with MB and those from the chainages along the Kildare Town Bypass) and from existing boreholes monitored by the Environmental Protection Agency (boreholes prefixed with EPA or Kild). The groundwater levels in the Mid-Kildare Aquifer were monitored from mid-June 1998 until September 2006 by the Monitoring Committee for the Kildare Town Bypass project at the locations shown in Figure 3.13. Figure 3.14 shows the hydrographs from the monitoring boreholes through time. These boreholes were affected by the dewatering for the Kildare Town Bypass construction. During this time, maximum groundwater heads were generally found each winter from February to April with the maximum over the total period being on February 18, 1999 when ten out of a total 31 monitoring boreholes showed a maximum head over the eight years of monitoring (Appendix C). The minimum groundwater levels

were found to occur from August to early December each year. Minimum heads were recorded in eight out of 31 monitoring boreholes in both December 2004 and November 2005. However the minimum heads in November 2005 lasted longer than those in December 2004 with three wells having minimum heads on October 3, 2005, eight wells having minimum heads on November 4, 2005, and four wells having minimum heads on November 25, 2005. Figures 3.15 and 3.16 show the contours determined from the maximum and minimum heads recorded on February 18, 1999 and November 4, 2005 and groundwater head patterns. The groundwater heads were gridded using the natural neighbours technique. Comparison of the contour patterns of groundwater head in Figures 3.15 and 3.16 show that the overall pattern of groundwater flow remains relativity constant regardless of the groundwater level.

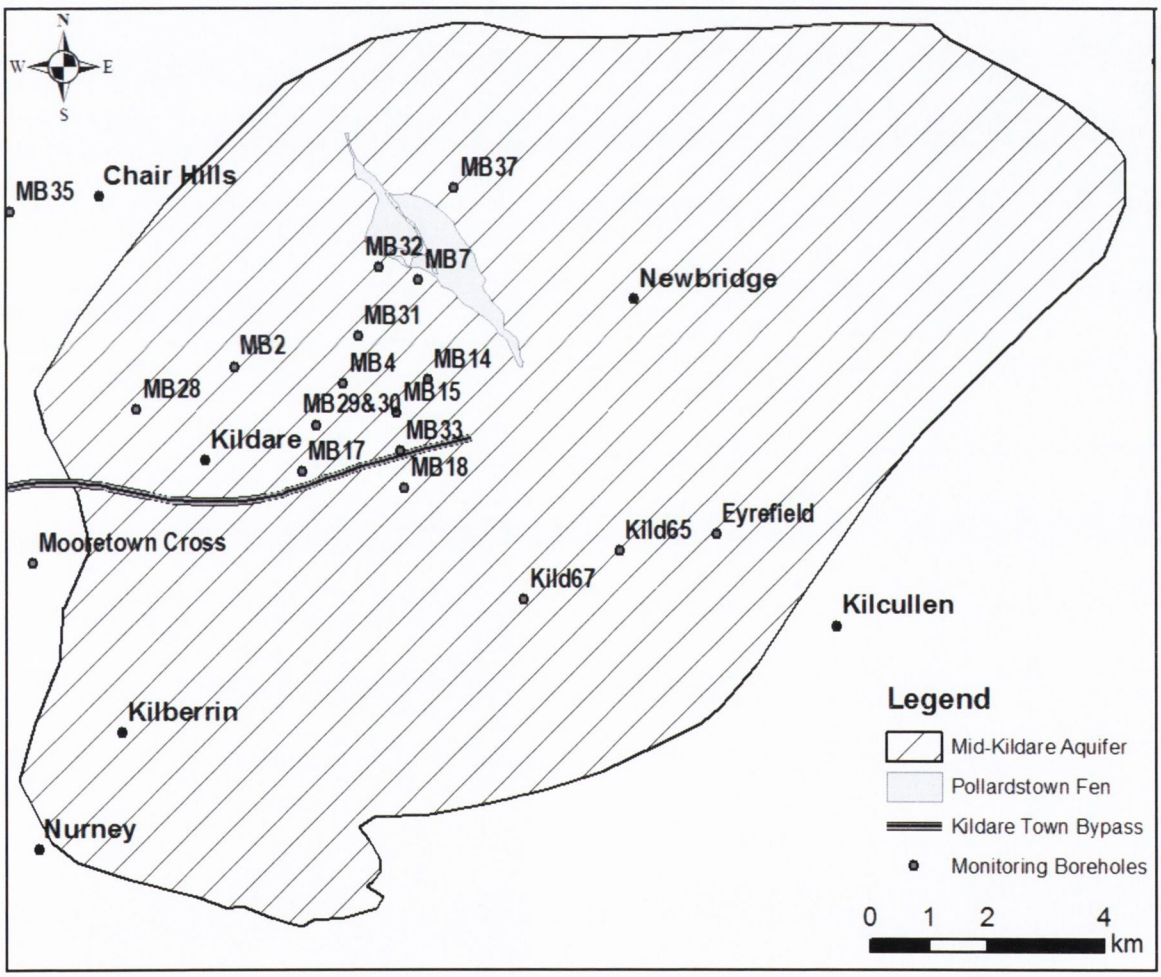


Figure 3.13: Locations of monitoring boreholes within the Mid-Kildare Aquifer which were used to monitor groundwater levels from June 1988 to September 2006. Data can be found in Appendix B.

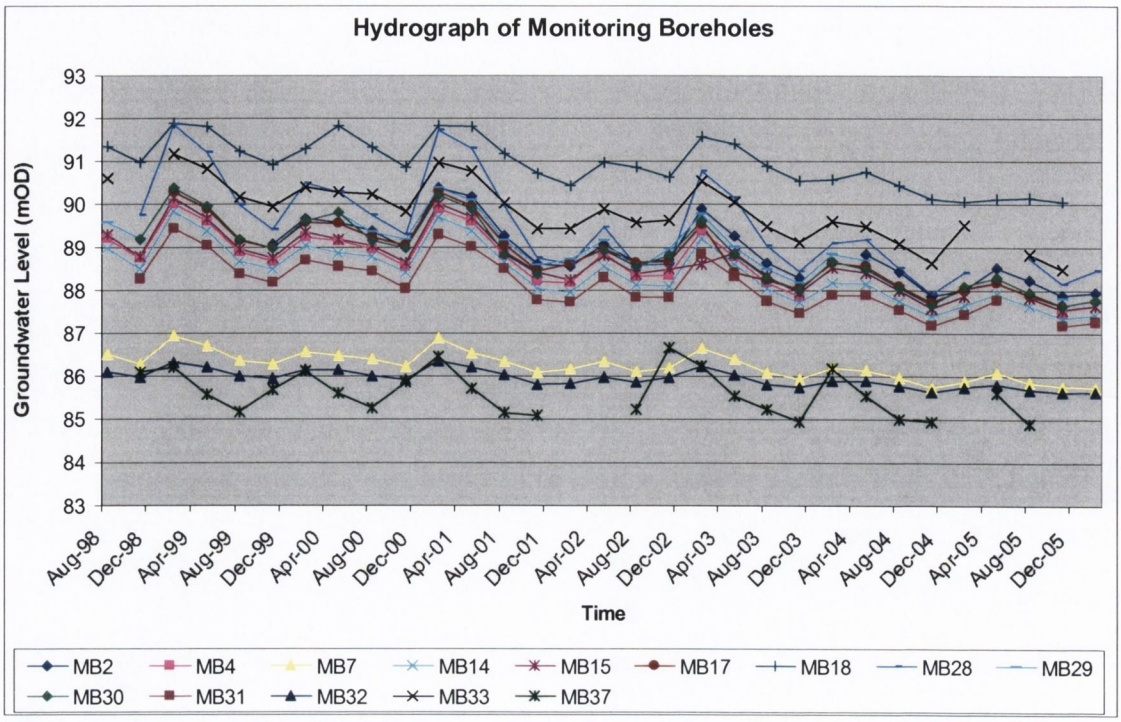


Figure 3.14: Hydrographs measured at the regional monitoring boreholes.

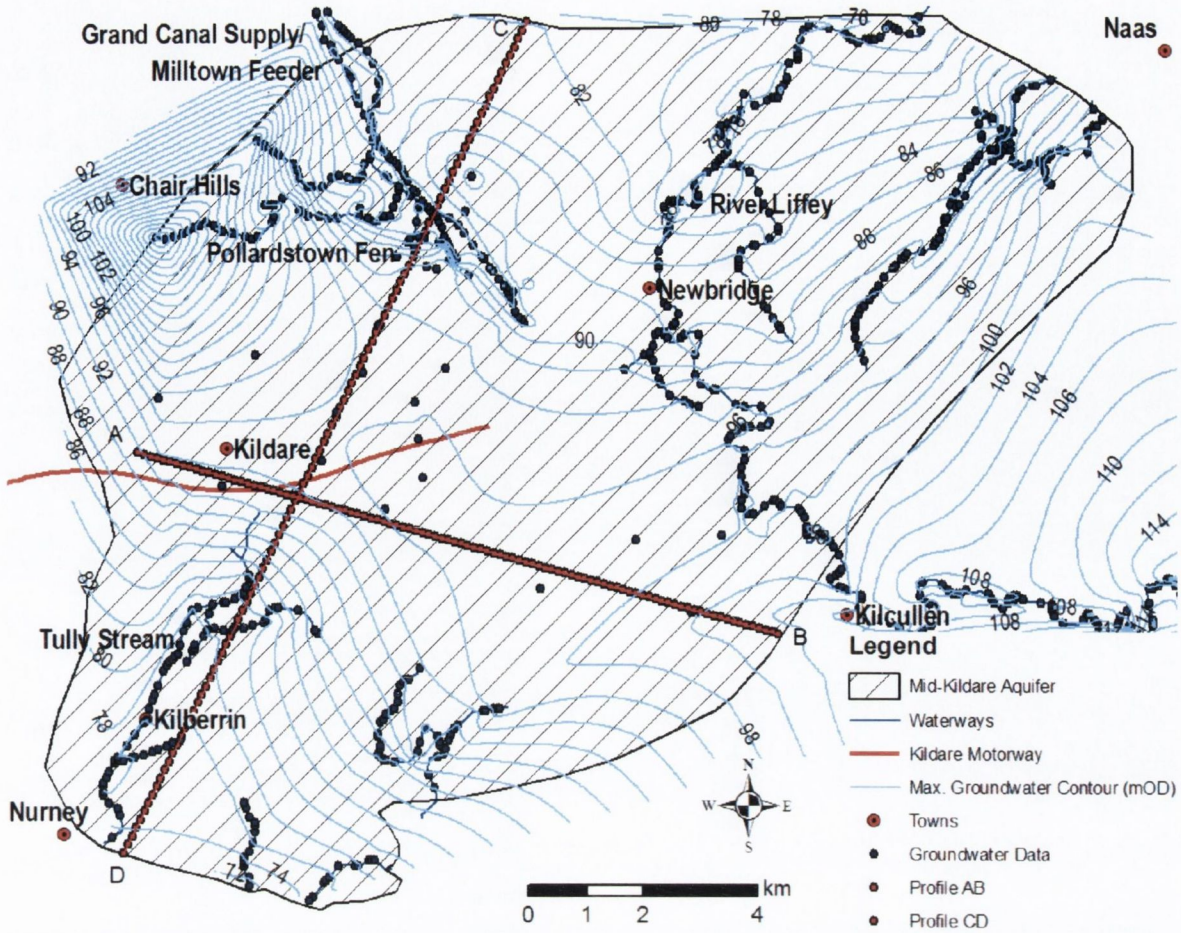


Figure 3.15: Maximum groundwater contours occurred in February 1999 as measured during the period from June 1998 to end of September 2006.

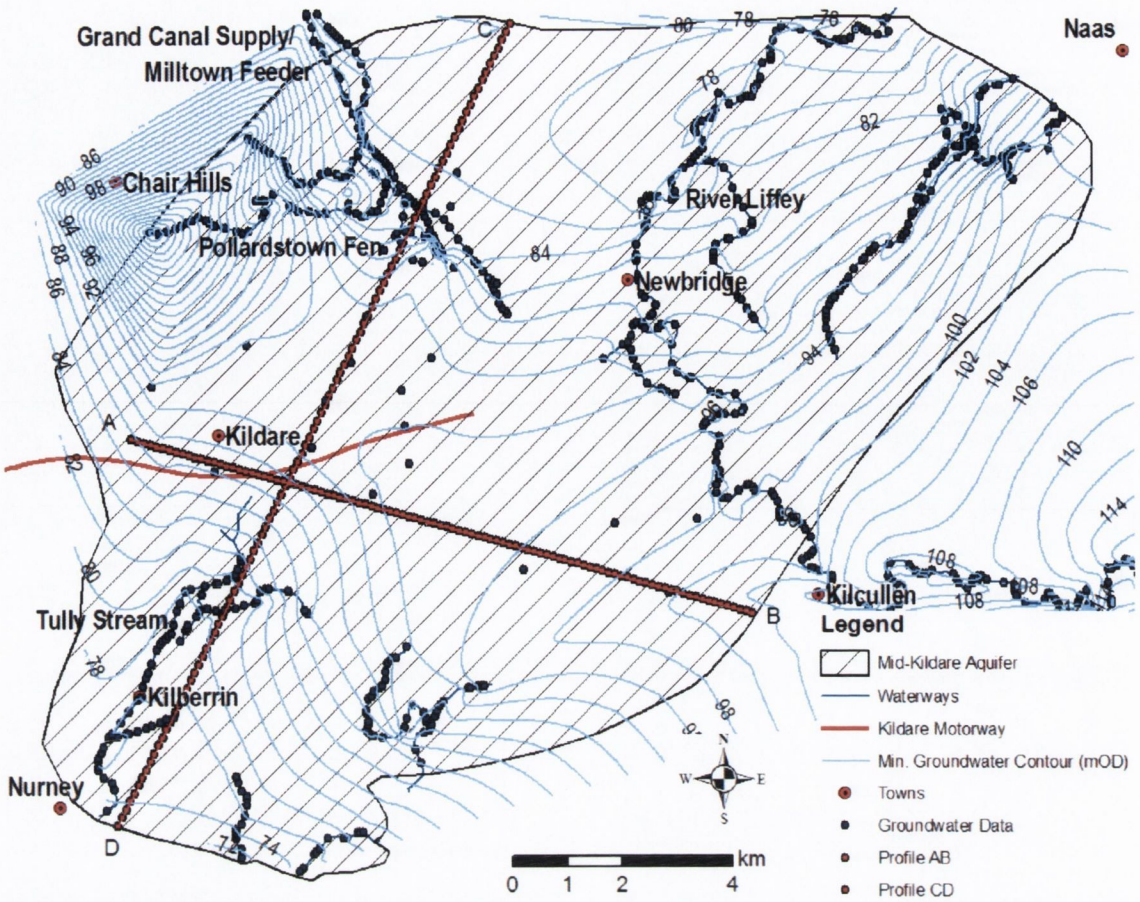


Figure 3.16: Minimum groundwater contours occurred in November 2005 as measured during the period from June 1998 to end of September 2006.

Figures 3.17 and 3.18 of profiles AB and CD illustrate the difference between the maximum and minimum head as recorded during the eight years of groundwater monitoring. The groundwater levels shown in Figures 3.17 and 3.18 are obtained from the gridded data and the measured data are shown as points along the line to indicate the gridding accuracy. The greatest change in head along profile AB can be found at monitoring borehole MB24 (just south of the Curragh Camp) which was approximately 2.6 m. The greatest change in head along profile CD can be found at monitoring borehole MB4 with a difference of approximately 1.5 m. These seasonal variations in head along the profiles lie comfortably within the natural seasonal fluctuation identified by Hayes *et al.* (2001) (1 - 2.5 m).

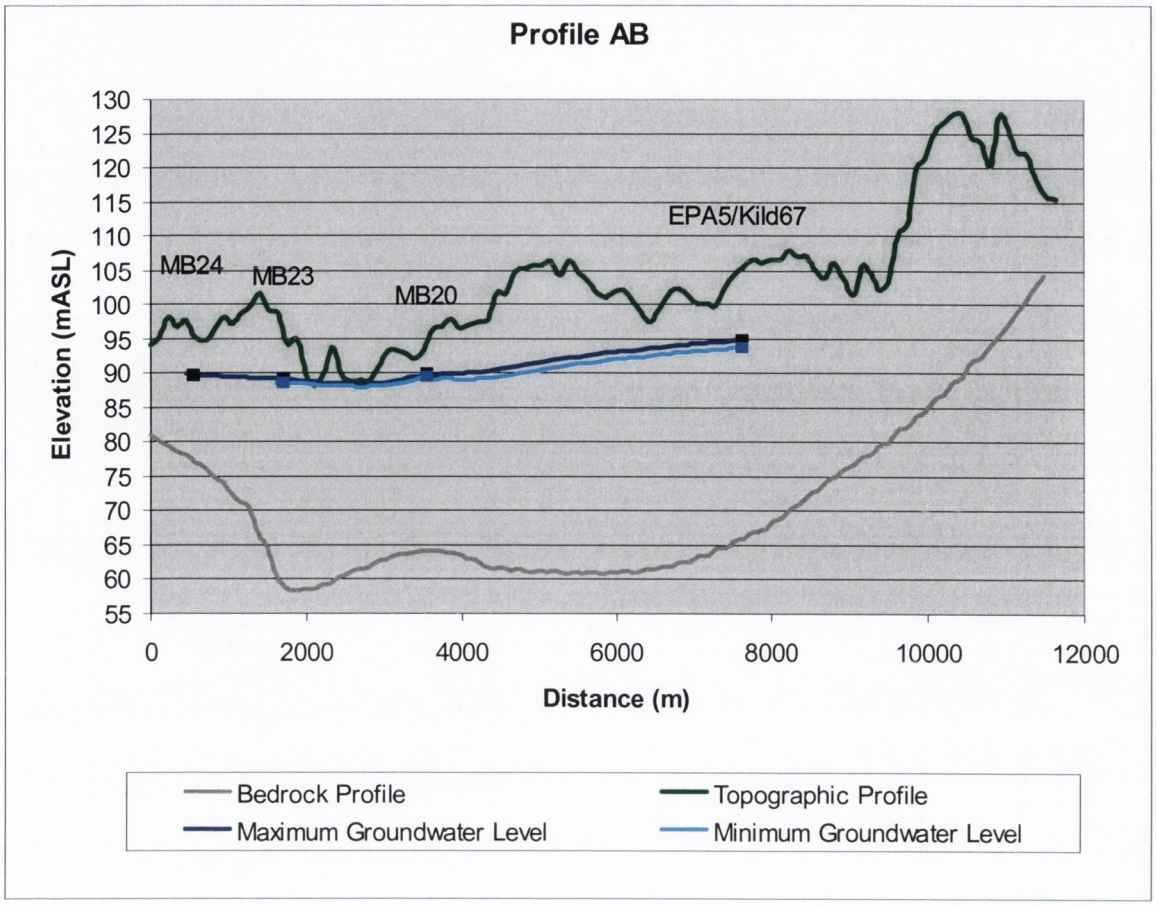


Figure 3.17: Maximum and minimum groundwater heads recorded from July 1998 to September 2006. The maximum head occurred in February 1999 and the minimum head occurred in November 2005.

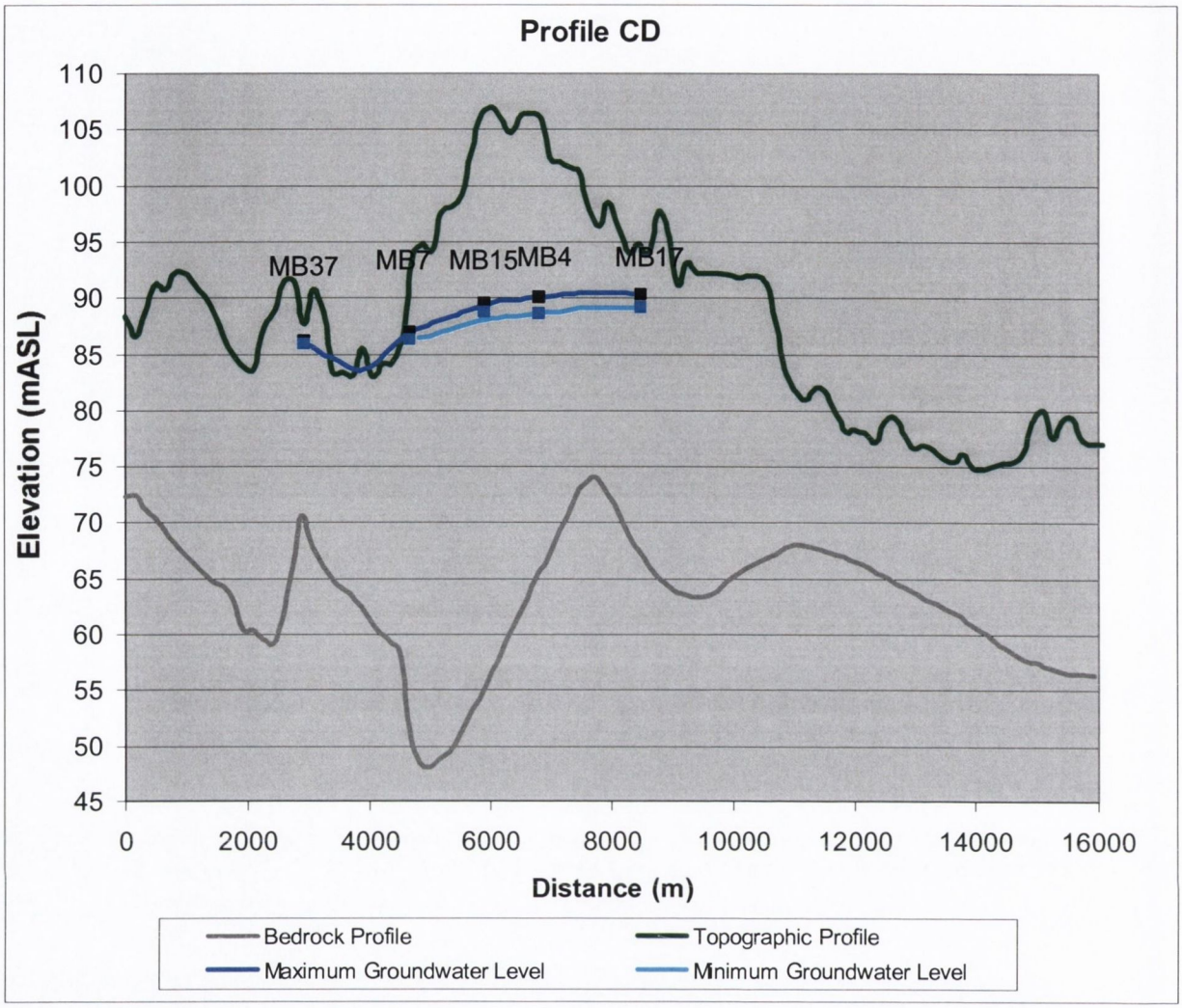


Figure 3.18: Maximum and minimum groundwater heads recorded from July 1998 to September 2006. The maximum head occurred in February 1999 and the minimum head occurred in November 2005. The watertable is close to the ground level between 11000 and 14000 m where it crosses the peat associated with the Tully Stream and is near or above the ground level near 4500 m which corresponds to the southwestern margin of Pollardstown Fen where there are known to be many springs and seepages.

The maximum and minimum groundwater levels were compared with the groundwater levels when dewatering began on May 31, 2001. The groundwater levels in late May 2001 were in between the maximum and minimum groundwater levels along the profile AB. The May 2001 groundwater levels could not be gridded for the area around MB24, MB23 and MB20 as there were no data for this date (Figure 3.19). Along the profile CD the levels in late May 2001 occur in between the maximum and minimum groundwater levels (Figure 3.20). MB37, on the eastern side of Pollardstown Fen, appears to be an area of higher ground and subsequently has higher groundwater levels which may

make it behave differently from the other boreholes which are on either side of the main groundwater divide.

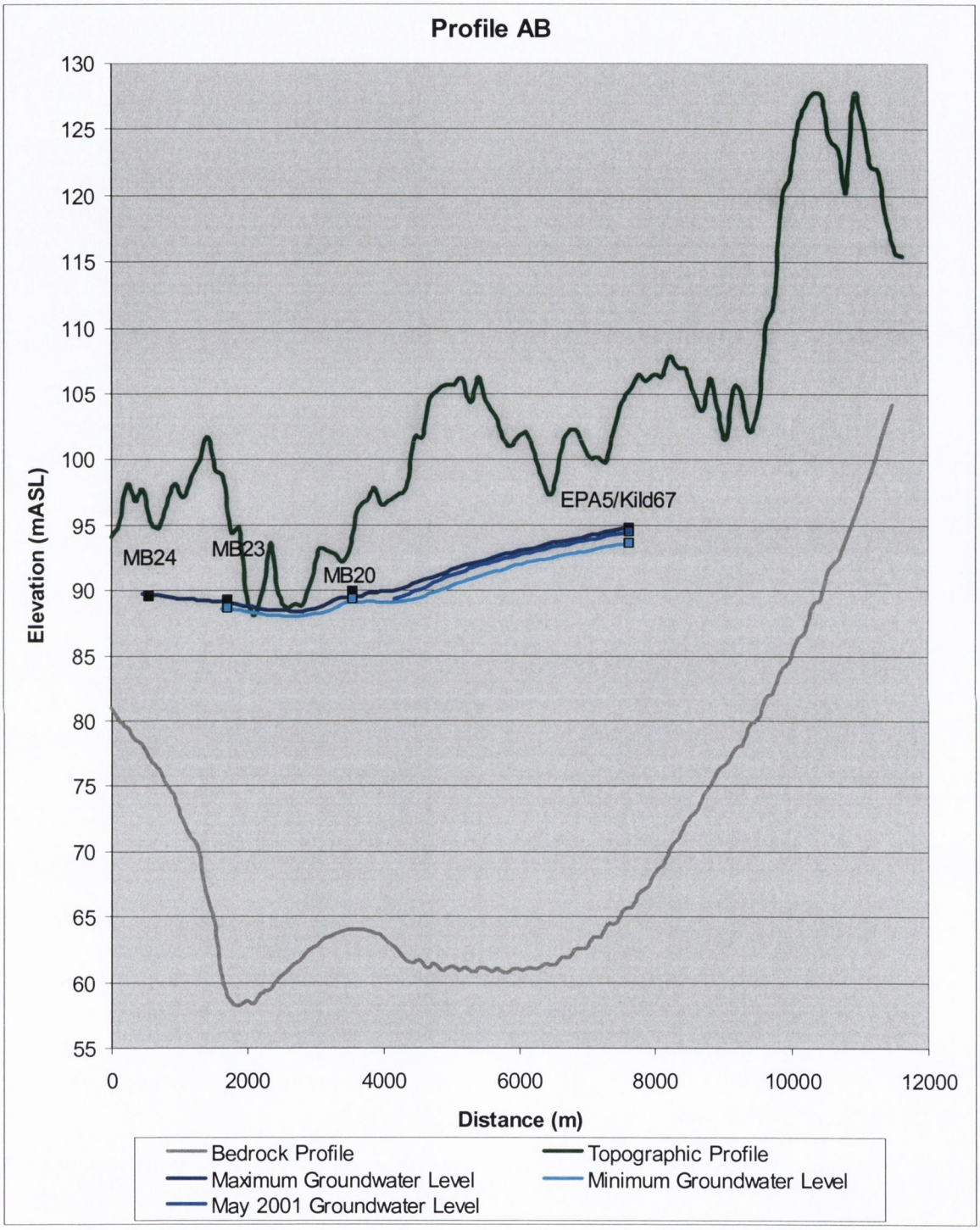


Figure 3.19: Profile along AB showing the maximum (February 1999), minimum (November 2005), and start of dewatering (May 2001) groundwater levels.

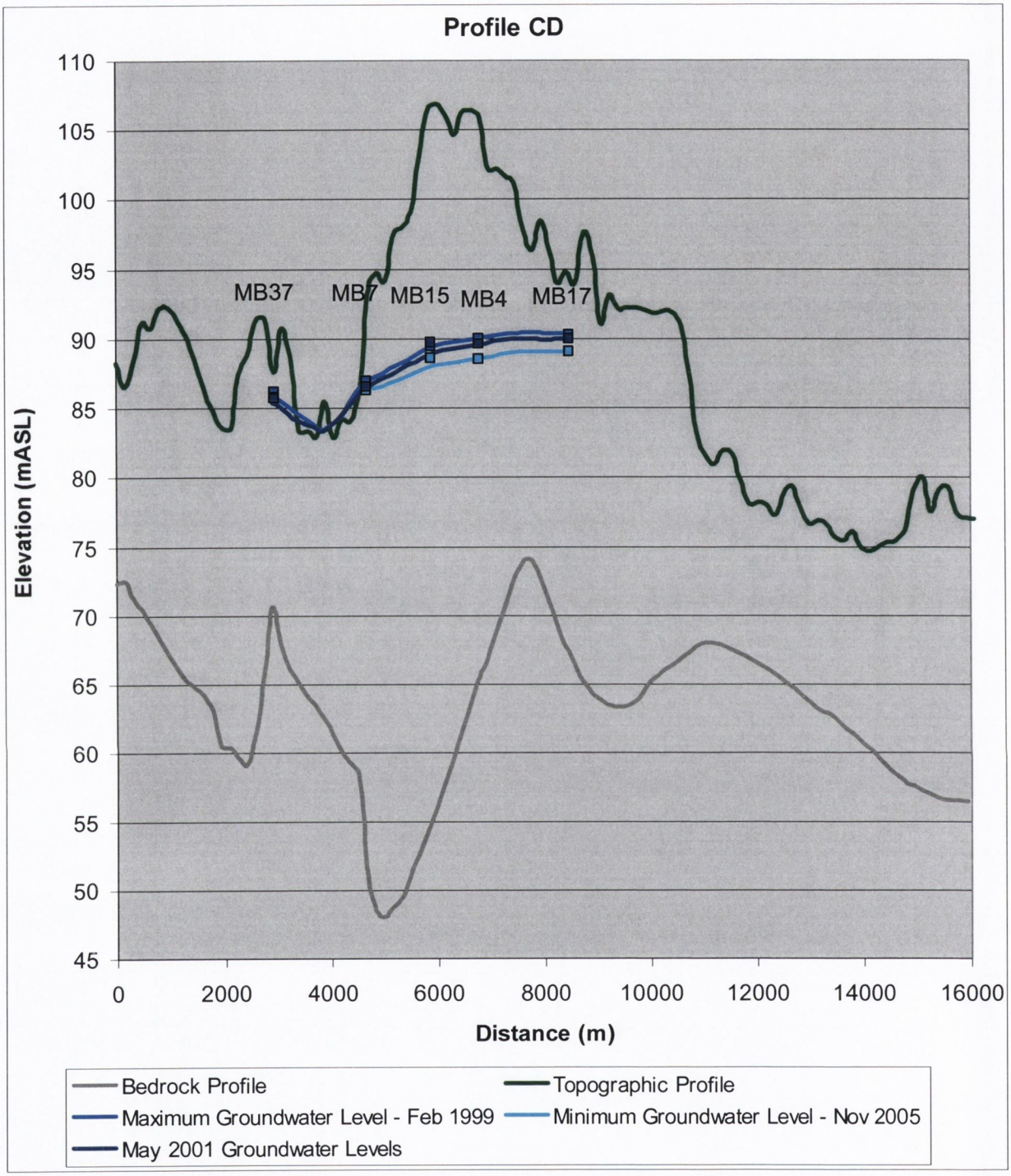


Figure 3.20: Profile along CD showing the maximum (February 1999), minimum (November 2005), and start of dewatering (May 2001) groundwater levels.

The groundwater level across the entire aquifer varies from the sediments being fully saturated with the groundwater level coinciding with the elevation of the topography to being over 25 m below the ground surface. For the purposes of the interpolation of the water levels for the pervious figures, the head levels for the rivers, assumed to be at ground

level, were extrapolated from the OSI topography data. This makes the assumption that the rivers are gaining streams, i.e. fed by groundwater. The data were interpolated using the natural neighbours method and with any interpolation method there is some scope for error. The error increases with increasing distance between points.

3.4.4 Rainfall and Evapotranspiration

The main source of recharge into an aquifer is from precipitation (Freeze and Cherry, 1979). Recharge cannot be measured directly and therefore must be calculated by subtracting the calculated evapotranspiration and runoff from the measured precipitation. Potential evapotranspiration is defined as the amount of water that would be removed from a vegetated surface if sufficient water were available in the soil to meet the water demand (Hiscock, 2005). Actual evapotranspiration is either the same or less than the potential evapotranspiration depending on the saturation of the soil.

The topography in the area of the Mid-Kildare Aquifer is generally flat with a few rolling hills resulting in low amounts of surface run-off and higher amounts of infiltration (Figure 3.10). Daily rainfall data were collected by Met Éireann at Naas CBS, Osberstown, and at Casement Aerodrome. An additional weather station monitored conditions at Pollardstown Fen from 2001 - 2005 as part of the doctoral studies undertaken by Ania Kuczynska (2007). Misstear and Brown (2007) analysed the rainfall data from January 1, 1971 to December 31, 2000 and found the mean annual rainfall for Naas CBS (796mm) to be 10% higher than that measured at Casement Aerodrome. The mean annual rainfall in the vicinity of the aquifer derived from measurements over various time periods by several authors are summarised in Table 3-2.

Table 3-2: Summary of rainfall, evapotranspiration, and recharge data.

AUTHOR	CALCULATION TIME PERIOD	RAINFALL (mm/year)	EVAPOTRANSPIRATION (mm/year)	RECHARGE (mm/year)
Wright (1998)	1941 - 1980	840	450	390
White Young Green Environmental (2003)	1971 - 2005	792.1	531.1 (Potential) 475.2 (Actual)	316.9
(Misstear and Brown, 2007)	1971 - 2000	795.9	474.5 - 533.5 (Potential) 429.2 - 474.4 (Actual - using higher RAW and TAW values)	321 - 366 (effective rainfall - recharge, interflow, and runoff)
Brown (2007)	1991 - 2006	833.5	500.2 (Potential) 475.2 (Actual)	376.3 (no runoff) 299.5 (runoff)

Evapotranspiration values have been calculated by many authors for County Kildare (Wright, 1988; White Young Green Environmental, 2003; Misstear and Brown, 2007; Brown, 2007) and are summarised in Table 3-2. Misstear and Brown (2007) estimated evapotranspiration to calculate the recharge for the Mid-Kildare Aquifer over a 30-year period from January 1, 1971 to December 31, 2000. For this they used the rainfall data collected at Naas CBS as it best represented the long-term rainfall record for the Mid-Kildare Aquifer. The potential evapotranspiration was calculated by Misstear and Brown (2007) using the FAO Penman-Monteith methodology (Allen *et al.*, 1998). This method requires air temperature, air humidity, net radiation and wind speed. The air temperature, air humidity and wind speed were obtained from Met Éireann while the net radiation was calculated using the recorded total sunshine hours from Met Éireann. The atmospheric pressure is determined using an average value (Allen *et al.*, 1998) and elevation and longitude are taken into account and used in the calculation for maximum daylight hours and sunset angle. Brown (2007) also estimated the potential evapotranspiration over the Mid-Kildare Aquifer. He assumed that more evapotranspiration occurs during the winter than other authors (e.g. Brown and Misstear, 2007) and therefore his estimate is on the high end of the estimates for the Kildare area.

The actual evapotranspiration is less than the potential evapotranspiration and is dependent on the total available water (TAW) and readily available water (RAW). TAW is calculated using rooting depth, water content at field capacity and wilting point, whilst RAW is calculated as a depletion factor of TAW (Misstear and Brown, 2007). A summary

of the estimated values of actual evapotranspiration can be found in Table 3-2. Misstear and Brown (2007) estimated the actual evapotranspiration from January 1, 1971 to December 31, 2000, for the Mid-Kildare Aquifer using the FAO Penman-Monteith and Penman-Grindley (Rushton) methods. The Penman-Grindley (Rushton) method is a modification of the Penman-Grindley method but, in this calculation, used interpolated daily potential evapotranspiration data from monthly data (Misstear and Brown, 2007). The actual evapotranspiration from 1971 to 2000 is dependent on the method used for the calculations and on the values of TAW and RAW used. In Appendix A, the recharge data use a readily available water (RAW) of 74 mm and a total available water (TAW) of 127 mm (Brown, 2007). Brown's (2007) estimate is on the high end of estimates for Kildare and is the value currently being used in the KAM model.

Misstear and Brown (2007) estimated the effective rainfall, which is the water available for recharge, interflow and surface run-off (Table 3-2). It is dependent on the estimate of actual evapotranspiration used and the method used in the calculations. Recharge values have been calculated by several authors for County Kildare (Wright, 1988; White Young Green Environmental, 2003; Brown, 2007) and are summarised in Table 3-2. Brown (2007) considered two scenarios in his recharge calculations, no runoff and with runoff. The areas near the Chair Hills towards the northwest and the Wicklow Mountains in the southeast are the primary location where runoff would be expected to occur. Very little run-off occurs in the flat plains of the central part of the aquifer. The soil moisture deficit varied between 0 mm during periods of high rainfall and a maximum of approximately 110 mm from April to October (Misstear and Brown, 2006). The Brown (2007) recharge calculation is lower than the recharge estimated by Wright (1988) and Misstear and Brown (2007) because Brown assumes that evapotranspiration occurs in the winter as well as in the summer and accounts for runoff (in one calculation) whereas Wright (1988) assumes that all rainfall in the winter is recharge. Wright (1988) calculates recharge as precipitation minus evapotranspiration and it is assumed therefore that runoff was not taken into account White Young Green (2003) assumes that there are three zones of runoff; the first having no runoff, the second having limited runoff, and the third having 67% runoff. The rainfall data, potential evapotranspiration, actual evapotranspiration and recharge data as calculated by Brown (2007) for the KAM model and used in the model of the Mid-Kildare Aquifer for this thesis can be found in Appendix A. The recharge values calculated by Brown (2007) (Appendix A) without runoff are used in the modelling of the

dewatering of the Mid-Kildare Aquifer in Chapter 6. There are very few drainage features in the Mid-Kildare Aquifer (especially in the area of interest near the Kildare Bypass), such as rivers or streams, which would allow the runoff to leave the aquifer catchment area. Furthermore, since very little run-off occurs in the flat plains of the central part of the aquifer, no allowance was made for runoff in the model. The Brown (2007) values are on the low end of the range of recharge values estimated by Misstear and Brown (2007).

Apart from recharge from precipitation, the Mid-Kildare Aquifer may also be recharged by overland flow infiltrating at the boundaries of the aquifer. This is likely to occur in the higher ground of the Chair Hills to the northwest and the Wicklow Mountains to the southeast. However, the exact quantity of water gained by the aquifer through this mechanism is unknown. The final mechanism where water may be gained by the aquifer is through artificial recharge. This did occur to some extent where water was pumped into the Japanese Gardens during construction of the Mid-Kildare Bypass to artificially keep the groundwater table close to the surface so that the lakes, streams and springs in the area would not dry out. Other sources of water to the aquifer are the seepage from septic tanks, sewers and water mains. However, there are no data regarding the amount or distributions on septic tank effluent in the area and therefore this was ignored as the input is likely to be small.

3.4.5 Outflows

The main outflows of water from the Mid-Kildare Aquifer are through rivers, springs, streams, fen, wells, and the dewatering project. The main surface water features are the River Liffey, the Tully Stream and Pollardstown Fen (Figure 3.21). The rivers have a complex feed back mechanism with the groundwater in that they can lose or gain water from the aquifer. The interaction between the different surface water types and the groundwater is generally dependent on the groundwater head difference with the flow out of the aquifer increasing linearly with an increase in head difference (Rushton, 2003). This implies that with a higher groundwater head more water is lost from the aquifer to rivers and streams.

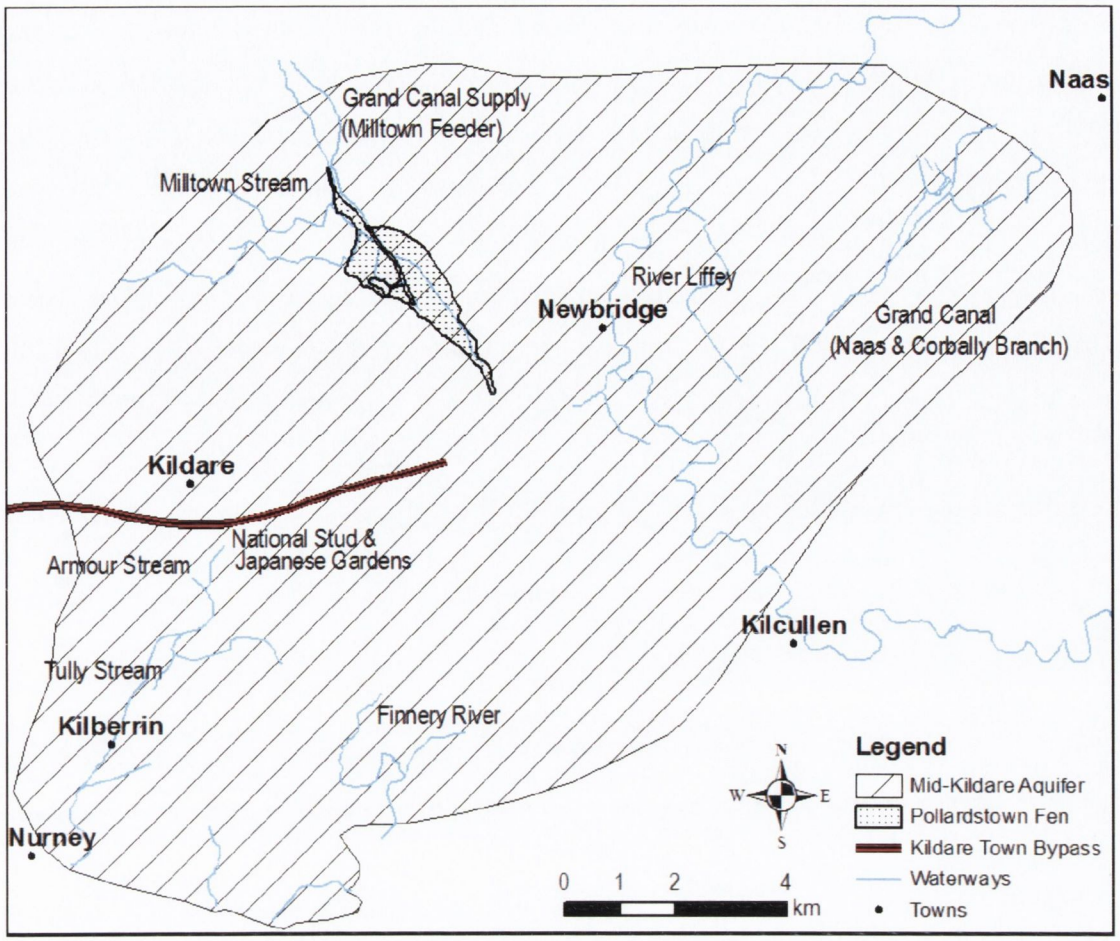


Figure 3.21: Locations of the River Liffey, Tully Stream, and Milltown Feeder/Grand Canal. Cross-hatched area shows the extent of the Mid-Kildare Aquifer.

As this study is only concerned with the groundwater rather than the surface waters of the Mid-Kildare Aquifer, only the baseflow of the River Liffey, the Tully Stream, and the Milltown Feeder/Grand Canal will be considered. The baseflow was estimated by Farrell and Devine (2006) by assuming the low flows that occur in the summer after a prolonged dry spell are sustained only by groundwater and not surface runoff. The baseflow from the aquifer to the River Liffey, estimated using flows recorded at the three dams along its length from 1997 to 2005, was between 1500 l/s and 2000 l/s (Farrell and Devine, 2006). Flow measurements in the canal feeder system including the Milltown Stream were recorded from 1997 until 2005 and used to estimate the baseflow which varied from 35 l/s to 80 l/s (Farrell and Devine, 2006).

The upper reaches of the Tully Stream are of particular importance due to their close proximity to the site of the Kildare Bypass. Some of the water extracted during dewatering was discharged into the Tully Stream and its tributaries. Several measurement stations

were installed at the locations shown in Figure 3.22, to measure the stream flow at each station (Entec UK Limited, 1999). The measurements were taken over a period from July 1997 to May 1999, except for those at Kilberrin which were obtained from 1976 to 1990 (Farrell and Devine, 2006). Farrell and Devine (2006) estimated the baseflow from hydrographs obtained from the Kilberrin data and found they were likely to be in the region of 290 l/s (Table 3-3). As water extracted during dewatering for the Kildare Bypass was discharged into the Tully Stream, the flows in the stream measured after May 2001 would reflect that. Rough estimates of baseflow by Farrell and Devine (2006) can be found in Table 3-3. The baseflow to the streams and rivers would be expected to experience seasonal variation which is related to the changes in groundwater head within the aquifer.

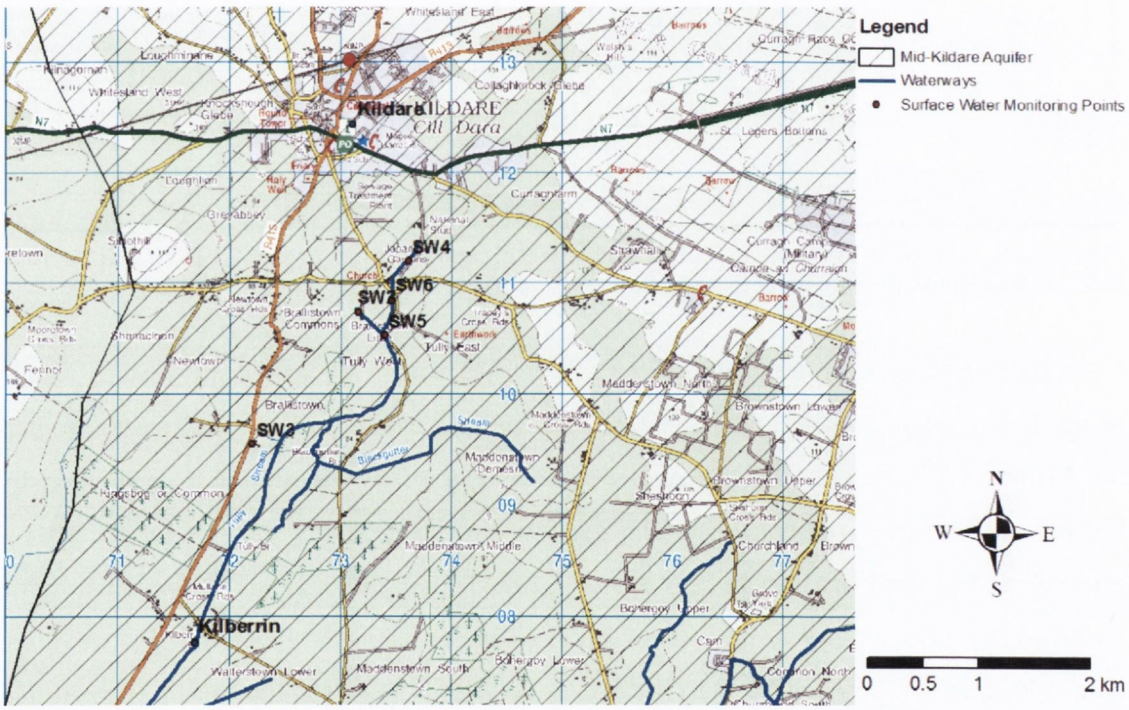


Figure 3.22: Location of surface water monitoring points on Tully Stream.

Table 3-3: Baseflow estimates made from hydrographs from before dewatering commenced at the Kildare Town Bypass (Farrell and Devine, 2006).

LOCATION	BASEFLOW ESTIMATES
Tully Stream above Japanese Gardens (SW4)	25 l/s
Armour Stream (SW2)	50 l/s
Tully Stream below the Japanese Gardens (SW6)	90 l/s
Tully Stream below the junction with Armour Stream (SW5)	140 l/s
Nurney Stream (SW3)	10 l/s
Tully Stream at Kilberrin	290 l/s

The Mid-Kildare Aquifer has significant seepage zones or springs at Pollardstown Fen (Figure 3.23). The seepage zones occur in areas of low topography where the groundwater table is high. They generally correspond to areas where there are peat deposits which have a low hydraulic conductivity. Springs and seepages occur when the groundwater table intersects with the ground surface or at the interface between higher and lower hydraulic conductivity material (Geological Survey of Ireland, 2004c). The discharges from the springs at Pollardstown Fen are thought to have originally been small seepages, which were enhanced by people to increase the flow (Geological Survey of Ireland, 2004c). Daly (1981) estimated the flow from the aquifer to the Milltown Feeder to be approximately 290 l/s.

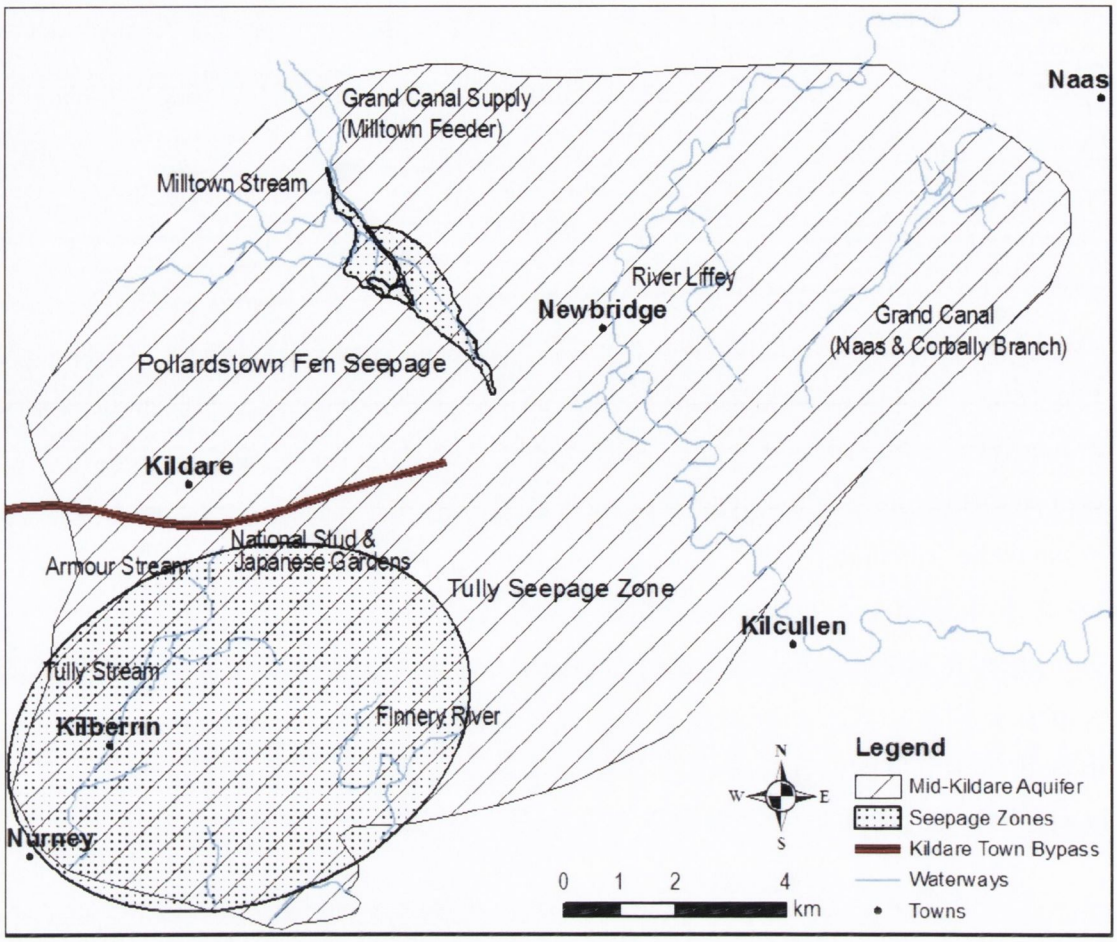


Figure 3.23: Seepage locations in the Mid-Kildare Aquifer at Pollardstown Fen, Japanese Gardens and Tully Stream.

Daly (1981) and Rushton (2003) studied the hydrology of Pollardstown Fen located approximately 5 km to the northeast of the dewatering site for the Kildare Bypass. The peat deposits of the fen are 12-15 m thick and are underlain by gravels. Water from the aquifer is lost along the margins of the fen by springs or by flowing vertically upward through the low permeability peat deposits. In the middle of the Fen, a slow upflow is required to ensure that the soil remains moist during the summer (Rushton, 2003). The groundwater head in the gravel deposits beneath the fen has been measured at 1.0 to 1.5 m above the ground surface (Rushton, 2003). The seepage upwards is thought to just balance the evapotranspiration in summer as the soil does not become water logged. Flow measurements were taken on the streams in and around Pollardstown Fen from 1997 to 2005 for the Monitoring Committee (Table 3-4).

Table 3-4: Baseflow estimates made from hydrographs from before dewatering commenced at the Kildare Town Bypass (Farrell and Devine, 2006).

LOCATION	BASEFLOW ESTIMATES
Milltown Stream	35 l/s to 80 l/s
Milltown Feeder	200 l/s to 470 l/s
Seven Springs/Pollardstown Fen	300 l/s

Water wells are an additional path through which water can leave the system. Wright (1998) estimated the total yield of the five major wells (Curragh Old Waterworks, Curragh, Osborne Lodge, Strand Hotel, and Rathbride Manor) in the area to be 45 l/s. The Curragh Military Camp, in addition, has two major wells which extract water from the Mid-Kildare Aquifer, the McDonagh and Hare Park deep wells, which typically yield approximately 12 l/s and 32 l/s, respectively (Geological Survey of Ireland, 2004b). The dewatering for the construction of the Kildare Bypass, which also represents a flow out of the aquifer is covered in the following chapter.

3.4.6 Hydraulic conductivity

As part of the ground investigation prior to the construction of the Kildare Town Bypass, particle size distributions tests (Irish Geotechnical Services, 1993; 1994; 1995a - n; and 1997), rising and falling head tests (Irish Geotechnical Services, 1991), and pump tests (K.T. Cullen & Co. Ltd., 1993; Irish Geotechnical Services, 1994) were conducted to determine the hydraulic conductivity of the Mid-Kildare Aquifer. The data collected were reassessed and analysed, where possible, for this study to determine the hydraulic conductivity for the various deposits that constitute the aquifer.

3.4.6.1 Particle Size Distribution Analyses

The particle size distribution analysis of samples taken from boreholes and trial pits along the Kildare Town Bypass were made available and are used in this thesis to confirm strata descriptions and to estimate the hydraulic conductivity. The samples were sieved (wet and dry) to determine their particle size distribution for granular fractions and a hydrometer was used for the sedimentation tests. The cobble and boulder content of the samples were excluded, leaving the maximum sized sieved at 63 mm (Irish Geotechnical Services, 1993). There were 984 individual particle size distribution analyses conducted on soils collected from boreholes and test pits along the length of the Kildare Bypass. The boreholes between Ch. 69+00 and 104+00 were the focus of this study where dewatering occurred. These samples were analysed using relationships between the hydraulic

conductivity and particle size distribution by Hazen (1911), Kozeny-Carman-Bear (Bear, 1972), Pavchich (Vuković and Soro, 1992; Kasenow, 2002), Harlemann (Chin, 1999), and Mbonimpa *et al.* (2002) as discussed in Chapter 2. Foy (2002) assessed various formulae used for estimating hydraulic conductivity and found the Pavchich method to be most accurate for fine-grained glacial tills in Ireland. This method consists of a simple formula which is a function of grain size only. This is similar to Hazen (1911) and Harlemann (Chin, 1999) which are also a function of grain size only whereas the Kozeny-Carman-Bear (Bear, 1972) also takes into account the porosity of the sample. The geometric mean was calculated for each soil type rather than the arithmetic mean as the larger hydraulic conductivity values would have had a greater weighting on the arithmetic mean (Shaw and Hendry, 1998; Fetter, 2001). The geometric mean is calculated by multiplying the numbers together and then taking the n^{th} root of the product where n is defined by the number of numbers being averaged. Thus, the geometric mean of $1x10^{-5}$ and $1x10^{5}$ is 1 whereas the arithmetic mean is 50000.

The hydraulic conductivity is highly dependent on the amount of fines present with those described as CLAY using the BS 5930 classification corresponding to low hydraulic conductivity and those described as SILT or SAND as either moderate or high hydraulic conductivity (Swartz, *et al.*, 2003). The samples collected from these boreholes were analysed using particle size distributions shown in Figure 3.24. The coarse-grained samples were analysed using the Hazen (1911), Kozeny-Carman-Bear (Bear, 1972), Harlemann (Chin, 1999) and Mbonimpa *et al.* (2002) methods. The coarse-grained samples are of particular importance to this study as they represent the units which host the aquifer. The results of the analysis of the particle size distribution analyses using the methods described in Chapter 2 can be found in Table 3-5 (fine-grained soil samples) and Table 3-6 (coarse-grained soil samples). Table 3-6 shows that for the same sample the hydraulic conductivity estimated from the various methods can differ widely. This results from the Hazen (1911), Harlemann (Chin, 1999) and Mbonimpa *et al.* (2002) methods use the effective grain size in mm, D_{10}, while the Kozeny-Carman Bear (Bear, 1972) and Pavchich (Vuković and Soro, 1992; Kasenow, 2002) methods use an effective grain size in mm of D_{17} and a mean particle size of the soil in mm, D_M, respectively. Generally, there is a good correlation between the main material type and the hydraulic conductivity calculated. For example, SILT/CLAY has very low hydraulic conductivity and the hydraulic conductivity increases with increasing grain size through SILT, SILT and

SAND, and GRAVEL which has the highest hydraulic conductivity of the samples collected (see Tables 3-5 and 3-6).

Table 3-5: Geometric mean of calculated permeabilities of fine-grained soil samples (m/s)

SOIL TYPE	HAZEN	PAVCHICH	KOZENY CARMAN BEAR	MBONIMPA *ET AL.*
Gravelly sandy CLAY	3.94×10^{-8}	1.54×10^{-7}	7.94×10^{-7}	1.04×10^{-7}
Gravelly silty sandy CLAY	1.00×10^{-8}	1.40×10^{-8}	1.96×10^{-8}	6.87×10^{-9}
Sandy CLAY with cobbles	9.00×10^{-8}	7.88×10^{-7}	2.45×10^{-6}	2.51×10^{-7}
Sandy CLAY with gravel	5.00×10^{-9}	7.00×10^{-9}	1.50×10^{-8}	3.31×10^{-9}
Sandy gravelly CLAY with peat	1.60×10^{-7}	3.16×10^{-7}	5.20×10^{-7}	3.02×10^{-7}
Sandy gravelly CLAY with roots	4.90×10^{-9}	7.88×10^{-9}	6.12×10^{-8}	6.76×10^{-9}
Sandy gravelly CLAY with silt	1.00×10^{-8}	1.40×10^{-8}	1.47×10^{-7}	1.66×10^{-8}
Silty sandy CLAY with gravel	6.40×10^{-9}	7.88×10^{-9}	1.35×10^{-8}	5.21×10^{-9}
Silty sandy gravelly CLAY	6.00×10^{-9}	4.20×10^{-8}	1.64×10^{-7}	1.02×10^{-8}
Gravelly CLAY/SILT	1.00×10^{-8}	1.85×10^{-8}	2.45×10^{-8}	7.56×10^{-9}
Gravelly sandy SILT/CLAY	2.14×10^{-8}	6.05×10^{-8}	1.44×10^{-7}	3.03×10^{-8}
Gravelly sandy SILT/CLAY (Peaty)	1.23×10^{-7}	2.24×10^{-7}	8.57×10^{-8}	9.48×10^{-8}
Gravelly sandy SILT/CLAY with cobbles	4.00×10^{-8}	5.60×10^{-8}	9.18×10^{-8}	4.18×10^{-8}
Gravelly sandy SILT/CLAY with roots	1.00×10^{-8}	3.15×10^{-8}	2.45×10^{-7}	1.48×10^{-8}
Gravelly SILT/CLAY	4.00×10^{-8}	2.24×10^{-7}	2.59×10^{-7}	5.57×10^{-8}
Sandy gravelly SILT/CLAY	1.50×10^{-8}	6.41×10^{-8}	1.39×10^{-7}	2.20×10^{-8}
Sandy gravelly SILT/CLAY with cobbles	2.50×10^{-8}	1.05×10^{-7}	1.73×10^{-6}	7.53×10^{-8}
Sandy SILT/CLAY	1.23×10^{-8}	1.40×10^{-8}	1.09×10^{-8}	6.51×10^{-9}
Sandy SILT/CLAY with gravel	8.35×10^{-9}	1.61×10^{-8}	2.21×10^{-8}	6.22×10^{-9}
Sandy silty gravelly SILT/CLAY	1.00×10^{-8}	2.24×10^{-7}	6.12×10^{-7}	3.00×10^{-8}
SILT/CLAY	7.88×10^{-9}	8.82×10^{-9}	6.75×10^{-9}	4.61×10^{-9}
SILT/CLAY with organic matter	6.40×10^{-9}	3.50×10^{-9}	6.12×10^{-9}	2.92×10^{-9}
Silty gravelly SILT/CLAY	1.60×10^{-8}	1.75×10^{-8}	1.01×10^{-7}	1.20×10^{-8}
Silty sandy gravelly SILT/CLAY	1.00×10^{-8}	5.60×10^{-8}	3.67×10^{-7}	1.96×10^{-8}
Clayey sandy SILT	4.90×10^{-9}	7.88×10^{-9}	1.10×10^{-8}	2.87×10^{-9}
Gravelly clayey SILT	1.00×10^{-8}	3.15×10^{-8}	7.71×10^{-8}	1.25×10^{-8}
Gravelly sandy clayey SILT with cobbles	1.00×10^{-8}	1.40×10^{-8}	3.06×10^{-8}	1.17×10^{-8}
Gravelly sandy SILT	7.69×10^{-8}	1.36×10^{-7}	7.81×10^{-8}	6.83×10^{-8}
Sandy clayey SILT	1.00×10^{-8}	7.88×10^{-9}	1.10×10^{-8}	5.45×10^{-9}
Sandy clayey SILT with gravel	1.00×10^{-8}	3.15×10^{-8}	8.14×10^{-8}	1.37×10^{-8}
Sandy clayey SILT with gravel and peat	4.00×10^{-8}	1.26×10^{-7}	8.57×10^{-8}	4.18×10^{-8}
Sandy gravelly SILT	5.24×10^{-8}	1.37×10^{-7}	1.89×10^{-7}	7.19×10^{-8}
Sandy gravelly SILT with clay	4.00×10^{-8}	8.75×10^{-8}	7.71×10^{-8}	4.54×10^{-8}
Sandy gravelly SILT with gravel	9.00×10^{-8}	1.26×10^{-7}	1.47×10^{-7}	1.04×10^{-7}
Sandy SILT	1.06×10^{-7}	1.38×10^{-7}	3.30×10^{-8}	5.07×10^{-8}
Sandy SILT with gravel	1.00×10^{-7}	1.33×10^{-7}	3.77×10^{-8}	5.65×10^{-8}
SILT	4.90×10^{-9}	3.50×10^{-9}	1.35×10^{-8}	3.01×10^{-9}
Gravelly SILT and SAND	4.90×10^{-7}	7.88×10^{-7}	1.22×10^{-7}	3.01×10^{-7}
SILT and SAND	1.95×10^{-6}	1.75×10^{-6}	9.16×10^{-8}	8.68×10^{-7}

Table 3-6: Geometric average of calculated permeabilities of coarse-grained soil samples (m/s)

SOIL TYPE	HAZEN	KOZENY CARMAN BEAR	HARLEMANN	MBONIMPA *ET AL.*
Clayey gravelly SAND	1.75×10^{-4}	2.72×10^{-7}	1.31×10^{-4}	7.43×10^{-5}
Gravelly clayey SAND	1.96×10^{-4}	1.84×10^{-6}	1.47×10^{-4}	1.05×10^{-4}
Gravelly SAND	3.52×10^{-4}	9.21×10^{-7}	2.64×10^{-4}	1.41×10^{-4}
Gravelly silty SAND	7.20×10^{-6}	7.03×10^{-7}	5.40×10^{-6}	4.94×10^{-6}
SAND with gravel	4.00×10^{-4}	5.20×10^{-7}	3.00×10^{-4}	1.20×10^{-4}
Silty clayey gravelly SAND	9.00×10^{-8}	2.59×10^{-7}	6.75×10^{-8}	8.80×10^{-8}
Silty clayey SAND with gravel	1.50×10^{-6}	2.93×10^{-7}	1.13×10^{-6}	9.40×10^{-7}
Silty gravelly SAND	4.07×10^{-5}	7.13×10^{-7}	3.06×10^{-5}	2.17×10^{-5}
Silty SAND	1.82×10^{-5}	2.35×10^{-7}	1.36×10^{-5}	6.94×10^{-6}
Silty SAND with gravel	1.39×10^{-5}	3.07×10^{-7}	1.04×10^{-5}	6.27×10^{-6}
Clayey SAND and GRAVEL	1.00×10^{-8}	7.34×10^{-8}	7.50×10^{-9}	1.15×10^{-8}
Clayey SAND and GRAVEL with cobbles	1.00×10^{-6}	3.06×10^{-6}	7.50×10^{-7}	1.96×10^{-6}
Clayey SAND and GRAVEL with roots and fibres	1.00×10^{-8}	1.84×10^{-6}	7.50×10^{-9}	4.42×10^{-8}
Clayey silty SAND and GRAVEL	7.37×10^{-8}	1.51×10^{-6}	5.53×10^{-8}	1.74×10^{-7}
Clayey silty SAND and GRAVEL with cobbles	9.00×10^{-4}	6.12×10^{-6}	6.75×10^{-4}	5.94×10^{-4}
Clayey silty SAND and GRAVEL with roots	4.90×10^{-9}	4.10×10^{-6}	3.68×10^{-9}	2.54×10^{-8}
SAND and GRAVEL	9.37×10^{-4}	2.61×10^{-6}	7.03×10^{-4}	4.69×10^{-4}
SAND and GRAVEL with cobbles	3.32×10^{-3}	3.88×10^{-6}	2.49×10^{-3}	1.76×10^{-3}
Silty clayey SAND and GRAVEL	8.45×10^{-8}	1.26×10^{-6}	6.34×10^{-8}	1.77×10^{-7}
Silty SAND and GRAVEL	3.91×10^{-6}	1.81×10^{-6}	2.94×10^{-6}	5.15×10^{-6}
Silty SAND and GRAVEL with clay	1.60×10^{-5}	2.82×10^{-6}	1.20×10^{-5}	1.91×10^{-5}
Clay or silt bound sandy GRAVEL	4.00×10^{-6}	4.10×10^{-6}	3.00×10^{-6}	5.57×10^{-6}
Clayey GRAVEL	2.08×10^{-2}	3.25×10^{-5}	1.56×10^{-2}	1.32×10^{-2}
Clayey GRAVEL with cobbles	9.00×10^{-6}	3.43×10^{-5}	6.75×10^{-6}	2.24×10^{-5}
Clayey sandy GRAVEL	2.53×10^{-4}	1.44×10^{-5}	1.90×10^{-4}	2.72×10^{-4}
Clayey sandy GRAVEL with cobbles	9.80×10^{-3}	2.55×10^{-5}	7.35×10^{-3}	6.63×10^{-3}
Clayey silty sandy GRAVEL	1.04×10^{-6}	6.45×10^{-6}	7.82×10^{-7}	2.26×10^{-6}
Clayey silty sandy GRAVEL with cobbles	5.87×10^{-5}	2.55×10^{-5}	4.40×10^{-5}	9.44×10^{-5}
GRAVEL	3.76×10^{-2}	3.52×10^{-5}	2.82×10^{-2}	2.24×10^{-2}
GRAVEL with clay	1.00×10^{-2}	2.33×10^{-5}	7.50×10^{-3}	6.79×10^{-3}
GRAVEL with cobbles	1.80×10^{-2}	1.59×10^{-5}	1.35×10^{-2}	9.87×10^{-3}
Sandy clayey GRAVEL	4.14×10^{-4}	1.55×10^{-5}	3.11×10^{-4}	4.11×10^{-4}
Sandy clayey GRAVEL with cobbles	7.43×10^{-3}	2.76×10^{-5}	5.57×10^{-3}	5.33×10^{-3}
Sandy GRAVEL	8.75×10^{-3}	1.33×10^{-5}	6.56×10^{-3}	4.94×10^{-3}
Sandy GRAVEL with clay	2.61×10^{-4}	1.73×10^{-5}	1.96×10^{-4}	2.87×10^{-4}
Sandy GRAVEL with cobbles	8.11×10^{-3}	1.40×10^{-5}	6.08×10^{-3}	4.78×10^{-3}
Sandy GRAVEL with silt	8.00×10^{-5}	1.10×10^{-5}	6.00×10^{-5}	9.96×10^{-5}
Sandy GRAVEL with silt/clay	1.20×10^{-3}	2.18×10^{-5}	9.02×10^{-4}	1.15×10^{-3}
Sandy silty clayey GRAVEL	2.51×10^{-7}	2.13×10^{-6}	1.88×10^{-7}	5.58×10^{-7}
Sandy silty GRAVEL	6.00×10^{-6}	3.11×10^{-6}	4.50×10^{-6}	7.80×10^{-6}
Sandy silty GRAVEL with cobbles	3.27×10^{-4}	2.33×10^{-5}	2.45×10^{-4}	3.70×10^{-4}
Silty clayey sandy GRAVEL	5.24×10^{-8}	1.57×10^{-6}	3.93×10^{-8}	1.32×10^{-7}
Silty GRAVEL	1.81×10^{-3}	3.67×10^{-5}	1.35×10^{-3}	1.82×10^{-3}
Silty GRAVEL with cobbles	1.12×10^{-1}	1.96×10^{-5}	8.42×10^{-2}	4.35×10^{-2}
Silty sandy clayey GRAVEL	6.25×10^{-6}	9.79×10^{-6}	4.69×10^{-6}	1.14×10^{-5}
Silty sandy GRAVEL	1.35×10^{-5}	5.23×10^{-6}	1.01×10^{-5}	1.78×10^{-5}
Silty sandy GRAVEL with cobbles	5.51×10^{-5}	8.04×10^{-6}	4.13×10^{-5}	7.12×10^{-5}



Figure 3.24: Hydraulic conductivity (m/s) estimates derived from particle size distribution analyses conducted on samples from boreholes along the length of the Kildare Bypass

The particle size distribution analyses are taken from identifiable strata and so can be related to the glacial geology. This allows for the spatial distribution of hydraulic conductivity to be examined and related to the geology which can be more challenging in larger scale tests. Although the soils have been disturbed, they are useful in identifying areas where the actual hydraulic conductivity may deviate from the average hydraulic conductivity which is more easily and accurately obtained by pumping tests. Even with the inherent errors involved in collecting and transporting samples the variation in hydraulic conductivity is evident (Figure 3.24). The estimations of the hydraulic conductivity from Table 3-5 can be averaged using the geometric mean to get an approximation of the hydraulic conductivity of the tills. Likewise the estimations from Table 3-6 can be averaged to get an approximation of the glacial outwash deposits. The geometric means of the fine- and coarse-grained soils are 1.7×10^{-7} m/s and 9.9×10^{-3} m/s, respectively. The particle size distribution analyses can be used to obtain a rough estimate of units (alluvium and esker identified in Figure 3.5) that were not tested with the variable head tests or the pumping test. One particle size distribution test was conducted on a sample of alluvium and this resulted in an estimation of 1.0×10^{-2} m/s as the hydraulic conductivity. An esker is located from Ch. 113+00 to 123+00 and 27 samples were taken. The estimations of hydraulic conductivity from these samples were averaged using the geometric mean and resulted in a hydraulic conductivity of the esker of 4.9×10^{-3} m/s.

3.4.6.2 Variable Head Tests

Variable head hydraulic conductivity tests (VHT), both rising and falling, were carried out in 200 mm diameter boreholes formed using light cable percussion methods (data from Irish Geotechnical Services Ltd., 1991). These VHT were conducted at 22 locations along the length of the motorway (Figure 3.25). The tests were carried out over a 1 m response zone formed by putting coarse gravel into the bottom of the borehole and retracting the casing. The hydraulic conductivity as interpreted by Irish Geotechnical Services Limited using the Hvorslev (1951) analysis is presented in Table 3-7. The basic data were not given in the Irish Geotechnical Services Ltd. (1991) report and could not be obtained from any source; therefore, they could not be reassessed or verified. Most of the variable head tests sampled the glacial outwash deposit; however, the test zone at Ch. 83+00 sampled the till.

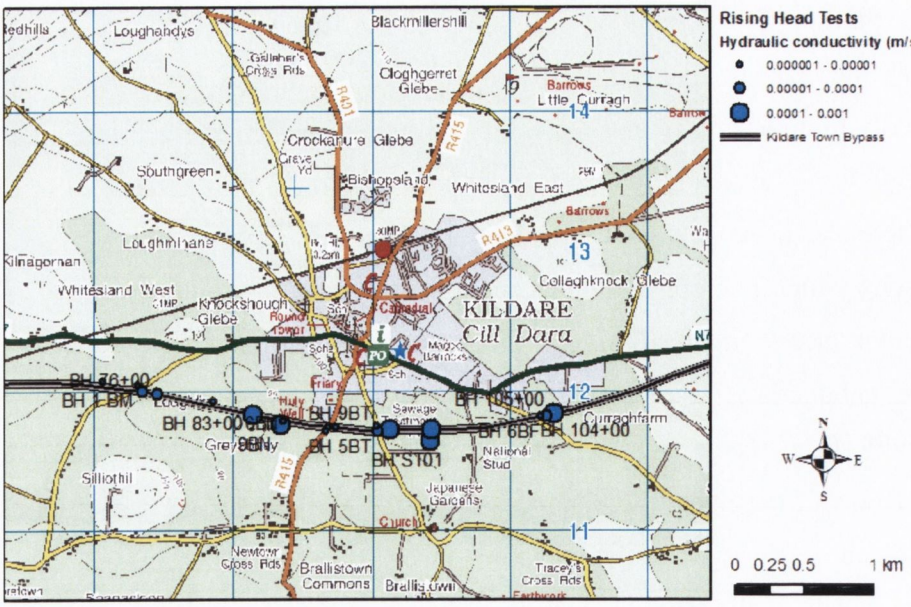


Figure 3.25: Variable head test locations.

Table 3-7: Rising and Falling Head Test Results (Irish Geotechnical Services Ltd., 1991)

BOREHOLE	FALLING HEAD HYDRAULIC CONDUCTIVITY (m/s)	RISING HEAD HYDRAULIC CONDUCTIVITY (m/s)
1 BM (71+00)	2.77×10^{-5}	
72+00N	4.53×10^{-7}	5.90×10^{-6}
75+00		4.20×10^{-5}
76+00	3.65×10^{-5}	9.39×10^{-5}
80+00N	1.69×10^{-3}	
83+00	9.21×10^{-6}	2.00×10^{-4}
9 BN (85+15)	8.16×10^{-4}	6.17×10^{-4}
5 GA (88+50)	1.70×10^{-4}	3.30×10^{-6}
9 GA (88+50)	2.29×10^{-5}	
89+00	1.29×10^{-5}	
5BT (91+70)	1.49×10^{-5}	3.68×10^{-5}
9 BT (91+70)	1.00×10^{-7}	
93+00	1.57×10^{-4}	1.14×10^{-4}
BH ST01 (95+50)	7.61×10^{-6}	3.76×10^{-4}
96+00	3.86×10^{-5}	1.86×10^{-4}
104+00	4.20×10^{-7}	1.89×10^{-6}
6 BF (104+50)	2.31×10^{-5}	1.96×10^{-5}
105+00	1.09×10^{-6}	1.11×10^{-4}

Figure 3.25 shows distribution of the results of the rising head tests along the length of the bypass and Figures 3.26 and 3.27 show the distribution of hydraulic conductivity with elevation. Figure 3.25 shows a general trend of lower hydraulic conductivity values along the western part of the cutting; this is consistent with the lower observed dewatering volumes in that area. Figure 3.28 illustrates the correlation between the hydraulic

conductivity determined from rising and falling head tests. Ideally the rising and falling head tests should cluster around the trend line showing that the same result is obtained regardless of the type of test. However, the rising head tests give higher hydraulic conductivity than the falling head tests on some occasions. This difference could be attributed to the loosening of fine material at the base of the boreholes in the rising head tests and sedimentation of fine material during falling head tests and illustrates the limitations of variable head tests.

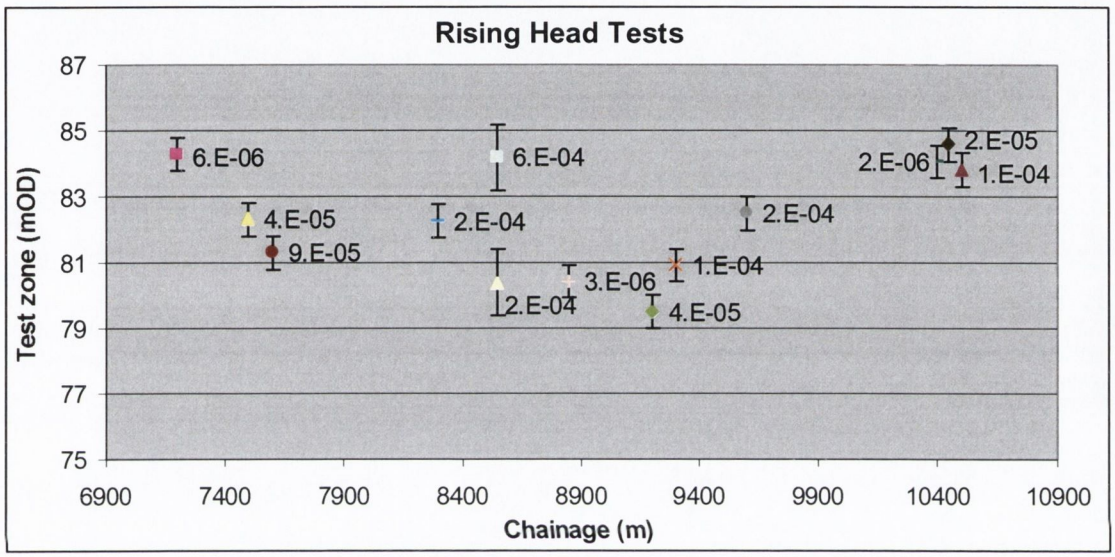


Figure 3.26: The distribution of rising head tests with depth along the length of the cutting for the Kildare Town Bypass. The error bars indicate the test zone.

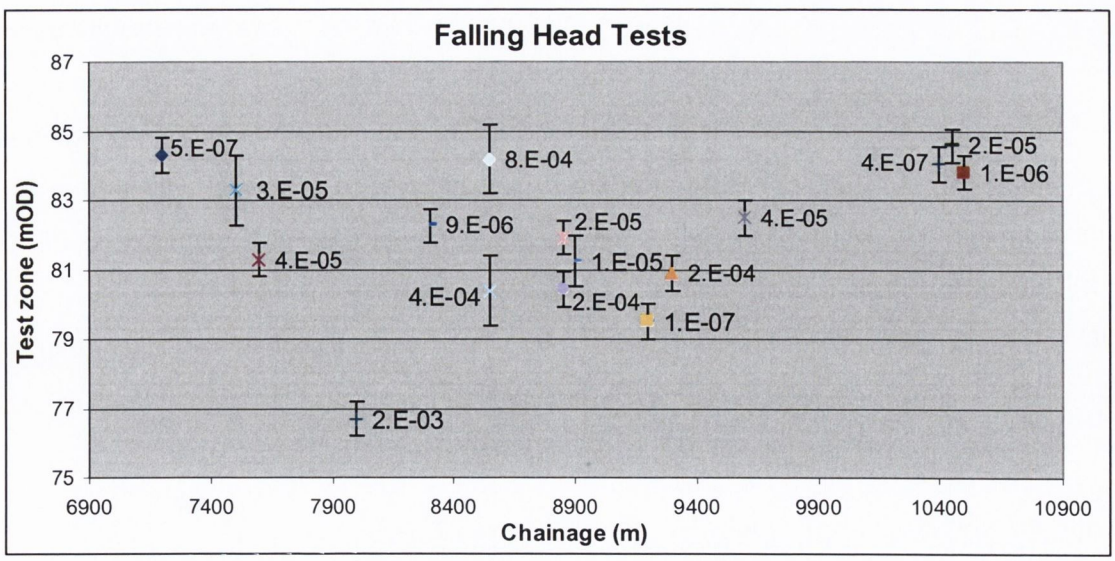


Figure 3.27: The distribution of falling head tests with depth along the length of the cutting for the Kildare Town Bypass. The error bars indicate the test zone.

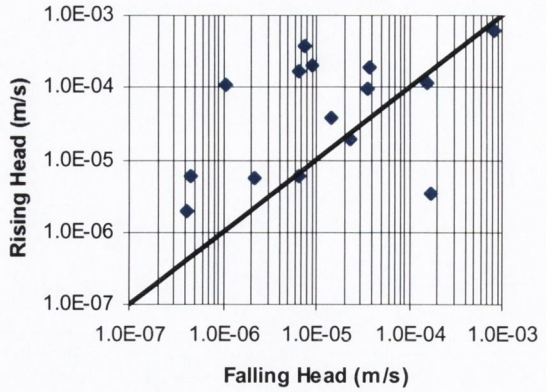


Figure 3.28: Comparison of rising and falling head tests

Test data were available for the reanalysis of two rising and two falling head tests conducted near the Sewage Treatment Works (Ch. 95+50) on June 14th, 1991 (Irish Geotechnical Services Ltd, 1991). Groundwater head measurements were taken every 15 minutes and the number of times the groundwater head was measured varied from 3 to 9 for various tests. The hydraulic conductivity was calculated using Hvorslev (1951) with an intake factor equal to $F = \frac{2\pi L}{\log_e\left[(L/D)+\sqrt{\left(1+(L/D)^2\right)}\right]}$ which corresponds to a well point or hole extended in a uniform soil. The hydraulic conductivity was estimated to be $2.0\text{x}10^{-4}$ m/s to $5.5\text{x}10^{-4}$ m/s for the two rising head tests and $7.2\text{x}10^{-6}$ m/s to $7.9\text{x}10^{-6}$ m/s for the two falling head tests.

The intake factor can have a significant impact on the estimated hydraulic conductivity and is a function of the geometry of the test cavity, the boundary conditions and the anisotropy of the soil (Ratnam *et al.*, 2001). The intake factor, for a borehole where the soil is flush with the bottom in a uniform soil and for a well point filter in a uniform soil, is examined through numerical modelling in further detail in Appendix B. This study showed that the intake factor is dependent on the borehole characteristics and the soil properties. However, the errors in intake factor values used in the calculations for hydraulic conductivity were not great enough to account for the differences found in the hydraulic conductivity estimated in the previous rising and falling head tests.

3.4.6.3 AQUIFER PUMP TESTS

Pump tests were conducted at six locations along the western part of the aquifer, namely the Mooretown Bridge Site (Ch. 71+00), Nurney Bridge Site (Ch. 84+15), Greyabbey Road (Ch. 88+50), Sewage Treatment Works (near 95+50) , Frenchfurze Road (Ch. 104+50), and Farm Underpass Site (5BU) (Figure 3.29). The Farm Underpass site was located outside of the Mid-Kildare Aquifer and so was excluded from this study. The pump tests at Mooretown Bridge and Nurney Bridge were conducted by Irish Geotechnical Services (1994) and the tests at Greyabbey Road, the Sewage Treatment Works and Frenchfurze Road were conducted by K.T. Cullen and Co. Ltd. (1993). The stratigraphy in the areas of the tests is illustrated in Figure 3.5. The pumping wells, for the tests conducted by K.T. Cullen and Co. Ltd. (1994), were cased with 6.0 m of stainless steel well screen with a slot size of 1.0 – 1.5 mm depending on the formation being screened. The borehole design was not specified for the pump tests conducted by Irish Geotechnical Services (1993). The minimum pumping time recommended in medium sand and coarse material is 4 hours and so the tests with durations less than 4 hours were not analysed (Kasenow, 2006).

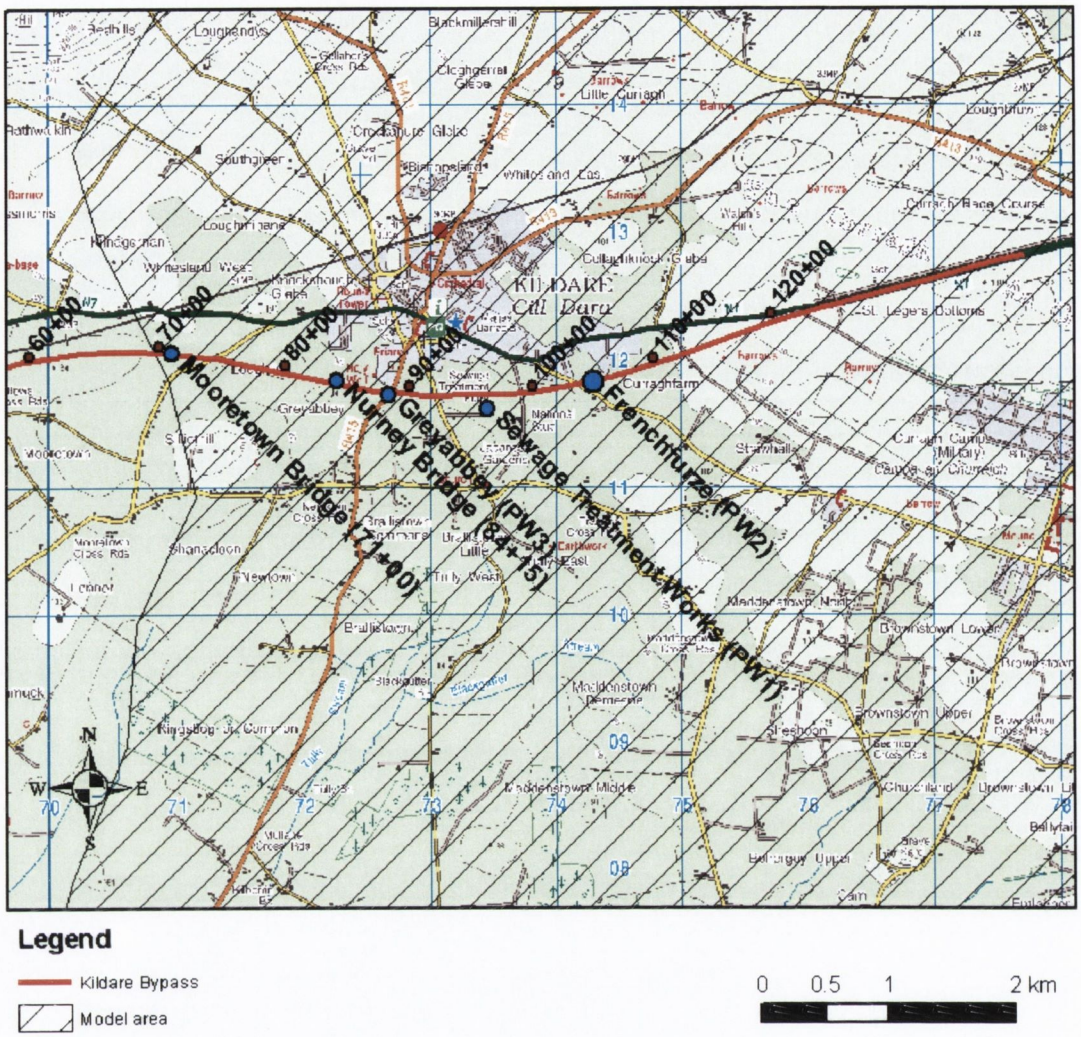


Figure 3.29: Locations of Pump Tests

3.4.6.3.1 MOORETOWN BRIDGE

A summary of the pumping and recovery tests at Mooretown Bridge is located in Table 3-8. The water levels during the recovery test responded slowly. Even when the water level was measured again at 20 and 72 hours after pumping ceased the water levels had not fully recovered. All the piezometers were located in thick gravel layers. The upper piezometers were located 6 m below the ground surface, in a band of gravel; however, clay overlies and underlies the gravel. The lower piezometers were located at 15 m below the ground level.

Table 3-8: Summary of pumping and recovery tests at Mooretown Bridge.

MOORETOWN BRIDGE SUMMARY		
Depth of Boreholes	PW - 14.0 m OB1 - 15.0 m OB2 - 15.0 m OB3 - 15.0 m OB4 - 15.0 m	
Distance from Pumping Well	OB1 - 16.0 m OB2 - 32.1 m OB3 - 12.6 m OB4 - 27.3 m	
Date	June 15th, 1994	June 15th, 1994
Duration	1 hour	47 hour
Discharge	21.7 l/s	21.7 l/s
Recovery Test Duration	360 minutes	
Depth to water	7.5 m	
Saturated Thickness	14.5 m	
Screened Interval	Not reported	

The drawdown versus time recorded for the 47-hour test area is shown on a semi-log plot on Figure 3.30 and on a log-log plot on Figure 3.31. The semi-log plots for the lower piezometers show an initial nearly instantaneous increase in drawdown followed by a period where little drawdown is observed and then a later increase in drawdown. This indicates that the aquifer is behaving as an unconfined aquifer. The log-log curves show that the upper piezometers seem to experience a delayed response to the dewatering of the aquifer.

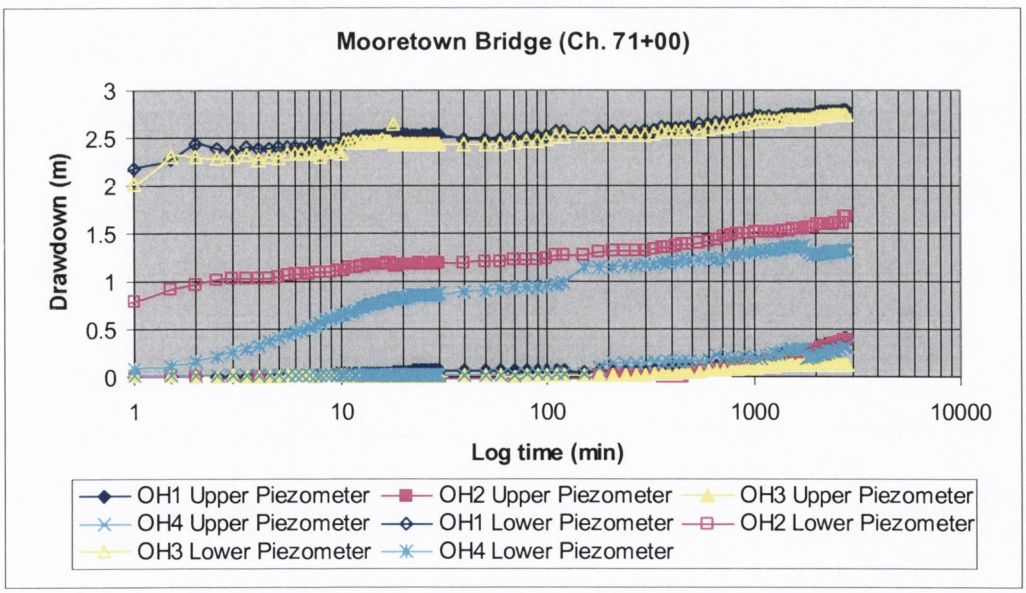


Figure 3.30: Drawdown versus time plot for Mooretown Bridge (Ch. 71+00) for the 47-hour test.

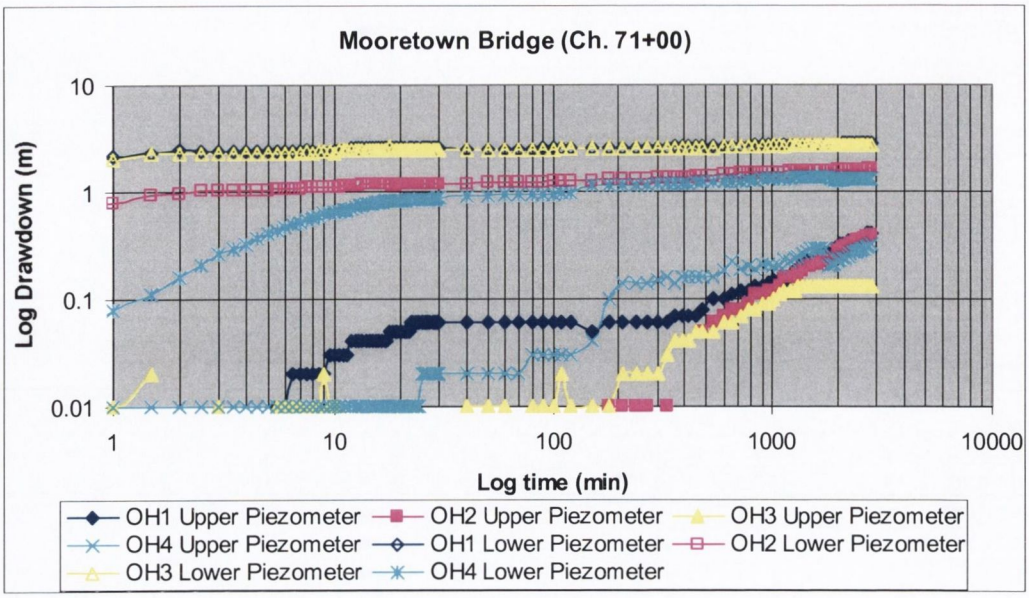


Figure 3.31: Log-log plot for Mooretown Bridge (Ch. 71+00) for the 47-hour test.

The groundwater level in the pumping well was at 7.5 m below ground level which corresponds with the contact between the overlying clays and the underlying gravels. This indicates that the aquifer is confined when the groundwater level is high and unconfined when the groundwater level is low. This site has a 22 m thick layer of sediments and a saturated thickness of 14.5 m. Therefore, some of the deviation from the ideal curve may be attributable to the effects of partial penetration inducing a vertical component to the flow. This would have a greater effect on the observation wells closer to the pumping well (OB1 & OB3) rather than the observation wells further away (OB2 & OB4).

It has been shown that partial penetration effects are negligible when the observation well is approximately 1.5 to 2.0 times the thickness of the aquifer in distance from the pumping well (Muskat, 1937 and Butler 1957 as cited in Kasenov, 2006). The effects of partial penetration of the wells are less pronounced when there is layering in the sediments resulting in a greater horizontal than vertical hydraulic conductivity. The sediments in this area are stratified, which may cause the horizontal hydraulic conductivity to be greater than the vertical hydraulic conductivity. The sediments within the test zone are highly heterogeneous and this may also contribute to the semi-log and log-log curves not conforming to the type curves for an unconfined aquifer.

Therefore, this pump test will be analysed using the Neuman method for unsteady-flow in an unconfined aquifer and the Streltsova method for unsteady-state flow into an unconfined aquifer with partially penetrating wells (Table 3-9).

Table 3-9: Results of pumping test analysis at Mooretown Bridge.

MOORETOWN BRIDGE SITE (71+00) 47 HOURS		
	Horizontal Hydraulic Conductivity (m/s)	Vertical Hydraulic Conductivity (m/s)
Neuman		
OH1	2.2×10^{-4}	
OH2	1.9×10^{-4}	
OH3	2.2×10^{-4}	
OH4	2.2×10^{-4}	
Streltsova		
OH1	4.5×10^{-4}	3.6×10^{-5}
OH2	3.9×10^{-4}	3.0×10^{-6}
OH3	8.6×10^{-4}	9.9×10^{-5}
OH4	2.3×10^{-4}	1.8×10^{-6}
Theis Recovery		
	9.2×10^{-4}	

The semi-log graph for the recovery test is shown below (Figure 3.32). It demonstrates that the upper piezometers showed very little recovery and therefore could not be analysed. The lower piezometers show some deviation from the theoretical straight line. The middle segment approximates a straight line, therefore, the recovery test can be analysed using the Theis recovery method. When the Theis recovery assumptions are satisfied the residual drawdown will intersect the origin at 0.1 (Kasenov, 2006). The lower piezometer curves satisfy this condition when the ratio of t/t' is small. The Theis recovery analysis resulted in a transmissivity of 1.3×10^{-2} m^2/s and a horizontal hydraulic conductivity of 9.2×10^{-4} m/s (using a saturated thickness of 14.5 m).

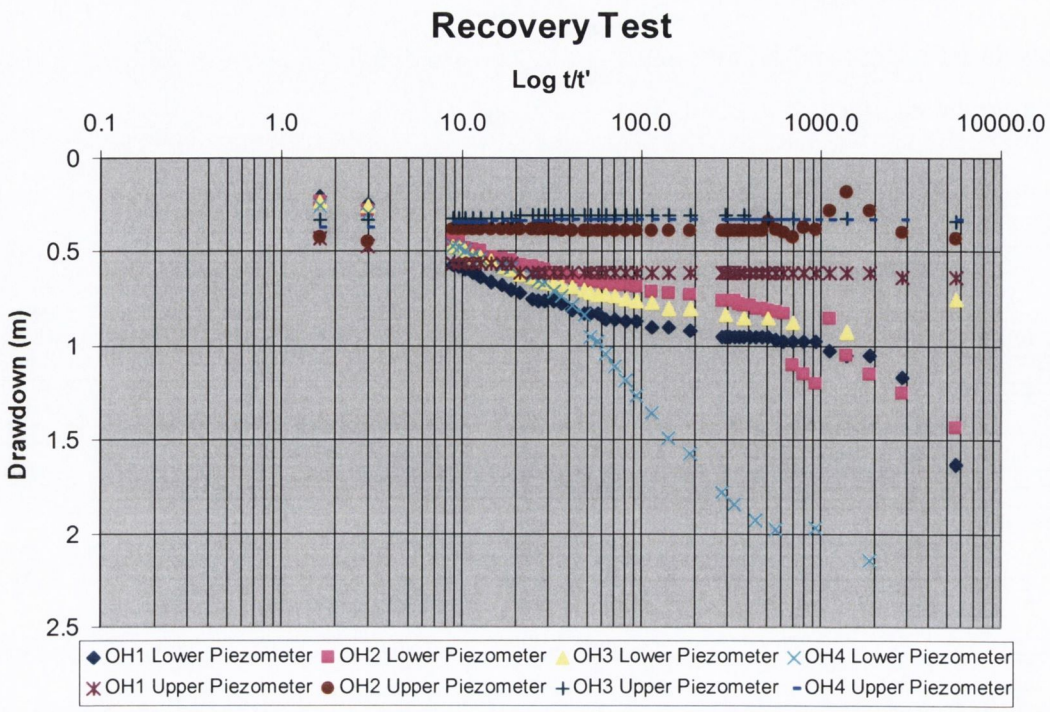


Figure 3.32: Semi-log plot of recovery test at Mooretown Bridge.

3.4.6.3.2 NURNEY BRIDGE

A summary of the pumping and recovery tests at Nurney Bridge is located in Table 3-10. During the 47-hour pumping test, a blockage obstructed the upper piezometer in observation borehole 4 after 80 minutes of pumping. The upper piezometers were located at 4.7m (OH1), 6 m (OH3), and 7 m (OH4) below the ground surface and a delayed response was observed in OH1 and OH3. All the piezometers are located in thick gravel layers. The upper piezometers may have been too shallow to measure the aquifer response to pumping. The lower piezometers, located at 14.5 m (OH1 & OH2) and 10 m (OH3 & OH4) below the ground level, do not show the delayed response in the log-log plot.

Table 3-10: Summary of pumping and recovery tests at Nurney Bridge.

NURNEY BRIDGE SUMMARY		
Depth of Boreholes	PW - 15.0 m OB1 - 14.5 m OB2 - 14.5 m OB3 - 10.0 m OB4 - 10.5 m	
Distance from Pumping Well	OB1 - 10.8 m OB2 - 27.8 m OB3 - 11.3 m OB4 - 25.2 m	
Date	June 28th, 1994	June 29th, 1994
Duration	1 hour	47 hour
Discharge	10.2 l/s	10.2 l/s
Recovery Test Duration	100 minutes	
Depth to water	3.8 m	
Saturated Thickness	27.6 m	
Screened Interval	Not reported	

The drawdown versus time recorded for the 47-hour test is shown on a semi-log plot on Figure 3.33 and a log-log plot for Figure 3.34. The drawdown at Observation Hole 2 is greater than that at Observation Hole 3 even though Observation Hole 3 is closer to the pumping well. This may be attributable to anisotropy in the sediments. The analysis is based on the first few hours of the test as an unexplained reduction in drawdown occurred after 200 to 300 minutes. This does not coincide with rainfall recorded at Osberstown and therefore may reflect either a deficiency in the test method (such as recirculation of pump water) or local recharge (i.e. a rain event not recorded at Osberstown). A reduction of discharge may have caused the observed recovery; however, discharge was not measured continuously so this cannot be confirmed.

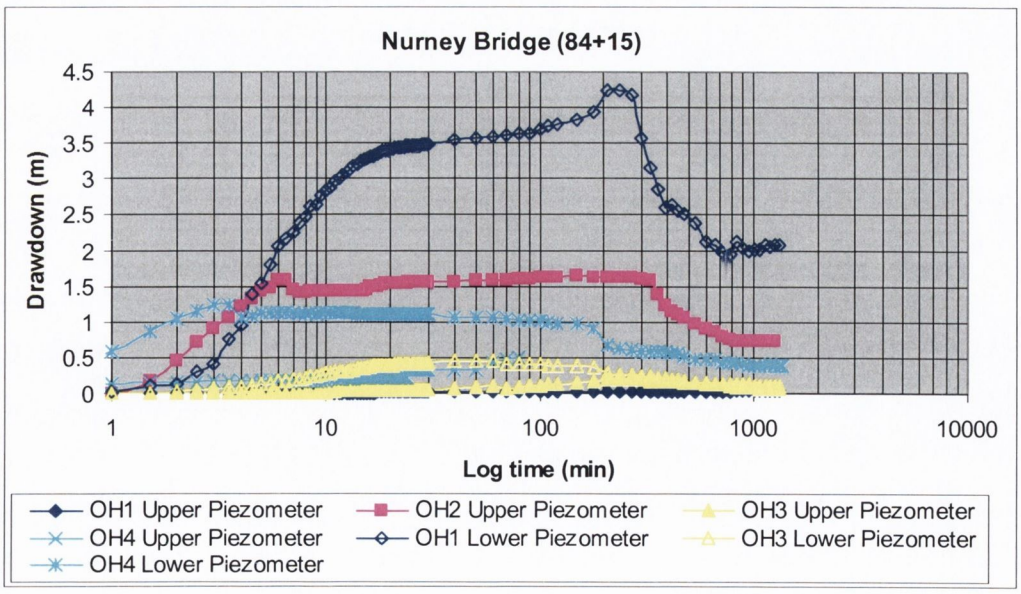


Figure 3.33: Drawdown versus time plot for Nurney Bridge (84+15) for the 47-hour test.

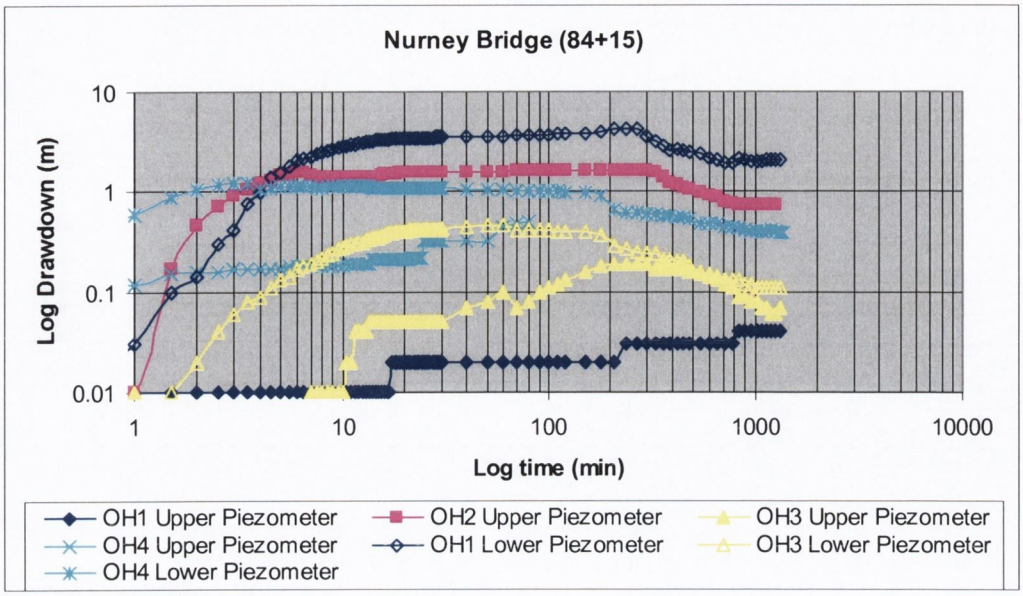


Figure 3.34: Log-log plot for Nurney Bridge (84+15) for the 47-hour test.

The groundwater level in the pumping well was at 3.8 m below ground level which corresponds with the contact between the overlying clays and the underlying gravels. This indicates that the aquifer is confined when the groundwater level is high and unconfined when the groundwater level is low. There are 31.4 m of sediments overlying the bedrock and 27.6 m of which are saturated. Therefore, some of the deviation from the ideal curve may be attributable to the effects of partial penetration inducing a vertical component to the flow. This would have a greater effect on the observation wells closer to the pumping well (OB1 & OB3) rather than the observation wells further away (OB2 & OB4). The effects of partial penetration of the wells is less pronounced when there is layering in the sediments resulting in a greater horizontal hydraulic conductivity than the vertical hydraulic conductivity. The sediments in the area around the Nurney Bridge are stratified which indicates that the horizontal hydraulic conductivity may be greater than the vertical hydraulic conductivity.

The semi-log plots for the lower piezometers, before there is a reduction in drawdown, show an initial increase in drawdown followed by a period where the drawdown levels off. This indicates that the aquifer is behaving as a confined aquifer. This may be the result of the total drawdown (4 m in OB1 and >2 m in OB2, OB3, and OB4) during the pump test being approximately 10% of the aquifer's original thickness (27.6 m). Kasenow (2006) states that when this is the case an unconfined aquifer can be

analysed using the equations derived for confined aquifers. The log-log curves show that the upper piezometers experience a delayed response to the dewatering of the aquifer.

Therefore, this pump test will be analysed using the Thiem method for steady-flow in a confined aquifer, Neuman method for unsteady-state flow in an unconfined aquifer and the Streltsova method for unsteady-state flow in an unconfined aquifer with partially penetrating wells (Table 3-11). The Thiem method was used to analyse the data before the point when the drawdown levels began to be reduced. As only this early drawdown versus time data is analysed, this should negate the effect of the reduced discharge rate or recharge during the test on the interpreted steady state hydraulic conductivity. However, a reduced drawdown would be expected to result in a higher estimate of the hydraulic conductivity. The recovery data were analysed using the Theis recovery method and resulted in a transmissivity of 2.2 $x10^{-2}$ m^2/s and a horizontal hydraulic conductivity of 7.9 $x10^{-4}$ m/s.

Table 3-11: Results of pumping test analysis at Nurney Bridge.

NURNEY BRIDGE (47-HOUR TEST)		
	Horizontal Hydraulic Conductivity (m/s)	Vertical Hydraulic Conductivity (m/s)
Thiem		
OH3&4	$4.3x10^{-4}$	
Neuman		
OH1	$1.4 x10^{-5}$	
OH2	$1.8 x10^{-5}$	
OH3	$1.2 x10^{-5}$	
OH4	$2.0 x10^{-5}$	
Streltsova		
OH1	$8.7 x10^{-5}$	$8.8 x10^{-6}$
OH2	$1.6 x10^{-5}$	$6.6 x10^{-6}$
OH3	$8.0 x10^{-4}$	$8.0 x10^{-6}$
OH4	$2.2 x10^{-5}$	$8.9 x10^{-6}$
Theis Recovery		
	$7.9 x10^{-4}$	

3.4.6.3.3 GREYABBEY ROAD

A summary of the pumping and recovery tests at Greyabbey Road is located in Table 3-12. The water levels during the recovery test responded slowly. The stratigraphy in this area consists of approximately 1 m of top soil, underlain by 3 m of clay, which is underlain by gravel through to bedrock. The groundwater level coincides with the clay/gravel

boundary. The Greyabbey site has a fully-penetrating well and the drawdown (>0.8 m) is less than 10% of the total saturated thickness of the aquifer (12 m).

Table 3-12: Summary of pumping and recovery tests at Greyabbey Road.

GREYABBEY ROAD SUMMARY	
Depth of Boreholes	PW - 15.0 m OB1 - 12.6 m OB2 - 14.6 m OB3 - 8.5 m
Distance from Pumping Well	OB1 - 8.0 m OB2 - 24.7 m OB3 - 50.0 m
Date	January 4 – 7, 1993
Duration	72 hours
Discharge	2.8 to 2.6 l/s
Recovery Test Duration	50 minutes
Depth to water	3.6 m
Saturated Thickness	12 m
Screened Interval	8-14 m

The drawdown versus time recorded for the 72-hour pump test are shown on a semi-log plot on Figure 3.35 and on a log-log plot on Figure 3.36. The semi-log plots show an initial slow response to the drawdown followed by an approximately linear response to pumping which is followed by a period of levelling off of the drawdown. This indicates that the aquifer is reaching a steady-state where the pumping is no longer drawing down the aquifer. This could be the result of either a leaky overlying layer or that the aquifer is being locally recharged. The semi-log plot is considered to be typical of a leaky-confined aquifer. Therefore, the pump test is analysed using the Walton method for unsteady-state flow in a leaky aquifer and the Jacob method for unsteady-state flow in a confined aquifer due to the approximately linear response to pumping (Table 3-13). The recovery data were analysed using the Theis recovery method and resulted in a transmissivity of 2.2 $x10^{-3}$ m^2/s and a hydraulic conductivity of 1.8 $x10^{-4}$ m/s.

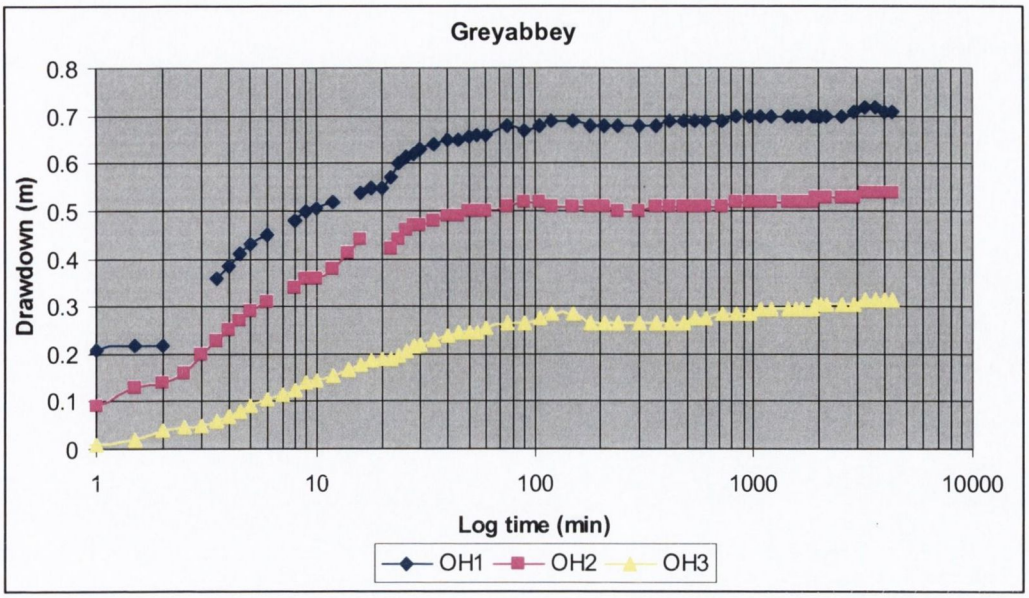


Figure 3.35: Drawdown versus log time plot for the Greyabbey Bridge site for a 72-hour pump test.

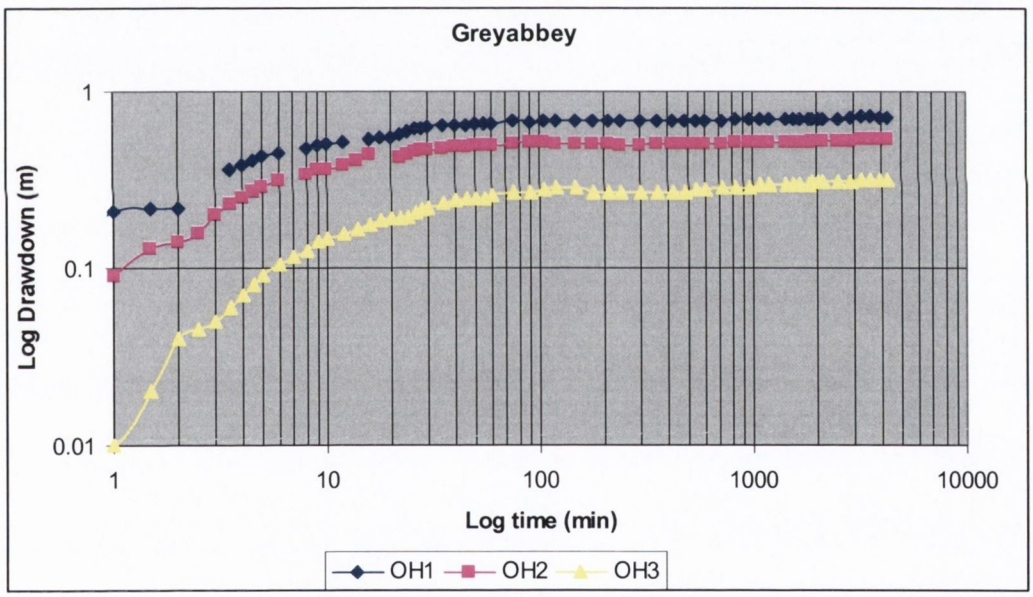


Figure 3.36: Log-log plot for the Greyabbey Bridge site for a 72-hour pump test.

Table 3-13: Calculated hydraulic conductivities from pumping tests at Greyabbey Road.

GREYABBEY ROAD 72-HOUR TEST	
Walton	Horizontal Hydraulic Conductivity (m/s)
GA OW1	5.0×10^{-5}
GA OW2	6.5×10^{-5}
GA OW3	5.9×10^{-5}
Jacob	
GA OW1	2.3×10^{-4}
GA OW2	2.6×10^{-4}
GA OW3	3.1×10^{-4}
Theis Recovery	
	1.8×10^{-4}

3.4.6.3.4 Sewage Treatment Works

A summary of the pumping and recovery tests at Sewage Treatment Works is located in Table 3-14. Data were not collected at OB4 for the 72-hour test. During the recovery tests, the wells showed a rapid response and were close to full recovery within 10 minutes. The stratigraphy at the site consists of approximately 1 m of top soil, underlain by 6 m of silt and clay, which is underlain by gravel interlayered with clay through to bedrock. The groundwater level lies within the silt layer at approximately 2.7 m below ground level. The area around the Sewage Treatment Works has a saturated thickness of 22 m. The partial-penetration of the wells may induce a vertical component to the flow which was only apparent in the boreholes OB1 as it is 4.25 m from the pumping well while the rest are further than 1.5 times the saturated thickness of the aquifer away from the pumping well. This means that the partial penetration effects are negligible, as the observation boreholes OB2 - OB4 are located at a distance further than 1.5 times the saturated thickness of the aquifer (Muskat, 1937 and Butler 1957 as cited in Kasenov, 2006). The drawdown (>1.4 m) is small (less than 10%) compared to the saturated thickness (22 m) of the aquifer at the Sewage Treatment Works and thus can be analysed as a confined aquifer.

Table 3-14: Summary of pumping and recovery tests at Sewage Treatment Works.

SEWAGE TREATMENT WORKS SUMMARY		
Depth of Boreholes	PW - 16.0 m OB1 - 12.2 m OB2 - 10.75 m OB3 - 9.6 m OB4 - 9.3 m	
Distance from Pumping Well	OB1 - 4.25 m OB2 - 38.3 m OB3 - 103 m OB4 - 62.2 m	
Date	December 16 – 19, 1992	January 7, 1993
Duration	72 hours	4.5 hours
Discharge	7.49 to 6.33 l/s after 34 hours	5.91 l/s
Recovery Test Duration	45 minutes	30 minutes
Depth to water	2.7 m	
Saturated Thickness	22 m	
Screened Interval	9 - 15 m	

The drawdown versus time recorded for the 4.5 hour and 72-hour pump tests are shown on semi-log plots on Figures 3.37 and 3.39 and on a log-log plot on Figures 3.38 and 3.40. The analysis of the 72-hour test could not be analysed due to an unexplained reduction in drawdown was observed after the first 20 minutes of the pump test. This reduction in drawdown may be attributed to rainfall which was recorded at Osberstown on December 17 (11.5 mm) or to a deficiency in the test method or local recharge. A reduction of discharge may have contributed toward the observed recovery; however, discharge was not measured continuously so this cannot be confirmed. The semi-log plots are considered to be typical of a leaky-confined aquifer. Therefore, the pump test conducted at the Sewage Treatment Works will be analysed using the Walton method for unsteady-state flow in a leaky aquifer and the Hantush-Jacob method for unsteady-state flow in a confined aquifer with partially penetrating wells (Table 3-15). The recovery data were analysed using the Theis recovery method and resulted in a transmissivity of 6.3×10^{-3} m^2/s and a horizontal hydraulic conductivity of 2.9×10^{-4} m/s.

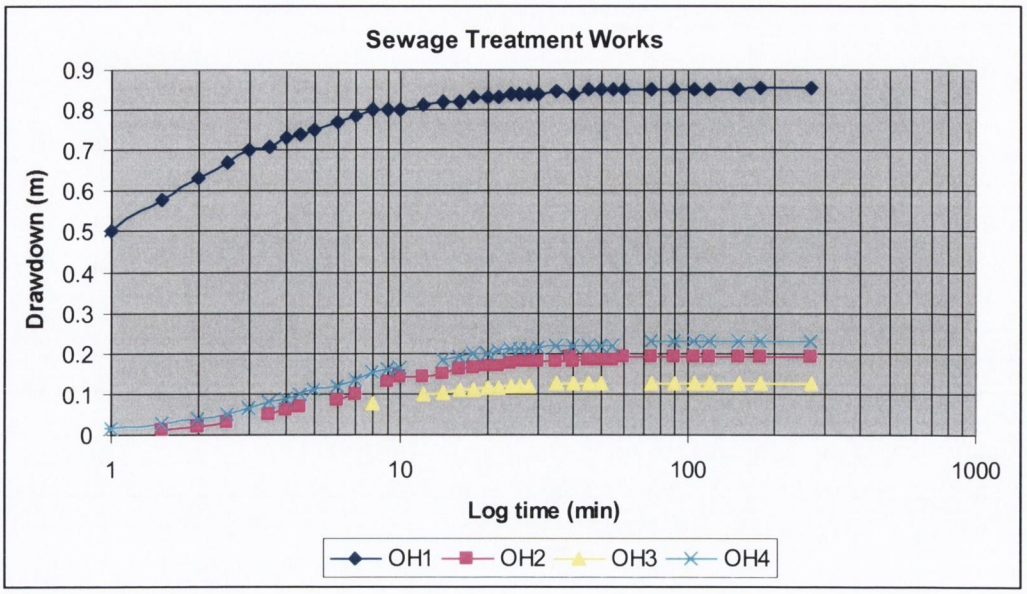


Figure 3.37: Drawdown versus log time plot for the Sewage Treatment Works for a 4.5 hour pump test.

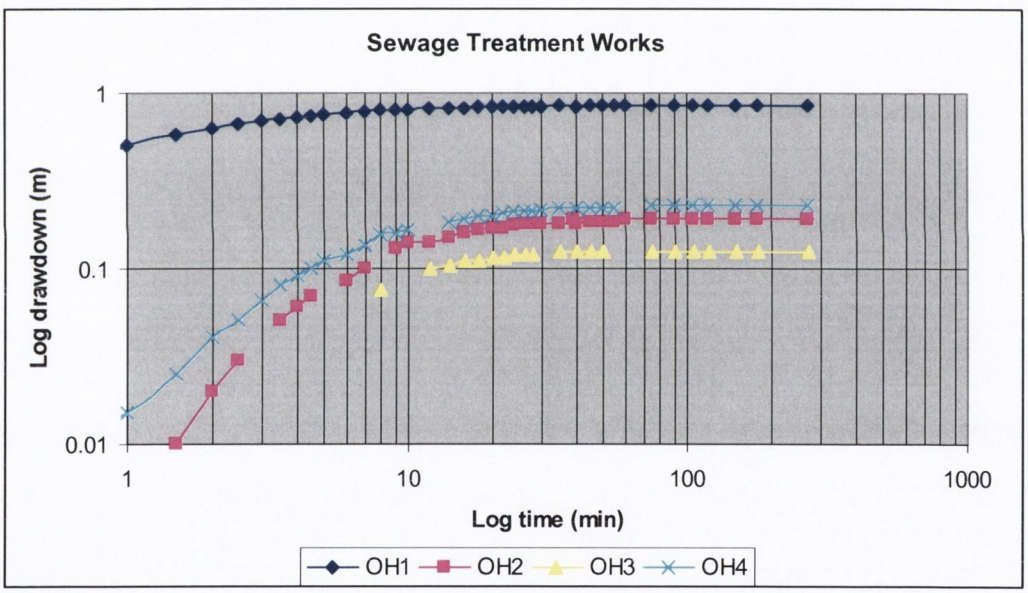


Figure 3.38: Log-log plot for the Sewage Treatment Works for a 4.5 hour pump test.

Table 3-15: Calculated hydraulic conductivities from pumping test analyses at the Sewage Treatment Works

SEWAGE TREATMENT WORKS	HORIZONTAL HYDRAULIC CONDUCTIVITY (m/s)
Walton	4.5-hour test
SW OW1	1.5×10^{-4}
SW OW2	2.3×10^{-4}
SW OW3	3.2×10^{-4}
SW OW4	1.8×10^{-4}
Hantush-Jacob	
SW OW1-4	1.4×10^{-4}
Theis Recovery	
	2.9×10^{-4}

3.4.6.3.5 FRENCHFURZE ROAD

A summary of the pumping and recovery tests at Frenchfurze Road is located in Table 3-16. The pump test at Frenchfurze Road site (Figures 3.41 - 3.44) showed very little change in water levels in the pumping well and four observation wells. No recovery data were collected for this test as it ended early due to a fault in the generator. A second pump test at Frenchfurze Road site experienced heavy rains on January 13 and 15, 1993, which corresponds to 48 hours and 91 hours into the pumping test. The water level began to rise after 90 hours of pumping and remained elevated for the remainder of the test. The recovery test responded very quickly with almost full recovery occurring within two minutes.

The stratigraphy at the site consists of approximately 3.5 m of clay which is underlain by gravel through to bedrock. The groundwater level lies within the clay layer at approximately 3 m below ground level and has a saturated thickness of 36 m. The partial-penetration of the wells may induce a vertical component to the flow which would only be apparent in the boreholes OB1 as it is 4.85 m from the pumping well while the rest are further than 1.5 times the saturated thickness of the aquifer away from the pumping well. Thus, for boreholes OB2 - OB4 the partial penetration effects can be ignored (Muskat, 1937 and Butler 1957 as cited in Kasenov, 2006). The drawdown (>2.2 m) is small (less than 10%) compared to the saturated thickness (36 m) of the aquifer at Frenchfurze and thus can be analysed as a confined aquifer.

Table 3-16: Summary of pumping and recovery tests at Frenchfurze Road.

FRENCHFURZE ROAD SUMMARY		
Depth of Boreholes	PW - 13.5 m OB1 - 11.0 m OB2 - 13.5 m OB3 - 10.0 m OB4 - 11.6 m	
Distance from Pumping Well	OB1 - 4.85 m OB2 - 50 m OB3 - 45 m OB4 - 100 m	
Date	December 19, 1992	January 11 – 18, 1993
Duration	42 hours	7 days
Discharge	17 l/s	34.3 to 34.0 l/s
Recovery Test Duration	none	80 minutes
Depth to water	2.8 m	
Saturated Thickness	36 m	
Screened Interval	6.5 - 12.5 m	

The drawdown versus time recorded for the 42 hour and 7 day pump tests are shown on semi-log plots on Figures 3.41 and 3.43, respectively and on a log-log plot on Figures 3.42 and 3.44, respectively. The semi-log plots show a nearly instantaneous initial response to the drawdown after which the drawdown levels out and becomes nearly constant. The heavy rains which fell during the 7 day test (Figures 3.41 and 3.42) make it impossible to analyse the later portion of the 7 day test once the observation wells show recharge. The log-log graphs show a nearly instantaneous drawdown and then a small but steady nearly linear increase in drawdown for the duration of the test. This makes them very difficult to analyse but the quick response to dewatering would indicate that this represents the water taken from storage immediately around the well. The nearly constant drawdown observed after a few minutes of pumping may represent the lag between the water coming from elastic storage of the aquifer and from dewatering of the aquifer. The gradual increase in drawdown towards the middle of the testing period may represent the dewatering of the aquifer. This suggests that the aquifer near Frenchfurze is behaving as an unconfined aquifer. The lack of defined curves in the Frenchfurze pump tests makes it difficult to estimate the specific yield. The pump test conducted at the Frenchfurze will be analysed using the Neuman method for unsteady-state flow in an unconfined aquifer (Table 3-17). The Thiem method for a steady-state confined aquifer was also used for comparison purposes although if recharge is occurring the assumptions for this method may not be fully satisfied. Recovery data were collected at the Frenchfurze Road site, however, they could not be analysed, as recovery was nearly instantaneous which is indicative of the very high hydraulic conductivity and recharge effects during the test.

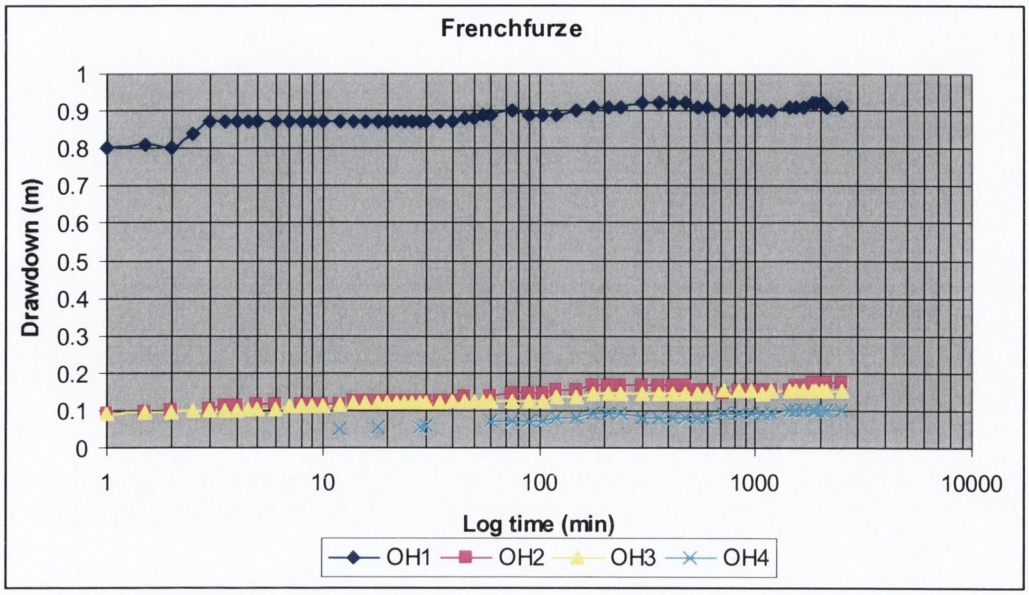


Figure 3.39: Drawdown versus log time plot for the Frenchfurze for a 42 hour pump test.

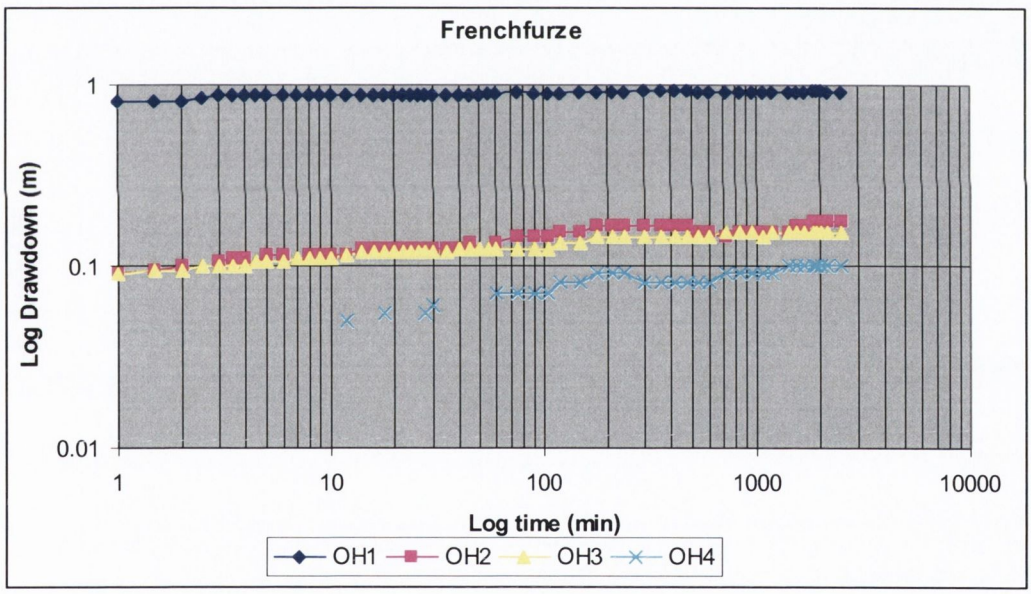


Figure 3.40: Log-log plot for the Frenchfurze for a 42 hour pump test.

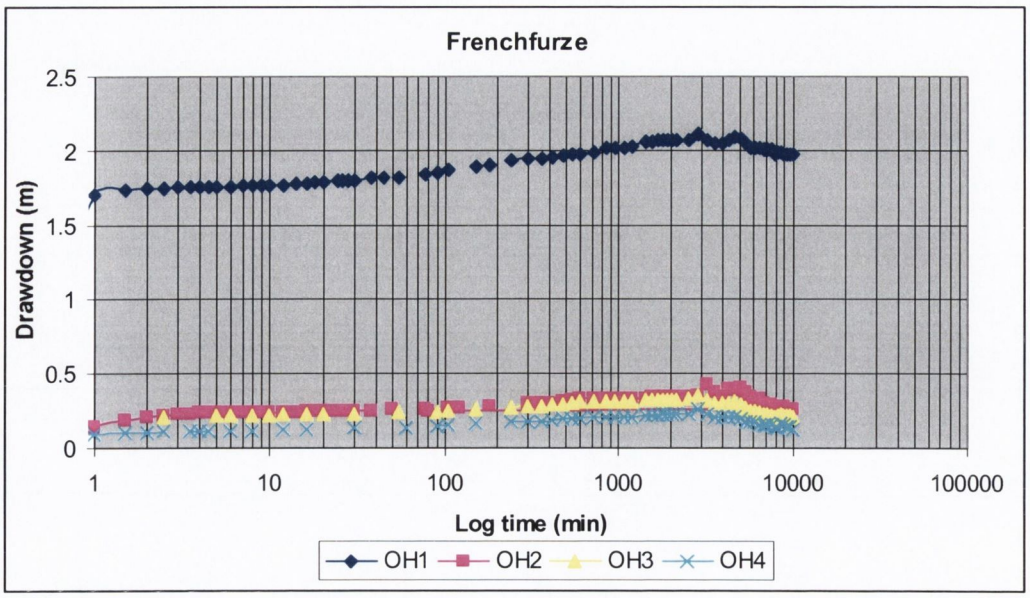


Figure 3.41: Drawdown versus log time plot for the Frenchfurze for a 7 day pump test.

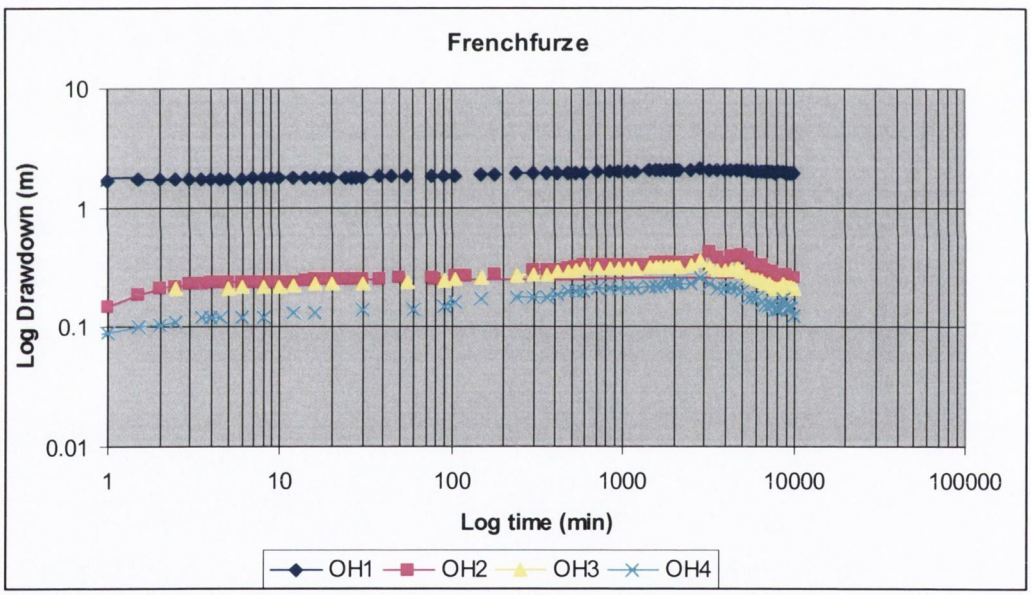


Figure 3.42: Log-log plot for the Frenchfurze for a 7 day pump test.

Table 3-17: Summary of the estimated hydraulic conductivities from the pump tests conducted at Frenchfurze Road.

FRENCHFURZE ROAD	HORIZONTAL HYDRAULIC CONDUCTIVITY (m/s)	
Thiem	42-hour	7-day
FF OW1&2	2.4×10^{-4}	2.1×10^{-4}
FF OW1&3	2.2×10^{-4}	1.9×10^{-4}
FF OW1&4	2.8×10^{-4}	2.5×10^{-4}
Neuman	42-hour	7-day
FF OW1	2.4×10^{-4}	2.2×10^{-4}
FF OW2	3.2×10^{-4}	3.0×10^{-4}
FF OW3	3.2×10^{-4}	3.0×10^{-4}
FF OW4	4.8×10^{-4}	6.0×10^{-4}

3.4.6.4 Specific Storage and Specific Yield

The storativity or the amount of water that an aquifer will readily take up or release can be calculated from pump test data (Misstear *et al.*, 2006). The same pumping tests used to calculate the hydraulic conductivity were also used to calculate the specific storage and the specific yield of the aquifer as defined in Section 2.3.2 (Tables 3-18 and 3-19). The data from the Nurney Bridge site could not be analysed for specific yield and specific storage as this location experienced some type of recharge after 200 to 300 minutes. The data from the Frenchfurze pump test could not be analysed due to the lack of drawdown during pumping and the recharge caused by rainfall during the test. The assumptions made with each analytical method can be found in Chapter 2. The specific storage and specific yield values were analysed using a number of methods (Walton, Cooper-Jacob, Hantush-Jacob, Moench and Neuman (Kruseman and de Ridder, 2000)). Of these methods those found to give the most reasonable results are given in Table 3-18 while the other methods which resulted in unreasonable values of specific yield and specific storage were omitted.

Table 3-18: Summary of specific storage and specific yield obtained through aquifer pumping tests in the Mid-Kildare Aquifer.

	SPECIFIC STORAGE (/m)		SPECIFIC YIELD
Mooretown Bridge Site (71+00) 47 hours			
	Neuman		Neuman
OH1	4.6×10^{-7}		4.6×10^{-3}
OH2	4.1×10^{-6}		4.1×10^{-2}
OH3	4.6×10^{-7}		4.6×10^{-3}
OH4	1.0×10^{-4}		3.4×10^{-2}
Greyabbey Road 72 hour			
	Walton		
GA OW1	2.4×10^{-4}		
GA OW2	4.0×10^{-4}		
GA OW3	1.4×10^{-3}		
Sewage Treatment Works 72 hours			
	Walton	Hantush-Jacob	
SW OW1	6.9×10^{-4}		
SW OW2	5.4×10^{-4}		
SW OW3	1.1×10^{-3}		
SW OW 1-3		6.5×10^{-4}	
Sewage Treatment Works 4.5 hour			
SW OW1	5.1×10^{-4}		
SW OW2	7.0×10^{-4}		
SW OW3	2.2×10^{-4}		
SW OW 4	2.9×10^{-4}		
SW OW 1-4		4.7×10^{-4}	

The specific storage average at Mooretown Bridge was 2.6×10^{-5} /m and the specific yield averaged at 0.021. The values derived for the specific storage and specific yield using the Neuman method are lower than what would be expected in a sand and gravel aquifer. The average specific storage for the two pump tests at the Sewage Treatment Works were 7.5×10^{-4} and 4.4×10^{-4} /m calculated using the Walton method. The specific storage at Greyabbey Road averaged 6.8×10^{-4} /m. The specific storage values had an average of 4.6×10^{-4} /m which is reasonable for a sand and gravel aquifer.

The specific yield, using the Neuman method, is approximately one order of magnitude lower than what would generally be expected for a sand and gravel aquifer (0.1-0.35) (Walton, 1991). Kruseman and de Ridder (2000) note that when using the Neuman method unreasonable low specific yield values are often obtained because flow in the saturated capillary fringe above the watertable is neglected. Due to the unreliability of the Neuman method in determining specific yield an approach suggested by Kasenov (2006) was used (see Section 2.3.2) (Table 3-19). This method is appropriate when the sediment size is no greater than coarse-grained sand with a hydraulic conductivity no greater than 7.0×10^{-4} m/s (Kasenov, 2006). The results derived using the Kasenov method are within the expected range for a sand and gravel aquifer.

Table 3-19: Specific yield results using the Kasenov (2006) method of estimation.

LOCATION	SPECIFIC YIELD
Mooretown Bridge	0.27
Nurney Bridge	0.14
Greyabbey Road	0.20
Sewage Treatment Works	0.27
Frenchfurze Road	0.30

3.4.6.5 PUMP TEST CONCLUSIONS

Various methods were selected which best represented the aquifer conditions in the area of the pump test. For the pump tests at Mooretown, Nurney, and Frenchfurze the hydraulic conductivity results from the Neuman method are considered the most representative, while at Greyabbey and the Sewage Treatment Works the estimates using the Walton method are considered the most representative. The average hydraulic conductivity estimated for Mooretown Bridge, Nurney Bridge, Greyabbey Road, the Sewage Treatment Works and Frenchfurze Road, are $2.1x10^{-4}$ m/s, $1.6x10^{-5}$ m/s, $5.8x10^{-5}$ m/s, $2.2x10^{-4}$ m/s and $3.5x10^{-4}$ m/s, respectively.

The results of the recovery tests are summarized and compared to the pumping test in Table 3-20. The recovery tests result in hydraulic conductivity values between two and four times greater than the pump tests. Recovery tests can be more accurate than pumping test analysis because there are no pump vibrations or turbulence with which to contend (Kasenow, 2006). However, in this case, the discrepancy between the recovery tests and the pump tests may be due to the early recovery of water levels observed during rain events in some of the pump tests preceding the recovery test. Another explanation is that the early recovery of water levels observed may be due to a possible reduction in pumping rates in some of the pump tests preceding the recovery test. Either of these events would affect the analyses of the pump and recovery tests.

Table 3-20: Comparison of the estimates of hydraulic conductivity from the recovery and pump tests.

	RECOVERY TEST (m/s)	PUMP TEST (m/s)
Mooretown Bridge (71+00)	$9.2 x10^{-3}$	$2.1x10^{-4}$
Nurney Bridge (84+15)	$7.7 x10^{-4}$	$1.6x10^{-5}$
Greyabbey Road	$1.8x10^{-4}$	$5.8x10^{-5}$
Sewage Treatment Works	$2.9x10^{-4}$	$2.2x10^{-4}$
Frenchfurze Road		$3.5x10^{-4}$

3.5 *CONCLUSIONS*

1) The boreholes from the site investigation indicate that the stratigraphy in the area around the Kildare Town Bypass consists of an upper glacial till layer dominated by clays and silts, which is absent in places, and a lower glacial outwash unit dominated by sands and gravels and hosts the Mid-Kildare Aquifer.
2) The particle size distribution analyses show that the methods which use the effective grain size (i.e. Hazen, Pavchich and Harlemann) over-predict the hydraulic conductivity for coarse-grained soils when compared to the methods which use geotechnical parameters (Kozeny-Carman-Bear and Mbonimpa *et al.*).
3) The particle size distribution analyses indicate that the hydraulic conductivity for the clay and silt dominated till is significantly lower (2 to 3 orders of magnitude) than the sands and gravels of the glacial outwash that were tested by the pumping and recovery tests.
4) The hydraulic conductivity estimated from the variable head tests ranged from $1x10^{-7}$ to $8x10^{-4}$ m/s (falling head) and $2x10^{-6}$ to $6x10^{-4}$ m/s (rising head).
5) The correlation was poor between the variable head tests conducted in the same location, with the hydraulic conductivity values derived from four out of twelve tests being two orders of magnitude below those derived from the rising head tests, three out of twelve tests being one order of magnitude below the rising head tests, and only five out of twelve tests having the same order of magnitude as rising head tests at the same location.
6) The hydraulic conductivity values calculated from the falling head tests would be expected to be less than those calculated from the rising head tests due to the possibility of siltation of the borehole in the former or due to loosening of the base by seepage forces in the latter. However, the magnitude of the difference in some of the tests is unexpected.
7) The study into the errors in intake factor values used in the calculations for hydraulic conductivity in Appendix B found that the errors in the intake factor were not great enough to account for the differences found in the hydraulic conductivity estimated in the previous rising and falling head tests.
8) The pump test methods that account for partial penetration generally give a lower hydraulic conductivity than those that do not. This is the reverse of what would generally be expected and may reflect limitations in the curve-matching technique.

9) The estimates of hydraulic conductivity of the sands and gravels estimated from the pump tests varied from $1.6x10^{-5}$ m/s to $3.5x10^{-4}$ m/s and in general increased from west to east.

10) The hydraulic conductivity of the sands and gravels of the glacial outwash deposit varies from $1.8x10^{-4}$ to $9.2x10^{-3}$ m/s as calculated from recovery tests, but did not show the same trend of increasing hydraulic conductivity from west to east.

11) The hydraulic conductivity values determined from recovery tests were two to four times greater than those determined from the pump tests. The discrepancy between the recovery tests and the pump tests may be due to recovery of water levels during the pump tests.

12) The results from the pumping test are considered to be the most representative of the hydraulic conductivity as they test the largest volume of ground and thus are best able to account for the heterogeneities in the soil.

13) The specific storage values calculated from the pumping tests had an average of $4.6x10^{-4}$ /m which is reasonable for a sand and gravel aquifer.

14) The specific yield values calculated from using the Neuman method were considered to give an unreasonably low value of specific yield so the Kasenov method was used. The Kasenov method indicated that the specific yield ranges between 0.14 and 0.30.

CHAPTER 4

GROUNDWATER RESPONSE TO EXCAVATION AND DEWATERING

4.1 INTRODUCTION

This chapter reviews the dewatering history of the Kildare Town Bypass and back-analyses the hydraulic conductivity of the ground along the motorway using the recorded pumping and groundwater drawdown data, simple Thiem models, and flow nets. Examining the groundwater response during dewatering is a useful exercise to define the aquifer properties and to learn which soil testing and investigation methods conducted prior to the dewatering of the Kildare Town Bypass produced the most useful and accurate results.

This chapter includes a summary of the schedule of the dewatering of the excavation, the groundwater levels recorded during construction, and an analysis of the dewatering requirements for the Kildare Town Bypass using traditional methods. The recorded groundwater level response during the excavation is used to estimate the hydraulic conductivity of the aquifer through back-analysis and compared to the dewatering estimates using traditional methods. A table of the measured groundwater levels at the excavation can be found in Appendix D.

4.2 SCHEDULE FOR DEWATERING THE EXCAVATION

The Kildare Town Bypass project required an excavation for 3.5 km in length and about 34 m wide to a depth of 3.3 m below the lowest point of the finished road level. This excavation progressed initially in stages of 500 m length; however, this was increased to 1000 m in May 2002 together with some isolated excavations for five bridge foundations. Dewatering commenced on May 29, 2001 at the Tully Bridge site with the first stage of the main excavation starting at Ch. 69+00 in August, 2001. As the stages were completed, the water level was allowed to recharge up to the weir level. The Kildare Town Bypass has a groundwater control system consisting of weirs and outlet pipes which maintain the groundwater within limiting levels. These weir levels are approximately 1.75 m above the finished road surface and represent the highest groundwater level possible in the vicinity of the Kildare Town Bypass after a stage was completed.

The excavations between Ch. 69+00 and 104+00 intersected the Mid-Kildare Aquifer. The motorway excavation west of Ch. 69+00 is outside the area defined by Wright (1988) as the Mid-Kildare Aquifer and so is not considered in this study. The

groundwater levels, the water pumped from the main excavation and the water pumped from the excavations for the bridge foundations were recorded by the engineering site staff.

During construction the groundwater levels were monitored in boreholes at 50 m intervals along the excavation from Ch. 69+20 to 103+70; of those, fifteen wells monitor the groundwater levels after construction at approximately every 100 m. Construction began west of Kildare Town (69+00) and progressed towards the east (104+00). The monitoring of the water extracted from the excavation occurred at the Mooretown, Nurney, Greyabbey, and Tully Bridge sites, the Storm Tanks site and in the main carrier drain for the site (Figure 4.1). The Storm Tanks are located just outside the motorway site approximately 300 m east of Tully Bridge at Ch. 96+00 and store the storm water collected in the drains of the bypass. The main carrier drain is a large central drain beneath the road which is part of the groundwater control system. The flows in the main carrier drain were recorded to measure the amount of water extracted during dewatering and after construction was completed.

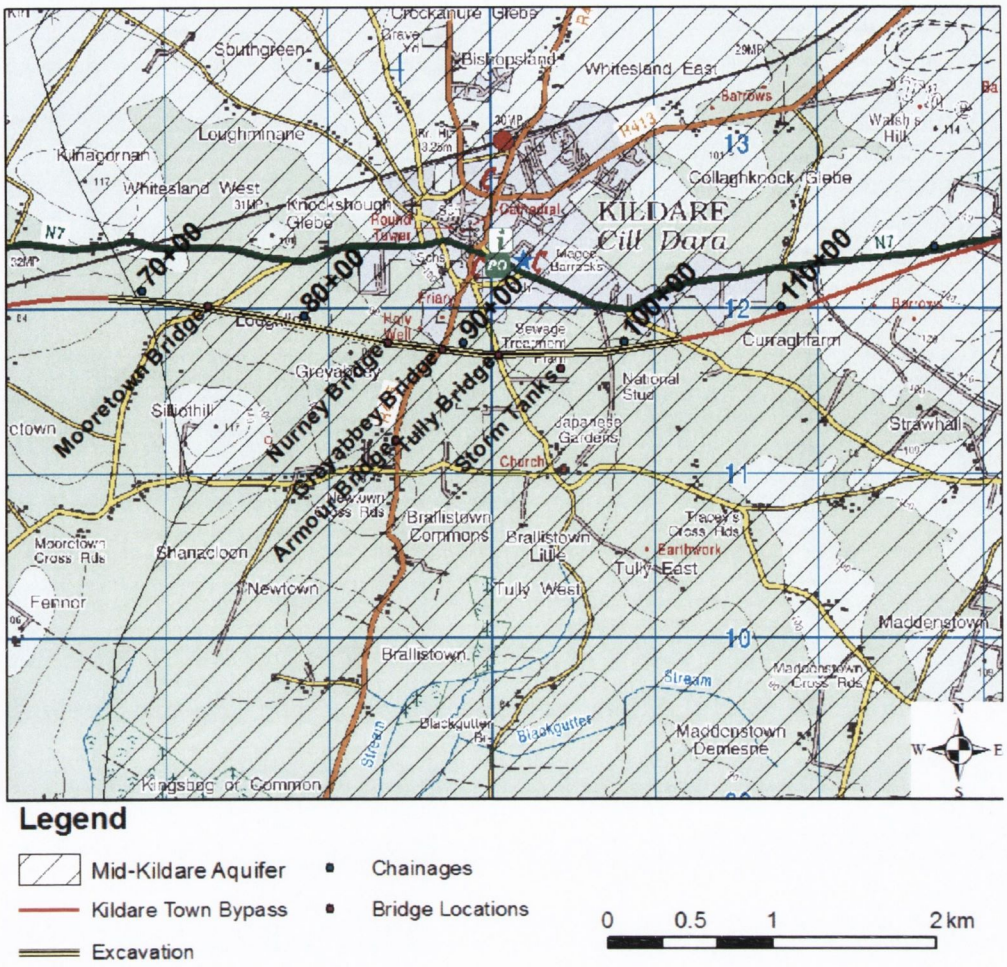


Figure 4.1: Location of chainages, bridges, and storm tanks along the excavated section of the Kildare Bypass

The volume of water pumped during the 2.25 year construction period was approximately 14.5×10^6 m^3 (Farrell and Devine, 2006). Figure 4.2 illustrates the total pumped from the excavation through time and includes rainfall and runoff into the excavation in addition to the dewatering of the excavation. Figure 4.3 shows the rainfall over the construction period.

The following sections summarise the dewatering and discharges of the open sections of the excavation through time. This does not represent the volume of water lost to the aquifer as it includes rain that fell on the cutting and surface water that flowed into the cutting. The water loss was also mitigated by the water pumped to the National Stud and Japanese Gardens and by the water lost through the base of the settling ponds at Nurney and at Mooretown Bridge which recharged the aquifer. The settling ponds were areas where water from the excavation was pumped to allow the fines to settle out of suspension. Farrell and Devine (2006) estimated the surface water contribution (rainfall

and runoff from the catchment area of the excavation) to the discharge to be $0.7x10^6$ m^3 over the 2.25 year construction period. This makes a revised estimate on the water lost to the aquifer of approximately $13.8x10^6$ m^3. This indicates that rainfall was approximately 5% of the pumped water out of the excavation. A simple calculation can be conducted to determine the expected rainfall component in the excavation. If the assumptions are made that the excavation is 500 m long and 34 m wide and has a rainfall of 2 mm/d (average daily rainfall over 25 years from Osberstown and Naas) then there would be 34 m^3/d of water pumped out of the entire excavation which would be directly due to rainfall. This value is less than that reported by Farrell and Devine (2006) as their value includes the runoff from the catchment area of the excavation. Also this value is for a 500 m long open excavation but at times during the actual excavation the excavated length was up to 1000 m long. A detailed table of the pumped water out of the excavation can be found in Appendix E. A summary of the methods used to dewater the excavation and the progression of the excavation can be found in Tables 4-1, 4-2, and 4-3.

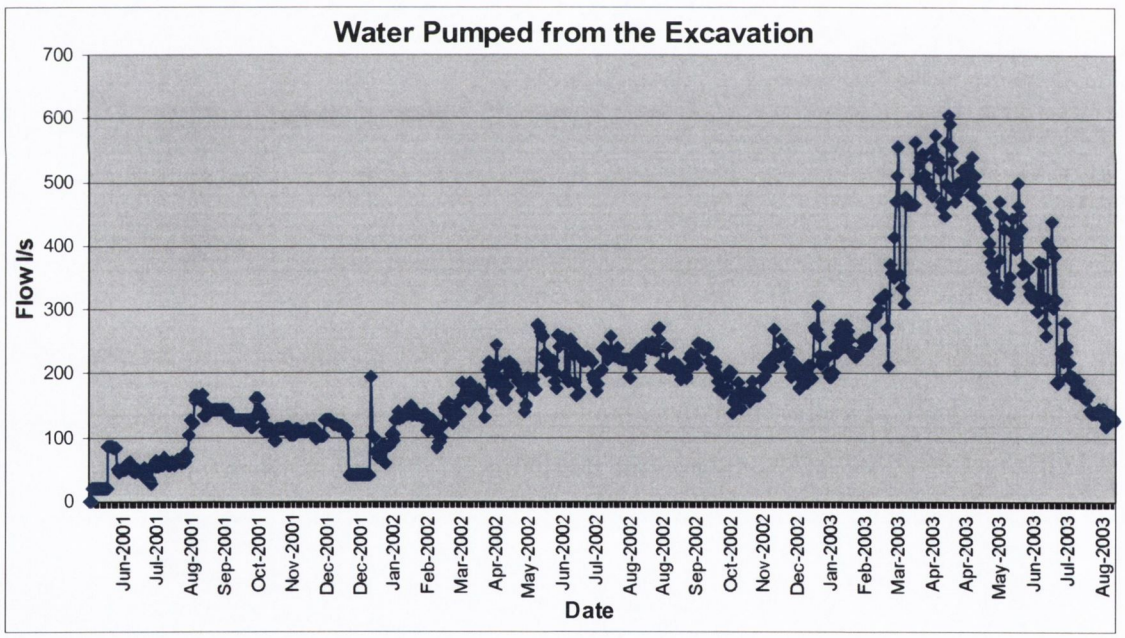


Figure 4.2: Total flow from the excavation for the Kildare Town Bypass during dewatering (modified from Farrell and Devine, 2006).

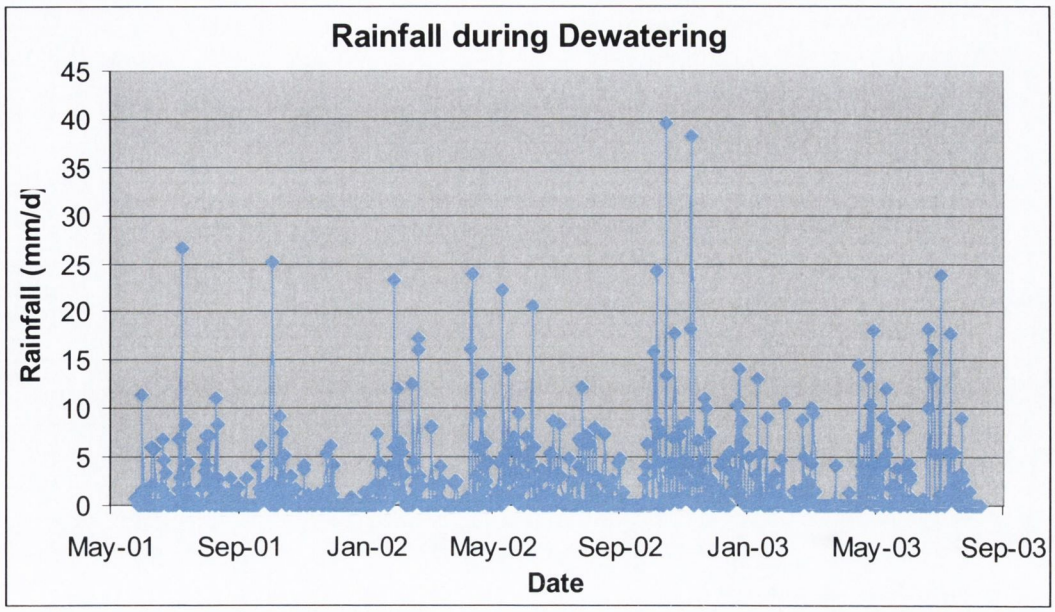


Figure 4.3: Rainfall measured at Naas and Osberstown during dewatering (Brown, 2007).

4.2.1 2001

Dewatering began for the Kildare Bypass at the Tully Bridge site (Ch 91+70) on May 31, 2001 (Figure 4.1). The Tully Bridge site was excavated down to 80.3 mOD (Malin Head), a depth of 9.5 m. The pumping level was raised to be 84.85 mOD on December 20, 2001, and it continued to be dewatered until construction was completed on October 23, 2002. This was the only location to be dewatered until August 13, 2001. The amount of water abstracted was not measured regularly until June 18 after which the flows were measured daily. On August 13 the main excavation (Ch 69+00 to 74+00), including the Mooretown Bridge site (71+00), began to be dewatered. On August 16 the Nurney Bridge site (Ch 85+00) began to be dewatered and was excavated to 82.5 mOD. Dewatering continued through the end of the year and a summary of the measured flows in 2001 can be found in Table 4-1. The discharge from the pumped excavation was measured using a combination of: a fixed installation flow meter; a Panametrics device, which measures instantaneous flows where possible on individual pumps; and a Valeport current meter in the carrier pipe. The flows were measured hourly and calibrated weekly using a float to determine flow using the velocity of flow and depth. The abstracted water from Tully Bridge was discharged at the National Stud, while the abstracted water from the main excavation was discharged through the main carrier drain and the water from Nurney Bridge and Greyabbey Bridge was discharged at Armour Bridge (Figure 4.1). The flow was verified by comparing the flows measured by the Panametrics device at the wells and

Valeport device within the main carrier drain. An example of this would be that on January 18, 2001, the Panametric device measured a total flow of 25 l/s in the main carrier drain while the Valeport device recorded a flow of 24 l/s.

Table 4-1: Summary of measured daily flows during 2001

EXCAVATION	DATE	FLOW RATE	AVERAGE FLOW RATE
Tully Bridge (flow rate measured by a combination of Valeport, panametrics, and mainstream devices)	May 31 - June 11, 2001	20 l/s	20 l/s
	June 12 - 18, 2001	84 - 86 l/s	85 l/s
	June 18 - 30, 2001	46 - 60 l/s	52 l/s
	July 1 - 15, 2001	32 - 52 l/s	43 l/s
	July 16 - 31, 2001	28 - 67 l/s	57 l/s
	August 1 - 15, 2001	56 - 66 l/s	61 l/s
	August 16 - 31, 2001	46 - 67 l/s	57 l/s
	September 1 - 15, 2001	46 l/s	46 l/s
	September 16 - 30, 2001	45 l/s	45 l/s
	October 1 - 15, 2001	30 - 54 l/s	42 l/s
	October 16 - 31, 2001	24 - 32 l/s	29 l/s
	November 1 - 15, 2001	29 - 33 l/s	31 l/s
	November 16 - 30, 2001	21 - 29 l/s	25 l/s
	December 1 - 15, 2001	29 - 33 l/s	30 l/s
	December 16 - 31, 2001	15 - 29 l/s	20 l/s
Main excavation (69+00 - 74+00) including Mooretown Bridge (flows measured using panametrics and Valeport on Dec 20 measured with Mainstream)	August 13 - 14, 2001	15 l/s	15 l/s
	August 15 - 31, 2001	40 - 50 l/s	42 l/s
	September 1 - 15, 2001	50 l/s	50 l/s
	September 16 - 30, 2001	44 - 50 l/s	45 l/s
	October 1 - 15, 2001	42 - 59 l/s	51 l/s
	October 16 - 31, 2001	31 - 42 l/s	35 l/s
	November 1 - 15, 2001	31 - 40 l/s	36 l/s
	November 16 - 30, 2001	40 - 45 l/s	42 l/s
	December 1 - 15, 2001	50 - 56 l/s	53 l/s
	December 16 - 31, 2001	25 - 51 l/s	33 l/s
	December 20 - 31, 2001	8 - 31 l/s	14 l/s
Nurney Bridge (flow rate measured by a combination of Valeport, panametrics, and Kent meters)	August 16 - 19, 2001	20 l/s	20 l/s
	August 20 - 31, 2001	47 - 59 l/s	53 l/s
	September 1 - 15, 2001	47 l/s	47 l/s
	September 16 - 30, 2001	38 l/s	38 l/s
	October 1 - 15, 2001	36 - 47 l/s	40 l/s
	October 16 - 31, 2001	37 - 51 l/s	46 l/s
	November 1 - 15, 2001	41 - 51 l/s	43 l/s
	November 16 - 30, 2001	36 - 44 l/s	40 l/s
	December 1 - 15, 2001	34 - 42 l/s	39 l/s
	December 16 - 20, 2001	33 - 35 l/s	33 l/s

4.2.2 2002

From January to March 2002 dewatering continued from Ch. 69+00 - 74+00 and the Nurney (85+00), Tully (91+70), and Greyabbey (87+50) bridge locations. Excavation commenced at the Greyabbey north abutment on March 11, 2002 with dewatering following on March 21. Some of the abstracted water from Mooretown Bridge was discharged near the Nurney Bridge site. It was not possible to accurately distinguish flows

attributed to Nurney Bridge during this brief re-routing of discharge from Mooretown Bridge, however significant increases in discharge volumes were measured by the Kent meters at Nurney Bridge (increase from 49 l/s to 95 l/s).

In April 2002, the main excavation advanced to the section between Ch. 74+00 and 80+00, while the section from Ch. 69+00 - 73+50 was allowed to recover. Dewatering at the Storm Tanks began on April 24, 2002 (Figure 4.1). From May until August 2002, dewatering in the main excavation advanced to the section between Ch. 75+00 and 85+00. A section of completed motorway up to Ch. 77+50 began to recover, except for the section from Ch. 73+50 - 75+00 at Mooretown Bridge in the third week in August, from which time the dewatering extended from Ch. 77+50 up to Greyabbey Bridge (Ch 87+50).

In September 2002 the main excavation advanced to the section between Ch. 80+00 and 90+00 and at the Tully Bridge (91+70) site and at the Storm Tanks, allowing the area up to Ch. 80+00 to recover. In October 2002, the main excavation advanced to the section between Ch. 82+00 and 92+00 and at the Storm Tanks. The section up to Ch. 82+00 was allowed to recover, which caused the water levels to rise significantly in that area. Dewatering finished at Mooretown which was allowed to recover to the weir levels. In November 2002, the main excavation advanced to the section between Ch. 82+00 and 93+50. The section up to Ch. 82+00 was allowed to recover and a significant rise in water levels was observed (up to 2.5 m from end of October to end of November). The water table levels at the Mooretown Bridge site recovered to the weir level.

In December 2002, the main excavation advanced to the section between Ch. 85+00 and 95+00. The section up to Ch. 85+00 was allowed to recover and approximately one kilometre, from Ch. 72+50 to 82+50, recovered to the weir level. The total flow in the main carrier drain was greater than the actual abstracted volumes as surface water formed part of the total flow. A summary of the measured flows in 2002 can be found in Table 4-2.

Table 4-2: Summary of daily flows in 2002.

EXCAVATION	DATE	FLOW RATE (l/s)			AVERAGE FLOW RATE (l/s)		
		V/ P/ M	Kent		V / P / M	Kent	
Tully Bridge (flow rate measured by a combination of Valeport, panametrics, and mainstream devices or a Kent meter)	January 1 - 15, 2002	14 - 16	N/A		15	N/A	
	January 16 - 31, 2002	15 - 18	N/A		16	N/A	
	February 1 - 15, 2002	17 - 21	N/A		20	N/A	
	February 16 - 28, 2002	19 - 25	N/A		22	N/A	
	March 1 - 15, 2002	21 - 24	21 - 26		22	25	
	March 16 - 31, 2002	18 - 20	19 - 24		19	22	
	April 1 - 15, 2002	14 - 19	15 - 20		17	18	
	April 16 - 30, 2002	15 - 17	15 - 23		16	18	
	May 1 - 15, 2002	15 - 19	14 - 17		17	16	
	May 16 - 31, 2002	15 - 16	14 - 18		15	16	
	June 1 - 15, 2002	15 - 17	18 - 22		16	20	
	June 16 - 30, 2002	12 - 19	17 - 21		17	19	
	July 1 - 15, 2002	18 - 23	15 - 43		21	25	
	July 16 - 31, 2002	40 - 46	40 - 42		43	41	
	August 1 - 15, 2002	34 - 43	38 - 40		40	40	
	August 16 - 31, 2002	30 - 34	35 - 39		33	36	
	September 1 - 15, 2002	27 - 32	30 - 36		29	33	
	September 16 -30, 2002		27 - 30			28	
	October 1 - 15, 2002		27			27	
	October 16 - 23, 2002		27			27	
		Pan/Val	Main.	Weir	Pan/Val	Main.	Weir
Main excavation (flows measured using Valeport, panametrics, mainstream, and weir after July 4) Jan - Mar (69+00 - 74+00) Apr (74+00 - 80+00) May - Jun (75+00 - 85+00) Aug (77+50 - 87+50) Sep (80+00 - 90+00) Oct (82+00 - 92+00) Nov (82+00 - 93+50) Dec (85+00 - 95+00)	January 1 - 15, 2002	15 - 34	12 - 38	N/A	23	23	N/A
	January 16 - 31, 2002	24 - 44	42 - 55	N/A	33	48	N/A
	February 1 - 15, 2002	38 - 50	57 - 71	N/A	46	65	N/A
	February 16 - 28, 2002	38 - 53	64 - 78	N/A	44	69	N/A
	March 1 - 15, 2002	38 - 84	42 - 86	N/A	59	63	N/A
	March 16 - 31, 2002	43 - 76	19 - 73	N/A	63	37	N/A
	April 1 - 15, 2002	42 - 85	43 - 85	N/A	57	71	N/A
	April 16 - 30, 2002	44 - 74	12 - 76	N/A	56	44	N/A
	May 1 - 15, 2002	32 - 54	25 - 57	N/A	42	37	N/A
	May 16 - 31, 2002	51 - 125	54 - 109	N/A	74	74	N/A
	June 1 - 15, 2002	59 - 92	58 - 142	N/A	111	82	N/A
	June 16 - 30, 2002	57 - 123	N/A	N/A	104	N/A	N/A
	July 1 - 15, 2002	94 - 136	33 - 117	72 - 100	123	98	85
	July 16 - 31, 2002	49 - 99	104 -135	73 - 92	84	109	79
	August 1 - 15, 2002	74 - 119	77 - 132	73 - 117	95	108	89
	August 16 - 31, 2002	104 -122	117 -136	92 - 106	114	127	100
	September 1 - 15, 2002	87 - 111	110 -126	90 - 96	96	119	94
	September 16 -30, 2002	97 - 139	89 - 148	89 - 154	122	121	113
	October 1 - 15, 2002	45	75 - 109	58 - 86	45	97	77
	October 16 - 31, 2002	40 - 218	74 - 165	62 - 201	155	112	122
	November 1 - 15, 2002	242 -260	135 -168	144	254	146	144
	November 16 -30, 2002	259 -362	170 -249	201 -277	298	194	230
	December 1 - 15, 2002	240 -356	175 -235	212 -291	284	202	231
	December 16 - 31, 2002	201 -210	185 -207	157 -253	205	189	195

EXCAVATION	DATE	FLOW RATE (l/s)			AVERAGE FLOW RATE (l/s)		
		Pan/Val	Kent		Pan/Val	Kent	
Nurney Bridge (flow rate measured by a combination of Valeport, panametrics, and Kent meters)	January 1 - 15, 2002	34 - 162	N/A		55	N/A	
	January 16 - 31, 2002	20 - 72	N/A		44	N/A	
	February 1 - 15, 2002	45 - 58	44 - 47		53	46	
	February 16 - 28, 2002	42 - 67	22 - 48		52	32	
	March 1 - 15, 2002	32 - 54	14 - 49		39	34	
	March 16 - 31, 2002	N/A	49 - 95		N/A	49	
	April 1 - 15, 2002	70 - 142	56 - 110		99	59	
	April 16 - 30, 2002	87 - 133	27 - 127		113	97	
	May 1 - 15, 2002	67 - 113	42 - 117		99	85	
	May 16 - 31, 2002	71 - 119	37 - 119		99	70	
	June 1 - 15, 2002	60 - 67	43 - 62		64	55	
	June 16 - 30, 2002	26 - 55	34 - 60		43	46	
	July 1 - 15, 2002	35 - 53	8 - 35		45	23	
	July 16 - 31, 2002	32 - 49	5 - 21		35	12	
	August 1 - 15, 2002	33	9 - 30		33	17	
	August 16 - 28, 2002	5 - 41	1 - 30		29	14	
		Pan/Val	Kent		Pan/Val	Kent	
Greyabbey Bridge (flow rate measured by a combination of Valeport, panametrics, and Kent meters)	March 21 - 31, 2002	16 - 32	16 - 17		22	17	
	April 1 - 15, 2002	12 - 35	3		17	3	
	April 16 - 30, 2002	23 - 58	3 - 33		32	14	
	May 1 - 15, 2002	24 - 28	8 - 27		26	19	
	May 16 - 31, 2002	21 - 45	5 - 25		35	14	
	June 1 - 15, 2002	18 - 26	25 - 29		23	26	
	June 16 - 30, 2002	22 - 24	24 - 26		23	25	
	July 1 - 15, 2002	20 - 28	22 - 25		22	23	
	July 16 - 31, 2002	20 - 84	21 - 24		30	23	
	August 1 - 15, 2002	22 - 32	16 - 25		28	24	
	August 16 - 31, 2002	28 - 49	N/A		34	N/A	
	September 1, 2002	35			35		
		Pan/Val	Kent		Pan/Val	Kent	
Storm Water Tanks (flow rate measured by a combination of Valeport, panametrics, and Kent meters)	April 24 - 30, 2002	17			17		
	May 1 - 15, 2002	13 - 24			18		
	May 16 - 31, 2002	19 - 53			26		
	June 1 - 15, 2002	21 - 23			22		
	June 16 - 30, 2002	18 - 23	20 - 21		19	21	
	July 1 - 15, 2002	16 - 21	20 - 21		18	20	
	July 16 - 31, 2002	16 - 22	19 - 20		19	20	
	August 1 - 15, 2002	18 - 24	19		21	19	
	August 16 - 31, 2002	15 - 17	18 - 19		16	19	
	September 1 - 15, 2002	15 - 16	18		16	18	
	September 16 -30, 2002		17 - 18			18	
	October 1 - 15, 2002		17 - 18			17	
	October 16 - 31, 2002		17 - 20			19	
	November 1 - 15, 2002	16 - 17	20 - 21		17	20	
	November 16 -30, 2002	17 - 19	19 - 21		18	19	
	December 1 - 15, 2002	17 - 20	18 - 20		18	19	
	December 16 - 31, 2002	16	18 - 19		16	18	

4.2.3 2003

In January 2003, the main excavation advanced to the section between Ch. 88+00 and 96+00 while water levels in the section up to Ch. 88+00 were recovering and the area between Ch. 72+50 and 82+50 recovered to the weir level. The abstracted water from the Storm Tanks was discharged to the lake at the National Stud, the surface water from the cutting and extracted water from Ch. 92+00 and 94+00 was discharged into the National Stud stream near the Sewage Treatment Works and the main carrier drain discharged into Simpson's Stream. During February 2003, the main excavation advanced to between Ch. 89+00 and 99+00 while the section up to Ch. 88+00 was allowed to recover and the section between Ch. 72+50 and 82+50 was recovered to the weir level.

During March 2003, the main excavation progressed to between Ch. 89+00 and 100+00 which by the end of March 2003 had shortened to between Ch. 92+60 and 100+00. Excavation beyond Ch. 100+00 was mostly above water table level, and up to Ch. 92+60 was recovered to the weir level. A permeable gravel lens was met near Ch. 100+00 which resulted in significantly higher dewatering flows by comparison with flow rates in January and February of 2003. During April 2003, dewatering and construction occurred between Ch. 89+00 and 102+00. The length was reduced to between Ch. 94+00 and 102+00 by the end of April 2003, at which time recovery extended up to Ch. 94+00. In May 2003, dewatering was in operation from Ch. 94+00 to 102+00 during the first half of May, and from Ch. 95+50 up to 102+00 at end of May. The section up to Ch. 88+00 and from Ch. 89+00 to 95+50 was allowed to recover by the end of May. Dewatering pumps were switched off to Ch. 95+50 on May 15.

In June 2003, dewatering for the main excavation extended from Ch. 96+50 up to 103+00 for the first half of the month but was reduced down to Ch. 99+50 to 103+00 for the remainder. The section up to Ch. 88+00 and from Ch. 89+00 to 99+00 was allowed to recover. Limited pumping was required at Ch. 103+00 in order to complete the construction over the last 150 m to Ch. 104+00. The water table elevation towards the east end recovered around 0.5 m due to the shutdown of pumps between Ch. 96+50 and 99+50, and at Ch. 100+00 (see Section 4.2 for groundwater levels). Water levels raised ~0.5 m between Ch. 97+00 and 104+00 by July 1. The permeable gravel lenses (near Ch. 100+00) in the excavation continued in July to have high dewatering flows. During July 2003, dewatering extended at Greyabbey and within the main excavation from Ch. 99+50 up to

103+00 for the first week of the month but was reduced down to just Ch. 101+50, which supplied the National Stud, for the remainder. The water table elevation between Ch. 97+00 and 104+00 recovered a further 1.2 m in July 2003. This was due to the removal of pumps between Ch. 99+50 and 104+00 and shutdown of the remaining pump at Ch. 100+00. By August 2003, dewatering was confined to Greyabbey Bridge as the passive groundwater control system neared completion. Dewatering continued at Ch. 101+50 until August 6 when it was shutdown. The last pump was shutdown around August 25. A summary of the measured flows in 2003 can be found in Table 4-3.

Table 4-3: Summary of dewatering daily flows for 2003.

EXCAVATION	DATE	FLOW RATE (l/s)			AVERAGE FLOW RATE (l/s)		
		Pan/Val	Main.	Weir	Pan/Val	Main	Weir
Main excavation (flows measured using Valeport, panametrics, Mainstream, and Weir) Jan (86+00 - 96+00) Feb (89+00 - 99+00) Mar (92+60 - 100+00) Apr (94+00 - 102+50) May (95+50 - 104+00) June (99+50 - 104+00) July (101+00-101+50) Aug 25 (dewatering complete)	January 1 - 15, 2003		175 -286	184 -231		203	200
	January 16 - 31, 2003		174 -222	183 -237		201	204
	February 1 - 15, 2003		212 -288			238	
	February 16 - 8, 2003		161 -320			289	
	March 1 - 15, 2003		270 -515			363	
	March 16 - 31, 2003	389 -401	320 -436		395	380	
	April 1 - 15, 2003		307 -439			362	
	April 16 - 30, 2003		317 -453			362	
	May 1 - 15, 2003		269 -360			307	
	May 16 - 31, 2003		180 -321			242	
	June 1 - 15, 2003		138 -279			204	
	June 16 - 30, 2003		121 -274			163	
	July 1 - 15, 2003		56 - 275			167	
	July 16 - 31, 2003		54 - 120			70	
	August 1 - 15, 2003		55 - 70			61	
	August 16 - 25, 2003		38 - 72			52	

		Pan/Val	Kent	Pan/Val	Kent
Storm Water Tanks (flow rate measured by a combination of Valeport, panametrics, and Kent meters)	January 1 - 15, 2003	25 - 28	18 - 19	27	19
	January 16 - 31, 2003	27 - 30	13 - 28	29	19
	February 1 - 15, 2003	31	8 - 21	31	13
	February 16 -28, 2003		7 - 11		8

		Panametrics	Panametrics
Sedimentation Pond at Mooretown Bridge (flow rate measured using a panametrics, Device)	March 3 - 15, 2003	300 - 484	367
	March 16 - 31, 2003	314 - 477	390
	April 1 - 15, 2003	371	371
	April 16 - 30, 2003	381	381
	May 1, 2003	352	352

		Siphon	Pump	Well	STW	Sip	Pmp	Well	STW
Supply lakes in the National Stud (Siphon at 96+00, Pencil Pumps at 96+40, Well at 100+00, and Sewage Treatment works at 96+00)	January 15 - 27, 2003		20 - 41				39		
	February 16 -28, 2003	50				50			
	March 1 - 15, 2003	50	30 - 40			50	38		
	March 16 - 31, 2003	34 - 50	30	48- 122		39	30	98	
	April 1 - 15, 2003	34 - 36	30	69- 107		35	30	80	
	April 16 - 30, 2003	34 - 36	30	88- 115		35	30	90	
	May 1 - 15, 2003	36 - 42	30	98- 115		38	30	106	
	May 16 - 31, 2003	32 - 42	30	98- 118		37	30	114	
	June 1 - 15, 2003		30 - 93	109-137			70	124	
	June 16 - 30, 2003		45 - 96	55 -21			87	86	
	July 1 - 15, 2003	56 - 65	44-102	55 - 83	14 - 24	59	59	76	16
	July 16 - 31, 2003	29 - 61	55 - 85		15 - 23	40	71		19
	August 1 - 15, 2003	29 - 55	55		16 -24	46	55		21
	August 16 - 25, 2003	53 - 56		19 - 24		56			23

4.2.4 2004 - POST CONSTRUCTION

After the completion of dewatering in August 2003, the supply of water to the lakes within the National Stud continued on a reduced phased basis until February 11, 2004 when the water levels had recovered sufficiently to sustain adequate levels within the lakes. Groundwater levels and flows were monitored from the end of August 2003 on a reduced frequency. A reduced number of monitoring wells (15 in total) were selected to be maintained after the bypass opened. The water table continued to recover over September, particularly on the eastern side of the tanked section by around 150 mm. The supply was in the order of 23.5 – 24 l/s and 23 - 23.5 l/s in September and October, respectively. Flow rates measured in the main carrier drain after construction was completed can be found in Table 4-4.

Table 4-4: Flows (l/s) in the main carrier drain after construction dewatering was complete in 2004

MEASUREMENT STATION	AUG 4	AUG 15	AUG 29	SEP 7	SEP 15	SEP 29	OCT 7	OCT 15	OCT 28
Ch69+00 LHS	0.0 *	0.0 *	0.0 *	0.0 *	0.0 *	0.0 *	0.0 *	0.0 *	0.0 *
Ch69+00 RHS	0.0 *	0.0 *	0.0 *	0.0 *	0.0 *	0.0 *	0.0 *	0.0 *	3.411 *
Ch83+00 LHS	0.0 *	0.0 *	0.0 *	0.0 *	0.0 *	0.0 *	0.0 *	0.0 *	0.0 *
Ch84+00 RHS	0.0 *	0.0 *	0.0 *	0.0 *	0.0 *	0.0 *	0.0 L/s *	0.0 L/s *	0.0 *
Ch88+20 RHS	0.0 *	0.0 *	0.12 *	0.11 *	0.0 *	0.0 *	0.0 *	0.0 *	0.0 *
Ch90+00 LHS	3.97 *	3.50 *	3.00 *	2.44 *	1.89 *	1.81 *	1.58 *	1.44 *	2.33 *
Ch90+00 RHS	4.86 *	4.36 *	3.64 *	2.86 *	2.31 *	2.11 *	1.92 *	1.75 *	2.67 *
Ch93+00 LHS	0.27 *	0.22 *	0.18 *	0.0 *	0.0 *	0.0 *	0.0 *	0.0 *	0.0 *
Ch93+00 RHS	0.0 *	0.0 *	0.0 *	0.0 *	0.0 *	0.0 *	0.0 *	0.0 *	0.0 *
Ch96+00 LHS	0.0 *	0.0 *	0.0 *	0.0 *	0.0 *	0.0 *	0.0 *	0.0 *	0.0 *
Ch97+00 RHS	0.0 *	0.0 *	0.0 *	0.0 *	0.0 *	0.0 *	0.0 *	0.0 *	0.0 *
Total	9.10	8.08	6.94	5.41	4.20	3.92	3.50	3.19	8.411
Mainstream Carrier Ch61+00	11.22	8.14	6.55	5.74	5.51	4.32	4.80	4.57	7.16

* indicates Kent meter reading

4.3 GROUNDWATER LEVELS DURING CONSTRUCTION

The groundwater levels, to the Malin Head datum, along the motorway at selected times during the dewatering are shown in Figures 4.4 to 4.20. The groundwater levels are lower towards the western edge of the bypass. The maximum annual water level variation measured in the Mid-Kildare Aquifer prior to construction was 2.9 m measured in monitoring borehole number 28 (MB28). On average, the annual water level variation was around 1.5 m. The final weir levels indicate the highest groundwater level possible at the cutting when construction is complete and are shown where they existed at the time in the

figures below. The groundwater levels used in Figures 4.4 through 4.20 can be found in Appendix D.

Until March 2002 the main excavation extended from Ch. 69+00 to 74+00 as well as at the Nurney (Ch 85+00), Greyabbey (Ch 87+50) and Tully (Ch 91+70) Bridge sites (Figure 4.4). There is an anomalously high groundwater head measured just before Nurney Bridge at approximately Ch 82+00 which was recorded in March, April and June. This may be the result of instrument error.

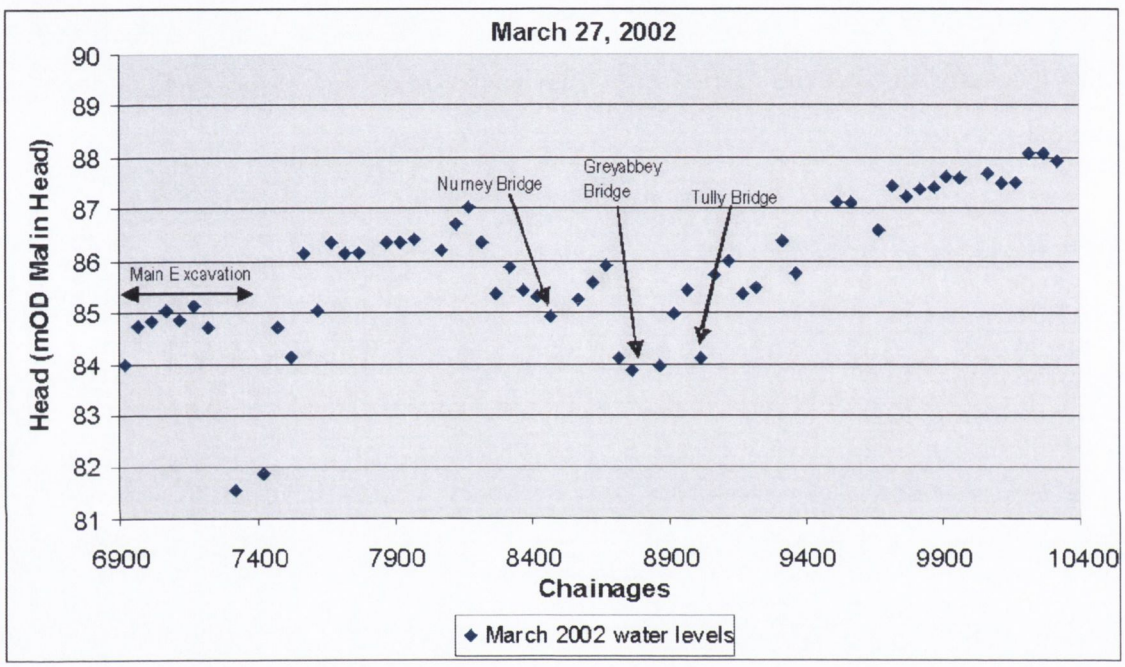


Figure 4.4: Groundwater levels after seven months of dewatering.

In April 2002, the main excavation had progressed to between Ch. 74+00 and 80+00 as well as at Nurney, Greyabbey, and Tully Bridges (Figure 4.5).

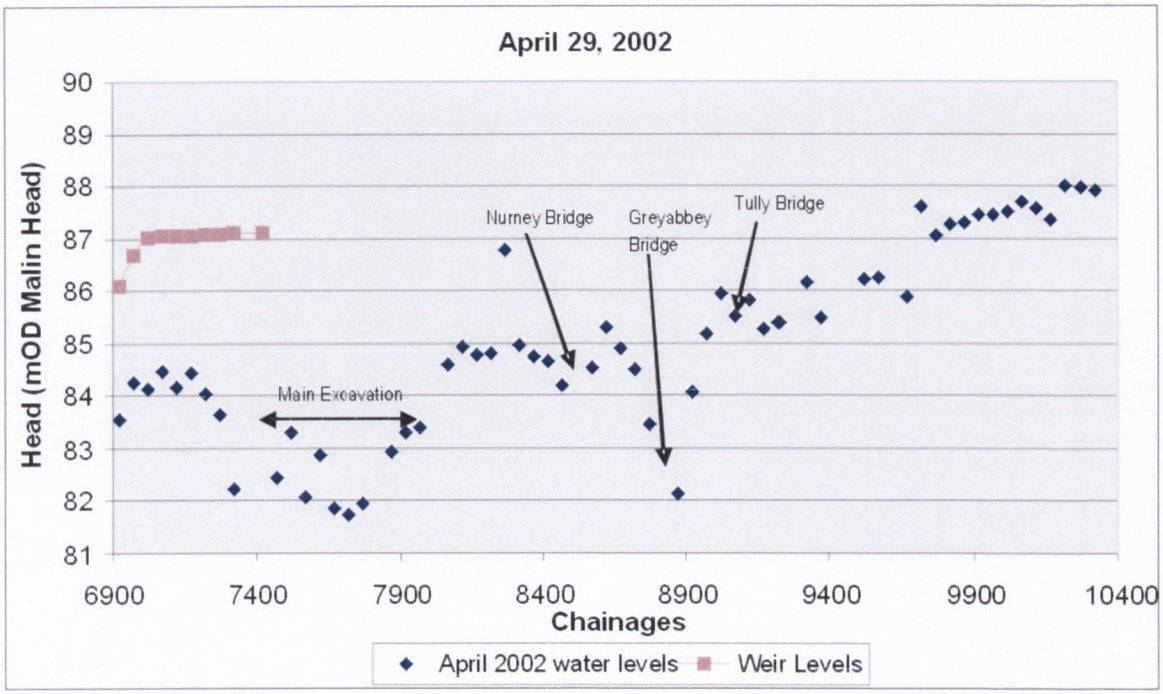


Figure 4.5: Groundwater levels at the end of April 2002 when the main excavation extended between Ch. 74+00 and 80+00. Note the lowered levels at Nurney (Ch. 85+00), Greyabbey (Ch. 87+50) and Tully (Ch. 91+70) Bridge sites.

From May to June 2002, the main excavation increased in length to one kilometre and progressed to between Ch. 75+00 and 85+00 as well as at Greyabbey, and Tully Bridges (Figure 4.6) allowing the area up to Ch. 75+00 to recover.

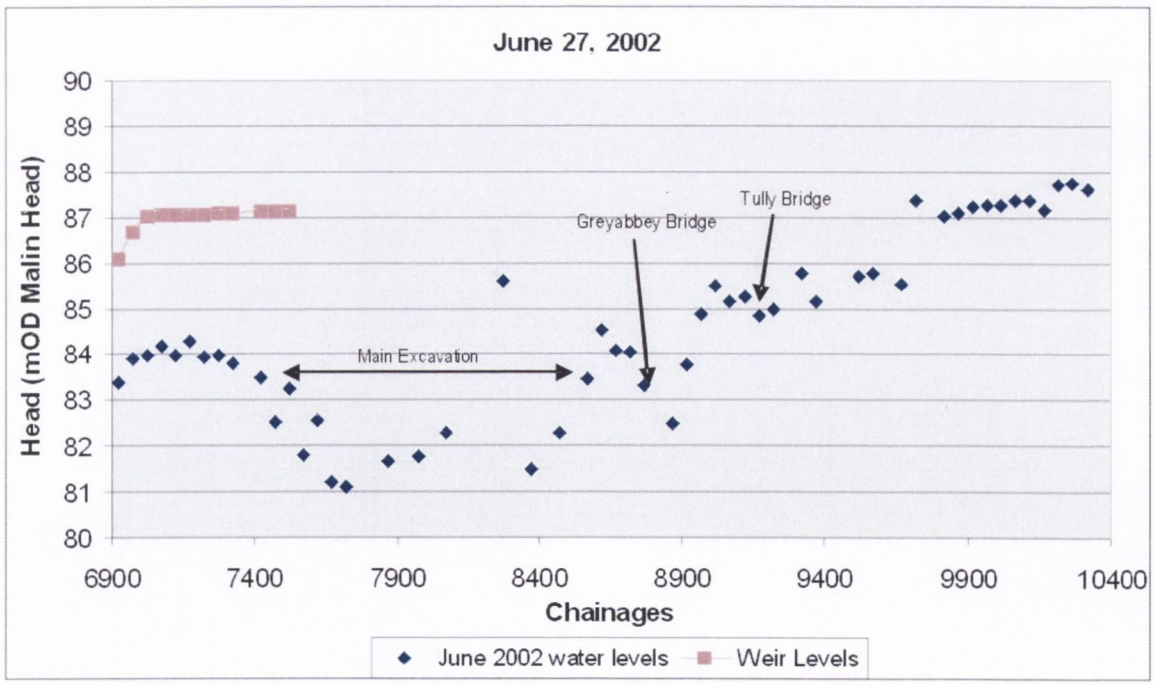


Figure 4.6: Groundwater levels at the end of June 2002 when the main excavation extended between Ch. 75+00 and 85+00. Note the lowered levels at Greyabbey (Ch. 87+50) and Tully (Ch. 91+70) Bridge sites.

In August 2002, the main excavation progressed to between Ch. 77+50 and 87+50 as well as at Tully Bridge (Figure 4.7) allowing the section up to Ch. 77+50 to recover.

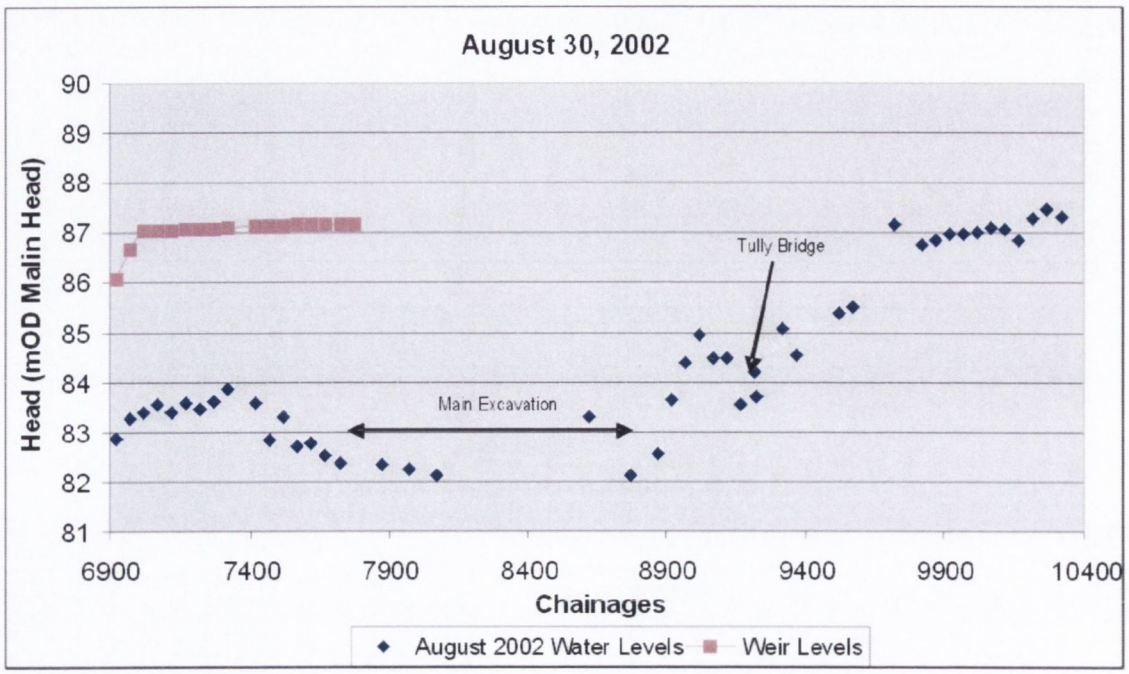


Figure 4.7: Groundwater levels at the end of August 2002 when the main excavation extended between Ch. 77+50 and 87+50. Note the lowered levels at the Tully (Ch. 91+70) Bridge site.

In September 2002, the main excavation progressed to between Ch. 80+00 and 90+00 as well as at Tully Bridge (Figure 4.8) allowing the section up to Ch. 80+00 to recover.

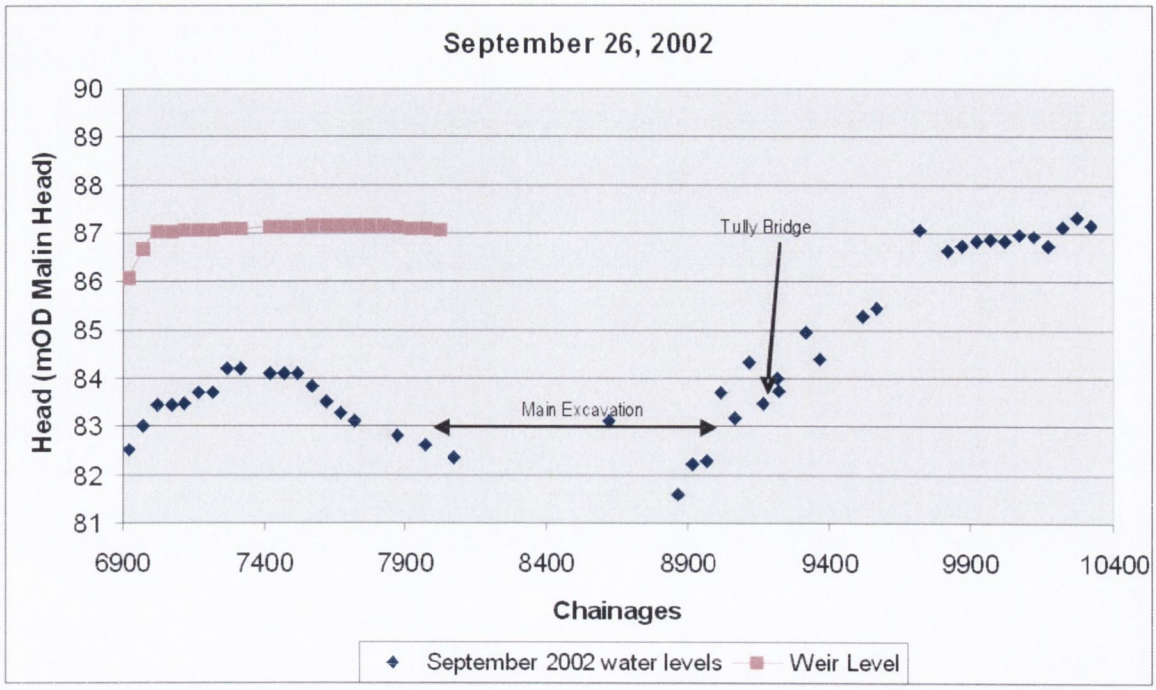


Figure 4.8: Groundwater levels at the end of September 2002 when the main excavation extended between Ch. 80+00 and 90+00. Note the lowered levels at the Tully (Ch. 91+70) Bridge site.

In October 2002, the main excavation progressed to between Ch. 82+00 and 92+00 (Figure 4.9) allowing the section up to Ch. 82+00 to recover.

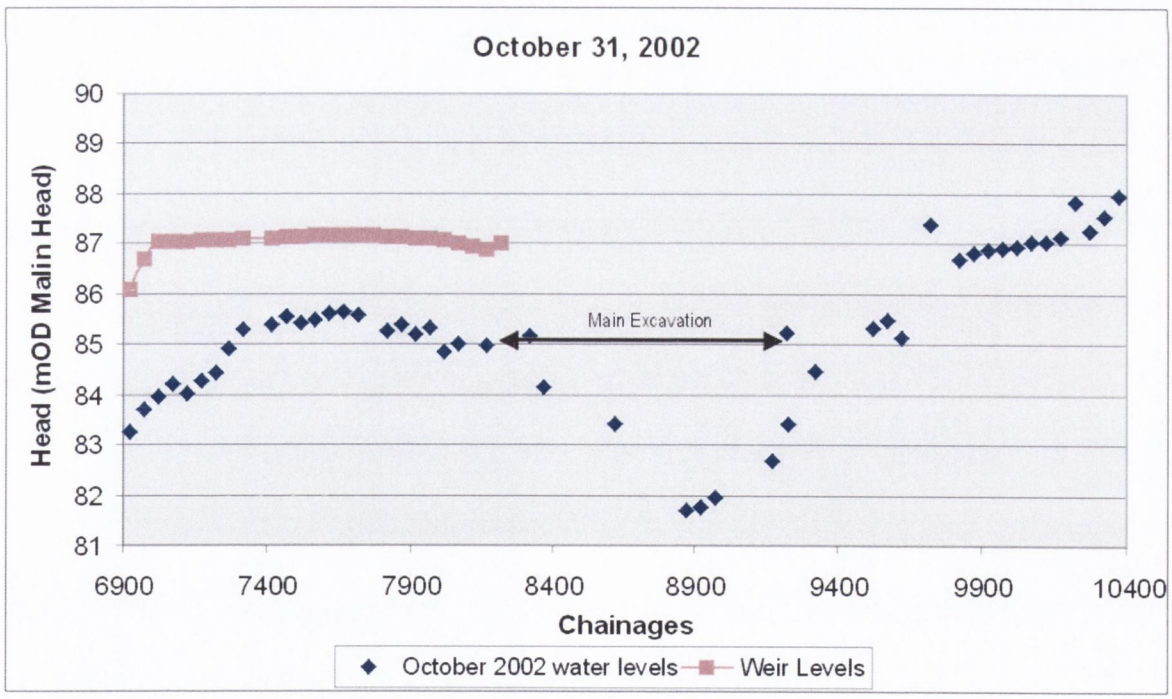


Figure 4.9: Groundwater levels at the end of October 2002 when the main excavation extended between Ch. 82+00 and 92+00.

In November 2002, the main excavation progressed to between Ch. 82+00 and 93+50 (Figure 4.10) allowing the section up to Ch. 82+00 to recover. An anomalously

high groundwater level was measured at Ch. 78+70 which may be the result of instrument error.

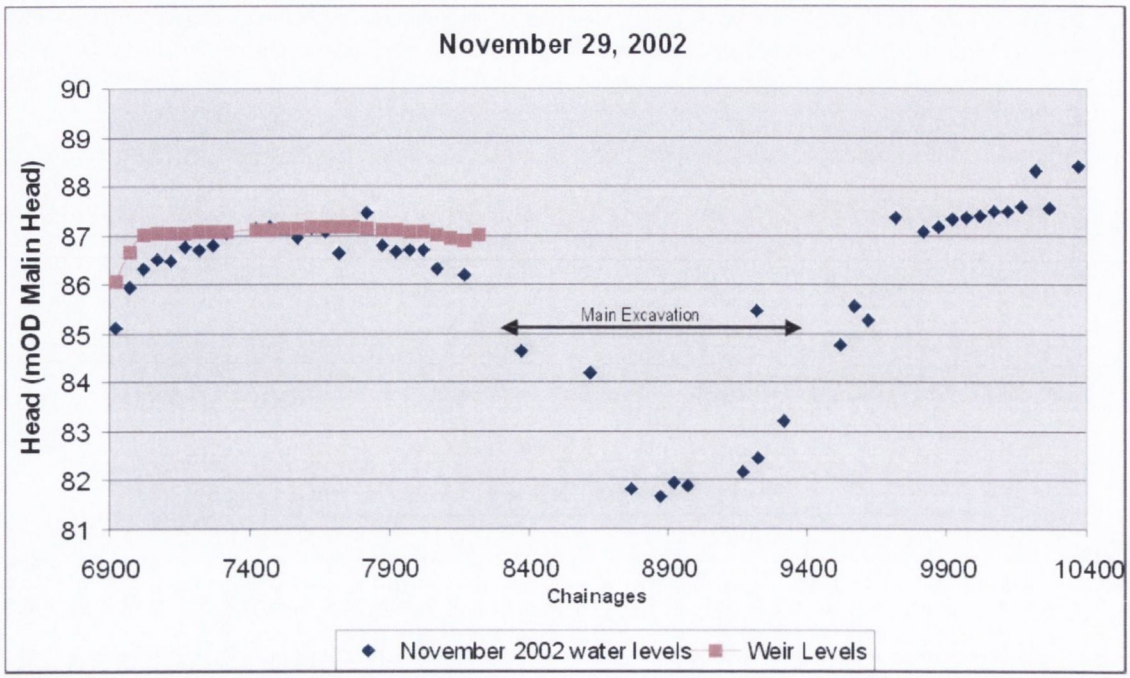


Figure 4.10: Groundwater levels at the end of November 2002 when the main excavation extended between Ch. 82+00 and 93+50.

In December 2002, the main excavation progressed to between Ch. 85+00 and 95+00 (Figure 4.11) allowing the section up to Ch. 85+00 to recover. An anomalous groundwater level was measured at Ch. 71+70 which may be the result of instrument error.

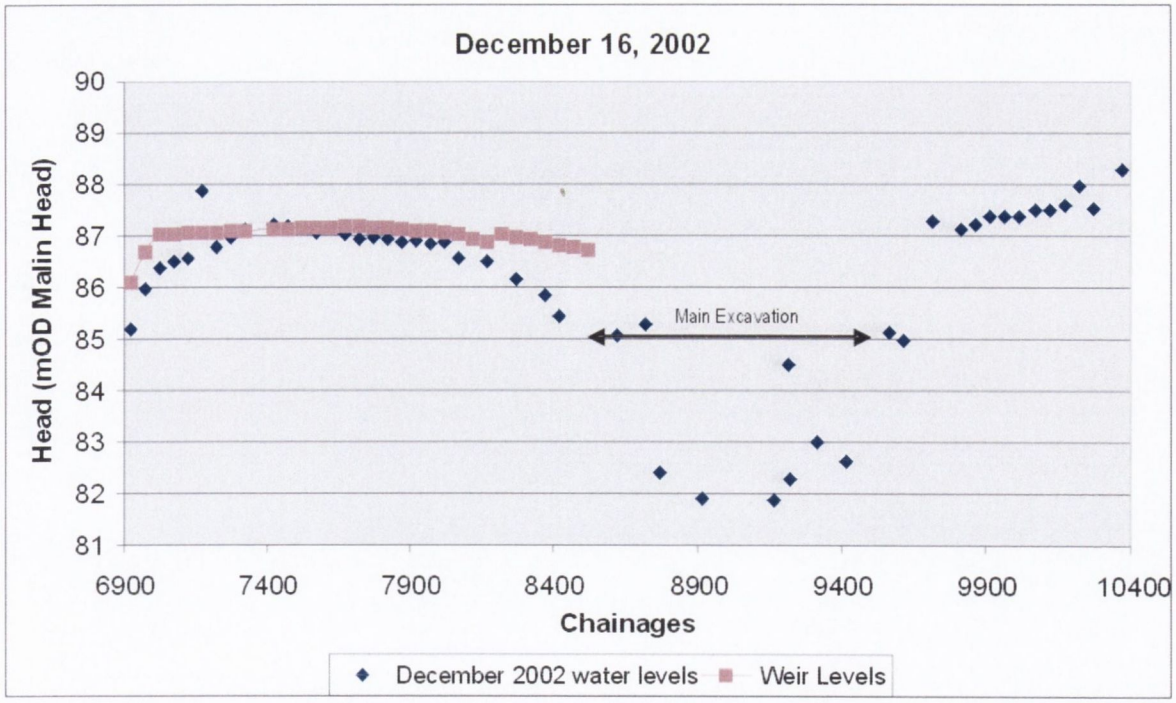


Figure 4.11: Groundwater levels at the end of December 2002 when the main excavation extended between Ch. 85+00 and 95+00.

In January 2003, the main excavation progressed to between Ch. 86+00 and 96+00 (Figure 4.12) allowing the section up to Ch. 86+00 to recover.

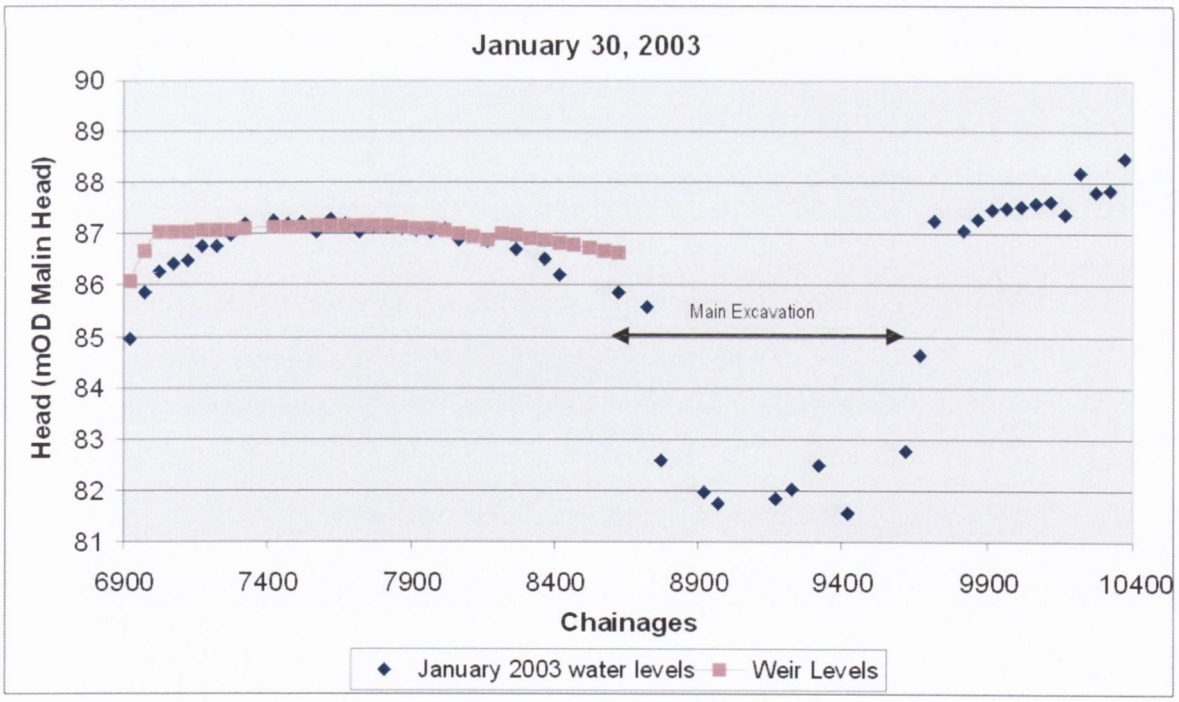


Figure 4.12: Groundwater levels at the end of January 2003 when the main excavation extended between Ch. 86+00 and 96+00.

In February 2003, the main excavation progressed to between Ch. 89+00 and 99+00 (Figure 4.13) allowing the section up to Ch. 89+00 to recover. The Greyabbey (Ch 87+50) Bridge site was also dewatered as can be observed with the lowered water level in that area. There are a few anomalously high groundwater levels recorded in February 2002 where the groundwater level appears to be higher than the weir level. This may be the result of instrument error or caused by the fact that the monitoring boreholes were located just outside of the cutting.

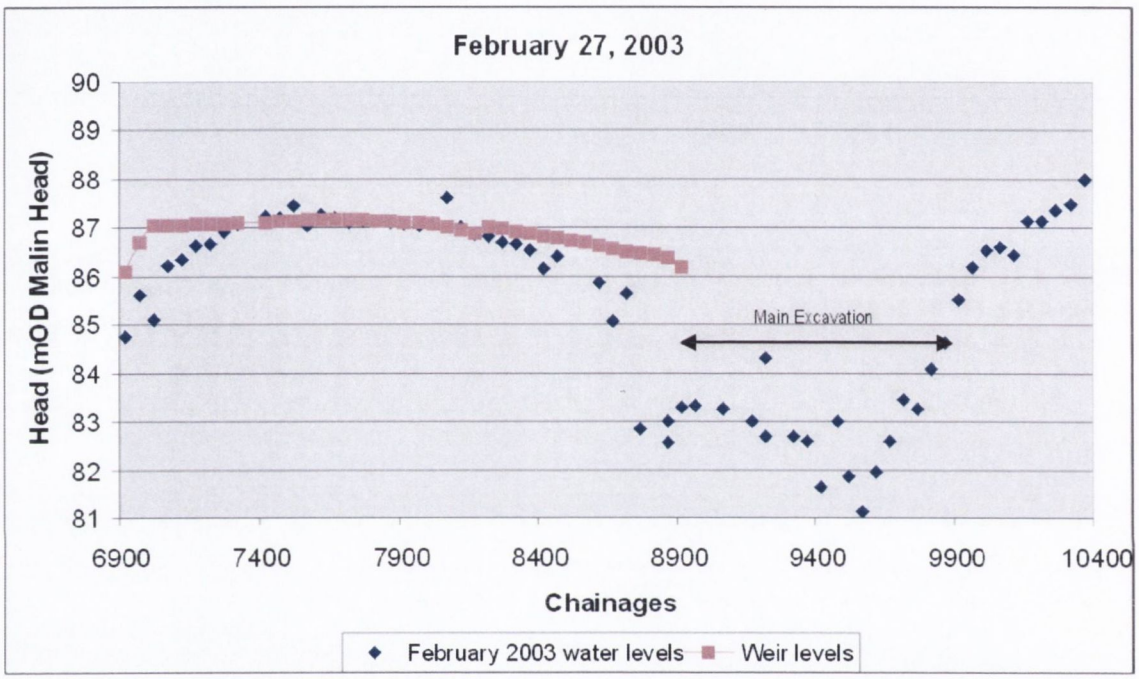


Figure 4.13: Groundwater levels at the end of February 2003 when the main excavation extended between Ch. 89+00 and 99+00.

In March 2003, the main excavation progressed to between Ch. 92+60 and 100+00 (Figure 4.14) allowing the section up to Ch. 92+60 to recover. The Greyabbey (Ch 87+50) Bridge site was also dewatered as can be observed with the lowered water level in that area.

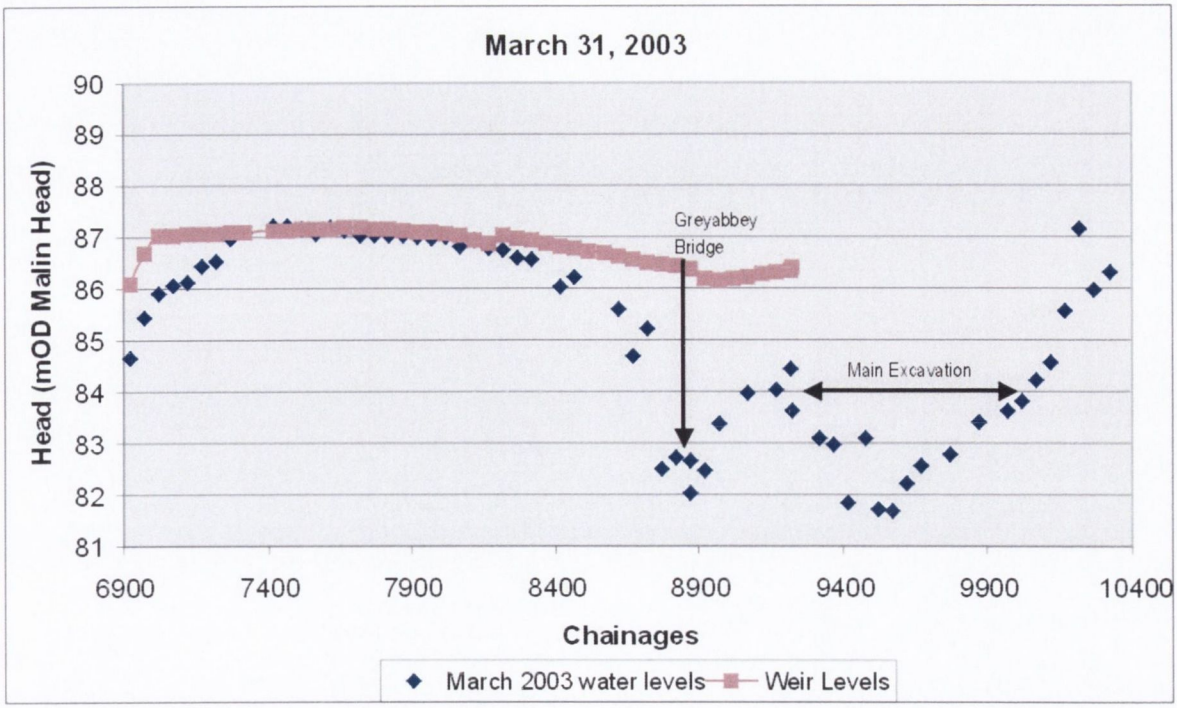


Figure 4.14: Groundwater levels at the end of March 2003 when the main excavation extended between Ch. 92+60 and 100+00.

In April 2003, the main excavation had progressed to between Ch. 94+00 and 102+50 (Figure 4.15) allowing the section up to Ch. 94+00 to recover. The Greyabbey (Ch 87+50) Bridge site was also dewatered as can be observed with the lowered water level in that area.

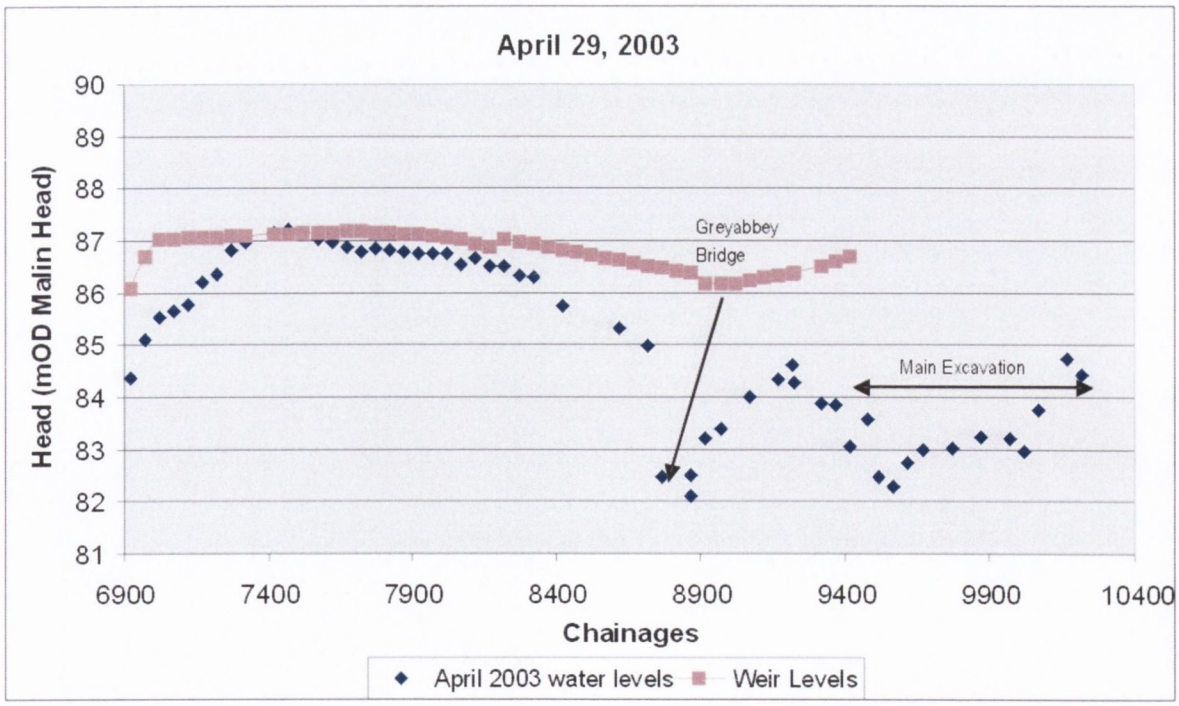


Figure 4.15: Groundwater levels at the end of April 2003 when the main excavation extended between Ch. 94+00 and 102+50.

In May 2003, the main excavation had progressed to between Ch. 95+50 and 104+00 (Figure 4.16) allowing the section up to Ch. 95+50 to recover. The Greyabbey (Ch 87+50) Bridge site was also dewatered as can be observed with the lowered water level in that area.

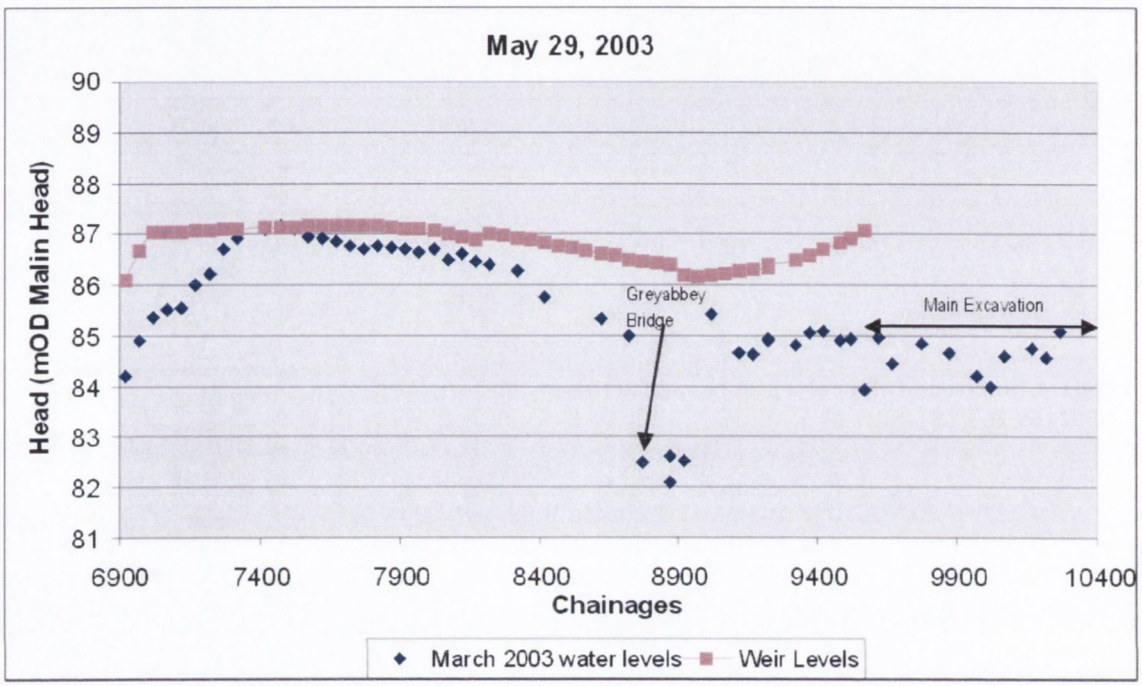


Figure 4.16: Groundwater levels at the end of May 2003 when the main excavation extended between Ch. 95+50 and 104+00.

In June 2003, the main excavation progressed to between Ch. 99+50 and 104+00 (Figure 4.17) allowing the section up to Ch. 99+50 to recover. The Greyabbey (Ch 87+50) Bridge site was also dewatered as can be observed with the lowered water level in that area.

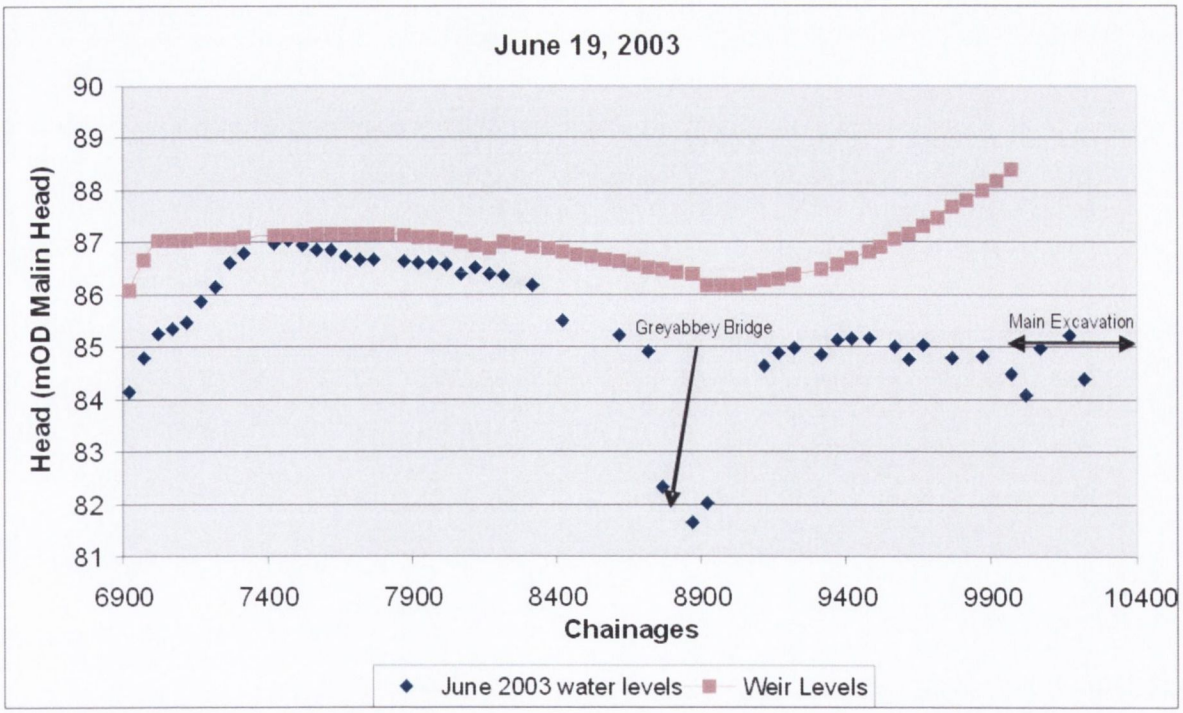


Figure 4.17: Groundwater levels at the end of June 2003 when the main excavation extended between Ch. 99+50 and 104+00.

In July 2003, the main excavation progressed to between Ch. 101+00 and 101+50 (Figure 4.18) allowing the section up to Ch. 92+60 to recover. The Greyabbey (Ch 87+50) Bridge site was also dewatered as can be observed with the lowered water level in that area.

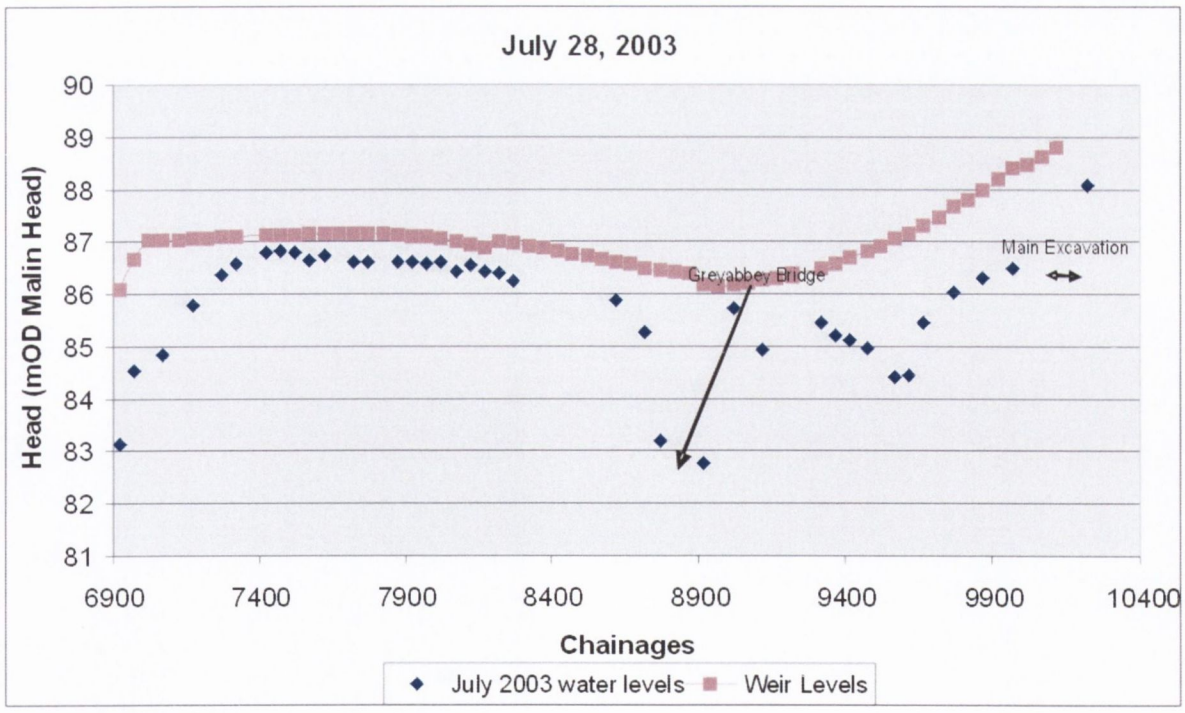


Figure 4.18: Groundwater levels at the end of July 2003 when the main excavation extended between Ch. 101+00 and 101+50.

Dewatering ceased on August 25, 2003 after which the entire bypass was allowed to recover (Figure 4.19).

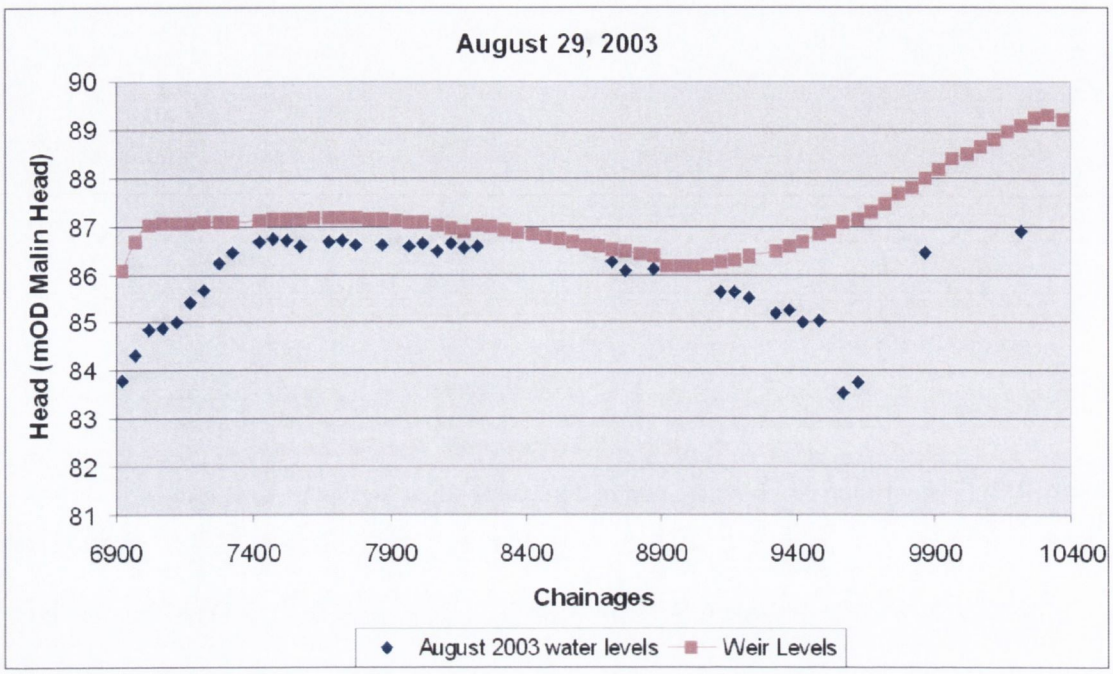


Figure 4.19: Groundwater levels at the end of August 2003. Dewatering ceased on August 25.

By February 3, 2004 the groundwater had four months to recover and therefore approaches the weir level (Figure 4.20). Figure 4.20 shows the position of the groundwater levels after dewatering had ceased in relation to the weir levels.

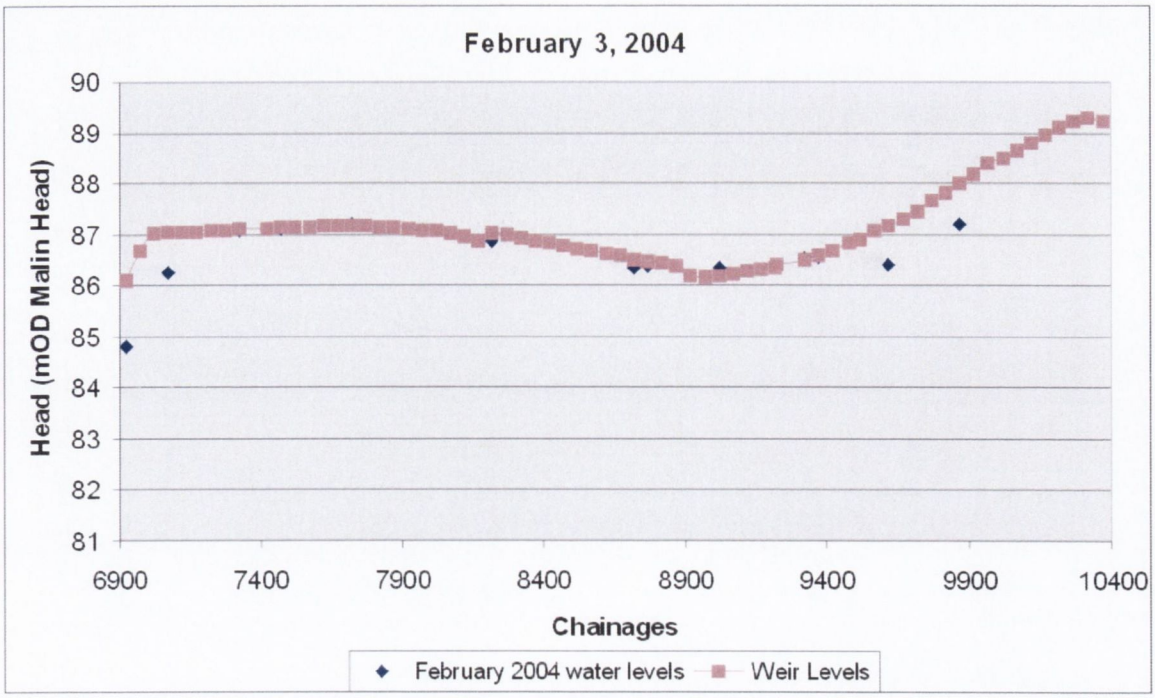


Figure 4.20: Groundwater levels after 4 months of recovery, they have reached the weir level in most places.

Figure 4.21 shows the variation in the groundwater head through time. This graph shows that at most locations the groundwater head varied by approximately 3 to 6 m. It also shows the anomalous readings at Ch. 71+70 and Ch. 78+70. These are most likely due to an error with the equipment measuring the water levels at those times.

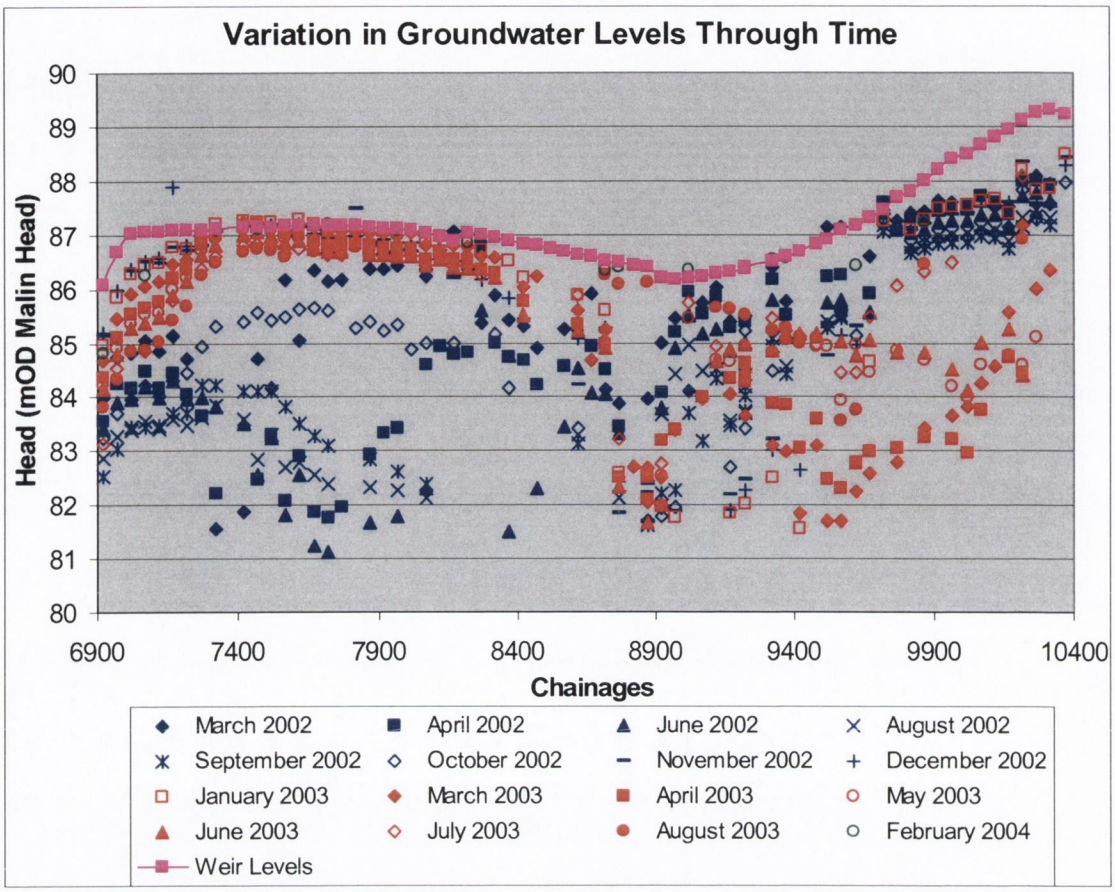


Figure 4.21: Variation in the groundwater head through time.

4.4 TRADITIONAL METHODS OF ESTIMATING DEWATERING REQUIREMENTS

The Thiem relationship (see Section 2.3.1.3.1), which assumes steady-state flow conditions, is commonly used to estimate the dewatering requirements for approximately square excavations. The essence of this relationship is that the hydraulic gradient is given by the slope of the drawdown curve; consequently this relationship can be used to estimate the hydraulic conductivity where the discharge and the drawdown curve associated from this discharge are known. It is considered that there were occasions at the early stage of the dewatering project when the drawdown curve for some of the bridge foundations could be assumed to be unaffected by other dewatering operations and therefore that the Thiem relationship could be used to estimate the hydraulic conductivity. One of these situations arose during the dewatering for the Tully bridge foundations and during the first stage of the main excavation, the location of which is shown on Figure 4.1, where the drawdown could be considered to be localised. The unaffected groundwater head was taken as a tangent to the groundwater levels and this level was used to estimate the drawdown curve.

Figure 4.22 illustrates the groundwater head measured during dewatering at the Tully Bridge site and in the main excavation (Ch. 69+00 - 74+00).

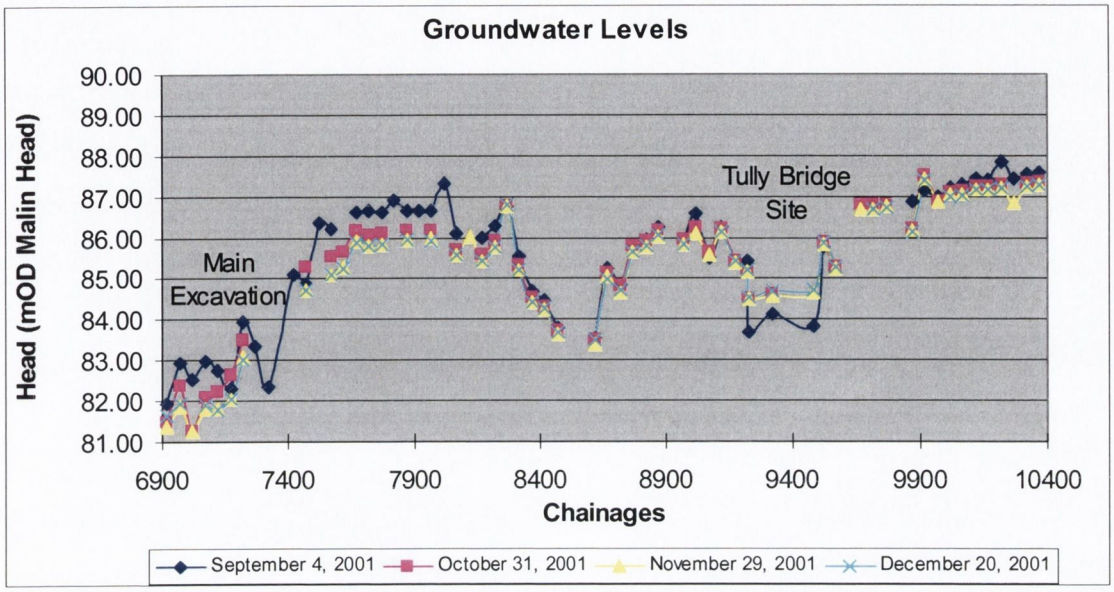


Figure 4.22: Groundwater head levels from September to December, 2001, showing the drawdown as the result of the dewatering in the main excavation (Ch. 69+00 - 74+00) and at Tully Bridge selected for pump test style analysis of hydraulic conductivity.

The back-analysis of the dewatering flows assumes a confined aquifer or that the drawdown is small (i.e. less than 10%) when compared to the overall saturated thickness of the aquifer. Therefore, the drawdown of the watertable can be ignored and the equations for a confined aquifer are valid. Steady-state conditions are also assumed for the back-analysis of the dewatering of the Kildare Town Bypass, because the dewatering was analysed for a single point in time where there were no overlapping cones of depression. The discharge for radial drainage is given by the Thiem equation (Eq. 2-15) which can be rearranged to give:

$$T = \frac{Q}{2\pi} * \frac{\ln\left(r_2 / r_1\right)}{\left(s_1 - s_2\right)} \qquad \textbf{Eq. 4-1}$$

where (s_1-s_2) is the change in drawdown between radial distances r_2 and r_1 from the excavations and T is the transmissivity. The transmissivity is equal to the hydraulic conductivity multiplied by the thickness of the aquifer. The term $\{ln(r_2/r_1)/ (s_1-s_2)\}$ is given by the inverse of the slope of the plot of the drawdown versus the log of the distance from the excavation.

The drawdown interpreted from the measured water levels from the Tully Bridge site (Ch 91+70) from September to December, 2001, is shown in Figures 4.23, 4.24, 4.25, and 4.26. The drawdown was estimated by plotting a curve and using the point of the highest groundwater elevation where the cone of depression levels off as the point of zero drawdown. The drawdown is subtracted from that value at all other locations. The point from which the drawdown was calculated was reassessed for each date that the drawdown was back analysed. Figures 4.24, 4.25, and 4.26 show a single point at approximately 550 m from the excavation with zero drawdown. This was ignored as an outlier point and may be the result of the heterogeneity of the sediments. Furthermore, as outlined in Section 2.5.1, because the estimation of hydraulic conductivity using this method is not very sensitive to changes in the radius of influence, this outlier was ignored.

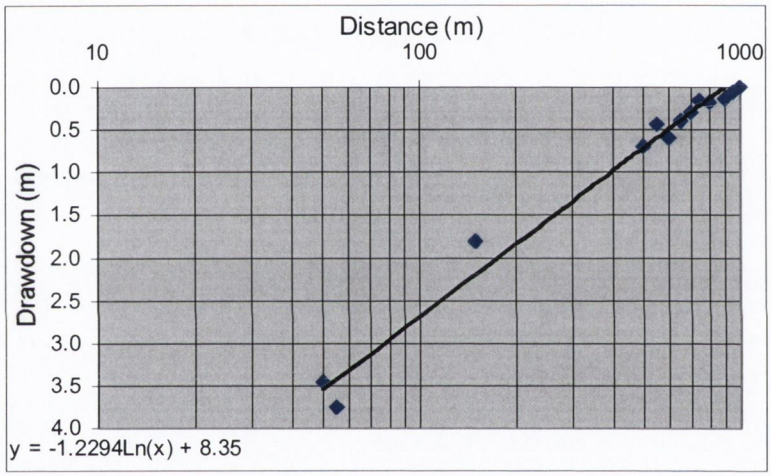


Figure 4.23: Distance-Drawdown curve for September 4, 2001 at Tully Bridge.

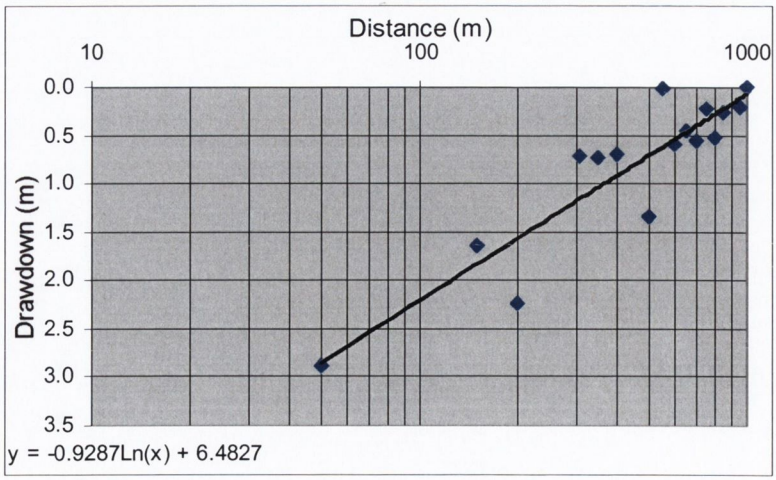


Figure 4.24: Distance-Drawdown curve for October 31, 2001 at Tully Bridge.

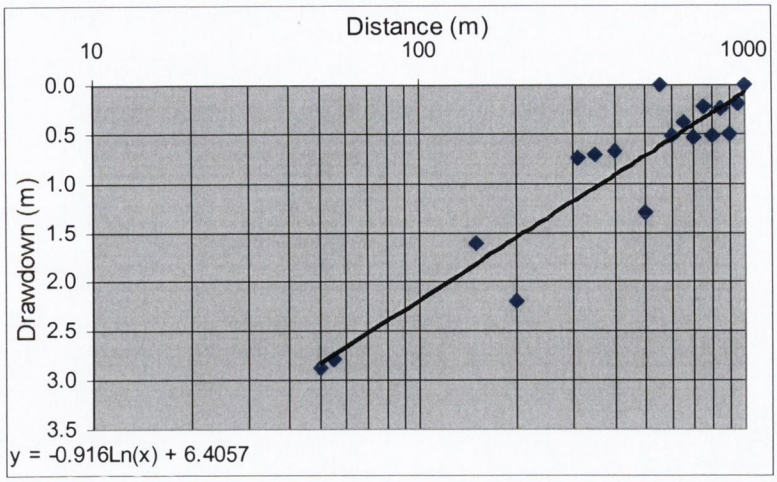


Figure 4.25: Distance-Drawdown curve for November 29, 2001 at Tully Bridge.

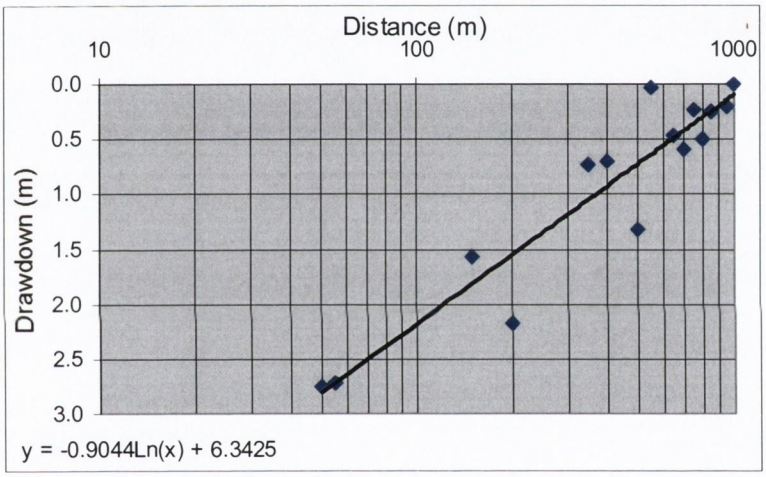


Figure 4.26: Distance-Drawdown curve for December 20, 2001 at Tully Bridge.

These figures illustrate that the radius of influence is limited to approximately 1000 m and that the slope of the line ranges from 1.2294, 0.9287, 0.916, and 0.9044 from September to December 2001 respectively. Therefore, $\{\ln(r_2/r_1)/ (s_1-s_2)\}$ is equal to 0.81, 1.08, 1.09, and 1.11, respectively. The discharge recorded at the Tully Bridge site (Ch 91+70) was 46, 33, 21, and 27 l/s from September to December 2001, respectively. The aquifer is approximately 33 m thick at this point. The effects of partial penetration are assumed to be negligible as the drawdown was measured at a distance greater than 1.5 to 2 times the saturated thickness of the aquifer (Kruseman and de Ridder, 2000). The back-analysis calculates the hydraulic conductivity in the area around Tully Bridge to be in the range of 1.1×10^{-4} to 1.8×10^{-4} m/s (Table 4-5).

Table 4-5: Summary of hydraulic conductivity (k) determined by isolating flow out of the Tully Bridge excavation.

	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER
$(s_2-s_1)/\ln(r_2/r_1)$ (slope of the line)	1.2294	0.9287	0.916	0.9044
$\ln(r_2/r_1)/(s_1-s_2)$ (inverse of slope)	0.813	1.077	1.092	1.106
Q (l/s)	46	33	21	27
$T(m^2/s) = \frac{Q}{2\pi}\frac{\ln\left(r_2/r_1\right)}{(s_1 - s_2)}$	5.96×10^{-3}	5.66×10^{-3}	3.65×10^{-3}	4.75×10^{-3}
D (m)	33	33	33	33
k (m/s) = T/D	1.80×10^{-4}	1.71×10^{-4}	1.11×10^{-4}	1.44×10^{-4}

Figures 4.27, 4.28, 4.29, and 4.30 show the drawdown versus distance curves for the main excavation from Ch. 69+00 to 74+00 from September to December, 2001. In the following graphs the drawdown was measured from Ch. 74+00, as the area between Ch. 69+00 and 74+00 was part of the main excavation and so was dewatered to the same level. The points after Ch. 74+00 are assumed to represent the cone of depression from the main excavation. The initial assessment of the groundwater response discovered that the water level drawdown curves showed a consistent shape, which when plotted on a semi-log plot indicated that the radius of influence of the dewatering is limited to about 600 m from the excavations. As in the case with the Tully Bridge, there are some outlying data which make it difficult to assess the exact radius of influence. However, as outlined in Section 2.5.1, the calculations are not very sensitive to changes in the radius of influence so some error in the estimate of the radius of influence will not result in a large difference in the estimated value of hydraulic conductivity.

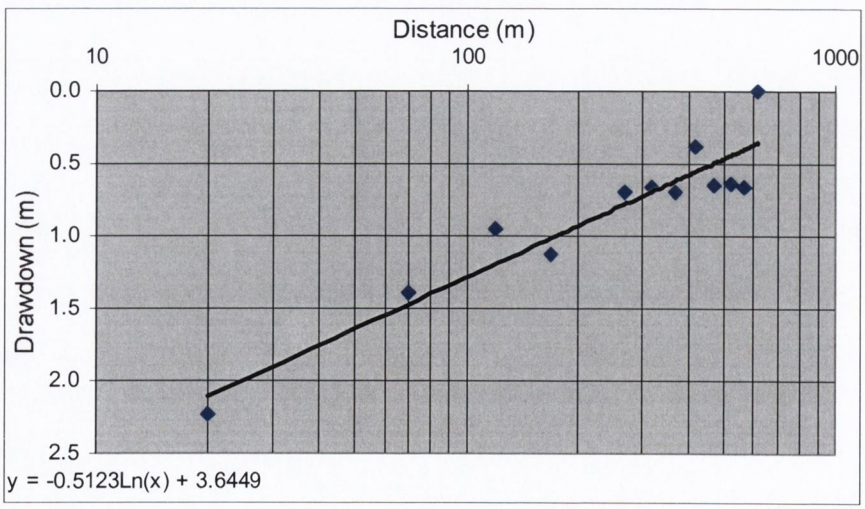


Figure 4.27: Distance-Drawdown curve for September 4, 2001 at the main excavation (Ch 69+00 - 74+00).

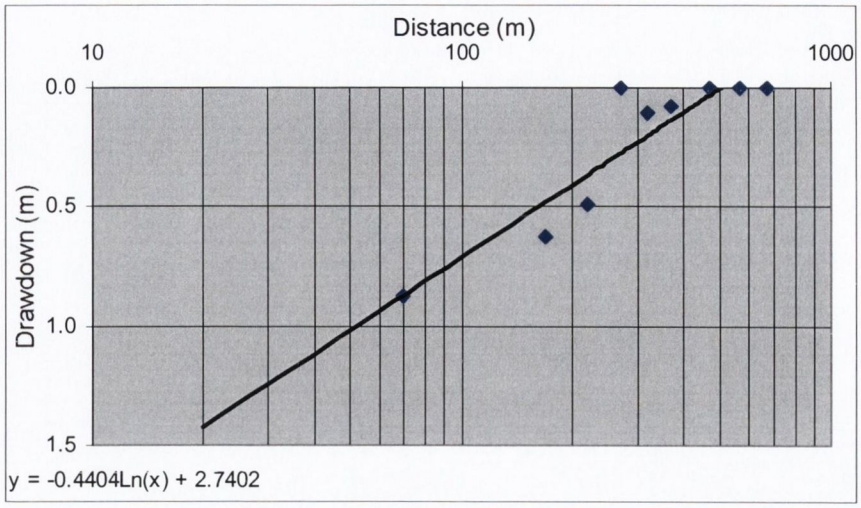


Figure 4.28: Distance-Drawdown curve for October 31, 2001 at the main excavation (Ch 69+00 - 74+00).

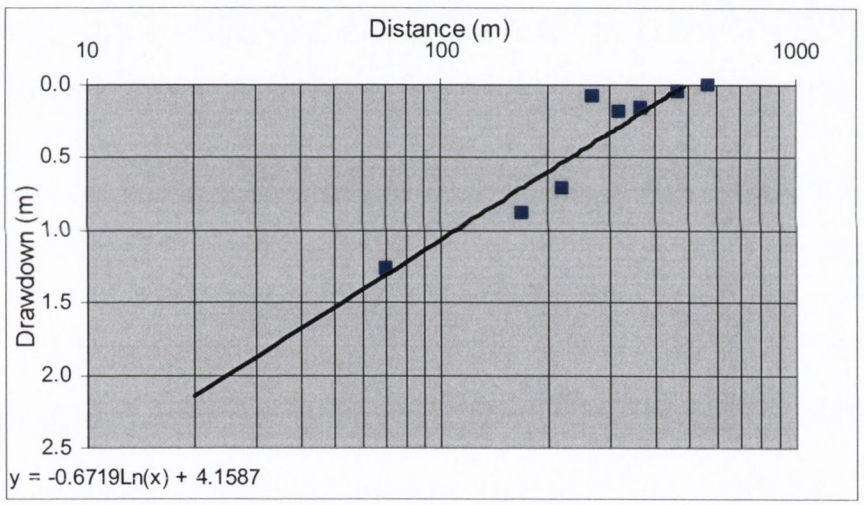


Figure 4.29: Distance-Drawdown curve for November 29, 2001 at the main excavation (Ch 69+00 - 74+00).

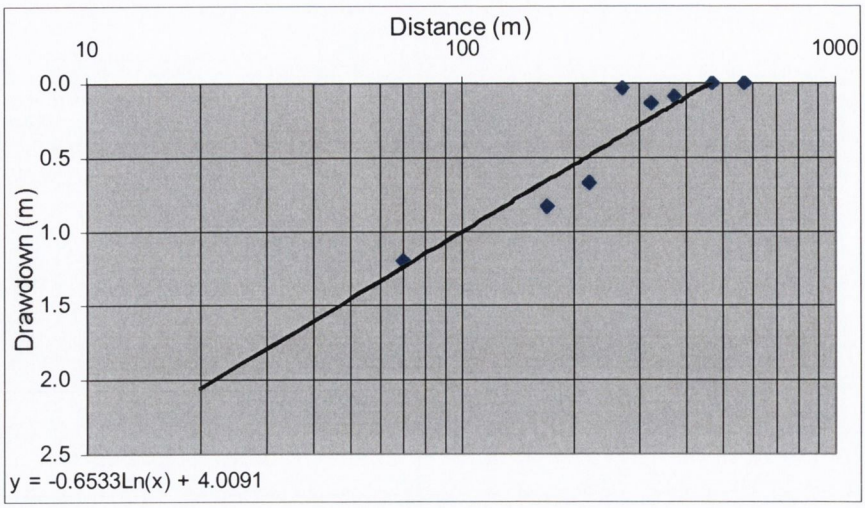


Figure 4.30: Distance-Drawdown curve for December 20, 2001 at the main excavation (Ch 69+00 - 74+00).

The slope of the drawdown curve is 0.5123, 0.4404, 0.6719, and 0.6533 for September to December, respectively. The inverse of the slope $\{\ln(r_2/r_1)/(s_1-s_2)\}$ is equal to 1.95, 2.27, 1.49, and 1.53, respectively. The flow into the excavation was 50, 31, 45, and 43 l/s from September to December 2001 respectively; however, this included the 500 m of the road cutting. The aquifer is 20 to 30 m thick underneath the main excavation (thinner towards Ch. 69+00 at the western edge of the excavation). The effects of partial penetration are assumed to be negligible as the drawdown was measured at a distance greater than 1.5 to 2 times the saturated thickness of the aquifer (Kruseman and de Ridder, 2000). The back-analysis calculates the hydraulic conductivity in the area around the main excavation to be in the range of 3.5×10^{-4} to 5.2×10^{-4} m/s (Table 4-6).

Table 4-6: Summary of permeabilities (k) determined by isolating flow out of the main excavation (Ch. 69+00 - 74+00).

	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER
$(s_2-s_1)/\ln(r_2/r_1)$ (slope of the line)	0.5123	0.4404	0.6719	0.6533
$\ln(r_2/r_1)/(s_1-s_2)$ (inverse of slope)	1.952	2.271	1.488	1.531
Q (l/s)	50	31	45	43
$T(m^2/s) = \frac{Q}{2\pi}\frac{\ln\left(r_2/r_1\right)}{(s_1 - s_2)}$	1.55×10^{-2}	1.12×10^{-2}	1.07×10^{-2}	1.05×10^{-2}
D (m)	30	30	30	30
k (m/s) = T/D	5.18×10^{-4}	3.73×10^{-4}	3.55×10^{-4}	3.49×10^{-4}

The average result from the back analysis (4.0×10^{-4} m/s) of the dewatering of the main excavation (Ch. 69+00 - 74+00) are twice as large as those from the analysed pump tests (2.1×10^{-4} m/s) and are lower than the recovery tests which were analysed (9.2×10^{-3} m/s) at the Mooretown Bridge site (Ch. 71+00). As previously stated, the over estimate of

the hydraulic conductivity from the recovery test may be due to either the fact that, in some of the tests, recovery of the water levels was observed during rain events or due to a possible reduction in pumping rates. Unfortunately, no pump and recovery tests were conducted at the Tully Bridge site (Ch. 91+70) and the closest points for comparison are the Greyabbey site (Ch. 87+50) and the Sewage Treatment Works (Ch. 95+50). This is roughly twice the value estimated using the pump tests at the Greyabbey site (5.8×10^{-5} m/s). However, it is in the same range as the value estimated using the recovery tests at the Greyabbey site (1.8×10^{-4} m/s). The pump test at the Sewage Treatment Works indicated a hydraulic conductivity only slightly higher than that indicated by the back-analysis (2.2×10^{-4} m/s). The recovery test at the Sewage Treatment Works resulted in an estimate of hydraulic conductivity roughly twice that from the back-analysis (2.9×10^{-4} m/s).

The back-analysis of the groundwater drawdown curves interpreted from the piezometer readings taken along the motorway from September to December 2001, indicated that the average hydraulic conductivity from September to December is approximately 1.5×10^{-4} m/s for the area around Tully Bridge (Ch. 91+70) and 4.0×10^{-4} m/s in the area around the main excavation (Ch. 69+00 - 74+00). The hydraulic conductivity interpreted from the five pumping tests and four recovery tests varied from 1.6×10^{-5} to 3.5×10^{-4} m/s and 1.8×10^{-4} to 9.2×10^{-3} m/s, respectively. The results from the back-analyses fit within the estimated hydraulic conductivities from the pump tests and indicate that the hydraulic conductivity of the aquifer is in the vicinity of 3.0×10^{-4} m/s. These results do not, however, reflect the zone of greater hydraulic conductivity experienced east of Ch. 97+50, as the locations where dewatering were back-analysed were west of that zone of greater hydraulic conductivity.

Darcy's Law can also be used to analyse the dewatering requirements for the Tully Bridge (Eq. 2-41) (Cedergren, 1968). The thickness of the saturated sediments at the radius of influence at the Tully Bridge site is equal to approximately 33 m (H). The thickness of the water bearing strata within the excavation (h_o) was approximately 23.5 m (the Tully was excavated down 9.5 m). The radius of excavation (r_o) is 17 m as the width of the excavation at its base is 34 m. The radius of influence (R_o) is generally unknown, however, from the back analysed data it can be estimated that the radius of influence is approximately 1000 m for the Tully Bridge excavation (see Figures 4.23 to 4.26). This method can also be used to back-analyse the flow data to obtain the hydraulic conductivity.

The flow out of the Tully Bridge excavation was steady at 46 l/s from August 27, 2001 until September 15, 2001. During this time the aquifer can be assumed to be approximately in steady-state. If all of the assumptions above are assumed to be true for the back-analysis a hydraulic conductivity of 3.1 x10^{-4} m/s is estimated for the area around the Tully Bridge excavation.

Flow nets can also be used to estimate seepage into an excavation. Seepage into an excavation is a three-dimensional problem, which can be simplified by reducing the analysis to two-dimensions, where it is assumed that the saturated thickness is relatively constant. If drawdown is small the problem can be simplified further by ignoring the drawdown in the depth direction and by considering the flow to the excavation in plan only. The outer boundary is considered to be the radius of influence, R_o, as discussed earlier. Using this approach, and drawing curvilinear squares for radial flow as shown on Figure 4.31 the discharge (the dewatering requirements for an excavation of a certain size) is given by:

$$Q = KhD\frac{n_f}{n_d} \qquad \textbf{Eq. 4-2}$$

where n_f is the number of flow lines and n_d is the number of equipotential drops, K is the hydraulic conductivity, h is the drawdown at the excavation, D, the saturated thickness of the aquifer, can be used to calculate the total quantity of flow, Q.

In order to check the accuracy of the flow net approach, a circular flow net was constructed to simulate an excavation as though it was a well (Figure 4.31). The circular excavation has 3 head drops and 8 flow lines giving a shape factor (n_f/n_d) of 2.67. When inserted into Eq. 4-3 the equation becomes $Q = 2.67KhD$, which can then be compared to the Thiem equation (Eq. 2-15). For the flow net in Figure 4.31, R_o is equal to 650 m and r_o equal to 50 m, which when substituted into Eq. 2-15, the equation becomes $Q = \frac{2\pi KD}{\ln\left(650/50\right)} = 2.45KhD$. Given that the value of hydraulic conductivity is generally imprecise, the value of Q in this equation is close to the approximation derived using the flow net.

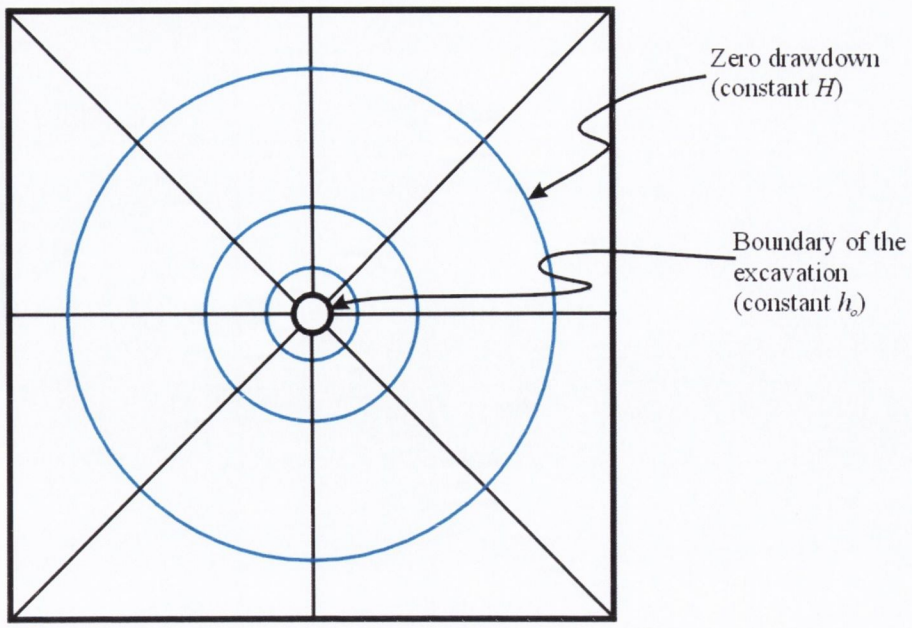


Figure 4.31: Circular excavation to check the validity of the flow net for the long narrow excavation. The blue lines represent the equipotential lines while the black lines are the flow lines.

This method can be used to back-analyse the flows to obtain the hydraulic conductivity. The flow out of the Tully Bridge excavation was steady at 46 l/s from August 27, 2001 until September 15, 2001. During this time the aquifer can be assumed to be in steady-state. If all of the assumptions above are assumed to be true for the back-analysis a hydraulic conductivity of 1.2×10^{-4} m/s is estimated for the area around the Tully Bridge excavation.

Using the flow net method, the shape factor for an excavation 500 m long by 40 m wide is 3.33 (Figure 4.32). Therefore, for a long thin excavation Eq. 4-3 becomes $Q = 3.33KhD$. The flow out of the main excavation when the section from Ch. 69+00 to 74+00 was being dewatered was steady at 50 l/s from August 30, 2001 until September 19, 2001. During this time the aquifer can be assumed to be in steady-state. If all of the assumptions above are assumed to be true for the back-analysis a hydraulic conductivity of 5.3×10^{-5} m/s is estimated for the area around the main excavation if the saturated thickness is approximately 30 m.

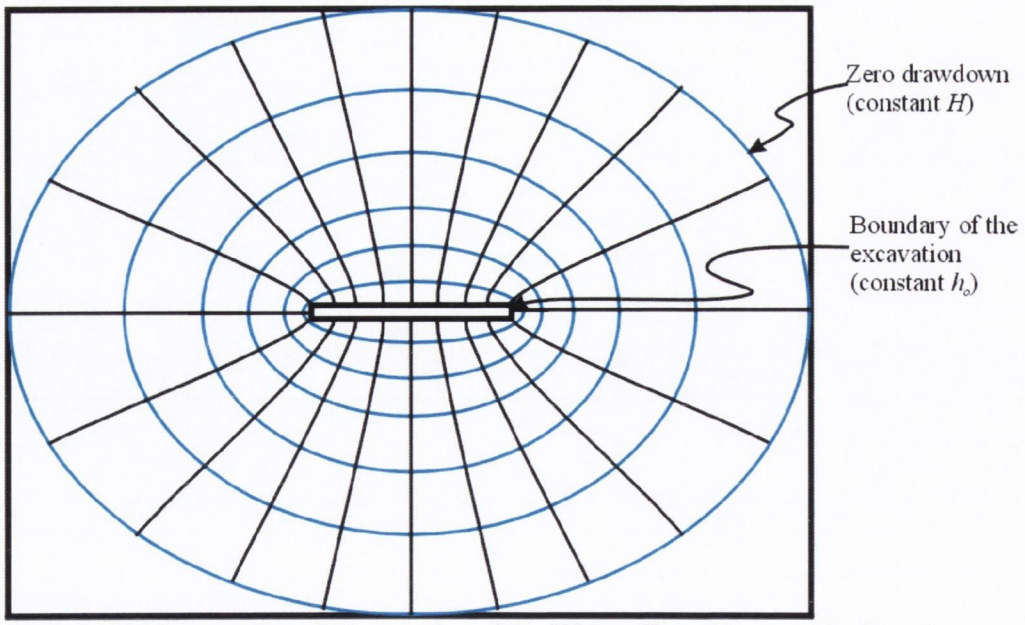


Figure 4.32: Flow net for a 500 m section of the Kildare Town Bypass. The blue lines represent the equipotential lines while the black lines are the flow lines. Drawing is to scale.

The Mansur and Kaufman (1958; Somerville, 1986) approach was used to estimate the flow when dewatering a long narrow trench in an unconfined aquifer. This method envisages the trench as a row of single well points and assumes that the trench only partially penetrates the saturated sediments (Eq. 2-42). The radius of influence was taken from the distance drawdown curves in Figures 4.27 to 4.30. The Mansur and Kaufman method can be used to back-analyse the flows to obtain the hydraulic conductivity. The flow out of the main excavation was steady at 50 l/s from August 30, 2001 until September 19, 2001. During this time the aquifer can be assumed to be in steady-state. If all of the assumptions above are assumed to be true for the back-analysis a hydraulic conductivity of 3.1×10^{-4} m/s is estimated for the area around the main excavation.

These three simple methods used to back-analyse the hydraulic conductivity values for the Kildare Town Bypass are within the range of hydraulic conductivity values estimated from the pump tests (1.6×10^{-5} - 3.5×10^{-4} m/s) and on the low end of the hydraulic conductivity values estimated from the recovery tests (1.8×10^{-4} - 9.2×10^{-3} m/s). However, the thickness of saturated sediments is not the same along the entire length of the excavated portion of the Bypass and the sediments are known to be heterogeneous rather than homogeneous as these methods assume. As indicated by the particle size distribution test and the geology, the hydraulic conductivity is likely to vary by more than one-order of magnitude over the entire section that required dewatering.

4.5 *ANALYSIS OF GROUNDWATER RESPONSE*

The response of the groundwater to dewatering depends on the vertical and horizontal hydraulic conductivity of the strata, on the uniformity of the ground conditions, and on factors such as the specific yield and specific storage of the aquifer. The average flows recorded from dewatering the excavation as discussed in Section 4.2 provide a good indication of the hydraulic conductivity of the sediments that were being excavated (Table 4-7).

Table 4-7: Summary of average monthly total flows.

DATE	FLOW (l/s)	EXCAVATED SECTION	LENGTH	RAINFALL (TOTAL mm)
May-01	20	Tully	Bridge	38.10
Jun-01	48	Tully	Bridge	48.90
Jul-01	50	Tully	Bridge	58.30
Aug-01	108	69+00-74+00 + Tully + Nurney	500 m + Bridges	67.30
Sep-01	135	69+00-74+00 + Tully + Nurney	500 m + Bridges	22.70
Oct-01	122	69+00-74+00 + Tully + Nurney	500 m + Bridges	72.10
Nov-01	108	69+00-74+00 + Tully + Nurney	500 m + Bridges	20.50
Dec-01	91	69+00-74+00 + Tully + Nurney	500 m + Bridges	14.00
Jan-02	86	72+00-74+50 + Tully + Nurney	250 m + Bridges	35.40
Feb-02	131	73+50-75+00 + Tully + Nurney	150 m + Bridges	129.20
Mar-02	143	73+50-75+00 + Tully + Nurney + Greyabbey	150 m + Bridges	30.20
Apr-02	187	73+50-78+50 + Tully + Nurney + Greyabbey + Storm Tanks	300 m + Bridges	91.30
May-02	201	75+00-85+00 + Mooretown + Tully + Greyabbey + Storm Tanks	1000 m + Bridges	91.20
Jun-02	218	75+00-85+00 + Mooretown + Tully + Greyabbey + Storm Tanks	1000 m + Bridges	86.10
Jul-02	219	75+00-85+00 + Mooretown + Tully + Greyabbey + Storm Tanks	1000 m + Bridges	67.40
Aug-02	229	77+50-87+50 + Mooretown + Tully + Storm Tanks	1000 m + Bridges	65.70
Sep-02	215	80+00-90+00 + Tully + Storm Tanks	1000 m + Bridges	18.40
Oct-02	193	82+00-92+00 + Storm Tanks	1000 m + Bridge	172.40
Nov-02	190	82+00-93+50 + Storm Tanks	1150 m + Bridge	148.70
Dec-02	214	85+00-95+00 + Storm Tanks	1000 m + Bridge	87.70
Jan-03	237	86+00-96+00 + Storm Tanks	1000 m + Bridge	59.30
Feb-03	275	89+00-99+00 + Greyabbey + Storm Tanks	1000 m + Bridge	38.20
Mar-03	455	92+60-100+00 + Greyabbey	740 m + Bridge	42.20
Apr-03	512	94+00-102+00 + Greyabbey	800 m + Bridge	37.00
May-03	435	95+50-104+00 + Greyabbey	850 m + Bridge	119.40
Jun-03	367	99+50-104+00 + Greyabbey	450 m + Bridge	83.00
Jul-03	250	101+00-101+50 + Greyabbey	50 m + Bridge	105.10
Aug-03	140	101+00-101+50 + Greyabbey	50 m + Bridge	13.20

Farrell and Devine (2006) estimated the total amount pumped out of the excavation to be $14.5x10^6$ m^3; of this total amount $0.7x10^6$ m^3 was attributed to surface water. Table 4-7 shows that although there is a relationship between the rainfall and flow out of the excavation, the flow out of the excavation is primarily affected by the permeability of the sediments being dewatered as the largest flow out of the excavation occurred in April 2003 but the rainfall in April and the months preceding it was low (37 to 59.3 mm).

The average monthly total flows in Table 4-7 are twice as much around Ch. 100+00 indicating an area with much higher hydraulic conductivity. A high hydraulic conductivity gravel layer was encountered at Ch. 97+50 (Brannelly, 2003) which agrees well with the flow data. The glacial geology through which the road was excavated (Figure 4.33) shows that the first part of the excavation from Ch. 69+00 to around 90+00 was excavated through a Lower Carboniferous Limestone Till which was underlain by sands and gravels (Section 3.3). Geologically this would be expected to be a low hydraulic conductivity unit as indicated by the particle size distribution analyses (Section 3.4.6.1). This is because tills typically contain a wide variety of grain sizes with large quantities of silts and clays resulting in a low porosity. Tills are also often over-consolidated by the advancing glacier which further reduces the porosity and hydraulic conductivity.

After Ch. 90+00 the sediment that was excavated was mapped as gravel (Glanville, 2000). A greater hydraulic conductivity would be naturally expected for this unit as indicated by the field testing in Section 3.4.6. Around this area, a very permeable gravel layer was reported (Ch 97+50), the Geological Survey of Ireland has mapped a unit of alluvium (Glanville, 2000). Alluvial deposits are clastic, detrital materials transported by a stream or river and deposited as the river flood plain. Alluvial deposits typically have high permeabilities and the particle size distribution test conducted in this area indicates a hydraulic conductivity of $1.0x10^{-1}$ m/s (Section 3.4.6.1). Although the particle size distribution analysis over estimates the hydraulic conductivity of the alluvium, it is indicative of a high hydraulic conductivity unit. Particle size distribution analyses were also taken in the esker deposit. When these are averaged using the geometric mean the estimated hydraulic conductivity is $4.9x10^{-3}$ m/s (Section 3.4.6.1). It is quite probable that the intersection with this alluvium unit is the cause of the hydraulic conductivity greatly increasing. Since all the material underlying the motorway is highly heterogeneous it is very probable that the gravels have a higher hydraulic conductivity in the area around Ch.

100+00. The aquifer also becomes thicker towards the east and so the transmissivity would be expected to increase as well.

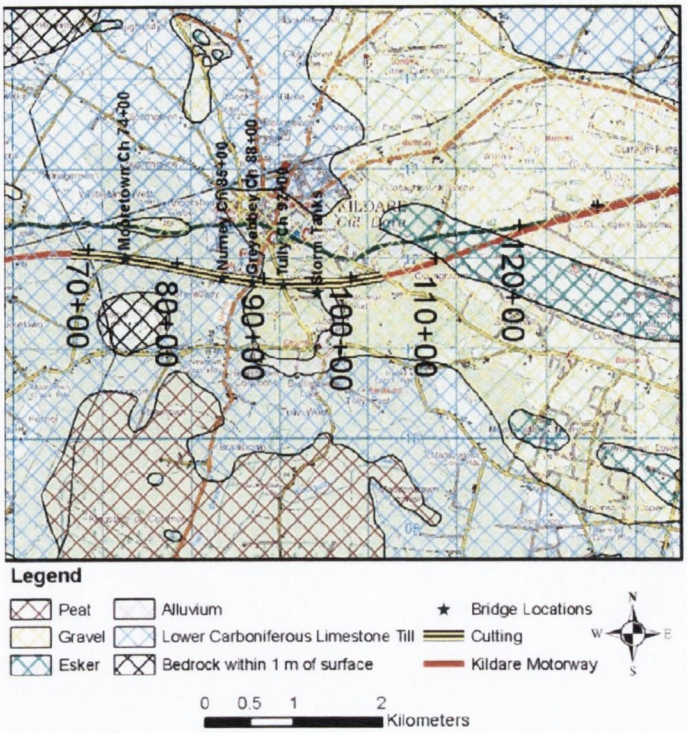


Figure 4.33: The glacial geology through which the excavation was dug.

The profile of the borehole logs taken along the same section of highway illustrates the heterogeneity in both the geology (Figure 4.34) and the hydraulic conductivity (Figure 4.35). At Ch. 98+00 the gravel layer is within 1 m of the ground surface and the particle size distribution test from the sample collected in this borehole show that the hydraulic conductivity is very high in this area. This gravel is surrounded above and on both sides by clays with very low permeabilities ($1x10^{-8}$ m/s) which would serve to impede seepage from the highly permeable unit until clay was excavated at which time a large volume of water would be expected to be released into the excavation. This raised area of gravel would also act as a conduit for the water to leave the lower gravel layer. The groundwater level in this area is one to two metres below the ground surface which would cause the water to flow into the excavation when the excavation reached the gravels at Ch. 98+00.

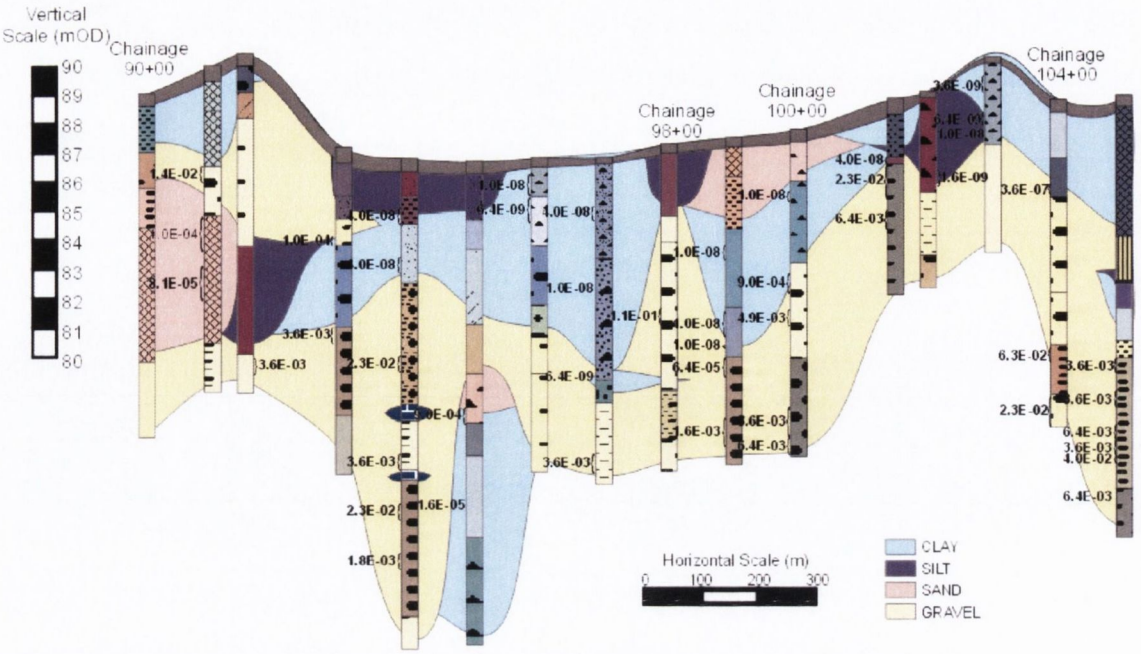


Figure 4.34: The glacial sediments as described in the boreholes taken at 100 m intervals along the length of the motorway.

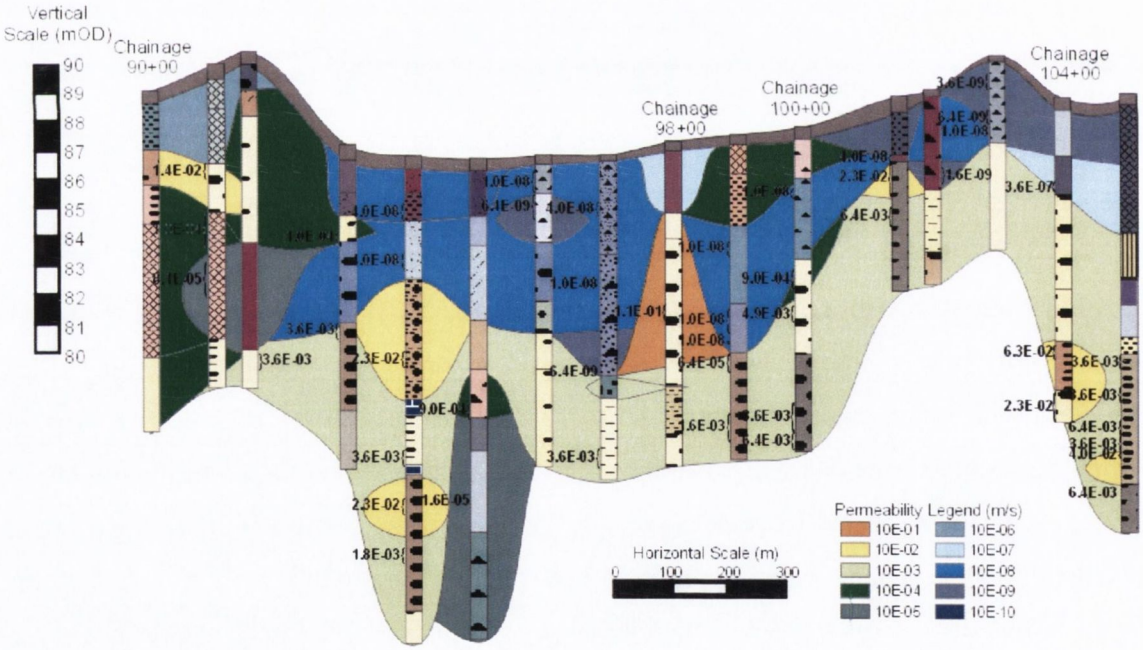


Figure 4.35: Hydraulic conductivity as derived from particle size distribution analyses conducted on samples taken from boreholes at approximately 100 m intervals along the length of the motorway.

4.6 CONCLUSIONS

1) The main excavation experienced flows between 100 to 200 l/s while dewatering from Ch. 69+00 to 94+00.
2) The area between Ch. 94+00 and 102+50 had recorded seepages in excess of 500 l/s.
3) This indicates that the hydraulic conductivity east of 94+00 exceeds the upper estimate from the pumping tests of 3.3×10^{-4} m/s.
4) The back-analysis using the Thiem equation determined the hydraulic conductivity of the main excavation from Ch. 69+00 to 74+00 and Tully Bridge site to be approximately 4.0×10^{-4} m/s and 1.5×10^{-4} m/s, respectively.
5) The back-analysis of dewatering data results in hydraulic conductivity estimates which are in the range of those obtained from the pump tests and on the low end of those obtained from the recovery tests.
6) The back-analysis to estimate the hydraulic conductivity using Darcy's Law and the flow net indicates that the hydraulic conductivity is between 1.2×10^{-4} and 3.1×10^{-4} m/s in the area around the Tully Bridge. The back-analysis to estimate the hydraulic conductivity using the Mansur and Kaufman (1958, Somerville, 1986) method and flow nets indicates that the hydraulic conductivity around the main excavation when Ch. 69+00 - 74+00 were being dewatered is between 5.3×10^{-5} and 3.1×10^{-4} m/s.

CHAPTER 5

DEVELOPMENT OF A CONCEPTUAL MODEL OF THE STUDY AREA

5.1 *INTRODUCTION*

This chapter presents the conceptual model for the aquifer. Such models are always simplifications of the actual groundwater system and try to capture only the essential features of the geology and hydrogeology. This allows the impact of a specific property to be observed which may be obscured if the model includes too many parameters. The initial conceptual model is kept as simple as possible, only increasing complexity where necessary to capture the system so that the effect of interactions between parameters could be assessed. In this chapter, the geology, hydrology, and hydrogeology described in Chapter 3, is simplified and compiled to construct a conceptual model of the Mid-Kildare Aquifer. The excavation and dewatering of the cutting as described in Chapter 4 is also simplified so that it can be incorporated in the model. The basic conceptual model of the aquifer is the same in steady and transient state, although any time-varying parameters (e.g. recharge and dewatering) were altered for the steady-state modelling. The finite-element analysis was developed to assess the regional impact of dewatering and to assess the hydrogeological properties of the aquifer in a more robust manner.

There are two main numerical modelling techniques used in groundwater modelling, finite-difference and finite-element. In order to assess which would be the best modelling technique to use for the dewatering of the Mid-Kildare Aquifer a comparison between MODFLOW and FEFLOW was conducted (Appendix F). In this study, FEFLOW will be used to model the Mid-Kildare Aquifer whereas the model designed for the Monitoring Committee, known as the KAM (Kildare Aquifer Model) used MODFLOW.

5.2 *VALIDATION*

Two validation exercises were carried out to assess the reliability of FEFLOW. The first, which can be found in Appendix G, uses a simple pump test to ensure that the drawdown modelled in FEFLOW in steady and transient state compares favourably with the traditional methods of calculating drawdowns (Thiem, DeGlee, Hantush-Jacob, Thiem-Dupuit, Theis, Jacob, Walton, Hantush, Walton, and Neuman, see Chapter 2 for equations and assumptions) for a confined, leaky confined, and unconfined aquifer. Appendix G lists the assumptions made in the modelling exercise. The second validation exercise, Appendix H, consisted of modelling a simple excavation and was compared to traditional methods of estimating flow (Thiem-Dupuit) for a square and a circular excavation. The

modelled flows were within 10% of those calculated using the Thiem-Dupuit method which is considered satisfactory.

5.3 *MODELLING THEORY*

There are four basic boundary conditions that can be used to constrain a model in FEFLOW. A head (m) (first type, Dirichlet) boundary condition which can be constrained by a maximum and minimum flux (m^3/d) is generally used to represent rivers, lakes, seepages, springs and lateral boundaries (Figure 5.1). To simulate seepage where water can freely leave the model space but cannot enter it, the head is set to be equal to the elevation and constrained by a maximum flux of zero m^3/d. This means that the head boundary condition is only active under exfiltrating conditions (e.g. negative flux which corresponds to the flux out of the model space).

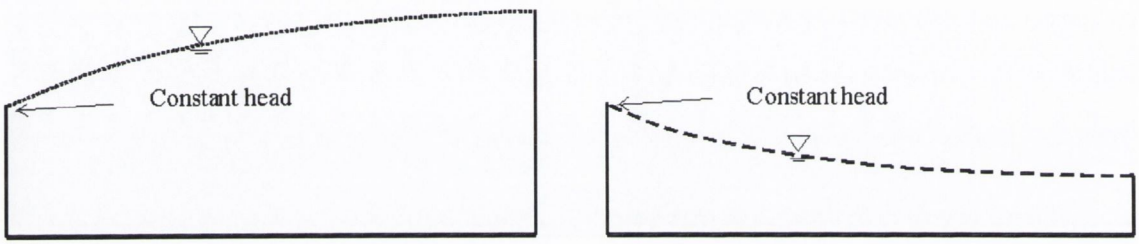


Figure 5.1: Diagram of a constant head boundary.

A flux (m^3/d) (second type, Neuman) boundary condition can be constrained by a maximum and minimum head (m) (Figure 5.2). The constraint condition causes the flux to only be active when the groundwater level is above or below a specified head. This boundary condition is only valid if the distance over which it should be active is defined by selecting adjacent nodes. This boundary condition can be used to represent recharge, wells, or a lateral flux.

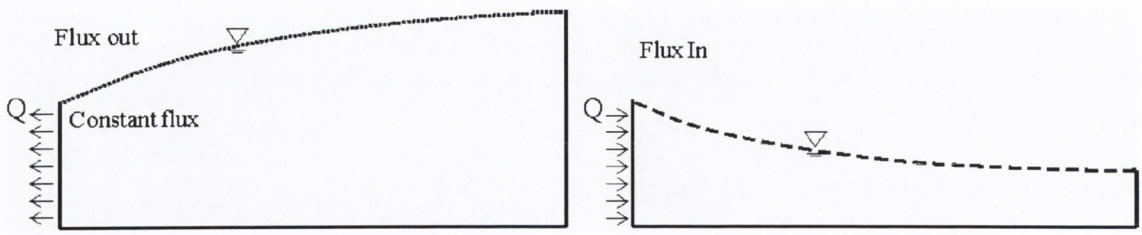


Figure 5.2: Diagram of a constant flux boundary.

A transfer boundary condition (m) (third type, Cauchy) defines a reference hydraulic head of a domain outside the model (Figure 5.3). This boundary condition is only valid if a segment is defined along which the transfer boundary should be active by selecting

adjacent nodes. A transfer rate also must be specified to define the leakage arising between this reference hydraulic head and the aquifer. A transfer boundary can be constrained by a maximum or minimum head (m) or flux (m^3/d). The transfer boundary condition is generally used to simulate the effect of a silt layer underlying a river which would cause a river to have a different head from the groundwater.

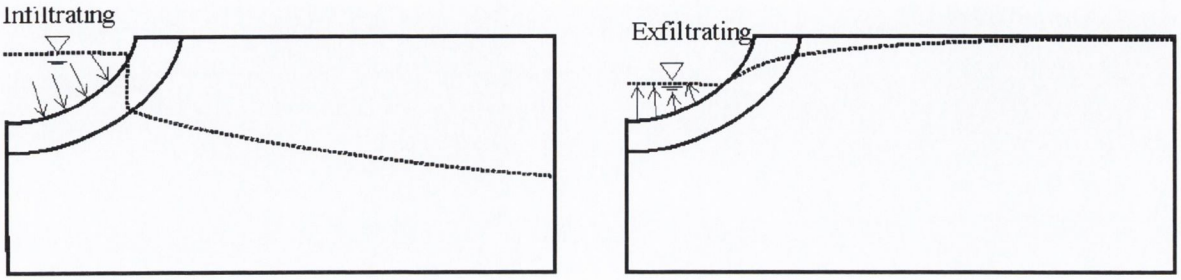


Figure 5.3: Diagram of a transfer boundary.

The fourth boundary condition is the well (m^3/d) (fourth type, single well type) which describes the injection or withdrawal of water at a single node (Figure 5.4). This boundary condition can be constrained by a maximum or minimum head (m). The well boundary condition is used to represent wells as the name implies. All the described boundary conditions can be set as constants or varying with time.

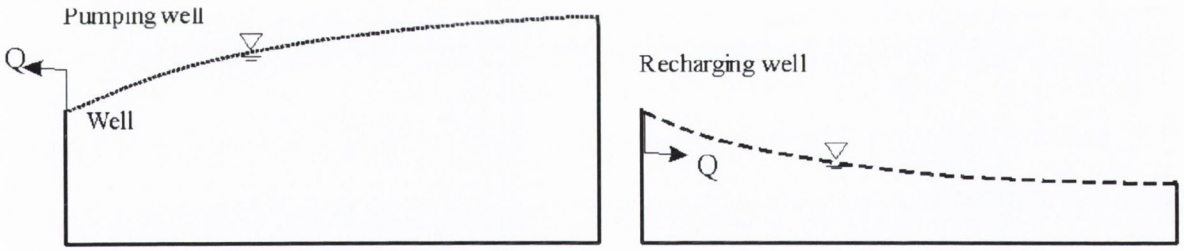


Figure 5.4: Diagram of a well boundary.

FEFLOW has four options for surface behaviour: free and moveable; unspecified; phreatic; and fixed. A free and moveable surface can be assigned to the top layer when it conforms to the phreatic surface. This allows the top surface to deform so that the model is always fully-saturated. If the top surface (phreatic level) falls below an underlying surface which has been set as unspecified then the free and moveable surface will cause the lower surface to also be moved and the material properties of both surfaces will be updated so that the original stratigraphy is still represented. A phreatic surface can be set anywhere a watertable is present in the model. This will not update the material properties should the phreatic surface fall below an unspecified surface. A fixed surface is fixed in space and cannot deform during the simulation. An unspecified surface can deform during the simulation if required by a phreatic or free and moveable surface.

When modelling a confined aquifer the layers of the model are fixed and the groundwater head should always be at or above the confining layer to satisfy the definition of a confined aquifer. When modelling an unconfined aquifer in a fully-saturated model, the problem arises as to how to treat unsaturated sediments should the watertable fall and rise. This is generally done by making the top surface correlate to the phreatic surface so that no unsaturated sediments are modelled. Another problem arises when the watertable falls below a change in stratigraphy, as if the water table falls below the upper stratigraphic unit and if the stratigraphic unit is fixed then an unsaturated zone is required. In a fully-saturated model this is not allowed and thus will cause numerical instability. To account for this FEFLOW allows for the phreatic surface to be set as free and movable as described above and the surface which divides the stratigraphy to be set as an unspecified surface. This then allows the water level to drop below the uppermost stratigraphic unit.

Therefore, for the case study, the uppermost surface of the model was set to be free and moveable which means that the surface will deform to coincide with the phreatic level. This ensures that the model stays fully-saturated regardless of inputs or outputs and provides numerical stability. The middle surface dividing the stratigraphy was set as an unspecified boundary which allows the model to automatically adapt that surface depending on how the uppermost surface is adapted. This technique is explained further in the following paragraph. The bottom surface representing the bedrock surface was set as fixed which means that it is a rigid stratigraphic unit that is not moved regardless of how the other two slices are adapted.

The stratigraphy is adapted using a technique known as BASD (best adaptation to stratigraphic data) which transforms and joins the model data containing the stratigraphic initial structure to a moving finite-element mesh which is appropriately adapted to the free-surface locations. In this adaptation process the mesh slices are aligned in such a manner that the adjusted mesh is exactly fitted to parameter discontinuities should they ever exist. Remaining slices can be shifted and repositioned to achieve a well-spaced nodal distribution. Figure 5.5 demonstrates the BASD technique. The initial stratigraphy consists of three layers each having a different hydraulic conductivity. At the initial time the water table is at a low position and the mesh is accordingly shrunk. The two lower layers completely fit within the K_3 stratigraphy. However, the upper layer crosses between the K_2 and K_3 stratigraphy and a special treatment is required. Such cross elements are

only formed if they are unavoidable. A proper 3D interpolation technique had been developed which allows a data joining for elements intersecting an arbitrary number of stratigraphic layers. If the water table rises the moving mesh totally fits the K_2 - K_3 stratum while the remaining slice is used to subdivide the widest nodal spacing, in this case, the K_3 layer. After a further rise in the water table the free surface rises completely within the K_1 layer and the other two layers completely fill the K_2 and K_3 layers (Diersch, 2002).

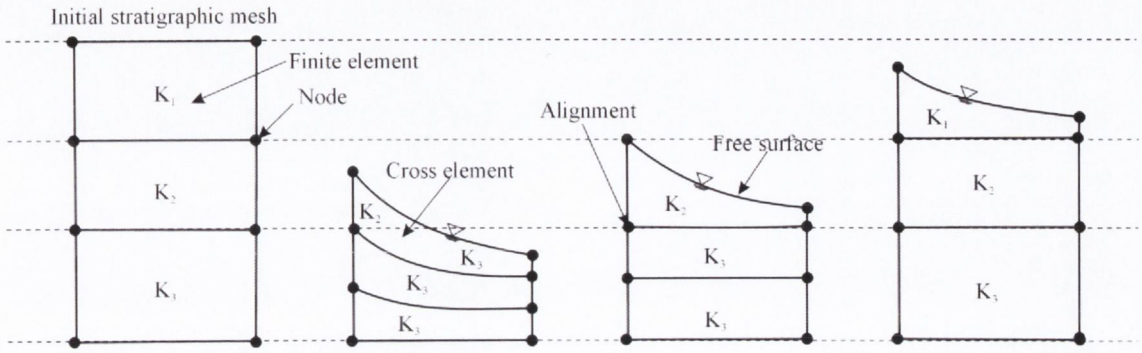


Figure 5.5: Moving mesh using the BASD technique of parameter adaptation applied to 3D surface problems. This example shows the mesh being adapted for groundwater rise (Diersch, 2002).

5.4 GEOLOGY

The geology of the Mid-Kildare Aquifer used in the conceptual model of the Mid-Kildare Aquifer was described in Sections 3.2 and 3.3. For the purposes of this model a simplifying assumption is made that the bedrock is impermeable and thus forms the lower boundary of the Mid-Kildare Aquifer. This assumption may not be strictly correct as limestones may contain sufficient large fractures and solution features to form bedrock aquifers. Thus, the bedrock will be considered the lower boundary of the Aquifer but this will be revisited in the calibration of the model to determine if this simplifying assumption is valid (Chapter 6).

The overburden is the main host of the groundwater in the study area as described in Section 3.2, the Quaternary and Recent deposits make up the Mid-Kildare Aquifer. The surface deposits include: till, peat, gravel, alluvium and an esker as can be seen in Figure 5.6 (Glanville, 2000). The map represents the sediments within 5 m of the surface, thus deviations are to be expected with depth. The surface deposits have been taken to represent the top layer of the model, the areas where peat and till are mapped being low hydraulic conductivity units which confine the underlying aquifer. Alluvial, esker, and gravel deposits are important as they are generally very permeable and where these occur

on the surface the aquifer is unconfined. The stratum below this surface layer is taken to consist of the sand and gravel outwash deposit as shown in Figure 3.5.

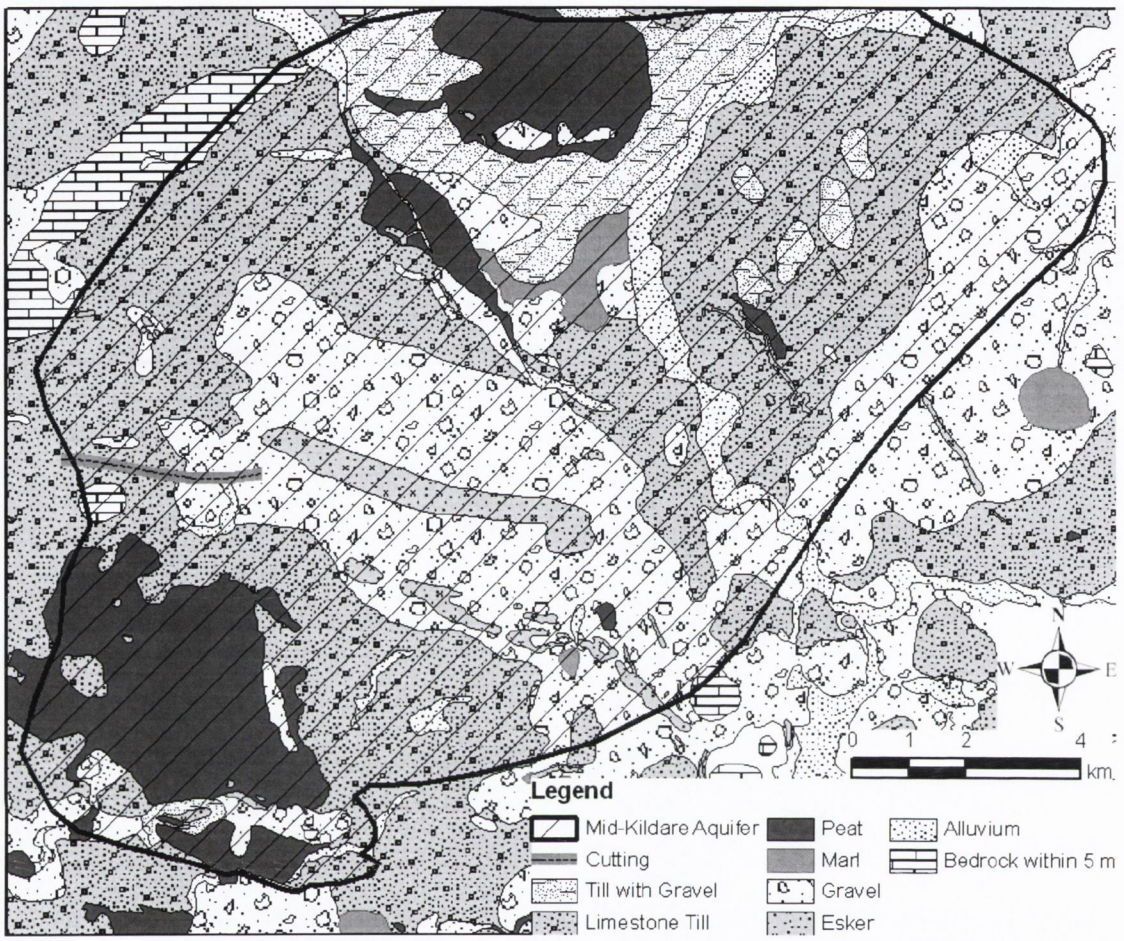


Figure 5.6: Quaternary geology within the Mid-Kildare Aquifer in the study area (modified from Glanville, 2000).

5.5 HYDROGEOLOGY

The hydraulic conductivity of the units was defined in Chapter 3 and the results used in the model are summarized below. Weeks (1969) and others have found that the horizontal hydraulic conductivity in glacial outwash can be 2 to 20 times greater than the vertical hydraulic conductivity due to anisotropy developed through the layering of the deposit. In order to capture this anisotropy, the vertical hydraulic conductivity was modelled as ten times lower than the horizontal hydraulic conductivity. The validity of this assumption will be assessed during the calibration of the numerical model.

The hydraulic conductivity data in Chapter 3 indicate that the glacial outwash deposits in the study area have permeabilities in the range of 10^{-3} to 10^{-5} m/s. The overlying till unit has an average thickness ranging from 2 - 5 m with a maximum

thickness of approximately 18 m and in some places it is non-existent. In the model the thickness of the upper layer will be assigned 12 m and will be thinned in areas were necessary. Where the till is non-existent, the upper layer is replaced by esker, alluvium or peat deposits. The large hydraulic conductivity for the alluvium deposit is probably an overestimation from the particle size distribution analyses. No testing was conducted on the peat deposits and the only published value of hydraulic conductivity available was from Rushton (2003) of a vertical hydraulic conductivity from $2x10^{-8}$ to $6x10^{-8}$ m/s. Bear (1972) suggests that the horizontal hydraulic conductivity of peat ranges from $1x10^{-4}$ m/s to $1x10^{-6}$ m/s. Paavilainen and Päivänen (1995) state that the horizontal hydraulic conductivity of peat can range from $4x10^{-4}$ m/s to $9x10^{-10}$ m/s. Therefore, the horizontal hydraulic conductivity could only be estimated and so a value of $1x10^{-6}$ m/s was initially used. The hydraulic conductivity values assigned to each stratigraphic unit can be found in Table 5-1 (Figure 5.7). The hydraulic conductivity in Table 5-1 can be compared to Table 3-1 for previous published hydraulic conductivity of the Mid-Kildare Aquifer. All of these hydraulic conductivities will be revisited in the calibration of the model to determine if they need to be adjusted to better represent the observed groundwater level variation. The main sand and gravel body was represented as a lower layer, which had a global horizontal and vertical hydraulic conductivity set to the same value as the glacial outwash unit on the upper layer.

Table 5-1: Summary of hydraulic conductivity values derived from various testing methods. The values chosen to be used in the numerical model are shown in bold type face.

UNIT	HYDRAULIC CONDUCTIVITY (m/s)	TESTING METHOD	REFERENCE
Glacial outwash (sand & gravel)	$1.6x\text{-}10^{-5}$ to $3.5x10^{-4}$	Pump Tests	Section 3.4.6.3
	$1.8x10^{-4}$ to $9.2x10^{-3}$	Recovery Tests	Section 3.4.6.5
	$1.5x10^{-4}$ to $4.0x10^{-4}$	Dewatering Analysis	Section 4.3
	$2.4x10^{-4}$	Geometric mean of all tests	Value used in numerical model
Till	$1x10^{-7}$	Average of fine-grained PSD	Section 3.4.6.1
	$9.2x10^{-6}$ to $2.0x10^{-4}$	Variable Head Tests	Section 3.4.6.2
	$5x10^{-5}$	Average of PSD and VHT	Value used in numerical model
Esker	$5x10^{-3}$	PSD tests	Section 3.4.6.1
Alluvium	$1x10^{-2}$	PSD tests	Section 3.4.6.1
Peat (Pollardstown Fen)	$2x10^{-8}$ to **$6x10^{-8}$** (vertical)		Rushton (2003)

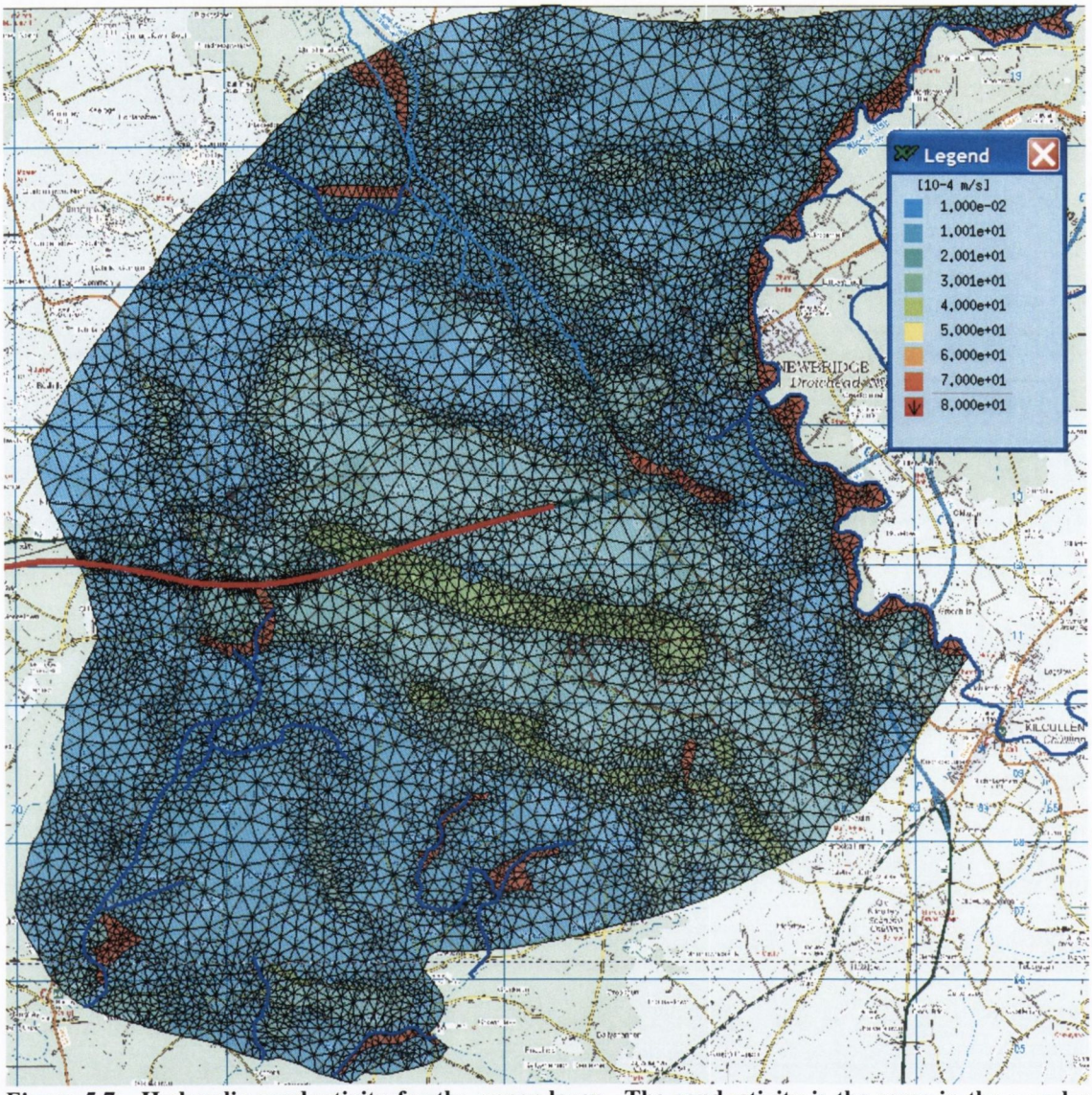


Figure 5.7: Hydraulic conductivity for the upper layer. The conductivity is the same in the x and y direction and one order of magnitude lower in the z direction except for the peat deposits underlying Pollardstown Fen which had a vertical hydraulic conductivity two orders of magnitude lower.

In the areas where the till or peat are present the aquifer was confined as a result of the contrast in hydraulic conductivity between the overlying low hydraulic conductivity till or peat deposit and the underlying high hydraulic conductivity gravel deposit. However, where the gravels are exposed at the ground surface or where eskers or alluvium are located the aquifer was unconfined.

When the head of the aquifer changes, water is either stored or expelled in transient-state modelling. The specific yield is a dimensionless parameter and was set to 0.13 for the gravels, alluvium and esker deposits (White Young Green Environmental, 2003). This specific yield was based on "pumping test analysis and other information about aquifer

response" (White Young Green Environmental, 2003). The specific yield estimate of 0.0001 for the till was taken from White Young Green Environmental (2003) and the specific yield estimate for the peat deposits of 0.5 was taken from Walton (1991) as the specific yield estimates as determined by the aquifer pump tests in Section 3.4.7 were deemed to be unreliable. As the published value for specific yield for peat could be considered high for this case study, a sensitivity analysis was carried out in Section 6.3.3. The specific storage, or as it is known in FEFLOW, the storage compressibility, has units of m^{-1} and the default value in FEFLOW is $1.0x10^{-4}$ m^{-1}. This is compared with the value determined in Section 3.4.7 in Section 6.3.3 which examines the sensitivity to specific yield and specific storage. The values of specific storage and specific yield will be revisited in the calibration of the transient-state model.

The extent of the aquifer is based on Wright's (1988) limits of the Mid-Kildare Aquifer. The aquifer east of the River Liffey was not included as it was not considered to influence the behaviour to the west and its absence would reduce the complexity of the model and reduce the run-time. The data for the topography were obtained from the Ordnance Survey of Ireland (OSI) as discussed in Section 3.4.2. This is the layer set as free and moveable so the OSI data formed an upper limit for the surface as it will deform to correspond with the phreatic level. As previously mentioned, the interface between the surface deposits and the sands and gravels was defined as being approximately 12 m below the topographic surface. In some cases around the edge of the aquifer, the thickness between the topography and bedrock is less than 12 m and so the upper layer was thinned progressively as needed (6 m, 3 m, 1m, 0.5 m, 0.2 m, 0.1 m, 0.01 m). The interface between the surface deposits and the sand and gravel deposits was set as an unspecified surface as is described in the modelling theory Section 5.2. This means that the top surface represented the water table which could move freely although the material properties would remain unaffected. The lower layer represented the main sand and gravel deposit and had the lower boundary defined by the bedrock elevation data obtained by the Geological Survey of Ireland (2004d). Figure 5.8 shows the mesh developed for the finite-element model.

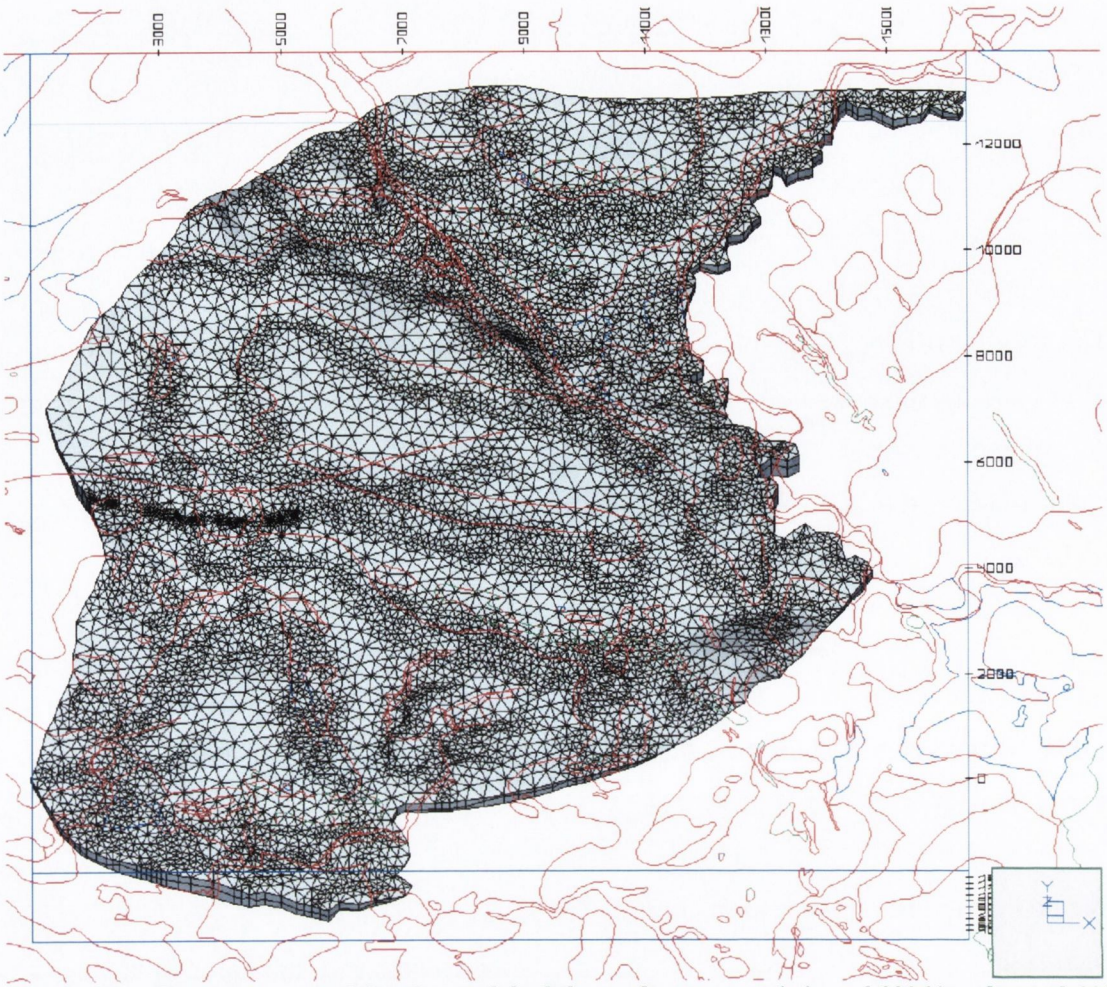


Figure 5.8: The mesh created for the model of the study area consisting of 23364 nodes and 30536 elements. A node occurs at each point where the lines intersect and each triangle forms an element. The vertical exaggeration is approximately 20:1.

5.5.1 INFLOWS

The rainfall and evapotranspiration data described in Section 3.4.4 were used to determine the recharge to be applied to the numerical model. The recharge was derived from the data obtained from Brown (2007) as found in Appendix A. The initial steady-state recharge was set at 0.9 mm/d uniformly on the upper model surface which was the mean recharge calculated using the FAO-Penman Monteith method. The recharge for the steady-state models were averaged for each month over the period from 1997 until 2006 and then those monthly averages were averaged to get an annual average. The model was also run with a recharge of 0.7 mm/d over the entire model space to simulate a drier year (20% below the average) and 1.1 mm/d to simulate a wetter year (20% above average). The annual variation in recharge calculated using climate data from Naas (after 2001) and Osberstown (before 2001) from 1992 to 2006 ranges from approximately 0.6 mm/d to 1.3 mm/d (Brown, 2007). Some recharge may also occur by groundwater flowing into the

model from northeast and southwest boundaries where the extent of the aquifer is not well defined. However, these areas may also be losing water from the aquifer so this was not considered as there is no supporting data as to how much water may be gained or lost where the aquifer is poorly defined. The recharge data was applied uniformly on the upper model surface and it was assumed that there was no runoff. As described in Section 3.4.4, the assumption of no runoff was made for the Mid-Kildare Aquifer as, overall, it has a flat topography and there are very few drainage features such as rivers and streams within the aquifer.

In transient state the recharge was applied on the upper model surface using an average daily value for each month from 1997 to 2006 (Brown, 2007, Appendix A). The averaged value was used rather than changing the recharge value daily to lessen the computational complexity and, therefore, time for each model run. The time-step of the model was set to automatic time-step control via predictor-corrector schemes. This means that the model picked the optimum time-step to minimize the run-time. The average value resulted in a sufficient representation of the groundwater response and one of the objectives of the modelling was to keep the model as simple as possible. Four modelled scenarios were run in transient state and each run assisted in calibrating the final model. These scenarios included:

1) Varying the monthly recharge in Table 5-2 in a cyclical fashion over 3 years.
2) Using the average daily recharge for each month from May 1998 to May 2001.
3) Assessing the sensitivity to hydraulic conductivity.
4) Assessing the sensitivity to specific yield and specific storage.
5) Adding the dewatering of the excavation, and extending the time period over which the model was run to 8.5 years until December 2006, and calibrating to the monitoring wells and the water levels along the Kildare Town Bypass.

The sensitivity to change in recharge was assessed by running a transient-state model over four years having the same properties as the steady-state model. The recharge initially applied to the model was obtained by averaging the monthly recharge amounts over a 10 year period and running those averages on an annual cycle (Table 5-2). This looses the annual variability that naturally occurs in which some years are dryer or wetter than others. To assess the impact of averaging the monthly recharge, the model was run using the calculated average monthly recharge from May 1997 to May 2001 and extended

to December 2006 for the dewatering scenarios (Appendix A) (Brown, 2007). The recharge estimate subtracts the actual evapotranspiration and the soil moisture deficit from the rainfall.

Table 5-2: Table 1: Average monthly recharge as calculated from 1997 to 2006 using the Penman-Monteith Method for the Mid-Kildare Aquifer (modified from Brown, 2007). This estimation assumes no run-off and uses a relatively high value for evapotranspiration.

	RAINFALL	ACTUAL EVAPOTRANSPIRATION	SOIL MOISTURE DEFICIT	RECHARGE
	mm/d	mm/d	mm/d	mm/d
January	2.32	0.53	0.00	1.79
February	2.17	0.73	0.00	1.44
March	1.82	1.13	0.00	0.68
April	2.31	1.71	0.00	0.60
May	2.24	2.35	0.11	0.00
June	1.99	2.74	0.86	0.00
July	1.83	2.68	1.70	0.00
August	2.11	2.33	1.92	0.00
September	2.31	1.57	1.19	0.00
October	3.05	0.93	0.00	0.93
November	2.73	0.52	0.00	2.21
December	2.56	0.44	0.00	2.12

5.5.2 RIVERS AND SPRINGS

In the east, the River Liffey cuts through the entire Mid-Kildare Aquifer and was therefore used as the boundary on the eastern side. The reason for using the river as the eastern boundary is two-fold: it makes the modelled area smaller thereby reducing the number of nodes and thus reducing the computational time for each run of the model; and the area where dewatering occurred was in the western part of the aquifer so the area east of the River Liffey should have very little effect on the aquifer response to dewatering around the motorway. The River Liffey and the Milltown Feeder/Grand Canal were modelled as fixed heads along the line of the river. These heads were set to the ground elevation taken from the OSI (2002) digital terrain model which had a horizontal resolution of 50 m. Although, these levels may not correspond with the exact head of the river they are assumed to be reasonably close given that the mesh spacing of the model is on the order of 100 to 200 m. Thus, unless the mesh is refined considerably additional accuracy in the heads will not result in additional accuracy in the model as the interpolation of the head is constrained by the mesh spacing. The rivers were modelled so that the constant head was maintained by flow from the river entering the aquifer or flow exiting the aquifer into the river.

The Tully Stream consists of a seepage system which is assumed to be fed by springs. The Milltown Stream and its tributaries, which flow from the Chair Hills in the northwest towards Pollardstown Fen, were considered to be sourced by springs. Seasonal streams occur when the groundwater table intersects with the ground surface during periods when the groundwater table is being recharged which usually occurs in the winter. In the summer the groundwater table may be below the ground surface causing the stream to dry up.

The Tully Stream and Milltown Stream and their associated tributaries, and the seepages on the edge of the Fen were represented as constant heads with the head equal to the surface elevation. However, these constant heads were constrained by a maximum flux of zero m^3/d (fluxes out of the model space are negative) so the head condition was only active under exfiltrating conditions. This means that the streams can have water flow out of the aquifer but no water from the stream will flow back into the aquifer. The seepages into the Tully Stream, Milltown Stream and their associated tributaries, and around Pollardstown Fen, and out of the aquifer were modelled where the constant head was only active when the groundwater level was at or above the surface elevation. Figure 5.9 shows the locations of the constant head boundary conditions applied to the rivers and springs in the model space and Figure 5.10 shows the location of the springs which were constrained by flux so that the head condition was only active under exfiltrating conditions. In the case of the Tully Stream and the Milltown Stream it was assumed that the stream was flowing when the groundwater head was equivalent to the surface elevation, however, the stream was assumed to be dry when the groundwater table fell below the surface elevation.

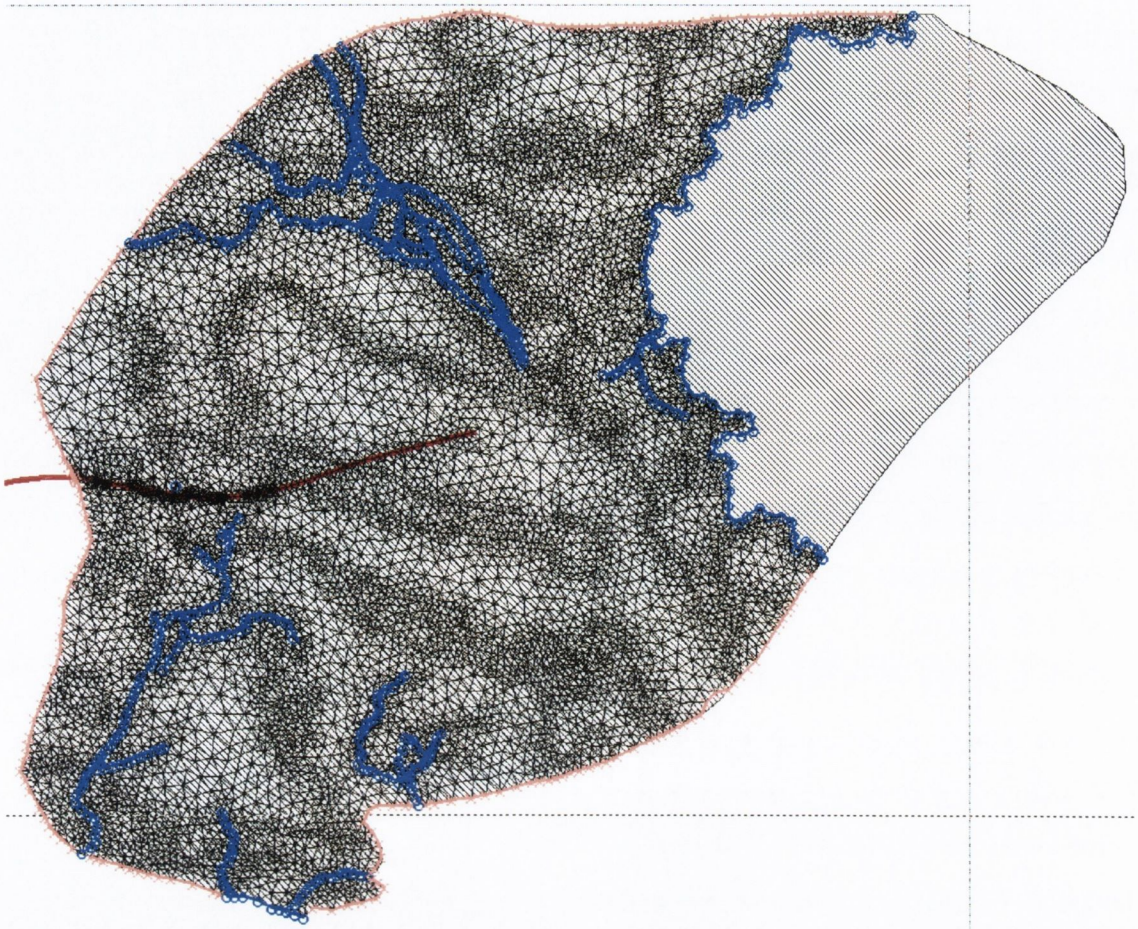


Figure 5.9: Boundary conditions of the Mid-Kildare Aquifer. The pink outer-boundary represents a zero-flux boundary on the outer edge of the aquifer while the blue represents the constant head boundary assigned to the rivers, streams, seepages and springs. The crossed-hatched section shows the eastern part of the aquifer which was excluded from the model.

The outer extent of the model to the north, west and southeast were set as zero flux boundaries as they coincided with the outer limits of the Mid-Kildare Aquifer as defined by Wright (1998). These areas can be seen in Figure 5.9 as the pink crosses on the outer edge of the model domain.

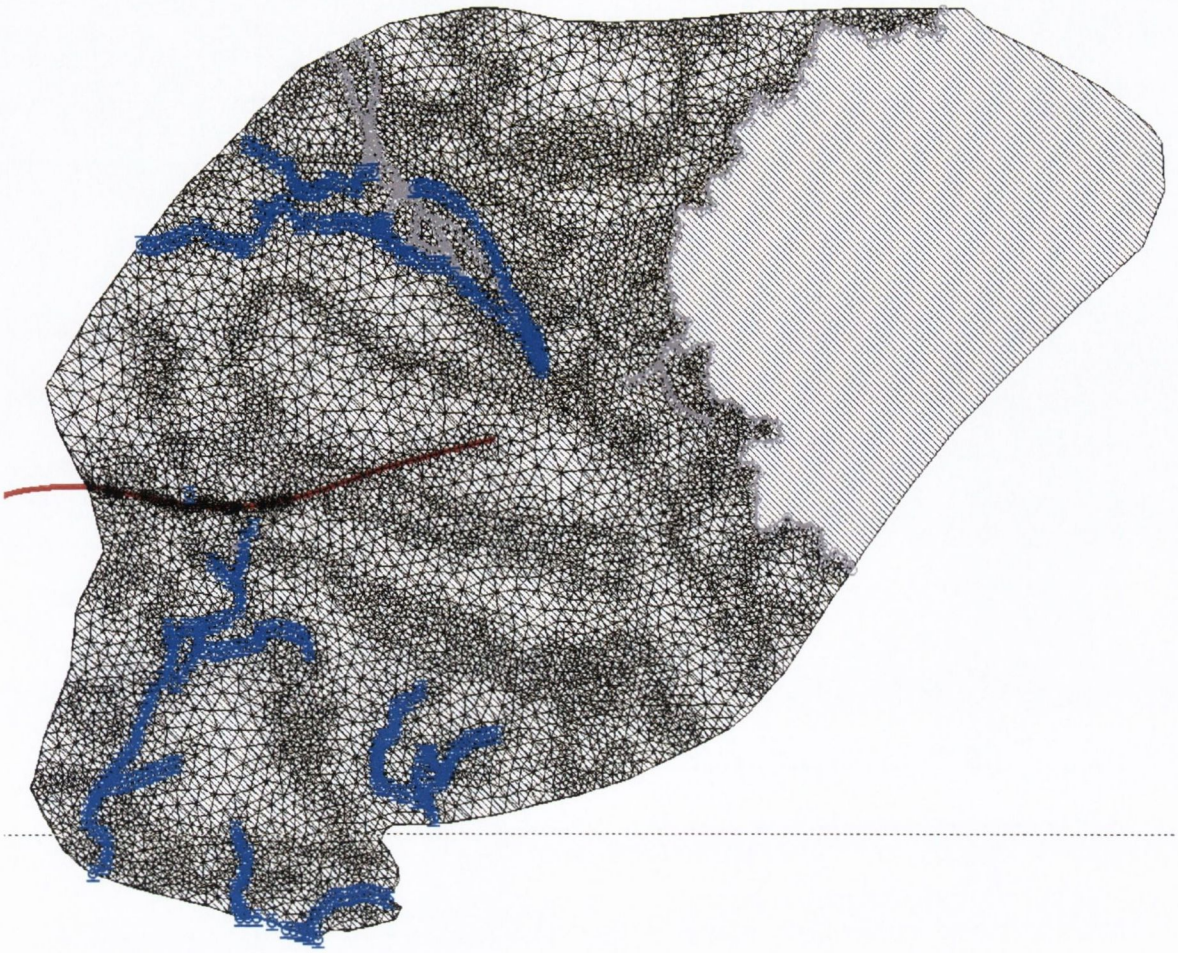


Figure 5.10: Boundary constraints (shown in blue) for the Mid-Kildare Aquifer. These areas represent springs or seepages where the head condition is restricted to be only active under exfiltrating conditions. The crossed-hatched section shows the eastern part of the aquifer which was excluded from the model.

5.5.3 SUMMARY

The flow into and out of the aquifer is summarized in Figure 5.11 in plan view and in cross-section in Figure 5.12. The main outflows in the aquifer, which are computed by the FEFLOW model, are the River Liffey, the Pollardstown Fen seepage system, which includes the Milltown Feeder/Grand Canal and other minor streams, and the Tully Stream seepage system, which includes Japanese Gardens, Armour Stream and many other minor streams. Recharge is the main mechanism through which water enters the model space. In cross-section, the upper layer of the aquifer corresponds to the Quaternary sediments mapped by Glanville (2000) and is underlain by a large sand and gravel outwash deposit. The initial water level, shown in blue, is taken from May 2001 data, as that is when dewatering began and thus the best approximation of the actual water levels at that time. Figure 5.12 shows the water level intersecting the till layer in places (near point A) which causes small areas where the aquifer would behave as though it were confined although the

vast majority of the aquifer is unconfined. The model is run as an unconfined model; however, both specific yield and specific storage values are entered in the model input. As there is only a relatively small area where the water level is high enough to intersect the tills and behave in a confined fashion this should be sufficient.

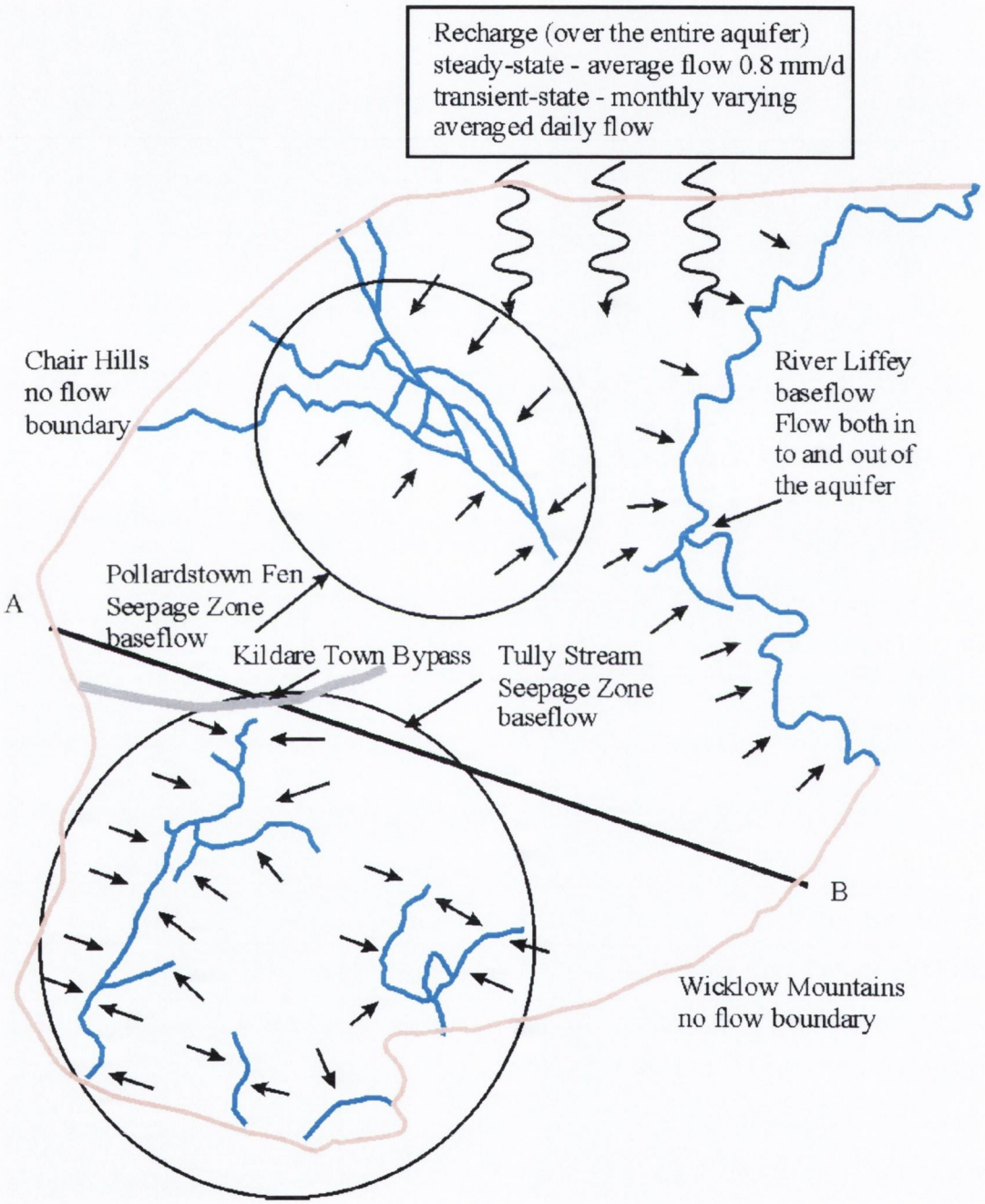


Figure 5.11: Conceptual model of inflows and outflows of the Mid-Kildare Aquifer.

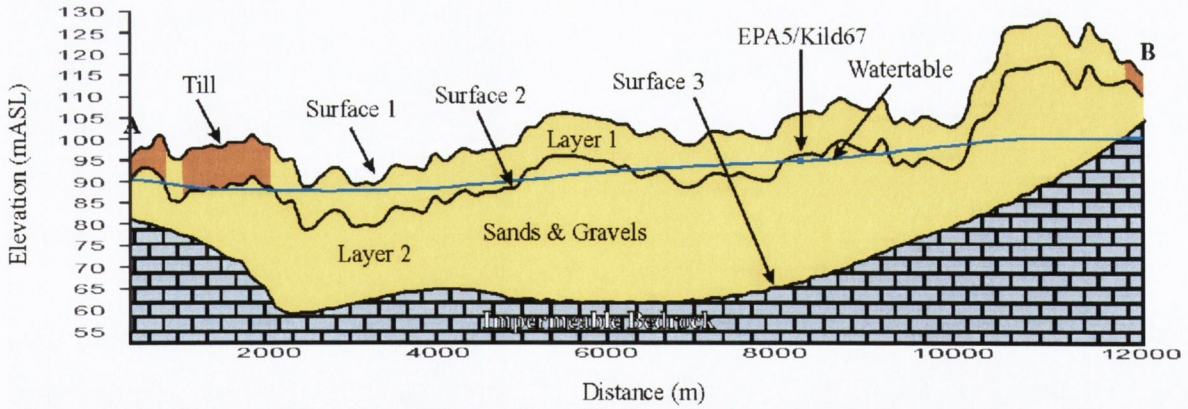


Figure 5.12: Cross-section of the conceptual model showing the upper surface corresponding to the topography, the middle surface corresponding to the boundary between the mapped Quaternary deposits and the sand and gravel outwash deposit, and the bottom surface corresponding to the bedrock surface. The water table is shown in blue for May 2001.

5.6 CONCEPTUAL MODEL OF THE DEWATERING OF THE CUTTING

In FEFLOW, the well boundary condition must be set with a flux into or out of the model space. This differs from MODFLOW where a well boundary condition can be set with either a groundwater head or a flux. As the measured flows described in Chapter 4 contain surface runoff and rainfall and therefore overestimate the flux out of the aquifer, the well boundary condition was further constrained in this model by the groundwater head. This constraint was set at the elevation of the bottom of the excavation and so limited the amount of groundwater flow allowed to leave the model space. This, in effect, is similar to MODFLOW where a well is set to dewater to a certain head and the groundwater flux is unconstrained. A limitation of the FEFLOW software is that does not have a drain feature similar to MODFLOW and thus modelling the excavation as wells is necessary.

The dewatering of the Mid-Kildare Aquifer was modelled based on the dewatering schedule and flows reported in Chapter 4. The flows out of the main excavation and all of the bridge sites were recorded daily (see Appendix E) and these values were incorporated into the model. The dewatering was entered into the model as a daily value as this was the focus of the modelling and therefore the highest temporal resolution was used. The dewatering was represented in the model as wells, which were constrained by the groundwater head so that the wells were only active when the groundwater level was above the excavation level. This means that the measured extracted water during dewatering (Appendix E) represents the maximum volume of water allowed to be extracted from the well in the model to lower the groundwater head to the excavation level.

Dewatering at bridge locations was assumed to be similar to a single well with the amount of water extracted or pumped being inputted from the daily measured values on site during dewatering. The trenches were envisaged as a series of wells depending on the length of the trench. In the cases where the trench length was 500 m, two wells were used and the amount of water extracted or pumped was half the measured daily value for each well. This meant that the combined total of water extracted was equal to the measured value of water leaving the system. In the cases where the trench length was 1000 m, three wells were used to represent the dewatering. The amount of water extracted or pumped from each well was then a third of the measured daily value so that the total water extracted from the trench was equal to the total measured value. The Kildare Town Bypass was dewatered in stages proceeding from west to east so western areas were allowed to recharge while areas in the east were being dewatered and vice versa. The length of the dewatered section was generally restricted to approximately 1000 m.

The well boundary condition had to be used rather than a constant head boundary condition because the constant head condition can not be turned off and on as the well boundary condition can. This is very important as the Kildare Town Bypass was a staged excavation, so sections in the west were recharging while sections to the east were being dewatered. The well boundary condition was the best suited condition to simulate the complexities of the dewatering of the Kildare Town Bypass using the FEFLOW modelling software.

The representation of the cutting is very different in Chapter 6 than in the KAM model. In the KAM model, the effect of dewatering was achieved using nodes which abstract water at a rate dependent on the difference between the natural groundwater level and pre-set drainage levels but which do not permit water to enter the model when the groundwater is below the drainage level. The conductance of the nodes was set at a high level that does not constrain the ability of the aquifer to deliver water to the drainage system (Hayes, *et al.*, 2001).

5.7 CONCLUSIONS

1) The validation modelling of FEFLOW shows that the software can model seepage into an excavation and pumping tests.

2) The conceptual model consists of a two-layer model with the top layer corresponding to the surface sediments mapped by Glanville (2000) and the bottom layer corresponding to the main sand and gravel aquifer.
3) The hydraulic conductivity of the units is based on the pump tests where available and particle size distribution tests or published values otherwise.
4) The specific yield and specific storage values are based on published values as the pump tests did not provide reliable estimates.
5) The outer boundary of the model is set as no-flow except where it coincides with rivers or streams where it is set as a constant head boundary.
6) The River Liffey is modelled as a constant head boundary and the seepages around Pollardstown Fen and the Tully Stream are constant head boundaries which are constrained to only be active when the groundwater head is at or above the elevation of the topography.
7) The excavation is modelled as a series of time-dependent wells that are constrained by time-dependent heads which are set at the excavation level or at the weir level after construction was completed.

CHAPTER 6

NUMERICAL MODELLING OF THE STUDY AREA

6.1 INTRODUCTION

This chapter describes the development of the numerical model to satisfy the conceptual model of the Mid-Kildare Aquifer as described in Chapter 5. Two types of numerical model were run to simulate the Mid-Kildare Aquifer: steady- and transient-state.

The steady-state model runs, which did not include the excavation dewatering, were conducted to ensure that:

1) The assumptions made in the conceptual model were consistent with the site data recorded prior to dewatering.
2) The numerical model adequately represented the conceptual model.
3) The response of the aquifer as indicated by the numerical model was reasonable and physically possible.

The transient-state model runs were developed building in complexity with each successive model and were used to:

1) Increase the model complexity as needed to represent the groundwater response and baseflow into rivers and streams.
2) Gain an understanding as to the effect of recharge, hydraulic conductivity, specific yield, specific storage, and dewatering on the groundwater response.
3) Model the dewatering for the Kildare Town Bypass as a staged excavation and observe the effects on the groundwater levels, baseflow into the rivers and the pumped flow out of the excavation.

6.2 STEADY-STATE MODEL

The first steady-state model was conducted in order to assess the effect of initial hydraulic heads input to the model on the final groundwater levels (Section 6.2.1). The following steady-state model runs assessed the effect of recharge (Section 6.2.2) and the effect of hydraulic conductivity (Section 6.2.3) on the groundwater levels and flows into the rivers, streams, and fen. The initial model run was not calibrated and used the parameters outlined in the conceptual model in Chapter 5. The calibration involved adjusting the model parameters to obtain a better correlation with the measured groundwater levels. The subsequent models were calibrated by adjusting the hydraulic

conductivity and allowing the groundwater level to fall below the bedrock. The groundwater level was allowed to fall below the bedrock because the limestones underlying the Mid-Kildare Aquifer are known to be aquifers themselves (see Section 3.2). This was only important in the area around the Chair Hills and the Wicklow Mountains where the overburden was thin and in order to obtain a correlation with the measured groundwater level with MB28, in particular, the groundwater level was allowed to fall below the bedrock. The steady-state model consisted of six runs:

1) Run #S1 - Uncalibrated model with 0.9 mm/d of recharge which corresponds to the average daily recharge from 1997 to 2006 recorded at Osberstown (before 2001) and Naas (after 2001) from Brown (2007). This model used the parameters set out in Chapter 5.
2) Run #S2- Calibrated model with 0.9 mm/d of recharge. This model was conducted to ensure that the groundwater levels and baseflow into the rivers and streams had a reasonable match with the observed levels and baseflow.
3) Run #S3 - Calibrated model with 0.7 mm/d of recharge which simulates the recharge in a drier year (using calibration of Run #S2). This model was conducted to ensure that the model responded appropriately to changes in recharge and that the modelled groundwater levels reflected those in drier periods.
4) Run #S4 - Calibrated model with 1.1 mm/d of recharge which simulates the recharge in a wetter year (using calibration of Run #S2). This model was conducted to ensure that the model responded appropriately to changes in recharge and that the modelled groundwater levels reflected those in wetter periods.
5) Run #S5 - One-layer model with uniform hydraulic conductivity and recharge input of 0.9 mm/d (using calibration of Run #S2). This model was conducted to assess the effect of hydraulic conductivity on the model.
6) Run #S6 - Two-layer model with uniform hydraulic conductivity on the upper and lower layer and recharge input of 0.9 mm/d (using calibration of Run #S2). This model was conducted to assess the effect of hydraulic conductivity on different layers of the model.

6.2.1 Effect of initial Hydraulic Head

The effect of initial hydraulic head input to the model was assessed to determine the effect on the modelled groundwater levels. A steady-state model using the initial hydraulic

heads recorded in May 2001 was compared with another model using significantly higher initial hydraulic heads from February 1999. Both resulted in the same modelled head (Figure 6.1). This indicates that the initial hydraulic heads input into a steady-state model is not relevant as the model converges on the same final hydraulic head.

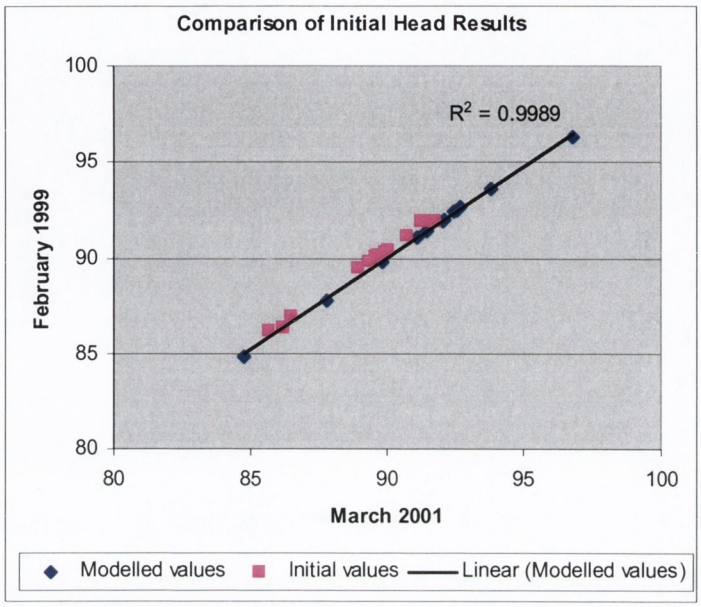


Figure 6.1: Comparison of modelled hydraulic heads (m above datum) showing that regardless of input the modelled steady-state head are the same as long as the input is reasonable. The monitoring boreholes are the points used to compare the heads in this figure.

6.2.2 Sensitivity to Recharge

Several steady-state models were run to assess the sensitivity to recharge. This tested the validity of the initial assumptions made in the conceptual model and the modelled response to changes in recharge. The groundwater levels obtained from Runs #S1, #S2, #S3 and #S4 are compared with each other and the measured water levels within the Mid-Kildare Aquifer. A hydrograph of the groundwater levels in the monitoring boreholes which forms the basis for comparison for these steady-state models is shown in Figure 6.2.

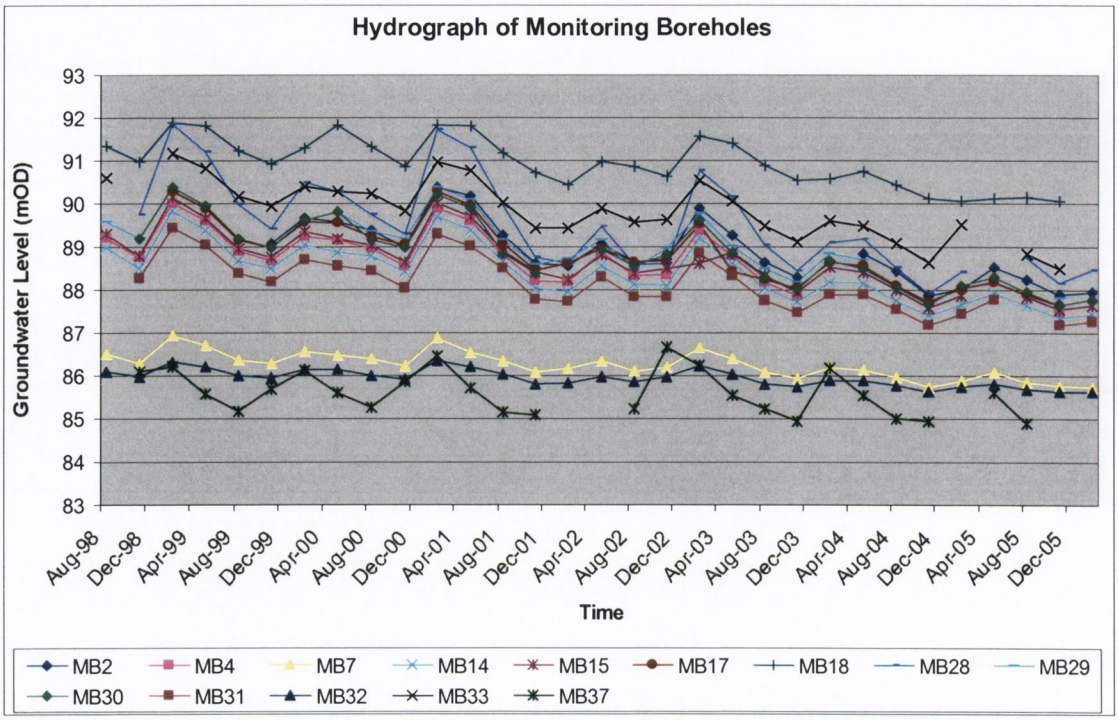


Figure 6.2: Hydrograph showing the groundwater variation through time in the monitoring boreholes.

The steady-state model Run #S1, which used the parameters set out in the conceptual model (Chapter 5), had groundwater levels which were much higher than those observed in the monitoring boreholes. It became apparent from the analysis that the hydraulic conductivity needed to be raised in order to lower the groundwater levels in the model (Table 6-1). In order to obtain a better correlation with monitoring borehole MB28 the model was altered so that the groundwater level could fall below the bedrock surface. The assumption that the bedrock is permeable is in accordance with the limestones underlying the Mid-Kildare Aquifer being identified as locally and regionally important aquifers (Geological Survey of Ireland, 2007). The KAM model also had to increase the hydraulic conductivity within the model to calibrate the model (White Young Green, 2004).

Table 6-1: Modified hydraulic conductivity for the steady-state model (Run #S2, #S3 and #S4). The horizontal and vertical hydraulic conductivity are indicated by (h) and (v), respectively.

UNIT	ORIGINAL HYDRAULIC CONDUCTIVITY (m/s)	MODIFIED HYDRAULIC CONDUCTIVITY (m/s)
Gravels (Glacial outwash) (upper layer)	$2.4x10^{-4}$ (h) $2.4x10^{-5}$ (v)	$2.0x10^{-3}$ (h) $2.0x10^{-4}$ (v)
Gravels (lower layer) Northwest	$2.4x10^{-4}$ (h) $2.4x10^{-5}$ (v)	$2.0x10^{-3}$ (h) $2.0x10^{-4}$ (v)
Gravels (lower layer) around MB28	$2.4x10^{-4}$ (h) $2.4x10^{-5}$ (v)	$1.0x10^{-3}$ (h) $1.0x10^{-4}$ (v)
Gravels (lower layer) around Pollardstown Fen (NE corner)	$2.4x10^{-4}$ (h) $2.4x10^{-5}$ (v)	$9.0x10^{-4}$ (h) $9.0x10^{-5}$ (v)
Gravels (lower layer) around MB18	$2.4x10^{-4}$ (h) $2.4x10^{-5}$ (v)	$5.0x10^{-5}$ (h) $5.0x10^{-6}$ (v)
Esker (upper layer)	$5.0x10^{-3}$ (h) $5.0x10^{-4}$ (v)	$4.0x10^{-3}$ (h) $4.0x10^{-4}$ (v)
Esker around MB18 (upper layer)	$5.0x10^{-3}$ (h) $5.0x10^{-4}$ (v)	$5.0x10^{-5}$ (h) $5.0x10^{-6}$ (v)
Alluvium (upper layer)	$1.0x10^{-2}$ (h) $1.0x10^{-3}$ (v)	$8.0x10^{-3}$ (h) $8.0x10^{-4}$ (v)
Carboniferous Limestone Till	$5.0x10^{-5}$ (h) $5.0x10^{-6}$ (v)	$1.0x10^{-4}$ (h) $1.0x10^{-5}$ (v)
Till with Gravel	$5.0x10^{-5}$ (h) $5.0x10^{-6}$ (v)	$7.0x10^{-5}$ (h) $7.0x10^{-6}$ (v)

The groundwater flow patterns resembled each other in all four models indicating that the entire groundwater table rises and falls similarly in response to recharge. Figure 6.3 shows the groundwater contours for Run #S2 (calibrated model with average recharge). This figure shows that the groundwater flow resembles the pattern shown in Section 3.4.3 indicating that it was adequately represented by the steady-state model. There is a hydraulic divide at the centre of the aquifer with the groundwater contours being controlled on the northwest and southeast due to proximity of the bedrock and those on the southwest by the Tully seepage system and to north by the Pollardstown Fen. The River Liffey controls the groundwater levels to the east.

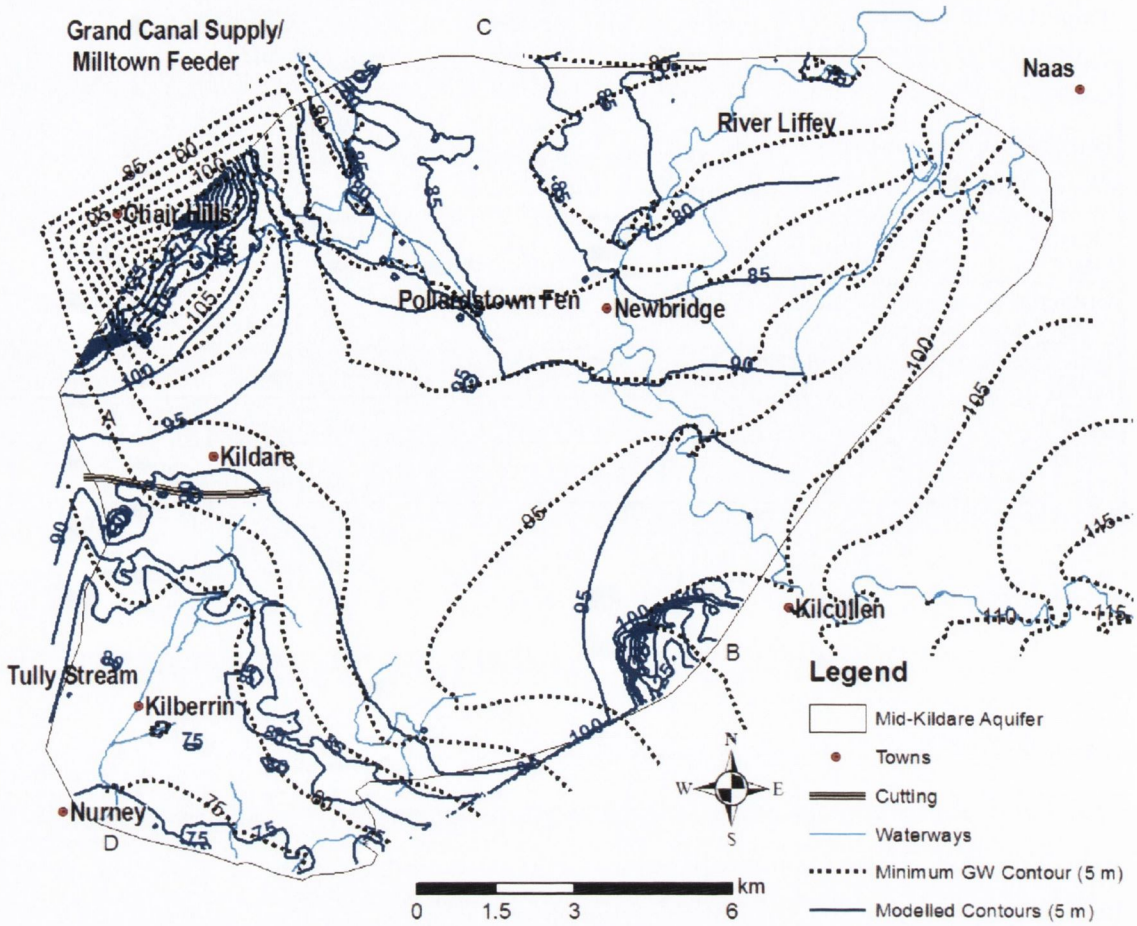


Figure 6.3: Steady-state groundwater contours for 0.9 mm/d recharge with the same calibration as the transient-state modelling. The minimum groundwater contours from Section 3.4.3 are superimposed on the modelled groundwater contours.

The groundwater levels of the four model runs with varying recharge were compared in Profiles AB and CD (locations shown in Figure 6.3). The measured groundwater levels from May 2001 were gridded using the natural neighbours technique using the monitoring borehole data and the river levels. The locations of the recorded data are illustrated in Figures 6.4 and 6.5. Where no data are present the accuracy of the water level is crude so a general match is sufficient to adequately represent the Mid-Kildare Aquifer.

Plots of the modelled groundwater levels and the measured groundwater levels in May 2001 across the profile AB and CD are shown in Figures 6.4 and 6.5. Figure 6.4 shows that there is only a small (~1 - 2 m) difference in groundwater levels with response to the recharge input values. However, the measured groundwater head in May 2001 at EPA5/Kild67 is closest to the modelled groundwater level for the steady-state condition where the recharge was 1.1 mm/d. The shape of the modelled groundwater levels reflects the bedrock and topography along the profile. The observed difference in head of 1 to 2 m

is within the accepted seasonal variation for the Mid-Kildare Aquifer as stated in Chapter 3, and with the maximum variations from 1998 to 2005 of 4.5 m as discussed in Chapter 5.

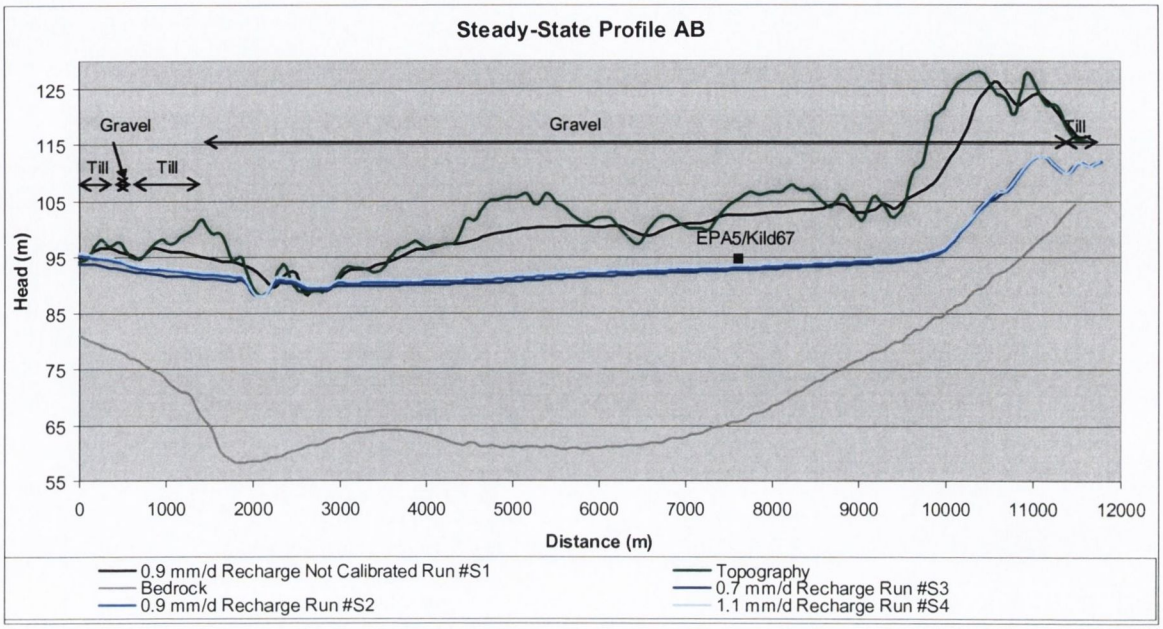


Figure 6.4: Modelled groundwater levels for the uncalibrated model (Run #S1), the calibrated models with 0.7 (Run #S3), 0.9 (Run #S2), and 1.1 (Run #S4) mm/d recharge and the measured groundwater levels from May 2001 is shown at the black box below EPA5/Kild67. The geology on this figure refers to the geology of Layer 1 in the model.

Figure 6.5 shows that there is only a small (~1 m) difference in groundwater levels with response to the recharge input values. However, the measured groundwater head for May 2001 in all the monitoring boreholes along Profile CD correlates best with the modelled recharge of 0.7 mm/d. The groundwater levels across profile CD show less variation between runs than along profile AB. The maximum variation observed across profile CD is approximately 1 m. The profiles show the effect of the hydraulic conductivity on the infiltration rate of the recharge. Profile CD illustrates that the low vertical hydraulic conductivity (till and peat) causes the groundwater level to be closer to the surface as the flow of recharge into the sediments below is impeded. Along profile CD, the measured and modelled groundwater levels are at or near the ground level where the peat deposits occur. The area from 3500 to 4500 m, which corresponds to Pollardstown Fen, shows water levels which are greater than the topographic surface. This is the location where the seepage boundary condition was put in place and in order for seepage to occur the water level must be above the ground surface. The low hydraulic conductivity of the peat also causes pore water pressures in the gravels beneath the peat to be elevated. This would lead to an upward gradient causing seepage from the gravels into

the peat deposits which is similar to what has been observed at Pollardstown Fen (Daly, 1981).

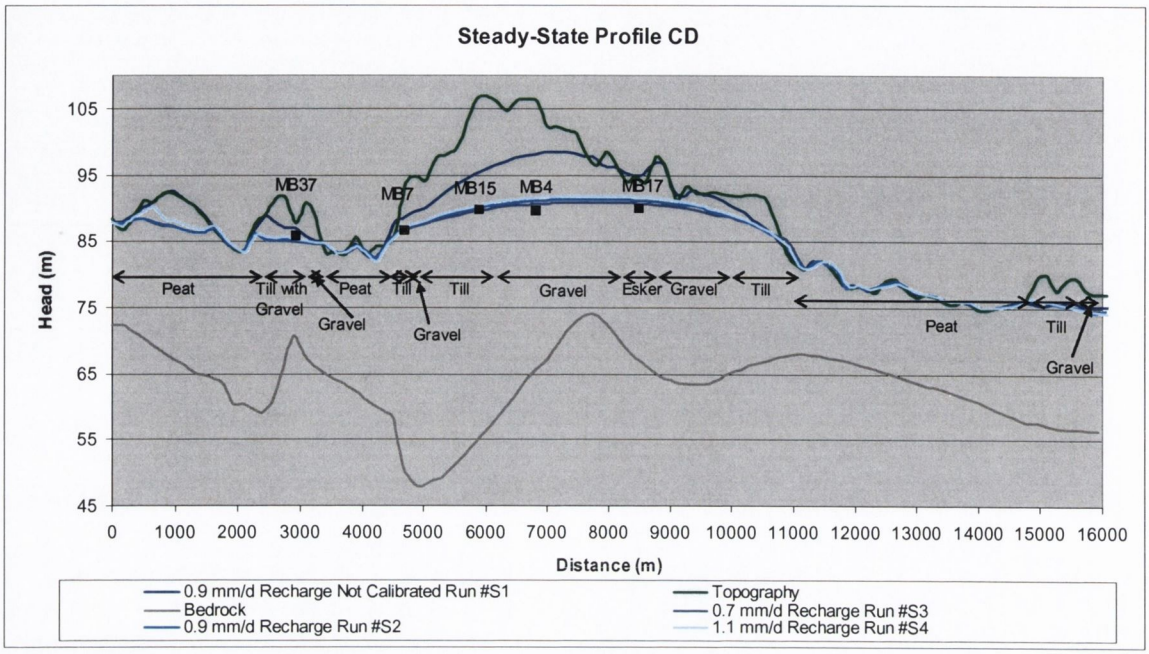


Figure 6.5: Modelled groundwater levels for the uncalibrated model (Run #S1), the calibrated models with 0.7 (Run #S3), 0.9 (Run #S2), and 1.1 (Run #S4) mm/d recharge and the measured groundwater levels from May 2001 is shown as a black box beneath the monitoring borehole labels. The geology on this figure refers to the geology of Layer 1 in the model.

The observed groundwater levels fit best with different recharge inputs in the two profiles, although, at this scale, recharge seems to have little effect. This emphasises the importance of the monitoring boreholes being evenly spaced around the aquifer so there are not large areas with no data being collected. Profile CD has many more monitoring boreholes as it passes by Kildare Bypass and Pollardstown Fen (the two areas where most monitoring took place) this allows for more accurate gridding of the groundwater levels, thus assisting with the correlation.

There are several observations which can be made by examining Figures 6.4 and 6.5. The topographic surface has a significant effect on the groundwater contours as shown by the steep gradient in the area of the Wicklow Mountains in the southeast (Profile AB - 9500 to 12000 m), and the hill just south the Fen in between Loughbrown and Ballymany (Profile CD ~3000 m). The low vertical hydraulic conductivity of the peat deposits at Pollardstown Fen keeps the groundwater levels near the ground surface and hinders infiltration so large groundwater gradients develop along the edges of the peat deposit. This result correlates well with the observations from the Pollardstown Fen deposit as

seepages and springs have been observed around the edges of the peat deposits and are likely to be caused by the contrast in hydraulic conductivity with the surrounding till and gravel deposits as suggested by Rushton (2003). The watertable is affected by the proximity to boundary conditions, e.g. those being close to fixed head boundaries show little difference in head as a result of increased recharge. It is also affected by the hydraulic conductivity of the unit to which the recharge is applied and the gradient of the head. An increase in the amount of recharge causes an increase in the groundwater levels.

Figure 6.6 compares the water levels measured in November 2000 and May 2001 to the results of the steady-state models using recharge rates of 0.7, 0.9 and 1.1 mm/d. This shows the natural variation in groundwater level between November 2000 (a low groundwater level) and May 2001 (a high groundwater level). The modelled steady-state results show a difference of a little over 1 m between the steady-state recharge of 0.7 mm/d and 1.1 mm/d. The recharge input of 1.1 mm/d best matches May 2001 as would be expected, as May is often near the annual high groundwater level, and 0.7 mm/d best matches November 2000, and November is often near the annual low groundwater level. The recharge (assuming no runoff; see Section 3.4.4) was applied globally over the entire model space which may be the reason why peaks at points such as MB18 in November 2000 are not represented. From the various weather stations it is known that over the area of the Mid-Kildare Aquifer rain does not fall uniformly and some monitoring boreholes may experience a rainfall event which other boreholes do not (Misstear and Brown, 2007). Figure 6.2 shows a hydrograph of the monitoring boreholes illustrating the variation in groundwater levels through time. As these models are steady-state and the actual aquifer is constantly in a dynamic flux it is not expected that a perfect match would be obtained using steady-state modelling.

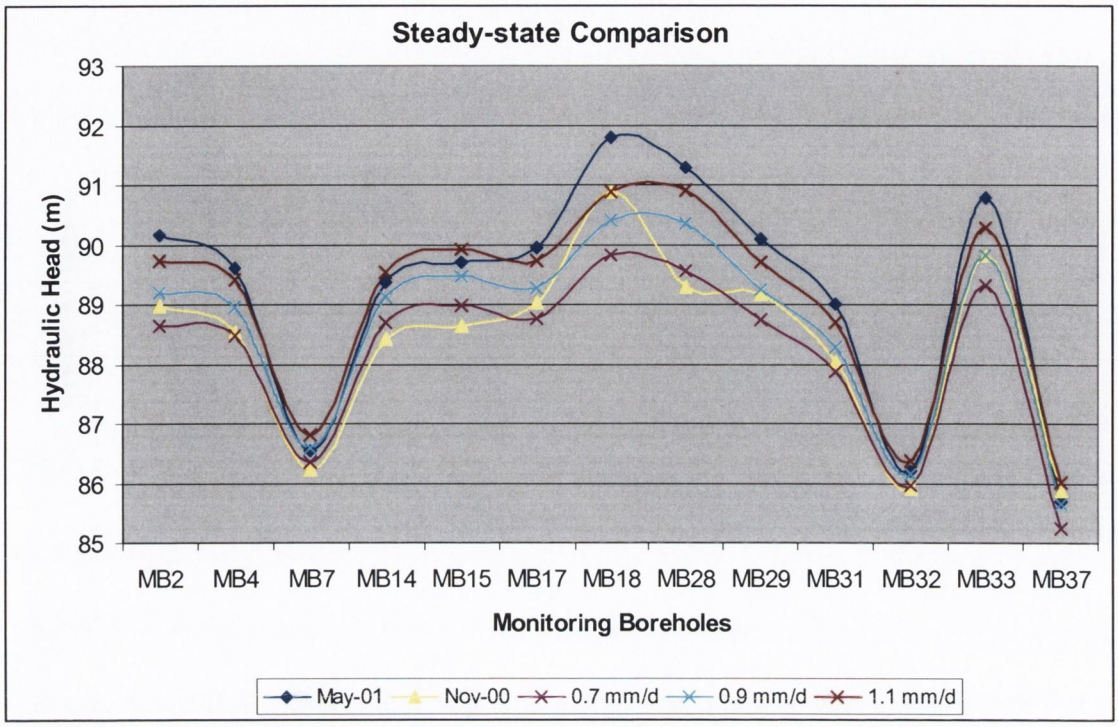


Figure 6.6: Comparison of the steady-state modelled groundwater heads and the measured heads in the monitoring boreholes in November 2000 and May 2001.

A water balance was conducted on the calibrated steady-state models (Runs #S2, #S3 and #S4) to assess if the baseflow into the River Liffey, Tully Stream and Pollardstown Fen were similar to the estimates from Farrell and Devine (2006). The groundwater flow leaves the model through the rivers and seepages. Flow can enter the model from recharge or the River Liffey. As this is a saturated model, no unsaturated zones can occur. In order to satisfy this condition, a minimum thickness of 0.01 m of saturated sediments must always exist in the model. This limitation of the model is acceptable as recharge in the aquifer should ensure that there is always at least 0.01 m of saturated sediments in the model. Figure 6.7 shows the flows in (red) and out (blue) for the model.

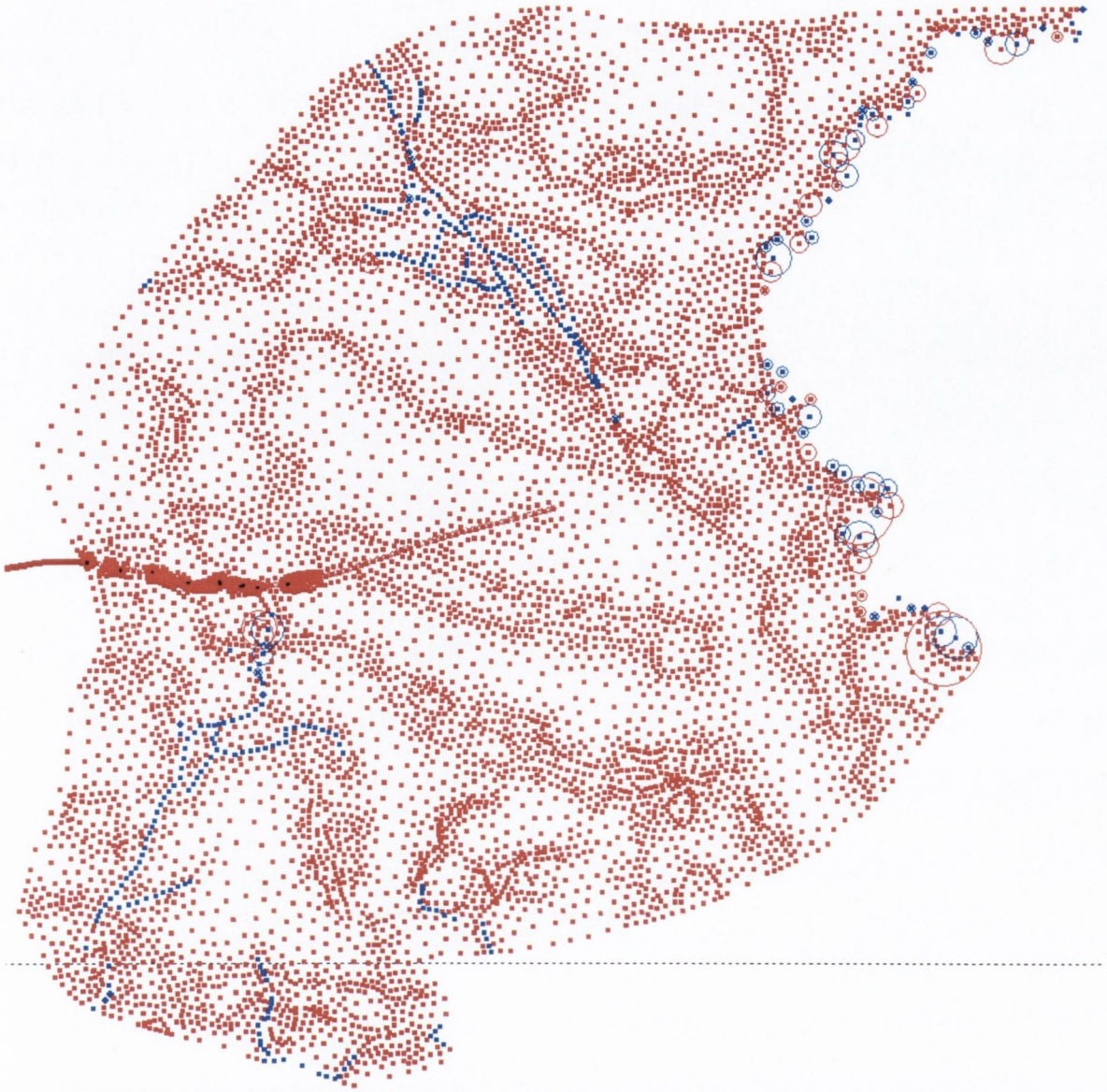


Figure 6.7: Map showing fluxes in and out of the model space for the steady-state 0.9 mm/d calibrated run (Run #S2). Red points are fluxes into the model and blue are fluxes out of the model. The circle radius corresponds linearly with the amount of flux.

The water budget is analysed by assessing the fluxes along outer or inner boundaries, e.g. borders occupied with head, flux, or transfer boundary conditions; injections or withdrawals through single wells; and aerial fluxes due to recharge. An imbalance is calculated by subtracting the outfluxes from the influxes. In a steady-state model, the imbalance represents a measure of computational accuracy. In addition to assessing the fluxes through all the nodes, they may also be assessed as parts or all of nodes, elements, borders, boxes, lines, or polygons. Fluxes through the outer borders of the nodes were assessed for the River Liffey. Fluxes out of the Tully Stream seepage system and the Milltown Feeder/Grand Canal/Pollardstown Fen were also examined. The north, western, and southeastern boundaries were set as zero flux so that no flow of water came through

these areas. The water budgets for computational accuracy and to determine the flows into and out of the River Liffey, Tully Stream, and Milltown Feeder can be found in Table 6-2. This table lists the total fluxes for all the nodes in the model (Total), the fluxes on the nodes representing the River Liffey (River Liffey), the fluxes on the nodes representing the Tully Stream (Tully Stream), and the fluxes on the nodes representing the area of the Pollardstown Fen (Milltown Feeder/Grand Canal, Pollardstown Fen). The fluxes were calculated for model runs 0.7 mm/d recharge (#S3), 0.9 mm/d recharge (#S2) and 1.1 mm/d recharge (#S4).

Table 6-2: Steady-state calibrated modelling results for various recharge levels.

	0.7 mm/d Recharge		0.9 mm/d Recharge		1.1 mm/d Recharge	
	(m^3/d)	(l/s)	(m^3/d)	(l/s)	(m^3/d)	(l/s)
Total						
In	469368	5432	465717	5390	462487	5353
Out	576447	6672	601281	6959	625422	7239
Recharge	103448	1197	133004	1539	162561	1881
Net	-3631	-42	-2560	-30	-375	-4
River Liffey						
In	346934	4015	344636	3989	342406	3963
Out	384539	4451	387557	4486	390462	4519
Recharge	742	9	954	11	1174	14
Net	-36863	-427	-41967	-486	-46882	-543
Tully Stream						
In	0	0	0	0	0	0
Out	29877	346	37386	433	40355	467
Recharge	556	6	694	8	895	10
Net	-29321	-339	-36692	-425	-39460	-457
Milltown Feeder/Grand Canal/Pollardstown Fen						
In	1574	18	2199	25	3603	42
Out	36904	427	42165	488	48130	557
Recharge	2284	26	2907	34	3603	42
Net	-33047	-382	-37059	-429	-40924	-474

The results from the water balance show that the computational accuracy is very good as the difference between the total influxes and outfluxes is small (Table 6-2, net imbalance over the entire model space is between 4 and 42 l/s). Figure 6.8 illustrates that the relationship between recharge and the flows into the River Liffey, Pollardstown Fen

and Tully Stream is approximately linear. The Tully Stream and Pollardstown Fen areas are fed entirely by groundwater and therefore have very little or no flux into the aquifer. The baseflow estimates from the model (427 - 543 l/s) are significantly less for the River Liffey than was estimated by Farrell and Devine (1500 - 2000 l/s) (2006). This may be because the baseflow estimated using low summer flows would incorporate flows from aquifers further upstream (which would contribute to the flows in the summer). Since the River Liffey forms the boundary of the model it would be receiving only half of the flow since there is no flow from the eastern part of the Mid-Kildare Aquifer in the model. Once this is taken into consideration the modelled flow into the River Liffey compares favourably with the estimate from Farrell and Devine (2006). The estimates by Farrell and Devine (2006) for the Tully Stream (~300 l/s) are lower than the modelled results (339 to 457 l/s), however, the estimates of Farrell and Devine (2006) are based on a monitoring station at Kilberrin which is approximately 2 km upstream from the edge of the model space. The flows in the model are measured along the entire length of the Tully and so would incorporate the baseflow from the 2 km down stream which are not included in the Farrell and Devine (2006) estimate. The Milltown Feeder/Grand Canal was estimated by Farrell and Devine (2006) to have a baseflow between 200 and 470 l/s. The flow measured in the model is on the higher end of the Farrell and Devine (2006) estimate ranging from 382 to 474 l/s. This is because the Farrell and Devine (2006) estimate is based on baseflow measurements in the Milltown Feeder only, whereas the model measures the baseflow in all of Pollardstown Fen, the springs and Milltown Stream.

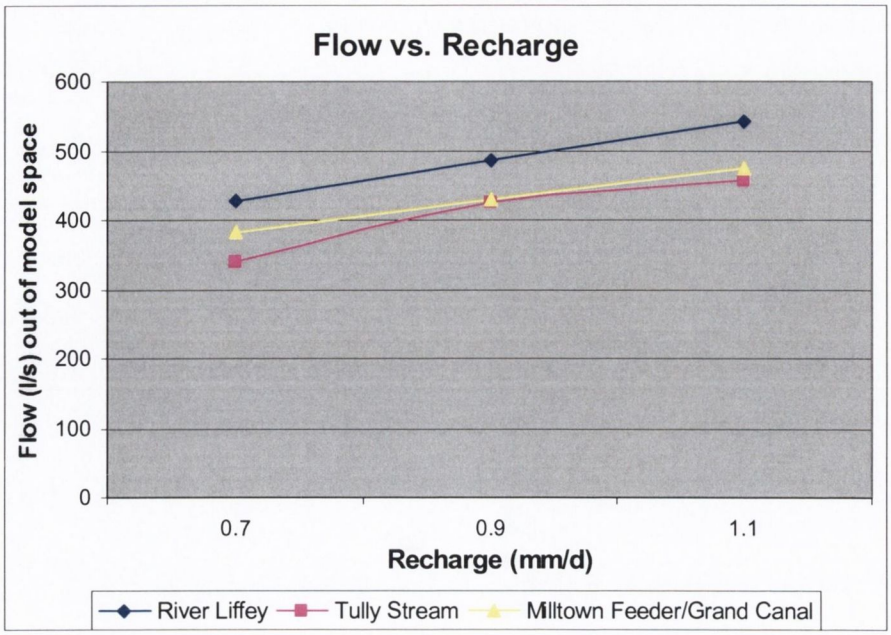


Figure 6.8: Plot of flow versus recharge for the rivers in the model domain (values from Table 6.2).

6.2.3 SENSITIVITY TO CHANGES IN HYDRAULIC CONDUCTIVITY

Several steady-state models were run to assess the sensitivity to hydraulic conductivity. An examination of the sensitivity of the groundwater response to changes in hydraulic conductivity was conducted by using the sediments mapped by the GSI and comparing them to a one layer model having the same hydraulic conductivity of the gravel ($2.0x10^{-3}$ m/s horizontal, $2.0x10^{-4}$ m/s vertical) (Run #S5), and a two-layer model with the upper layer having the hydraulic conductivity of the till ($1x10^{-4}$ m/s horizontal, $1x10^{-5}$ m/s vertical) and the lower layer having the conductivity of the gravel ($2.0x10^{-3}$ m/s horizontal, $2.0x10^{-4}$ m/s vertical) (Run #S6). The sensitivity to changes in surface sediments was assessed for the condition where there was 0.9 mm/d of recharge in the model. The results of Run #S5 and #S6 are compared with the results from Run #S2 where the surface sediments are variable.

Profile AB illustrates that the groundwater is lower when a simple one-layer model is used with uniform hydraulic conductivity of gravel ($2.0x10^{-3}$ m/s horizontal, $2.0x10^{-4}$ m/s vertical) (Figure 6.9). Profile CD, which crosses through more complex geology, shows the same effect (Figure 6.10). A comparison of Figures 6.9 and 6.10 with Figures 6.4 and 6.5 shows that there is a greater change in water level as a response to changes in hydraulic conductivity than for changes in recharge. The steady-state model is sensitive to changes in hydraulic conductivity and it can be noted that an increase in hydraulic conductivity

results in the groundwater table being lowered. The maximum difference in groundwater head observed between Run #S2 and Run #S5 along Profile AB was 2.3 m and it increased to 4.0 m along Profile CD. This can be compared to the difference in head observed between Run #S3 and Run #S4 which had a head difference of 2.1 m along Profile AB and 2.4 m along Profile CD.

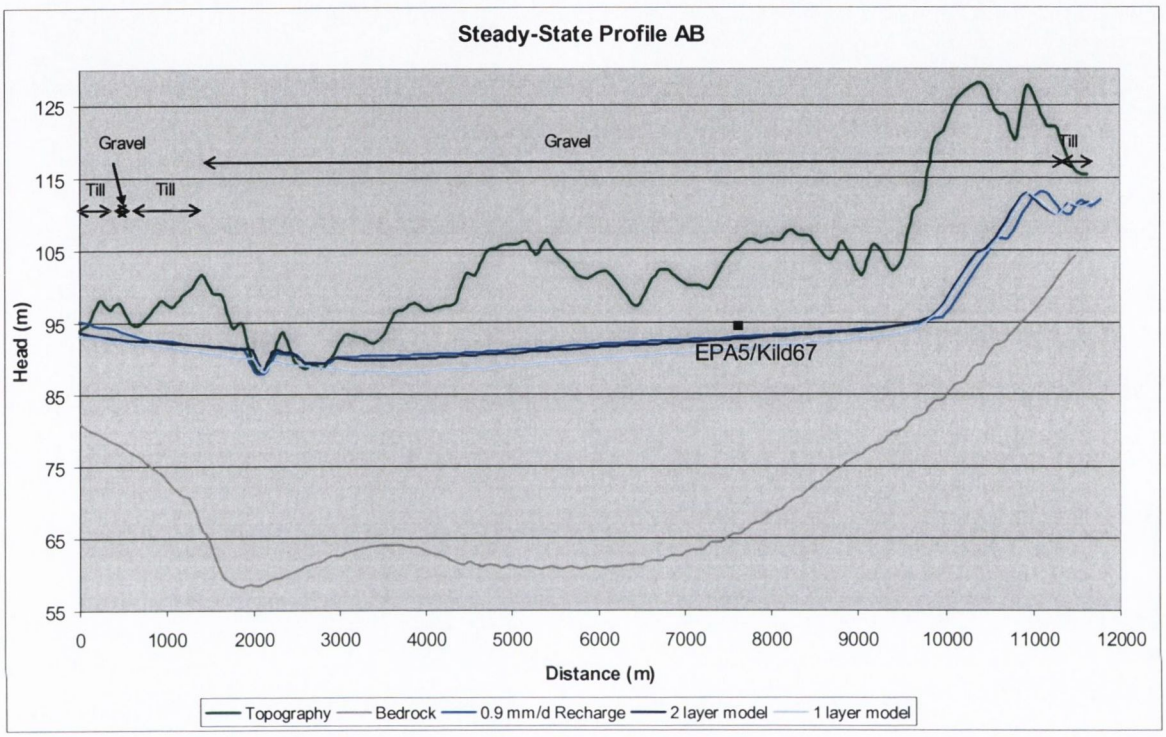


Figure 6.9: Profile AB showing the effect of changing the surface sediments on the groundwater head. The two layer model consists of a bottom layer of gravel and an upper layer of till and the one layer model consists entirely of gravel.

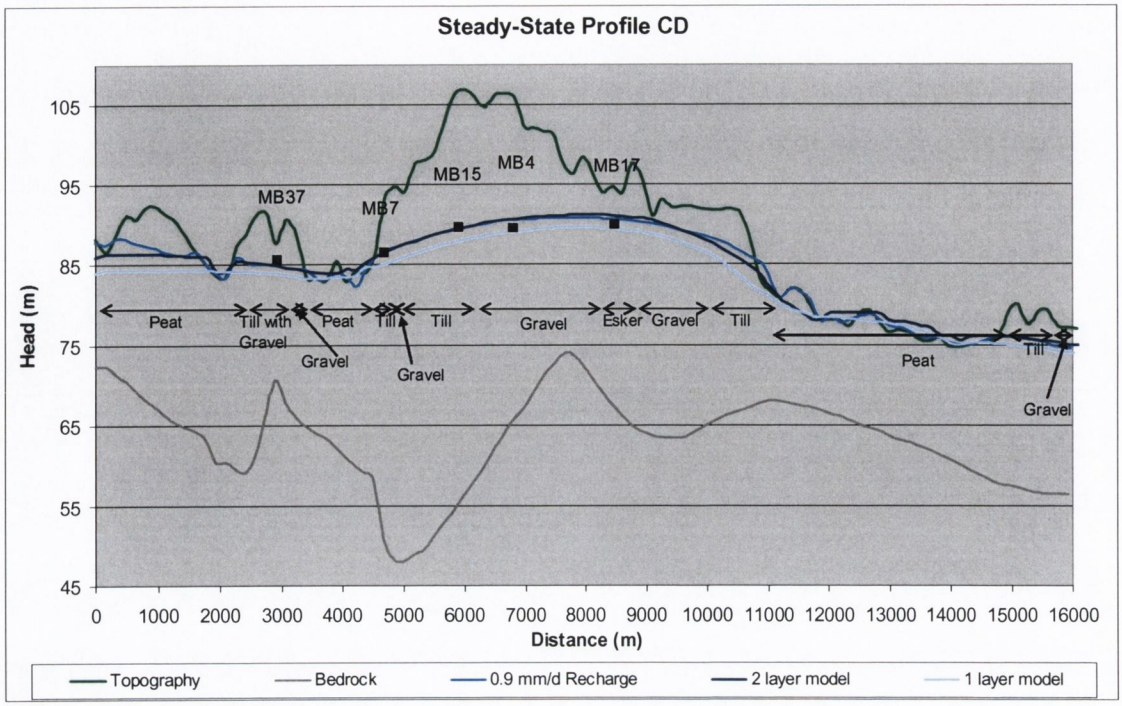


Figure 6.10: Profile CD showing the effect of changing the surface sediments on the groundwater head. The two layer model consists of a bottom layer of gravel and an upper layer of till and the one layer model consists entirely of gravel.

The goal of the modelling exercise was not to produce exact matches to the observed data at one moment in time but to match the generalized pattern of behaviour for the aquifer. The steady-state model illustrated that after calibration the basic conceptual model and boundary conditions were reasonable. In the model, the changes in recharge caused a change in groundwater level of 2.1 to 2.4 m while changes in the hydraulic conductivity caused a change in groundwater level of 2.3 to 4.0 m. The modelled flows out of the aquifer from the River Liffey, the Tully Stream and the Milltown Feeder/Grand Canal/Pollardstown Fen agree quite well with previous estimates of baseflow. Therefore, the response of the aquifer to recharge and discharge through rivers, streams, and seepages was captured through numerical modelling indicating that the conceptual model and boundary conditions were reasonable. Transient-state modelling is required to bring in the time-varying properties necessary to model the dewatering of the aquifer.

6.3 TRANSIENT-STATE MODEL

Several transient-state models were developed in order to increase the complexity of the model where needed, to gain an understanding of the effect of various parameters in transient-state, and to model the dewatering of a staged excavation. The transient-state models used the same boundary conditions and material properties as the calibrated steady-

state model Run #S2. The recharge and the progression of the dewatering of the excavation varied in time in the transient-state models.

The recharge was applied as an annual cycle and as daily averages for each month in order to assess the level of complexity needed to accurately reflect the groundwater response to recharge. The transient-state models run to assess sensitivity to recharge are as follows:

1) Run #T1 - a 15-year average recharge for each month which was then repeated on an annual cycle using the same boundary conditions and material properties as the calibrated steady-state model Run #S2.
2) Run #T2 - an average daily recharge for each month from May 1998 until May 2001 using the same boundary conditions and material properties as the calibrated steady-state model Run #S2.

The hydraulic conductivity was varied to determine its effect on groundwater response in transient-state. The effect of hydraulic conductivity on the groundwater levels and flows into the rivers, streams, and fen were assessed in two additional runs which were compared to Run #T2:

3) Run #T3 - one-layer model with uniform hydraulic conductivity of a gravel.
4) Run #T4 - two-layer model with the hydraulic conductivity of a till on the upper layer and the hydraulic conductivity of a gravel lower layer.

The specific yield and specific storage were varied to assess their effect on the groundwater levels and response as well as the baseflow into the rivers, streams, and fen. The effects of specific yield and specific storage on the groundwater model were examined through two additional runs which are compared to Run #T2:

5) Run #T5 - increase specific yield of the gravels from 0.13 to 0.20; decrease the specific yield of the peat from 0.5 to 0.05.
6) Run #T6 - increase the specific storage of the tills from 0.0001 to 0.0005.

The dewatering was modelled as a staged excavation and the effect of dewatering on the groundwater levels and baseflow into the rivers, streams and fen were examined through two additional transient-state models:

7) Run #T7 - staged excavation and dewatering and was run over a period of 8.5 years (May 1998 until December 2006).
8) Run #T8 - same as Run #T7 but without dewatering for comparison purposes.

6.3.1 SENSITIVITY TO CHANGES IN RECHARGE

The recharge was applied as an annual cycle (Run #T1) and as daily averages for each month (Run #T2) in order to assess the level of complexity needed to accurately reflect the groundwater response to recharge. The sensitivity to changes in recharge was assessed by running a transient-state model over 3 years and comparing the results to observed groundwater levels and baseflow into the River Liffey, Tully Stream and Pollardstown Fen. Data were recorded in the monitoring boreholes from June 1998 (Appendix C) and so the model was run from May 31, 1998 until May 31, 2001 when dewatering began. The average daily recharge for each month was repeated on an annual cycle. This was conducted to assess if a simplistic annual recharge was sufficient to model the Mid-Kildare Aquifer. The locations of the monitoring boreholes, used to calibrate the model, are shown on Figure 6.11.

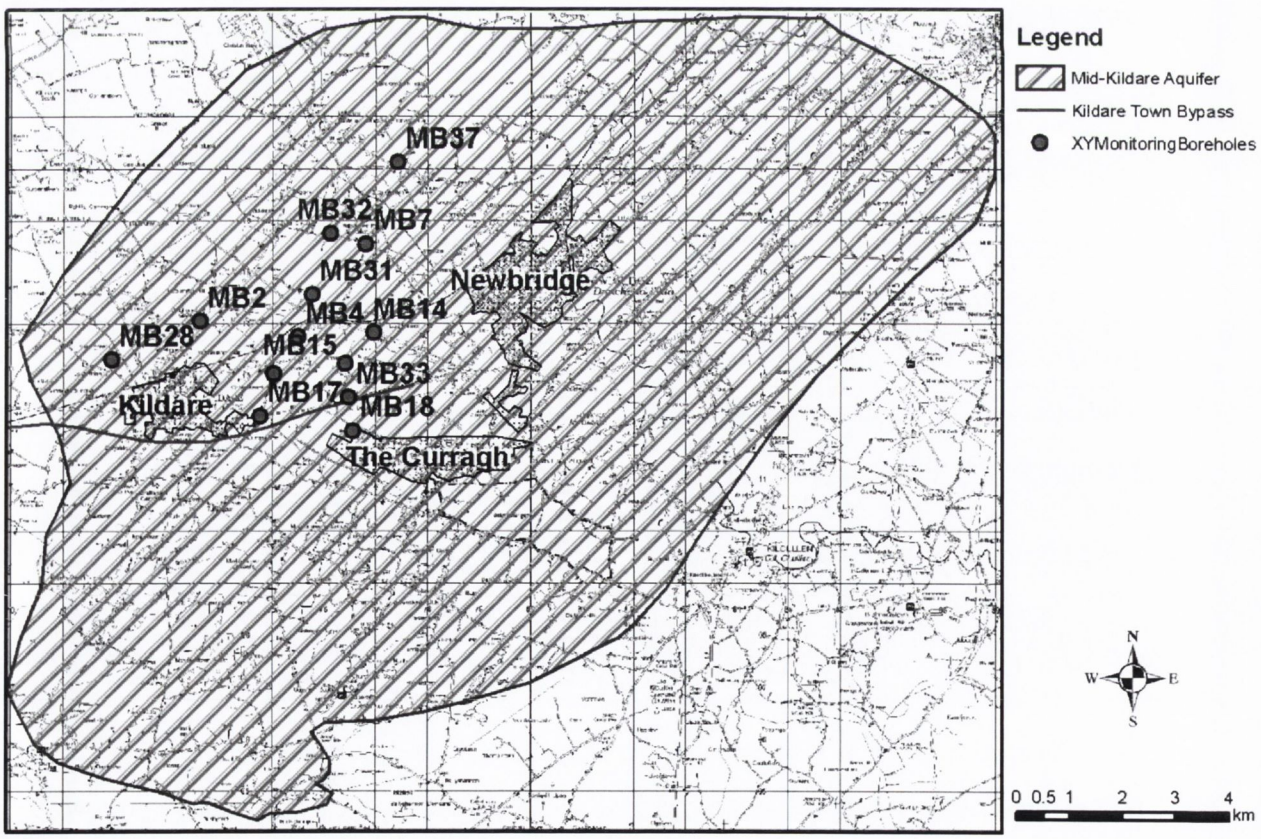


Figure 6.11: Location of boreholes where head was measured.

The modelled results from Run #T1 of MB15, 17, 37 are shown in Figure 6.12 along with the measured water levels in the same boreholes. Although this transient-state model has similar groundwater levels and amplitudes, the cyclical recharge does not capture the annual groundwater variation observed in the monitoring boreholes.

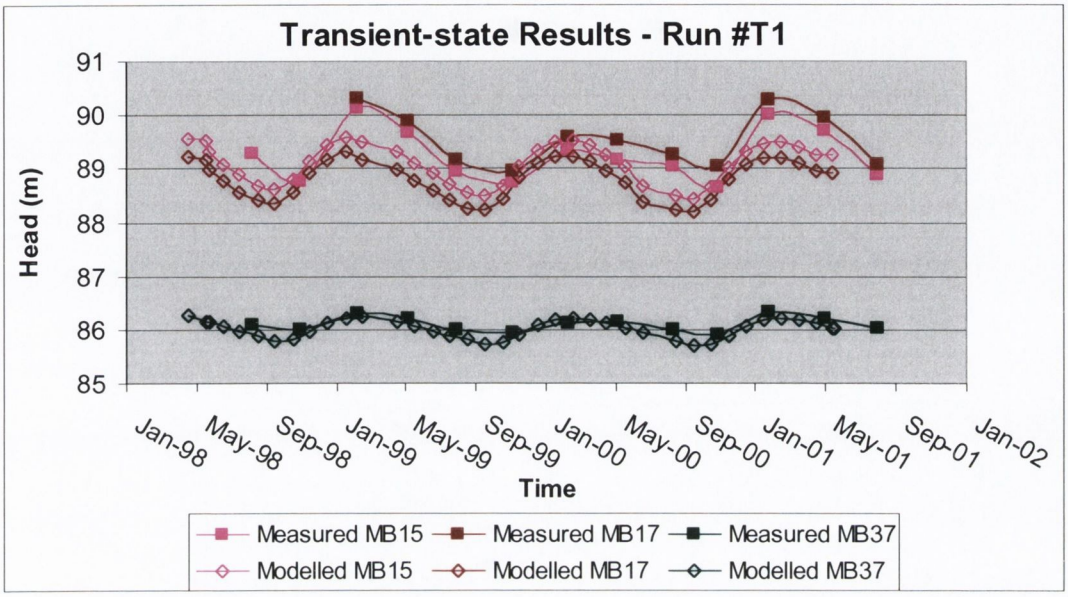


Figure 6.12: Comparison of the modelled (Run #T1) and measured water levels in selected monitoring boreholes.

In transient-state modelling the difference between the fluxes into and out of the model represent the rate of change in the volume of water stored in the aquifer. Figure 6.13 illustrates the change in the water stored in the aquifer throughout time with respect to the fluxes into and out of the model through the boundary conditions and flux into the model due to recharge. The change in the water stored in the aquifer (or storage) is directly correlated to the recharge (yellow line in Figures 6.13 to 6.16). The storage varied in Run #T1 (cyclical recharge) from roughly 193204 m^3/d (2236 l/s) in to -131238 m^3/d (-1519 l/s) out. In the winter the storage of the aquifer rises along with an increase in recharge while in the summer water comes out of storage to maintain the baseflow in the rivers and streams. During the recharge periods in the winter large fluxes into and out of the model are observed.

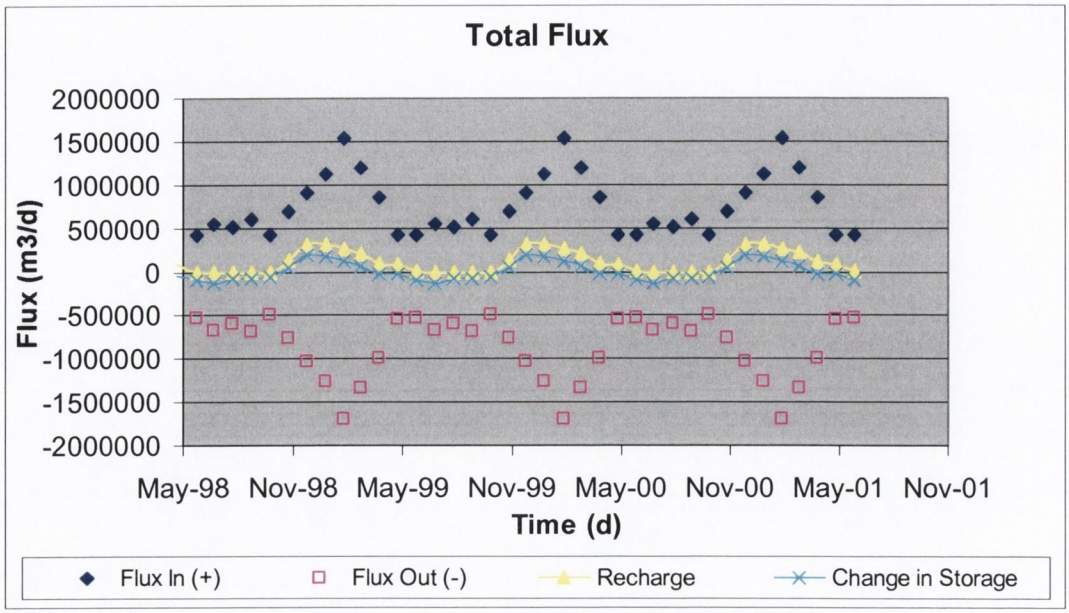


Figure 6.13: Total fluxes in to and out of the model space over the three years that the model was run (Run T1).

The total flux in and out of the nodes as shown in Figure 6.13 may be slightly higher than they should be due to a small amount of numerical instability which is explained further for the following model run, where the effects are more pronounced. The transient flow from the aquifer into the River Liffey is illustrated in Figure 6.14. The baseflow (loss from the aquifer) into the River Liffey fluctuates with the seasons from a high of 44495 m^3/d (515 l/s) in the winter to a low of 31348 m^3/d (363 l/s) in the summer. When compared to the steady-state flow (427-543 l/s depending on recharge input) the baseflow into the River Liffey from the transient-model is lower than those calculated from steady-state conditions. This is because the transient-state model (Run #T1) is in unsteady-state and never reaches the steady-state conditions calculated in the steady-state models.

The recharge applied to the nodes representing the River Liffey ranges from 0.0 m^3/d to $2.3x10^3$ m^3/d for the area representing the river in the model. The variation in recharge is difficult to see in Figure 6.14 as the maximum recharge in the model is two orders of magnitude less than the flux in and out of the river. The recharge is comparatively small for the River Liffey as it is only calculated on the nodes along the river and the fluxes in and out are significantly larger (one order of magnitude) than those at the Milltown Feeder/Grand Canal/Pollardstown Fen or Tully Stream.

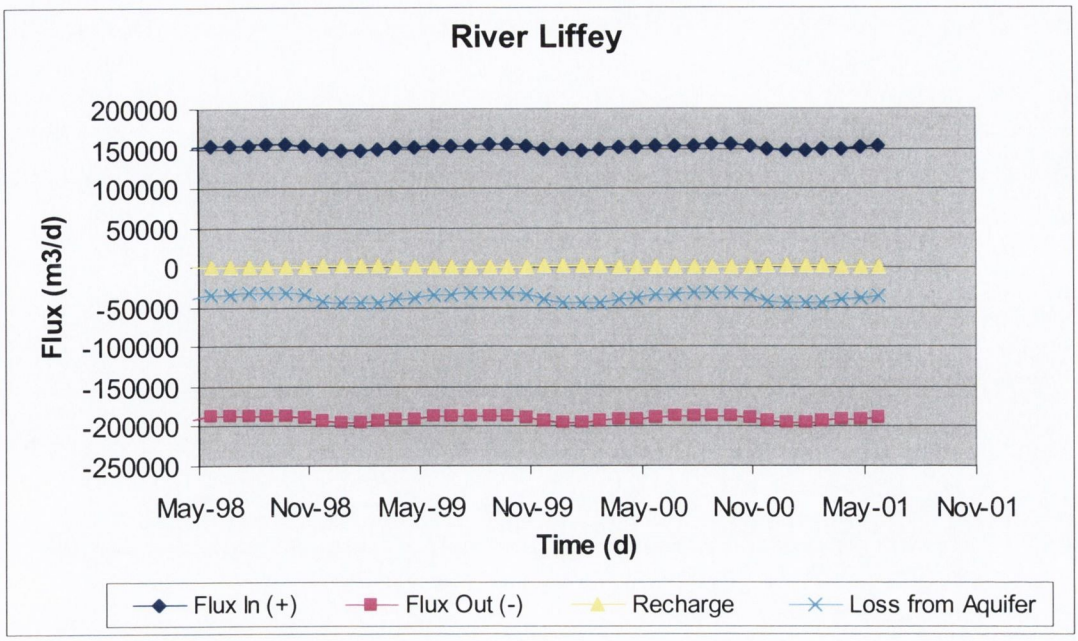


Figure 6.14: Total fluxes in to and out of the River Liffey over the three years that the model was run (Run #T1).

The Tully Steam and the Milltown Feeder/Grand Canal/Pollardstown Fen transient-state flows were plotted in the same manner (Figures 6.15 and 6.16). The transient-state flow into the Tully Stream (loss from the aquifer) varied from a high of 26120 m^3/d (302 l/s) in the winter to a low of 19224 m^3/d (223 l/s) in the summer. The seasonal variation and flow into the Tully Stream is less than was indicated through steady-state modelling (339-457 l/s). The transient-state flow into the Milltown Feeder/Grand Canal/Pollardstown Fen (loss from the aquifer) varied from a high of 64750 m^3/d (749 l/s) in the winter to a low of 17163 m^3/d (199 l/s) in the summer. The seasonal variation is greater than what was indicated through steady-state modelling (382-474 l/s). The transient-state flow results agree fairly well with the estimated baseflow (River Liffey 1500-2000 l/s, Tully Stream ~300 l/s, Pollardstown Fen - 200 - 470 l/s (Farrell and Devine, 2006)) from the aquifer indicating that the transient-state model (Run #T1) sufficiently represents flows in the aquifer.

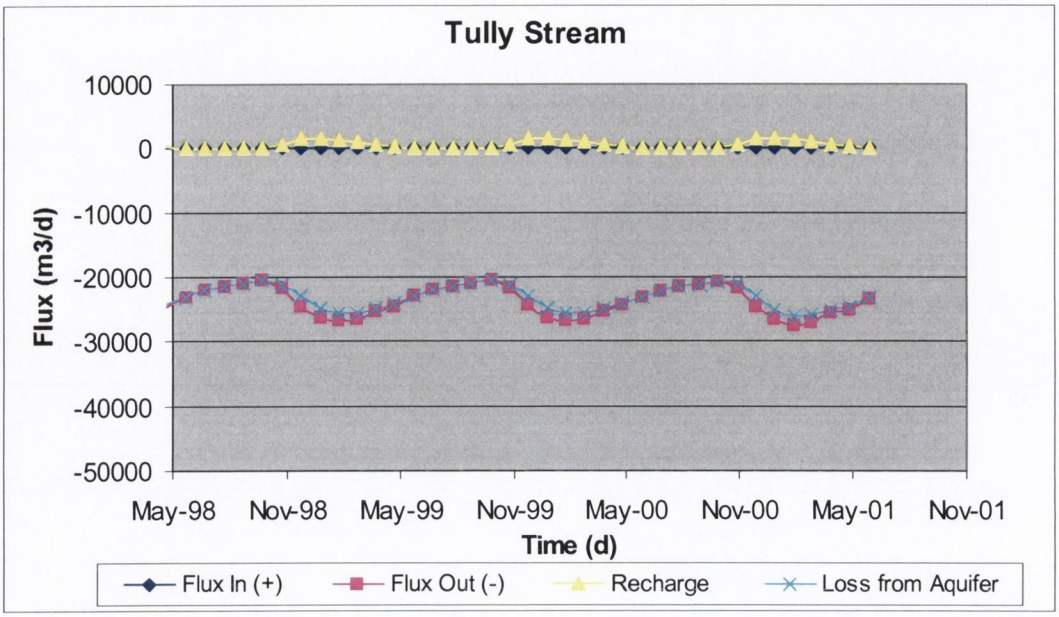


Figure 6.15: Total fluxes in to and out of the Tully Stream over the three years that the model was run (Run #T1).

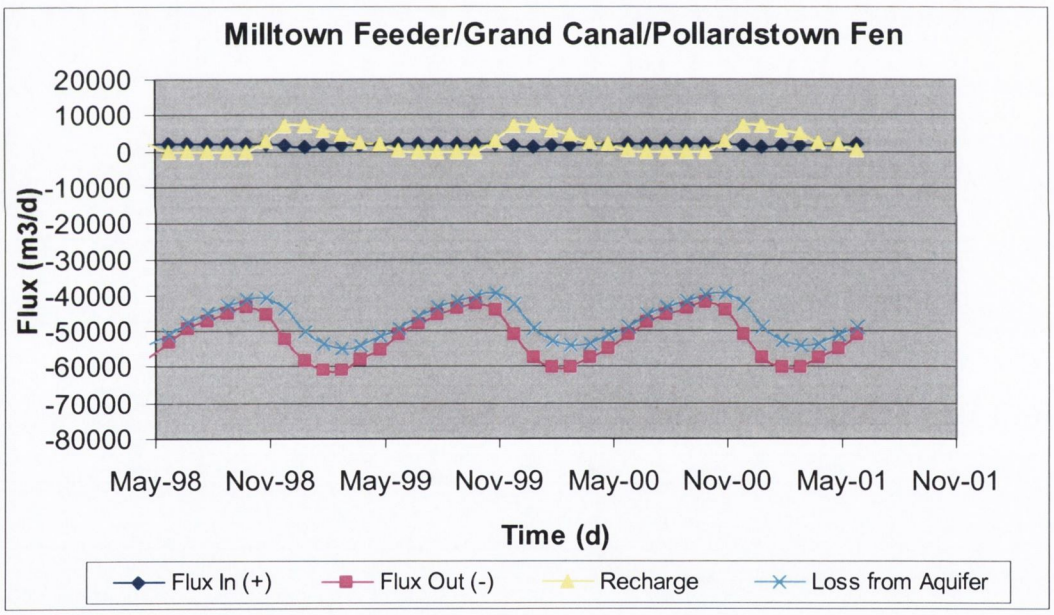


Figure 6.16: Total fluxes in to and out of the Milltown Feeder/Grand Canal/Pollardstown Fen over the three years that the model was run (Run #T1).

The previous model (Run #T1) did not capture the annual groundwater variation. Therefore, subsequent models were increased in temporal complexity to use the average daily recharge for each month from 1998 to 2001. To assess the impact of averaging the monthly recharge, the transient-state model (Run #T2) was run using the calculated average daily recharge (assuming no runoff) for each month from May 1998 to May 2001 (Appendix A) (Brown, 2007). These values have been suggested by Brown (2007) to more accurately reflect the amount of recharge entering the aquifer as it is highly permeable.

The water levels given by the model were compared with the measured water levels in the monitoring boreholes (Figures 6.17, 6.18, 6.19, and 6.20). All the model parameters were kept the same as Run #T1 except for the recharge input. The averaged monthly recharge is a better match than 15-year averaged monthly recharge as the latter has discrepancies between the modelled and measured values by up to a metre while the former has smaller discrepancies (< 1 m).

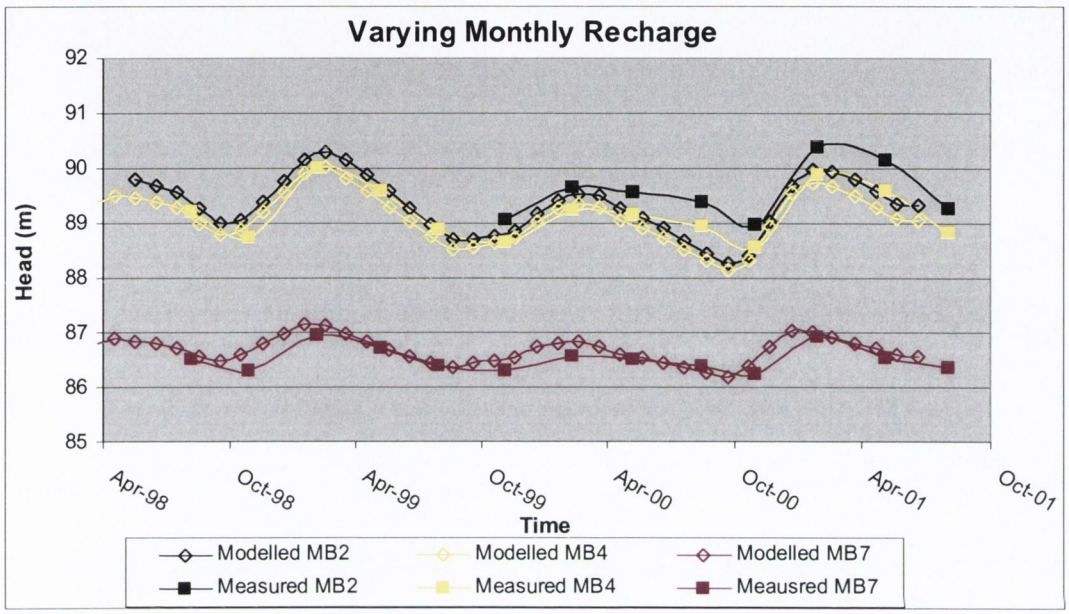


Figure 6.17: Comparison of measured and modelled heads in monitoring boreholes (MB) 2, 4, and 7 (Run #T2).

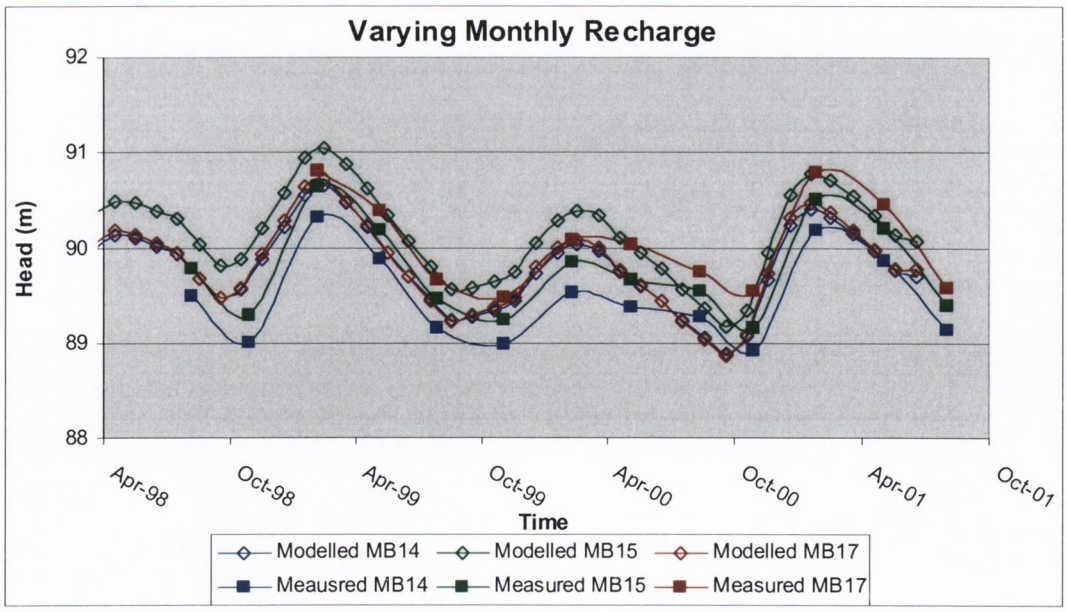


Figure 6.18: Comparison of measured and modelled heads in monitoring boreholes (MB) 14, 15, and 17 (Run #T2).

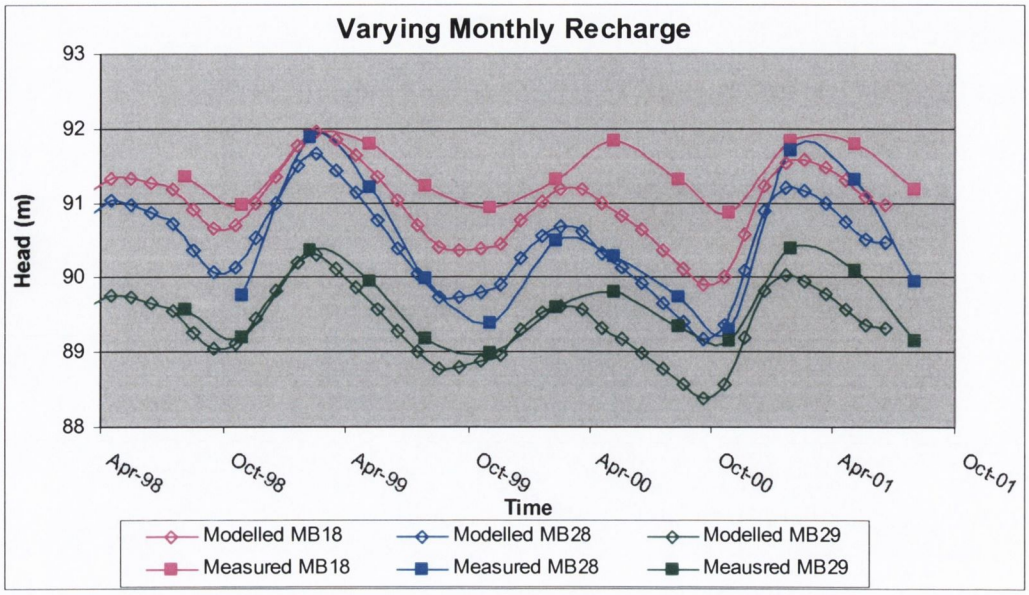


Figure 6.19: Comparison of measured and modelled heads in monitoring boreholes (MB) 18, 28, and 29 (Run #T2).

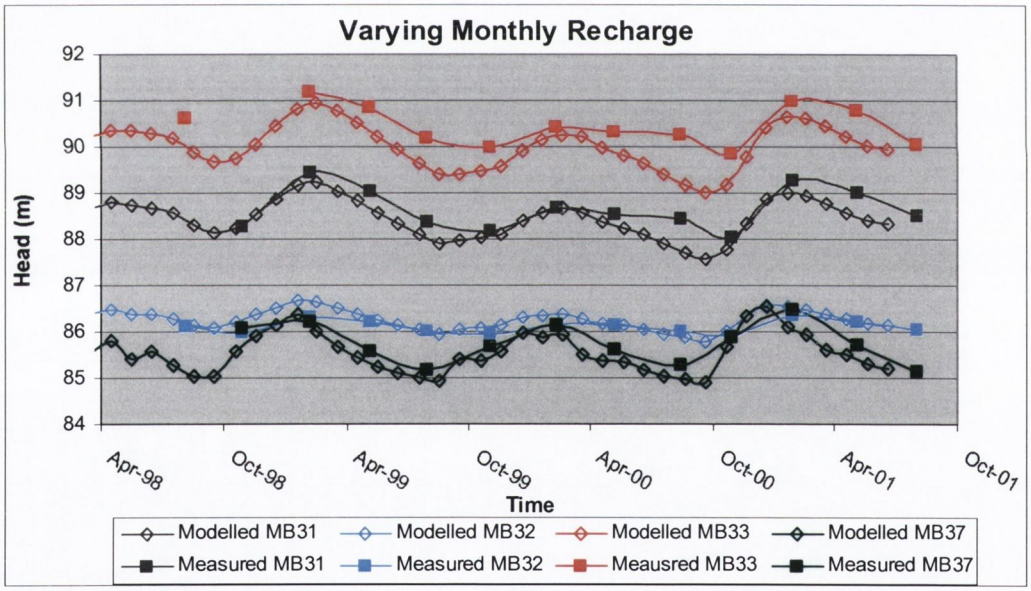


Figure 6.20: Comparison of measured and modelled heads in monitoring boreholes (MB) 31, 32, 33 and 37 (Run #T2).

The total flux through the transient-state model (Run #T2) shows the change in the water stored within the aquifer (storage) with respect to the influxes and outfluxes through the boundary conditions as well as the recharge (Figure 6.21). In this model (Run #T2) the storage varies from 341665 m^3/d (3954 l/s) in to -129019 m^3/d (-1493 l/s) out. The model using the recharge calculated for the period of May 1998 to May 2001 shows a greater

variation in storage than that using the average monthly values (Run #T1). This shows that this model (Run #T2) is sensitive to changes in recharge thus it is important to use time-varying recharge data which accounts for the annual variation in recharge.

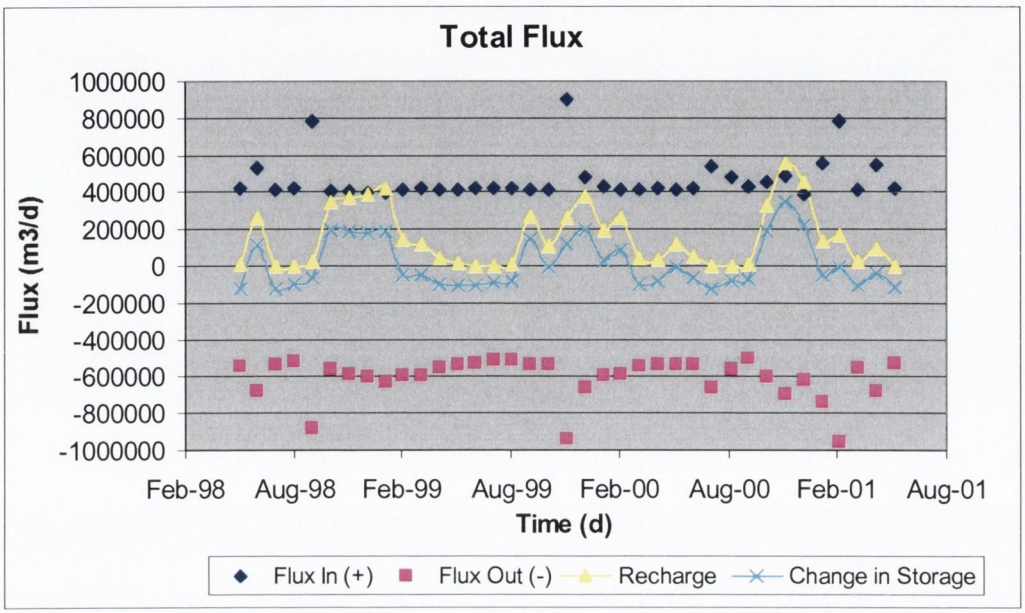


Figure 6.21: Total fluxes in to and out of the model space over the three years that the model was run (Run #T2).

The spikes in the total flux in and total flux out in Figure 6.21 represent a small amount of numerical instability in the model due to the presence of very thin layers at the model margins. The numerical instability in this case is due to the presence of very thin layers (1 cm thick) in the model. In a model, a single calculation can sometimes be achieved in several ways, all of which are algebraically equivalent in terms of ideal numbers, but in practice when performed digitally yield different results. In this case, very thin layers were created near the Chair Hills and in other areas where bedrock was very near the surface. The effects of the numerical instability can be demonstrated if the model is run without the very thin layers. The total fluxes for a model run, where the depth to bedrock was set at 50 mOD is shown in Figure 6.22 below. This illustrates that spikes in the total fluxes (and therefore the numerical instability) are removed when the very thin layers are absent but this is not modelling the physical reality of the Mid Kildare Aquifer. The numerical error in the actual model is small, the model still converges, and the total fluxes in and out of the model are balanced so the overall storage in the aquifer is accurate.

This numerical instability has insignificant effects on the groundwater head, fluxes, the aquifer's response to changes, etc. (other than total flux in and out of the model which shows the spikes) and does not compromise the results from the model or interpretations drawn from them.

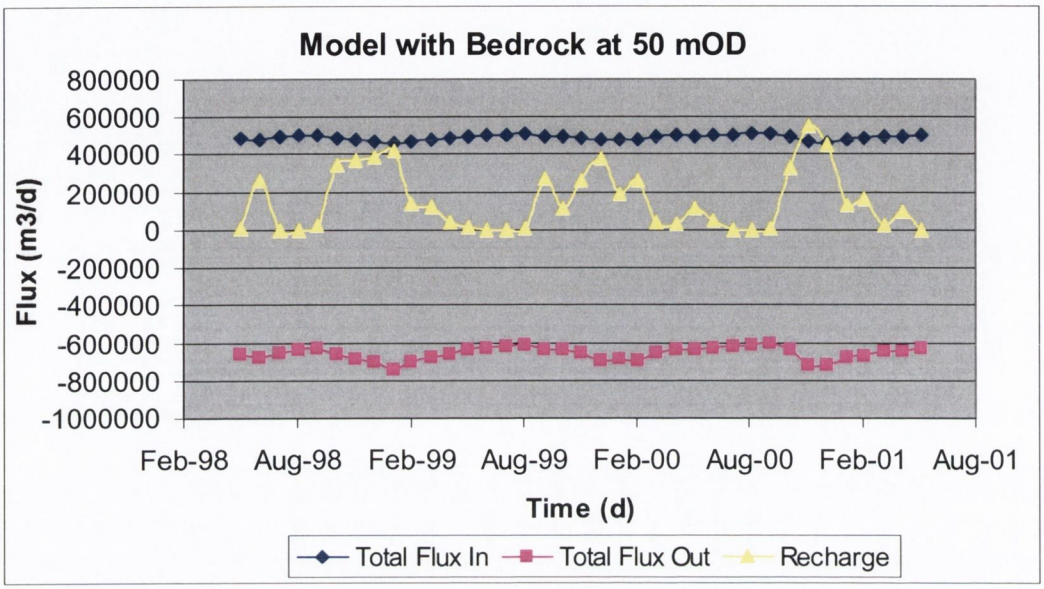


Figure 6.22: Model with no numerical instabilities. This is the same model as Run #T2 except that the elevation of bedrock has been changed to 50 mOD. As this removes the very thin layers it removes the small amount of numerical instability.

The baseflow into the River Liffey (Figure 6.23), the Tully Stream (Figure 6.24) and the Milltown Feeder/Grand Canal/Pollardstown Fen (Figure 6.25) were plotted to assess their sensitivity to changes in recharge. The baseflow (loss from the aquifer) into the River Liffey fluctuates with the seasons from a high of 59066 m^3/d (684 l/s) in the winter to a low of 15755 m^3/d (182 l/s) in the summer. A comparison with the steady-state flow (427-543 l/s depending on recharge input) and transient flow (Run #T1) (363 - 515 l/s), reveals the effect of recharge on baseflow in the Liffey. This illustrates that the averaged monthly values used in Run #T1 lose the variation in baseflow associated with wetter or dryer than average months.

The recharge applied to the nodes representing the River Liffey ranges from 0.0 m^3/d to 4.0×10^3 m^3/d for the area representing the river in the model. The variation in recharge is difficult to see in Figure 6.23 as the maximum recharge in the model is two orders of magnitude less than the flux in and out of the river.

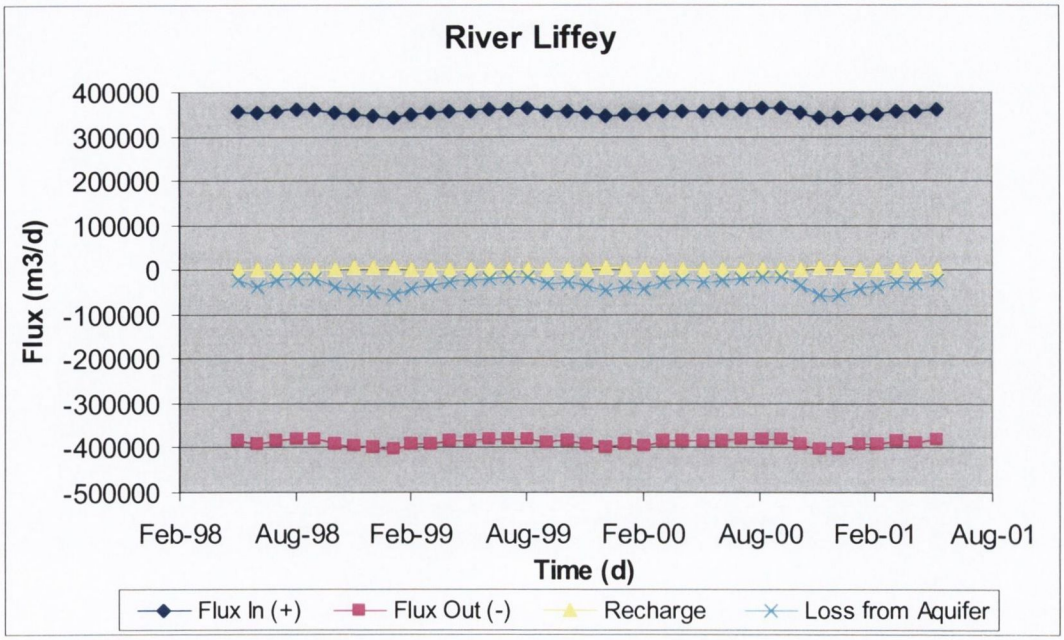


Figure 6.23: Total fluxes in to and out of the River Liffey over the three years that the model was run.

The transient-state flow into the Tully Stream (loss from the aquifer) varied from a high of 34051 m^3/d (394 l/s) in the winter to a low of 23523 m^3/d (272 l/s) in the summer. The seasonal variation is similar to what was indicated through steady-state modelling although the flow into the Tully Stream is less (339-457 l/s). The baseflow is greater than it was in Run #T1 with averaged monthly flows (223 l/s minimum and 302 l/s maximum). The years from 1998 to 2001 were wetter than the average monthly values (Appendix A can be compared with Table 5-2) thus causing the baseflow to be larger in Run #T2 than in Run #T1. The Tully Stream is very sensitive to changes in recharge as it is controlled by seepages so all flow into the stream comes from the aquifer.

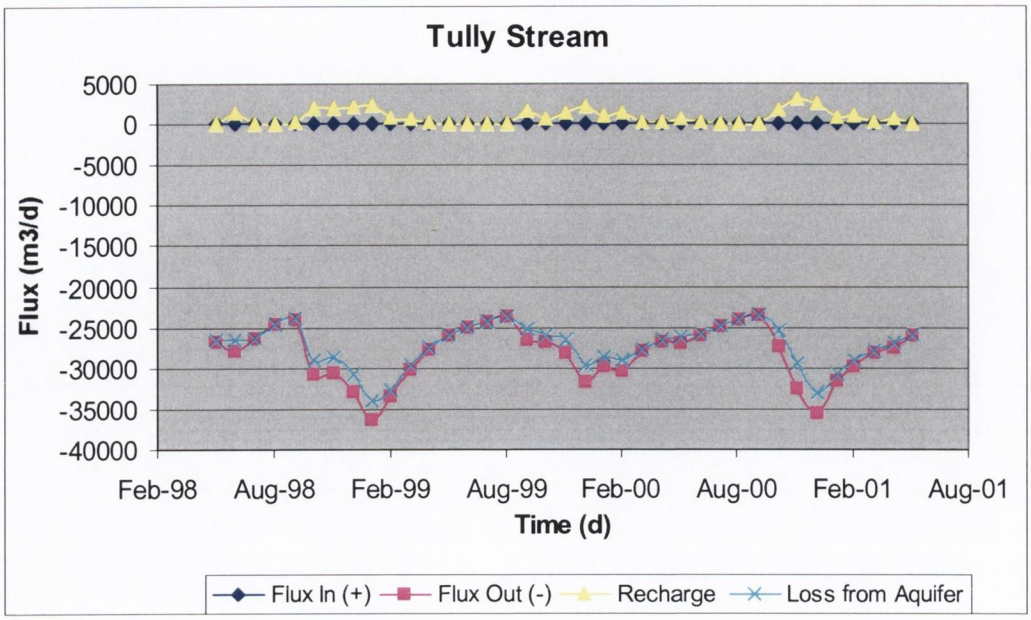


Figure 6.24: Total fluxes in to and out of the Tully Stream over the three years that the model was run.

The transient-state flow into the Milltown Feeder/Grand Canal/Pollardstown Fen (loss from the aquifer) varied from a high of 67353 m^3/d (780 l/s) in the winter to a low of 43048 m^3/d (498 l/s) in the summer. The seasonal variation is greater than that indicated through steady-state modelling (382-474 l/s). The baseflow shows less seasonal variation than transient-state model with the averaged monthly flows (199 l/s minimum and 749 l/s maximum) and a greater rate of flow.

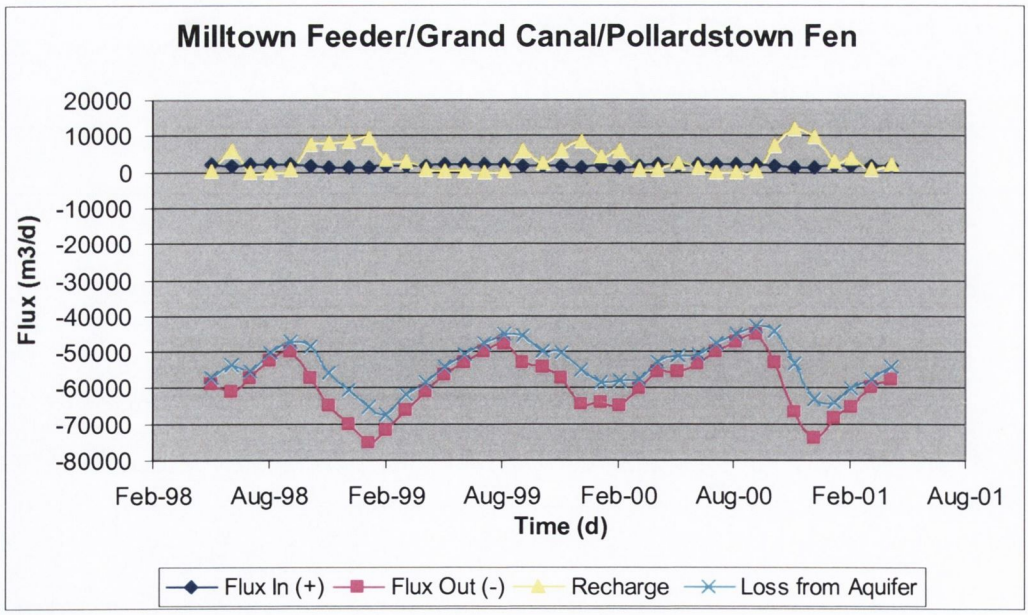


Figure 6.25: Total fluxes in to and out of the Milltown Feeder/Grand Canal/Pollardstown Fen over the three years that the model was run.

The transient-state models which assess the sensitivity to recharge show through the comparison with the measured groundwater levels, that it is necessary to use the average daily recharge for each month to obtain a model that adequately represents the seasonal and annual variations in recharge and groundwater response. The recharge values from Appendix A are used in all subsequent model runs (Run #T3- #T8). Both transient-state models produce baseflows which are consistent with the estimates made by Farrell and Devine (2006).

6.3.2 SENSITIVITY TO CHANGES IN HYDRAULIC CONDUCTIVITY

The hydraulic conductivity was varied to determine its effect on groundwater response. An examination of the effect of the hydraulic conductivity on groundwater levels in the transient-state model was conducted by using Run #T2 (with the same calibration as Run #S2) and comparing them to a one-layer model (Run #T3) with the same input parameters as Run #S5 (other than recharge), and a two-layer model (Run #T4) with the same input parameters as Run #S6 (other than recharge).

Figures 6.26, 6.27, 6.28, and 6.29 compare the difference between the calculated heads in Run #T2, #T3, #T4 and the observed heads. The variation in groundwater level at the monitoring boreholes differs according to the sediments in which the monitoring borehole is located. In general, Run #T3 (one layer model with gravel) results in lower groundwater levels than Run #T2 with the varied sediments. Run #T4 (2 layer model with till overlying gravel) results in similar groundwater levels where the stratigraphy of Run #T2 is a till overlying a gravel, as expected. However, in the cases where the stratigraphy differs from Run #T2, the groundwater levels are lower with Run #T4 than Run #T2. This illustrates that a greater hydraulic conductivity causes the groundwater levels to be lower. This relationship was used to calibrate the model. These graphs demonstrate the importance of using the GSI glacial and recent sediment maps to create a complex multi-sediment model when modelling a glacial aquifer. The groundwater response to changes in hydraulic conductivity can then be used to obtain a better correlation between the observed and modelled groundwater response.

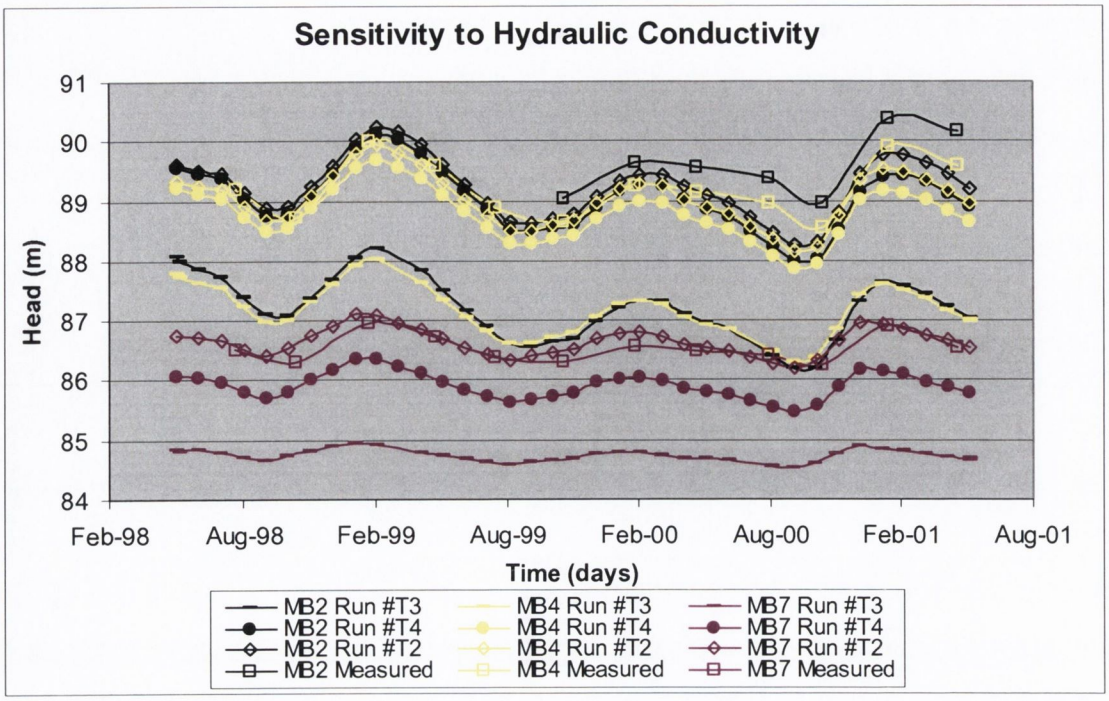


Figure 6.26: Groundwater levels at MB2, MB4, and MB7, obtained by running the model for three years Run #T3 (Gravel), Run #T4 (Till), and Run #T2 (varied sediments).

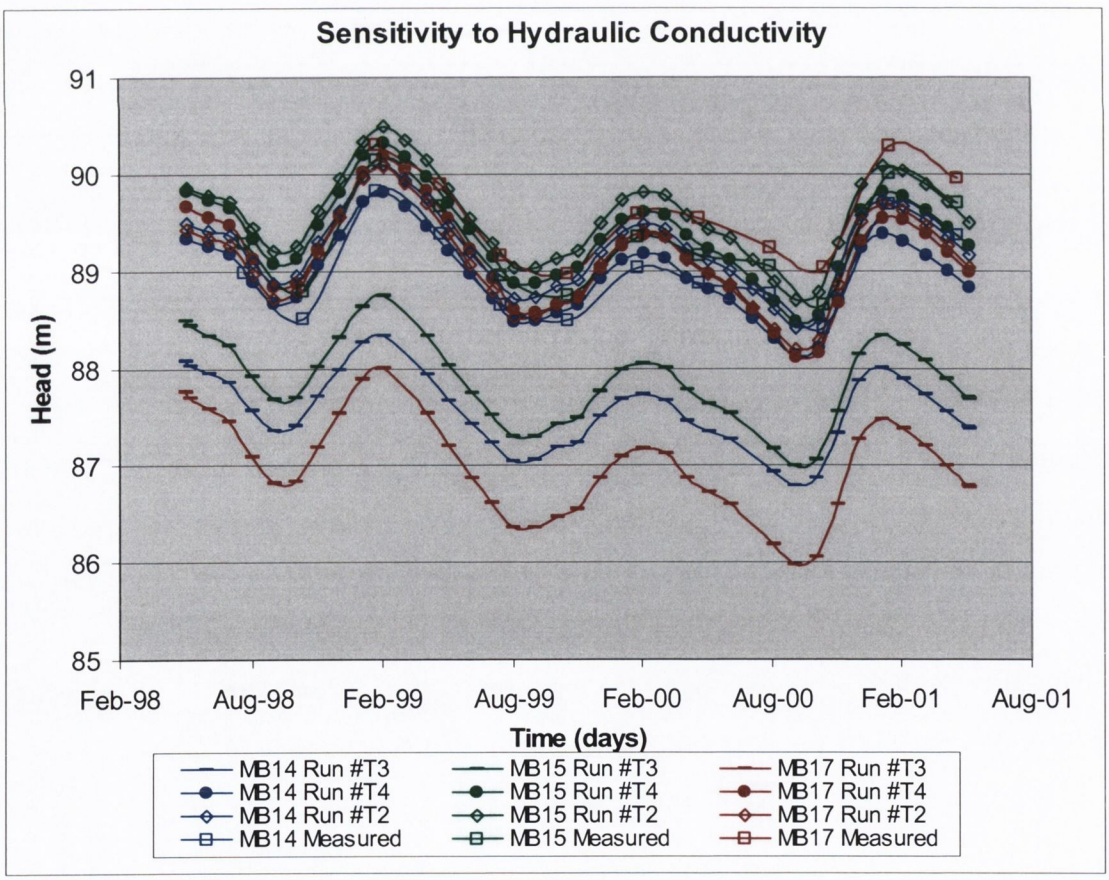


Figure 6.27: Groundwater levels at MB14, MB15, MB17 obtained by running the model for three years Run #T3 (Gravel), Run #T4 (Till), and Run #T2 (varied sediments).

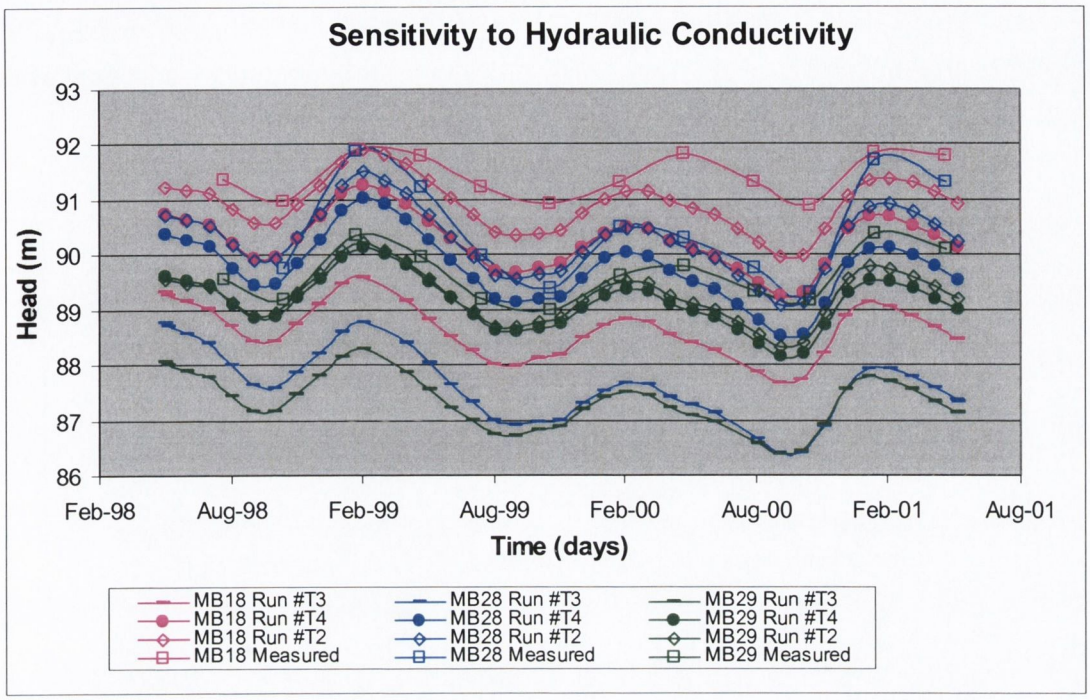


Figure 6.28: Groundwater levels at MB18, MB28 and MB29, obtained by running the model for three years Run #T3 (Gravel), Run #T4 (Till), and Run #T2 (varied sediments).

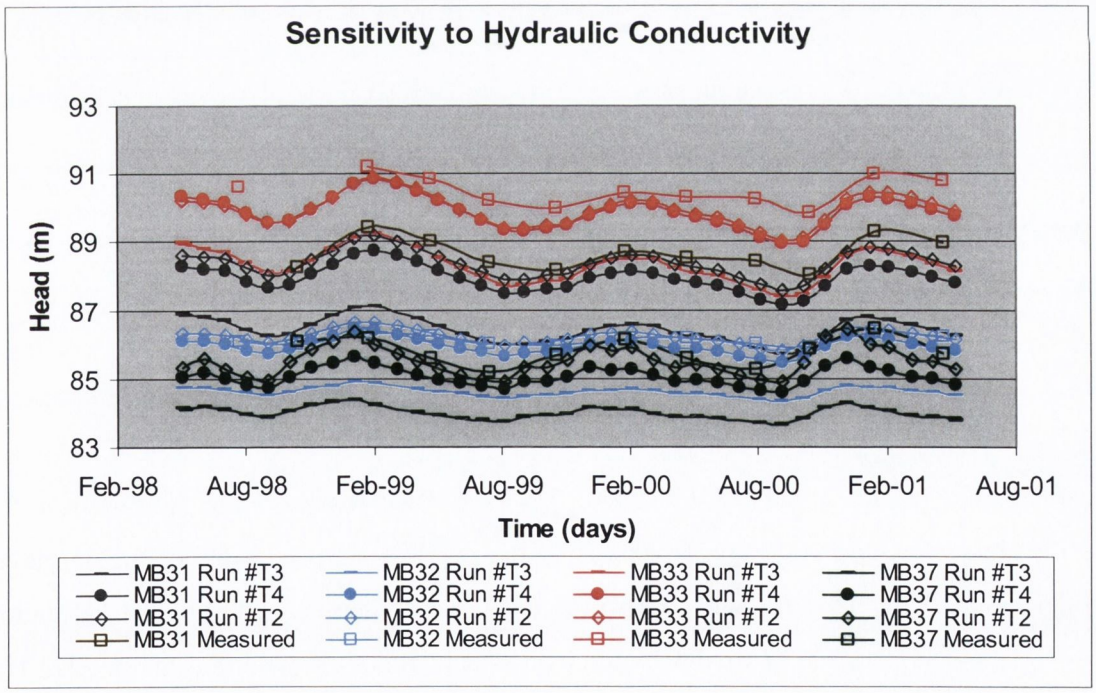


Figure 6.29: Groundwater levels at MB31, MB32, MB33 and MB37, obtained by running the model for three years Run #T3 (Gravel), Run #T4 (Till), and Run #T2 (varied sediments).

The model using the recharge calculated for the period of May 1998 to May 2001 shows less total flux in and out of the model for the tills than for the gravels (Figure 6.30).

However, the recharge applied is the same, and the storage is similar as both the influxes and outfluxes are less for the till than the gravel by the same amount. The storage from Run #T2 is also plotted for comparison which indicates overall the storage in and out of the aquifer is sensitive to the hydraulic conductivity assigned.

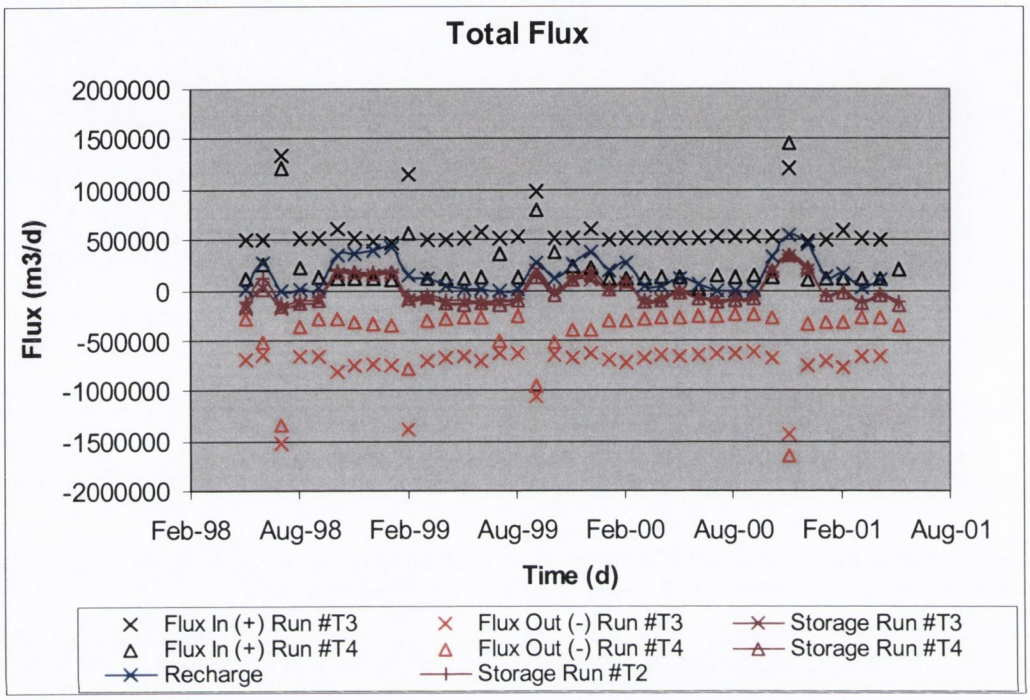


Figure 6.30: Total fluxes in to and out of the model space over the three years that the model was run.

As previously stated, the spikes in the total flux in and total flux out in Figure 6.30 represent a small amount of numerical instability in the model due to the presence of very thin layers at the model margins. The baseflow (loss from the aquifer) into the River Liffey (Figure 6.31) was plotted for Run #T3 (one layer model), Run #T4 (two layer model) and for comparison Run #T2 (varied sediments). As with the total fluxes plotted in Figure 6.30, Run #T4 has less loss from the aquifer (maximum loss 37428 m^3/d (433 l/s)) than Run #T3 (maximum loss 53995 m^3/d (625 l/s)). When compared to the loss from the aquifer when the sediments varied (Run #T2) the result is similar to that of the one layer model (Run #T3). This is because the sediments immediately adjacent to the Liffey are alluvial deposits which typically have high hydraulic conductivities similar to gravels. The higher the hydraulic conductivity assigned to the unit where water is allowed to exfiltrate the model the greater the flux out of the model space.

The recharge applied to the nodes representing the River Liffey ranges from 0.0 m^3/d to $4.0x10^3$ m^3/d for the area representing the river in the model. The variation in recharge is difficult to see in Figure 6.31 as the maximum recharge in the model is two orders of magnitude less than the flux in and out of the river.

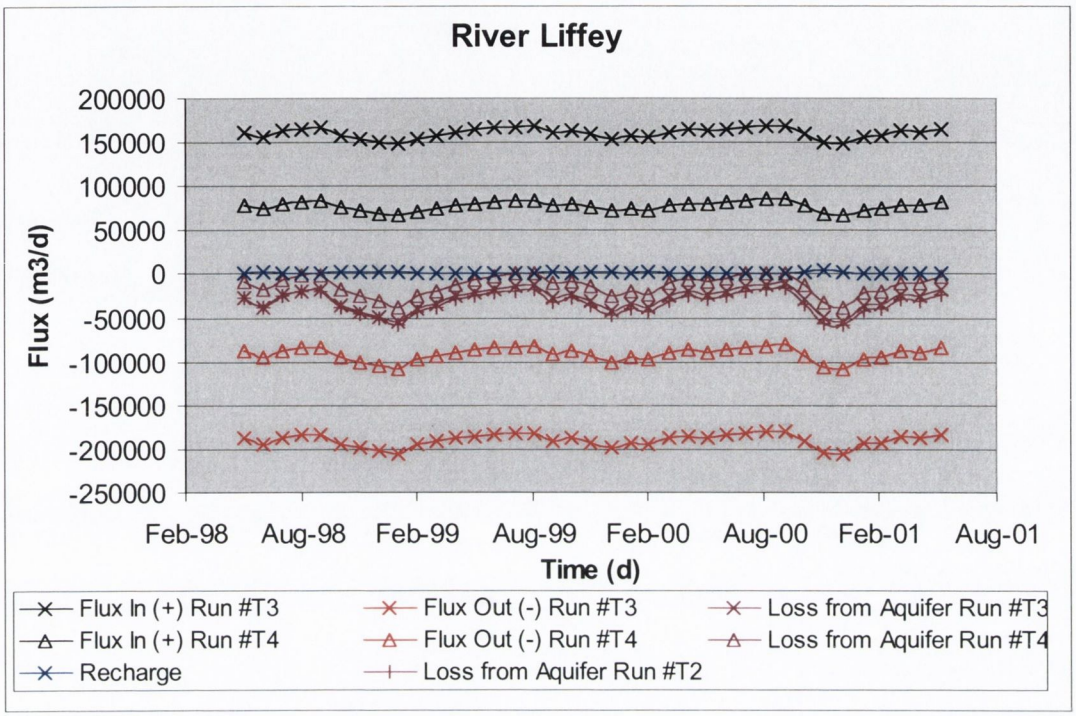


Figure 6.31: Total fluxes in to and out of the River Liffey over the three years that the model was run.

The baseflow into the Tully Stream (loss from the aquifer) (Figure 6.32) was plotted for the same three model runs. The total loss from the aquifer was greater for Run #T3 (25160-48716 m^3/d (291-567 l/s)) than Run #T4 (22775-35036 m^3/d (264-406 l/s)). Run #T4 had a total loss from the aquifer similar to Run #T2 (23523-34051 m^3/d (272-394 l/s)). The Tully Stream, which is fed by seepage, flows primarily over peat deposits which have a lower hydraulic conductivity than tills or gravels.

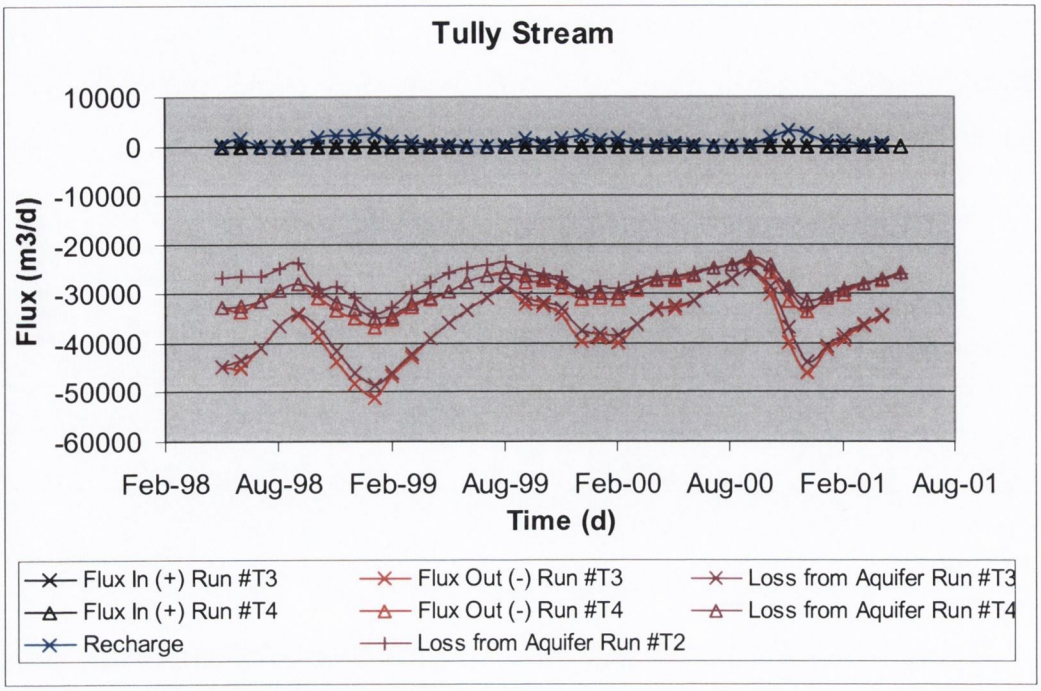


Figure 6.32: Total fluxes in to and out of the Tully Stream over the three years that the model was run.

The baseflow into the Milltown Feeder/Grand Canal/Pollardstown Fen (loss from the aquifer) (Figure 6.33) was plotted for the same three model runs. The results were similar to that of the Tully Stream as would be expected given that the Fen is composed of low hydraulic conductivity peat deposits. The loss from the aquifer was between 102561-140154 m^3/d (1187-1622 l/s) for Run #T3, 47837-75768 m^3/d (554-877 l/s) for Run #T4, and 43048-67353 m^3/d (498-780 l/s) for Run #T2.

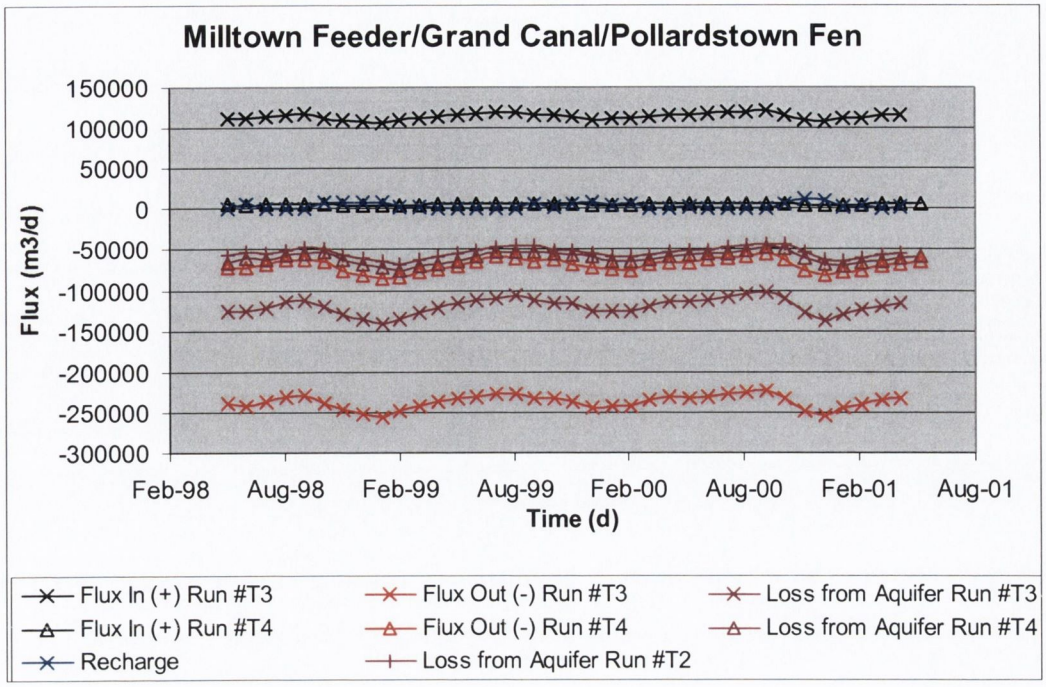


Figure 6.33: Total fluxes in to and out of the Milltown Feeder/Grand Canal/Pollardstown Fen over the three years that the model was run.

The modelling of the sensitivity to changes in hydraulic conductivity showed that raising the hydraulic conductivity on the lower layer causes the groundwater heads to be decreased and that lowering the hydraulic conductivity on the upper layer causes a larger variation in the groundwater response to seasonal fluctuations in recharge (see Figures 6.26 to 6.29). These runs show that the flows out of the aquifer are strongly influenced by the hydraulic conductivity and that the greater the hydraulic conductivity the greater the flux out of the model (see Figures 6.31 to 6.33). The complexity of using the GSI glacial and recent geology map (Run #T2) as a basis for assigning the hydraulic conductivity is necessary to obtain the observed groundwater response and baseflow in to the River Liffey, Tully Stream and Pollardstown Fen (see Figures 6.26 to 6.29).

6.3.3 Sensitivity to Changes in Specific Yield and Specific Storage

The specific yield and specific storage were varied to assess their effect on the groundwater levels and response as well as the baseflow into the rivers, streams, and fen. An examination of the effect of the specific yield and specific storage on the transient-state model was conducted by using Run #T2 and comparing them to a model (Run #T5) where the specific yield of the gravel is raised from 0.13 to 0.20 and specific yield of the peat is lowered from 0.5 to 0.05, and a model (Run #T6) where the specific storage of the tills is

increased from 0.0001 /m to 0.0005 /m which is the specific storage calculated by the aquifer pump tests in Section 3.4.7. All other properties were kept the same as Run #T2.

Figures 6.34, 6.35, 6.36, and 6.37 compare the difference between the calculated heads in Run #T2, #T5, #T6 and the observed heads. There is very little difference between the three model runs indicating that the model is not very sensitive to changes in specific yield and specific storage. In general, increasing the specific yield or specific storage causes a slight increase in the groundwater heads in the model. An increase in the specific yield also causes less seasonal variation in the groundwater levels (i.e. a reduction in the amplitude of the hydrographs). As there is very little difference between the groundwater heads calculated in the three model runs (Run #T2, #T5 and #T6) it cannot be discerned which variation produces a better match with the observed groundwater heads. In general, it appears that Run #T6 does not produce a better match to the observed results. Run #T2 and #T5 are very similar and in the case of some of the hydrographs each run better matches different parts of the observed groundwater head. For example, in Figure 6.36, the hydrographs for MB29 show that in February, 1999 Run #T2 is closer to the observed groundwater head while in August, 1999 Run #T5 is closer to the observed groundwater head. Therefore, changes in specific yield and specific storage have very little effects on the modelled groundwater heads.

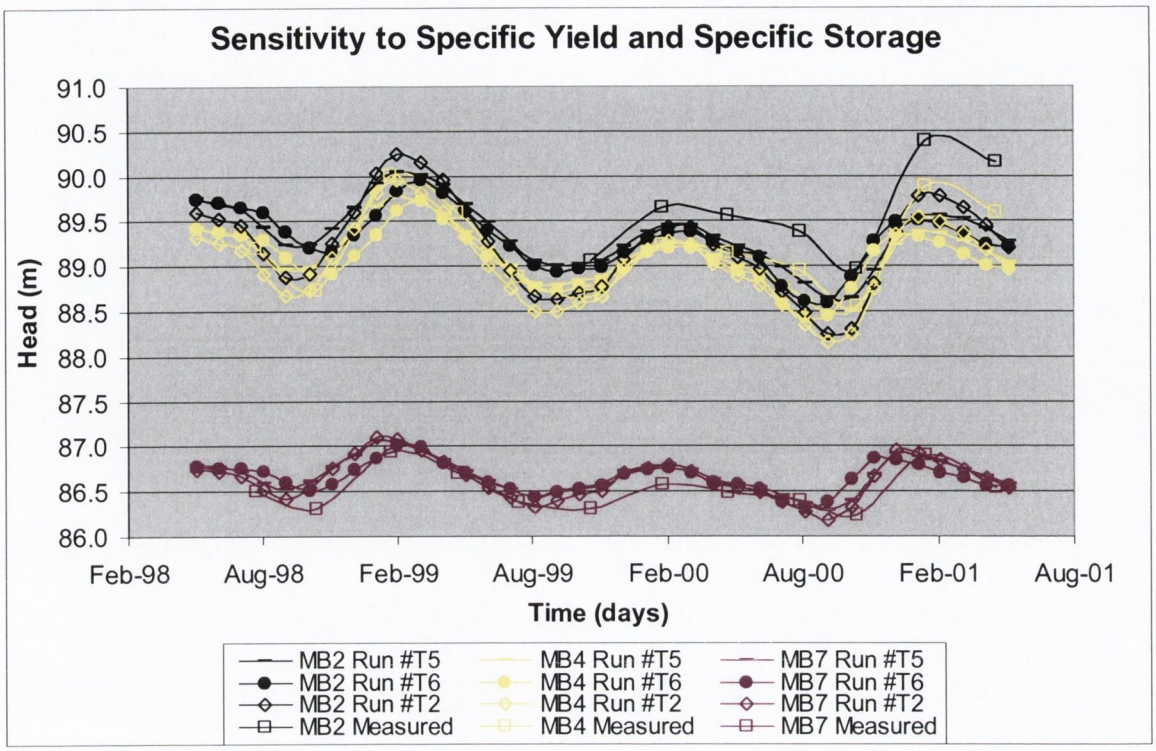


Figure 6.34: Groundwater levels at MB2, MB4, and MB7, obtained by running the model for three years Run #T5 (varying specific yield), Run #T6 (varying specific storage), and Run #T2 (original specific yield and specific storage).

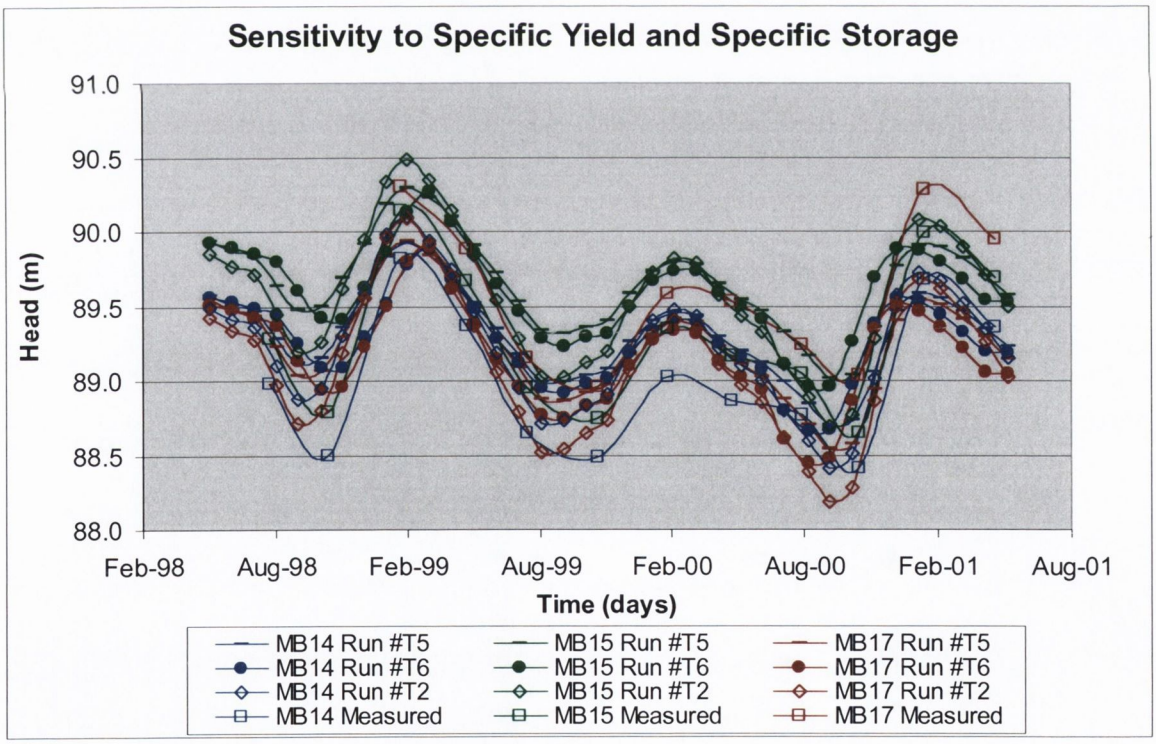


Figure 6.35: Groundwater levels at MB14, MB15, MB17 obtained by running the model for three years Run #T5 (varying specific yield), Run #T6 (varying specific storage), and Run #T2 (original specific yield and specific storage).

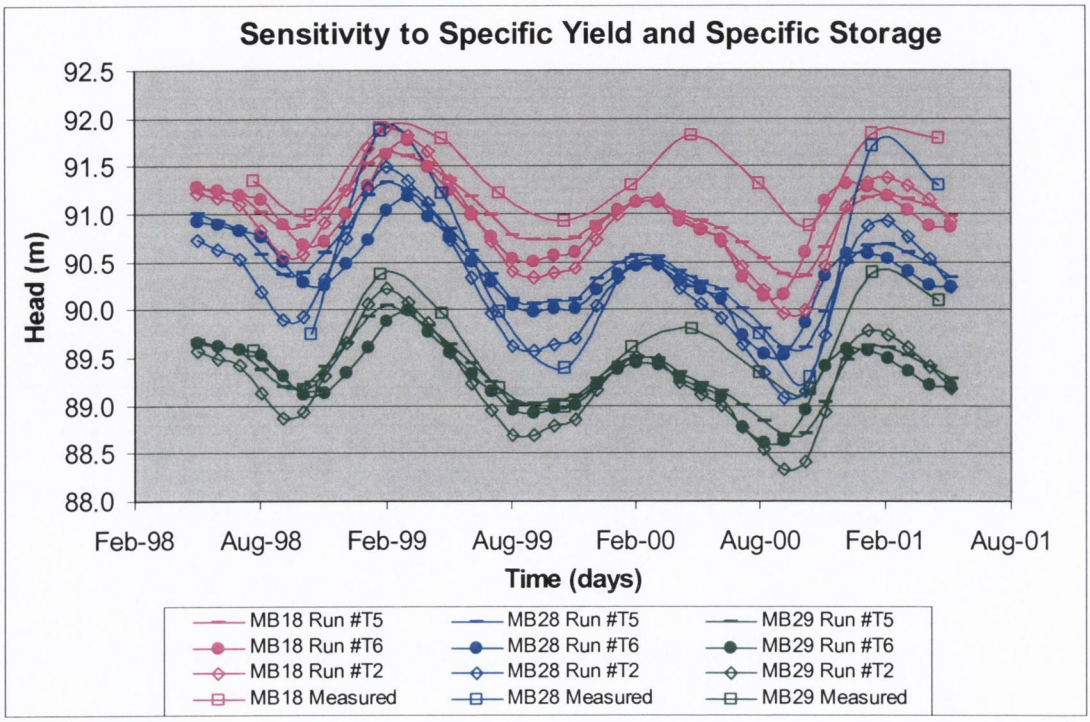


Figure 6.36: Groundwater levels at MB18, MB28 and MB29, obtained by running the model for three years Run #T5 (varying specific yield), Run #T6 (varying specific storage), and Run #T2 (original specific yield and specific storage).

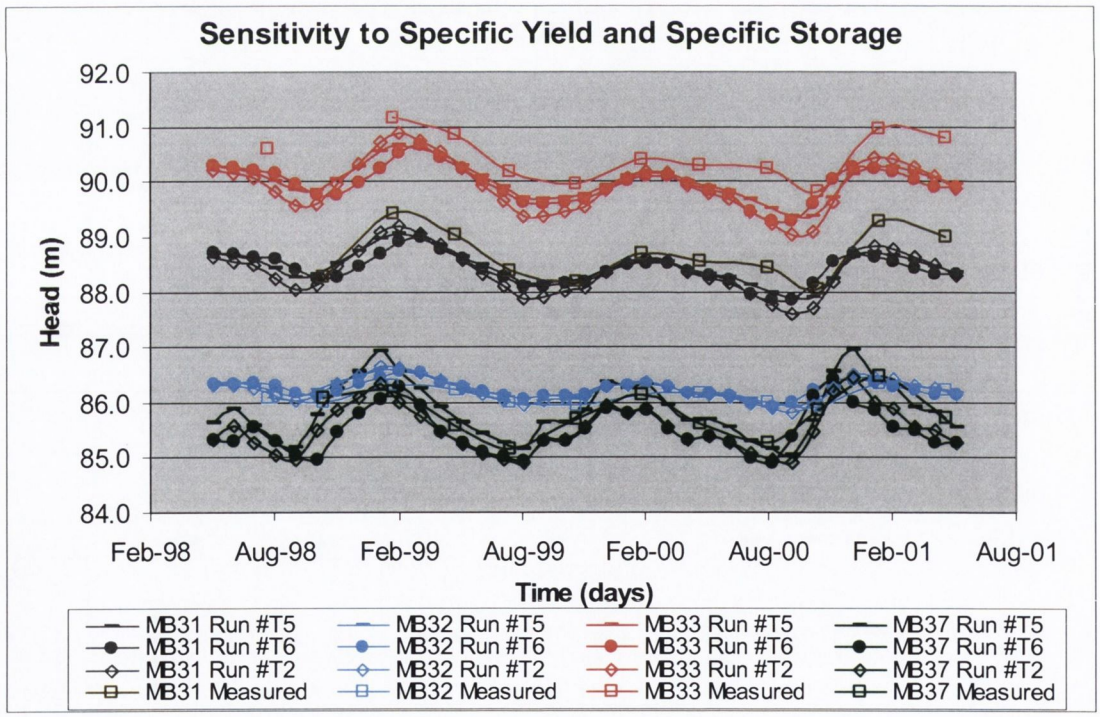


Figure 6.37: Groundwater levels at MB31, MB32, MB33 and MB37, obtained by running the model for three years Run #T5 (varying specific yield), Run #T6 (varying specific storage), and Run #T2 (original specific yield and specific storage).

The model shows that the fluxes in and out of the aquifer as well as the change in the water stored in the aquifer (storage) are similar for all three runs (Figure 6.38). The flux in and out is greater for Run #T6 where the specific storage is increased. Run #T6 has a slight delay in response to water storage of the aquifer when compared to Run #T2 or Run #T5. This delay in response is what would be expected as an increase in specific storage correlates with a larger volume of water available to cause a change in head.

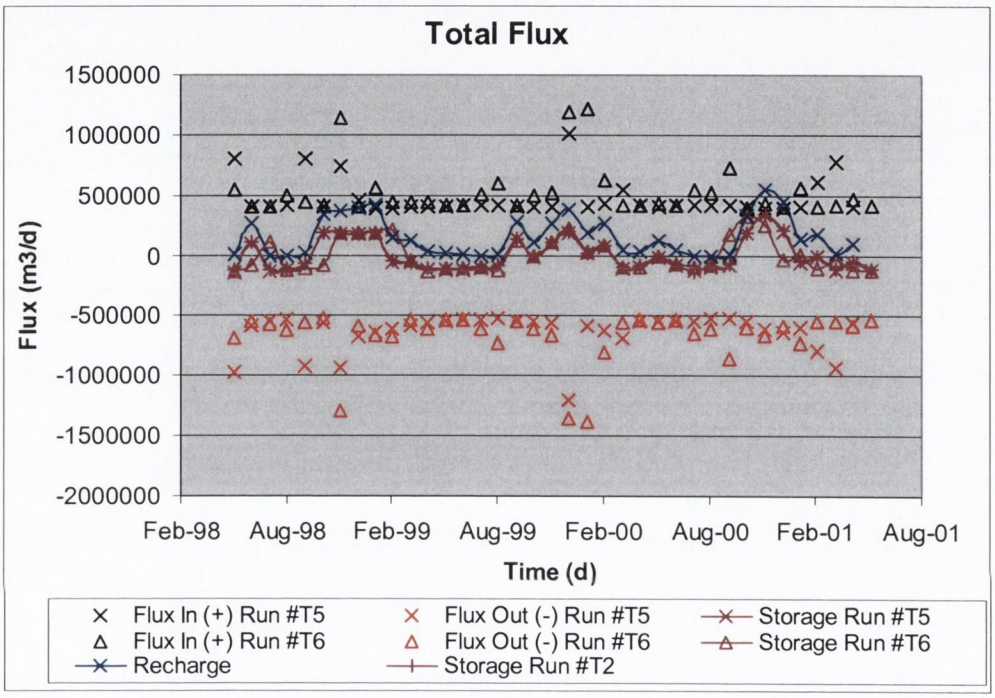


Figure 6.38: Total fluxes in to and out of the model space over the three years that the model was run.

As previously stated, the spikes in the total flux in and total flux out in Figure 6.38 represent a small amount of numerical instability in the model due to the presence of very thin layers at the model margins. The baseflow into the River Liffey (loss from the aquifer) (Figure 6.39) was plotted for the three models. The flux in, flux out and loss of water from the aquifer is the same for all three models regardless of the values inputted for specific yield or specific storage.

The recharge applied to the nodes representing the River Liffey ranges from 0.0 m^3/d to $4.0x10^3$ m^3/d for the area representing the river in the model. The variation in recharge is difficult to see in Figure 6.39 as the maximum recharge in the model is two orders of magnitude less than the flux in and out of the river.

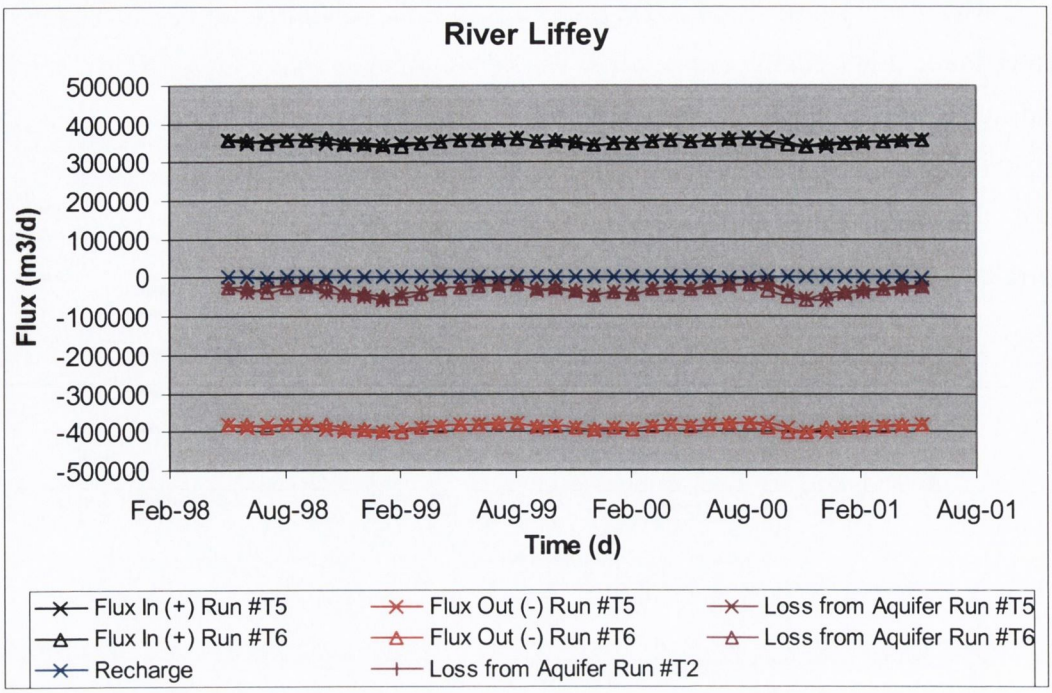


Figure 6.39: Total fluxes in to and out of the River Liffey over the three years that the model was run.

The baseflow into the Tully Stream (loss from the aquifer) (Figure 6.40) was plotted for the same three model runs. The decrease of the specific yield in the peat and the increase of the specific storage of the till had a slight effect on the flux out and the loss of water from the aquifer. The water loss varied from 24206-37485 m^3/d (280-434 l/s) for Run #T5 and 21560-30106 m^3/d (250-348 l/s) for Run #T6. This can be compared to the flow into the Tully Stream in Run #T2 which varied from 23523-34051 m^3/d (272-394 l/s).

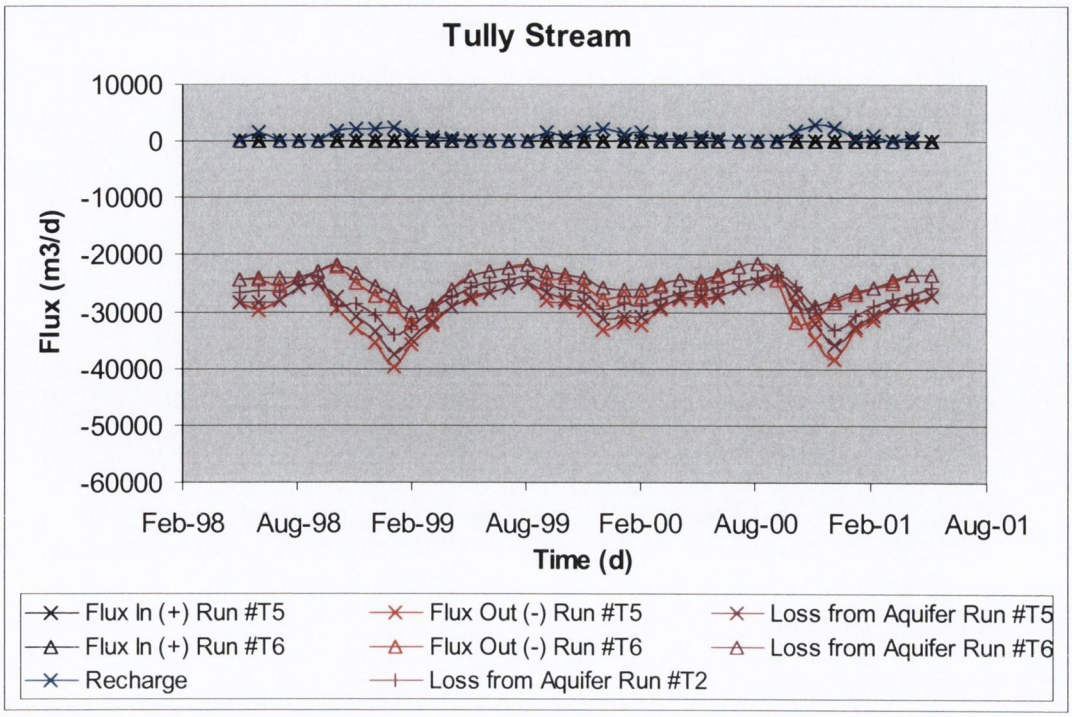


Figure 6.40: Total fluxes in to and out of the Tully Stream over the three years that the model was run.

The baseflow into the Milltown Feeder/Grand Canal/Pollardstown Fen (loss from the aquifer) (Figure 6.41) was plotted for the same three model runs. The decrease of the specific yield in the peat and the increase of the specific storage of the till had a slight effect on the flux out and the loss of water from the aquifer. The water loss varied from 45491-68732 m^3/d (527-796 l/s) for Run #T5 and 44891-65231 m^3/d (520-755 l/s) for Run #T6. This can be compared to the flow into the Tully Stream in Run #T2 which varied from 43048-67353 m^3/d (498-780 l/s).

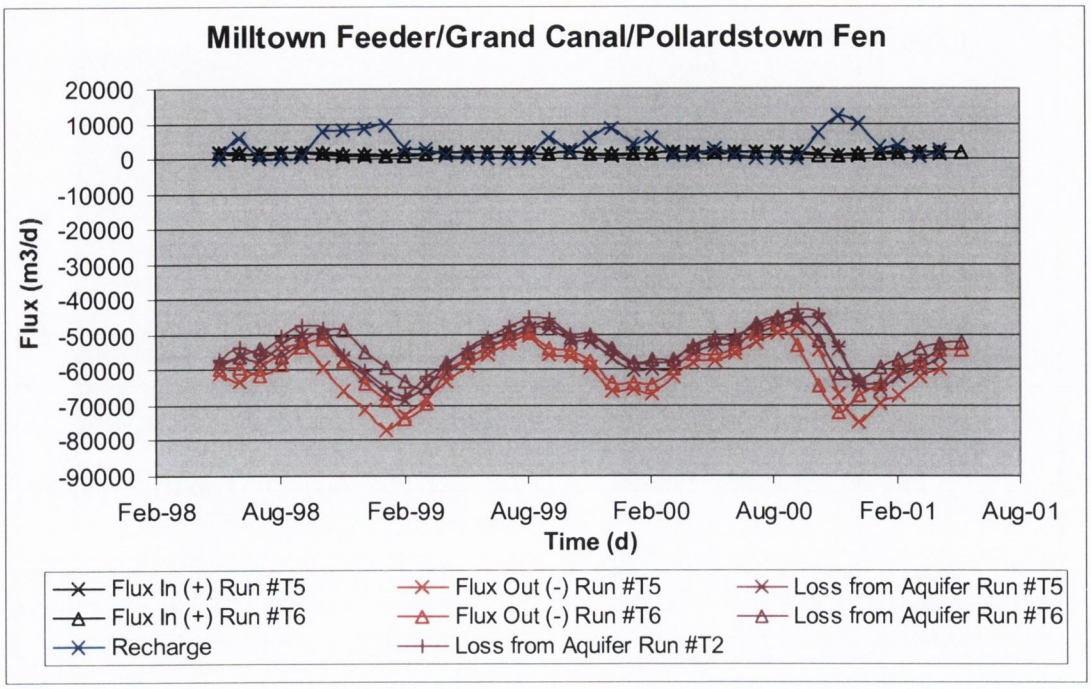


Figure 6.41: Total fluxes in to and out of the Milltown Feeder/Grand Canal/Pollardstown Fen over the three years that the model was run.

This analysis reveals that the model is not very sensitive to changes in specific yield and specific storage. In general, the flux out of the model is greater for Run #T6 where the specific storage is increased which also caused a slight delay in response to water storage of the aquifer when compared to Run #T2 or Run #T5. Run #T2 best fits the known baseflow of the rivers and streams.

6.4 NUMERICAL MODELLING OF THE EXCAVATION

The dewatering was modelled as a staged excavation to assess the effect of dewatering on the groundwater levels and baseflow into the rivers, streams and fen. The numerical model of the excavation for the Kildare Bypass was run over an 8.5 year period from May 1998 until December 2006. This allowed for a three year period prior to the commencement of dewatering, then dewatering from May 31, 2001 until mid-August 2003, and then nearly three years of recovery to be modelled. The recharge data used was the daily average recharge for each month as calculated by Brown (2007) (Appendix A). The dewatering was modelled as well boundary conditions as previously explained in Chapter 5. The dewatering model (Run #T7) was compared to Run #T2 which was extended to run for the 8.5 year period without the dewatering to examine the impact of the dewatering on the aquifer (extended run is referred to as Run #T8). Run #T7 was also

compared to a model which included a constant head at the Japanese Gardens to simulate the elevated heads due to the extracted water from the excavation being discharged into lakes at this location. Runs #T7 and #T8 were compared to the measured water levels in the monitoring boreholes. The run including the Japanese Gardens did not show any difference from Run #T7 and so was not included in Figures 6.42 to 6.46. Figures 6.42, 6.43, 6.44, 6.45 and 6.46 show the results of the three model runs plus the measured water levels in the regional monitoring boreholes.

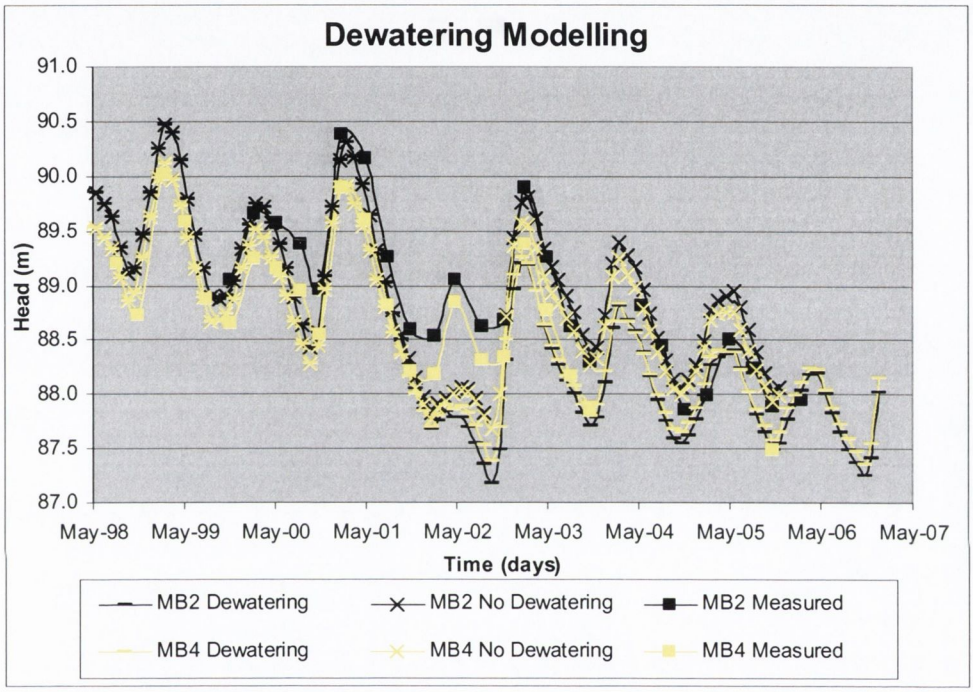


Figure 6.42: Comparison of model with Run #T7 (dewatering), Run #T8 (no dewatering), and measured water levels in monitoring boreholes for MB2 and MB4.

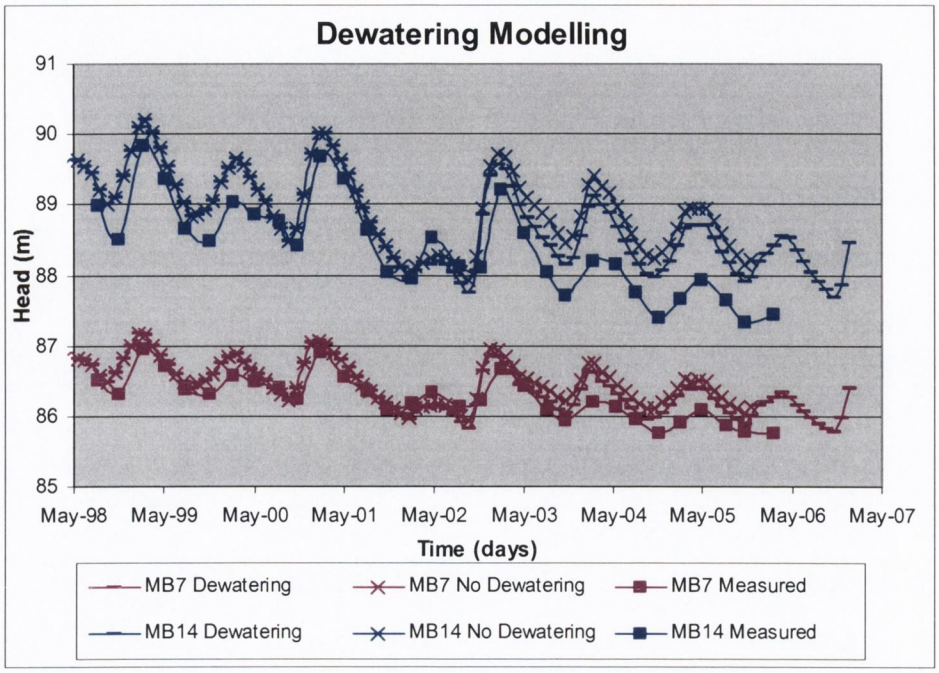


Figure 6.43: Comparison of model with Run #T7 (dewatering), Run #T8 (no dewatering), and measured water levels in monitoring boreholes for MB7 and MB14.

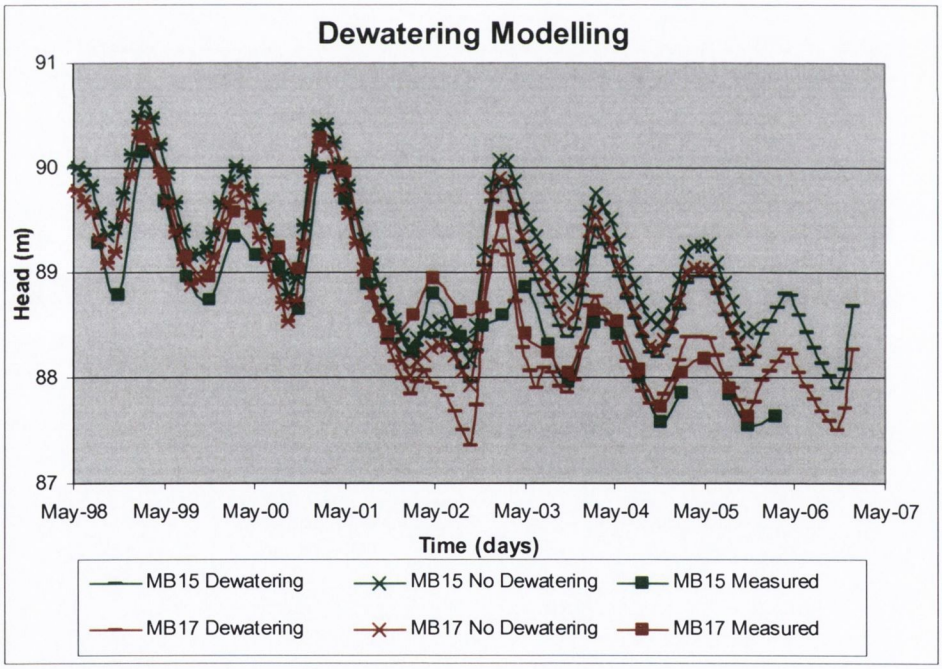


Figure 6.44: Comparison of model with Run #T7 (dewatering), Run #T8 (no dewatering), and measured water levels in monitoring boreholes for MB15 and MB17.

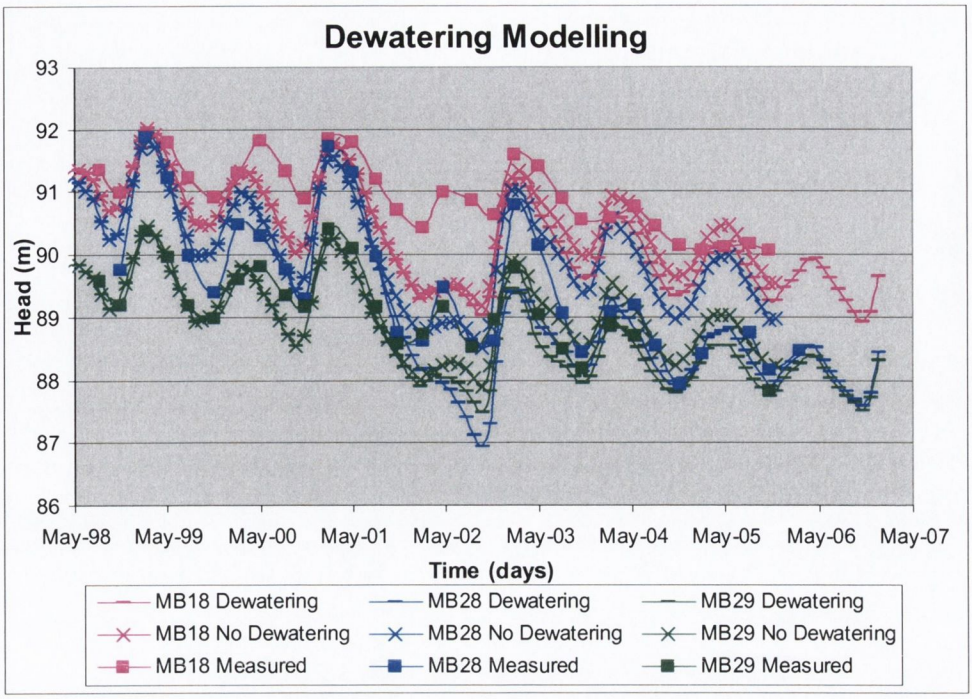


Figure 6.45: Comparison of model with Run #T7 (dewatering), Run #T8 (no dewatering), and measured water levels in monitoring boreholes for MB18, MB28, and MB29.

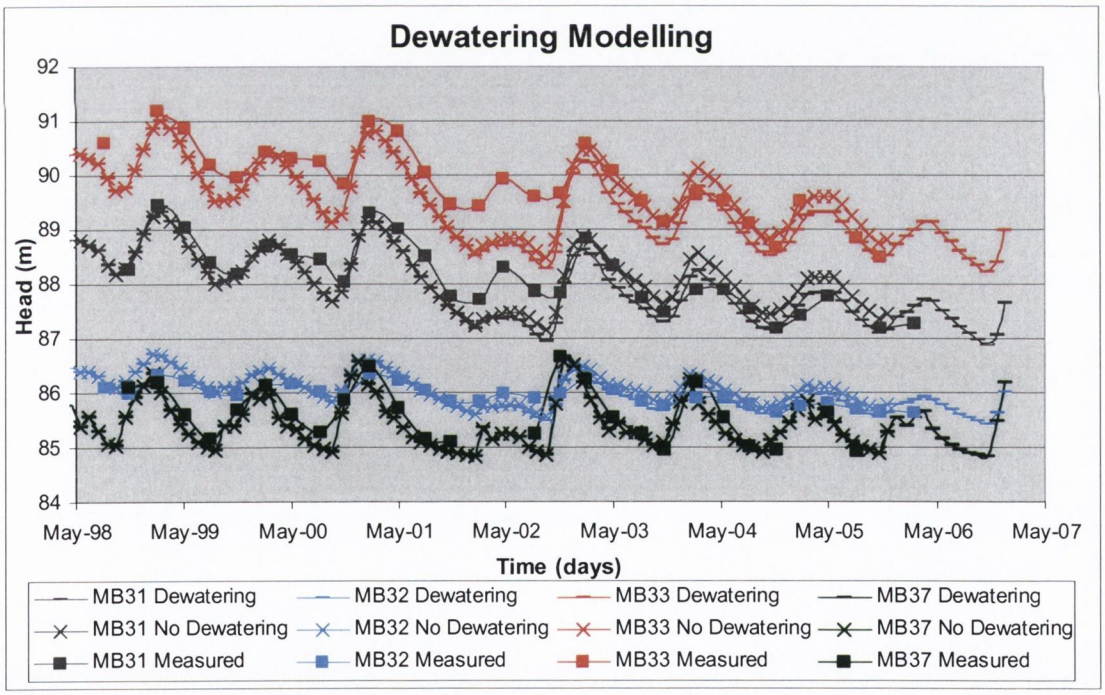


Figure 6.46: Comparison of model with Run #T7 (dewatering), Run #T8 (no dewatering), and measured water levels in monitoring boreholes for MB31, MB32, MB33 and MB37.

Figures 6.42 to 6.46 show that the two models correlate well with the measured water levels in the monitoring boreholes. The difference between the groundwater levels with dewatering (Run #T7) and without dewatering (Run #T8) ranges from 0.04 m at

MB37 to 1.6 m at MB28 with the majority of the boreholes (6 out of 13) falling in the range from 0.3 to 0.6 m.

In addition, to comparing the dewatering model results to the regional monitoring boreholes the Run #T7 was also compared with the monitoring points along the sides of the motorway. These points were monitored for a short period of time during dewatering. Figures 6.47, 6.48, and 6.49 show the modelled water levels and the measured water levels for seven points adjacent to the motorway. The names of the monitoring points refer to the chainages at which they were located. The correlation between the modelled and measured groundwater levels is weakest for Ch. 7570 in Figure 6.47 (differences up to 2 m); this is due to boundary effects as it was the closest to the outer boundary of the model. In reality, there is probably some groundwater flow past the western boundary defined by Wright (1988). The groundwater levels measured at other chainages further away from the boundary conditions have better correlations between the modelled and measured values.

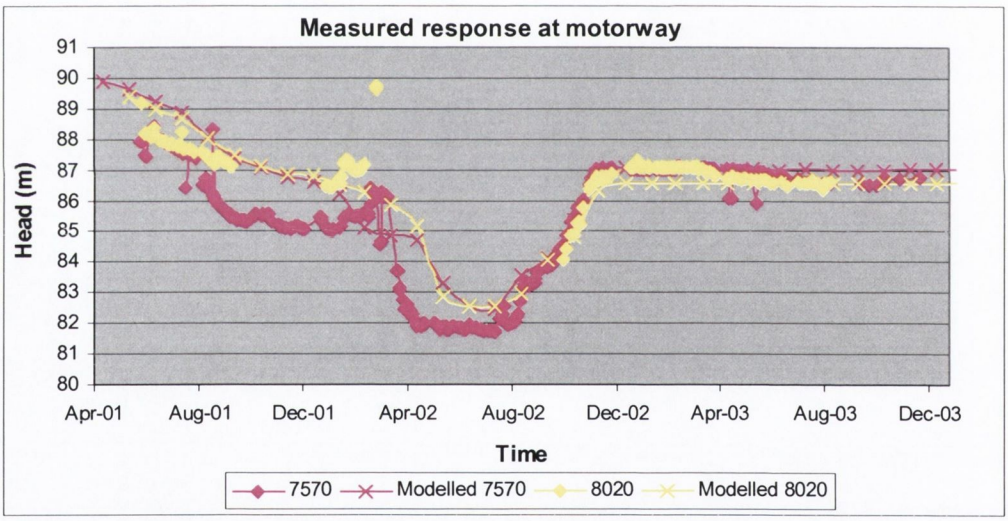


Figure 6.47: Comparison of modelled and measured water levels at monitoring points at Ch. 7570 and 8020.

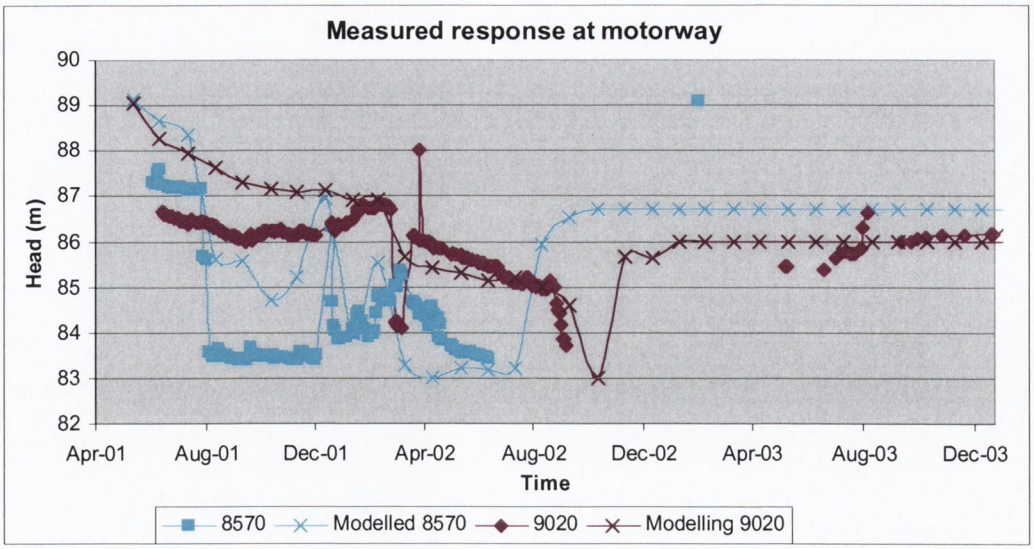


Figure 6.48: Comparison of modelled and measured water levels at monitoring points at Ch. 8570 and 9020.

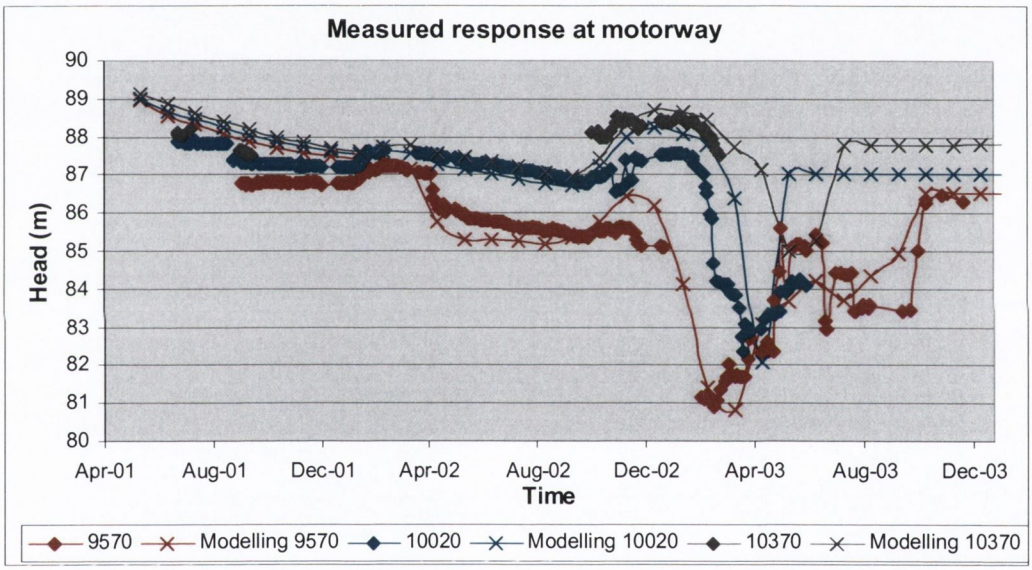


Figure 6.49: Comparison of modelled and measured water levels at monitoring points at Ch. 9570, 10020 and 10370.

In order to obtain the correlations in Figures 6.47 to 6.49 the hydraulic conductivity in the area of the motorway had to be adjusted from Run #T2 to the values shown in Table 6-3. The area around chainage 9020 is on the contact between the tills and gravels so it is likely that the contact was mapped slightly too far to the west or that the contact is gradational rather than sharp so the hydraulic conductivity was modified accordingly. Local variation in the hydraulic conductivity is likely to be present over the entire area of the Mid-Kildare Aquifer. However, the lack of data in other areas makes it impossible to accurately model this variation in the sediments. Figures 6.50 and 6.51 show the hydraulic conductivity for the upper layer and lower layer respectively.

Table 6-3: Modified hydraulic conductivity for the dewatering transient-state model (Run #T5). The horizontal and vertical hydraulic conductivity are indicated by (h) and (v), respectively.

UNIT	ORIGINAL HYDRAULIC CONDUCTIVITY (m/s)	MODIFIED HYDRAULIC CONDUCTIVITY (m/s)
Alluvium near Ch. 9570 (upper layer)	$8.0x10^{-3}$ (h) $8.0x10^{-4}$ (v)	$8.0x10^{-4}$ (h) $8.0x10^{-5}$ (v)
Gravels near Ch. 9020 (upper layer)	$2.0x10^{-3}$ (h) $2.0x10^{-4}$ (v)	$1.0x10^{-4}$ (h) $1.0x10^{-5}$ (v)
Tills from Ch. 7070 to 8570 (upper layer)	$1.0x10^{-4}$ (h) $1.0x10^{-5}$ (v)	$1.0x10^{-5}$ (h) $1.0x10^{-6}$ (v)
Gravels on western margin (lower layer)	$2.0x10^{-4}$ (v)	$2.0x10^{-3}$ (v)
Gravels around Ch 7570 (lower layer)	$2.0x10^{-4}$ (v)	$5.0x10^{-4}$ (v)
Gravels around Ch 8020 (lower layer)	$2.0x10^{-3}$ (h) $2.0x10^{-4}$ (v)	$1.0x10^{-3}$ (h) $1.0x10^{-4}$ (v)
Gravels around Ch 9020 (lower layer)	$2.0x10^{-4}$ (v)	$1.0x10^{-3}$ (v)
Gravels between Ch 9570 and 10370 (lower layer)	$2.0x10^{-4}$ (v)	$2.0x10^{-3}$ (v)

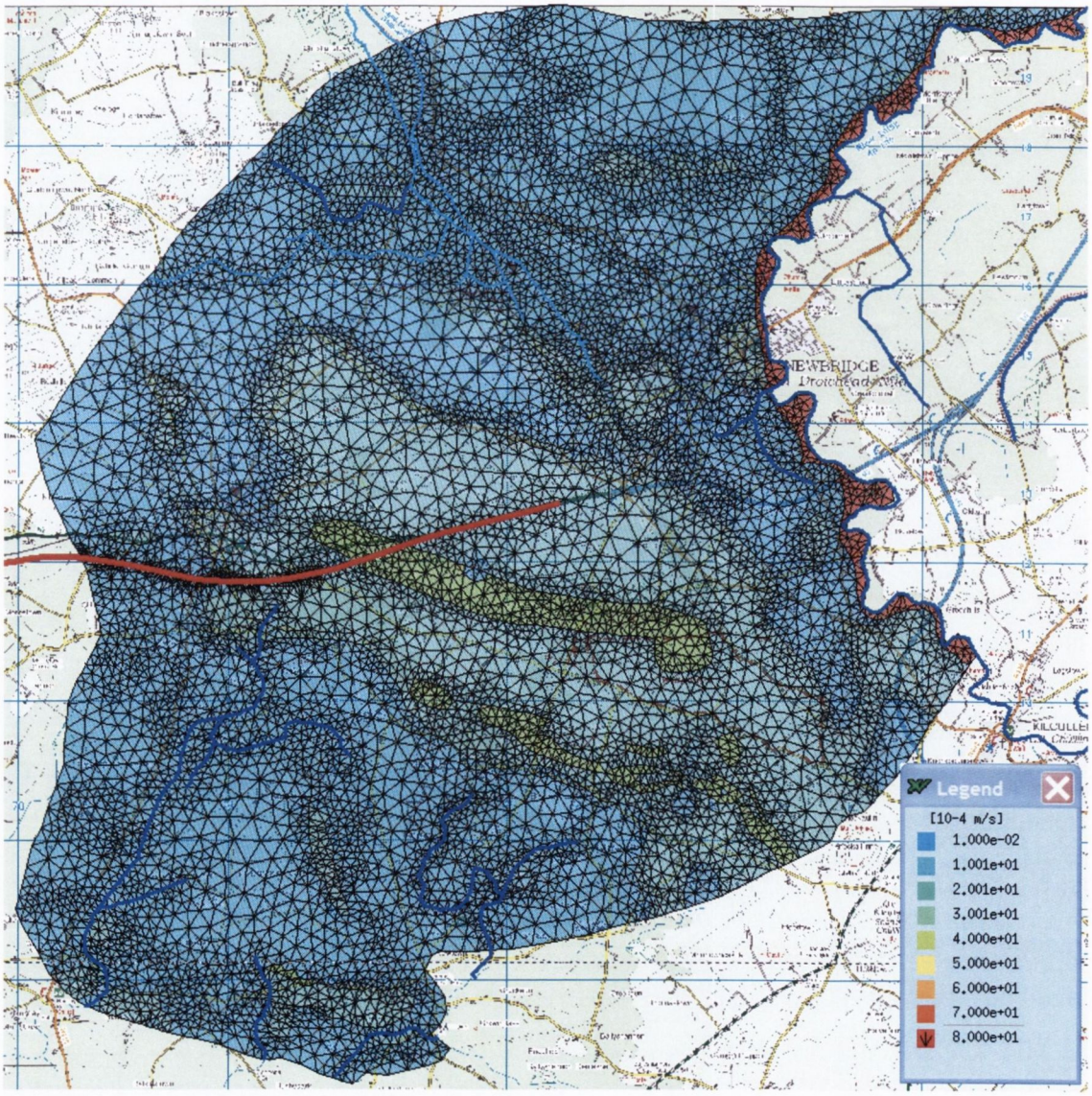


Figure 6.50: Horizontal hydraulic conductivity of the upper layer, in general the vertical hydraulic conductivity is one order of magnitude lower except where specified previously in this chapter.

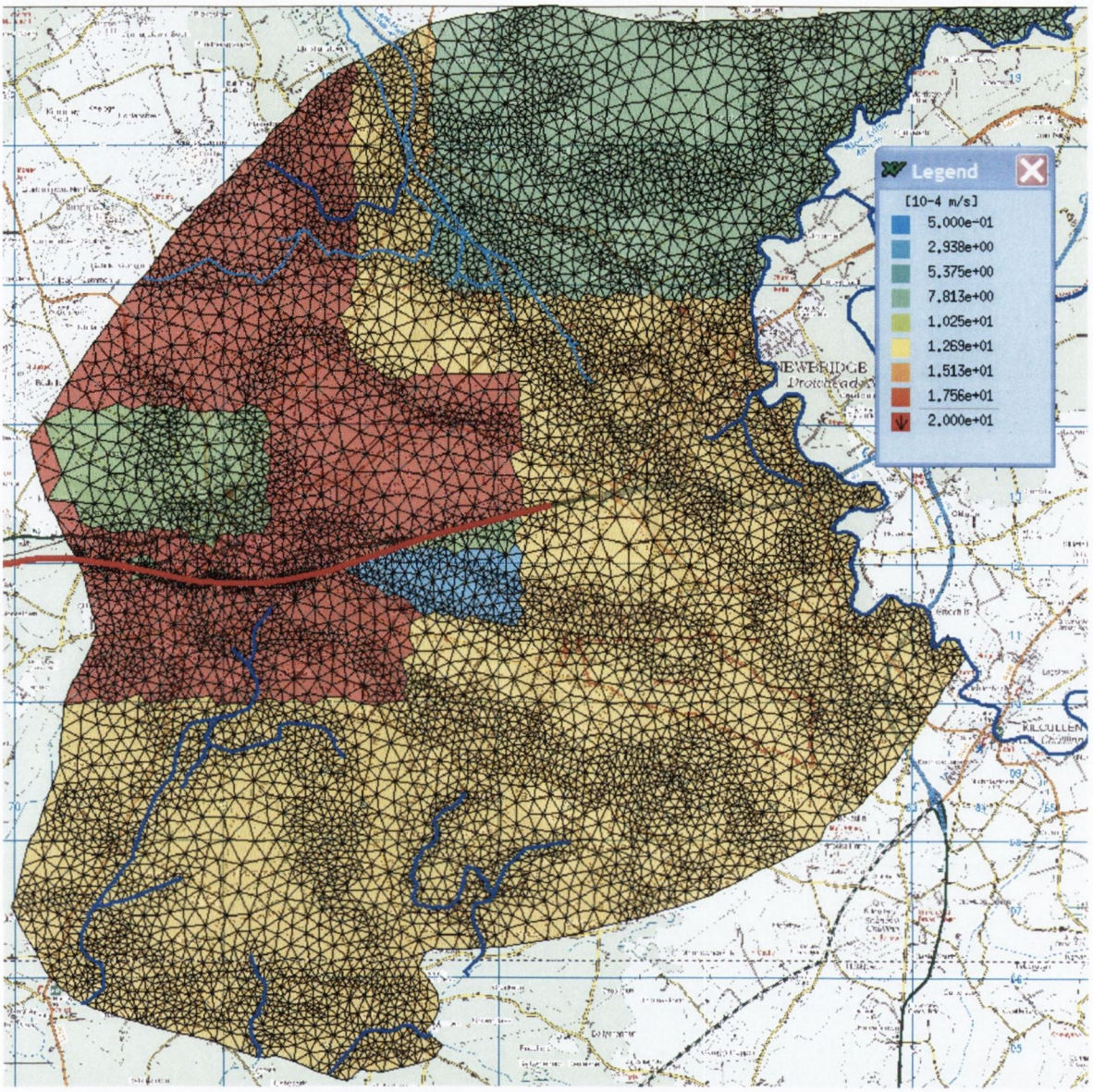


Figure 6.51: Horizontal hydraulic conductivity of the lower layer. In general, the vertical hydraulic conductivity is one order of magnitude less except where previously specified in this chapter.

The effects of dewatering were examined further by subtracting the groundwater levels derived from Run #T7 from Run #T8. This allows a comparison of what the difference would be if the dewatering for the motorway had never taken place and if the drainage system beneath the motorway had never been installed. At the onset of dewatering in May 2001, there is a clear rise in the difference between the modelled groundwater head with and without the dewatering (Figure 6.52). Monitoring boreholes MB17 and 28 show the largest change in groundwater head of approximately 1.2 and 1.6 m, respectively. MB28 is the borehole located 1.5 km north of the western part of the bypass where dewatering began and correspondingly shows a sharp rise in the early part of dewatering. MB17 is located 650 m northeast of the eastern part of the bypass which was

the last part to be dewatered and correspondingly shows a sharp rise towards the later stages of dewatering. As these monitoring boreholes occur closest to the location of dewatering it is expected that they should show the greatest change in head. Monitoring boreholes further away from the dewatering such as MB2, 4, 14, 15, 18, 29, 31, and 33 had a maximum change in head between 0.35 - 0.79 m. The borehole furthest away MB37, which is on the far side of the fen, had a maximum lowering of the watertable of 0.04 m.

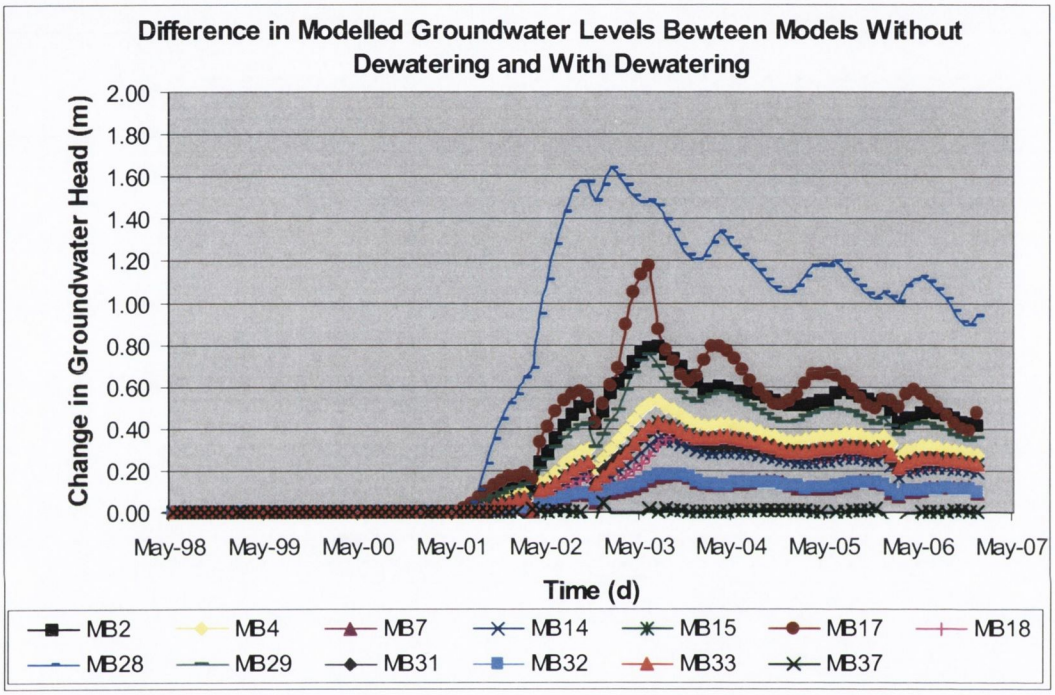


Figure 6.52: Comparison of Run #T7 and Run #T8.

By December 2006 the modelled groundwater levels had, in general, recovered to a minimum of 50% of the level they would have been without dewatering. Most of the boreholes are between 0.1 and 0.4 m lower than they would have been without dewatering except for MB28 where the water table is 0.9 m. By the end of December 2006, the groundwater level at MB37 was the same as it would have been without dewatering. All of the curves are on a downward trend which indicates that the groundwater levels would continue to recover if the model was run for a longer period. In the immediate vicinity of the Kildare Town Bypass the groundwater level will be permanently lowered to the weir level. Therefore, the monitoring boreholes closest to the Bypass will show the greatest permanent lowering of the groundwater levels.

In addition to examining the effects on groundwater head as a result of dewatering, the effects on the storage of the aquifer and the baseflow on the rivers and streams were

also considered. The total flux shows the change in storage for Run #T7 and the amount of dewatering required to bring the water levels down to those observed along the motorway (shown as wells in Figure 6.53). The modelled losses from the aquifer into the River Liffey are 13200-57600 m^3/ d (153-667 l/s), into the Tully Stream are 20183-28357 m^3/d (234-328 l/s) and into Pollardstown Fen are 38861-58774 m^3/d (450-680 l/s). The baseflow into the River Liffey is similar with and without dewatering (see Figure 6.54). However, the baseflow into the Tully Stream and Pollardstown Fen from the aquifer are up to 57 l/s and 32 l/s less, respectively, with dewatering than without (see Figures 6.55 and 6.56). The loss from the aquifer is similar regardless of whether or not the flow into the Japanese Gardens is considered. This is probably due to the relatively small amount of water being added to the system from the Japanese Gardens.

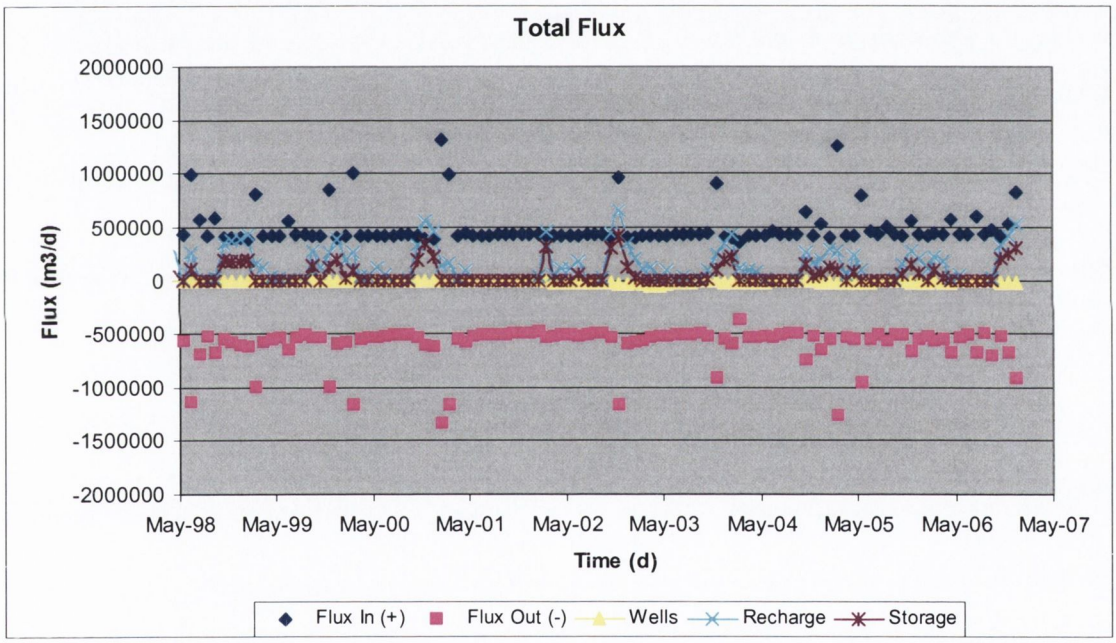


Figure 6.53: Total fluxes into and out of the aquifer, out from wells, in from recharge, and change in storage for the model Run #T7 (dewatering).

As previously stated, the spikes in the total flux in and total flux out in Figure 6.53 represent a small amount of numerical instability in the model due to the presence of very thin layers at the model margins. The recharge applied to the nodes representing the River Liffey ranges from 0.0 m^3/d to $4.7x10^3$ m^3/d for the area representing the river in the model. The variation in recharge is difficult to see in Figure 6.54 as the maximum recharge is two orders of magnitude less than the flux in and out of the river. The recharge is comparatively small for the River Liffey as it is only calculated on the nodes along the

river and the fluxes in and out are significantly larger (one order of magnitude) than those at the Milltown Feeder/Grand Canal/Pollardstown Fen or Tully Stream.

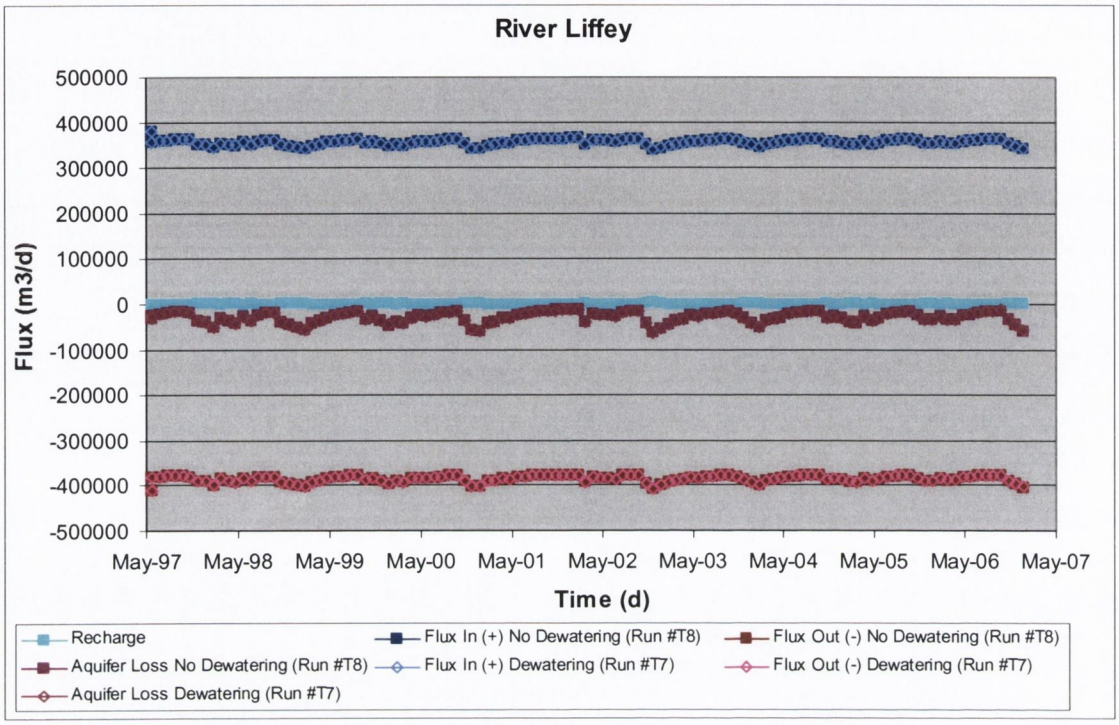


Figure 6.54: Fluxes into and out of the River Liffey, in from recharge, and loss from the aquifer for the model Run #T7 (dewatering) and Run #T8 (no dewatering).

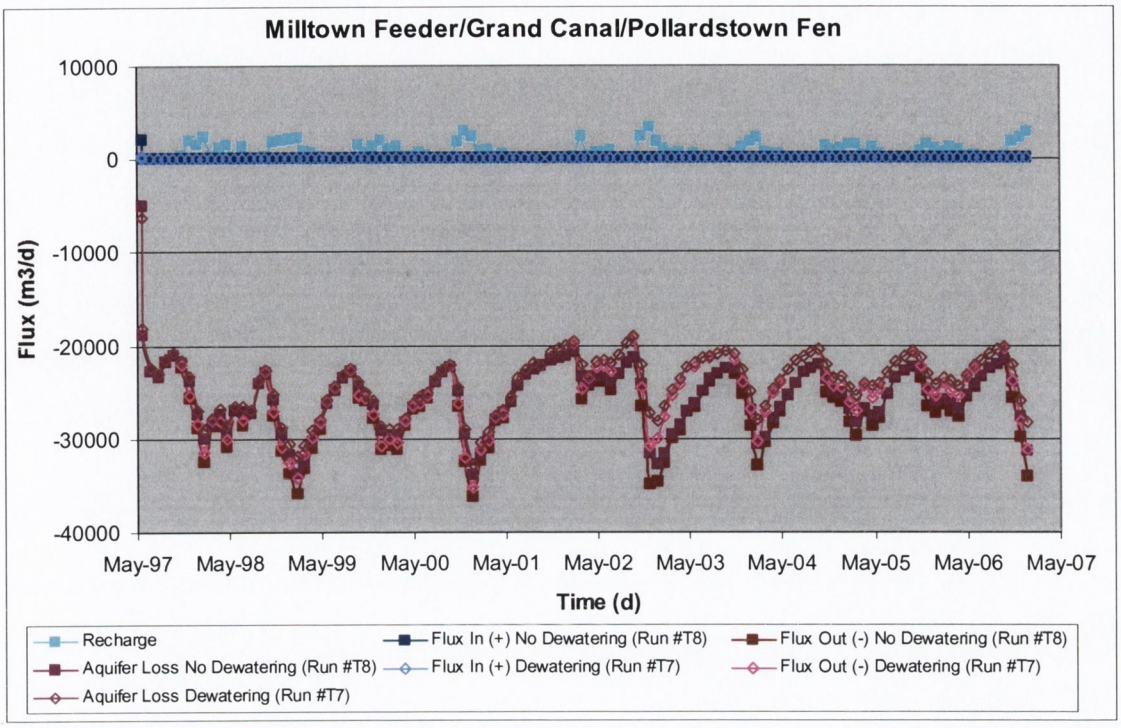


Figure 6.55: Fluxes into and out of the Milltown Feeder/Grand Canal/Pollardstown Fen, in from recharge, and loss from the aquifer for the model Run #T7 (dewatering) and Run #T8 (no dewatering).

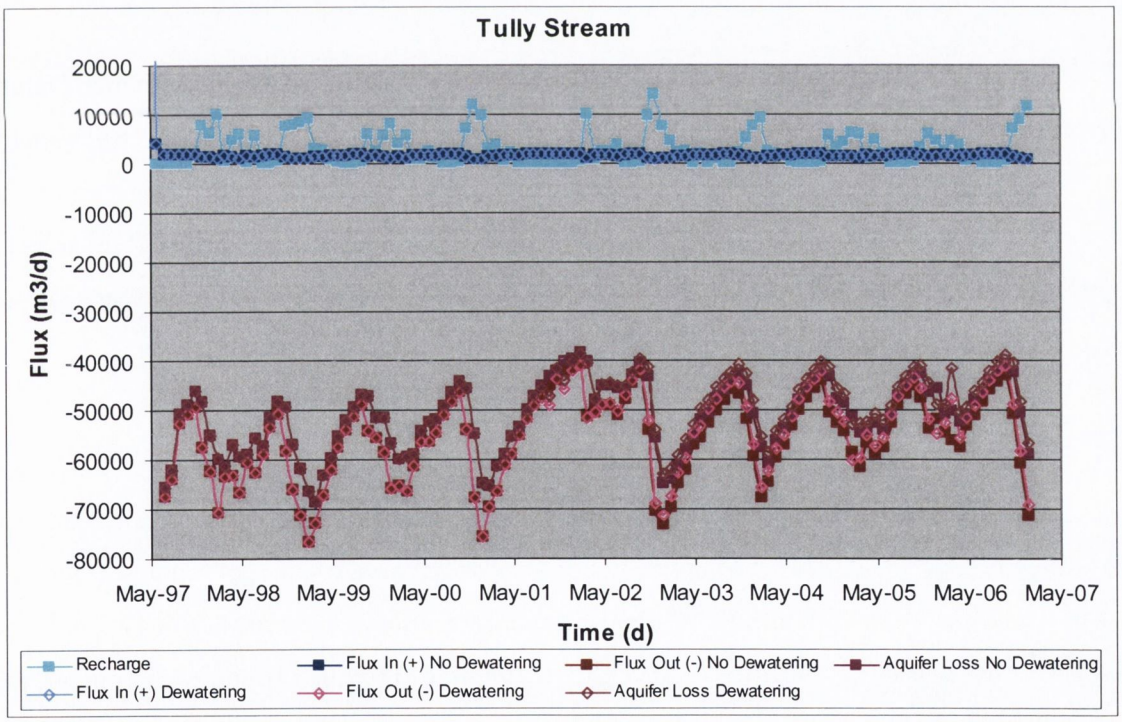


Figure 6.56: Fluxes into and out of the Tully Stream, in from recharge, and loss from the aquifer for the model Run #T7 (dewatering) and Run #T8 (no dewatering).

6.5 *COMPARISON WITH KAM MODEL*

The Kildare Aquifer Model (KAM) as stated in Section 3.4 is a detailed finite-difference numerical model of the Mid-Kildare Aquifer which was developed for the Monitoring Committee. This section compares the input variables in the KAM model and in the model in this chapter (referred to hereafter as the KMC model). The input variables considered include: the datum; topography; grid formulation; model extent; model layers; aquifer parameters; boundary conditions; time-steps; recharge; and the modelled representation of dewatering. The results of the two models are compared in Section 7.5.

6.5.1 DATUM

The KAM model uses the Poolbeg datum whereas the KMC model uses the Malin Head datum which succeeded the Poolbeg datum as the official datum for elevation in Ireland in 1970 and is the datum that the Ordnance Survey of Ireland (OSI) recommends for use.

6.5.2 TOPOGRAPHY

The top of layer 1 in the KAM model was set at a uniform 300 m Ordnance Datum (mOD) (White Young Green, 2004) which is significantly higher than the topography derived from the OSI digital terrain model (DTM). The topography, which represented the Surface 1 in the KMC model, was derived from a DTM obtained from the OSI which has a horizontal resolution of 50 m. This results in a more accurate representation of topography.

6.5.3 GRID FORMULATION

Being a finite-difference model, the KAM model is based on a rectangular grid with a grid-size of 250 m. The grid was refined in the area of the cutting resulting in a grid-size of 62.5 m which is larger than the dewatered width of the cutting at 47.5 m. The KAM model had 68 rows and 82 columns resulting in 5576 cells. In the KMC model, the dewatering occurred at the nodes rather than in the centre of the cells. This results in a point source for dewatering rather than an area which is drained. The KMC model consisted of 23364 nodes and 30536 elements. The KMC model had average element size of approximately 100 m and in the area around the cutting it was refined to an element size of 5-10 m.

6.5.4 MODELLED EXTENT

The KAM model defined the model space based on the delineation of the Mid-Kildare Aquifer by Wright (1988). This was modified in the KMC model to exclude the area of the Mid-Kildare Aquifer east of the River Liffey as this was assumed to have no effect on the dewatering requirements or groundwater response to dewatering and there was very little information available on the aquifer properties east of the River Liffey.

6.5.5 LAYERS

The KAM model consisted of four layers, the three lower levels representing gravels and the top layer representing tills. The KAM model assumed Layer 1 (till) to be 5 m thick. The top of Layer 3 (gravel) was set at 60% of the way up the gravel. The top of Layer 4 was set at 75 mOD unless the base of the aquifer was above this elevation or would produce a very thin layer. The KMC model was a two layered model and assumed Layer 1 (upper layer) to have a maximum thickness of 12 m which was then thinned where necessary. Layer 1 was based on Quaternary geology maps produced by the Geological Survey of Ireland (Glanville, 2000) and aquifer properties were assigned accordingly. Layer 2 (lower layer) was assumed to be the predominant body of the Mid-Kildare Aquifer and therefore represented gravel. The aquifer is unconfined and all available depth to bedrock data were used to delineate the bottom surface of the model.

6.5.6 AQUIFER PARAMETERS

The hydraulic conductivity, specific yield and specific storage values used in the KAM model are listed below (Table 6-4). The modelled parameters for the KMC model can be found in Section 6.3 and are summarized briefly in Table 6-5. The sensitivity to specific yield and specific storage was assessed using the KAM model (White Young Green, 2004). It is reported that when the specific yield was increased from 0.13 to 0.25 the amplitude of the graphs narrowed and the accuracy of the model predictions was reduced (White Young Green, 2004). Lowering the specific yield to 0.03 and modifications to the specific storage were reported to cause no difference in the KAM model (White Young Green, 2004). White Young Green (2004) demonstrated that a reduction in horizontal hydraulic conductivity caused an increase in elevation in the groundwater level in the KAM model. This was also the case in the KMC model (see Section 6.2and 6.3).

Table 6-4: KAM model parameters for run Kild46 (Entec, 1999).

UNIT	HYDRAULIC CONDUCTIVITY (m/s)		SPECIFIC YIELD	SPECIFIC STORAGE (/m)
	Horizontal	Vertical		
Till	5.8×10^{-5}	2.3×10^{-6}	0.13	0.0001
Gravel	1.2×10^{-3}	4.6×10^{-5}	0.13	0.0001
Gravel (NW area)	4.6×10^{-4}	1.4×10^{-5}	0.07	0.0001
Gravel (SW area)	4.6×10^{-4}	1.4×10^{-5}	0.13	0.0001
Gravel (West area)	3.5×10^{-4}	4.6×10^{-5}	Not specified	Not specified
Seven Springs	2.3×10^{-3}	9.3×10^{-5}	Not specified	Not specified

Table 6-5: KMC model parameters.

UNIT	HYDRAULIC CONDUCTIVITY (m/s)	SPECIFIC YIELD	SPECIFIC STORAGE (/m)
Gravels (Glacial outwash) (upper layer)	2.0×10^{-3} (h) 2.0×10^{-4} (v)	0.13	1.0×10^{-4}
Gravels (lower layer) Northwest	2.0×10^{-3} (h) 2.0×10^{-4} (v)	0.13	1.0×10^{-4}
Gravels (lower layer) around MB28	1.0×10^{-3} (h) 1.0×10^{-4} (v)	0.13	1.0×10^{-4}
Gravels (lower layer) around Pollardstown Fen (NE corner)	9.0×10^{-4} (h) 9.0×10^{-5} (v)	0.13	1.0×10^{-4}
Gravels (lower layer) around MB18	5.0×10^{-5} (h) 5.0×10^{-6} (v)	0.13	1.0×10^{-4}
Esker (upper layer)	4.0×10^{-3} (h) 4.0×10^{-4} (v)	0.13	1.0×10^{-4}
Esker around MB18 (upper layer)	5.0×10^{-5} (h) 5.0×10^{-6} (v)	0.13	1.0×10^{-4}
Alluvium (upper layer)	8.0×10^{-3} (h) 8.0×10^{-4} (v)	0.13	1.0×10^{-4}
Carboniferous Limestone Till	1.0×10^{-4} (h) 1.0×10^{-5} (v)	0.0001	1.0×10^{-4}
Till with Gravel	7.0×10^{-5} (h) 7.0×10^{-6} (v)	0.0001	1.0×10^{-4}
Alluvium near Ch. 9570 (upper layer)	8.0×10^{-4} (h) 8.0×10^{-5} (v)	0.13	1.0×10^{-4}
Gravels near Ch. 9020 (upper layer)	1.0×10^{-4} (h) 1.0×10^{-5} (v)	0.13	1.0×10^{-4}
Tills from Ch. 7070 to 8570 (upper layer)	1.0×10^{-5} (h) 1.0×10^{-6} (v)	0.0001	1.0×10^{-4}
Gravels on western margin (lower layer)	2.0×10^{-3} (v)	0.13	1.0×10^{-4}
Gravels around Ch 7570 (lower layer)	5.0×10^{-4} (v)	0.13	1.0×10^{-4}
Gravels around Ch 8020 (lower layer)	1.0×10^{-3} (h) 1.0×10^{-4} (v)	0.13	1.0×10^{-4}
Gravels around Ch 9020 (lower layer)	1.0×10^{-3} (v)	0.13	1.0×10^{-4}
Gravels between Ch 9570 and 10370 (lower layer)	2.0×10^{-3} (v)	0.13	1.0×10^{-4}
Peat (Pollardstown Fen)	1.0×10^{-6} (h) 6×10^{-8} (v)	0.50	1.0×10^{-4}

6.5.7 Boundary Conditions

The outer boundaries in the KAM model are 'no flow' apart from three areas to the northwest and one area from the southeast where runoff recharge could occur (Entec, 1999). The KAM model also assumed that there was no upflow from the bedrock (Entec, 1999). The boundary conditions in the KMC model assumed that the groundwater level was allowed to fall within the bedrock, that all outer boundaries were no-flow except for the boundary at the River Liffey which was represented by a constant head.

The KAM model represented the rivers as a river boundary condition in MODFLOW which incorporates parameters such as stage elevation, bed elevation, and conductance among others. Rivers were set to have a stage elevation higher than the bed elevation whereas springs around the fen were modelled as having the stage and bed elevation as the same level (Entec, 1999). The rivers and springs were applied to Layer 2 (top gravel layer). Where available the water levels in the Tully Stream were taken from survey results (Entec, 1999). The fen was represented using river boundary conditions with cells in Layer 2 representing seepage through the sides of the fen valley, cells in Layer 3 representing springs around the fen, and cells in Layer 4 representing upflow through the clay beneath the fen (Entec, 1999). The rivers and fen in the KMC model were represented as a constant head boundary condition as there is no river boundary condition in FEFLOW. The seepages in the Tully Stream and around Pollardstown Fen were represented by placing a constraint on the constant head condition to only make it active under exfiltrating conditions. The constant head boundary conditions at the rivers and seepages were set to the elevation of the topographic surface.

6.5.8 Time-steps

The KAM model had time-steps of two per month and was run from 1992 initially to 1998 (Entec 1999) and extended as time went on. The construction period was initially modelled to start in April 1995 but in later models was modelled at the actual time of construction. The KMC model had the time steps adjusted by the FEFLOW program. The initial time-step was set at 0.001 days and the maximum time-step was 14 days.

6.5.9 Recharge

The KAM model used the recharge available at the time the model was run. The rainfall data, based on measurements at Naas CBS and potential evapotranspiration,

calculated by Met Éireann, was applied on a fortnightly basis (KT Cullen & Co. Ltd, 2002 - run Kild79). This rainfall data were later updated by Brown (2007) which are the same data used in the KMC model. Three zones were constructed: with Zone 1 having no runoff; Zone 2 assumed limited runoff; and Zone 3 assumed recharge was 33% less than no-runoff (Entec, 1999). The recharge was applied to the top of Layer 3 (White Young Green, 2004). The KMC model used the recharge values calculated by Brown (2007) obtained from Osberstown up until 2001 and then collected from Naas CBS and assumed no-run off over the entire model space. The recharge was applied to the top of Layer 1 and varied monthly. As described in Section 3.4.4, the assumption of no runoff was based on topography and the lack of surface drainage features such as rivers and streams within the majority of the aquifer. The data was applied monthly to the KMC model to reduce the numerical complexity of the model.

6.5.10 Dewatering

The KAM model represented the dewatering as a set of drain cells at which the head is constrained to be less than or very close to the invert level of the groundwater drainage pipe (Entec, 1999). This was achieved by putting in head-dependent flow cells with very high conductance terms. Flow occurs at a rate of 10^6 m^3/d per meter head difference when the head is above the invert level and set to vary with time (Entec, 1999). The dewatering in the KMC was modelled as a series of wells with a maximum pumping rate corresponding to those recorded on site. The pumping rate changed daily in the model and was constrained to shut off when the groundwater levels went below the base of the excavation. The wells turned on and off sequentially to dewater the sections of the bypass from west to east and continued to pump after dewatering was completed if the groundwater heads rose above the drainage level for the bypass.

6.5.11 Conclusions

Many of the input parameters are different for the KAM and KMC models. The KMC model uses the currently recommended datum by the Ordnance Survey of Ireland, a more representative topography, and a higher resolution grid formulation than the KAM model. The KAM has a greater model extent including the aquifer east of the River Liffey. The KAM is a four layer model while the KMC model consists of two layers. The KMC reflects the heterogeneity by having more variation in the hydraulic conductivity than the

KAM model. The boundary conditions were similar with the two models except that the KAM model incorporated recharge boundary conditions to the northwest and southeast. Recharge was applied differently, with the KAM model it was applied as three different zones assuming varying amounts of run-off and was applied fortnightly, while in the KMC model it was applied uniformly over the upper layer of the model, assumed no runoff and was an averaged monthly value. The KAM represented the excavation as a drain boundary condition while in the KMC it was represented as a series of well boundary conditions that were constrained by the head level. The two models used different approaches to model the aquifer which reflects the different objectives of the models: to model the effects of the bypass on Pollardstown Fen (KAM) and to model the dewatering of a staged excavation in heterogeneous glacial sediments (KMC).

6.6 CONCLUSIONS

1) The steady-state model verified the assumptions made in the conceptual model before more complicated modelling was performed.
2) A transient-state model was required to reflect the time varying properties such as recharge and dewatering.
3) Recharge applied on an annual cycle was found to be too general to accurately model the aquifer response to annual variations, so the average daily recharge for each month calculated by Brown (2007) was used.
4) The sensitivity analysis of the model to changes in hydraulic conductivity showed that it was important to consider the variation in surface deposits in the model as they have an effect on fluxes and heads.
5) The hydraulic conductivity obtained from the aquifer pump tests and from the back-analysis of the dewatering were approximately an order of magnitude less than that required in the numerical model to obtain close agreement with the observed groundwater behaviour. This is attributed to the anisotropy in the model where the vertical hydraulic conductivity is assumed to be one order of magnitude less than the horizontal hydraulic conductivity.
6) The sensitivity analysis of specific yield and specific storage showed that the model is not very sensitive to changes in specific storage. An increase in the specific yield was found to cause slightly less seasonal variation in the groundwater levels (i.e. a reduction in the amplitude of the hydrographs). Both the modelled groundwater heads with the run using a specific yield of 0.13 (Run #T2) and the run with a

specific yield of 0.20 (Run #T5) had a good correlation with the measured groundwater heads; however, neither showed a better correlation with the measured groundwater heads than the other.

7) The water extracted from the excavation being discharged into the Japanese Gardens did not have a significant impact on the groundwater heads.
8) During dewatering the difference in head between the model with dewatering and without dewatering was between 0.3 and 0.6 m for most boreholes with the maximum difference calculated in a monitoring borehole (MB28) of 1.6 m.
9) The dewatering continued to have an effect on the modelled groundwater levels until December 2006 when the model ended where the drawdown was between 0.0 and 0.4 m for all the monitoring boreholes except for MB28 which was lower by approximately 0.9 m due to dewatering.
10) The fluxes into the River Liffey were found to be similar with dewatering and without dewatering. However, the fluxes into the Pollardstown Fen and Tully Stream were found to be reduced by up to 32 l/s and 57 l/s, respectively.
11) Two models, KAM (Entec, 1999) and KMC (this study) used different approaches to model the aquifer which reflects the different objectives of the models: to model the effects of the bypass on Pollardstown Fen (KAM) and to model the dewatering of a staged excavation in heterogeneous glacial sediments (KMC).

CHAPTER 7

DISCUSSION

7.1 *Introduction*

The Mid-Kildare Aquifer has complex geology and hydrogeology which makes it challenging to assess the hydrogeological parameters needed to predict the aquifer response to dewatering. The volume and variety of data available on the Mid-Kildare Aquifer (GSI, OSI, Met Éireann, the site investigation carried out prior to the construction of the Kildare Town Bypass and the Monitoring Committee) allowed for a comprehensive analysis of the aquifer response to seasonal variation and dewatering. These data were compiled and analysed to: develop a three-dimensional model of the aquifer; assess the hydraulic conductivity from pump tests, variable head tests, and particle size distribution analyses; determine the flows into the excavation using simplified calculations; determine the hydraulic conductivity of the aquifer by back-analysing the measured flow data; and examine the groundwater response and the effect of dewatering using numerical modelling.

7.2 *Geology and Hydrogeology*

7.2.1 Three-dimensional model of the Aquifer

The boreholes from the site investigation indicate that the basic stratigraphy in the area around the Kildare Town Bypass consists of an upper glacial till layer dominated by CLAY and SILT, which is absent in places, and a lower glacial outwash unit dominated by SAND and GRAVEL and hosts the Mid-Kildare Aquifer. Figure 7.1 shows the three-dimensional model of the aquifer that was formed by combining the topographic and depth to bedrock data.

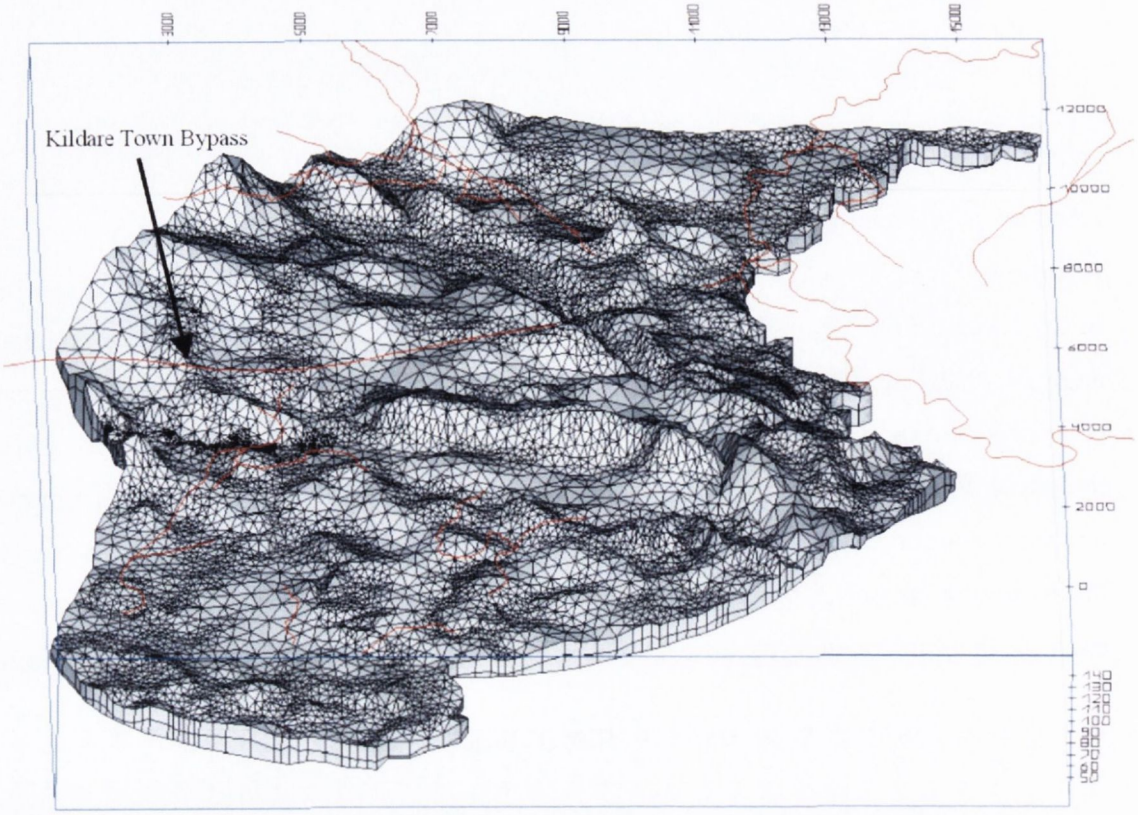


Figure 7.1: Three-dimensional representation of the Mid-Kildare Aquifer.

7.2.2 HYDRAULIC CONDUCTIVITY

The drawdown data and geology were analysed for five pump tests conducted as part of the ground investigation for the Kildare Town Bypass. From this, the appropriate method of analysis way selected (Thiem (1906), Walton (1962), Hantush-Jacob (1955), Neuman (1975), and Streltsova (1974)) (Tables 3-9, 3-11, 3-13, 3-15 and 3-17). These methods make different assumptions as to whether: the aquifer is confined, leaky, or unconfined; the aquifer is isotropic or anisotropic; and the wells partially or fully penetrate the aquifer.

The hydraulic conductivity values determined from recovery tests were two to four times greater than those determined from the pump tests (Table 7-1). The difference between the recovery and pump test analysis could be due to a variety of factors: pump tests generally involve variations in pumping rates in the early stages of the test which can make them more difficult to analyse (See Section 3.4.6.3); Theis recovery method assumes that the piezometric surface is horizontal which may not be the case after the pump test was completed; and the recovery test does not account for partial penetration of some of the boreholes. In addition, there were rain events during some of the pumping tests which

resulted in a reduction in drawdown and the pumping rate was not continuously monitored so some reduction in pumping may have occurred prior to the onset of the recovery tests. Any or all of these factors could result in the differences between the pump test and recovery test analyses of hydraulic conductivity. The horizontal hydraulic conductivity of the SAND and GRAVEL of the glacial outwash deposit is approximately 10^{-4} m/s as calculated from the pumping and recovery tests (Table 7-1). In general, the hydraulic conductivity increases from west to east.

Table 7-1: Summary of pump tests, calculated using the Neuman method, and recovery test results.

SITE	PUMPING TEST HYDRAULIC CONDUCTIVITY (m/s)	RECOVERY TEST HYDRAULIC CONDUCTIVITY (m/s)
Mooretown Bridge Site (71+00)	$2.1x10^{-4}$	$9.2x10^{-3}$
Nurney Bridge Site (84+15)	$1.6x10^{-5}$	$7.7x10^{-4}$
Greyabbey Road site	$6.3x10^{-5}$	$1.8x10^{-4}$
Sewage Treatment Works	$2.2x10^{-4}$	$2.9x10^{-4}$
Frenchfurze Road site	$3.3x10^{-4}$	

Hydraulic conductivity was assessed from particle size distribution analyses using the Hazen (1911), Kozeny-Carman-Bear (Bear, 1972), Pavchich (Vuković and Soro, 1992, Kasenow, 2002,) and Mbonimpa *et al.* (2002) methods for the fine-grained soils (Table 3-5) and Hazen (1911), Kozeny-Carman-Bear (Bear, 1972), Harlemann (Chin, 1999) and Mbonimpa *et al.* (2002) methods for the coarse-grained soils (Table 3-6). These analyses show that the methods which use the effective grain size (i.e. Hazen, Pavchich and Harlemann) over-predict the hydraulic conductivity for coarse-grained soils when compared to the methods which use geotechnical parameters (Kozeny-Carman-Bear and Mbonimpa *et al.*). The hydraulic conductivity calculated by each method for the fine-grained soils was not significantly different (less than one order of magnitude). Table 7-2 summarises the estimates of the hydraulic conductivity obtained by taking the geometric mean of the particle size distribution analyses for the various units within the aquifer. The particle size distribution analyses indicate that the hydraulic conductivity for the CLAY and SILT dominated till is significantly lower (2 to 3 orders of magnitude) than the SAND and GRAVEL of the glacial outwash that were tested by the pumping and recovery tests. However, the accuracy of the results from the particle size distribution analyses is questionable as they are from disturbed samples.

Table 7-2: Summary of particle size distribution analyses calculated using the Mbonimpa *et al.* (2002) method.

UNIT	HYDRAULIC CONDUCTIVITY (m/s)
CLAY and SILT	1.7×10^{-7}
SAND and GRAVEL	9.9×10^{-3}
Alluvium	1.0×10^{-2}
Esker	4.9×10^{-3}

The hydraulic conductivity estimated from the variable head tests ranged from 1×10^{-7} to 8×10^{-4} m/s (falling head) and 2×10^{-6} to 6×10^{-4} m/s (rising head). The correlation was poor between the variable head tests conducted in the same location, with the results from the falling head tests being up to two orders of magnitude less than those from the rising head tests (Figure 3.27). The falling head tests would be expected to be less than the rising head tests due to the possibility of siltation of the borehole in the former or due to loosening of the base by seepage forces in the latter. However, the magnitude of the difference in some of the tests is unexpected.

The results from the pump tests are considered to be the most representative of the hydraulic conductivity of the aquifer and have been used to compare the results of particle size distribution analyses and variable head tests from the same sites. The pump tests measure the hydraulic conductivity over the widest volume of ground and thus are best able to account for the heterogeneities in the soil. A simplified geology, based on correlating borehole logs, is shown on Figure 7.2. Given that the boreholes, from which the particle size distributions were obtained, are not at the exact location of the boreholes, from which the pump and variable head tests were obtained, and that the aquifer is highly heterogeneous; the tested sediments may be different from the sediments in the closest logged borehole. The particle size distribution analyses represent point locations and are shown at the location along the borehole where the sample was collected while the pump tests and variable head tests are shown as test zones on Figure 7.2. In general, Figure 7.2 shows that near the cutting, there is a lower hydraulic conductivity SILT/CLAY layer overlying the main aquifer which consists of higher hydraulic conductivity SAND/GRAVEL. The SILT/CLAY layer does not have a uniform thickness and is discontinuous. Figure 7.2 also shows that there is a broad correlation between the soil type and the estimated hydraulic conductivity; however, the value of hydraulic conductivity is dependent on the method used to determine it.

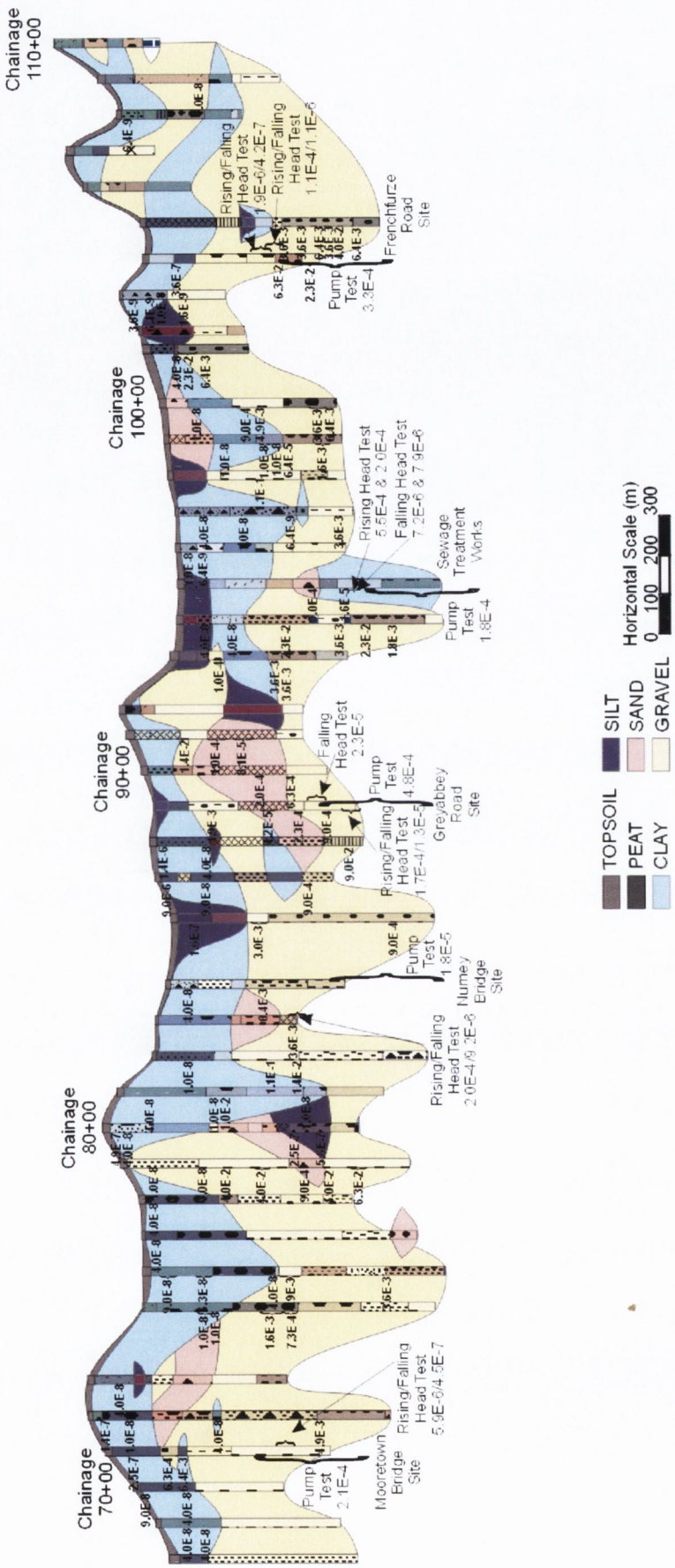


Figure 7.2: Correlation of borehole logs showing geological units where the pump test, variable head tests and particle size analyses were located. Hydraulic conductivity estimates are given in m/s.

A comparison of the hydraulic conductivity values obtained by the various methods within the zone of influence of the pump tests gives an opportunity to assess their reliability. Figure 7.3 shows that the particle size distributions over-predict the hydraulic conductivity while the variable head tests under-predict the hydraulic conductivity when compared with the pump test at the Frenchfurze Road site. This finding, of course, is dependent on the units tested by the particle size distribution and variable head tests. There is a general trend, within the particle size analyses, of the shallower units having a lower hydraulic conductivity than the deeper units which can be correlated to the upper till layer and the lower outwash unit.

Figure 7.4 shows the data at the Nurney Bridge site and indicates that the hydraulic conductivity estimated by particle size distribution analyses is evenly distributed regardless of depth. The hydraulic conductivity estimated by the pump test falls in the middle of those estimated by particle size distribution analyses and variable head tests. This results from the larger test zone of the pumping test and so the heterogeneity of the aquifer is better represented. The falling head test hydraulic conductivity estimates are consistently much lower than the pumping tests. The rising head test results are closer to the pump test results but do not reflect the differences in hydraulic conductivity in the different locations that are given from the pump tests. Frenchfurze Road has the largest calculated hydraulic conductivity from the pump tests yet the smallest from the rising and falling head tests.

The results of the variable head tests correlate poorly with the pumping tests as shown in Figures 7.3 and 7.4. For this reason, the variable head tests in the case of the Mid-Kildare Aquifer did little to aid in the assessment of the hydraulic conductivity of the aquifer. The rising head tests did correlate better than the falling head tests with the pump and particle size distribution analyses but not well enough that there is any real confidence in the estimations derived from the rising head tests. The variable head tests are subjected to the same scale effects as the particle size distribution tests and because of the small volume of ground tested they frequently underestimate the hydraulic conductivity in heterogeneous sediments (Shaw and Hendry, 1998).

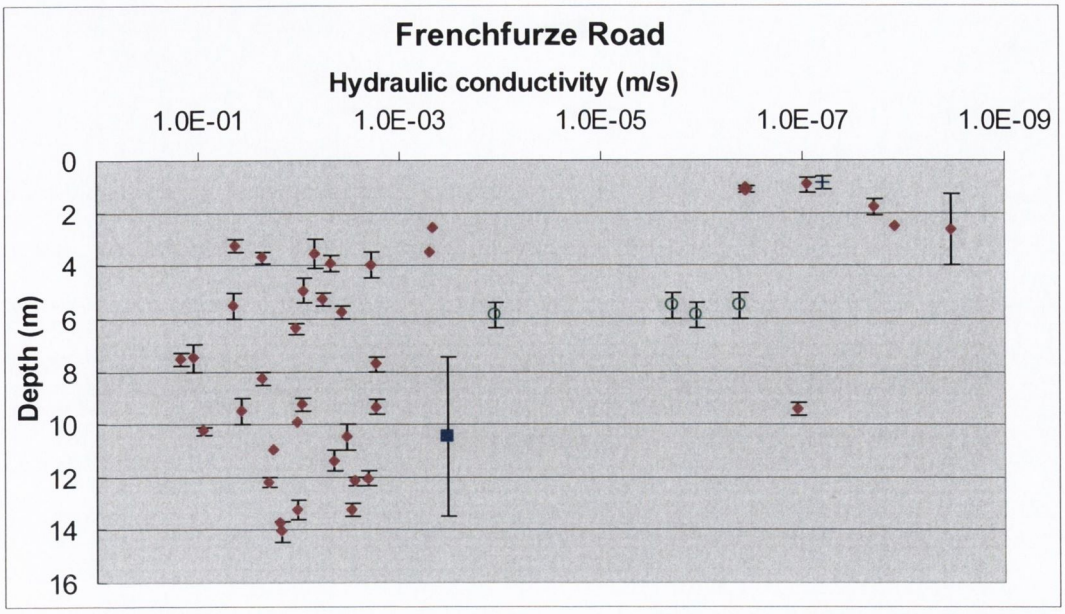


Figure 7.3: Comparison of the pump test (blue), variable head tests (green), and particle size distribution analyses (pink) at the Frenchfurze Road site. The error bars indicate the test zone.

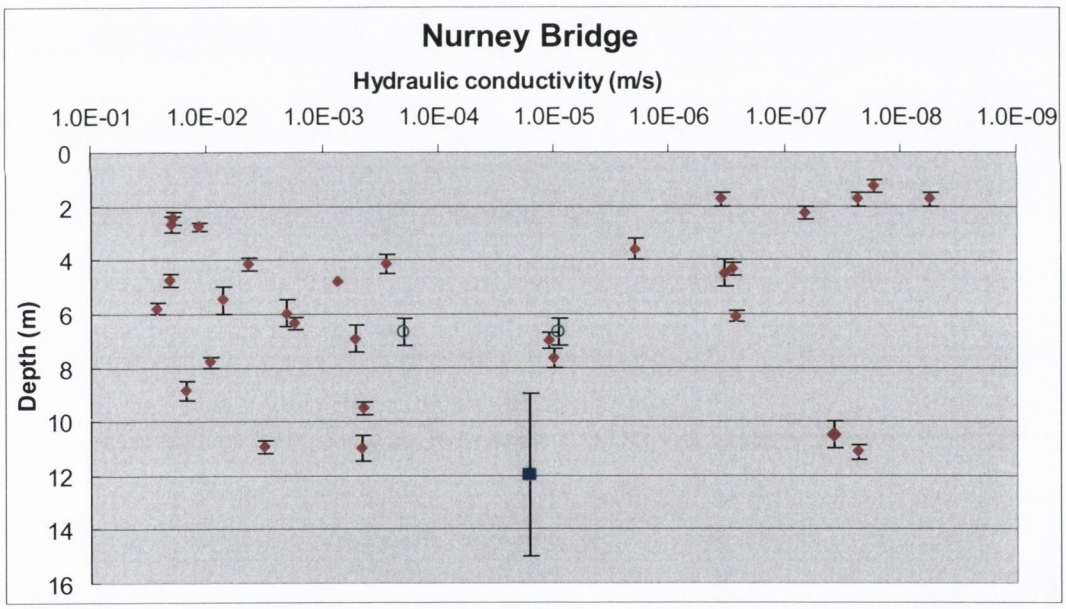


Figure 7.4: Comparison of the pump test (blue), variable head tests (green), and particle size distribution analyses (pink) at the Nurney Bridge site. The error bars indicate the test zone.

7.3 GROUNDWATER RESPONSE TO EXCAVATION AND DEWATERING

Traditional methods were used to back-analyse the hydraulic conductivity using the recorded pumped water from the excavation. The dewatering of the main excavation and the Tully Bridge site from September to December 2001 was back-analysed using the Thiem equation which determined the hydraulic conductivity of the main excavation from

Ch. 69+00 to 74+00 and Tully Bridge site to be approximately $4.0x10^{-4}$ m/s and $1.5x10^{-4}$ m/s, respectively.

The traditional methods of estimating the dewatering requirements for an excavation (Darcy's Law, flow nets, and Mansur and Kaufman (1958, Somerville, 1986) were used to back-analyse the hydraulic conductivity for the Tully Bridge site and the main excavation from Ch. 69+00 -74+00. These produced estimates of the hydraulic conductivity between $1.2x10^{-4}$ and $3.1x10^{-4}$ m/s for the Tully Bridge site and $5.3x10^{-5}$ and $3.1x10^{-4}$ m/s for the main excavation from Ch. 69+00 -74+00. However, the finite-element calibration required the gravels to have a horizontal hydraulic conductivity of $2x10^{-3}$ m/s (vertical hydraulic conductivity $2x10^{-4}$ m/s) to obtain a correlation with the observed groundwater levels. The effect of anisotropy when using these methods to determine flow is examined further in Section 7.4 which shows that these estimates may underestimate the hydraulic conductivity when the assumptions of a steady-state, isotropic, and heterogeneous aquifer are not satisfied.

The main excavation experienced flows between 100 to 200 l/s while dewatering from Ch. 69+00 to 94+00. East of Ch. 94+00 the flows into the excavation increased significantly. The area between Ch. 94+00 and 102+50 had recorded seepages in excess of 500 l/s. This indicates that the hydraulic conductivity east of 94+00 exceeds the upper estimate from the pumping tests of $3.5x10^{-4}$ m/s. Using the same traditional methods of estimating flows and assuming all other parameters are the same, the hydraulic conductivity in this area would be $2.5x10^{-3}$ m/s. This is similar to the horizontal hydraulic conductivity used in the model.

7.4 NUMERICAL MODELLING

The steady-state numerical model provided an opportunity to test whether the assumptions made in the conceptual model were valid before more complicated modelling was performed. The steady-state model showed the effect of changes in recharge and hydraulic conductivity on the groundwater heads and baseflow into rivers, streams and seepages.

The transient-state models found that the 15-year average daily rainfall data for each month on an annual cycle were too general to accurately reflect the aquifer response, so the average daily recharge data for each month calculated by Brown (2007) were used instead.

These recharge values may be on the low end of estimates for the aquifer since they assume that evapotranspiration occurs in the winter as well as in the summer. This allowed for the effect of wet and dry years to be observed. The sensitivity of the upper model layer to changes in hydraulic conductivity was also examined by removing the geological complexity from the model for comparison. This demonstrated that it was important to consider the variation in surface deposits in the model as they have an effect on fluxes and heads (see Section 6.3.2 Figures 6.25 to 6.32). A numerical instability causing spikes in the total fluxes due to the presence of very thin layers at some the model margins represents a limitation in the transient-state model. This limitation has been shown to not affect the modelled groundwater levels or the discharges from the aquifer into the rivers and streams.

The hydraulic conductivity obtained from the aquifer pump tests and from the back-analysis of the dewatering was approximately an order of magnitude less than what was required in the numerical model to obtain close agreement with the observed groundwater behaviour. This was attributed to the anisotropy incorporated in the model where the vertical hydraulic conductivity is assumed to be one order of magnitude less than the horizontal hydraulic conductivity and to the heterogeneity of the aquifer. This is similar to the findings of the KAM model produced for the Monitoring Committee which required the hydraulic conductivity of the gravels to be up to 1.2×10^{-3} m/s. The importance of the peat units with their significantly lower hydraulic conductivity was also highlighted through this modelling.

The numerical modelling of the excavation illustrated the effect the dewatering had on the groundwater heads. Figure 7.5 shows contours derived from the finite-element analysis of groundwater levels on November 30, 2002, during dewatering the excavation showing the cone of depression around the bypass due to dewatering. The water extracted from the cutting being discharged into the Japanese Gardens did not have a significant impact on the groundwater heads. The dewatering continued to have an effect on the modelled groundwater levels until December 2006 when the model runs ended, where the drawdown was between 0.0 and 0.4 m for all the monitoring boreholes except for MB28 which was lower by approximately 0.9 m due to dewatering. MB28, on the west side of the aquifer, experiences the largest drawdown due to dewatering as it occurs within a comparatively thin layer of unconsolidated sediments (~16 m) resulting in a much lower

transmissivity (hydraulic conductivity multiplied by thickness of the unit) than the other boreholes. Specific yield may also have had an effect. This indicates the importance of establishing the depth to bedrock in an area that is to be dewatered with a good degree of accuracy to determine the most susceptible areas.

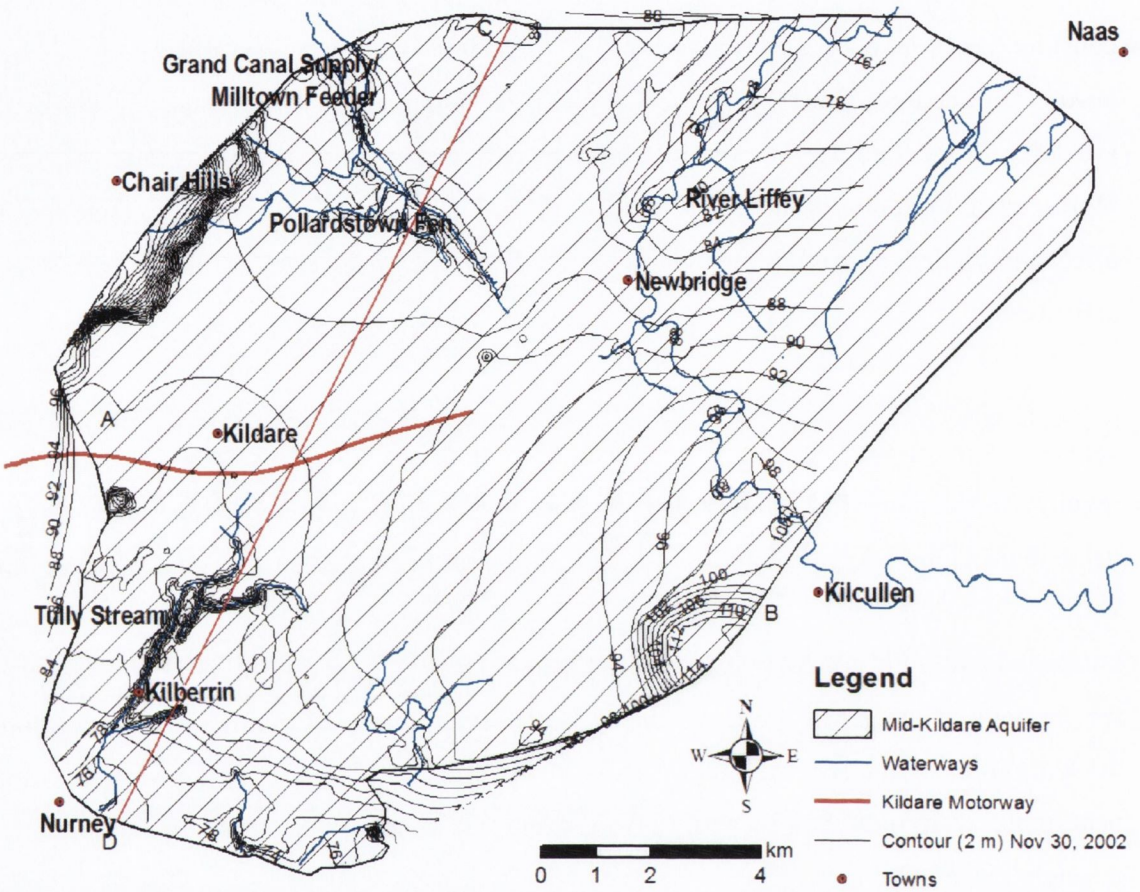


Figure 7.5: Modelled groundwater contours (2 m intervals) from November 30, 2002 showing the contours around the bypass, Pollardstown Fen, and Tully Stream.

The groundwater levels observed in the Mid-Kildare Aquifer are sensitive to recharge and so the averaged monthly recharge data were used rather than a recharge averaged over a number of years. This makes it difficult to predict the groundwater levels of the Mid-Kildare Aquifer into the future.

The fluxes out of the wells during dewatering were plotted over time and compared to the measured flows from dewatering (Farrell and Devine, 2006) (Figure 7.5). The flows out of the aquifer in the model are similar to those recorded during dewatering (see Section 6.4). The range in measured flows over short periods of time can be attributed to variations due to rainfall. Towards the end of dewatering, when the excavation progressed to a more permeable area the increase in modelled flows correlated with the increase in the

measured flows. The total amount of water extracted during dewatering in the model was $16.2x10^6$ m^3 which is similar to that estimated by Farrell and Devine (2006) ($14.5 x10^6$ m^3). The anomalous drop in modelled flow rate around the end of October, 2002, may be the result of the dewatering at the Tully Bridge being completed so there was less dewatering required once the Tully Bridge pump had been shut off in the model. The measured flow rate also shows this drop although not as pronounced. This drop in flow rate also comes after three months where no recharge was applied to the model. This may have lowered the groundwater levels just enough to be below the specified head constraint which would cause other wells to become made inactive, thereby further reducing the flow rate in the model.

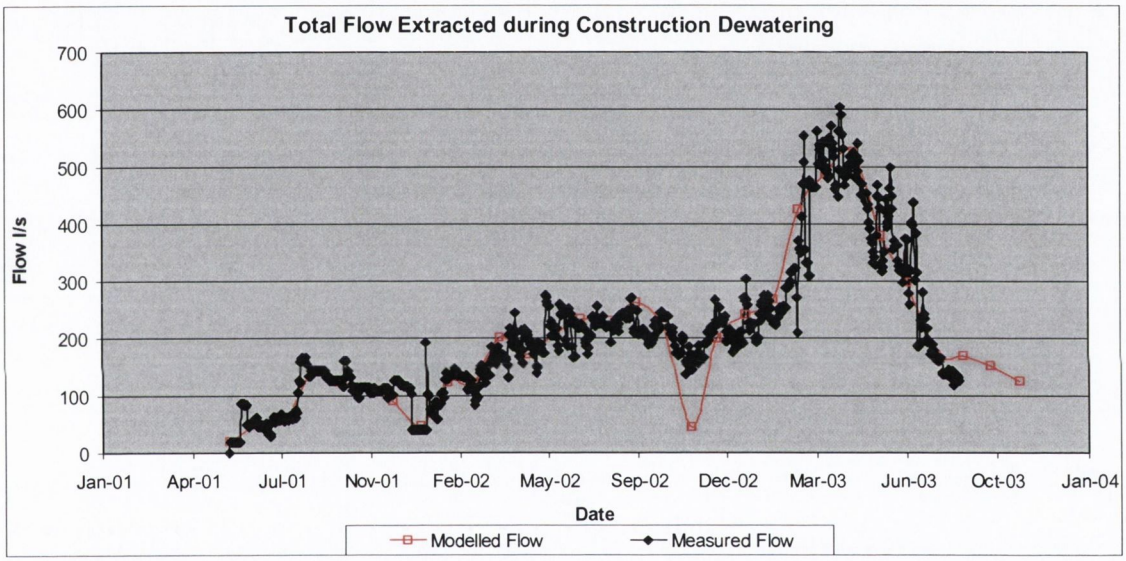


Figure 7.6: Total flows measured and modelled during construction dewatering (modified from Farrell and Devine, 2006).

When the modelled groundwater heads were compared with those measured in the Mid-Kildare Aquifer before, during and after dewatering, the monitoring boreholes had very similar heads and the same groundwater response to recharge and dewatering. This means that the model can be used to determine the effect of dewatering and recharge on the groundwater heads.

The modelled baseflow into the River Liffey was found to be similar with dewatering and without dewatering. However, the modelled baseflow into the Pollardstown Fen and Tully Stream were found to be reduced by up to 32 l/s and 57 l/s, respectively with dewatering. The model shows the importance of recharge in maintaining groundwater

levels in the Mid-Kildare Aquifer. The aquifer is sensitive to recharge, thus dry years can cause a significant lowering of the groundwater table.

The hydraulic conductivities in Table 7.3 are higher than the estimated hydraulic conductivity values from the pumping tests ($2x10^{-5}$ m/s to $3x10^{-4}$ m/s) and from the dewatering data ($3x10^{-4}$ m/s). The modelled data from Run #T7 were analysed using the modified Thiem equation (Eq. 4-1) in the same manner as the measured drawdown data in Section 4.4. This was conducted in an effort to explain this discrepancy, given that the observed and modelled groundwater levels and dewatered flows out of the excavation agreed well. The drawdown at Tully was analysed from the modelled output from August 31, 2001. The distance and drawdown data were analysed for two directions (towards the west and east) and determined that the hydraulic conductivity was between $6x10^{-4}$ and $7x10^{-4}$ m/s (Table 7-4, Figures 7.7 and 7.8).

Table 7-3: Summary of hydraulic conductivity values used in Thiem model near the Kildare Town Bypass.

LOCATION	HORIZONTAL HYDRAULIC CONDUCTIVITY	VERTICAL HYDRAULIC CONDUCTIVITY
Ch 69+00 and 90+00 (Layer 1)	$1x10^{-5}$ m/s	$1x10^{-6}$ m/s
Ch 90+00 to 104+00 (Layer 1)	$2x10^{-3}$ m/s	$2x10^{-4}$ m/s
Ch 95+00 (Layer 1)	$8x10^{-4}$ m/s	$8x10^{-5}$ m/s
All areas except Ch 80+00 (Layer 2)	$2x10^{-3}$ m/s	$2x10^{-4}$ m/s
Ch 80+00 (Layer 2)	$1x10^{-3}$ m/s	$1x10^{-4}$ m/s

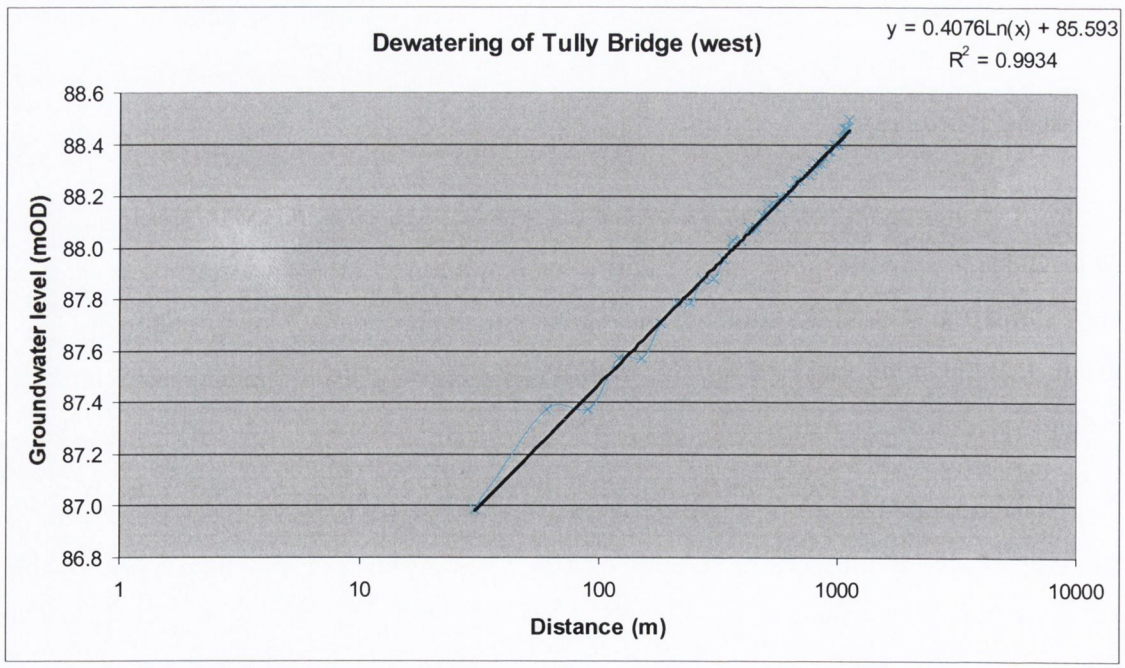


Figure 7.7: Distance-drawdown curve for the modelled output west of Tully Bridge.

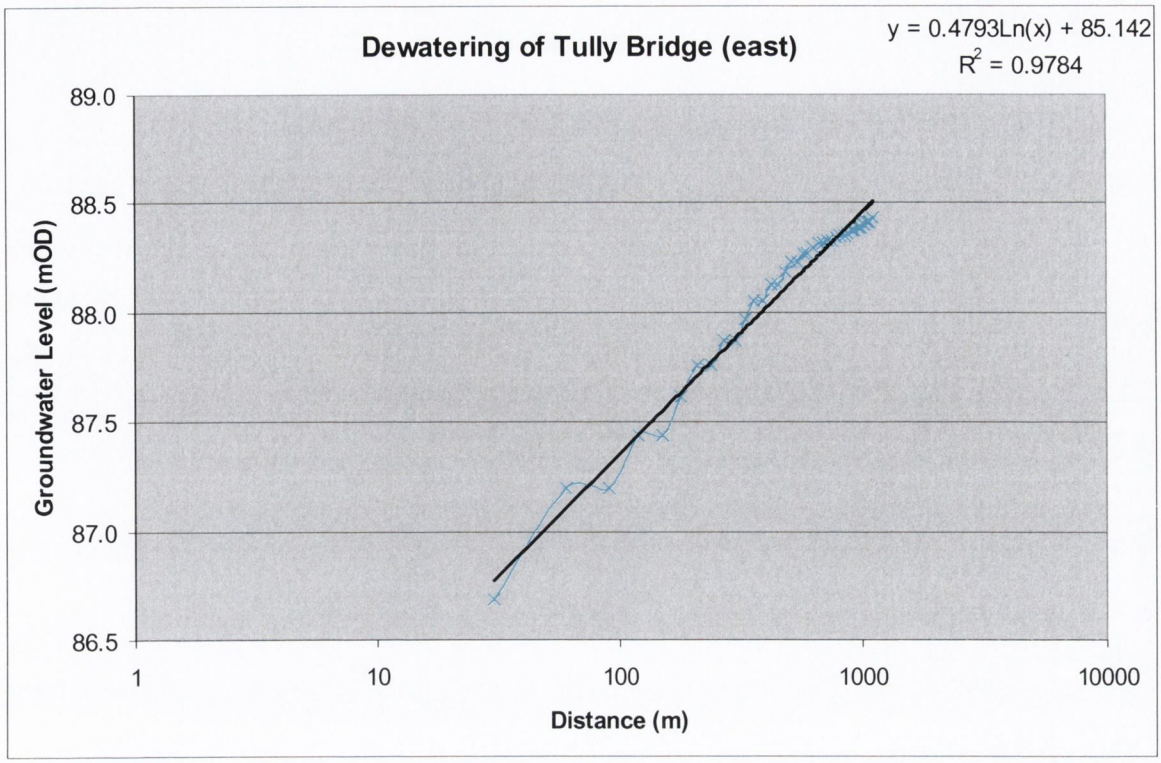


Figure 7.8: Distance-drawdown curve for the modelled output east of Tully Bridge.

Table 7-4: Results from analysis of modelled drawdowns around Tully Bridge.

	TULLY (WEST)	TULLY (EAST)
$(s_2-s_1)/\ln(r_2/r_1)$ (slope of the line)	0.4076	0.4793
$\ln(r_2/r_1)/(s_2-s_1)$ (inverse of slope)	2.453	2.086
Q (l/s)	56	56
$T(m^2/s) = \frac{Q}{2\pi}\frac{\ln\left(r_2/r_1\right)}{(s_2-s_1)}$	5.60×10^{-2}	5.60×10^{-2}
D (m) (thickness of saturated sediments)	33	33
K (m/s) = T/D	6.63×10^{-4}	5.81×10^{-4}

This analysis shows the effect of using the Thiem method which assumes a steady-state isotropic homogeneous soil on one that is in an unsteady-state, anisotropic and heterogeneous. As most soils are not perfectly in steady-state, homogeneous or isotropic this probably occurs in most cases where the Thiem equation is applied to analyse pump tests or dewatering. Therefore, if anisotropy is being taken into account in a model it may be necessary to use a higher horizontal hydraulic conductivity than what was obtained from a pump test analysis if that analysis assumes a steady-state, homogeneous, isotropic soil.

7.5 Comparison of Modelled Results with the KAM Model

The results of the KAM and KMC models are compared below. As many of the initial assumptions differ between the KAM and KMC models, it is very difficult to attribute any of the differences or similarities in the modelled output to the modelling method (finite- difference vs. finite-element) or to the initial assumptions. The KAM model used in these comparisons is from the report "Kildare Aquifer Model Review for Kildare County Council - April 2004" (White Young Green, 2004). The modifications in this report were made to run Kild89 and 16 scenarios were considered.

7.5.1 Dewatering Discharges

The KAM model overestimated discharge volumes typically by 20-60% from June 2001 to March 2003 and from March 2003 to July 2003 the model underestimated dewatering discharges typically by 85-120% (White Young Green, 2004). Figure 7.6 shows that the flows in the KMC model correlate very well with the measured flows. As the KAM model remains unpublished, no data were available to represent the KAM modelled flows for direct comparison.

7.5.2 Dewatering Groundwater Levels

The KAM model consistently overestimated drawdown near the excavation from the onset of dewatering (White Young Green, 2004). At MB26 the KAM model predicted a drawdown of 6 m when the measured drawdown was 2 m. The modelled and measured drawdowns in the monitoring boreholes along the length of the bypass in the KMC were well correlated (Figures 6.47, 6.48 and 6.49).

7.5.3 Regional Groundwater Levels

The modelled and measured results in the regional monitoring boreholes in the KAM model, in general, correlate well with the maximum difference observed in MB28 of 2.5 m. However, the majority of the boreholes had a maximum difference of less than 1 m (White Young Green, 2004). The maximum difference between the modelled and measured groundwater levels in the KMC model is approximately 1.8 m (MB28) (Figures 6.42, 6.43, 6.44, 6.45 and 6.46). The rest of the regional monitoring boreholes generally show a difference between the modelled (KMC) and measured results to be less than 1 m.

7.6 CONCLUSIONS

1) The particle size distribution analyses were found to over-predict the hydraulic conductivity while the variable head tests were found to under-predict the hydraulic conductivity when compared with the pump test.
2) The results of the back-analysis of dewatering using Thiem, Darcy's Law (Cedergren, 1989), flow nets and Mansur and Kaufman (1958, Somerville, 1986) resulted is estimates of hydraulic conductivity that agreed well with the pump tests indicating that the pump tests provided reliable estimates of the hydraulic conductivity.
3) The modelled anisotropic hydraulic conductivity values in the gravel, needed to achieve groundwater levels and responses similar to those observed required hydraulic conductivities one order of magnitude higher from those obtained through the pump tests analysis. However, when the modelled data from Run #T7 was analysed using the modified Thiem equation in the same manner as in Section 4.4 a lower hydraulic conductivity was obtained.
4) Both the KAM and KMC models have a good correlation with the regional monitoring boreholes and baseflow into the rivers, streams and fens.
5) The KMC model has achieved a better correlation with the groundwater levels in the vicinity of the excavation and with the flows out of the excavation.
6) The dewatering was modelled successfully in FEFLOW as a series of wells in spite of FEFLOW not having a drain boundary condition.

CHAPTER 8

CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE WORK

8.1 CONCLUSIONS

This thesis presents the findings of a case study of dewatering a major staged 3.5 km excavation in a heterogeneous, unconsolidated aquifer, the Mid-Kildare Aquifer. The case study provides a unique opportunity to study a heterogeneous glacial aquifer due to the large volume of data collected before, during and after construction of the Kildare Town Bypass. The objectives of this thesis were to compile all the information available on the hydrogeological properties of the aquifer and on the dewatering project, to analyse this information, to compare the parameters predicted from the ground investigation with those back-analysed from the recorded aquifer response using traditional methods, and to further the understanding of the groundwater response and the effect of construction dewatering on a heterogeneous unconsolidated aquifer. These objectives were achieved through the analysis of the ground investigation tests, back-analysing the data collected during dewatering, and the development of a numerical model.

The analysis of the ground investigation tests determined that:

1) The geology of the aquifer is highly variable both with depth and laterally (see Section 3.2 and 3.3).
2) The pumping tests produced the best estimate of hydraulic conductivity of 10^{-4} m/s due to the large volume of soil tested (see Section 3.4.6).
3) Recovery tests produced hydraulic conductivity results two to four times greater than the pump tests (see Section 3.4.6.3).
4) The specific storage values calculated from the pumping tests produce reasonable estimates for a sand and gravel aquifer, however, the specific yield calculated from pumping tests produced results approximately one order of magnitude lower than what would be expected for a sand and gravel aquifer (see Section 3.4.7).
5) Particle size distribution analyses generally were found to overestimate the hydraulic conductivity and variable head tests were found to underestimate the hydraulic conductivity (see Section 7.2.2).
6) The errors in intake factor values used in the calculations for hydraulic conductivity were not great enough to account for the differences found in the hydraulic conductivity estimated in the previous rising and falling head tests (see Appendix B).

The back-analysis of the data collected during dewatering determined that:

1) The results using the Thiem, Darcy's Law (Cedergren, 1989), flow nets and Mansur and Kaufman (1958; Somerville, 1986) methods show that the estimates of hydraulic conductivity agreed well with the pumping tests indicating that they provided reliable estimates of the hydraulic conductivity (see Section 4.4).
2) The hydraulic conductivity estimated from the flows at Ch. 94+00-102+50 using the same traditional methods was 2.5 $x10^{-3}$ m/s indicating the values assigned to the gravels in the model are reasonable (see Section 7.3).

The analysis of FEFLOW as a useable software to model the Mid-Kildare Aquifer found that:

1) The comparison of FEFLOW and MODFLOW found that an unconfined heterogeneous environment such as the Mid-Kildare Aquifer could be modelled effectively using finite-element and finite-difference techniques (see Section 6.5, 7.5 and Appendix F).
2) The verification of FEFLOW by modelling the pumping tests found that the values of hydraulic conductivity derived through curve-matching methods and modelling were similar, however, the values of specific yield and specific storage were generally much lower when calculated using curve-matching techniques than in the model (see Appendix G).
3) The verification of FEFLOW by modelling seepage into an excavation which compared the modelled seepages to those calculated using the Thiem equation, found the results to be similar when the excavation penetrated more than 50% of the aquifer thickness. When the excavation penetrated less than 50% of the aquifer thickness deviations were found between the results calculated by the model and those calculated by Thiem. The deviation in the results was attributed to a shallow excavation not satisfying the assumptions of the Thiem equation (in particular that all flow is horizontal and that flow is not in steady-state) (see Appendix H).

The steady-state numerical model was used to:

1) Confirm the validity of the conceptual model by showing that the boundary conditions produced reasonable groundwater flow patterns and that the

flows/seepages into rivers/streams/fen are similar to estimated baseflow (see Section 6.2).

2) Show that the modelled response to variations in recharge is similar to those measured in the Mid-Kildare Aquifer (see Section 6.2.2).
3) Show that the model could be calibrated to match the observed groundwater response and baseflow by altering the hydraulic conductivity of the gravels and tills (see Section 6.2)
4) Establish that in order to obtain a correlation with the groundwater levels (particularly in MB28) the bedrock surface had to be assumed to be permeable (see Section 6.2).

The transient-state numerical model was used to:

1) Demonstrate that raising the hydraulic conductivity on the lower layer (gravel) of the model lowers the groundwater table (see Section 6.3).
2) Demonstrate that lowering the hydraulic conductivity on the upper layer (varied sediments) of the model causes larger variations in the groundwater response to seasonal fluctuations in groundwater levels (see Section 6.3).
3) Demonstrate that average daily recharge values for each month are necessary to adequately represent seasonal and annual variations in recharge and groundwater response and reflect the flows and seepages out of the aquifer. These recharge values may be on the low end of estimates for the aquifer since they assume that evapotranspiration occurs in the winter as well as in the summer (see Section 6.3.1).
4) Show that a by using the Quaternary geology map produced by Glanville (2000) for the upper layer, the model produces a better correlation with observed groundwater levels than by assuming a homogeneous upper layer (see Section 6.3.2).
5) Establish through a sensitivity analysis of specific yield and specific storage that the model is not very sensitive to changes in specific storage and specific yield. An increase in the specific yield was found to cause slightly less seasonal variation in the groundwater levels (i.e. a reduction in the amplitude of the hydrographs). No value of specific yield, 0.13 or 0.2, provided a better match over the other (see Section 6.3.3).
6) Establish that the numerical instability which caused spikes in the total fluxes was due to the presence of very thin layers at some of the model margins is a limitation

in the transient-state model. However, this limitation has been shown to not affect the modelled groundwater levels or the discharges from the aquifer into the rivers and streams (Section 6.3).

7) Establish that the modelled flows and groundwater levels at the excavation are similar to what was observed on site (see Section 6.4 and 7.4)
8) Show that if anisotropy is used in a numerical model then the horizontal hydraulic conductivity may have to be higher than that estimated from pumping tests if they assume a homogeneous, isotropic aquifer (see Section 7.4).
9) Show that dewatering of the excavation was modelled successfully in FEFLOW as a series of wells in spite of FEFLOW not having a drain boundary condition (see Section 7.4 and 7.5).

8.2 RECOMMENDATIONS FOR FURTHER WORK

1) Extend the numerical model to consider the effect of the unsaturated zone on dewatering.
2) Assess the effect of anisotropy through numerical modelling and field testing.
3) Assess the hydraulic conductivity of the bedrock underlying the Mid-Kildare Aquifer, particularly the Rickardstown and Boston Hill Formations which may have significant secondary hydraulic conductivity.
4) Better constrain the numerical model using geophysical surveys to obtain bedrock elevations, water table elevation, and identify geological units and layering.
5) Evaluate the effect of runoff in more detail by creating recharge zones that assume varying amounts of runoff which correlate to the surface Quaternary geology and examining how it varies in time and space.

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APPENDICES

APPENDIX A

RAINFALL, EVAPOTRANSPIRATION, SOIL MOISTURE DEFICIT, RUNOFF AND RECHARGE DATA

Table A-1: Data was provided by Brown (2007) from work with White Young Green using the FAO Penman-Monteith method of analysis. These recharge calculations are based on a readily available water (RAW) of 74 mm and a total available water (TAW) of 127 mm. These recharge data incorporate a 4 week delay from rainfall to recharge (i.e. the rainfall of January 1 is used to calculate recharge on February 1). Rainfall data was collected at Osberstown up to 2001 and then at Naas CBS.

			WITHOUT RUNOFF				WITH RUNOFF				
	Daily Rainfall Osberstown & Naas	Daily PE Casement	Stress factor	AE	Soil Moisture Deficit	**Recharge 100% ER**	Pot. Runoff IF P<5 RO=0	Runoff 1 IF 5<P<20 RO=0.2*P	Runoff 2 IF P>20 RO=0.3*P	Runoff	Recharge
	mm	mm		mm	mm	**mm**	mm	mm	mm	mm	mm
01/01/1997	0.70	0.71	1.0000	0.71	4.57	**0.00**	0.00	0.00	0.00	0.00	0.00
02/01/1997	4.00	0.19	1.0000	0.19	0.75	**0.00**	0.00	0.00	0.00	0.00	0.00
03/01/1997	3.40	0.32	1.0000	0.32	0.00	**2.33**	0.00	0.00	0.00	0.00	2.33
04/01/1997	3.50	0.63	1.0000	0.63	0.00	**2.87**	0.00	0.00	0.00	0.00	2.87
05/01/1997	0.00	0.89	1.0000	0.89	0.89	**0.00**	0.00	0.00	0.00	0.00	0.00
06/01/1997	0.00	0.59	1.0000	0.59	1.47	**0.00**	0.00	0.00	0.00	0.00	0.00
07/01/1997	0.00	0.71	1.0000	0.71	2.18	**0.00**	0.00	0.00	0.00	0.00	0.00
08/01/1997	0.00	0.56	1.0000	0.56	2.74	**0.00**	0.00	0.00	0.00	0.00	0.00
09/01/1997	0.00	0.76	1.0000	0.76	3.51	**0.00**	0.00	0.00	0.00	0.00	0.00
10/01/1997	1.50	0.81	1.0000	0.81	2.81	**0.00**	0.00	0.00	0.00	0.00	0.00
11/01/1997	0.00	0.75	1.0000	0.75	3.56	**0.00**	0.00	0.00	0.00	0.00	0.00
12/01/1997	0.00	0.89	1.0000	0.89	4.45	**0.00**	0.00	0.00	0.00	0.00	0.00
13/01/1997	0.00	0.59	1.0000	0.59	5.03	**0.00**	0.00	0.00	0.00	0.00	0.00
14/01/1997	0.00	0.34	1.0000	0.34	5.38	**0.00**	0.00	0.00	0.00	0.00	0.00
15/01/1997	0.00	0.23	1.0000	0.23	5.61	**0.00**	0.00	0.00	0.00	0.00	0.00
16/01/1997	2.00	0.53	1.0000	0.53	4.13	**0.00**	0.00	0.00	0.00	0.00	0.00
17/01/1997	0.30	0.51	1.0000	0.51	4.35	**0.00**	0.00	0.00	0.00	0.00	0.00
18/01/1997	0.00	0.65	1.0000	0.65	5.00	**0.00**	0.00	0.00	0.00	0.00	0.00
19/01/1997	0.00	0.39	1.0000	0.39	5.39	**0.00**	0.00	0.00	0.00	0.00	0.00
20/01/1997	0.00	0.16	1.0000	0.16	5.55	**0.00**	0.00	0.00	0.00	0.00	0.00
21/01/1997	0.00	0.30	1.0000	0.30	5.85	**0.00**	0.00	0.00	0.00	0.00	0.00
22/01/1997	0.00	0.34	1.0000	0.34	6.19	**0.00**	0.00	0.00	0.00	0.00	0.00
23/01/1997	0.00	0.26	1.0000	0.26	6.45	**0.00**	0.00	0.00	0.00	0.00	0.00
24/01/1997	1.60	0.45	1.0000	0.45	5.30	**0.00**	0.00	0.00	0.00	0.00	0.00
25/01/1997	0.00	0.23	1.0000	0.23	5.52	**0.00**	0.00	0.00	0.00	0.00	0.00
26/01/1997	0.20	0.27	1.0000	0.27	5.59	**0.00**	0.00	0.00	0.00	0.00	0.00
27/01/1997	0.00	0.27	1.0000	0.27	5.86	**0.00**	0.00	0.00	0.00	0.00	0.00
28/01/1997	0.00	0.18	1.0000	0.18	6.05	**0.00**	0.00	0.00	0.00	0.00	0.00
29/01/1997	0.00	0.19	1.0000	0.19	6.24	**0.00**	0.00	0.00	0.00	0.00	0.00
30/01/1997	0.00	0.68	1.0000	0.68	6.92	**0.00**	0.00	0.00	0.00	0.00	0.00
31/01/1997	2.10	0.69	1.0000	0.69	5.50	**0.00**	0.00	0.00	0.00	0.00	0.00
01/02/1997	0.70	0.53	1.0000	0.53	5.33	**0.00**	0.00	0.00	0.00	0.00	0.00
02/02/1997	0.00	0.43	1.0000	0.43	5.76	**0.00**	0.00	0.00	0.00	0.00	0.00
03/02/1997	12.50	0.47	1.0000	0.47	0.00	**6.27**	7.50	1.50	0.00	1.50	4.77
04/02/1997	0.00	0.35	1.0000	0.35	0.35	**0.00**	0.00	0.00	0.00	0.00	0.00
05/02/1997	0.00	0.51	1.0000	0.51	0.86	**0.00**	0.00	0.00	0.00	0.00	0.00
06/02/1997	3.70	1.06	1.0000	1.06	0.00	**1.78**	0.00	0.00	0.00	0.00	1.78
07/02/1997	0.00	0.57	1.0000	0.57	0.57	**0.00**	0.00	0.00	0.00	0.00	0.00
08/02/1997	2.80	1.13	1.0000	1.13	0.00	**1.11**	0.00	0.00	0.00	0.00	1.11
09/02/1997	3.90	0.61	1.0000	0.61	0.00	**3.29**	0.00	0.00	0.00	0.00	3.29
10/02/1997	1.20	0.92	1.0000	0.92	0.00	**0.28**	0.00	0.00	0.00	0.00	0.28
11/02/1997	4.00	0.63	1.0000	0.63	0.00	**3.37**	0.00	0.00	0.00	0.00	3.37
12/02/1997	2.60	0.70	1.0000	0.70	0.00	**1.90**	0.00	0.00	0.00	0.00	1.90
13/02/1997	2.00	0.77	1.0000	0.77	0.00	**1.23**	0.00	0.00	0.00	0.00	1.23
14/02/1997	0.00	0.55	1.0000	0.55	0.55	**0.00**	0.00	0.00	0.00	0.00	0.00
15/02/1997	4.90	0.82	1.0000	0.82	0.00	**3.53**	0.00	0.00	0.00	0.00	3.53
16/02/1997	3.10	1.06	1.0000	1.06	0.00	**2.04**	0.00	0.00	0.00	0.00	2.04
17/02/1997	7.50	0.74	1.0000	0.74	0.00	**6.76**	2.50	0.50	0.00	0.50	6.26
18/02/1997	10.00	0.86	1.0000	0.86	0.00	**9.14**	5.00	1.00	0.00	1.00	8.14
19/02/1997	8.60	0.97	1.0000	0.97	0.00	**7.64**	3.60	0.72	0.00	0.72	6.92
20/02/1997	4.00	1.05	1.0000	1.05	0.00	**2.95**	0.00	0.00	0.00	0.00	2.95
21/02/1997	1.70	1.26	1.0000	1.26	0.00	**0.44**	0.00	0.00	0.00	0.00	0.44
22/02/1997	2.80	1.32	1.0000	1.32	0.00	**1.48**	0.00	0.00	0.00	0.00	1.48
23/02/1997	3.30	1.09	1.0000	1.09	0.00	**2.22**	0.00	0.00	0.00	0.00	2.22
24/02/1997	2.60	1.31	1.0000	1.31	0.00	**1.29**	0.00	0.00	0.00	0.00	1.29
25/02/1997	8.00	1.22	1.0000	1.22	0.00	**6.78**	3.00	0.60	0.00	0.60	6.18
26/02/1997	2.10	1.34	1.0000	1.34	0.00	**0.76**	0.00	0.00	0.00	0.00	0.76
27/02/1997	2.20	1.01	1.0000	1.01	0.00	**1.19**	0.00	0.00	0.00	0.00	1.19
28/02/1997	0.20	0.99	1.0000	0.99	0.79	**0.00**	0.00	0.00	0.00	0.00	0.00
01/03/1997	5.10	1.16	1.0000	1.16	0.00	**3.14**	0.10	0.02	0.00	0.02	3.12
02/03/1997	0.20	1.12	1.0000	1.12	0.92	**0.00**	0.00	0.00	0.00	0.00	0.00
03/03/1997	0.00	0.97	1.0000	0.97	1.90	**0.00**	0.00	0.00	0.00	0.00	0.00
04/03/1997	0.00	0.86	1.0000	0.86	2.76	**0.00**	0.00	0.00	0.00	0.00	0.00

Date	Rainfall	PE	S.F.	AE	SMD	**Recharge**	Pot. Runoff	Runoff 1	Runoff 2	Runoff	Recharge
05/03/1997	2.30	0.67	1.0000	0.67	1.12	**0.00**	0.00	0.00	0.00	0.00	0.00
06/03/1997	0.00	0.88	1.0000	0.88	2.01	**0.00**	0.00	0.00	0.00	0.00	0.00
07/03/1997	1.10	0.71	1.0000	0.71	1.62	**0.00**	0.00	0.00	0.00	0.00	0.00
08/03/1997	0.00	1.00	1.0000	1.00	2.62	**0.00**	0.00	0.00	0.00	0.00	0.00
09/03/1997	0.10	0.71	1.0000	0.71	3.23	**0.00**	0.00	0.00	0.00	0.00	0.00
10/03/1997	0.00	1.18	1.0000	1.18	4.41	**0.00**	0.00	0.00	0.00	0.00	0.00
11/03/1997	0.20	1.07	1.0000	1.07	5.28	**0.00**	0.00	0.00	0.00	0.00	0.00
12/03/1997	0.00	1.37	1.0000	1.37	6.65	**0.00**	0.00	0.00	0.00	0.00	0.00
13/03/1997	1.20	1.15	1.0000	1.15	6.60	**0.00**	0.00	0.00	0.00	0.00	0.00
14/03/1997	0.00	1.15	1.0000	1.15	7.75	**0.00**	0.00	0.00	0.00	0.00	0.00
15/03/1997	0.00	0.99	1.0000	0.99	8.74	**0.00**	0.00	0.00	0.00	0.00	0.00
16/03/1997	0.00	1.18	1.0000	1.18	9.93	**0.00**	0.00	0.00	0.00	0.00	0.00
17/03/1997	0.50	0.71	1.0000	0.71	10.14	**0.00**	0.00	0.00	0.00	0.00	0.00
18/03/1997	0.00	1.58	1.0000	1.58	11.72	**0.00**	0.00	0.00	0.00	0.00	0.00
19/03/1997	0.00	1.53	1.0000	1.53	13.25	**0.00**	0.00	0.00	0.00	0.00	0.00
20/03/1997	0.00	0.87	1.0000	0.87	14.11	**0.00**	0.00	0.00	0.00	0.00	0.00
21/03/1997	0.00	1.30	1.0000	1.30	15.41	**0.00**	0.00	0.00	0.00	0.00	0.00
22/03/1997	1.00	1.08	1.0000	1.08	15.49	**0.00**	0.00	0.00	0.00	0.00	0.00
23/03/1997	1.60	1.16	1.0000	1.16	15.05	**0.00**	0.00	0.00	0.00	0.00	0.00
24/03/1997	0.80	1.65	1.0000	1.65	15.90	**0.00**	0.00	0.00	0.00	0.00	0.00
25/03/1997	0.50	1.16	1.0000	1.16	16.55	**0.00**	0.00	0.00	0.00	0.00	0.00
26/03/1997	0.20	1.88	1.0000	1.88	18.24	**0.00**	0.00	0.00	0.00	0.00	0.00
27/03/1997	3.00	0.87	1.0000	0.87	16.10	**0.00**	0.00	0.00	0.00	0.00	0.00
28/03/1997	0.00	1.59	1.0000	1.59	17.69	**0.00**	0.00	0.00	0.00	0.00	0.00
29/03/1997	0.00	1.24	1.0000	1.24	18.93	**0.00**	0.00	0.00	0.00	0.00	0.00
30/03/1997	0.00	1.70	1.0000	1.70	20.63	**0.00**	0.00	0.00	0.00	0.00	0.00
31/03/1997	0.00	2.21	1.0000	2.21	22.83	**0.00**	0.00	0.00	0.00	0.00	0.00
01/04/1997	0.00	1.56	1.0000	1.56	24.39	**0.00**	0.00	0.00	0.00	0.00	0.00
02/04/1997	0.40	1.50	1.0000	1.50	25.49	**0.00**	0.00	0.00	0.00	0.00	0.00
03/04/1997	0.00	1.60	1.0000	1.60	27.09	**0.00**	0.00	0.00	0.00	0.00	0.00
04/04/1997	0.00	1.18	1.0000	1.18	28.27	**0.00**	0.00	0.00	0.00	0.00	0.00
05/04/1997	0.50	1.66	1.0000	1.66	29.44	**0.00**	0.00	0.00	0.00	0.00	0.00
06/04/1997	0.00	1.09	1.0000	1.09	30.53	**0.00**	0.00	0.00	0.00	0.00	0.00
07/04/1997	0.00	1.85	1.0000	1.85	32.38	**0.00**	0.00	0.00	0.00	0.00	0.00
08/04/1997	0.00	2.07	1.0000	2.07	34.44	**0.00**	0.00	0.00	0.00	0.00	0.00
09/04/1997	0.00	2.05	1.0000	2.05	36.50	**0.00**	0.00	0.00	0.00	0.00	0.00
10/04/1997	0.00	2.27	1.0000	2.27	38.77	**0.00**	0.00	0.00	0.00	0.00	0.00
11/04/1997	0.00	1.60	1.0000	1.60	40.36	**0.00**	0.00	0.00	0.00	0.00	0.00
12/04/1997	0.00	2.30	1.0000	2.30	42.67	**0.00**	0.00	0.00	0.00	0.00	0.00
13/04/1997	0.00	1.87	1.0000	1.87	44.53	**0.00**	0.00	0.00	0.00	0.00	0.00
14/04/1997	0.00	1.55	1.0000	1.55	46.08	**0.00**	0.00	0.00	0.00	0.00	0.00
15/04/1997	0.00	1.71	1.0000	1.71	47.78	**0.00**	0.00	0.00	0.00	0.00	0.00
16/04/1997	0.00	2.36	1.0000	2.36	50.14	**0.00**	0.00	0.00	0.00	0.00	0.00
17/04/1997	0.00	2.09	1.0000	2.09	52.23	**0.00**	0.00	0.00	0.00	0.00	0.00
18/04/1997	0.00	1.27	1.0000	1.27	53.49	**0.00**	0.00	0.00	0.00	0.00	0.00
19/04/1997	0.00	1.00	1.0000	1.00	54.49	**0.00**	0.00	0.00	0.00	0.00	0.00
20/04/1997	0.00	2.40	1.0000	2.40	56.88	**0.00**	0.00	0.00	0.00	0.00	0.00
21/04/1997	0.00	1.56	1.0000	1.56	58.45	**0.00**	0.00	0.00	0.00	0.00	0.00
22/04/1997	0.00	2.21	1.0000	2.21	60.65	**0.00**	0.00	0.00	0.00	0.00	0.00
23/04/1997	0.00	2.68	1.0000	2.68	63.33	**0.00**	0.00	0.00	0.00	0.00	0.00
24/04/1997	15.70	1.59	1.0000	1.59	49.22	**0.00**	10.70	2.14	0.00	2.14	-2.14
25/04/1997	3.00	0.60	1.0000	0.60	46.82	**0.00**	0.00	0.00	0.00	0.00	0.00
26/04/1997	3.00	1.12	1.0000	1.12	44.94	**0.00**	0.00	0.00	0.00	0.00	0.00
27/04/1997	5.10	1.40	1.0000	1.40	41.24	**0.00**	0.10	0.02	0.00	0.02	-0.02
28/04/1997	2.00	1.32	1.0000	1.32	40.56	**0.00**	0.00	0.00	0.00	0.00	0.00
29/04/1997	0.00	2.28	1.0000	2.28	42.84	**0.00**	0.00	0.00	0.00	0.00	0.00
30/04/1997	0.00	2.86	1.0000	2.86	45.70	**0.00**	0.00	0.00	0.00	0.00	0.00
01/05/1997	0.00	3.19	1.0000	3.19	48.89	**0.00**	0.00	0.00	0.00	0.00	0.00
02/05/1997	0.00	3.44	1.0000	3.44	52.33	**0.00**	0.00	0.00	0.00	0.00	0.00
03/05/1997	1.00	1.97	1.0000	1.97	53.29	**0.00**	0.00	0.00	0.00	0.00	0.00
04/05/1997	9.00	2.10	1.0000	2.10	46.40	**0.00**	4.00	0.80	0.00	0.80	-0.80
05/05/1997	6.50	1.12	1.0000	1.12	41.02	**0.00**	1.50	0.30	0.00	0.30	-0.30
06/05/1997	3.30	2.15	1.0000	2.15	39.87	**0.00**	0.00	0.00	0.00	0.00	0.00
07/05/1997	1.20	1.75	1.0000	1.75	40.42	**0.00**	0.00	0.00	0.00	0.00	0.00
08/05/1997	11.10	1.56	1.0000	1.56	30.88	**0.00**	6.10	1.22	0.00	1.22	-1.22
09/05/1997	6.60	1.85	1.0000	1.85	26.13	**0.00**	1.60	0.32	0.00	0.32	-0.32
10/05/1997	8.40	1.66	1.0000	1.66	19.39	**0.00**	3.40	0.68	0.00	0.68	-0.68
11/05/1997	1.30	1.82	1.0000	1.82	19.91	**0.00**	0.00	0.00	0.00	0.00	0.00
12/05/1997	7.60	2.07	1.0000	2.07	14.38	**0.00**	2.60	0.52	0.00	0.52	-0.52
13/05/1997	1.10	2.57	1.0000	2.57	15.85	**0.00**	0.00	0.00	0.00	0.00	0.00
14/05/1997	0.00	2.19	1.0000	2.19	18.04	**0.00**	0.00	0.00	0.00	0.00	0.00
15/05/1997	0.00	3.15	1.0000	3.15	21.19	**0.00**	0.00	0.00	0.00	0.00	0.00
16/05/1997	0.00	2.72	1.0000	2.72	23.91	**0.00**	0.00	0.00	0.00	0.00	0.00
17/05/1997	6.10	2.23	1.0000	2.23	20.04	**0.00**	1.10	0.22	0.00	0.22	-0.22
18/05/1997	1.00	1.19	1.0000	1.19	20.23	**0.00**	0.00	0.00	0.00	0.00	0.00
19/05/1997	3.70	1.63	1.0000	1.63	18.15	**0.00**	0.00	0.00	0.00	0.00	0.00
20/05/1997	0.00	2.88	1.0000	2.88	21.03	**0.00**	0.00	0.00	0.00	0.00	0.00
21/05/1997	1.50	1.51	1.0000	1.51	21.04	**0.00**	0.00	0.00	0.00	0.00	0.00

Date	Rainfall	PE	S.F.	AE	SMD	**Recharge**	Pot. Runoff	Runoff 1	Runoff 2	Runoff	Recharge
22/05/1997	0.00	2.19	1.0000	2.19	23.23	**0.00**	0.00	0.00	0.00	0.00	0.00
23/05/1997	0.00	2.51	1.0000	2.51	25.75	**0.00**	0.00	0.00	0.00	0.00	0.00
24/05/1997	0.00	3.03	1.0000	3.03	28.78	**0.00**	0.00	0.00	0.00	0.00	0.00
25/05/1997	0.00	3.25	1.0000	3.25	32.03	**0.00**	0.00	0.00	0.00	0.00	0.00
26/05/1997	0.00	2.26	1.0000	2.26	34.29	**0.00**	0.00	0.00	0.00	0.00	0.00
27/05/1997	0.00	2.35	1.0000	2.35	36.64	**0.00**	0.00	0.00	0.00	0.00	0.00
28/05/1997	0.00	3.63	1.0000	3.63	40.27	**0.00**	0.00	0.00	0.00	0.00	0.00
29/05/1997	0.00	4.14	1.0000	4.14	44.41	**0.00**	0.00	0.00	0.00	0.00	0.00
30/05/1997	0.00	4.05	1.0000	4.05	48.46	**0.00**	0.00	0.00	0.00	0.00	0.00
31/05/1997	0.00	3.82	1.0000	3.82	52.28	**0.00**	0.00	0.00	0.00	0.00	0.00
01/06/1997	0.00	3.77	1.0000	3.77	56.05	**0.00**	0.00	0.00	0.00	0.00	0.00
02/06/1997	0.00	4.07	1.0000	4.07	60.12	**0.00**	0.00	0.00	0.00	0.00	0.00
03/06/1997	0.00	3.66	1.0000	3.66	63.78	**0.00**	0.00	0.00	0.00	0.00	0.00
04/06/1997	0.00	3.14	1.0000	3.14	66.92	**0.00**	0.00	0.00	0.00	0.00	0.00
05/06/1997	16.20	1.99	1.0000	1.99	52.71	**0.00**	11.20	2.24	0.00	2.24	-2.24
06/06/1997	1.80	1.93	1.0000	1.93	52.83	**0.00**	0.00	0.00	0.00	0.00	0.00
07/06/1997	3.30	2.59	1.0000	2.59	52.12	**0.00**	0.00	0.00	0.00	0.00	0.00
08/06/1997	0.50	2.42	1.0000	2.42	54.04	**0.00**	0.00	0.00	0.00	0.00	0.00
09/06/1997	1.10	2.80	1.0000	2.80	55.73	**0.00**	0.00	0.00	0.00	0.00	0.00
10/06/1997	14.50	1.10	1.0000	1.10	42.33	**0.00**	9.50	1.90	0.00	1.90	-1.90
11/06/1997	0.00	2.12	1.0000	2.12	44.45	**0.00**	0.00	0.00	0.00	0.00	0.00
12/06/1997	5.00	1.94	1.0000	1.94	41.39	**0.00**	0.00	0.00	0.00	0.00	0.00
13/06/1997	0.20	1.26	1.0000	1.26	42.45	**0.00**	0.00	0.00	0.00	0.00	0.00
14/06/1997	0.00	2.03	1.0000	2.03	44.48	**0.00**	0.00	0.00	0.00	0.00	0.00
15/06/1997	0.00	2.68	1.0000	2.68	47.16	**0.00**	0.00	0.00	0.00	0.00	0.00
16/06/1997	0.00	2.82	1.0000	2.82	49.98	**0.00**	0.00	0.00	0.00	0.00	0.00
17/06/1997	0.50	2.82	1.0000	2.82	52.29	**0.00**	0.00	0.00	0.00	0.00	0.00
18/06/1997	2.00	2.33	1.0000	2.33	52.62	**0.00**	0.00	0.00	0.00	0.00	0.00
19/06/1997	4.00	2.47	1.0000	2.47	51.09	**0.00**	0.00	0.00	0.00	0.00	0.00
20/06/1997	22.00	0.78	1.0000	0.78	29.86	**0.00**	17.00	0.00	5.10	5.10	-5.10
21/06/1997	3.60	0.92	1.0000	0.92	27.18	**0.00**	0.00	0.00	0.00	0.00	0.00
22/06/1997	0.00	2.26	1.0000	2.26	29.44	**0.00**	0.00	0.00	0.00	0.00	0.00
23/06/1997	0.00	2.30	1.0000	2.30	31.74	**0.00**	0.00	0.00	0.00	0.00	0.00
24/06/1997	11.00	2.03	1.0000	2.03	22.78	**0.00**	6.00	1.20	0.00	1.20	-1.20
25/06/1997	1.20	0.91	1.0000	0.91	22.48	**0.00**	0.00	0.00	0.00	0.00	0.00
26/06/1997	2.00	2.79	1.0000	2.79	23.27	**0.00**	0.00	0.00	0.00	0.00	0.00
27/06/1997	0.00	2.01	1.0000	2.01	25.28	**0.00**	0.00	0.00	0.00	0.00	0.00
28/06/1997	0.20	1.56	1.0000	1.56	26.64	**0.00**	0.00	0.00	0.00	0.00	0.00
29/06/1997	0.00	1.93	1.0000	1.93	28.57	**0.00**	0.00	0.00	0.00	0.00	0.00
30/06/1997	0.00	1.82	1.0000	1.82	30.39	**0.00**	0.00	0.00	0.00	0.00	0.00
01/07/1997	2.40	1.12	1.0000	1.12	29.11	**0.00**	0.00	0.00	0.00	0.00	0.00
02/07/1997	4.00	1.21	1.0000	1.21	26.32	**0.00**	0.00	0.00	0.00	0.00	0.00
03/07/1997	1.40	2.26	1.0000	2.26	27.17	**0.00**	0.00	0.00	0.00	0.00	0.00
04/07/1997	0.00	2.75	1.0000	2.75	29.92	**0.00**	0.00	0.00	0.00	0.00	0.00
05/07/1997	0.00	2.63	1.0000	2.63	32.54	**0.00**	0.00	0.00	0.00	0.00	0.00
06/07/1997	0.00	2.96	1.0000	2.96	35.50	**0.00**	0.00	0.00	0.00	0.00	0.00
07/07/1997	0.00	3.95	1.0000	3.95	39.45	**0.00**	0.00	0.00	0.00	0.00	0.00
08/07/1997	0.00	3.59	1.0000	3.59	43.04	**0.00**	0.00	0.00	0.00	0.00	0.00
09/07/1997	0.00	4.09	1.0000	4.09	47.13	**0.00**	0.00	0.00	0.00	0.00	0.00
10/07/1997	0.00	2.91	1.0000	2.91	50.05	**0.00**	0.00	0.00	0.00	0.00	0.00
11/07/1997	0.00	2.46	1.0000	2.46	52.50	**0.00**	0.00	0.00	0.00	0.00	0.00
12/07/1997	0.00	1.46	1.0000	1.46	53.96	**0.00**	0.00	0.00	0.00	0.00	0.00
13/07/1997	2.20	2.62	1.0000	2.62	54.37	**0.00**	0.00	0.00	0.00	0.00	0.00
14/07/1997	1.80	1.88	1.0000	1.88	54.45	**0.00**	0.00	0.00	0.00	0.00	0.00
15/07/1997	0.00	2.59	1.0000	2.59	57.04	**0.00**	0.00	0.00	0.00	0.00	0.00
16/07/1997	14.00	1.89	1.0000	1.89	44.92	**0.00**	9.00	1.80	0.00	1.80	-1.80
17/07/1997	0.00	1.85	1.0000	1.85	46.78	**0.00**	0.00	0.00	0.00	0.00	0.00
18/07/1997	0.00	2.17	1.0000	2.17	48.94	**0.00**	0.00	0.00	0.00	0.00	0.00
19/07/1997	0.00	3.58	1.0000	3.58	52.52	**0.00**	0.00	0.00	0.00	0.00	0.00
20/07/1997	0.00	3.10	1.0000	3.10	55.62	**0.00**	0.00	0.00	0.00	0.00	0.00
21/07/1997	0.00	3.90	1.0000	3.90	59.53	**0.00**	0.00	0.00	0.00	0.00	0.00
22/07/1997	0.50	4.10	1.0000	4.10	63.12	**0.00**	0.00	0.00	0.00	0.00	0.00
23/07/1997	3.00	2.20	1.0000	2.20	62.32	**0.00**	0.00	0.00	0.00	0.00	0.00
24/07/1997	0.20	1.96	1.0000	1.96	64.08	**0.00**	0.00	0.00	0.00	0.00	0.00
25/07/1997	2.00	2.83	1.0000	2.83	64.91	**0.00**	0.00	0.00	0.00	0.00	0.00
26/07/1997	5.80	1.88	1.0000	1.88	60.99	**0.00**	0.80	0.16	0.00	0.16	-0.16
27/07/1997	0.40	3.19	1.0000	3.19	63.78	**0.00**	0.00	0.00	0.00	0.00	0.00
28/07/1997	0.00	3.49	1.0000	3.49	67.26	**0.00**	0.00	0.00	0.00	0.00	0.00
29/07/1997	7.00	1.78	1.0000	1.78	62.04	**0.00**	2.00	0.40	0.00	0.40	-0.40
30/07/1997	1.20	2.82	1.0000	2.82	63.66	**0.00**	0.00	0.00	0.00	0.00	0.00
31/07/1997	0.00	1.80	1.0000	1.80	65.46	**0.00**	0.00	0.00	0.00	0.00	0.00
01/08/1997	0.00	2.22	1.0000	2.22	67.68	**0.00**	0.00	0.00	0.00	0.00	0.00
02/08/1997	3.00	2.42	1.0000	2.42	67.10	**0.00**	0.00	0.00	0.00	0.00	0.00
03/08/1997	8.50	1.27	1.0000	1.27	59.87	**0.00**	3.50	0.70	0.00	0.70	-0.70
04/08/1997	14.50	1.19	1.0000	1.19	46.55	**0.00**	9.50	1.90	0.00	1.90	-1.90
05/08/1997	12.20	1.12	1.0000	1.12	35.48	**0.00**	7.20	1.44	0.00	1.44	-1.44
06/08/1997	0.80	1.67	1.0000	1.67	36.34	**0.00**	0.00	0.00	0.00	0.00	0.00
07/08/1997	0.00	2.24	1.0000	2.24	38.58	**0.00**	0.00	0.00	0.00	0.00	0.00

Date	Rainfall	PE	S.F.	AE	SMD	**Recharge**	Pot. Runoff	Runoff 1	Runoff 2	Runoff	Recharge
08/08/1997	0.00	3.02	1.0000	3.02	41.60	**0.00**	0.00	0.00	0.00	0.00	0.00
09/08/1997	0.00	2.21	1.0000	2.21	43.81	**0.00**	0.00	0.00	0.00	0.00	0.00
10/08/1997	4.60	2.65	1.0000	2.65	41.86	**0.00**	0.00	0.00	0.00	0.00	0.00
11/08/1997	0.00	3.64	1.0000	3.64	45.50	**0.00**	0.00	0.00	0.00	0.00	0.00
12/08/1997	0.60	3.28	1.0000	3.28	48.18	**0.00**	0.00	0.00	0.00	0.00	0.00
13/08/1997	0.00	2.62	1.0000	2.62	50.80	**0.00**	0.00	0.00	0.00	0.00	0.00
14/08/1997	0.30	3.21	1.0000	3.21	53.71	**0.00**	0.00	0.00	0.00	0.00	0.00
15/08/1997	0.50	2.99	1.0000	2.99	56.20	**0.00**	0.00	0.00	0.00	0.00	0.00
16/08/1997	0.00	2.63	1.0000	2.63	58.83	**0.00**	0.00	0.00	0.00	0.00	0.00
17/08/1997	0.00	2.60	1.0000	2.60	61.43	**0.00**	0.00	0.00	0.00	0.00	0.00
18/08/1997	0.00	3.14	1.0000	3.14	64.57	**0.00**	0.00	0.00	0.00	0.00	0.00
19/08/1997	3.00	1.71	1.0000	1.71	63.28	**0.00**	0.00	0.00	0.00	0.00	0.00
20/08/1997	1.30	2.52	1.0000	2.52	64.51	**0.00**	0.00	0.00	0.00	0.00	0.00
21/08/1997	1.80	1.64	1.0000	1.64	64.35	**0.00**	0.00	0.00	0.00	0.00	0.00
22/08/1997	2.00	2.17	1.0000	2.17	64.51	**0.00**	0.00	0.00	0.00	0.00	0.00
23/08/1997	5.50	1.19	1.0000	1.19	60.21	**0.00**	0.50	0.10	0.00	0.10	-0.10
24/08/1997	0.00	2.13	1.0000	2.13	62.34	**0.00**	0.00	0.00	0.00	0.00	0.00
25/08/1997	0.00	3.15	1.0000	3.15	65.48	**0.00**	0.00	0.00	0.00	0.00	0.00
26/08/1997	9.60	2.22	1.0000	2.22	58.11	**0.00**	4.60	0.92	0.00	0.92	-0.92
27/08/1997	0.80	3.08	1.0000	3.08	60.39	**0.00**	0.00	0.00	0.00	0.00	0.00
28/08/1997	5.00	2.58	1.0000	2.58	57.96	**0.00**	0.00	0.00	0.00	0.00	0.00
29/08/1997	0.00	2.88	1.0000	2.88	60.85	**0.00**	0.00	0.00	0.00	0.00	0.00
30/08/1997	8.90	2.10	1.0000	2.10	54.04	**0.00**	3.90	0.78	0.00	0.78	-0.78
31/08/1997	9.60	1.11	1.0000	1.11	45.55	**0.00**	4.60	0.92	0.00	0.92	-0.92
01/09/1997	0.70	2.38	1.0000	2.38	47.23	**0.00**	0.00	0.00	0.00	0.00	0.00
02/09/1997	2.00	2.15	1.0000	2.15	47.38	**0.00**	0.00	0.00	0.00	0.00	0.00
03/09/1997	3.00	2.29	1.0000	2.29	46.67	**0.00**	0.00	0.00	0.00	0.00	0.00
04/09/1997	0.00	2.65	1.0000	2.65	49.32	**0.00**	0.00	0.00	0.00	0.00	0.00
05/09/1997	0.00	2.14	1.0000	2.14	51.46	**0.00**	0.00	0.00	0.00	0.00	0.00
06/09/1997	0.30	0.86	1.0000	0.86	52.02	**0.00**	0.00	0.00	0.00	0.00	0.00
07/09/1997	0.00	2.32	1.0000	2.32	54.33	**0.00**	0.00	0.00	0.00	0.00	0.00
08/09/1997	0.00	1.99	1.0000	1.99	56.32	**0.00**	0.00	0.00	0.00	0.00	0.00
09/09/1997	0.00	2.10	1.0000	2.10	58.42	**0.00**	0.00	0.00	0.00	0.00	0.00
10/09/1997	0.40	1.98	1.0000	1.98	60.00	**0.00**	0.00	0.00	0.00	0.00	0.00
11/09/1997	1.80	0.88	1.0000	0.88	59.07	**0.00**	0.00	0.00	0.00	0.00	0.00
12/09/1997	0.50	1.58	1.0000	1.58	60.15	**0.00**	0.00	0.00	0.00	0.00	0.00
13/09/1997	0.50	1.73	1.0000	1.73	61.38	**0.00**	0.00	0.00	0.00	0.00	0.00
14/09/1997	0.00	2.27	1.0000	2.27	63.65	**0.00**	0.00	0.00	0.00	0.00	0.00
15/09/1997	8.90	1.49	1.0000	1.49	56.25	**0.00**	3.90	0.78	0.00	0.78	-0.78
16/09/1997	8.80	0.80	1.0000	0.80	48.24	**0.00**	3.80	0.76	0.00	0.76	-0.76
17/09/1997	0.00	1.40	1.0000	1.40	49.64	**0.00**	0.00	0.00	0.00	0.00	0.00
18/09/1997	0.00	1.76	1.0000	1.76	51.40	**0.00**	0.00	0.00	0.00	0.00	0.00
19/09/1997	0.50	0.66	1.0000	0.66	51.55	**0.00**	0.00	0.00	0.00	0.00	0.00
20/09/1997	0.30	1.34	1.0000	1.34	52.59	**0.00**	0.00	0.00	0.00	0.00	0.00
21/09/1997	0.00	1.35	1.0000	1.35	53.94	**0.00**	0.00	0.00	0.00	0.00	0.00
22/09/1997	0.00	1.58	1.0000	1.58	55.52	**0.00**	0.00	0.00	0.00	0.00	0.00
23/09/1997	0.00	1.67	1.0000	1.67	57.18	**0.00**	0.00	0.00	0.00	0.00	0.00
24/09/1997	0.00	2.06	1.0000	2.06	59.24	**0.00**	0.00	0.00	0.00	0.00	0.00
25/09/1997	0.00	1.20	1.0000	1.20	60.44	**0.00**	0.00	0.00	0.00	0.00	0.00
26/09/1997	0.00	0.90	1.0000	0.90	61.35	**0.00**	0.00	0.00	0.00	0.00	0.00
27/09/1997	0.00	1.13	1.0000	1.13	62.48	**0.00**	0.00	0.00	0.00	0.00	0.00
28/09/1997	0.00	1.59	1.0000	1.59	64.06	**0.00**	0.00	0.00	0.00	0.00	0.00
29/09/1997	1.00	0.99	1.0000	0.99	64.05	**0.00**	0.00	0.00	0.00	0.00	0.00
30/09/1997	2.80	0.87	1.0000	0.87	62.13	**0.00**	0.00	0.00	0.00	0.00	0.00
01/10/1997	0.00	1.19	1.0000	1.19	63.32	**0.00**	0.00	0.00	0.00	0.00	0.00
02/10/1997	0.00	1.01	1.0000	1.01	64.32	**0.00**	0.00	0.00	0.00	0.00	0.00
03/10/1997	0.20	0.89	1.0000	0.89	65.01	**0.00**	0.00	0.00	0.00	0.00	0.00
04/10/1997	0.50	0.96	1.0000	0.96	65.48	**0.00**	0.00	0.00	0.00	0.00	0.00
05/10/1997	6.00	1.35	1.0000	1.35	60.82	**0.00**	1.00	0.20	0.00	0.20	-0.20
06/10/1997	0.00	1.07	1.0000	1.07	61.89	**0.00**	0.00	0.00	0.00	0.00	0.00
07/10/1997	2.80	1.44	1.0000	1.44	60.53	**0.00**	0.00	0.00	0.00	0.00	0.00
08/10/1997	18.00	1.05	1.0000	1.05	43.58	**0.00**	13.00	2.60	0.00	2.60	-2.60
09/10/1997	5.20	0.89	1.0000	0.89	39.27	**0.00**	0.20	0.04	0.00	0.04	-0.04
10/10/1997	7.10	1.40	1.0000	1.40	33.57	**0.00**	2.10	0.42	0.00	0.42	-0.42
11/10/1997	27.80	0.41	1.0000	0.41	6.19	**0.00**	22.80	0.00	6.84	6.84	-6.84
12/10/1997	0.30	0.84	1.0000	0.84	6.73	**0.00**	0.00	0.00	0.00	0.00	0.00
13/10/1997	0.00	0.86	1.0000	0.86	7.59	**0.00**	0.00	0.00	0.00	0.00	0.00
14/10/1997	3.50	0.42	1.0000	0.42	4.51	**0.00**	0.00	0.00	0.00	0.00	0.00
15/10/1997	5.20	0.66	1.0000	0.66	0.00	**0.03**	0.20	0.04	0.00	0.04	-0.01
16/10/1997	13.80	1.32	1.0000	1.32	0.00	**12.48**	8.80	1.76	0.00	1.76	10.72
17/10/1997	1.00	1.22	1.0000	1.22	0.22	**0.00**	0.00	0.00	0.00	0.00	0.00
18/10/1997	0.00	0.84	1.0000	0.84	1.06	**0.00**	0.00	0.00	0.00	0.00	0.00
19/10/1997	0.40	0.39	1.0000	0.39	1.04	**0.00**	0.00	0.00	0.00	0.00	0.00
20/10/1997	0.00	1.02	1.0000	1.02	2.06	**0.00**	0.00	0.00	0.00	0.00	0.00
21/10/1997	0.00	1.25	1.0000	1.25	3.31	**0.00**	0.00	0.00	0.00	0.00	0.00
22/10/1997	0.00	0.89	1.0000	0.89	4.20	**0.00**	0.00	0.00	0.00	0.00	0.00
23/10/1997	0.00	0.85	1.0000	0.85	5.06	**0.00**	0.00	0.00	0.00	0.00	0.00
24/10/1997	0.00	0.56	1.0000	0.56	5.61	**0.00**	0.00	0.00	0.00	0.00	0.00

Date	Rainfall	PE	S.F.	AE	SMD	**Recharge**	Pot. Runoff	Runoff 1	Runoff 2	Runoff	Recharge
25/10/1997	0.00	0.51	1.0000	0.51	6.12	**0.00**	0.00	0.00	0.00	0.00	0.00
26/10/1997	0.00	0.56	1.0000	0.56	6.68	**0.00**	0.00	0.00	0.00	0.00	0.00
27/10/1997	0.00	0.77	1.0000	0.77	7.45	**0.00**	0.00	0.00	0.00	0.00	0.00
28/10/1997	0.00	1.12	1.0000	1.12	8.56	**0.00**	0.00	0.00	0.00	0.00	0.00
29/10/1997	1.30	1.09	1.0000	1.09	8.36	**0.00**	0.00	0.00	0.00	0.00	0.00
30/10/1997	3.00	0.39	1.0000	0.39	5.75	**0.00**	0.00	0.00	0.00	0.00	0.00
31/10/1997	0.40	0.41	1.0000	0.41	5.75	**0.00**	0.00	0.00	0.00	0.00	0.00
01/11/1997	1.40	0.30	1.0000	0.30	4.65	**0.00**	0.00	0.00	0.00	0.00	0.00
02/11/1997	0.00	0.36	1.0000	0.36	5.01	**0.00**	0.00	0.00	0.00	0.00	0.00
03/11/1997	0.00	0.56	1.0000	0.56	5.58	**0.00**	0.00	0.00	0.00	0.00	0.00
04/11/1997	5.40	0.82	1.0000	0.82	0.99	**0.00**	0.40	0.08	0.00	0.08	-0.08
05/11/1997	12.00	0.35	1.0000	0.35	0.00	**10.66**	7.00	1.40	0.00	1.40	9.26
06/11/1997	0.00	0.35	1.0000	0.35	0.35	**0.00**	0.00	0.00	0.00	0.00	0.00
07/11/1997	0.20	0.27	1.0000	0.27	0.42	**0.00**	0.00	0.00	0.00	0.00	0.00
08/11/1997	1.50	0.35	1.0000	0.35	0.00	**0.73**	0.00	0.00	0.00	0.00	0.73
09/11/1997	3.70	0.38	1.0000	0.38	0.00	**3.32**	0.00	0.00	0.00	0.00	3.32
10/11/1997	0.10	0.72	1.0000	0.72	0.62	**0.00**	0.00	0.00	0.00	0.00	0.00
11/11/1997	0.00	0.68	1.0000	0.68	1.30	**0.00**	0.00	0.00	0.00	0.00	0.00
12/11/1997	0.70	0.36	1.0000	0.36	0.97	**0.00**	0.00	0.00	0.00	0.00	0.00
13/11/1997	0.50	0.34	1.0000	0.34	0.80	**0.00**	0.00	0.00	0.00	0.00	0.00
14/11/1997	1.60	0.69	1.0000	0.69	0.00	**0.10**	0.00	0.00	0.00	0.00	0.10
15/11/1997	3.80	0.70	1.0000	0.70	0.00	**3.10**	0.00	0.00	0.00	0.00	3.10
16/11/1997	2.20	1.03	1.0000	1.03	0.00	**1.17**	0.00	0.00	0.00	0.00	1.17
17/11/1997	33.20	1.16	1.0000	1.16	0.00	**32.04**	28.20	0.00	8.46	8.46	23.58
18/11/1997	3.50	1.05	1.0000	1.05	0.00	**2.45**	0.00	0.00	0.00	0.00	2.45
19/11/1997	1.20	0.80	1.0000	0.80	0.00	**0.40**	0.00	0.00	0.00	0.00	0.40
20/11/1997	3.00	0.66	1.0000	0.66	0.00	**2.34**	0.00	0.00	0.00	0.00	2.34
21/11/1997	0.30	0.45	1.0000	0.45	0.15	**0.00**	0.00	0.00	0.00	0.00	0.00
22/11/1997	0.00	0.26	1.0000	0.26	0.40	**0.00**	0.00	0.00	0.00	0.00	0.00
23/11/1997	6.00	0.63	1.0000	0.63	0.00	**4.97**	1.00	0.20	0.00	0.20	4.77
24/11/1997	4.50	0.64	1.0000	0.64	0.00	**3.86**	0.00	0.00	0.00	0.00	3.86
25/11/1997	8.70	0.66	1.0000	0.66	0.00	**8.04**	3.70	0.74	0.00	0.74	7.30
26/11/1997	0.50	0.40	1.0000	0.40	0.00	**0.10**	0.00	0.00	0.00	0.00	0.10
27/11/1997	0.70	0.36	1.0000	0.36	0.00	**0.34**	0.00	0.00	0.00	0.00	0.34
28/11/1997	0.20	0.37	1.0000	0.37	0.17	**0.00**	0.00	0.00	0.00	0.00	0.00
29/11/1997	0.00	0.32	1.0000	0.32	0.49	**0.00**	0.00	0.00	0.00	0.00	0.00
30/11/1997	0.30	0.26	1.0000	0.26	0.46	**0.00**	0.00	0.00	0.00	0.00	0.00
01/12/1997	0.00	0.25	1.0000	0.25	0.71	**0.00**	0.00	0.00	0.00	0.00	0.00
02/12/1997	0.00	0.26	1.0000	0.26	0.97	**0.00**	0.00	0.00	0.00	0.00	0.00
03/12/1997	0.00	0.06	1.0000	0.06	1.04	**0.00**	0.00	0.00	0.00	0.00	0.00
04/12/1997	0.00	0.13	1.0000	0.13	1.16	**0.00**	0.00	0.00	0.00	0.00	0.00
05/12/1997	1.00	1.03	1.0000	1.03	1.19	**0.00**	0.00	0.00	0.00	0.00	0.00
06/12/1997	0.50	1.13	1.0000	1.13	1.82	**0.00**	0.00	0.00	0.00	0.00	0.00
07/12/1997	7.00	0.95	1.0000	0.95	0.00	**4.23**	2.00	0.40	0.00	0.40	3.83
08/12/1997	0.50	0.81	1.0000	0.81	0.31	**0.00**	0.00	0.00	0.00	0.00	0.00
09/12/1997	19.00	0.65	1.0000	0.65	0.00	**18.04**	14.00	2.80	0.00	2.80	15.24
10/12/1997	4.50	0.33	1.0000	0.33	0.00	**4.17**	0.00	0.00	0.00	0.00	4.17
11/12/1997	0.00	0.61	1.0000	0.61	0.61	**0.00**	0.00	0.00	0.00	0.00	0.00
12/12/1997	0.00	0.42	1.0000	0.42	1.02	**0.00**	0.00	0.00	0.00	0.00	0.00
13/12/1997	0.00	0.59	1.0000	0.59	1.61	**0.00**	0.00	0.00	0.00	0.00	0.00
14/12/1997	0.00	0.50	1.0000	0.50	2.12	**0.00**	0.00	0.00	0.00	0.00	0.00
15/12/1997	0.00	0.99	1.0000	0.99	3.11	**0.00**	0.00	0.00	0.00	0.00	0.00
16/12/1997	0.00	1.42	1.0000	1.42	4.52	**0.00**	0.00	0.00	0.00	0.00	0.00
17/12/1997	5.00	0.98	1.0000	0.98	0.50	**0.00**	0.00	0.00	0.00	0.00	0.00
18/12/1997	0.00	0.80	1.0000	0.80	1.30	**0.00**	0.00	0.00	0.00	0.00	0.00
19/12/1997	0.00	0.01	1.0000	0.01	1.31	**0.00**	0.00	0.00	0.00	0.00	0.00
20/12/1997	0.00	0.19	1.0000	0.19	1.50	**0.00**	0.00	0.00	0.00	0.00	0.00
21/12/1997	0.10	0.24	1.0000	0.24	1.64	**0.00**	0.00	0.00	0.00	0.00	0.00
22/12/1997	3.50	0.81	1.0000	0.81	0.00	**1.05**	0.00	0.00	0.00	0.00	1.05
23/12/1997	3.00	0.77	1.0000	0.77	0.00	**2.24**	0.00	0.00	0.00	0.00	2.24
24/12/1997	10.00	1.18	1.0000	1.18	0.00	**8.82**	5.00	1.00	0.00	1.00	7.82
25/12/1997	5.00	0.98	1.0000	0.98	0.00	**4.02**	0.00	0.00	0.00	0.00	4.02
26/12/1997	0.00	0.36	1.0000	0.36	0.36	**0.00**	0.00	0.00	0.00	0.00	0.00
27/12/1997	0.00	0.30	1.0000	0.30	0.65	**0.00**	0.00	0.00	0.00	0.00	0.00
28/12/1997	1.30	0.48	1.0000	0.48	0.00	**0.17**	0.00	0.00	0.00	0.00	0.17
29/12/1997	8.40	0.39	1.0000	0.39	0.00	**8.01**	3.40	0.68	0.00	0.68	7.33
30/12/1997	7.40	0.53	1.0000	0.53	0.00	**6.87**	2.40	0.48	0.00	0.48	6.39
31/12/1997	0.00	0.30	1.0000	0.30	0.30	**0.00**	0.00	0.00	0.00	0.00	0.00
01/01/1998	13.70	1.03	1.0000	1.03	0.00	**12.37**	8.70	1.74	0.00	1.74	10.63
02/01/1998	5.80	0.81	1.0000	0.81	0.00	**4.99**	0.80	0.16	0.00	0.16	4.83
03/01/1998	11.20	0.93	1.0000	0.93	0.00	**10.27**	6.20	1.24	0.00	1.24	9.03
04/01/1998	16.00	0.41	1.0000	0.41	0.00	**15.59**	11.00	2.20	0.00	2.20	13.39
05/01/1998	3.10	0.50	1.0000	0.50	0.00	**2.60**	0.00	0.00	0.00	0.00	2.60
06/01/1998	1.70	0.78	1.0000	0.78	0.00	**0.92**	0.00	0.00	0.00	0.00	0.92
07/01/1998	19.90	0.76	1.0000	0.76	0.00	**19.14**	14.90	2.98	0.00	2.98	16.16
08/01/1998	4.20	0.72	1.0000	0.72	0.00	**3.48**	0.00	0.00	0.00	0.00	3.48
09/01/1998	0.00	1.12	1.0000	1.12	1.12	**0.00**	0.00	0.00	0.00	0.00	0.00
10/01/1998	0.00	2.15	1.0000	2.15	3.27	**0.00**	0.00	0.00	0.00	0.00	0.00

Date	Rainfall	PE	S.F.	AE	SMD	**Recharge**	Pot. Runoff	Runoff 1	Runoff 2	Runoff	Recharge
11/01/1998	1.00	1.21	1.0000	1.21	3.48	**0.00**	0.00	0.00	0.00	0.00	0.00
12/01/1998	4.30	0.65	1.0000	0.65	0.00	**0.17**	0.00	0.00	0.00	0.00	0.17
13/01/1998	11.70	0.41	1.0000	0.41	0.00	**11.29**	6.70	1.34	0.00	1.34	9.95
14/01/1998	6.10	0.64	1.0000	0.64	0.00	**5.46**	1.10	0.22	0.00	0.22	5.24
15/01/1998	0.10	0.85	1.0000	0.85	0.75	**0.00**	0.00	0.00	0.00	0.00	0.00
16/01/1998	0.00	0.46	1.0000	0.46	1.21	**0.00**	0.00	0.00	0.00	0.00	0.00
17/01/1998	3.50	0.66	1.0000	0.66	0.00	**1.64**	0.00	0.00	0.00	0.00	1.64
18/01/1998	8.40	0.49	1.0000	0.49	0.00	**7.91**	3.40	0.68	0.00	0.68	7.23
19/01/1998	0.30	0.15	1.0000	0.15	0.00	**0.15**	0.00	0.00	0.00	0.00	0.15
20/01/1998	4.30	0.30	1.0000	0.30	0.00	**4.00**	0.00	0.00	0.00	0.00	4.00
21/01/1998	0.30	1.24	1.0000	1.24	0.94	**0.00**	0.00	0.00	0.00	0.00	0.00
22/01/1998	0.30	0.64	1.0000	0.64	1.28	**0.00**	0.00	0.00	0.00	0.00	0.00
23/01/1998	0.00	0.52	1.0000	0.52	1.80	**0.00**	0.00	0.00	0.00	0.00	0.00
24/01/1998	0.00	0.81	1.0000	0.81	2.61	**0.00**	0.00	0.00	0.00	0.00	0.00
25/01/1998	0.00	0.93	1.0000	0.93	3.54	**0.00**	0.00	0.00	0.00	0.00	0.00
26/01/1998	0.00	0.23	1.0000	0.23	3.77	**0.00**	0.00	0.00	0.00	0.00	0.00
27/01/1998	0.00	0.39	1.0000	0.39	4.15	**0.00**	0.00	0.00	0.00	0.00	0.00
28/01/1998	0.00	0.41	1.0000	0.41	4.56	**0.00**	0.00	0.00	0.00	0.00	0.00
29/01/1998	0.00	0.33	1.0000	0.33	4.89	**0.00**	0.00	0.00	0.00	0.00	0.00
30/01/1998	0.20	0.47	1.0000	0.47	5.17	**0.00**	0.00	0.00	0.00	0.00	0.00
31/01/1998	0.00	0.24	1.0000	0.24	5.40	**0.00**	0.00	0.00	0.00	0.00	0.00
01/02/1998	0.00	0.33	1.0000	0.33	5.73	**0.00**	0.00	0.00	0.00	0.00	0.00
02/02/1998	0.00	0.41	1.0000	0.41	6.14	**0.00**	0.00	0.00	0.00	0.00	0.00
03/02/1998	0.00	0.47	1.0000	0.47	6.61	**0.00**	0.00	0.00	0.00	0.00	0.00
04/02/1998	0.00	0.77	1.0000	0.77	7.38	**0.00**	0.00	0.00	0.00	0.00	0.00
05/02/1998	0.00	0.99	1.0000	0.99	8.37	**0.00**	0.00	0.00	0.00	0.00	0.00
06/02/1998	5.90	0.79	1.0000	0.79	3.25	**0.00**	0.90	0.18	0.00	0.18	-0.18
07/02/1998	1.60	0.81	1.0000	0.81	2.46	**0.00**	0.00	0.00	0.00	0.00	0.00
08/02/1998	0.00	1.03	1.0000	1.03	3.50	**0.00**	0.00	0.00	0.00	0.00	0.00
09/02/1998	1.10	0.93	1.0000	0.93	3.33	**0.00**	0.00	0.00	0.00	0.00	0.00
10/02/1998	0.50	0.66	1.0000	0.66	3.49	**0.00**	0.00	0.00	0.00	0.00	0.00
11/02/1998	0.30	1.13	1.0000	1.13	4.31	**0.00**	0.00	0.00	0.00	0.00	0.00
12/02/1998	0.00	0.93	1.0000	0.93	5.24	**0.00**	0.00	0.00	0.00	0.00	0.00
13/02/1998	0.20	1.02	1.0000	1.02	6.06	**0.00**	0.00	0.00	0.00	0.00	0.00
14/02/1998	0.00	1.61	1.0000	1.61	7.67	**0.00**	0.00	0.00	0.00	0.00	0.00
15/02/1998	0.00	1.60	1.0000	1.60	9.26	**0.00**	0.00	0.00	0.00	0.00	0.00
16/02/1998	0.00	0.88	1.0000	0.88	10.15	**0.00**	0.00	0.00	0.00	0.00	0.00
17/02/1998	0.00	0.58	1.0000	0.58	10.72	**0.00**	0.00	0.00	0.00	0.00	0.00
18/02/1998	0.00	0.47	1.0000	0.47	11.19	**0.00**	0.00	0.00	0.00	0.00	0.00
19/02/1998	0.00	1.13	1.0000	1.13	12.31	**0.00**	0.00	0.00	0.00	0.00	0.00
20/02/1998	2.50	0.88	1.0000	0.88	10.69	**0.00**	0.00	0.00	0.00	0.00	0.00
21/02/1998	2.00	0.74	1.0000	0.74	9.43	**0.00**	0.00	0.00	0.00	0.00	0.00
22/02/1998	0.00	0.90	1.0000	0.90	10.32	**0.00**	0.00	0.00	0.00	0.00	0.00
23/02/1998	0.00	1.05	1.0000	1.05	11.38	**0.00**	0.00	0.00	0.00	0.00	0.00
24/02/1998	0.00	1.06	1.0000	1.06	12.44	**0.00**	0.00	0.00	0.00	0.00	0.00
25/02/1998	0.30	1.32	1.0000	1.32	13.45	**0.00**	0.00	0.00	0.00	0.00	0.00
26/02/1998	0.00	1.11	1.0000	1.11	14.56	**0.00**	0.00	0.00	0.00	0.00	0.00
27/02/1998	1.90	1.24	1.0000	1.24	13.90	**0.00**	0.00	0.00	0.00	0.00	0.00
28/02/1998	0.60	1.08	1.0000	1.08	14.38	**0.00**	0.00	0.00	0.00	0.00	0.00
01/03/1998	1.50	1.00	1.0000	1.00	13.88	**0.00**	0.00	0.00	0.00	0.00	0.00
02/03/1998	13.60	0.59	1.0000	0.59	0.87	**0.00**	8.60	1.72	0.00	1.72	-1.72
03/03/1998	10.50	0.51	1.0000	0.51	0.00	**9.12**	5.50	1.10	0.00	1.10	8.02
04/03/1998	6.10	1.22	1.0000	1.22	0.00	**4.88**	1.10	0.22	0.00	0.22	4.66
05/03/1998	10.30	0.99	1.0000	0.99	0.00	**9.31**	5.30	1.06	0.00	1.06	8.25
06/03/1998	11.80	0.53	1.0000	0.53	0.00	**11.27**	6.80	1.36	0.00	1.36	9.91
07/03/1998	3.40	0.86	1.0000	0.86	0.00	**2.54**	0.00	0.00	0.00	0.00	2.54
08/03/1998	0.00	0.65	1.0000	0.65	0.65	**0.00**	0.00	0.00	0.00	0.00	0.00
09/03/1998	0.00	1.10	1.0000	1.10	1.75	**0.00**	0.00	0.00	0.00	0.00	0.00
10/03/1998	3.60	1.39	1.0000	1.39	0.00	**0.45**	0.00	0.00	0.00	0.00	0.45
11/03/1998	0.00	1.38	1.0000	1.38	1.38	**0.00**	0.00	0.00	0.00	0.00	0.00
12/03/1998	0.00	0.93	1.0000	0.93	2.31	**0.00**	0.00	0.00	0.00	0.00	0.00
13/03/1998	0.00	0.95	1.0000	0.95	3.26	**0.00**	0.00	0.00	0.00	0.00	0.00
14/03/1998	0.00	0.86	1.0000	0.86	4.12	**0.00**	0.00	0.00	0.00	0.00	0.00
15/03/1998	0.00	1.01	1.0000	1.01	5.12	**0.00**	0.00	0.00	0.00	0.00	0.00
16/03/1998	0.00	0.96	1.0000	0.96	6.08	**0.00**	0.00	0.00	0.00	0.00	0.00
17/03/1998	0.00	0.83	1.0000	0.83	6.91	**0.00**	0.00	0.00	0.00	0.00	0.00
18/03/1998	0.00	1.02	1.0000	1.02	7.93	**0.00**	0.00	0.00	0.00	0.00	0.00
19/03/1998	0.00	1.21	1.0000	1.21	9.14	**0.00**	0.00	0.00	0.00	0.00	0.00
20/03/1998	0.00	0.97	1.0000	0.97	10.10	**0.00**	0.00	0.00	0.00	0.00	0.00
21/03/1998	0.00	0.88	1.0000	0.88	10.99	**0.00**	0.00	0.00	0.00	0.00	0.00
22/03/1998	0.00	0.80	1.0000	0.80	11.79	**0.00**	0.00	0.00	0.00	0.00	0.00
23/03/1998	6.00	1.03	1.0000	1.03	6.82	**0.00**	1.00	0.20	0.00	0.20	-0.20
24/03/1998	10.70	0.82	1.0000	0.82	0.00	**3.06**	5.70	1.14	0.00	1.14	1.92
25/03/1998	8.20	0.98	1.0000	0.98	0.00	**7.22**	3.20	0.64	0.00	0.64	6.58
26/03/1998	0.10	1.40	1.0000	1.40	1.30	**0.00**	0.00	0.00	0.00	0.00	0.00
27/03/1998	0.00	2.62	1.0000	2.62	3.92	**0.00**	0.00	0.00	0.00	0.00	0.00
28/03/1998	0.00	2.17	1.0000	2.17	6.09	**0.00**	0.00	0.00	0.00	0.00	0.00
29/03/1998	2.40	0.74	1.0000	0.74	4.43	**0.00**	0.00	0.00	0.00	0.00	0.00

Date	Rainfall	PE	S.F.	AE	SMD	**Recharge**	Pot. Runoff	Runoff 1	Runoff 2	Runoff	Recharge
30/03/1998	0.00	1.54	1.0000	1.54	5.97	**0.00**	0.00	0.00	0.00	0.00	0.00
31/03/1998	0.00	1.67	1.0000	1.67	7.63	**0.00**	0.00	0.00	0.00	0.00	0.00
01/04/1998	9.80	0.62	1.0000	0.62	0.00	**1.55**	4.80	0.96	0.00	0.96	0.59
02/04/1998	6.20	1.74	1.0000	1.74	0.00	**4.46**	1.20	0.24	0.00	0.24	4.22
03/04/1998	6.80	1.15	1.0000	1.15	0.00	**5.65**	1.80	0.36	0.00	0.36	5.29
04/04/1998	2.60	0.88	1.0000	0.88	0.00	**1.72**	0.00	0.00	0.00	0.00	1.72
05/04/1998	2.60	1.14	1.0000	1.14	0.00	**1.46**	0.00	0.00	0.00	0.00	1.46
06/04/1998	0.00	1.10	1.0000	1.10	1.10	**0.00**	0.00	0.00	0.00	0.00	0.00
07/04/1998	2.30	1.43	1.0000	1.43	0.23	**0.00**	0.00	0.00	0.00	0.00	0.00
08/04/1998	28.30	1.70	1.0000	1.70	0.00	**26.37**	23.30	0.00	6.99	6.99	19.38
09/04/1998	1.30	0.91	1.0000	0.91	0.00	**0.39**	0.00	0.00	0.00	0.00	0.39
10/04/1998	0.00	1.41	1.0000	1.41	1.41	**0.00**	0.00	0.00	0.00	0.00	0.00
11/04/1998	0.00	2.02	1.0000	2.02	3.43	**0.00**	0.00	0.00	0.00	0.00	0.00
12/04/1998	0.30	1.73	1.0000	1.73	4.86	**0.00**	0.00	0.00	0.00	0.00	0.00
13/04/1998	2.60	1.50	1.0000	1.50	3.76	**0.00**	0.00	0.00	0.00	0.00	0.00
14/04/1998	0.00	1.54	1.0000	1.54	5.30	**0.00**	0.00	0.00	0.00	0.00	0.00
15/04/1998	0.10	1.66	1.0000	1.66	6.86	**0.00**	0.00	0.00	0.00	0.00	0.00
16/04/1998	0.00	1.75	1.0000	1.75	8.61	**0.00**	0.00	0.00	0.00	0.00	0.00
17/04/1998	1.10	1.99	1.0000	1.99	9.50	**0.00**	0.00	0.00	0.00	0.00	0.00
18/04/1998	2.00	1.73	1.0000	1.73	9.23	**0.00**	0.00	0.00	0.00	0.00	0.00
19/04/1998	2.90	1.18	1.0000	1.18	7.51	**0.00**	0.00	0.00	0.00	0.00	0.00
20/04/1998	0.00	2.04	1.0000	2.04	9.55	**0.00**	0.00	0.00	0.00	0.00	0.00
21/04/1998	2.70	1.27	1.0000	1.27	8.12	**0.00**	0.00	0.00	0.00	0.00	0.00
22/04/1998	3.10	1.58	1.0000	1.58	6.60	**0.00**	0.00	0.00	0.00	0.00	0.00
23/04/1998	1.10	1.32	1.0000	1.32	6.82	**0.00**	0.00	0.00	0.00	0.00	0.00
24/04/1998	0.40	2.23	1.0000	2.23	8.65	**0.00**	0.00	0.00	0.00	0.00	0.00
25/04/1998	7.30	2.09	1.0000	2.09	3.44	**0.00**	2.30	0.46	0.00	0.46	-0.46
26/04/1998	1.60	1.54	1.0000	1.54	3.38	**0.00**	0.00	0.00	0.00	0.00	0.00
27/04/1998	15.60	1.74	1.0000	1.74	0.00	**10.47**	10.60	2.12	0.00	2.12	8.35
28/04/1998	7.00	1.30	1.0000	1.30	0.00	**5.70**	2.00	0.40	0.00	0.40	5.30
29/04/1998	0.00	1.90	1.0000	1.90	1.90	**0.00**	0.00	0.00	0.00	0.00	0.00
30/04/1998	0.00	1.55	1.0000	1.55	3.45	**0.00**	0.00	0.00	0.00	0.00	0.00
01/05/1998	0.00	2.38	1.0000	2.38	5.83	**0.00**	0.00	0.00	0.00	0.00	0.00
02/05/1998	0.00	1.59	1.0000	1.59	7.41	**0.00**	0.00	0.00	0.00	0.00	0.00
03/05/1998	0.00	2.62	1.0000	2.62	10.04	**0.00**	0.00	0.00	0.00	0.00	0.00
04/05/1998	0.70	2.05	1.0000	2.05	11.39	**0.00**	0.00	0.00	0.00	0.00	0.00
05/05/1998	2.30	1.54	1.0000	1.54	10.63	**0.00**	0.00	0.00	0.00	0.00	0.00
06/05/1998	2.10	1.47	1.0000	1.47	10.00	**0.00**	0.00	0.00	0.00	0.00	0.00
07/05/1998	6.00	2.09	1.0000	2.09	6.10	**0.00**	1.00	0.20	0.00	0.20	-0.20
08/05/1998	2.00	1.70	1.0000	1.70	5.79	**0.00**	0.00	0.00	0.00	0.00	0.00
09/05/1998	2.70	2.10	1.0000	2.10	5.20	**0.00**	0.00	0.00	0.00	0.00	0.00
10/05/1998	4.50	1.99	1.0000	1.99	2.68	**0.00**	0.00	0.00	0.00	0.00	0.00
11/05/1998	0.00	1.26	1.0000	1.26	3.94	**0.00**	0.00	0.00	0.00	0.00	0.00
12/05/1998	0.00	1.11	1.0000	1.11	5.05	**0.00**	0.00	0.00	0.00	0.00	0.00
13/05/1998	0.70	1.41	1.0000	1.41	5.76	**0.00**	0.00	0.00	0.00	0.00	0.00
14/05/1998	0.00	1.56	1.0000	1.56	7.32	**0.00**	0.00	0.00	0.00	0.00	0.00
15/05/1998	0.00	3.44	1.0000	3.44	10.76	**0.00**	0.00	0.00	0.00	0.00	0.00
16/05/1998	0.00	3.46	1.0000	3.46	14.22	**0.00**	0.00	0.00	0.00	0.00	0.00
17/05/1998	0.00	3.26	1.0000	3.26	17.47	**0.00**	0.00	0.00	0.00	0.00	0.00
18/05/1998	0.00	3.56	1.0000	3.56	21.04	**0.00**	0.00	0.00	0.00	0.00	0.00
19/05/1998	0.00	4.01	1.0000	4.01	25.04	**0.00**	0.00	0.00	0.00	0.00	0.00
20/05/1998	0.00	3.79	1.0000	3.79	28.83	**0.00**	0.00	0.00	0.00	0.00	0.00
21/05/1998	0.00	2.05	1.0000	2.05	30.88	**0.00**	0.00	0.00	0.00	0.00	0.00
22/05/1998	0.00	2.28	1.0000	2.28	33.16	**0.00**	0.00	0.00	0.00	0.00	0.00
23/05/1998	0.00	1.96	1.0000	1.96	35.12	**0.00**	0.00	0.00	0.00	0.00	0.00
24/05/1998	0.10	2.39	1.0000	2.39	37.41	**0.00**	0.00	0.00	0.00	0.00	0.00
25/05/1998	0.60	1.91	1.0000	1.91	38.72	**0.00**	0.00	0.00	0.00	0.00	0.00
26/05/1998	0.00	2.01	1.0000	2.01	40.73	**0.00**	0.00	0.00	0.00	0.00	0.00
27/05/1998	3.60	1.73	1.0000	1.73	38.86	**0.00**	0.00	0.00	0.00	0.00	0.00
28/05/1998	13.20	1.92	1.0000	1.92	27.58	**0.00**	8.20	1.64	0.00	1.64	-1.64
29/05/1998	0.50	1.65	1.0000	1.65	28.73	**0.00**	0.00	0.00	0.00	0.00	0.00
30/05/1998	0.00	2.68	1.0000	2.68	31.42	**0.00**	0.00	0.00	0.00	0.00	0.00
31/05/1998	1.70	2.76	1.0000	2.76	32.48	**0.00**	0.00	0.00	0.00	0.00	0.00
01/06/1998	2.50	2.75	1.0000	2.75	32.73	**0.00**	0.00	0.00	0.00	0.00	0.00
02/06/1998	17.70	0.58	1.0000	0.58	15.61	**0.00**	12.70	2.54	0.00	2.54	-2.54
03/06/1998	0.30	1.95	1.0000	1.95	17.26	**0.00**	0.00	0.00	0.00	0.00	0.00
04/06/1998	0.00	2.93	1.0000	2.93	20.19	**0.00**	0.00	0.00	0.00	0.00	0.00
05/06/1998	25.30	2.68	1.0000	2.68	0.00	**2.43**	20.30	0.00	6.09	6.09	-3.66
06/06/1998	2.20	2.68	1.0000	2.68	0.48	**0.00**	0.00	0.00	0.00	0.00	0.00
07/06/1998	1.20	2.38	1.0000	2.38	1.67	**0.00**	0.00	0.00	0.00	0.00	0.00
08/06/1998	2.20	1.57	1.0000	1.57	1.03	**0.00**	0.00	0.00	0.00	0.00	0.00
09/06/1998	6.30	2.32	1.0000	2.32	0.00	**2.94**	1.30	0.26	0.00	0.26	2.68
10/06/1998	3.50	2.08	1.0000	2.08	0.00	**1.42**	0.00	0.00	0.00	0.00	1.42
11/06/1998	1.70	3.19	1.0000	3.19	1.49	**0.00**	0.00	0.00	0.00	0.00	0.00
12/06/1998	19.50	2.42	1.0000	2.42	0.00	**15.59**	14.50	2.90	0.00	2.90	12.69
13/06/1998	11.10	1.57	1.0000	1.57	0.00	**9.53**	6.10	1.22	0.00	1.22	8.31
14/06/1998	0.00	2.89	1.0000	2.89	2.89	**0.00**	0.00	0.00	0.00	0.00	0.00
15/06/1998	0.00	2.91	1.0000	2.91	5.80	**0.00**	0.00	0.00	0.00	0.00	0.00

Date	Rainfall	PE	S.F.	AE	SMD	**Recharge**	Pot. Runoff	Runoff 1	Runoff 2	Runoff	Recharge
16/06/1998	6.30	3.39	1.0000	3.39	2.89	**0.00**	1.30	0.26	0.00	0.26	-0.26
17/06/1998	17.60	1.44	1.0000	1.44	0.00	**13.27**	12.60	2.52	0.00	2.52	10.75
18/06/1998	0.50	2.59	1.0000	2.59	2.09	**0.00**	0.00	0.00	0.00	0.00	0.00
19/06/1998	0.00	3.75	1.0000	3.75	5.85	**0.00**	0.00	0.00	0.00	0.00	0.00
20/06/1998	1.30	2.71	1.0000	2.71	7.25	**0.00**	0.00	0.00	0.00	0.00	0.00
21/06/1998	0.70	2.99	1.0000	2.99	9.54	**0.00**	0.00	0.00	0.00	0.00	0.00
22/06/1998	3.40	1.79	1.0000	1.79	7.94	**0.00**	0.00	0.00	0.00	0.00	0.00
23/06/1998	10.30	2.74	1.0000	2.74	0.37	**0.00**	5.30	1.06	0.00	1.06	-1.06
24/06/1998	3.20	2.61	1.0000	2.61	0.00	**0.22**	0.00	0.00	0.00	0.00	0.22
25/06/1998	10.30	2.09	1.0000	2.09	0.00	**8.21**	5.30	1.06	0.00	1.06	7.15
26/06/1998	2.60	3.09	1.0000	3.09	0.49	**0.00**	0.00	0.00	0.00	0.00	0.00
27/06/1998	2.80	2.30	1.0000	2.30	0.00	**0.01**	0.00	0.00	0.00	0.00	0.01
28/06/1998	0.20	2.37	1.0000	2.37	2.17	**0.00**	0.00	0.00	0.00	0.00	0.00
29/06/1998	0.00	1.97	1.0000	1.97	4.14	**0.00**	0.00	0.00	0.00	0.00	0.00
30/06/1998	0.00	1.79	1.0000	1.79	5.92	**0.00**	0.00	0.00	0.00	0.00	0.00
01/07/1998	0.00	2.92	1.0000	2.92	8.85	**0.00**	0.00	0.00	0.00	0.00	0.00
02/07/1998	0.00	2.14	1.0000	2.14	10.98	**0.00**	0.00	0.00	0.00	0.00	0.00
03/07/1998	0.00	1.75	1.0000	1.75	12.73	**0.00**	0.00	0.00	0.00	0.00	0.00
04/07/1998	0.00	2.74	1.0000	2.74	15.47	**0.00**	0.00	0.00	0.00	0.00	0.00
05/07/1998	0.00	1.77	1.0000	1.77	17.24	**0.00**	0.00	0.00	0.00	0.00	0.00
06/07/1998	0.70	1.29	1.0000	1.29	17.83	**0.00**	0.00	0.00	0.00	0.00	0.00
07/07/1998	0.00	2.20	1.0000	2.20	20.02	**0.00**	0.00	0.00	0.00	0.00	0.00
08/07/1998	2.90	2.30	1.0000	2.30	19.42	**0.00**	0.00	0.00	0.00	0.00	0.00
09/07/1998	0.00	2.58	1.0000	2.58	22.00	**0.00**	0.00	0.00	0.00	0.00	0.00
10/07/1998	1.80	2.36	1.0000	2.36	22.56	**0.00**	0.00	0.00	0.00	0.00	0.00
11/07/1998	6.40	1.53	1.0000	1.53	17.69	**0.00**	1.40	0.28	0.00	0.28	-0.28
12/07/1998	0.00	1.75	1.0000	1.75	19.44	**0.00**	0.00	0.00	0.00	0.00	0.00
13/07/1998	0.20	3.25	1.0000	3.25	22.49	**0.00**	0.00	0.00	0.00	0.00	0.00
14/07/1998	0.30	2.17	1.0000	2.17	24.36	**0.00**	0.00	0.00	0.00	0.00	0.00
15/07/1998	0.00	2.91	1.0000	2.91	27.27	**0.00**	0.00	0.00	0.00	0.00	0.00
16/07/1998	2.20	2.75	1.0000	2.75	27.82	**0.00**	0.00	0.00	0.00	0.00	0.00
17/07/1998	2.80	2.81	1.0000	2.81	27.83	**0.00**	0.00	0.00	0.00	0.00	0.00
18/07/1998	2.50	2.93	1.0000	2.93	28.26	**0.00**	0.00	0.00	0.00	0.00	0.00
19/07/1998	1.30	2.31	1.0000	2.31	29.27	**0.00**	0.00	0.00	0.00	0.00	0.00
20/07/1998	0.00	3.10	1.0000	3.10	32.36	**0.00**	0.00	0.00	0.00	0.00	0.00
21/07/1998	0.40	2.50	1.0000	2.50	34.47	**0.00**	0.00	0.00	0.00	0.00	0.00
22/07/1998	11.90	2.00	1.0000	2.00	24.56	**0.00**	6.90	1.38	0.00	1.38	-1.38
23/07/1998	0.00	2.33	1.0000	2.33	26.89	**0.00**	0.00	0.00	0.00	0.00	0.00
24/07/1998	0.00	2.56	1.0000	2.56	29.46	**0.00**	0.00	0.00	0.00	0.00	0.00
25/07/1998	6.90	2.12	1.0000	2.12	24.67	**0.00**	1.90	0.38	0.00	0.38	-0.38
26/07/1998	0.40	2.10	1.0000	2.10	26.37	**0.00**	0.00	0.00	0.00	0.00	0.00
27/07/1998	2.70	2.11	1.0000	2.11	25.78	**0.00**	0.00	0.00	0.00	0.00	0.00
28/07/1998	1.20	1.72	1.0000	1.72	26.30	**0.00**	0.00	0.00	0.00	0.00	0.00
29/07/1998	1.30	2.41	1.0000	2.41	27.41	**0.00**	0.00	0.00	0.00	0.00	0.00
30/07/1998	2.20	1.64	1.0000	1.64	26.86	**0.00**	0.00	0.00	0.00	0.00	0.00
31/07/1998	0.70	1.36	1.0000	1.36	27.52	**0.00**	0.00	0.00	0.00	0.00	0.00
01/08/1998	0.00	1.95	1.0000	1.95	29.47	**0.00**	0.00	0.00	0.00	0.00	0.00
02/08/1998	11.10	2.08	1.0000	2.08	20.44	**0.00**	6.10	1.22	0.00	1.22	-1.22
03/08/1998	1.10	1.84	1.0000	1.84	21.18	**0.00**	0.00	0.00	0.00	0.00	0.00
04/08/1998	0.00	3.45	1.0000	3.45	24.62	**0.00**	0.00	0.00	0.00	0.00	0.00
05/08/1998	0.00	3.16	1.0000	3.16	27.78	**0.00**	0.00	0.00	0.00	0.00	0.00
06/08/1998	0.00	2.07	1.0000	2.07	29.85	**0.00**	0.00	0.00	0.00	0.00	0.00
07/08/1998	0.00	2.32	1.0000	2.32	32.18	**0.00**	0.00	0.00	0.00	0.00	0.00
08/08/1998	0.00	3.19	1.0000	3.19	35.36	**0.00**	0.00	0.00	0.00	0.00	0.00
09/08/1998	0.00	4.37	1.0000	4.37	39.73	**0.00**	0.00	0.00	0.00	0.00	0.00
10/08/1998	0.00	2.68	1.0000	2.68	42.41	**0.00**	0.00	0.00	0.00	0.00	0.00
11/08/1998	0.00	2.88	1.0000	2.88	45.29	**0.00**	0.00	0.00	0.00	0.00	0.00
12/08/1998	0.70	2.75	1.0000	2.75	47.34	**0.00**	0.00	0.00	0.00	0.00	0.00
13/08/1998	3.10	1.31	1.0000	1.31	45.54	**0.00**	0.00	0.00	0.00	0.00	0.00
14/08/1998	0.10	1.42	1.0000	1.42	46.86	**0.00**	0.00	0.00	0.00	0.00	0.00
15/08/1998	0.00	2.88	1.0000	2.88	49.74	**0.00**	0.00	0.00	0.00	0.00	0.00
16/08/1998	7.10	2.71	1.0000	2.71	45.35	**0.00**	2.10	0.42	0.00	0.42	-0.42
17/08/1998	0.00	1.71	1.0000	1.71	47.06	**0.00**	0.00	0.00	0.00	0.00	0.00
18/08/1998	0.00	2.65	1.0000	2.65	49.71	**0.00**	0.00	0.00	0.00	0.00	0.00
19/08/1998	0.00	2.00	1.0000	2.00	51.72	**0.00**	0.00	0.00	0.00	0.00	0.00
20/08/1998	2.60	1.23	1.0000	1.23	50.35	**0.00**	0.00	0.00	0.00	0.00	0.00
21/08/1998	0.00	1.79	1.0000	1.79	52.13	**0.00**	0.00	0.00	0.00	0.00	0.00
22/08/1998	4.50	2.57	1.0000	2.57	50.20	**0.00**	0.00	0.00	0.00	0.00	0.00
23/08/1998	8.50	1.89	1.0000	1.89	43.59	**0.00**	3.50	0.70	0.00	0.70	-0.70
24/08/1998	1.00	2.42	1.0000	2.42	45.02	**0.00**	0.00	0.00	0.00	0.00	0.00
25/08/1998	1.80	1.77	1.0000	1.77	44.99	**0.00**	0.00	0.00	0.00	0.00	0.00
26/08/1998	0.00	1.81	1.0000	1.81	46.79	**0.00**	0.00	0.00	0.00	0.00	0.00
27/08/1998	0.00	2.45	1.0000	2.45	49.24	**0.00**	0.00	0.00	0.00	0.00	0.00
28/08/1998	0.00	2.07	1.0000	2.07	51.31	**0.00**	0.00	0.00	0.00	0.00	0.00
29/08/1998	0.00	2.23	1.0000	2.23	53.53	**0.00**	0.00	0.00	0.00	0.00	0.00
30/08/1998	0.00	2.72	1.0000	2.72	56.26	**0.00**	0.00	0.00	0.00	0.00	0.00
31/08/1998	0.30	1.84	1.0000	1.84	57.80	**0.00**	0.00	0.00	0.00	0.00	0.00
01/09/1998	16.50	2.11	1.0000	2.11	43.41	**0.00**	11.50	2.30	0.00	2.30	-2.30

Date	Rainfall	PE	S.F.	AE	SMD	**Recharge**	Pot. Runoff	Runoff 1	Runoff 2	Runoff	Recharge
02/09/1998	0.00	1.87	1.0000	1.87	45.28	**0.00**	0.00	0.00	0.00	0.00	0.00
03/09/1998	0.50	2.04	1.0000	2.04	46.82	**0.00**	0.00	0.00	0.00	0.00	0.00
04/09/1998	3.90	0.93	1.0000	0.93	43.85	**0.00**	0.00	0.00	0.00	0.00	0.00
05/09/1998	0.30	1.39	1.0000	1.39	44.95	**0.00**	0.00	0.00	0.00	0.00	0.00
06/09/1998	13.20	1.69	1.0000	1.69	33.44	**0.00**	8.20	1.64	0.00	1.64	-1.64
07/09/1998	1.30	2.16	1.0000	2.16	34.30	**0.00**	0.00	0.00	0.00	0.00	0.00
08/09/1998	3.80	2.15	1.0000	2.15	32.64	**0.00**	0.00	0.00	0.00	0.00	0.00
09/09/1998	8.70	2.05	1.0000	2.05	25.99	**0.00**	3.70	0.74	0.00	0.74	-0.74
10/09/1998	3.20	0.82	1.0000	0.82	23.61	**0.00**	0.00	0.00	0.00	0.00	0.00
11/09/1998	4.80	1.77	1.0000	1.77	20.58	**0.00**	0.00	0.00	0.00	0.00	0.00
12/09/1998	2.80	1.44	1.0000	1.44	19.23	**0.00**	0.00	0.00	0.00	0.00	0.00
13/09/1998	0.00	1.75	1.0000	1.75	20.98	**0.00**	0.00	0.00	0.00	0.00	0.00
14/09/1998	1.50	1.61	1.0000	1.61	21.09	**0.00**	0.00	0.00	0.00	0.00	0.00
15/09/1998	0.30	1.31	1.0000	1.31	22.09	**0.00**	0.00	0.00	0.00	0.00	0.00
16/09/1998	0.00	1.85	1.0000	1.85	23.94	**0.00**	0.00	0.00	0.00	0.00	0.00
17/09/1998	2.70	1.22	1.0000	1.22	22.46	**0.00**	0.00	0.00	0.00	0.00	0.00
18/09/1998	0.00	1.88	1.0000	1.88	24.34	**0.00**	0.00	0.00	0.00	0.00	0.00
19/09/1998	0.00	1.66	1.0000	1.66	26.01	**0.00**	0.00	0.00	0.00	0.00	0.00
20/09/1998	0.00	2.02	1.0000	2.02	28.03	**0.00**	0.00	0.00	0.00	0.00	0.00
21/09/1998	0.10	1.88	1.0000	1.88	29.81	**0.00**	0.00	0.00	0.00	0.00	0.00
22/09/1998	0.00	1.25	1.0000	1.25	31.06	**0.00**	0.00	0.00	0.00	0.00	0.00
23/09/1998	0.00	1.38	1.0000	1.38	32.44	**0.00**	0.00	0.00	0.00	0.00	0.00
24/09/1998	2.40	1.50	1.0000	1.50	31.54	**0.00**	0.00	0.00	0.00	0.00	0.00
25/09/1998	5.10	0.91	1.0000	0.91	27.35	**0.00**	0.10	0.02	0.00	0.02	-0.02
26/09/1998	1.70	0.60	1.0000	0.60	26.25	**0.00**	0.00	0.00	0.00	0.00	0.00
27/09/1998	2.20	0.74	1.0000	0.74	24.79	**0.00**	0.00	0.00	0.00	0.00	0.00
28/09/1998	0.00	1.09	1.0000	1.09	25.88	**0.00**	0.00	0.00	0.00	0.00	0.00
29/09/1998	3.30	1.48	1.0000	1.48	24.06	**0.00**	0.00	0.00	0.00	0.00	0.00
30/09/1998	29.80	0.55	1.0000	0.55	0.00	**5.20**	24.80	0.00	7.44	7.44	-2.24
01/10/1998	0.00	0.95	1.0000	0.95	0.95	**0.00**	0.00	0.00	0.00	0.00	0.00
02/10/1998	0.00	1.28	1.0000	1.28	2.23	**0.00**	0.00	0.00	0.00	0.00	0.00
03/10/1998	0.00	1.12	1.0000	1.12	3.34	**0.00**	0.00	0.00	0.00	0.00	0.00
04/10/1998	6.70	0.82	1.0000	0.82	0.00	**2.54**	1.70	0.34	0.00	0.34	2.20
05/10/1998	5.10	0.88	1.0000	0.88	0.00	**4.22**	0.10	0.02	0.00	0.02	4.20
06/10/1998	0.10	1.14	1.0000	1.14	1.04	**0.00**	0.00	0.00	0.00	0.00	0.00
07/10/1998	0.00	0.91	1.0000	0.91	1.95	**0.00**	0.00	0.00	0.00	0.00	0.00
08/10/1998	0.00	0.94	1.0000	0.94	2.88	**0.00**	0.00	0.00	0.00	0.00	0.00
09/10/1998	4.20	1.18	1.0000	1.18	0.00	**0.14**	0.00	0.00	0.00	0.00	0.14
10/10/1998	1.60	0.89	1.0000	0.89	0.00	**0.71**	0.00	0.00	0.00	0.00	0.71
11/10/1998	0.00	0.85	1.0000	0.85	0.85	**0.00**	0.00	0.00	0.00	0.00	0.00
12/10/1998	0.40	1.07	1.0000	1.07	1.51	**0.00**	0.00	0.00	0.00	0.00	0.00
13/10/1998	11.40	1.03	1.0000	1.03	0.00	**8.86**	6.40	1.28	0.00	1.28	7.58
14/10/1998	0.00	0.76	1.0000	0.76	0.76	**0.00**	0.00	0.00	0.00	0.00	0.00
15/10/1998	7.60	1.17	1.0000	1.17	0.00	**5.67**	2.60	0.52	0.00	0.52	5.15
16/10/1998	0.50	1.02	1.0000	1.02	0.52	**0.00**	0.00	0.00	0.00	0.00	0.00
17/10/1998	0.00	0.87	1.0000	0.87	1.40	**0.00**	0.00	0.00	0.00	0.00	0.00
18/10/1998	0.00	0.98	1.0000	0.98	2.38	**0.00**	0.00	0.00	0.00	0.00	0.00
19/10/1998	1.40	0.99	1.0000	0.99	1.97	**0.00**	0.00	0.00	0.00	0.00	0.00
20/10/1998	15.50	0.75	1.0000	0.75	0.00	**12.78**	10.50	2.10	0.00	2.10	10.68
21/10/1998	5.00	0.99	1.0000	0.99	0.00	**4.01**	0.00	0.00	0.00	0.00	4.01
22/10/1998	0.50	1.16	1.0000	1.16	0.66	**0.00**	0.00	0.00	0.00	0.00	0.00
23/10/1998	9.80	0.57	1.0000	0.57	0.00	**8.57**	4.80	0.96	0.00	0.96	7.61
24/10/1998	5.70	1.11	1.0000	1.11	0.00	**4.59**	0.70	0.14	0.00	0.14	4.45
25/10/1998	1.10	0.98	1.0000	0.98	0.00	**0.12**	0.00	0.00	0.00	0.00	0.12
26/10/1998	12.90	0.74	1.0000	0.74	0.00	**12.16**	7.90	1.58	0.00	1.58	10.58
27/10/1998	5.10	1.01	1.0000	1.01	0.00	**4.09**	0.10	0.02	0.00	0.02	4.07
28/10/1998	3.00	1.15	1.0000	1.15	0.00	**1.85**	0.00	0.00	0.00	0.00	1.85
29/10/1998	0.80	0.74	1.0000	0.74	0.00	**0.06**	0.00	0.00	0.00	0.00	0.06
30/10/1998	2.20	0.88	1.0000	0.88	0.00	**1.32**	0.00	0.00	0.00	0.00	1.32
31/10/1998	0.90	0.30	1.0000	0.30	0.00	**0.60**	0.00	0.00	0.00	0.00	0.60
01/11/1998	9.10	0.63	1.0000	0.63	0.00	**8.47**	4.10	0.82	0.00	0.82	7.65
02/11/1998	13.50	0.67	1.0000	0.67	0.00	**12.83**	8.50	1.70	0.00	1.70	11.13
03/11/1998	0.00	0.54	1.0000	0.54	0.54	**0.00**	0.00	0.00	0.00	0.00	0.00
04/11/1998	0.10	0.50	1.0000	0.50	0.93	**0.00**	0.00	0.00	0.00	0.00	0.00
05/11/1998	0.00	1.00	1.0000	1.00	1.93	**0.00**	0.00	0.00	0.00	0.00	0.00
06/11/1998	0.00	0.66	1.0000	0.66	2.59	**0.00**	0.00	0.00	0.00	0.00	0.00
07/11/1998	8.80	1.27	1.0000	1.27	0.00	**4.93**	3.80	0.76	0.00	0.76	4.17
08/11/1998	7.10	0.77	1.0000	0.77	0.00	**6.33**	2.10	0.42	0.00	0.42	5.91
09/11/1998	7.60	1.24	1.0000	1.24	0.00	**6.36**	2.60	0.52	0.00	0.52	5.84
10/11/1998	0.00	0.61	1.0000	0.61	0.61	**0.00**	0.00	0.00	0.00	0.00	0.00
11/11/1998	6.50	0.69	1.0000	0.69	0.00	**5.20**	1.50	0.30	0.00	0.30	4.90
12/11/1998	0.30	0.78	1.0000	0.78	0.48	**0.00**	0.00	0.00	0.00	0.00	0.00
13/11/1998	5.40	0.56	1.0000	0.56	0.00	**4.36**	0.40	0.08	0.00	0.08	4.28
14/11/1998	0.00	0.25	1.0000	0.25	0.25	**0.00**	0.00	0.00	0.00	0.00	0.00
15/11/1998	0.00	0.22	1.0000	0.22	0.47	**0.00**	0.00	0.00	0.00	0.00	0.00
16/11/1998	0.60	0.28	1.0000	0.28	0.14	**0.00**	0.00	0.00	0.00	0.00	0.00
17/11/1998	6.20	0.55	1.0000	0.55	0.00	**5.51**	1.20	0.24	0.00	0.24	5.27
18/11/1998	0.00	0.35	1.0000	0.35	0.35	**0.00**	0.00	0.00	0.00	0.00	0.00

Date	Rainfall	PE	S.F.	AE	SMD	**Recharge**	Pot. Runoff	Runoff 1	Runoff 2	Runoff	Recharge
19/11/1998	0.90	0.59	1.0000	0.59	0.04	**0.00**	0.00	0.00	0.00	0.00	0.00
20/11/1998	0.00	0.59	1.0000	0.59	0.63	**0.00**	0.00	0.00	0.00	0.00	0.00
21/11/1998	8.00	1.27	1.0000	1.27	0.00	**6.10**	3.00	0.60	0.00	0.60	5.50
22/11/1998	0.20	0.32	1.0000	0.32	0.12	**0.00**	0.00	0.00	0.00	0.00	0.00
23/11/1998	8.00	0.43	1.0000	0.43	0.00	**7.45**	3.00	0.60	0.00	0.60	6.85
24/11/1998	0.20	0.19	1.0000	0.19	0.00	**0.01**	0.00	0.00	0.00	0.00	0.01
25/11/1998	0.20	0.41	1.0000	0.41	0.21	**0.00**	0.00	0.00	0.00	0.00	0.00
26/11/1998	2.50	0.49	1.0000	0.49	0.00	**1.80**	0.00	0.00	0.00	0.00	1.80
27/11/1998	5.70	0.46	1.0000	0.46	0.00	**5.24**	0.70	0.14	0.00	0.14	5.10
28/11/1998	0.00	0.29	1.0000	0.29	0.29	**0.00**	0.00	0.00	0.00	0.00	0.00
29/11/1998	0.30	0.13	1.0000	0.13	0.12	**0.00**	0.00	0.00	0.00	0.00	0.00
30/11/1998	0.10	0.03	1.0000	0.03	0.04	**0.00**	0.00	0.00	0.00	0.00	0.00
01/12/1998	0.60	0.00	1.0000	0.00	0.00	**0.56**	0.00	0.00	0.00	0.00	0.56
02/12/1998	0.70	0.24	1.0000	0.24	0.00	**0.46**	0.00	0.00	0.00	0.00	0.46
03/12/1998	1.10	0.18	1.0000	0.18	0.00	**0.92**	0.00	0.00	0.00	0.00	0.92
04/12/1998	0.00	0.13	1.0000	0.13	0.13	**0.00**	0.00	0.00	0.00	0.00	0.00
05/12/1998	0.30	0.18	1.0000	0.18	0.01	**0.00**	0.00	0.00	0.00	0.00	0.00
06/12/1998	0.00	0.35	1.0000	0.35	0.36	**0.00**	0.00	0.00	0.00	0.00	0.00
07/12/1998	3.60	0.96	1.0000	0.96	0.00	**2.28**	0.00	0.00	0.00	0.00	2.28
08/12/1998	1.00	0.49	1.0000	0.49	0.00	**0.51**	0.00	0.00	0.00	0.00	0.51
09/12/1998	11.40	0.67	1.0000	0.67	0.00	**10.73**	6.40	1.28	0.00	1.28	9.45
10/12/1998	1.40	0.43	1.0000	0.43	0.00	**0.97**	0.00	0.00	0.00	0.00	0.97
11/12/1998	4.40	0.52	1.0000	0.52	0.00	**3.88**	0.00	0.00	0.00	0.00	3.88
12/12/1998	1.80	0.63	1.0000	0.63	0.00	**1.17**	0.00	0.00	0.00	0.00	1.17
13/12/1998	9.40	0.90	1.0000	0.90	0.00	**8.50**	4.40	0.88	0.00	0.88	7.62
14/12/1998	4.20	0.70	1.0000	0.70	0.00	**3.50**	0.00	0.00	0.00	0.00	3.50
15/12/1998	0.00	0.50	1.0000	0.50	0.50	**0.00**	0.00	0.00	0.00	0.00	0.00
16/12/1998	0.00	1.04	1.0000	1.04	1.54	**0.00**	0.00	0.00	0.00	0.00	0.00
17/12/1998	4.60	0.60	1.0000	0.60	0.00	**2.45**	0.00	0.00	0.00	0.00	2.45
18/12/1998	2.40	0.51	1.0000	0.51	0.00	**1.89**	0.00	0.00	0.00	0.00	1.89
19/12/1998	0.00	0.23	1.0000	0.23	0.23	**0.00**	0.00	0.00	0.00	0.00	0.00
20/12/1998	0.00	0.00	1.0000	0.00	0.23	**0.00**	0.00	0.00	0.00	0.00	0.00
21/12/1998	2.20	0.35	1.0000	0.35	0.00	**1.62**	0.00	0.00	0.00	0.00	1.62
22/12/1998	2.70	0.14	1.0000	0.14	0.00	**2.56**	0.00	0.00	0.00	0.00	2.56
23/12/1998	2.10	0.31	1.0000	0.31	0.00	**1.79**	0.00	0.00	0.00	0.00	1.79
24/12/1998	4.50	0.56	1.0000	0.56	0.00	**3.94**	0.00	0.00	0.00	0.00	3.94
25/12/1998	2.40	0.59	1.0000	0.59	0.00	**1.81**	0.00	0.00	0.00	0.00	1.81
26/12/1998	14.90	1.17	1.0000	1.17	0.00	**13.73**	9.90	1.98	0.00	1.98	11.75
27/12/1998	1.30	0.85	1.0000	0.85	0.00	**0.45**	0.00	0.00	0.00	0.00	0.45
28/12/1998	0.30	0.56	1.0000	0.56	0.26	**0.00**	0.00	0.00	0.00	0.00	0.00
29/12/1998	13.90	0.78	1.0000	0.78	0.00	**12.86**	8.90	1.78	0.00	1.78	11.08
30/12/1998	1.20	0.55	1.0000	0.55	0.00	**0.65**	0.00	0.00	0.00	0.00	0.65
31/12/1998	4.40	0.66	1.0000	0.66	0.00	**3.74**	0.00	0.00	0.00	0.00	3.74
01/01/1999	5.80	0.83	1.0000	0.83	0.00	**4.97**	0.80	0.16	0.00	0.16	4.81
02/01/1999	10.40	0.94	1.0000	0.94	0.00	**9.46**	5.40	1.08	0.00	1.08	8.38
03/01/1999	7.40	0.51	1.0000	0.51	0.00	**6.89**	2.40	0.48	0.00	0.48	6.41
04/01/1999	8.90	1.01	1.0000	1.01	0.00	**7.89**	3.90	0.78	0.00	0.78	7.11
05/01/1999	0.80	0.48	1.0000	0.48	0.00	**0.32**	0.00	0.00	0.00	0.00	0.32
06/01/1999	0.40	0.33	1.0000	0.33	0.00	**0.07**	0.00	0.00	0.00	0.00	0.07
07/01/1999	5.10	0.48	1.0000	0.48	0.00	**4.62**	0.10	0.02	0.00	0.02	4.60
08/01/1999	0.00	0.19	1.0000	0.19	0.19	**0.00**	0.00	0.00	0.00	0.00	0.00
09/01/1999	0.00	0.12	1.0000	0.12	0.30	**0.00**	0.00	0.00	0.00	0.00	0.00
10/01/1999	0.00	0.00	1.0000	0.00	0.30	**0.00**	0.00	0.00	0.00	0.00	0.00
11/01/1999	13.50	0.03	1.0000	0.03	0.00	**13.17**	8.50	1.70	0.00	1.70	11.47
12/01/1999	4.30	0.31	1.0000	0.31	0.00	**3.99**	0.00	0.00	0.00	0.00	3.99
13/01/1999	0.90	0.54	1.0000	0.54	0.00	**0.36**	0.00	0.00	0.00	0.00	0.36
14/01/1999	7.10	0.54	1.0000	0.54	0.00	**6.56**	2.10	0.42	0.00	0.42	6.14
15/01/1999	15.20	0.72	1.0000	0.72	0.00	**14.48**	10.20	2.04	0.00	2.04	12.44
16/01/1999	0.00	0.57	1.0000	0.57	0.57	**0.00**	0.00	0.00	0.00	0.00	0.00
17/01/1999	0.40	0.70	1.0000	0.70	0.87	**0.00**	0.00	0.00	0.00	0.00	0.00
18/01/1999	3.90	0.84	1.0000	0.84	0.00	**2.20**	0.00	0.00	0.00	0.00	2.20
19/01/1999	5.30	0.69	1.0000	0.69	0.00	**4.61**	0.30	0.06	0.00	0.06	4.55
20/01/1999	0.00	0.23	1.0000	0.23	0.23	**0.00**	0.00	0.00	0.00	0.00	0.00
21/01/1999	0.00	0.38	1.0000	0.38	0.61	**0.00**	0.00	0.00	0.00	0.00	0.00
22/01/1999	0.60	0.71	1.0000	0.71	0.72	**0.00**	0.00	0.00	0.00	0.00	0.00
23/01/1999	0.80	0.71	1.0000	0.71	0.62	**0.00**	0.00	0.00	0.00	0.00	0.00
24/01/1999	1.30	0.74	1.0000	0.74	0.06	**0.00**	0.00	0.00	0.00	0.00	0.00
25/01/1999	3.30	0.52	1.0000	0.52	0.00	**2.72**	0.00	0.00	0.00	0.00	2.72
26/01/1999	2.40	0.32	1.0000	0.32	0.00	**2.08**	0.00	0.00	0.00	0.00	2.08
27/01/1999	3.20	0.36	1.0000	0.36	0.00	**2.84**	0.00	0.00	0.00	0.00	2.84
28/01/1999	3.20	0.36	1.0000	0.36	0.00	**2.84**	0.00	0.00	0.00	0.00	2.84
29/01/1999	0.90	0.21	1.0000	0.21	0.00	**0.69**	0.00	0.00	0.00	0.00	0.69
30/01/1999	0.20	0.28	1.0000	0.28	0.08	**0.00**	0.00	0.00	0.00	0.00	0.00
31/01/1999	0.00	0.44	1.0000	0.44	0.52	**0.00**	0.00	0.00	0.00	0.00	0.00
01/02/1999	0.00	0.38	1.0000	0.38	0.90	**0.00**	0.00	0.00	0.00	0.00	0.00
02/02/1999	0.00	0.76	1.0000	0.76	1.66	**0.00**	0.00	0.00	0.00	0.00	0.00
03/02/1999	0.20	0.70	1.0000	0.70	2.16	**0.00**	0.00	0.00	0.00	0.00	0.00
04/02/1999	0.10	0.74	1.0000	0.74	2.80	**0.00**	0.00	0.00	0.00	0.00	0.00

Date	Rainfall	PE	S.F.	AE	SMD	**Recharge**	Pot. Runoff	Runoff 1	Runoff 2	Runoff	Recharge
05/02/1999	0.30	0.88	1.0000	0.88	3.38	**0.00**	0.00	0.00	0.00	0.00	0.00
06/02/1999	5.10	0.45	1.0000	0.45	0.00	**1.27**	0.10	0.02	0.00	0.02	1.25
07/02/1999	5.40	0.46	1.0000	0.46	0.00	**4.94**	0.40	0.08	0.00	0.08	4.86
08/02/1999	0.60	0.45	1.0000	0.45	0.00	**0.15**	0.00	0.00	0.00	0.00	0.15
09/02/1999	0.00	0.37	1.0000	0.37	0.37	**0.00**	0.00	0.00	0.00	0.00	0.00
10/02/1999	0.00	0.35	1.0000	0.35	0.72	**0.00**	0.00	0.00	0.00	0.00	0.00
11/02/1999	0.00	0.59	1.0000	0.59	1.31	**0.00**	0.00	0.00	0.00	0.00	0.00
12/02/1999	0.30	0.57	1.0000	0.57	1.58	**0.00**	0.00	0.00	0.00	0.00	0.00
13/02/1999	0.70	0.58	1.0000	0.58	1.46	**0.00**	0.00	0.00	0.00	0.00	0.00
14/02/1999	0.80	0.38	1.0000	0.38	1.05	**0.00**	0.00	0.00	0.00	0.00	0.00
15/02/1999	0.10	0.47	1.0000	0.47	1.42	**0.00**	0.00	0.00	0.00	0.00	0.00
16/02/1999	0.60	0.38	1.0000	0.38	1.20	**0.00**	0.00	0.00	0.00	0.00	0.00
17/02/1999	0.70	0.44	1.0000	0.44	0.93	**0.00**	0.00	0.00	0.00	0.00	0.00
18/02/1999	1.90	0.39	1.0000	0.39	0.00	**0.57**	0.00	0.00	0.00	0.00	0.57
19/02/1999	0.00	0.56	1.0000	0.56	0.56	**0.00**	0.00	0.00	0.00	0.00	0.00
20/02/1999	5.00	0.77	1.0000	0.77	0.00	**3.67**	0.00	0.00	0.00	0.00	3.67
21/02/1999	4.00	0.64	1.0000	0.64	0.00	**3.36**	0.00	0.00	0.00	0.00	3.36
22/02/1999	0.00	1.05	1.0000	1.05	1.05	**0.00**	0.00	0.00	0.00	0.00	0.00
23/02/1999	4.40	0.43	1.0000	0.43	0.00	**2.92**	0.00	0.00	0.00	0.00	2.92
24/02/1999	0.00	0.47	1.0000	0.47	0.47	**0.00**	0.00	0.00	0.00	0.00	0.00
25/02/1999	0.90	1.06	1.0000	1.06	0.63	**0.00**	0.00	0.00	0.00	0.00	0.00
26/02/1999	1.00	1.00	1.0000	1.00	0.63	**0.00**	0.00	0.00	0.00	0.00	0.00
27/02/1999	0.30	1.21	1.0000	1.21	1.54	**0.00**	0.00	0.00	0.00	0.00	0.00
28/02/1999	8.70	0.69	1.0000	0.69	0.00	**6.47**	3.70	0.74	0.00	0.74	5.73
01/03/1999	12.00	0.90	1.0000	0.90	0.00	**11.10**	7.00	1.40	0.00	1.40	9.70
02/03/1999	11.70	0.67	1.0000	0.67	0.00	**11.03**	6.70	1.34	0.00	1.34	9.69
03/03/1999	4.70	0.73	1.0000	0.73	0.00	**3.97**	0.00	0.00	0.00	0.00	3.97
04/03/1999	0.00	0.85	1.0000	0.85	0.85	**0.00**	0.00	0.00	0.00	0.00	0.00
05/03/1999	0.80	1.07	1.0000	1.07	1.12	**0.00**	0.00	0.00	0.00	0.00	0.00
06/03/1999	0.30	0.84	1.0000	0.84	1.66	**0.00**	0.00	0.00	0.00	0.00	0.00
07/03/1999	0.00	0.74	1.0000	0.74	2.39	**0.00**	0.00	0.00	0.00	0.00	0.00
08/03/1999	0.20	0.92	1.0000	0.92	3.11	**0.00**	0.00	0.00	0.00	0.00	0.00
09/03/1999	0.10	0.86	1.0000	0.86	3.87	**0.00**	0.00	0.00	0.00	0.00	0.00
10/03/1999	0.00	0.69	1.0000	0.69	4.56	**0.00**	0.00	0.00	0.00	0.00	0.00
11/03/1999	1.50	0.50	1.0000	0.50	3.56	**0.00**	0.00	0.00	0.00	0.00	0.00
12/03/1999	1.00	0.97	1.0000	0.97	3.54	**0.00**	0.00	0.00	0.00	0.00	0.00
13/03/1999	0.00	1.51	1.0000	1.51	5.05	**0.00**	0.00	0.00	0.00	0.00	0.00
14/03/1999	0.00	1.50	1.0000	1.50	6.55	**0.00**	0.00	0.00	0.00	0.00	0.00
15/03/1999	0.00	1.57	1.0000	1.57	8.12	**0.00**	0.00	0.00	0.00	0.00	0.00
16/03/1999	0.00	1.79	1.0000	1.79	9.90	**0.00**	0.00	0.00	0.00	0.00	0.00
17/03/1999	0.10	1.77	1.0000	1.77	11.58	**0.00**	0.00	0.00	0.00	0.00	0.00
18/03/1999	0.00	1.19	1.0000	1.19	12.77	**0.00**	0.00	0.00	0.00	0.00	0.00
19/03/1999	0.00	1.42	1.0000	1.42	14.19	**0.00**	0.00	0.00	0.00	0.00	0.00
20/03/1999	3.80	1.07	1.0000	1.07	11.46	**0.00**	0.00	0.00	0.00	0.00	0.00
21/03/1999	0.00	1.50	1.0000	1.50	12.97	**0.00**	0.00	0.00	0.00	0.00	0.00
22/03/1999	1.60	0.66	1.0000	0.66	12.03	**0.00**	0.00	0.00	0.00	0.00	0.00
23/03/1999	0.60	1.29	1.0000	1.29	12.72	**0.00**	0.00	0.00	0.00	0.00	0.00
24/03/1999	0.00	1.32	1.0000	1.32	14.04	**0.00**	0.00	0.00	0.00	0.00	0.00
25/03/1999	0.00	1.22	1.0000	1.22	15.27	**0.00**	0.00	0.00	0.00	0.00	0.00
26/03/1999	0.00	1.47	1.0000	1.47	16.73	**0.00**	0.00	0.00	0.00	0.00	0.00
27/03/1999	0.20	1.24	1.0000	1.24	17.77	**0.00**	0.00	0.00	0.00	0.00	0.00
28/03/1999	16.20	0.88	1.0000	0.88	2.46	**0.00**	11.20	2.24	0.00	2.24	-2.24
29/03/1999	0.00	2.05	1.0000	2.05	4.51	**0.00**	0.00	0.00	0.00	0.00	0.00
30/03/1999	0.00	2.11	1.0000	2.11	6.61	**0.00**	0.00	0.00	0.00	0.00	0.00
31/03/1999	0.00	1.75	1.0000	1.75	8.37	**0.00**	0.00	0.00	0.00	0.00	0.00
01/04/1999	2.00	2.88	1.0000	2.88	9.25	**0.00**	0.00	0.00	0.00	0.00	0.00
02/04/1999	0.00	1.55	1.0000	1.55	10.79	**0.00**	0.00	0.00	0.00	0.00	0.00
03/04/1999	0.00	1.34	1.0000	1.34	12.13	**0.00**	0.00	0.00	0.00	0.00	0.00
04/04/1999	0.10	1.71	1.0000	1.71	13.74	**0.00**	0.00	0.00	0.00	0.00	0.00
05/04/1999	3.00	1.59	1.0000	1.59	12.33	**0.00**	0.00	0.00	0.00	0.00	0.00
06/04/1999	6.30	1.40	1.0000	1.40	7.43	**0.00**	1.30	0.26	0.00	0.26	-0.26
07/04/1999	1.70	1.31	1.0000	1.31	7.03	**0.00**	0.00	0.00	0.00	0.00	0.00
08/04/1999	0.00	1.07	1.0000	1.07	8.11	**0.00**	0.00	0.00	0.00	0.00	0.00
09/04/1999	0.20	2.57	1.0000	2.57	10.47	**0.00**	0.00	0.00	0.00	0.00	0.00
10/04/1999	0.10	1.45	1.0000	1.45	11.82	**0.00**	0.00	0.00	0.00	0.00	0.00
11/04/1999	8.90	1.24	1.0000	1.24	4.16	**0.00**	3.90	0.78	0.00	0.78	-0.78
12/04/1999	1.10	1.99	1.0000	1.99	5.05	**0.00**	0.00	0.00	0.00	0.00	0.00
13/04/1999	11.90	1.47	1.0000	1.47	0.00	**5.39**	6.90	1.38	0.00	1.38	4.01
14/04/1999	1.80	1.20	1.0000	1.20	0.00	**0.60**	0.00	0.00	0.00	0.00	0.60
15/04/1999	0.40	1.63	1.0000	1.63	1.23	**0.00**	0.00	0.00	0.00	0.00	0.00
16/04/1999	0.20	1.42	1.0000	1.42	2.45	**0.00**	0.00	0.00	0.00	0.00	0.00
17/04/1999	0.90	1.92	1.0000	1.92	3.47	**0.00**	0.00	0.00	0.00	0.00	0.00
18/04/1999	1.20	2.09	1.0000	2.09	4.36	**0.00**	0.00	0.00	0.00	0.00	0.00
19/04/1999	2.90	1.74	1.0000	1.74	3.20	**0.00**	0.00	0.00	0.00	0.00	0.00
20/04/1999	4.50	1.72	1.0000	1.72	0.42	**0.00**	0.00	0.00	0.00	0.00	0.00
21/04/1999	3.70	1.64	1.0000	1.64	0.00	**1.64**	0.00	0.00	0.00	0.00	1.64
22/04/1999	1.60	2.39	1.0000	2.39	0.79	**0.00**	0.00	0.00	0.00	0.00	0.00
23/04/1999	1.90	1.95	1.0000	1.95	0.85	**0.00**	0.00	0.00	0.00	0.00	0.00

Date	Rainfall	PE	S.F.	AE	SMD	**Recharge**	Pot. Runoff	Runoff 1	Runoff 2	Runoff	Recharge
24/04/1999	0.20	2.53	1.0000	2.53	3.18	**0.00**	0.00	0.00	0.00	0.00	0.00
25/04/1999	4.50	1.00	1.0000	1.00	0.00	**0.32**	0.00	0.00	0.00	0.00	0.32
26/04/1999	0.00	1.14	1.0000	1.14	1.14	**0.00**	0.00	0.00	0.00	0.00	0.00
27/04/1999	0.00	2.51	1.0000	2.51	3.65	**0.00**	0.00	0.00	0.00	0.00	0.00
28/04/1999	0.00	2.98	1.0000	2.98	6.63	**0.00**	0.00	0.00	0.00	0.00	0.00
29/04/1999	0.00	2.68	1.0000	2.68	9.31	**0.00**	0.00	0.00	0.00	0.00	0.00
30/04/1999	0.00	1.77	1.0000	1.77	11.08	**0.00**	0.00	0.00	0.00	0.00	0.00
01/05/1999	0.00	2.38	1.0000	2.38	13.46	**0.00**	0.00	0.00	0.00	0.00	0.00
02/05/1999	0.00	1.60	1.0000	1.60	15.06	**0.00**	0.00	0.00	0.00	0.00	0.00
03/05/1999	0.00	2.84	1.0000	2.84	17.90	**0.00**	0.00	0.00	0.00	0.00	0.00
04/05/1999	0.00	2.57	1.0000	2.57	20.47	**0.00**	0.00	0.00	0.00	0.00	0.00
05/05/1999	0.50	2.09	1.0000	2.09	22.06	**0.00**	0.00	0.00	0.00	0.00	0.00
06/05/1999	0.40	1.74	1.0000	1.74	23.40	**0.00**	0.00	0.00	0.00	0.00	0.00
07/05/1999	0.00	2.15	1.0000	2.15	25.55	**0.00**	0.00	0.00	0.00	0.00	0.00
08/05/1999	1.40	2.00	1.0000	2.00	26.14	**0.00**	0.00	0.00	0.00	0.00	0.00
09/05/1999	5.30	2.02	1.0000	2.02	22.86	**0.00**	0.30	0.06	0.00	0.06	-0.06
10/05/1999	0.70	2.77	1.0000	2.77	24.93	**0.00**	0.00	0.00	0.00	0.00	0.00
11/05/1999	10.30	2.93	1.0000	2.93	17.56	**0.00**	5.30	1.06	0.00	1.06	-1.06
12/05/1999	9.70	2.25	1.0000	2.25	10.11	**0.00**	4.70	0.94	0.00	0.94	-0.94
13/05/1999	11.20	1.78	1.0000	1.78	0.69	**0.00**	6.20	1.24	0.00	1.24	-1.24
14/05/1999	5.60	1.64	1.0000	1.64	0.00	**3.27**	0.60	0.12	0.00	0.12	3.15
15/05/1999	0.00	2.01	1.0000	2.01	2.01	**0.00**	0.00	0.00	0.00	0.00	0.00
16/05/1999	0.00	1.76	1.0000	1.76	3.77	**0.00**	0.00	0.00	0.00	0.00	0.00
17/05/1999	0.00	2.30	1.0000	2.30	6.08	**0.00**	0.00	0.00	0.00	0.00	0.00
18/05/1999	0.00	3.26	1.0000	3.26	9.34	**0.00**	0.00	0.00	0.00	0.00	0.00
19/05/1999	0.00	2.82	1.0000	2.82	12.17	**0.00**	0.00	0.00	0.00	0.00	0.00
20/05/1999	1.50	3.60	1.0000	3.60	14.27	**0.00**	0.00	0.00	0.00	0.00	0.00
21/05/1999	1.40	2.17	1.0000	2.17	15.04	**0.00**	0.00	0.00	0.00	0.00	0.00
22/05/1999	0.00	2.25	1.0000	2.25	17.29	**0.00**	0.00	0.00	0.00	0.00	0.00
23/05/1999	2.20	2.44	1.0000	2.44	17.54	**0.00**	0.00	0.00	0.00	0.00	0.00
24/05/1999	1.20	2.63	1.0000	2.63	18.97	**0.00**	0.00	0.00	0.00	0.00	0.00
25/05/1999	0.00	2.75	1.0000	2.75	21.72	**0.00**	0.00	0.00	0.00	0.00	0.00
26/05/1999	0.00	2.97	1.0000	2.97	24.69	**0.00**	0.00	0.00	0.00	0.00	0.00
27/05/1999	19.10	3.07	1.0000	3.07	8.65	**0.00**	14.10	2.82	0.00	2.82	-2.82
28/05/1999	3.10	1.76	1.0000	1.76	7.32	**0.00**	0.00	0.00	0.00	0.00	0.00
29/05/1999	0.00	2.38	1.0000	2.38	9.70	**0.00**	0.00	0.00	0.00	0.00	0.00
30/05/1999	0.00	1.10	1.0000	1.10	10.80	**0.00**	0.00	0.00	0.00	0.00	0.00
31/05/1999	0.00	1.89	1.0000	1.89	12.69	**0.00**	0.00	0.00	0.00	0.00	0.00
01/06/1999	0.30	2.40	1.0000	2.40	14.79	**0.00**	0.00	0.00	0.00	0.00	0.00
02/06/1999	13.00	0.65	1.0000	0.65	2.43	**0.00**	8.00	1.60	0.00	1.60	-1.60
03/06/1999	2.10	2.11	1.0000	2.11	2.45	**0.00**	0.00	0.00	0.00	0.00	0.00
04/06/1999	5.00	2.00	1.0000	2.00	0.00	**0.55**	0.00	0.00	0.00	0.00	0.55
05/06/1999	1.10	3.07	1.0000	3.07	1.97	**0.00**	0.00	0.00	0.00	0.00	0.00
06/06/1999	0.30	1.87	1.0000	1.87	3.54	**0.00**	0.00	0.00	0.00	0.00	0.00
07/06/1999	0.00	2.18	1.0000	2.18	5.72	**0.00**	0.00	0.00	0.00	0.00	0.00
08/06/1999	0.00	2.81	1.0000	2.81	8.54	**0.00**	0.00	0.00	0.00	0.00	0.00
09/06/1999	0.00	2.42	1.0000	2.42	10.96	**0.00**	0.00	0.00	0.00	0.00	0.00
10/06/1999	0.00	2.19	1.0000	2.19	13.15	**0.00**	0.00	0.00	0.00	0.00	0.00
11/06/1999	0.00	1.86	1.0000	1.86	15.02	**0.00**	0.00	0.00	0.00	0.00	0.00
12/06/1999	0.00	2.76	1.0000	2.76	17.78	**0.00**	0.00	0.00	0.00	0.00	0.00
13/06/1999	2.60	1.71	1.0000	1.71	16.89	**0.00**	0.00	0.00	0.00	0.00	0.00
14/06/1999	0.00	3.05	1.0000	3.05	19.94	**0.00**	0.00	0.00	0.00	0.00	0.00
15/06/1999	0.00	2.09	1.0000	2.09	22.03	**0.00**	0.00	0.00	0.00	0.00	0.00
16/06/1999	0.50	3.56	1.0000	3.56	25.08	**0.00**	0.00	0.00	0.00	0.00	0.00
17/06/1999	0.00	3.62	1.0000	3.62	28.71	**0.00**	0.00	0.00	0.00	0.00	0.00
18/06/1999	0.00	1.91	1.0000	1.91	30.62	**0.00**	0.00	0.00	0.00	0.00	0.00
19/06/1999	6.00	1.67	1.0000	1.67	26.29	**0.00**	1.00	0.20	0.00	0.20	-0.20
20/06/1999	0.50	2.58	1.0000	2.58	28.38	**0.00**	0.00	0.00	0.00	0.00	0.00
21/06/1999	0.00	2.98	1.0000	2.98	31.36	**0.00**	0.00	0.00	0.00	0.00	0.00
22/06/1999	1.10	2.04	1.0000	2.04	32.30	**0.00**	0.00	0.00	0.00	0.00	0.00
23/06/1999	0.00	2.16	1.0000	2.16	34.46	**0.00**	0.00	0.00	0.00	0.00	0.00
24/06/1999	0.00	3.86	1.0000	3.86	38.33	**0.00**	0.00	0.00	0.00	0.00	0.00
25/06/1999	0.00	4.51	1.0000	4.51	42.83	**0.00**	0.00	0.00	0.00	0.00	0.00
26/06/1999	4.20	1.87	1.0000	1.87	40.50	**0.00**	0.00	0.00	0.00	0.00	0.00
27/06/1999	2.10	2.60	1.0000	2.60	41.01	**0.00**	0.00	0.00	0.00	0.00	0.00
28/06/1999	4.30	2.49	1.0000	2.49	39.20	**0.00**	0.00	0.00	0.00	0.00	0.00
29/06/1999	0.00	2.74	1.0000	2.74	41.94	**0.00**	0.00	0.00	0.00	0.00	0.00
30/06/1999	12.00	2.87	1.0000	2.87	32.80	**0.00**	7.00	1.40	0.00	1.40	-1.40
01/07/1999	4.20	1.48	1.0000	1.48	30.08	**0.00**	0.00	0.00	0.00	0.00	0.00
02/07/1999	0.00	2.94	1.0000	2.94	33.02	**0.00**	0.00	0.00	0.00	0.00	0.00
03/07/1999	0.00	3.30	1.0000	3.30	36.32	**0.00**	0.00	0.00	0.00	0.00	0.00
04/07/1999	0.00	3.38	1.0000	3.38	39.70	**0.00**	0.00	0.00	0.00	0.00	0.00
05/07/1999	2.40	2.78	1.0000	2.78	40.08	**0.00**	0.00	0.00	0.00	0.00	0.00
06/07/1999	0.00	2.38	1.0000	2.38	42.47	**0.00**	0.00	0.00	0.00	0.00	0.00
07/07/1999	0.00	2.43	1.0000	2.43	44.90	**0.00**	0.00	0.00	0.00	0.00	0.00
08/07/1999	0.00	4.16	1.0000	4.16	49.06	**0.00**	0.00	0.00	0.00	0.00	0.00
09/07/1999	0.00	4.38	1.0000	4.38	53.44	**0.00**	0.00	0.00	0.00	0.00	0.00
10/07/1999	0.00	2.91	1.0000	2.91	56.35	**0.00**	0.00	0.00	0.00	0.00	0.00

Date	Rainfall	PE	S.F.	AE	SMD	**Recharge**	Pot. Runoff	Runoff 1	Runoff 2	Runoff	Recharge
11/07/1999	0.00	3.62	1.0000	3.62	59.97	**0.00**	0.00	0.00	0.00	0.00	0.00
12/07/1999	1.10	4.06	1.0000	4.06	62.93	**0.00**	0.00	0.00	0.00	0.00	0.00
13/07/1999	0.40	2.62	1.0000	2.62	65.16	**0.00**	0.00	0.00	0.00	0.00	0.00
14/07/1999	0.00	3.77	1.0000	3.77	68.93	**0.00**	0.00	0.00	0.00	0.00	0.00
15/07/1999	0.10	3.44	1.0000	3.44	72.27	**0.00**	0.00	0.00	0.00	0.00	0.00
16/07/1999	0.00	2.96	1.0000	2.96	75.23	**0.00**	0.00	0.00	0.00	0.00	0.00
17/07/1999	16.20	2.57	0.9768	2.51	61.54	**0.00**	11.20	2.24	0.00	2.24	-2.24
18/07/1999	1.10	1.40	1.0000	1.40	61.84	**0.00**	0.00	0.00	0.00	0.00	0.00
19/07/1999	6.50	1.48	1.0000	1.48	56.82	**0.00**	1.50	0.30	0.00	0.30	-0.30
20/07/1999	0.00	2.14	1.0000	2.14	58.95	**0.00**	0.00	0.00	0.00	0.00	0.00
21/07/1999	0.00	2.59	1.0000	2.59	61.55	**0.00**	0.00	0.00	0.00	0.00	0.00
22/07/1999	0.00	3.25	1.0000	3.25	64.80	**0.00**	0.00	0.00	0.00	0.00	0.00
23/07/1999	0.00	2.09	1.0000	2.09	66.89	**0.00**	0.00	0.00	0.00	0.00	0.00
24/07/1999	0.00	3.72	1.0000	3.72	70.61	**0.00**	0.00	0.00	0.00	0.00	0.00
25/07/1999	0.00	2.35	1.0000	2.35	72.96	**0.00**	0.00	0.00	0.00	0.00	0.00
26/07/1999	0.00	3.58	1.0000	3.58	76.54	**0.00**	0.00	0.00	0.00	0.00	0.00
27/07/1999	0.00	3.03	0.9522	2.88	79.42	**0.00**	0.00	0.00	0.00	0.00	0.00
28/07/1999	0.00	3.24	0.8978	2.91	82.33	**0.00**	0.00	0.00	0.00	0.00	0.00
29/07/1999	0.00	3.70	0.8429	3.12	85.44	**0.00**	0.00	0.00	0.00	0.00	0.00
30/07/1999	0.00	3.39	0.7841	2.66	88.10	**0.00**	0.00	0.00	0.00	0.00	0.00
31/07/1999	0.00	3.58	0.7340	2.62	90.73	**0.00**	0.00	0.00	0.00	0.00	0.00
01/08/1999	1.30	3.64	0.6844	2.49	91.92	**0.00**	0.00	0.00	0.00	0.00	0.00
02/08/1999	1.50	2.27	0.6619	1.50	91.92	**0.00**	0.00	0.00	0.00	0.00	0.00
03/08/1999	0.00	2.76	0.6618	1.83	93.75	**0.00**	0.00	0.00	0.00	0.00	0.00
04/08/1999	25.50	1.67	0.6273	1.05	69.30	**0.00**	20.50	0.00	6.15	6.15	-6.15
05/08/1999	0.10	2.04	1.0000	2.04	71.24	**0.00**	0.00	0.00	0.00	0.00	0.00
06/08/1999	7.30	2.24	1.0000	2.24	66.18	**0.00**	2.30	0.46	0.00	0.46	-0.46
07/08/1999	0.10	2.00	1.0000	2.00	68.08	**0.00**	0.00	0.00	0.00	0.00	0.00
08/08/1999	1.70	1.04	1.0000	1.04	67.41	**0.00**	0.00	0.00	0.00	0.00	0.00
09/08/1999	0.40	1.16	1.0000	1.16	68.18	**0.00**	0.00	0.00	0.00	0.00	0.00
10/08/1999	0.00	3.17	1.0000	3.17	71.34	**0.00**	0.00	0.00	0.00	0.00	0.00
11/08/1999	0.00	2.29	1.0000	2.29	73.63	**0.00**	0.00	0.00	0.00	0.00	0.00
12/08/1999	0.90	2.59	1.0000	2.59	75.31	**0.00**	0.00	0.00	0.00	0.00	0.00
13/08/1999	1.70	2.04	0.9752	1.99	75.60	**0.00**	0.00	0.00	0.00	0.00	0.00
14/08/1999	2.90	2.22	0.9698	2.16	74.86	**0.00**	0.00	0.00	0.00	0.00	0.00
15/08/1999	0.00	2.79	0.9838	2.75	77.61	**0.00**	0.00	0.00	0.00	0.00	0.00
16/08/1999	6.30	2.77	0.9319	2.58	73.89	**0.00**	1.30	0.26	0.00	0.26	-0.26
17/08/1999	4.40	2.36	1.0000	2.36	71.85	**0.00**	0.00	0.00	0.00	0.00	0.00
18/08/1999	5.00	1.53	1.0000	1.53	68.38	**0.00**	0.00	0.00	0.00	0.00	0.00
19/08/1999	0.00	2.15	1.0000	2.15	70.53	**0.00**	0.00	0.00	0.00	0.00	0.00
20/08/1999	0.00	2.14	1.0000	2.14	72.67	**0.00**	0.00	0.00	0.00	0.00	0.00
21/08/1999	0.00	2.77	1.0000	2.77	75.44	**0.00**	0.00	0.00	0.00	0.00	0.00
22/08/1999	1.60	2.11	0.9729	2.05	75.89	**0.00**	0.00	0.00	0.00	0.00	0.00
23/08/1999	1.70	1.48	0.9643	1.42	75.61	**0.00**	0.00	0.00	0.00	0.00	0.00
24/08/1999	7.20	1.33	0.9696	1.29	69.70	**0.00**	2.20	0.44	0.00	0.44	-0.44
25/08/1999	0.00	1.69	1.0000	1.69	71.39	**0.00**	0.00	0.00	0.00	0.00	0.00
26/08/1999	2.90	1.71	1.0000	1.71	70.20	**0.00**	0.00	0.00	0.00	0.00	0.00
27/08/1999	0.00	2.27	1.0000	2.27	72.47	**0.00**	0.00	0.00	0.00	0.00	0.00
28/08/1999	0.00	2.04	1.0000	2.04	74.51	**0.00**	0.00	0.00	0.00	0.00	0.00
29/08/1999	2.40	1.66	0.9904	1.65	73.76	**0.00**	0.00	0.00	0.00	0.00	0.00
30/08/1999	0.00	1.56	1.0000	1.56	75.31	**0.00**	0.00	0.00	0.00	0.00	0.00
31/08/1999	0.00	1.91	0.9752	1.86	77.17	**0.00**	0.00	0.00	0.00	0.00	0.00
01/09/1999	0.10	2.03	0.9401	1.91	78.98	**0.00**	0.00	0.00	0.00	0.00	0.00
02/09/1999	0.00	1.49	0.9060	1.35	80.33	**0.00**	0.00	0.00	0.00	0.00	0.00
03/09/1999	0.00	2.29	0.8805	2.01	82.35	**0.00**	0.00	0.00	0.00	0.00	0.00
04/09/1999	0.00	1.66	0.8425	1.40	83.74	**0.00**	0.00	0.00	0.00	0.00	0.00
05/09/1999	0.10	2.54	0.8162	2.07	85.71	**0.00**	0.00	0.00	0.00	0.00	0.00
06/09/1999	16.90	1.69	0.7790	1.31	70.13	**0.00**	11.90	2.38	0.00	2.38	-2.38
07/09/1999	0.80	2.26	1.0000	2.26	71.59	**0.00**	0.00	0.00	0.00	0.00	0.00
08/09/1999	14.90	1.79	1.0000	1.79	58.47	**0.00**	9.90	1.98	0.00	1.98	-1.98
09/09/1999	0.00	2.76	1.0000	2.76	61.23	**0.00**	0.00	0.00	0.00	0.00	0.00
10/09/1999	23.10	2.12	1.0000	2.12	40.25	**0.00**	18.10	0.00	5.43	5.43	-5.43
11/09/1999	8.90	1.01	1.0000	1.01	32.36	**0.00**	3.90	0.78	0.00	0.78	-0.78
12/09/1999	3.80	1.21	1.0000	1.21	29.77	**0.00**	0.00	0.00	0.00	0.00	0.00
13/09/1999	0.40	1.68	1.0000	1.68	31.04	**0.00**	0.00	0.00	0.00	0.00	0.00
14/09/1999	0.00	1.81	1.0000	1.81	32.85	**0.00**	0.00	0.00	0.00	0.00	0.00
15/09/1999	7.60	1.33	1.0000	1.33	26.58	**0.00**	2.60	0.52	0.00	0.52	-0.52
16/09/1999	7.10	1.78	1.0000	1.78	21.25	**0.00**	2.10	0.42	0.00	0.42	-0.42
17/09/1999	0.90	2.22	1.0000	2.22	22.57	**0.00**	0.00	0.00	0.00	0.00	0.00
18/09/1999	11.50	1.65	1.0000	1.65	12.72	**0.00**	6.50	1.30	0.00	1.30	-1.30
19/09/1999	0.20	1.45	1.0000	1.45	13.97	**0.00**	0.00	0.00	0.00	0.00	0.00
20/09/1999	62.90	0.40	1.0000	0.40	0.00	**48.53**	57.90	0.00	17.37	17.37	31.16
21/09/1999	0.00	1.89	1.0000	1.89	1.89	**0.00**	0.00	0.00	0.00	0.00	0.00
22/09/1999	4.10	0.95	1.0000	0.95	0.00	**1.26**	0.00	0.00	0.00	0.00	1.26
23/09/1999	1.10	1.96	1.0000	1.96	0.86	**0.00**	0.00	0.00	0.00	0.00	0.00
24/09/1999	0.20	1.60	1.0000	1.60	2.25	**0.00**	0.00	0.00	0.00	0.00	0.00
25/09/1999	2.40	0.79	1.0000	0.79	0.64	**0.00**	0.00	0.00	0.00	0.00	0.00
26/09/1999	0.50	1.25	1.0000	1.25	1.39	**0.00**	0.00	0.00	0.00	0.00	0.00

Date	Rainfall	PE	S.F.	AE	SMD	**Recharge**	Pot. Runoff	Runoff 1	Runoff 2	Runoff	Recharge
27/09/1999	3.20	0.83	1.0000	0.83	0.00	**0.98**	0.00	0.00	0.00	0.00	0.98
28/09/1999	0.90	0.78	1.0000	0.78	0.00	**0.12**	0.00	0.00	0.00	0.00	0.12
29/09/1999	1.30	1.46	1.0000	1.46	0.16	**0.00**	0.00	0.00	0.00	0.00	0.00
30/09/1999	5.30	0.89	1.0000	0.89	0.00	**4.24**	0.30	0.06	0.00	0.06	4.18
01/10/1999	15.30	0.78	1.0000	0.78	0.00	**14.52**	10.30	2.06	0.00	2.06	12.46
02/10/1999	1.60	1.25	1.0000	1.25	0.00	**0.35**	0.00	0.00	0.00	0.00	0.35
03/10/1999	0.00	1.38	1.0000	1.38	1.38	**0.00**	0.00	0.00	0.00	0.00	0.00
04/10/1999	0.00	1.20	1.0000	1.20	2.58	**0.00**	0.00	0.00	0.00	0.00	0.00
05/10/1999	0.00	0.95	1.0000	0.95	3.54	**0.00**	0.00	0.00	0.00	0.00	0.00
06/10/1999	1.60	1.22	1.0000	1.22	3.16	**0.00**	0.00	0.00	0.00	0.00	0.00
07/10/1999	5.40	0.72	1.0000	0.72	0.00	**1.52**	0.40	0.08	0.00	0.08	1.44
08/10/1999	0.00	0.84	1.0000	0.84	0.84	**0.00**	0.00	0.00	0.00	0.00	0.00
09/10/1999	2.30	0.94	1.0000	0.94	0.00	**0.52**	0.00	0.00	0.00	0.00	0.52
10/10/1999	0.30	0.76	1.0000	0.76	0.46	**0.00**	0.00	0.00	0.00	0.00	0.00
11/10/1999	0.00	1.26	1.0000	1.26	1.72	**0.00**	0.00	0.00	0.00	0.00	0.00
12/10/1999	0.00	1.08	1.0000	1.08	2.79	**0.00**	0.00	0.00	0.00	0.00	0.00
13/10/1999	0.00	0.90	1.0000	0.90	3.70	**0.00**	0.00	0.00	0.00	0.00	0.00
14/10/1999	0.00	0.87	1.0000	0.87	4.56	**0.00**	0.00	0.00	0.00	0.00	0.00
15/10/1999	0.30	0.96	1.0000	0.96	5.22	**0.00**	0.00	0.00	0.00	0.00	0.00
16/10/1999	0.00	0.76	1.0000	0.76	5.98	**0.00**	0.00	0.00	0.00	0.00	0.00
17/10/1999	0.00	0.85	1.0000	0.85	6.83	**0.00**	0.00	0.00	0.00	0.00	0.00
18/10/1999	0.00	1.20	1.0000	1.20	8.03	**0.00**	0.00	0.00	0.00	0.00	0.00
19/10/1999	0.00	1.39	1.0000	1.39	9.42	**0.00**	0.00	0.00	0.00	0.00	0.00
20/10/1999	0.00	1.19	1.0000	1.19	10.61	**0.00**	0.00	0.00	0.00	0.00	0.00
21/10/1999	1.20	0.58	1.0000	0.58	9.99	**0.00**	0.00	0.00	0.00	0.00	0.00
22/10/1999	6.90	0.85	1.0000	0.85	3.93	**0.00**	1.90	0.38	0.00	0.38	-0.38
23/10/1999	1.30	0.82	1.0000	0.82	3.45	**0.00**	0.00	0.00	0.00	0.00	0.00
24/10/1999	0.00	0.51	1.0000	0.51	3.96	**0.00**	0.00	0.00	0.00	0.00	0.00
25/10/1999	0.00	0.62	1.0000	0.62	4.58	**0.00**	0.00	0.00	0.00	0.00	0.00
26/10/1999	0.00	0.64	1.0000	0.64	5.22	**0.00**	0.00	0.00	0.00	0.00	0.00
27/10/1999	0.00	0.97	1.0000	0.97	6.19	**0.00**	0.00	0.00	0.00	0.00	0.00
28/10/1999	0.00	0.54	1.0000	0.54	6.72	**0.00**	0.00	0.00	0.00	0.00	0.00
29/10/1999	0.60	0.70	1.0000	0.70	6.83	**0.00**	0.00	0.00	0.00	0.00	0.00
30/10/1999	7.80	1.34	1.0000	1.34	0.37	**0.00**	2.80	0.56	0.00	0.56	-0.56
31/10/1999	7.30	1.11	1.0000	1.11	0.00	**5.82**	2.30	0.46	0.00	0.46	5.36
01/11/1999	3.50	0.62	1.0000	0.62	0.00	**2.88**	0.00	0.00	0.00	0.00	2.88
02/11/1999	0.80	0.43	1.0000	0.43	0.00	**0.37**	0.00	0.00	0.00	0.00	0.37
03/11/1999	0.10	0.81	1.0000	0.81	0.71	**0.00**	0.00	0.00	0.00	0.00	0.00
04/11/1999	20.50	1.13	1.0000	1.13	0.00	**18.66**	15.50	0.00	4.65	4.65	14.01
05/11/1999	3.50	0.44	1.0000	0.44	0.00	**3.06**	0.00	0.00	0.00	0.00	3.06
06/11/1999	0.00	0.57	1.0000	0.57	0.57	**0.00**	0.00	0.00	0.00	0.00	0.00
07/11/1999	0.80	0.66	1.0000	0.66	0.44	**0.00**	0.00	0.00	0.00	0.00	0.00
08/11/1999	0.60	0.33	1.0000	0.33	0.17	**0.00**	0.00	0.00	0.00	0.00	0.00
09/11/1999	0.00	0.22	1.0000	0.22	0.39	**0.00**	0.00	0.00	0.00	0.00	0.00
10/11/1999	0.00	0.36	1.0000	0.36	0.75	**0.00**	0.00	0.00	0.00	0.00	0.00
11/11/1999	0.00	0.46	1.0000	0.46	1.21	**0.00**	0.00	0.00	0.00	0.00	0.00
12/11/1999	1.20	0.43	1.0000	0.43	0.44	**0.00**	0.00	0.00	0.00	0.00	0.00
13/11/1999	0.10	0.42	1.0000	0.42	0.76	**0.00**	0.00	0.00	0.00	0.00	0.00
14/11/1999	0.00	0.31	1.0000	0.31	1.07	**0.00**	0.00	0.00	0.00	0.00	0.00
15/11/1999	0.80	0.22	1.0000	0.22	0.49	**0.00**	0.00	0.00	0.00	0.00	0.00
16/11/1999	0.20	0.46	1.0000	0.46	0.75	**0.00**	0.00	0.00	0.00	0.00	0.00
17/11/1999	7.50	0.32	1.0000	0.32	0.00	**6.43**	2.50	0.50	0.00	0.50	5.93
18/11/1999	0.00	0.03	1.0000	0.03	0.03	**0.00**	0.00	0.00	0.00	0.00	0.00
19/11/1999	0.00	0.18	1.0000	0.18	0.21	**0.00**	0.00	0.00	0.00	0.00	0.00
20/11/1999	0.00	0.05	1.0000	0.05	0.26	**0.00**	0.00	0.00	0.00	0.00	0.00
21/11/1999	0.70	0.00	1.0000	0.00	0.00	**0.44**	0.00	0.00	0.00	0.00	0.44
22/11/1999	0.50	0.25	1.0000	0.25	0.00	**0.25**	0.00	0.00	0.00	0.00	0.25
23/11/1999	5.00	0.69	1.0000	0.69	0.00	**4.31**	0.00	0.00	0.00	0.00	4.31
24/11/1999	0.00	0.43	1.0000	0.43	0.43	**0.00**	0.00	0.00	0.00	0.00	0.00
25/11/1999	1.20	0.71	1.0000	0.71	0.00	**0.05**	0.00	0.00	0.00	0.00	0.05
26/11/1999	9.10	0.84	1.0000	0.84	0.00	**8.26**	4.10	0.82	0.00	0.82	7.44
27/11/1999	6.70	0.74	1.0000	0.74	0.00	**5.96**	1.70	0.34	0.00	0.34	5.62
28/11/1999	2.10	0.97	1.0000	0.97	0.00	**1.13**	0.00	0.00	0.00	0.00	1.13
29/11/1999	0.10	0.48	1.0000	0.48	0.38	**0.00**	0.00	0.00	0.00	0.00	0.00
30/11/1999	2.40	0.73	1.0000	0.73	0.00	**1.30**	0.00	0.00	0.00	0.00	1.30
01/12/1999	0.00	0.43	1.0000	0.43	0.43	**0.00**	0.00	0.00	0.00	0.00	0.00
02/12/1999	5.80	0.53	1.0000	0.53	0.00	**4.84**	0.80	0.16	0.00	0.16	4.68
03/12/1999	0.00	0.40	1.0000	0.40	0.40	**0.00**	0.00	0.00	0.00	0.00	0.00
04/12/1999	0.00	0.39	1.0000	0.39	0.79	**0.00**	0.00	0.00	0.00	0.00	0.00
05/12/1999	1.10	0.33	1.0000	0.33	0.02	**0.00**	0.00	0.00	0.00	0.00	0.00
06/12/1999	6.10	0.42	1.0000	0.42	0.00	**5.66**	1.10	0.22	0.00	0.22	5.44
07/12/1999	4.80	0.42	1.0000	0.42	0.00	**4.38**	0.00	0.00	0.00	0.00	4.38
08/12/1999	3.10	0.79	1.0000	0.79	0.00	**2.31**	0.00	0.00	0.00	0.00	2.31
09/12/1999	1.50	0.49	1.0000	0.49	0.00	**1.01**	0.00	0.00	0.00	0.00	1.01
10/12/1999	10.90	0.37	1.0000	0.37	0.00	**10.53**	5.90	1.18	0.00	1.18	9.35
11/12/1999	0.80	0.27	1.0000	0.27	0.00	**0.53**	0.00	0.00	0.00	0.00	0.53
12/12/1999	0.00	0.40	1.0000	0.40	0.40	**0.00**	0.00	0.00	0.00	0.00	0.00
13/12/1999	0.00	0.13	1.0000	0.13	0.52	**0.00**	0.00	0.00	0.00	0.00	0.00

Date	Rainfall	PE	S.F.	AE	SMD	**Recharge**	Pot. Runoff	Runoff 1	Runoff 2	Runoff	Recharge
14/12/1999	0.00	0.30	1.0000	0.30	0.82	**0.00**	0.00	0.00	0.00	0.00	0.00
15/12/1999	0.00	0.23	1.0000	0.23	1.06	**0.00**	0.00	0.00	0.00	0.00	0.00
16/12/1999	7.80	0.35	1.0000	0.35	0.00	**6.39**	2.80	0.56	0.00	0.56	5.83
17/12/1999	1.00	0.32	1.0000	0.32	0.00	**0.68**	0.00	0.00	0.00	0.00	0.68
18/12/1999	0.30	0.35	1.0000	0.35	0.05	**0.00**	0.00	0.00	0.00	0.00	0.00
19/12/1999	0.00	0.18	1.0000	0.18	0.23	**0.00**	0.00	0.00	0.00	0.00	0.00
20/12/1999	5.60	0.61	1.0000	0.61	0.00	**4.76**	0.60	0.12	0.00	0.12	4.64
21/12/1999	3.30	0.33	1.0000	0.33	0.00	**2.97**	0.00	0.00	0.00	0.00	2.97
22/12/1999	5.60	0.77	1.0000	0.77	0.00	**4.83**	0.60	0.12	0.00	0.12	4.71
23/12/1999	7.00	0.82	1.0000	0.82	0.00	**6.18**	2.00	0.40	0.00	0.40	5.78
24/12/1999	11.60	0.86	1.0000	0.86	0.00	**10.74**	6.60	1.32	0.00	1.32	9.42
25/12/1999	1.90	0.51	1.0000	0.51	0.00	**1.39**	0.00	0.00	0.00	0.00	1.39
26/12/1999	0.10	0.36	1.0000	0.36	0.26	**0.00**	0.00	0.00	0.00	0.00	0.00
27/12/1999	0.00	0.30	1.0000	0.30	0.56	**0.00**	0.00	0.00	0.00	0.00	0.00
28/12/1999	0.00	0.16	1.0000	0.16	0.72	**0.00**	0.00	0.00	0.00	0.00	0.00
29/12/1999	12.90	0.13	1.0000	0.13	0.00	**12.05**	7.90	1.58	0.00	1.58	10.47
30/12/1999	1.80	0.21	1.0000	0.21	0.00	**1.59**	0.00	0.00	0.00	0.00	1.59
31/12/1999	0.20	0.24	1.0000	0.24	0.04	**0.00**	0.00	0.00	0.00	0.00	0.00
01/01/2000	0.00	0.31	1.0000	0.31	0.34	**0.00**	0.00	0.00	0.00	0.00	0.00
02/01/2000	0.90	0.54	1.0000	0.54	0.00	**0.02**	0.00	0.00	0.00	0.00	0.02
03/01/2000	4.70	0.45	1.0000	0.45	0.00	**4.25**	0.00	0.00	0.00	0.00	4.25
04/01/2000	0.30	0.60	1.0000	0.60	0.30	**0.00**	0.00	0.00	0.00	0.00	0.00
05/01/2000	1.60	1.13	1.0000	1.13	0.00	**0.17**	0.00	0.00	0.00	0.00	0.17
06/01/2000	0.00	0.60	1.0000	0.60	0.60	**0.00**	0.00	0.00	0.00	0.00	0.00
07/01/2000	2.10	0.98	1.0000	0.98	0.00	**0.51**	0.00	0.00	0.00	0.00	0.51
08/01/2000	0.20	0.59	1.0000	0.59	0.39	**0.00**	0.00	0.00	0.00	0.00	0.00
09/01/2000	0.00	0.30	1.0000	0.30	0.69	**0.00**	0.00	0.00	0.00	0.00	0.00
10/01/2000	2.60	0.58	1.0000	0.58	0.00	**1.33**	0.00	0.00	0.00	0.00	1.33
11/01/2000	22.60	0.41	1.0000	0.41	0.00	**22.19**	17.60	0.00	5.28	5.28	16.91
12/01/2000	7.40	0.31	1.0000	0.31	0.00	**7.09**	2.40	0.48	0.00	0.48	6.61
13/01/2000	0.00	0.36	1.0000	0.36	0.36	**0.00**	0.00	0.00	0.00	0.00	0.00
14/01/2000	0.00	0.44	1.0000	0.44	0.80	**0.00**	0.00	0.00	0.00	0.00	0.00
15/01/2000	0.00	0.22	1.0000	0.22	1.02	**0.00**	0.00	0.00	0.00	0.00	0.00
16/01/2000	0.00	0.24	1.0000	0.24	1.26	**0.00**	0.00	0.00	0.00	0.00	0.00
17/01/2000	0.00	0.31	1.0000	0.31	1.57	**0.00**	0.00	0.00	0.00	0.00	0.00
18/01/2000	0.00	0.34	1.0000	0.34	1.90	**0.00**	0.00	0.00	0.00	0.00	0.00
19/01/2000	0.00	0.35	1.0000	0.35	2.25	**0.00**	0.00	0.00	0.00	0.00	0.00
20/01/2000	0.00	0.18	1.0000	0.18	2.43	**0.00**	0.00	0.00	0.00	0.00	0.00
21/01/2000	1.30	0.27	1.0000	0.27	1.41	**0.00**	0.00	0.00	0.00	0.00	0.00
22/01/2000	0.00	0.56	1.0000	0.56	1.96	**0.00**	0.00	0.00	0.00	0.00	0.00
23/01/2000	0.00	0.37	1.0000	0.37	2.33	**0.00**	0.00	0.00	0.00	0.00	0.00
24/01/2000	0.00	0.27	1.0000	0.27	2.60	**0.00**	0.00	0.00	0.00	0.00	0.00
25/01/2000	0.20	0.15	1.0000	0.15	2.55	**0.00**	0.00	0.00	0.00	0.00	0.00
26/01/2000	0.00	0.15	1.0000	0.15	2.69	**0.00**	0.00	0.00	0.00	0.00	0.00
27/01/2000	1.30	0.20	1.0000	0.20	1.59	**0.00**	0.00	0.00	0.00	0.00	0.00
28/01/2000	1.10	0.40	1.0000	0.40	0.89	**0.00**	0.00	0.00	0.00	0.00	0.00
29/01/2000	3.60	0.62	1.0000	0.62	0.00	**2.10**	0.00	0.00	0.00	0.00	2.10
30/01/2000	1.50	0.67	1.0000	0.67	0.00	**0.83**	0.00	0.00	0.00	0.00	0.83
31/01/2000	2.20	0.78	1.0000	0.78	0.00	**1.42**	0.00	0.00	0.00	0.00	1.42
01/02/2000	1.60	0.32	1.0000	0.32	0.00	**1.28**	0.00	0.00	0.00	0.00	1.28
02/02/2000	0.00	0.71	1.0000	0.71	0.71	**0.00**	0.00	0.00	0.00	0.00	0.00
03/02/2000	3.80	0.52	1.0000	0.52	0.00	**2.57**	0.00	0.00	0.00	0.00	2.57
04/02/2000	0.00	1.15	1.0000	1.15	1.15	**0.00**	0.00	0.00	0.00	0.00	0.00
05/02/2000	2.20	0.77	1.0000	0.77	0.00	**0.28**	0.00	0.00	0.00	0.00	0.28
06/02/2000	4.40	0.88	1.0000	0.88	0.00	**3.52**	0.00	0.00	0.00	0.00	3.52
07/02/2000	1.90	1.00	1.0000	1.00	0.00	**0.90**	0.00	0.00	0.00	0.00	0.90
08/02/2000	2.50	0.65	1.0000	0.65	0.00	**1.85**	0.00	0.00	0.00	0.00	1.85
09/02/2000	7.70	1.26	1.0000	1.26	0.00	**6.44**	2.70	0.54	0.00	0.54	5.90
10/02/2000	0.00	0.74	1.0000	0.74	0.74	**0.00**	0.00	0.00	0.00	0.00	0.00
11/02/2000	5.50	0.89	1.0000	0.89	0.00	**3.87**	0.50	0.10	0.00	0.10	3.77
12/02/2000	1.70	0.49	1.0000	0.49	0.00	**1.21**	0.00	0.00	0.00	0.00	1.21
13/02/2000	5.50	0.73	1.0000	0.73	0.00	**4.77**	0.50	0.10	0.00	0.10	4.67
14/02/2000	5.70	0.86	1.0000	0.86	0.00	**4.84**	0.70	0.14	0.00	0.14	4.70
15/02/2000	5.70	0.58	1.0000	0.58	0.00	**5.12**	0.70	0.14	0.00	0.14	4.98
16/02/2000	0.00	0.58	1.0000	0.58	0.58	**0.00**	0.00	0.00	0.00	0.00	0.00
17/02/2000	2.30	0.39	1.0000	0.39	0.00	**1.32**	0.00	0.00	0.00	0.00	1.32
18/02/2000	1.10	0.71	1.0000	0.71	0.00	**0.39**	0.00	0.00	0.00	0.00	0.39
19/02/2000	0.00	0.62	1.0000	0.62	0.62	**0.00**	0.00	0.00	0.00	0.00	0.00
20/02/2000	4.20	0.64	1.0000	0.64	0.00	**2.94**	0.00	0.00	0.00	0.00	2.94
21/02/2000	0.00	0.79	1.0000	0.79	0.79	**0.00**	0.00	0.00	0.00	0.00	0.00
22/02/2000	0.10	1.00	1.0000	1.00	1.69	**0.00**	0.00	0.00	0.00	0.00	0.00
23/02/2000	0.40	0.83	1.0000	0.83	2.12	**0.00**	0.00	0.00	0.00	0.00	0.00
24/02/2000	0.70	1.01	1.0000	1.01	2.43	**0.00**	0.00	0.00	0.00	0.00	0.00
25/02/2000	0.00	1.03	1.0000	1.03	3.46	**0.00**	0.00	0.00	0.00	0.00	0.00
26/02/2000	11.80	0.93	1.0000	0.93	0.00	**7.41**	6.80	1.36	0.00	1.36	6.05
27/02/2000	2.60	0.79	1.0000	0.79	0.00	**1.81**	0.00	0.00	0.00	0.00	1.81
28/02/2000	0.20	1.22	1.0000	1.22	1.02	**0.00**	0.00	0.00	0.00	0.00	0.00
29/02/2000	3.60	0.81	1.0000	0.81	0.00	**1.78**	0.00	0.00	0.00	0.00	1.78

Date	Rainfall	PE	S.F.	AE	SMD	**Recharge**	Pot. Runoff	Runoff 1	Runoff 2	Runoff	Recharge
01/03/2000	0.50	1.06	1.0000	1.06	0.56	**0.00**	0.00	0.00	0.00	0.00	0.00
02/03/2000	7.90	0.72	1.0000	0.72	0.00	**6.62**	2.90	0.58	0.00	0.58	6.04
03/03/2000	0.00	0.74	1.0000	0.74	0.74	**0.00**	0.00	0.00	0.00	0.00	0.00
04/03/2000	0.00	0.92	1.0000	0.92	1.66	**0.00**	0.00	0.00	0.00	0.00	0.00
05/03/2000	0.00	0.81	1.0000	0.81	2.47	**0.00**	0.00	0.00	0.00	0.00	0.00
06/03/2000	1.50	1.43	1.0000	1.43	2.40	**0.00**	0.00	0.00	0.00	0.00	0.00
07/03/2000	5.40	0.95	1.0000	0.95	0.00	**2.05**	0.40	0.08	0.00	0.08	1.97
08/03/2000	0.00	0.69	1.0000	0.69	0.69	**0.00**	0.00	0.00	0.00	0.00	0.00
09/03/2000	0.00	1.01	1.0000	1.01	1.70	**0.00**	0.00	0.00	0.00	0.00	0.00
10/03/2000	0.00	0.85	1.0000	0.85	2.55	**0.00**	0.00	0.00	0.00	0.00	0.00
11/03/2000	0.00	1.17	1.0000	1.17	3.72	**0.00**	0.00	0.00	0.00	0.00	0.00
12/03/2000	0.30	0.76	1.0000	0.76	4.18	**0.00**	0.00	0.00	0.00	0.00	0.00
13/03/2000	0.60	1.60	1.0000	1.60	5.18	**0.00**	0.00	0.00	0.00	0.00	0.00
14/03/2000	0.00	0.72	1.0000	0.72	5.90	**0.00**	0.00	0.00	0.00	0.00	0.00
15/03/2000	0.00	0.87	1.0000	0.87	6.78	**0.00**	0.00	0.00	0.00	0.00	0.00
16/03/2000	0.00	0.77	1.0000	0.77	7.55	**0.00**	0.00	0.00	0.00	0.00	0.00
17/03/2000	0.00	0.86	1.0000	0.86	8.41	**0.00**	0.00	0.00	0.00	0.00	0.00
18/03/2000	0.60	0.88	1.0000	0.88	8.69	**0.00**	0.00	0.00	0.00	0.00	0.00
19/03/2000	0.00	1.27	1.0000	1.27	9.97	**0.00**	0.00	0.00	0.00	0.00	0.00
20/03/2000	0.00	0.86	1.0000	0.86	10.83	**0.00**	0.00	0.00	0.00	0.00	0.00
21/03/2000	0.00	0.97	1.0000	0.97	11.80	**0.00**	0.00	0.00	0.00	0.00	0.00
22/03/2000	0.20	0.84	1.0000	0.84	12.44	**0.00**	0.00	0.00	0.00	0.00	0.00
23/03/2000	1.40	1.04	1.0000	1.04	12.08	**0.00**	0.00	0.00	0.00	0.00	0.00
24/03/2000	0.30	1.43	1.0000	1.43	13.22	**0.00**	0.00	0.00	0.00	0.00	0.00
25/03/2000	2.50	1.27	1.0000	1.27	11.99	**0.00**	0.00	0.00	0.00	0.00	0.00
26/03/2000	2.70	1.11	1.0000	1.11	10.40	**0.00**	0.00	0.00	0.00	0.00	0.00
27/03/2000	0.00	1.49	1.0000	1.49	11.89	**0.00**	0.00	0.00	0.00	0.00	0.00
28/03/2000	0.00	1.04	1.0000	1.04	12.93	**0.00**	0.00	0.00	0.00	0.00	0.00
29/03/2000	0.00	1.49	1.0000	1.49	14.42	**0.00**	0.00	0.00	0.00	0.00	0.00
30/03/2000	1.30	1.02	1.0000	1.02	14.14	**0.00**	0.00	0.00	0.00	0.00	0.00
31/03/2000	0.30	0.80	1.0000	0.80	14.63	**0.00**	0.00	0.00	0.00	0.00	0.00
01/04/2000	4.40	0.61	1.0000	0.61	10.84	**0.00**	0.00	0.00	0.00	0.00	0.00
02/04/2000	6.40	1.32	1.0000	1.32	5.76	**0.00**	1.40	0.28	0.00	0.28	-0.28
03/04/2000	0.00	1.48	1.0000	1.48	7.24	**0.00**	0.00	0.00	0.00	0.00	0.00
04/04/2000	0.00	2.05	1.0000	2.05	9.29	**0.00**	0.00	0.00	0.00	0.00	0.00
05/04/2000	0.00	1.63	1.0000	1.63	10.91	**0.00**	0.00	0.00	0.00	0.00	0.00
06/04/2000	0.00	2.09	1.0000	2.09	13.01	**0.00**	0.00	0.00	0.00	0.00	0.00
07/04/2000	0.00	2.03	1.0000	2.03	15.04	**0.00**	0.00	0.00	0.00	0.00	0.00
08/04/2000	0.00	1.07	1.0000	1.07	16.10	**0.00**	0.00	0.00	0.00	0.00	0.00
09/04/2000	0.00	1.81	1.0000	1.81	17.91	**0.00**	0.00	0.00	0.00	0.00	0.00
10/04/2000	4.70	1.43	1.0000	1.43	14.64	**0.00**	0.00	0.00	0.00	0.00	0.00
11/04/2000	2.20	1.47	1.0000	1.47	13.91	**0.00**	0.00	0.00	0.00	0.00	0.00
12/04/2000	4.40	0.69	1.0000	0.69	10.20	**0.00**	0.00	0.00	0.00	0.00	0.00
13/04/2000	1.40	1.45	1.0000	1.45	10.24	**0.00**	0.00	0.00	0.00	0.00	0.00
14/04/2000	0.00	1.48	1.0000	1.48	11.73	**0.00**	0.00	0.00	0.00	0.00	0.00
15/04/2000	3.10	1.71	1.0000	1.71	10.34	**0.00**	0.00	0.00	0.00	0.00	0.00
16/04/2000	2.30	1.33	1.0000	1.33	9.37	**0.00**	0.00	0.00	0.00	0.00	0.00
17/04/2000	0.10	1.08	1.0000	1.08	10.35	**0.00**	0.00	0.00	0.00	0.00	0.00
18/04/2000	0.00	1.38	1.0000	1.38	11.73	**0.00**	0.00	0.00	0.00	0.00	0.00
19/04/2000	0.60	1.24	1.0000	1.24	12.37	**0.00**	0.00	0.00	0.00	0.00	0.00
20/04/2000	1.90	2.34	1.0000	2.34	12.81	**0.00**	0.00	0.00	0.00	0.00	0.00
21/04/2000	0.60	2.37	1.0000	2.37	14.57	**0.00**	0.00	0.00	0.00	0.00	0.00
22/04/2000	1.20	2.14	1.0000	2.14	15.51	**0.00**	0.00	0.00	0.00	0.00	0.00
23/04/2000	1.90	2.51	1.0000	2.51	16.12	**0.00**	0.00	0.00	0.00	0.00	0.00
24/04/2000	7.60	2.08	1.0000	2.08	10.59	**0.00**	2.60	0.52	0.00	0.52	-0.52
25/04/2000	9.00	0.59	1.0000	0.59	2.18	**0.00**	4.00	0.80	0.00	0.80	-0.80
26/04/2000	6.80	0.77	1.0000	0.77	0.00	**3.84**	1.80	0.36	0.00	0.36	3.48
27/04/2000	0.00	0.79	1.0000	0.79	0.79	**0.00**	0.00	0.00	0.00	0.00	0.00
28/04/2000	5.00	2.08	1.0000	2.08	0.00	**2.13**	0.00	0.00	0.00	0.00	2.13
29/04/2000	1.40	1.52	1.0000	1.52	0.12	**0.00**	0.00	0.00	0.00	0.00	0.00
30/04/2000	0.00	2.65	1.0000	2.65	2.76	**0.00**	0.00	0.00	0.00	0.00	0.00
01/05/2000	0.00	3.13	1.0000	3.13	5.89	**0.00**	0.00	0.00	0.00	0.00	0.00
02/05/2000	0.00	3.16	1.0000	3.16	9.05	**0.00**	0.00	0.00	0.00	0.00	0.00
03/05/2000	0.00	2.79	1.0000	2.79	11.85	**0.00**	0.00	0.00	0.00	0.00	0.00
04/05/2000	0.00	2.17	1.0000	2.17	14.01	**0.00**	0.00	0.00	0.00	0.00	0.00
05/05/2000	0.00	1.97	1.0000	1.97	15.98	**0.00**	0.00	0.00	0.00	0.00	0.00
06/05/2000	0.00	2.87	1.0000	2.87	18.86	**0.00**	0.00	0.00	0.00	0.00	0.00
07/05/2000	0.00	2.96	1.0000	2.96	21.82	**0.00**	0.00	0.00	0.00	0.00	0.00
08/05/2000	0.00	3.70	1.0000	3.70	25.52	**0.00**	0.00	0.00	0.00	0.00	0.00
09/05/2000	0.00	3.10	1.0000	3.10	28.62	**0.00**	0.00	0.00	0.00	0.00	0.00
10/05/2000	0.00	3.04	1.0000	3.04	31.66	**0.00**	0.00	0.00	0.00	0.00	0.00
11/05/2000	0.00	1.64	1.0000	1.64	33.30	**0.00**	0.00	0.00	0.00	0.00	0.00
12/05/2000	0.00	1.40	1.0000	1.40	34.70	**0.00**	0.00	0.00	0.00	0.00	0.00
13/05/2000	0.00	3.28	1.0000	3.28	37.98	**0.00**	0.00	0.00	0.00	0.00	0.00
14/05/2000	0.00	3.31	1.0000	3.31	41.29	**0.00**	0.00	0.00	0.00	0.00	0.00
15/05/2000	15.70	3.58	1.0000	3.58	29.17	**0.00**	10.70	2.14	0.00	2.14	-2.14
16/05/2000	52.40	1.25	1.0000	1.25	0.00	**21.98**	47.40	0.00	14.22	14.22	7.76
17/05/2000	5.60	1.80	1.0000	1.80	0.00	**3.80**	0.60	0.12	0.00	0.12	3.68

Date	Rainfall	PE	S.F.	AE	SMD	**Recharge**	Pot. Runoff	Runoff 1	Runoff 2	Runoff	Recharge
18/05/2000	0.40	1.89	1.0000	1.89	1.49	**0.00**	0.00	0.00	0.00	0.00	0.00
19/05/2000	2.10	2.76	1.0000	2.76	2.15	**0.00**	0.00	0.00	0.00	0.00	0.00
20/05/2000	0.50	1.59	1.0000	1.59	3.24	**0.00**	0.00	0.00	0.00	0.00	0.00
21/05/2000	0.20	2.51	1.0000	2.51	5.55	**0.00**	0.00	0.00	0.00	0.00	0.00
22/05/2000	3.10	2.94	1.0000	2.94	5.39	**0.00**	0.00	0.00	0.00	0.00	0.00
23/05/2000	0.30	1.78	1.0000	1.78	6.88	**0.00**	0.00	0.00	0.00	0.00	0.00
24/05/2000	4.40	2.79	1.0000	2.79	5.27	**0.00**	0.00	0.00	0.00	0.00	0.00
25/05/2000	2.80	2.42	1.0000	2.42	4.89	**0.00**	0.00	0.00	0.00	0.00	0.00
26/05/2000	0.50	2.36	1.0000	2.36	6.75	**0.00**	0.00	0.00	0.00	0.00	0.00
27/05/2000	0.50	2.35	1.0000	2.35	8.60	**0.00**	0.00	0.00	0.00	0.00	0.00
28/05/2000	2.30	2.29	1.0000	2.29	8.58	**0.00**	0.00	0.00	0.00	0.00	0.00
29/05/2000	1.50	2.94	1.0000	2.94	10.03	**0.00**	0.00	0.00	0.00	0.00	0.00
30/05/2000	0.00	3.38	1.0000	3.38	13.40	**0.00**	0.00	0.00	0.00	0.00	0.00
31/05/2000	2.10	1.75	1.0000	1.75	13.05	**0.00**	0.00	0.00	0.00	0.00	0.00
01/06/2000	1.70	2.28	1.0000	2.28	13.63	**0.00**	0.00	0.00	0.00	0.00	0.00
02/06/2000	22.90	1.59	1.0000	1.59	0.00	**7.68**	17.90	0.00	5.37	5.37	2.31
03/06/2000	2.10	0.85	1.0000	0.85	0.00	**1.25**	0.00	0.00	0.00	0.00	1.25
04/06/2000	0.00	1.31	1.0000	1.31	1.31	**0.00**	0.00	0.00	0.00	0.00	0.00
05/06/2000	5.10	2.19	1.0000	2.19	0.00	**1.60**	0.10	0.02	0.00	0.02	1.58
06/06/2000	0.00	3.03	1.0000	3.03	3.03	**0.00**	0.00	0.00	0.00	0.00	0.00
07/06/2000	3.60	2.07	1.0000	2.07	1.49	**0.00**	0.00	0.00	0.00	0.00	0.00
08/06/2000	0.40	1.40	1.0000	1.40	2.49	**0.00**	0.00	0.00	0.00	0.00	0.00
09/06/2000	0.50	1.67	1.0000	1.67	3.66	**0.00**	0.00	0.00	0.00	0.00	0.00
10/06/2000	0.70	2.43	1.0000	2.43	5.39	**0.00**	0.00	0.00	0.00	0.00	0.00
11/06/2000	0.00	2.04	1.0000	2.04	7.44	**0.00**	0.00	0.00	0.00	0.00	0.00
12/06/2000	0.30	3.47	1.0000	3.47	10.61	**0.00**	0.00	0.00	0.00	0.00	0.00
13/06/2000	3.70	3.27	1.0000	3.27	10.18	**0.00**	0.00	0.00	0.00	0.00	0.00
14/06/2000	0.50	1.97	1.0000	1.97	11.65	**0.00**	0.00	0.00	0.00	0.00	0.00
15/06/2000	0.00	2.38	1.0000	2.38	14.03	**0.00**	0.00	0.00	0.00	0.00	0.00
16/06/2000	0.00	4.50	1.0000	4.50	18.53	**0.00**	0.00	0.00	0.00	0.00	0.00
17/06/2000	0.00	3.02	1.0000	3.02	21.55	**0.00**	0.00	0.00	0.00	0.00	0.00
18/06/2000	0.00	4.98	1.0000	4.98	26.53	**0.00**	0.00	0.00	0.00	0.00	0.00
19/06/2000	0.00	3.80	1.0000	3.80	30.33	**0.00**	0.00	0.00	0.00	0.00	0.00
20/06/2000	1.40	3.16	1.0000	3.16	32.08	**0.00**	0.00	0.00	0.00	0.00	0.00
21/06/2000	3.30	2.42	1.0000	2.42	31.20	**0.00**	0.00	0.00	0.00	0.00	0.00
22/06/2000	1.20	2.56	1.0000	2.56	32.56	**0.00**	0.00	0.00	0.00	0.00	0.00
23/06/2000	0.00	2.34	1.0000	2.34	34.90	**0.00**	0.00	0.00	0.00	0.00	0.00
24/06/2000	0.00	2.54	1.0000	2.54	37.44	**0.00**	0.00	0.00	0.00	0.00	0.00
25/06/2000	0.00	1.33	1.0000	1.33	38.77	**0.00**	0.00	0.00	0.00	0.00	0.00
26/06/2000	0.00	3.44	1.0000	3.44	42.21	**0.00**	0.00	0.00	0.00	0.00	0.00
27/06/2000	0.00	3.52	1.0000	3.52	45.73	**0.00**	0.00	0.00	0.00	0.00	0.00
28/06/2000	0.00	2.95	1.0000	2.95	48.68	**0.00**	0.00	0.00	0.00	0.00	0.00
29/06/2000	0.00	4.00	1.0000	4.00	52.68	**0.00**	0.00	0.00	0.00	0.00	0.00
30/06/2000	2.10	2.58	1.0000	2.58	53.15	**0.00**	0.00	0.00	0.00	0.00	0.00
01/07/2000	7.80	1.03	1.0000	1.03	46.38	**0.00**	2.80	0.56	0.00	0.56	-0.56
02/07/2000	27.80	2.09	1.0000	2.09	20.67	**0.00**	22.80	0.00	6.84	6.84	-6.84
03/07/2000	0.50	3.05	1.0000	3.05	23.22	**0.00**	0.00	0.00	0.00	0.00	0.00
04/07/2000	0.00	3.06	1.0000	3.06	26.28	**0.00**	0.00	0.00	0.00	0.00	0.00
05/07/2000	7.60	2.62	1.0000	2.62	21.30	**0.00**	2.60	0.52	0.00	0.52	-0.52
06/07/2000	0.00	2.16	1.0000	2.16	23.46	**0.00**	0.00	0.00	0.00	0.00	0.00
07/07/2000	0.00	2.66	1.0000	2.66	26.13	**0.00**	0.00	0.00	0.00	0.00	0.00
08/07/2000	2.30	1.45	1.0000	1.45	25.28	**0.00**	0.00	0.00	0.00	0.00	0.00
09/07/2000	1.50	2.37	1.0000	2.37	26.15	**0.00**	0.00	0.00	0.00	0.00	0.00
10/07/2000	0.40	2.50	1.0000	2.50	28.24	**0.00**	0.00	0.00	0.00	0.00	0.00
11/07/2000	0.90	3.07	1.0000	3.07	30.42	**0.00**	0.00	0.00	0.00	0.00	0.00
12/07/2000	2.60	2.17	1.0000	2.17	29.98	**0.00**	0.00	0.00	0.00	0.00	0.00
13/07/2000	0.00	1.92	1.0000	1.92	31.91	**0.00**	0.00	0.00	0.00	0.00	0.00
14/07/2000	0.10	1.92	1.0000	1.92	33.72	**0.00**	0.00	0.00	0.00	0.00	0.00
15/07/2000	0.00	2.29	1.0000	2.29	36.01	**0.00**	0.00	0.00	0.00	0.00	0.00
16/07/2000	0.00	3.34	1.0000	3.34	39.35	**0.00**	0.00	0.00	0.00	0.00	0.00
17/07/2000	0.00	3.69	1.0000	3.69	43.04	**0.00**	0.00	0.00	0.00	0.00	0.00
18/07/2000	0.00	2.72	1.0000	2.72	45.76	**0.00**	0.00	0.00	0.00	0.00	0.00
19/07/2000	0.00	3.69	1.0000	3.69	49.45	**0.00**	0.00	0.00	0.00	0.00	0.00
20/07/2000	0.00	2.86	1.0000	2.86	52.30	**0.00**	0.00	0.00	0.00	0.00	0.00
21/07/2000	0.00	3.56	1.0000	3.56	55.87	**0.00**	0.00	0.00	0.00	0.00	0.00
22/07/2000	0.00	3.79	1.0000	3.79	59.65	**0.00**	0.00	0.00	0.00	0.00	0.00
23/07/2000	0.00	1.53	1.0000	1.53	61.19	**0.00**	0.00	0.00	0.00	0.00	0.00
24/07/2000	0.00	2.30	1.0000	2.30	63.49	**0.00**	0.00	0.00	0.00	0.00	0.00
25/07/2000	0.00	2.80	1.0000	2.80	66.29	**0.00**	0.00	0.00	0.00	0.00	0.00
26/07/2000	0.00	2.32	1.0000	2.32	68.62	**0.00**	0.00	0.00	0.00	0.00	0.00
27/07/2000	0.00	2.64	1.0000	2.64	71.26	**0.00**	0.00	0.00	0.00	0.00	0.00
28/07/2000	0.00	3.07	1.0000	3.07	74.33	**0.00**	0.00	0.00	0.00	0.00	0.00
29/07/2000	0.00	2.50	0.9938	2.49	76.82	**0.00**	0.00	0.00	0.00	0.00	0.00
30/07/2000	11.10	2.11	0.9469	2.00	67.71	**0.00**	6.10	1.22	0.00	1.22	-1.22
31/07/2000	1.10	2.69	1.0000	2.69	69.30	**0.00**	0.00	0.00	0.00	0.00	0.00
01/08/2000	15.20	3.33	1.0000	3.33	57.43	**0.00**	10.20	2.04	0.00	2.04	-2.04
02/08/2000	7.10	1.97	1.0000	1.97	52.30	**0.00**	2.10	0.42	0.00	0.42	-0.42
03/08/2000	0.00	2.18	1.0000	2.18	54.49	**0.00**	0.00	0.00	0.00	0.00	0.00

Date	Rainfall	PE	S.F.	AE	SMD	**Recharge**	Pot. Runoff	Runoff 1	Runoff 2	Runoff	Recharge
04/08/2000	0.00	2.12	1.0000	2.12	56.61	**0.00**	0.00	0.00	0.00	0.00	0.00
05/08/2000	0.30	1.89	1.0000	1.89	58.21	**0.00**	0.00	0.00	0.00	0.00	0.00
06/08/2000	0.00	2.08	1.0000	2.08	60.28	**0.00**	0.00	0.00	0.00	0.00	0.00
07/08/2000	5.30	2.11	1.0000	2.11	57.09	**0.00**	0.30	0.06	0.00	0.06	-0.06
08/08/2000	1.40	2.66	1.0000	2.66	58.35	**0.00**	0.00	0.00	0.00	0.00	0.00
09/08/2000	0.60	2.32	1.0000	2.32	60.07	**0.00**	0.00	0.00	0.00	0.00	0.00
10/08/2000	0.00	2.12	1.0000	2.12	62.18	**0.00**	0.00	0.00	0.00	0.00	0.00
11/08/2000	0.00	3.03	1.0000	3.03	65.21	**0.00**	0.00	0.00	0.00	0.00	0.00
12/08/2000	0.10	2.16	1.0000	2.16	67.27	**0.00**	0.00	0.00	0.00	0.00	0.00
13/08/2000	7.10	2.15	1.0000	2.15	62.31	**0.00**	2.10	0.42	0.00	0.42	-0.42
14/08/2000	1.20	1.88	1.0000	1.88	63.00	**0.00**	0.00	0.00	0.00	0.00	0.00
15/08/2000	5.00	2.22	1.0000	2.22	60.22	**0.00**	0.00	0.00	0.00	0.00	0.00
16/08/2000	11.80	3.01	1.0000	3.01	51.43	**0.00**	6.80	1.36	0.00	1.36	-1.36
17/08/2000	5.40	2.36	1.0000	2.36	48.39	**0.00**	0.40	0.08	0.00	0.08	-0.08
18/08/2000	4.50	2.78	1.0000	2.78	46.67	**0.00**	0.00	0.00	0.00	0.00	0.00
19/08/2000	0.00	2.21	1.0000	2.21	48.88	**0.00**	0.00	0.00	0.00	0.00	0.00
20/08/2000	0.50	2.05	1.0000	2.05	50.43	**0.00**	0.00	0.00	0.00	0.00	0.00
21/08/2000	0.00	2.37	1.0000	2.37	52.80	**0.00**	0.00	0.00	0.00	0.00	0.00
22/08/2000	0.00	2.33	1.0000	2.33	55.13	**0.00**	0.00	0.00	0.00	0.00	0.00
23/08/2000	0.00	2.82	1.0000	2.82	57.95	**0.00**	0.00	0.00	0.00	0.00	0.00
24/08/2000	0.00	3.03	1.0000	3.03	60.98	**0.00**	0.00	0.00	0.00	0.00	0.00
25/08/2000	14.00	1.94	1.0000	1.94	48.92	**0.00**	9.00	1.80	0.00	1.80	-1.80
26/08/2000	2.60	1.74	1.0000	1.74	48.06	**0.00**	0.00	0.00	0.00	0.00	0.00
27/08/2000	0.20	2.05	1.0000	2.05	49.91	**0.00**	0.00	0.00	0.00	0.00	0.00
28/08/2000	0.00	2.24	1.0000	2.24	52.15	**0.00**	0.00	0.00	0.00	0.00	0.00
29/08/2000	0.00	2.61	1.0000	2.61	54.76	**0.00**	0.00	0.00	0.00	0.00	0.00
30/08/2000	2.90	2.38	1.0000	2.38	54.24	**0.00**	0.00	0.00	0.00	0.00	0.00
31/08/2000	3.80	2.43	1.0000	2.43	52.87	**0.00**	0.00	0.00	0.00	0.00	0.00
01/09/2000	1.20	1.71	1.0000	1.71	53.38	**0.00**	0.00	0.00	0.00	0.00	0.00
02/09/2000	0.00	2.01	1.0000	2.01	55.39	**0.00**	0.00	0.00	0.00	0.00	0.00
03/09/2000	0.00	2.09	1.0000	2.09	57.48	**0.00**	0.00	0.00	0.00	0.00	0.00
04/09/2000	3.90	1.60	1.0000	1.60	55.18	**0.00**	0.00	0.00	0.00	0.00	0.00
05/09/2000	2.40	2.13	1.0000	2.13	54.91	**0.00**	0.00	0.00	0.00	0.00	0.00
06/09/2000	0.40	2.44	1.0000	2.44	56.95	**0.00**	0.00	0.00	0.00	0.00	0.00
07/09/2000	1.00	1.70	1.0000	1.70	57.65	**0.00**	0.00	0.00	0.00	0.00	0.00
08/09/2000	0.40	1.97	1.0000	1.97	59.22	**0.00**	0.00	0.00	0.00	0.00	0.00
09/09/2000	7.70	1.27	1.0000	1.27	52.78	**0.00**	2.70	0.54	0.00	0.54	-0.54
10/09/2000	0.00	1.51	1.0000	1.51	54.29	**0.00**	0.00	0.00	0.00	0.00	0.00
11/09/2000	0.60	1.98	1.0000	1.98	55.67	**0.00**	0.00	0.00	0.00	0.00	0.00
12/09/2000	0.00	1.01	1.0000	1.01	56.68	**0.00**	0.00	0.00	0.00	0.00	0.00
13/09/2000	7.30	1.44	1.0000	1.44	50.83	**0.00**	2.30	0.46	0.00	0.46	-0.46
14/09/2000	1.30	1.25	1.0000	1.25	50.78	**0.00**	0.00	0.00	0.00	0.00	0.00
15/09/2000	0.30	1.01	1.0000	1.01	51.49	**0.00**	0.00	0.00	0.00	0.00	0.00
16/09/2000	1.50	0.98	1.0000	0.98	50.97	**0.00**	0.00	0.00	0.00	0.00	0.00
17/09/2000	11.80	0.96	1.0000	0.96	40.13	**0.00**	6.80	1.36	0.00	1.36	-1.36
18/09/2000	0.00	1.86	1.0000	1.86	41.99	**0.00**	0.00	0.00	0.00	0.00	0.00
19/09/2000	0.10	1.17	1.0000	1.17	43.06	**0.00**	0.00	0.00	0.00	0.00	0.00
20/09/2000	1.00	1.61	1.0000	1.61	43.67	**0.00**	0.00	0.00	0.00	0.00	0.00
21/09/2000	5.00	1.68	1.0000	1.68	40.35	**0.00**	0.00	0.00	0.00	0.00	0.00
22/09/2000	0.80	1.79	1.0000	1.79	41.34	**0.00**	0.00	0.00	0.00	0.00	0.00
23/09/2000	5.20	1.85	1.0000	1.85	37.99	**0.00**	0.20	0.04	0.00	0.04	-0.04
24/09/2000	0.00	1.25	1.0000	1.25	39.24	**0.00**	0.00	0.00	0.00	0.00	0.00
25/09/2000	0.00	1.37	1.0000	1.37	40.61	**0.00**	0.00	0.00	0.00	0.00	0.00
26/09/2000	1.60	0.74	1.0000	0.74	39.75	**0.00**	0.00	0.00	0.00	0.00	0.00
27/09/2000	11.50	0.88	1.0000	0.88	29.12	**0.00**	6.50	1.30	0.00	1.30	-1.30
28/09/2000	1.80	1.38	1.0000	1.38	28.70	**0.00**	0.00	0.00	0.00	0.00	0.00
29/09/2000	4.80	0.72	1.0000	0.72	24.62	**0.00**	0.00	0.00	0.00	0.00	0.00
30/09/2000	0.00	0.90	1.0000	0.90	25.52	**0.00**	0.00	0.00	0.00	0.00	0.00
01/10/2000	8.30	0.71	1.0000	0.71	17.94	**0.00**	3.30	0.66	0.00	0.66	-0.66
02/10/2000	0.50	1.58	1.0000	1.58	19.02	**0.00**	0.00	0.00	0.00	0.00	0.00
03/10/2000	2.80	1.40	1.0000	1.40	17.62	**0.00**	0.00	0.00	0.00	0.00	0.00
04/10/2000	4.50	1.22	1.0000	1.22	14.34	**0.00**	0.00	0.00	0.00	0.00	0.00
05/10/2000	0.30	1.29	1.0000	1.29	15.32	**0.00**	0.00	0.00	0.00	0.00	0.00
06/10/2000	0.00	0.82	1.0000	0.82	16.15	**0.00**	0.00	0.00	0.00	0.00	0.00
07/10/2000	0.60	1.01	1.0000	1.01	16.56	**0.00**	0.00	0.00	0.00	0.00	0.00
08/10/2000	8.00	1.28	1.0000	1.28	9.83	**0.00**	3.00	0.60	0.00	0.60	-0.60
09/10/2000	2.10	0.72	1.0000	0.72	8.45	**0.00**	0.00	0.00	0.00	0.00	0.00
10/10/2000	2.20	1.12	1.0000	1.12	7.37	**0.00**	0.00	0.00	0.00	0.00	0.00
11/10/2000	7.60	0.66	1.0000	0.66	0.43	**0.00**	2.60	0.52	0.00	0.52	-0.52
12/10/2000	0.10	0.78	1.0000	0.78	1.10	**0.00**	0.00	0.00	0.00	0.00	0.00
13/10/2000	3.40	0.81	1.0000	0.81	0.00	**1.48**	0.00	0.00	0.00	0.00	1.48
14/10/2000	0.00	0.97	1.0000	0.97	0.97	**0.00**	0.00	0.00	0.00	0.00	0.00
15/10/2000	11.60	1.13	1.0000	1.13	0.00	**9.49**	6.60	1.32	0.00	1.32	8.17
16/10/2000	0.00	0.62	1.0000	0.62	0.62	**0.00**	0.00	0.00	0.00	0.00	0.00
17/10/2000	8.80	0.65	1.0000	0.65	0.00	**7.53**	3.80	0.76	0.00	0.76	6.77
18/10/2000	0.00	1.16	1.0000	1.16	1.16	**0.00**	0.00	0.00	0.00	0.00	0.00
19/10/2000	2.80	1.15	1.0000	1.15	0.00	**0.49**	0.00	0.00	0.00	0.00	0.49
20/10/2000	0.00	0.52	1.0000	0.52	0.52	**0.00**	0.00	0.00	0.00	0.00	0.00

Date	Rainfall	PE	S.F.	AE	SMD	**Recharge**	Pot. Runoff	Runoff 1	Runoff 2	Runoff	Recharge
21/10/2000	0.00	0.80	1.0000	0.80	1.32	**0.00**	0.00	0.00	0.00	0.00	0.00
22/10/2000	3.60	0.73	1.0000	0.73	0.00	**1.55**	0.00	0.00	0.00	0.00	1.55
23/10/2000	0.10	1.04	1.0000	1.04	0.94	**0.00**	0.00	0.00	0.00	0.00	0.00
24/10/2000	11.60	0.54	1.0000	0.54	0.00	**10.12**	6.60	1.32	0.00	1.32	8.80
25/10/2000	0.10	0.60	1.0000	0.60	0.50	**0.00**	0.00	0.00	0.00	0.00	0.00
26/10/2000	15.80	0.71	1.0000	0.71	0.00	**14.59**	10.80	2.16	0.00	2.16	12.43
27/10/2000	0.30	0.63	1.0000	0.63	0.33	**0.00**	0.00	0.00	0.00	0.00	0.00
28/10/2000	6.00	1.20	1.0000	1.20	0.00	**4.47**	1.00	0.20	0.00	0.20	4.27
29/10/2000	4.20	0.51	1.0000	0.51	0.00	**3.69**	0.00	0.00	0.00	0.00	3.69
30/10/2000	9.90	0.53	1.0000	0.53	0.00	**9.37**	4.90	0.98	0.00	0.98	8.39
31/10/2000	3.50	0.59	1.0000	0.59	0.00	**2.91**	0.00	0.00	0.00	0.00	2.91
01/11/2000	7.80	0.87	1.0000	0.87	0.00	**6.93**	2.80	0.56	0.00	0.56	6.37
02/11/2000	6.70	0.42	1.0000	0.42	0.00	**6.28**	1.70	0.34	0.00	0.34	5.94
03/11/2000	0.00	0.60	1.0000	0.60	0.60	**0.00**	0.00	0.00	0.00	0.00	0.00
04/11/2000	0.00	0.51	1.0000	0.51	1.11	**0.00**	0.00	0.00	0.00	0.00	0.00
05/11/2000	42.00	0.29	1.0000	0.29	0.00	**40.60**	37.00	0.00	11.10	11.10	29.50
06/11/2000	16.30	0.46	1.0000	0.46	0.00	**15.84**	11.30	2.26	0.00	2.26	13.58
07/11/2000	1.00	0.71	1.0000	0.71	0.00	**0.29**	0.00	0.00	0.00	0.00	0.29
08/11/2000	0.00	0.68	1.0000	0.68	0.68	**0.00**	0.00	0.00	0.00	0.00	0.00
09/11/2000	0.00	0.60	1.0000	0.60	1.28	**0.00**	0.00	0.00	0.00	0.00	0.00
10/11/2000	4.00	0.36	1.0000	0.36	0.00	**2.36**	0.00	0.00	0.00	0.00	2.36
11/11/2000	0.00	0.63	1.0000	0.63	0.63	**0.00**	0.00	0.00	0.00	0.00	0.00
12/11/2000	0.40	0.65	1.0000	0.65	0.88	**0.00**	0.00	0.00	0.00	0.00	0.00
13/11/2000	0.50	0.27	1.0000	0.27	0.65	**0.00**	0.00	0.00	0.00	0.00	0.00
14/11/2000	0.00	0.41	1.0000	0.41	1.06	**0.00**	0.00	0.00	0.00	0.00	0.00
15/11/2000	6.50	0.38	1.0000	0.38	0.00	**5.07**	1.50	0.30	0.00	0.30	4.77
16/11/2000	0.60	0.34	1.0000	0.34	0.00	**0.26**	0.00	0.00	0.00	0.00	0.26
17/11/2000	0.30	0.44	1.0000	0.44	0.14	**0.00**	0.00	0.00	0.00	0.00	0.00
18/11/2000	5.70	0.43	1.0000	0.43	0.00	**5.13**	0.70	0.14	0.00	0.14	4.99
19/11/2000	0.70	0.44	1.0000	0.44	0.00	**0.26**	0.00	0.00	0.00	0.00	0.26
20/11/2000	0.00	0.25	1.0000	0.25	0.25	**0.00**	0.00	0.00	0.00	0.00	0.00
21/11/2000	6.10	0.29	1.0000	0.29	0.00	**5.56**	1.10	0.22	0.00	0.22	5.34
22/11/2000	0.00	0.20	1.0000	0.20	0.20	**0.00**	0.00	0.00	0.00	0.00	0.00
23/11/2000	0.00	0.27	1.0000	0.27	0.47	**0.00**	0.00	0.00	0.00	0.00	0.00
24/11/2000	6.50	0.46	1.0000	0.46	0.00	**5.57**	1.50	0.30	0.00	0.30	5.27
25/11/2000	5.50	0.87	1.0000	0.87	0.00	**4.63**	0.50	0.10	0.00	0.10	4.53
26/11/2000	0.60	0.94	1.0000	0.94	0.34	**0.00**	0.00	0.00	0.00	0.00	0.00
27/11/2000	4.20	0.78	1.0000	0.78	0.00	**3.08**	0.00	0.00	0.00	0.00	3.08
28/11/2000	7.40	1.14	1.0000	1.14	0.00	**6.26**	2.40	0.48	0.00	0.48	5.78
29/11/2000	0.40	0.97	1.0000	0.97	0.57	**0.00**	0.00	0.00	0.00	0.00	0.00
30/11/2000	6.30	0.89	1.0000	0.89	0.00	**4.84**	1.30	0.26	0.00	0.26	4.58
01/12/2000	1.10	0.74	1.0000	0.74	0.00	**0.36**	0.00	0.00	0.00	0.00	0.36
02/12/2000	0.00	0.60	1.0000	0.60	0.60	**0.00**	0.00	0.00	0.00	0.00	0.00
03/12/2000	16.60	0.61	1.0000	0.61	0.00	**15.39**	11.60	2.32	0.00	2.32	13.07
04/12/2000	4.80	0.69	1.0000	0.69	0.00	**4.11**	0.00	0.00	0.00	0.00	4.11
05/12/2000	1.00	0.77	1.0000	0.77	0.00	**0.23**	0.00	0.00	0.00	0.00	0.23
06/12/2000	0.00	0.57	1.0000	0.57	0.57	**0.00**	0.00	0.00	0.00	0.00	0.00
07/12/2000	18.10	0.39	1.0000	0.39	0.00	**17.14**	13.10	2.62	0.00	2.62	14.52
08/12/2000	3.00	0.30	1.0000	0.30	0.00	**2.70**	0.00	0.00	0.00	0.00	2.70
09/12/2000	1.60	0.59	1.0000	0.59	0.00	**1.01**	0.00	0.00	0.00	0.00	1.01
10/12/2000	5.00	0.80	1.0000	0.80	0.00	**4.20**	0.00	0.00	0.00	0.00	4.20
11/12/2000	4.50	0.40	1.0000	0.40	0.00	**4.10**	0.00	0.00	0.00	0.00	4.10
12/12/2000	7.20	0.51	1.0000	0.51	0.00	**6.69**	2.20	0.44	0.00	0.44	6.25
13/12/2000	4.30	0.39	1.0000	0.39	0.00	**3.91**	0.00	0.00	0.00	0.00	3.91
14/12/2000	0.00	0.05	1.0000	0.05	0.05	**0.00**	0.00	0.00	0.00	0.00	0.00
15/12/2000	3.90	0.04	1.0000	0.04	0.00	**3.81**	0.00	0.00	0.00	0.00	3.81
16/12/2000	0.00	0.19	1.0000	0.19	0.19	**0.00**	0.00	0.00	0.00	0.00	0.00
17/12/2000	1.80	0.37	1.0000	0.37	0.00	**1.24**	0.00	0.00	0.00	0.00	1.24
18/12/2000	0.10	0.36	1.0000	0.36	0.26	**0.00**	0.00	0.00	0.00	0.00	0.00
19/12/2000	19.40	0.48	1.0000	0.48	0.00	**18.65**	14.40	2.88	0.00	2.88	15.77
20/12/2000	4.20	0.60	1.0000	0.60	0.00	**3.60**	0.00	0.00	0.00	0.00	3.60
21/12/2000	0.00	0.21	1.0000	0.21	0.21	**0.00**	0.00	0.00	0.00	0.00	0.00
22/12/2000	0.00	0.23	1.0000	0.23	0.44	**0.00**	0.00	0.00	0.00	0.00	0.00
23/12/2000	0.00	0.28	1.0000	0.28	0.71	**0.00**	0.00	0.00	0.00	0.00	0.00
24/12/2000	4.50	0.72	1.0000	0.72	0.00	**3.06**	0.00	0.00	0.00	0.00	3.06
25/12/2000	0.50	0.79	1.0000	0.79	0.29	**0.00**	0.00	0.00	0.00	0.00	0.00
26/12/2000	0.00	0.73	1.0000	0.73	1.02	**0.00**	0.00	0.00	0.00	0.00	0.00
27/12/2000	0.20	0.25	1.0000	0.25	1.07	**0.00**	0.00	0.00	0.00	0.00	0.00
28/12/2000	2.60	0.19	1.0000	0.19	0.00	**1.34**	0.00	0.00	0.00	0.00	1.34
29/12/2000	0.00	0.00	1.0000	0.00	0.00	**0.00**	0.00	0.00	0.00	0.00	0.00
30/12/2000	1.60	0.04	1.0000	0.04	0.00	**1.56**	0.00	0.00	0.00	0.00	1.56
31/12/2000	6.30	0.45	1.0000	0.45	0.00	**5.85**	1.30	0.26	0.00	0.26	5.59
01/01/2001	3.30	0.70	1.0000	0.70	0.00	**2.60**	0.00	0.00	0.00	0.00	2.60
02/01/2001	0.80	0.38	1.0000	0.38	0.00	**0.42**	0.00	0.00	0.00	0.00	0.42
03/01/2001	4.30	0.46	1.0000	0.46	0.00	**3.84**	0.00	0.00	0.00	0.00	3.84
04/01/2001	0.10	0.13	1.0000	0.13	0.03	**0.00**	0.00	0.00	0.00	0.00	0.00
05/01/2001	0.00	0.18	1.0000	0.18	0.21	**0.00**	0.00	0.00	0.00	0.00	0.00
06/01/2001	0.00	0.38	1.0000	0.38	0.59	**0.00**	0.00	0.00	0.00	0.00	0.00

Date	Rainfall	PE	S.F.	AE	SMD	**Recharge**	Pot. Runoff	Runoff 1	Runoff 2	Runoff	Recharge
07/01/2001	0.00	0.38	1.0000	0.38	0.97	**0.00**	0.00	0.00	0.00	0.00	0.00
08/01/2001	0.00	0.21	1.0000	0.21	1.19	**0.00**	0.00	0.00	0.00	0.00	0.00
09/01/2001	0.00	0.23	1.0000	0.23	1.42	**0.00**	0.00	0.00	0.00	0.00	0.00
10/01/2001	2.70	0.81	1.0000	0.81	0.00	**0.46**	0.00	0.00	0.00	0.00	0.46
11/01/2001	0.00	1.33	1.0000	1.33	1.33	**0.00**	0.00	0.00	0.00	0.00	0.00
12/01/2001	0.00	0.66	1.0000	0.66	1.99	**0.00**	0.00	0.00	0.00	0.00	0.00
13/01/2001	0.00	0.37	1.0000	0.37	2.37	**0.00**	0.00	0.00	0.00	0.00	0.00
14/01/2001	0.00	0.29	1.0000	0.29	2.65	**0.00**	0.00	0.00	0.00	0.00	0.00
15/01/2001	0.00	0.02	1.0000	0.02	2.67	**0.00**	0.00	0.00	0.00	0.00	0.00
16/01/2001	0.00	0.29	1.0000	0.29	2.96	**0.00**	0.00	0.00	0.00	0.00	0.00
17/01/2001	0.00	0.44	1.0000	0.44	3.40	**0.00**	0.00	0.00	0.00	0.00	0.00
18/01/2001	0.00	0.18	1.0000	0.18	3.58	**0.00**	0.00	0.00	0.00	0.00	0.00
19/01/2001	0.00	0.26	1.0000	0.26	3.85	**0.00**	0.00	0.00	0.00	0.00	0.00
20/01/2001	3.10	0.17	1.0000	0.17	0.92	**0.00**	0.00	0.00	0.00	0.00	0.00
21/01/2001	4.70	0.34	1.0000	0.34	0.00	**3.44**	0.00	0.00	0.00	0.00	3.44
22/01/2001	2.00	0.86	1.0000	0.86	0.00	**1.14**	0.00	0.00	0.00	0.00	1.14
23/01/2001	10.80	0.79	1.0000	0.79	0.00	**10.01**	5.80	1.16	0.00	1.16	8.85
24/01/2001	0.00	0.74	1.0000	0.74	0.74	**0.00**	0.00	0.00	0.00	0.00	0.00
25/01/2001	2.80	0.63	1.0000	0.63	0.00	**1.43**	0.00	0.00	0.00	0.00	1.43
26/01/2001	0.00	0.48	1.0000	0.48	0.48	**0.00**	0.00	0.00	0.00	0.00	0.00
27/01/2001	0.00	0.32	1.0000	0.32	0.80	**0.00**	0.00	0.00	0.00	0.00	0.00
28/01/2001	0.00	0.14	1.0000	0.14	0.93	**0.00**	0.00	0.00	0.00	0.00	0.00
29/01/2001	5.50	0.32	1.0000	0.32	0.00	**4.25**	0.50	0.10	0.00	0.10	4.15
30/01/2001	0.40	0.25	1.0000	0.25	0.00	**0.15**	0.00	0.00	0.00	0.00	0.15
31/01/2001	0.10	0.31	1.0000	0.31	0.21	**0.00**	0.00	0.00	0.00	0.00	0.00
01/02/2001	1.40	0.56	1.0000	0.56	0.00	**0.62**	0.00	0.00	0.00	0.00	0.62
02/02/2001	4.50	0.42	1.0000	0.42	0.00	**4.08**	0.00	0.00	0.00	0.00	4.08
03/02/2001	5.80	0.21	1.0000	0.21	0.00	**5.59**	0.80	0.16	0.00	0.16	5.43
04/02/2001	2.80	0.28	1.0000	0.28	0.00	**2.52**	0.00	0.00	0.00	0.00	2.52
05/02/2001	10.20	0.40	1.0000	0.40	0.00	**9.80**	5.20	1.04	0.00	1.04	8.76
06/02/2001	3.50	0.81	1.0000	0.81	0.00	**2.69**	0.00	0.00	0.00	0.00	2.69
07/02/2001	1.10	0.47	1.0000	0.47	0.00	**0.63**	0.00	0.00	0.00	0.00	0.63
08/02/2001	0.00	0.50	1.0000	0.50	0.50	**0.00**	0.00	0.00	0.00	0.00	0.00
09/02/2001	0.80	0.60	1.0000	0.60	0.30	**0.00**	0.00	0.00	0.00	0.00	0.00
10/02/2001	6.00	0.97	1.0000	0.97	0.00	**4.73**	1.00	0.20	0.00	0.20	4.53
11/02/2001	1.80	0.96	1.0000	0.96	0.00	**0.84**	0.00	0.00	0.00	0.00	0.84
12/02/2001	0.00	0.58	1.0000	0.58	0.58	**0.00**	0.00	0.00	0.00	0.00	0.00
13/02/2001	0.00	0.65	1.0000	0.65	1.23	**0.00**	0.00	0.00	0.00	0.00	0.00
14/02/2001	0.00	0.73	1.0000	0.73	1.96	**0.00**	0.00	0.00	0.00	0.00	0.00
15/02/2001	0.00	0.36	1.0000	0.36	2.32	**0.00**	0.00	0.00	0.00	0.00	0.00
16/02/2001	0.00	0.36	1.0000	0.36	2.68	**0.00**	0.00	0.00	0.00	0.00	0.00
17/02/2001	0.00	0.46	1.0000	0.46	3.14	**0.00**	0.00	0.00	0.00	0.00	0.00
18/02/2001	0.90	0.78	1.0000	0.78	3.02	**0.00**	0.00	0.00	0.00	0.00	0.00
19/02/2001	0.50	0.35	1.0000	0.35	2.87	**0.00**	0.00	0.00	0.00	0.00	0.00
20/02/2001	1.10	0.27	1.0000	0.27	2.04	**0.00**	0.00	0.00	0.00	0.00	0.00
21/02/2001	0.40	0.35	1.0000	0.35	1.99	**0.00**	0.00	0.00	0.00	0.00	0.00
22/02/2001	0.20	0.64	1.0000	0.64	2.44	**0.00**	0.00	0.00	0.00	0.00	0.00
23/02/2001	0.00	0.65	1.0000	0.65	3.09	**0.00**	0.00	0.00	0.00	0.00	0.00
24/02/2001	0.00	0.61	1.0000	0.61	3.69	**0.00**	0.00	0.00	0.00	0.00	0.00
25/02/2001	2.10	0.82	1.0000	0.82	2.41	**0.00**	0.00	0.00	0.00	0.00	0.00
26/02/2001	3.40	0.38	1.0000	0.38	0.00	**0.60**	0.00	0.00	0.00	0.00	0.60
27/02/2001	0.00	0.30	1.0000	0.30	0.30	**0.00**	0.00	0.00	0.00	0.00	0.00
28/02/2001	0.00	0.49	1.0000	0.49	0.79	**0.00**	0.00	0.00	0.00	0.00	0.00
01/03/2001	0.00	0.52	1.0000	0.52	1.31	**0.00**	0.00	0.00	0.00	0.00	0.00
02/03/2001	0.00	0.62	1.0000	0.62	1.93	**0.00**	0.00	0.00	0.00	0.00	0.00
03/03/2001	0.00	0.80	1.0000	0.80	2.73	**0.00**	0.00	0.00	0.00	0.00	0.00
04/03/2001	0.00	0.87	1.0000	0.87	3.59	**0.00**	0.00	0.00	0.00	0.00	0.00
05/03/2001	0.00	1.34	1.0000	1.34	4.94	**0.00**	0.00	0.00	0.00	0.00	0.00
06/03/2001	5.00	1.01	1.0000	1.01	0.95	**0.00**	0.00	0.00	0.00	0.00	0.00
07/03/2001	0.20	1.74	1.0000	1.74	2.49	**0.00**	0.00	0.00	0.00	0.00	0.00
08/03/2001	0.50	1.49	1.0000	1.49	3.48	**0.00**	0.00	0.00	0.00	0.00	0.00
09/03/2001	1.30	0.95	1.0000	0.95	3.13	**0.00**	0.00	0.00	0.00	0.00	0.00
10/03/2001	0.60	1.05	1.0000	1.05	3.58	**0.00**	0.00	0.00	0.00	0.00	0.00
11/03/2001	4.40	1.03	1.0000	1.03	0.20	**0.00**	0.00	0.00	0.00	0.00	0.00
12/03/2001	0.20	1.25	1.0000	1.25	1.25	**0.00**	0.00	0.00	0.00	0.00	0.00
13/03/2001	1.40	1.03	1.0000	1.03	0.88	**0.00**	0.00	0.00	0.00	0.00	0.00
14/03/2001	0.00	1.16	1.0000	1.16	2.04	**0.00**	0.00	0.00	0.00	0.00	0.00
15/03/2001	1.50	0.94	1.0000	0.94	1.48	**0.00**	0.00	0.00	0.00	0.00	0.00
16/03/2001	1.20	0.74	1.0000	0.74	1.02	**0.00**	0.00	0.00	0.00	0.00	0.00
17/03/2001	0.00	0.84	1.0000	0.84	1.86	**0.00**	0.00	0.00	0.00	0.00	0.00
18/03/2001	0.00	1.02	1.0000	1.02	2.88	**0.00**	0.00	0.00	0.00	0.00	0.00
19/03/2001	0.00	1.12	1.0000	1.12	4.00	**0.00**	0.00	0.00	0.00	0.00	0.00
20/03/2001	1.20	1.76	1.0000	1.76	4.56	**0.00**	0.00	0.00	0.00	0.00	0.00
21/03/2001	1.70	0.55	1.0000	0.55	3.40	**0.00**	0.00	0.00	0.00	0.00	0.00
22/03/2001	0.90	0.76	1.0000	0.76	3.26	**0.00**	0.00	0.00	0.00	0.00	0.00
23/03/2001	0.00	0.66	1.0000	0.66	3.93	**0.00**	0.00	0.00	0.00	0.00	0.00
24/03/2001	0.00	0.59	1.0000	0.59	4.52	**0.00**	0.00	0.00	0.00	0.00	0.00
25/03/2001	0.00	1.37	1.0000	1.37	5.89	**0.00**	0.00	0.00	0.00	0.00	0.00

Date	Rainfall	PE	S.F.	AE	SMD	**Recharge**	Pot. Runoff	Runoff 1	Runoff 2	Runoff	Recharge
26/03/2001	5.30	1.28	1.0000	1.28	1.87	**0.00**	0.30	0.06	0.00	0.06	-0.06
27/03/2001	4.60	0.56	1.0000	0.56	0.00	**2.17**	0.00	0.00	0.00	0.00	2.17
28/03/2001	3.40	1.28	1.0000	1.28	0.00	**2.12**	0.00	0.00	0.00	0.00	2.12
29/03/2001	0.00	1.39	1.0000	1.39	1.39	**0.00**	0.00	0.00	0.00	0.00	0.00
30/03/2001	2.30	1.17	1.0000	1.17	0.25	**0.00**	0.00	0.00	0.00	0.00	0.00
31/03/2001	0.10	1.95	1.0000	1.95	2.10	**0.00**	0.00	0.00	0.00	0.00	0.00
01/04/2001	0.90	1.61	1.0000	1.61	2.82	**0.00**	0.00	0.00	0.00	0.00	0.00
02/04/2001	0.00	2.02	1.0000	2.02	4.83	**0.00**	0.00	0.00	0.00	0.00	0.00
03/04/2001	3.00	1.73	1.0000	1.73	3.56	**0.00**	0.00	0.00	0.00	0.00	0.00
04/04/2001	6.60	1.72	1.0000	1.72	0.00	**1.31**	1.60	0.32	0.00	0.32	0.99
05/04/2001	7.60	0.88	1.0000	0.88	0.00	**6.72**	2.60	0.52	0.00	0.52	6.20
06/04/2001	5.40	1.32	1.0000	1.32	0.00	**4.08**	0.40	0.08	0.00	0.08	4.00
07/04/2001	0.10	1.16	1.0000	1.16	1.06	**0.00**	0.00	0.00	0.00	0.00	0.00
08/04/2001	7.60	0.65	1.0000	0.65	0.00	**5.89**	2.60	0.52	0.00	0.52	5.37
09/04/2001	3.30	1.59	1.0000	1.59	0.00	**1.71**	0.00	0.00	0.00	0.00	1.71
10/04/2001	0.00	1.42	1.0000	1.42	1.42	**0.00**	0.00	0.00	0.00	0.00	0.00
11/04/2001	0.20	1.91	1.0000	1.91	3.13	**0.00**	0.00	0.00	0.00	0.00	0.00
12/04/2001	2.40	1.18	1.0000	1.18	1.91	**0.00**	0.00	0.00	0.00	0.00	0.00
13/04/2001	0.00	0.78	1.0000	0.78	2.69	**0.00**	0.00	0.00	0.00	0.00	0.00
14/04/2001	3.10	1.57	1.0000	1.57	1.17	**0.00**	0.00	0.00	0.00	0.00	0.00
15/04/2001	0.00	1.63	1.0000	1.63	2.80	**0.00**	0.00	0.00	0.00	0.00	0.00
16/04/2001	0.00	1.79	1.0000	1.79	4.58	**0.00**	0.00	0.00	0.00	0.00	0.00
17/04/2001	3.90	1.27	1.0000	1.27	1.96	**0.00**	0.00	0.00	0.00	0.00	0.00
18/04/2001	0.00	1.83	1.0000	1.83	3.78	**0.00**	0.00	0.00	0.00	0.00	0.00
19/04/2001	0.00	2.01	1.0000	2.01	5.80	**0.00**	0.00	0.00	0.00	0.00	0.00
20/04/2001	0.20	1.99	1.0000	1.99	7.58	**0.00**	0.00	0.00	0.00	0.00	0.00
21/04/2001	9.60	1.24	1.0000	1.24	0.00	**0.78**	4.60	0.92	0.00	0.92	-0.14
22/04/2001	0.90	1.67	1.0000	1.67	0.77	**0.00**	0.00	0.00	0.00	0.00	0.00
23/04/2001	0.40	2.19	1.0000	2.19	2.56	**0.00**	0.00	0.00	0.00	0.00	0.00
24/04/2001	2.90	1.00	1.0000	1.00	0.65	**0.00**	0.00	0.00	0.00	0.00	0.00
25/04/2001	1.80	1.53	1.0000	1.53	0.38	**0.00**	0.00	0.00	0.00	0.00	0.00
26/04/2001	0.00	1.95	1.0000	1.95	2.33	**0.00**	0.00	0.00	0.00	0.00	0.00
27/04/2001	2.60	1.03	1.0000	1.03	0.76	**0.00**	0.00	0.00	0.00	0.00	0.00
28/04/2001	2.20	1.88	1.0000	1.88	0.44	**0.00**	0.00	0.00	0.00	0.00	0.00
29/04/2001	0.80	1.67	1.0000	1.67	1.31	**0.00**	0.00	0.00	0.00	0.00	0.00
30/04/2001	0.00	1.94	1.0000	1.94	3.24	**0.00**	0.00	0.00	0.00	0.00	0.00
01/05/2001	0.00	2.65	1.0000	2.65	5.90	**0.00**	0.00	0.00	0.00	0.00	0.00
02/05/2001	1.20	2.83	1.0000	2.83	7.52	**0.00**	0.00	0.00	0.00	0.00	0.00
03/05/2001	0.00	1.97	1.0000	1.97	9.50	**0.00**	0.00	0.00	0.00	0.00	0.00
04/05/2001	0.00	1.77	1.0000	1.77	11.26	**0.00**	0.00	0.00	0.00	0.00	0.00
05/05/2001	0.00	2.19	1.0000	2.19	13.45	**0.00**	0.00	0.00	0.00	0.00	0.00
06/05/2001	0.00	2.22	1.0000	2.22	15.67	**0.00**	0.00	0.00	0.00	0.00	0.00
07/05/2001	0.00	2.86	1.0000	2.86	18.54	**0.00**	0.00	0.00	0.00	0.00	0.00
08/05/2001	0.00	3.05	1.0000	3.05	21.59	**0.00**	0.00	0.00	0.00	0.00	0.00
09/05/2001	0.00	2.58	1.0000	2.58	24.17	**0.00**	0.00	0.00	0.00	0.00	0.00
10/05/2001	0.00	2.66	1.0000	2.66	26.82	**0.00**	0.00	0.00	0.00	0.00	0.00
11/05/2001	0.20	1.85	1.0000	1.85	28.47	**0.00**	0.00	0.00	0.00	0.00	0.00
12/05/2001	0.00	3.20	1.0000	3.20	31.68	**0.00**	0.00	0.00	0.00	0.00	0.00
13/05/2001	1.10	2.49	1.0000	2.49	33.06	**0.00**	0.00	0.00	0.00	0.00	0.00
14/05/2001	2.20	3.37	1.0000	3.37	34.23	**0.00**	0.00	0.00	0.00	0.00	0.00
15/05/2001	6.20	1.23	1.0000	1.23	29.26	**0.00**	1.20	0.24	0.00	0.24	-0.24
16/05/2001	10.20	1.46	1.0000	1.46	20.52	**0.00**	5.20	1.04	0.00	1.04	-1.04
17/05/2001	0.30	1.55	1.0000	1.55	21.77	**0.00**	0.00	0.00	0.00	0.00	0.00
18/05/2001	0.00	2.27	1.0000	2.27	24.04	**0.00**	0.00	0.00	0.00	0.00	0.00
19/05/2001	0.00	1.82	1.0000	1.82	25.87	**0.00**	0.00	0.00	0.00	0.00	0.00
20/05/2001	0.00	2.12	1.0000	2.12	27.98	**0.00**	0.00	0.00	0.00	0.00	0.00
21/05/2001	0.00	3.53	1.0000	3.53	31.51	**0.00**	0.00	0.00	0.00	0.00	0.00
22/05/2001	0.00	3.65	1.0000	3.65	35.15	**0.00**	0.00	0.00	0.00	0.00	0.00
23/05/2001	0.00	3.77	1.0000	3.77	38.92	**0.00**	0.00	0.00	0.00	0.00	0.00
24/05/2001	0.00	3.93	1.0000	3.93	42.85	**0.00**	0.00	0.00	0.00	0.00	0.00
25/05/2001	5.50	2.42	1.0000	2.42	39.77	**0.00**	0.50	0.10	0.00	0.10	-0.10
26/05/2001	2.10	2.67	1.0000	2.67	40.34	**0.00**	0.00	0.00	0.00	0.00	0.00
27/05/2001	6.40	2.24	1.0000	2.24	36.18	**0.00**	1.40	0.28	0.00	0.28	-0.28
28/05/2001	0.00	3.38	1.0000	3.38	39.56	**0.00**	0.00	0.00	0.00	0.00	0.00
29/05/2001	0.00	2.92	1.0000	2.92	42.48	**0.00**	0.00	0.00	0.00	0.00	0.00
30/05/2001	2.00	2.72	1.0000	2.72	43.20	**0.00**	0.00	0.00	0.00	0.00	0.00
31/05/2001	0.70	2.40	1.0000	2.40	44.90	**0.00**	0.00	0.00	0.00	0.00	0.00
01/06/2001	0.90	2.88	1.0000	2.88	46.88	**0.00**	0.00	0.00	0.00	0.00	0.00
02/06/2001	0.00	2.25	1.0000	2.25	49.13	**0.00**	0.00	0.00	0.00	0.00	0.00
03/06/2001	0.00	2.20	1.0000	2.20	51.34	**0.00**	0.00	0.00	0.00	0.00	0.00
04/06/2001	0.00	2.70	1.0000	2.70	54.03	**0.00**	0.00	0.00	0.00	0.00	0.00
05/06/2001	1.50	2.73	1.0000	2.73	55.26	**0.00**	0.00	0.00	0.00	0.00	0.00
06/06/2001	11.30	1.31	1.0000	1.31	45.27	**0.00**	6.30	1.26	0.00	1.26	-1.26
07/06/2001	0.00	2.70	1.0000	2.70	47.97	**0.00**	0.00	0.00	0.00	0.00	0.00
08/06/2001	1.00	2.91	1.0000	2.91	49.88	**0.00**	0.00	0.00	0.00	0.00	0.00
09/06/2001	0.90	2.74	1.0000	2.74	51.71	**0.00**	0.00	0.00	0.00	0.00	0.00
10/06/2001	0.00	3.08	1.0000	3.08	54.80	**0.00**	0.00	0.00	0.00	0.00	0.00
11/06/2001	0.00	2.19	1.0000	2.19	56.98	**0.00**	0.00	0.00	0.00	0.00	0.00

Date	Rainfall	PE	S.F.	AE	SMD	**Recharge**	Pot. Runoff	Runoff 1	Runoff 2	Runoff	Recharge
12/06/2001	0.00	2.10	1.0000	2.10	59.09	**0.00**	0.00	0.00	0.00	0.00	0.00
13/06/2001	0.00	2.23	1.0000	2.23	61.32	**0.00**	0.00	0.00	0.00	0.00	0.00
14/06/2001	6.10	1.85	1.0000	1.85	57.08	**0.00**	1.10	0.22	0.00	0.22	-0.22
15/06/2001	2.10	2.97	1.0000	2.97	57.94	**0.00**	0.00	0.00	0.00	0.00	0.00
16/06/2001	0.00	1.09	1.0000	1.09	59.03	**0.00**	0.00	0.00	0.00	0.00	0.00
17/06/2001	0.00	1.85	1.0000	1.85	60.88	**0.00**	0.00	0.00	0.00	0.00	0.00
18/06/2001	5.80	2.08	1.0000	2.08	57.16	**0.00**	0.80	0.16	0.00	0.16	-0.16
19/06/2001	1.80	3.63	1.0000	3.63	59.00	**0.00**	0.00	0.00	0.00	0.00	0.00
20/06/2001	0.00	3.21	1.0000	3.21	62.21	**0.00**	0.00	0.00	0.00	0.00	0.00
21/06/2001	0.00	2.33	1.0000	2.33	64.54	**0.00**	0.00	0.00	0.00	0.00	0.00
22/06/2001	0.00	3.60	1.0000	3.60	68.14	**0.00**	0.00	0.00	0.00	0.00	0.00
23/06/2001	0.00	2.69	1.0000	2.69	70.83	**0.00**	0.00	0.00	0.00	0.00	0.00
24/06/2001	0.00	3.97	1.0000	3.97	74.80	**0.00**	0.00	0.00	0.00	0.00	0.00
25/06/2001	6.90	3.80	0.9850	3.75	71.64	**0.00**	1.90	0.38	0.00	0.38	-0.38
26/06/2001	1.60	1.96	1.0000	1.96	72.00	**0.00**	0.00	0.00	0.00	0.00	0.00
27/06/2001	4.70	2.30	1.0000	2.30	69.60	**0.00**	0.00	0.00	0.00	0.00	0.00
28/06/2001	3.30	2.10	1.0000	2.10	68.40	**0.00**	0.00	0.00	0.00	0.00	0.00
29/06/2001	1.00	3.59	1.0000	3.59	70.99	**0.00**	0.00	0.00	0.00	0.00	0.00
30/06/2001	0.00	3.21	1.0000	3.21	74.19	**0.00**	0.00	0.00	0.00	0.00	0.00
01/07/2001	0.00	2.67	0.9963	2.66	76.85	**0.00**	0.00	0.00	0.00	0.00	0.00
02/07/2001	0.00	4.61	0.9462	4.36	81.21	**0.00**	0.00	0.00	0.00	0.00	0.00
03/07/2001	0.70	2.13	0.8639	1.84	82.35	**0.00**	0.00	0.00	0.00	0.00	0.00
04/07/2001	0.00	1.79	0.8424	1.51	83.86	**0.00**	0.00	0.00	0.00	0.00	0.00
05/07/2001	0.00	2.86	0.8139	2.33	86.19	**0.00**	0.00	0.00	0.00	0.00	0.00
06/07/2001	0.10	1.94	0.7700	1.50	87.59	**0.00**	0.00	0.00	0.00	0.00	0.00
07/07/2001	0.20	1.32	0.7436	0.98	88.37	**0.00**	0.00	0.00	0.00	0.00	0.00
08/07/2001	0.00	2.11	0.7289	1.54	89.91	**0.00**	0.00	0.00	0.00	0.00	0.00
09/07/2001	0.30	3.13	0.6999	2.19	91.79	**0.00**	0.00	0.00	0.00	0.00	0.00
10/07/2001	6.90	2.86	0.6643	1.90	86.79	**0.00**	1.90	0.38	0.00	0.38	-0.38
11/07/2001	1.60	2.92	0.7586	2.22	87.41	**0.00**	0.00	0.00	0.00	0.00	0.00
12/07/2001	2.80	2.59	0.7470	1.94	86.55	**0.00**	0.00	0.00	0.00	0.00	0.00
13/07/2001	26.60	2.10	0.7633	1.61	61.55	**0.00**	21.60	0.00	6.48	6.48	-6.48
14/07/2001	3.00	2.07	1.0000	2.07	60.62	**0.00**	0.00	0.00	0.00	0.00	0.00
15/07/2001	0.00	2.90	1.0000	2.90	63.52	**0.00**	0.00	0.00	0.00	0.00	0.00
16/07/2001	0.70	2.88	1.0000	2.88	65.70	**0.00**	0.00	0.00	0.00	0.00	0.00
17/07/2001	8.40	1.21	1.0000	1.21	58.51	**0.00**	3.40	0.68	0.00	0.68	-0.68
18/07/2001	0.00	2.98	1.0000	2.98	61.49	**0.00**	0.00	0.00	0.00	0.00	0.00
19/07/2001	0.00	2.54	1.0000	2.54	64.03	**0.00**	0.00	0.00	0.00	0.00	0.00
20/07/2001	4.40	2.09	1.0000	2.09	61.73	**0.00**	0.00	0.00	0.00	0.00	0.00
21/07/2001	1.50	1.99	1.0000	1.99	62.22	**0.00**	0.00	0.00	0.00	0.00	0.00
22/07/2001	0.00	3.04	1.0000	3.04	65.25	**0.00**	0.00	0.00	0.00	0.00	0.00
23/07/2001	0.90	2.69	1.0000	2.69	67.04	**0.00**	0.00	0.00	0.00	0.00	0.00
24/07/2001	0.00	2.49	1.0000	2.49	69.53	**0.00**	0.00	0.00	0.00	0.00	0.00
25/07/2001	0.00	1.77	1.0000	1.77	71.30	**0.00**	0.00	0.00	0.00	0.00	0.00
26/07/2001	0.00	3.55	1.0000	3.55	74.84	**0.00**	0.00	0.00	0.00	0.00	0.00
27/07/2001	0.00	2.65	0.9841	2.61	77.45	**0.00**	0.00	0.00	0.00	0.00	0.00
28/07/2001	0.00	3.87	0.9349	3.62	81.07	**0.00**	0.00	0.00	0.00	0.00	0.00
29/07/2001	0.00	2.78	0.8665	2.41	83.48	**0.00**	0.00	0.00	0.00	0.00	0.00
30/07/2001	0.20	3.61	0.8211	2.96	86.24	**0.00**	0.00	0.00	0.00	0.00	0.00
31/07/2001	0.00	1.81	0.7690	1.39	87.63	**0.00**	0.00	0.00	0.00	0.00	0.00
01/08/2001	1.90	3.80	0.7427	2.83	88.56	**0.00**	0.00	0.00	0.00	0.00	0.00
02/08/2001	5.80	2.45	0.7253	1.78	84.54	**0.00**	0.80	0.16	0.00	0.16	-0.16
03/08/2001	0.00	2.67	0.8012	2.14	86.68	**0.00**	0.00	0.00	0.00	0.00	0.00
04/08/2001	3.50	2.70	0.7608	2.05	85.23	**0.00**	0.00	0.00	0.00	0.00	0.00
05/08/2001	7.20	3.14	0.7881	2.48	80.51	**0.00**	2.20	0.44	0.00	0.44	-0.44
06/08/2001	4.20	1.76	0.8772	1.54	77.85	**0.00**	0.00	0.00	0.00	0.00	0.00
07/08/2001	2.10	1.81	0.9274	1.68	77.43	**0.00**	0.00	0.00	0.00	0.00	0.00
08/08/2001	7.20	1.98	0.9353	1.85	72.08	**0.00**	2.20	0.44	0.00	0.44	-0.44
09/08/2001	0.00	2.49	1.0000	2.49	74.58	**0.00**	0.00	0.00	0.00	0.00	0.00
10/08/2001	0.70	2.48	0.9891	2.45	76.33	**0.00**	0.00	0.00	0.00	0.00	0.00
11/08/2001	2.70	1.93	0.9561	1.85	75.47	**0.00**	0.00	0.00	0.00	0.00	0.00
12/08/2001	1.80	1.13	0.9722	1.09	74.77	**0.00**	0.00	0.00	0.00	0.00	0.00
13/08/2001	0.00	3.01	0.9855	2.97	77.74	**0.00**	0.00	0.00	0.00	0.00	0.00
14/08/2001	11.00	1.67	0.9295	1.55	68.29	**0.00**	6.00	1.20	0.00	1.20	-1.20
15/08/2001	0.00	1.70	1.0000	1.70	69.99	**0.00**	0.00	0.00	0.00	0.00	0.00
16/08/2001	8.40	1.97	1.0000	1.97	63.55	**0.00**	3.40	0.68	0.00	0.68	-0.68
17/08/2001	1.00	1.82	1.0000	1.82	64.37	**0.00**	0.00	0.00	0.00	0.00	0.00
18/08/2001	2.70	0.88	1.0000	0.88	62.55	**0.00**	0.00	0.00	0.00	0.00	0.00
19/08/2001	1.50	2.35	1.0000	2.35	63.41	**0.00**	0.00	0.00	0.00	0.00	0.00
20/08/2001	0.00	2.84	1.0000	2.84	66.24	**0.00**	0.00	0.00	0.00	0.00	0.00
21/08/2001	0.00	1.77	1.0000	1.77	68.02	**0.00**	0.00	0.00	0.00	0.00	0.00
22/08/2001	0.00	2.91	1.0000	2.91	70.93	**0.00**	0.00	0.00	0.00	0.00	0.00
23/08/2001	0.00	2.36	1.0000	2.36	73.29	**0.00**	0.00	0.00	0.00	0.00	0.00
24/08/2001	0.00	1.80	1.0000	1.80	75.09	**0.00**	0.00	0.00	0.00	0.00	0.00
25/08/2001	1.20	2.08	0.9795	2.04	75.93	**0.00**	0.00	0.00	0.00	0.00	0.00
26/08/2001	0.00	2.75	0.9637	2.65	78.58	**0.00**	0.00	0.00	0.00	0.00	0.00
27/08/2001	0.00	2.45	0.9136	2.23	80.81	**0.00**	0.00	0.00	0.00	0.00	0.00
28/08/2001	0.00	2.67	0.8715	2.33	83.14	**0.00**	0.00	0.00	0.00	0.00	0.00

Date	Rainfall	PE	S.F.	AE	SMD	**Recharge**	Pot. Runoff	Runoff 1	Runoff 2	Runoff	Recharge
29/08/2001	2.90	2.57	0.8275	2.13	82.37	**0.00**	0.00	0.00	0.00	0.00	0.00
30/08/2001	0.00	2.38	0.8421	2.01	84.38	**0.00**	0.00	0.00	0.00	0.00	0.00
31/08/2001	1.50	2.41	0.8042	1.94	84.82	**0.00**	0.00	0.00	0.00	0.00	0.00
01/09/2001	0.80	1.44	0.7959	1.15	85.17	**0.00**	0.00	0.00	0.00	0.00	0.00
02/09/2001	0.00	1.71	0.7893	1.35	86.52	**0.00**	0.00	0.00	0.00	0.00	0.00
03/09/2001	0.00	1.25	0.7638	0.95	87.47	**0.00**	0.00	0.00	0.00	0.00	0.00
04/09/2001	0.00	2.50	0.7458	1.87	89.34	**0.00**	0.00	0.00	0.00	0.00	0.00
05/09/2001	1.80	1.19	0.7106	0.85	88.39	**0.00**	0.00	0.00	0.00	0.00	0.00
06/09/2001	0.40	2.45	0.7286	1.79	89.77	**0.00**	0.00	0.00	0.00	0.00	0.00
07/09/2001	0.00	1.93	0.7024	1.36	91.13	**0.00**	0.00	0.00	0.00	0.00	0.00
08/09/2001	0.00	1.69	0.6768	1.14	92.27	**0.00**	0.00	0.00	0.00	0.00	0.00
09/09/2001	0.00	1.84	0.6553	1.20	93.48	**0.00**	0.00	0.00	0.00	0.00	0.00
10/09/2001	0.00	1.83	0.6325	1.16	94.63	**0.00**	0.00	0.00	0.00	0.00	0.00
11/09/2001	0.20	1.57	0.6107	0.96	95.39	**0.00**	0.00	0.00	0.00	0.00	0.00
12/09/2001	2.90	1.06	0.5964	0.63	93.12	**0.00**	0.00	0.00	0.00	0.00	0.00
13/09/2001	0.00	1.56	0.6392	0.99	94.12	**0.00**	0.00	0.00	0.00	0.00	0.00
14/09/2001	0.00	1.38	0.6205	0.85	94.97	**0.00**	0.00	0.00	0.00	0.00	0.00
15/09/2001	0.00	1.78	0.6043	1.08	96.05	**0.00**	0.00	0.00	0.00	0.00	0.00
16/09/2001	0.00	1.56	0.5840	0.91	96.96	**0.00**	0.00	0.00	0.00	0.00	0.00
17/09/2001	0.00	1.56	0.5668	0.88	97.84	**0.00**	0.00	0.00	0.00	0.00	0.00
18/09/2001	0.00	1.34	0.5502	0.74	98.58	**0.00**	0.00	0.00	0.00	0.00	0.00
19/09/2001	0.00	1.53	0.5363	0.82	99.40	**0.00**	0.00	0.00	0.00	0.00	0.00
20/09/2001	0.00	1.12	0.5208	0.59	99.98	**0.00**	0.00	0.00	0.00	0.00	0.00
21/09/2001	0.00	1.15	0.5097	0.58	100.57	**0.00**	0.00	0.00	0.00	0.00	0.00
22/09/2001	0.00	0.97	0.4987	0.48	101.05	**0.00**	0.00	0.00	0.00	0.00	0.00
23/09/2001	0.00	1.36	0.4896	0.66	101.72	**0.00**	0.00	0.00	0.00	0.00	0.00
24/09/2001	4.00	1.10	0.4771	0.53	98.24	**0.00**	0.00	0.00	0.00	0.00	0.00
25/09/2001	1.60	1.26	0.5426	0.69	97.33	**0.00**	0.00	0.00	0.00	0.00	0.00
26/09/2001	6.20	0.88	0.5599	0.49	91.62	**0.00**	1.20	0.24	0.00	0.24	-0.24
27/09/2001	1.10	1.18	0.6675	0.79	91.31	**0.00**	0.00	0.00	0.00	0.00	0.00
28/09/2001	0.50	1.67	0.6734	1.12	91.93	**0.00**	0.00	0.00	0.00	0.00	0.00
29/09/2001	1.70	1.73	0.6616	1.14	91.38	**0.00**	0.00	0.00	0.00	0.00	0.00
30/09/2001	1.50	1.93	0.6722	1.30	91.18	**0.00**	0.00	0.00	0.00	0.00	0.00
01/10/2001	0.60	2.56	0.6759	1.73	92.31	**0.00**	0.00	0.00	0.00	0.00	0.00
02/10/2001	1.00	1.82	0.6546	1.19	92.50	**0.00**	0.00	0.00	0.00	0.00	0.00
03/10/2001	0.40	1.42	0.6509	0.92	93.02	**0.00**	0.00	0.00	0.00	0.00	0.00
04/10/2001	1.00	1.31	0.6410	0.84	92.86	**0.00**	0.00	0.00	0.00	0.00	0.00
05/10/2001	2.40	1.28	0.6441	0.82	91.29	**0.00**	0.00	0.00	0.00	0.00	0.00
06/10/2001	0.00	1.84	0.6738	1.24	92.53	**0.00**	0.00	0.00	0.00	0.00	0.00
07/10/2001	25.10	0.98	0.6504	0.64	68.06	**0.00**	20.10	0.00	6.03	6.03	-6.03
08/10/2001	1.00	1.21	1.0000	1.21	68.27	**0.00**	0.00	0.00	0.00	0.00	0.00
09/10/2001	0.00	1.18	1.0000	1.18	69.46	**0.00**	0.00	0.00	0.00	0.00	0.00
10/10/2001	0.00	1.06	1.0000	1.06	70.51	**0.00**	0.00	0.00	0.00	0.00	0.00
11/10/2001	0.00	1.84	1.0000	1.84	72.35	**0.00**	0.00	0.00	0.00	0.00	0.00
12/10/2001	0.00	1.36	1.0000	1.36	73.71	**0.00**	0.00	0.00	0.00	0.00	0.00
13/10/2001	4.60	0.93	1.0000	0.93	70.04	**0.00**	0.00	0.00	0.00	0.00	0.00
14/10/2001	9.20	0.54	1.0000	0.54	61.38	**0.00**	4.20	0.84	0.00	0.84	-0.84
15/10/2001	2.00	1.10	1.0000	1.10	60.48	**0.00**	0.00	0.00	0.00	0.00	0.00
16/10/2001	1.00	1.46	1.0000	1.46	60.95	**0.00**	0.00	0.00	0.00	0.00	0.00
17/10/2001	7.60	1.38	1.0000	1.38	54.73	**0.00**	2.60	0.52	0.00	0.52	-0.52
18/10/2001	0.60	1.17	1.0000	1.17	55.30	**0.00**	0.00	0.00	0.00	0.00	0.00
19/10/2001	5.20	0.94	1.0000	0.94	51.04	**0.00**	0.20	0.04	0.00	0.04	-0.04
20/10/2001	0.20	0.69	1.0000	0.69	51.53	**0.00**	0.00	0.00	0.00	0.00	0.00
21/10/2001	0.00	0.40	1.0000	0.40	51.92	**0.00**	0.00	0.00	0.00	0.00	0.00
22/10/2001	1.70	0.53	1.0000	0.53	50.75	**0.00**	0.00	0.00	0.00	0.00	0.00
23/10/2001	0.70	0.87	1.0000	0.87	50.92	**0.00**	0.00	0.00	0.00	0.00	0.00
24/10/2001	1.80	1.04	1.0000	1.04	50.16	**0.00**	0.00	0.00	0.00	0.00	0.00
25/10/2001	3.00	0.88	1.0000	0.88	48.03	**0.00**	0.00	0.00	0.00	0.00	0.00
26/10/2001	1.30	1.07	1.0000	1.07	47.80	**0.00**	0.00	0.00	0.00	0.00	0.00
27/10/2001	0.00	0.70	1.0000	0.70	48.50	**0.00**	0.00	0.00	0.00	0.00	0.00
28/10/2001	0.00	0.53	1.0000	0.53	49.03	**0.00**	0.00	0.00	0.00	0.00	0.00
29/10/2001	0.00	1.05	1.0000	1.05	50.08	**0.00**	0.00	0.00	0.00	0.00	0.00
30/10/2001	1.70	1.15	1.0000	1.15	49.53	**0.00**	0.00	0.00	0.00	0.00	0.00
31/10/2001	0.00	0.79	1.0000	0.79	50.32	**0.00**	0.00	0.00	0.00	0.00	0.00
01/11/2001	0.00	0.89	1.0000	0.89	51.21	**0.00**	0.00	0.00	0.00	0.00	0.00
02/11/2001	0.00	1.00	1.0000	1.00	52.21	**0.00**	0.00	0.00	0.00	0.00	0.00
03/11/2001	0.00	0.38	1.0000	0.38	52.59	**0.00**	0.00	0.00	0.00	0.00	0.00
04/11/2001	0.40	0.39	1.0000	0.39	52.57	**0.00**	0.00	0.00	0.00	0.00	0.00
05/11/2001	0.20	0.31	1.0000	0.31	52.69	**0.00**	0.00	0.00	0.00	0.00	0.00
06/11/2001	3.60	0.43	1.0000	0.43	49.52	**0.00**	0.00	0.00	0.00	0.00	0.00
07/11/2001	4.20	0.13	1.0000	0.13	45.45	**0.00**	0.00	0.00	0.00	0.00	0.00
08/11/2001	0.00	0.42	1.0000	0.42	45.87	**0.00**	0.00	0.00	0.00	0.00	0.00
09/11/2001	0.20	0.37	1.0000	0.37	46.03	**0.00**	0.00	0.00	0.00	0.00	0.00
10/11/2001	0.00	0.69	1.0000	0.69	46.72	**0.00**	0.00	0.00	0.00	0.00	0.00
11/11/2001	1.10	0.50	1.0000	0.50	46.13	**0.00**	0.00	0.00	0.00	0.00	0.00
12/11/2001	0.20	0.33	1.0000	0.33	46.26	**0.00**	0.00	0.00	0.00	0.00	0.00
13/11/2001	0.30	0.07	1.0000	0.07	46.02	**0.00**	0.00	0.00	0.00	0.00	0.00
14/11/2001	0.00	0.30	1.0000	0.30	46.33	**0.00**	0.00	0.00	0.00	0.00	0.00

Date	Rainfall	PE	S.F.	AE	SMD	**Recharge**	Pot. Runoff	Runoff 1	Runoff 2	Runoff	Recharge
15/11/2001	0.20	0.14	1.0000	0.14	46.26	**0.00**	0.00	0.00	0.00	0.00	0.00
16/11/2001	0.00	0.35	1.0000	0.35	46.61	**0.00**	0.00	0.00	0.00	0.00	0.00
17/11/2001	0.00	0.41	1.0000	0.41	47.03	**0.00**	0.00	0.00	0.00	0.00	0.00
18/11/2001	0.00	0.07	1.0000	0.07	47.09	**0.00**	0.00	0.00	0.00	0.00	0.00
19/11/2001	0.20	0.26	1.0000	0.26	47.15	**0.00**	0.00	0.00	0.00	0.00	0.00
20/11/2001	0.50	0.38	1.0000	0.38	47.03	**0.00**	0.00	0.00	0.00	0.00	0.00
21/11/2001	1.20	0.46	1.0000	0.46	46.29	**0.00**	0.00	0.00	0.00	0.00	0.00
22/11/2001	0.10	0.03	1.0000	0.03	46.21	**0.00**	0.00	0.00	0.00	0.00	0.00
23/11/2001	0.00	0.39	1.0000	0.39	46.61	**0.00**	0.00	0.00	0.00	0.00	0.00
24/11/2001	0.60	0.59	1.0000	0.59	46.60	**0.00**	0.00	0.00	0.00	0.00	0.00
25/11/2001	0.00	0.48	1.0000	0.48	47.08	**0.00**	0.00	0.00	0.00	0.00	0.00
26/11/2001	0.50	0.24	1.0000	0.24	46.82	**0.00**	0.00	0.00	0.00	0.00	0.00
27/11/2001	0.00	0.52	1.0000	0.52	47.34	**0.00**	0.00	0.00	0.00	0.00	0.00
28/11/2001	5.30	0.49	1.0000	0.49	42.53	**0.00**	0.30	0.06	0.00	0.06	-0.06
29/11/2001	1.70	0.43	1.0000	0.43	41.26	**0.00**	0.00	0.00	0.00	0.00	0.00
30/11/2001	0.00	0.74	1.0000	0.74	42.00	**0.00**	0.00	0.00	0.00	0.00	0.00
01/12/2001	0.00	0.46	1.0000	0.46	42.46	**0.00**	0.00	0.00	0.00	0.00	0.00
02/12/2001	0.00	0.69	1.0000	0.69	43.15	**0.00**	0.00	0.00	0.00	0.00	0.00
03/12/2001	6.20	1.02	1.0000	1.02	37.97	**0.00**	1.20	0.24	0.00	0.24	-0.24
04/12/2001	1.20	0.21	1.0000	0.21	36.98	**0.00**	0.00	0.00	0.00	0.00	0.00
05/12/2001	0.00	0.46	1.0000	0.46	37.43	**0.00**	0.00	0.00	0.00	0.00	0.00
06/12/2001	4.20	0.52	1.0000	0.52	33.75	**0.00**	0.00	0.00	0.00	0.00	0.00
07/12/2001	0.00	0.42	1.0000	0.42	34.18	**0.00**	0.00	0.00	0.00	0.00	0.00
08/12/2001	0.00	0.00	1.0000	0.00	34.18	**0.00**	0.00	0.00	0.00	0.00	0.00
09/12/2001	0.00	0.08	1.0000	0.08	34.26	**0.00**	0.00	0.00	0.00	0.00	0.00
10/12/2001	0.00	0.68	1.0000	0.68	34.94	**0.00**	0.00	0.00	0.00	0.00	0.00
11/12/2001	0.00	0.38	1.0000	0.38	35.33	**0.00**	0.00	0.00	0.00	0.00	0.00
12/12/2001	0.00	0.00	1.0000	0.00	35.33	**0.00**	0.00	0.00	0.00	0.00	0.00
13/12/2001	0.00	0.15	1.0000	0.15	35.47	**0.00**	0.00	0.00	0.00	0.00	0.00
14/12/2001	0.00	0.24	1.0000	0.24	35.72	**0.00**	0.00	0.00	0.00	0.00	0.00
15/12/2001	0.00	0.33	1.0000	0.33	36.05	**0.00**	0.00	0.00	0.00	0.00	0.00
16/12/2001	0.00	0.68	1.0000	0.68	36.73	**0.00**	0.00	0.00	0.00	0.00	0.00
17/12/2001	0.00	0.00	1.0000	0.00	36.73	**0.00**	0.00	0.00	0.00	0.00	0.00
18/12/2001	0.00	0.20	1.0000	0.20	36.93	**0.00**	0.00	0.00	0.00	0.00	0.00
19/12/2001	0.00	0.25	1.0000	0.25	37.18	**0.00**	0.00	0.00	0.00	0.00	0.00
20/12/2001	0.40	0.07	1.0000	0.07	36.85	**0.00**	0.00	0.00	0.00	0.00	0.00
21/12/2001	0.40	0.30	1.0000	0.30	36.75	**0.00**	0.00	0.00	0.00	0.00	0.00
22/12/2001	0.00	0.01	1.0000	0.01	36.76	**0.00**	0.00	0.00	0.00	0.00	0.00
23/12/2001	0.90	0.10	1.0000	0.10	35.96	**0.00**	0.00	0.00	0.00	0.00	0.00
24/12/2001	0.60	0.49	1.0000	0.49	35.85	**0.00**	0.00	0.00	0.00	0.00	0.00
25/12/2001	0.00	0.00	1.0000	0.00	35.85	**0.00**	0.00	0.00	0.00	0.00	0.00
26/12/2001	0.10	0.28	1.0000	0.28	36.03	**0.00**	0.00	0.00	0.00	0.00	0.00
27/12/2001	0.00	0.46	1.0000	0.46	36.49	**0.00**	0.00	0.00	0.00	0.00	0.00
28/12/2001	0.00	0.45	1.0000	0.45	36.94	**0.00**	0.00	0.00	0.00	0.00	0.00
29/12/2001	0.00	0.00	1.0000	0.00	36.94	**0.00**	0.00	0.00	0.00	0.00	0.00
30/12/2001	0.00	0.06	1.0000	0.06	37.00	**0.00**	0.00	0.00	0.00	0.00	0.00
31/12/2001	0.00	0.12	1.0000	0.12	37.12	**0.00**	0.00	0.00	0.00	0.00	0.00
01/01/2002	0.00	0.21	1.0000	0.21	37.33	**0.00**	0.00	0.00	0.00	0.00	0.00
02/01/2002	0.00	0.79	1.0000	0.79	38.12	**0.00**	0.00	0.00	0.00	0.00	0.00
03/01/2002	0.00	0.89	1.0000	0.89	39.01	**0.00**	0.00	0.00	0.00	0.00	0.00
04/01/2002	1.40	0.37	1.0000	0.37	37.97	**0.00**	0.00	0.00	0.00	0.00	0.00
05/01/2002	0.00	0.15	1.0000	0.15	38.13	**0.00**	0.00	0.00	0.00	0.00	0.00
06/01/2002	0.00	0.21	1.0000	0.21	38.34	**0.00**	0.00	0.00	0.00	0.00	0.00
07/01/2002	1.40	0.45	1.0000	0.45	37.39	**0.00**	0.00	0.00	0.00	0.00	0.00
08/01/2002	0.00	0.30	1.0000	0.30	37.69	**0.00**	0.00	0.00	0.00	0.00	0.00
09/01/2002	0.00	0.30	1.0000	0.30	37.99	**0.00**	0.00	0.00	0.00	0.00	0.00
10/01/2002	0.00	0.22	1.0000	0.22	38.21	**0.00**	0.00	0.00	0.00	0.00	0.00
11/01/2002	0.00	0.60	1.0000	0.60	38.81	**0.00**	0.00	0.00	0.00	0.00	0.00
12/01/2002	0.20	1.09	1.0000	1.09	39.69	**0.00**	0.00	0.00	0.00	0.00	0.00
13/01/2002	0.00	0.52	1.0000	0.52	40.21	**0.00**	0.00	0.00	0.00	0.00	0.00
14/01/2002	2.10	0.64	1.0000	0.64	38.75	**0.00**	0.00	0.00	0.00	0.00	0.00
15/01/2002	0.00	0.27	1.0000	0.27	39.02	**0.00**	0.00	0.00	0.00	0.00	0.00
16/01/2002	7.40	0.48	1.0000	0.48	32.10	**0.00**	2.40	0.48	0.00	0.48	-0.48
17/01/2002	4.50	0.13	1.0000	0.13	27.73	**0.00**	0.00	0.00	0.00	0.00	0.00
18/01/2002	1.50	0.56	1.0000	0.56	26.79	**0.00**	0.00	0.00	0.00	0.00	0.00
19/01/2002	0.00	0.69	1.0000	0.69	27.48	**0.00**	0.00	0.00	0.00	0.00	0.00
20/01/2002	0.10	0.97	1.0000	0.97	28.35	**0.00**	0.00	0.00	0.00	0.00	0.00
21/01/2002	0.20	0.98	1.0000	0.98	29.13	**0.00**	0.00	0.00	0.00	0.00	0.00
22/01/2002	1.50	0.60	1.0000	0.60	28.23	**0.00**	0.00	0.00	0.00	0.00	0.00
23/01/2002	1.60	0.67	1.0000	0.67	27.30	**0.00**	0.00	0.00	0.00	0.00	0.00
24/01/2002	2.40	0.24	1.0000	0.24	25.14	**0.00**	0.00	0.00	0.00	0.00	0.00
25/01/2002	2.10	0.66	1.0000	0.66	23.71	**0.00**	0.00	0.00	0.00	0.00	0.00
26/01/2002	0.00	0.72	1.0000	0.72	24.43	**0.00**	0.00	0.00	0.00	0.00	0.00
27/01/2002	1.80	0.86	1.0000	0.86	23.49	**0.00**	0.00	0.00	0.00	0.00	0.00
28/01/2002	4.00	1.08	1.0000	1.08	20.56	**0.00**	0.00	0.00	0.00	0.00	0.00
29/01/2002	1.20	0.95	1.0000	0.95	20.31	**0.00**	0.00	0.00	0.00	0.00	0.00
30/01/2002	0.50	0.43	1.0000	0.43	20.25	**0.00**	0.00	0.00	0.00	0.00	0.00
31/01/2002	1.50	0.71	1.0000	0.71	19.46	**0.00**	0.00	0.00	0.00	0.00	0.00

Date	Rainfall	PE	S.F.	AE	SMD	**Recharge**	Pot. Runoff	Runoff 1	Runoff 2	Runoff	Recharge
01/02/2002	23.30	1.32	1.0000	1.32	0.00	**2.53**	18.30	0.00	5.49	5.49	-2.96
02/02/2002	6.00	1.22	1.0000	1.22	0.00	**4.78**	1.00	0.20	0.00	0.20	4.58
03/02/2002	3.00	0.60	1.0000	0.60	0.00	**2.40**	0.00	0.00	0.00	0.00	2.40
04/02/2002	12.00	0.60	1.0000	0.60	0.00	**11.40**	7.00	1.40	0.00	1.40	10.00
05/02/2002	1.20	0.76	1.0000	0.76	0.00	**0.44**	0.00	0.00	0.00	0.00	0.44
06/02/2002	6.20	0.58	1.0000	0.58	0.00	**5.62**	1.20	0.24	0.00	0.24	5.38
07/02/2002	1.30	0.88	1.0000	0.88	0.00	**0.42**	0.00	0.00	0.00	0.00	0.42
08/02/2002	6.50	0.71	1.0000	0.71	0.00	**5.79**	1.50	0.30	0.00	0.30	5.49
09/02/2002	0.80	1.00	1.0000	1.00	0.20	**0.00**	0.00	0.00	0.00	0.00	0.00
10/02/2002	5.50	0.63	1.0000	0.63	0.00	**4.67**	0.50	0.10	0.00	0.10	4.57
11/02/2002	3.20	0.64	1.0000	0.64	0.00	**2.56**	0.00	0.00	0.00	0.00	2.56
12/02/2002	0.00	1.36	1.0000	1.36	1.36	**0.00**	0.00	0.00	0.00	0.00	0.00
13/02/2002	0.00	0.46	1.0000	0.46	1.82	**0.00**	0.00	0.00	0.00	0.00	0.00
14/02/2002	0.00	0.46	1.0000	0.46	2.28	**0.00**	0.00	0.00	0.00	0.00	0.00
15/02/2002	0.00	0.65	1.0000	0.65	2.94	**0.00**	0.00	0.00	0.00	0.00	0.00
16/02/2002	0.00	0.82	1.0000	0.82	3.75	**0.00**	0.00	0.00	0.00	0.00	0.00
17/02/2002	0.00	0.77	1.0000	0.77	4.52	**0.00**	0.00	0.00	0.00	0.00	0.00
18/02/2002	0.00	0.76	1.0000	0.76	5.28	**0.00**	0.00	0.00	0.00	0.00	0.00
19/02/2002	12.50	0.57	1.0000	0.57	0.00	**6.65**	7.50	1.50	0.00	1.50	5.15
20/02/2002	4.50	0.50	1.0000	0.50	0.00	**4.00**	0.00	0.00	0.00	0.00	4.00
21/02/2002	1.00	0.37	1.0000	0.37	0.00	**0.63**	0.00	0.00	0.00	0.00	0.63
22/02/2002	2.00	0.77	1.0000	0.77	0.00	**1.23**	0.00	0.00	0.00	0.00	1.23
23/02/2002	2.00	1.15	1.0000	1.15	0.00	**0.85**	0.00	0.00	0.00	0.00	0.85
24/02/2002	16.00	0.46	1.0000	0.46	0.00	**15.54**	11.00	2.20	0.00	2.20	13.34
25/02/2002	17.20	0.65	1.0000	0.65	0.00	**16.55**	12.20	2.44	0.00	2.44	14.11
26/02/2002	3.00	0.54	1.0000	0.54	0.00	**2.46**	0.00	0.00	0.00	0.00	2.46
27/02/2002	2.00	0.82	1.0000	0.82	0.00	**1.18**	0.00	0.00	0.00	0.00	1.18
28/02/2002	0.00	0.96	1.0000	0.96	0.96	**0.00**	0.00	0.00	0.00	0.00	0.00
01/03/2002	0.00	0.89	1.0000	0.89	1.85	**0.00**	0.00	0.00	0.00	0.00	0.00
02/03/2002	0.00	0.62	1.0000	0.62	2.47	**0.00**	0.00	0.00	0.00	0.00	0.00
03/03/2002	0.00	0.67	1.0000	0.67	3.15	**0.00**	0.00	0.00	0.00	0.00	0.00
04/03/2002	0.00	0.69	1.0000	0.69	3.83	**0.00**	0.00	0.00	0.00	0.00	0.00
05/03/2002	0.00	1.13	1.0000	1.13	4.96	**0.00**	0.00	0.00	0.00	0.00	0.00
06/03/2002	0.00	1.04	1.0000	1.04	5.99	**0.00**	0.00	0.00	0.00	0.00	0.00
07/03/2002	0.00	1.42	1.0000	1.42	7.41	**0.00**	0.00	0.00	0.00	0.00	0.00
08/03/2002	8.10	1.05	1.0000	1.05	0.36	**0.00**	3.10	0.62	0.00	0.62	-0.62
09/03/2002	8.20	0.75	1.0000	0.75	0.00	**7.09**	3.20	0.64	0.00	0.64	6.45
10/03/2002	2.10	1.18	1.0000	1.18	0.00	**0.92**	0.00	0.00	0.00	0.00	0.92
11/03/2002	0.00	1.64	1.0000	1.64	1.64	**0.00**	0.00	0.00	0.00	0.00	0.00
12/03/2002	0.00	1.01	1.0000	1.01	2.65	**0.00**	0.00	0.00	0.00	0.00	0.00
13/03/2002	0.00	1.61	1.0000	1.61	4.26	**0.00**	0.00	0.00	0.00	0.00	0.00
14/03/2002	0.00	1.62	1.0000	1.62	5.88	**0.00**	0.00	0.00	0.00	0.00	0.00
15/03/2002	0.00	0.76	1.0000	0.76	6.64	**0.00**	0.00	0.00	0.00	0.00	0.00
16/03/2002	0.70	1.67	1.0000	1.67	7.60	**0.00**	0.00	0.00	0.00	0.00	0.00
17/03/2002	1.90	0.89	1.0000	0.89	6.59	**0.00**	0.00	0.00	0.00	0.00	0.00
18/03/2002	4.00	0.87	1.0000	0.87	3.46	**0.00**	0.00	0.00	0.00	0.00	0.00
19/03/2002	0.50	0.79	1.0000	0.79	3.76	**0.00**	0.00	0.00	0.00	0.00	0.00
20/03/2002	2.50	0.92	1.0000	0.92	2.18	**0.00**	0.00	0.00	0.00	0.00	0.00
21/03/2002	0.00	1.76	1.0000	1.76	3.94	**0.00**	0.00	0.00	0.00	0.00	0.00
22/03/2002	0.00	1.15	1.0000	1.15	5.09	**0.00**	0.00	0.00	0.00	0.00	0.00
23/03/2002	0.00	1.21	1.0000	1.21	6.30	**0.00**	0.00	0.00	0.00	0.00	0.00
24/03/2002	0.00	1.10	1.0000	1.10	7.39	**0.00**	0.00	0.00	0.00	0.00	0.00
25/03/2002	0.00	0.80	1.0000	0.80	8.19	**0.00**	0.00	0.00	0.00	0.00	0.00
26/03/2002	0.00	1.66	1.0000	1.66	9.85	**0.00**	0.00	0.00	0.00	0.00	0.00
27/03/2002	0.00	1.88	1.0000	1.88	11.74	**0.00**	0.00	0.00	0.00	0.00	0.00
28/03/2002	0.00	1.71	1.0000	1.71	13.45	**0.00**	0.00	0.00	0.00	0.00	0.00
29/03/2002	0.00	1.93	1.0000	1.93	15.38	**0.00**	0.00	0.00	0.00	0.00	0.00
30/03/2002	0.00	1.46	1.0000	1.46	16.84	**0.00**	0.00	0.00	0.00	0.00	0.00
31/03/2002	2.20	1.51	1.0000	1.51	16.15	**0.00**	0.00	0.00	0.00	0.00	0.00
01/04/2002	2.50	1.24	1.0000	1.24	14.90	**0.00**	0.00	0.00	0.00	0.00	0.00
02/04/2002	2.50	1.27	1.0000	1.27	13.67	**0.00**	0.00	0.00	0.00	0.00	0.00
03/04/2002	0.00	1.63	1.0000	1.63	15.30	**0.00**	0.00	0.00	0.00	0.00	0.00
04/04/2002	0.00	1.36	1.0000	1.36	16.66	**0.00**	0.00	0.00	0.00	0.00	0.00
05/04/2002	0.00	1.45	1.0000	1.45	18.11	**0.00**	0.00	0.00	0.00	0.00	0.00
06/04/2002	0.00	2.24	1.0000	2.24	20.35	**0.00**	0.00	0.00	0.00	0.00	0.00
07/04/2002	0.00	2.51	1.0000	2.51	22.86	**0.00**	0.00	0.00	0.00	0.00	0.00
08/04/2002	0.00	1.61	1.0000	1.61	24.47	**0.00**	0.00	0.00	0.00	0.00	0.00
09/04/2002	0.00	1.55	1.0000	1.55	26.01	**0.00**	0.00	0.00	0.00	0.00	0.00
10/04/2002	0.00	1.69	1.0000	1.69	27.70	**0.00**	0.00	0.00	0.00	0.00	0.00
11/04/2002	0.10	1.43	1.0000	1.43	29.03	**0.00**	0.00	0.00	0.00	0.00	0.00
12/04/2002	0.10	1.25	1.0000	1.25	30.18	**0.00**	0.00	0.00	0.00	0.00	0.00
13/04/2002	0.80	1.72	1.0000	1.72	31.10	**0.00**	0.00	0.00	0.00	0.00	0.00
14/04/2002	0.00	1.55	1.0000	1.55	32.65	**0.00**	0.00	0.00	0.00	0.00	0.00
15/04/2002	0.00	2.22	1.0000	2.22	34.87	**0.00**	0.00	0.00	0.00	0.00	0.00
16/04/2002	16.30	2.32	1.0000	2.32	20.89	**0.00**	11.30	2.26	0.00	2.26	-2.26
17/04/2002	24.00	0.67	1.0000	0.67	0.00	**2.44**	19.00	0.00	5.70	5.70	-3.26
18/04/2002	0.00	1.45	1.0000	1.45	1.45	**0.00**	0.00	0.00	0.00	0.00	0.00
19/04/2002	0.00	2.20	1.0000	2.20	3.65	**0.00**	0.00	0.00	0.00	0.00	0.00

Date	Rainfall	PE	S.F.	AE	SMD	**Recharge**	Pot. Runoff	Runoff 1	Runoff 2	Runoff	Recharge
20/04/2002	6.00	1.75	1.0000	1.75	0.00	**0.60**	1.00	0.20	0.00	0.20	0.40
21/04/2002	3.00	1.77	1.0000	1.77	0.00	**1.23**	0.00	0.00	0.00	0.00	1.23
22/04/2002	0.00	2.27	1.0000	2.27	2.27	**0.00**	0.00	0.00	0.00	0.00	0.00
23/04/2002	0.00	2.35	1.0000	2.35	4.62	**0.00**	0.00	0.00	0.00	0.00	0.00
24/04/2002	0.80	2.46	1.0000	2.46	6.29	**0.00**	0.00	0.00	0.00	0.00	0.00
25/04/2002	9.50	1.86	1.0000	1.86	0.00	**1.35**	4.50	0.90	0.00	0.90	0.45
26/04/2002	0.20	2.16	1.0000	2.16	1.96	**0.00**	0.00	0.00	0.00	0.00	0.00
27/04/2002	13.50	1.12	1.0000	1.12	0.00	**10.42**	8.50	1.70	0.00	1.70	8.72
28/04/2002	4.00	1.75	1.0000	1.75	0.00	**2.25**	0.00	0.00	0.00	0.00	2.25
29/04/2002	6.40	2.35	1.0000	2.35	0.00	**4.05**	1.40	0.28	0.00	0.28	3.77
30/04/2002	1.60	2.26	1.0000	2.26	0.66	**0.00**	0.00	0.00	0.00	0.00	0.00
01/05/2002	2.50	1.85	1.0000	1.85	0.00	**0.00**	0.00	0.00	0.00	0.00	0.00
02/05/2002	4.50	2.20	1.0000	2.20	0.00	**2.30**	0.00	0.00	0.00	0.00	2.30
03/05/2002	0.00	2.17	1.0000	2.17	2.17	**0.00**	0.00	0.00	0.00	0.00	0.00
04/05/2002	0.00	2.17	1.0000	2.17	4.34	**0.00**	0.00	0.00	0.00	0.00	0.00
05/05/2002	0.00	3.02	1.0000	3.02	7.36	**0.00**	0.00	0.00	0.00	0.00	0.00
06/05/2002	0.00	2.55	1.0000	2.55	9.91	**0.00**	0.00	0.00	0.00	0.00	0.00
07/05/2002	0.70	2.00	1.0000	2.00	11.21	**0.00**	0.00	0.00	0.00	0.00	0.00
08/05/2002	0.00	2.19	1.0000	2.19	13.40	**0.00**	0.00	0.00	0.00	0.00	0.00
09/05/2002	0.00	2.53	1.0000	2.53	15.93	**0.00**	0.00	0.00	0.00	0.00	0.00
10/05/2002	0.00	2.06	1.0000	2.06	17.99	**0.00**	0.00	0.00	0.00	0.00	0.00
11/05/2002	0.00	3.17	1.0000	3.17	21.16	**0.00**	0.00	0.00	0.00	0.00	0.00
12/05/2002	1.50	2.71	1.0000	2.71	22.37	**0.00**	0.00	0.00	0.00	0.00	0.00
13/05/2002	4.50	1.84	1.0000	1.84	19.71	**0.00**	0.00	0.00	0.00	0.00	0.00
14/05/2002	0.50	3.06	1.0000	3.06	22.27	**0.00**	0.00	0.00	0.00	0.00	0.00
15/05/2002	0.00	2.46	1.0000	2.46	24.73	**0.00**	0.00	0.00	0.00	0.00	0.00
16/05/2002	0.80	2.93	1.0000	2.93	26.87	**0.00**	0.00	0.00	0.00	0.00	0.00
17/05/2002	22.30	0.96	1.0000	0.96	5.53	**0.00**	17.30	0.00	5.19	5.19	-5.19
18/05/2002	0.30	2.41	1.0000	2.41	7.65	**0.00**	0.00	0.00	0.00	0.00	0.00
19/05/2002	5.30	2.08	1.0000	2.08	4.42	**0.00**	0.30	0.06	0.00	0.06	-0.06
20/05/2002	1.10	2.20	1.0000	2.20	5.53	**0.00**	0.00	0.00	0.00	0.00	0.00
21/05/2002	2.70	1.34	1.0000	1.34	4.17	**0.00**	0.00	0.00	0.00	0.00	0.00
22/05/2002	14.00	2.42	1.0000	2.42	0.00	**7.41**	9.00	1.80	0.00	1.80	5.61
23/05/2002	6.00	2.31	1.0000	2.31	0.00	**3.69**	1.00	0.20	0.00	0.20	3.49
24/05/2002	2.60	2.16	1.0000	2.16	0.00	**0.44**	0.00	0.00	0.00	0.00	0.44
25/05/2002	3.30	2.27	1.0000	2.27	0.00	**1.03**	0.00	0.00	0.00	0.00	1.03
26/05/2002	0.80	2.47	1.0000	2.47	1.67	**0.00**	0.00	0.00	0.00	0.00	0.00
27/05/2002	7.10	2.44	1.0000	2.44	0.00	**2.99**	2.10	0.42	0.00	0.42	2.57
28/05/2002	5.50	2.30	1.0000	2.30	0.00	**3.20**	0.50	0.10	0.00	0.10	3.10
29/05/2002	3.50	2.54	1.0000	2.54	0.00	**0.96**	0.00	0.00	0.00	0.00	0.96
30/05/2002	1.50	3.07	1.0000	3.07	1.57	**0.00**	0.00	0.00	0.00	0.00	0.00
31/05/2002	0.20	2.66	1.0000	2.66	4.03	**0.00**	0.00	0.00	0.00	0.00	0.00
01/06/2002	9.50	2.35	1.0000	2.35	0.00	**3.12**	4.50	0.90	0.00	0.90	2.22
02/06/2002	3.30	1.81	1.0000	1.81	0.00	**1.49**	0.00	0.00	0.00	0.00	1.49
03/06/2002	3.00	2.77	1.0000	2.77	0.00	**0.23**	0.00	0.00	0.00	0.00	0.23
04/06/2002	0.30	2.01	1.0000	2.01	1.71	**0.00**	0.00	0.00	0.00	0.00	0.00
05/06/2002	0.00	2.85	1.0000	2.85	4.56	**0.00**	0.00	0.00	0.00	0.00	0.00
06/06/2002	3.00	1.51	1.0000	1.51	3.07	**0.00**	0.00	0.00	0.00	0.00	0.00
07/06/2002	2.00	1.15	1.0000	1.15	2.22	**0.00**	0.00	0.00	0.00	0.00	0.00
08/06/2002	5.20	1.46	1.0000	1.46	0.00	**1.52**	0.20	0.04	0.00	0.04	1.48
09/06/2002	7.00	2.75	1.0000	2.75	0.00	**4.25**	2.00	0.40	0.00	0.40	3.85
10/06/2002	4.50	2.79	1.0000	2.79	0.00	**1.71**	0.00	0.00	0.00	0.00	1.71
11/06/2002	4.70	2.47	1.0000	2.47	0.00	**2.23**	0.00	0.00	0.00	0.00	2.23
12/06/2002	0.20	2.41	1.0000	2.41	2.21	**0.00**	0.00	0.00	0.00	0.00	0.00
13/06/2002	4.50	1.47	1.0000	1.47	0.00	**0.82**	0.00	0.00	0.00	0.00	0.82
14/06/2002	20.60	1.99	1.0000	1.99	0.00	**18.61**	15.60	0.00	4.68	4.68	13.93
15/06/2002	0.00	2.25	1.0000	2.25	2.25	**0.00**	0.00	0.00	0.00	0.00	0.00
16/06/2002	6.00	1.56	1.0000	1.56	0.00	**2.19**	1.00	0.20	0.00	0.20	1.99
17/06/2002	0.00	3.59	1.0000	3.59	3.59	**0.00**	0.00	0.00	0.00	0.00	0.00
18/06/2002	0.00	3.13	1.0000	3.13	6.72	**0.00**	0.00	0.00	0.00	0.00	0.00
19/06/2002	0.20	2.99	1.0000	2.99	9.51	**0.00**	0.00	0.00	0.00	0.00	0.00
20/06/2002	2.50	3.71	1.0000	3.71	10.71	**0.00**	0.00	0.00	0.00	0.00	0.00
21/06/2002	0.10	3.10	1.0000	3.10	13.72	**0.00**	0.00	0.00	0.00	0.00	0.00
22/06/2002	0.80	3.11	1.0000	3.11	16.03	**0.00**	0.00	0.00	0.00	0.00	0.00
23/06/2002	3.70	2.84	1.0000	2.84	15.17	**0.00**	0.00	0.00	0.00	0.00	0.00
24/06/2002	0.00	1.99	1.0000	1.99	17.16	**0.00**	0.00	0.00	0.00	0.00	0.00
25/06/2002	0.00	2.78	1.0000	2.78	19.94	**0.00**	0.00	0.00	0.00	0.00	0.00
26/06/2002	0.70	2.07	1.0000	2.07	21.31	**0.00**	0.00	0.00	0.00	0.00	0.00
27/06/2002	0.00	3.11	1.0000	3.11	24.42	**0.00**	0.00	0.00	0.00	0.00	0.00
28/06/2002	0.00	2.84	1.0000	2.84	27.26	**0.00**	0.00	0.00	0.00	0.00	0.00
29/06/2002	1.30	2.46	1.0000	2.46	28.42	**0.00**	0.00	0.00	0.00	0.00	0.00
30/06/2002	3.00	1.39	1.0000	1.39	26.81	**0.00**	0.00	0.00	0.00	0.00	0.00
01/07/2002	5.30	1.99	1.0000	1.99	23.50	**0.00**	0.30	0.06	0.00	0.06	-0.06
02/07/2002	0.00	2.26	1.0000	2.26	25.77	**0.00**	0.00	0.00	0.00	0.00	0.00
03/07/2002	1.00	2.49	1.0000	2.49	27.26	**0.00**	0.00	0.00	0.00	0.00	0.00
04/07/2002	8.70	1.43	1.0000	1.43	19.99	**0.00**	3.70	0.74	0.00	0.74	-0.74
05/07/2002	0.90	2.74	1.0000	2.74	21.83	**0.00**	0.00	0.00	0.00	0.00	0.00
06/07/2002	0.00	2.14	1.0000	2.14	23.98	**0.00**	0.00	0.00	0.00	0.00	0.00

Date	Rainfall	PE	S.F.	AE	SMD	**Recharge**	Pot. Runoff	Runoff 1	Runoff 2	Runoff	Recharge
07/07/2002	2.70	2.41	1.0000	2.41	23.69	**0.00**	0.00	0.00	0.00	0.00	0.00
08/07/2002	0.30	2.37	1.0000	2.37	25.76	**0.00**	0.00	0.00	0.00	0.00	0.00
09/07/2002	3.30	2.11	1.0000	2.11	24.57	**0.00**	0.00	0.00	0.00	0.00	0.00
10/07/2002	8.40	2.30	1.0000	2.30	18.47	**0.00**	3.40	0.68	0.00	0.68	-0.68
11/07/2002	8.30	2.66	1.0000	2.66	12.83	**0.00**	3.30	0.66	0.00	0.66	-0.66
12/07/2002	3.00	2.70	1.0000	2.70	12.53	**0.00**	0.00	0.00	0.00	0.00	0.00
13/07/2002	0.10	2.97	1.0000	2.97	15.40	**0.00**	0.00	0.00	0.00	0.00	0.00
14/07/2002	0.00	3.39	1.0000	3.39	18.79	**0.00**	0.00	0.00	0.00	0.00	0.00
15/07/2002	0.10	2.05	1.0000	2.05	20.74	**0.00**	0.00	0.00	0.00	0.00	0.00
16/07/2002	0.00	1.83	1.0000	1.83	22.57	**0.00**	0.00	0.00	0.00	0.00	0.00
17/07/2002	0.00	2.52	1.0000	2.52	25.09	**0.00**	0.00	0.00	0.00	0.00	0.00
18/07/2002	0.60	2.75	1.0000	2.75	27.24	**0.00**	0.00	0.00	0.00	0.00	0.00
19/07/2002	4.90	1.78	1.0000	1.78	24.12	**0.00**	0.00	0.00	0.00	0.00	0.00
20/07/2002	0.00	1.43	1.0000	1.43	25.56	**0.00**	0.00	0.00	0.00	0.00	0.00
21/07/2002	0.00	3.15	1.0000	3.15	28.70	**0.00**	0.00	0.00	0.00	0.00	0.00
22/07/2002	2.50	2.78	1.0000	2.78	28.98	**0.00**	0.00	0.00	0.00	0.00	0.00
23/07/2002	0.00	2.17	1.0000	2.17	31.15	**0.00**	0.00	0.00	0.00	0.00	0.00
24/07/2002	0.00	2.13	1.0000	2.13	33.28	**0.00**	0.00	0.00	0.00	0.00	0.00
25/07/2002	0.00	2.92	1.0000	2.92	36.20	**0.00**	0.00	0.00	0.00	0.00	0.00
26/07/2002	0.00	3.01	1.0000	3.01	39.21	**0.00**	0.00	0.00	0.00	0.00	0.00
27/07/2002	0.00	2.97	1.0000	2.97	42.18	**0.00**	0.00	0.00	0.00	0.00	0.00
28/07/2002	6.90	1.65	1.0000	1.65	36.93	**0.00**	1.90	0.38	0.00	0.38	-0.38
29/07/2002	4.00	1.75	1.0000	1.75	34.67	**0.00**	0.00	0.00	0.00	0.00	0.00
30/07/2002	0.10	1.60	1.0000	1.60	36.17	**0.00**	0.00	0.00	0.00	0.00	0.00
31/07/2002	6.30	1.18	1.0000	1.18	31.06	**0.00**	1.30	0.26	0.00	0.26	-0.26
01/08/2002	12.20	1.40	1.0000	1.40	20.25	**0.00**	7.20	1.44	0.00	1.44	-1.44
02/08/2002	6.40	0.74	1.0000	0.74	14.60	**0.00**	1.40	0.28	0.00	0.28	-0.28
03/08/2002	3.00	1.33	1.0000	1.33	12.92	**0.00**	0.00	0.00	0.00	0.00	0.00
04/08/2002	0.00	2.91	1.0000	2.91	15.84	**0.00**	0.00	0.00	0.00	0.00	0.00
05/08/2002	0.00	3.45	1.0000	3.45	19.29	**0.00**	0.00	0.00	0.00	0.00	0.00
06/08/2002	7.20	1.71	1.0000	1.71	13.80	**0.00**	2.20	0.44	0.00	0.44	-0.44
07/08/2002	0.40	1.60	1.0000	1.60	15.00	**0.00**	0.00	0.00	0.00	0.00	0.00
08/08/2002	6.30	1.06	1.0000	1.06	9.76	**0.00**	1.30	0.26	0.00	0.26	-0.26
09/08/2002	0.00	2.44	1.0000	2.44	12.19	**0.00**	0.00	0.00	0.00	0.00	0.00
10/08/2002	1.30	2.76	1.0000	2.76	13.65	**0.00**	0.00	0.00	0.00	0.00	0.00
11/08/2002	0.10	2.53	1.0000	2.53	16.08	**0.00**	0.00	0.00	0.00	0.00	0.00
12/08/2002	1.60	2.21	1.0000	2.21	16.69	**0.00**	0.00	0.00	0.00	0.00	0.00
13/08/2002	8.00	2.37	1.0000	2.37	11.06	**0.00**	3.00	0.60	0.00	0.60	-0.60
14/08/2002	3.00	2.28	1.0000	2.28	10.34	**0.00**	0.00	0.00	0.00	0.00	0.00
15/08/2002	0.00	2.83	1.0000	2.83	13.17	**0.00**	0.00	0.00	0.00	0.00	0.00
16/08/2002	0.00	2.97	1.0000	2.97	16.14	**0.00**	0.00	0.00	0.00	0.00	0.00
17/08/2002	0.00	2.75	1.0000	2.75	18.89	**0.00**	0.00	0.00	0.00	0.00	0.00
18/08/2002	0.00	1.73	1.0000	1.73	20.62	**0.00**	0.00	0.00	0.00	0.00	0.00
19/08/2002	0.90	1.41	1.0000	1.41	21.13	**0.00**	0.00	0.00	0.00	0.00	0.00
20/08/2002	0.00	1.73	1.0000	1.73	22.86	**0.00**	0.00	0.00	0.00	0.00	0.00
21/08/2002	0.00	2.53	1.0000	2.53	25.39	**0.00**	0.00	0.00	0.00	0.00	0.00
22/08/2002	7.30	1.94	1.0000	1.94	20.03	**0.00**	2.30	0.46	0.00	0.46	-0.46
23/08/2002	2.50	2.40	1.0000	2.40	19.93	**0.00**	0.00	0.00	0.00	0.00	0.00
24/08/2002	0.00	1.82	1.0000	1.82	21.75	**0.00**	0.00	0.00	0.00	0.00	0.00
25/08/2002	0.00	2.51	1.0000	2.51	24.26	**0.00**	0.00	0.00	0.00	0.00	0.00
26/08/2002	0.00	2.53	1.0000	2.53	26.79	**0.00**	0.00	0.00	0.00	0.00	0.00
27/08/2002	0.80	1.29	1.0000	1.29	27.29	**0.00**	0.00	0.00	0.00	0.00	0.00
28/08/2002	1.80	2.00	1.0000	2.00	27.48	**0.00**	0.00	0.00	0.00	0.00	0.00
29/08/2002	0.30	1.74	1.0000	1.74	28.92	**0.00**	0.00	0.00	0.00	0.00	0.00
30/08/2002	2.60	1.12	1.0000	1.12	27.45	**0.00**	0.00	0.00	0.00	0.00	0.00
31/08/2002	0.00	1.86	1.0000	1.86	29.31	**0.00**	0.00	0.00	0.00	0.00	0.00
01/09/2002	0.00	2.37	1.0000	2.37	31.69	**0.00**	0.00	0.00	0.00	0.00	0.00
02/09/2002	0.00	2.59	1.0000	2.59	34.28	**0.00**	0.00	0.00	0.00	0.00	0.00
03/09/2002	0.00	2.35	1.0000	2.35	36.62	**0.00**	0.00	0.00	0.00	0.00	0.00
04/09/2002	0.30	1.45	1.0000	1.45	37.78	**0.00**	0.00	0.00	0.00	0.00	0.00
05/09/2002	4.30	1.15	1.0000	1.15	34.63	**0.00**	0.00	0.00	0.00	0.00	0.00
06/09/2002	4.80	1.66	1.0000	1.66	31.49	**0.00**	0.00	0.00	0.00	0.00	0.00
07/09/2002	0.60	1.38	1.0000	1.38	32.27	**0.00**	0.00	0.00	0.00	0.00	0.00
08/09/2002	0.00	1.23	1.0000	1.23	33.50	**0.00**	0.00	0.00	0.00	0.00	0.00
09/09/2002	1.40	1.39	1.0000	1.39	33.49	**0.00**	0.00	0.00	0.00	0.00	0.00
10/09/2002	0.10	2.01	1.0000	2.01	35.40	**0.00**	0.00	0.00	0.00	0.00	0.00
11/09/2002	0.00	2.27	1.0000	2.27	37.68	**0.00**	0.00	0.00	0.00	0.00	0.00
12/09/2002	0.00	1.25	1.0000	1.25	38.92	**0.00**	0.00	0.00	0.00	0.00	0.00
13/09/2002	0.00	1.97	1.0000	1.97	40.89	**0.00**	0.00	0.00	0.00	0.00	0.00
14/09/2002	0.00	1.06	1.0000	1.06	41.94	**0.00**	0.00	0.00	0.00	0.00	0.00
15/09/2002	0.00	1.21	1.0000	1.21	43.16	**0.00**	0.00	0.00	0.00	0.00	0.00
16/09/2002	0.00	1.10	1.0000	1.10	44.26	**0.00**	0.00	0.00	0.00	0.00	0.00
17/09/2002	0.00	1.16	1.0000	1.16	45.42	**0.00**	0.00	0.00	0.00	0.00	0.00
18/09/2002	0.00	1.18	1.0000	1.18	46.61	**0.00**	0.00	0.00	0.00	0.00	0.00
19/09/2002	0.00	1.17	1.0000	1.17	47.78	**0.00**	0.00	0.00	0.00	0.00	0.00
20/09/2002	0.00	1.41	1.0000	1.41	49.19	**0.00**	0.00	0.00	0.00	0.00	0.00
21/09/2002	0.00	1.43	1.0000	1.43	50.62	**0.00**	0.00	0.00	0.00	0.00	0.00
22/09/2002	0.00	0.96	1.0000	0.96	51.58	**0.00**	0.00	0.00	0.00	0.00	0.00

Date	Rainfall	PE	S.F.	AE	SMD	**Recharge**	Pot. Runoff	Runoff 1	Runoff 2	Runoff	Recharge
23/09/2002	0.00	1.33	1.0000	1.33	52.91	**0.00**	0.00	0.00	0.00	0.00	0.00
24/09/2002	0.00	1.38	1.0000	1.38	54.29	**0.00**	0.00	0.00	0.00	0.00	0.00
25/09/2002	0.00	1.41	1.0000	1.41	55.70	**0.00**	0.00	0.00	0.00	0.00	0.00
26/09/2002	0.00	1.13	1.0000	1.13	56.83	**0.00**	0.00	0.00	0.00	0.00	0.00
27/09/2002	0.00	1.22	1.0000	1.22	58.05	**0.00**	0.00	0.00	0.00	0.00	0.00
28/09/2002	0.00	1.32	1.0000	1.32	59.37	**0.00**	0.00	0.00	0.00	0.00	0.00
29/09/2002	2.90	1.95	1.0000	1.95	58.42	**0.00**	0.00	0.00	0.00	0.00	0.00
30/09/2002	4.00	1.56	1.0000	1.56	55.98	**0.00**	0.00	0.00	0.00	0.00	0.00
01/10/2002	0.50	1.21	1.0000	1.21	56.69	**0.00**	0.00	0.00	0.00	0.00	0.00
02/10/2002	6.40	0.87	1.0000	0.87	51.16	**0.00**	1.40	0.28	0.00	0.28	-0.28
03/10/2002	0.00	1.44	1.0000	1.44	52.60	**0.00**	0.00	0.00	0.00	0.00	0.00
04/10/2002	0.00	1.35	1.0000	1.35	53.94	**0.00**	0.00	0.00	0.00	0.00	0.00
05/10/2002	0.00	1.55	1.0000	1.55	55.49	**0.00**	0.00	0.00	0.00	0.00	0.00
06/10/2002	0.00	0.92	1.0000	0.92	56.41	**0.00**	0.00	0.00	0.00	0.00	0.00
07/10/2002	0.10	1.17	1.0000	1.17	57.48	**0.00**	0.00	0.00	0.00	0.00	0.00
08/10/2002	15.90	1.13	1.0000	1.13	42.71	**0.00**	10.90	2.18	0.00	2.18	-2.18
09/10/2002	0.20	0.96	1.0000	0.96	43.46	**0.00**	0.00	0.00	0.00	0.00	0.00
10/10/2002	8.70	1.17	1.0000	1.17	35.93	**0.00**	3.70	0.74	0.00	0.74	-0.74
11/10/2002	24.20	0.46	1.0000	0.46	12.18	**0.00**	19.20	0.00	5.76	5.76	-5.76
12/10/2002	8.00	1.13	1.0000	1.13	5.32	**0.00**	3.00	0.60	0.00	0.60	-0.60
13/10/2002	0.00	0.51	1.0000	0.51	5.83	**0.00**	0.00	0.00	0.00	0.00	0.00
14/10/2002	4.60	0.69	1.0000	0.69	1.92	**0.00**	0.00	0.00	0.00	0.00	0.00
15/10/2002	7.60	0.66	1.0000	0.66	0.00	**5.02**	2.60	0.52	0.00	0.52	4.50
16/10/2002	0.00	0.71	1.0000	0.71	0.71	**0.00**	0.00	0.00	0.00	0.00	0.00
17/10/2002	0.60	0.51	1.0000	0.51	0.63	**0.00**	0.00	0.00	0.00	0.00	0.00
18/10/2002	0.00	0.66	1.0000	0.66	1.28	**0.00**	0.00	0.00	0.00	0.00	0.00
19/10/2002	0.70	0.65	1.0000	0.65	1.24	**0.00**	0.00	0.00	0.00	0.00	0.00
20/10/2002	39.50	0.50	1.0000	0.50	0.00	**37.76**	34.50	0.00	10.35	10.35	27.41
21/10/2002	13.40	0.54	1.0000	0.54	0.00	**12.86**	8.40	1.68	0.00	1.68	11.18
22/10/2002	0.40	0.45	1.0000	0.45	0.05	**0.00**	0.00	0.00	0.00	0.00	0.00
23/10/2002	0.10	0.80	1.0000	0.80	0.75	**0.00**	0.00	0.00	0.00	0.00	0.00
24/10/2002	3.30	0.59	1.0000	0.59	0.00	**1.96**	0.00	0.00	0.00	0.00	1.96
25/10/2002	4.50	0.94	1.0000	0.94	0.00	**3.56**	0.00	0.00	0.00	0.00	3.56
26/10/2002	7.10	0.67	1.0000	0.67	0.00	**6.43**	2.10	0.42	0.00	0.42	6.01
27/10/2002	0.80	0.91	1.0000	0.91	0.11	**0.00**	0.00	0.00	0.00	0.00	0.00
28/10/2002	17.70	0.81	1.0000	0.81	0.00	**16.78**	12.70	2.54	0.00	2.54	14.24
29/10/2002	4.00	0.39	1.0000	0.39	0.00	**3.61**	0.00	0.00	0.00	0.00	3.61
30/10/2002	3.70	0.51	1.0000	0.51	0.00	**3.19**	0.00	0.00	0.00	0.00	3.19
31/10/2002	0.40	0.58	1.0000	0.58	0.18	**0.00**	0.00	0.00	0.00	0.00	0.00
01/11/2002	7.20	0.34	1.0000	0.34	0.00	**6.68**	2.20	0.44	0.00	0.44	6.24
02/11/2002	4.30	0.48	1.0000	0.48	0.00	**3.82**	0.00	0.00	0.00	0.00	3.82
03/11/2002	8.20	1.00	1.0000	1.00	0.00	**7.20**	3.20	0.64	0.00	0.64	6.56
04/11/2002	0.40	0.56	1.0000	0.56	0.16	**0.00**	0.00	0.00	0.00	0.00	0.00
05/11/2002	4.10	0.42	1.0000	0.42	0.00	**3.52**	0.00	0.00	0.00	0.00	3.52
06/11/2002	1.00	0.38	1.0000	0.38	0.00	**0.62**	0.00	0.00	0.00	0.00	0.62
07/11/2002	2.80	0.55	1.0000	0.55	0.00	**2.25**	0.00	0.00	0.00	0.00	2.25
08/11/2002	4.70	0.40	1.0000	0.40	0.00	**4.30**	0.00	0.00	0.00	0.00	4.30
09/11/2002	8.50	0.33	1.0000	0.33	0.00	**8.17**	3.50	0.70	0.00	0.70	7.47
10/11/2002	0.70	0.44	1.0000	0.44	0.00	**0.26**	0.00	0.00	0.00	0.00	0.26
11/11/2002	2.40	0.82	1.0000	0.82	0.00	**1.58**	0.00	0.00	0.00	0.00	1.58
12/11/2002	0.40	0.79	1.0000	0.79	0.39	**0.00**	0.00	0.00	0.00	0.00	0.00
13/11/2002	18.20	0.40	1.0000	0.40	0.00	**17.40**	13.20	2.64	0.00	2.64	14.76
14/11/2002	38.20	0.29	1.0000	0.29	0.00	**37.91**	33.20	0.00	9.96	9.96	27.95
15/11/2002	3.80	0.42	1.0000	0.42	0.00	**3.38**	0.00	0.00	0.00	0.00	3.38
16/11/2002	0.00	0.37	1.0000	0.37	0.37	**0.00**	0.00	0.00	0.00	0.00	0.00
17/11/2002	0.40	0.17	1.0000	0.17	0.14	**0.00**	0.00	0.00	0.00	0.00	0.00
18/11/2002	2.50	0.57	1.0000	0.57	0.00	**1.79**	0.00	0.00	0.00	0.00	1.79
19/11/2002	0.40	0.53	1.0000	0.53	0.13	**0.00**	0.00	0.00	0.00	0.00	0.00
20/11/2002	6.70	0.33	1.0000	0.33	0.00	**6.24**	1.70	0.34	0.00	0.34	5.90
21/11/2002	3.20	0.67	1.0000	0.67	0.00	**2.53**	0.00	0.00	0.00	0.00	2.53
22/11/2002	0.70	0.60	1.0000	0.60	0.00	**0.10**	0.00	0.00	0.00	0.00	0.10
23/11/2002	4.50	0.63	1.0000	0.63	0.00	**3.87**	0.00	0.00	0.00	0.00	3.87
24/11/2002	0.00	0.55	1.0000	0.55	0.55	**0.00**	0.00	0.00	0.00	0.00	0.00
25/11/2002	2.70	0.49	1.0000	0.49	0.00	**1.67**	0.00	0.00	0.00	0.00	1.67
26/11/2002	11.00	0.82	1.0000	0.82	0.00	**10.18**	6.00	1.20	0.00	1.20	8.98
27/11/2002	10.00	0.92	1.0000	0.92	0.00	**9.08**	5.00	1.00	0.00	1.00	8.08
28/11/2002	0.20	0.53	1.0000	0.53	0.33	**0.00**	0.00	0.00	0.00	0.00	0.00
29/11/2002	1.20	0.21	1.0000	0.21	0.00	**0.67**	0.00	0.00	0.00	0.00	0.67
30/11/2002	0.30	0.33	1.0000	0.33	0.03	**0.00**	0.00	0.00	0.00	0.00	0.00
01/12/2002	7.50	0.84	1.0000	0.84	0.00	**6.64**	2.50	0.50	0.00	0.50	6.14
02/12/2002	1.70	0.59	1.0000	0.59	0.00	**1.11**	0.00	0.00	0.00	0.00	1.11
03/12/2002	2.70	0.40	1.0000	0.40	0.00	**2.30**	0.00	0.00	0.00	0.00	2.30
04/12/2002	0.00	0.20	1.0000	0.20	0.20	**0.00**	0.00	0.00	0.00	0.00	0.00
05/12/2002	0.00	0.05	1.0000	0.05	0.25	**0.00**	0.00	0.00	0.00	0.00	0.00
06/12/2002	0.00	0.03	1.0000	0.03	0.28	**0.00**	0.00	0.00	0.00	0.00	0.00
07/12/2002	1.80	0.29	1.0000	0.29	0.00	**1.23**	0.00	0.00	0.00	0.00	1.23
08/12/2002	0.10	0.83	1.0000	0.83	0.73	**0.00**	0.00	0.00	0.00	0.00	0.00
09/12/2002	0.00	0.81	1.0000	0.81	1.54	**0.00**	0.00	0.00	0.00	0.00	0.00

Date	Rainfall	PE	S.F.	AE	SMD	**Recharge**	Pot. Runoff	Runoff 1	Runoff 2	Runoff	Recharge
10/12/2002	0.00	1.31	1.0000	1.31	2.85	**0.00**	0.00	0.00	0.00	0.00	0.00
11/12/2002	0.00	0.63	1.0000	0.63	3.47	**0.00**	0.00	0.00	0.00	0.00	0.00
12/12/2002	4.10	0.54	1.0000	0.54	0.00	**0.08**	0.00	0.00	0.00	0.00	0.08
13/12/2002	0.20	0.29	1.0000	0.29	0.09	**0.00**	0.00	0.00	0.00	0.00	0.00
14/12/2002	4.70	0.39	1.0000	0.39	0.00	**4.22**	0.00	0.00	0.00	0.00	4.22
15/12/2002	1.10	0.44	1.0000	0.44	0.00	**0.66**	0.00	0.00	0.00	0.00	0.66
16/12/2002	0.00	0.32	1.0000	0.32	0.32	**0.00**	0.00	0.00	0.00	0.00	0.00
17/12/2002	0.00	0.35	1.0000	0.35	0.66	**0.00**	0.00	0.00	0.00	0.00	0.00
18/12/2002	0.00	0.62	1.0000	0.62	1.28	**0.00**	0.00	0.00	0.00	0.00	0.00
19/12/2002	0.00	0.40	1.0000	0.40	1.69	**0.00**	0.00	0.00	0.00	0.00	0.00
20/12/2002	3.50	0.31	1.0000	0.31	0.00	**1.50**	0.00	0.00	0.00	0.00	1.50
21/12/2002	5.50	0.40	1.0000	0.40	0.00	**5.10**	0.50	0.10	0.00	0.10	5.00
22/12/2002	1.50	0.19	1.0000	0.19	0.00	**1.31**	0.00	0.00	0.00	0.00	1.31
23/12/2002	2.50	0.77	1.0000	0.77	0.00	**1.73**	0.00	0.00	0.00	0.00	1.73
24/12/2002	1.60	0.63	1.0000	0.63	0.00	**0.97**	0.00	0.00	0.00	0.00	0.97
25/12/2002	3.40	0.37	1.0000	0.37	0.00	**3.03**	0.00	0.00	0.00	0.00	3.03
26/12/2002	10.30	0.17	1.0000	0.17	0.00	**10.13**	5.30	1.06	0.00	1.06	9.07
27/12/2002	1.10	0.23	1.0000	0.23	0.00	**0.87**	0.00	0.00	0.00	0.00	0.87
28/12/2002	10.40	0.27	1.0000	0.27	0.00	**10.13**	5.40	1.08	0.00	1.08	9.05
29/12/2002	14.00	0.43	1.0000	0.43	0.00	**13.57**	9.00	1.80	0.00	1.80	11.77
30/12/2002	1.30	0.24	1.0000	0.24	0.00	**1.06**	0.00	0.00	0.00	0.00	1.06
31/12/2002	8.70	0.49	1.0000	0.49	0.00	**8.21**	3.70	0.74	0.00	0.74	7.47
01/01/2003	0.50	0.35	1.0000	0.35	0.00	**0.15**	0.00	0.00	0.00	0.00	0.15
02/01/2003	6.60	0.35	1.0000	0.35	0.00	**6.25**	1.60	0.32	0.00	0.32	5.93
03/01/2003	0.00	0.08	1.0000	0.08	0.08	**0.00**	0.00	0.00	0.00	0.00	0.00
04/01/2003	0.00	0.06	1.0000	0.06	0.14	**0.00**	0.00	0.00	0.00	0.00	0.00
05/01/2003	0.00	0.15	1.0000	0.15	0.29	**0.00**	0.00	0.00	0.00	0.00	0.00
06/01/2003	0.00	0.45	1.0000	0.45	0.74	**0.00**	0.00	0.00	0.00	0.00	0.00
07/01/2003	0.00	0.98	1.0000	0.98	1.72	**0.00**	0.00	0.00	0.00	0.00	0.00
08/01/2003	5.10	0.57	1.0000	0.57	0.00	**2.81**	0.10	0.02	0.00	0.02	2.79
09/01/2003	0.00	0.46	1.0000	0.46	0.46	**0.00**	0.00	0.00	0.00	0.00	0.00
10/01/2003	0.00	0.29	1.0000	0.29	0.75	**0.00**	0.00	0.00	0.00	0.00	0.00
11/01/2003	0.00	0.22	1.0000	0.22	0.97	**0.00**	0.00	0.00	0.00	0.00	0.00
12/01/2003	0.80	0.41	1.0000	0.41	0.59	**0.00**	0.00	0.00	0.00	0.00	0.00
13/01/2003	0.10	0.35	1.0000	0.35	0.84	**0.00**	0.00	0.00	0.00	0.00	0.00
14/01/2003	3.10	0.93	1.0000	0.93	0.00	**1.34**	0.00	0.00	0.00	0.00	1.34
15/01/2003	0.10	0.44	1.0000	0.44	0.34	**0.00**	0.00	0.00	0.00	0.00	0.00
16/01/2003	13.10	0.82	1.0000	0.82	0.00	**11.94**	8.10	1.62	0.00	1.62	10.32
17/01/2003	0.40	0.46	1.0000	0.46	0.06	**0.00**	0.00	0.00	0.00	0.00	0.00
18/01/2003	5.50	0.67	1.0000	0.67	0.00	**4.77**	0.50	0.10	0.00	0.10	4.67
19/01/2003	5.40	0.48	1.0000	0.48	0.00	**4.92**	0.40	0.08	0.00	0.08	4.84
20/01/2003	0.80	0.37	1.0000	0.37	0.00	**0.43**	0.00	0.00	0.00	0.00	0.43
21/01/2003	0.20	0.19	1.0000	0.19	0.00	**0.01**	0.00	0.00	0.00	0.00	0.01
22/01/2003	0.00	0.45	1.0000	0.45	0.45	**0.00**	0.00	0.00	0.00	0.00	0.00
23/01/2003	0.00	0.26	1.0000	0.26	0.71	**0.00**	0.00	0.00	0.00	0.00	0.00
24/01/2003	9.10	0.88	1.0000	0.88	0.00	**7.51**	4.10	0.82	0.00	0.82	6.69
25/01/2003	0.10	0.50	1.0000	0.50	0.40	**0.00**	0.00	0.00	0.00	0.00	0.00
26/01/2003	0.00	0.61	1.0000	0.61	1.01	**0.00**	0.00	0.00	0.00	0.00	0.00
27/01/2003	0.80	0.74	1.0000	0.74	0.95	**0.00**	0.00	0.00	0.00	0.00	0.00
28/01/2003	2.40	0.78	1.0000	0.78	0.00	**0.67**	0.00	0.00	0.00	0.00	0.67
29/01/2003	2.70	0.50	1.0000	0.50	0.00	**2.20**	0.00	0.00	0.00	0.00	2.20
30/01/2003	0.00	0.21	1.0000	0.21	0.21	**0.00**	0.00	0.00	0.00	0.00	0.00
31/01/2003	2.50	0.19	1.0000	0.19	0.00	**2.10**	0.00	0.00	0.00	0.00	2.10
01/02/2003	1.10	0.57	1.0000	0.57	0.00	**0.53**	0.00	0.00	0.00	0.00	0.53
02/02/2003	3.10	0.42	1.0000	0.42	0.00	**2.68**	0.00	0.00	0.00	0.00	2.68
03/02/2003	0.40	0.44	1.0000	0.44	0.04	**0.00**	0.00	0.00	0.00	0.00	0.00
04/02/2003	0.00	0.48	1.0000	0.48	0.53	**0.00**	0.00	0.00	0.00	0.00	0.00
05/02/2003	1.00	0.46	1.0000	0.46	0.00	**0.01**	0.00	0.00	0.00	0.00	0.01
06/02/2003	1.20	0.58	1.0000	0.58	0.00	**0.62**	0.00	0.00	0.00	0.00	0.62
07/02/2003	0.20	0.66	1.0000	0.66	0.46	**0.00**	0.00	0.00	0.00	0.00	0.00
08/02/2003	4.70	0.56	1.0000	0.56	0.00	**3.69**	0.00	0.00	0.00	0.00	3.69
09/02/2003	0.60	0.45	1.0000	0.45	0.00	**0.15**	0.00	0.00	0.00	0.00	0.15
10/02/2003	10.50	0.79	1.0000	0.79	0.00	**9.71**	5.50	1.10	0.00	1.10	8.61
11/02/2003	0.00	0.36	1.0000	0.36	0.36	**0.00**	0.00	0.00	0.00	0.00	0.00
12/02/2003	0.00	0.35	1.0000	0.35	0.72	**0.00**	0.00	0.00	0.00	0.00	0.00
13/02/2003	0.10	0.43	1.0000	0.43	1.05	**0.00**	0.00	0.00	0.00	0.00	0.00
14/02/2003	0.00	0.34	1.0000	0.34	1.39	**0.00**	0.00	0.00	0.00	0.00	0.00
15/02/2003	0.00	0.77	1.0000	0.77	2.15	**0.00**	0.00	0.00	0.00	0.00	0.00
16/02/2003	0.00	0.93	1.0000	0.93	3.09	**0.00**	0.00	0.00	0.00	0.00	0.00
17/02/2003	0.00	0.61	1.0000	0.61	3.69	**0.00**	0.00	0.00	0.00	0.00	0.00
18/02/2003	0.00	1.18	1.0000	1.18	4.87	**0.00**	0.00	0.00	0.00	0.00	0.00
19/02/2003	0.00	1.16	1.0000	1.16	6.03	**0.00**	0.00	0.00	0.00	0.00	0.00
20/02/2003	1.50	0.43	1.0000	0.43	4.96	**0.00**	0.00	0.00	0.00	0.00	0.00
21/02/2003	0.00	0.93	1.0000	0.93	5.89	**0.00**	0.00	0.00	0.00	0.00	0.00
22/02/2003	1.30	1.21	1.0000	1.21	5.81	**0.00**	0.00	0.00	0.00	0.00	0.00
23/02/2003	0.00	1.33	1.0000	1.33	7.14	**0.00**	0.00	0.00	0.00	0.00	0.00
24/02/2003	0.00	0.61	1.0000	0.61	7.74	**0.00**	0.00	0.00	0.00	0.00	0.00
25/02/2003	0.40	1.09	1.0000	1.09	8.43	**0.00**	0.00	0.00	0.00	0.00	0.00

Date	Rainfall	PE	S.F.	AE	SMD	**Recharge**	Pot. Runoff	Runoff 1	Runoff 2	Runoff	Recharge
26/02/2003	1.60	0.88	1.0000	0.88	7.71	**0.00**	0.00	0.00	0.00	0.00	0.00
27/02/2003	1.60	0.81	1.0000	0.81	6.91	**0.00**	0.00	0.00	0.00	0.00	0.00
28/02/2003	8.90	0.83	1.0000	0.83	0.00	**1.16**	3.90	0.78	0.00	0.78	0.38
01/03/2003	5.10	0.96	1.0000	0.96	0.00	**4.14**	0.10	0.02	0.00	0.02	4.12
02/03/2003	0.80	1.21	1.0000	1.21	0.41	**0.00**	0.00	0.00	0.00	0.00	0.00
03/03/2003	1.80	0.68	1.0000	0.68	0.00	**0.71**	0.00	0.00	0.00	0.00	0.71
04/03/2003	0.70	0.88	1.0000	0.88	0.18	**0.00**	0.00	0.00	0.00	0.00	0.00
05/03/2003	0.00	1.44	1.0000	1.44	1.63	**0.00**	0.00	0.00	0.00	0.00	0.00
06/03/2003	2.50	1.45	1.0000	1.45	0.58	**0.00**	0.00	0.00	0.00	0.00	0.00
07/03/2003	1.50	1.01	1.0000	1.01	0.09	**0.00**	0.00	0.00	0.00	0.00	0.00
08/03/2003	10.00	0.85	1.0000	0.85	0.00	**9.07**	5.00	1.00	0.00	1.00	8.07
09/03/2003	4.30	1.27	1.0000	1.27	0.00	**3.03**	0.00	0.00	0.00	0.00	3.03
10/03/2003	9.60	1.23	1.0000	1.23	0.00	**8.37**	4.60	0.92	0.00	0.92	7.45
11/03/2003	1.50	1.16	1.0000	1.16	0.00	**0.34**	0.00	0.00	0.00	0.00	0.34
12/03/2003	0.00	1.10	1.0000	1.10	1.10	**0.00**	0.00	0.00	0.00	0.00	0.00
13/03/2003	0.00	1.05	1.0000	1.05	2.15	**0.00**	0.00	0.00	0.00	0.00	0.00
14/03/2003	0.00	1.41	1.0000	1.41	3.56	**0.00**	0.00	0.00	0.00	0.00	0.00
15/03/2003	0.00	1.51	1.0000	1.51	5.06	**0.00**	0.00	0.00	0.00	0.00	0.00
16/03/2003	0.00	1.73	1.0000	1.73	6.80	**0.00**	0.00	0.00	0.00	0.00	0.00
17/03/2003	0.00	1.63	1.0000	1.63	8.43	**0.00**	0.00	0.00	0.00	0.00	0.00
18/03/2003	0.00	1.22	1.0000	1.22	9.65	**0.00**	0.00	0.00	0.00	0.00	0.00
19/03/2003	0.00	1.17	1.0000	1.17	10.83	**0.00**	0.00	0.00	0.00	0.00	0.00
20/03/2003	0.00	0.94	1.0000	0.94	11.77	**0.00**	0.00	0.00	0.00	0.00	0.00
21/03/2003	0.00	1.55	1.0000	1.55	13.32	**0.00**	0.00	0.00	0.00	0.00	0.00
22/03/2003	0.00	1.33	1.0000	1.33	14.65	**0.00**	0.00	0.00	0.00	0.00	0.00
23/03/2003	0.00	1.77	1.0000	1.77	16.42	**0.00**	0.00	0.00	0.00	0.00	0.00
24/03/2003	0.00	1.62	1.0000	1.62	18.05	**0.00**	0.00	0.00	0.00	0.00	0.00
25/03/2003	0.00	1.64	1.0000	1.64	19.68	**0.00**	0.00	0.00	0.00	0.00	0.00
26/03/2003	0.00	1.66	1.0000	1.66	21.34	**0.00**	0.00	0.00	0.00	0.00	0.00
27/03/2003	0.00	1.79	1.0000	1.79	23.13	**0.00**	0.00	0.00	0.00	0.00	0.00
28/03/2003	0.00	0.97	1.0000	0.97	24.11	**0.00**	0.00	0.00	0.00	0.00	0.00
29/03/2003	0.20	1.65	1.0000	1.65	25.55	**0.00**	0.00	0.00	0.00	0.00	0.00
30/03/2003	0.00	1.45	1.0000	1.45	27.00	**0.00**	0.00	0.00	0.00	0.00	0.00
31/03/2003	4.20	1.74	1.0000	1.74	24.54	**0.00**	0.00	0.00	0.00	0.00	0.00
01/04/2003	0.20	1.42	1.0000	1.42	25.76	**0.00**	0.00	0.00	0.00	0.00	0.00
02/04/2003	0.00	1.56	1.0000	1.56	27.33	**0.00**	0.00	0.00	0.00	0.00	0.00
03/04/2003	0.00	0.99	1.0000	0.99	28.32	**0.00**	0.00	0.00	0.00	0.00	0.00
04/04/2003	0.00	2.06	1.0000	2.06	30.38	**0.00**	0.00	0.00	0.00	0.00	0.00
05/04/2003	0.00	1.75	1.0000	1.75	32.13	**0.00**	0.00	0.00	0.00	0.00	0.00
06/04/2003	0.00	0.95	1.0000	0.95	33.08	**0.00**	0.00	0.00	0.00	0.00	0.00
07/04/2003	0.00	1.10	1.0000	1.10	34.18	**0.00**	0.00	0.00	0.00	0.00	0.00
08/04/2003	0.00	2.17	1.0000	2.17	36.35	**0.00**	0.00	0.00	0.00	0.00	0.00
09/04/2003	0.00	1.97	1.0000	1.97	38.32	**0.00**	0.00	0.00	0.00	0.00	0.00
10/04/2003	0.00	1.74	1.0000	1.74	40.06	**0.00**	0.00	0.00	0.00	0.00	0.00
11/04/2003	0.00	1.07	1.0000	1.07	41.12	**0.00**	0.00	0.00	0.00	0.00	0.00
12/04/2003	0.00	1.61	1.0000	1.61	42.73	**0.00**	0.00	0.00	0.00	0.00	0.00
13/04/2003	1.30	1.15	1.0000	1.15	42.59	**0.00**	0.00	0.00	0.00	0.00	0.00
14/04/2003	0.00	2.44	1.0000	2.44	45.03	**0.00**	0.00	0.00	0.00	0.00	0.00
15/04/2003	0.00	3.01	1.0000	3.01	48.04	**0.00**	0.00	0.00	0.00	0.00	0.00
16/04/2003	0.00	3.38	1.0000	3.38	51.42	**0.00**	0.00	0.00	0.00	0.00	0.00
17/04/2003	0.00	3.45	1.0000	3.45	54.87	**0.00**	0.00	0.00	0.00	0.00	0.00
18/04/2003	0.00	2.71	1.0000	2.71	57.58	**0.00**	0.00	0.00	0.00	0.00	0.00
19/04/2003	0.00	2.68	1.0000	2.68	60.26	**0.00**	0.00	0.00	0.00	0.00	0.00
20/04/2003	0.00	2.15	1.0000	2.15	62.41	**0.00**	0.00	0.00	0.00	0.00	0.00
21/04/2003	14.50	0.83	1.0000	0.83	48.74	**0.00**	9.50	1.90	0.00	1.90	-1.90
22/04/2003	0.00	2.15	1.0000	2.15	50.90	**0.00**	0.00	0.00	0.00	0.00	0.00
23/04/2003	0.00	2.50	1.0000	2.50	53.39	**0.00**	0.00	0.00	0.00	0.00	0.00
24/04/2003	4.10	1.63	1.0000	1.63	50.92	**0.00**	0.00	0.00	0.00	0.00	0.00
25/04/2003	3.00	2.05	1.0000	2.05	49.97	**0.00**	0.00	0.00	0.00	0.00	0.00
26/04/2003	1.30	2.51	1.0000	2.51	51.18	**0.00**	0.00	0.00	0.00	0.00	0.00
27/04/2003	7.00	2.78	1.0000	2.78	46.96	**0.00**	2.00	0.40	0.00	0.40	-0.40
28/04/2003	0.30	1.25	1.0000	1.25	47.91	**0.00**	0.00	0.00	0.00	0.00	0.00
29/04/2003	3.10	2.53	1.0000	2.53	47.34	**0.00**	0.00	0.00	0.00	0.00	0.00
30/04/2003	2.20	2.15	1.0000	2.15	47.30	**0.00**	0.00	0.00	0.00	0.00	0.00
01/05/2003	13.20	1.68	1.0000	1.68	35.77	**0.00**	8.20	1.64	0.00	1.64	-1.64
02/05/2003	0.10	1.76	1.0000	1.76	37.44	**0.00**	0.00	0.00	0.00	0.00	0.00
03/05/2003	10.30	1.19	1.0000	1.19	28.33	**0.00**	5.30	1.06	0.00	1.06	-1.06
04/05/2003	4.20	0.97	1.0000	0.97	25.10	**0.00**	0.00	0.00	0.00	0.00	0.00
05/05/2003	18.10	2.54	1.0000	2.54	9.54	**0.00**	13.10	2.62	0.00	2.62	-2.62
06/05/2003	1.60	2.23	1.0000	2.23	10.17	**0.00**	0.00	0.00	0.00	0.00	0.00
07/05/2003	0.00	1.92	1.0000	1.92	12.08	**0.00**	0.00	0.00	0.00	0.00	0.00
08/05/2003	0.00	2.70	1.0000	2.70	14.79	**0.00**	0.00	0.00	0.00	0.00	0.00
09/05/2003	3.70	2.32	1.0000	2.32	13.41	**0.00**	0.00	0.00	0.00	0.00	0.00
10/05/2003	2.80	2.71	1.0000	2.71	13.31	**0.00**	0.00	0.00	0.00	0.00	0.00
11/05/2003	4.50	2.44	1.0000	2.44	11.26	**0.00**	0.00	0.00	0.00	0.00	0.00
12/05/2003	1.80	2.18	1.0000	2.18	11.63	**0.00**	0.00	0.00	0.00	0.00	0.00
13/05/2003	0.50	2.56	1.0000	2.56	13.69	**0.00**	0.00	0.00	0.00	0.00	0.00
14/05/2003	0.00	2.29	1.0000	2.29	15.98	**0.00**	0.00	0.00	0.00	0.00	0.00

Date	Rainfall	PE	S.F.	AE	SMD	**Recharge**	Pot. Runoff	Runoff 1	Runoff 2	Runoff	Recharge
15/05/2003	9.00	2.03	1.0000	2.03	9.01	**0.00**	4.00	0.80	0.00	0.80	-0.80
16/05/2003	4.30	1.66	1.0000	1.66	6.37	**0.00**	0.00	0.00	0.00	0.00	0.00
17/05/2003	5.40	1.77	1.0000	1.77	2.74	**0.00**	0.40	0.08	0.00	0.08	-0.08
18/05/2003	12.00	2.20	1.0000	2.20	0.00	**7.07**	7.00	1.40	0.00	1.40	5.67
19/05/2003	7.60	1.93	1.0000	1.93	0.00	**5.67**	2.60	0.52	0.00	0.52	5.15
20/05/2003	8.50	1.81	1.0000	1.81	0.00	**6.69**	3.50	0.70	0.00	0.70	5.99
21/05/2003	0.00	1.15	1.0000	1.15	1.15	**0.00**	0.00	0.00	0.00	0.00	0.00
22/05/2003	0.00	2.59	1.0000	2.59	3.74	**0.00**	0.00	0.00	0.00	0.00	0.00
23/05/2003	1.70	2.73	1.0000	2.73	4.77	**0.00**	0.00	0.00	0.00	0.00	0.00
24/05/2003	2.20	1.96	1.0000	1.96	4.53	**0.00**	0.00	0.00	0.00	0.00	0.00
25/05/2003	0.10	2.31	1.0000	2.31	6.74	**0.00**	0.00	0.00	0.00	0.00	0.00
26/05/2003	1.90	1.75	1.0000	1.75	6.59	**0.00**	0.00	0.00	0.00	0.00	0.00
27/05/2003	2.00	1.91	1.0000	1.91	6.51	**0.00**	0.00	0.00	0.00	0.00	0.00
28/05/2003	3.80	2.01	1.0000	2.01	4.71	**0.00**	0.00	0.00	0.00	0.00	0.00
29/05/2003	0.10	2.57	1.0000	2.57	7.18	**0.00**	0.00	0.00	0.00	0.00	0.00
30/05/2003	0.00	3.76	1.0000	3.76	10.95	**0.00**	0.00	0.00	0.00	0.00	0.00
31/05/2003	0.00	3.88	1.0000	3.88	14.83	**0.00**	0.00	0.00	0.00	0.00	0.00
01/06/2003	1.00	2.15	1.0000	2.15	15.97	**0.00**	0.00	0.00	0.00	0.00	0.00
02/06/2003	0.30	3.94	1.0000	3.94	19.61	**0.00**	0.00	0.00	0.00	0.00	0.00
03/06/2003	8.20	1.43	1.0000	1.43	12.84	**0.00**	3.20	0.64	0.00	0.64	-0.64
04/06/2003	0.10	2.31	1.0000	2.31	15.05	**0.00**	0.00	0.00	0.00	0.00	0.00
05/06/2003	0.80	2.39	1.0000	2.39	16.63	**0.00**	0.00	0.00	0.00	0.00	0.00
06/06/2003	0.00	3.64	1.0000	3.64	20.28	**0.00**	0.00	0.00	0.00	0.00	0.00
07/06/2003	3.50	2.93	1.0000	2.93	19.70	**0.00**	0.00	0.00	0.00	0.00	0.00
08/06/2003	4.40	3.40	1.0000	3.40	18.70	**0.00**	0.00	0.00	0.00	0.00	0.00
09/06/2003	3.20	1.59	1.0000	1.59	17.10	**0.00**	0.00	0.00	0.00	0.00	0.00
10/06/2003	2.70	3.08	1.0000	3.08	17.47	**0.00**	0.00	0.00	0.00	0.00	0.00
11/06/2003	0.60	3.43	1.0000	3.43	20.30	**0.00**	0.00	0.00	0.00	0.00	0.00
12/06/2003	0.00	3.17	1.0000	3.17	23.47	**0.00**	0.00	0.00	0.00	0.00	0.00
13/06/2003	0.00	2.68	1.0000	2.68	26.15	**0.00**	0.00	0.00	0.00	0.00	0.00
14/06/2003	0.00	4.15	1.0000	4.15	30.30	**0.00**	0.00	0.00	0.00	0.00	0.00
15/06/2003	0.00	2.72	1.0000	2.72	33.02	**0.00**	0.00	0.00	0.00	0.00	0.00
16/06/2003	0.00	3.34	1.0000	3.34	36.36	**0.00**	0.00	0.00	0.00	0.00	0.00
17/06/2003	0.10	2.99	1.0000	2.99	39.25	**0.00**	0.00	0.00	0.00	0.00	0.00
18/06/2003	0.00	2.93	1.0000	2.93	42.18	**0.00**	0.00	0.00	0.00	0.00	0.00
19/06/2003	0.00	3.19	1.0000	3.19	45.37	**0.00**	0.00	0.00	0.00	0.00	0.00
20/06/2003	0.00	3.00	1.0000	3.00	48.37	**0.00**	0.00	0.00	0.00	0.00	0.00
21/06/2003	0.70	2.47	1.0000	2.47	50.13	**0.00**	0.00	0.00	0.00	0.00	0.00
22/06/2003	0.00	2.09	1.0000	2.09	52.23	**0.00**	0.00	0.00	0.00	0.00	0.00
23/06/2003	0.00	2.86	1.0000	2.86	55.08	**0.00**	0.00	0.00	0.00	0.00	0.00
24/06/2003	0.00	4.01	1.0000	4.01	59.09	**0.00**	0.00	0.00	0.00	0.00	0.00
25/06/2003	0.00	4.52	1.0000	4.52	63.61	**0.00**	0.00	0.00	0.00	0.00	0.00
26/06/2003	10.00	2.89	1.0000	2.89	56.51	**0.00**	5.00	1.00	0.00	1.00	-1.00
27/06/2003	18.20	1.42	1.0000	1.42	39.72	**0.00**	13.20	2.64	0.00	2.64	-2.64
28/06/2003	0.00	2.50	1.0000	2.50	42.23	**0.00**	0.00	0.00	0.00	0.00	0.00
29/06/2003	16.00	3.09	1.0000	3.09	29.32	**0.00**	11.00	2.20	0.00	2.20	-2.20
30/06/2003	13.20	0.96	1.0000	0.96	17.08	**0.00**	8.20	1.64	0.00	1.64	-1.64
01/07/2003	13.20	2.35	1.0000	2.35	6.22	**0.00**	8.20	1.64	0.00	1.64	-1.64
02/07/2003	5.30	3.37	1.0000	3.37	4.30	**0.00**	0.30	0.06	0.00	0.06	-0.06
03/07/2003	0.20	2.36	1.0000	2.36	6.46	**0.00**	0.00	0.00	0.00	0.00	0.00
04/07/2003	0.00	1.39	1.0000	1.39	7.84	**0.00**	0.00	0.00	0.00	0.00	0.00
05/07/2003	0.00	1.64	1.0000	1.64	9.49	**0.00**	0.00	0.00	0.00	0.00	0.00
06/07/2003	0.50	3.05	1.0000	3.05	12.04	**0.00**	0.00	0.00	0.00	0.00	0.00
07/07/2003	1.00	3.08	1.0000	3.08	14.12	**0.00**	0.00	0.00	0.00	0.00	0.00
08/07/2003	23.70	2.59	1.0000	2.59	0.00	**6.99**	18.70	0.00	5.61	5.61	1.38
09/07/2003	0.10	2.77	1.0000	2.77	2.67	**0.00**	0.00	0.00	0.00	0.00	0.00
10/07/2003	0.60	2.91	1.0000	2.91	4.98	**0.00**	0.00	0.00	0.00	0.00	0.00
11/07/2003	0.00	2.76	1.0000	2.76	7.74	**0.00**	0.00	0.00	0.00	0.00	0.00
12/07/2003	0.00	3.63	1.0000	3.63	11.37	**0.00**	0.00	0.00	0.00	0.00	0.00
13/07/2003	0.40	4.22	1.0000	4.22	15.19	**0.00**	0.00	0.00	0.00	0.00	0.00
14/07/2003	1.30	3.17	1.0000	3.17	17.06	**0.00**	0.00	0.00	0.00	0.00	0.00
15/07/2003	5.50	2.17	1.0000	2.17	13.73	**0.00**	0.50	0.10	0.00	0.10	-0.10
16/07/2003	0.80	3.08	1.0000	3.08	16.02	**0.00**	0.00	0.00	0.00	0.00	0.00
17/07/2003	17.70	0.60	1.0000	0.60	0.00	**1.08**	12.70	2.54	0.00	2.54	-1.46
18/07/2003	2.00	3.43	1.0000	3.43	1.43	**0.00**	0.00	0.00	0.00	0.00	0.00
19/07/2003	1.20	3.68	1.0000	3.68	3.91	**0.00**	0.00	0.00	0.00	0.00	0.00
20/07/2003	5.60	3.23	1.0000	3.23	1.54	**0.00**	0.60	0.12	0.00	0.12	-0.12
21/07/2003	2.80	3.08	1.0000	3.08	1.82	**0.00**	0.00	0.00	0.00	0.00	0.00
22/07/2003	2.50	1.68	1.0000	1.68	1.00	**0.00**	0.00	0.00	0.00	0.00	0.00
23/07/2003	0.70	2.55	1.0000	2.55	2.85	**0.00**	0.00	0.00	0.00	0.00	0.00
24/07/2003	2.50	2.36	1.0000	2.36	2.71	**0.00**	0.00	0.00	0.00	0.00	0.00
25/07/2003	1.40	2.86	1.0000	2.86	4.18	**0.00**	0.00	0.00	0.00	0.00	0.00
26/07/2003	0.00	2.67	1.0000	2.67	6.85	**0.00**	0.00	0.00	0.00	0.00	0.00
27/07/2003	0.00	2.78	1.0000	2.78	9.63	**0.00**	0.00	0.00	0.00	0.00	0.00
28/07/2003	9.00	1.87	1.0000	1.87	2.50	**0.00**	4.00	0.80	0.00	0.80	-0.80
29/07/2003	3.30	1.72	1.0000	1.72	0.92	**0.00**	0.00	0.00	0.00	0.00	0.00
30/07/2003	2.70	2.76	1.0000	2.76	0.98	**0.00**	0.00	0.00	0.00	0.00	0.00
31/07/2003	1.10	2.32	1.0000	2.32	2.20	**0.00**	0.00	0.00	0.00	0.00	0.00

Date	Rainfall	PE	S.F.	AE	SMD	**Recharge**	Pot. Runoff	Runoff 1	Runoff 2	Runoff	Recharge
23/09/2002	0.00	1.33	1.0000	1.33	52.91	**0.00**	0.00	0.00	0.00	0.00	0.00
24/09/2002	0.00	1.38	1.0000	1.38	54.29	**0.00**	0.00	0.00	0.00	0.00	0.00
25/09/2002	0.00	1.41	1.0000	1.41	55.70	**0.00**	0.00	0.00	0.00	0.00	0.00
26/09/2002	0.00	1.13	1.0000	1.13	56.83	**0.00**	0.00	0.00	0.00	0.00	0.00
27/09/2002	0.00	1.22	1.0000	1.22	58.05	**0.00**	0.00	0.00	0.00	0.00	0.00
28/09/2002	0.00	1.32	1.0000	1.32	59.37	**0.00**	0.00	0.00	0.00	0.00	0.00
29/09/2002	2.90	1.95	1.0000	1.95	58.42	**0.00**	0.00	0.00	0.00	0.00	0.00
30/09/2002	4.00	1.56	1.0000	1.56	55.98	**0.00**	0.00	0.00	0.00	0.00	0.00
01/10/2002	0.50	1.21	1.0000	1.21	56.69	**0.00**	0.00	0.00	0.00	0.00	0.00
02/10/2002	6.40	0.87	1.0000	0.87	51.16	**0.00**	1.40	0.28	0.00	0.28	-0.28
03/10/2002	0.00	1.44	1.0000	1.44	52.60	**0.00**	0.00	0.00	0.00	0.00	0.00
04/10/2002	0.00	1.35	1.0000	1.35	53.94	**0.00**	0.00	0.00	0.00	0.00	0.00
05/10/2002	0.00	1.55	1.0000	1.55	55.49	**0.00**	0.00	0.00	0.00	0.00	0.00
06/10/2002	0.00	0.92	1.0000	0.92	56.41	**0.00**	0.00	0.00	0.00	0.00	0.00
07/10/2002	0.10	1.17	1.0000	1.17	57.48	**0.00**	0.00	0.00	0.00	0.00	0.00
08/10/2002	15.90	1.13	1.0000	1.13	42.71	**0.00**	10.90	2.18	0.00	2.18	-2.18
09/10/2002	0.20	0.96	1.0000	0.96	43.46	**0.00**	0.00	0.00	0.00	0.00	0.00
10/10/2002	8.70	1.17	1.0000	1.17	35.93	**0.00**	3.70	0.74	0.00	0.74	-0.74
11/10/2002	24.20	0.46	1.0000	0.46	12.18	**0.00**	19.20	0.00	5.76	5.76	-5.76
12/10/2002	8.00	1.13	1.0000	1.13	5.32	**0.00**	3.00	0.60	0.00	0.60	-0.60
13/10/2002	0.00	0.51	1.0000	0.51	5.83	**0.00**	0.00	0.00	0.00	0.00	0.00
14/10/2002	4.60	0.69	1.0000	0.69	1.92	**0.00**	0.00	0.00	0.00	0.00	0.00
15/10/2002	7.60	0.66	1.0000	0.66	0.00	**5.02**	2.60	0.52	0.00	0.52	4.50
16/10/2002	0.00	0.71	1.0000	0.71	0.71	**0.00**	0.00	0.00	0.00	0.00	0.00
17/10/2002	0.60	0.51	1.0000	0.51	0.63	**0.00**	0.00	0.00	0.00	0.00	0.00
18/10/2002	0.00	0.66	1.0000	0.66	1.28	**0.00**	0.00	0.00	0.00	0.00	0.00
19/10/2002	0.70	0.65	1.0000	0.65	1.24	**0.00**	0.00	0.00	0.00	0.00	0.00
20/10/2002	39.50	0.50	1.0000	0.50	0.00	**37.76**	34.50	0.00	10.35	10.35	27.41
21/10/2002	13.40	0.54	1.0000	0.54	0.00	**12.86**	8.40	1.68	0.00	1.68	11.18
22/10/2002	0.40	0.45	1.0000	0.45	0.05	**0.00**	0.00	0.00	0.00	0.00	0.00
23/10/2002	0.10	0.80	1.0000	0.80	0.75	**0.00**	0.00	0.00	0.00	0.00	0.00
24/10/2002	3.30	0.59	1.0000	0.59	0.00	**1.96**	0.00	0.00	0.00	0.00	1.96
25/10/2002	4.50	0.94	1.0000	0.94	0.00	**3.56**	0.00	0.00	0.00	0.00	3.56
26/10/2002	7.10	0.67	1.0000	0.67	0.00	**6.43**	2.10	0.42	0.00	0.42	6.01
27/10/2002	0.80	0.91	1.0000	0.91	0.11	**0.00**	0.00	0.00	0.00	0.00	0.00
28/10/2002	17.70	0.81	1.0000	0.81	0.00	**16.78**	12.70	2.54	0.00	2.54	14.24
29/10/2002	4.00	0.39	1.0000	0.39	0.00	**3.61**	0.00	0.00	0.00	0.00	3.61
30/10/2002	3.70	0.51	1.0000	0.51	0.00	**3.19**	0.00	0.00	0.00	0.00	3.19
31/10/2002	0.40	0.58	1.0000	0.58	0.18	**0.00**	0.00	0.00	0.00	0.00	0.00
01/11/2002	7.20	0.34	1.0000	0.34	0.00	**6.68**	2.20	0.44	0.00	0.44	6.24
02/11/2002	4.30	0.48	1.0000	0.48	0.00	**3.82**	0.00	0.00	0.00	0.00	3.82
03/11/2002	8.20	1.00	1.0000	1.00	0.00	**7.20**	3.20	0.64	0.00	0.64	6.56
04/11/2002	0.40	0.56	1.0000	0.56	0.16	**0.00**	0.00	0.00	0.00	0.00	0.00
05/11/2002	4.10	0.42	1.0000	0.42	0.00	**3.52**	0.00	0.00	0.00	0.00	3.52
06/11/2002	1.00	0.38	1.0000	0.38	0.00	**0.62**	0.00	0.00	0.00	0.00	0.62
07/11/2002	2.80	0.55	1.0000	0.55	0.00	**2.25**	0.00	0.00	0.00	0.00	2.25
08/11/2002	4.70	0.40	1.0000	0.40	0.00	**4.30**	0.00	0.00	0.00	0.00	4.30
09/11/2002	8.50	0.33	1.0000	0.33	0.00	**8.17**	3.50	0.70	0.00	0.70	7.47
10/11/2002	0.70	0.44	1.0000	0.44	0.00	**0.26**	0.00	0.00	0.00	0.00	0.26
11/11/2002	2.40	0.82	1.0000	0.82	0.00	**1.58**	0.00	0.00	0.00	0.00	1.58
12/11/2002	0.40	0.79	1.0000	0.79	0.39	**0.00**	0.00	0.00	0.00	0.00	0.00
13/11/2002	18.20	0.40	1.0000	0.40	0.00	**17.40**	13.20	2.64	0.00	2.64	14.76
14/11/2002	38.20	0.29	1.0000	0.29	0.00	**37.91**	33.20	0.00	9.96	9.96	27.95
15/11/2002	3.80	0.42	1.0000	0.42	0.00	**3.38**	0.00	0.00	0.00	0.00	3.38
16/11/2002	0.00	0.37	1.0000	0.37	0.37	**0.00**	0.00	0.00	0.00	0.00	0.00
17/11/2002	0.40	0.17	1.0000	0.17	0.14	**0.00**	0.00	0.00	0.00	0.00	0.00
18/11/2002	2.50	0.57	1.0000	0.57	0.00	**1.79**	0.00	0.00	0.00	0.00	1.79
19/11/2002	0.40	0.53	1.0000	0.53	0.13	**0.00**	0.00	0.00	0.00	0.00	0.00
20/11/2002	6.70	0.33	1.0000	0.33	0.00	**6.24**	1.70	0.34	0.00	0.34	5.90
21/11/2002	3.20	0.67	1.0000	0.67	0.00	**2.53**	0.00	0.00	0.00	0.00	2.53
22/11/2002	0.70	0.60	1.0000	0.60	0.00	**0.10**	0.00	0.00	0.00	0.00	0.10
23/11/2002	4.50	0.63	1.0000	0.63	0.00	**3.87**	0.00	0.00	0.00	0.00	3.87
24/11/2002	0.00	0.55	1.0000	0.55	0.55	**0.00**	0.00	0.00	0.00	0.00	0.00
25/11/2002	2.70	0.49	1.0000	0.49	0.00	**1.67**	0.00	0.00	0.00	0.00	1.67
26/11/2002	11.00	0.82	1.0000	0.82	0.00	**10.18**	6.00	1.20	0.00	1.20	8.98
27/11/2002	10.00	0.92	1.0000	0.92	0.00	**9.08**	5.00	1.00	0.00	1.00	8.08
28/11/2002	0.20	0.53	1.0000	0.53	0.33	**0.00**	0.00	0.00	0.00	0.00	0.00
29/11/2002	1.20	0.21	1.0000	0.21	0.00	**0.67**	0.00	0.00	0.00	0.00	0.67
30/11/2002	0.30	0.33	1.0000	0.33	0.03	**0.00**	0.00	0.00	0.00	0.00	0.00
01/12/2002	7.50	0.84	1.0000	0.84	0.00	**6.64**	2.50	0.50	0.00	0.50	6.14
02/12/2002	1.70	0.59	1.0000	0.59	0.00	**1.11**	0.00	0.00	0.00	0.00	1.11
03/12/2002	2.70	0.40	1.0000	0.40	0.00	**2.30**	0.00	0.00	0.00	0.00	2.30
04/12/2002	0.00	0.20	1.0000	0.20	0.20	**0.00**	0.00	0.00	0.00	0.00	0.00
05/12/2002	0.00	0.05	1.0000	0.05	0.25	**0.00**	0.00	0.00	0.00	0.00	0.00
06/12/2002	0.00	0.03	1.0000	0.03	0.28	**0.00**	0.00	0.00	0.00	0.00	0.00
07/12/2002	1.80	0.29	1.0000	0.29	0.00	**1.23**	0.00	0.00	0.00	0.00	1.23
08/12/2002	0.10	0.83	1.0000	0.83	0.73	**0.00**	0.00	0.00	0.00	0.00	0.00
09/12/2002	0.00	0.81	1.0000	0.81	1.54	**0.00**	0.00	0.00	0.00	0.00	0.00

Date	Rainfall	PE	S.F.	AE	SMD	**Recharge**	Pot. Runoff	Runoff 1	Runoff 2	Runoff	Recharge
10/12/2002	0.00	1.31	1.0000	1.31	2.85	**0.00**	0.00	0.00	0.00	0.00	0.00
11/12/2002	0.00	0.63	1.0000	0.63	3.47	**0.00**	0.00	0.00	0.00	0.00	0.00
12/12/2002	4.10	0.54	1.0000	0.54	0.00	**0.08**	0.00	0.00	0.00	0.00	0.08
13/12/2002	0.20	0.29	1.0000	0.29	0.09	**0.00**	0.00	0.00	0.00	0.00	0.00
14/12/2002	4.70	0.39	1.0000	0.39	0.00	**4.22**	0.00	0.00	0.00	0.00	4.22
15/12/2002	1.10	0.44	1.0000	0.44	0.00	**0.66**	0.00	0.00	0.00	0.00	0.66
16/12/2002	0.00	0.32	1.0000	0.32	0.32	**0.00**	0.00	0.00	0.00	0.00	0.00
17/12/2002	0.00	0.35	1.0000	0.35	0.66	**0.00**	0.00	0.00	0.00	0.00	0.00
18/12/2002	0.00	0.62	1.0000	0.62	1.28	**0.00**	0.00	0.00	0.00	0.00	0.00
19/12/2002	0.00	0.40	1.0000	0.40	1.69	**0.00**	0.00	0.00	0.00	0.00	0.00
20/12/2002	3.50	0.31	1.0000	0.31	0.00	**1.50**	0.00	0.00	0.00	0.00	1.50
21/12/2002	5.50	0.40	1.0000	0.40	0.00	**5.10**	0.50	0.10	0.00	0.10	5.00
22/12/2002	1.50	0.19	1.0000	0.19	0.00	**1.31**	0.00	0.00	0.00	0.00	1.31
23/12/2002	2.50	0.77	1.0000	0.77	0.00	**1.73**	0.00	0.00	0.00	0.00	1.73
24/12/2002	1.60	0.63	1.0000	0.63	0.00	**0.97**	0.00	0.00	0.00	0.00	0.97
25/12/2002	3.40	0.37	1.0000	0.37	0.00	**3.03**	0.00	0.00	0.00	0.00	3.03
26/12/2002	10.30	0.17	1.0000	0.17	0.00	**10.13**	5.30	1.06	0.00	1.06	9.07
27/12/2002	1.10	0.23	1.0000	0.23	0.00	**0.87**	0.00	0.00	0.00	0.00	0.87
28/12/2002	10.40	0.27	1.0000	0.27	0.00	**10.13**	5.40	1.08	0.00	1.08	9.05
29/12/2002	14.00	0.43	1.0000	0.43	0.00	**13.57**	9.00	1.80	0.00	1.80	11.77
30/12/2002	1.30	0.24	1.0000	0.24	0.00	**1.06**	0.00	0.00	0.00	0.00	1.06
31/12/2002	8.70	0.49	1.0000	0.49	0.00	**8.21**	3.70	0.74	0.00	0.74	7.47
01/01/2003	0.50	0.35	1.0000	0.35	0.00	**0.15**	0.00	0.00	0.00	0.00	0.15
02/01/2003	6.60	0.35	1.0000	0.35	0.00	**6.25**	1.60	0.32	0.00	0.32	5.93
03/01/2003	0.00	0.08	1.0000	0.08	0.08	**0.00**	0.00	0.00	0.00	0.00	0.00
04/01/2003	0.00	0.06	1.0000	0.06	0.14	**0.00**	0.00	0.00	0.00	0.00	0.00
05/01/2003	0.00	0.15	1.0000	0.15	0.29	**0.00**	0.00	0.00	0.00	0.00	0.00
06/01/2003	0.00	0.45	1.0000	0.45	0.74	**0.00**	0.00	0.00	0.00	0.00	0.00
07/01/2003	0.00	0.98	1.0000	0.98	1.72	**0.00**	0.00	0.00	0.00	0.00	0.00
08/01/2003	5.10	0.57	1.0000	0.57	0.00	**2.81**	0.10	0.02	0.00	0.02	2.79
09/01/2003	0.00	0.46	1.0000	0.46	0.46	**0.00**	0.00	0.00	0.00	0.00	0.00
10/01/2003	0.00	0.29	1.0000	0.29	0.75	**0.00**	0.00	0.00	0.00	0.00	0.00
11/01/2003	0.00	0.22	1.0000	0.22	0.97	**0.00**	0.00	0.00	0.00	0.00	0.00
12/01/2003	0.80	0.41	1.0000	0.41	0.59	**0.00**	0.00	0.00	0.00	0.00	0.00
13/01/2003	0.10	0.35	1.0000	0.35	0.84	**0.00**	0.00	0.00	0.00	0.00	0.00
14/01/2003	3.10	0.93	1.0000	0.93	0.00	**1.34**	0.00	0.00	0.00	0.00	1.34
15/01/2003	0.10	0.44	1.0000	0.44	0.34	**0.00**	0.00	0.00	0.00	0.00	0.00
16/01/2003	13.10	0.82	1.0000	0.82	0.00	**11.94**	8.10	1.62	0.00	1.62	10.32
17/01/2003	0.40	0.46	1.0000	0.46	0.06	**0.00**	0.00	0.00	0.00	0.00	0.00
18/01/2003	5.50	0.67	1.0000	0.67	0.00	**4.77**	0.50	0.10	0.00	0.10	4.67
19/01/2003	5.40	0.48	1.0000	0.48	0.00	**4.92**	0.40	0.08	0.00	0.08	4.84
20/01/2003	0.80	0.37	1.0000	0.37	0.00	**0.43**	0.00	0.00	0.00	0.00	0.43
21/01/2003	0.20	0.19	1.0000	0.19	0.00	**0.01**	0.00	0.00	0.00	0.00	0.01
22/01/2003	0.00	0.45	1.0000	0.45	0.45	**0.00**	0.00	0.00	0.00	0.00	0.00
23/01/2003	0.00	0.26	1.0000	0.26	0.71	**0.00**	0.00	0.00	0.00	0.00	0.00
24/01/2003	9.10	0.88	1.0000	0.88	0.00	**7.51**	4.10	0.82	0.00	0.82	6.69
25/01/2003	0.10	0.50	1.0000	0.50	0.40	**0.00**	0.00	0.00	0.00	0.00	0.00
26/01/2003	0.00	0.61	1.0000	0.61	1.01	**0.00**	0.00	0.00	0.00	0.00	0.00
27/01/2003	0.80	0.74	1.0000	0.74	0.95	**0.00**	0.00	0.00	0.00	0.00	0.00
28/01/2003	2.40	0.78	1.0000	0.78	0.00	**0.67**	0.00	0.00	0.00	0.00	0.67
29/01/2003	2.70	0.50	1.0000	0.50	0.00	**2.20**	0.00	0.00	0.00	0.00	2.20
30/01/2003	0.00	0.21	1.0000	0.21	0.21	**0.00**	0.00	0.00	0.00	0.00	0.00
31/01/2003	2.50	0.19	1.0000	0.19	0.00	**2.10**	0.00	0.00	0.00	0.00	2.10
01/02/2003	1.10	0.57	1.0000	0.57	0.00	**0.53**	0.00	0.00	0.00	0.00	0.53
02/02/2003	3.10	0.42	1.0000	0.42	0.00	**2.68**	0.00	0.00	0.00	0.00	2.68
03/02/2003	0.40	0.44	1.0000	0.44	0.04	**0.00**	0.00	0.00	0.00	0.00	0.00
04/02/2003	0.00	0.48	1.0000	0.48	0.53	**0.00**	0.00	0.00	0.00	0.00	0.00
05/02/2003	1.00	0.46	1.0000	0.46	0.00	**0.01**	0.00	0.00	0.00	0.00	0.01
06/02/2003	1.20	0.58	1.0000	0.58	0.00	**0.62**	0.00	0.00	0.00	0.00	0.62
07/02/2003	0.20	0.66	1.0000	0.66	0.46	**0.00**	0.00	0.00	0.00	0.00	0.00
08/02/2003	4.70	0.56	1.0000	0.56	0.00	**3.69**	0.00	0.00	0.00	0.00	3.69
09/02/2003	0.60	0.45	1.0000	0.45	0.00	**0.15**	0.00	0.00	0.00	0.00	0.15
10/02/2003	10.50	0.79	1.0000	0.79	0.00	**9.71**	5.50	1.10	0.00	1.10	8.61
11/02/2003	0.00	0.36	1.0000	0.36	0.36	**0.00**	0.00	0.00	0.00	0.00	0.00
12/02/2003	0.00	0.35	1.0000	0.35	0.72	**0.00**	0.00	0.00	0.00	0.00	0.00
13/02/2003	0.10	0.43	1.0000	0.43	1.05	**0.00**	0.00	0.00	0.00	0.00	0.00
14/02/2003	0.00	0.34	1.0000	0.34	1.39	**0.00**	0.00	0.00	0.00	0.00	0.00
15/02/2003	0.00	0.77	1.0000	0.77	2.15	**0.00**	0.00	0.00	0.00	0.00	0.00
16/02/2003	0.00	0.93	1.0000	0.93	3.09	**0.00**	0.00	0.00	0.00	0.00	0.00
17/02/2003	0.00	0.61	1.0000	0.61	3.69	**0.00**	0.00	0.00	0.00	0.00	0.00
18/02/2003	0.00	1.18	1.0000	1.18	4.87	**0.00**	0.00	0.00	0.00	0.00	0.00
19/02/2003	0.00	1.16	1.0000	1.16	6.03	**0.00**	0.00	0.00	0.00	0.00	0.00
20/02/2003	1.50	0.43	1.0000	0.43	4.96	**0.00**	0.00	0.00	0.00	0.00	0.00
21/02/2003	0.00	0.93	1.0000	0.93	5.89	**0.00**	0.00	0.00	0.00	0.00	0.00
22/02/2003	1.30	1.21	1.0000	1.21	5.81	**0.00**	0.00	0.00	0.00	0.00	0.00
23/02/2003	0.00	1.33	1.0000	1.33	7.14	**0.00**	0.00	0.00	0.00	0.00	0.00
24/02/2003	0.00	0.61	1.0000	0.61	7.74	**0.00**	0.00	0.00	0.00	0.00	0.00
25/02/2003	0.40	1.09	1.0000	1.09	8.43	**0.00**	0.00	0.00	0.00	0.00	0.00

Date	Rainfall	PE	S.F.	AE	SMD	**Recharge**	Pot. Runoff	Runoff 1	Runoff 2	Runoff	Recharge
26/02/2003	1.60	0.88	1.0000	0.88	7.71	**0.00**	0.00	0.00	0.00	0.00	0.00
27/02/2003	1.60	0.81	1.0000	0.81	6.91	**0.00**	0.00	0.00	0.00	0.00	0.00
28/02/2003	8.90	0.83	1.0000	0.83	0.00	**1.16**	3.90	0.78	0.00	0.78	0.38
01/03/2003	5.10	0.96	1.0000	0.96	0.00	**4.14**	0.10	0.02	0.00	0.02	4.12
02/03/2003	0.80	1.21	1.0000	1.21	0.41	**0.00**	0.00	0.00	0.00	0.00	0.00
03/03/2003	1.80	0.68	1.0000	0.68	0.00	**0.71**	0.00	0.00	0.00	0.00	0.71
04/03/2003	0.70	0.88	1.0000	0.88	0.18	**0.00**	0.00	0.00	0.00	0.00	0.00
05/03/2003	0.00	1.44	1.0000	1.44	1.63	**0.00**	0.00	0.00	0.00	0.00	0.00
06/03/2003	2.50	1.45	1.0000	1.45	0.58	**0.00**	0.00	0.00	0.00	0.00	0.00
07/03/2003	1.50	1.01	1.0000	1.01	0.09	**0.00**	0.00	0.00	0.00	0.00	0.00
08/03/2003	10.00	0.85	1.0000	0.85	0.00	**9.07**	5.00	1.00	0.00	1.00	8.07
09/03/2003	4.30	1.27	1.0000	1.27	0.00	**3.03**	0.00	0.00	0.00	0.00	3.03
10/03/2003	9.60	1.23	1.0000	1.23	0.00	**8.37**	4.60	0.92	0.00	0.92	7.45
11/03/2003	1.50	1.16	1.0000	1.16	0.00	**0.34**	0.00	0.00	0.00	0.00	0.34
12/03/2003	0.00	1.10	1.0000	1.10	1.10	**0.00**	0.00	0.00	0.00	0.00	0.00
13/03/2003	0.00	1.05	1.0000	1.05	2.15	**0.00**	0.00	0.00	0.00	0.00	0.00
14/03/2003	0.00	1.41	1.0000	1.41	3.56	**0.00**	0.00	0.00	0.00	0.00	0.00
15/03/2003	0.00	1.51	1.0000	1.51	5.06	**0.00**	0.00	0.00	0.00	0.00	0.00
16/03/2003	0.00	1.73	1.0000	1.73	6.80	**0.00**	0.00	0.00	0.00	0.00	0.00
17/03/2003	0.00	1.63	1.0000	1.63	8.43	**0.00**	0.00	0.00	0.00	0.00	0.00
18/03/2003	0.00	1.22	1.0000	1.22	9.65	**0.00**	0.00	0.00	0.00	0.00	0.00
19/03/2003	0.00	1.17	1.0000	1.17	10.83	**0.00**	0.00	0.00	0.00	0.00	0.00
20/03/2003	0.00	0.94	1.0000	0.94	11.77	**0.00**	0.00	0.00	0.00	0.00	0.00
21/03/2003	0.00	1.55	1.0000	1.55	13.32	**0.00**	0.00	0.00	0.00	0.00	0.00
22/03/2003	0.00	1.33	1.0000	1.33	14.65	**0.00**	0.00	0.00	0.00	0.00	0.00
23/03/2003	0.00	1.77	1.0000	1.77	16.42	**0.00**	0.00	0.00	0.00	0.00	0.00
24/03/2003	0.00	1.62	1.0000	1.62	18.05	**0.00**	0.00	0.00	0.00	0.00	0.00
25/03/2003	0.00	1.64	1.0000	1.64	19.68	**0.00**	0.00	0.00	0.00	0.00	0.00
26/03/2003	0.00	1.66	1.0000	1.66	21.34	**0.00**	0.00	0.00	0.00	0.00	0.00
27/03/2003	0.00	1.79	1.0000	1.79	23.13	**0.00**	0.00	0.00	0.00	0.00	0.00
28/03/2003	0.00	0.97	1.0000	0.97	24.11	**0.00**	0.00	0.00	0.00	0.00	0.00
29/03/2003	0.20	1.65	1.0000	1.65	25.55	**0.00**	0.00	0.00	0.00	0.00	0.00
30/03/2003	0.00	1.45	1.0000	1.45	27.00	**0.00**	0.00	0.00	0.00	0.00	0.00
31/03/2003	4.20	1.74	1.0000	1.74	24.54	**0.00**	0.00	0.00	0.00	0.00	0.00
01/04/2003	0.20	1.42	1.0000	1.42	25.76	**0.00**	0.00	0.00	0.00	0.00	0.00
02/04/2003	0.00	1.56	1.0000	1.56	27.33	**0.00**	0.00	0.00	0.00	0.00	0.00
03/04/2003	0.00	0.99	1.0000	0.99	28.32	**0.00**	0.00	0.00	0.00	0.00	0.00
04/04/2003	0.00	2.06	1.0000	2.06	30.38	**0.00**	0.00	0.00	0.00	0.00	0.00
05/04/2003	0.00	1.75	1.0000	1.75	32.13	**0.00**	0.00	0.00	0.00	0.00	0.00
06/04/2003	0.00	0.95	1.0000	0.95	33.08	**0.00**	0.00	0.00	0.00	0.00	0.00
07/04/2003	0.00	1.10	1.0000	1.10	34.18	**0.00**	0.00	0.00	0.00	0.00	0.00
08/04/2003	0.00	2.17	1.0000	2.17	36.35	**0.00**	0.00	0.00	0.00	0.00	0.00
09/04/2003	0.00	1.97	1.0000	1.97	38.32	**0.00**	0.00	0.00	0.00	0.00	0.00
10/04/2003	0.00	1.74	1.0000	1.74	40.06	**0.00**	0.00	0.00	0.00	0.00	0.00
11/04/2003	0.00	1.07	1.0000	1.07	41.12	**0.00**	0.00	0.00	0.00	0.00	0.00
12/04/2003	0.00	1.61	1.0000	1.61	42.73	**0.00**	0.00	0.00	0.00	0.00	0.00
13/04/2003	1.30	1.15	1.0000	1.15	42.59	**0.00**	0.00	0.00	0.00	0.00	0.00
14/04/2003	0.00	2.44	1.0000	2.44	45.03	**0.00**	0.00	0.00	0.00	0.00	0.00
15/04/2003	0.00	3.01	1.0000	3.01	48.04	**0.00**	0.00	0.00	0.00	0.00	0.00
16/04/2003	0.00	3.38	1.0000	3.38	51.42	**0.00**	0.00	0.00	0.00	0.00	0.00
17/04/2003	0.00	3.45	1.0000	3.45	54.87	**0.00**	0.00	0.00	0.00	0.00	0.00
18/04/2003	0.00	2.71	1.0000	2.71	57.58	**0.00**	0.00	0.00	0.00	0.00	0.00
19/04/2003	0.00	2.68	1.0000	2.68	60.26	**0.00**	0.00	0.00	0.00	0.00	0.00
20/04/2003	0.00	2.15	1.0000	2.15	62.41	**0.00**	0.00	0.00	0.00	0.00	0.00
21/04/2003	14.50	0.83	1.0000	0.83	48.74	**0.00**	9.50	1.90	0.00	1.90	-1.90
22/04/2003	0.00	2.15	1.0000	2.15	50.90	**0.00**	0.00	0.00	0.00	0.00	0.00
23/04/2003	0.00	2.50	1.0000	2.50	53.39	**0.00**	0.00	0.00	0.00	0.00	0.00
24/04/2003	4.10	1.63	1.0000	1.63	50.92	**0.00**	0.00	0.00	0.00	0.00	0.00
25/04/2003	3.00	2.05	1.0000	2.05	49.97	**0.00**	0.00	0.00	0.00	0.00	0.00
26/04/2003	1.30	2.51	1.0000	2.51	51.18	**0.00**	0.00	0.00	0.00	0.00	0.00
27/04/2003	7.00	2.78	1.0000	2.78	46.96	**0.00**	2.00	0.40	0.00	0.40	-0.40
28/04/2003	0.30	1.25	1.0000	1.25	47.91	**0.00**	0.00	0.00	0.00	0.00	0.00
29/04/2003	3.10	2.53	1.0000	2.53	47.34	**0.00**	0.00	0.00	0.00	0.00	0.00
30/04/2003	2.20	2.15	1.0000	2.15	47.30	**0.00**	0.00	0.00	0.00	0.00	0.00
01/05/2003	13.20	1.68	1.0000	1.68	35.77	**0.00**	8.20	1.64	0.00	1.64	-1.64
02/05/2003	0.10	1.76	1.0000	1.76	37.44	**0.00**	0.00	0.00	0.00	0.00	0.00
03/05/2003	10.30	1.19	1.0000	1.19	28.33	**0.00**	5.30	1.06	0.00	1.06	-1.06
04/05/2003	4.20	0.97	1.0000	0.97	25.10	**0.00**	0.00	0.00	0.00	0.00	0.00
05/05/2003	18.10	2.54	1.0000	2.54	9.54	**0.00**	13.10	2.62	0.00	2.62	-2.62
06/05/2003	1.60	2.23	1.0000	2.23	10.17	**0.00**	0.00	0.00	0.00	0.00	0.00
07/05/2003	0.00	1.92	1.0000	1.92	12.08	**0.00**	0.00	0.00	0.00	0.00	0.00
08/05/2003	0.00	2.70	1.0000	2.70	14.79	**0.00**	0.00	0.00	0.00	0.00	0.00
09/05/2003	3.70	2.32	1.0000	2.32	13.41	**0.00**	0.00	0.00	0.00	0.00	0.00
10/05/2003	2.80	2.71	1.0000	2.71	13.31	**0.00**	0.00	0.00	0.00	0.00	0.00
11/05/2003	4.50	2.44	1.0000	2.44	11.26	**0.00**	0.00	0.00	0.00	0.00	0.00
12/05/2003	1.80	2.18	1.0000	2.18	11.63	**0.00**	0.00	0.00	0.00	0.00	0.00
13/05/2003	0.50	2.56	1.0000	2.56	13.69	**0.00**	0.00	0.00	0.00	0.00	0.00
14/05/2003	0.00	2.29	1.0000	2.29	15.98	**0.00**	0.00	0.00	0.00	0.00	0.00

Date	Rainfall	PE	S.F.	AE	SMD	**Recharge**	Pot. Runoff	Runoff 1	Runoff 2	Runoff	Recharge
15/05/2003	9.00	2.03	1.0000	2.03	9.01	**0.00**	4.00	0.80	0.00	0.80	-0.80
16/05/2003	4.30	1.66	1.0000	1.66	6.37	**0.00**	0.00	0.00	0.00	0.00	0.00
17/05/2003	5.40	1.77	1.0000	1.77	2.74	**0.00**	0.40	0.08	0.00	0.08	-0.08
18/05/2003	12.00	2.20	1.0000	2.20	0.00	**7.07**	7.00	1.40	0.00	1.40	5.67
19/05/2003	7.60	1.93	1.0000	1.93	0.00	**5.67**	2.60	0.52	0.00	0.52	5.15
20/05/2003	8.50	1.81	1.0000	1.81	0.00	**6.69**	3.50	0.70	0.00	0.70	5.99
21/05/2003	0.00	1.15	1.0000	1.15	1.15	**0.00**	0.00	0.00	0.00	0.00	0.00
22/05/2003	0.00	2.59	1.0000	2.59	3.74	**0.00**	0.00	0.00	0.00	0.00	0.00
23/05/2003	1.70	2.73	1.0000	2.73	4.77	**0.00**	0.00	0.00	0.00	0.00	0.00
24/05/2003	2.20	1.96	1.0000	1.96	4.53	**0.00**	0.00	0.00	0.00	0.00	0.00
25/05/2003	0.10	2.31	1.0000	2.31	6.74	**0.00**	0.00	0.00	0.00	0.00	0.00
26/05/2003	1.90	1.75	1.0000	1.75	6.59	**0.00**	0.00	0.00	0.00	0.00	0.00
27/05/2003	2.00	1.91	1.0000	1.91	6.51	**0.00**	0.00	0.00	0.00	0.00	0.00
28/05/2003	3.80	2.01	1.0000	2.01	4.71	**0.00**	0.00	0.00	0.00	0.00	0.00
29/05/2003	0.10	2.57	1.0000	2.57	7.18	**0.00**	0.00	0.00	0.00	0.00	0.00
30/05/2003	0.00	3.76	1.0000	3.76	10.95	**0.00**	0.00	0.00	0.00	0.00	0.00
31/05/2003	0.00	3.88	1.0000	3.88	14.83	**0.00**	0.00	0.00	0.00	0.00	0.00
01/06/2003	1.00	2.15	1.0000	2.15	15.97	**0.00**	0.00	0.00	0.00	0.00	0.00
02/06/2003	0.30	3.94	1.0000	3.94	19.61	**0.00**	0.00	0.00	0.00	0.00	0.00
03/06/2003	8.20	1.43	1.0000	1.43	12.84	**0.00**	3.20	0.64	0.00	0.64	-0.64
04/06/2003	0.10	2.31	1.0000	2.31	15.05	**0.00**	0.00	0.00	0.00	0.00	0.00
05/06/2003	0.80	2.39	1.0000	2.39	16.63	**0.00**	0.00	0.00	0.00	0.00	0.00
06/06/2003	0.00	3.64	1.0000	3.64	20.28	**0.00**	0.00	0.00	0.00	0.00	0.00
07/06/2003	3.50	2.93	1.0000	2.93	19.70	**0.00**	0.00	0.00	0.00	0.00	0.00
08/06/2003	4.40	3.40	1.0000	3.40	18.70	**0.00**	0.00	0.00	0.00	0.00	0.00
09/06/2003	3.20	1.59	1.0000	1.59	17.10	**0.00**	0.00	0.00	0.00	0.00	0.00
10/06/2003	2.70	3.08	1.0000	3.08	17.47	**0.00**	0.00	0.00	0.00	0.00	0.00
11/06/2003	0.60	3.43	1.0000	3.43	20.30	**0.00**	0.00	0.00	0.00	0.00	0.00
12/06/2003	0.00	3.17	1.0000	3.17	23.47	**0.00**	0.00	0.00	0.00	0.00	0.00
13/06/2003	0.00	2.68	1.0000	2.68	26.15	**0.00**	0.00	0.00	0.00	0.00	0.00
14/06/2003	0.00	4.15	1.0000	4.15	30.30	**0.00**	0.00	0.00	0.00	0.00	0.00
15/06/2003	0.00	2.72	1.0000	2.72	33.02	**0.00**	0.00	0.00	0.00	0.00	0.00
16/06/2003	0.00	3.34	1.0000	3.34	36.36	**0.00**	0.00	0.00	0.00	0.00	0.00
17/06/2003	0.10	2.99	1.0000	2.99	39.25	**0.00**	0.00	0.00	0.00	0.00	0.00
18/06/2003	0.00	2.93	1.0000	2.93	42.18	**0.00**	0.00	0.00	0.00	0.00	0.00
19/06/2003	0.00	3.19	1.0000	3.19	45.37	**0.00**	0.00	0.00	0.00	0.00	0.00
20/06/2003	0.00	3.00	1.0000	3.00	48.37	**0.00**	0.00	0.00	0.00	0.00	0.00
21/06/2003	0.70	2.47	1.0000	2.47	50.13	**0.00**	0.00	0.00	0.00	0.00	0.00
22/06/2003	0.00	2.09	1.0000	2.09	52.23	**0.00**	0.00	0.00	0.00	0.00	0.00
23/06/2003	0.00	2.86	1.0000	2.86	55.08	**0.00**	0.00	0.00	0.00	0.00	0.00
24/06/2003	0.00	4.01	1.0000	4.01	59.09	**0.00**	0.00	0.00	0.00	0.00	0.00
25/06/2003	0.00	4.52	1.0000	4.52	63.61	**0.00**	0.00	0.00	0.00	0.00	0.00
26/06/2003	10.00	2.89	1.0000	2.89	56.51	**0.00**	5.00	1.00	0.00	1.00	-1.00
27/06/2003	18.20	1.42	1.0000	1.42	39.72	**0.00**	13.20	2.64	0.00	2.64	-2.64
28/06/2003	0.00	2.50	1.0000	2.50	42.23	**0.00**	0.00	0.00	0.00	0.00	0.00
29/06/2003	16.00	3.09	1.0000	3.09	29.32	**0.00**	11.00	2.20	0.00	2.20	-2.20
30/06/2003	13.20	0.96	1.0000	0.96	17.08	**0.00**	8.20	1.64	0.00	1.64	-1.64
01/07/2003	13.20	2.35	1.0000	2.35	6.22	**0.00**	8.20	1.64	0.00	1.64	-1.64
02/07/2003	5.30	3.37	1.0000	3.37	4.30	**0.00**	0.30	0.06	0.00	0.06	-0.06
03/07/2003	0.20	2.36	1.0000	2.36	6.46	**0.00**	0.00	0.00	0.00	0.00	0.00
04/07/2003	0.00	1.39	1.0000	1.39	7.84	**0.00**	0.00	0.00	0.00	0.00	0.00
05/07/2003	0.00	1.64	1.0000	1.64	9.49	**0.00**	0.00	0.00	0.00	0.00	0.00
06/07/2003	0.50	3.05	1.0000	3.05	12.04	**0.00**	0.00	0.00	0.00	0.00	0.00
07/07/2003	1.00	3.08	1.0000	3.08	14.12	**0.00**	0.00	0.00	0.00	0.00	0.00
08/07/2003	23.70	2.59	1.0000	2.59	0.00	**6.99**	18.70	0.00	5.61	5.61	1.38
09/07/2003	0.10	2.77	1.0000	2.77	2.67	**0.00**	0.00	0.00	0.00	0.00	0.00
10/07/2003	0.60	2.91	1.0000	2.91	4.98	**0.00**	0.00	0.00	0.00	0.00	0.00
11/07/2003	0.00	2.76	1.0000	2.76	7.74	**0.00**	0.00	0.00	0.00	0.00	0.00
12/07/2003	0.00	3.63	1.0000	3.63	11.37	**0.00**	0.00	0.00	0.00	0.00	0.00
13/07/2003	0.40	4.22	1.0000	4.22	15.19	**0.00**	0.00	0.00	0.00	0.00	0.00
14/07/2003	1.30	3.17	1.0000	3.17	17.06	**0.00**	0.00	0.00	0.00	0.00	0.00
15/07/2003	5.50	2.17	1.0000	2.17	13.73	**0.00**	0.50	0.10	0.00	0.10	-0.10
16/07/2003	0.80	3.08	1.0000	3.08	16.02	**0.00**	0.00	0.00	0.00	0.00	0.00
17/07/2003	17.70	0.60	1.0000	0.60	0.00	**1.08**	12.70	2.54	0.00	2.54	-1.46
18/07/2003	2.00	3.43	1.0000	3.43	1.43	**0.00**	0.00	0.00	0.00	0.00	0.00
19/07/2003	1.20	3.68	1.0000	3.68	3.91	**0.00**	0.00	0.00	0.00	0.00	0.00
20/07/2003	5.60	3.23	1.0000	3.23	1.54	**0.00**	0.60	0.12	0.00	0.12	-0.12
21/07/2003	2.80	3.08	1.0000	3.08	1.82	**0.00**	0.00	0.00	0.00	0.00	0.00
22/07/2003	2.50	1.68	1.0000	1.68	1.00	**0.00**	0.00	0.00	0.00	0.00	0.00
23/07/2003	0.70	2.55	1.0000	2.55	2.85	**0.00**	0.00	0.00	0.00	0.00	0.00
24/07/2003	2.50	2.36	1.0000	2.36	2.71	**0.00**	0.00	0.00	0.00	0.00	0.00
25/07/2003	1.40	2.86	1.0000	2.86	4.18	**0.00**	0.00	0.00	0.00	0.00	0.00
26/07/2003	0.00	2.67	1.0000	2.67	6.85	**0.00**	0.00	0.00	0.00	0.00	0.00
27/07/2003	0.00	2.78	1.0000	2.78	9.63	**0.00**	0.00	0.00	0.00	0.00	0.00
28/07/2003	9.00	1.87	1.0000	1.87	2.50	**0.00**	4.00	0.80	0.00	0.80	-0.80
29/07/2003	3.30	1.72	1.0000	1.72	0.92	**0.00**	0.00	0.00	0.00	0.00	0.00
30/07/2003	2.70	2.76	1.0000	2.76	0.98	**0.00**	0.00	0.00	0.00	0.00	0.00
31/07/2003	1.10	2.32	1.0000	2.32	2.20	**0.00**	0.00	0.00	0.00	0.00	0.00

Date	Rainfall	PE	S.F.	AE	SMD	**Recharge**	Pot. Runoff	Runoff 1	Runoff 2	Runoff	Recharge
01/08/2003	0.00	2.13	1.0000	2.13	4.33	**0.00**	0.00	0.00	0.00	0.00	0.00
02/08/2003	0.00	3.27	1.0000	3.27	7.60	**0.00**	0.00	0.00	0.00	0.00	0.00
03/08/2003	0.00	2.89	1.0000	2.89	10.49	**0.00**	0.00	0.00	0.00	0.00	0.00
04/08/2003	0.00	3.35	1.0000	3.35	13.84	**0.00**	0.00	0.00	0.00	0.00	0.00
05/08/2003	1.50	3.43	1.0000	3.43	15.76	**0.00**	0.00	0.00	0.00	0.00	0.00
06/08/2003	0.00	1.72	1.0000	1.72	17.48	**0.00**	0.00	0.00	0.00	0.00	0.00
07/08/2003	0.00	4.13	1.0000	4.13	21.61	**0.00**	0.00	0.00	0.00	0.00	0.00
08/08/2003	0.00	3.68	1.0000	3.68	25.29	**0.00**	0.00	0.00	0.00	0.00	0.00
09/08/2003	0.00	2.80	1.0000	2.80	28.09	**0.00**	0.00	0.00	0.00	0.00	0.00
10/08/2003	0.00	3.29	1.0000	3.29	31.38	**0.00**	0.00	0.00	0.00	0.00	0.00
11/08/2003	0.00	2.87	1.0000	2.87	34.25	**0.00**	0.00	0.00	0.00	0.00	0.00
12/08/2003	0.00	3.04	1.0000	3.04	37.28	**0.00**	0.00	0.00	0.00	0.00	0.00
13/08/2003	0.00	3.26	1.0000	3.26	40.55	**0.00**	0.00	0.00	0.00	0.00	0.00
14/08/2003	0.00	2.59	1.0000	2.59	43.14	**0.00**	0.00	0.00	0.00	0.00	0.00
15/08/2003	0.00	2.27	1.0000	2.27	45.40	**0.00**	0.00	0.00	0.00	0.00	0.00
16/08/2003	0.00	3.02	1.0000	3.02	48.42	**0.00**	0.00	0.00	0.00	0.00	0.00
17/08/2003	2.10	2.44	1.0000	2.44	48.76	**0.00**	0.00	0.00	0.00	0.00	0.00
18/08/2003	0.00	2.74	1.0000	2.74	51.51	**0.00**	0.00	0.00	0.00	0.00	0.00
19/08/2003	0.00	2.54	1.0000	2.54	54.05	**0.00**	0.00	0.00	0.00	0.00	0.00
20/08/2003	0.00	2.55	1.0000	2.55	56.60	**0.00**	0.00	0.00	0.00	0.00	0.00
21/08/2003	2.90	2.67	1.0000	2.67	56.37	**0.00**	0.00	0.00	0.00	0.00	0.00
22/08/2003	0.20	1.13	1.0000	1.13	57.30	**0.00**	0.00	0.00	0.00	0.00	0.00
23/08/2003	0.00	2.88	1.0000	2.88	60.17	**0.00**	0.00	0.00	0.00	0.00	0.00
24/08/2003	0.00	2.81	1.0000	2.81	62.98	**0.00**	0.00	0.00	0.00	0.00	0.00
25/08/2003	0.00	2.27	1.0000	2.27	65.25	**0.00**	0.00	0.00	0.00	0.00	0.00
26/08/2003	0.00	2.18	1.0000	2.18	67.43	**0.00**	0.00	0.00	0.00	0.00	0.00
27/08/2003	0.00	2.48	1.0000	2.48	69.91	**0.00**	0.00	0.00	0.00	0.00	0.00
28/08/2003	2.90	1.29	1.0000	1.29	68.30	**0.00**	0.00	0.00	0.00	0.00	0.00
29/08/2003	3.60	2.05	1.0000	2.05	66.75	**0.00**	0.00	0.00	0.00	0.00	0.00
30/08/2003	0.00	2.26	1.0000	2.26	69.01	**0.00**	0.00	0.00	0.00	0.00	0.00
31/08/2003	0.00	1.66	1.0000	1.66	70.68	**0.00**	0.00	0.00	0.00	0.00	0.00
01/09/2003	0.00	1.79	1.0000	1.79	72.47	**0.00**	0.00	0.00	0.00	0.00	0.00
02/09/2003	0.00	1.75	1.0000	1.75	74.21	**0.00**	0.00	0.00	0.00	0.00	0.00
03/09/2003	0.00	1.58	0.9960	1.57	75.78	**0.00**	0.00	0.00	0.00	0.00	0.00
04/09/2003	0.00	2.38	0.9663	2.30	78.08	**0.00**	0.00	0.00	0.00	0.00	0.00
05/09/2003	0.60	1.72	0.9230	1.59	79.07	**0.00**	0.00	0.00	0.00	0.00	0.00
06/09/2003	0.00	2.56	0.9043	2.31	81.38	**0.00**	0.00	0.00	0.00	0.00	0.00
07/09/2003	8.10	1.26	0.8607	1.08	74.37	**0.00**	3.10	0.62	0.00	0.62	-0.62
08/09/2003	0.00	1.93	0.9931	1.91	76.28	**0.00**	0.00	0.00	0.00	0.00	0.00
09/09/2003	1.20	1.41	0.9570	1.35	76.43	**0.00**	0.00	0.00	0.00	0.00	0.00
10/09/2003	5.60	1.83	0.9542	1.74	72.57	**0.00**	0.60	0.12	0.00	0.12	-0.12
11/09/2003	0.60	2.14	1.0000	2.14	74.11	**0.00**	0.00	0.00	0.00	0.00	0.00
12/09/2003	0.10	1.98	0.9978	1.97	75.99	**0.00**	0.00	0.00	0.00	0.00	0.00
13/09/2003	0.00	2.78	0.9625	2.67	78.66	**0.00**	0.00	0.00	0.00	0.00	0.00
14/09/2003	0.00	2.77	0.9121	2.52	81.18	**0.00**	0.00	0.00	0.00	0.00	0.00
15/09/2003	0.00	2.11	0.8645	1.83	83.01	**0.00**	0.00	0.00	0.00	0.00	0.00
16/09/2003	0.00	2.66	0.8300	2.21	85.22	**0.00**	0.00	0.00	0.00	0.00	0.00
17/09/2003	0.00	3.67	0.7883	2.89	88.11	**0.00**	0.00	0.00	0.00	0.00	0.00
18/09/2003	6.20	1.57	0.7338	1.15	83.06	**0.00**	1.20	0.24	0.00	0.24	-0.24
19/09/2003	1.80	1.05	0.8290	0.87	82.13	**0.00**	0.00	0.00	0.00	0.00	0.00
20/09/2003	0.80	0.59	0.8465	0.50	81.84	**0.00**	0.00	0.00	0.00	0.00	0.00
21/09/2003	7.00	1.76	0.8521	1.50	76.33	**0.00**	2.00	0.40	0.00	0.40	-0.40
22/09/2003	0.10	1.07	0.9560	1.02	77.25	**0.00**	0.00	0.00	0.00	0.00	0.00
23/09/2003	0.00	1.27	0.9386	1.19	78.45	**0.00**	0.00	0.00	0.00	0.00	0.00
24/09/2003	0.00	1.70	0.9161	1.55	80.00	**0.00**	0.00	0.00	0.00	0.00	0.00
25/09/2003	1.40	1.91	0.8868	1.69	80.29	**0.00**	0.00	0.00	0.00	0.00	0.00
26/09/2003	0.00	1.29	0.8812	1.14	81.43	**0.00**	0.00	0.00	0.00	0.00	0.00
27/09/2003	0.00	1.42	0.8598	1.22	82.65	**0.00**	0.00	0.00	0.00	0.00	0.00
28/09/2003	0.50	1.39	0.8368	1.16	83.31	**0.00**	0.00	0.00	0.00	0.00	0.00
29/09/2003	3.40	1.02	0.8243	0.84	80.75	**0.00**	0.00	0.00	0.00	0.00	0.00
30/09/2003	2.60	0.79	0.8726	0.69	78.84	**0.00**	0.00	0.00	0.00	0.00	0.00
01/10/2003	0.00	1.08	0.9086	0.98	79.83	**0.00**	0.00	0.00	0.00	0.00	0.00
02/10/2003	0.00	1.15	0.8900	1.02	80.85	**0.00**	0.00	0.00	0.00	0.00	0.00
03/10/2003	0.00	1.12	0.8708	0.97	81.82	**0.00**	0.00	0.00	0.00	0.00	0.00
04/10/2003	0.80	1.06	0.8524	0.90	81.92	**0.00**	0.00	0.00	0.00	0.00	0.00
05/10/2003	5.80	0.44	0.8505	0.38	76.50	**0.00**	0.80	0.16	0.00	0.16	-0.16
06/10/2003	2.50	1.61	0.9528	1.53	75.53	**0.00**	0.00	0.00	0.00	0.00	0.00
07/10/2003	3.40	0.85	0.9711	0.83	72.96	**0.00**	0.00	0.00	0.00	0.00	0.00
08/10/2003	0.10	1.11	1.0000	1.11	73.97	**0.00**	0.00	0.00	0.00	0.00	0.00
09/10/2003	0.60	1.41	1.0000	1.41	74.78	**0.00**	0.00	0.00	0.00	0.00	0.00
10/10/2003	0.00	0.88	0.9853	0.87	75.65	**0.00**	0.00	0.00	0.00	0.00	0.00
11/10/2003	0.00	0.99	0.9688	0.96	76.61	**0.00**	0.00	0.00	0.00	0.00	0.00
12/10/2003	2.50	1.01	0.9507	0.96	75.07	**0.00**	0.00	0.00	0.00	0.00	0.00
13/10/2003	0.00	0.72	0.9797	0.70	75.78	**0.00**	0.00	0.00	0.00	0.00	0.00
14/10/2003	0.00	0.67	0.9665	0.65	76.42	**0.00**	0.00	0.00	0.00	0.00	0.00
15/10/2003	0.00	0.79	0.9543	0.76	77.18	**0.00**	0.00	0.00	0.00	0.00	0.00
16/10/2003	0.00	1.24	0.9400	1.17	78.35	**0.00**	0.00	0.00	0.00	0.00	0.00
17/10/2003	0.00	1.07	0.9179	0.98	79.33	**0.00**	0.00	0.00	0.00	0.00	0.00

Date	Rainfall	PE	S.F.	AE	SMD	**Recharge**	Pot. Runoff	Runoff 1	Runoff 2	Runoff	Recharge
18/10/2003	0.00	0.65	0.8994	0.59	79.92	**0.00**	0.00	0.00	0.00	0.00	0.00
19/10/2003	3.10	0.98	0.8883	0.87	77.69	**0.00**	0.00	0.00	0.00	0.00	0.00
20/10/2003	0.20	0.72	0.9304	0.67	78.16	**0.00**	0.00	0.00	0.00	0.00	0.00
21/10/2003	19.30	0.59	0.9215	0.55	59.41	**0.00**	14.30	2.86	0.00	2.86	-2.86
22/10/2003	55.70	0.40	1.0000	0.40	4.11	**0.00**	50.70	0.00	15.21	15.21	-15.21
23/10/2003	0.70	0.57	1.0000	0.57	3.98	**0.00**	0.00	0.00	0.00	0.00	0.00
24/10/2003	0.00	0.57	1.0000	0.57	4.56	**0.00**	0.00	0.00	0.00	0.00	0.00
25/10/2003	0.90	0.40	1.0000	0.40	4.05	**0.00**	0.00	0.00	0.00	0.00	0.00
26/10/2003	0.00	0.45	1.0000	0.45	4.51	**0.00**	0.00	0.00	0.00	0.00	0.00
27/10/2003	0.40	0.66	1.0000	0.66	4.76	**0.00**	0.00	0.00	0.00	0.00	0.00
28/10/2003	5.80	0.37	1.0000	0.37	0.00	**0.67**	0.80	0.16	0.00	0.16	0.51
29/10/2003	0.60	0.54	1.0000	0.54	0.00	**0.06**	0.00	0.00	0.00	0.00	0.06
30/10/2003	17.60	0.40	1.0000	0.40	0.00	**17.20**	12.60	2.52	0.00	2.52	14.68
31/10/2003	0.00	0.66	1.0000	0.66	0.66	**0.00**	0.00	0.00	0.00	0.00	0.00
01/11/2003	0.00	0.44	1.0000	0.44	1.10	**0.00**	0.00	0.00	0.00	0.00	0.00
02/11/2003	8.80	0.68	1.0000	0.68	0.00	**7.02**	3.80	0.76	0.00	0.76	6.26
03/11/2003	0.20	0.89	1.0000	0.89	0.69	**0.00**	0.00	0.00	0.00	0.00	0.00
04/11/2003	0.00	1.02	1.0000	1.02	1.71	**0.00**	0.00	0.00	0.00	0.00	0.00
05/11/2003	1.30	1.42	1.0000	1.42	1.83	**0.00**	0.00	0.00	0.00	0.00	0.00
06/11/2003	0.00	0.63	1.0000	0.63	2.46	**0.00**	0.00	0.00	0.00	0.00	0.00
07/11/2003	0.00	0.85	1.0000	0.85	3.31	**0.00**	0.00	0.00	0.00	0.00	0.00
08/11/2003	0.00	1.28	1.0000	1.28	4.59	**0.00**	0.00	0.00	0.00	0.00	0.00
09/11/2003	0.00	1.05	1.0000	1.05	5.64	**0.00**	0.00	0.00	0.00	0.00	0.00
10/11/2003	0.50	0.40	1.0000	0.40	5.54	**0.00**	0.00	0.00	0.00	0.00	0.00
11/11/2003	4.50	0.57	1.0000	0.57	1.61	**0.00**	0.00	0.00	0.00	0.00	0.00
12/11/2003	0.50	0.51	1.0000	0.51	1.62	**0.00**	0.00	0.00	0.00	0.00	0.00
13/11/2003	10.00	0.66	1.0000	0.66	0.00	**7.72**	5.00	1.00	0.00	1.00	6.72
14/11/2003	0.50	0.72	1.0000	0.72	0.22	**0.00**	0.00	0.00	0.00	0.00	0.00
15/11/2003	0.00	0.29	1.0000	0.29	0.51	**0.00**	0.00	0.00	0.00	0.00	0.00
16/11/2003	0.60	0.22	1.0000	0.22	0.12	**0.00**	0.00	0.00	0.00	0.00	0.00
17/11/2003	0.80	0.70	1.0000	0.70	0.02	**0.00**	0.00	0.00	0.00	0.00	0.00
18/11/2003	1.50	0.80	1.0000	0.80	0.00	**0.68**	0.00	0.00	0.00	0.00	0.68
19/11/2003	15.70	0.51	1.0000	0.51	0.00	**15.19**	10.70	2.14	0.00	2.14	13.05
20/11/2003	0.20	0.29	1.0000	0.29	0.09	**0.00**	0.00	0.00	0.00	0.00	0.00
21/11/2003	0.00	0.24	1.0000	0.24	0.33	**0.00**	0.00	0.00	0.00	0.00	0.00
22/11/2003	0.00	0.15	1.0000	0.15	0.48	**0.00**	0.00	0.00	0.00	0.00	0.00
23/11/2003	0.10	0.09	1.0000	0.09	0.47	**0.00**	0.00	0.00	0.00	0.00	0.00
24/11/2003	2.50	0.28	1.0000	0.28	0.00	**1.75**	0.00	0.00	0.00	0.00	1.75
25/11/2003	4.00	0.40	1.0000	0.40	0.00	**3.60**	0.00	0.00	0.00	0.00	3.60
26/11/2003	0.00	0.37	1.0000	0.37	0.37	**0.00**	0.00	0.00	0.00	0.00	0.00
27/11/2003	0.00	0.45	1.0000	0.45	0.81	**0.00**	0.00	0.00	0.00	0.00	0.00
28/11/2003	12.40	0.47	1.0000	0.47	0.00	**11.11**	7.40	1.48	0.00	1.48	9.63
29/11/2003	1.80	0.66	1.0000	0.66	0.00	**1.14**	0.00	0.00	0.00	0.00	1.14
30/11/2003	0.00	0.18	1.0000	0.18	0.18	**0.00**	0.00	0.00	0.00	0.00	0.00
01/12/2003	11.50	0.22	1.0000	0.22	0.00	**11.11**	6.50	1.30	0.00	1.30	9.81
02/12/2003	0.70	0.18	1.0000	0.18	0.00	**0.52**	0.00	0.00	0.00	0.00	0.52
03/12/2003	0.00	0.28	1.0000	0.28	0.28	**0.00**	0.00	0.00	0.00	0.00	0.00
04/12/2003	0.00	0.17	1.0000	0.17	0.45	**0.00**	0.00	0.00	0.00	0.00	0.00
05/12/2003	0.20	0.26	1.0000	0.26	0.51	**0.00**	0.00	0.00	0.00	0.00	0.00
06/12/2003	0.00	0.63	1.0000	0.63	1.14	**0.00**	0.00	0.00	0.00	0.00	0.00
07/12/2003	0.00	0.32	1.0000	0.32	1.46	**0.00**	0.00	0.00	0.00	0.00	0.00
08/12/2003	1.60	0.28	1.0000	0.28	0.14	**0.00**	0.00	0.00	0.00	0.00	0.00
09/12/2003	0.00	0.53	1.0000	0.53	0.67	**0.00**	0.00	0.00	0.00	0.00	0.00
10/12/2003	0.00	0.92	1.0000	0.92	1.59	**0.00**	0.00	0.00	0.00	0.00	0.00
11/12/2003	12.00	0.00	1.0000	0.00	0.00	**10.41**	7.00	1.40	0.00	1.40	9.01
12/12/2003	4.20	0.37	1.0000	0.37	0.00	**3.83**	0.00	0.00	0.00	0.00	3.83
13/12/2003	2.60	0.36	1.0000	0.36	0.00	**2.24**	0.00	0.00	0.00	0.00	2.24
14/12/2003	0.00	0.47	1.0000	0.47	0.47	**0.00**	0.00	0.00	0.00	0.00	0.00
15/12/2003	0.00	0.03	1.0000	0.03	0.50	**0.00**	0.00	0.00	0.00	0.00	0.00
16/12/2003	0.00	0.56	1.0000	0.56	1.06	**0.00**	0.00	0.00	0.00	0.00	0.00
17/12/2003	0.00	0.10	1.0000	0.10	1.16	**0.00**	0.00	0.00	0.00	0.00	0.00
18/12/2003	0.40	0.21	1.0000	0.21	0.97	**0.00**	0.00	0.00	0.00	0.00	0.00
19/12/2003	7.00	0.09	1.0000	0.09	0.00	**5.94**	2.00	0.40	0.00	0.40	5.54
20/12/2003	0.80	0.43	1.0000	0.43	0.00	**0.37**	0.00	0.00	0.00	0.00	0.37
21/12/2003	0.00	0.21	1.0000	0.21	0.21	**0.00**	0.00	0.00	0.00	0.00	0.00
22/12/2003	1.70	0.26	1.0000	0.26	0.00	**1.22**	0.00	0.00	0.00	0.00	1.22
23/12/2003	0.00	0.24	1.0000	0.24	0.24	**0.00**	0.00	0.00	0.00	0.00	0.00
24/12/2003	0.50	0.57	1.0000	0.57	0.32	**0.00**	0.00	0.00	0.00	0.00	0.00
25/12/2003	16.20	0.49	1.0000	0.49	0.00	**15.39**	11.20	2.24	0.00	2.24	13.15
26/12/2003	2.20	0.46	1.0000	0.46	0.00	**1.74**	0.00	0.00	0.00	0.00	1.74
27/12/2003	0.00	0.28	1.0000	0.28	0.28	**0.00**	0.00	0.00	0.00	0.00	0.00
28/12/2003	0.00	0.23	1.0000	0.23	0.51	**0.00**	0.00	0.00	0.00	0.00	0.00
29/12/2003	6.40	0.00	1.0000	0.00	0.00	**5.89**	1.40	0.28	0.00	0.28	5.61
30/12/2003	0.20	0.31	1.0000	0.31	0.11	**0.00**	0.00	0.00	0.00	0.00	0.00
31/12/2003	13.60	0.29	1.0000	0.29	0.00	**13.20**	8.60	1.72	0.00	1.72	11.48
01/01/2004	0.00	0.45	1.0000	0.45	0.45	**0.00**	0.00	0.00	0.00	0.00	0.00
02/01/2004	8.60	0.25	1.0000	0.25	0.00	**7.90**	3.60	0.72	0.00	0.72	7.18
03/01/2004	0.20	0.16	1.0000	0.16	0.00	**0.04**	0.00	0.00	0.00	0.00	0.04

Date	Rainfall	PE	S.F.	AE	SMD	**Recharge**	Pot. Runoff	Runoff 1	Runoff 2	Runoff	Recharge
04/01/2004	0.80	0.24	1.0000	0.24	0.00	**0.56**	0.00	0.00	0.00	0.00	0.56
05/01/2004	3.70	0.45	1.0000	0.45	0.00	**3.25**	0.00	0.00	0.00	0.00	3.25
06/01/2004	0.50	0.55	1.0000	0.55	0.05	**0.00**	0.00	0.00	0.00	0.00	0.00
07/01/2004	15.70	0.69	1.0000	0.69	0.00	**14.96**	10.70	2.14	0.00	2.14	12.82
08/01/2004	2.30	0.52	1.0000	0.52	0.00	**1.78**	0.00	0.00	0.00	0.00	1.78
09/01/2004	1.10	0.63	1.0000	0.63	0.00	**0.47**	0.00	0.00	0.00	0.00	0.47
10/01/2004	14.70	0.98	1.0000	0.98	0.00	**13.72**	9.70	1.94	0.00	1.94	11.78
11/01/2004	0.20	0.48	1.0000	0.48	0.28	**0.00**	0.00	0.00	0.00	0.00	0.00
12/01/2004	4.10	0.47	1.0000	0.47	0.00	**3.35**	0.00	0.00	0.00	0.00	3.35
13/01/2004	0.40	0.49	1.0000	0.49	0.09	**0.00**	0.00	0.00	0.00	0.00	0.00
14/01/2004	3.10	0.33	1.0000	0.33	0.00	**2.68**	0.00	0.00	0.00	0.00	2.68
15/01/2004	19.70	0.58	1.0000	0.58	0.00	**19.12**	14.70	2.94	0.00	2.94	16.18
16/01/2004	0.20	0.29	1.0000	0.29	0.09	**0.00**	0.00	0.00	0.00	0.00	0.00
17/01/2004	0.00	0.12	1.0000	0.12	0.21	**0.00**	0.00	0.00	0.00	0.00	0.00
18/01/2004	0.00	0.36	1.0000	0.36	0.57	**0.00**	0.00	0.00	0.00	0.00	0.00
19/01/2004	0.10	0.57	1.0000	0.57	1.04	**0.00**	0.00	0.00	0.00	0.00	0.00
20/01/2004	0.00	0.54	1.0000	0.54	1.57	**0.00**	0.00	0.00	0.00	0.00	0.00
21/01/2004	1.20	0.75	1.0000	0.75	1.12	**0.00**	0.00	0.00	0.00	0.00	0.00
22/01/2004	0.60	0.30	1.0000	0.30	0.82	**0.00**	0.00	0.00	0.00	0.00	0.00
23/01/2004	5.50	0.46	1.0000	0.46	0.00	**4.22**	0.50	0.10	0.00	0.10	4.12
24/01/2004	0.00	0.51	1.0000	0.51	0.51	**0.00**	0.00	0.00	0.00	0.00	0.00
25/01/2004	0.20	0.21	1.0000	0.21	0.52	**0.00**	0.00	0.00	0.00	0.00	0.00
26/01/2004	7.50	0.23	1.0000	0.23	0.00	**6.75**	2.50	0.50	0.00	0.50	6.25
27/01/2004	0.60	0.26	1.0000	0.26	0.00	**0.34**	0.00	0.00	0.00	0.00	0.34
28/01/2004	0.00	0.36	1.0000	0.36	0.36	**0.00**	0.00	0.00	0.00	0.00	0.00
29/01/2004	0.70	0.58	1.0000	0.58	0.24	**0.00**	0.00	0.00	0.00	0.00	0.00
30/01/2004	13.90	0.83	1.0000	0.83	0.00	**12.83**	8.90	1.78	0.00	1.78	11.05
31/01/2004	3.60	0.60	1.0000	0.60	0.00	**3.00**	0.00	0.00	0.00	0.00	3.00
01/02/2004	3.90	0.72	1.0000	0.72	0.00	**3.18**	0.00	0.00	0.00	0.00	3.18
02/02/2004	8.90	0.76	1.0000	0.76	0.00	**8.14**	3.90	0.78	0.00	0.78	7.36
03/02/2004	6.00	0.80	1.0000	0.80	0.00	**5.20**	1.00	0.20	0.00	0.20	5.00
04/02/2004	3.80	0.76	1.0000	0.76	0.00	**3.04**	0.00	0.00	0.00	0.00	3.04
05/02/2004	0.00	1.53	1.0000	1.53	1.53	**0.00**	0.00	0.00	0.00	0.00	0.00
06/02/2004	0.00	0.96	1.0000	0.96	2.48	**0.00**	0.00	0.00	0.00	0.00	0.00
07/02/2004	0.00	1.17	1.0000	1.17	3.66	**0.00**	0.00	0.00	0.00	0.00	0.00
08/02/2004	0.00	0.58	1.0000	0.58	4.23	**0.00**	0.00	0.00	0.00	0.00	0.00
09/02/2004	0.00	0.57	1.0000	0.57	4.80	**0.00**	0.00	0.00	0.00	0.00	0.00
10/02/2004	0.00	0.93	1.0000	0.93	5.74	**0.00**	0.00	0.00	0.00	0.00	0.00
11/02/2004	0.00	0.48	1.0000	0.48	6.22	**0.00**	0.00	0.00	0.00	0.00	0.00
12/02/2004	1.30	0.64	1.0000	0.64	5.56	**0.00**	0.00	0.00	0.00	0.00	0.00
13/02/2004	0.00	0.53	1.0000	0.53	6.09	**0.00**	0.00	0.00	0.00	0.00	0.00
14/02/2004	0.20	0.42	1.0000	0.42	6.31	**0.00**	0.00	0.00	0.00	0.00	0.00
15/02/2004	0.60	0.59	1.0000	0.59	6.30	**0.00**	0.00	0.00	0.00	0.00	0.00
16/02/2004	0.50	0.72	1.0000	0.72	6.53	**0.00**	0.00	0.00	0.00	0.00	0.00
17/02/2004	0.00	0.56	1.0000	0.56	7.09	**0.00**	0.00	0.00	0.00	0.00	0.00
18/02/2004	0.00	0.56	1.0000	0.56	7.65	**0.00**	0.00	0.00	0.00	0.00	0.00
19/02/2004	0.00	0.53	1.0000	0.53	8.18	**0.00**	0.00	0.00	0.00	0.00	0.00
20/02/2004	0.00	1.36	1.0000	1.36	9.54	**0.00**	0.00	0.00	0.00	0.00	0.00
21/02/2004	0.00	1.08	1.0000	1.08	10.62	**0.00**	0.00	0.00	0.00	0.00	0.00
22/02/2004	0.00	0.93	1.0000	0.93	11.55	**0.00**	0.00	0.00	0.00	0.00	0.00
23/02/2004	1.90	0.79	1.0000	0.79	10.44	**0.00**	0.00	0.00	0.00	0.00	0.00
24/02/2004	0.80	0.48	1.0000	0.48	10.12	**0.00**	0.00	0.00	0.00	0.00	0.00
25/02/2004	0.00	0.63	1.0000	0.63	10.74	**0.00**	0.00	0.00	0.00	0.00	0.00
26/02/2004	0.00	0.72	1.0000	0.72	11.47	**0.00**	0.00	0.00	0.00	0.00	0.00
27/02/2004	0.00	0.80	1.0000	0.80	12.27	**0.00**	0.00	0.00	0.00	0.00	0.00
28/02/2004	0.00	0.82	1.0000	0.82	13.09	**0.00**	0.00	0.00	0.00	0.00	0.00
29/02/2004	0.00	0.77	1.0000	0.77	13.86	**0.00**	0.00	0.00	0.00	0.00	0.00
01/03/2004	0.00	0.97	1.0000	0.97	14.83	**0.00**	0.00	0.00	0.00	0.00	0.00
02/03/2004	11.00	0.81	1.0000	0.81	4.64	**0.00**	6.00	1.20	0.00	1.20	-1.20
03/03/2004	4.50	0.68	1.0000	0.68	0.82	**0.00**	0.00	0.00	0.00	0.00	0.00
04/03/2004	1.30	1.10	1.0000	1.10	0.62	**0.00**	0.00	0.00	0.00	0.00	0.00
05/03/2004	0.00	0.82	1.0000	0.82	1.44	**0.00**	0.00	0.00	0.00	0.00	0.00
06/03/2004	0.90	0.89	1.0000	0.89	1.42	**0.00**	0.00	0.00	0.00	0.00	0.00
07/03/2004	0.00	1.01	1.0000	1.01	2.44	**0.00**	0.00	0.00	0.00	0.00	0.00
08/03/2004	0.00	1.02	1.0000	1.02	3.46	**0.00**	0.00	0.00	0.00	0.00	0.00
09/03/2004	0.00	0.75	1.0000	0.75	4.21	**0.00**	0.00	0.00	0.00	0.00	0.00
10/03/2004	0.40	1.18	1.0000	1.18	4.99	**0.00**	0.00	0.00	0.00	0.00	0.00
11/03/2004	1.70	0.83	1.0000	0.83	4.12	**0.00**	0.00	0.00	0.00	0.00	0.00
12/03/2004	0.50	0.59	1.0000	0.59	4.20	**0.00**	0.00	0.00	0.00	0.00	0.00
13/03/2004	9.80	1.07	1.0000	1.07	0.00	**4.52**	4.80	0.96	0.00	0.96	3.56
14/03/2004	2.00	1.21	1.0000	1.21	0.00	**0.79**	0.00	0.00	0.00	0.00	0.79
15/03/2004	1.50	1.47	1.0000	1.47	0.00	**0.03**	0.00	0.00	0.00	0.00	0.03
16/03/2004	2.60	1.17	1.0000	1.17	0.00	**1.43**	0.00	0.00	0.00	0.00	1.43
17/03/2004	0.30	1.91	1.0000	1.91	1.61	**0.00**	0.00	0.00	0.00	0.00	0.00
18/03/2004	9.00	1.11	1.0000	1.11	0.00	**6.27**	4.00	0.80	0.00	0.80	5.47
19/03/2004	2.90	1.06	1.0000	1.06	0.00	**1.84**	0.00	0.00	0.00	0.00	1.84
20/03/2004	5.60	0.92	1.0000	0.92	0.00	**4.68**	0.60	0.12	0.00	0.12	4.56
21/03/2004	1.10	1.38	1.0000	1.38	0.28	**0.00**	0.00	0.00	0.00	0.00	0.00

Date	Rainfall	PE	S.F.	AE	SMD	**Recharge**	Pot. Runoff	Runoff 1	Runoff 2	Runoff	Recharge
22/03/2004	1.30	1.17	1.0000	1.17	0.14	**0.00**	0.00	0.00	0.00	0.00	0.00
23/03/2004	0.50	1.31	1.0000	1.31	0.95	**0.00**	0.00	0.00	0.00	0.00	0.00
24/03/2004	1.00	1.25	1.0000	1.25	1.20	**0.00**	0.00	0.00	0.00	0.00	0.00
25/03/2004	0.00	1.72	1.0000	1.72	2.92	**0.00**	0.00	0.00	0.00	0.00	0.00
26/03/2004	0.50	0.84	1.0000	0.84	3.26	**0.00**	0.00	0.00	0.00	0.00	0.00
27/03/2004	0.00	0.91	1.0000	0.91	4.17	**0.00**	0.00	0.00	0.00	0.00	0.00
28/03/2004	0.00	1.19	1.0000	1.19	5.36	**0.00**	0.00	0.00	0.00	0.00	0.00
29/03/2004	0.00	1.17	1.0000	1.17	6.53	**0.00**	0.00	0.00	0.00	0.00	0.00
30/03/2004	0.00	1.57	1.0000	1.57	8.10	**0.00**	0.00	0.00	0.00	0.00	0.00
31/03/2004	0.00	1.92	1.0000	1.92	10.02	**0.00**	0.00	0.00	0.00	0.00	0.00
01/04/2004	2.50	1.27	1.0000	1.27	8.79	**0.00**	0.00	0.00	0.00	0.00	0.00
02/04/2004	11.10	1.79	1.0000	1.79	0.00	**0.52**	6.10	1.22	0.00	1.22	-0.70
03/04/2004	1.80	1.68	1.0000	1.68	0.00	**0.12**	0.00	0.00	0.00	0.00	0.12
04/04/2004	2.10	1.45	1.0000	1.45	0.00	**0.65**	0.00	0.00	0.00	0.00	0.65
05/04/2004	1.60	1.50	1.0000	1.50	0.00	**0.10**	0.00	0.00	0.00	0.00	0.10
06/04/2004	0.80	1.78	1.0000	1.78	0.98	**0.00**	0.00	0.00	0.00	0.00	0.00
07/04/2004	0.00	1.68	1.0000	1.68	2.65	**0.00**	0.00	0.00	0.00	0.00	0.00
08/04/2004	4.50	0.92	1.0000	0.92	0.00	**0.93**	0.00	0.00	0.00	0.00	0.93
09/04/2004	1.70	0.93	1.0000	0.93	0.00	**0.77**	0.00	0.00	0.00	0.00	0.77
10/04/2004	0.00	1.06	1.0000	1.06	1.06	**0.00**	0.00	0.00	0.00	0.00	0.00
11/04/2004	0.00	1.01	1.0000	1.01	2.08	**0.00**	0.00	0.00	0.00	0.00	0.00
12/04/2004	0.00	1.43	1.0000	1.43	3.51	**0.00**	0.00	0.00	0.00	0.00	0.00
13/04/2004	0.20	0.85	1.0000	0.85	4.16	**0.00**	0.00	0.00	0.00	0.00	0.00
14/04/2004	11.50	1.99	1.0000	1.99	0.00	**5.35**	6.50	1.30	0.00	1.30	4.05
15/04/2004	2.70	1.40	1.0000	1.40	0.00	**1.30**	0.00	0.00	0.00	0.00	1.30
16/04/2004	0.50	1.89	1.0000	1.89	1.39	**0.00**	0.00	0.00	0.00	0.00	0.00
17/04/2004	7.80	0.82	1.0000	0.82	0.00	**5.59**	2.80	0.56	0.00	0.56	5.03
18/04/2004	1.10	1.79	1.0000	1.79	0.69	**0.00**	0.00	0.00	0.00	0.00	0.00
19/04/2004	4.00	1.97	1.0000	1.97	0.00	**1.34**	0.00	0.00	0.00	0.00	1.34
20/04/2004	1.00	1.12	1.0000	1.12	0.12	**0.00**	0.00	0.00	0.00	0.00	0.00
21/04/2004	2.20	2.48	1.0000	2.48	0.40	**0.00**	0.00	0.00	0.00	0.00	0.00
22/04/2004	0.00	2.27	1.0000	2.27	2.66	**0.00**	0.00	0.00	0.00	0.00	0.00
23/04/2004	0.00	2.21	1.0000	2.21	4.87	**0.00**	0.00	0.00	0.00	0.00	0.00
24/04/2004	0.00	2.89	1.0000	2.89	7.76	**0.00**	0.00	0.00	0.00	0.00	0.00
25/04/2004	0.00	2.85	1.0000	2.85	10.61	**0.00**	0.00	0.00	0.00	0.00	0.00
26/04/2004	0.00	1.92	1.0000	1.92	12.53	**0.00**	0.00	0.00	0.00	0.00	0.00
27/04/2004	2.70	1.91	1.0000	1.91	11.74	**0.00**	0.00	0.00	0.00	0.00	0.00
28/04/2004	0.00	2.24	1.0000	2.24	13.99	**0.00**	0.00	0.00	0.00	0.00	0.00
29/04/2004	0.20	2.01	1.0000	2.01	15.79	**0.00**	0.00	0.00	0.00	0.00	0.00
30/04/2004	0.00	1.24	1.0000	1.24	17.03	**0.00**	0.00	0.00	0.00	0.00	0.00
01/05/2004	0.00	2.80	1.0000	2.80	19.83	**0.00**	0.00	0.00	0.00	0.00	0.00
02/05/2004	0.00	1.91	1.0000	1.91	21.75	**0.00**	0.00	0.00	0.00	0.00	0.00
03/05/2004	12.10	2.22	1.0000	2.22	11.87	**0.00**	7.10	1.42	0.00	1.42	-1.42
04/05/2004	14.50	1.78	1.0000	1.78	0.00	**0.85**	9.50	1.90	0.00	1.90	-1.05
05/05/2004	2.40	1.67	1.0000	1.67	0.00	**0.73**	0.00	0.00	0.00	0.00	0.73
06/05/2004	0.50	2.15	1.0000	2.15	1.65	**0.00**	0.00	0.00	0.00	0.00	0.00
07/05/2004	0.00	2.16	1.0000	2.16	3.81	**0.00**	0.00	0.00	0.00	0.00	0.00
08/05/2004	0.00	2.18	1.0000	2.18	5.99	**0.00**	0.00	0.00	0.00	0.00	0.00
09/05/2004	0.10	1.10	1.0000	1.10	6.98	**0.00**	0.00	0.00	0.00	0.00	0.00
10/05/2004	0.00	1.50	1.0000	1.50	8.49	**0.00**	0.00	0.00	0.00	0.00	0.00
11/05/2004	0.00	1.11	1.0000	1.11	9.59	**0.00**	0.00	0.00	0.00	0.00	0.00
12/05/2004	0.00	0.85	1.0000	0.85	10.44	**0.00**	0.00	0.00	0.00	0.00	0.00
13/05/2004	0.00	1.49	1.0000	1.49	11.93	**0.00**	0.00	0.00	0.00	0.00	0.00
14/05/2004	0.00	1.72	1.0000	1.72	13.65	**0.00**	0.00	0.00	0.00	0.00	0.00
15/05/2004	0.00	2.96	1.0000	2.96	16.61	**0.00**	0.00	0.00	0.00	0.00	0.00
16/05/2004	0.00	3.55	1.0000	3.55	20.15	**0.00**	0.00	0.00	0.00	0.00	0.00
17/05/2004	0.00	3.33	1.0000	3.33	23.48	**0.00**	0.00	0.00	0.00	0.00	0.00
18/05/2004	0.00	3.67	1.0000	3.67	27.15	**0.00**	0.00	0.00	0.00	0.00	0.00
19/05/2004	0.00	2.08	1.0000	2.08	29.23	**0.00**	0.00	0.00	0.00	0.00	0.00
20/05/2004	0.00	2.51	1.0000	2.51	31.74	**0.00**	0.00	0.00	0.00	0.00	0.00
21/05/2004	0.00	2.34	1.0000	2.34	34.08	**0.00**	0.00	0.00	0.00	0.00	0.00
22/05/2004	0.00	3.09	1.0000	3.09	37.17	**0.00**	0.00	0.00	0.00	0.00	0.00
23/05/2004	0.00	3.39	1.0000	3.39	40.56	**0.00**	0.00	0.00	0.00	0.00	0.00
24/05/2004	0.00	2.35	1.0000	2.35	42.91	**0.00**	0.00	0.00	0.00	0.00	0.00
25/05/2004	0.00	3.17	1.0000	3.17	46.08	**0.00**	0.00	0.00	0.00	0.00	0.00
26/05/2004	0.00	3.47	1.0000	3.47	49.55	**0.00**	0.00	0.00	0.00	0.00	0.00
27/05/2004	2.00	3.24	1.0000	3.24	50.79	**0.00**	0.00	0.00	0.00	0.00	0.00
28/05/2004	0.00	2.33	1.0000	2.33	53.12	**0.00**	0.00	0.00	0.00	0.00	0.00
29/05/2004	0.00	3.56	1.0000	3.56	56.68	**0.00**	0.00	0.00	0.00	0.00	0.00
30/05/2004	2.00	2.36	1.0000	2.36	57.04	**0.00**	0.00	0.00	0.00	0.00	0.00
31/05/2004	2.80	2.12	1.0000	2.12	56.36	**0.00**	0.00	0.00	0.00	0.00	0.00
01/06/2004	0.00	3.67	1.0000	3.67	60.03	**0.00**	0.00	0.00	0.00	0.00	0.00
02/06/2004	0.20	2.29	1.0000	2.29	62.12	**0.00**	0.00	0.00	0.00	0.00	0.00
03/06/2004	2.10	1.77	1.0000	1.77	61.80	**0.00**	0.00	0.00	0.00	0.00	0.00
04/06/2004	0.10	1.99	1.0000	1.99	63.69	**0.00**	0.00	0.00	0.00	0.00	0.00
05/06/2004	0.00	2.49	1.0000	2.49	66.18	**0.00**	0.00	0.00	0.00	0.00	0.00
06/06/2004	0.00	3.00	1.0000	3.00	69.18	**0.00**	0.00	0.00	0.00	0.00	0.00
07/06/2004	0.00	4.05	1.0000	4.05	73.22	**0.00**	0.00	0.00	0.00	0.00	0.00

Date	Rainfall	PE	S.F.	AE	SMD	**Recharge**	Pot. Runoff	Runoff 1	Runoff 2	Runoff	Recharge
08/06/2004	0.00	2.82	1.0000	2.82	76.04	**0.00**	0.00	0.00	0.00	0.00	0.00
09/06/2004	0.10	4.30	0.9615	4.14	80.08	**0.00**	0.00	0.00	0.00	0.00	0.00
10/06/2004	7.40	3.42	0.8853	3.03	75.71	**0.00**	2.40	0.48	0.00	0.48	-0.48
11/06/2004	2.20	2.60	0.9677	2.52	76.03	**0.00**	0.00	0.00	0.00	0.00	0.00
12/06/2004	0.00	2.24	0.9617	2.15	78.18	**0.00**	0.00	0.00	0.00	0.00	0.00
13/06/2004	0.00	3.21	0.9211	2.96	81.14	**0.00**	0.00	0.00	0.00	0.00	0.00
14/06/2004	0.00	5.29	0.8652	4.57	85.72	**0.00**	0.00	0.00	0.00	0.00	0.00
15/06/2004	0.00	2.38	0.7789	1.86	87.57	**0.00**	0.00	0.00	0.00	0.00	0.00
16/06/2004	0.00	5.05	0.7439	3.76	91.33	**0.00**	0.00	0.00	0.00	0.00	0.00
17/06/2004	0.00	2.29	0.6730	1.54	92.87	**0.00**	0.00	0.00	0.00	0.00	0.00
18/06/2004	4.30	2.09	0.6439	1.35	89.92	**0.00**	0.00	0.00	0.00	0.00	0.00
19/06/2004	0.10	2.69	0.6996	1.88	91.70	**0.00**	0.00	0.00	0.00	0.00	0.00
20/06/2004	5.80	2.26	0.6660	1.51	87.41	**0.00**	0.80	0.16	0.00	0.16	-0.16
21/06/2004	0.20	2.73	0.7470	2.04	89.25	**0.00**	0.00	0.00	0.00	0.00	0.00
22/06/2004	11.20	2.32	0.7123	1.65	79.70	**0.00**	6.20	1.24	0.00	1.24	-1.24
23/06/2004	4.70	1.25	0.8925	1.11	76.11	**0.00**	0.00	0.00	0.00	0.00	0.00
24/06/2004	1.10	2.68	0.9602	2.57	77.58	**0.00**	0.00	0.00	0.00	0.00	0.00
25/06/2004	1.30	3.72	0.9324	3.47	79.75	**0.00**	0.00	0.00	0.00	0.00	0.00
26/06/2004	0.30	3.94	0.8915	3.52	82.97	**0.00**	0.00	0.00	0.00	0.00	0.00
27/06/2004	0.40	3.39	0.8308	2.81	85.38	**0.00**	0.00	0.00	0.00	0.00	0.00
28/06/2004	6.70	2.25	0.7853	1.77	80.45	**0.00**	1.70	0.34	0.00	0.34	-0.34
29/06/2004	0.50	2.39	0.8784	2.10	82.04	**0.00**	0.00	0.00	0.00	0.00	0.00
30/06/2004	1.50	2.95	0.8482	2.50	83.04	**0.00**	0.00	0.00	0.00	0.00	0.00
01/07/2004	6.00	3.21	0.8294	2.66	79.71	**0.00**	1.00	0.20	0.00	0.20	-0.20
02/07/2004	2.40	2.20	0.8923	1.96	79.27	**0.00**	0.00	0.00	0.00	0.00	0.00
03/07/2004	3.00	2.50	0.9006	2.25	78.52	**0.00**	0.00	0.00	0.00	0.00	0.00
04/07/2004	1.30	2.09	0.9148	1.91	79.13	**0.00**	0.00	0.00	0.00	0.00	0.00
05/07/2004	5.50	3.13	0.9032	2.82	76.45	**0.00**	0.50	0.10	0.00	0.10	-0.10
06/07/2004	0.80	2.82	0.9537	2.69	78.34	**0.00**	0.00	0.00	0.00	0.00	0.00
07/07/2004	0.50	2.81	0.9181	2.58	80.42	**0.00**	0.00	0.00	0.00	0.00	0.00
08/07/2004	0.00	2.62	0.8788	2.30	82.73	**0.00**	0.00	0.00	0.00	0.00	0.00
09/07/2004	0.20	3.76	0.8354	3.14	85.67	**0.00**	0.00	0.00	0.00	0.00	0.00
10/07/2004	3.10	2.21	0.7799	1.72	84.29	**0.00**	0.00	0.00	0.00	0.00	0.00
11/07/2004	3.40	2.55	0.8058	2.05	82.94	**0.00**	0.00	0.00	0.00	0.00	0.00
12/07/2004	0.00	2.72	0.8312	2.26	85.20	**0.00**	0.00	0.00	0.00	0.00	0.00
13/07/2004	1.50	2.49	0.7886	1.96	85.66	**0.00**	0.00	0.00	0.00	0.00	0.00
14/07/2004	1.80	2.07	0.7799	1.62	85.48	**0.00**	0.00	0.00	0.00	0.00	0.00
15/07/2004	6.20	1.23	0.7834	0.96	80.24	**0.00**	1.20	0.24	0.00	0.24	-0.24
16/07/2004	2.50	2.40	0.8822	2.12	79.86	**0.00**	0.00	0.00	0.00	0.00	0.00
17/07/2004	0.00	2.68	0.8895	2.38	82.24	**0.00**	0.00	0.00	0.00	0.00	0.00
18/07/2004	0.00	3.20	0.8446	2.71	84.94	**0.00**	0.00	0.00	0.00	0.00	0.00
19/07/2004	0.10	2.79	0.7935	2.21	87.05	**0.00**	0.00	0.00	0.00	0.00	0.00
20/07/2004	1.40	1.89	0.7537	1.42	87.08	**0.00**	0.00	0.00	0.00	0.00	0.00
21/07/2004	0.20	3.16	0.7533	2.38	89.26	**0.00**	0.00	0.00	0.00	0.00	0.00
22/07/2004	0.00	3.74	0.7121	2.66	91.92	**0.00**	0.00	0.00	0.00	0.00	0.00
23/07/2004	0.00	3.00	0.6619	1.99	93.91	**0.00**	0.00	0.00	0.00	0.00	0.00
24/07/2004	0.10	2.04	0.6244	1.27	95.08	**0.00**	0.00	0.00	0.00	0.00	0.00
25/07/2004	1.70	1.73	0.6023	1.04	94.42	**0.00**	0.00	0.00	0.00	0.00	0.00
26/07/2004	0.30	1.05	0.6147	0.65	94.77	**0.00**	0.00	0.00	0.00	0.00	0.00
27/07/2004	0.00	2.00	0.6082	1.22	95.98	**0.00**	0.00	0.00	0.00	0.00	0.00
28/07/2004	0.00	2.66	0.5852	1.56	97.54	**0.00**	0.00	0.00	0.00	0.00	0.00
29/07/2004	2.50	1.67	0.5558	0.93	95.97	**0.00**	0.00	0.00	0.00	0.00	0.00
30/07/2004	0.00	3.22	0.5855	1.89	97.86	**0.00**	0.00	0.00	0.00	0.00	0.00
31/07/2004	0.00	3.25	0.5498	1.79	99.65	**0.00**	0.00	0.00	0.00	0.00	0.00
01/08/2004	0.00	3.27	0.5161	1.69	101.33	**0.00**	0.00	0.00	0.00	0.00	0.00
02/08/2004	0.00	2.72	0.4843	1.32	102.65	**0.00**	0.00	0.00	0.00	0.00	0.00
03/08/2004	9.30	1.96	0.4594	0.90	94.25	**0.00**	4.30	0.86	0.00	0.86	-0.86
04/08/2004	0.00	1.80	0.6179	1.11	95.36	**0.00**	0.00	0.00	0.00	0.00	0.00
05/08/2004	4.80	2.83	0.5969	1.69	92.25	**0.00**	0.00	0.00	0.00	0.00	0.00
06/08/2004	0.00	2.40	0.6556	1.57	93.82	**0.00**	0.00	0.00	0.00	0.00	0.00
07/08/2004	0.50	2.85	0.6260	1.79	95.11	**0.00**	0.00	0.00	0.00	0.00	0.00
08/08/2004	0.00	1.78	0.6017	1.07	96.18	**0.00**	0.00	0.00	0.00	0.00	0.00
09/08/2004	0.00	2.80	0.5815	1.63	97.81	**0.00**	0.00	0.00	0.00	0.00	0.00
10/08/2004	0.00	3.19	0.5508	1.75	99.56	**0.00**	0.00	0.00	0.00	0.00	0.00
11/08/2004	1.30	2.63	0.5177	1.36	99.62	**0.00**	0.00	0.00	0.00	0.00	0.00
12/08/2004	1.20	3.42	0.5166	1.77	100.19	**0.00**	0.00	0.00	0.00	0.00	0.00
13/08/2004	2.20	2.73	0.5059	1.38	99.37	**0.00**	0.00	0.00	0.00	0.00	0.00
14/08/2004	0.00	2.86	0.5213	1.49	100.86	**0.00**	0.00	0.00	0.00	0.00	0.00
15/08/2004	16.00	2.87	0.4932	1.41	86.27	**0.00**	11.00	2.20	0.00	2.20	-2.20
16/08/2004	1.20	2.11	0.7684	1.62	86.69	**0.00**	0.00	0.00	0.00	0.00	0.00
17/08/2004	21.50	2.32	0.7605	1.76	66.95	**0.00**	16.50	0.00	4.95	4.95	-4.95
18/08/2004	13.80	1.56	1.0000	1.56	54.71	**0.00**	8.80	1.76	0.00	1.76	-1.76
19/08/2004	11.60	1.51	1.0000	1.51	44.62	**0.00**	6.60	1.32	0.00	1.32	-1.32
20/08/2004	0.00	2.12	1.0000	2.12	46.74	**0.00**	0.00	0.00	0.00	0.00	0.00
21/08/2004	4.60	2.03	1.0000	2.03	44.16	**0.00**	0.00	0.00	0.00	0.00	0.00
22/08/2004	13.30	1.24	1.0000	1.24	32.11	**0.00**	8.30	1.66	0.00	1.66	-1.66
23/08/2004	7.60	2.46	1.0000	2.46	26.97	**0.00**	2.60	0.52	0.00	0.52	-0.52
24/08/2004	1.50	1.50	1.0000	1.50	26.96	**0.00**	0.00	0.00	0.00	0.00	0.00

Date	Rainfall	PE	S.F.	AE	SMD	**Recharge**	Pot. Runoff	Runoff 1	Runoff 2	Runoff	Recharge
25/08/2004	0.70	1.50	1.0000	1.50	27.76	**0.00**	0.00	0.00	0.00	0.00	0.00
26/08/2004	1.50	1.66	1.0000	1.66	27.92	**0.00**	0.00	0.00	0.00	0.00	0.00
27/08/2004	0.00	2.12	1.0000	2.12	30.04	**0.00**	0.00	0.00	0.00	0.00	0.00
28/08/2004	1.00	1.97	1.0000	1.97	31.02	**0.00**	0.00	0.00	0.00	0.00	0.00
29/08/2004	0.00	2.59	1.0000	2.59	33.61	**0.00**	0.00	0.00	0.00	0.00	0.00
30/08/2004	0.00	1.94	1.0000	1.94	35.55	**0.00**	0.00	0.00	0.00	0.00	0.00
31/08/2004	0.00	2.57	1.0000	2.57	38.12	**0.00**	0.00	0.00	0.00	0.00	0.00
01/09/2004	0.40	1.37	1.0000	1.37	39.09	**0.00**	0.00	0.00	0.00	0.00	0.00
02/09/2004	0.00	1.40	1.0000	1.40	40.48	**0.00**	0.00	0.00	0.00	0.00	0.00
03/09/2004	0.00	2.22	1.0000	2.22	42.70	**0.00**	0.00	0.00	0.00	0.00	0.00
04/09/2004	0.00	2.62	1.0000	2.62	45.33	**0.00**	0.00	0.00	0.00	0.00	0.00
05/09/2004	0.00	1.95	1.0000	1.95	47.28	**0.00**	0.00	0.00	0.00	0.00	0.00
06/09/2004	0.00	1.22	1.0000	1.22	48.50	**0.00**	0.00	0.00	0.00	0.00	0.00
07/09/2004	0.00	1.87	1.0000	1.87	50.37	**0.00**	0.00	0.00	0.00	0.00	0.00
08/09/2004	0.00	2.72	1.0000	2.72	53.09	**0.00**	0.00	0.00	0.00	0.00	0.00
09/09/2004	0.00	2.55	1.0000	2.55	55.63	**0.00**	0.00	0.00	0.00	0.00	0.00
10/09/2004	0.40	0.98	1.0000	0.98	56.21	**0.00**	0.00	0.00	0.00	0.00	0.00
11/09/2004	1.00	1.74	1.0000	1.74	56.95	**0.00**	0.00	0.00	0.00	0.00	0.00
12/09/2004	7.50	1.16	1.0000	1.16	50.62	**0.00**	2.50	0.50	0.00	0.50	-0.50
13/09/2004	2.00	2.06	1.0000	2.06	50.68	**0.00**	0.00	0.00	0.00	0.00	0.00
14/09/2004	0.00	1.60	1.0000	1.60	52.28	**0.00**	0.00	0.00	0.00	0.00	0.00
15/09/2004	0.80	1.73	1.0000	1.73	53.21	**0.00**	0.00	0.00	0.00	0.00	0.00
16/09/2004	7.80	1.04	1.0000	1.04	46.45	**0.00**	2.80	0.56	0.00	0.56	-0.56
17/09/2004	6.30	1.76	1.0000	1.76	41.91	**0.00**	1.30	0.26	0.00	0.26	-0.26
18/09/2004	0.10	1.64	1.0000	1.64	43.45	**0.00**	0.00	0.00	0.00	0.00	0.00
19/09/2004	6.10	1.23	1.0000	1.23	38.58	**0.00**	1.10	0.22	0.00	0.22	-0.22
20/09/2004	0.00	1.33	1.0000	1.33	39.91	**0.00**	0.00	0.00	0.00	0.00	0.00
21/09/2004	2.10	1.85	1.0000	1.85	39.65	**0.00**	0.00	0.00	0.00	0.00	0.00
22/09/2004	1.60	1.22	1.0000	1.22	39.27	**0.00**	0.00	0.00	0.00	0.00	0.00
23/09/2004	0.00	0.79	1.0000	0.79	40.06	**0.00**	0.00	0.00	0.00	0.00	0.00
24/09/2004	0.80	1.06	1.0000	1.06	40.33	**0.00**	0.00	0.00	0.00	0.00	0.00
25/09/2004	0.30	1.25	1.0000	1.25	41.28	**0.00**	0.00	0.00	0.00	0.00	0.00
26/09/2004	0.50	1.30	1.0000	1.30	42.08	**0.00**	0.00	0.00	0.00	0.00	0.00
27/09/2004	0.50	1.22	1.0000	1.22	42.80	**0.00**	0.00	0.00	0.00	0.00	0.00
28/09/2004	2.50	0.81	1.0000	0.81	41.11	**0.00**	0.00	0.00	0.00	0.00	0.00
29/09/2004	15.40	1.05	1.0000	1.05	26.76	**0.00**	10.40	2.08	0.00	2.08	-2.08
30/09/2004	0.00	1.01	1.0000	1.01	27.77	**0.00**	0.00	0.00	0.00	0.00	0.00
01/10/2004	2.80	1.23	1.0000	1.23	26.20	**0.00**	0.00	0.00	0.00	0.00	0.00
02/10/2004	4.30	1.73	1.0000	1.73	23.63	**0.00**	0.00	0.00	0.00	0.00	0.00
03/10/2004	17.00	1.00	1.0000	1.00	7.63	**0.00**	12.00	2.40	0.00	2.40	-2.40
04/10/2004	0.00	1.18	1.0000	1.18	8.81	**0.00**	0.00	0.00	0.00	0.00	0.00
05/10/2004	1.30	1.54	1.0000	1.54	9.05	**0.00**	0.00	0.00	0.00	0.00	0.00
06/10/2004	0.00	1.28	1.0000	1.28	10.33	**0.00**	0.00	0.00	0.00	0.00	0.00
07/10/2004	0.10	1.12	1.0000	1.12	11.35	**0.00**	0.00	0.00	0.00	0.00	0.00
08/10/2004	0.00	0.59	1.0000	0.59	11.94	**0.00**	0.00	0.00	0.00	0.00	0.00
09/10/2004	0.00	0.77	1.0000	0.77	12.72	**0.00**	0.00	0.00	0.00	0.00	0.00
10/10/2004	0.00	1.00	1.0000	1.00	13.71	**0.00**	0.00	0.00	0.00	0.00	0.00
11/10/2004	0.00	0.63	1.0000	0.63	14.35	**0.00**	0.00	0.00	0.00	0.00	0.00
12/10/2004	2.80	0.79	1.0000	0.79	12.34	**0.00**	0.00	0.00	0.00	0.00	0.00
13/10/2004	4.74	0.78	1.0000	0.78	8.38	**0.00**	0.00	0.00	0.00	0.00	0.00
14/10/2004	2.40	0.49	1.0000	0.49	6.47	**0.00**	0.00	0.00	0.00	0.00	0.00
15/10/2004	1.00	0.93	1.0000	0.93	6.39	**0.00**	0.00	0.00	0.00	0.00	0.00
16/10/2004	0.60	0.64	1.0000	0.64	6.44	**0.00**	0.00	0.00	0.00	0.00	0.00
17/10/2004	5.00	0.78	1.0000	0.78	2.22	**0.00**	0.00	0.00	0.00	0.00	0.00
18/10/2004	0.20	0.92	1.0000	0.92	2.94	**0.00**	0.00	0.00	0.00	0.00	0.00
19/10/2004	26.00	0.68	1.0000	0.68	0.00	**22.38**	21.00	0.00	6.30	6.30	16.08
20/10/2004	0.60	0.46	1.0000	0.46	0.00	**0.14**	0.00	0.00	0.00	0.00	0.14
21/10/2004	14.80	1.13	1.0000	1.13	0.00	**13.67**	9.80	1.96	0.00	1.96	11.71
22/10/2004	0.60	0.64	1.0000	0.64	0.04	**0.00**	0.00	0.00	0.00	0.00	0.00
23/10/2004	0.00	0.35	1.0000	0.35	0.39	**0.00**	0.00	0.00	0.00	0.00	0.00
24/10/2004	0.00	0.94	1.0000	0.94	1.34	**0.00**	0.00	0.00	0.00	0.00	0.00
25/10/2004	0.00	0.71	1.0000	0.71	2.05	**0.00**	0.00	0.00	0.00	0.00	0.00
26/10/2004	0.00	0.68	1.0000	0.68	2.73	**0.00**	0.00	0.00	0.00	0.00	0.00
27/10/2004	9.90	0.90	1.0000	0.90	0.00	**6.28**	4.90	0.98	0.00	0.98	5.30
28/10/2004	13.30	0.74	1.0000	0.74	0.00	**12.56**	8.30	1.66	0.00	1.66	10.90
29/10/2004	1.70	0.52	1.0000	0.52	0.00	**1.18**	0.00	0.00	0.00	0.00	1.18
30/10/2004	1.10	0.41	1.0000	0.41	0.00	**0.69**	0.00	0.00	0.00	0.00	0.69
31/10/2004	0.00	0.28	1.0000	0.28	0.28	**0.00**	0.00	0.00	0.00	0.00	0.00
01/11/2004	0.00	0.36	1.0000	0.36	0.64	**0.00**	0.00	0.00	0.00	0.00	0.00
02/11/2004	0.80	0.50	1.0000	0.50	0.34	**0.00**	0.00	0.00	0.00	0.00	0.00
03/11/2004	1.00	0.44	1.0000	0.44	0.00	**0.22**	0.00	0.00	0.00	0.00	0.22
04/11/2004	0.00	0.69	1.0000	0.69	0.69	**0.00**	0.00	0.00	0.00	0.00	0.00
05/11/2004	0.00	0.60	1.0000	0.60	1.29	**0.00**	0.00	0.00	0.00	0.00	0.00
06/11/2004	0.00	0.59	1.0000	0.59	1.88	**0.00**	0.00	0.00	0.00	0.00	0.00
07/11/2004	1.00	0.33	1.0000	0.33	1.21	**0.00**	0.00	0.00	0.00	0.00	0.00
08/11/2004	0.90	0.43	1.0000	0.43	0.74	**0.00**	0.00	0.00	0.00	0.00	0.00
09/11/2004	0.50	0.40	1.0000	0.40	0.63	**0.00**	0.00	0.00	0.00	0.00	0.00
10/11/2004	0.60	0.54	1.0000	0.54	0.57	**0.00**	0.00	0.00	0.00	0.00	0.00

Date	Rainfall	PE	S.F.	AE	SMD	**Recharge**	Pot. Runoff	Runoff 1	Runoff 2	Runoff	Recharge
11/11/2004	0.40	0.35	1.0000	0.35	0.52	**0.00**	0.00	0.00	0.00	0.00	0.00
12/11/2004	0.20	0.16	1.0000	0.16	0.49	**0.00**	0.00	0.00	0.00	0.00	0.00
13/11/2004	0.00	0.38	1.0000	0.38	0.86	**0.00**	0.00	0.00	0.00	0.00	0.00
14/11/2004	0.20	0.55	1.0000	0.55	1.21	**0.00**	0.00	0.00	0.00	0.00	0.00
15/11/2004	0.80	0.45	1.0000	0.45	0.87	**0.00**	0.00	0.00	0.00	0.00	0.00
16/11/2004	0.40	0.29	1.0000	0.29	0.76	**0.00**	0.00	0.00	0.00	0.00	0.00
17/11/2004	6.00	0.39	1.0000	0.39	0.00	**4.85**	1.00	0.20	0.00	0.20	4.65
18/11/2004	10.80	0.29	1.0000	0.29	0.00	**10.51**	5.80	1.16	0.00	1.16	9.35
19/11/2004	6.00	0.16	1.0000	0.16	0.00	**5.84**	1.00	0.20	0.00	0.20	5.64
20/11/2004	8.60	0.38	1.0000	0.38	0.00	**8.22**	3.60	0.72	0.00	0.72	7.50
21/11/2004	1.00	0.22	1.0000	0.22	0.00	**0.78**	0.00	0.00	0.00	0.00	0.78
22/11/2004	0.00	0.56	1.0000	0.56	0.56	**0.00**	0.00	0.00	0.00	0.00	0.00
23/11/2004	0.00	0.29	1.0000	0.29	0.85	**0.00**	0.00	0.00	0.00	0.00	0.00
24/11/2004	0.00	0.28	1.0000	0.28	1.13	**0.00**	0.00	0.00	0.00	0.00	0.00
25/11/2004	1.20	0.60	1.0000	0.60	0.53	**0.00**	0.00	0.00	0.00	0.00	0.00
26/11/2004	0.00	0.09	1.0000	0.09	0.63	**0.00**	0.00	0.00	0.00	0.00	0.00
27/11/2004	1.80	0.37	1.0000	0.37	0.00	**0.80**	0.00	0.00	0.00	0.00	0.80
28/11/2004	0.00	0.12	1.0000	0.12	0.12	**0.00**	0.00	0.00	0.00	0.00	0.00
29/11/2004	0.00	0.17	1.0000	0.17	0.30	**0.00**	0.00	0.00	0.00	0.00	0.00
30/11/2004	0.00	0.53	1.0000	0.53	0.82	**0.00**	0.00	0.00	0.00	0.00	0.00
01/12/2004	4.00	0.20	1.0000	0.20	0.00	**2.98**	0.00	0.00	0.00	0.00	2.98
02/12/2004	0.70	0.01	1.0000	0.01	0.00	**0.69**	0.00	0.00	0.00	0.00	0.69
03/12/2004	0.20	0.53	1.0000	0.53	0.33	**0.00**	0.00	0.00	0.00	0.00	0.00
04/12/2004	0.30	0.34	1.0000	0.34	0.37	**0.00**	0.00	0.00	0.00	0.00	0.00
05/12/2004	0.10	0.16	1.0000	0.16	0.43	**0.00**	0.00	0.00	0.00	0.00	0.00
06/12/2004	0.70	0.37	1.0000	0.37	0.11	**0.00**	0.00	0.00	0.00	0.00	0.00
07/12/2004	0.60	0.13	1.0000	0.13	0.00	**0.37**	0.00	0.00	0.00	0.00	0.37
08/12/2004	0.00	0.60	1.0000	0.60	0.60	**0.00**	0.00	0.00	0.00	0.00	0.00
09/12/2004	0.00	0.63	1.0000	0.63	1.24	**0.00**	0.00	0.00	0.00	0.00	0.00
10/12/2004	0.80	0.33	1.0000	0.33	0.77	**0.00**	0.00	0.00	0.00	0.00	0.00
11/12/2004	0.00	0.48	1.0000	0.48	1.25	**0.00**	0.00	0.00	0.00	0.00	0.00
12/12/2004	0.00	0.45	1.0000	0.45	1.70	**0.00**	0.00	0.00	0.00	0.00	0.00
13/12/2004	1.70	0.63	1.0000	0.63	0.63	**0.00**	0.00	0.00	0.00	0.00	0.00
14/12/2004	4.70	0.85	1.0000	0.85	0.00	**3.21**	0.00	0.00	0.00	0.00	3.21
15/12/2004	0.70	0.13	1.0000	0.13	0.00	**0.57**	0.00	0.00	0.00	0.00	0.57
16/12/2004	10.60	0.61	1.0000	0.61	0.00	**9.99**	5.60	1.12	0.00	1.12	8.87
17/12/2004	1.70	0.34	1.0000	0.34	0.00	**1.36**	0.00	0.00	0.00	0.00	1.36
18/12/2004	1.50	0.50	1.0000	0.50	0.00	**1.00**	0.00	0.00	0.00	0.00	1.00
19/12/2004	0.00	0.46	1.0000	0.46	0.46	**0.00**	0.00	0.00	0.00	0.00	0.00
20/12/2004	0.00	0.53	1.0000	0.53	0.99	**0.00**	0.00	0.00	0.00	0.00	0.00
21/12/2004	9.10	0.00	1.0000	0.00	0.00	**8.11**	4.10	0.82	0.00	0.82	7.29
22/12/2004	2.00	0.33	1.0000	0.33	0.00	**1.67**	0.00	0.00	0.00	0.00	1.67
23/12/2004	0.80	0.80	1.0000	0.80	0.00	**0.00**	0.00	0.00	0.00	0.00	0.00
24/12/2004	3.40	0.45	1.0000	0.45	0.00	**2.95**	0.00	0.00	0.00	0.00	2.95
25/12/2004	2.10	0.29	1.0000	0.29	0.00	**1.81**	0.00	0.00	0.00	0.00	1.81
26/12/2004	0.20	0.26	1.0000	0.26	0.06	**0.00**	0.00	0.00	0.00	0.00	0.00
27/12/2004	4.10	0.32	1.0000	0.32	0.00	**3.72**	0.00	0.00	0.00	0.00	3.72
28/12/2004	0.10	0.43	1.0000	0.43	0.33	**0.00**	0.00	0.00	0.00	0.00	0.00
29/12/2004	0.20	0.46	1.0000	0.46	0.58	**0.00**	0.00	0.00	0.00	0.00	0.00
30/12/2004	2.50	0.76	1.0000	0.76	0.00	**1.15**	0.00	0.00	0.00	0.00	1.15
31/12/2004	0.50	0.23	1.0000	0.23	0.00	**0.27**	0.00	0.00	0.00	0.00	0.27
01/01/2005	3.30	0.65	1.0000	0.65	0.00	**2.65**	0.00	0.00	0.00	0.00	2.65
02/01/2005	0.20	0.48	1.0000	0.48	0.28	**0.00**	0.00	0.00	0.00	0.00	0.00
03/01/2005	3.40	0.76	1.0000	0.76	0.00	**2.36**	0.00	0.00	0.00	0.00	2.36
04/01/2005	0.10	0.56	1.0000	0.56	0.46	**0.00**	0.00	0.00	0.00	0.00	0.00
05/01/2005	1.90	0.64	1.0000	0.64	0.00	**0.80**	0.00	0.00	0.00	0.00	0.80
06/01/2005	0.70	1.02	1.0000	1.02	0.32	**0.00**	0.00	0.00	0.00	0.00	0.00
07/01/2005	31.30	0.79	1.0000	0.79	0.00	**30.19**	26.30	0.00	7.89	7.89	22.30
08/01/2005	0.30	0.40	1.0000	0.40	0.10	**0.00**	0.00	0.00	0.00	0.00	0.00
09/01/2005	0.00	0.88	1.0000	0.88	0.97	**0.00**	0.00	0.00	0.00	0.00	0.00
10/01/2005	0.10	0.80	1.0000	0.80	1.67	**0.00**	0.00	0.00	0.00	0.00	0.00
11/01/2005	1.10	0.70	1.0000	0.70	1.27	**0.00**	0.00	0.00	0.00	0.00	0.00
12/01/2005	0.00	0.98	1.0000	0.98	2.26	**0.00**	0.00	0.00	0.00	0.00	0.00
13/01/2005	0.00	0.39	1.0000	0.39	2.64	**0.00**	0.00	0.00	0.00	0.00	0.00
14/01/2005	2.10	0.79	1.0000	0.79	1.33	**0.00**	0.00	0.00	0.00	0.00	0.00
15/01/2005	1.80	0.84	1.0000	0.84	0.37	**0.00**	0.00	0.00	0.00	0.00	0.00
16/01/2005	1.30	0.75	1.0000	0.75	0.00	**0.18**	0.00	0.00	0.00	0.00	0.18
17/01/2005	4.80	0.31	1.0000	0.31	0.00	**4.49**	0.00	0.00	0.00	0.00	4.49
18/01/2005	4.30	0.57	1.0000	0.57	0.00	**3.73**	0.00	0.00	0.00	0.00	3.73
19/01/2005	4.80	0.61	1.0000	0.61	0.00	**4.19**	0.00	0.00	0.00	0.00	4.19
20/01/2005	1.80	0.82	1.0000	0.82	0.00	**0.98**	0.00	0.00	0.00	0.00	0.98
21/01/2005	6.70	0.42	1.0000	0.42	0.00	**6.28**	1.70	0.34	0.00	0.34	5.94
22/01/2005	0.00	0.55	1.0000	0.55	0.55	**0.00**	0.00	0.00	0.00	0.00	0.00
23/01/2005	0.00	0.11	1.0000	0.11	0.66	**0.00**	0.00	0.00	0.00	0.00	0.00
24/01/2005	2.40	0.28	1.0000	0.28	0.00	**1.47**	0.00	0.00	0.00	0.00	1.47
25/01/2005	2.30	0.30	1.0000	0.30	0.00	**2.00**	0.00	0.00	0.00	0.00	2.00
26/01/2005	0.00	0.30	1.0000	0.30	0.30	**0.00**	0.00	0.00	0.00	0.00	0.00
27/01/2005	1.00	0.44	1.0000	0.44	0.00	**0.26**	0.00	0.00	0.00	0.00	0.26

Date	Rainfall	PE	S.F.	AE	SMD	**Recharge**	Pot. Runoff	Runoff 1	Runoff 2	Runoff	Recharge
28/01/2005	0.00	0.52	1.0000	0.52	0.52	**0.00**	0.00	0.00	0.00	0.00	0.00
29/01/2005	0.50	0.47	1.0000	0.47	0.49	**0.00**	0.00	0.00	0.00	0.00	0.00
30/01/2005	0.10	0.46	1.0000	0.46	0.85	**0.00**	0.00	0.00	0.00	0.00	0.00
31/01/2005	0.00	0.46	1.0000	0.46	1.31	**0.00**	0.00	0.00	0.00	0.00	0.00
01/02/2005	0.00	0.55	1.0000	0.55	1.85	**0.00**	0.00	0.00	0.00	0.00	0.00
02/02/2005	0.00	0.33	1.0000	0.33	2.19	**0.00**	0.00	0.00	0.00	0.00	0.00
03/02/2005	0.00	0.37	1.0000	0.37	2.56	**0.00**	0.00	0.00	0.00	0.00	0.00
04/02/2005	2.60	0.94	1.0000	0.94	0.89	**0.00**	0.00	0.00	0.00	0.00	0.00
05/02/2005	0.50	0.24	1.0000	0.24	0.64	**0.00**	0.00	0.00	0.00	0.00	0.00
06/02/2005	7.00	0.33	1.0000	0.33	0.00	**6.03**	2.00	0.40	0.00	0.40	5.63
07/02/2005	0.20	0.47	1.0000	0.47	0.27	**0.00**	0.00	0.00	0.00	0.00	0.00
08/02/2005	2.70	0.88	1.0000	0.88	0.00	**1.56**	0.00	0.00	0.00	0.00	1.56
09/02/2005	5.20	0.73	1.0000	0.73	0.00	**4.47**	0.20	0.04	0.00	0.04	4.43
10/02/2005	0.20	0.38	1.0000	0.38	0.18	**0.00**	0.00	0.00	0.00	0.00	0.00
11/02/2005	7.80	0.53	1.0000	0.53	0.00	**7.09**	2.80	0.56	0.00	0.56	6.53
12/02/2005	4.00	0.68	1.0000	0.68	0.00	**3.32**	0.00	0.00	0.00	0.00	3.32
13/02/2005	0.30	0.92	1.0000	0.92	0.62	**0.00**	0.00	0.00	0.00	0.00	0.00
14/02/2005	0.00	0.70	1.0000	0.70	1.32	**0.00**	0.00	0.00	0.00	0.00	0.00
15/02/2005	0.00	0.40	1.0000	0.40	1.72	**0.00**	0.00	0.00	0.00	0.00	0.00
16/02/2005	1.40	0.37	1.0000	0.37	0.69	**0.00**	0.00	0.00	0.00	0.00	0.00
17/02/2005	0.10	0.42	1.0000	0.42	1.01	**0.00**	0.00	0.00	0.00	0.00	0.00
18/02/2005	0.40	0.93	1.0000	0.93	1.54	**0.00**	0.00	0.00	0.00	0.00	0.00
19/02/2005	0.00	0.75	1.0000	0.75	2.29	**0.00**	0.00	0.00	0.00	0.00	0.00
20/02/2005	1.20	0.93	1.0000	0.93	2.03	**0.00**	0.00	0.00	0.00	0.00	0.00
21/02/2005	10.70	0.53	1.0000	0.53	0.00	**8.15**	5.70	1.14	0.00	1.14	7.01
22/02/2005	7.00	0.81	1.0000	0.81	0.00	**6.19**	2.00	0.40	0.00	0.40	5.79
23/02/2005	5.80	0.58	1.0000	0.58	0.00	**5.22**	0.80	0.16	0.00	0.16	5.06
24/02/2005	7.00	0.63	1.0000	0.63	0.00	**6.37**	2.00	0.40	0.00	0.40	5.97
25/02/2005	3.80	0.97	1.0000	0.97	0.00	**2.83**	0.00	0.00	0.00	0.00	2.83
26/02/2005	0.50	0.74	1.0000	0.74	0.24	**0.00**	0.00	0.00	0.00	0.00	0.00
27/02/2005	0.10	0.73	1.0000	0.73	0.87	**0.00**	0.00	0.00	0.00	0.00	0.00
28/02/2005	1.20	0.84	1.0000	0.84	0.50	**0.00**	0.00	0.00	0.00	0.00	0.00
01/03/2005	0.30	0.91	1.0000	0.91	1.11	**0.00**	0.00	0.00	0.00	0.00	0.00
02/03/2005	0.40	1.04	1.0000	1.04	1.75	**0.00**	0.00	0.00	0.00	0.00	0.00
03/03/2005	2.60	0.72	1.0000	0.72	0.00	**0.13**	0.00	0.00	0.00	0.00	0.13
04/03/2005	0.00	1.16	1.0000	1.16	1.16	**0.00**	0.00	0.00	0.00	0.00	0.00
05/03/2005	0.00	1.10	1.0000	1.10	2.27	**0.00**	0.00	0.00	0.00	0.00	0.00
06/03/2005	0.00	0.85	1.0000	0.85	3.12	**0.00**	0.00	0.00	0.00	0.00	0.00
07/03/2005	0.00	0.77	1.0000	0.77	3.89	**0.00**	0.00	0.00	0.00	0.00	0.00
08/03/2005	0.00	0.74	1.0000	0.74	4.63	**0.00**	0.00	0.00	0.00	0.00	0.00
09/03/2005	0.20	0.73	1.0000	0.73	5.16	**0.00**	0.00	0.00	0.00	0.00	0.00
10/03/2005	0.00	1.06	1.0000	1.06	6.22	**0.00**	0.00	0.00	0.00	0.00	0.00
11/03/2005	0.10	1.44	1.0000	1.44	7.57	**0.00**	0.00	0.00	0.00	0.00	0.00
12/03/2005	0.00	1.12	1.0000	1.12	8.69	**0.00**	0.00	0.00	0.00	0.00	0.00
13/03/2005	0.00	0.90	1.0000	0.90	9.59	**0.00**	0.00	0.00	0.00	0.00	0.00
14/03/2005	5.50	0.93	1.0000	0.93	5.02	**0.00**	0.50	0.10	0.00	0.10	-0.10
15/03/2005	0.10	1.30	1.0000	1.30	6.22	**0.00**	0.00	0.00	0.00	0.00	0.00
16/03/2005	0.00	2.27	1.0000	2.27	8.49	**0.00**	0.00	0.00	0.00	0.00	0.00
17/03/2005	0.00	1.77	1.0000	1.77	10.26	**0.00**	0.00	0.00	0.00	0.00	0.00
18/03/2005	0.00	1.42	1.0000	1.42	11.68	**0.00**	0.00	0.00	0.00	0.00	0.00
19/03/2005	0.00	1.29	1.0000	1.29	12.98	**0.00**	0.00	0.00	0.00	0.00	0.00
20/03/2005	7.40	1.53	1.0000	1.53	7.10	**0.00**	2.40	0.48	0.00	0.48	-0.48
21/03/2005	9.00	0.89	1.0000	0.89	0.00	**1.00**	4.00	0.80	0.00	0.80	0.20
22/03/2005	0.10	1.69	1.0000	1.69	1.59	**0.00**	0.00	0.00	0.00	0.00	0.00
23/03/2005	1.50	1.89	1.0000	1.89	1.99	**0.00**	0.00	0.00	0.00	0.00	0.00
24/03/2005	0.50	1.82	1.0000	1.82	3.30	**0.00**	0.00	0.00	0.00	0.00	0.00
25/03/2005	0.10	1.07	1.0000	1.07	4.27	**0.00**	0.00	0.00	0.00	0.00	0.00
26/03/2005	0.00	1.16	1.0000	1.16	5.44	**0.00**	0.00	0.00	0.00	0.00	0.00
27/03/2005	0.10	0.89	1.0000	0.89	6.22	**0.00**	0.00	0.00	0.00	0.00	0.00
28/03/2005	4.00	1.25	1.0000	1.25	3.47	**0.00**	0.00	0.00	0.00	0.00	0.00
29/03/2005	3.60	0.98	1.0000	0.98	0.85	**0.00**	0.00	0.00	0.00	0.00	0.00
30/03/2005	1.30	0.99	1.0000	0.99	0.54	**0.00**	0.00	0.00	0.00	0.00	0.00
31/03/2005	7.70	1.19	1.0000	1.19	0.00	**5.96**	2.70	0.54	0.00	0.54	5.42
01/04/2005	0.00	1.57	1.0000	1.57	1.57	**0.00**	0.00	0.00	0.00	0.00	0.00
02/04/2005	0.00	2.12	1.0000	2.12	3.70	**0.00**	0.00	0.00	0.00	0.00	0.00
03/04/2005	1.20	1.66	1.0000	1.66	4.16	**0.00**	0.00	0.00	0.00	0.00	0.00
04/04/2005	2.60	1.93	1.0000	1.93	3.49	**0.00**	0.00	0.00	0.00	0.00	0.00
05/04/2005	13.20	1.50	1.0000	1.50	0.00	**8.21**	8.20	1.64	0.00	1.64	6.57
06/04/2005	9.20	1.44	1.0000	1.44	0.00	**7.76**	4.20	0.84	0.00	0.84	6.92
07/04/2005	0.90	1.47	1.0000	1.47	0.57	**0.00**	0.00	0.00	0.00	0.00	0.00
08/04/2005	0.00	1.83	1.0000	1.83	2.40	**0.00**	0.00	0.00	0.00	0.00	0.00
09/04/2005	0.10	1.51	1.0000	1.51	3.82	**0.00**	0.00	0.00	0.00	0.00	0.00
10/04/2005	0.00	2.02	1.0000	2.02	5.84	**0.00**	0.00	0.00	0.00	0.00	0.00
11/04/2005	3.50	1.64	1.0000	1.64	3.98	**0.00**	0.00	0.00	0.00	0.00	0.00
12/04/2005	2.30	1.77	1.0000	1.77	3.45	**0.00**	0.00	0.00	0.00	0.00	0.00
13/04/2005	5.90	2.08	1.0000	2.08	0.00	**0.37**	0.90	0.18	0.00	0.18	0.19
14/04/2005	2.40	0.90	1.0000	0.90	0.00	**1.50**	0.00	0.00	0.00	0.00	1.50
15/04/2005	0.00	1.62	1.0000	1.62	1.62	**0.00**	0.00	0.00	0.00	0.00	0.00

Date	Rainfall	PE	S.F.	AE	SMD	**Recharge**	Pot. Runoff	Runoff 1	Runoff 2	Runoff	Recharge
16/04/2005	12.60	1.46	1.0000	1.46	0.00	**9.52**	7.60	1.52	0.00	1.52	8.00
17/04/2005	8.70	0.96	1.0000	0.96	0.00	**7.74**	3.70	0.74	0.00	0.74	7.00
18/04/2005	6.90	1.45	1.0000	1.45	0.00	**5.45**	1.90	0.38	0.00	0.38	5.07
19/04/2005	1.00	1.58	1.0000	1.58	0.58	**0.00**	0.00	0.00	0.00	0.00	0.00
20/04/2005	0.30	0.77	1.0000	0.77	1.05	**0.00**	0.00	0.00	0.00	0.00	0.00
21/04/2005	0.00	2.50	1.0000	2.50	3.55	**0.00**	0.00	0.00	0.00	0.00	0.00
22/04/2005	7.50	2.63	1.0000	2.63	0.00	**1.32**	2.50	0.50	0.00	0.50	0.82
23/04/2005	1.80	0.99	1.0000	0.99	0.00	**0.81**	0.00	0.00	0.00	0.00	0.81
24/04/2005	0.00	2.21	1.0000	2.21	2.21	**0.00**	0.00	0.00	0.00	0.00	0.00
25/04/2005	0.70	1.96	1.0000	1.96	3.48	**0.00**	0.00	0.00	0.00	0.00	0.00
26/04/2005	4.10	2.49	1.0000	2.49	1.86	**0.00**	0.00	0.00	0.00	0.00	0.00
27/04/2005	9.60	2.39	1.0000	2.39	0.00	**5.35**	4.60	0.92	0.00	0.92	4.43
28/04/2005	0.60	2.72	1.0000	2.72	2.12	**0.00**	0.00	0.00	0.00	0.00	0.00
29/04/2005	4.20	2.96	1.0000	2.96	0.88	**0.00**	0.00	0.00	0.00	0.00	0.00
30/04/2005	3.50	1.45	1.0000	1.45	0.00	**1.16**	0.00	0.00	0.00	0.00	1.16
01/05/2005	0.70	2.32	1.0000	2.32	1.62	**0.00**	0.00	0.00	0.00	0.00	0.00
02/05/2005	22.00	2.16	1.0000	2.16	0.00	**18.22**	17.00	0.00	5.10	5.10	13.12
03/05/2005	5.10	1.72	1.0000	1.72	0.00	**3.38**	0.10	0.02	0.00	0.02	3.36
04/05/2005	0.00	2.73	1.0000	2.73	2.73	**0.00**	0.00	0.00	0.00	0.00	0.00
05/05/2005	0.80	2.23	1.0000	2.23	4.17	**0.00**	0.00	0.00	0.00	0.00	0.00
06/05/2005	0.20	1.77	1.0000	1.77	5.74	**0.00**	0.00	0.00	0.00	0.00	0.00
07/05/2005	0.40	2.47	1.0000	2.47	7.81	**0.00**	0.00	0.00	0.00	0.00	0.00
08/05/2005	1.50	2.48	1.0000	2.48	8.79	**0.00**	0.00	0.00	0.00	0.00	0.00
09/05/2005	0.50	2.15	1.0000	2.15	10.44	**0.00**	0.00	0.00	0.00	0.00	0.00
10/05/2005	0.00	2.54	1.0000	2.54	12.98	**0.00**	0.00	0.00	0.00	0.00	0.00
11/05/2005	0.00	2.05	1.0000	2.05	15.03	**0.00**	0.00	0.00	0.00	0.00	0.00
12/05/2005	0.00	2.95	1.0000	2.95	17.98	**0.00**	0.00	0.00	0.00	0.00	0.00
13/05/2005	0.00	2.89	1.0000	2.89	20.87	**0.00**	0.00	0.00	0.00	0.00	0.00
14/05/2005	0.00	2.88	1.0000	2.88	23.75	**0.00**	0.00	0.00	0.00	0.00	0.00
15/05/2005	0.00	3.76	1.0000	3.76	27.50	**0.00**	0.00	0.00	0.00	0.00	0.00
16/05/2005	0.30	1.52	1.0000	1.52	28.72	**0.00**	0.00	0.00	0.00	0.00	0.00
17/05/2005	0.00	2.85	1.0000	2.85	31.57	**0.00**	0.00	0.00	0.00	0.00	0.00
18/05/2005	3.50	1.66	1.0000	1.66	29.73	**0.00**	0.00	0.00	0.00	0.00	0.00
19/05/2005	1.00	3.07	1.0000	3.07	31.81	**0.00**	0.00	0.00	0.00	0.00	0.00
20/05/2005	5.50	2.30	1.0000	2.30	28.61	**0.00**	0.50	0.10	0.00	0.10	-0.10
21/05/2005	10.50	2.84	1.0000	2.84	20.94	**0.00**	5.50	1.10	0.00	1.10	-1.10
22/05/2005	5.00	2.19	1.0000	2.19	18.13	**0.00**	0.00	0.00	0.00	0.00	0.00
23/05/2005	7.40	2.78	1.0000	2.78	13.51	**0.00**	2.40	0.48	0.00	0.48	-0.48
24/05/2005	6.20	2.57	1.0000	2.57	9.88	**0.00**	1.20	0.24	0.00	0.24	-0.24
25/05/2005	4.50	2.19	1.0000	2.19	7.57	**0.00**	0.00	0.00	0.00	0.00	0.00
26/05/2005	1.30	3.48	1.0000	3.48	9.75	**0.00**	0.00	0.00	0.00	0.00	0.00
27/05/2005	0.20	1.86	1.0000	1.86	11.41	**0.00**	0.00	0.00	0.00	0.00	0.00
28/05/2005	0.00	2.43	1.0000	2.43	13.84	**0.00**	0.00	0.00	0.00	0.00	0.00
29/05/2005	0.00	2.85	1.0000	2.85	16.69	**0.00**	0.00	0.00	0.00	0.00	0.00
30/05/2005	2.10	1.68	1.0000	1.68	16.27	**0.00**	0.00	0.00	0.00	0.00	0.00
31/05/2005	0.20	1.94	1.0000	1.94	18.01	**0.00**	0.00	0.00	0.00	0.00	0.00
01/06/2005	2.00	2.31	1.0000	2.31	18.32	**0.00**	0.00	0.00	0.00	0.00	0.00
02/06/2005	0.70	2.42	1.0000	2.42	20.04	**0.00**	0.00	0.00	0.00	0.00	0.00
03/06/2005	2.50	2.88	1.0000	2.88	20.41	**0.00**	0.00	0.00	0.00	0.00	0.00
04/06/2005	1.50	2.70	1.0000	2.70	21.61	**0.00**	0.00	0.00	0.00	0.00	0.00
05/06/2005	0.00	2.53	1.0000	2.53	24.14	**0.00**	0.00	0.00	0.00	0.00	0.00
06/06/2005	0.00	3.43	1.0000	3.43	27.57	**0.00**	0.00	0.00	0.00	0.00	0.00
07/06/2005	0.00	2.44	1.0000	2.44	30.02	**0.00**	0.00	0.00	0.00	0.00	0.00
08/06/2005	0.00	3.03	1.0000	3.03	33.05	**0.00**	0.00	0.00	0.00	0.00	0.00
09/06/2005	0.00	2.15	1.0000	2.15	35.20	**0.00**	0.00	0.00	0.00	0.00	0.00
10/06/2005	0.00	3.44	1.0000	3.44	38.63	**0.00**	0.00	0.00	0.00	0.00	0.00
11/06/2005	0.00	3.55	1.0000	3.55	42.18	**0.00**	0.00	0.00	0.00	0.00	0.00
12/06/2005	0.00	2.29	1.0000	2.29	44.47	**0.00**	0.00	0.00	0.00	0.00	0.00
13/06/2005	0.00	2.81	1.0000	2.81	47.28	**0.00**	0.00	0.00	0.00	0.00	0.00
14/06/2005	2.20	2.33	1.0000	2.33	47.41	**0.00**	0.00	0.00	0.00	0.00	0.00
15/06/2005	2.20	3.37	1.0000	3.37	48.58	**0.00**	0.00	0.00	0.00	0.00	0.00
16/06/2005	2.00	3.78	1.0000	3.78	50.36	**0.00**	0.00	0.00	0.00	0.00	0.00
17/06/2005	0.00	2.80	1.0000	2.80	53.16	**0.00**	0.00	0.00	0.00	0.00	0.00
18/06/2005	0.00	2.69	1.0000	2.69	55.85	**0.00**	0.00	0.00	0.00	0.00	0.00
19/06/2005	0.00	3.91	1.0000	3.91	59.75	**0.00**	0.00	0.00	0.00	0.00	0.00
20/06/2005	0.00	3.20	1.0000	3.20	62.96	**0.00**	0.00	0.00	0.00	0.00	0.00
21/06/2005	0.00	2.78	1.0000	2.78	65.74	**0.00**	0.00	0.00	0.00	0.00	0.00
22/06/2005	0.00	5.09	1.0000	5.09	70.83	**0.00**	0.00	0.00	0.00	0.00	0.00
23/06/2005	2.80	2.47	1.0000	2.47	70.49	**0.00**	0.00	0.00	0.00	0.00	0.00
24/06/2005	0.60	1.38	1.0000	1.38	71.28	**0.00**	0.00	0.00	0.00	0.00	0.00
25/06/2005	0.00	1.91	1.0000	1.91	73.19	**0.00**	0.00	0.00	0.00	0.00	0.00
26/06/2005	0.00	3.60	1.0000	3.60	76.79	**0.00**	0.00	0.00	0.00	0.00	0.00
27/06/2005	0.00	4.26	0.9474	4.03	80.82	**0.00**	0.00	0.00	0.00	0.00	0.00
28/06/2005	3.30	2.74	0.8712	2.39	79.91	**0.00**	0.00	0.00	0.00	0.00	0.00
29/06/2005	3.40	2.82	0.8885	2.50	79.02	**0.00**	0.00	0.00	0.00	0.00	0.00
30/06/2005	2.20	2.72	0.9054	2.46	79.28	**0.00**	0.00	0.00	0.00	0.00	0.00
01/07/2005	2.80	2.13	0.9005	1.91	78.39	**0.00**	0.00	0.00	0.00	0.00	0.00
02/07/2005	0.20	3.28	0.9172	3.00	81.19	**0.00**	0.00	0.00	0.00	0.00	0.00

Date	Rainfall	PE	S.F.	AE	SMD	**Recharge**	Pot. Runoff	Runoff 1	Runoff 2	Runoff	Recharge
03/07/2005	8.20	3.20	0.8643	2.76	75.76	**0.00**	3.20	0.64	0.00	0.64	-0.64
04/07/2005	1.50	3.58	0.9668	3.46	77.72	**0.00**	0.00	0.00	0.00	0.00	0.00
05/07/2005	6.00	2.61	0.9299	2.42	74.14	**0.00**	1.00	0.20	0.00	0.20	-0.20
06/07/2005	1.50	2.04	0.9973	2.03	74.67	**0.00**	0.00	0.00	0.00	0.00	0.00
07/07/2005	0.80	1.61	0.9873	1.59	75.46	**0.00**	0.00	0.00	0.00	0.00	0.00
08/07/2005	1.50	2.04	0.9724	1.99	75.95	**0.00**	0.00	0.00	0.00	0.00	0.00
09/07/2005	0.30	1.87	0.9632	1.80	77.45	**0.00**	0.00	0.00	0.00	0.00	0.00
10/07/2005	0.00	4.24	0.9349	3.97	81.42	**0.00**	0.00	0.00	0.00	0.00	0.00
11/07/2005	0.00	4.77	0.8600	4.10	85.52	**0.00**	0.00	0.00	0.00	0.00	0.00
12/07/2005	0.00	4.43	0.7826	3.47	88.99	**0.00**	0.00	0.00	0.00	0.00	0.00
13/07/2005	0.00	4.13	0.7172	2.96	91.95	**0.00**	0.00	0.00	0.00	0.00	0.00
14/07/2005	0.00	2.98	0.6614	1.97	93.92	**0.00**	0.00	0.00	0.00	0.00	0.00
15/07/2005	0.00	3.61	0.6242	2.25	96.17	**0.00**	0.00	0.00	0.00	0.00	0.00
16/07/2005	0.00	3.84	0.5817	2.23	98.40	**0.00**	0.00	0.00	0.00	0.00	0.00
17/07/2005	0.00	3.16	0.5396	1.71	100.11	**0.00**	0.00	0.00	0.00	0.00	0.00
18/07/2005	1.70	2.89	0.5074	1.47	99.87	**0.00**	0.00	0.00	0.00	0.00	0.00
19/07/2005	0.10	2.65	0.5118	1.35	101.13	**0.00**	0.00	0.00	0.00	0.00	0.00
20/07/2005	0.00	3.33	0.4881	1.63	102.76	**0.00**	0.00	0.00	0.00	0.00	0.00
21/07/2005	0.00	3.29	0.4574	1.50	104.26	**0.00**	0.00	0.00	0.00	0.00	0.00
22/07/2005	0.00	1.64	0.4291	0.70	104.96	**0.00**	0.00	0.00	0.00	0.00	0.00
23/07/2005	0.00	1.58	0.4158	0.66	105.62	**0.00**	0.00	0.00	0.00	0.00	0.00
24/07/2005	0.00	1.26	0.4034	0.51	106.13	**0.00**	0.00	0.00	0.00	0.00	0.00
25/07/2005	0.00	2.93	0.3938	1.16	107.29	**0.00**	0.00	0.00	0.00	0.00	0.00
26/07/2005	0.10	3.15	0.3720	1.17	108.36	**0.00**	0.00	0.00	0.00	0.00	0.00
27/07/2005	0.60	4.05	0.3517	1.43	109.18	**0.00**	0.00	0.00	0.00	0.00	0.00
28/07/2005	16.70	0.89	0.3361	0.30	92.78	**0.00**	11.70	2.34	0.00	2.34	-2.34
29/07/2005	11.80	0.82	0.6456	0.53	81.51	**0.00**	6.80	1.36	0.00	1.36	-1.36
30/07/2005	9.20	1.24	0.8582	1.06	73.37	**0.00**	4.20	0.84	0.00	0.84	-0.84
31/07/2005	2.80	1.70	1.0000	1.70	72.27	**0.00**	0.00	0.00	0.00	0.00	0.00
01/08/2005	0.00	2.49	1.0000	2.49	74.76	**0.00**	0.00	0.00	0.00	0.00	0.00
02/08/2005	0.00	2.08	0.9857	2.05	76.81	**0.00**	0.00	0.00	0.00	0.00	0.00
03/08/2005	0.00	3.91	0.9469	3.70	80.51	**0.00**	0.00	0.00	0.00	0.00	0.00
04/08/2005	7.50	1.95	0.8772	1.71	74.72	**0.00**	2.50	0.50	0.00	0.50	-0.50
05/08/2005	0.40	3.33	0.9864	3.28	77.60	**0.00**	0.00	0.00	0.00	0.00	0.00
06/08/2005	0.20	1.96	0.9320	1.83	79.23	**0.00**	0.00	0.00	0.00	0.00	0.00
07/08/2005	0.00	3.36	0.9013	3.03	82.26	**0.00**	0.00	0.00	0.00	0.00	0.00
08/08/2005	0.00	3.26	0.8442	2.75	85.01	**0.00**	0.00	0.00	0.00	0.00	0.00
09/08/2005	0.00	1.94	0.7922	1.54	86.55	**0.00**	0.00	0.00	0.00	0.00	0.00
10/08/2005	0.00	2.71	0.7632	2.07	88.62	**0.00**	0.00	0.00	0.00	0.00	0.00
11/08/2005	0.00	1.88	0.7241	1.36	89.98	**0.00**	0.00	0.00	0.00	0.00	0.00
12/08/2005	3.10	2.05	0.6984	1.43	88.32	**0.00**	0.00	0.00	0.00	0.00	0.00
13/08/2005	4.90	2.23	0.7298	1.63	85.05	**0.00**	0.00	0.00	0.00	0.00	0.00
14/08/2005	0.00	1.83	0.7916	1.45	86.50	**0.00**	0.00	0.00	0.00	0.00	0.00
15/08/2005	0.00	1.54	0.7642	1.18	87.67	**0.00**	0.00	0.00	0.00	0.00	0.00
16/08/2005	0.00	2.65	0.7420	1.96	89.64	**0.00**	0.00	0.00	0.00	0.00	0.00
17/08/2005	3.50	1.89	0.7049	1.33	87.47	**0.00**	0.00	0.00	0.00	0.00	0.00
18/08/2005	3.80	1.70	0.7458	1.27	84.94	**0.00**	0.00	0.00	0.00	0.00	0.00
19/08/2005	0.00	2.26	0.7935	1.79	86.73	**0.00**	0.00	0.00	0.00	0.00	0.00
20/08/2005	0.00	2.85	0.7598	2.17	88.90	**0.00**	0.00	0.00	0.00	0.00	0.00
21/08/2005	4.00	1.92	0.7189	1.38	86.28	**0.00**	0.00	0.00	0.00	0.00	0.00
22/08/2005	0.00	2.79	0.7683	2.14	88.42	**0.00**	0.00	0.00	0.00	0.00	0.00
23/08/2005	7.20	1.60	0.7279	1.17	82.39	**0.00**	2.20	0.44	0.00	0.44	-0.44
24/08/2005	0.70	1.99	0.8417	1.67	83.36	**0.00**	0.00	0.00	0.00	0.00	0.00
25/08/2005	5.30	2.30	0.8233	1.90	79.96	**0.00**	0.30	0.06	0.00	0.06	-0.06
26/08/2005	0.50	1.93	0.8876	1.71	81.17	**0.00**	0.00	0.00	0.00	0.00	0.00
27/08/2005	0.00	2.07	0.8647	1.79	82.96	**0.00**	0.00	0.00	0.00	0.00	0.00
28/08/2005	1.10	2.48	0.8309	2.06	83.92	**0.00**	0.00	0.00	0.00	0.00	0.00
29/08/2005	0.00	2.52	0.8128	2.05	85.97	**0.00**	0.00	0.00	0.00	0.00	0.00
30/08/2005	0.20	2.38	0.7741	1.84	87.62	**0.00**	0.00	0.00	0.00	0.00	0.00
31/08/2005	0.50	1.77	0.7431	1.32	88.43	**0.00**	0.00	0.00	0.00	0.00	0.00
01/09/2005	0.00	2.35	0.7277	1.71	90.14	**0.00**	0.00	0.00	0.00	0.00	0.00
02/09/2005	0.00	2.70	0.6955	1.87	92.02	**0.00**	0.00	0.00	0.00	0.00	0.00
03/09/2005	0.00	3.30	0.6601	2.18	94.20	**0.00**	0.00	0.00	0.00	0.00	0.00
04/09/2005	0.00	1.74	0.6190	1.07	95.27	**0.00**	0.00	0.00	0.00	0.00	0.00
05/09/2005	0.00	2.46	0.5987	1.47	96.74	**0.00**	0.00	0.00	0.00	0.00	0.00
06/09/2005	0.00	2.72	0.5709	1.55	98.29	**0.00**	0.00	0.00	0.00	0.00	0.00
07/09/2005	1.00	2.12	0.5416	1.15	98.44	**0.00**	0.00	0.00	0.00	0.00	0.00
08/09/2005	4.80	1.56	0.5389	0.84	94.48	**0.00**	0.00	0.00	0.00	0.00	0.00
09/09/2005	9.00	0.61	0.6136	0.37	85.85	**0.00**	4.00	0.80	0.00	0.80	-0.80
10/09/2005	0.00	0.92	0.7763	0.72	86.57	**0.00**	0.00	0.00	0.00	0.00	0.00
11/09/2005	0.00	1.72	0.7628	1.31	87.88	**0.00**	0.00	0.00	0.00	0.00	0.00
12/09/2005	0.00	2.33	0.7381	1.72	89.60	**0.00**	0.00	0.00	0.00	0.00	0.00
13/09/2005	0.00	2.56	0.7057	1.80	91.40	**0.00**	0.00	0.00	0.00	0.00	0.00
14/09/2005	6.00	1.35	0.6716	0.90	86.31	**0.00**	1.00	0.20	0.00	0.20	-0.20
15/09/2005	3.50	0.72	0.7678	0.55	83.36	**0.00**	0.00	0.00	0.00	0.00	0.00
16/09/2005	0.00	1.26	0.8235	1.04	84.39	**0.00**	0.00	0.00	0.00	0.00	0.00
17/09/2005	0.00	1.56	0.8039	1.25	85.64	**0.00**	0.00	0.00	0.00	0.00	0.00
18/09/2005	0.00	2.22	0.7803	1.73	87.37	**0.00**	0.00	0.00	0.00	0.00	0.00

Date	Rainfall	PE	S.F.	AE	SMD	**Recharge**	Pot. Runoff	Runoff 1	Runoff 2	Runoff	Recharge
19/09/2005	3.80	1.13	0.7477	0.85	84.42	**0.00**	0.00	0.00	0.00	0.00	0.00
20/09/2005	0.00	1.63	0.8034	1.31	85.73	**0.00**	0.00	0.00	0.00	0.00	0.00
21/09/2005	0.00	2.12	0.7787	1.65	87.38	**0.00**	0.00	0.00	0.00	0.00	0.00
22/09/2005	2.50	1.94	0.7476	1.45	86.33	**0.00**	0.00	0.00	0.00	0.00	0.00
23/09/2005	0.70	1.17	0.7674	0.90	86.52	**0.00**	0.00	0.00	0.00	0.00	0.00
24/09/2005	6.20	1.28	0.7637	0.98	81.30	**0.00**	1.20	0.24	0.00	0.24	-0.24
25/09/2005	1.00	1.64	0.8622	1.41	81.71	**0.00**	0.00	0.00	0.00	0.00	0.00
26/09/2005	8.20	1.31	0.8544	1.12	74.63	**0.00**	3.20	0.64	0.00	0.64	-0.64
27/09/2005	0.40	1.80	0.9880	1.78	76.01	**0.00**	0.00	0.00	0.00	0.00	0.00
28/09/2005	15.00	1.33	0.9620	1.28	62.30	**0.00**	10.00	2.00	0.00	2.00	-2.00
29/09/2005	2.10	0.92	1.0000	0.92	61.12	**0.00**	0.00	0.00	0.00	0.00	0.00
30/09/2005	0.30	1.42	1.0000	1.42	62.24	**0.00**	0.00	0.00	0.00	0.00	0.00
01/10/2005	0.20	1.25	1.0000	1.25	63.30	**0.00**	0.00	0.00	0.00	0.00	0.00
02/10/2005	0.00	1.16	1.0000	1.16	64.46	**0.00**	0.00	0.00	0.00	0.00	0.00
03/10/2005	0.00	1.12	1.0000	1.12	65.58	**0.00**	0.00	0.00	0.00	0.00	0.00
04/10/2005	0.00	1.11	1.0000	1.11	66.69	**0.00**	0.00	0.00	0.00	0.00	0.00
05/10/2005	0.00	1.31	1.0000	1.31	68.00	**0.00**	0.00	0.00	0.00	0.00	0.00
06/10/2005	0.00	1.11	1.0000	1.11	69.11	**0.00**	0.00	0.00	0.00	0.00	0.00
07/10/2005	6.40	1.74	1.0000	1.74	64.45	**0.00**	1.40	0.28	0.00	0.28	-0.28
08/10/2005	0.00	0.97	1.0000	0.97	65.41	**0.00**	0.00	0.00	0.00	0.00	0.00
09/10/2005	1.30	1.63	1.0000	1.63	65.74	**0.00**	0.00	0.00	0.00	0.00	0.00
10/10/2005	22.00	1.07	1.0000	1.07	44.81	**0.00**	17.00	0.00	5.10	5.10	-5.10
11/10/2005	8.60	0.52	1.0000	0.52	36.73	**0.00**	3.60	0.72	0.00	0.72	-0.72
12/10/2005	0.00	0.93	1.0000	0.93	37.65	**0.00**	0.00	0.00	0.00	0.00	0.00
13/10/2005	0.00	0.98	1.0000	0.98	38.63	**0.00**	0.00	0.00	0.00	0.00	0.00
14/10/2005	0.00	0.67	1.0000	0.67	39.30	**0.00**	0.00	0.00	0.00	0.00	0.00
15/10/2005	0.00	1.33	1.0000	1.33	40.63	**0.00**	0.00	0.00	0.00	0.00	0.00
16/10/2005	1.10	0.86	1.0000	0.86	40.40	**0.00**	0.00	0.00	0.00	0.00	0.00
17/10/2005	0.00	1.13	1.0000	1.13	41.52	**0.00**	0.00	0.00	0.00	0.00	0.00
18/10/2005	0.10	0.81	1.0000	0.81	42.24	**0.00**	0.00	0.00	0.00	0.00	0.00
19/10/2005	2.70	0.58	1.0000	0.58	40.12	**0.00**	0.00	0.00	0.00	0.00	0.00
20/10/2005	0.50	0.98	1.0000	0.98	40.60	**0.00**	0.00	0.00	0.00	0.00	0.00
21/10/2005	7.00	0.52	1.0000	0.52	34.12	**0.00**	2.00	0.40	0.00	0.40	-0.40
22/10/2005	1.00	0.59	1.0000	0.59	33.71	**0.00**	0.00	0.00	0.00	0.00	0.00
23/10/2005	23.20	0.57	1.0000	0.57	11.08	**0.00**	18.20	0.00	5.46	5.46	-5.46
24/10/2005	4.70	0.65	1.0000	0.65	7.02	**0.00**	0.00	0.00	0.00	0.00	0.00
25/10/2005	0.30	1.04	1.0000	1.04	7.76	**0.00**	0.00	0.00	0.00	0.00	0.00
26/10/2005	0.30	1.15	1.0000	1.15	8.61	**0.00**	0.00	0.00	0.00	0.00	0.00
27/10/2005	2.00	1.98	1.0000	1.98	8.59	**0.00**	0.00	0.00	0.00	0.00	0.00
28/10/2005	10.00	0.96	1.0000	0.96	0.00	**0.45**	5.00	1.00	0.00	1.00	-0.55
29/10/2005	20.00	1.09	1.0000	1.09	0.00	**18.91**	15.00	0.00	0.00	0.00	18.91
30/10/2005	6.00	1.10	1.0000	1.10	0.00	**4.90**	1.00	0.20	0.00	0.20	4.70
31/10/2005	5.00	0.92	1.0000	0.92	0.00	**4.08**	0.00	0.00	0.00	0.00	4.08
01/11/2005	6.50	0.73	1.0000	0.73	0.00	**5.77**	1.50	0.30	0.00	0.30	5.47
02/11/2005	9.00	0.95	1.0000	0.95	0.00	**8.05**	4.00	0.80	0.00	0.80	7.25
03/11/2005	7.40	0.61	1.0000	0.61	0.00	**6.79**	2.40	0.48	0.00	0.48	6.31
04/11/2005	4.50	0.77	1.0000	0.77	0.00	**3.73**	0.00	0.00	0.00	0.00	3.73
05/11/2005	4.50	0.71	1.0000	0.71	0.00	**3.79**	0.00	0.00	0.00	0.00	3.79
06/11/2005	0.10	0.82	1.0000	0.82	0.72	**0.00**	0.00	0.00	0.00	0.00	0.00
07/11/2005	14.50	0.97	1.0000	0.97	0.00	**12.81**	9.50	1.90	0.00	1.90	10.91
08/11/2005	0.20	0.64	1.0000	0.64	0.44	**0.00**	0.00	0.00	0.00	0.00	0.00
09/11/2005	4.20	0.55	1.0000	0.55	0.00	**3.21**	0.00	0.00	0.00	0.00	3.21
10/11/2005	2.70	0.58	1.0000	0.58	0.00	**2.12**	0.00	0.00	0.00	0.00	2.12
11/11/2005	2.80	0.90	1.0000	0.90	0.00	**1.90**	0.00	0.00	0.00	0.00	1.90
12/11/2005	0.00	0.54	1.0000	0.54	0.54	**0.00**	0.00	0.00	0.00	0.00	0.00
13/11/2005	0.00	0.33	1.0000	0.33	0.87	**0.00**	0.00	0.00	0.00	0.00	0.00
14/11/2005	0.60	0.41	1.0000	0.41	0.68	**0.00**	0.00	0.00	0.00	0.00	0.00
15/11/2005	0.20	0.27	1.0000	0.27	0.75	**0.00**	0.00	0.00	0.00	0.00	0.00
16/11/2005	0.00	0.18	1.0000	0.18	0.93	**0.00**	0.00	0.00	0.00	0.00	0.00
17/11/2005	0.00	0.16	1.0000	0.16	1.09	**0.00**	0.00	0.00	0.00	0.00	0.00
18/11/2005	0.20	0.75	1.0000	0.75	1.64	**0.00**	0.00	0.00	0.00	0.00	0.00
19/11/2005	0.00	0.12	1.0000	0.12	1.77	**0.00**	0.00	0.00	0.00	0.00	0.00
20/11/2005	0.00	0.17	1.0000	0.17	1.94	**0.00**	0.00	0.00	0.00	0.00	0.00
21/11/2005	0.00	0.00	1.0000	0.00	1.94	**0.00**	0.00	0.00	0.00	0.00	0.00
22/11/2005	0.00	0.00	1.0000	0.00	1.94	**0.00**	0.00	0.00	0.00	0.00	0.00
23/11/2005	0.00	0.29	1.0000	0.29	2.23	**0.00**	0.00	0.00	0.00	0.00	0.00
24/11/2005	0.60	0.50	1.0000	0.50	2.13	**0.00**	0.00	0.00	0.00	0.00	0.00
25/11/2005	3.70	0.53	1.0000	0.53	0.00	**1.04**	0.00	0.00	0.00	0.00	1.04
26/11/2005	0.10	0.56	1.0000	0.56	0.46	**0.00**	0.00	0.00	0.00	0.00	0.00
27/11/2005	0.00	0.19	1.0000	0.19	0.65	**0.00**	0.00	0.00	0.00	0.00	0.00
28/11/2005	0.50	0.15	1.0000	0.15	0.30	**0.00**	0.00	0.00	0.00	0.00	0.00
29/11/2005	4.00	0.24	1.0000	0.24	0.00	**3.46**	0.00	0.00	0.00	0.00	3.46
30/11/2005	5.00	0.32	1.0000	0.32	0.00	**4.68**	0.00	0.00	0.00	0.00	4.68
01/12/2005	14.50	0.49	1.0000	0.49	0.00	**14.01**	9.50	1.90	0.00	1.90	12.11
02/12/2005	12.50	0.36	1.0000	0.36	0.00	**12.14**	7.50	1.50	0.00	1.50	10.64
03/12/2005	1.50	0.21	1.0000	0.21	0.00	**1.29**	0.00	0.00	0.00	0.00	1.29
04/12/2005	0.20	0.35	1.0000	0.35	0.15	**0.00**	0.00	0.00	0.00	0.00	0.00
05/12/2005	0.00	0.42	1.0000	0.42	0.56	**0.00**	0.00	0.00	0.00	0.00	0.00

Date	Rainfall	PE	S.F.	AE	SMD	**Recharge**	Pot. Runoff	Runoff 1	Runoff 2	Runoff	Recharge
06/12/2005	0.00	0.21	1.0000	0.21	0.77	**0.00**	0.00	0.00	0.00	0.00	0.00
07/12/2005	10.70	0.39	1.0000	0.39	0.00	**9.53**	5.70	1.14	0.00	1.14	8.39
08/12/2005	2.10	0.25	1.0000	0.25	0.00	**1.85**	0.00	0.00	0.00	0.00	1.85
09/12/2005	0.40	0.41	1.0000	0.41	0.01	**0.00**	0.00	0.00	0.00	0.00	0.00
10/12/2005	0.00	0.59	1.0000	0.59	0.60	**0.00**	0.00	0.00	0.00	0.00	0.00
11/12/2005	0.20	0.67	1.0000	0.67	1.07	**0.00**	0.00	0.00	0.00	0.00	0.00
12/12/2005	0.00	0.00	1.0000	0.00	1.07	**0.00**	0.00	0.00	0.00	0.00	0.00
13/12/2005	0.00	0.00	1.0000	0.00	1.07	**0.00**	0.00	0.00	0.00	0.00	0.00
14/12/2005	0.10	0.28	1.0000	0.28	1.25	**0.00**	0.00	0.00	0.00	0.00	0.00
15/12/2005	0.50	0.44	1.0000	0.44	1.18	**0.00**	0.00	0.00	0.00	0.00	0.00
16/12/2005	0.00	0.23	1.0000	0.23	1.42	**0.00**	0.00	0.00	0.00	0.00	0.00
17/12/2005	0.00	0.01	1.0000	0.01	1.42	**0.00**	0.00	0.00	0.00	0.00	0.00
18/12/2005	1.60	0.33	1.0000	0.33	0.15	**0.00**	0.00	0.00	0.00	0.00	0.00
19/12/2005	0.00	0.54	1.0000	0.54	0.70	**0.00**	0.00	0.00	0.00	0.00	0.00
20/12/2005	0.20	0.77	1.0000	0.77	1.27	**0.00**	0.00	0.00	0.00	0.00	0.00
21/12/2005	0.80	0.22	1.0000	0.22	0.69	**0.00**	0.00	0.00	0.00	0.00	0.00
22/12/2005	0.00	1.04	1.0000	1.04	1.72	**0.00**	0.00	0.00	0.00	0.00	0.00
23/12/2005	1.50	0.75	1.0000	0.75	0.97	**0.00**	0.00	0.00	0.00	0.00	0.00
24/12/2005	0.00	0.19	1.0000	0.19	1.16	**0.00**	0.00	0.00	0.00	0.00	0.00
25/12/2005	0.00	0.00	1.0000	0.00	1.16	**0.00**	0.00	0.00	0.00	0.00	0.00
26/12/2005	0.50	0.29	1.0000	0.29	0.95	**0.00**	0.00	0.00	0.00	0.00	0.00
27/12/2005	0.00	0.22	1.0000	0.22	1.17	**0.00**	0.00	0.00	0.00	0.00	0.00
28/12/2005	0.00	0.18	1.0000	0.18	1.35	**0.00**	0.00	0.00	0.00	0.00	0.00
29/12/2005	9.40	0.64	1.0000	0.64	0.00	**7.41**	4.40	0.88	0.00	0.88	6.53
30/12/2005	0.80	0.53	1.0000	0.53	0.00	**0.27**	0.00	0.00	0.00	0.00	0.27
31/12/2005	0.00	0.49	1.0000	0.49	0.49	**0.00**	0.00	0.00	0.00	0.00	0.00
01/01/2006	0.00	0.39	1.0000	0.39	0.89	**0.00**	0.00	0.00	0.00	0.00	0.00
02/01/2006	1.00	0.38	1.0000	0.38	0.27	**0.00**	0.00	0.00	0.00	0.00	0.00
03/01/2006	0.00	0.01	1.0000	0.01	0.28	**0.00**	0.00	0.00	0.00	0.00	0.00
04/01/2006	0.20	0.00	1.0000	0.00	0.08	**0.00**	0.00	0.00	0.00	0.00	0.00
05/01/2006	0.00	0.82	1.0000	0.82	0.90	**0.00**	0.00	0.00	0.00	0.00	0.00
06/01/2006	0.00	0.32	1.0000	0.32	1.22	**0.00**	0.00	0.00	0.00	0.00	0.00
07/01/2006	0.00	0.45	1.0000	0.45	1.67	**0.00**	0.00	0.00	0.00	0.00	0.00
08/01/2006	0.00	0.32	1.0000	0.32	1.98	**0.00**	0.00	0.00	0.00	0.00	0.00
09/01/2006	9.40	0.61	1.0000	0.61	0.00	**6.81**	4.40	0.88	0.00	0.88	5.93
10/01/2006	6.30	0.60	1.0000	0.60	0.00	**5.70**	1.30	0.26	0.00	0.26	5.44
11/01/2006	0.20	0.56	1.0000	0.56	0.36	**0.00**	0.00	0.00	0.00	0.00	0.00
12/01/2006	1.20	1.42	1.0000	1.42	0.57	**0.00**	0.00	0.00	0.00	0.00	0.00
13/01/2006	1.40	0.83	1.0000	0.83	0.00	**0.00**	0.00	0.00	0.00	0.00	0.00
14/01/2006	0.20	0.23	1.0000	0.23	0.03	**0.00**	0.00	0.00	0.00	0.00	0.00
15/01/2006	3.00	1.05	1.0000	1.05	0.00	**1.93**	0.00	0.00	0.00	0.00	1.93
16/01/2006	2.00	0.53	1.0000	0.53	0.00	**1.47**	0.00	0.00	0.00	0.00	1.47
17/01/2006	0.80	0.23	1.0000	0.23	0.00	**0.57**	0.00	0.00	0.00	0.00	0.57
18/01/2006	0.40	0.47	1.0000	0.47	0.07	**0.00**	0.00	0.00	0.00	0.00	0.00
19/01/2006	4.20	0.78	1.0000	0.78	0.00	**3.35**	0.00	0.00	0.00	0.00	3.35
20/01/2006	0.10	0.73	1.0000	0.73	0.63	**0.00**	0.00	0.00	0.00	0.00	0.00
21/01/2006	0.00	0.28	1.0000	0.28	0.91	**0.00**	0.00	0.00	0.00	0.00	0.00
22/01/2006	0.00	0.47	1.0000	0.47	1.38	**0.00**	0.00	0.00	0.00	0.00	0.00
23/01/2006	0.00	0.88	1.0000	0.88	2.26	**0.00**	0.00	0.00	0.00	0.00	0.00
24/01/2006	0.00	0.43	1.0000	0.43	2.70	**0.00**	0.00	0.00	0.00	0.00	0.00
25/01/2006	0.00	0.83	1.0000	0.83	3.53	**0.00**	0.00	0.00	0.00	0.00	0.00
26/01/2006	0.00	1.04	1.0000	1.04	4.57	**0.00**	0.00	0.00	0.00	0.00	0.00
27/01/2006	0.50	0.57	1.0000	0.57	4.64	**0.00**	0.00	0.00	0.00	0.00	0.00
28/01/2006	0.00	0.39	1.0000	0.39	5.03	**0.00**	0.00	0.00	0.00	0.00	0.00
29/01/2006	0.00	0.33	1.0000	0.33	5.35	**0.00**	0.00	0.00	0.00	0.00	0.00
30/01/2006	0.00	0.15	1.0000	0.15	5.50	**0.00**	0.00	0.00	0.00	0.00	0.00
31/01/2006	0.00	0.11	1.0000	0.11	5.61	**0.00**	0.00	0.00	0.00	0.00	0.00
01/02/2006	0.30	0.34	1.0000	0.34	5.65	**0.00**	0.00	0.00	0.00	0.00	0.00
02/02/2006	0.00	0.31	1.0000	0.31	5.96	**0.00**	0.00	0.00	0.00	0.00	0.00
03/02/2006	0.00	0.30	1.0000	0.30	6.26	**0.00**	0.00	0.00	0.00	0.00	0.00
04/02/2006	0.00	0.34	1.0000	0.34	6.60	**0.00**	0.00	0.00	0.00	0.00	0.00
05/02/2006	0.00	0.48	1.0000	0.48	7.07	**0.00**	0.00	0.00	0.00	0.00	0.00
06/02/2006	0.00	0.98	1.0000	0.98	8.05	**0.00**	0.00	0.00	0.00	0.00	0.00
07/02/2006	3.00	0.53	1.0000	0.53	5.58	**0.00**	0.00	0.00	0.00	0.00	0.00
08/02/2006	0.00	0.59	1.0000	0.59	6.17	**0.00**	0.00	0.00	0.00	0.00	0.00
09/02/2006	0.00	0.44	1.0000	0.44	6.61	**0.00**	0.00	0.00	0.00	0.00	0.00
10/02/2006	0.00	0.48	1.0000	0.48	7.09	**0.00**	0.00	0.00	0.00	0.00	0.00
11/02/2006	6.70	0.82	1.0000	0.82	1.21	**0.00**	1.70	0.34	0.00	0.34	-0.34
12/02/2006	0.70	0.53	1.0000	0.53	1.04	**0.00**	0.00	0.00	0.00	0.00	0.00
13/02/2006	20.30	0.89	1.0000	0.89	0.00	**18.37**	15.30	0.00	4.59	4.59	13.78
14/02/2006	8.20	0.96	1.0000	0.96	0.00	**7.24**	3.20	0.64	0.00	0.64	6.60
15/02/2006	1.00	0.97	1.0000	0.97	0.00	**0.03**	0.00	0.00	0.00	0.00	0.03
16/02/2006	2.50	1.01	1.0000	1.01	0.00	**1.49**	0.00	0.00	0.00	0.00	1.49
17/02/2006	0.10	0.76	1.0000	0.76	0.66	**0.00**	0.00	0.00	0.00	0.00	0.00
18/02/2006	0.00	0.42	1.0000	0.42	1.07	**0.00**	0.00	0.00	0.00	0.00	0.00
19/02/2006	0.00	0.50	1.0000	0.50	1.58	**0.00**	0.00	0.00	0.00	0.00	0.00
20/02/2006	1.20	0.84	1.0000	0.84	1.22	**0.00**	0.00	0.00	0.00	0.00	0.00
21/02/2006	3.60	0.70	1.0000	0.70	0.00	**1.68**	0.00	0.00	0.00	0.00	1.68

Date	Rainfall	PE	S.F.	AE	SMD	**Recharge**	Pot. Runoff	Runoff 1	Runoff 2	Runoff	Recharge
22/02/2006	1.30	1.06	1.0000	1.06	0.00	**0.24**	0.00	0.00	0.00	0.00	0.24
23/02/2006	12.20	0.77	1.0000	0.77	0.00	**11.43**	7.20	1.44	0.00	1.44	9.99
24/02/2006	1.00	1.02	1.0000	1.02	0.02	**0.00**	0.00	0.00	0.00	0.00	0.00
25/02/2006	0.00	1.34	1.0000	1.34	1.36	**0.00**	0.00	0.00	0.00	0.00	0.00
26/02/2006	0.00	1.45	1.0000	1.45	2.81	**0.00**	0.00	0.00	0.00	0.00	0.00
27/02/2006	0.00	0.64	1.0000	0.64	3.45	**0.00**	0.00	0.00	0.00	0.00	0.00
28/02/2006	0.00	0.70	1.0000	0.70	4.16	**0.00**	0.00	0.00	0.00	0.00	0.00
01/03/2006	0.00	0.88	1.0000	0.88	5.04	**0.00**	0.00	0.00	0.00	0.00	0.00
02/03/2006	0.00	0.60	1.0000	0.60	5.64	**0.00**	0.00	0.00	0.00	0.00	0.00
03/03/2006	0.00	0.75	1.0000	0.75	6.39	**0.00**	0.00	0.00	0.00	0.00	0.00
04/03/2006	0.00	0.91	1.0000	0.91	7.30	**0.00**	0.00	0.00	0.00	0.00	0.00
05/03/2006	1.60	0.91	1.0000	0.91	6.60	**0.00**	0.00	0.00	0.00	0.00	0.00
06/03/2006	8.00	0.99	1.0000	0.99	0.00	**0.41**	3.00	0.60	0.00	0.60	-0.19
07/03/2006	4.20	0.64	1.0000	0.64	0.00	**3.56**	0.00	0.00	0.00	0.00	3.56
08/03/2006	3.60	0.63	1.0000	0.63	0.00	**2.97**	0.00	0.00	0.00	0.00	2.97
09/03/2006	1.10	1.24	1.0000	1.24	0.14	**0.00**	0.00	0.00	0.00	0.00	0.00
10/03/2006	0.00	1.54	1.0000	1.54	1.68	**0.00**	0.00	0.00	0.00	0.00	0.00
11/03/2006	9.60	0.80	1.0000	0.80	0.00	**7.11**	4.60	0.92	0.00	0.92	6.19
12/03/2006	0.20	0.92	1.0000	0.92	0.72	**0.00**	0.00	0.00	0.00	0.00	0.00
13/03/2006	5.60	0.99	1.0000	0.99	0.00	**3.89**	0.60	0.12	0.00	0.12	3.77
14/03/2006	1.20	0.86	1.0000	0.86	0.00	**0.34**	0.00	0.00	0.00	0.00	0.34
15/03/2006	0.20	0.59	1.0000	0.59	0.39	**0.00**	0.00	0.00	0.00	0.00	0.00
16/03/2006	3.10	1.14	1.0000	1.14	0.00	**1.57**	0.00	0.00	0.00	0.00	1.57
17/03/2006	0.20	0.93	1.0000	0.93	0.73	**0.00**	0.00	0.00	0.00	0.00	0.00
18/03/2006	0.00	1.34	1.0000	1.34	2.07	**0.00**	0.00	0.00	0.00	0.00	0.00
19/03/2006	0.50	1.45	1.0000	1.45	3.02	**0.00**	0.00	0.00	0.00	0.00	0.00
20/03/2006	1.40	0.95	1.0000	0.95	2.57	**0.00**	0.00	0.00	0.00	0.00	0.00
21/03/2006	0.30	1.13	1.0000	1.13	3.40	**0.00**	0.00	0.00	0.00	0.00	0.00
22/03/2006	0.20	1.44	1.0000	1.44	4.64	**0.00**	0.00	0.00	0.00	0.00	0.00
23/03/2006	4.10	1.02	1.0000	1.02	1.56	**0.00**	0.00	0.00	0.00	0.00	0.00
24/03/2006	2.00	0.49	1.0000	0.49	0.05	**0.00**	0.00	0.00	0.00	0.00	0.00
25/03/2006	5.00	1.18	1.0000	1.18	0.00	**3.76**	0.00	0.00	0.00	0.00	3.76
26/03/2006	10.00	1.20	1.0000	1.20	0.00	**8.80**	5.00	1.00	0.00	1.00	7.80
27/03/2006	3.20	1.46	1.0000	1.46	0.00	**1.74**	0.00	0.00	0.00	0.00	1.74
28/03/2006	0.50	0.97	1.0000	0.97	0.47	**0.00**	0.00	0.00	0.00	0.00	0.00
29/03/2006	4.20	1.15	1.0000	1.15	0.00	**2.58**	0.00	0.00	0.00	0.00	2.58
30/03/2006	1.80	1.66	1.0000	1.66	0.00	**0.14**	0.00	0.00	0.00	0.00	0.14
31/03/2006	3.80	1.72	1.0000	1.72	0.00	**2.08**	0.00	0.00	0.00	0.00	2.08
01/04/2006	5.10	1.71	1.0000	1.71	0.00	**3.39**	0.10	0.02	0.00	0.02	3.37
02/04/2006	2.70	1.47	1.0000	1.47	0.00	**1.23**	0.00	0.00	0.00	0.00	1.23
03/04/2006	0.10	1.65	1.0000	1.65	1.55	**0.00**	0.00	0.00	0.00	0.00	0.00
04/04/2006	0.00	1.83	1.0000	1.83	3.38	**0.00**	0.00	0.00	0.00	0.00	0.00
05/04/2006	0.00	2.00	1.0000	2.00	5.38	**0.00**	0.00	0.00	0.00	0.00	0.00
06/04/2006	2.00	1.57	1.0000	1.57	4.95	**0.00**	0.00	0.00	0.00	0.00	0.00
07/04/2006	4.80	1.53	1.0000	1.53	1.68	**0.00**	0.00	0.00	0.00	0.00	0.00
08/04/2006	0.20	1.82	1.0000	1.82	3.30	**0.00**	0.00	0.00	0.00	0.00	0.00
09/04/2006	1.00	1.76	1.0000	1.76	4.06	**0.00**	0.00	0.00	0.00	0.00	0.00
10/04/2006	2.80	1.96	1.0000	1.96	3.22	**0.00**	0.00	0.00	0.00	0.00	0.00
11/04/2006	1.60	2.13	1.0000	2.13	3.75	**0.00**	0.00	0.00	0.00	0.00	0.00
12/04/2006	1.00	1.08	1.0000	1.08	3.83	**0.00**	0.00	0.00	0.00	0.00	0.00
13/04/2006	0.30	2.07	1.0000	2.07	5.60	**0.00**	0.00	0.00	0.00	0.00	0.00
14/04/2006	0.00	2.33	1.0000	2.33	7.94	**0.00**	0.00	0.00	0.00	0.00	0.00
15/04/2006	0.00	1.61	1.0000	1.61	9.55	**0.00**	0.00	0.00	0.00	0.00	0.00
16/04/2006	0.00	1.97	1.0000	1.97	11.52	**0.00**	0.00	0.00	0.00	0.00	0.00
17/04/2006	0.80	1.97	1.0000	1.97	12.69	**0.00**	0.00	0.00	0.00	0.00	0.00
18/04/2006	4.00	1.52	1.0000	1.52	10.21	**0.00**	0.00	0.00	0.00	0.00	0.00
19/04/2006	0.00	2.11	1.0000	2.11	12.32	**0.00**	0.00	0.00	0.00	0.00	0.00
20/04/2006	0.50	1.39	1.0000	1.39	13.21	**0.00**	0.00	0.00	0.00	0.00	0.00
21/04/2006	0.00	2.50	1.0000	2.50	15.71	**0.00**	0.00	0.00	0.00	0.00	0.00
22/04/2006	2.00	2.20	1.0000	2.20	15.91	**0.00**	0.00	0.00	0.00	0.00	0.00
23/04/2006	0.00	2.48	1.0000	2.48	18.38	**0.00**	0.00	0.00	0.00	0.00	0.00
24/04/2006	0.80	1.85	1.0000	1.85	19.43	**0.00**	0.00	0.00	0.00	0.00	0.00
25/04/2006	0.00	2.06	1.0000	2.06	21.49	**0.00**	0.00	0.00	0.00	0.00	0.00
26/04/2006	0.20	2.02	1.0000	2.02	23.31	**0.00**	0.00	0.00	0.00	0.00	0.00
27/04/2006	0.00	2.52	1.0000	2.52	25.83	**0.00**	0.00	0.00	0.00	0.00	0.00
28/04/2006	0.00	2.75	1.0000	2.75	28.58	**0.00**	0.00	0.00	0.00	0.00	0.00
29/04/2006	0.00	1.43	1.0000	1.43	30.01	**0.00**	0.00	0.00	0.00	0.00	0.00
30/04/2006	8.00	1.05	1.0000	1.05	23.06	**0.00**	3.00	0.60	0.00	0.60	-0.60
01/05/2006	0.50	2.55	1.0000	2.55	25.11	**0.00**	0.00	0.00	0.00	0.00	0.00
02/05/2006	7.40	1.85	1.0000	1.85	19.56	**0.00**	2.40	0.48	0.00	0.48	-0.48
03/05/2006	0.10	2.44	1.0000	2.44	21.90	**0.00**	0.00	0.00	0.00	0.00	0.00
04/05/2006	6.00	1.24	1.0000	1.24	17.15	**0.00**	1.00	0.20	0.00	0.20	-0.20
05/05/2006	0.00	3.00	1.0000	3.00	20.15	**0.00**	0.00	0.00	0.00	0.00	0.00
06/05/2006	0.00	2.91	1.0000	2.91	23.06	**0.00**	0.00	0.00	0.00	0.00	0.00
07/05/2006	2.90	3.34	1.0000	3.34	23.50	**0.00**	0.00	0.00	0.00	0.00	0.00
08/05/2006	0.00	1.02	1.0000	1.02	24.52	**0.00**	0.00	0.00	0.00	0.00	0.00
09/05/2006	3.90	2.20	1.0000	2.20	22.82	**0.00**	0.00	0.00	0.00	0.00	0.00
10/05/2006	0.10	3.26	1.0000	3.26	25.98	**0.00**	0.00	0.00	0.00	0.00	0.00

Date	Rainfall	PE	S.F.	AE	SMD	**Recharge**	Pot. Runoff	Runoff 1	Runoff 2	Runoff	Recharge
11/05/2006	3.80	3.64	1.0000	3.64	25.82	**0.00**	0.00	0.00	0.00	0.00	0.00
12/05/2006	5.40	2.87	1.0000	2.87	23.28	**0.00**	0.40	0.08	0.00	0.08	-0.08
13/05/2006	10.00	1.66	1.0000	1.66	14.95	**0.00**	5.00	1.00	0.00	1.00	-1.00
14/05/2006	1.50	1.90	1.0000	1.90	15.35	**0.00**	0.00	0.00	0.00	0.00	0.00
15/05/2006	0.10	1.72	1.0000	1.72	16.97	**0.00**	0.00	0.00	0.00	0.00	0.00
16/05/2006	0.40	2.60	1.0000	2.60	19.17	**0.00**	0.00	0.00	0.00	0.00	0.00
17/05/2006	3.40	1.57	1.0000	1.57	17.34	**0.00**	0.00	0.00	0.00	0.00	0.00
18/05/2006	0.00	2.77	1.0000	2.77	20.11	**0.00**	0.00	0.00	0.00	0.00	0.00
19/05/2006	0.00	2.26	1.0000	2.26	22.38	**0.00**	0.00	0.00	0.00	0.00	0.00
20/05/2006	26.10	2.13	1.0000	2.13	0.00	**1.60**	21.10	0.00	6.33	6.33	-4.73
21/05/2006	1.70	0.84	1.0000	0.84	0.00	**0.86**	0.00	0.00	0.00	0.00	0.86
22/05/2006	7.00	1.71	1.0000	1.71	0.00	**5.29**	2.00	0.40	0.00	0.40	4.89
23/05/2006	0.10	2.15	1.0000	2.15	2.05	**0.00**	0.00	0.00	0.00	0.00	0.00
24/05/2006	9.50	2.99	1.0000	2.99	0.00	**4.46**	4.50	0.90	0.00	0.90	3.56
25/05/2006	0.10	2.46	1.0000	2.46	2.36	**0.00**	0.00	0.00	0.00	0.00	0.00
26/05/2006	3.30	2.06	1.0000	2.06	1.12	**0.00**	0.00	0.00	0.00	0.00	0.00
27/05/2006	0.00	2.37	1.0000	2.37	3.50	**0.00**	0.00	0.00	0.00	0.00	0.00
28/05/2006	0.00	2.15	1.0000	2.15	5.64	**0.00**	0.00	0.00	0.00	0.00	0.00
29/05/2006	0.00	2.84	1.0000	2.84	8.48	**0.00**	0.00	0.00	0.00	0.00	0.00
30/05/2006	0.00	2.98	1.0000	2.98	11.46	**0.00**	0.00	0.00	0.00	0.00	0.00
31/05/2006	0.00	3.33	1.0000	3.33	14.79	**0.00**	0.00	0.00	0.00	0.00	0.00
01/06/2006	0.00	3.82	1.0000	3.82	18.62	**0.00**	0.00	0.00	0.00	0.00	0.00
02/06/2006	0.00	3.83	1.0000	3.83	22.45	**0.00**	0.00	0.00	0.00	0.00	0.00
03/06/2006	0.00	4.38	1.0000	4.38	26.83	**0.00**	0.00	0.00	0.00	0.00	0.00
04/06/2006	0.00	4.11	1.0000	4.11	30.94	**0.00**	0.00	0.00	0.00	0.00	0.00
05/06/2006	0.00	4.10	1.0000	4.10	35.05	**0.00**	0.00	0.00	0.00	0.00	0.00
06/06/2006	0.00	4.44	1.0000	4.44	39.49	**0.00**	0.00	0.00	0.00	0.00	0.00
07/06/2006	0.00	4.09	1.0000	4.09	43.58	**0.00**	0.00	0.00	0.00	0.00	0.00
08/06/2006	0.00	4.29	1.0000	4.29	47.87	**0.00**	0.00	0.00	0.00	0.00	0.00
09/06/2006	0.00	5.22	1.0000	5.22	53.10	**0.00**	0.00	0.00	0.00	0.00	0.00
10/06/2006	0.00	4.50	1.0000	4.50	57.59	**0.00**	0.00	0.00	0.00	0.00	0.00
11/06/2006	0.10	4.14	1.0000	4.14	61.63	**0.00**	0.00	0.00	0.00	0.00	0.00
12/06/2006	0.00	4.23	1.0000	4.23	65.86	**0.00**	0.00	0.00	0.00	0.00	0.00
13/06/2006	0.00	2.57	1.0000	2.57	68.42	**0.00**	0.00	0.00	0.00	0.00	0.00
14/06/2006	0.00	2.66	1.0000	2.66	71.09	**0.00**	0.00	0.00	0.00	0.00	0.00
15/06/2006	0.00	3.12	1.0000	3.12	74.21	**0.00**	0.00	0.00	0.00	0.00	0.00
16/06/2006	0.00	3.34	0.9960	3.33	77.54	**0.00**	0.00	0.00	0.00	0.00	0.00
17/06/2006	1.20	4.29	0.9332	4.00	80.34	**0.00**	0.00	0.00	0.00	0.00	0.00
18/06/2006	7.10	2.03	0.8803	1.79	75.03	**0.00**	2.10	0.42	0.00	0.42	-0.42
19/06/2006	0.20	1.76	0.9805	1.73	76.56	**0.00**	0.00	0.00	0.00	0.00	0.00
20/06/2006	2.50	2.04	0.9516	1.94	76.00	**0.00**	0.00	0.00	0.00	0.00	0.00
21/06/2006	1.00	3.13	0.9623	3.01	78.01	**0.00**	0.00	0.00	0.00	0.00	0.00
22/06/2006	0.00	3.04	0.9244	2.81	80.82	**0.00**	0.00	0.00	0.00	0.00	0.00
23/06/2006	1.10	3.34	0.8714	2.91	82.63	**0.00**	0.00	0.00	0.00	0.00	0.00
24/06/2006	1.00	1.26	0.8372	1.06	82.69	**0.00**	0.00	0.00	0.00	0.00	0.00
25/06/2006	0.10	3.93	0.8361	3.28	85.87	**0.00**	0.00	0.00	0.00	0.00	0.00
26/06/2006	0.80	0.87	0.7761	0.68	85.74	**0.00**	0.00	0.00	0.00	0.00	0.00
27/06/2006	0.00	1.14	0.7784	0.89	86.63	**0.00**	0.00	0.00	0.00	0.00	0.00
28/06/2006	0.00	2.79	0.7616	2.12	88.76	**0.00**	0.00	0.00	0.00	0.00	0.00
29/06/2006	10.00	2.46	0.7216	1.78	80.53	**0.00**	5.00	1.00	0.00	1.00	-1.00
30/06/2006	0.30	3.25	0.8767	2.85	83.08	**0.00**	0.00	0.00	0.00	0.00	0.00
01/07/2006	0.00	4.22	0.8287	3.50	86.58	**0.00**	0.00	0.00	0.00	0.00	0.00
02/07/2006	1.90	2.15	0.7627	1.64	86.32	**0.00**	0.00	0.00	0.00	0.00	0.00
03/07/2006	0.00	2.64	0.7676	2.03	88.34	**0.00**	0.00	0.00	0.00	0.00	0.00
04/07/2006	0.00	2.32	0.7293	1.70	90.04	**0.00**	0.00	0.00	0.00	0.00	0.00
05/07/2006	0.00	3.48	0.6974	2.43	92.47	**0.00**	0.00	0.00	0.00	0.00	0.00
06/07/2006	0.00	2.79	0.6516	1.82	94.28	**0.00**	0.00	0.00	0.00	0.00	0.00
07/07/2006	0.00	3.36	0.6173	2.07	96.36	**0.00**	0.00	0.00	0.00	0.00	0.00
08/07/2006	9.50	1.77	0.5782	1.02	87.88	**0.00**	4.50	0.90	0.00	0.90	-0.90
09/07/2006	0.00	2.35	0.7381	1.74	89.62	**0.00**	0.00	0.00	0.00	0.00	0.00
10/07/2006	0.10	3.23	0.7053	2.28	91.79	**0.00**	0.00	0.00	0.00	0.00	0.00
11/07/2006	0.00	3.40	0.6643	2.26	94.05	**0.00**	0.00	0.00	0.00	0.00	0.00
12/07/2006	0.00	1.94	0.6216	1.20	95.26	**0.00**	0.00	0.00	0.00	0.00	0.00
13/07/2006	0.00	3.62	0.5989	2.17	97.43	**0.00**	0.00	0.00	0.00	0.00	0.00
14/07/2006	0.00	4.07	0.5580	2.27	99.69	**0.00**	0.00	0.00	0.00	0.00	0.00
15/07/2006	0.00	4.03	0.5152	2.08	101.77	**0.00**	0.00	0.00	0.00	0.00	0.00
16/07/2006	0.00	4.43	0.4760	2.11	103.88	**0.00**	0.00	0.00	0.00	0.00	0.00
17/07/2006	0.00	4.93	0.4362	2.15	106.03	**0.00**	0.00	0.00	0.00	0.00	0.00
18/07/2006	0.00	5.21	0.3957	2.06	108.09	**0.00**	0.00	0.00	0.00	0.00	0.00
19/07/2006	0.00	5.04	0.3568	1.80	109.89	**0.00**	0.00	0.00	0.00	0.00	0.00
20/07/2006	0.00	3.73	0.3229	1.20	111.09	**0.00**	0.00	0.00	0.00	0.00	0.00
21/07/2006	0.00	3.59	0.3002	1.08	112.17	**0.00**	0.00	0.00	0.00	0.00	0.00
22/07/2006	0.00	3.73	0.2798	1.04	113.21	**0.00**	0.00	0.00	0.00	0.00	0.00
23/07/2006	0.00	3.36	0.2602	0.87	114.09	**0.00**	0.00	0.00	0.00	0.00	0.00
24/07/2006	0.00	4.41	0.2437	1.08	115.16	**0.00**	0.00	0.00	0.00	0.00	0.00
25/07/2006	0.00	3.94	0.2234	0.88	116.04	**0.00**	0.00	0.00	0.00	0.00	0.00
26/07/2006	0.00	3.58	0.2068	0.74	116.78	**0.00**	0.00	0.00	0.00	0.00	0.00
27/07/2006	0.00	3.55	0.1928	0.68	117.47	**0.00**	0.00	0.00	0.00	0.00	0.00

Date	Rainfall	PE	S.F.	AE	SMD	**Recharge**	Pot. Runoff	Runoff 1	Runoff 2	Runoff	Recharge
28/07/2006	2.50	2.56	0.1799	0.46	115.43	**0.00**	0.00	0.00	0.00	0.00	0.00
29/07/2006	0.10	3.11	0.2183	0.68	116.01	**0.00**	0.00	0.00	0.00	0.00	0.00
30/07/2006	4.80	3.75	0.2074	0.78	111.99	**0.00**	0.00	0.00	0.00	0.00	0.00
31/07/2006	2.60	2.64	0.2833	0.75	110.13	**0.00**	0.00	0.00	0.00	0.00	0.00
01/08/2006	0.00	3.68	0.3182	1.17	111.30	**0.00**	0.00	0.00	0.00	0.00	0.00
02/08/2006	0.00	3.26	0.2962	0.96	112.27	**0.00**	0.00	0.00	0.00	0.00	0.00
03/08/2006	0.00	3.30	0.2780	0.92	113.19	**0.00**	0.00	0.00	0.00	0.00	0.00
04/08/2006	0.00	1.45	0.2606	0.38	113.56	**0.00**	0.00	0.00	0.00	0.00	0.00
05/08/2006	5.50	2.80	0.2535	0.71	108.77	**0.00**	0.50	0.10	0.00	0.10	-0.10
06/08/2006	0.20	1.22	0.3439	0.42	108.99	**0.00**	0.00	0.00	0.00	0.00	0.00
07/08/2006	0.00	3.04	0.3397	1.03	110.03	**0.00**	0.00	0.00	0.00	0.00	0.00
08/08/2006	1.90	2.30	0.3202	0.74	108.86	**0.00**	0.00	0.00	0.00	0.00	0.00
09/08/2006	0.00	2.73	0.3422	0.93	109.80	**0.00**	0.00	0.00	0.00	0.00	0.00
10/08/2006	0.20	1.78	0.3246	0.58	110.18	**0.00**	0.00	0.00	0.00	0.00	0.00
11/08/2006	0.50	2.09	0.3174	0.66	110.34	**0.00**	0.00	0.00	0.00	0.00	0.00
12/08/2006	0.00	1.62	0.3143	0.51	110.85	**0.00**	0.00	0.00	0.00	0.00	0.00
13/08/2006	0.00	2.12	0.3047	0.65	111.50	**0.00**	0.00	0.00	0.00	0.00	0.00
14/08/2006	7.00	1.88	0.2925	0.55	105.05	**0.00**	2.00	0.40	0.00	0.40	-0.40
15/08/2006	1.00	1.03	0.4142	0.43	104.47	**0.00**	0.00	0.00	0.00	0.00	0.00
16/08/2006	0.00	1.50	0.4250	0.64	105.11	**0.00**	0.00	0.00	0.00	0.00	0.00
17/08/2006	1.50	2.31	0.4130	0.95	104.56	**0.00**	0.00	0.00	0.00	0.00	0.00
18/08/2006	43.00	2.31	0.4233	0.98	62.54	**0.00**	38.00	0.00	11.40	11.40	-11.40
19/08/2006	4.70	1.33	1.0000	1.33	59.17	**0.00**	0.00	0.00	0.00	0.00	0.00
20/08/2006	3.00	2.42	1.0000	2.42	58.59	**0.00**	0.00	0.00	0.00	0.00	0.00
21/08/2006	0.00	2.43	1.0000	2.43	61.02	**0.00**	0.00	0.00	0.00	0.00	0.00
22/08/2006	0.10	2.14	1.0000	2.14	63.05	**0.00**	0.00	0.00	0.00	0.00	0.00
23/08/2006	1.90	2.27	1.0000	2.27	63.42	**0.00**	0.00	0.00	0.00	0.00	0.00
24/08/2006	5.90	2.76	1.0000	2.76	60.28	**0.00**	0.90	0.18	0.00	0.18	-0.18
25/08/2006	2.50	1.59	1.0000	1.59	59.37	**0.00**	0.00	0.00	0.00	0.00	0.00
26/08/2006	0.00	2.31	1.0000	2.31	61.68	**0.00**	0.00	0.00	0.00	0.00	0.00
27/08/2006	0.30	2.43	1.0000	2.43	63.81	**0.00**	0.00	0.00	0.00	0.00	0.00
28/08/2006	3.20	2.31	1.0000	2.31	62.92	**0.00**	0.00	0.00	0.00	0.00	0.00
29/08/2006	1.30	2.39	1.0000	2.39	64.01	**0.00**	0.00	0.00	0.00	0.00	0.00
30/08/2006	2.40	1.44	1.0000	1.44	63.05	**0.00**	0.00	0.00	0.00	0.00	0.00
31/08/2006	0.10	2.32	1.0000	2.32	65.27	**0.00**	0.00	0.00	0.00	0.00	0.00
01/09/2006	9.40	2.41	1.0000	2.41	58.28	**0.00**	4.40	0.88	0.00	0.88	-0.88
02/09/2006	8.00	2.29	1.0000	2.29	52.57	**0.00**	3.00	0.60	0.00	0.60	-0.60
03/09/2006	0.00	2.16	1.0000	2.16	54.73	**0.00**	0.00	0.00	0.00	0.00	0.00
04/09/2006	5.30	1.39	1.0000	1.39	50.83	**0.00**	0.30	0.06	0.00	0.06	-0.06
05/09/2006	3.40	2.69	1.0000	2.69	50.12	**0.00**	0.00	0.00	0.00	0.00	0.00
06/09/2006	0.10	1.51	1.0000	1.51	51.52	**0.00**	0.00	0.00	0.00	0.00	0.00
07/09/2006	0.00	2.04	1.0000	2.04	53.57	**0.00**	0.00	0.00	0.00	0.00	0.00
08/09/2006	0.00	2.70	1.0000	2.70	56.26	**0.00**	0.00	0.00	0.00	0.00	0.00
09/09/2006	0.00	2.32	1.0000	2.32	58.59	**0.00**	0.00	0.00	0.00	0.00	0.00
10/09/2006	0.00	2.00	1.0000	2.00	60.59	**0.00**	0.00	0.00	0.00	0.00	0.00
11/09/2006	5.20	1.42	1.0000	1.42	56.81	**0.00**	0.20	0.04	0.00	0.04	-0.04
12/09/2006	1.10	1.91	1.0000	1.91	57.62	**0.00**	0.00	0.00	0.00	0.00	0.00
13/09/2006	7.70	1.54	1.0000	1.54	51.47	**0.00**	2.70	0.54	0.00	0.54	-0.54
14/09/2006	0.00	2.10	1.0000	2.10	53.57	**0.00**	0.00	0.00	0.00	0.00	0.00
15/09/2006	0.00	2.11	1.0000	2.11	55.68	**0.00**	0.00	0.00	0.00	0.00	0.00
16/09/2006	0.10	2.00	1.0000	2.00	57.58	**0.00**	0.00	0.00	0.00	0.00	0.00
17/09/2006	0.00	1.61	1.0000	1.61	59.19	**0.00**	0.00	0.00	0.00	0.00	0.00
18/09/2006	17.30	1.61	1.0000	1.61	43.50	**0.00**	12.30	2.46	0.00	2.46	-2.46
19/09/2006	3.00	2.26	1.0000	2.26	42.76	**0.00**	0.00	0.00	0.00	0.00	0.00
20/09/2006	14.60	1.60	1.0000	1.60	29.77	**0.00**	9.60	1.92	0.00	1.92	-1.92
21/09/2006	0.70	2.85	1.0000	2.85	31.92	**0.00**	0.00	0.00	0.00	0.00	0.00
22/09/2006	3.00	2.03	1.0000	2.03	30.94	**0.00**	0.00	0.00	0.00	0.00	0.00
23/09/2006	6.00	1.57	1.0000	1.57	26.52	**0.00**	1.00	0.20	0.00	0.20	-0.20
24/09/2006	5.50	1.66	1.0000	1.66	22.68	**0.00**	0.50	0.10	0.00	0.10	-0.10
25/09/2006	0.20	1.37	1.0000	1.37	23.85	**0.00**	0.00	0.00	0.00	0.00	0.00
26/09/2006	5.00	1.31	1.0000	1.31	20.17	**0.00**	0.00	0.00	0.00	0.00	0.00
27/09/2006	0.40	1.13	1.0000	1.13	20.89	**0.00**	0.00	0.00	0.00	0.00	0.00
28/09/2006	0.50	1.55	1.0000	1.55	21.94	**0.00**	0.00	0.00	0.00	0.00	0.00
29/09/2006	0.60	1.59	1.0000	1.59	22.93	**0.00**	0.00	0.00	0.00	0.00	0.00
30/09/2006	5.20	1.17	1.0000	1.17	18.90	**0.00**	0.20	0.04	0.00	0.04	-0.04
01/10/2006	2.20	1.05	1.0000	1.05	17.75	**0.00**	0.00	0.00	0.00	0.00	0.00
02/10/2006	1.20	1.21	1.0000	1.21	17.76	**0.00**	0.00	0.00	0.00	0.00	0.00
03/10/2006	0.00	1.50	1.0000	1.50	19.26	**0.00**	0.00	0.00	0.00	0.00	0.00
04/10/2006	8.10	1.31	1.0000	1.31	12.47	**0.00**	3.10	0.62	0.00	0.62	-0.62
05/10/2006	11.70	0.88	1.0000	0.88	1.65	**0.00**	6.70	1.34	0.00	1.34	-1.34
06/10/2006	6.30	1.50	1.0000	1.50	0.00	**3.15**	1.30	0.26	0.00	0.26	2.89
07/10/2006	0.10	1.26	1.0000	1.26	1.16	**0.00**	0.00	0.00	0.00	0.00	0.00
08/10/2006	6.60	0.99	1.0000	0.99	0.00	**4.45**	1.60	0.32	0.00	0.32	4.13
09/10/2006	0.00	1.15	1.0000	1.15	1.15	**0.00**	0.00	0.00	0.00	0.00	0.00
10/10/2006	18.20	0.88	1.0000	0.88	0.00	**16.16**	13.20	2.64	0.00	2.64	13.52
11/10/2006	0.30	1.09	1.0000	1.09	0.79	**0.00**	0.00	0.00	0.00	0.00	0.00
12/10/2006	0.00	1.67	1.0000	1.67	2.46	**0.00**	0.00	0.00	0.00	0.00	0.00
13/10/2006	0.00	1.30	1.0000	1.30	3.76	**0.00**	0.00	0.00	0.00	0.00	0.00

Date	Rainfall	PE	S.F.	AE	SMD	**Recharge**	Pot. Runoff	Runoff 1	Runoff 2	Runoff	Recharge
14/10/2006	0.00	1.30	1.0000	1.30	5.06	**0.00**	0.00	0.00	0.00	0.00	0.00
15/10/2006	0.00	0.71	1.0000	0.71	5.77	**0.00**	0.00	0.00	0.00	0.00	0.00
16/10/2006	0.00	0.77	1.0000	0.77	6.54	**0.00**	0.00	0.00	0.00	0.00	0.00
17/10/2006	6.00	0.74	1.0000	0.74	1.28	**0.00**	1.00	0.20	0.00	0.20	-0.20
18/10/2006	3.90	1.00	1.0000	1.00	0.00	**1.62**	0.00	0.00	0.00	0.00	1.62
19/10/2006	5.70	0.48	1.0000	0.48	0.00	**5.22**	0.70	0.14	0.00	0.14	5.08
20/10/2006	1.00	0.55	1.0000	0.55	0.00	**0.45**	0.00	0.00	0.00	0.00	0.45
21/10/2006	4.80	1.28	1.0000	1.28	0.00	**3.52**	0.00	0.00	0.00	0.00	3.52
22/10/2006	0.30	0.93	1.0000	0.93	0.63	**0.00**	0.00	0.00	0.00	0.00	0.00
23/10/2006	0.00	0.75	1.0000	0.75	1.38	**0.00**	0.00	0.00	0.00	0.00	0.00
24/10/2006	0.00	0.95	1.0000	0.95	2.33	**0.00**	0.00	0.00	0.00	0.00	0.00
25/10/2006	34.50	0.78	1.0000	0.78	0.00	**31.40**	29.50	0.00	8.85	8.85	22.55
26/10/2006	1.00	0.98	1.0000	0.98	0.00	**0.02**	0.00	0.00	0.00	0.00	0.02
27/10/2006	0.70	0.93	1.0000	0.93	0.23	**0.00**	0.00	0.00	0.00	0.00	0.00
28/10/2006	1.00	0.56	1.0000	0.56	0.00	**0.21**	0.00	0.00	0.00	0.00	0.21
29/10/2006	0.30	0.49	1.0000	0.49	0.19	**0.00**	0.00	0.00	0.00	0.00	0.00
30/10/2006	0.80	0.84	1.0000	0.84	0.23	**0.00**	0.00	0.00	0.00	0.00	0.00
31/10/2006	0.00	0.80	1.0000	0.80	1.03	**0.00**	0.00	0.00	0.00	0.00	0.00
01/11/2006	0.00	0.50	1.0000	0.50	1.53	**0.00**	0.00	0.00	0.00	0.00	0.00
02/11/2006	0.00	0.35	1.0000	0.35	1.88	**0.00**	0.00	0.00	0.00	0.00	0.00
03/11/2006	0.20	0.44	1.0000	0.44	2.12	**0.00**	0.00	0.00	0.00	0.00	0.00
04/11/2006	0.00	0.69	1.0000	0.69	2.81	**0.00**	0.00	0.00	0.00	0.00	0.00
05/11/2006	0.00	0.60	1.0000	0.60	3.41	**0.00**	0.00	0.00	0.00	0.00	0.00
06/11/2006	0.70	0.50	1.0000	0.50	3.21	**0.00**	0.00	0.00	0.00	0.00	0.00
07/11/2006	3.20	0.60	1.0000	0.60	0.61	**0.00**	0.00	0.00	0.00	0.00	0.00
08/11/2006	0.40	0.39	1.0000	0.39	0.60	**0.00**	0.00	0.00	0.00	0.00	0.00
09/11/2006	0.10	0.38	1.0000	0.38	0.88	**0.00**	0.00	0.00	0.00	0.00	0.00
10/11/2006	2.80	0.94	1.0000	0.94	0.00	**0.98**	0.00	0.00	0.00	0.00	0.98
11/11/2006	0.10	0.72	1.0000	0.72	0.62	**0.00**	0.00	0.00	0.00	0.00	0.00
12/11/2006	1.50	0.64	1.0000	0.64	0.00	**0.24**	0.00	0.00	0.00	0.00	0.24
13/11/2006	3.00	0.77	1.0000	0.77	0.00	**2.24**	0.00	0.00	0.00	0.00	2.24
14/11/2006	5.70	0.68	1.0000	0.68	0.00	**5.02**	0.70	0.14	0.00	0.14	4.88
15/11/2006	21.50	0.44	1.0000	0.44	0.00	**21.06**	16.50	0.00	4.95	4.95	16.11
16/11/2006	7.80	0.60	1.0000	0.60	0.00	**7.20**	2.80	0.56	0.00	0.56	6.64
17/11/2006	1.80	0.50	1.0000	0.50	0.00	**1.30**	0.00	0.00	0.00	0.00	1.30
18/11/2006	0.20	0.67	1.0000	0.67	0.47	**0.00**	0.00	0.00	0.00	0.00	0.00
19/11/2006	10.50	0.81	1.0000	0.81	0.00	**9.22**	5.50	1.10	0.00	1.10	8.12
20/11/2006	1.20	0.63	1.0000	0.63	0.00	**0.57**	0.00	0.00	0.00	0.00	0.57
21/11/2006	0.70	0.87	1.0000	0.87	0.17	**0.00**	0.00	0.00	0.00	0.00	0.00
22/11/2006	8.60	0.50	1.0000	0.50	0.00	**7.94**	3.60	0.72	0.00	0.72	7.22
23/11/2006	1.00	1.02	1.0000	1.02	0.01	**0.00**	0.00	0.00	0.00	0.00	0.00
24/11/2006	6.00	0.75	1.0000	0.75	0.00	**5.23**	1.00	0.20	0.00	0.20	5.03
25/11/2006	0.10	0.72	1.0000	0.72	0.62	**0.00**	0.00	0.00	0.00	0.00	0.00
26/11/2006	5.00	0.50	1.0000	0.50	0.00	**3.88**	0.00	0.00	0.00	0.00	3.88
27/11/2006	4.00	1.17	1.0000	1.17	0.00	**2.83**	0.00	0.00	0.00	0.00	2.83
28/11/2006	0.40	0.82	1.0000	0.82	0.42	**0.00**	0.00	0.00	0.00	0.00	0.00
29/11/2006	0.00	1.15	1.0000	1.15	1.57	**0.00**	0.00	0.00	0.00	0.00	0.00
30/11/2006	18.60	1.64	1.0000	1.64	0.00	**15.39**	13.60	2.72	0.00	2.72	12.67
01/12/2006	1.50	0.72	1.0000	0.72	0.00	**0.79**	0.00	0.00	0.00	0.00	0.79
02/12/2006	6.00	1.08	1.0000	1.08	0.00	**4.92**	1.00	0.20	0.00	0.20	4.72
03/12/2006	1.20	1.17	1.0000	1.17	0.00	**0.03**	0.00	0.00	0.00	0.00	0.03
04/12/2006	15.00	0.94	1.0000	0.94	0.00	**14.06**	10.00	2.00	0.00	2.00	12.06
05/12/2006	1.40	0.95	1.0000	0.95	0.00	**0.45**	0.00	0.00	0.00	0.00	0.45
06/12/2006	3.00	0.98	1.0000	0.98	0.00	**2.02**	0.00	0.00	0.00	0.00	2.02
07/12/2006	7.70	1.18	1.0000	1.18	0.00	**6.52**	2.70	0.54	0.00	0.54	5.98
08/12/2006	0.10	0.40	1.0000	0.40	0.30	**0.00**	0.00	0.00	0.00	0.00	0.00
09/12/2006	5.10	0.26	1.0000	0.26	0.00	**4.54**	0.10	0.02	0.00	0.02	4.52
10/12/2006	9.50	1.02	1.0000	1.02	0.00	**8.48**	4.50	0.90	0.00	0.90	7.58
11/12/2006	1.00	0.33	1.0000	0.33	0.00	**0.67**	0.00	0.00	0.00	0.00	0.67
12/12/2006	0.50	0.90	1.0000	0.90	0.40	**0.00**	0.00	0.00	0.00	0.00	0.00
13/12/2006	2.50	1.07	1.0000	1.07	0.00	**1.03**	0.00	0.00	0.00	0.00	1.03
14/12/2006	28.00	0.70	1.0000	0.70	0.00	**27.30**	23.00	0.00	6.90	6.90	20.40
15/12/2006	4.20	0.42	1.0000	0.42	0.00	**3.78**	0.00	0.00	0.00	0.00	3.78
16/12/2006	1.80	0.31	1.0000	0.31	0.00	**1.49**	0.00	0.00	0.00	0.00	1.49
17/12/2006	2.00	0.31	1.0000	0.31	0.00	**1.70**	0.00	0.00	0.00	0.00	1.70
18/12/2006	0.20	0.20	1.0000	0.20	0.00	**0.00**	0.00	0.00	0.00	0.00	0.00
19/12/2006	0.00	0.05	1.0000	0.05	0.05	**0.00**	0.00	0.00	0.00	0.00	0.00
20/12/2006	0.00	0.00	1.0000	0.00	0.05	**0.00**	0.00	0.00	0.00	0.00	0.00
21/12/2006	0.00	0.38	1.0000	0.38	0.43	**0.00**	0.00	0.00	0.00	0.00	0.00
22/12/2006	0.00	0.07	1.0000	0.07	0.50	**0.00**	0.00	0.00	0.00	0.00	0.00
23/12/2006	0.20	0.07	1.0000	0.07	0.38	**0.00**	0.00	0.00	0.00	0.00	0.00
24/12/2006	0.20	0.00	1.0000	0.00	0.18	**0.00**	0.00	0.00	0.00	0.00	0.00
25/12/2006	0.20	0.38	1.0000	0.38	0.36	**0.00**	0.00	0.00	0.00	0.00	0.00
26/12/2006	4.00	0.52	1.0000	0.52	0.00	**3.12**	0.00	0.00	0.00	0.00	3.12
27/12/2006	6.30	0.47	1.0000	0.47	0.00	**5.83**	1.30	0.26	0.00	0.26	5.57
28/12/2006	9.20	0.34	1.0000	0.34	0.00	**8.86**	4.20	0.84	0.00	0.84	8.02
29/12/2006	8.00	1.11	1.0000	1.11	0.00	**6.89**	3.00	0.60	0.00	0.60	6.29
30/12/2006	1.10	0.81	1.0000	0.81	0.00	**0.29**	0.00	0.00	0.00	0.00	0.29

Date	Rainfall	PE	S.F.	AE	SMD	**Recharge**	Pot. Runoff	Runoff 1	Runoff 2	Runoff	Recharge
31/12/2006	9.10	0.74	1.0000	0.74	0.00	**8.36**	4.10	0.82	0.00	0.82	7.54

Table A-2: Summary of recharge values that were used as modelled inputs.

Date	Recharge mm/month	Date	Recharge mm/month	Date	Recharge mm/month
Jan-97	**5.20**	Dec-00	**98.98**	Nov-04	**31.23**
Feb-97	**65.45**	Jan-01	**27.75**	Dec-04	**39.84**
Mar-97	**3.14**	Feb-01	**32.11**	Jan-05	**59.58**
Apr-97	**0.00**	Mar-01	**4.29**	Feb-05	**51.22**
May-97	**0.00**	Apr-01	**20.49**	Mar-05	**7.10**
Jun-97	**0.00**	May-01	**0.00**	Apr-05	**49.20**
Jul-97	**0.00**	Jun-01	**0.00**	May-05	**21.60**
Aug-97	**0.00**	Jul-01	**0.00**	Jun-05	**0.00**
Sep-97	**0.00**	Aug-01	**0.00**	Jul-05	**0.00**
Oct-97	**12.52**	Sep-01	**0.00**	Aug-05	**0.00**
Nov-97	**73.63**	Oct-01	**0.00**	Sep-05	**0.00**
Dec-97	**57.61**	Nov-01	**0.00**	Oct-05	**28.35**
Jan-98	**99.97**	Dec-01	**0.00**	Nov-05	**57.36**
Feb-98	**0.00**	Jan-02	**0.00**	Dec-05	**46.49**
Mar-98	**47.86**	Feb-02	**89.70**	Jan-06	**19.81**
Apr-98	**57.78**	Mar-02	**8.01**	Feb-06	**40.49**
May-98	**0.00**	Apr-02	**22.34**	Mar-06	**38.94**
Jun-98	**53.62**	May-02	**22.03**	Apr-06	**4.61**
Jul-98	**0.00**	Jun-02	**36.17**	May-06	**12.21**
Aug-98	**0.00**	Jul-02	**0.00**	Jun-06	**0.00**
Sep-98	**5.20**	Aug-02	**0.00**	Jul-06	**0.00**
Oct-98	**72.30**	Sep-02	**0.00**	Aug-06	**0.00**
Nov-98	**74.59**	Oct-02	**91.18**	Sep-06	**0.00**
Dec-98	**80.98**	Nov-02	**133.20**	Oct-06	**66.20**
Jan-99	**90.76**	Dec-02	**73.86**	Nov-06	**83.10**
Feb-99	**23.35**	Jan-03	**45.10**	Dec-06	**111.12**
Mar-99	**26.11**	Feb-03	**18.55**		
Apr-99	**7.95**	Mar-03	**25.66**		
May-99	**3.27**	Apr-03	**0.00**		
Jun-99	**0.55**	May-03	**19.43**		
Jul-99	**0.00**	Jun-03	**0.00**		
Aug-99	**0.00**	Jul-03	**8.08**		
Sep-99	**55.13**	Aug-03	**0.00**		
Oct-99	**22.73**	Sep-03	**0.00**		
Nov-99	**53.09**	Oct-03	**17.93**		
Dec-99	**80.82**	Nov-03	**48.21**		
Jan-00	**39.91**	Dec-03	**71.86**		
Feb-00	**52.27**	Jan-04	**94.96**		
Mar-00	**8.67**	Feb-04	**19.55**		
Apr-00	**5.97**	Mar-04	**19.56**		
May-00	**25.78**	Apr-04	**16.67**		
Jun-00	**10.52**	May-04	**1.57**		
Jul-00	**0.00**	Jun-04	**0.00**		
Aug-00	**0.00**	Jul-04	**0.00**		
Sep-00	**0.00**	Aug-04	**0.00**		
Oct-00	**65.69**	Sep-04	**0.00**		
Nov-00	**112.98**	Oct-04	**56.90**		

APPENDIX B

ASSESSMENT OF VARIABLE HEAD TEST

B.1 INTRODUCTION

This section includes a brief literature review of the methods used to analyse variable head tests (VHT) and then analyses two borehole configurations under varying conditions using numerical modelling. The VHT assume a rigid aquifer with no change in total head. Hvorslev (1951) developed seven cases labelled Cases A to G for which formulae were developed to determine the permeability by a constant or variable head test. For the purposes of the modelling Case C, a borehole flush bottom in a uniform soil, (Eq. B-1, B-2, and B-3), and Case G, a well point filter in a uniform soil, (Eq. B-4 - B-7) will be examined (Hvorslev, 1951). The mean hydraulic conductivity, K_m, is defined using the diameter of the intake, D, the diameter of the standpipe, d, the piezometer head H_1, for time ,t_1, the piezometer head H_2, for time ,t_2, and the basic time lag, T.

$$K_m = \frac{\pi \cdot d^2}{11 \cdot D \cdot (t_2 - t_1)} \ln \frac{H_1}{H_2} \qquad \textbf{Eq. B-1}$$

or

$$K_m = \frac{\pi \cdot D}{11(t_2 - t_1)} \ln \frac{H_1}{H_2} \text{ for d = D} \qquad \textbf{Eq. B-2}$$

and

$$K_m = \frac{\pi \cdot d^2}{11 \cdot D \cdot T} \text{ and } K_m = \frac{\pi \cdot D}{11 \cdot T} \qquad \textbf{Eq. B-3}$$

for $d = D$ as a basic time lag equation.

$$K_h = \frac{d^2 \cdot \ln\left[\frac{mL}{D} + \sqrt{1 + \left(\frac{mL}{D}\right)^2}\right]}{8 \cdot L \cdot (t_2 - t_1)} \ln \frac{H_1}{H_2} \qquad \textbf{Eq. B-4}$$

or

$$K_h = \frac{d^2 \cdot \ln\left(\frac{2mL}{D}\right)}{8 \cdot L \cdot (t_2 - t_1)} \ln \frac{H_1}{H_2} \text{ for } \frac{mL}{D} > 4 \qquad \textbf{Eq. B-5}$$

and

$$k_h = \frac{d^2 \cdot \ln\left[\frac{mL}{D} + \sqrt{1 + \left(\frac{mL}{D}\right)^2}\right]}{8 \cdot L \cdot T} \qquad \textbf{Eq. B-6}$$

or

$$K_h = \frac{d^2 \cdot \ln\left(\frac{2mL}{D}\right)}{8 \cdot L \cdot T} \text{ for } \frac{mL}{D} > 4 \qquad \textbf{Eq. B-7}$$

B.2 PLAXIS GROUNDWATER FLOW EQUATION

The groundwater flow equation in PLAXIS is based on Darcy's Law. Considering flow in a vertical x-y-plane the flowing equations apply:

$$q_x = -K_x \frac{\partial h}{\partial x} \;,\; q_y = -K_y \frac{\partial h}{\partial y} \qquad \textbf{Eq. B-8}$$

The equations express that the specific discharge, q, follows from the permeability, K, and the gradient of the groundwater head. The head, h, is defined using the vertical position, y, the stress in the pore fluid (negative for pressure), p, and the unit weight of the pore fluid, γ_w.

$$h = y - \frac{p}{\gamma_w} \qquad \textbf{Eq. B-9}$$

For steady flow the continuity condition applies.

$$\frac{\partial q_x}{\partial x} + \frac{\partial q_y}{\partial y} = 0 \qquad \textbf{Eq. B-10}$$

This equation expresses that there is no net inflow or outflow in an elementary area, as illustrated in Figure B.1.

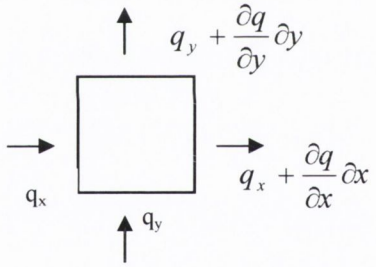


Figure B.1: Flows in and out of an elementary area.

B.3 PLAXIS MODELLING

Variable head tests (VHT) were modelled using the finite element modelling software, PLAXIS, to determine the intake factor for the Case C and Case G well geometries. The intake factor is dependant of the length (L) and diameter (d) of the borehole cavity. Thus to examine the intake factor, various boreholes were examined with changes to L and d. Two VHTs were modelled, one with the well casing extending the entire depth of the borehole and another with the casing extending for the majority of the borehole to a gravel pack at the bottom 1 m of the borehole. The geometry of the two tests is shown in Figures B.1 and B.2. Each case was simulated with borehole diameters of 0.2 m, 0.6 m, and 1 m.

A two-dimensional axisymmetric mesh, having the dimensions of 10 m wide by 10 m deep as shown in Figures B.2 was used. The VHT were modelled for a borehole within an isotropic, homogeneous, sandy gravel (parameters are located in Table B-1). The mesh was refined within the clusters surrounding the bottom of the borehole, within the borehole and around the line at the bottom of the borehole and the line of the well edge to obtain a more accurate calculation of the flow into the well. The Case C and Case G geometries are shown in Figures B.3 and B.4. The area above the groundwater level within the borehole was made inactive as it would be filled with air and would not affect the VHT. The well casing is represented in the model by a beam element (shown in blue) with the material properties of steel (parameters are located in Table B-2). The interface boundary of the steel is set to be impermeable for this model. The outside boundary of the model is set as a no-flow boundary and the right outer boundary is set as a constant head.

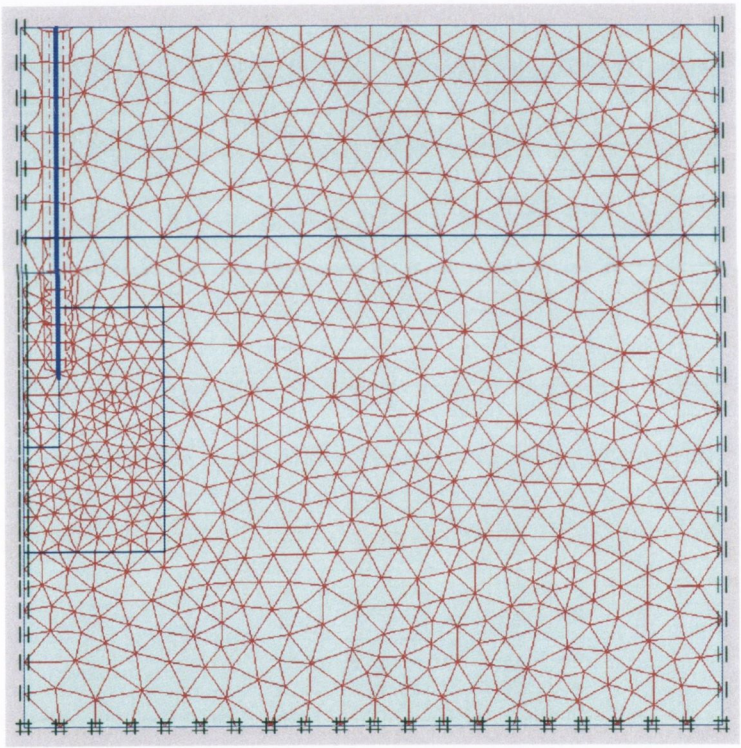


Figure B.2: Finite element mesh for the PLAXIS modelling. The mesh was refined around the edge of the well and the bottom of the borehole.

Table B-1: Soil parameters for the PLAXIS VHT modelling

MODEL PARAMETER	SETTING
Material Model	Mohr-Coulomb
Material Type	Drained
γ_{dry} , γ_{wet}	20 kN/m^3
Hydraulic Conductivity K_x, K_y	1.0x10^{-4} m/s
Void Ratio e_{init}	1.0

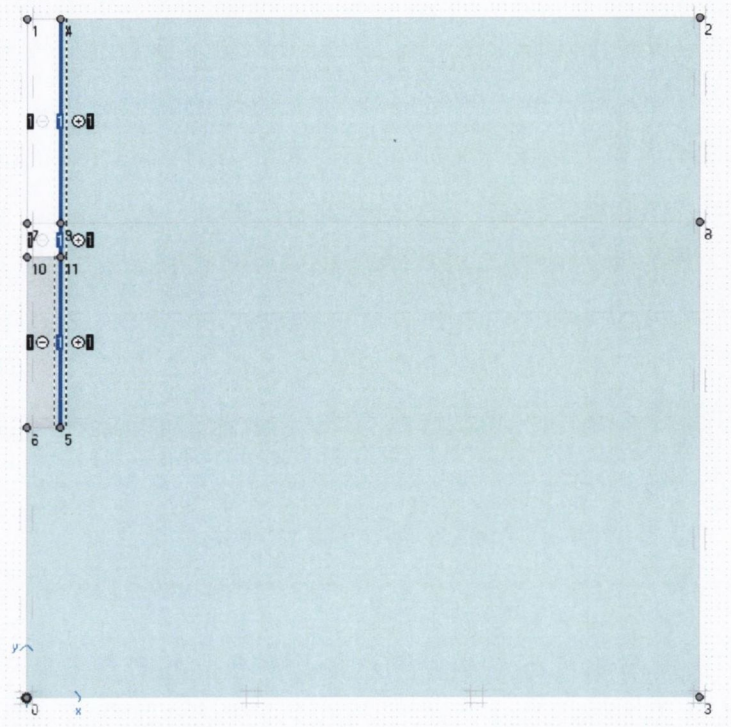


Figure B.3: Case C well geometry. The turquoise colour represents the sandy gravel and the darker turquoise is the water filling the borehole.

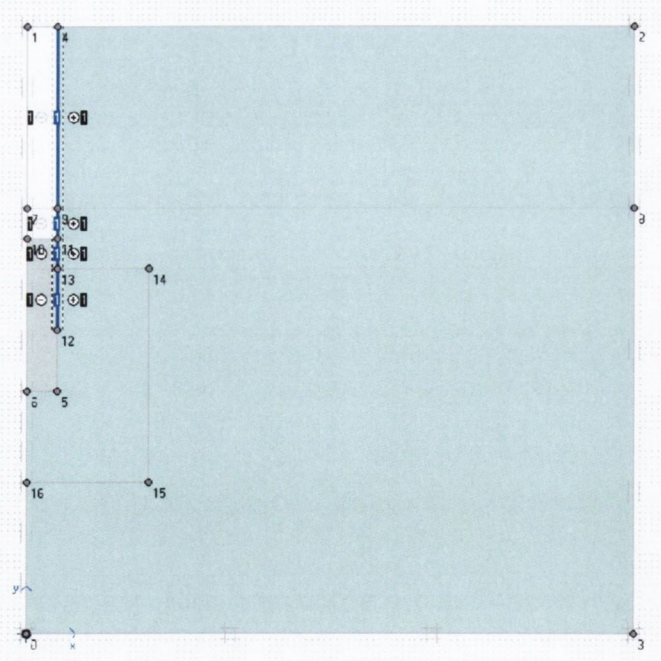


Figure B.4: Case G well geometry. The turquoise colour represents the sandy gravel and the darker turquoise is the water filling the borehole.

Table B-2: Steel parameters used to represent the well casing.

MODEL PARAMETER	SETTING
Axial stiffness EA	$7.6 \times 10^{+6}$ kN/m
Flexural rigidity EI	$1.0 \times 10^{+6}$ kNm^2/m
Thickness d	1.257 m
Weight w	7.8 kN/m/m
Poisson's ratio	0.300

The VHT was modelled as a staged construction where the initial stage had uniform sandy gravel with a horizontal phreatic line. The second stage involved the borehole being filled with water to the phreatic line and the area above the phreatic line being made inactive. Figures B.5 and B.6 show the resultant hydraulic heads for the VHT and Figure B.7 and B.8 show the flow paths for Case C and G, respectively.

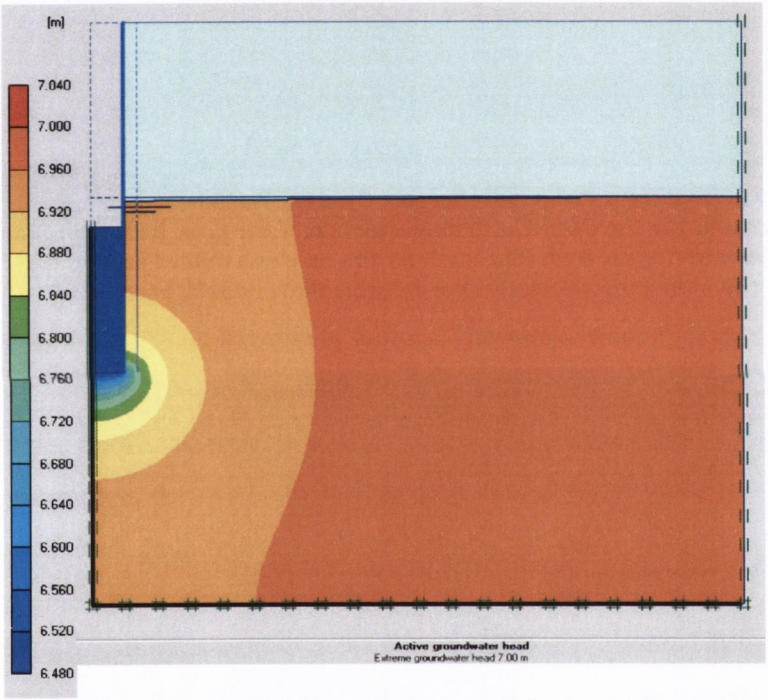


Figure B.5: Groundwater heads derived from Plaxis modelling for Case C. The flow is primarily horizontal except for at close proximity to the well. The model calculates drawdown of the watertable.

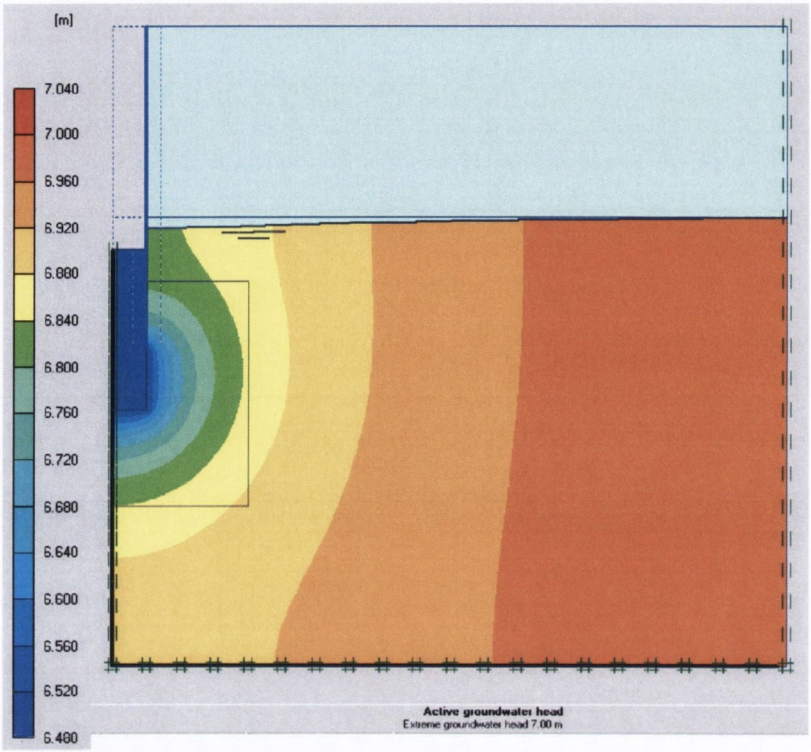


Figure B.6: Groundwater heads derived from Plaxis modelling for Case G. The flow is primarily horizontal except for at close proximity to the well. The drawdown of the water table is more pronounced in this case as there is more water entering the well. The mesh for this case was refined around the borehole, within the blue box, in an attempt to calculate more accurate flows into the borehole.

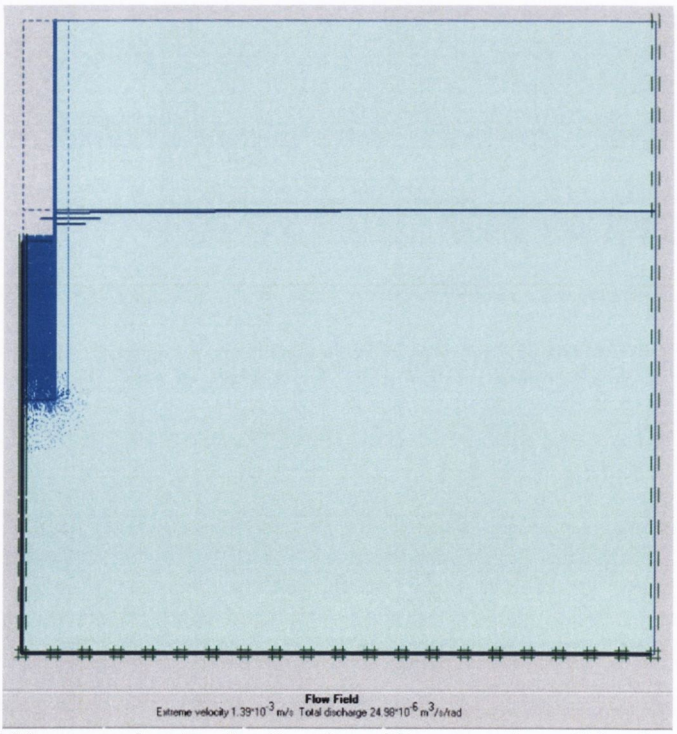


Figure B.7: Flow field arrows showing the direction of flow near the well for Case C. Note that the total discharge for this well configuration was 24.98×10^{-6} $m^3/s/rad$.

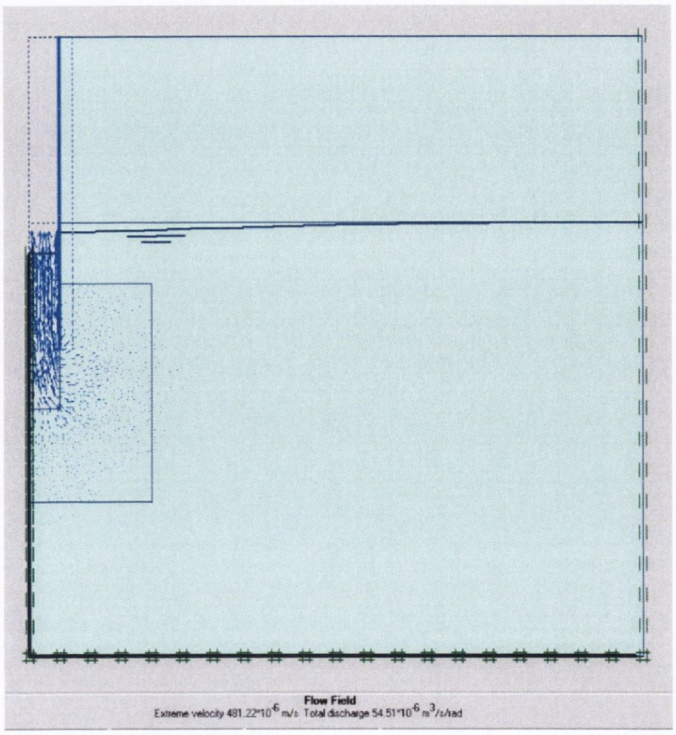


Figure B.8: Flow field arrows showing the direction of flow near the well for Case G. Note that the total discharge for this well configuration was 54.51×10^{-6} $m^3/s/rad$.

Table B-3 contains the values for total discharge obtained by Plaxis modelling that were used to calculate the intake factor. The intake factor for each scenario was divided by the diameter of the borehole well so that they could be directly compared. In addition several other published methods of determining the intake factor were calculated using the same parameters that were used in the Plaxis modelling. When comparing the results the Plaxis modelling gave the highest F/D value. The value that it most closely approached was that derived by Ratnam et al. (2001). The F/D value derived by Hvorslev (1951) for Case C clearly acknowledges that it is only estimation and that there are inconsistencies as Case G approaches Case C. For the zero length condition Hvorslev gives the empirical expression F = 2.75D. For Case G where L > 0 Hvorslev presents the approximation of the form:

$$F = \frac{2\pi L}{\ln\left\{ L/D + \sqrt{\left(1 + L/D\right)^2} \right\}} \qquad \textbf{Eq. B-11}$$

Table B-3: Data used to calculate F/D values for the zero length scenario (Case C)

	RADIUS 0.1 M	RADIUS 0.3 M	RADIUS 0.5 M	
Total discharge $m^3/s/rad$	2.63×10^{-5}	1.58×10^{-5}	5.44×10^{-6}	
Discharge q (m^3/s)	1.65×10^{-4}	9.90×10^{-5}	3.42×10^{-5}	
Permeability K (m/s)	1.00×10^{-4}	1.00×10^{-4}	1.00×10^{-4}	
Head H (m)	0.50	0.50	0.50	Average Values for F/D
Intake factor F=Q/KH	3.31	1.98	0.68	
Radius r (m)	0.50	0.30	0.10	
Diameter D=2r (m)	1.00	0.60	0.20	
Length L (m)	0.00	0.00	0.00	
L/D	0.00	0.00	0.00	
Plaxis F/D	3.31	3.30	3.42	3.34
Hvorslev F/D				2.75
Youngs (1980)				2.80
Brand & Premchitt (1980)				2.63
Luthin & Kirkham (1949)				2.50
Ratnam et al (2001)				3.14

The VHT were also modelled for a borehole with a drop in head of 0.5 m and a screened length of 1 m and 0.5 m (Case G). Both screened lengths were modelled for boreholes with diameters of 0.2 m, 0.6 m, and 1 m. This gives a range of L/D ratios to be plotted against the calculated F/D ratios in an effort to examine the intake factors. The data for the Case G models is located in Table B-4 and the graph showing the results of the PLAXIS modelling as well as the results for the same well configurations from Hvorslev (1951), Schneebeli (1954), and Ratnam *et al.* (2001).

Table B-4: Data used for the scenario where the length of the screened section varies from 0.5 m to 1 m (Case G)

TOTAL DISCHARGE $m^3/s/rad$		4.76×10^{-5}	3.59×10^{-5}	6.08×10^{-5}	4.4×10^{-5}	1.78×10^{-5}	2.59×10^{-5}
Discharge q (m^3/s)		2.99×10^{-4}	2.26×10^{-4}	3.82×10^{-4}	2.80×10^{-4}	1.12×10^{-4}	1.63×10^{-4}
Extreme velocity (m/s)		4.82×10^{-4}	8.84×10^{-4}	5.50×10^{-4}	1.04×10^{-3}	3.55×10^{-3}	5.12×10^{-3}
Permeability K (m/s)		0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Head H (m)		0.5	0.5	0.5	0.5	0.5	0.5
Intake factor F=Q/KH		5.98	4.51	7.64	5.61	2.23	3.25
Radius r (m)		0.5	0.3	0.5	0.3	0.1	0.1
Diameter D=2r (m)	Case C results	1	0.6	1	0.6	0.2	0.2
Length L (m)	0	0.5	0.5	1	1	0.5	1
L/D	0	0.50	0.83	1.00	1.67	2.50	5.00
Plaxis F/D	3.34	5.98	7.52	7.64	9.34	11.16	16.27
Hvorslev (1951)	2.75	6.53	6.90	7.13	8.16	9.54	13.59
Schneebeli (1954)	3.14	5.44	6.54	7.02	8.70	10.42	14.40
Ratnam et al (2001)	3.14	4.81	5.52	5.86	7.10	8.54	12.52

As illustrated in Figure B.10 the intake factors calculated using PLAXIS are greater than the other equations. Only the intake factor calculated using Hvorslev's equation for an aspect ratio (L/D) of 0.5 was greater than that calculated using PLAXIS for the same aspect ratio. The equation derived by Ratnam et al. gives the smallest intake factor for all aspect ratios greater than zero. An explanation as to why the intake factors calculated using PLAXIS are larger is that the aquifer is drawndown when the variable head test is conducted. The other methods assume that the water table remains constant during the test as only a small amount of water is injected or removed during a VHT. This appears to be a limitation of the PLAXIS finite element software. Thus another software package SVFlux was used to analyse the VHT and model the flows into the boreholes. These results are compared to those calculated using the PLAXIS model.

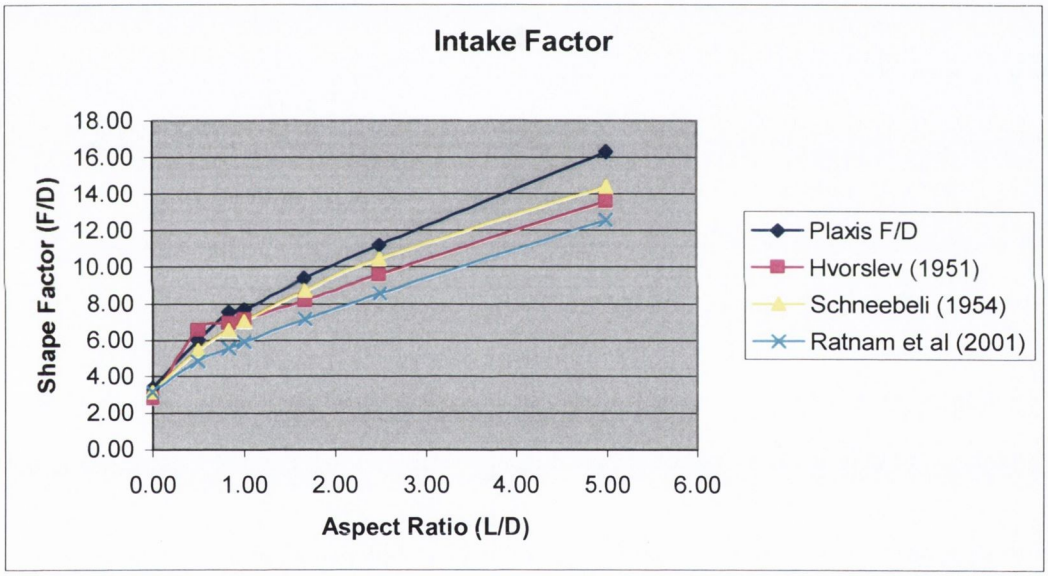


Figure B.9: Graph of the intake factor as calculated using Plaxis, Hvorslev's equation, Schneebeli's equation, and Ratnam et al.'s equation.

B.4 SVFLUX MODELLING

SVFlux is a finite element groundwater modelling program. SVFlux automatically optimizes the mesh to have the maximum refinement in the areas which need it the most. SVFlux also robustly handles both saturated and unsaturated soils. For unsaturated soils a soil water characteristic curve (SWCC) can be copied from its sister product SoilVision which contains a database of soil properties.

As with all FE software packages the problem is descretized into nodes and elements. The governing equations are written for each element and solved simultaneously. Variational calculus is then employed to develop a solution of which the

Galerkin method is the most common. In SVFlux the governing equation (Laplace) for steady-state flow in 2D is:

$$\frac{\partial}{\partial x}\left(K_x \frac{\partial}{\partial x}\right)+\frac{\partial}{\partial y}\left(K_y \frac{\partial}{\partial y}\right)=0 \qquad \textbf{Eq. B-12}$$

The modelled soil properties were similar to those in PLAXIS. The hydraulic conductivity of the soil was $1.0x10^{-4}$ m/s to simulate a sandy gravel. The screened portion of the borehole was modelled with a permeability of 1.0 m/s. The well was modelled as having a radius of 0.5 m, 0.3 m, and 0.1 m. The drop in head from the sandy gravels to the well was 0.5 m. A no-flow boundary condition was set on the three sides of the model while the top of the model was had a constant head of 7 m. The interface between the sandy gravels and the borehole was set to allow flow through. Fluxes were set at the borehole interface with the sandy gravel so that the flow into the borehole could be measured and the intake factor calculated.

To determine the extent of the model the width was varied until no change in flow was observed. A borehole with a radius of 0.5 m and a screened length of 1 m was the scenario selected. The width where variation in results ceased to occur was 100 m which gave the same results as 500 m. Table B-5 shows the variation in the results with different widths. An interesting effect was that the flows did not vary linearly with the change in boundary condition but instead were lower at very close distances to the borehole (5 m) and then were much larger at mid-range distances (20 – 40 m) and then came back down towards the final result at further distances out (75 m). All the values are within published results; therefore, the range in previously published results may be partly to do with the boundary conditions being closer than ideal.

Table B-5: Results from varying the outer boundary. An outer boundary at 100 m was selected to be used for all models

BOUNDARY	5 M	20 M	40 M	75 M	100 M	500 M
Discharge q (m^3/s)	0.000307	0.000345	0.000349	0.000344	0.000333	0.000333
Permeability K (m/s)	$1.00 x10^{-4}$	$1.00 x10^{-4}$	$1.00 x10^{-4}$	$1.00 x10^{-4}$	$1.00 x10^{-4}$	$1.00 x10^{-4}$
Head H (m)	0.50	0.50	0.50	0.50	0.50	0.50
Intake factor F=q/KH	6.13	6.91	6.98	6.88	6.65	6.65
Radius r (m)	0.50	0.50	0.50	0.50	0.50	0.50
Diameter D=2r (m)	1.00	1.00	1.00	1.00	1.00	1.00
Length L (m)	1.00	1.00	1.00	1.00	1.00	1.00
L/D	1.00	1.00	1.00	1.00	1.00	1.00
Plaxis F/D	6.13	6.91	6.98	6.88	6.65	6.65
Hvorslev (1951)	7.13	7.13	7.13	7.13	7.13	7.13
Schneebeli (1954)	7.02	7.02	7.02	7.02	7.02	7.02
Ratnam et al (2001)	5.86	5.86	5.86	5.86	5.86	5.86

The same process of extending the boundary was preformed for the vertical boundary. The result for a vertical boundary extended to 50 m was found to be equivalent for that at 75 m. Thus a vertical depth of 50 m was used for all the subsequent modelling. Once again the difference in the intake factors calculated is within published values at all depths. The flows obtained at different depths can be found in the Table B-6.

Table B-6: Results obtained by varying the vertical boundary in the model. The value to be used in the modelling is 50 m depth

BOUNDARY	-25 M	-50 M	-75 M
Discharge q (m^3/s)	0.000339	0.000336	0.000336
Permeability K (m/s)	1.00×10^{-4}	1.00×10^{-4}	1.00×10^{-4}
Head H (m)	0.50	0.50	0.50
Intake factor F=q/KH	6.77	6.72	6.72
Radius r (m)	0.50	0.50	0.50
Diameter D=2r (m)	1.00	1.00	1.00
Length L (m)	1.00	1.00	1.00
L/D	1.00	1.00	1.00
Plaxis F/D	6.77	6.72	6.72
Hvorslev (1951)	7.13	7.13	7.13
Schneebeli (1954)	7.02	7.02	7.02
Ratnam et al (2001)	5.86	5.86	5.86

B.5 SVFLUX RESULTS

To determine the intake factor the model was run with wells of varying radius and screen length (Table B-7). The aspect ratio (L/D) is plotted against the intake factor (F/D) and compared with the published results from Hvorslev (1951), Schneebeli (1954), and Ratnam et al (2001) in Figure B.11. This plot shows that for very small aspect ratios (L/D < 1) the intake factors calculated from the flows given in SVFlux are smaller than those published. For mid-range aspect ratios (1 < L/D > 2.5) the intake factors calculated from the flows given in SVFlux are similar published values. For large aspect ratios (L/D > 2.5) the intake factors calculated from flows are larger than published values. This suggests that the relationship between L/D and F/D may not be linear.

Table B-7: Results from intake factor modelling of VHTs

DISCHARGE Q (m^3/s)	$1.97X10^{-4}$	$1.45X10^{-4}$	$3.36X10^{-4}$	$4.05X10^{-4}$	$2.43X10^{-4}$	$4.58X10^{-4}$
Permeability K (m/s)	$1.00x10^{-4}$	$1.00x10^{-4}$	$1.00x10^{-4}$	$1.00x10^{-4}$	$1.00x10^{-4}$	$1.00x10^{-4}$
Head H (m)	0.50	0.50	0.50	0.50	0.50	0.50
Intake factor F=q/KH	3.95	2.89	6.72	8.10	4.87	9.15
Radius r (m)	0.50	0.30	0.50	0.50	0.30	0.50
Diameter D=2r (m)	1.00	0.60	1.00	1.00	0.60	1.00
Length L (m)	0.50	0.50	1.00	1.50	1.00	2.00
L/D	0.50	0.83	1.00	1.50	1.67	2.00
SVFlux F/D	3.95	4.82	6.72	8.10	8.11	9.15
Hvorslev (1951)	6.53	6.90	7.13	7.89	8.16	8.70
Schneebeli (1954)	5.44	6.54	7.02	8.31	8.70	9.42
Ratnam et al (2001)	4.81	5.52	5.86	6.80	7.10	7.69
Discharge q (m^3/s)	$9.40x10^{-5}$	$3.15x10^{-4}$	$3.78x10^{-4}$	$1.48x10^{-4}$	$1.96x10^{-4}$	$2.45x10^{-4}$
Permeability K (m/s)	$1.00x10^{-4}$	$1.00x10^{-4}$	$1.00x10^{-4}$	$1.00x10^{-4}$	$1.00x10^{-4}$	$1.00x10^{-4}$
Head H (m)	0.50	0.50	0.50	0.50	0.50	0.50
Intake factor F=q/KH	1.88	6.29	7.57	2.95	3.93	4.90
Radius r (m)	0.10	0.30	0.30	0.10	0.10	0.10
Diameter D=2r (m)	0.20	0.60	0.60	0.20	0.20	0.20
Length L (m)	0.50	1.50	2.00	1.00	1.50	2.00
L/D	2.50	2.50	3.33	5.00	7.50	10.00
SVFlux F/D	9.40	10.49	12.61	14.77	19.64	24.50
Hvorslev (1951)	9.54	9.54	10.91	13.59	17.37	20.96
Schneebeli (1954)	10.42	10.42	11.89	14.40	17.49	20.12
Ratnam et al (2001)	8.54	8.54	9.91	12.52	16.27	19.90

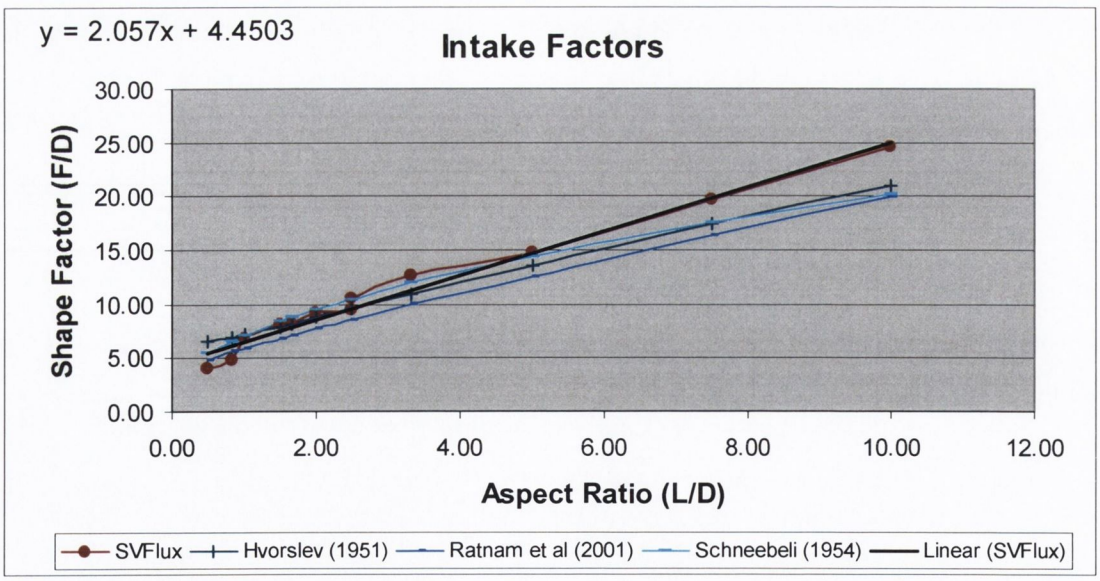


Figure B.10: Plot of intake fact verses aspect ratio as calculated from the SVFlux model. In addition, previous intake factors and aspect ratios as published by Hvorslev (1951), Schneebeli (1954) and Ratnam et al. (2001) are also plotted for comparison.

To examine the Case C the model was constructed in the same manner with the difference that the flux was measured across the top of the model. These results are similar to those obtained using the PLAXIS software (Table B-8).

Table B-8: Intake factors for the zero length case

DISCHARGE Q (m^3/s)	$1.58 X10^{-4}$	$9.40 X10^{-5}$	$3.24 X10^{-5}$
Permeability K (m/s)	$1.00 x10^{-4}$	$1.00 x10^{-4}$	$1.00 x10^{-4}$
Head H (m)	0.50	0.50	0.50
Intake factor F=q/KH	3.31	1.99	0.73
Radius r (m)	0.50	0.30	0.10
Diameter D=2r (m)	1.00	0.60	0.20
Length L (m)	0.00	0.00	0.00
L/D	0.00	0.00	0.00
SVFlux F/D	3.17	3.13	3.24

The initial scenario modelled consisted of fully saturated sandy gravels with all the flow coming from the top of the aquifer. The boundary conditions were changed to unconfined aquifer conditions with a layer of unsaturated sandy gravels, and leaky confined conditions.

The unsaturated case was modelled with the sandy gravel layer extending above the water table so that a zone of unsaturated material was created. The constant head boundary was set at the top of the model (head = 7 m) and the three other sides of the model were set as no-flow boundaries. The unsaturated model results in a lower intake factor than the fully-saturated model (Table B-9).

Table B-9: Comparison of fully-saturated and unsaturated model conditions. The fully-saturated condition is the condition which was modelled previously to determine the intake factors.

	FULLY-SATURATED	UNSATURATED
Discharge q (m^3/s)	$3.36 x10^{-4}$	$3.17 x10^{-4}$
Permeability K (m/s)	$1.00 x10^{-4}$	$1.00 x10^{-4}$
Head H (m)	0.50	0.50
Intake factor F=q/KH	6.72	6.34
Radius r (m)	0.50	0.50
Diameter D=2r (m)	1.00	1.00
Length L (m)	1.00	1.00
L/D	1.00	1.00
SVFlux F/D	6.72	6.34
Hvorslev (1951)	7.13	7.13
Schneebeli (1954)	7.02	7.02
Ratnam et al (2001)	5.86	5.86

Most published intake factors assume homogeneous isotropic soil conditions. However, this is rarely the case in reality. Most soils have a lower vertical hydraulic

conductivity than horizontal hydraulic conductivity. Thus the effect of anisotropy was for a borehole with a screened length of 1 m and radius of 0.1 m, 0.3 m, and 0.5 m. The dimensions and soil properties of the model were the same as the fully-saturated case in the previous section. Both the case where the horizontal conductivity is larger than the vertical conductivity and vice versa were considered. In each case the vertical anisotropy was increased or decreased by one order of magnitude (Table B-10 and Figures B.12, B.13, and B.14).

Table B-10: Results of anisotropy on various borehole configurations

	ANISOTROPIC K_Z RATIO 0.1			ANISOTROPIC K_Z RATIO 10		
Discharge q (m^3/s)	2.01×10^{-4}	1.37×10^{-4}	8.77×10^{-4}	3.29×10^{-4}	2.47×10^{-4}	1.62×10^{-4}
Permeability K (m/s)	1.00×10^{-4}	1.00×10^{-4}	1.00×10^{-4}	1.00×10^{-4}	1.00×10^{-4}	1.00×10^{-4}
Head H (m)	0.50	0.50	0.50	0.50	0.50	0.50
Intake factor F=q/KH	4.03	2.74	1.75	6.58	4.93	3.25
Radius r (m)	0.50	0.30	0.10	0.50	0.30	0.10
Diameter D=2r (m)	1.00	0.60	0.20	1.00	0.60	0.20
Length L (m)	1.00	1.00	1.00	1.00	1.00	1.00
L/D	1.00	1.67	5.00	1.00	1.67	5.00
Plaxis F/D	4.03	4.57	8.77	6.58	8.22	16.23
Hvorslev (1951)	7.13	8.16	13.59	7.13	8.16	13.59
Schneebeli (1954)	7.02	8.70	14.40	7.02	8.70	14.40
Ratnam et al (2001)	5.86	7.10	12.52	5.86	7.10	12.52

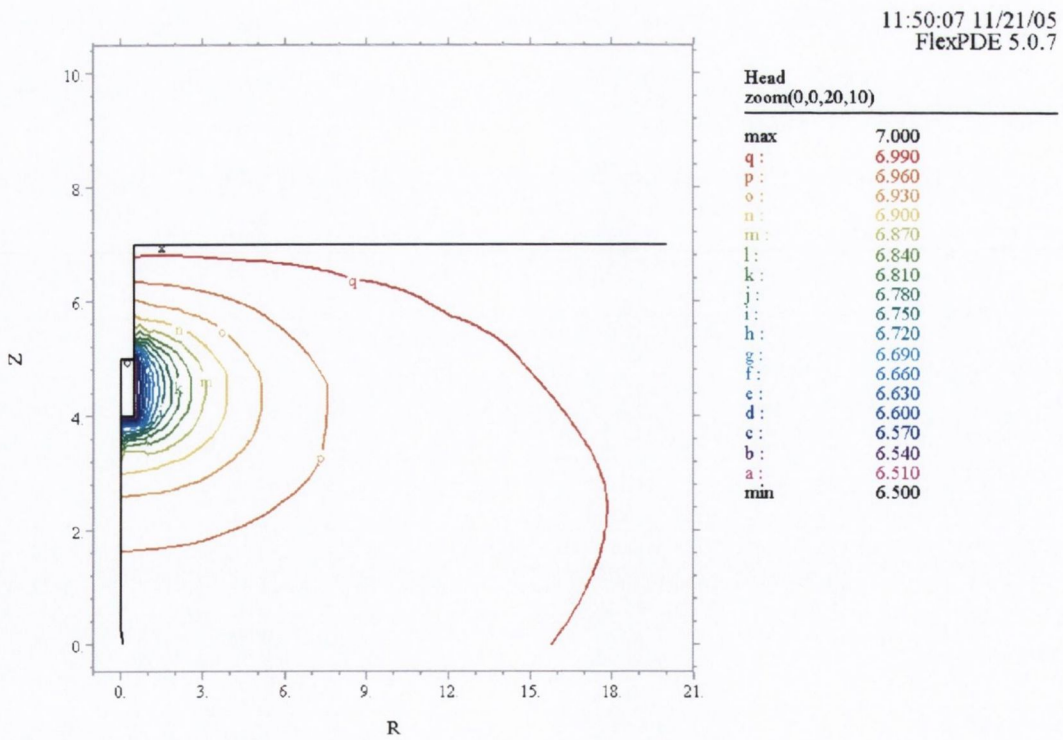
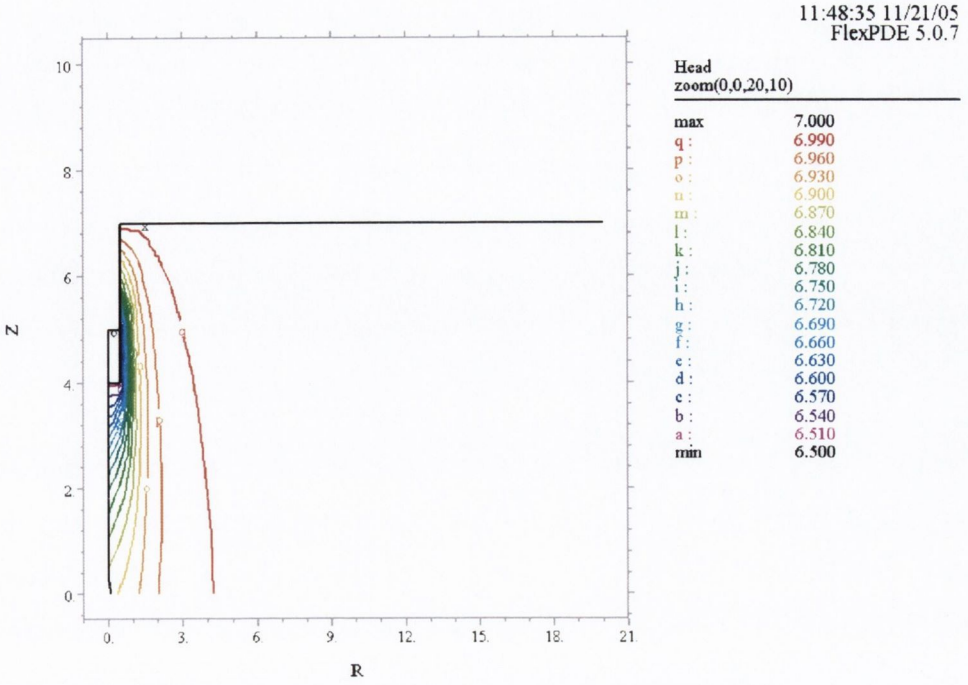
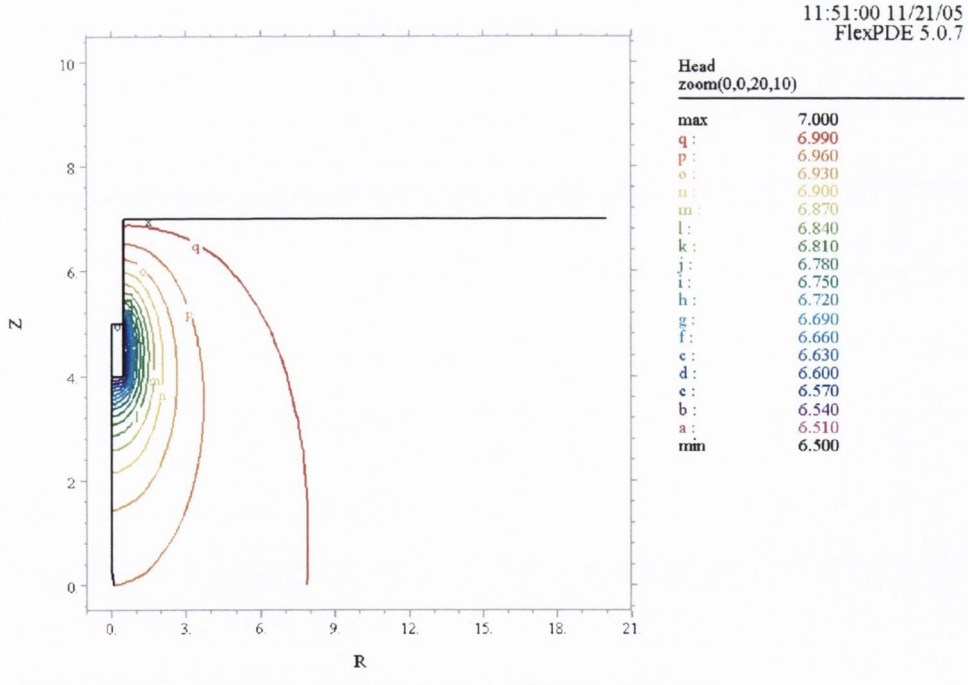


Figure B.11: Finite element mesh for the PLAXIS modelling. The mesh was refined around the edge of the well and the bottom of the borehole.



Variable_Head_Test_Anisotropy: Grid#1 p2 Nodes=733 Cells=338 RMS Err= 0.0018
Stage 1 Vol_Integral= 61753.84

Figure B.12: Heads for the anisotropic case where the K_z ratio is 10. Flow is predominantly in the vertical direction.



Variable_Head_Test_Anisotropy: Grid#2 p2 Nodes=800 Cells=371 RMS Err= 6.e-4
Stage 1 Vol_Integral= 61722.23

Figure B.13: Heads for the isotropic case for comparison to the two anisotropic cases.

B.6 CONCLUSIONS

Variable head tests are often attractive in that they are seen as a quick, easy, and relatively inexpensive method of determining the hydraulic conductivity of an aquifer. However, the value of hydraulic conductivity obtained is dependant on the intake factor which is very changeable depending on the soil conditions. Previous studies have shown that the Hvorslev (1951) calculation frequently overestimates the hydraulic conductivity. The hydraulic conductivity can be overestimated, underestimated or accurate depending on the borehole characteristics and the soil properties.

When varying the length of the screen and borehole radius and the intake factor was plotted against the aspect ratio the slope of the intake factor was greater than those previously published. This means that at small screened lengths to borehole diameter ratios the hydraulic conductivity is overestimated where as at large screened lengths to borehole diameter ratios the hydraulic conductivity is underestimated. This implies that there is an ideal aspect ratio which avoids under- or overestimation of hydraulic conductivity (L/D is between 1 and 2.5). The results of the Case C modelling shows that the intake factor does approach a value close to π as previously suggested by Schneebeli (1954) and Ratnam et al. (2001).

The effect of an unsaturated zone and anisotropic soils on the intake factor was also considered. An unsaturated zone resulted in a lower intake factor than the fully-saturated model. Anisotropy has the largest effect on intake factor of all the parameters considered in this study. When the K_z ratio is set at 0.1 the intake factors were roughly half of those previously published. This would cause a severe overestimation of hydraulic conductivity. This case would not be normally seen in soils but may occasionally be found in rock aquifers with many interconnected joints or overturned bedrock where bedding planes are in the subvertical position which could cause the vertical permeability to be greater than the horizontal permeability. The second anisotropic case is the most commonly found in nature where the horizontal hydraulic conductivity is greater by one order of magnitude than the vertical hydraulic conductivity. This case results in an underestimation of hydraulic conductivity which is more pronounced at greater L/D ratios. This should always be kept in mind when conducting variable head tests in areas where the horizontal hydraulic conductivity is greater than the vertical hydraulic conductivity.

The results from variable head tests are approximate at best if analysed with previously published equations as aquifers rarely are isotropic and homogeneous as the

published equations assume. In order to obtain a hydraulic conductivity that is more than just estimation, a model of the area should be developed to determine an intake factor valid for the physical properties of the aquifer. This process of determining the intake factor detracts from the advantages of variable head tests over other tests such as pump tests, in that it increases the time taken to obtain a hydraulic conductivity and the expense involved.

APPENDIX C

MONITORING BOREHOLE DATA

Table C-1: Groundwater levels in monitoring boreholes.

DATE	MB2			MB4	MB5	MB6	MB7			MB14		MB15	MB17	MB18	MB19		MB28	MB29	MB30	MB31	MB32	MB33	MB35	MB36	MB37	MB 38	MB39	MB41	MB42	MB43	MB44	MB45
	Shallow	Middle	Deep				Shallow	Middle	Deep	Middle	Deep				Shallow	Deep															
11-Jun-98				92.05		89.33											93.88	92.24				93.45				98.34	96.447	96.885	96.2	92.14	93.28	91.95
15-Jun-98																																
17-Jul-98				92.21		89.48											94.8	92.61														
21-Jul-98				92.07		89.36						92.15						92.5				93.44										
27-Jul-98				92.04	91.48	89.33						92.11						92.44				93.4										
11-Aug-98				91.96	91.45	89.28				91.73	91.72		92.2				93.43	92.33			88.82	93.34	86.31								
20-Aug-98				91.9		89.26	89.21	90.83	90.8	91.68	91.66	91.98		94.05				92.26			88.79	93.3										
03-Sep-98	92.49	92.31	92.03	91.8	91.33		89.18	90.76	90.75				92.03	94.01	92.54	93.17	93.17	92.13	92.11	91.33	88.78		86.01		88.08							
22-Sep-98				91.65	91.18	89.15	89.09	90.64	90.65	91.45	91.44	91.72	91.89	93.92	92.37	92.95	92.91	91.95	91.94	91.18	88.73		85.52	84.59	87.93							
12-Oct-98				91.52	91.03	89.07	89.04	90.54	90.55	91.32	91.32	91.57	91.75	93.82	92.24	92.82	92.66	91.8	91.77	91.05	88.68	92.91	85.1	84.69	87.9							
10-Nov-98				91.43	90.92	89.04	89	90.5	90.5	91.2	91.2	91.48		93.68	92.17	92.87	92.45	91.89	91.87	90.96	88.68		85.05	84.84	88.78							
26-Nov-98				91.58	91.06		89.07	90.6	90.62	91.33	91.33	91.66	91.89	93.82	92.32	93.09	92.58	92	91.99	91.07	88.71		85.63	84.85	88.89							
15-Dec-98				91.71	91.2	89.18	89.16	90.7	90.72	91.48	91.48	91.8	92	93.8	92.45	93.23	92.74	92.09	92.08	91.21	88.74	93.06	86.19	84.85	88.85							
11-Jan-99				92.18	91.58		89.38	91.11	91.11	91.91	91.92	92.31	92.53	94.01	92.96	93.83	93.59	92.74	92.72	91.58	88.89	93.49	87.56	84.85	89.35							
03-Feb-99				92.64	92.05	89.62	89.61	91.45	91.44	92.42	92.4	92.76	92.92	94.38	93.4	94.2	94.35	93.04	93.04	92.05	89	93.8	89.04	84.85	89.14							
18-Feb-99				92.71	92.13	89.65	89.64	91.5	91.5	92.52	92.48	92.84	93	94.6	93.53	94.24	94.56	93.06	93.07	92.13	89.01	93.87	89.35	84.85	88.89							
08-Mar-99				92.68	92.1	89.63	89.63	91.49	91.49	92.53	92.44	92.8	93.06	94.71	93.56	94.22	94.59	93.13	93.13	92.09	89.02	93.87	89.23	84.85	89.07							
24-Mar-99				92.7	92.11	89.62	89.61	91.47	91.49	92.48	92.46	92.81	93.01	94.74	93.56	94.19	94.59	93.1	93.09	92.11	89.02	93.91	89.12	84.85	88.76							
08-Apr-99				92.6	92.02	89.56	89.56	91.39	91.39	92.38	92.35	92.7	92.89	94.69	93.44	94.08	94.7	92.98	92.98	92.02	88.99	93.82	88.65	84.85	88.54							
21-Apr-99				92.56	91.99	89.54	89.55	91.37	91.37	92.34	92.32	92.66	92.85	93.82	92.55	93.15	94.37	92.93	92.93	91.98	88.97	93.77	88.27	84.85	88.45							
28-Apr-99				92.46	91.9	89.51	89.5	91.29	91.29	92.23	92.21	92.56	92.75	93.62	93.3	93.92	94.22	92.81	92.82	91.89	88.94	93.72	87.79	84.84	88.43							
20-May-99				92.29	91.73	89.42	89.41	91.15	91.15	92.07	92.05	92.37	92.58	94.49	93.01	93.73	93.91	92.65	92.64	91.72	88.91	93.54	87.23	84.77	88.28							
08-Jun-99				92.11	91.57	89.35	89.33	91.01	91.02	91.9	91.88	92.19	92.42	94.35	92.97	93.59	93.62	92.47	92.47	91.56	88.85	93.38	86.6	84.75	88.2							
23-Jun-99				91.99	91.47	89.28	89.26	90.92	90.92	91.78	91.76	92.07	92.33	94.26	92.83	93.49	93.4	92.35	92.35	91.44	88.84	93.28	86.2	84.68	88.12							
06-Jul-99				91.87	91.36	89.23	89.21	90.84	90.84	91.68	91.66	91.97	92.19	94.17	92.72	93.37	93.22	92.22	92.21	91.34	88.83	93.19	85.92	84.66	88.04							
23-Jul-99				91.73	91.21	89.13	89.12	90.69	90.71	91.5	91.48	91.81	92.05	94.03	92.59	93.23	92.97	92.08	92.08	91.2	88.74	93.04	85.55	84.7	87.98							
11-Aug-99				91.58	91.08	89.08	89.07	90.61	90.61	91.35	91.35	91.65	91.85	93.92	92.37	93.03	92.68	91.88	91.88	91.08	88.69	92.88	85.11	84.6	87.86							
27-Aug-99				91.45	90.98	89.03	89.01	90.48	90.51	91.26	91.24	91.53	91.71	93.86	92.24	92.91	92.47	91.74	91.75	90.99	88.65	92.77	84.78	84.55	87.79							
15-Sep-99				91.31	90.85	88.98	88.98	90.4	90.4	91.15	91.13	91.4	91.57	93.73	92.08	92.73	92.24	91.59	91.62	90.84	88.61	92.66	84.48	84.7	87.77							
29-Sep-99				91.37	90.86	89	89.01	90.45	90.46	91.18	91.18	91.46	91.71	93.67	92.18	92.88	92.17	91.8	91.8	90.86	88.68	92.68	84.6	84.75	88.36							
12-Oct-99	91.93	91.81	91.57	91.38	90.89	89.02	89	90.45	90.45	91.18	91.18	91.45	91.7	93.63	92.18	92.94	92.12	91.75	91.75	90.89	88.65	92.68	85.1	84.75	88.42							
04-Nov-99	91.89	91.77	91.55	91.38	90.91	89.03	89.02	90.46	90.46	91.21	91.2	91.46	91.65	93.63	92.16	92.89	92.1	91.68	91.69	90.91	88.66	92.67	85.5	84.75	88.21							
15-Nov-99	91.86	91.75	91.52	91.36	90.88	89.01	89	90.44	90.44	91.18	91.18	91.44	91.66	93.62	92.19	92.91	92.09	91.68	91.68	90.88	88.64	92.65	85.55	84.77	88.38							
03-Dec-99	91.84	91.73	91.52	91.33	90.86	89	88.99	90.43	90.41	91.14	91.14	91.41	91.63	93.63	92.14	92.88	92.09	91.64	91.65	90.85	88.64	92.62	85.6	84.8	88.4							
13-Dec-99	91.84	91.73	91.54	91.35	90.86	89.02	89.01	90.46	90.46	91.17	91.16	91.44	91.68	93.65	92.16	92.9	92.12	91.67	91.66	90.87	88.65	92.64	85.61	84.85	88.62							
18-Jan-00	92.28	92.16	91.97	91.85	91.24	89.22	89.22	90.8	90.78	91.55	91.57	91.9	92.12	93.78	92.49	93.41	92.37	92.18	92.17	91.24	88.84	93.01	85.99	84.85	89.02							
07-Feb-00	92.34	92.22	92.02	91.89	91.33	89.25	89.24	90.83	90.83	91.63	91.64		92.21	93.89	92.65	93.48	92.27	92.25	92.24	91.39	88.83	93.06	86.01	84.85	88.96							
21-Feb-00	92.47	92.35	92.12	91.94	91.4	89.27	89.27	90.88	90.88	91.72	91.71	92.04	92.28	94	92.8	93.54	93.18	92.3	92.3	91.38	88.83	93.1	86	84.85	88.82							
15-Mar-00	92.49	92.31	92.1	91.92	91.36	89.23	89.21	90.91	90.91	91.71	91.7	92.06	92.29	94.56	92.82	93.51	93.22	92.31	92.32	91.4	88.82	93.14	86.02	84.85	88.67							
31-Mar-00	92.61	92.46	92.19	92	91.46	89.28	89.27	90.92	90.93	91.76	91.74	92.11	92.3	94.75	92.85	93.53	93.36	92.34	92.34	91.43	88.83	93.16	86.07	84.85	88.41							
13-Apr-00	92.51	92.36	92.18	91.94	91.39	89.23	89.2	90.86	90.86	91.71	91.69	92.06	92.22	94.69	92.82	93.46	93.34	92.3	92.3	91.38	88.81	93.09	86.02	84.85	88.37							
27-Apr-00	92.49	92.32	92.05	91.85	91.34	89.21	89.21	90.8	90.8	91.67	91.64	91.98	92.15	94.64	92.79	93.34	93.32	92.17	92.18	91.32	88.8	93.03	85.99	84.85	88.33							
18-May-00	92.4	92.27	92.02	91.85	91.26	89.21	89.19	90.78	90.79	91.56	91.56	91.86	92.23	94.52	92.7	93.24	92.99	92.49	92.49	91.24	88.85	92.99	86.39	84.8	88.3							
06-Jun-00	92.49	92.38	92.11	91.97	91.35	89.24	89.22	90.85	90.81	91.71	91.68	92.01	92.28	94.29	92.73	93.41	92.97	92.41	92.42	91.35	88.86	93.14	86.22	84.81	88.37							
20-Jun-00	92.58	92.44	92.17	92.03	91.47	89.29	89.29	90.92	90.92	91.81	91.78	92.14	92.32	94.12	92.74	93.57	92.96	92.37	92.37	91.44	88.85	93.25	85.9	84.8	88.43							
06-Jul-00	92.51	92.36	92.09	91.95	91.42	89.22	89.25	90.84	90.85	91.74	91.72	92.07	92.26	94.13	92.78	93.5	92.83	92.29	92.29	91.39	88.82	93.18	85.59	84.73	88.24							
20-Jul-00	92.46	92.31	92.04	91.89	91.38	89.25	89.24	90.82	90.83	91.7	91.68	91.99	92.19	94.15	92.64	93.41	92.76	92.29	92.11	91.35	88.78	93.13	85.38		88.21							
04-Aug-00	92.34	92.19	91.935	91.8		89.185	89.18	90.63	90.48	91.58	91.56	91.87	92.11	94.13	92.65	93.31	92.59	92.21	92.03	91.24	88.75	93.05	85.03		88.09							
24-Aug-00	92.22	92.08	91.8	91.65	91.16	89.13	89.09	90.6	90.64	91.46	91.435	91.74	91.94	94.005	92.48	93.13	92.44	92.04	91.85	91.13	88.7	92.925	84.73		87.96							
08-Sep-00	92.06	91.91	91.66	91.5	90.97	89.07	89.04	90.54	90.54	91.33	91.31	91.59	91.87	93.89	92.32	92.99	92.43	91.9	91.71	90.94	88.67	92.78	84.66		87.91							
20-Sep-00	91.99	91.85	91.49	91.36	90.91	89.02	89.03	90.46	90.47	91.19	91.17	91.45	91.72	93.85	92.26	92.885	92.16	91.8	91.63	90.88	88.64	92.64	84.29		87.49							
04-Oct-00	91.9	91.75	91.51	91.34	90.88	88.99	88.99	90.41	90.41	91.18	91.18	91.44	91.64	93.76	92.13	92.78	92.05	91.72	91.54	90.85	88.63	92.64	84.18	84.74	87.89							
20-Oct-00	91.75	91.62	91.4	91.21	90.76	88.94	88.93	90.33	90.34	91.05	91.035	91.3		93.67	92.02	92.66	91.89	91.6	91.41	90.73	88.59	92.49	84.23	84.775	87.93							
08-Nov-00	91.76	91.67	91.47	91.25	90.75	88.96	88.94	90.32	90.31	91.11	91.11	91.34	91.73	93.57	92.125	92.83	91.99	91.86	91.68	90.73	88.61	92.52	84.64	84.84	88.56							
20-Nov-00	92.05	91.95	91.74	91.53		89.1	89.1	90.58	90.59	91.29	91.32	91.64	91.86	93.6	92.27	93.03	92.4	92.04	91.87	91.05	88.72	92.76	85.66	84.86	89.02							
30-Nov-00	92.12	92.01	91.79	91.63	91.11	89.14	89.14	90.67	90.68	91.45	91.43	91.75	91.95	93.67	92.41	93.16	92.59	92.11	91.93	91.08	88.74	92.84	86.1	84.86	89.09							
20-Dec-00	92.22	91.92	91.91	91.55	90.6	89.44	89.14	90.71	90.72	91.22	91.25	91.85	92.41		92.84	93.67	92.93	92.42	92.26	91.26	88.63	92.7	86.68	84.87	89.42							
08-Jan-01	93.03	92.95	92.65	92.49	91.91	89.56				92.28	92.25	92.61	92.77	94.14	93.21	94.07	94.04	92.96	92.81	91.88	89	93.55	88.43	84.86	89.23							
19-Jan-01	93.15	93	92.72	92.56	91.99	89.57	89.58	91.33	91.35	92.35	92.32	92.67	92.86	94.335	93.33	94.2	94.27	93.03	92.85	91.955	89	93.6		84.86	88.99							
07-Feb-01	93.24	93.08	92.79	92.585	92	89.59	89.6	91.39	91.39	92.38	92.36	92.69	92.98	94.525	93.46	94.19	94.4	93.08	92.91	91.975	89.03	93.665	88.94	84.87	89.16							
23-Feb-01	93.38	93.23	92.93	92.66	92.05	89.6				92.45	92.42	92.78	93.01	94.65	93.57	94.27	94.57	93.16	92.99	92.02	89.01	93.76	89.29	84.87	88.98							
11-May-01				92.3	91.725	89.405				92.06	92.04	92.39	92.65		93.105	93.86	94	92.79	92.59	91.69	88.91	93.475	87.69	84.84	88.41							
14-May-01	93.02	92.86	92.55				89.24	90.98	90.99					94.49																	
30-May-01				92.135			89.24	90.98	90.99	91.89	91.87			94.4							88.88	93.21		84.85							

Date	MB2 S	MB2 M	MB2 D	MB4	MB5	MB6	MB7 S	MB7 M	MB7 D	MB14 M	MB14 D	MB15	MB17	MB18	MB19 S	MB19 M	MB28	MB29	MB30	MB31	MB32	MB33	MB35	MB36	MB37	MB 38	MB39	MB41	MB42	MB43	MB44	MB45
31-May-01	92.84	92.68	92.36		91.54	89.3						92.225	92.48		92.93	93.685	93.705	92.61	92.425	91.54					88.24							
15-Jun-01	92.25	92.56	92.84	92.03	91.59	89.27	89.27	90.91	90.91	91.78	92.17		92.36	94.27				92.49	92.32	91.44	88.84										
18-Jun-01												92.01			92.89	93.58						93.19	86.68	84.83	88.16						
04-Jul-01	92.15	92.41	92.58		91.38	89.235	89.24	90.83	90.83				92.36		92.61	93.36	93.3		92.22	91.35	88.81				88.05	89.04	88.537				
16-Jul-01	91.96	92.27	92.45			89.19		90.7	91.2									92.21	92.04	91.8		92.95			87.98						
17-Jul-01				91.8	91.57					91.55	91.62	92.13	92.07	94.03	92.58	93.23	93.1				88.76		86.61	84.83		88.91	88.507				
31-Jul-01	92.31	92.14		91.67			89.11	90.64	90.88	91.44	91.41										88.75										
01-Aug-01					90.83	89.07						91.7	91.89	93.92	92.32	93.06	92.87	92.02	91.85	91.45		92.89	86.02	84.83	87.89						
13-Aug-01	92.13	91.96	91.79	91.51	91.06	89.06	89.05	90.52	90.5	91.33	91.33	91.58	91.77	93.88	92.21	92.96	92.64	91.85	91.54	91.2	88.73	92.72	85.19	84.85	87.84						
30-Aug-01	92.01	91.84	91.51	91.41	90.94	89.02	89.09	90.58	90.5	91.2	91.2	91.46	91.65	93.79	92.08	92.84	92.42	91.81	91.6	91.65	88.69	92.6	84.89	84.82	87.78						
12-Sep-01	91.85	91.7	91.42	91.31		89.38	89.07	90.55	90.52	91.08	91.08	91.35	91.48	93.72	91.96	92.73	92.17	91.66	91.49		88.62	92.5	84.59	84.78							
25-Sep-01	91.72	91.5	91.29	91.17		88.91	89.07	90.52	90.52	90.98	90.96	91.23	91.37	94.19	91.81	92.55	91.96	91.54	91.36		88.8	92.42	84.38	84.79	87.67						
08-Oct-01	91.57	91.44	91.16	91.07	90.3	88.84	89.18	90.55	90.56	90.87	90.87	91.11	91.29	93.95	91.77	92.44	91.95	91.4	91.22	90.91	88.86	92.3	85.13	84.82	87.72						
24-Oct-01	91.61	91.46	91.26	90.98	90.37	88.84	89.15	90.37	90.35	90.83	90.81	91.18	91.18	93.44	91.68	92.37		91.33	91.14	90.93	88.83	92.22	83.93	84.81							
07-Nov-01	91.41	91.29	91.05	90.91	90.48	88.81	88.78	90.05	90.06	90.74	90.71	91.1	91.13	93.4	91.61	92.31	91.43	91.27	91.07	90.46	88.51	92.14	84.03	84.82	87.8						
25-Nov-01	91.33	91.2	90.95	90.81	90.4	88.78	88.74	89.98	89.97	90.67	90.67	90.89	91.07	93.34	91.33	92.26	91.26	91.23	91.05	90.42	88.94	92.09	83.81	84.82	87.66						
14-Dec-01	91.26	90.89	91.13	90.79	90.37	88.73	88.82	89.94	90.04	90.59	90.59		91.02	93.27	91.45	92.22	91.22	91.28	90.98	90.35	88.52	92.01	83.74	84.78							
03-Jan-02	91.18	91.07	90.85	90.73		88.72	89.99	89.96	90.59	90.59	90.84	90.96	93.25	91.4	92.2	91.12	91.1	90.93		88.9	91.97	83.97	84.78							
16-Jan-02	91.03	91.03	90.82	90.71	90.28	88.68	88.75	90.01	89.97	90.51	90.51	90.74	90.94	93.14	91.37	92.15	91.1	91.17	90.89	90.29	88.91	91.92	83.89		87.92						
31-Jan-02	90.77	90.99	90.76	90.73	90.27	88.69	88.76	90.04	89.95	90.5	90.5	90.73	90.93	95.34	91.36	92.2	91.04	91.18	90.9		88.46	91.91	83.83								
14-Feb-02	91.31	91.23	91.07	90.88	90.43	88.86	88.88	90.14	90.14	90.64	90.64	90.94	91.29	93.12	91.56	92.38	91.3	91.42		90.42	88.53	92.12	85.17	84.81				92.065	91.99	88.43	89.88	89.84
06-Mar-02	91.65	91.55	91.34	91.25	90.77	89.01	89	90.4	90.42	91.08	91.1	91.4	91.54	93.32	91.94	92.87	91.71	91.78	91.59	90.68	88.66	92.52	85.55	84.81	89.09	88.81	88.357	89.545	90.32	87.51	89.75	90.02
25-Mar-02	92.13	91.75	91.48	91.46	90.99	89.1	89.1	90.5	90.5	91.26	91.28	91.52	91.67	93.46	92.07	92.13	92.12	91.88	91.69	90.96	88.68	92.65	86.33	84.81	88.76	88.76			91.19	87.72	89.43	89.89
09-Apr-02	91.93	91.8	91.56	91.47	91.02	89.07	89.06	90.47	90.51	91.31	91.27	91.58	91.66	93.59	92.08	92.98	92.22	91.86	91.67	90.99	88.68	92.66	86.36	84.81		88.77	88.397	89.575	90.24	87.47	89.28	89.07
23-Apr-02	91.91	91.78	91.52	91.42	90.98	89.05	89.06	90.47	90.49	91.27	91.25	91.53	91.66	93.65	92.17	92.91		91.8	91.82	90.99	88.68	92.62	86.22	84.79	88.48	88.86	88.387	89.415	90.24	89.3	89.3	89.13
07-May-02	91.87	91.75	91.47	91.55	90.92	89.02	89.03	90.46	90.44	91.23	91.21	91.5	91.64	93.68	92.04	92.87	92.17	91.85	91.62	90.98	88.67	92.6	86.18	84.79		88.81	88.337		90.18	87.56	89.37	89.16
25-May-02	91.84	91.73	91.45	91.49	90.89	89.01	89.04	90.4	90.42	91.18	91.18	91.47	91.6	93.71	92.01	92.87	92.04	91.76	91.63	90.87	88.69	92.61	86.17	84.81	88.67	88.74	88.367	89.525	90.27	87.63	89.39	89.18
10-Jun-02	91.83	91.68	91.41	91.34	90.89	88.99	88.99	90.42	90.08	91.16	91.15	91.43	91.55	93.43	92.07	92.86	91.91	91.72	91.56	90.84	88.72	92.56	86.23		88.49	88.7	88.347	89.485	90.21	87.41	89.22	89
24-Jun-02	91.78	91.63	91.38	91.29	90.87	88.98	88.97	90.4	90.05	91.11	91.09		91.48	93.68	92.24	92.84	91.8	91.68	91.6	90.79	88.65	92.54	86.35	84.83	88.38	88.69	88.337	89.475	90.22	87.31	89.15	88.92
10-Jul-02	91.75	91.6	91.35	91.05	90.84	89	88.96	90.31	90.02	91.1	91.05	91.35	91.5	93.69	91.94	92.75	91.73	91.63	91.04	90.74	88.62	92.5	86.29	84.8	88.4	88.68	88.327	89.455	90.18	87.25	89.1	88.87
25-Jul-02	91.69	91.53	91.27	91.21	90.79	88.93	88.94	90.19	90.21	91.04	91	91.11	91.31	93.54	91.91	92.67		91.55	91.66	90.68	88.6	92.39	85.83	84.69	88.14	88.67	88.257			87.07	88.94	88.45
13-Aug-02						88.86									91.84				91.24													
24-Aug-02	91.47	91.32	91.07	91.01	90.56	88.86	88.82	90.12	90.12	90.82	90.84	91.08	91.32	93.55	91.68	92.52	91.27	91.2	91.24	90.54	88.57	92.28	85.39	84.55	87.93	88.57	88.227	89.335		86.86	88.8	88.33
10-Sep-02	91.37	91.22	90.97	90.94	90.52	88.8	88.77	90.05	90.05	90.75	90.77	91.01	91.11	93.5	91.55	92.4		91.27	91.04	90.51	88.48	92.23	85.16	84.5	87.86	88.53	88.187	89.315	89.93	86.77	88.73	88.2
25-Sep-02	91.12	91.26	90.88	90.84	90.46	88.8	88.75	89.97	89.96	90.68	90.64	90.92	91.02	93.45	91.47	92.3	91.01	91.13	90.96	90.41	88.5	92.13	84.91	84.41	87.77	88.48	88.147	89.385	89.9	86.69	88.67	88.14
09-Oct-02	91.01	91.16	90.77	90.76	90.34	88.7	88.7	89.9	89.9	90.6	90.59	90.82	90.87	93.49	91.47	92.24		91.06	90.85	90.35	88.54	92.06	84.65	84.47	87.72	88.42	88.087	89.385	89.86	86.6	88.62	88.05
24-Oct-02	90.94	91.11	90.73	90.67	90.27	88.7	88.69	89.87	89.87	90.5	90.5	90.74	90.87	93.33	91.44	92.17		91	90.8	90.29	88.46	91.96	84.45	84.82	88.08	88.42	88.117	89.285	89.91	86.89	89.1	88.85
05-Nov-02	91.01	91.11	90.83	90.71	90.29	88.74	88.72	89.93	89.93	90.53	90.53	90.78	91	93.84	91.5	92.31	90.92	91.14	90.96	90.3	88.52	92.02	84.73	84.85	88.77	88.45	88.147	89.335	90.08	87.68	89.61	89.47
19-Nov-02	91.32	91.38	91.12	91.05	90.54	88.91	88.91	90.19	90.2	90.8	90.83	91.18	91.36	93.33	91.61		91.31	91.65	91.5	90.53	88.66	92.34	85.6	84.85	89.35	88.64	88.327	89.455	90.4	88.51	90.18	90.29
09-Dec-02	91.9	92	91.67	91.59	91.07	89.12	89.15	90.58	90.6	91.34	91.33	91.71	91.73	93.6	92.3	93.23	92.18	92.06	91.91	91.05	88.77	92.79	87.35	84.85	89.25	88.84	88.477	89.685	90.55	88.33	89.98	89.97
06-Jan-03	92.17	92.28	91.92	91.88	91.36	89.29	89.29	90.81	90.83	91.68	91.67	91.99	92.06	93.98			92.94	92.29	92.12	91.34	88.87	93.03	89.05	84.85	89.2	-	-	89.685	90.68	88.25	89.94	89.87
20-Jan-03	92.4	92.49	92.08	92	91.48	89.33	89.36	90.92	90.96	91.79	91.79	92.16	92.18	94.1	92.79	93.6	93.2	92.51	92.23	91.47	88.9	93.12	89.07	84.85	89.16	-	-	89.765	90.71	88.09	89.84	89.9
03-Feb-03				92.07		89.36	89.37	90.99	91.02	91.88	91.86		92.25								88.9	93.26		84.85		89.05	88.637			88.02	89.72	
12-Feb-03	92.4	92.6	92.17	92.07	91.55	89.35	89.36	90.96	90.98	91.9	91.9		92.21	94.28	92.92	93.69	93.48	92.46	92.3	91.53	88.94	93.25	89.3	84.85	88.94	89.05	88.647	89.765	90.68	87.88	89.59	89.85
28-Feb-03	92.42	92.6	92.11	92.05	91.55	89.34	89.35	90.94	90.93	91.87	91.87	92.16	92.13	-	92.85	93.58	93.45	92.34	92.25	91.49	88.87	93.23	89.07	84.85	88.76	89.04	88.637	89.755	90.65	87.71	89.5	89.54
19-Mar-03	92.33	92.51	91.97	91.96	91.47	89.3	89.29	90.83	90.85	91.76	91.77	91.89	91.9	94.32	92.73	93.43	93.4	92.34	92.15	91.42	88.84	93.16	88.88	84.76	88.8	88.99	88.597	89.715	90.66	87.75	89.53	89.45
02-Apr-03	92.23	92.42	91.87	91.88	91.39	89.27	89.36	90.76	90.78	91.64	91.7	91.98	91.74	94.32	92.61	93.3	93.3	92.22	92.05	91.35	88.84	93.13	88.6	84.67	88.59	88.98	88.587	89.685	90.62	87.53	89.3	89.13
11-Apr-03													91.59																			
16-Apr-03	92.12	92.31	91.75	91.76	91.31	89.22	89.26	90.66	90.68	91.6	91.52	91.86	91.51	94.27	92.34	93.11	93.18	92.04	91.9	91.28	88.77	93.03	88.31	84.63	88.44	88.92	88.537	89.635	90.49	87.39	89.21	88.96
24-Apr-03													91.37					91.94	91.77			92.95										
29-Apr-03	91.93	92.14	91.62	91.64	91.29	89.15	89.18	90.56	90.58	91.47	91.39	91.73	91.3	94.2	92.3	92.94	93.04	91.89	91.71	91.17	88.77	92.89	87.82	84.66	88.32	88.89	88.497	89.595	90.4	87.25	89.12	88.81
09-May-03				91.53									91.19					91.76	91.59			92.8										
15-May-03	91.77	91.96	91.44	91.47	91.06	89.1	89.11	90.46	90.48	91.29	91.25	91.56	91.11	94.11	92.14	92.74	92.83	91.71	91.52	91.02	88.72	92.77	87.35	84.7	88.23	88.84	88.437	89.545	90.32	87.17	89.05	88.71
22-May-03													91.05					91.63	91.45			92.71										
27-May-03	91.45	91.82	91.34	91.35	90.91	89.05	89.06	90.38	90.41	91.21	90.94	91.46	91.01	94.03	92.04	92.63	92.66	91.59	91.4	90.9	88.69	92.68	86.94	84.7	88.33	88.78	88.397	89.505	90.31	87.15	89.18	88.93
10-Jun-03	91.53	91.69	91.25	91.24	90.84	88.98	88.99	90.28	90.3	91.07	91.05	91.36	90.93	93.92	91.89	92.54	92.5	91.47	91.3	90.8	88.78	92.57	86.6	84.7	88.28	88.69	88.347	89.455	90.27	87.19	89.1	88.75
19-Jun-03										91.01	90.97		90.86					91.4	91.21			92.5										
23-Jun-03	91.41	91.58	91.14	91.11	90.71	88.92	88.93	90.21	90.21	90.97	90.93	91.23	90.85	93.88	91.71	92.43	92.32	91.37	91.18	90.68	88.63	92.47	86.25	84.54	88.15	88.66	88.297	89.445	90.18	87.09	88.98	88.5
04-Jul-03				91.05						90.91	90.86		90.81					91.31	91.12													
07-Jul-03	91.34	91.49	91.07	91.04	90.64	88.88	88.87	90.14	90.16	90.87	90.84	91.16	90.84	93.79	91.71	92.37	92.16	91.29	91.11	90.59	88.62	92.39	86	84.61	88.2	88.62	88.257	89.415	90.15	87.11	89	88.56
18-Jul-03				90.99									90.9					91.28	91.1			92.37										
23-Jul-03	91.38	91.42	91.06	90.98	90.57	88.84	88.85	90.14	90.15	90.83	90.82	91.12	90.92	93.72	91.72	92.39	92	91.28	91.1	90.53	88.56	92.34	85.71	84.57	88.14	88.58	88.217	89.405	90.11	87.05	88.95	88.52
04-Aug-03				90.94	90.51	88.82	88.82	90.11	90.12	90.79	90.78	91.07	90.94	93.51	91.58	92.37	91.89	91.24	91.04	90.47	88.56	92.29	85.5	84.54	88.05	88.56	88.177	89.375	90.06	86.97	88.8	88.42
14-Aug-03													90.95																			
19-Aug-03	91.18	91.33	90.99	90.87	90.46	88.78	88.79	90.05	90.06	90.73	90.71	91.01	90.94	93.58	91.54	92.33	91.74	91.18	90.98	90.45	88.51	92.2	85.14	84.42	87.94	88.52	88.167	89.315		86.88	88.8	
01-Sep-03	91.15	91.27	90.94	90.82	90.46	88.78	88.75	89.97	90	90.67	90.64	90.93	90.9	93.5	91.49	92.29	91.64	91.12	90.93	90.39	88.54		84.95		87.88	88.5	88.147	89.325		86.79	88.73	88.23
17-Sep-03	91.07	91.21	90.87	90.76	90.36	88.74	88.73	89.98	89.98	90.63	90.6	90.88	90.85	93.45	91.41	92.21	91.5	91.07	90.88	90.34	88.52	92.08	84.67	84.34	87.78	88.45	88.117	89.285		86.71	88.66	88.1

Date	MB2 S	MB2 M	MB2 D	MB4	MB5	MB6	MB7 S	MB7 M	MB7 D	MB14 M	MB14 D	MB15	MB17	MB18	MB19 S	MB19 M	MB28	MB29	MB30	MB31	MB32	MB33	MB35	MB36	MB37	MB 38	MB39	MB41	MB42	MB43	MB44	MB45
29-Sep-03	91.02	91.16	90.83	90.71	90.31	88.7	88.7	89.92	89.93	90.55	90.53	90.84	90.82	93.4	91.34	92.15	91.42	91.02	90.84	90.32	88.51	91.9		84.31	87.74	88.45	88.097	89.235	89.84	86.69	88.62	88.06
21-Oct-03						88.65	88.66	89.83	89.84	90.47	90.45	90.71									88.45			84.31		88.42	88.067	89.205	89.79		88.5	87.95
24-Oct-03	90.92	90.99	90.73	90.61	90.22								90.76	93.28	91.29	92.01	91.22	90.92	90.73	90.2		91.88	84.04									
04-Nov-03	90.88	91	90.69	90.57	90.2	88.63	88.63	89.77	89.78	90.41	90.39	90.65	90.74	93.25	91.24	91.97	91.14	90.88	90.69	90.17	88.43	91.82	83.86	84.5	87.65	88.39	88.057			86.25	88.58	88.02
18-Nov-03	90.87	90.95	90.68	90.54		88.6	88.61	89.76	89.77	90.38	90.37	90.61	90.7	93.2	91.11	91.93	91.06	90.84	90.65		88.44	91.77	83.69	84.55	87.67	88.36	88.027	89.155	89.7	86.54	88.54	88.05
04-Dec-03	90.81	90.9	90.6		90.11	88.59	88.65	89.72	89.74	90.34	90.33	90.57	90.7	93.15	91.18	91.9		90.79	90.6	90.04	88.39	91.72		84.57	87.78	88.34	88.017	89.145	89.59	86.67	88.68	88.1
16-Dec-03	90.76	90.87	90.6		90.07	88.57	88.56	89.73	89.76	90.33	90.32	90.56	90.7	93.11	91.15	91.89	90.91	90.79	90.6	90.06	88.4	91.69		84.6	87.93	88.34	87.997	89.135	89.71	86.83	88.83	88.49
07-Jan-04	90.78	90.87	90.63			88.59	88.6	89.77	89.78				90.81		91.27	92	90.94	90.8			88.43	91.7		84.8	88.55	88.35	88.037	89.175	89.82	87.44	89.33	89.15
23-Jan-04					90.24	88.7	88.69	89.91	89.92	90.5	90.46	90.77	91.01	93.08	91.41	92.28	91.18		91.01	90.1	88.5	91.89		84.73	88.9	88.46	88.147	89.255	90	87.86	89.56	89.43
04-Feb-04					90.4	88.79	88.79	90.06	90.07	90.69	90.68	90.98	91.16	93.15	91.57	92.45	91.38			90.38	88.53	92.07		84.72		88.55		89.305	90.1				
19-Feb-04					90.61	88.89	88.89	90.21	90.23	90.88	90.88	91.21	91.33	93.27	91.79	92.67	91.78	91.54	91.35	90.59	88.59	92.31		84.67	88.88	88.62	88.267	89.325	90.14	87.82	89.53	89.4
04-Mar-04					90.76	88.93	88.95	90.31	90.31	91.04	91.01	91.32	91.4	93.39	91.89	92.71	92.02	91.56	91.37	90.72	88.62	92.4		84.66	88.55	88.67	88.307	89.385	90.11	87.44	89.23	89
29-Mar-04	91.52	91.62	91.31		90.76	88.95	88.95	90.3	90.32	91.04	91.03	91.28	91.39	93.49	91.89	92.65	92.09		91.35	90.73	88.63	92.37		84.67	88.52	88.66	88.307	89.395	90.13	87.48	89.3	89.09
06-Apr-04	91.51	91.62	91.3		90.75	88.93	88.93	90.27	90.28	91.01	91	91.26	91.38	93.5	91.88	92.62	92		91.34	90.72	88.63	92.33		84.68	88.56	88.7	88.297	89.385	90.09	87.39	89.21	88.95
19-Apr-04	91.47	91.62	91.29		90.72	88.91	88.91	90.25	90.25	90.99	90.98	91.24	91.38	93.52	91.87	92.68	92.05		91.34	90.7	88.63	92.31		84.73	88.39	88.66	88.287	89.375	90.06	87.29	89.13	88.93
28-Apr-04	91.48	91.6	91.26		90.68	88.9	88.91	90.23	90.24	90.94	90.96	91.21	91.35	93.5	91.86	92.66	92	91.49	91.3	90.67	88.61	92.3		84.64	88.38	88.64	88.277	89.385	90.07	87.31	89.16	88.87
10-May-04						88.85	88.84	90.15	90.16												88.58											
26-May-04	91.39	91.52	91.17		90.6	88.85	88.84	90.14	90.15	90.84	90.85	91.11	91.23	93.44	91.62	92.41	91.87	91.38	91.19	90.58	88.58	92.2		84.535	88.23	88.61	88.247	89.325	89.99	87.08	88.95	88.54
12-Jun-04						88.78	88.84	90.12	90.13												88.54											
21-Jun-04	91.27	91.41	91.01		90.49	88.8	88.8	90.03	90.05	90.7	90.72	90.99	91.1	93.37	91.46	92.25	91.67	91.25	91.05	90.48	88.56	92.08				88.58	88.187	89.295	89.9			
06-Jul-04						88.76		90.01	90.02												88.54			84.34	87.85	88.53	88.157	89.285	89.86	86.8	88.74	88.21
20-Jul-04	91.13	91.27	90.91		90.4	88.74	88.73	89.95	89.96	90.6	90.63	90.87	90.97	93.25	91.39	92.08	91.47	91.11	90.92	90.37	88.51	91.94		84.32	87.84	88.49	88.127	89.215	89.82	86.72	88.68	88.15
04-Aug-04						88.69	88.66	89.85	89.86												88.47											
17-Aug-04	91.01	91.14	90.78		90.23	88.64	88.66	89.81	89.84	90.44	90.44	90.7	90.78	93.13	91.2	91.9	91.22		90.77	90.24	88.46	91.78		84.29	87.69	88.42	88.067	89.195	89.73	86.56	88.55	87.97
25-Aug-04						88.61	88.59	89.78	89.76												88.43											
21-Sep-04	90.76	90.9	90.56		90.05	88.56	88.55	89.69	89.68	90.28	90.28	90.49	90.59	93	91.01	91.68	90.94		90.56	90.06	88.39	91.57		84.272	87.57	88.36	87.987	89.125	89.63	86.44	88.44	87.83
05-Oct-04						88.51	88.47	89.61	89.61																							
20-Oct-04	90.76	90.63	90.44		89.95	88.5	88.49	89.59		90.17	90.17	90.37	90.47	92.9	90.85	91.53	90.74		90.41	89.95	88.35	91.41		84.41	87.45	88.27	87.927	89.075	89.55	86.4	88.42	87.8
04-Nov-04						88.45	88.48	89.58	89.6												88.3											
17-Nov-04	90.74	90.56			89.89	88.46	88.45	89.55	89.54	90.09	90.09	90.28	90.42	92.82	90.78	91.44	90.61		90.36	89.88	88.32	91.34		84.52	87.65	88.23	87.897	89.045	89.55	86.58	88.58	88.09
08-Dec-04	90.61	90.5	90.32		89.84	88.44	88.42	89.51	89.5	90.05	90.03	90.24	90.39	92.75	90.71		90.55		90.34	89.84	88.3	91.27		84.57	87.83	88.21		89.015	89.53	86.73	88.7	88.24
11-Jan-05	90.64	90.62			89.85	88.48	88.47	89.6	89.57	90.12	90.09	90.27	90.53	92.65	90.8	91.52	90.63		90.48	89.85	88.37	91.28		84.75	88.53	88.24	87.927		89.7	87.35	89.36	89.18
10-Feb-05	90.85	90.69			90.14	88.61	88.6	89.79	89.74	90.36	90.35	90.56	90.74	92.76	91.05	91.82	91.11		90.79	90.12	88.44	92.21		84.67		88.39	88.047	89.175	89.78	87.44	89.22	89.03
28-Feb-05						88.64	88.63	89.8	89.82												88.47											88.91
16-Mar-05	91.09	90.99	90.82		90.29	88.7	88.68	89.89	89.87	90.55	90.49	90.69	90.87	92.82	91.16	91.89	91.49		90.85	90.28	88.46	92.21		84.64	88.35	88.47	88.067	89.175	89.82	87.22	89.07	88.76
04-Apr-05	91.12	91.03	90.86		90.31	88.71	88.7	89.91	89.89	90.53	90.52	90.85	90.94	92.93	91.24	91.92	91.54		90.88	90.31	88.5	91.76		84.61	88.35	88.47	88.117	89.195	89.86	87.2	89.07	88.76
10-May-05						88.71	88.69	89.92	89.9												88.51											
12-May-05	91.31	91.21	90.97		90.43	88.72	88.78	90.03	89.99	90.62	90.64		90.88	92.81	91.23				90.98	90.46	88.5			84.56	88.31			89.265	89.84	87.13	88.88	88.74
24-May-05						88.71	88.68	89.92	89.91												88.44											
08-Jun-05	91.29	91.14	90.95		90.43	88.72	88.74	90.03	89.95	90.59	90.6	90.77	90.9	92.92	91.19	91.96	91.77		90.92	90.36	88.52	91.81		84.61	88.04	88.43		89.045	89.78	87.01	88.88	88.43
21-Jun-05						88.66	88.65	89.9	89.88												88.48											
08-Jul-05	91.19	91.08	90.85		90.29	88.69	88.67	89.86	89.84	90.51	90.52	90.68	90.8		91.06	91.77	91.66		90.85	90.34	88.48	91.7		84.61	88	88.48	88.087	89.175	89.78	86.98	88.86	88.19
18-Jul-05						88.63	88.62	89.81	89.8												88.46											
09-Aug-05	91.03	90.94	90.73		90.15									92.93	90.93	91.6	91.44			90.15												
19-Aug-05						88.54		89.66													88.39											
25-Aug-05						88.6	88.57	89.71		90.33	90.34	90.54	90.6	92.85					90.63		88.4	91.52		84.39	87.6	88.39	88.017	89.085	89.63	86.57	88.55	87.94
01-Sep-05	90.93	90.8	90.57		90.08	88.57	88.56	89.67	89.67	90.26	90.29	90.45	90.54	92.82	90.81	91.46	91.25		90.56	90.07	88.41	91.48		84.33	87.55	88.39	87.987	89.095	89.57	86.5	88.5	87.9
15-Sep-05						88.64	88.48	89.59	89.61												88.3						96.447					
03-Oct-05	90.77	90.65	90.65		89.95	88.51	88.49	89.55	89.55	90.17	90.18	90.31	90.4	92.77			91		90.41	89.94	88.34	91.31		84.42	87.45	88.29		89.005	89.47	86.42	88.44	87.82
14-Oct-05						88.4	88.48	89.52	89.55																							
04-Nov-05	90.69	90.59	90.35	90.19	89.87	88.43	88.47	89.49	89.52	90.03	90.05	90.24	90.33	92.75	90.61	91.21	90.85	90.51	90.32	89.87	88.34	91.18	83.6	84.35				89.055	89.48	86.53	88.63	88.24
10-Nov-05						88.4	88.52	89.56	89.56												88.32											
25-Nov-05	90.65	90.55	90.36		89.83	88.45	88.43	89.48	89.53	90.04	90.05	90.22	90.36	92.85	90.67	91.26	90.83		90.35	89.82	88.26	91.37		84.58	87.92	88.24		88.995				
09-Dec-05						88.4	88.53	89.53	89.56												88.3								89.51	86.85	88.83	88.33
22-Dec-09	90.65	90.56	90.36		89.81	88.46	88.44	89.49	89.5	90.01	90.03	90.24	90.37	92.62	90.62	91.27	90.8		90.38	89.83		91.19		84.56	88.11	88.24		88.985	89.53	87.02	88.9	88.49
12-Jan-06						88.44	88.54	89.52	89.53												88.32											
30-Jan-06	90.7	90.58	90.39		89.85	88.48	88.46	89.53	89.55	90.06	90.09	90.26		92.59	90.67	91.29	91.07		90.43	89.92					88.15	88.24		89.035	89.58	87.11	88.96	88.56
08-Feb-06						88.49	88.51	89.54	89.55												88.36											
27-Feb-06	90.73	90.64	90.45		89.95	88.51	88.45	89.57	89.63	90.13	90.14	90.33					91.16		90.46	89.96	88.33					88.26		89.025	89.58			
28-Feb-06													90.46	92.62	90.72	91.33						91.35		84.71	88.16				87.08	88.96	88.63
10-Mar-06						88.54	88.51	89.57	89.58												88.37											
14-Mar-06	90.76	90.63	90.47	90.29	89.93	88.52	88.5	89.58	89.6	90.14	90.13	90.32	90.48	92.61	90.74	91.37	91.18	90.73	90.49	89.94	88.37	91.35	85.21	84.75		88.28	Lost					
15-Mar-06																									88.29			89.005	89.61	87.15	89.08	88.87
27-Mar-06				90.38	90	88.55	88.54	89.64	89.65	90.19	90.19	90.42	90.59					90.8	90.61	89.99		91.43						89.045	89.67			88.87
28-Mar-06	90.83	90.73	90.52											92.63	90.81	91.42	91.3				88.4		85.42	84.76	88.39	88.3				87.25	89.16	
10-Apr-06	90.92	90.81	90.63	90.44	90.06	88.26	88.57	89.72	89.71	90.27	90.27	90.5	90.68				91.42	90.88	90.7	90.08	88.42	91.53	85.71	84.74	88.47	88.35		89.125	89.74	87.39	89.2	88.97

Date	MB2 S	MB2 M	MB2 D	MB4	MB5	MB6	MB7 S	MB7 M	MB7 D	MB14 M	MB14 D	MB15	MB17	MB18	MB19 S	MB19 M	MB28	MB29	MB30	MB31	MB32	MB33	MB35	MB36	MB37	MB 38	MB39	MB41	MB42	MB43	MB44	MB45
11-Apr-06														92.68	90.93	91.57															
24-Apr-06	91.02	90.91	90.72	90.54		88.63	88.61	89.79	89.79	90.37	90.35	90.59	90.75					90.96	90.78		88.45	91.66	85.96	84.63	88.29	88.41		89.105	89.75	87.25	89.07	88.79
26-Apr-06					90.15									92.72	90.97	91.62	91.56			90.2												
08-May-06	91.07	90.96	90.75	90.6	90.22	88.66	88.64	89.82	89.82	90.41	90.44	90.64	90.79				91.66	91	90.8	90.24	88.46	91.67	86	84.62	88.19	88.43		89.125	89.74	87.1	88.96	88.61
09-May-06														92.77	91.02	91.65															
Maximum	93.38	93.23	92.93	92.71	92.13	89.65	89.64	91.5	91.5	92.53	92.48	92.84	93.06	95.34	93.57	94.27	94.8	93.16	93.13	92.13	89.03	93.91	89.35	84.87	89.42	89.05	96.447	92.065	91.99	89.3	90.18	90.29
Minimum	90.61	90.5	90.32	90.19	89.81	88.26	88.42	89.48	89.5	90.01	90.03	90.22	90.33	92.59	90.61	91.21	90.55	90.51	90.32	89.82	88.26	91.18	83.6	84.272	87.45	88.21	87.897	88.985	89.47	86.25	88.42	87.8

APPENDIX D

Groundwater Levels Measured in Boreholes Adjacent to the Excavation

Table D-1: Groundwater levels at the excavation.

OBSERVATION POINTS		6920	6970	7020	7070	7120	7170	7220	7270
Easting (m)		270776	270823	270877	270922	270878	271022	271079	271119
Northing (m)		212094	212033	212090	212024	212086	212012	212077	211999
EGL (m OD) Malin Head		89.422	89.165	90.164	90.618	92.636	91.735	93.147	92.401
Top of Casing - Rev.0		90.047	89.727	90.744	91.154	93.181	92.259	93.686	92.856
Top of Casing - Rev.1	Malin Head								
Top of Casing - Rev.2									
Top of Casing - Rev. 3 Jan/Feb 2003									
Top of Well Cap - Rev.4 Jan04		89.390			90.820				
Well Depth (m)		11.080	9.060	11.540	10.090	12.470	11.800	13.370	11.080
Bottom of well (m OD)		78.967	80.667	79.204	81.064	80.711	80.459	80.316	81.776
Lowest FRL (m OD)		85.258	85.269	85.281	85.292	85.303	85.314	85.326	85.337
Weir Level - Low. FRL+1.85m		87.008	87.019	87.031	87.042	87.053	87.064	87.076	87.087
Lowest FRL - 3.70m		81.558	81.569	81.581	81.592	81.603	81.614	81.626	81.637
Critical Level		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
POST CONTRACT WELLS									
Date		(m OD)	(m OD)	(m OD)	(m OD)	(m OD)	(m OD)	(m OD)	(m OD)
May-01	31/05/2001								
Jun-01	29/06/2001	84.057	85.547	86.174	86.324	86.631	87.139	87.276	87.906
Jul-01	31/07/2001	82.457	83.327	82.594		83.111	84.919	84.686	87.056
Aug-01	31/08/2001	81.997	82.997	82.564	83.084	82.831	82.299	84.076	84.306
Sep-01	27/09/2001	81.657	82.647	82.354	82.624	82.521	82.669	83.516	80.936
Oct-01	31/10/2001	81.467	82.387	81.244	82.094	82.211	82.639	83.506	
Nov-01	29/11/2001	81.367	81.867	81.264	81.824	81.801	82.039	83.076	
Dec-01	20/12/2001	81.617	81.947		81.904	81.781	82.029	83.006	
Jan-02	30/01/2002	82.917	83.027	82.904	83.044	81.941	83.159	82.226	
Feb-02	28/02/2002	84.037	84.717	84.784	85.094	84.831	85.189	84.626	
Mar-02	27/03/2002	83.987	84.737	84.814	85.034	84.851	85.129	84.696	
Apr-02	29/04/2002	83.547	84.247	84.144	84.484	84.161	84.439	84.036	83.636
May-02	31/05/2002	83.477	84.017	84.064	84.334	84.091	84.439	84.066	84.236
Jun-02	27/06/2002	83.407	83.897	83.964	84.184	83.991	84.299	83.946	83.976
Jul-02	31/07/2002	83.237	83.597	83.644	83.854	83.651	83.849	83.616	83.596
Aug-02	30/08/2002	82.877	83.277	83.394	83.554	83.411	83.589	83.456	83.616
Sep-02	26/09/2002	82.527	83.027	83.434	83.434	83.471	83.689	83.706	84.206
Oct-02	31/10/2002	83.247	83.697	83.944	84.204	84.011	84.289	84.446	84.916
Nov-02	29/11/2002	85.127	85.947	86.324	86.524	86.481	86.759	86.716	86.786
Dec-02	16/12/2002	85.187	85.967	86.374	86.494	86.571	87.869	86.796	86.966
Jan-03	30/01/2003	84.967	85.857	86.274	86.434	86.481	86.759	86.746	86.976
Feb-03	27/02/2003	84.747	85.627	85.094	86.224	86.351	86.629	86.676	86.926
Mar-03	31/03/2003	84.667	85.437	85.894	86.054	86.131	86.449	86.536	86.956
Apr-03	29/04/2003	84.367	85.087	85.544	85.654	85.761	86.199	86.366	86.806
May-03	29/05/2003	84.217	84.907	85.364	85.524	85.561	85.989	86.216	86.706
Jun-03	19/06/2003	84.147	84.797	85.264	85.354	85.461	85.879	86.136	86.616
Jul-03	28/07/2003	83.127	84.527		84.854		85.779		86.356
Aug-03	29/08/2003	83.797	84.327	84.844	84.884	85.011	85.409	85.666	86.236
Oct-03	30/10/2003	83.587	83.957	84.624	84.644	84.801	85.209	85.506	86.166
Nov-03	17/11/2003	83.577	83.967	84.614	84.634	84.801	85.209	85.526	86.186
Dec-03	11/12/2003	83.697	84.127	84.714	84.754	84.901	85.309	85.636	86.256
Jan-04	27/01/2004	84.740			86.080				
Feb-04	03/02/2004	84.800			86.240				

7320	7420	7470	7520	7570	7620	7670	7720	7770	7820	7870
271080	271279	271316	271377	271414	271476	271512	271573	271610	271672	271708
212064	212047	211974	212025	211956	212006	211935	211983	211915	211966	211892
93.703	92.764	89.859	91.126	89.073	91.020	89.220	90.839	88.909	91.354	89.309
94.300	93.344	90.300	91.807	89.471	91.585	89.589	91.346	89.489	91.819	89.728
					91.783		91.393	88.946	92.022	
93.830		89.850					90.290			
13.160	12.780	9.280	12.050	10.100	10.460	10.120		9.210	10.510	9.780
81.140	80.564	81.020	79.757	79.371	81.125	79.469		80.279	81.309	79.948
85.348	85.371	85.382	85.393	85.404	85.416	85.427	85.425	85.416	85.402	85.382
87.098	87.121	87.132	87.143	87.154	87.166	87.177	87.175	87.166	87.152	87.132
81.648	81.671	81.682	81.693	81.704	81.716	81.727	81.725	81.716	81.702	81.682
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(m OD)	(m OD)	(m OD)	(m OD)	(m OD)	(m OD)	(m OD)	(m OD)	(m OD)	(m OD)	(m OD)
87.870	88.334	88.420	88.567	88.461	88.545	88.249	87.656	88.259	88.289	88.278
86.170	87.144	87.330	87.697	87.581	89.803	87.509	87.526	87.529	87.579	87.583
83.440	85.384	86.150	86.587	86.401		86.709	86.716	86.749	86.999	86.788
80.480	84.014	85.140	85.737	85.471	85.655	86.189	86.056	86.109	86.369	86.128
		85.280		85.531	85.665	86.159	86.046	86.079		86.158
		84.720		85.101	85.275	85.909	85.796	85.829		85.938
		84.730		85.091	85.255	85.889	85.786	85.839		85.928
		84.520		85.101	85.305	86.079	85.956	86.009		86.138
82.440	82.584	84.840		85.621	85.855	86.659	86.556	86.629		86.698
81.550	81.864	84.700	84.147	86.151	85.035	86.339	86.136	86.149		86.358
82.220		82.450	83.307	82.061	82.885	81.869	81.746	81.939		82.928
84.260	83.844	82.630	83.357	81.891	82.665	81.319	81.236			81.818
83.800	83.494	82.540	83.247	81.811	82.555	81.219	81.106			81.658
83.530	83.304	82.430	83.157	81.741	82.505	81.179	81.096			81.678
83.850	83.574	82.850	83.307	82.701	82.785	82.539	82.376			82.328
84.210	84.104	84.100	84.107	83.821	83.495	83.259	83.106			82.828
85.300	85.394	85.560	85.407	85.471	85.603	85.649	85.593		85.262	85.398
87.050	87.154	87.180	87.157	86.971	87.143	87.089	86.643		87.472	86.788
87.120	87.204	87.190	87.167	87.071	87.143	87.029	86.943	86.966	86.952	86.888
87.200	87.244	87.200	87.217	87.041	87.283	87.189	87.043	87.146	87.142	87.118
87.090	87.244	87.200	87.445	87.031	87.253	87.189	87.093	87.146	87.142	87.108
87.080	87.224	87.230	87.147	87.061	87.183	87.129	87.043	87.046	87.042	87.028
86.980	87.144	87.210	87.147	87.021	86.983	86.889	86.793	86.836	86.822	86.778
86.920	87.104	87.150	87.087	86.941	86.933	86.859	86.753	86.706	86.762	86.738
86.800	86.994	87.050	86.957	86.841	86.863	86.739	86.673	86.666		86.628
86.590	86.794	86.820	86.787	86.651	86.733		86.623	86.616		86.608
86.470	86.664	86.730	86.707	86.591		86.689	86.713	86.626		86.628
86.450	86.704	86.900	86.717	86.661		86.789	86.853	86.726		86.838
86.450	86.734	86.900	86.807	86.731		86.829	86.933	86.716		86.838
86.500	86.744	86.950	86.857	86.801		86.889	87.093	86.796		86.928
87.080		87.120					87.100			
87.080		87.120					87.190			

7920	7970	8020	8070	8120	8170	8220	8270	8320	8370	8420
271770	271805	271869	271901	271970	272000	272068	272092	272163	272198	272257
211950	211871	211933	211851	211909	211829	211886	211808	211874	211794	211839
92.591	89.223	94.264	89.113	91.337	88.503	88.848	88.380	88.561	88.515	88.062
93.201	89.796	94.794	89.697	91.800	89.021	89.276	88.919	89.023	88.987	88.534
93.060		93.990		91.700			88.800	90.150	90.150	88.050
				92.427		88.999		88.886		
	89.360					88.800				
10.900	9.400	11.560	8.110	14.720	8.120	10.480		8.910	8.910	8.850
82.301	80.396	83.234	81.587	77.080	80.901	78.796		80.113	80.077	79.684
85.358	85.344	85.325	85.267	85.201	85.132	85.268	85.229	85.179	85.128	85.078
87.108	87.094	87.075	87.017	86.951	86.882	87.018	86.979	86.929	86.878	86.828
81.658	81.644	81.625	81.567	81.501	81.432	81.568	81.529	81.479	81.428	81.378
N/A	N/A	N/A	N/A	86.50	86.33	86.43	86.44	86.38	86.34	86.28
(m OD)	(m OD)	(m OD)	(m OD)	(m OD)	(m OD)	(m OD)	(m OD)	(m OD)	(m OD)	(m OD)
88.321	88.256	88.384	88.007	88.370	87.751	88.256	87.609		87.767	
87.631	87.646	88.234	87.367	87.650	87.341	87.636	87.479	87.533	87.237	87.234
86.821	86.836	87.384	86.207		86.671	86.386	86.889	85.633	84.687	84.504
86.181	86.216	87.114	85.717		85.611	85.936	86.409	85.313	84.497	84.334
	86.156		85.687		85.571	85.926	86.769	85.323	84.517	84.324
	85.986		85.557	86.030	85.431	85.766	86.779	85.203	84.407	84.254
	85.926		85.567		85.421	85.766	86.809	85.213	84.437	84.274
86.101	86.136	86.604	85.767	86.290	85.641	85.976	86.979	85.473	84.697	84.554
86.631	86.746	87.194	86.397	86.890	86.271	86.556	87.119	86.053	85.337	85.184
86.351	86.426		86.217	86.710	87.051	86.366	85.359	85.883	85.427	85.294
83.311	83.406		84.597	84.920	84.791	84.806	86.769	84.973	84.737	84.664
	82.026		82.867	83.150	83.161	82.506	86.359	83.283	81.717	82.264
	81.766		82.297				85.589		81.487	
	81.806		82.137							
	82.256		82.117							
	82.606		82.367							
85.210	85.316	84.860	84.997		84.991			85.160	84.150	
86.660	86.696	86.690	86.327		86.191				84.640	
86.900	86.846	86.860	86.547		86.501		86.150		85.830	85.430
87.060	87.056	87.090	86.887		86.861		86.700		86.510	86.190
87.060	87.056	87.070	87.617	86.997	86.841	86.819	86.700	86.676	86.520	86.160
87.010	86.976	87.010	86.797	86.927	86.781	86.749	86.600	86.556		86.030
86.760	86.746	86.740	86.537	86.677	86.521	86.499	86.320	86.286		85.750
86.700	86.656	86.700	86.497	86.617	86.461	86.409		86.266		85.760
86.610	86.596	86.590	86.407	86.527	86.401	86.349		86.186		85.500
86.600	86.586	86.600	86.427	86.547	86.431	86.409	86.260			
	86.596	86.640	86.497	86.637	86.541	86.569				
86.610	86.596		86.597	86.677	86.641	86.659	86.600		86.530	
86.640	86.596		86.597	86.697	86.641	86.689	86.610		86.540	
86.760	86.676		86.697	86.827	86.721	86.749	86.690			
	87.080					86.900				
	87.080					86.860				

8470	8520	8570	8620	8670	8720	8770	8820	8870	8870	8920	8970
272297		272394	272454	272495	272552	272597	272657		272696	272757	272795
211776		211758	211807	211741	211792	211712	211792		211703	211778	211696
88.094		87.912	89.199	89.054	88.786	89.353	88.866	88.860	89.281	88.983	89.261
88.709		88.465	89.716	89.606	89.226	89.752	89.386	89.340	89.846	89.410	89.612
88.890		88.320		88.460		90.130					
88.753				88.984					89.292		
					89.000	89.500					
9.210		8.450	10.350	9.010	10.920	9.710	0.720			8.010	
79.499		80.015	79.366	80.596	78.306	80.042	88.666			81.400	
85.028	84.977	84.927	84.877	84.826	84.756	84.725	84.676	84.636	84.636	84.432	84.418
86.778	86.727	86.677	86.627	86.576	86.506	86.475	86.426	86.386	86.386	86.182	86.168
81.328	81.277	81.227	81.177	81.126	81.056	81.025	80.976	80.936	80.936	80.732	80.718
86.22											
(m OD)	(m OD)	(m OD)	(m OD)	(m OD)	(m OD)	(m OD)	(m OD)		(m OD)	(m OD)	(m OD)
87.599		87.575	87.786	87.626	87.506	87.142					
87.149		87.135	87.246	87.126	86.936	86.572	86.796		86.336	86.820	85.542
83.799		83.555	85.286	84.896	85.906	85.992	86.346		86.046	86.670	85.612
83.709		83.385	85.156	84.716	85.676	85.742	86.066		85.776	86.090	85.392
83.709		83.475	85.146	84.826	85.786	85.892	86.186		85.936	86.230	85.632
83.659		83.395	85.066	84.636	85.656	85.772	86.026		85.836	86.110	85.582
83.679		83.485	84.976	84.706	85.656	85.792	86.056		85.836		
83.979		84.065	85.416	85.476	86.079	86.172	86.366		86.196	86.400	85.962
84.679		84.785	85.586	85.626	86.476	86.502	86.736		86.576	86.800	86.322
84.909		85.255	85.586	85.896	84.116	83.872			83.966	84.980	85.432
84.209		84.545	85.306	84.916	84.506	83.452			82.126	84.080	85.192
82.449		83.575	84.666	84.216	84.166	83.382			82.576	83.890	84.032
82.279		83.445	84.536	84.066	84.046	83.312			82.496	83.780	84.892
			84.296	83.836	83.876	83.192			82.446	83.600	84.532
			83.296			82.122			82.546	83.660	84.402
			83.126						81.596	82.210	82.272
			83.416						81.696	81.770	81.962
			84.216			81.820			81.676	81.960	81.872
			85.066		85.276	82.400				81.910	
			85.866		85.576	82.580				81.960	81.752
86.413			85.876	85.074	85.656	82.840		83.002	82.572	83.280	83.332
86.223			85.596	84.684	85.216	82.490	82.706	82.660	82.042	82.480	83.382
			85.316		84.966	82.480		82.490	82.092	83.190	83.392
			85.326		84.986	82.480		82.620	82.102	82.530	
			85.216		84.906	82.310			81.652	82.020	
			85.876		85.256	83.200				82.760	
					86.256	86.080		86.100			
			86.886		86.426			86.300			
					86.456						
					86.576						
					86.320	86.350					
					86.330	86.380					

9020	9070	9120	9170	9220	9225	9320	9370	9420	9480	9520	9570
272851	272895	272956	273019	273047	273082	273145	TBA	TBA	273306	273346	273396
211767	211693	21177	211690	211754	211690	211749	TBA	TBA	211696	211743	211700
90.239	90.505	91.939		89.490	89.050	88.278	87.450	87.290	88.227	87.513	87.426
90.635	91.075	92.547	90.430	89.826	89.870	88.700	87.910	87.750	88.725	88.167	88.478
			90.480	90.170		88.400		88.4	88.770		
	91.046						88.596		88.560	88.964	88.101
89.320						88.210	88.120				
10.230		9.240	12.100		10.650						
80.405		83.307	78.330		79.220						
84.435	84.471	84.533	84.562	84.602	84.648	84.748	84.839	84.940	85.071	85.160	85.325
86.185	86.221	86.283	86.312	86.352	86.398	86.498	86.589	86.690	86.821	86.910	87.075
80.735	80.771	80.833	80.862	80.902	80.948	81.048	81.139	81.240	81.371	81.460	81.625
(m OD)	(m OD)	(m OD)	(m OD)	(m OD)	(m OD)	(m OD)	(m OD)	(m OD)	(m OD)	(m OD)	(m OD)
		87.027	86.290		86.456	87.240					
		86.687	83.520		83.760	86.220					
86.395	85.125	85.727	83.060			85.690					
86.335		85.437	84.210	84.206	84.380	85.970					
86.045	85.095	85.167	83.610	83.276	83.750	85.620	84.990		86.185	86.687	86.748
86.225	85.435	85.127	84.500	84.626		85.870	85.280		86.805	86.787	86.808
86.115	85.385	85.177	84.490	84.556	84.630	85.820	85.230		86.685	86.707	86.748
86.125	85.425	85.207	84.530	84.676	84.720	85.860	85.260			86.697	86.738
86.485	85.975	85.947	85.440	85.526	85.560	86.240	85.650			86.867	86.868
86.815	86.315	86.177	85.580	85.626	85.720	86.350	85.950			87.227	87.218
84.095	85.725	86.007	85.380	85.486		86.380	85.760			87.137	87.128
85.935	85.525	85.837	85.282	85.396	85.390	86.150	85.500			86.217	86.238
85.715	85.345	86.047	85.030	85.286	85.110	85.980	85.290			85.837	85.948
85.495	85.165	85.257	84.830	84.986	84.970	85.790	85.150			85.717	85.778
85.105	84.615	84.667	83.610	84.196	83.760	85.210	84.690			85.477	85.618
84.965	84.475	84.497	83.550	84.196	83.700	85.070	84.550			85.387	85.508
83.705	83.185	84.327	83.480	84.006	83.720	84.940	84.400			85.277	85.438
			82.680	85.220	83.420	84.460				85.327	85.488
			82.180	85.470	82.450	83.220				84.767	85.578
			81.880	84.490	82.270	83.010		82.640			85.138
			81.830		82.020	82.490		81.550			
	83.256		83.010	84.300	82.690	82.700	82.596	81.650	83.010	81.844	81.131
	83.956		84.040	84.430	83.640	83.100	82.976	81.840	83.090	81.704	81.691
	83.996		84.330	84.620	84.270	83.880	83.836	83.050	83.580	82.464	82.301
85.435		84.667	84.640	84.940	84.920	84.800	85.056	85.100	84.920	84.934	83.921
		84.637	84.880		84.970	84.850	85.116	85.150	85.160		85.001
85.735		84.927				85.440	85.206	85.110	84.960		84.431
		85.647	85.630		85.510	85.210	85.276	85.000	85.060		83.551
86.100		86.147			86.070	85.900	86.176	86.230	86.170		86.271
86.120		86.247			86.150	86.020	86.286	86.400	86.310		86.461
86.120		86.197			86.130	85.950	86.246	86.320	86.250		86.301
86.340						86.520	86.470				
86.340						86.530	86.570				

9620	9670	9720	9770	9820	9870	9920	9970	10020	10070	10120	10170
273444	273497	273543	273596	273943	273696	273741	273716	273839	273897	273940	273995
211746	211705	211750	211714	211759	211722	211765	211732	211751	211747	211794	211761
87.821	87.775	87.677	87.694	88.655	88.070	88.372	88.485	88.928	88.613	89.625	89.578
88.470	88.511	88.450	88.350	89.093	88.649	88.906	88.714	89.559	89.286	90.289	90.155
	88.550	88.308	88.319	89.126	88.828	88.886	88.970	89.570	89.195	90.303	90.017
											90.340
88.955	88.445	87.567	87.903	89.534	88.699	88.731	89.197	89.511	89.802	89.450	90.056
88.920					88.770						
	6.240	7.320	7.410	8.670	3.480	6.760	4.340	1.720	6.240	4.000	6.530
	82.271	81.130	80.940	80.423	85.169	82.146	84.374	87.839	83.046	86.289	83.625
85.412	85.556	85.711	85.923	86.055	86.245	86.446	86.659	86.883	87.127	87.391	87.677
87.162	87.306	87.461	87.673	87.805	87.995	88.196	88.409	88.484	88.641	88.796	88.954
81.712	81.856	82.011	82.223	82.355	82.545	82.746	82.959	83.183	83.427	83.691	83.977
(m OD)	(m OD)	(m OD)	(m OD)	(m OD)	(m OD)	(m OD)	(m OD)	(m OD)	(m OD)	(m OD)	(m OD)
	86.961	86.760	87.140	87.363	87.149	87.606	87.594	87.879	87.616		87.785
	86.931	87.180	87.020	87.243	87.289	87.466	87.454	87.829	87.486	87.559	87.615
	86.170		86.869		87.108		87.250		87.235		87.407
	86.210	87.500	86.889	87.096	87.128	87.266	87.240	87.270		87.323	87.377
	86.160	87.420	86.879	87.076	87.068	87.186	87.160	87.200	86.825	87.243	87.287
	86.150	87.410		87.006	87.018	87.176	87.190	87.200		87.253	87.297
	86.240	87.650	86.889	87.066	87.078	87.206	87.180	87.220	87.285	87.303	87.037
	86.670	87.610	87.309	87.406	87.458	87.646	87.620	87.670	87.885	87.753	88.527
	86.600	87.460	87.259	87.406	87.428	87.626	87.600		87.695	87.513	87.507
	85.890	87.600	87.049	87.276	87.288	87.456	87.460	87.520	87.695	87.583	87.367
	85.610	87.550		86.986	87.188	87.306	87.370	87.370	87.465	87.513	87.257
	85.550	87.380		87.026	87.088	87.226	87.250	87.260	87.365	87.373	87.147
		87.150		86.886	86.968	87.086	87.130	87.130	87.225	87.233	87.017
		87.160		86.776	86.848	86.966	86.990	87.010	87.095	87.083	86.867
		87.060		86.646	86.728	86.826	86.860	86.840	86.955	86.933	86.737
85.120		87.380		86.696	86.818	86.896	86.930	86.940	87.045	87.033	87.140
85.290		87.360		87.076	87.178	87.346	87.370	87.390	87.495	87.493	87.590
84.970		87.280		87.126	87.228	87.386	87.370	87.370	87.495	87.503	87.590
82.770	84.630	87.250		87.066	87.278	87.466	87.500	87.550	87.615	87.643	87.387
81.955	82.595	83.437	83.273	84.084	84.629	85.531	86.197	86.531	86.582	86.450	87.136
82.225	82.575		82.783		83.399		83.627	83.821	84.232	84.550	85.556
82.755	82.985		83.023		83.249		83.197	82.951	83.752		84.726
84.955	84.445		84.843		84.669		84.197	83.991	84.592		84.746
84.755	85.045		84.803		84.819		84.497	84.091	84.982		85.236
84.435	85.465		86.033		86.309		86.477				
83.755					86.449						
85.955				86.584							
86.235				86.634							
85.955				86.604							
86.300					87.130						
86.420					87.220						

10220	10270	10320	10370	JAP. GARDENS	CHILLING	STW (KILDARE)
274037	274093	274149	274212	273527	274785	273429
211810	211778	211827	211800	210926	212223	211631
90.572	89.932	89.419	89.057			88.299
91.179	90.772	90.200	89.672	85.838	97.206	
91.426	90.862	90.066	89.732			
	90.670					
91.091	90.477					
	90.210					
6.620	4.880	5.970	5.120			
84.559	85.892	84.230	84.552			
87.983	88.312	88.659	89.029			
89.105	89.247	89.300	89.230			
84.283	84.612	84.959	85.329			
(m OD)	(m OD)	(m OD)	(m OD)	(m OD)	(m OD)	(m OD)
				85.298	89.496	
87.869	87.812	87.790		85.148		
87.709	87.672	87.740		85.248	88.876	
	87.482		87.562	85.228	88.626	
87.656		87.576		85.238	88.446	86.409
87.556		87.426		85.228	88.296	86.329
87.636		87.446		85.228	88.246	86.339
88.026	87.352	87.646		85.238	88.196	86.389
88.456	88.182	88.106		85.378	88.706	86.769
88.076	88.082	87.926		85.368	88.946	86.719
88.006	87.982	87.906		85.288	88.926	86.239
87.936	87.872	87.776		85.268	88.826	85.839
87.706	87.762	87.616		85.328	88.746	85.959
87.456	87.602	87.456		85.188	88.576	85.809
87.296	87.462	87.316		85.158	88.376	
87.126	87.332	87.156		85.128	88.216	85.599
87.836	87.270	87.556	87.972	85.168	88.186	85.639
88.336	87.570		88.422	85.238	88.786	85.799
87.976	87.540		88.282	85.218	89.056	85.779
88.206	87.812	87.846	88.482	85.248	89.456	85.149
87.141	87.367	87.476	88.012	85.078	89.306	83.049
87.161	85.977	86.326		84.888	89.026	83.209
84.441				84.778	88.566	83.419
84.581	85.087			84.948	88.246	84.879
84.381				84.898	88.116	85.049
88.091						
86.911				85.098	88.176	84.719
	87.657					
	87.667					
				85.458	88.316	86.519

APPENDIX E

RECORDED FLOWS DURING DEWATERING

Table E-1: Recorded flows during dewatering (data obtained from Pat Devine).

													SUPPLY TO LAKES IN NATIONAL STUD				DISCHARGE FROM SITE			
	Carrier Pipe @ CH6700			Tully Bridge		Nurney Bridge		Greyabbey Bridge		Storm Tanks		Set. Pond @ Mooretn	Well @ CH10000	pencil pumps CH9640	Siphon @ CH9600	STW @ CH9600	National Stud	Armour Bridge	Carrier Pipe @ CH6700	Total Flow
Date	Main	Weir	Pan/Val	Pan/Val/ Mainstr	Kent	Pan/Val	Kent	Pan/Val	Kent	Pan/Val	Kent	Pan								
	L/s	L/s	L/s	L/s	L/s	L/s	L/s	L/s	L/s	L/s	L/s	L/s	L/s	L/s	L/s	L/s	L/s	L/s	L/s	L/s
30/05/2001																				0
31/05/2001				20													20			20
01/06/2001				20													20			20
02/06/2001				20													20			20
03/06/2001				20													20			20
04/06/2001				20													20			20
05/06/2001				20													20			20
06/06/2001				20													20			20
07/06/2001				20													20			20
08/06/2001				20													20			20
09/06/2001				20													20			20
10/06/2001				20													20			20
11/06/2001				20													20			20
12/06/2001				86													86			86
13/06/2001				86													86			86
14/06/2001				86													86			86
15/06/2001				86													86			86
16/06/2001				84													84			84
17/06/2001				84													84			84
18/06/2001				84													84			84
19/06/2001				51													51			51
20/06/2001				50													50			50
21/06/2001				46													46			46
22/06/2001				47													47			47
23/06/2001				49													49			49
24/06/2001				50													50			50
25/06/2001				50													50			50
26/06/2001				57													56.6			56.6
27/06/2001				54													53.8			53.8
28/06/2001				55													55.2			55.2
29/06/2001				60													60.4			60.4
30/06/2001				49													48.6			48.6
01/07/2001				47													46.8			46.8
02/07/2001				47													46.6			46.6
03/07/2001				46													46.0			46.0
04/07/2001				49													49.0			49.0
05/07/2001				48													48.0			48.0
06/07/2001				48													47.6			47.6
07/07/2001				45													45.0			45.0
08/07/2001				42													42.4			42.4
09/07/2001				42													42.4			42.4
10/07/2001				52													51.7			51.7
11/07/2001				43													43.3			43.3
12/07/2001				39													38.7			38.7
13/07/2001				33													33.0			33.0
14/07/2001				35													35.0			35.0
15/07/2001				32													31.6			31.6
16/07/2001				28													28.2			28.2
17/07/2001				54													53.9			53.9
18/07/2001				58													57.5			57.5
19/07/2001				63													62.8			62.8
20/07/2001				53.2													53.2			53.2
21/07/2001				59.9													59.9			59.9
22/07/2001				55.13													55.1			55.1
23/07/2001				60.35													60.3			60.3
24/07/2001				57.35													57.3			57.3
25/07/2001				57.54													57.5			57.5
26/07/2001				67.32													67.3			67.3
27/07/2001				64.42													64.4			64.4
28/07/2001				66.21													66.2			66.2
29/07/2001				59.72													59.7			59.7
30/07/2001				55.99													55.9			55.9
31/07/2001				56.24													56.2			56.2
01/08/2001				60.36													60.3			60.3
02/08/2001				59.32													59.3			59.3
03/08/2001				59.06													59.0			59.0
04/08/2001				56.65													56.6			56.6
05/08/2001				58.87													58.8			58.8
06/08/2001				65.83													65.8			65.8
07/08/2001				63.51													63.5			63.5
08/08/2001				64.06													64.0			64.0
09/08/2001				58.85													58.8			58.8
10/08/2001				62.66													62.6			62.6
11/08/2001				62.85													62.8			62.8
12/08/2001				61.23													61.2			61.2
13/08/2001			15	59.58													59.5		15	74.5
14/08/2001			15	56.04													56.0		15	71.0
15/08/2001			43	61.66													61.6		43	104.7
16/08/2001			43	63.72		20											63.7	20	43	126.7
17/08/2001			43	62.13		20											62.1	20	43	125.1
18/08/2001			43	59.48		20											59.4	20	43	122.5
19/08/2001			43	56.98		59											56.9	59	43	159
20/08/2001			43	62.41		59											62.4	59	43	164.4
21/08/2001			43	63.54		59											63.5	59	43	165.5
22/08/2001			40	63.45		59											63.4	59	40	162.5

23/08/2001		40	63.08	59										63.0	59	40	162.1
24/08/2001		40	59.47	59										59.4	59	40	158.5
25/08/2001		40	67.16	59										67.1	59	40	166.2
26/08/2001		40	67.16	47										67.16	47	40	154.2
27/08/2001		40	46	47										46	47	40	133
28/08/2001		40	46	47										46	47	40	133
29/08/2001		40	46	47										46	47	40	133
30/08/2001		49.5	46	47										46	47	49.5	142.5
31/08/2001		49.5	46	47										46	47	49.5	142.5
01/09/2001		49.5	46	47										46	47	49.5	142.5
02/09/2001		49.5	46	47										46	47	49.5	142.5
03/09/2001		49.5	46	47										46	47	49.5	142.5
04/09/2001		49.5	46	47										46	47	49.5	142.5
05/09/2001		49.5	46	47										46	47	49.5	142.5
06/09/2001		49.5	46	47										46	47	49.5	142.5
07/09/2001		49.5	46	47										46	47	49.5	142.5
08/09/2001		49.5	46	47										46	47	49.5	142.5
09/09/2001		49.5	46	47										46	47	49.5	142.5
10/09/2001		49.5	46	47										46	47	49.5	142.5
11/09/2001		49.5	46	47										46	47	49.5	142.5
12/09/2001		49.5	46	47										46	47	49.5	142.5
13/09/2001		49.5	46	47										46	47	49.5	142.5
14/09/2001		49.5	46	47										46	47	49.5	142.5
15/09/2001		49.5	46	47										46	47	49.5	142.5
16/09/2001		49.5	44.5	38										44.5	38	49.5	132
17/09/2001		49.5	44.5	38										44.5	38	49.5	132
18/09/2001		49.5	44.5	38										44.5	38	49.5	132
19/09/2001		49.5	44.5	38										44.5	38	49.5	132
20/09/2001		44	44.5	38										44.5	38	44	126.5
21/09/2001		44	44.5	38										44.5	38	44	126.5
22/09/2001		44	44.5	38										44.5	38	44	126.5
23/09/2001		44	44.5	38										44.5	38	44	126.5
24/09/2001		44	44.5	38										44.5	38	44	126.5
25/09/2001		44	44.5	38										44.5	38	44	126.5
26/09/2001		44	44.5	38										44.5	38	44	126.5
27/09/2001		44	44.5	38										44.5	38	44	126.5
28/09/2001		44	44.5	38										44.5	38	44	126.5
29/09/2001		44	44.5	38										44.5	38	44	126.5
30/09/2001		44	44.5	38										44.5	38	44	126.5
01/10/2001		44	44.5	38										44.5	38	44	126.5
02/10/2001		44	44.5	38										44.5	38	44	126.5
03/10/2001		44	44.5	38										44.5	38	44	126.5
04/10/2001		44	36	36										36	36	44	116
05/10/2001		44	36	36										36	36	44	116
06/10/2001		59	36	36										36	36	59	131
07/10/2001		59	54	47										54	47	59	160
08/10/2001		59	54	47										54	47	59	160
09/10/2001		59	54	47										54	47	59	160
10/10/2001		59	42.5	41										42.5	41	59	142.5
11/10/2001		53	42	41										42	41	53	136
12/10/2001		53	42	41										42	41	53	136
13/10/2001		53	42	36.5										42	36.5	53	131.5
14/10/2001		53	30	36.5										30	36.5	53	119.5
15/10/2001		42	30	36.5										30	36.5	42	108.5
16/10/2001		42	30	36.5										30	36.5	42	108.5
17/10/2001		42	27.5	44.5										27.5	44.5	42	114
18/10/2001		42	27.5	44.5										27.5	44.5	42	114
19/10/2001		42	27.5	44.5										27.5	44.5	42	114
20/10/2001		42	27.5	44.5										27.5	44.5	42	114
21/10/2001		42	24	40										24	40	42	106
22/10/2001		31	24	40										24	40	31	95
23/10/2001		31	24	40										24	40	31	95
24/10/2001		31	32	51										32	51	31	114
25/10/2001		31	32	51										32	51	31	114
26/10/2001		31	32	51										32	51	31	114
27/10/2001		31	32	51										32	51	31	114
28/10/2001		31	32	51										32	51	31	114
29/10/2001		31	32	51										32	51	31	114
30/10/2001		31	32	51										32	51	31	114
31/10/2001		31	33	51										33	51	31	115
01/11/2001		31	33	51										33	51	31	115
02/11/2001		31	33	51										33	51	31	115
03/11/2001		31	33	51										33	51	31	115
04/11/2001		31	33	40.5										33	40.5	31	104.5
05/11/2001		31	33	40.5										33	40.5	31	104.5
06/11/2001		31	33	40.5										33	40.5	31	104.5
07/11/2001		31	33	40.5										33	40.5	31	104.5
08/11/2001		40	33	40.5										33	40.5	40	113.5
09/11/2001		40	33	40.5										33	40.5	40	113.5
10/11/2001		40	29	40.5										29	40.5	40	109.5
11/11/2001		40	29	40.5										29	40.5	40	109.5
12/11/2001		40	29	40.5										29	40.5	40	109.5
13/11/2001		40	29	40.5										29	40.5	40	109.5
14/11/2001		40	29	40.5										29	40.5	40	109.5
15/11/2001		40	29	40.5										29	40.5	40	109.5
16/11/2001		40	29	40.5										29	40.5	40	109.5
17/11/2001		40	29	40.5										29	40.5	40	109.5
18/11/2001		40	29	44										29	44	40	113
19/11/2001		40	29	44										29	44	40	113
20/11/2001		40	29	44										29	44	40	113
21/11/2001		40	29	44										29	44	40	113
22/11/2001		40	29	44										29	44	40	113
23/11/2001		40	29	44										29	44	40	113
24/11/2001		40	21	35.5										21	35.5	40	96.5
25/11/2001		45	21	35.5										21	35.5	45	101.5
26/11/2001		45	21	35.5										21	35.5	45	101.5
27/11/2001		45	21	35.5										21	35.5	45	101.5
28/11/2001		45	21	35.5										21	35.5	45	101.5

29/11/2001		45	21		35.5											21	35.5	45	101.5
30/11/2001		45	21		35.5											21	35.5	45	101.5
01/12/2001		55.5	28.5		42											28.5	42	55.5	126
02/12/2001		55.5	28.5		42											28.5	42	55.5	126
03/12/2001		55.5	28.5		42											28.5	42	55.5	126
04/12/2001		55.5	28.5		42											28.5	42	55.5	126
05/12/2001		55.5	28.5		42											28.5	42	55.5	126
06/12/2001		55.5	28.5		42											28.5	42	55.5	126
07/12/2001		52	28.5		42											28.5	42	52	122.5
08/12/2001		52	33		34											33	34	52	119
09/12/2001		52	33		34											33	34	52	119
10/12/2001		52	33		34											33	34	52	119
11/12/2001		52	33		34											33	34	52	119
12/12/2001		50	29		38											29	38	50	117
13/12/2001		50	29		38											29	38	50	117
14/12/2001		50	29		38											29	38	50	117
15/12/2001		50	29		38											29	38	50	117
16/12/2001		51	29		32.5											29	32.5	51	112.5
17/12/2001		51	29		32.5											29	32.5	51	112.5
18/12/2001		51	29		32.5											29	32.5	51	112.5
19/12/2001		51	29		32.5											29	32.5	51	112.5
20/12/2001	31	43	26.5		34.5											26.5	34.5	43	104
21/12/2001	26	25	15													15	0	25	40
22/12/2001	8.3	25	15													15	0	25	40
23/12/2001	21	25	15													15	0	25	40
24/12/2001	10	25	15													15	0	25	40
25/12/2001	8.2	25	15													15	0	25	40
26/12/2001	12	25	15													15	0	25	40
27/12/2001	8.8	25	15													15	0	25	40
28/12/2001	25	25	15													15	0	25	40
29/12/2001	12	25	15													15	0	25	40
30/12/2001	9.5	25	15													15	0	25	40
31/12/2001	17	25	15													15	0	25	40
01/01/2002	26	25	15													15	0	25	40
02/01/2002	12	25	15													15	0	25	40
03/01/2002	13	25	15													15	0	25	40
04/01/2002	12	25	15													15	0	25	40
05/01/2002	16	25	15													15	0	25	40
06/01/2002	22	25	15													15	0	25	40
07/01/2002	33	17	15		162											15	162	17	194
08/01/2002	15	17	15.5		70											15.5	70	17	102.5
09/01/2002	37	34	15		51											15	51	34	100
10/01/2002	38	27	16		33											16	33	27	76
11/01/2002	32	27	14		36											14	36	27	77
12/01/2002	22	27	14		36											14	36	27	77
13/01/2002		16	16		35											16	35	16	67
14/01/2002	19	16	16		35											16	35	16	67
15/01/2002		15	16		34											16	34	15	65
16/01/2002		36	16		36											16	36	36	88
17/01/2002		36	16		36											16	36	36	88
18/01/2002		24	16		20											16	20	24	60
19/01/2002		24	15		20											15	20	24	59
20/01/2002		30	15		40											15	40	30	85
21/01/2002		30	15		40											15	40	30	85
22/01/2002		31	15		40											15	40	31	86
23/01/2002	43	35	18		43											18	43	42.7	103.7
24/01/2002	44	34	18		43											18	43	44.2	105.2
25/01/2002	51	42	17		37											17	37	50.9	104.9
26/01/2002	42		17		37											17	37	41.9	95.92
27/01/2002	47		17		63											17	63	47.4	127.5
28/01/2002	48	27	17		63											17	63	47.6	127.7
29/01/2002	51	28	17		72											17	72	51.3	140.4
30/01/2002	54	40	18		57											18	57	53.6	128.6
31/01/2002	55	44	17		58											17	58	55.0	130.1
01/02/2002	57		17		58											17	58	56.6	131.7
02/02/2002	58		17		58											17	58	58.3	133.3
03/02/2002	59		20		55											20	55	59.3	134.3
04/02/2002	62	45.5	20		55											20	55	61.8	136.9
05/02/2002	60	38	20		55											20	55	60.3	135.4
06/02/2002	58	44.5	21		57											21	57	57.7	135.8
07/02/2002	70		21		57											21	57	59.5	147.6
08/02/2002	71	49	19		58											19	58	71.0	148
09/02/2002	68		19		58											19	58	68.3	145.4
10/02/2002	67		20		46											20	46	67.2	133.2
11/02/2002	71	50	20		46	46.9										20	46.9	71.3	138.2
12/02/2002	70	50	20			46.9										20	46.9	70.1	137
13/02/2002	68	48	20		47	46.1										20	46.1	67.6	133.7
14/02/2002	69	47.5	20			46.1										20	46.1	69.2	135.3
15/02/2002	68	44	22		45	44										22	44	68.1	134.1
16/02/2002	67		22			44										22	44	67.2	133.3
17/02/2002	68		19			44										19	44	68.3	131.4
18/02/2002	69	45	19		46	44										19	44	68.7	131.7
19/02/2002	67		19			48.3										19	48.3	67.4	134.7
20/02/2002	67	38	20		51	48.3										20	48.3	67.4	135.8
21/02/2002	67		20			23.1										20	23.1	67.1	110.3
22/02/2002	68		20			23.1										20	23.1	68.3	111.4
23/02/2002	66		25			23.1										25	23.1	66.2	114.3
24/02/2002	72		25			23.1										25	23.1	72.2	120.3
25/02/2002	73	53	25		67	23.1										25	23.1	72.7	120.9
26/02/2002	78		25			21.9										25	21.9	78.4	125.4
27/02/2002	74	51	22			21.9										22	21.9	73.5	117.4
28/02/2002	64	35	22		42	21.9										22	21.9	63.7	107.7
01/03/2002	49		22			13.8										22	13.8	48.6	84.47
02/03/2002	42		22			28.3										22	28.3	41.5	91.9
03/03/2002	42		22			28.3										22	28.3	41.5	91.84
04/03/2002	48		22			28.3										22	28.3	48.1	98.44
05/03/2002	48		22			28.3										22	28.3	47.9	98.28
06/03/2002	66	40	22		32	28.3										22	28.3	66.4	116.7

07/03/2002	86		40	23		33	36.4										23	36.4	85.7	145.1
08/03/2002	78		84	23	26	34	36										25.9	36	77.9	139.8
09/03/2002	82				26		42										25.9	42	82.3	150.2
10/03/2002	85				26		42										25.9	42	85.2	153.1
11/03/2002	83				26		42										25.9	42	82.5	150.4
12/03/2002	78		76	21	26	33	42										25.9	42	77.9	145.8
13/03/2002	64		38	21	21		45.1										21.4	45.1	64.0	130.6
14/03/2002	54		71.5	24	21	45	29.6										21.4	29.6	71.5	122.5
15/03/2002	37		63	22	24	54	48.8										23.9	48.8	63	135.7
16/03/2002	33		63		24		48.8										23.7	48.8	63	135.5
17/03/2002	27		63		24		48.8										23.7	48.8	63	135.5
18/03/2002	31		63		24		48.8										23.7	48.8	63	135.5
19/03/2002	30		63		24		48.8										23.7	48.8	63	135.5
20/03/2002	28		76		25		55.5										24.8	55.5	76	156.3
21/03/2002	35		76	20	22		55.5	32									22	87.5	76	185.5
22/03/2002	37		55		22		55.1	32									22	87.1	55	164.1
23/03/2002	32		55		21		55.1	32									20.8	87.1	55	162.9
24/03/2002	26		76		21		55.1	16.5									20.8	71.6	76	168.4
25/03/2002	21		76		21		55.1	16.5									20.8	71.6	76	168.4
26/03/2002	20		63		21		55.1	16.5									20.8	71.6	63	155.4
27/03/2002	19		52	18	19		94.6	16.5									18.9	111.06	52	182
28/03/2002	70		43		20		78.5		17								19.59	94.98	70.2	184.8
29/03/2002	73				20		58.3		17								20.03	75.69	73.0	168.8
30/03/2002	72				20		57.8		16								19.92	74.15	72.3	166.4
31/03/2002	72				20		55.7	16.4									20	72.09	72.3	164.4
01/04/2002	73				20		58.8	16.4									19.76	75.19	73.3	168.3
02/04/2002	75		60	18	20	74	60.3	16.4									19.58	76.71	75.0	171.3
03/04/2002	74				20		63.1	16.4									19.74	79.54	73.7	173.1
04/04/2002	74				19		58.9	12									19.25	70.91	74.4	164.6
05/04/2002	75		67	19	19	70	62.8	12									19.06	74.84	74.6	168.6
06/04/2002	73				19		61.4	12									18.82	73.44	73.4	165.7
07/04/2002	73				19		59.1	12									18.71	71.05	72.5	162.3
08/04/2002	43		55	15	15	81	61.1	12									15.37	73.1	43.3	131.8
09/04/2002	52				16		73.9	12									15.72	85.86	51.8	153.4
10/04/2002	73		85	17	16	91	92.6	24									16.41	116.56	73.1	206.1
11/04/2002	71		42		16		107	24									16.47	130.55	70.8	217.9
12/04/2002	73		45	17	17	142	110	17									17.03	126.68	72.6	216.3
13/04/2002	85				18		74	17									18.11	90.99	84.6	193.7
14/04/2002	83				18		67.1	17									17.92	84.07	82.6	184.6
15/04/2002	76		48	14	15	133	76.7	35	3.4								15.4	111.66	75.9	203
16/04/2002	70		44		16		78	35	3.4								15.96	112.96	70.0	199
17/04/2002	76		46	15	23	132	111	35	3.4								22.77	145.61	75.5	243.9
18/04/2002	64		52	17	18	126	106	23	3.4								17.69	128.54	64.1	210.3
19/04/2002	57				17		94	23	3.4								17.21	117.01	56.9	191.2
20/04/2002	54				18		87.5	23	3.4								17.53	110.54	53.5	181.6
21/04/2002	53				19		95	23	3.4								18.78	118.01	53.4	190.3
22/04/2002	42		54		17		85.6	23	3.4								17.37	108.64	41.5	167.6
23/04/2002	43		55		16		86.9	23	11								15.84	109.86	42.9	168.7
24/04/2002	43		51	16	15	88	81.6	58	11	17							32.13	139.64	42.6	214.4
25/04/2002	39		52		15		72.4	58	14	17							32.37	86.01	38.7	157.1
26/04/2002	40		64	16	18	87	82.7	28	22	17							34.85	104.26	39.9	179
27/04/2002	34				17		109		33	17							34.22	142.31	34.1	210.7
28/04/2002	21				19		127		33	17							35.63	159.8	21.1	216.6
29/04/2002	12		74	16	18	133	121	26	33	17							34.78	153.99	12.3	201.1
30/04/2002	18				18		122		33	17							34.66	154.76	17.9	207.3
01/05/2002	44		45	16	17	113	109	27	27	17							33.95	135.53	43.7	213.2
02/05/2002	33			15	17	112	117	27	26	13							29.7	143.61	32.9	206.3
03/05/2002	32				17		111		26	13							29.63	137.41	31.8	198.9
04/05/2002	33				17		99.4		26	13							29.58	125.66	33.1	188.4
05/05/2002	36				16		96.4		26	18							34.48	122.7	35.7	193
06/05/2002	29				16		94.8		26	18							34.39	121.11	28.8	184.3
07/05/2002	31		45	17	16	104	93.6	25	26	18							33.92	118.6	30.5	183.1
08/05/2002	25		37		16	91	87.3	25	14	18							34.12	112.26	25.3	171.8
09/05/2002	30				16		95.8	24	14	18							33.57	119.75	30.4	183.8
10/05/2002	41		32	17	14	112	41.8	24	14	18							32.45	65.78	41.2	139.5
11/05/2002	42				16		49.2	24	8.1	18							33.58	73.24	41.8	148.6
12/05/2002	39				16		49.5	27	8.1	20							35.88	76.48	38.7	151.1
13/05/2002	43		40	18	16	67	87.1	27	8.1	20							35.98	114.05	42.6	192.6
14/05/2002	45		54		15		78.5	27	19	20							34.94	105.46	45.1	185.6
15/05/2002	57			19	14	94	58.2	28	19	24							38.05	86.23	57.0	181.3
16/05/2002	71		52		14		44.3	28	10	24							37.95	72.32	70.8	181.1
17/05/2002	80			16	18	95	41.8	30	10	19							37.44	71.79	80.0	189.3
18/05/2002	73				16		36.9	30	7.7	19							34.91	66.92	72.7	174.5
19/05/2002	72				16		36.9	30	7.7	19							34.81	66.92	72.0	173.8
20/05/2002	69		64		15		36.9	30	7.7	23							38.49	66.92	69.4	174.8
21/05/2002	73		65		15		119	45	7.7	23							38.49	164	73.1	275.6
22/05/2002	70		52	15	14	119	119	45		23							37.33	164	69.9	271.2
23/05/2002	70		54	15	16	114	114	45		20							35.5	159	70.0	264.6
24/05/2002	61				17		114	45		20							36.86	159	61.4	257.3
25/05/2002	62				16		114	45		20							35.61	159	61.8	256.4
26/05/2002	54				15		71	28		53							58.31	99	53.7	221.1
27/05/2002	64		119	15	14	71	71	28	5	53							67.18	99	64.2	230.4
28/05/2002	66		125		18		71		25	23							40.92	96.41	66.4	203.7
29/05/2002	109		51	15	19	96	43.6	21	25	23							42.21	68.4	109.0	219.7
30/05/2002	97		84		17		42.9		25	23							40.05	67.78	96.6	204.5
31/05/2002	92		77	15	18		48.2		25	23							40.6	72.84	91.5	205
01/06/2002	92				20		58.9		25	23							43.02	83.98	92.3	219.4
02/06/2002	89				21		58.9		27	23							43.93	85.48	88.8	218.3
03/06/2002	92				21		43.4		25	21							41.54	68.74	91.5	201.8
04/06/2002	79		131		19		43.4		25	21							39.8	68.22	78.5	186.5
05/06/2002	59		130		20		51.7		25	21							41.21	76.89	58.8	176.9
06/06/2002			142		18		52.7		25	21							39.42	77.89	142	259.3
07/06/2002			121	15	21		51.7	26	27	21							41.96	78.16	121	241.1
08/06/2002			121		21		52.3		27	21							42.29	79.69	121	243
09/06/2002			128		22		54.8		29	21							43.07	83.39	128	254.5
10/06/2002			128		21		54.4		27	22							43.47	81.13	128	252.6
11/06/2002			126		20		58.9		26	22							41.74	85.05	126	252.8
12/06/2002			70	17	18	60	61.2	26	25	22							40.36	85.77	70	196.1

13/06/2002			120		20		62		25	22							42.12	86.85	120	249
14/06/2002			58		21	67	51.4	18	25	23							44.12	86.28	58	188.4
15/06/2002			58		21		59.7		25	23							43.9	84.6	58	186.5
16/06/2002			123		21		60.1		25	23							44.19	84.97	123	252.2
17/06/2002			123		18		58.1		25	19							36.9	82.76	123	242.7
18/06/2002			110		17		57		25	19							35.8	81.72	110	227.5
19/06/2002			123	19	17	26	57	23	25	19	21						37.33	81.73	123	242.1
20/06/2002			67		17	55	57	24	24	18	21						37.66	81.07	67	185.7
21/06/2002			57		19	54	44.5	23	24	20	21						40.01	68.76	57	165.8
22/06/2002			57		20		44.5		26		21						40.41	70.1	57	167.5
23/06/2002			57		21		45		25		21						41.46	70.19	57	168.7
24/06/2002			120	19	19	44	44.5	22	26	18	20						39.15	70.35	120	229.5
25/06/2002			120		17	41	44.5	23	25	18	20						37.33	69.38	120	226.7
26/06/2002			120	12	21	44	34.4	23	25	18	20						41.01	59.35	120	220.4
27/06/2002			118		20	38	34.4	23	25	19	20						40.66	59.43	118	218.1
28/06/2002			123		17	38	33.8	22	25	19	21						38.06	58.9	123	220
29/06/2002			123		21		35.1		25		21						41.17	60.15	123	224.3
30/06/2002			123		21		35.3		25		21						41.58	60.59	123	225.2
01/07/2002			123	21	20	36	35	23	25	18	21						40.54	59.92	123	223.5
02/07/2002	33		123		19	35	33.9	22	22	19	21						39.97	55.74	123	218.7
03/07/2002	68		123		18		33.5		22		20						38.08	55.7	123	216.8
04/07/2002	106	83	136		15	37	33.1	21	22	16	20						35.53	55.23	106.3	197.1
05/07/2002	107	84		21	21		19.1	22	23	18	20						40.81	42.31	107.4	190.6
06/07/2002	103	72			20		19.1		23		20						40.14	42.53	102.9	185.7
07/07/2002	86	72			20		21.7		24		20						40.18	45.22	86.1	171.5
08/07/2002	98	91	123		19		21.7		24		20						39.41	45.9	97.6	183
09/07/2002	116	93	139	20	19	49	21.7	21	24	18	20						39.05	45.45	116.3	200.9
10/07/2002	117				20		22.2		23	17	20						39.83	45.62	116.9	202.4
11/07/2002	112	87	124	18	21	53	30	22	23	18	20						41.33	53.27	111.8	206.4
12/07/2002	104	100	121	23	37	53	18.1	28	23	21	20						57.21	76.38	104.4	238
13/07/2002	101	86			43	53	11.9		23		20						62.84	75.51	101.4	239.8
14/07/2002	104	86			42	43	10.6		22		20						62.45	65.45	104.0	231.9
15/07/2002	109	86	94.2		41	43	8.22	20	22	20	20						60.97	64.88	109.1	235
16/07/2002	104	92	99	40	42	33	5.66	23	23	16	20						61.93	55.68	103.8	221.4
17/07/2002	111	88	48.9	40	42	33	5.23	21	21	18	20						61.7	53.8	111.2	226.7
18/07/2002	135	78		46	42	39	4.7	20	21	18	20						61.73	60.4	134.8	257
19/07/2002	110			40	41	38	5.02	21	24	17	20						60.95	61.83	109.9	232.7
20/07/2002	110				41	38	15.2		23		20						60.8	61.2	109.9	232
21/07/2002	110				41	35	12.2		23		20						60.71	58.39	109.9	229.1
22/07/2002	110	78		45	41	35	12.2	84	21	21	20						60.58	55.51	109.9	226
23/07/2002	105			46	41	39	15.9	26	23	22	20						60.43	62.26	104.8	227.5
24/07/2002	106	78		45	40	49	14.1	28	23	20	20						59.79	72.44	106.2	238.5
25/07/2002	108	77	99	44	41	32	13.8	22	24	16	20						60.37	55.55	108.3	224.3
26/07/2002	108	78	96.6		41	32	13.5		24		19						60.17	55.54	108.3	224.1
27/07/2002	108	78			41	32	13.5		23		19						60.01	54.83	108.3	223.2
28/07/2002	105	78			41	32	13.5		23		19						60.09	55.45	104.6	220.2
29/07/2002	105	78			41	33	20.5		24		19						60.22	57.13	104.6	222
30/07/2002	105	77	80.4		41	33	15.5		24		19						59.98	57.33	104.6	221.9
31/07/2002	106	73	80.4	41	40	33	9.53	27	24	22	19						58.96	56.97	105.8	221.8
01/08/2002	105	73	89.6	43	40	33	8.61		24		19						59.63	56.97	104.9	221.5
02/08/2002	77	73	104		40	33	10.8		24		19						59.81	56.97	76.5	193.3
03/08/2002	77	73			40	33	22.7		24		19						59.27	56.97	76.5	192.8
04/08/2002	101	73			40	33	11.1		24		19						59.25	57.25	100.8	217.3
05/08/2002	98	73			40	33	10.2		24		19						59.03	57.25	98.3	214.6
06/08/2002	105	91	96.6	42	40	33	9.45	25	24	18	19						59.22	57.25	104.5	221.1
07/08/2002	101		86.8	42	40	33	9.45	26	24	22	19						59.19	57.31	101.0	217.5
08/08/2002	115				40	33	9.45		25		19						59.54	58.49	115.0	233.1
09/08/2002	116			34	40		20.7	22	24	24	19						59.21	44.93	116.4	220.6
10/08/2002	113				40		25.4		24		19						58.83	49.27	112.5	220.6
11/08/2002	112				40		30.3		24		19						58.88	54.31	112.4	225.6
12/08/2002	116	90	74.1		40		21.3		16		19						58.94	37.11	115.6	211.7
13/08/2002	130	117			38		21	32			19						57.55	53	130.3	240.9
14/08/2002	128	116	97.8		39		19.4	32			19						58.64	51.44	128.2	238.3
15/08/2002	132	114	119		39		19.7	32			19						58.62	51.72	132.2	242.6
16/08/2002	136	106	116		39		19	32			19						58.56	50.98	135.8	245.3
17/08/2002	132	106			39		16.6	32			19						58.46	48.57	131.6	238.7
18/08/2002	135	105			36		16.9	32			19						55.08	48.88	135.2	239.2
19/08/2002	136	106			36		16	32			19						54.92	47.98	136.1	239
20/08/2002	133	103	122		36	16	0.54	32			19						54.9	47.98	133.1	236.1
21/08/2002	127	100	104	30	36	34.4		32		15	19						55.07	66.4	127.2	248.8
22/08/2002	126				36	29		28			19						54.6	57	125.7	237.4
23/08/2002	127				36	29		28			19						54.52	57	126.9	238.4
24/08/2002	124				36	29		28			18						54.1	57	124.0	235.2
25/08/2002	125				36	41		48.5			19						54.3	89.5	125.1	268.9
26/08/2002	127	101		34	36	41		48.5		17	19						55.52	89.5	126.8	271.8
27/08/2002	123	93		34	35	41		35		17	19						54.24	76	122.8	253.1
28/08/2002	117	92		33	36	4.5		35			19						54.51	39.5	117.2	211.2
29/08/2002	126	100			36			35			18						54.01	35	126.3	215.4
30/08/2002	123	98			36			35			18						54.17	35	122.8	212
31/08/2002	123	95			36			35			18						54.27	35	122.5	211.8
01/09/2002	122	96			36			35			18						54.23	35	121.6	210.9
02/09/2002	122	96		32	36					15	18						54.24	32.3	122.0	208.6
03/09/2002	120	95		27	36					16	18						54.15	32.3	120.4	206.9
04/09/2002	118	94	94.4	29	36						19						54.59	35.3	118.4	208.3
05/09/2002	118	93			36						19						54.63	35.3	118.4	208.3
06/09/2002	119	90	91		36						19						54.64	35.3	119.3	209.3
07/09/2002	126				36						19						54.74	35.3	126.1	216.2
08/09/2002	121				32						19						50.61	39	121.2	210.9
09/09/2002	123		87.2		32						18						49.99	39	123.2	212.3
10/09/2002	124				31						18						48.87	39	124.4	212.3
11/09/2002	121		96.6		30						18						47.92	39	121.1	208.1
12/09/2002	119				30						18						48.36	31.7	119.4	199.5
13/09/2002	110		111		30						18						48.13	31.7	110.2	190.1
14/09/2002	113				30						18						47.89	31.7	112.6	192.2
15/09/2002	114				30						18						47.56	34.6	113.5	195.8
16/09/2002	113		123		29						18						46.68	34.6	112.9	194.2
17/09/2002	111				29						18						46.52	34.6	110.9	192.1
18/09/2002	115		139		28						18						46.26	34.6	115.2	196.1

19/09/2002	119				28						18						46.18	39.8	118.8	204.8
20/09/2002	137				28						18						46.07	39.8	136.7	222.6
21/09/2002	146				28						18						45.78	39.8	145.5	231.2
22/09/2002	146				28						18						45.63	35.5	145.9	227.1
23/09/2002	148		132		28						18						45.67	35.5	147.7	228.9
24/09/2002	136	154			28						18						45.66	35.5	135.6	216.8
25/09/2002	89	136	96.6		27						18						44.56	80.8	89.3	214.7
26/09/2002	96	122			27						17						44.82	80.8	96.2	221.9
27/09/2002	120	97			27						17						44.66	80.8	119.9	245.4
28/09/2002	118	98			30						17						47.89	80.8	117.6	246.3
29/09/2002	117	98			28						17						44.99	80.8	116.6	242.4
30/09/2002	110	89			27						17						44.63	88.7	109.6	242.9
01/10/2002	104	80			27						17						44.53	88.7	104.1	237.4
02/10/2002	106	83			27						17						44.56	88.7	106.0	239.3
03/10/2002	107	84			27						17						44.55	85.7	107.1	237.4
04/10/2002	107	85			27						17						44.4	85.7	107.1	237.2
05/10/2002	109	85			27						17						44.36	85.7	108.5	238.6
06/10/2002	106	86			27						17						44.32	69.5	106.2	220.1
07/10/2002	105	82			27						17						44.29	69.5	104.9	218.8
08/10/2002	95	75			27						17						44.29	69.5	94.8	208.6
09/10/2002	93	70			27						18						44.87	68.4	92.7	206
10/10/2002	97	75			27						17						44.29	68.4	96.8	209.6
11/10/2002	104	83			27						17						44.58	68.4	104.3	217.4
12/10/2002	85	61			27						17						44.49	68.4	85.3	198.2
13/10/2002	75	58			27						17						44.29	68.4	74.7	187.5
14/10/2002	77	71			27						17						44.47	52	77.3	173.8
15/10/2002	80	68	44.8		27						17						44.32	52	80.0	176.4
16/10/2002	79	66			27						17						44.43	52	79.4	175.9
17/10/2002	74	62			27						17						44.2	52	74.1	170.3
18/10/2002	77	64	40.1		27						17						44.14	52	76.6	172.8
19/10/2002	75	64			27						17						44.09	52	75.1	171.2
20/10/2002	79	81			27						17						44.61	52	78.7	175.3
21/10/2002	97	102			27						19						46.02	52	97.0	195
22/10/2002	106	97			27						19						45.91	52	105.9	203.9
23/10/2002	102	104			27						19						46.67	52	101.6	200.3
24/10/2002	119	148	181								19						19.08		119.3	138.5
25/10/2002	139	154	181								19						19.07		139.0	158.1
26/10/2002	135	159									19						19.1		135.1	154.2
27/10/2002	142	163									19						19.2		142.2	161.5
28/10/2002	132	155									19						19.11		131.8	151
29/10/2002	165	201									20						19.69		165.1	184.8
30/10/2002	152	179	218								20						19.82		151.5	171.4
31/10/2002	125	157									20						19.85		125.0	144.9
01/11/2002	135	144									20						19.79		135.2	155.1
02/11/2002	149										20						19.92		149.3	169.3
03/11/2002	144										20						19.91		144.2	164.1
04/11/2002	140		242								20						19.95		140.1	160.1
05/11/2002	141										20						19.96		141.0	161
06/11/2002	146									16	20						19.88		145.8	165.7
07/11/2002	137										20						19.8		136.8	156.6
08/11/2002	154										20						19.93		154.2	174.1
09/11/2002	168										20						20.01		167.8	187.9
10/11/2002	155										20						20.19		154.6	174.9
11/11/2002	144										20						20.12		143.5	163.6
12/11/2002	145		260							17	20						20.25		144.9	165.2
13/11/2002	145									17	20						20.1		144.9	165.1
14/11/2002	145										20						20.19		144.9	165.2
15/11/2002	145		259								21						20.59		144.9	165.6
16/11/2002	170										20						20.36		170.1	190.5
17/11/2002	170										20						20.23		170.1	190.4
18/11/2002	170		263							17	20						20.41		170.1	190.6
19/11/2002	190	237									21						20.87		189.9	210.9
20/11/2002	176	201	263							17	20						20.35		176.1	196.5
21/11/2002	187	219								17	21						20.6		187.4	208
22/11/2002	199	234	276								21						20.62		199.3	219.9
23/11/2002	190	215									21						20.53		189.5	210.1
24/11/2002	189	217									21						20.57		188.5	209.1
25/11/2002	189	213	325								21						20.8		189.2	210
26/11/2002	201	222								18	20						19.71		200.8	220.6
27/11/2002	249	277									20						19.52		249.1	268.7
28/11/2002	212	250	362							19	19						18.77		211.8	230.6
29/11/2002	209	237									19						18.79		209.1	227.9
30/11/2002	207	244									19						18.95		207.3	226.3
01/12/2002	207	227									19						18.97		207.4	226.4
02/12/2002	235	291	356								19						18.92		234.8	253.8
03/12/2002	214	246								18	19						19.45		214.0	233.5
04/12/2002	215	244	327								20						19.67		214.7	234.5
05/12/2002	211	245								18	20						19.99		210.8	230.9
06/12/2002	207	245	295								20						19.82		207.1	227
07/12/2002	214	241									20						19.65		213.9	233.6
08/12/2002	219	238									20						19.51		219.1	238.7
09/12/2002	193	216								17	19						19.46		193.0	212.5
10/12/2002	175	213	241								19						19.41		175.2	194.7
11/12/2002	176	212	248							20	19						19.24		176.0	195.3
12/12/2002	187	219									19						18.78		186.5	205.3
13/12/2002	198	221	240							18	19						18.55		197.6	216.2
14/12/2002	193	216									18						18.44		192.7	211.1
15/12/2002	194	218									18						18.4		193.9	212.4
16/12/2002	179	207	210							16	18						18.38		179.0	197.5
17/12/2002	157	185									18						18.29		156.8	175.2
18/12/2002	160	196									18						18.02		160.3	178.4
19/12/2002	164	194	201								18						18.01		163.5	181.5
20/12/2002	173	194									18						17.93		173.2	191.2
21/12/2002	175										18						17.95		174.9	192.9
22/12/2002	184										18						18.03		184.2	202.3
23/12/2002	167										18						18.12		166.8	185
24/12/2002	193										18						18.15		193.0	211.2
25/12/2002	175										18						18.13		175.0	193.2

26/12/2002	178										18						18.15		177.8	196
27/12/2002	194										18						18.28		193.9	212.3
28/12/2002	173										18						18.22		173.3	191.6
29/12/2002	253										19						18.88		252.8	271.7
30/12/2002	248										19						18.72		247.5	266.3
31/12/2002	249										19						18.77		249.2	268
01/01/2003	286										19						19.08		285.6	304.7
02/01/2003	239										19						18.91		239.3	258.2
03/01/2003	209										19						18.84		209.0	227.9
04/01/2003	196										19						18.82		195.8	214.7
05/01/2003	200										19						18.83		200.4	219.3
06/01/2003	208	231									19						18.81		208.0	226.8
07/01/2003	206	219									19						18.72		205.8	224.5
08/01/2003	206	217									19						19.45		205.6	225.1
09/01/2003	208	214									18						18.21		207.9	226.1
10/01/2003	182	189								28	19						18.72		181.7	200.5
11/01/2003	176	185									19						18.63		175.7	194.4
12/01/2003	175	184									19						18.61		174.9	193.6
13/01/2003	184	189								28	19						18.57		184.2	202.8
14/01/2003	182	187									18						18.43		181.5	200
15/01/2003	183	188								25	18			41			59		183.3	242.3
16/01/2003	174	183								30	17			41			58.09		174.0	232.2
17/01/2003	201	210								27	16			41			57.31		201.0	258.3
18/01/2003	207	221									16			41			56.54		207.0	263.5
19/01/2003	190	204									15			41			56.46		190.0	246.5
20/01/2003	216	237									18			41			58.99		216.2	275.3
21/01/2003	197	208									17			41			58.14		197.3	255.5
22/01/2003	185	194								29	16			41			56.81		185.3	242.2
23/01/2003	178	189									28			41			58.56		178.3	246.9
24/01/2003	191	194								28	28			41			58.56		191.2	259.8
25/01/2003	207										28			41			58.56		206.5	275.1
26/01/2003	198										27			41			58.26		198.4	266.7
27/01/2003	205										27			20			47.26		204.6	251.9
28/01/2003	222										13						13.44		222.3	235.8
29/01/2003	218										13						13.44		218.2	231.7
30/01/2003	219										15						14.6		218.6	233.3
31/01/2003	208										17						17.02		208.0	225.1
01/02/2003	216										13						13.21		216.0	229.3
02/02/2003	212										12						12.45		212.2	224.7
03/02/2003	215									31	13						13.45		214.8	228.3
04/02/2003	219										16						16.25		218.7	235
05/02/2003	216										21						20.8		215.9	236.8
06/02/2003	232										18						18.24		232.3	250.6
07/02/2003	240										14						13.51		240.3	253.8
08/02/2003	235										12						11.71		234.6	246.3
09/02/2003	231										14						13.5		231.3	244.8
10/02/2003	237										13						12.89		237.3	250.2
11/02/2003	245										11						10.71		245.1	255.9
12/02/2003	246										9.4						9.41		245.8	255.2
13/02/2003	254										9.4								253.5	253.5
14/02/2003	288										8.6								287.9	287.9
15/02/2003	288										8.1								288.2	288.3
16/02/2003	290										7.8								289.7	289.7
17/02/2003	292										7.7								292.3	292.3
18/02/2003	298										7.6								298.3	298.4
19/02/2003	300										9.1								300.0	300
20/02/2003	308										7.6						7.64		308.1	315.7
21/02/2003	311										8.3						8.33		310.8	319.2
22/02/2003	312										7.3						7.25		312.0	319.3
23/02/2003	312										11						10.72		312.3	323.1
24/02/2003	315										8.2						8.22		315.3	323.6
25/02/2003	316										6.8						6.76		316.2	323
26/02/2003	221														50		50		220.7	270.8
27/02/2003	161														50		50		161.1	211.2
28/02/2003	320														50		50		320.3	370.4
01/03/2003	308											372.563			50		50		307.7	357.8
02/03/2003	306														50		50		306.1	356.1
03/03/2003	301											316			50		50		300.5	350.5
04/03/2003	363														50		50		363.0	413.1
05/03/2003	430													40			40		429.8	469.9
06/03/2003	470											300		40			40		469.5	509.6
07/03/2003	515													40			40		515.4	555.4
08/03/2003	315													40			40		314.9	355
09/03/2003	294													40			40		293.5	333.6
10/03/2003	294													40			40		293.6	333.6
11/03/2003	270													40			40		269.6	309.7
12/03/2003	270													40			40		269.7	309.7
13/03/2003	436											484		40			40		435.7	475.7
14/03/2003	436													30			30		435.7	465.7
15/03/2003	436													30			30		435.7	465.7
16/03/2003	436											390.25		30			30		435.7	465.7
17/03/2003	436													30			30		435.7	465.7
18/03/2003	436													30			30		435.7	465.7
19/03/2003	436		401									477		30			30		435.7	465.7
20/03/2003	436													30			30		435.7	465.7
21/03/2003	399												83	30	50		163		399.4	562.4
22/03/2003	343												83	30	50		163		342.6	505.6
23/03/2003	367												83	30	50		163		366.6	529.6
24/03/2003	365		389									360	110	30	34		174		365.3	539.4
25/03/2003	362												110	30	34		174		361.8	535.8
26/03/2003	394												48	30	34		112		394.3	506.3
27/03/2003	358												122	30	34		186		357.7	543.7
28/03/2003	336											314	113	30	34		177		336.4	513.4
29/03/2003	321												113	30	34		177		320.8	497.9
30/03/2003	330												106	30	35		171		330.1	501.1
31/03/2003	320											410	106	30	35		171		320.0	491.1
01/04/2003	322												107	30	36		173		321.6	494.7
02/04/2003	307												107	30	36		173		306.5	479.6

03/04/2003	310												107	30	36		173		309.9	483
04/04/2003	377												107	30	36		173		377.3	550.3
05/04/2003	404												69	30	35		134		404.0	538.1
06/04/2003	439												69	30	35		134		438.5	572.5
07/04/2003	406												69	30	35		134		406.4	540.4
08/04/2003	397												69	30	35		134		396.6	530.7
09/04/2003	385											371	69	30	35		134		384.9	519
10/04/2003	327												69	30	35		134		326.5	460.5
11/04/2003	335												69	30	35		134		335.1	469.1
12/04/2003	332												69	30	35		134		331.7	465.7
13/04/2003	314												69	30	35		134		314.1	448.2
14/04/2003	362												69	30	35		134		362.0	496
15/04/2003	410												88	30	34		152		409.5	561.5
16/04/2003	453											381	88	30	34		152		453.1	605.1
17/04/2003	439												88	30	34		152		439.3	591.4
18/04/2003	404												88	30	34		152		403.6	555.7
19/04/2003	380												88	30	34		152		380.0	532.1
20/04/2003	334												88	30	34		152		333.7	485.7
21/04/2003	317												88	30	34		152		316.7	468.7
22/04/2003	329												88	30	34		152		329.2	481.3
23/04/2003	347												88	30	34		152		347.0	499.1
24/04/2003	337												88	30	34		152		336.5	488.5
25/04/2003	341												88	30	34		152		341.3	493.3
26/04/2003	351												88	30	36		154		350.6	504.7
27/04/2003	364												88	30	36		154		364.2	518.2
28/04/2003	363												88	30	36		154		363.2	517.2
29/04/2003	352												88	30	36		154		351.7	505.8
30/04/2003	325												115	30	36		181		325.0	506
01/05/2003	346											352	115	30	36		181		345.6	526.7
02/05/2003	325												115	30	36		181		325.1	506.1
03/05/2003	301												115	30	36		181		300.9	482
04/05/2003	337												114	30	36		180		337.4	517.4
05/05/2003	360												114	30	36		180		360.3	540.4
06/05/2003	314												114	30	36		180		313.8	493.8
07/05/2003	331												114	30	36		180		330.5	510.6
08/05/2003	307												101	30	36		167		306.5	473.5
09/05/2003	284												101	30	36		167		283.7	450.7
10/05/2003	297												101	30	42		173		296.9	470
11/05/2003	284												98	30	42		170		284.1	454.2
12/05/2003	284												98	30	42		170		284.1	454.2
13/05/2003	275												98	30	42		170		274.9	445
14/05/2003	269												98	30	42		170		269.4	439.5
15/05/2003	284												98	30	42		170		283.6	453.6
16/05/2003	264												98	30	42		170		264.1	434.1
17/05/2003	299												98	30			128		299.0	427.1
18/05/2003	256												118	30			148		256.3	404.3
19/05/2003	244												118	30			148		243.6	391.7
20/05/2003	227												118	30			148		226.5	374.5
21/05/2003	220												118	30			148		219.7	367.7
22/05/2003	203												118	30			148		203.2	351.2
23/05/2003	184												118	30			148		183.9	331.9
24/05/2003	195												118	30			148		194.6	342.7
25/05/2003	180												118	30			148		180.1	328.1
26/05/2003	232												118	30			148		232.0	380.1
27/05/2003	321												118	30			148		320.8	468.8
28/05/2003	276												112	30	32		174		276.2	450.2
29/05/2003	304											293	112	30			142		304.0	446
30/05/2003	286												112	30			142		285.8	427.9
31/05/2003	184												112	30			142		184.4	326.4
01/06/2003	178												109	30			139		178.3	317.4
02/06/2003	187												109	30			139		186.9	325.9
03/06/2003	197												109	30			139		197.4	336.4
04/06/2003	191												109	53			162		190.6	352.7
05/06/2003	229											271	137	56			193		229.3	422.4
06/06/2003	251												137	56			193		250.5	443.5
07/06/2003	211												137	56			193		210.7	403.7
08/06/2003	175												130	90			220		175.1	395.1
09/06/2003	194												130	90			220		193.7	413.8
10/06/2003	242											270	130	90			220		241.9	461.9
11/06/2003	279												130	90			220		278.6	498.7
12/06/2003	232												125	93			218		231.7	449.7
13/06/2003	209											175	125	93			218		208.5	426.5
14/06/2003	138												125	93			218		137.8	355.8
15/06/2003	152												125	93			218		152.2	370.2
16/06/2003	160												121	81			202		160.0	362.1
17/06/2003	160												121	81			202		159.7	361.8
18/06/2003	161												121	81			202		161.3	363.4
19/06/2003	178												77	81			158		178.2	336.2
20/06/2003	157												77	92			169		157.2	326.3
21/06/2003	151												77	92			169		150.7	319.7
22/06/2003	153												77	96			173		152.5	325.5
23/06/2003	148												77	96			173		147.6	320.6
24/06/2003	138												82	96			178		137.7	315.7
25/06/2003	121												82	96			178		121.1	299.2
26/06/2003	141												82	91			173		140.9	313.9
27/06/2003	202												82	91			173		201.8	374.9
28/06/2003	152												82	91			173		152.4	325.5
29/06/2003	144												82	91			173		143.5	316.5
30/06/2003	274												54.9	45			99.9		273.8	373.7
01/07/2003	179												54.9	45			99.9		179.4	279.4
02/07/2003	161												54.9	44			98.9		161.2	260.1
03/07/2003	192												83.3	44			127.3		191.6	318.9
04/07/2003	275												83.3	46			129.3		275.0	404.4
05/07/2003	271												83.3	46			129.3		271.2	400.6
06/07/2003	269												83.3	46			129.3		268.7	398
07/07/2003	267												83.3	88			171.3		267.1	438.4
08/07/2003	131												83.3	88			171.3		130.8	302.1
09/07/2003	233													62	65	24	151		233.0	384

10/07/2003	193												48	59	15	122		193.4	315.4
11/07/2003	69												48	56	14	118		68.98	187
12/07/2003	68												48	56	14	118		67.5	185.5
13/07/2003	67												48	59	15	122		67.3	189.4
14/07/2003	56												102	59	15	176		55.5	231.6
15/07/2003	81												85	59	15	159		80.5	239.5
16/07/2003	59												85	61	15	161		58.9	219.9
17/07/2003	120												85	61	15	161		119.7	280.7
18/07/2003	82												85	61	15	161		82.1	243.2
19/07/2003	74												85	61	15	161		74.4	235.4
20/07/2003	66												81	35	15	131		66.0	197
21/07/2003	86												81	35	15	131		86.1	217.2
22/07/2003	62												81	35	15	131		61.9	192.9
23/07/2003	66												81	35	15	131		66.4	197.4
24/07/2003	54												81	35	23	139		54.0	193.1
25/07/2003	60												57	32	23	112		59.5	171.6
26/07/2003	59												57	32	23	112		59.2	171.3
27/07/2003	67												57	32	23	112		66.7	178.7
28/07/2003	77												57	32	23	112		76.7	188.8
29/07/2003	67												57	32	23	112		66.9	178.9
30/07/2003	61												57	32	23	112		60.6	172.6
31/07/2003	64												55	29	22	106		64.0	170.1
01/08/2003	57												55	29	22	106		56.5	162.5
02/08/2003	55												55	29	22	106		54.9	161
03/08/2003	55												55	29	22	106		54.5	160.5
04/08/2003	55												55	32	22	109		55.0	164.1
05/08/2003	58												55	32	22	109		58.2	167.2
06/08/2003	63													55	24	79		63.4	142.4
07/08/2003	58													55	24	79		58.1	137.2
08/08/2003	62													55	20	75		61.8	136.8
09/08/2003	64													55	20	75		64.3	139.3
10/08/2003	63													55	20	75		63.4	138.4
11/08/2003	61													55	21	76		60.7	136.7
12/08/2003	65													55	21	76		65.0	141
13/08/2003	70													55	21	76		69.5	145.6
14/08/2003	64													53	19	72		64.1	136.1
15/08/2003	63													53	16	69		63.1	132.1
16/08/2003	72													53	19	72		71.5	143.5
17/08/2003	67													55	21	76		66.8	142.8
18/08/2003	52													55	21	76		51.6	127.6
19/08/2003	38													56	24	80		38.2	118.3
20/08/2003	41													56	24	80		40.9	121
21/08/2003	45													56	24	80		44.8	124.8
22/08/2003	55													56	24	80		55.3	135.3
23/08/2003	50													56	24	80		49.5	129.6
24/08/2003	52													56	24	80		51.7	131.8
25/08/2003	46													56	24	80		45.6	125.6

APPENDIX F

COMPARISON OF MODELLING TECHNIQUES

F.1 INTRODUCTION

Finite-element and finite-difference techniques are compared below in terms of the efficiency and accuracy of: the mesh development; the boundary conditions; the representation of stratigraphy and water levels; and other practical concerns such as the ease of use, availability, and analytical features.

F.2 MESH DEVELOPMENT

The finite element package, FEFLOW, has advantages over the finite difference software, MODFLOW. The use of triangles in the finite-element method allows for curves to be more accurately represented. In the FEFLOW image (Figure F.1) the mesh consist of 2000 elements with low-refinement around the line/point add-ins (i.e. rivers and motorways) and low-refinement around the super-element borders. The MODFLOW grid (Figure F.2) consists of 90 rows and 107 columns for a total of 9630 cells in two-dimensions. The benefit of triangles over rectangles can be seen immediately as the model boundaries are represented more naturally with the finite elements. In MODFLOW, even though there is nearly five times the number as cells as elements in FEFLOW, the boundary is represented very pixelly. In order to get the outer boundary to fit as well as it does in FEFLOW an inefficient number of cells would have to be used. As FEFLOW has fewer elements the computation time is much less. As mesh refinement is targeted around the areas of interest the model is more accurate in these areas then MODFLOW which is constrained to refining an entire row or column.

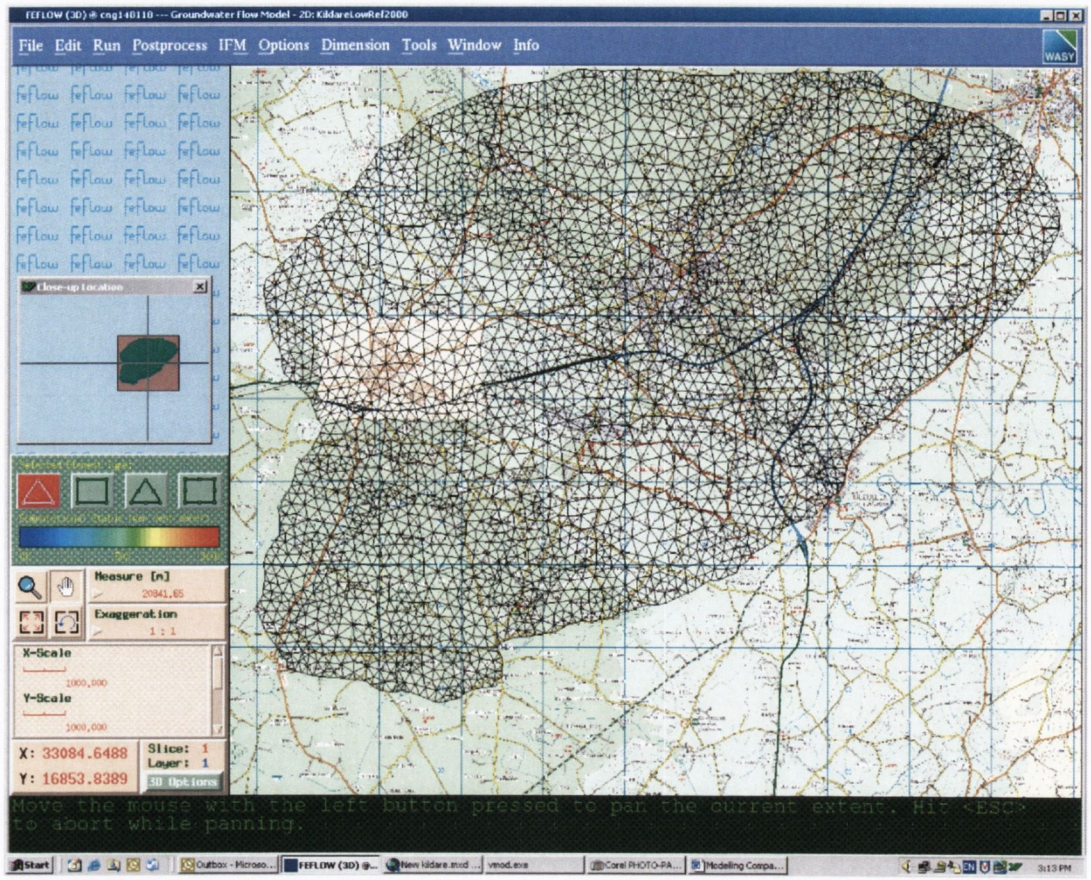


Figure F.1: Screen capture of FEFLOW mesh for the Mid-Kildare Aquifer.

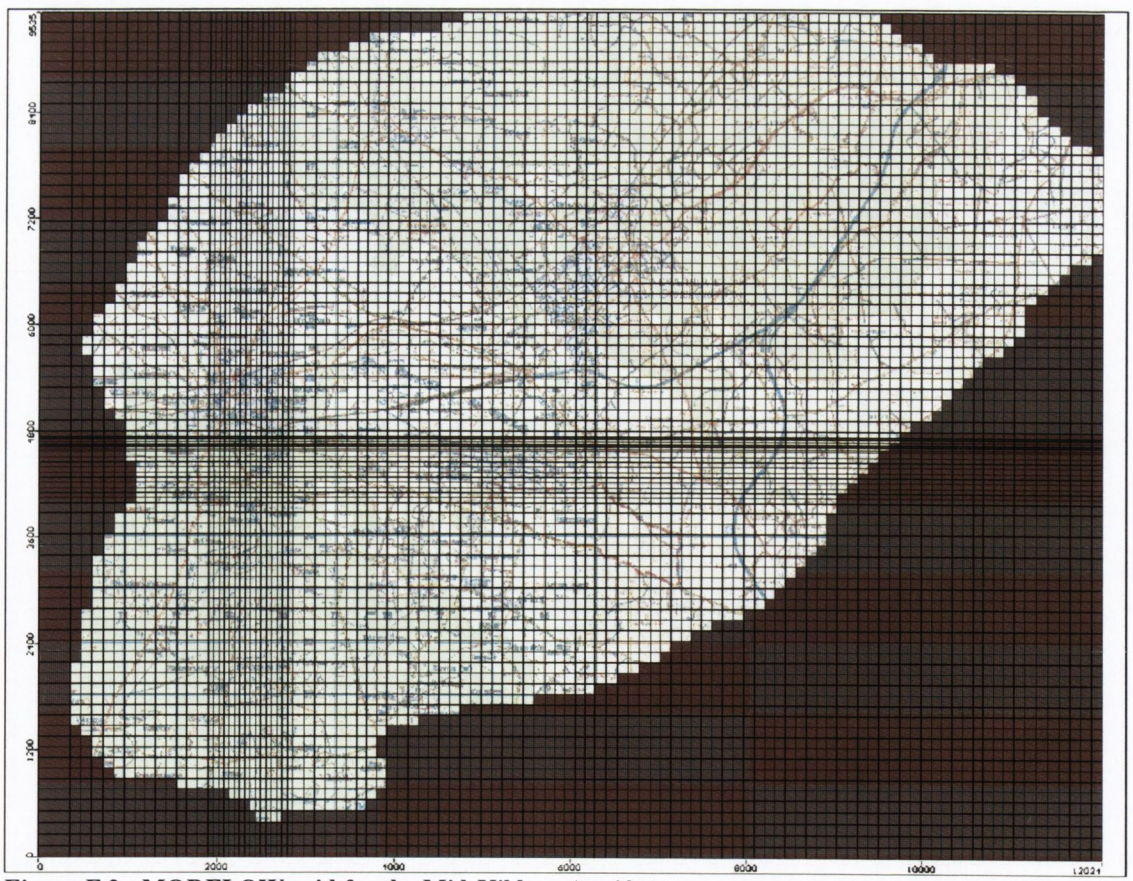


Figure F.2: MODFLOW grid for the Mid-Kildare Aquifer.

Figures F.1 and F.2 also show how much more efficiently the grid/mesh can be refined in FEFLOW as opposed to MODFLOW. In FEFLOW, the mesh has been refined around the borders as well as around the rivers and around the entire length of the M7 (including the Kildare Town Bypass). However, in MODFLOW grid refinement is limited to occurring within the rows and columns and it must continue for the entire length of the row or column. This is very inefficient as features are rarely straight for the entire length of the model domain so the model often ends up with areas of no interest being refined because an area above or below needed to be refined. Another advantage of FEFLOW is that the finite element mesh only exists inside the model domain. This greatly reduces the number of elements needed. In MODFLOW, the entire map area must be gridded and then the cells outside of the model domain are marked as inactive (green on Figure F.2).

F.3 BOUNDARY CONDITIONS

Figures F.3 and F.4 show that the boundary conditions are represented very differently in the two programs. In FEFLOW, the boundary conditions are represented naturally and at a discrete location. This can be seen with the outer constant head boundary, shown in blue in Figure F.3, which follows the curved outline of the Aquifer's extent. In contrast, the outer constant head boundary condition in MODFLOW, shown in burgundy in Figure F.4, is blocky and does not represent the actual natural condition.

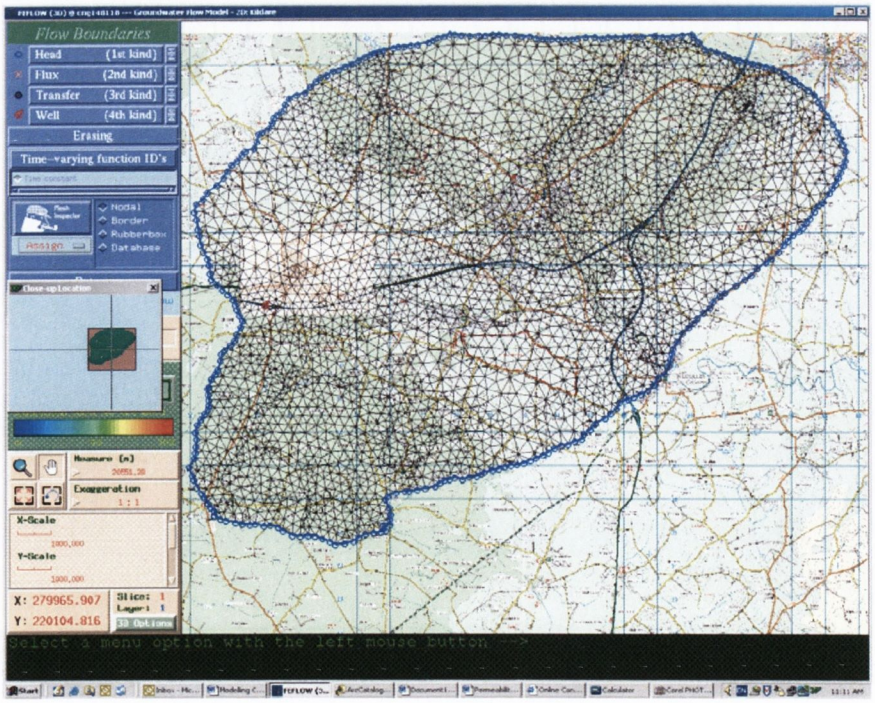


Figure F.3: FEFLOW constant head boundary (blue) and well boundary (red) are represented naturally and at discrete locations.

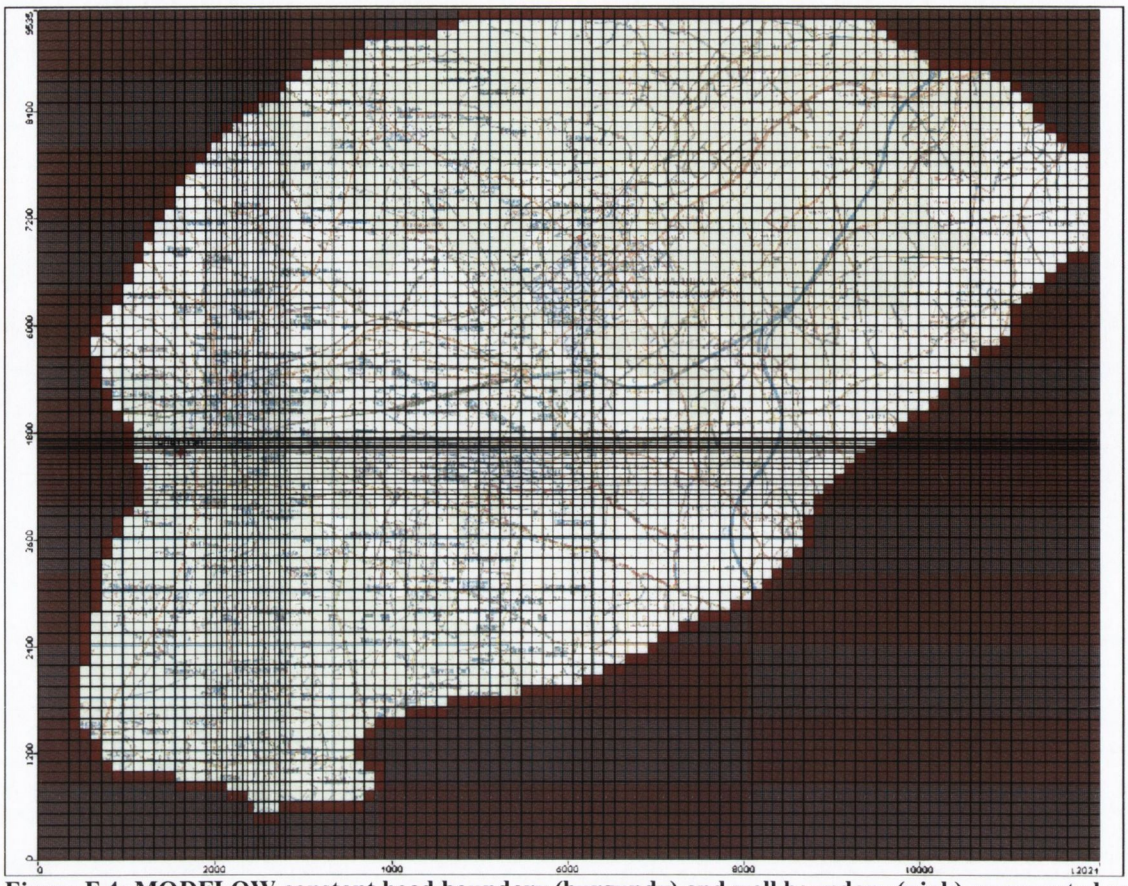


Figure F.4: MODFLOW constant head boundary (burgundy) and well boundary (pink) represented as entire cells

Figures F.5 and F.6 are zoomed in to show the well (red in FEFLOW and pink in MODFLOW) and the constant head boundary condition. These figures illustrate that in FEFLOW the constant head boundary and the well boundary occur at discrete locations at the elemental node. In MODFLOW, the well boundary and constant head boundary take up the entire cell, which in the least refined case has an area of 200 m x 200 m = 0.04 km^2. Even in the case of the well where the grid has been refined significantly the well has an area of 50 m x 200 m = 0.01 km^2. The inability of MODFLOW to represent a well at a discrete location can introduce significant errors once the actual size of the well is taken into consideration. In the case of the wells in the Mid-Kildare Aquifer, many of the wells had diameters of 0.2 m, while the actual physical area is closer to 3.14 x 10^{-8} km^2. It is clear that by assigning the well properties to an area six orders of magnitude larger in the model than in the actual case, the results of the model must be less accurate than they would be if the well was represented more accurately in the model.

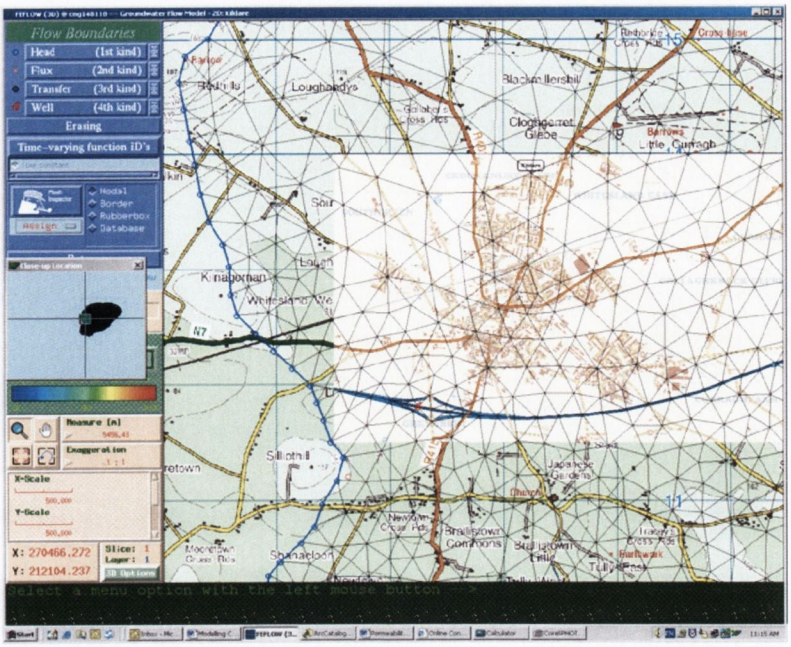


Figure F.5: FEFLOW close-up of well at a discrete location and constant head boundaries.

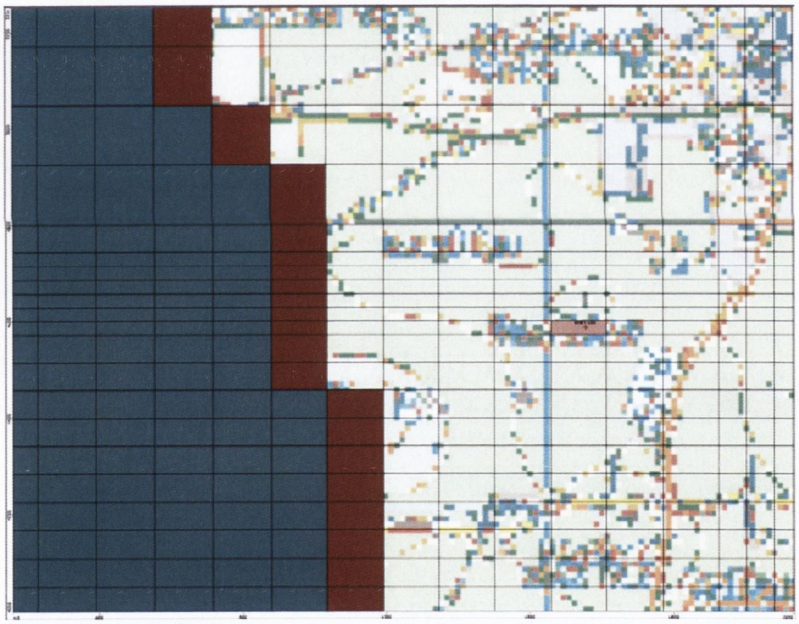


Figure F.6: MODFLOW close-up of well boundary that is applied over the entire cell.

FEFLOW can also mix element types unlike MODFLOW. This means that in a three-dimensional model, wells can be represented as a one-dimensional line and fractures can be represented as a two-dimensional plane. By using a one-dimensional line to represent a well the model can compute the flux from different layers. This allows for the computation of things such as well-bore storage.

F.4 STRATIGRAPHY AND GROUNDWATER LEVELS

The unstructured mesh in FEFLOW allows the stratigraphy and watertable to be represented more naturally as can be seen in Figure F.7. The same topography data can be

represented in MODFLOW but the result is much blockier as can be seen in Figure F.8. In MODFLOW cell re-wetting at the watertable can be problematic there are plans to introduce tools in the future that would allow the integration of saturated and unsaturated zones but these are currently not available. The finite element mesh in FEFLOW can deform to the watertable position. This results in a stable (linear) solution for the watertable position. FEFLOW can also work in a saturated/unsaturated mode; this leaves all elements active and does not "turn off" cells as in MODFLOW. In the third dimension the FEFLOW mesh follows sloping layers more accurately and requires fewer layers than the less accurate non-deforming finite difference grid in MODFLOW. FEFLOW can generate the finite element mesh to follow stratigraphic layering and then project the mesh laterally to represent discontinuous layers. It represents complex geology much more naturally.

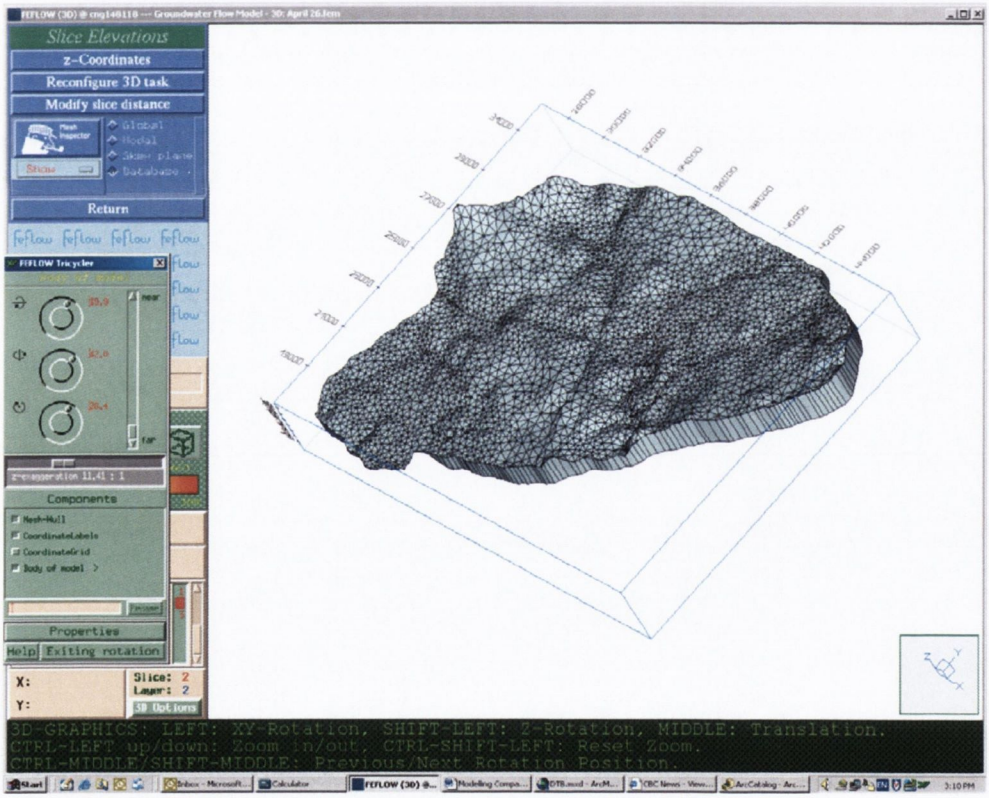


Figure F.7: FEFLOW three-dimensional model for the Mid-Kildare Aquifer

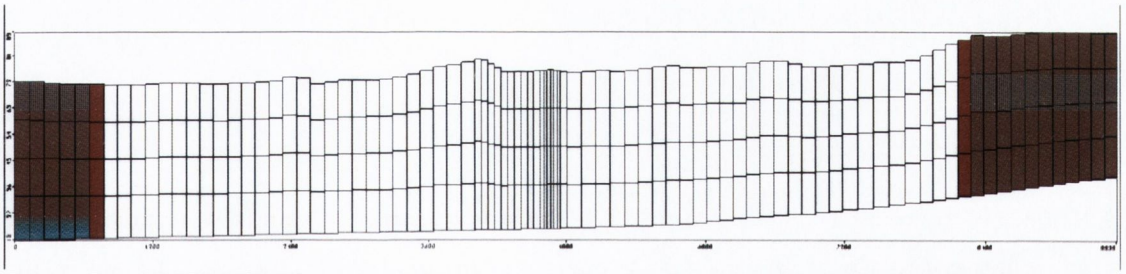


Figure F.8: MODFLOW three-dimensional section showing inactive cells and boundary cells

The final major advantage of FEFLOW over MODFLOW is that it represents anisotropy more accurately. In FEFLOW the finite element mesh can follow variable principal conductivity directions naturally. This is often needed because in nature deformed strata are often found whereas in MODFLOW the principle conductivity direction must be along the co-ordinate axes. This means that MODFLOW can only accurately represent horizontally bedded strata.

F.5 USABILITY, AVAILABILITY, AND ANALYTICAL FEATURES

The finite difference software package, MODFLOW, has several advantages over the finite element software, FEFLOW. MODFLOW is conceptually much simpler - thus it is easier to understand how the groundwater flow equation is being solved. MODFLOW also has a more user-friendly interface that is more intuitive to users. The interface is similar to other Windows based programs. In contrast, FEFLOW has a far steeper learning curve and its user-interface is based on the standard Unix interface. This requires much more time to become familiar with and functions are often initially harder to find. Another advantage of finite difference modelling over finite element modelling is the availability of software. There are many different commercially available finite difference modelling software packages with a range of prices and functionality. However, with finite elements there are fewer commercially available groundwater software. The final major advantage of finite difference modelling over finite element modelling is that with finite differences mass is always locally conserved. This is because when a variable hydraulic conductivity is represented in a cell-centred finite difference model the hydraulic conductivity is calculated using a harmonic mean at the interfaces. The interfacial fluxes are therefore continuous in a cell-centred finite difference model. This results in the model providing a better basis for particle tracking. With finite elements, FEFLOW does not always conserve mass locally. This can result in erroneous mass balance calculations when looking at very small scales modelling contaminant transport.

F.6 CONCLUSIONS

Finite element modelling can provide a robust model for a geologically complex situation. The Mid-Kildare Aquifer is an unconfined aquifer and so the ability to model saturated and unsaturated flow is a major advantage. The stratigraphy is also complex containing lenses of clay and gravel, layers that pinch out, and undulating surfaces. These can all be represented more accurately using FEFLOW than MODFLOW. In conclusion, an unconfined heterogeneous environment such as the Mid-Kildare Aquifer can be modelled effectively using finite elements.

APPENDIX G

FEFLOW VALIDATION USING SIMPLE PUMP TESTS

G.2 INTRODUCTION

In order to assess the accuracy of the modelled results from the software program FEFLOW, pump tests were modelled and then compared with calculations of pump tests with the same input parameters. The pump tests were modelled and calculated for steady state conditions for a leaky-confined and unconfined aquifer, and then modelled and calculated in transient state for each aquifer type.

G.3 MODEL DESIGN

In order to compare the modelled and calculated drawdowns in a well that is subjected to pumping, the assumptions made for the calculations needed to be satisfied in the model. All the traditional methods to assess pump tests have the following assumptions (Kruseman and de Ridder, 2000):

1) The aquifer has a seemingly infinite extent
2) The aquifer is homogeneous, isotropic, and of uniform thickness over the area influenced by the test.
3) Prior to pumping, the piezometric surface is horizontal (or nearly so) over the area that will be influenced by the test
4) The aquifer is pumped at a constant discharge rate
5) The well penetrates the entire thickness of the aquifer and thus receives water by horizontal flow

In the finite element software FEFLOW the previous assumptions were accommodated in the following manner:

1) The model boundaries were increased to a point where the drawdown in the well didn't extend close to the model boundaries. To achieve this, the modelled extent was 9934 m x 7970 m and the well was placed in the middle of the model area. Drawdown was observed in the vicinity up to 1000 m around the pumping well, thus, the condition that the aquifer has a seemingly infinite extent is satisfied.
2) The material properties set for each layer had the same value inputted for K_x, K_y, and K_z, the thickness of the model was set to be 50 m over the entire model space. The input parameters were set globally so that the condition of a homogeneous, isotropic, aquifer of uniform thickness was satisfied.

3) The initial heads were set globally to 50 m and the outer boundary of the model was set to have a constant head of 50 m. This was done to satisfy the initial condition that prior to pumping; the piezometric surface is horizontal over the area that will be influenced by the test.
4) The pumping rate at the well was set at a constant rate of 1000 m^3/d ($1.16x10^{-2}$ m^3/s) satisfies the constant pumping rate condition.
5) The well was set with a pumping rate of 1000 m^3/d on the lower most slice of the aquifer and set at a pumping rate of 0 m^3/d on the upper most slice of the aquifer. In the software program FEFLOW, this simulates a well that penetrates the entire aquifer thickness and thus receives water by horizontal flow satisfying the final condition.

G.3 STEADY-STATE MODELLING

The modelling and calculations were initially conducted for steady-state conditions. Observation wells were located at 5 m, 10 m, 25 m, 50 m, and 100 m from the well which recorded the modelled drawdown levels.

G.3.1 LEAKY-CONFINED AQUIFER

The leaky-confined aquifer was modelled to have a total model thickness of 50 m. A leaky-confined aquifer commonly consists of an unconfined aquifer underlain by an aquitard which is underlain by the leaky-confined aquifer. The aquitard in this case is not completely impermeable but allows some of the water from the unconfined aquifer above it to travel vertically through the aquitard to recharge the leaky-confined aquifer. In the FEFLOW model the unconfined upper aquifer had a thickness of 25 m, the aquitard had a thickness of 5 m and the leaky-confined aquifer had a thickness of 20 m. The initial hydraulic head was set at 50 m for all slices and the boundary condition for the outer parameter of the model was a constant head of 50 m for each slice. The material properties for each layer can be found in Table G-2.

Table G-1: Material properties used for the model.

	UNCONFINED AQUIFER	AQUITARD	LEAKY-UNCONFINED AQUIFER
Hydraulic conductivity (K_x, K_y, K_z)	0.1 m/s	$1.0x10^{-7}$ m/s	$1.0x10^{-4}$ m/s
Storativity	0.2	0.002	0.2
Compressibility	$1.0x10^{-4}$ m^{-1}	$1.0x10^{-4}$ m^{-1}	$1.0x10^{-4}$ m^{-1}

When this scenario was modelled using FEFLOW the drawdowns at each observation well were as follows:

r = 5 m → 3.85 m

r = 10 m → 3.22 m

r = 25 m → 2.38 m

r = 50 m → 1.77 m

r = 100 m → 1.21 m

The hand calculations used to validate the modelled results were done using both DeGlee's Method and Hantush-Jacob's Method.

G.4.1.1 DEGLEE'S (1930, 1951) METHOD

DeGlee derived the following formula:

$$s_m = \frac{Q}{2\pi KD} K_o\left(\frac{r}{L}\right) \qquad \textbf{Eq. G-1}$$

where

s_m = steady-state drawdown in m in a piezometer at a distance r in m from the well

Q = discharge from the well in m^3/d

L = $\sqrt{KDc}$: leakage factor in m

c = D'/K': hydraulic resistance of the aquitard in d

D' = saturated thickness of the aquitard in m

K' = hydraulic conductivity of the aquitard for vertical flow in m/d

K_0 (x) = modified Bessel function of the second kind of zero order (Hankel function)

The method is a curve-fitting method which is generally not expected to obtain as exact of a solution as a purely mathematical solution due to the inevitable errors involved in matching the curves and reading off points from the logarithmic graphs. Figure G-1 shows that the curve matching is imprecise which would be expected to lead to errors in calculation. There aren't many points on the graph as there are only five observation wells. The point in pink is the match point which is used to read off values used in the DeGlee formula.

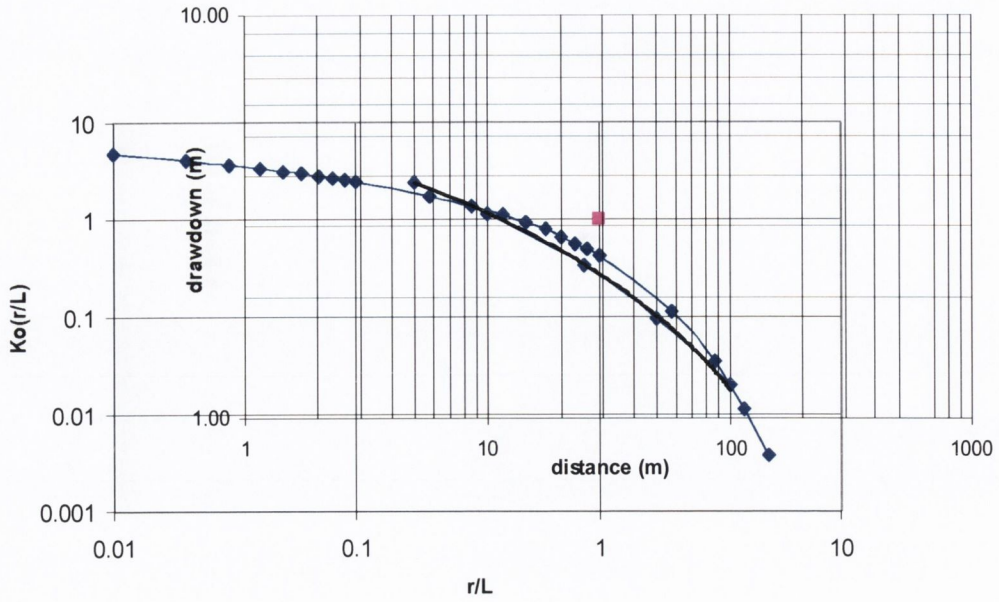


Figure G.1: Curve-matching graph for the DeGlee method

From the graph in Figure G-1 we can see that the point where r/L = 1 and $K_o(r/L) = 1$ corresponds to the point where s_m = ~3 m and r = ~30 m. These values can then be substituted into Eq. G-2 and G-3 to determine KD.

$$KD = \frac{Q}{2\pi s_m} K_0\left(\frac{r}{L}\right) = \frac{1000m^3/d}{2\pi(3m)} \times 1 = 53m^2/d \qquad \textbf{Eq. G-2}$$

However, KD is equal to 172 m^2/d (8.64 m/d * 20 m) in the model input. As the percent difference between the calculated and modelled results is 69% the correlation is unacceptable and must be due to poor matching of the curves.

G.3.1.2 HANTUSH-JACOB'S (1955) METHOD

The Hantush-Jacob's Method produces significantly better results with a good correlation between calculated and modelled drawdowns. This method uses a plot of s_m against r on semi-log paper (Figure E-2), with r on the logarithmic scale and shows a straight line relationship where r/L is small. The slope of the straight portion of the curve, i.e. the drawdown difference of Δs_m per log cycle of r, is expressed by

$$\Delta s_m = \frac{2.30Q}{2\pi KD} \qquad \textbf{Eq. G-3}$$

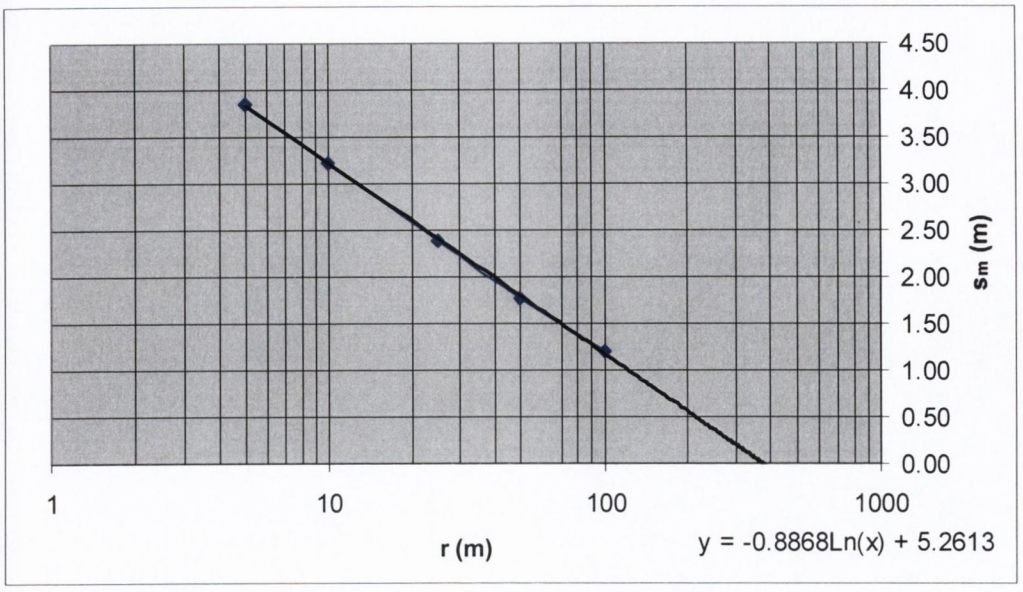


Figure G.2: Semi-log plot used for the Hantush-Jacob calculation

From the graph in Figure G.2 the Δs_m value can be read off for one log cycle and the known value of Q can also be substituted in to Eq. G-4 as follows:

$$\Delta s_m = \frac{2.30Q}{2\pi KD} = 2.01m = \frac{2.30(1000m^3/d)}{2\pi KD} = KD = 182m^2/d \qquad \textbf{Eq. G-4}$$

When this transmissivity value is compared to the model inputs (K = 8.64 m/d, D = 20 m) KD = 173 m^2/d we find that the correlation is very good, with a percent difference of 5%, and thus it can be concluded that the modelled scenario fits the Hantush-Jacob's assumptions much better than the DeGlee's assumptions. The close agreement between the modelled result and the hand calculation confirms that FEFLOW treats the steady-state case of a leaky-confined aquifer correctly.

G.4.2 UNCONFINED AQUIFER

Although true steady-state flow cannot be reached in a pumped unconfined aquifer of infinite aerial extent due to the fact that it is being dewatered, it does eventually reach a point where the drawdown differences gradually diminish until they become negligibly small. Once the drawdown becomes negligible it can be treated as though it was steady state. The unconfined aquifer had a total model thickness of 50 m and consisted of one layer (2 slices). The initial hydraulic head was set at 50 m on both slices which also had a constant head boundary condition applied to the out parameter of the model set to 50 m. The hydraulic conductivity in the x, y, and z directions was set at 1.0×10^{-4} m/s, the storativity was set to 0.2 and the compressibility was set at 1.0×10^{-4} m^{-1}.

When this scenario was modelled using FEFLOW the drawdowns at each observation well were as follows:

r = 5 m → 2.48 m

r = 10 m → 2.25 m

r = 25 m → 1.92 m

r = 50 m → 1.65 m

r = 100 m → 1.42 m

G.3.2.1 THIEM-DUPUIT'S (1863) METHOD

The Thiem-Dupuit's equation was used to validate the modelled results. The Thiem-Dupuit equation is as follows:

$$Q = \frac{2\pi KD(s'_{m1} - s'_{m2})}{2.3\log\left(r_2/r_1\right)} \qquad \textbf{Eq. G-5}$$

where s' = corrected drawdown = s' = s - (s^2/2D)

Eq. G-5 was rearranged to determine the value of (s'_{m1} - s'_{m2}) and the known values of K, D, Q, r_1 and r_2 were substituted in. The results of the calculations and modelling can be found in Table G-3. The correlation between the modelling and hand calculations is very good and confirms that FEFLOW treats the case of an unconfined aquifer pumped under steady-state conditions correctly.

$$s'_{m1} - s'_{m2} = \frac{Q2.3\log\left(r_2/r_1\right)}{2\pi KD} = \frac{(1000m^3/d)(2.3)\log\left(10/5\right)}{2\pi(8.64m/d)(50m)} = 0.26 \qquad \textbf{Eq. G-6}$$

Table G-2: Comparison of results of hand calculations and modelled drawdowns

	CALCULATED	MODELLED	% DIFFERENCE
s'_1-s'_2	0.26	0.23	12 %
s'_2-s'_3	0.34	0.31	9 %
s'_3-s'_4	0.26	0.26	0 %
s'_4-s'_5	0.26	0.22	15 %

G.4 TRANSIENT-STATE MODELLING

After validating that the pumping tests were modelled correctly using FEFLOW in leaky-confined and unconfined environments, transient-state conditions were then

modelled. Attempts were made to keep all input parameters the same as they were for steady-state conditions so that direct comparisons could be made. The time period used for each transient state model was one day of pumping. The drawdowns were recorded at the observation wells found at the same locations as in the steady-state scenarios.

G.5.1 LEAKY-CONFINED AQUIFER

The drawdowns recorded after 1 day of pumping in the FEFLOW model at each observation well were as follows:

r = 5 m → 3.61 m
r = 10 m → 3.01 m
r = 25 m → 2.25 m
r = 50 m → 1.62 m
r = 100 m → 1.04 m

When a leaky-confined aquifer is being pumped in a transient state, the water discharged by the well is derived not only from leakage through the aquitard but also from a reduction in storage within both the aquitard and the pumped aquifer. There are four different methods that can be used to analyse unsteady state flow to a leaky-confined aquifer. The Walton curve fitting method and the Hantush inflection-point method neglect the aquitard storage. The Hantush curve-fitting method and the Neuman-Witherspoon ratio method which take into account the aquitard storage. The Hantush curve-fitting method and Neuman-Witherspoon method were used as they are valid in the case where t > S'D'/10K'. So when the model input is substituted into the equation the results is 1 day > (0.002) (5 m)/10(8.64×10^{-3} m/d) which equals 1 > 0.116, so this condition is true and therefore the Hantush curve-fitting method and Neuman-Witherspoon method can be used.

G.5.1.1 WALTON'S (HANTUSH AND JACOB, 1955) METHOD

Walton's method (Hantush and Jacob, 1955) was initially used to analyse the leaky confined aquifer (Eq. 2-22 and Eq. 2-23). Figure G.5 shows the Walton type-curves for early-time data as well as the data curves for each observation point. The match point, shown in green, was set at the coordinates where u = 10 and W(u, r/L) = 1. Table G-5 shows the values for time and drawdown used in the Walton equations.

Figure E.5 and Table E-5 show the correlation between the calculations and the modelling results are mostly below 10% for the observation wells for the data. The

storativity values are a bit more variable in the calculated values than the model input parameters, however, this may be due to inaccuracies in reading off the data from the log graphs.

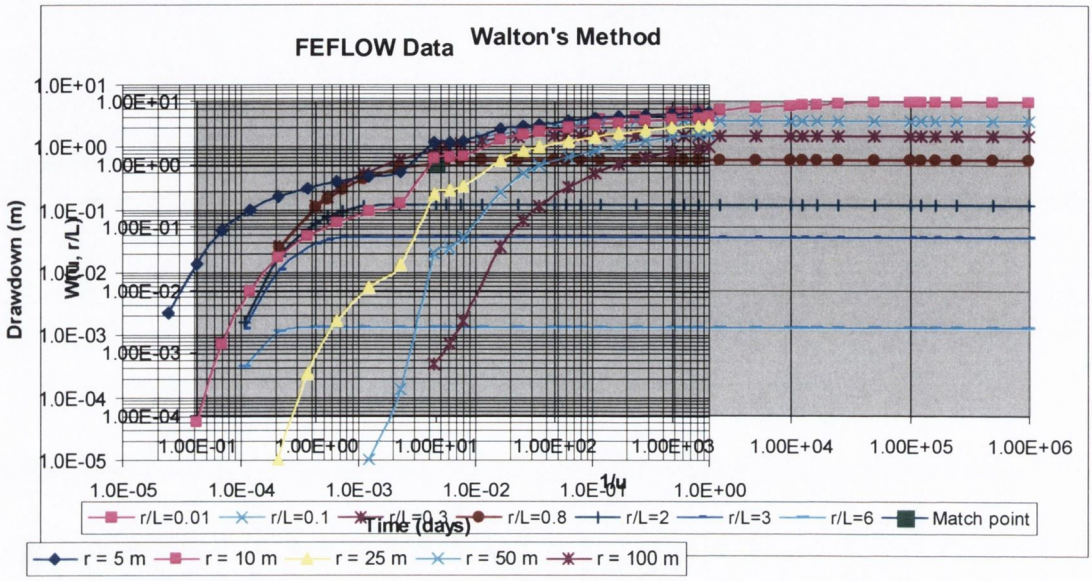


Figure G.3: Curve-matching for the Walton Method

Table G-3: Data for Walton Method

	R = 5 M	R = 10 M	R = 25 M	R = 50 M	R = 100 M
W(u, r/L)	1	1	1	1	1
1/u	10	10	10	10	10
s	0.5	0.6	0.5	0.5	0.4
t	4.00×10^{-3}	1.00×10^{-2}	4.00×10^{-2}	1.30×10^{-1}	2.70×10^{-1}
Q (m^3/d)	1000	1000	1000	1000	1000
K (m/d)	8.64	8.64	8.64	8.64	8.64
D (m)	20	20	20	20	20
KD (calculated)	159	133	159	159	199
KD(modelled)	173	173	173	173	173
% Difference	8%	23%	8%	8%	13%
S (calculated)	0.01	0.03	0.11	0.36	0.75
S (modelled)	0.2	0.2	0.2	0.2	0.2

G.4.1.2 HANTUSH'S (1956) INFLECTION POINT METHOD

Hantush developed several procedures for the analysis of pumping test data based on Walton's equation. The procedure below uses the data from a single piezometer or observation well which is plotted on a semi-log curve of drawdown verses time (Figure G.6). This is used to determine the inflection point and a host of other variables needed for the equations below.

$$s_p = 0.5 s_m = \frac{Q}{4\pi KD} K_0\left(\frac{r}{L}\right) \qquad \text{Eq. G-7}$$

$$\Delta s_p = \frac{2.30Q}{4\pi KD} e^{-r/L} \qquad \text{Eq. G-8}$$

$$2.30 \frac{s_p}{\Delta s_p} = e^{r/L} K_0\left(r/L\right) \qquad \text{Eq. G-9}$$

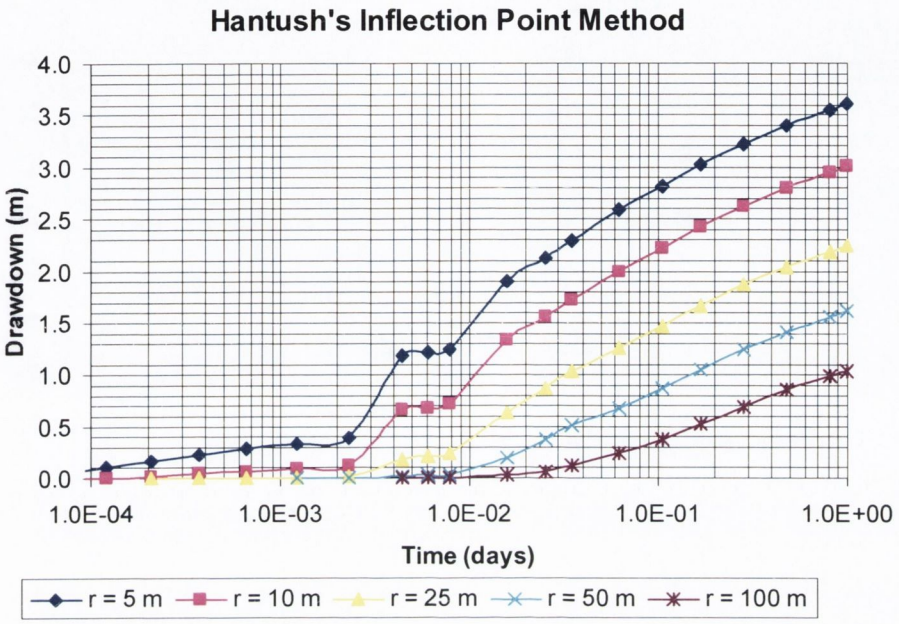


Figure G.4: Semi-log plot used for Hantush's Inflection Point Method. Only the later straight portions of the graph are used for the calculations

Figure G.6 and Table G-6 demonstrate that the correlation between the hand calculations and the modelling results is within 10% for the near observation wells. The calculated storativity values are a bit lower than the model input parameters; however, this may be due to inaccuracies in reading off the time which is used in the calculation from the log graphs.

Table G-4: Data for Hantush's Inflection Point Method

	R = 5 M	R = 10 M	R = 25 M	R = 50 M	R = 100 M
Δs_p (m)	1	1.1	0.9	0.75	0.7
s_m (m)	3.85	3.22	2.38	1.77	1.21
s_p (m)	1.92	1.61	1.19	0.89	0.60
t_p (days)	1.60×10^{-2}	2.50×10^{-2}	5.00×10^{-2}	1.10×10^{-1}	2.20×10^{-1}
$e^{r/L}K_0(r/L)$	4.426	3.368	3.041	2.720	1.981
r/L	0.014	0.045	0.065	0.096	0.25
L (m)	357	222	385	521	400
Q (m^3/d)	1000	1000	1000	1000	1000
$x10^{-r/L}$	0.986	0.956	0.937	0.908	0.779
KD (m^2/d) (calculated)	180	159	191	222	204
KD (m^2/d) (model)	173	173	173	173	173

Table G-4: Data for Hantush's Inflection Point Method

	R = 5 M	R = 10 M	R = 25 M	R = 50 M	R = 100 M
Δs_p (m)	1	1.1	0.9	0.75	0.7
s_m (m)	3.85	3.22	2.38	1.77	1.21
s_p (m)	1.92	1.61	1.19	0.89	0.60
t_p (days)	1.60×10^{-2}	2.50×10^{-2}	5.00×10^{-2}	1.10×10^{-1}	2.20×10^{-1}
$e^{r/L}K_0(r/L)$	4.426	3.368	3.041	2.720	1.981
r/L	0.014	0.045	0.065	0.096	0.25
L (m)	357	222	385	521	400
Q (m^3/d)	1000	1000	1000	1000	1000
$x10^{-r/L}$	0.986	0.956	0.937	0.908	0.779
KD (m^2/d) (calculated)	180	159	191	222	204
KD (m^2/d) (model)	173	173	173	173	173
% Difference	4%	8%	9%	22%	15%
S (calculated)	0.003	0.004	0.002	0.001	0.002
S (modeled)	0.2	0.2	0.2	0.2	0.2

G.4.2 UNCONFINED AQUIFER

The drawdowns recorded after 1 day of pumping in the FEFLOW model at each observation well were as follows:

r = 5 m → 0.97 m

r = 10 m → 0.73 m

r = 25 m → 0.44 m

r = 50 m → 0.21 m

r = 100 m → 0.06 m

G.4.2.1 NEUMAN'S (1972) METHOD

Neuman (1972) developed a theory for analysing the response of an unconfined aquifer under constant pumping (Eq. 2-24). Unlike confined aquifers, unconfined aquifers always have some degree of vertical flow so his solution for drawdown is a function of both the distance from the well r and the elevation head. Figure G.7 shows the Neuman type-curves for early-time data as well as the data curves for each observation point. The match point, shown in green, was set at the coordinates where $u_A = 1$ and $W(u_A, \beta) = 1$. Table G-7 shows the values for time and drawdown used in the Neuman equations.

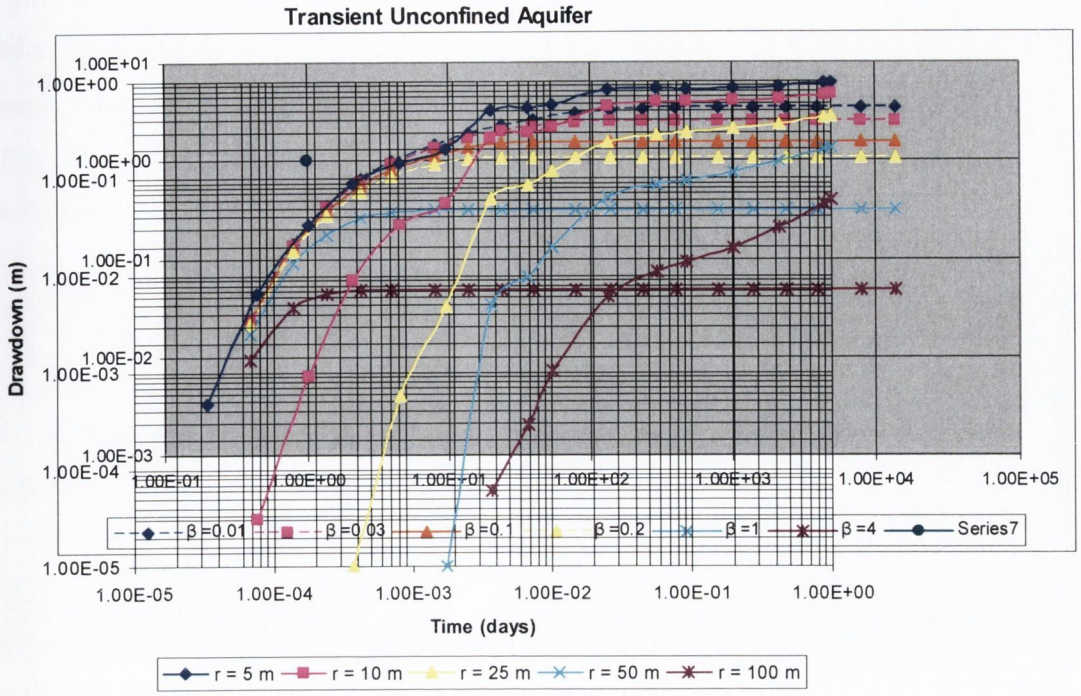


Figure G.5: Curve matching for the Neuman Method

Table G-5: Data for early-time Neuman Method

	R = 5 M	R = 10 M	R = 25 M	R = 50 M	R = 100 M
$W(u_A, B)$	1	1	1	1	1
Q (m^3/d)	1000	1000	1000	1000	1000
K (m/d)	8.64	8.64	8.64	8.64	8.64
D (m)	50	50	50	50	50
s (m)	0.15	0.18	0.20	0.22	0.19
u_A	1	1	1	1	1
t (days)	1.80X10-04	8.00X10-04	3.50X10-03	1.50X10-02	3.00X10-02
KD (m^2/d) (Calculated)	531	442	398	362	419
KD (m^2/d) (Modelled)	432	432	432	432	432
% Difference	19%	2%	8%	16%	3%
S_A (Calculated)	0.012	0.014	0.010	0.010	0.005
S_A (Modelled)	0.2	0.2	0.2	0.2	0.2

As can be seen from Figure G.7 and Table G-7 the correlation between the hand calculations and the modelling results is within 10% for most of the observation wells for the early-time data. The storativity values are a bit lower in the calculated values than the model input parameters, however, this may be due to inaccuracies in reading off the data from the log graphs.

Figure G.8 shows the Neuman type-curves for late-time data as well as the data curves for each observation point. The match point, shown in green, was set at the coordinates where $u_B = 1$ and $W(u_B, \beta) = 1$. Table G-8 shows the values for time and drawdown used in the Neuman equations. Overall the correlation is good so it is confirmed that the FEFLOW modelling of a pumping well in an unconfined aquifer under transient conditions is correct.

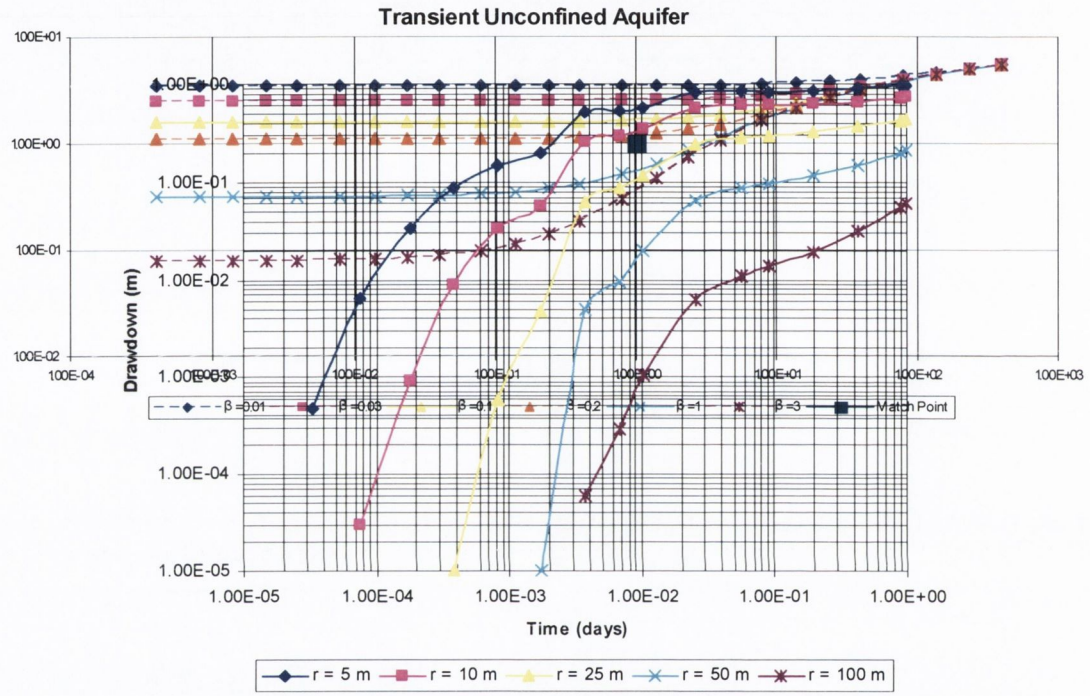


Figure G.6: Late-time curves and data curves for Neuman Method

Table G-6: Data for late-time analysis using Neuman's Method

	R = 5 M	R = 10 M	R = 25 M	R = 50 M	R = 100 M
W(uB, B)	1	1	1	1	1
Q (m^3/d)	1000	1000	1000	1000	1000
K (m/d)	8.64	8.64	8.64	8.64	8.64
D (m)	50	50	50	50	50
s (m)	0.20	0.18	0.20	0.22	0.15
u_A	1	1	1	1	1
t (days)	1.00×10^{-2}	5.00×10^{-2}	1.50×10^{-1}	2.50×10^{-1}	8.00×10^{-1}
KD (m^2/d) (Calculated)	398	442	398	362	531
KD (m^2/d) (Modelled)	432	432	432	432	432
% Difference	8%	2%	8%	16%	23%
S_A (Calculated)	0.69	0.86	0.42	0.17	0.14
S_A (Modelled)	0.2	0.2	0.2	0.2	0.2

Figure G.8 and Table G-8 show the correlation between the hand calculations and the modelling results is within 10% for most of the observation wells for the late-time data. The storativity values are a bit lower in the calculated values than the model input parameters, however, this may be due to inaccuracies in reading off the data from the log graphs.

G.6 CONCLUSIONS

The drawdowns obtained from the FEFLOW modelling in steady- and transient-state are consistent with the hand calculations. The drawdowns or transmissivities obtained from the hand calculations are accurate to one significant figure because of the limitations in reading off values from log-log or semi-log plots. Once this is taken into account the FEFLOW results agree very well with the hand calculations. The storativity values derived from the hand calculations did not agree as well with the input values in FEFLOW. This is likely due to the inevitable inaccuracies in the observed and corrected data used in the calculations and especially due to the use of graphic methods. In FEFLOW, the storativity is set by the user so the inaccuracies should not affect the model results. From this assessment of FEFLOW modelling and hand calculations for simple pumping well tests, it has been determined that the FEFLOW modelling produces as accurate results as the hand calculations.

APPENDIX H

FEFLOW VALIDATION USING SIMPLE EXCAVATION

H.2 INTRODUCTION

A comparative study was carried out as part of the validation of FEFLOW by modelling the steady state condition a simple circular excavation and comparing the flows and heads with those determined using Thiem equation for a homogeneous, isotropic, gravity aquifer of uniform thickness (Eq. 2-16). The excavation fully penetrated the aquifer to give flow conditions similar to those implied by Thiem's equation. The excavation was 5 m in diameter and the outer boundary conditions were modelled as constant heads at 10 m at distances of 20 m, 30 m, 40 m, 50 m, 100 m, 125 m and 150 m from the centre of the excavation.

H.3 MODEL ASSUMPTIONS

To compare the seepages into an excavation derived from modelling and the Thiem equation, the assumptions made for the hand calculations also needed to be satisfied in the model. The traditional method to assess seepage in an excavation is to treat it as though it was a well. Therefore, the following assumptions are made: (Kruseman and de Ridder, 2000) the aquifer is unconfined, has a seemingly infinite aerial extent, is homogeneous, isotropic, and of uniform thickness over the area influenced by the test, is pumped at a constant discharge rate, prior to pumping, the watertable is horizontal over the area that will be influenced by the test, the well penetrates the entire thickness of the aquifer and thus receives water by horizontal flow, and the flow to the well is in a steady state. The Dupuit (1863) assumptions also must be satisfied: the velocity of flow is proportional to the tangent of the hydraulic gradient instead of the sine as it is in reality. The flow is horizontal and uniform everywhere in a vertical section through the axis of the well.

In the finite element software program, FEFLOW, the previous assumptions were accommodated in the following manner:

1) The model was set as unconfined and the top slice was set to be at the phreatic level, thus the condition that the aquifer is unconfined is satisfied.
2) The model boundary was set to have a constant head which meant that it was fully saturated since no drawdown occurred around the edge of the model space the condition that the aquifer has a seemingly infinite extent is satisfied.
3) The permeability of the aquifer was set to 1.0×10^{-4} m/s in the x-, y-, and z-directions; the model was set to have a uniform thickness of over the entire model space, except for the excavation which was 10 m deep. The input parameters were

space, except for the excavation which was 10 m deep. The input parameters were set globally so that the condition of a homogeneous, isotropic, aquifer of uniform thickness was satisfied.

4) The initial heads were set globally and the outer boundary of the model was set to have a constant head. The excavation was set to have a seepage boundary condition where the head is equal to the elevation when water is seeping into the excavation but is otherwise inactive. This was done to satisfy the initial condition that prior to excavation; the piezometric surface is horizontal over the area that will be influenced by the test.
5) No pumping rate was set since this was a seepage problem and the flow into the excavation was what was being measured. However, since this was under steady state conditions the flow into the excavation is assumed to be constant.
6) The condition that the excavation fully penetrates the aquifer was satisfied in the initial run of this model.
7) The flow to the well was modelled under steady state conditions so this assumption is valid.
8) The Dupuit assumption is valid for the first case where the excavation fully penetrates the aquifer.

H.3 MODEL DESIGN

The excavation was modelled in FEFLOW with two configurations to determine if the geometry of the excavation and the model domain had any effect on the seepages. The model was first designed with a circular excavation and a circular model domain (Figure H.1) and was then modelled with a square geometry with the same area (Figure H.2). In each case the excavation was 10 m deep and the outer boundary of the model space was varied and had diameters of 40 m, 60 m, 80 m, 100 m, 200 m, 250 m and 300 m. Both models were varied in terms of the model thickness to determine the effects of full and partial penetration on the seepages into the excavation and the accuracy of the hand calculation. The Thiem equation assumes that the excavation fully penetrates the aquifer, so all of the flow to the excavation is horizontal. To satisfy this assumption the model was first run with a thickness of 10 m and the excavation was 9.99 m deep. The 0.01 m thick layer below the excavation was left to create stability within the model as very thin layers can lead to model instability. Two configurations were run to assess the effect of partial penetration on the seepages into the excavation. In first case, the model thickness was set to be 20 m with the excavation being 10 m deep and in the second case; the model

show the modelled excavation in three-dimensions when the outer boundary diameter was set to 100 m (or equivalent) for the circular and the square geometries. The two cases where the excavation partially penetrated the aquifer assess deviation from the calculated results as the modelled results will account for vertical flow. However, the excavation in the case study did not penetrate the entire aquifer thickness and such simple equations are commonly used by engineers to determine seepages even if the excavation does not fully penetrate the aquifer.

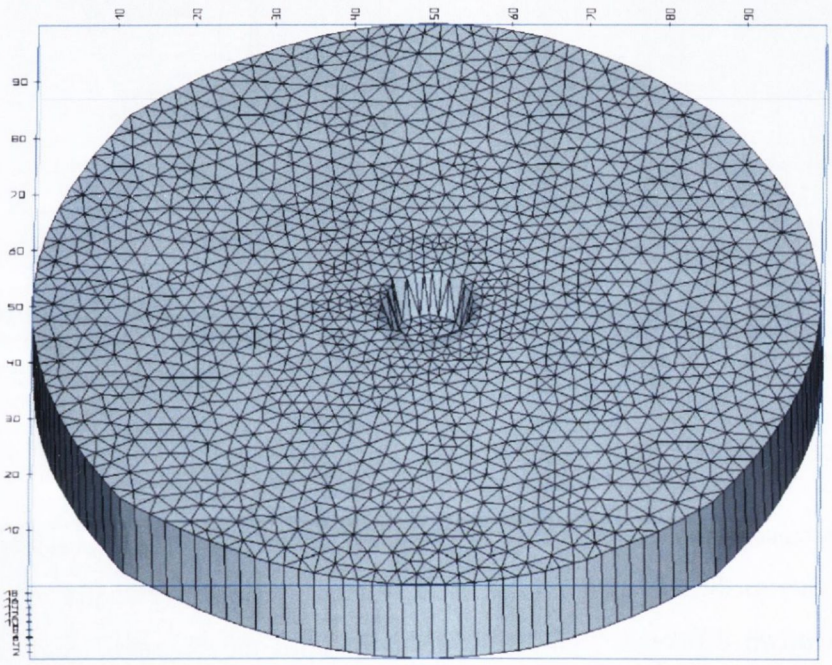


Figure H.1: Three-dimensional model of an excavation. The excavation has a diameter and depth of 10 m and the model space has a diameter of 100 m and a depth of 20 m.

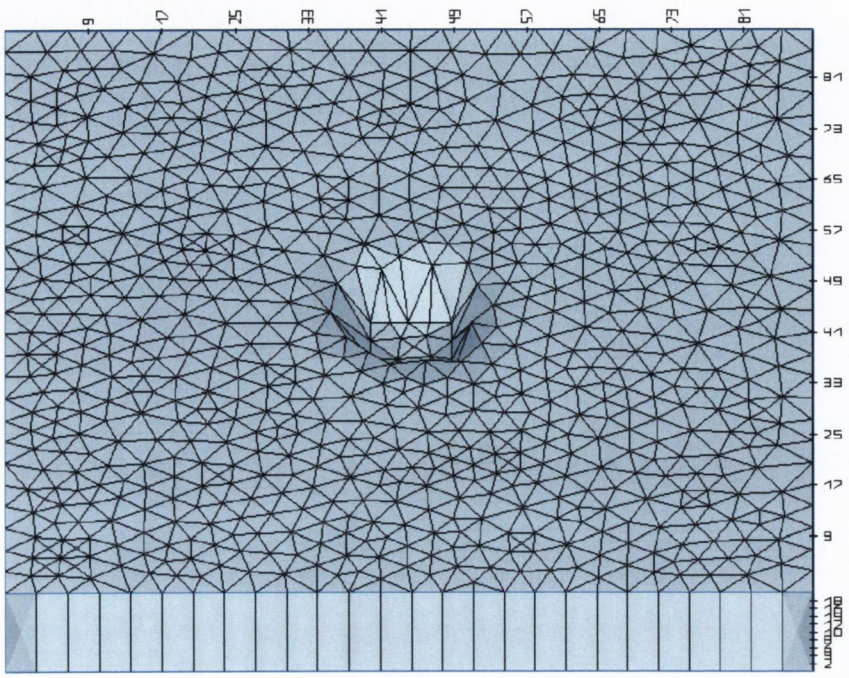


Figure H.2: Three-dimensional model of an excavation. The excavation has a diameter and depth of 8.86 m and the model space has a diameter of 88.62 m and a depth of 20 m.

H.4 MODEL RESULTS

Although true steady-state flow cannot be reached in an unconfined aquifer of infinite aerial extent due to the fact that it is being dewatered, it does eventually reach a point where the drawdown differences gradually diminish until they become negligibly small. Once the drawdown becomes negligible it can be treated as though it was steady state. The model thickness was varied from 10 m, 20 m, and 50 m and consisted of one layer (2 slices). The initial hydraulic head was set to the model thickness on both slices which also had a constant head boundary condition applied to the outer parameter of the model set to the same value (Figure H.3 and H.4). The seepage condition was set at the excavation where the head was set to be the same as the elevation (0.01 m, 10 m, and 40 m respectively) which was constrained to be active only under exfiltrating conditions. The hydraulic conductivity in the x, y, and z directions was set at 1.0×10^{-4} m/s. The resultant groundwater heads are shown in Figures H.5 and H.6.

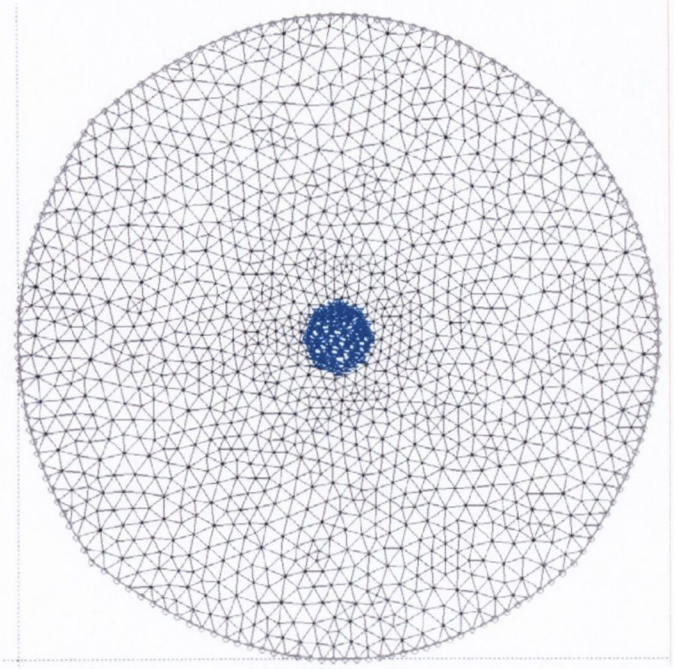


Figure H.3: Boundary conditions for the FEFLOW model. The grey circles on the outer boundary are the constant head while the blue circles represent the seepage condition at the excavation where the head was set when under exfiltrating conditions.

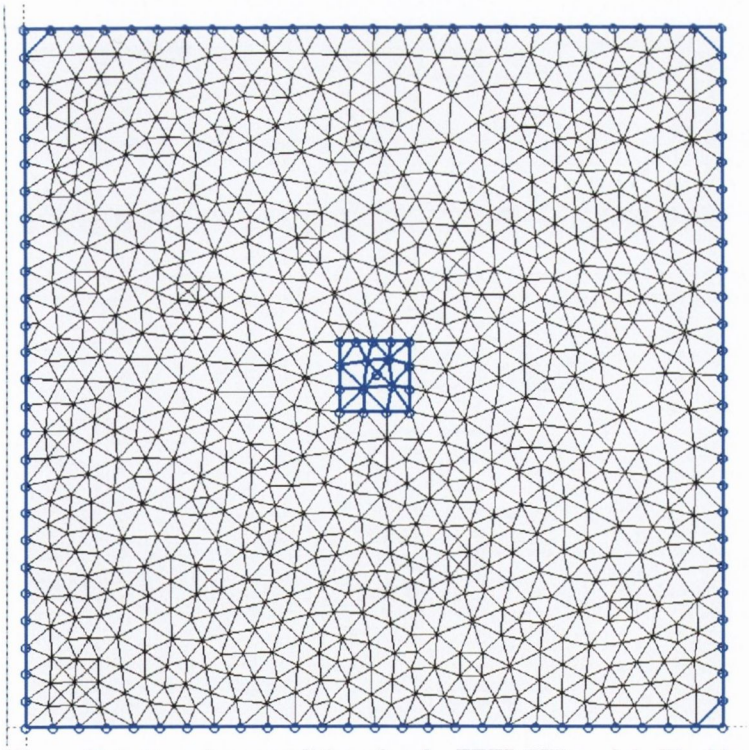


Figure H.4: Boundary conditions for the FEFLOW model. The blue circles on the outer boundary are the constant head while the inner blue circles represent the seepage condition at the excavation where the head was set when under exfiltrating conditions.

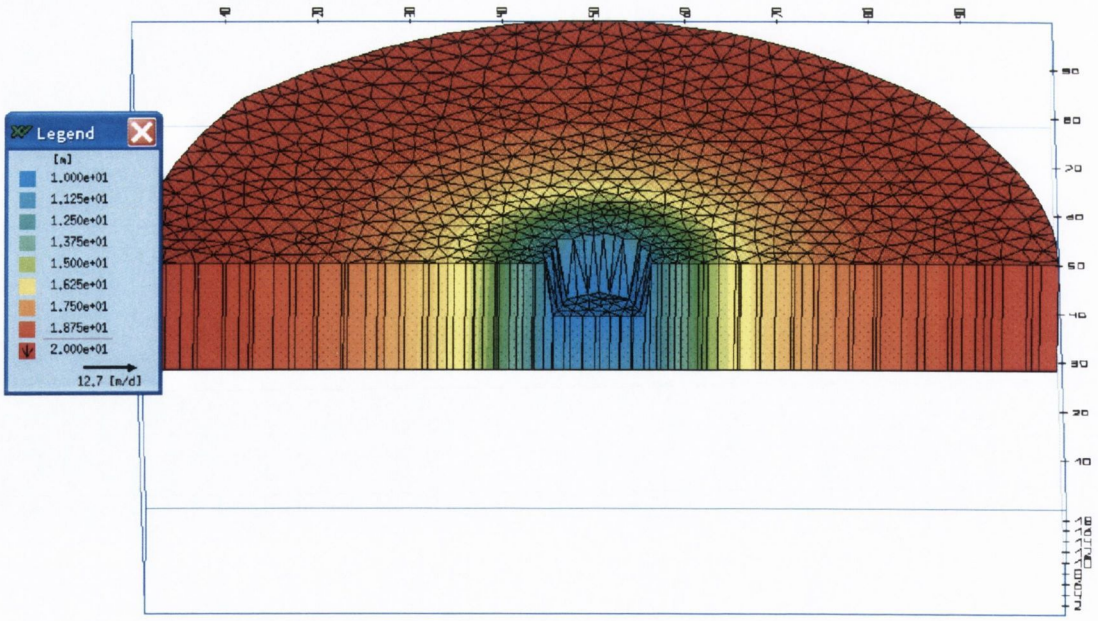


Figure H.5: Modelled heads for the excavation under steady state conditions. The total seepage into the excavation in this case was 3346 m^3/d.

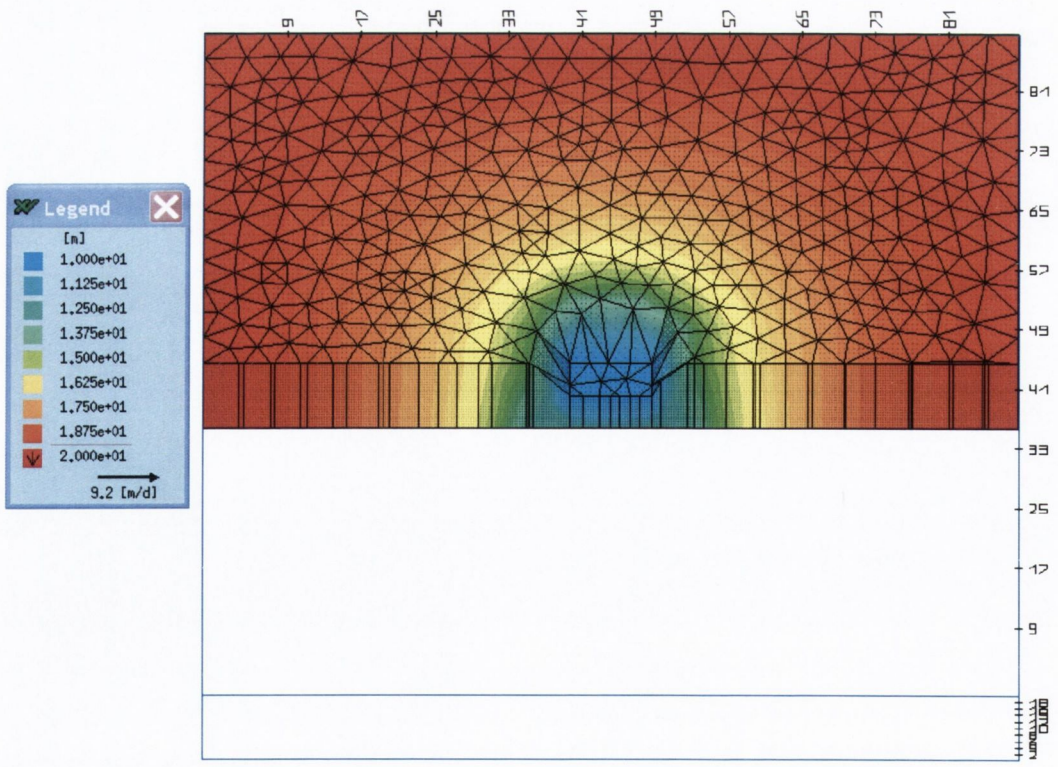


Figure H.6: Modelled heads for the excavation under steady state conditions. The total seepage into the excavation in this case was 3486 m^3/d.

The hand calculations used to validate the modelled results were done using Thiem-Dupuit's Method. The Thiem-Dupuit equation is as follows:

$$Q = \frac{2\pi K\left(H^2 - h_o^2\right)}{\ln\left(R/r_o\right)} \qquad \textbf{Eq. H-1}$$

The known values of K, D, H, h_o, R and r_o were substituted in. The results of the hand calculations as well as the modelling (Table H-1). The correlation between the modelling and hand calculations is within 10% which confirms that FEFLOW treats the case of an excavation in an unconfined aquifer under steady-state conditions correctly.

Table H-1: Comparison of results of hand calculations and modelled seepages (m^3/d)

FULLY PENETRATING							
	R = 20 m	R = 30 m	R = 40 m	R = 50 m	R = 100 m	R = 125 m	R = 150 m
Square	2234	1681	1397	1284	959	884	841
Round	1879	1554	1293	1135	937	870	797
Calculated	1958	1515	1305	1179	906	843	798
% difference square	14%	11%	7%	9%	6%	5%	5%
% difference round	4%	3%	1%	4%	3%	3%	0%
20 m saturated thickness							
	R = 20 m	R = 30 m	R = 40 m	R = 50 m	R = 100 m	R = 125 m	R = 150 m
Square	5948	4493	3878	3486	2721	2509	2375
Round	5467	4231	3680	3346	2539	2420	2287
Calculated	5874	4545	3916	3536	2718	2530	2394
% difference square	1%	1%	1%	1%	0%	1%	1%
% difference round	7%	7%	6%	5%	7%	4%	4%
50 m saturated thickness							
	R = 20 m	R = 30 m	R = 40 m	R = 50 m	R = 100 m	R = 125 m	R = 150 m
Square	9315	7535	6821	6377	5467	5164	4975
Round	8568	7087	6473	6080	5067	4939	4752
Calculated	17622	13634	11748	10609	8155	7589	7182
% difference square	47%	45%	42%	40%	33%	32%	31%
% difference round	51%	48%	45%	43%	38%	35%	34%

H.6 CONCLUSIONS

The modelled results show that the geometry of the model and excavation has no effect on the seepage into the excavation as long as the areas are equivalent. It appears that although the hand calculation assumes a circular well and a circular area of influence around the well, the results for the square excavation are closer to the results from the hand

calculation. However, FEFLOW does not have a draw tool that allows the user to create perfect circles to in reality this difference probably reflects the deviation from the modelled space from a perfect circle rather than inaccuracies in the model calculation of seepage.

The modelled and calculated seepages into the excavation are within 10% of each other when the excavation fully penetrates the aquifer or when the depth of the excavation is half (or more) the thickness of the aquifer. When the excavation is less than half of the thickness of the aquifer the hand calculation is no longer valid as can be seen by the scenario when the aquifer thickness was 50 m and the excavation was 10 m deep (20% of the aquifer thickness). This case resulted in the hand calculation over estimating the seepages by up to 50%. This is significant because the seepage into an excavation can be used to determine the permeability by back-analysis. If this is done for a case where the excavation only penetrates 20% of the aquifer thickness, the permeability calculated by this back-analysis could be underestimated by up to 50%.

From this assessment of FEFLOW modelling and hand calculations for seepage into a simple excavation, it has been determined that the FEFLOW modelling produces as accurate results as the hand calculations except for in the case where the excavation penetrates less than 50% of the aquifer thickness in which case the FEFLOW results are more accurate. This also highlights the errors which can be produced when equations are used when the assumptions on which they are based are not satisfied.