A REVIEW OF THE HYDROGEOLOGICAL INFORMATION FOR THE THOMPSON AND MERTON AREAS, NORFOLK

File No: Chalk Groundwater Unit 10, Wissey

A REVIEW OF THE HYDROGEOLOGICAL INFORMATION FOR THE THOMPSON AND MERTON AREAS, NORFOLK INCLUDING PREDICTIONS OF THE IMPACT OF NEARBY CHALK WATER ABSTRACTIONS ON WATER LEVELS AT THOMPSON WATER, CARR AND COMMON SSSI AND CANDIDATE SAC

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February 1999

DOCUMENT CONTROL SHEET

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Title: A Review of the Hydrogeological Information for the Thompson and Merton Areas, Norfolk, including Predictions of the Impact of Nearby Chalk Water Abstractions on Water Levels at Thompson Water, Carr and Common SSSI and Candidate SAC

File Reference: Chalk Groundwater Unit 10, Wissey

Document Approval and Amendment Record

Version No: 1

Status: Internal Agency Document

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Checked: February 1999, Chris Taylor, Team Leader – Hydrogeology

Purpose: Review of Hydrogeological Information Available for Thompson Water, Carr Common SSSI and Candidate SAC

Distribution List	Copy No[s]
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Document History:

Version 1 15/02/1999

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1. INTRODUCTION

1.1 The scope of this study is primarily a desk study of available hydrogeological information on the Thompson & Merton areas supplemented by field readings from sources outside the Agency as well as data on Agency records.

1.2 The primary aim of the report is to present information that can be referred to by Agency Water Resources Staff when determining abstraction licence applications in the study area. Some of the information included is simply graphical presentation of existing data from Agency records (such as observation borehole hydrographs). The report also includes results of further analysis and interpretation of data carried out by the author, such as contour plotting of geological information and interpretation in terms of the possibility for groundwater recharge to Chalk via leakage through Drift and discharge from the Chalk to Drift and surface water.

1.3 The Thompson & Merton areas are located in the south east of the Wissey catchment, south of the Watton area. The general location of the area of study is shown on fig.1.1. The specific area covered for the purpose of this review is the whole of sheet **TL 99 NW** on the OS 1:10000 series, plus the northern section of sheet **TL 99 SW** north of grid line 294000, together referred to as the 'study area' in this report.

1.4 The main feature of conservation interest in the area is Thompson Water, Carr and Common SSSI which is part of the Norfolk Valley Fens candidate SAC under the EC Habitats Directive. The current policy of the Agency is to protect candidate SACs as if they were designated SACs. As the hydrogeology of this valley feature is distinctive, a separate section (6) is given over to this subject. The section includes a study of the relationship between surface water levels and Chalk groundwater levels.

1.5 Section 7 of the report includes the results of some calculations on the potential effects of abstraction in the area on Chalk groundwater heads. Examples are given of predicted drawdowns at three different locations in the study area, indicating the potential effects of various licenced and proposed abstractions. The method used may be applicable to other locations for proposed abstractions within the study area.

1.6 This report identifies that the available information suggests that the Chalk aquifer is recharged through the drift cover and that discharge from the Chalk aquifer occurs in the valley of the Thompson Stream which flows though the centre of the site of Thompson Water Carr and Common SSSI. It is concluded that the interference effects of nearby Chalk water abstraction have the potential to reduce the head in the Chalk aquifer beneath Thompson Water Carr and Common SSSI and if this occurs there will be a reduction in the amount of Chalk groundwater which is discharged via the drift deposits which are in turn drained by the Thompson Stream.

1.7 Rainfall data have not been reviewed here although recognised as important for correlation with water level trends. Further understanding of the hydrogeology of the study area should be gained by study of future field readings.

2. SOURCES OF INFORMATION ON THE STUDY AREA

2.1 Previous studies covering the Thompson & Merton areas

2.1.1 A study of the Wissey catchment, carried out by Land & Water Resource Consultants was published in December 1987 and accepted by the newly established NRA unit of the AWA in July 1989.

2.1.2 'A Review of the Water Resources of the Catchment of the River Wissey, Norfolk' carried out for the NRA by Aspinwall & Company was published in August 1992. The study incorporated a groundwater model of the Wissey catchment using the FLOWPATH numerical model, representing steady-state groundwater flow in the catchment.

2.1.3 Two studies of the possible impact of abstraction in the Watton area were published in 1992 and 1993. 'A Review of the Possible Impact of Public Water Supply Abstraction on Surface Water Flow in the Watton Area' by Aspinwall & Company was published in April 1992. 'A Review of the Possible Impact of Groundwater Abstraction for Public Water Supplies on Caudlesprings Fen, Watton, Norfolk' by Simpson & Partners was published in August 1993. Although these studies do not specifically cover the Thompson & Merton area, they contain some information which is relevant to this area.

2.1.4 The NRA published an internal dossier 'Interim Wetland Hydrological Report for Thompson Common SSSI, Site No.18' (June 1995) as part of the NRA Project 9035011 Hydrological Monitoring of Wetlands.

2.1.5 The most recent Hydrological Report for Thompson Common, Site 18, by HSI was published in May 1998 as part of Hydrological Monitoring of Wetlands Project KVW35011. This report includes the results of monitoring carried out at the site since 1992 and details of new monitoring borehole installations in 1997 by Soil Mechanics.

2.2 Data Sources For This Report

2.2.1 Topographic data was obtained from the OS 1:10 000 series sheet TL 99 NW and part of sheet TL 99 SW. These sheets were used as base maps in this study. For smaller scale mapping of the area, the OS 1:25 000 sheet TL 99 and OS 1:50 000 sheet 144 were used as base maps.

2.2.2 Geological data was taken from strata records on Agency Well Archives TL 99 and TL 98. Some of strata records have apparently been copied from historic data, others have been provided by drillers. The accuracy of most of the strata information cannot be verified. For the purpose of constructing contours of estimated geological layer thickness, the strata record data was summarised and entered onto a spreadsheet (MERTGEOL.XLS) reproduced in Appendix B. An updated BGS 1:50 000 Geological Map covering this area has not yet been published.

2.2.3 Water level data for observation boreholes on the Agency OBH network was obtained from Hydrodat. For the most part the construction records of these boreholes is as supplied by the contractors and has not been verified. The data was derived from manual dip readings taken by Agency staff at approximately monthly intervals. Water level data (also on Hydrodat) for gauge boards and observation boreholes at Thompson Water, Carr and Common SSSI was measured by an employee of Mr J Raker, the holder of groundwater abstraction licence 6/33/48/G/197. This data was forwarded to the Agency by Land and Water Resource Consultants Ltd.

2.2.4 The BGS 'Hydrogeological Map of Northern East Anglia', Sheet 1, 1981 was referred to for general information on the hydrogeology of the wider area such as extent of Chalk aquifer and regional groundwater flow direction. The geology indicated on this map on a scale of 1:125 000 was not used to construct a larger scale geology map for the study area because the detail on the BGS Hydrogeological map may not be sufficiently accurate for this purpose. In at least one instance, information on the BGS Hydrogeological map appears to conflict with the record of an existing borehole in the area (refer section 6.7.1).

2.2.5 Abstraction data for licenced abstractions in the area was obtained from Agency records of annual abstraction returns provided by the licence holders. Some of this data was retrieved from the Agency's main-frame data base, additional data was found on paper archives of the original abstraction returns. In some instances the data may be incomplete eg. Merton Farms may have abstracted in 1997 at a time when they did not hold a valid abstraction licence.

2.2.6 Aquifer characteristics for the area (refer table 4.4) were taken from data on Agency technical files and for the most part rely on previous interpretation of historic pumping test data.

2.2.7 Stream flow data for watercourses on Thompson Common was measured by Agency Water Resources staff using an Ott current meter, or in the case of very low flows by estimation.

3. DESCRIPTION OF THE STUDY AREA

3.1 Topography and Drainage

3.1.1 The Merton area is located on land at an elevation of 45 to 55 mAOD, situated between the Watton valley to the north and the Thompson valley to the south and east. As well as farm land there are a number of woodlands in the Merton area, including Wayland Wood and Merton Wood. The Thompson area includes land at an elevation of 50 mAOD falling to 30 mAOD in the Thompson valley. The land is mainly farm land with some woodland. In the Thompson valley there are areas of Fen meadow and open grassland within the boundary of Thompson Water, Carr and Common SSSI.

3.1.2 Surface water drainage in the area is generally towards the Thompson stream (see fig 3.1). The Thompson stream runs initially south-eastwards from its head near Low Common Farm and turns southwards then flows westwards along the Thompson valley where it enters Thompson Water at TL 9165 9497. A tributary of the Thompson stream arises in the area of Caston Common and flows south-westwards, joining the Thompson stream at about TL 934 961. Local drainage near Merton Hall and Broadflash does not appear to reach the Thompson valley and feeds into a number of ponds in the vicinity of Merton Hall. A letter to the NRA from Lord Walsingham dated 11 December 1989 and filed on 503/2996 includes some information on the history of ponds in the Merton area.

3.2 Geology

3.2.1 The BGS Hydrogeology map for northern East Anglia indicates that the geology in the area is Upper/Middle Chalk overlain in most places by Drift which includes undifferentiated Boulder Clay and/or fluvio-glacial sand and gravel, alluvial deposits etc. An up to date BGS 1:50000 Geological Map covering this area has not yet been published.

3.2.2 Information from boreholes in the vicinity suggest that the thickness and nature of the Drift cover vary considerably. The upper layers of Drift recorded in several borehole logs consist mainly of sand, silt and gravel while the lower part of the Drift apparently consists predominantly of grey clay. Borehole information suggests the existence of a Drift filled buried chalk valley to the south and east of the site of TL 99/143 (NB the accuracy of these logs is not known). The deepest Drift encountered in a borehole here is recorded as 39.3m at TL 99/041. Estimated contours of the clay-rich layer of Drift were derived from borehole log data in the area. These contours are shown overlain on a 1:10000 map of the area (fig.3.2). The approximate line of the Drift filled buried chalk valley can be identified on this map. The archived borehole information indicates that the clay-rich layer of Drift thins in the area of Thompson Common and in one borehole TL 99/167 appears to be completely absent. Estimated contours of the sandy layer of Drift were derived from borehole log data in the area. These contours are shown overlain on a 1:10000 map of the area (fig.3.3). The deepest recorded sandy Drift in the area is 19.8m at TL 99/017B near the centre of the Drift filled buried chalk valley. Borehole information at Thompson Common indicates that thicknesses of sandy Drift here can range from 0.4 m at TL 99/167 to greater than 4 m at TL 99/169. Fig 3.4 shows estimated total Drift thickness contours on a 20000 scale map, as generated from available borehole data using the Surfer contouring program. The contouring method used in Surfer was triangulation with linear interpolation, a low degree of smoothing was incorporated. The data points used are shown on fig 3.4 and the data reproduced in Appendix A. The distribution of data points is very sparse in some areas. Contours must be regarded as estimates only, in particular contours in areas without data points may not be representative of actual drift thicknesses.

3.2.3 The Chalk in this region is believed from BGS mapping to dip eastwards at less than 1° and generally thickens in the same direction resulting in a thickness of more than 450 m at locations east of Norwich as more of the Chalk succession is present here. Borehole information indicates that the top of the Chalk is close to the ground surface within parts of Thompson Common, eg. 0.4 mBGL at TL 99/167 and 7.0 mBGL at both TL 99/173 and TL 99/201. A contour plot of estimated Chalk surface levels, based on available borehole information and generated with the Surfer contouring program, is shown on fig.3.5. The contouring method used in Surfer was triangulation with linear interpolation, a low degree of smoothing was incorporated. It is noted that a north-south geological section through the Watton and Griston areas (fig 10 of 'A Review of the Possible Impact of Groundwater Abstraction for Public Water Supplies on Caudlesprings Fen, Watton, Norfolk', August 1993) indicates a high in the Chalk surface near TL 99/054, with gradients falling northwards to the Watton valley and southwards through Griston.

3.2.4 No geophysical logs of boreholes in the area were found. Out of 33 strata logs found for boreholes intersecting Chalk in the area, 8 specifically indicated Upper Chalk while the remaining records showed undefined Chalk. The strata logs where Upper Chalk was specifically indicated were for boreholes: TL 99/004, TL 99/005, TL 99/027, TL 99/031, TL 99/032, TL 99/034, TL 99/153 and TL 99/154. It was noted that none of the records specifically mentioned the 'hard band' known as the Chalk Rock horizon, it is difficult to draw any further conclusion as to whether any of the boreholes did actually intersect the Chalk Rock or enter Middle Chalk.

4. HYDROGEOLOGY

4.1 Introduction to Hydrogeology of the Area

4.1.1 The aquifer in the area is shown on the 'Hydrogeological Map of Northern East Anglia', 1981 as Upper/Middle Chalk. Borehole information in the area does not provide any clear indication of the Chalk Rock horizon and it may be that this has not been intersected by existing boreholes or more likely that the level of geological recording has been inadequate to identify its presence. It appears that the Chalk is covered for the most part by a semi-confining layer of Boulder Clay plus glacial/fluvial sand and gravel deposits which where they are in hydraulic continuity with the underlying Chalk aquifer are regarded as part of the Chalk aquifer.

4.1.2 For background information on hydrogeology of the Wissey catchment refer to sections II and IV of the Wissey study carried out for the NRA by Land & Water Resource Consultants (December 1987) and chapter 2 of 'A Review of the Water Resources of the Catchment of the River Wissey, Norfolk' carried out for the NRA by Aspinwall & Co (August 1992).

4.1.3 It is believed that the Boulder Clay acts as a leaky, semi-confining layer. It is stated in section 2.3 of 'A Review of the Water Resources of the Catchment of the River Wissey, Norfolk' (August 1992) that 'pumping tests in the "confined" Chalk of several days duration or longer usually indicate leaky conditions'. The results of the modelling exercise conducted during the same study also indicated that the Boulder Clay acts a semi-confining layer on a catchment scale, but on a local scale its behaviour may vary over short distances, reflecting lateral changes in the permeability of the different lithologies present.

4.2 Groundwater Flow

4.2.1 Groundwater contours on the BGS Hydrogeology map for northern East Anglia indicate that regional groundwater flow is towards the south-west, however more local groundwater features such as a 'high' area approximately 1 km south of Thompson Common suggest that local groundwater flow patterns may be more complicated. There is currently insufficient groundwater level data available for the Thompson/Merton area to enable groundwater contours for the area to be plotted on a 1:10000 scale. The component of local groundwater flow variations, within the regional south-westerly flow direction are therefore unknown.

4.2.2 Vertical flow is considered in this paragraph. It is very likely that vertical leakage through the Drift deposits occurs throughout the area. However the velocity and direction of leakage will vary considerably according to location and season, depending mainly on the nature of the Drift deposits at any location and the difference in hydraulic head across the semi-confining layer or layers. Evidence of artesian conditions identified in some Chalk boreholes (such as TL 99/124 and TL 99/173) during some winter months indicate that the direction of leakage at these locations will be upward under certain conditions. An estimate of leakage coefficient of the Drift deposits in the Thompson area has been made by further analysis of the pumping test carried out on TL99/153 in November 1990 (see section 4.4.4). The range of values calculated from the results of this test was checked against recorded drawdowns due to abstraction from other boreholes in the area to see if it gave a reasonable indication of average leakage coefficient of Drift in the locality (see section 4.4.8).

4.2.3 The hydraulic significance of the Drift filled buried chalk valley to the south and east of the site of TL 99/143 is unknown. A controlled pumping test with extensive water level monitoring would probably be necessary to provide information on the hydraulic significance of this feature. Chalk groundwater levels both to the north and the south of the buried chalk valley would need to be monitored if useful information was to be obtained from a long pumping test.

4.3 Observation Boreholes

4.3.1 There are 11 observation boreholes within the study area with records available on Hydrodat. Table 4.1 gives details of these boreholes, locations are shown on fig 4.1. According to the borehole construction and strata records, most of these boreholes penetrate Chalk, however there are a few with 2 separate installations within the main borehole apparently monitoring water levels in different horizons. As there are no construction details of these installations it is not certain which horizons are being monitored. In addition to these 11 observation boreholes there are currently a further 6 shallow monitoring boreholes purpose built to separately monitor water levels in the Drift at Thompson Water, Carr and Common SSSI. Details of these 6 monitoring boreholes are shown on table 6.1 in the section on Thompson Water, Carr and Common SSSI.

4.3.2 In order to try to understand the status of readings from TL 99/017A and TL 99/017B the depth of both internal installations was measured by R.Maxey on 16 July 1998. The depth of TL 99/017A was confirmed at 24.2 mBGL, the depth of TL 99/017B was confirmed at 7.85 mBGL. Hydrographs of TL 99/017A and TL 99/017B are shown on fig 4.2. TL99/017B may indicate groundwater levels in the upper, predominantly sandy Drift. TL99/017A is blocked at a recorded depth of 24.2 mBGL where the strata log indicates chalky Boulder Clay, therefore the hydrograph of TL 99/017A may represent potentiometric levels in the lower Drift if the installation is open to the drift at about 24m. Levels in TL99/017A generally fall from the start of the record in 1975 until the end of 1992 when they appear to stabilise at around 39.5mAOD.

4.3.3 Chalk OBH TL 99/004 (fig 4.3) indicates relatively stable groundwater conditions at this location from 1970 to 1990, with seasonal fluctuations from 30.0 m to 34.0 mAOD. From 1991 onwards, summer groundwater levels generally drop below 30.0 mAOD.

4.3.4 Chalk OBH TL 99/005 (fig 4.4) indicates a trend of generally falling groundwater levels at this location from 1970 onwards. It should be noted that this observation borehole is located approximately 1.2 km from a major groundwater abstraction at Watton by Anglian Water Services Ltd. The top of the Chalk at TL 99/005 is shown on the well record as 39.71 m AOD. Assuming this is correct, the Chalk would have become unconfined here during periods of low groundwater levels in 1990-1992 and again in 1996-1997. In this report unconfined conditions in Chalk are taken as applying where Chalk groundwater heads fall below the top of the Chalk aquifer, whether the Chalk is covered by Drift or not.

Table 4.1 : Observation Boreholes in Thompson & Merton Areas					
Well Ref	**NGR**	**Type**	**Location**	**Drift/Ck Interface mAOD**	**Range in WL mAOD**
TL 99/004	TL 9176 9678	Chalk	West Verge, Thompson	32.05m	27.8m to 34.0m
TL 99/005	TL 9236 9941	Chalk	Verge,A1075, Wayland Wood, Nr Watton	39.71m	38.0m to 46.3m
TL 99/007A TL 99/007B	TL 9369 9828	Chalk ? L Drift ?	Verge, Griston Cross Roads	35.23m	41.6 - 47.4m 43.1 - 47.7m
TL 99/008	TL 9440 9640	Chalk	Stow Bedon	??	36.2m to 39.9m
TL 99/017A TL 99/017B	TL 915 976	L Drift ? U Drift ?	Verge, Merton Cross Roads	15.12m	39.4 - 43.0m 45.8 - 48.5m
TL 99/027	TL 9158 9729	Chalk	Verge, North of Thompson	27.89m	32.3m to 40.4 m
TL 99/032	TL 9395 9442	Chalk	Breckles Heath	-3.33m	32.1m to 36.8m
TL 99/034	TL 9144 9457	Chalk	Nr. Thompson Water	5.55 m	26.0m to 31.4m
TL 99/167	TL 9374 9648	Chalk	Thompson Common 4	36.6 m	33.8m to 36.9m
TL 99/173	TL 9333 9642	Chalk	Thompson Common 1	28 m	32.8m to 35.1m
TL 99/201	TL 9328 9570	Chalk	Thompson Common (new 1997)	26.3 m	33.86 m 12.02.1998

4.3.5 Chalk OBH TL 99/007A (fig 4.5), located 2.1 km west of TL 99/143, indicates relatively stable groundwater conditions at this location from 1970 to 1990, with seasonal fluctuations from 43.7 m to 47.5 mAOD. From 1989 onwards, summer groundwater levels generally drop below 43.0 mAOD. Hydrograph TL 99/007B follows the pattern of TL 99/007A quite closely, except that levels at TL 99/007B do not drop as low as comparable low levels at TL 99/007A during summer/autumn. It is thought by the author that TL 99/007B indicates levels in the lower sandy clay Drift, not far from the top of the Chalk aquifer. The well record indicates that tube 'B' extends to 11.6 m and shows the top of the Chalk at 14m below ground level. Piezometer depths measured by R.Maxey on 16 July 1998 were 11.05 mBGL for TL 99/007B and 28.62mBGL for TL 99/007A.

4.3.6 Chalk OBH TL 99/027 (fig 4.6), located 840 m south of TL 99/143, indicates relatively stable groundwater conditions at this location from 1970 to 1989, with seasonal fluctuations from 35.9 m to 40.3 mAOD. From 1990 onwards, levels have generally declined, with summer/autumn levels falling below 34 mAOD in 1996 and 1997. Also since 1990, winter levels have failed to recover near to the generally high winter levels of the 1970's and 1980's.

4.3.7 The general trend of the hydrograph of TL 99/008 (fig 4.7) indicates relatively stable groundwater conditions at this location since 1976. The hydrograph of TL 99/034 (fig 4.8) shows wider fluctuations than TL 99/008, probably reflecting the fact that confined conditions were prevalent (ie.groundwater heads above top of Chalk) whereas TL 99/008 may be located in an area where groundwater heads were below the top of the Chalk.

4.3.8 The general trend of the hydrograph of TL 99/032 (fig 4.9) indicates a similar pattern to that of TL 99/034, with a full recovery of winter levels in 1994 and 1998 after previous low summer levels.

4.3.9 Hydrographs of TL 99/167 and TL 99/173 are shown on fig 4.10. These indicate Chalk groundwater levels from May 1992 to April 1998 at TL 99/167 and TL 99/173. Seasonal fluctuations are observed with minimum groundwater levels of about 33.8m and 32.85m respectively indicated in September 1997.

4.3.10 The following table 4.2 shows 2 observation boreholes into Chalk in the area that are at least 5 km distant from any major abstraction in the area and are useful as indicators of regional Chalk groundwater levels against which hydrographs from other boreholes may be compared (refer section 4.5.4). The hydrographs of TL 89/019 and TL 89/020 are reproduced on figures 4.11 and 4.12. It should be noted that conditions in the Chalk are unconfined at the location of these boreholes but the strata logs of both boreholes indicate that the Chalk is covered by Drift at TL 89/019 and TL 89/020 .

Table 4.2 : Chalk Observation Boreholes Distant from Major Abstractions

Well Ref	NGR	Type	Depth (m)	Location	Drift/Chalk Interface mAOD	Range in Water Level mAOD
TL 89/019	TL 8778 9778	Chalk	39.62	Verge near The Arms	30.54 m	23.0 to 28.5m
TL 89/020	TL 8898 9302	Chalk	51.82	Redcross Plantation	44.82 m	22.6 to 28.8m

4.4 Aquifer Characteristics

4.4.1 A number of pumping tests of varying quality have been carried out on boreholes in the area since 1977, mainly in support of abstraction licence applications. Some of these tests were for a pumping duration of several days. Few of these tests had the benefit of observation boreholes measured regularly. Test details and aquifer characteristics as found on Agency technical files are summarised in table 4.4 and in the following paragraphs.

4.4.2 A pumping test was carried out on borehole TL 99/107 (P L Brown)from 30 July 1985 to

6 August 1985. The average pumping rate over the 7 day period was 1279 m^3/day. Water levels at the nearest observation borehole TL 99/48, at 87m distance from TL 99/107, were monitored at frequent intervals during the test.

Table 4.4 : Aquifer Characteristics from Results of Previous Tests in the Area					
Method of Calculation	**ABH**	**OBH (distance in m)**	**T (m^2/day)**	**L (m)**	**S**
Jacob-Cooper approximation Drawdown Data	TL 99/107	TL 99/48 (87 m)	349		.00122
Theis Calculated Recovery	TL 99/107	TL 99/48 (87 m)	378		.00264
Theis Calculated Recovery Oct/Nov 1977 test	TL 99/124		256		-
Jacob-Cooper approximation Dec 1990 test drawdown	TL 99/124		221		-
Theis Calculated Recovery Dec 1990 test	TL 99/124		267		-
Theis Log/Log Drawdown Data	TL 99/153	TL 99/154 (40 m)	470.6		.003
Jacob-Cooper Drawdown Data Nov 1990 test	TL 99/153	TL 99/154 (40 m)	395.9		.0058
Theis Calculated Recovery	TL 99/153		240.4		-
Watton Method Log/Log Drawdown Data	TL 99/153	TL 99/154 (40 m)	355	2000 to 4000	.001?
Range in Values			**221 - 470**	**2000 to 4000**	**.001 - .006**

4.4.3 Pumping tests were carried out on TL 99/124 (Merton Farming Co Ltd) in October/November 1977 and again in December 1990 when the borehole was pumped for 7 days at an average rate of 4225 m^3/day. Aquifer characteristics previously calculated from these tests are shown on table 4.4.

4.4.4 A 7 day pumping test was carried out on TL 99/153 in November 1990. The pumping rate was maintained at about 136.4 m^3/hour for the first 16 hours of the test, the rate then fell to about 104.5 m^3/hour until the valve was opened again at 72 hours into the test. Frequent readings were taken at TL 99/153 and observation borehole TL 99/154, about 40 m distant from TL 99/153, during the test and recovery phase. Aquifer characteristics as given in the licence application C/0064 technical report for TL 99/153 are shown on table 4.4. In addition, the drawdown data at observation borehole TL 99/154 was analysed by the author using the Walton method which assumes a leaky confined aquifer with no delayed yield. Although the drawdown curve of the observation borehole TL 99/154 indicates an element of delayed yield up to t=100 minutes, the late data fits approximately to Walton type curves for r/L values of 0.01 and 0.02 (leakage coefficient L= 2000 to 4000m). Bearing in mind the geological nature of the drift succession that overlies the Chalk, estimation of a leakage coefficient is relevant when the drift is partly saturated as it is considered by the author that the long-term drawdown response of the Chalk aquifer in the Thompson area could be approximated to that of a leaky confined system. It is noted that an estimated leakage coefficient of L= 2000 to 4000m is not inconsistent with a thickness of 4 to 20 metres of low permeability glacial deposits that could have a vertical hydraulic conductivity in the order of 10^{-8} to 10^{-9} m/sec (approximately 10^{-3} to 10^{-4} m/day). In practice the variability of the low permeability deposits in the area would mean that leakage coefficients would have a considerable range.

4.5 Trials of Aquifer Characteristics and Drawdown Prediction Methods

4.5.1 Two different methods of predicting groundwater level drawdowns were tested to check whether they were applicable to the aquifer conditions in the area. A range of aquifer characteristics (based on those shown on table 4.4) were applied with each method. Predicted drawdowns were compared with measured water level changes at observation boreholes. The results obtained enabled more informed choices to be made about the aquifer characteristics and methods best applied when making drawdown predictions for the area.

4.5.2 The Theis time-drawdown method was trialed with aquifer characteristics as follows:

T = 300 to 400 m^2/day S = 0.002 to 0.005

A pumping time of 122 days was used as this was assumed to be the duration of the summer irrigation season over which abstraction rates were averaged.

4.5.3 The De Glee steady state method for leaky confined aquifers was trialed using aquifer characteristics of:

T = 300 to 400 m^3/day L = 3000 to 4000 m

It is assumed for this method that drawdowns due to abstraction have reached equilibrium by the end of a summer irrigation season. The DeGlee condition of only a small change in head in 'near surface recharge source' is assumed to apply.

4.5.4 Each method was trialed against net change in Chalk water levels recorded on a range observation boreholes in the area from September 1992 to September 1996 (see table 4.5). In order to separate the effects of 'natural' changes in Chalk water levels from the effects of local abstraction it was also necessary to find observation boreholes in an adjacent area located some distance from any major abstraction. From inspection of the hydrographs of TL 89/019 and TL 89/020 both of which are located in Chalk at least 5 km from any major groundwater abstraction, it is estimated that the 'natural' change in Chalk water levels from September 1992 to September 1996 was a net fall of about 0.1 m. It is assumed that the 'natural' change in Chalk water levels includes the net change due to rainfall in the area. It is assumed that any additional lowering of groundwater levels in the Thompson/Merton area over the same period is due to the effects of local groundwater abstraction.

Table 4.5 Change in Chalk Water Levels Recorded at Boreholes in the Study Area						
Well Ref	**NGR**	**Location**	**Drift/Ck Interface mAOD**	**1992 (Sept) Water Level mAOD**	**Change in WL 1992 to 1996 Aug/Sept**	**Confined/ Unconfined C / UC (Sept 1992)**
TL 99/004	TL 9176 9678	West Verge, Thompson	32.05m	28.28	- 1.1	UC
TL 99/005	TL 9236 9941	Verge,A1075, Wayland Wood	39.71m	39.23 *	- 0.37 *	UC
TL 99/007A	TL 9369 9828	Verge, Griston Cross Roads	35.23m	42.01	dry 1996	C
TL 99/008	TL 9440 9640	Stow Bedon	no strata record	37.1	- 0.64	??
TL 99/027	TL 9158 9729	Verge, North of Thompson	27.89m	34.9	- 1.05	C
TL 99/034	TL 9144 9457	Nr. Thompson Water	5.55 m	26.4	- 0.4	C
TL 99/167	TL 9374 9648	Thompson Common 4	36.6 m	34.5	- 0.65	UC
TL 99/173	TL 9333 9642	Thompson Common 1	28 m	33.58	- 0.72	C
TL 99/201	TL 9328 9570	New monitoring BH (1997)	26.3 m	N/A	N/A	C
TL 89/019	TL 8778 9778	Verge near The Arms	30.54 m	23.24	- 0.12	UC
TL 89/020	TL 8898 9302	Redcross Plantation	44.82 m	23.0	- 0.04	UC

Note: * Storage effects at the top of the Chalk may significantly attenuate water level changes around 39-40mAOD at TL 99/005.

4.5.5 The predicted drawdown effects of abstraction under the sum of the licences listed on table 5.1 except for licence 6/33/48/G/256 were calculated by both the Theis and the DeGlee methods. Actual abstracted quantities for each licence during the summer irrigation seasons of 1992 and 1996 were used in the drawdown calculations. Licence 6/33/48/G/256 was omitted from the drawdown calculation as the available contoured water level information suggests it is far enough down-gradient of the site for interference drawdown to be small.

4.5.6 The results of these predictions were compared with the recorded change in levels noted from the hydrographs of the relevant observation borehole (see tables 4.6 and 4.7).

Table 4.6 Theis Predicted Change in Chalk Water Levels and Actual Change Recorded in OBHs (September 1992 compared to September 1996)

	RECORDED	EXPECTED	THEIS	THEIS	THEIS	THEIS
Well Ref OBH	**Net Change Recorded at OBH (m)**	**Net Change Less'Natural' Change 0.1 m (m)**	**t=122days T = 400 S= 0.002 (m)**	**t=122days T = 400 S= 0.005 (m)**	**t=122days T = 300 S= 0.002 (m)**	**t=122days T = 300 S= 0.005 (m)**
TL 99/004	- 1.1	**- 1.0**	- 1.27	**- 0.99**	- 1.58	- 1.21
TL 99/005	- 0.37	**- 0.27**	- 0.81	- 0.56	- 0.97	- 0.64
TL 99/008	- 0.64	**- 0.54**	- 0.77	**- 0.51**	- 0.91	**- 0.58**
TL 99/027	- 1.05	**- 0.95**	- 1.11	- 0.84	- 1.37	**- 1.00**
TL 99/034	- 0.4	**- 0.3**	- 0.68	- 0.43	- 0.80	- 0.48
TL 99/167	- 0.65	**- 0.55**	- 0.95	- 0.68	- 1.16	- 0.80
TL 99/173	- 0.72	**- 0.62**	- 1.10	- 0.82	- 1.35	- 0.99

Note: predicted figures in bold are those that agree within 10 % of figure derived from relevant hydrograph

4.5.7 From inspection of figures in table 4.6 the following observations are made:

1) Theis method using T = 400 m^2/day and S= 0.005 appears to give reasonable estimates of drawdowns in the Chalk at TL 99/004 and TL 99/008.

2) Theis method using T = 300 m^2/day and S= 0.005 appears to give reasonable estimates of drawdowns in the Chalk at TL 99/008 and TL 99/027.

3) Theis method using the range of T and S values chosen appears to overestimate drawdowns in the Chalk in the vicinity of TL 99/034, TL 99/167 & TL 99/173 located in the Thompson valley area.

Table 4.7 DeGlee Predicted Change in Chalk Water Levels and Actual Change Recorded in OBHs (September 1992 compared to September 1996)						
	RECORD	**EXPECTED**	**DEGLEE**	**DEGLEE**	**DEGLEE**	**DEGLEE**
Well Ref OBH	**Change Recorded at OBH (m)**	**Net Change Less'Natural' Change 0.1 m (m)**	**T = 300 L= 3000m (m)**	**T = 300 L= 4000m (m)**	**T = 400 L= 3000m (m)**	**T = 400 L= 4000m (m)**
TL 99/004	- 1.1	**- 1.0**	**- 1.10**	- 1.31	- 0.82	**- 0.98**
TL 99/005	- 0.37	- 0.27	- 0.60	- 0.77	- 0.45	- 0.58
TL 99/008	- 0.64	**- 0.54**	**- 0.53**	- 0.70	- 0.39	**- 0.53**
TL 99/027	- 1.05	**- 0.95**	**- 0.90**	- 1.11	- 0.67	- 0.83
TL 99/034	- 0.4	**- 0.3**	- 0.44	- 0.61	**- 0.33**	- 0.46
TL 99/167	- 0.65	- 0.55	- 0.73	- 0.92	**- 0.54**	- 0.69
TL 99/173	- 0.72	**- 0.62**	- 0.89	- 1.10	**- 0.67**	- 0.82

Note: predicted figures in bold are those that agree within 10 % of figure derived from relevant hydrograph

4.5.8 From inspection of figures in table 4.7 the following observations are made:

1) DeGlee method using T = 300 m^2/day and L = 3000 m appears to give reasonable estimates of drawdowns in the Chalk at TL 99/004, TL 99/008 and TL 99/027.

2) DeGlee method using T = 400 m^2/day and L = 4000 m appears to give reasonable estimates of drawdowns in the Chalk at TL 99/004 and TL 99/008.

3) DeGlee method using T = 400 m^2/day and L = 3000 m appears to give reasonable estimates of drawdowns in the Chalk in the vicinity of TL 99/034, TL 99/167 & TL 99/173 located in the Thompson valley area.

4.6 Choice of Best Available Method for Predicting Drawdown Effects

4.6.1 On the basis of the results shown in tables 4.6 and 4.7 and available hydrogeological information on the area, the following aquifer characteristics and methods are assessed as the best available at the current time for predicting drawdown effects of abstraction in the area:

1) The DeGlee method using values of L= 3000 m and T= 400 m^2/day for estimating long-term drawdowns in the Chalk in some parts of the Thompson valley area where the Chalk

is covered by Drift (but not where the Chalk is uncovered).

2) The DeGlee method using values of L= 3000 m and T= 300 m^2/day for estimating long-term drawdowns in the Chalk in the Thompson/Merton area apart from the Thompson valley area.

3) The Theis method using values of T= 300 m^2/day and S= 0.005 could be applied. This is likely to overestimate drawdowns in the Chalk in the Thompson & Merton areas, but would be consistent with the Agency's duty to apply the 'precautionary principle' when assessing potential derogation effects.

4.6.2 One advantage of the DeGlee method for estimating the effects of long-term abstraction in this area is that it takes into account an element of recharge as leakage through the Drift, it also models a steady state condition in which uncertainties in aquifer storage coefficient are of no concern. The main uncertainty in the DeGlee method is the value of leakage coefficient used, and the limiting assumptions of the method which may or may not be satisfied. It should be recognised that the method assumes one permeability value for the area, whereas in practice the Drift varies in permeabiliy according to locality. It should also be noted that at some localities and during some seasons, relative heads in the Chalk and upper Drift will be such that groundwater will leak upwards from the Chalk into the Drift. This point is addressed further in section 5.3.1.

4.6.3 The Theis method may be preferred when estimating the effects of abstractions of shorter duration, however it should be noted that local variations in storage coefficient in the Chalk and complications of transient effects at confined/unconfined boundaries could mean that estimates made by the Theis method may be open to a higher margin of error.

5 WATER RESOURCES

5.1 Water Resources Licencing Policy

5.1.1 Most of the study area is located in the Middle Wissey Sub-Unit (B) of the Chalk 10 (Wissey) Groundwater Unit, with just a small section in the north of the area falling in the Upper Wissey Sub-Unit (see fig.5.1). The Chalk 10 (Wissey) Groundwater Unit has a nominal resource surplus of 22300 m^3/day according to the NRA document 'Abstraction Licensing, Technical Guidelines' (February, 1996).

5.1.2 A draft Water Resources Management Plan was also prepared for the Chalk 10 (Wissey) Groundwater Unit by the Agency in November 1996. Over the whole unit this report suggests that there is a resource surplus of 18450 m^3/day.

5.1.3 Information from a draft report on the water resources of the Wissey, yet to be published, indicates that the Middle Wissey Sub-Unit had a nominal surplus of 14300 m^3/day in 1997. In licencing terms there is water available for licencing in the Middle Wissey Sub-Unit. It should be noted however that the water licenced (1996 situation) for spray irrigation in the Merton & Thompson area accounts for nearly all of the quantity licenced for spray irrigation in the Middle Wissey Sub-Unit (approximately 2000 m^3/day).

5.2 Abstraction in the Area

5.2.1 There are currently 3 major licenced groundwater abstractions in the study area, plus 2 major licences recently expired for which renewal applications are being considered by the Agency. In addition to these, there are a few smaller abstractions for agricultural purposes in the area and a number of domestic sources.

5.2.2 The spray irrigation licences recently expired are 6/33/48/G/172 (P L Brown) spray irrigation part expired 30 September 1996 and 6/33/48/G/196 (Merton Farming Co) expired 31 March 1997. In addition a time limited variation of licence 6/33/48/138 held by A P (East Anglia) Ltd expired on 31 July 1997. A renewal application for this part of licence 6/33/48/138 is also being considered by the Agency.

5.2.3 The following table 5.1 gives details of the 5 major abstractions in the area including the 3 applications pending. Details of a smaller abstraction at TL 99/126 for spray irrigation are also given in the table, this is included as it is situated near the eastern boundary of Thompson Water, Carr and Common SSSI. The location of the abstraction boreholes is shown on fig 4.1.

Table 5.1 Details of Spray Irrigation and Industrial Abstractions in Merton Area					
Agency Borehole Reference	**National grid reference**	**Application/ licence**	**Use**	**Daily abstraction rate (m^3/day)**	**Annual abstraction (m^3/year)**
TL 99/107 (PL Brown)	TL 9201 9894	Application CN/1788	Spray irrigation	1276.4	113,600
TL 99/113 (Pilkington)	TL 9465 9410	6/33/48/G/256	Spray irrigation	1820	100,000
TL 99/124 (Merton Farming Co)	TL 9263 9792	Application CN/2006	Spray irrigation and agriculture	4254.5	213,800
TL 99/126 (MF Warren)	TL 941 965	6/33/48/G/219	Spray irrigation and agriculture	230.5	13450
TL 99/143 AP (East Anglia) Ltd	TL 9159 9813	6/33/48/138	Industrial	273 m^3/day (1 April to 20 June) 727 m^3/day (21 June to 31 March)	162,000
		Application CV/2087	Industrial	1250	300,000
TL 99/153 (J Raker)	TL 9235 9641	6/33/48/G/197 *	Spray irrigation	3000	185,000

* Note: licence 6/33/48/G/197 is due to expire on 30 September 1998

5.2.4 Recorded annual abstractions for 5 of the above licences since 1992 are shown in the following table 5.2. Abstractions under licence 6/33/48/G/219 are not included as licenced quantities are very small relative to the other 5 licences listed on table 5.1.

Table 5.2 : Recorded Major Spray Irrigation and Industrial Abstractions (m^3) in the Thompson & Merton Area						
Year	**TL 99/107 PL Brown**	**TL 99/113 Pilkington**	**TL 99/124 Merton Farming Co**	**TL 99/143 AP (East Anglia) Ltd**	**TL 99/153 (J Raker)**	**Total m^3**
1992	38664	25890	84535	198979	0	348068
1993	9137	??	73351	291935	29040	403463
1994	55894	??	135060	242985	88950	522889
1995	70865	78233	167282	251518	120639	688537
1996	66675	76886	114789	239953	121694	619997
1997	34823	27071	??	182865	62529	307288 *

* 1997 abstraction from TL 99/124 not reported and so cannot be included in total

5.2.5 Fig.5.2 is a graph of total mean daily abstraction rates for all SI and industrial users in Merton area since 1983 as listed on table 5.1, excluding abstractions from TL 99/113. It should be noted that figures for abstraction by Anglian Processors Ltd before 1992 are not available on Agency records and therefore could not be included in pre-1992 totals for the area. It should also be noted that figures for abstraction by Merton Farming Company in 1997 are not available on Agency records (licence 6/33/48/G/196 had expired) and therefore are not included in the total for the year. Fig 5.3 shows a breakdown of mean daily abstraction rates for 4 major licences listed on table 5.1 excluding abstraction from TL99/113 (Pilkington) and TL 99/126 (MF Warren). Mean daily values were derived by dividing monthly totals by the number of days in that month.

5.2.6 Inspection of table 5.2 and figure 5.2 indicates that there has been a significant increase in groundwater abstraction in the area since 1989, peaking in 1995. This appears to be due to increases by all the major abstractors and the granting of licence 6/33/48/G/197 in 1992.

5.3 Groundwater Recharge and Discharge

5.3.1 It is thought that the main recharge mechanism operating in part of the study area is downward leakage through the Drift deposits into the Chalk. The source of water to the Drift deposits is thought to be infiltration of rainwater, with runoff also contributing to recharge at some locations, according to the season. Available geological information suggests that the permeability of the Drift, which covers most of the study area, varies considerably according to thickness and nature of the Drift deposits. Therefore the rate and amount of recharge reaching the Chalk may vary considerably according to locality. It follows from the DeGlee equation that the rate of recharge to or indeed natural discharge from the Chalk is also likely to vary considerably in time according to changing seasonal groundwater head differentials across the Chalk/Drift interface. In the Thompson valley area for example this changing direction and rate of recharge is likely to occur according to relative changes in Chalk and Drift groundwater heads in the vicinity.

5.3.2 In order to obtain an estimate of the recharge from rainfall potentially available to this area, the approximate groundwater sub-catchment of the upper Thompson valley was first outlined from the BGS hydrogeological map of Northern East Anglia. The area of this sub-catchment is estimated as 20 km^2. The Thompson/Merton area is situated in MORECS square 130. The mean annual rainfall for this square for the period 1961 to 1994 was 638mm, the mean annual actual evaporation was 496mm, therefore the effective precipitation for this period was 142mm/year according to MORECS. The estimated potential recharge available to the area is therefore 2840000 m^3/year. In practice a proportion of this recharge will be lost through surface runoff in some seasons.

5.3.3 It is not possible within the scope of this study to carry out a water resource balance for the study area because the groundwater and surface water outflows from the area are not known. However for the purpose of a simple comparison with the estimated potential recharge available to the area, it is noted that the total of major licenced groundwater resources as on 1 April 1996 in the study area amounted to 1087850 m^3/year. In view of the fact that much of the abstraction in the area is licenced for spray irrigation during the summer months, it could be that abstraction of these quantities would deplete resources in the Chalk aquifer and reduce natural stream discharge.

6 HYDROGEOLOGY OF THOMPSON WATER, CARR AND COMMON SSSI AND CANDIDATE SAC

6.1 Introduction

6.1.1 The most sensitive site of conservation interest in the area is Thompson Water, Carr and Common SSSI, part of the Norfolk Valley Fens cSAC. As it is primarily a wetland site, water resources available to the environment at this site are a key factor in preserving the integrity of the site. In 1991 the viewpoint of English Nature about the water resources of the site was that it was surface water fed. It is now realised by the Agency, after further study of the site, that groundwater provides a significant contribution to the water resources of the site, particularly in 'drier' years when surface water inputs are relatively low.

6.1.2 The site is located on the northern edge of the Breckland area of Norfolk. The boundary of the site is marked on fig 6.1. The site is part of the Norfolk Valley Fens cSAC and as such comes under the scope of the EC Habitats Directive. A large part of the site is owned by the Norfolk Wildlife Trust.

6.1.3 Borehole information at Thompson Common (grid square TL 93 95) indicates that the Chalk is relatively near to the surface at the northern part of Thompson Common, minimum recorded depth 0.4 mBGL at TL 99/167. Information from boreholes TL 99/126 and TL 99/173 suggests that the Drift cover above the Chalk thickens to 7 or 8m at both east and west edges of Thompson Common as well as to the south at borehole TL 99/201 (see fig.3.4). Borehole information indicates the presence of mainly sandy Drift near the surface of the Common, underlain in some places by clay-rich Drift of thickness 4m at TL 99/173 and 3.3m at TL 99/201.

6.2 Surface Hydrology and Habitat

6.2.1 Thompson Water, Carr and Common SSSI is situated in a south-west trending valley of a tributary of the river Wissey. Two streams flow into the site, from the north. These meet on the site and flow south-west towards Thompson Water, an artificial lake at the boundary of the site (see fig.6.1). Downstream of the confluence of the two main tributary streams we understand that the channel in Thompson Stream was realigned (straightened) and deepened circa 1973, in order to improve the drainage characteristics for upstream housing developments. As part of the drainage improvement works, the bed of the stream channel was cut to circa 2m below surrounding ground level, which resulted in the chalk being exposed in places in the stream bed and banks, e.g. close to borehole TL 99/201. The spoil which was excavated was placed on the eastern bank of the stream channel to form a low bund. For further information on the hydrology of the site refer 'Hydrological Monitoring of Wetlands Project KVW35011, Hydrological Report, Site 18' HSI, May 1998.

6.2.2 The surface of Thompson Common is gently undulating, with a number of depressions known as 'pingos'. The SSSI site comprises a variety of habitats supporting a wide range of plant communities which have developed in response to variations in topography, soil type and wetness. The diversity of the grassland communities is enhanced by the depressions known as 'pingos' some of which are damp or water filled throughout the year, although others are dry for much of the year. For further information refer 'Interim Wetland Hydrological Report for Thompson Common SSSI, Site No.18' NRA, June 1995.

6.2.3 The site supports an exceptional number of plant and animal species, including an invertebrate fauna of considerable national importance. Further details are given in the SSSI citation issued by English Nature (28 November 1988).

6.3 Conservation Objectives

6.3.1 The Norfolk Valley Fens area is being considered as a possible SAC because it contains habitat types and/or species which are rare or threatened within a European context. The Norfolk Valley Fens area supports the following European interests:

1) Calcium-rich spring water fed fens*
   - for which this is considered one of the best areas in the UK
   - for which the area contains more than 10% of the UK resource.

*These are wetland areas that are supplied with base-rich groundwater. The water level is permanently high. Many plants that are rare or scarce in the UK occur in alkaline fens.

6.3.2 English Nature, in a letter to the Agency Water Resources Manager on 20 February 1998, stated the conservation objectives for Thompson Water, Carr and Common SSSI as follows:

1) Maintain the internationally important population of Desmoulin's snail.
2) Maintain and enhance the notifiable communities of swamp, mire and grassland vegetation.
3) Maintain and enhance the ecological and geomorphological interest of the pingos.
4) Ensure water levels and water quality are maintained to achieve these objectives.
5) Increase understanding of invertebrates, especially Red Data Book species, and manipulate management, where appropriate, to meet their needs.
6) Maintain and enhance populations of rare and nationally scarce vascular plants.
7) Maintain and enhance the alder woodland.
8) Enhance the diversity of community types and habitat structure.

The most directly relevant of these objectives in terms of water resources is the general statement (4) to ensure water levels and water quality are maintained in order to achieve objectives 1, 2 & 3.

6.4 Water Levels at Thompson Water, Carr and Common SSSI

6.4.1 A total of 9 gauge boards were installed at Thompson Common in 1992 by the holder of abstraction licence 6/33/48/G/197. Single readings of these gauge boards have been taken on a monthly basis since April 1992 by the holder of licence 6/33/48/G/197. A further 4 gauge boards were installed in 1997 as part of the Agency Wetland Hydrological Monitoring Project and are monitored by the Agency, 3 of these effectively replaced gauge boards TL 99/194, TL 99/195 and TL 99/199 which became submerged at times of high water level. However the original 3 gauge boards were retained and renumbered as TL

99/213, TL 99/214 and TL 99/215 respectively. The locations of the gauge boards are shown on fig 6.2. Plots of the hydrographs of the 9 gauge boards installed in 1992 are shown on figures 6.3 and 6.4.

6.4.2 A total of 7 monitoring boreholes were installed at Thompson Common in 1992 as a condition of abstraction licence 6/33/48/G/197. Of these 7 boreholes, 2 penetrated into the Chalk and 5 finished in Drift above the top of the Chalk. These have all been monitored on a monthly basis since April 1992 as a condition of licence 6/33/48/G/197. A further 2 monitoring boreholes TL 99/201 (Chalk) and TL 99/202 (Drift) were installed in 1997 as part of the Agency Wetland Hydrological Monitoring Project and are monitored by the Agency. The locations of all these boreholes are shown on fig 6.2. Details of the Drift monitoring boreholes are given in table 6.1 below. Details of the Chalk monitoring boreholes were included in table 4.1.

Table 6.1 : Shallow Drift Monitoring Boreholes at Thompson Common

Well Ref	NGR	Depth (m)	Location	Drift/Ck Interface mAOD	Range in Water Level mAOD
TL 99/168	TL 9365 9644	2.94	Thompson Common 3	< 34.0 m	34.3 to 36.4 m
TL 99/169	TL 9346 9643	3.98	Thompson Common 2	< 30.9 m	33.1 to 34.3 m
TL 99/170	TL 9296 9561	3.54	Thompson Common 5	< 30.2 m	30.7 to 33.1 m
TL 99/171	TL 9301 9557	3.60	Thompson Common 6	< 29.4 m	30.6 to 32.6 m
TL 99/172	TL 9308 9543	3.51	Thompson Common 7	< 29.2 m	30.8 to 32.5 m
TL 99/202	TL 9328 9570	4.00	New Monitoring BH (1997)	< 29.2 m	32.28 m 12.02.98

6.4.3 Hydrographs of the Drift monitoring boreholes (apart from TL 99/202) are shown on figures 6.5 and 6.6. The hydrograph of Chalk monitoring borehole TL 99/173 is also shown on fig.6.6 for comparison. All the Drift hydrographs show a similar seasonal pattern although the magnitude of seasonal changes appears to vary according to location of the borehole.

6.4.4 The hydrographs of readings recorded by data loggers on TL 99/201 (chalk) and adjacent TL 99/202 (Drift) are shown on fig.6.7. The hydrographs of TL 99/201 and TL 99/173 both indicate that at times the water level has not been constrained by the structure and has been overflowing. This confirms that groundwater head in the Chalk in the vicinity of Thompson Common was above the Chalk/Drift interface for periods during some recent winter/spring seasons at least. It follows that where low permeabiltiy drift is absent then water from the Chalk would be able to discharge directly upwards into permeable drift and surface water features.

6.4.5 Fig 6.8 shows hydrographs of boreholes TL 99/167 (Chalk OBH), TL 99/168 (Drift OBH) and gauge board TL 99/214. These are all located within 120 m of each other, on the east side of Thompson Common SSSI. Comparison of these hydrographs indicates some degree of hydraulic connection between water levels at all three points. This observation is developed further in section 6.5. The reason why water levels at gauge board TL 99/214 are higher than those in TL 99/168 or TL 99/167 is not know, it may be that ground level and groundwater levels around TL 99/214 are higher relative to levels at TL 99/168 and TL99/167.

6.4.6 Fig 6.9 shows hydrographs of boreholes TL 99/173 (Chalk OBH), TL 99/169 (Drift OBH) and gauge board TL 99/197. TL 99/169 (Drift OBH) and gauge board TL 99/197 are located within 100 m of each other on the west side of Thompson Common SSSI, TL 99/173 (Chalk OBH) is located just outside the western edge of Thompson Common SSSI about 130m west of TL 99/169 (Drift OBH). Comparison of these hydrographs indicates some degree of hydraulic connection between water levels at all three points. This observation is developed further in section 6.5. Gauge board TL 99/197 readings suggest that the water feature concerned was dry for periods during 1992, 1995, 1996 and 1997.

6.5 Relationship Between Drift Water Levels at Thompson Common and Chalk Groundwater Levels

6.5.1 It has already been noted (section 3.2) from borehole records that clay-rich Drift at Thompson Common is relatively thin in places and non-existent at the location of TL99/167. Several of the borehole logs at Thompson Common indicate the presence of at least 3 m of sandy Drift near the surface. One of the 7 sites drilled at Thompson Common (TL 99/167) indicates the absence of low permeability drift ie a ‘flow window’ at this location. On the basis of this geological information it is not unreasonable to assume that there are other potential routes for Chalk groundwater to flow upwards into the Drift and support or contribute to storage of groundwater in the shallow Drift deposits in this area. Overflowing conditions recorded at TL 99/173 and TL 99/201 (see section 6.4.4) show that heads in the Chalk are sufficient at times such that upward flow into the Drift could occur.

6.5.2 Comparison of Chalk and Drift water levels at Thompson Common such as those shown on figs 6.8 and 6.9 suggests that Chalk groundwater heads could support groundwater levels in the shallow Drift deposits during some seasons. It should be noted however that since the monitoring points for Chalk and Drift data on figs 6.8 and 6.9 are not in exactly the same location, relative levels on these graphs do not necessarily reflect the hydraulic gradient across the Chalk/Drift interface.

6.5.3 In order to study more closely the relationship between Chalk, Drift and surface water levels, a number of cross-plots were derived from the water level data recorded from 1992 to 1998. Where applicable, linear regression lines were fitted to the data and R^2 values calculated to give an indication of the closeness of fit of the data to the regression line (R=Pearson correlation coefficient). The formulae of the regression lines are also shown on the graphs. In this study an R^2 value of greater than 0.75 is taken as indication of a significant correlation between the two variables. In cases where the correlation appears to be significant, the gradient of the regression line gives an indication of the average change in Drift or surface water levels for a given change in Chalk water levels.

6.5.4 Cross-plot 1 (fig 6.10) shows TL 99/169 Drift water levels and TL 99/197 gauge board levels plotted against TL 99/173 Chalk water levels. Correlation of TL 99/169 and TL 99/173 levels indicated an R^2 value of about 0.79. It should be noted (see fig 6.9) that seasonal recovery of Drift water levels at TL 99/169 leads recovery of Chalk water levels at TL 99/173 by approximately 1 month. This may be due to the proximity of TL 99/169 to the main stream running through Thompson Common which could provide additional surface water recharge to the Drift before Chalk groundwater levels become high enough to support Drift water levels. During this period the Chalk could benefit from recharge from the overlying Drift.

6.5.5 Cross-plot 2 (fig 6.11) shows TL 99/168 Drift water levels and TL 99/214 gauge board levels plotted against TL 99/167 Chalk water levels. Linear regression of TL 99/168 and TL 99/167 levels indicated an R^2 value of about 0.85 which suggests a positive correlation between the two data sets.

6.5.6 TL 99/168 Drift water levels and TL 99/214 gauge board levels were also plotted against TL 99/173 Chalk water levels in cross-plot 3 (fig 6.12). The plots show a similar pattern to cross-plot 2 but a different gradient of the regression line. The result is useful in that it indicates that approximate water levels in Drift at TL 99/168 could be predicted on the basis of Chalk water levels some 400m away at TL 99/173.

6.5.7 Cross plot 4 (fig 6.13) shows TL 99/170 Drift water levels and TL 99/215 gauge board levels plotted against TL 99/173 Chalk water levels, about 950m away. The correlation of the two data sets appears to be significant ($R^2 = 0.884$), indicating that approximate water levels in the Drift at TL 99/170 could be predicted on the basis of Chalk water levels readings at TL 99/173.

6.5.8 The above cross-plot analysis strongly suggests hydraulic connection between Chalk groundwater heads and Drift water levels at Thompson Common which also suggests that Chalk groundwater head is an important factor in the maintenance of water levels in the sandy Drift that has been found in several boreholes on the SSSI. It is reasonable to assume that if permeable Drift exists directly over the Chalk then there is a pathway for groundwater to migrate from the Chalk to the Drift and vice versa. It is understood that in the past groundwater heads in the area were much higher because there was little groundwater abstraction, therefore it is likely that generally much higher quantities of water were discharging from the Chalk into the Drift at Thompson Common.

6.6 Relationship Between Surface Water Levels at Thompson Common and Chalk Groundwater Levels

6.6.1 Comparison of Chalk groundwater levels and surface water levels at Thompson Common such as those shown on figs 6.8 and 6.9 suggests that Chalk groundwater could indirectly support water levels in surface features during some seasons. It should be noted however that since the monitoring points for Chalk and gauge board data on figs 6.8 and 6.9 are not in exactly the same location, relative levels on these graphs do not reflect the true difference in Chalk and surface water levels at the water feature.

6.6.2 In order to study more closely the relationship between Chalk groundwater levels and surface water levels, a number of cross-plots were derived from the water level data recorded from 1992 to 1998. Where applicable, linear regression lines were fitted to the data and R^2 values calculated to give an indication of the closeness of fit of the data to the regression line.

6.6.3 TL 99/197 gauge board levels are shown on cross-plot 1 (fig 6.10) plotted against TL99/173 Chalk water levels. Data recorded when the gauge board was evidently dry has been omitted from the cross-plot. The plot of TL 99/197 and TL 99/173 data indicates an R^2 value of about 0.8 which suggests a positive correlation between the two data sets.

6.6.4 TL 99/214 gauge board levels are shown plotted against TL 99/167 Chalk water levels on cross-plot 2 (fig 6.11) . The cross-plot of TL 99/214 gauge board data indicates that the water level at the gauge board started to rise (non linearly) when Chalk groundwater levels at TL 99/167 increased above about 35.8 mAOD. After reaching a maximum of about 37.25 mAOD, water levels at the gauge board appeared to fall again in a non-linear relationship to Chalk water levels. The overall pattern indicates a hysteresis effect, whereby the rise in surface water levels lags the rise in Chalk levels during winter and similarly the fall in surface water levels lags the fall in Chalk levels during summer. One explanation of the hysteresis effect may be that changes in surface water levels at this feature may be groundwater driven, with storage in the Drift probably acting as a buffer.

6.6.5 TL 99/214 gauge board levels were also plotted against TL 99/173 Chalk water levels in cross-plot 3 (fig 6.12). Again, the result shows a similar pattern to cross-plot 2 with hysteresis observed. The result may also be useful in that it indicates that approximate water levels at gauge board TL99/214 could in some conditions be predicted on the basis of Chalk water levels about 400m away at TL 99/173.

6.6.6 TL 99/215 gauge board levels are shown plotted against TL 99/173 Chalk water levels on Cross plot 4 (fig 6.13). The scatter of data is quite high in this case and the relatively low R^2 value indicates that correlation between the two data sets is low. It should be noted that TL 99/215 gauge board is situated about 950m away from TL 99/173.

6.6.7 Cross-plot 5 shows TL 99/193 and TL 99/198 gauge board data plotted against TL 99/173 Chalk groundwater levels. Both data sets indicate a significant correlation between Chalk groundwater levels at TL 99/173 and surface water levels in the features concerned.

6.6.8 The above cross plot analysis indicates a link between Chalk groundwater levels and surface water levels in some water features at Thompson Common. This link may be via the sandy Drift that has been found in several boreholes on the SSSI. It has been concluded in section 6.5.8 that Chalk groundwater head is an important factor in the maintenance of water levels in the sandy Drift that has been found in several boreholes on the SSSI. It is reasonable to conclude that Chalk groundwater heads may be an important factor in maintaining surface water levels in features such as 'pingos' during some seasons. Overall the analysis indicates a reasonably good hydraulic connection between Chalk groundwater levels and surface water levels at Thompson Common. This is strong supporting evidence for the current understanding that surface water features at Thompson Common are mainly groundwater supported.

6.6.9 On the basis of the above analysis it is also suggested that it may be possible in future to set cessation levels based on TL99/173 for example, if it is confirmed that the state of the surface water features or Drift water levels at Thompson Common could be predicted from Chalk groundwater level data. More trialling is needed with more frequent data to see if the suggested correlation holds in different seasonal conditions. The data on which the current study is based was only read on a monthly basis. The effect of rainfall on the surface water features was not considered in the analysis.

6.7 Possible Relationship Between Water Levels at Thompson Water and Surrounding Chalk Groundwater Levels

6.7.1 Thompson Water is fed by surface water from the main stream running south-west through Thompson Carr. The water level in the lake is controlled by a sluice close to Peddar's Way on the south-west edge of the lake. No water level readings on Thompson Water are available, however in the absence of detailed information the maximum water level of the lake is estimated from nearby ground level and gauge board TL 99/203 readings to be about 31.0 mAOD. The hydrogeological map of Northern East Anglia indicates that Thompson Water is located partly on valley gravels and Chalk. This is inconsistent with the log of observation borehole TL 99/034 which indicates a total thickness of 25.4 m of Drift over Upper Chalk, the lower section of Drift being described as 7.6 m of marl, 3.0m of ballast (presumably drillers description of gravel) and 10.4 m of blue soft clay. TL99/034 is located approximately 100 m south of the southern edge of Thompson Water where the hydrogeological map of Northern East Anglia indicates exposed Chalk.

6.7.2 The following 2 points in the Hydrological Report on Thompson Common (HSI - May 1998) appear to be inconsistent with geological and water level data from TL 99/034:
a) schematic cross-section figure 5 of the above report indicates that the water level in Thompson Water is the same as adjacent Chalk Groundwater levels.
b) it is stated in section 7.2 that 'The Thompson Lake, in addition to flow from the stream that runs through the site, also probably receives groundwater from the underlying Chalk.'

Both these points appear to be inconsistent with groundwater levels recorded at observation borehole TL 99/034 which have only risen above 31 mAOD during 8 months over the last 20 years, and since 1989 have rarely risen above 30 mAOD according to Agency records. The outfall of Thompson Water (south-westwards) falls into a stream bed approximately 2 m below the highest level of the lake.

6.7.3 The above information suggests that it is not known for certain that Thompson Water is in hydraulic continuity with Chalk groundwater apart from minor seepages through the thickness of boulder clay that is considered by the author to underlie most of Thompson Water. There remains the possibility that considerable amounts of water could be transfered through windows of higher permeability drift. If any correlation between changes in groundwater heads in the Chalk and water levels in Thompson Water is indicated as a result of future observations, it is suggested that routes of water input to Thompson Water other than direct groundwater input are considered.

6.8 Surface Water Flow at Thompson Water, Carr and Common SSSI

6.8.1 Flow data available this site is very limited. The only information found on Agency records was current metering data as given on table 6.2. Locations of the current metering points are shown on fig 6.15.

Table 6.2 Current Metering Results for Sites on Thompson Common SSSI

Site No (fig. 6.14)	Location	NGR	Recorded Flow on 25.04.95	Recorded Flow on 19.06.96	Recorded Flow on 27.01.97
1	downstream of road culvert (NE stream)	TL 9404 9661	6.9 l/s	0	5.3 l/s
2	upstream of confluence (NE stream)	TL 9343 9606	10.3 l/s	<0.001 l/s	8.2 l/s
3	upstream of confluence (NW stream)	TL 9340 9608	26.0 l/s	0.65 l/s	18.3 l/s
4	downstream of bridge (combined stream)	TL 9309 9547	42.0 l/s	1.2 l/s *	20.2 l/s

note: * this low flow was estimated

6.9 Relationship Between Stream Flow at Thompson Water, Carr and Common SSSI and Chalk Groundwater Levels

6.9.1 There is currently insufficient data on surface water flows in the area to be able to make any conclusions on this question. More current metering data for the main streams on Thompson Common is required. It is noted that gauge boards TL 99/200 and TL99/203 are located in the Thompson Steam at the south of Thompson Common. If in future stage/discharge relationships could be established at these points then data from these gauge boards could be used to derive approximate stream flows. Further study may reveal more about the way in which stream baseflow may relate to Drift water levels and Chalk groundwater heads at Thompson Common.

7 PREDICTION OF POTENTIAL EFFECTS OF ABSTRACTION IN THE AREA

7.1 Introduction

7.1.1 The potential effects of major abstractions in the area have been assessed in terms of the predicted drawdowns in Chalk water levels that could occur as a result of these abstractions. In section 4.6 conclusions were reached regarding choice of best available methods for predicting drawdown effects in this area. In this section these conclusions are applied to three examples where predicted drawdowns as a result of major abstractions in the area are estimated.

7.1.2 The locations selected for drawdown predictions are all sites of existing boreholes into Chalk so that predicted drawdowns may be compared with measured changes if desired.

Table 7.1 Locations Selected for Chalk Head Drawdown Prediction

Agency BH Ref	Current Use	Location	NGR	Reason for Selection
TL 99/027	OBH Agency	Verge of Road North of Thompson (OBH on Agency network)	TL 9160 9730	Site with thicker drift. Long existing WL record
TL 99/052	Occasional Domestic	North of College Farm Thompson Owner: Mr Baldock	TL 9315 9673	Upper Thompson valley Potential derogation
TL 99/173	OBH J.Raker	Western Edge of Thompson Common	TL 9333 9642	Proximity to Thompson Common SSSI

Boreholes TL 99/027 and TL 99/052 were both equipped by the Agency with transducers and data loggers on 8 September 1998. Domestic borehole TL 99/052 is drilled in the base of a well which is used occasionally for garden watering by the owners, Mr & Mrs Baldock.

7.1.3 The potential effects of abstractions as listed on table 5.1, apart from licence 6/33/48/G/256 (see section 4.5.5), have been estimated. Licences 6/33/48/G/172 (P L Brown) and 6/33/48/G/196 (Merton Farming Co) have now expired, however applications for renewal of these licences at rates previously licenced are currently being considered by the Agency. The potential effects of these abstractions have therefore also been considered. The potential effects of large abstractions by AWS at Watton and East Watton, located about 4 km to the north/north-east of Thompson Common have not been considered in this assessment. The potential effects of these abstractions are uncertain because they are located north of a groundwater divide that forms the northern boundary of the Middle Wissey sub-unit.

7.2 Predicted drawdown effects at TL 99/027

7.2.1 It has been concluded in section 4.6.1 of this report that the DeGlee method with aquifer characteristics applied of T= 300 m^2/day and L= 3000 m appears to be the more accurate of the methods trialed for estimating long-term changes in head in the Chalk in the study area, apart from the Thompson valley. The above aquifer characteristics have been assumed to apply at the location of TL 99/027 on the basis of previous trials of a range of aquifer characteristics (see table 4.7). It should be noted that this method models a steady state solution, assuming a constant head of recharge in the aquitard above the aquifer concerned. A range of leakage values L= 3000m and 4000m has been applied in order to show the sensitivity of the method to variations in this parameter.

7.2.2 Table 7.2 shows DeGlee predicted head changes in the Chalk at the location of observation borehole TL 99/027 (NGR: TL 9158 9729). Total predicted head changes in the Chalk at TL 99/027, as a result of the possible abstractions listed on the table, are estimated by this method at approximately 5.9 m, possibly up to 7.2 m if a value of L= 4000m applies.

Table 7.2 Predicted Effect of Abstraction at Licenced and Proposed Rates on Head in Chalk Near TL 99/027

Borehole Reference	Application/ Licence	Daily Quantity (m^3/day)	Distance from TL 99/027 (m)	DeGlee Predicted Head Change T=300 m2/day L=3000 m	DeGlee Predicted Head Change T=300 m2/day L=4000 m
TL 99/143 (A P)	6/33/48/138	727	840	0.55	0.66
TL 99/143 (A P)	6/33/48/138 + CV/2087	1250	840	0.95	1.13
TL 99/107 PL Brown	Application CN/1788	1276.4	1705	0.56	0.72
TL 99/124 Merton Farming	Application CN/2006	4254.5	1225	2.48	3.06
TL 99/126 Mr Warren	6/33/48/G/219	230.5	2640	0.06	0.09
TL 99/153 J Raker	6/33/48/G/197 (exp 30.09.98)	3000	1170	1.81	2.22
Totals	Lics + Applics	10011.4		5.9	7.2

7.2.3 The predicted changes in head have not been observed in practice at TL 99/027 because total abstraction rates in the area have not approached a seasonal mean of 10011 m^3/day in recent years. Abstraction returns indicate that the highest mean monthly total on record abstracted from the boreholes listed in table 7.2 was 5463 m^3/day in August 1995.

7.2.4 Further estimation of drawdowns by the DeGlee method at rates actually abstracted and comparison with measured changes at TL 99/027 may possibly help in understanding the hydraulic significance of the relatively deep Drift encountered at this location.

7.3 Predicted drawdown effects at TL 99/052

7.3.1 It has been concluded in section 4.6.1 of this report that the DeGlee method with aquifer characteristics applied of T= 400 m^2/day and L= 3000 m appears to be the more accurate of the methods trialed for estimating long-term changes in head in the Chalk in the vicinity of Thompson Common in that it produced drawdowns of the right order of magnitude. As TL 99/052 is located in the Thompson valley area, the above aquifer characteristics have been assumed to apply at the location of TL 99/052. It should be noted that this method models a steady state solution, assuming a constant head of recharge in the aquitard above the aquifer concerned and that the hydraulic properties of the aquitard can be approximated by using average values to represent what in practice may be a wide range of permeabilities. A range of leakage values L= 3000m and 4000m has been applied in order to show the sensitivity of the method to variations in this parameter.

7.3.2 Table 7.3 shows DeGlee predicted head changes in the Chalk at the location of observation borehole TL 99/052 (NGR: TL 9315 9673). Total predicted head changes in the Chalk at this location, as a result of the possible abstractions listed on the table, are estimated by this method as approximately 4.2 m, possibly up to 5.2 m if a value of L= 4000m applies.

Table 7.3 Predicted Effect of Abstraction at Licenced and Proposed Rates on Head in Chalk Near TL 99/052

Borehole Reference	Application/ Licence	Daily Quantity (m^3/day)	Distance from TL 99/052 (m)	DeGlee Predicted Head Change T=400 m2/day L=3000 m	DeGlee Predicted Head Change T=400 m2/day L=4000 m
TL 99/143 (A P)	6/33/48/138	727	2095	0.19	0.26
TL 99/143 (A P)	6/33/48/138 + CV/2087	1250	2095	0.33	0.44
TL 99/107 PL Brown	Application CN/1788	1276.4	2485	0.28	0.38
TL 99/124 Merton Farming	Application CN/2006	4254.5	1300	1.77	2.20
TL 99/126 Mr Warren	6/33/48/G/219	230.5	975	0.12	0.14
TL 99/153 J Raker	6/33/48/G/197 (exp 30.09.98)	3000	860	1.69	2.01
Totals	Lics + Applics	10011.4		**4.2**	**5.2**

7.3.3 It is very unlikely that the predicted changes in head have been observed in practice at TL99/052 because total abstraction rates in the area have not approached a seasonal mean of 10011 m^3/day in recent years. Further monitoring of water levels at TL 99/052 and comparison with actual abstraction rates at the above boreholes may provide useful information.

7.3.4 It is thought that the supply to the domestic well at TL 99/052 relies in dry seasons on groundwater overtopping the borehole casing and refilling the well. The top of the borehole casing was measured by Agency staff on 8 September 1998 as 2.25 mBGL. Water level at this time was measured as 2.28 mBGL. Predicted changes in head at TL 99/052 suggest that there may potentially be a derogation risk at this protected right due primarily to abstractions from TL 99/124 and TL 99/153. Assessment of the risk is outside the scope of this report but is recommended that this issue is considered in future licence determinations concerning abstraction from TL 99/124 and TL 99/153.

7.4 Predicted drawdown effects at TL 99/173

7.4.1 It has been concluded in section 4.6.1 of this report that the DeGlee method with aquifer characteristics applied of T= 400 m^2/day and L= 3000 m appears to be the more accurate of the methods trialed for estimating long-term changes in head in the Chalk in the vicinity of Thompson Common. The above aquifer characteristics have been assumed to apply at the location of TL 99/173 on the basis of previous trials of a range of aquifer characteristics (see table 4.7). It should be noted that this method models a steady state solution, assuming a constant head of recharge in the aquitard above the aquifer concerned. A range of leakage values L= 3000m and 4000m has been applied in order to show the sensitivity of the method to variations in this parameter.

7.4.2 Table 7.4 shows DeGlee predicted head changes in the Chalk at the location of observation borehole TL 99/173 (NGR: TL 9333 9642) at the western edge of the SSSI. Predicted changes are given for T= 400 m^2/day, L= 3000m and 4000m. The results are also shown as a bar chart in fig 7.1. Total predicted head changes in the Chalk at this location at the western edge of the SSSI, as a result of the abstractions listed on the table, are estimated by this method as approximately 3.6 m, possibly up to 4.6 m if a value of L= 4000m applies.

Table 7.4 Predicted Effect of Abstraction at Licenced and Proposed Rates on Head in Chalk at Western Edge of Thompson Common SSSI (near TL 99/173)					
Borehole Reference	**Application/ Licence**	**Daily Quantity (m^3/day)**	**Distance from TL 99/173 (m)**	**DeGlee Predicted Head Change T=400 m2/day L=3000 m**	**DeGlee Predicted Head Change T=400 m2/day L=4000 m**
TL 99/143 (A P)	6/33/48/138	727	2440	0.16	0.22
TL 99/143 (A P)	6/33/48/138 + CV/2087	1250	2440	0.28	0.38
TL 99/107 PL Brown	Application CN/1788	1276.4	2845	0.23	0.33
TL 99/124 Merton Farming	Application CN/2006	4254.5	1655	1.43	1.84
TL 99/126 Mr Warren	6/33/48/G/219	230.5	774	0.14	0.16
TL 99/153 J Raker	6/33/48/G/197 (exp 30.09.98)	3000	980	1.55	1.86
Totals	Lics +Applics	10011.4	N/A	**3.6**	**4.6**

7.5 Potential Effect of Groundwater Abstraction on Drift Water Levels and Surface Water Levels At Thompson Water, Carr and Common SSSI

7.5.1 Potential effects on the SSSI have been estimated on the basis of groundwater level changes as a result of licenced and proposed abstractions in the area (refer section 7.4).

7.5.2 It has been concluded in section 6.5.8 that cross plots of Drift levels and gauge board levels against Chalk water levels (figures 6.10 to 6.13) suggest hydraulic connection between Chalk, Drift and surface water levels at Thompson Common. It therefore follows from the DeGlee equation that the predicted Chalk water level changes at the location of TL 99/173 would result in corresponding changes in Drift water levels and in some seasons changes in surface water levels at Thompson Common and discharge into the Thompson Stream.

7.5.3 The magnitude of changes in Drift water levels relative to changes in Chalk water levels at TL 99/173 may be estimated from the gradients of the relevant cross-plots. Estimated changes in Drift water levels relative to a range of possible changes in Chalk water levels at TL 99/173 are shown on table 7.5. TL 99/173 is used as the reference for Chalk water levels in preference to TL 99/167 because TL 99/167 penetrates only the top 3m of Chalk and readings from TL 99/173 (which penetrates 8m of Chalk) are considered to be more representative of Chalk groundwater levels in the Thompson valley.

Table 7.5 Estimated Changes in Drift Water Levels Relative to a Range of Possible Chalk Water Level Changes at TL 99/173				
Possible Change at TL 99/173	Estimated change TL 99/168 (Drift)	Estimated change TL 99/169 (Drift)	Estimated change TL 99/170 (Drift)	Remarks
0.25 m	0.2 m	0.1 m	0.25 m	
0.5 m	0.4 m	0.2 m	0.5 m	
1.0 m	0.8 m	0.4 m	0.95 m	
1.5 m	1.2 m	0.6 m	1.45 m	
2.0 m	1.6 m	0.8 m	1.9 m	
Range of Drift levels applicable:	34.4 to 36.3 mAOD	33.4 to 34.2 mAOD	30.8 to 33.0 mAOD	Estimates in table are not valid outside ranges

It should be noted that TL 99/169 is located nearer the main stream at Thompson Common than either TL 99/168 or TL 99/170, this may explain why the gradient of the cross-plot of TL 99/169 data is considerably less than that of TL 99/168 and TL 99/170 data.

7.5.4 On the basis of the above estimates, it is suggested that a change in Chalk water levels at TL 99/173 may result in an equivalent change in Drift water levels at some areas of Thompson Common. In others areas of Thompson Common the change in Drift water levels may be less than the change in Chalk water levels. It follows from the DeGlee equation that changes in groundwater head differentials across the Chalk and shallow Drift is likely to produces changes in the groundwater inputs to or outflows from the Drift. Therefore lowering of groundwater head differentials across the Chalk and shallow Drift as a result of abstraction in the area is likely to reduce the discharge of groundwater from the Chalk into the Drift at times of the year when this would naturally occur. It should also be noted that rate of discharge from the Chalk into the Drift will also vary according to locality, depending on the presence or absence of a lower permeability layer in the Drift and the leakage coefficient of that layer.

7.5.5 The magnitude of changes in water levels at some surface water features relative to changes in Chalk water levels at TL 99/173 may also be estimated from the gradients of the relevant cross-plots. Estimated changes in surface water levels relative to a possible range of changes in Chalk water levels at TL 99/173 are shown on table 7.5. TL 99/173 is used as the reference for Chalk water levels in preference to TL 99/167 because TL 99/167 penetrates only the top 3m of Chalk and readings from TL 99/173 (which penetrates 8m of Chalk) are considered to be more representative of Chalk groundwater levels in the Thompson valley.

Table 7.6 Estimated Changes in Surface Water Levels Relative to a Range of Possible Chalk Water Level Changes at TL 99/173				
Possible Change at TL 99/173 (Chalk)	Estimated change TL 99/193 (Gauge board)	Estimated change TL 99/197 (Gauge board)	Estimated change TL 99/198 (Gauge board)	Remarks
0.25 m	0.1	0.07	0.1	
0.5 m	0.2	0.15	0.2	
1.0 m	0.47	0.28	0.47	
1.5 m	0.7	0.4	0.7	
2.0 m	0.9	0.6	0.9	
Range of Surface water levels applicable	35.4 to 36.2 mAOD	34.2 to 34.6 mAOD	33.45 to 34.1 mAOD	Estimates in table are not valid outside ranges

The location of TL 99/197 nearer the main stream at Thompson Common may possibly explain why the gradient of the cross-plot of TL 99/197 data is considerably less than that of TL 99/193 and TL 99/198 data. Estimates of surface water levels changes at TL 99/215 were not made because the scatter of points on cross-plot 4(fig 6.13) is too great to allow correlation of surface water levels at TL 99/215 with Chalk water levels at TL 99/173.

7.5.6 On the basis of the above estimates, it is suggested that a change in Chalk water levels as measured at TL 99/173 may result in smaller changes in surface water levels at some water features at Thompson Common. On the assumption that the response of the water features monitored at gaugeboards TL 99/193, TL 99/197 and TL 99/198 is typical of water features at Thompson Common, it is suggested that changes for example of 0.25m or more in Chalk water levels beneath Thompson Common may perhaps have a measurable effect on water levels in some water features at Thompson Common.

8 CONCLUSIONS

8.1 The hydrogeology of the area has been approximated to a semi-confined Chalk aquifer overlain by glacial Drift of average leakage coefficient (L) of between 3000 and 4000m. In reality it appears that the Drift varies in thickness and permeability over short distances. Trials of a range of aquifer characteristics using the DeGlee and Theis methods for drawdown prediction indicated that the DeGlee method was probably more suitable than Theis for predicting drawdowns in this area. Two ranges of aquifer characteristics have been suggested in section 4.6 as best applicable to the valley and 'upland' parts of the area which approximately correspond to the local discharge and recharge areas of the Chalk aquifer.

8.2 The relative effects of the various licenced and proposed abstractions in the study area could be assessed in terms of the changes in Chalk head predicted using the DeGlee method applicable to semi-confined conditions. The predicted head changes at three locations in the area have been calculated by the DeGlee method and are shown on tables 7.2, 7.3 & 7.4. The significance of changes in Chalk head and variations in leakage coefficient (L) are explained in section 7.5 as regards reductions in discharge from the Chalk aquifer into Thompson Common.

8.3 On the basis of what is currently known about the hydrogeology of the area it is likely that abstraction during summer months at some of the locations and licenced/proposed rates listed on table 5.1 would have a measurable effect on water levels in the Drift deposits at Thompson Water, Carr and Common SSSI and consequently on the levels in those water features on the SSSI that are supported by groundwater in the Drift deposits. Groundwater abstraction is likely to cause general drying out of the site which in extremes could result in drying up of groundwater-supported water features that would otherwise have remained damp throughout the summer season.

8.4 From a review of water level data and geological information it seems reasonable to conclude that Thompson Water, Carr and Common SSSI and candidate SAC is in part fed by groundwater discharged from the underlying Chalk aquifer and in consequence abstraction from the Chalk aquifer can reduce groundwater heads beneath the site which in turn may reduce groundwater heads in the chalk and overlying Drift deposits and reduce discharge into the Thompson stream.

Prepared by: **Andrew MacKenney-Jeffs**
2.10.98

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A REVIEW OF THE HYDROGEOLOGY OF THOMPSON AND MERTON AREAS, NORFOLK

FIGURES

FIGURES continued

APPENDIX A

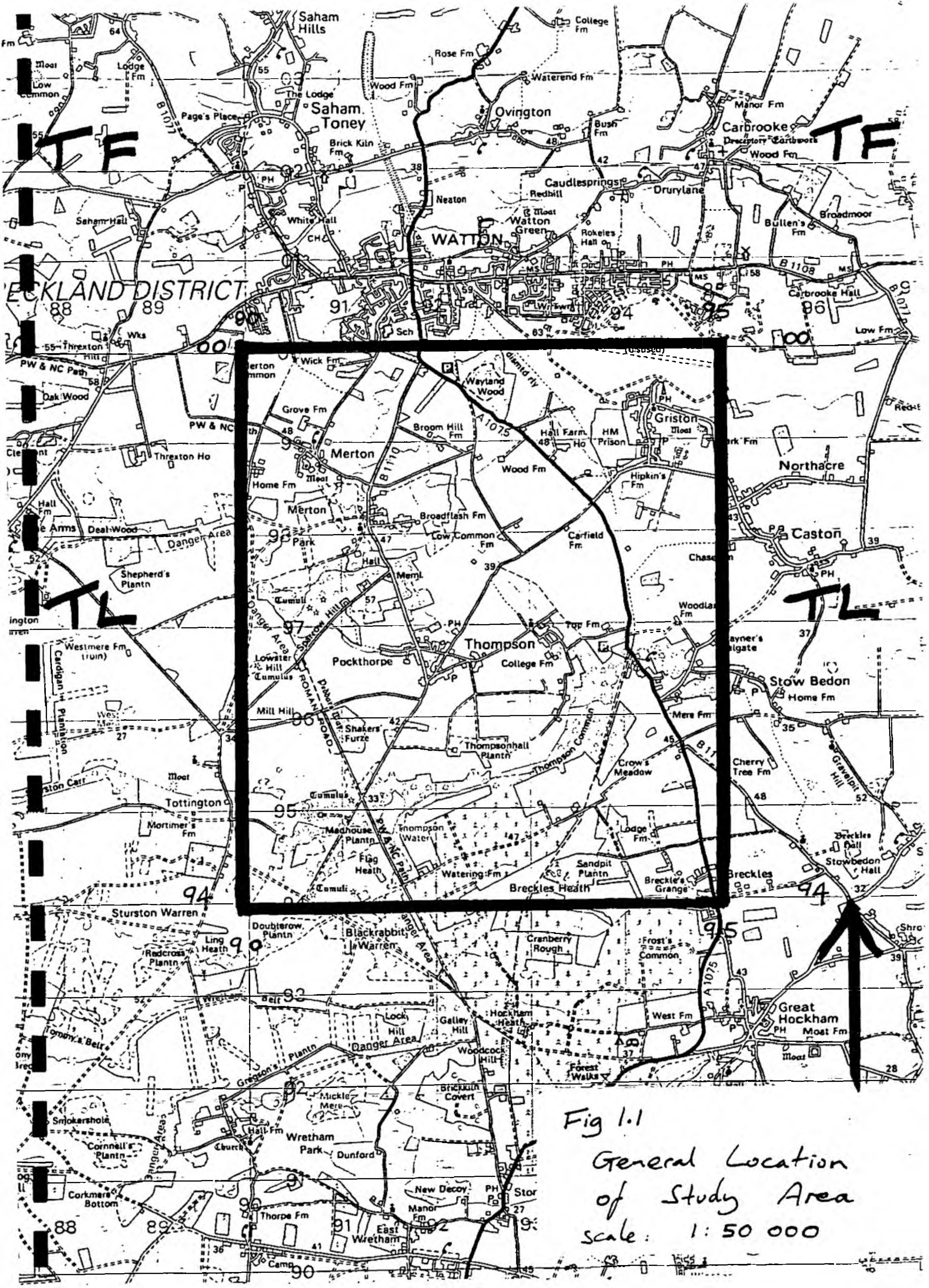
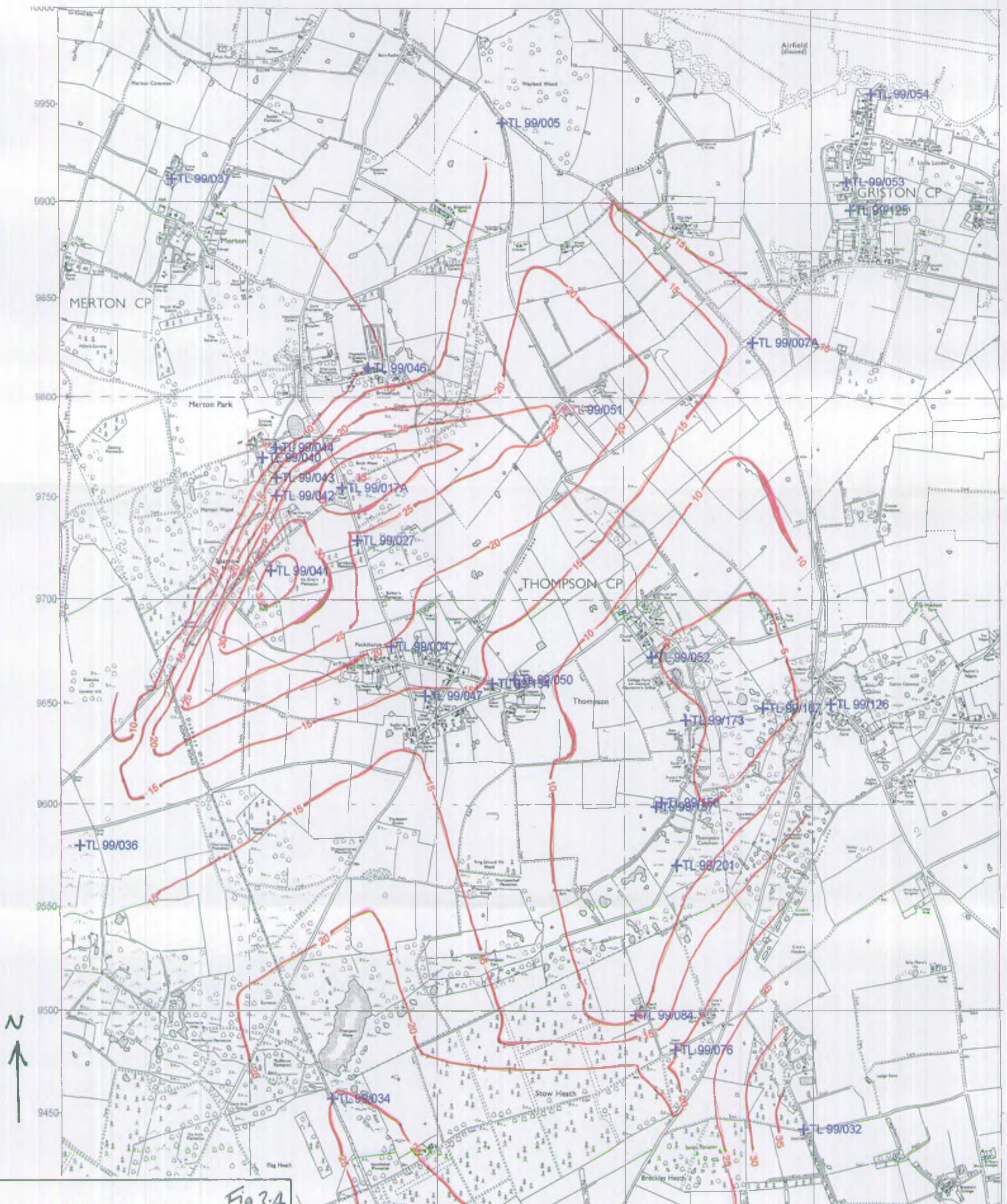


Fig 1.1
General Location of Study Area
scale: 1: 50 000

FIG 3.1 TOPOGRAPHY & DRAINAGE OF THE AREA

scale 1:40 000

N



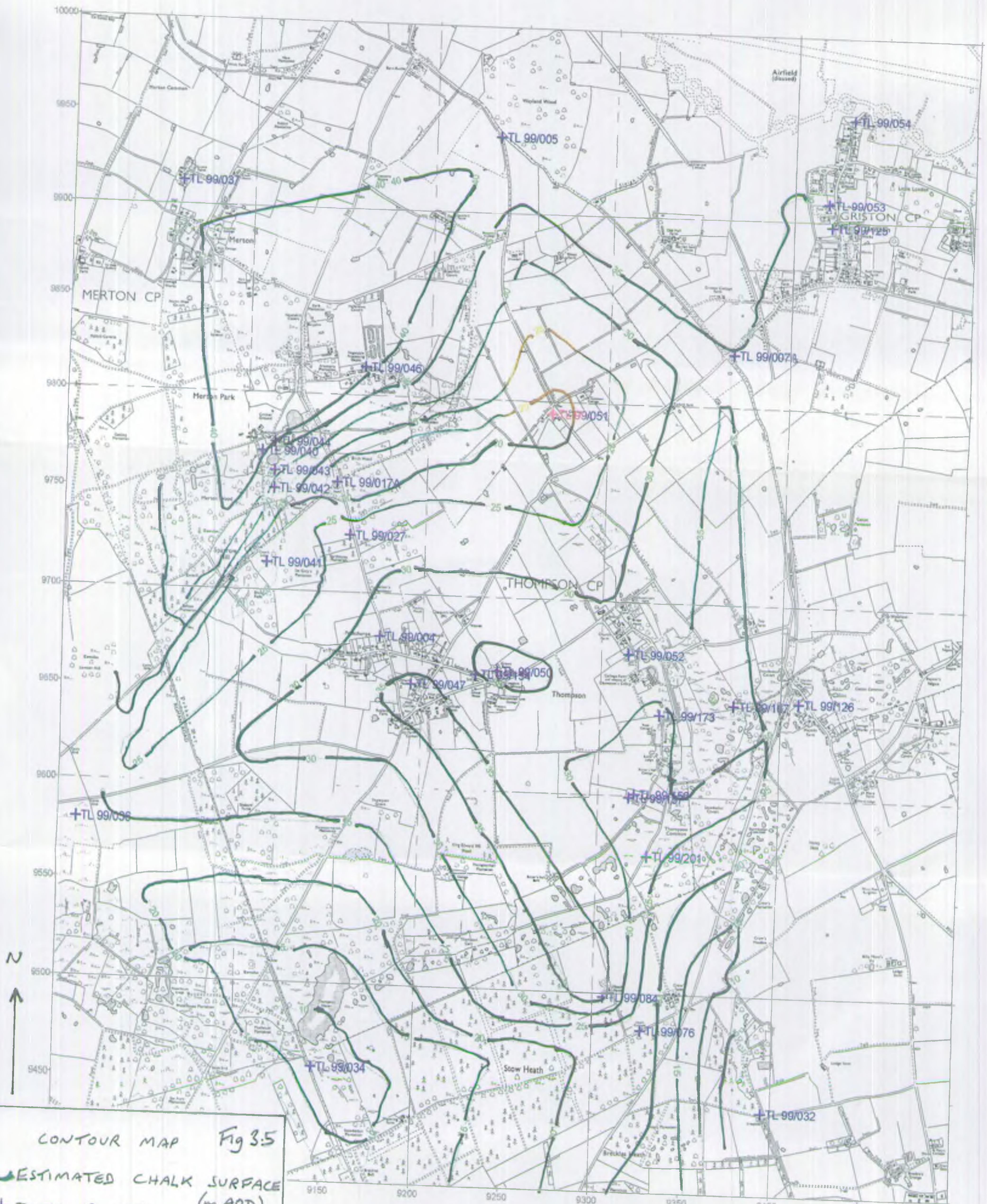
CONTOUR MAP Fig 3.4

ESTIMATED DRIFT THICKNESS (m)

\+ DATA POINTS

scale 1: 20 000

see section 3.2.2 of report for comments about contouring



CONTOUR MAP Fig 3.5

ESTIMATED CHALK SURFACE (m AOD)

\+ DATA POINTS

scale 1: 20 000

see section 3.2.3 of report for comments

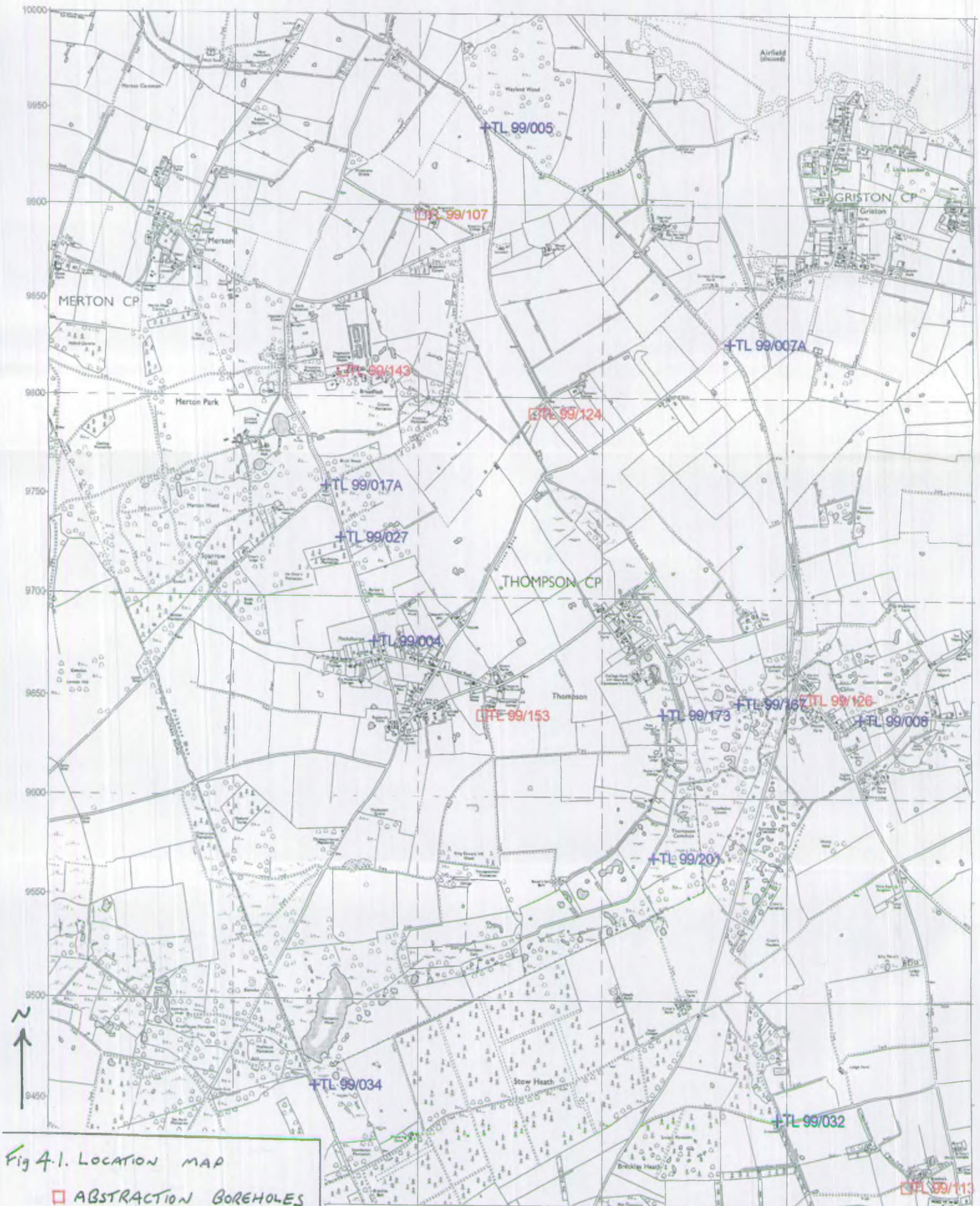


Fig 4.1. LOCATION MAP

□ ABSTRACTION BOREHOLES

+ CHALK WATER LEVEL OBSERVATION BOREHOLES

Scale: 1:20 000

Fig 4.

DRIFT OBH TL 99/017A and B - Merton Cross Roads
NGR: TL 9150 9761

* see Appendix B

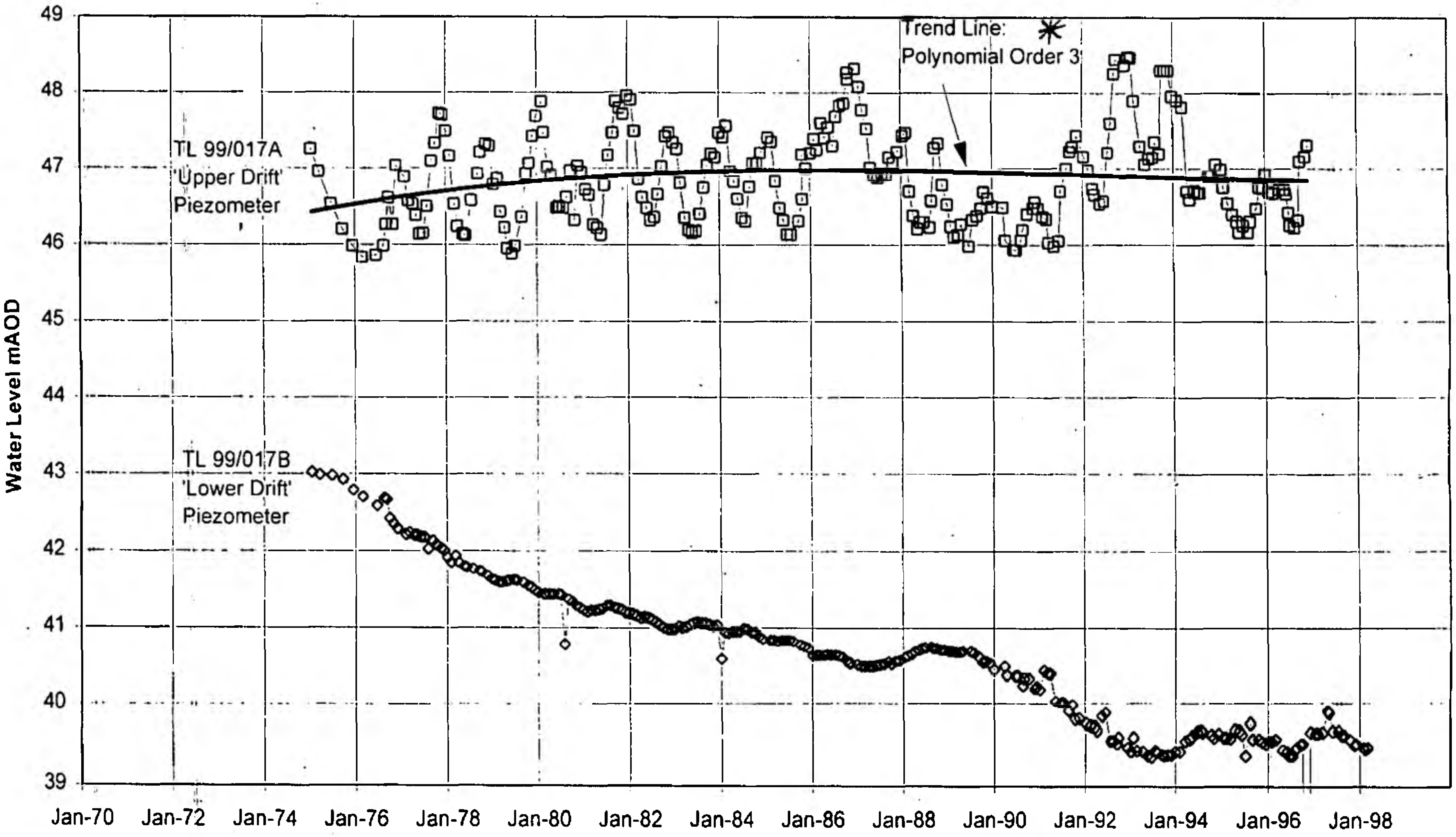


Fig 4.3

Chalk OBH TL 99/004 west verge of road near Thompson
NGR: TL 9169 9672

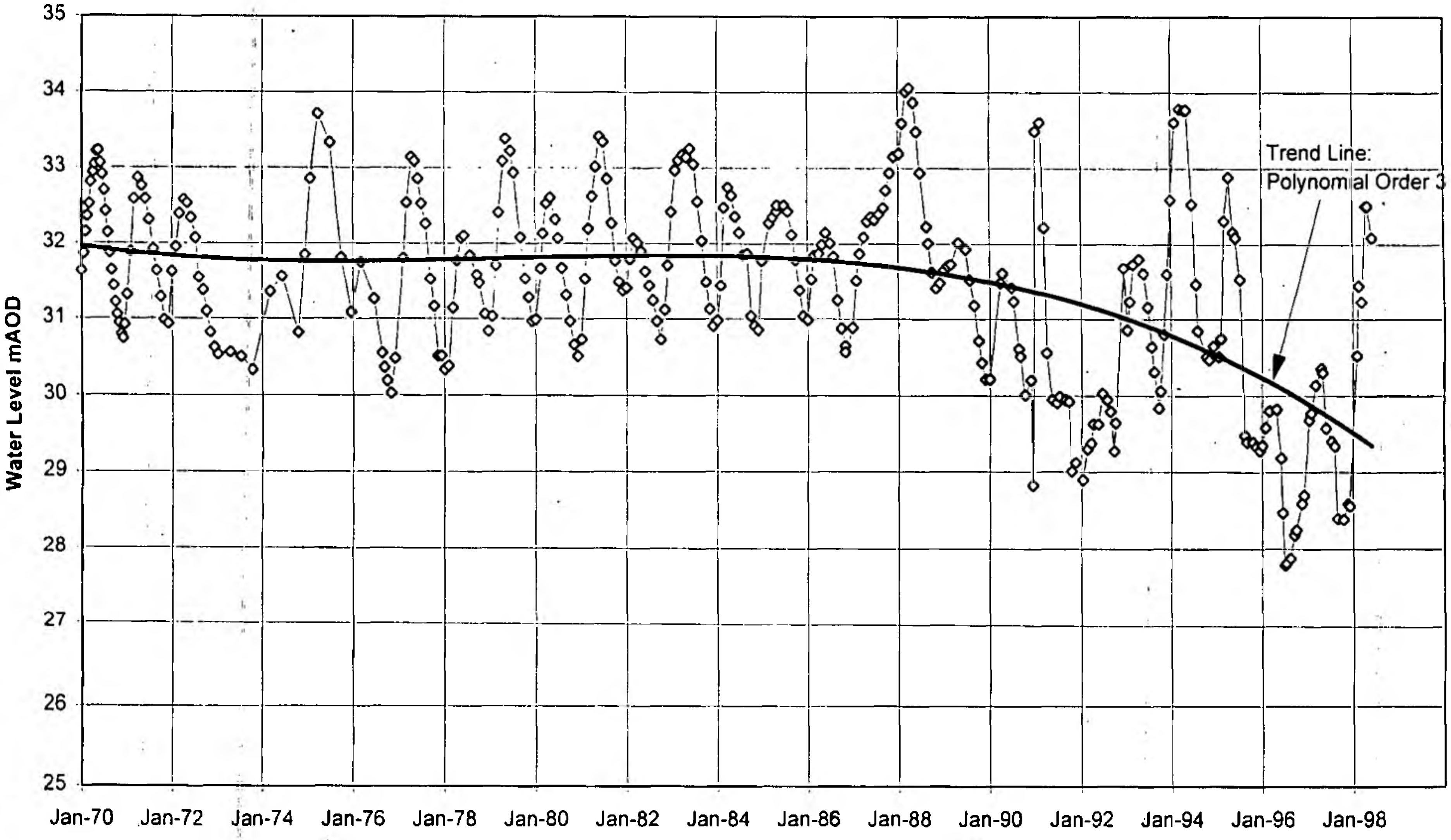
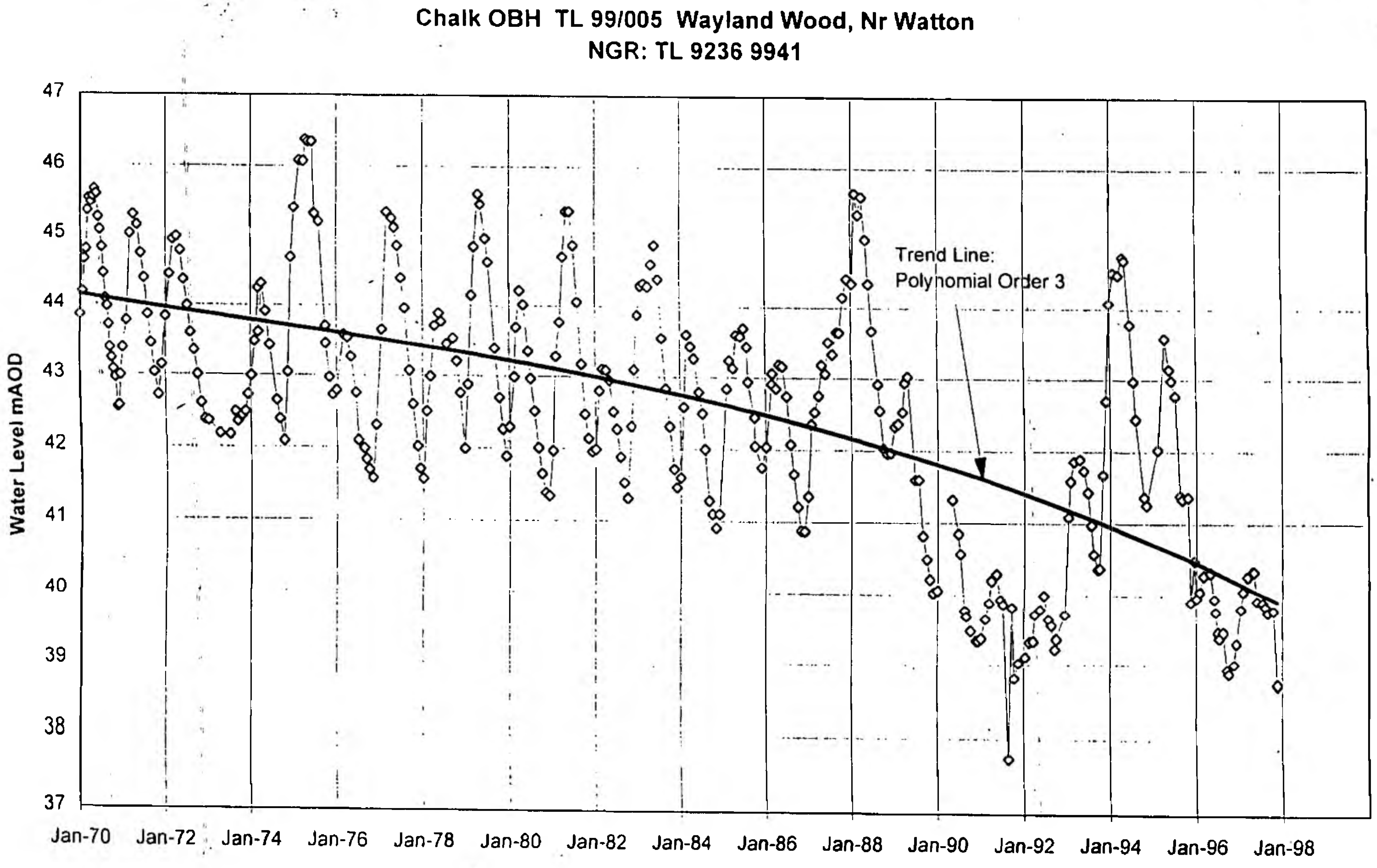


Fig 4.4

Fig 4.4



Chalk OBH TL 99/005 Wayland Wood, Nr Watton
NGR: TL 9236 9941
Water Level mAOD
47
46
45
44
43
42
41
40
39
38
37
Trend Line:
Polynomial Order 3
Jan-70
Jan-72
Jan-74
Jan-76
Jan-78
Jan-80
Jan-82
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98

Fig 4.5

Fig 4.5

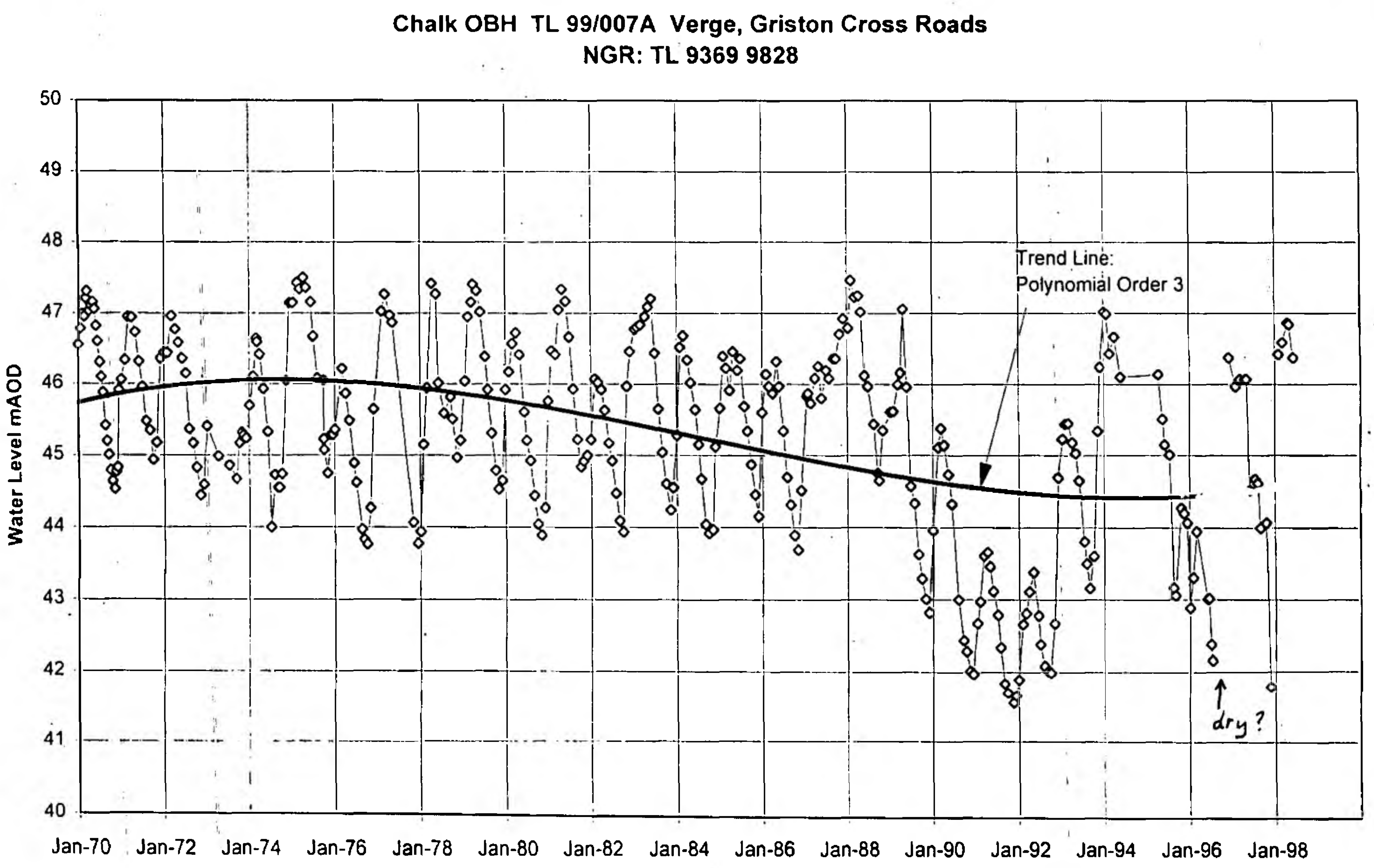

Chalk OBH TL 99/007A Verge, Griston Cross Roads
NGR: TL 9369 9828
Water Level mAOD
50
49
48
47
46
45
44
43
42
41
40
Jan-70
Jan-72
Jan-74
Jan-76
Jan-78
Jan-80
Jan-82
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Trend Line:
Polynomial Order 3
dry ?

Fig 4.6

Fig 4.6

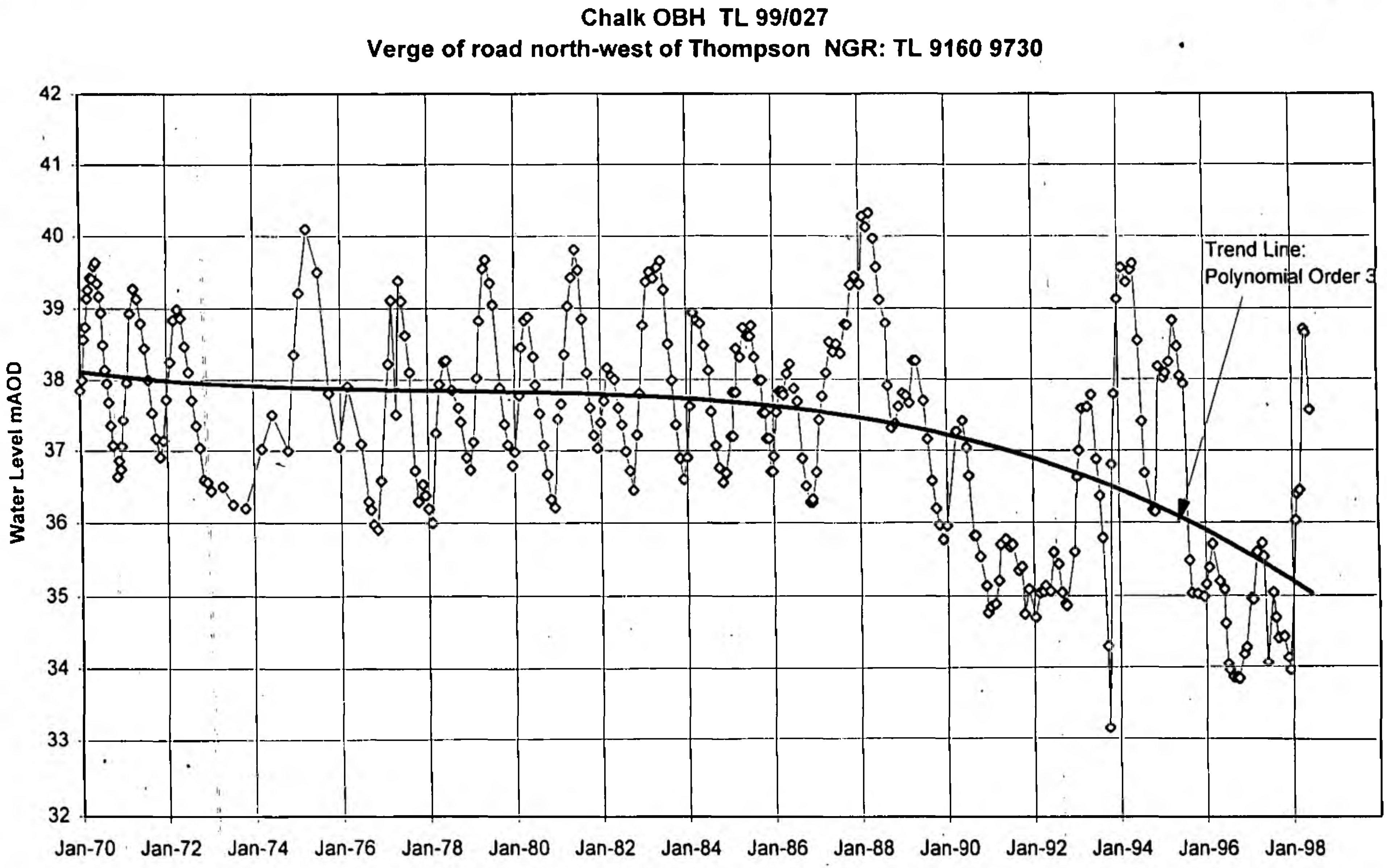

Chalk OBH TL 99/027
Verge of road north-west of Thompson NGR: TL 9160 9730
Water Level mAOD
42
41
40
39
38
37
36
35
34
33
32
Jan-70
Jan-72
Jan-74
Jan-76
Jan-78
Jan-80
Jan-82
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Trend Line:
Polynomial Order 3

Fig 4.7

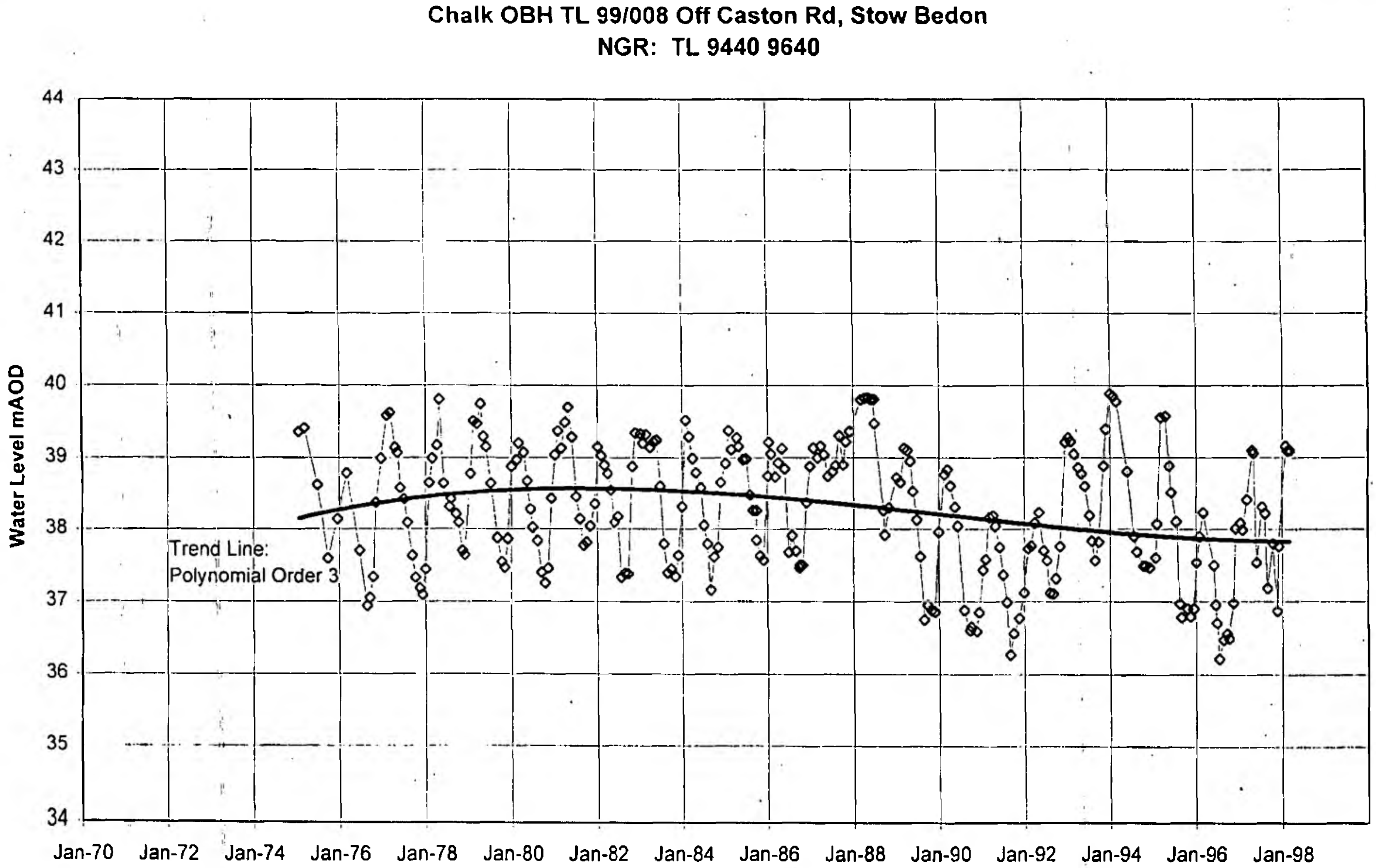

Chalk OBH TL 99/008 Off Caston Rd, Stow Bedon
NGR: TL 9440 9640
Water Level mAOD
44
43
42
41
40
39
38
37
36
35
34
Trend Line:
Polynomial Order 3
Jan-70
Jan-72
Jan-74
Jan-76
Jan-78
Jan-80
Jan-82
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98

Fig 4.8

Fig 4.8

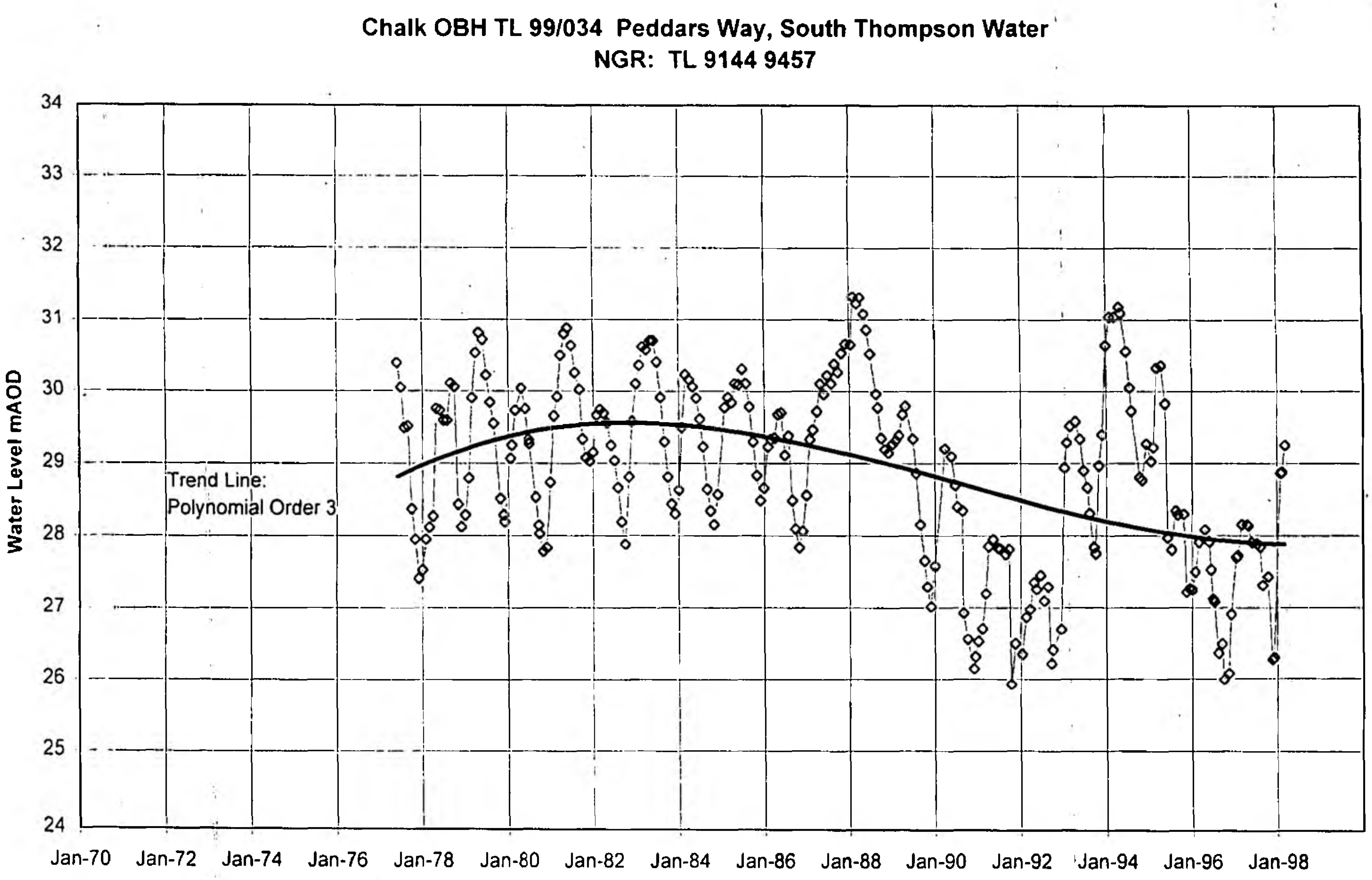
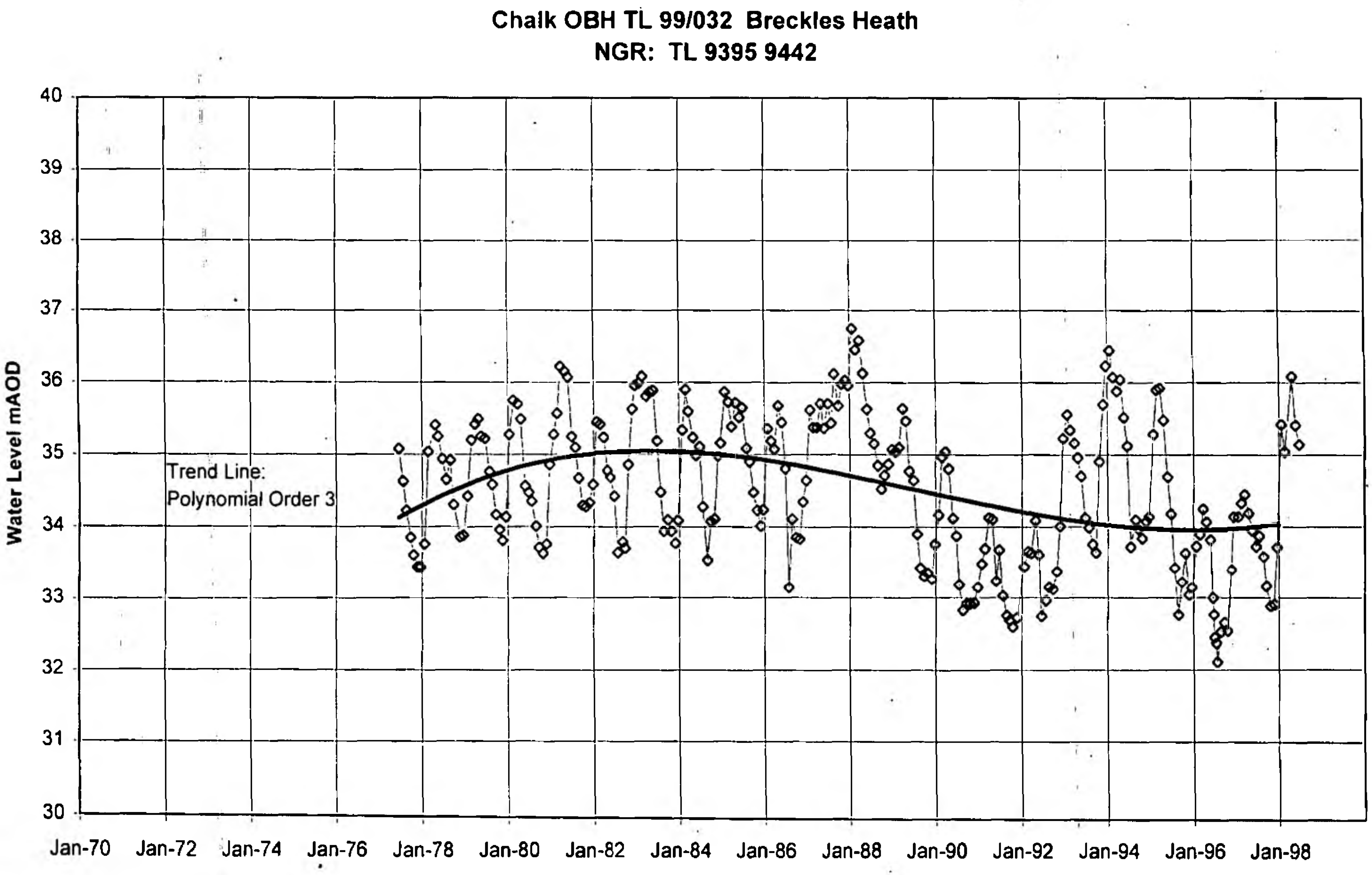

Chalk OBH TL 99/034 Peddars Way, South Thompson Water
NGR: TL 9144 9457
Water Level mAOD
34
33
32
31
30
29
28
27
26
25
24
Trend Line:
Polynomial Order 3
Jan-70
Jan-72
Jan-74
Jan-76
Jan-78
Jan-80
Jan-82
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98

Fig 4.9

Fig 4.9



Chalk OBH TL 99/032 Breckles Heath
NGR: TL 9395 9442
Water Level mAOD
40
39
38
37
36
35
34
33
32
31
30
Trend Line:
Polynomial Order 3
Jan-70
Jan-72
Jan-74
Jan-76
Jan-78
Jan-80
Jan-82
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98

Fig 4.10

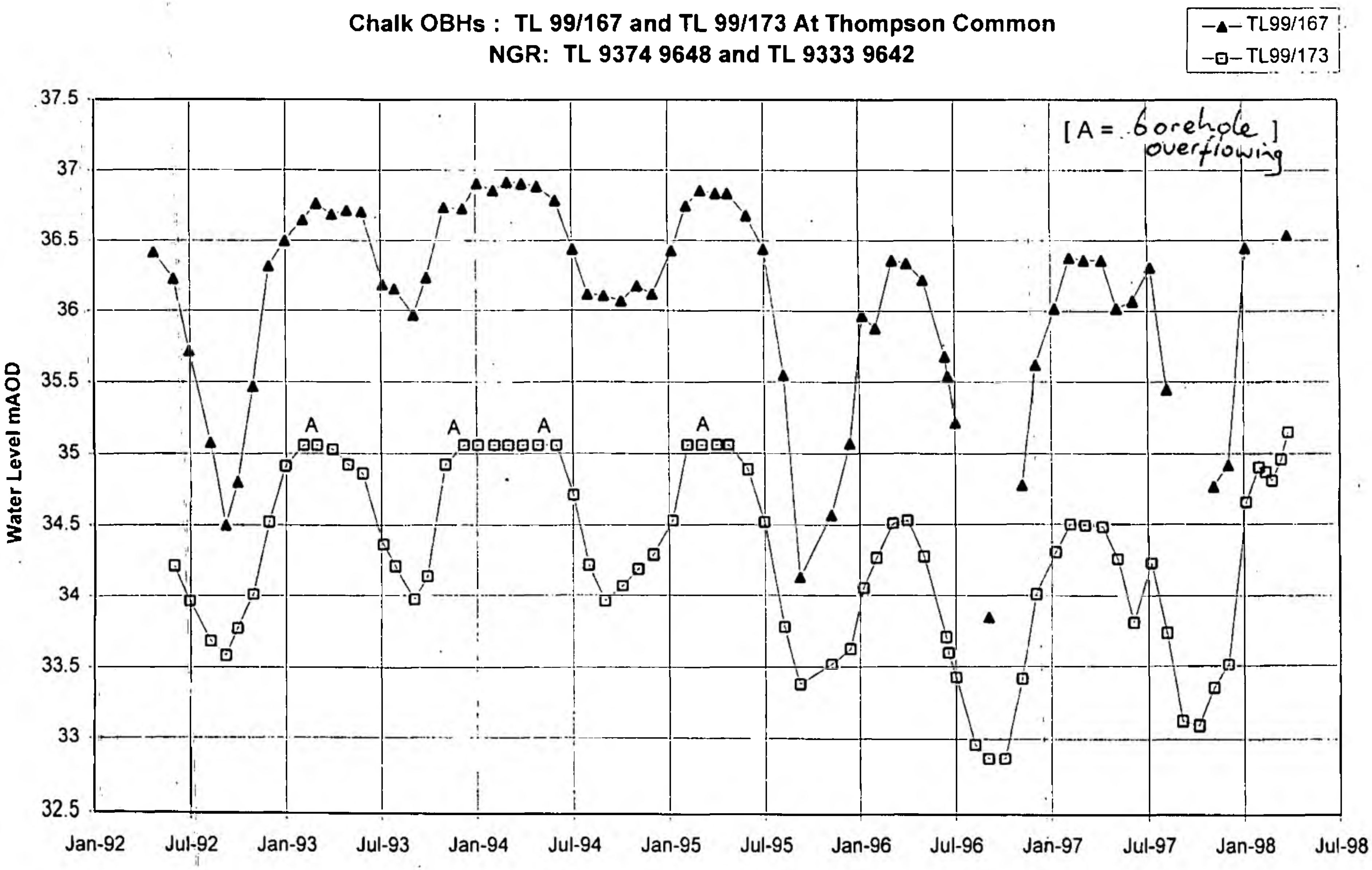

Chalk OBHs : TL 99/167 and TL 99/173 At Thompson Common
NGR: TL 9374 9648 and TL 9333 9642
TL99/167
TL99/173
[A = borehole overflowing]
Water Level mAOD
37.5
37
36.5
36
35.5
35
34.5
34
33.5
33
32.5
A
A
A
A
Jan-92
Jul-92
Jan-93
Jul-93
Jan-94
Jul-94
Jan-95
Jul-95
Jan-96
Jul-96
Jan-97
Jul-97
Jan-98
Jul-98

Fig 4.11

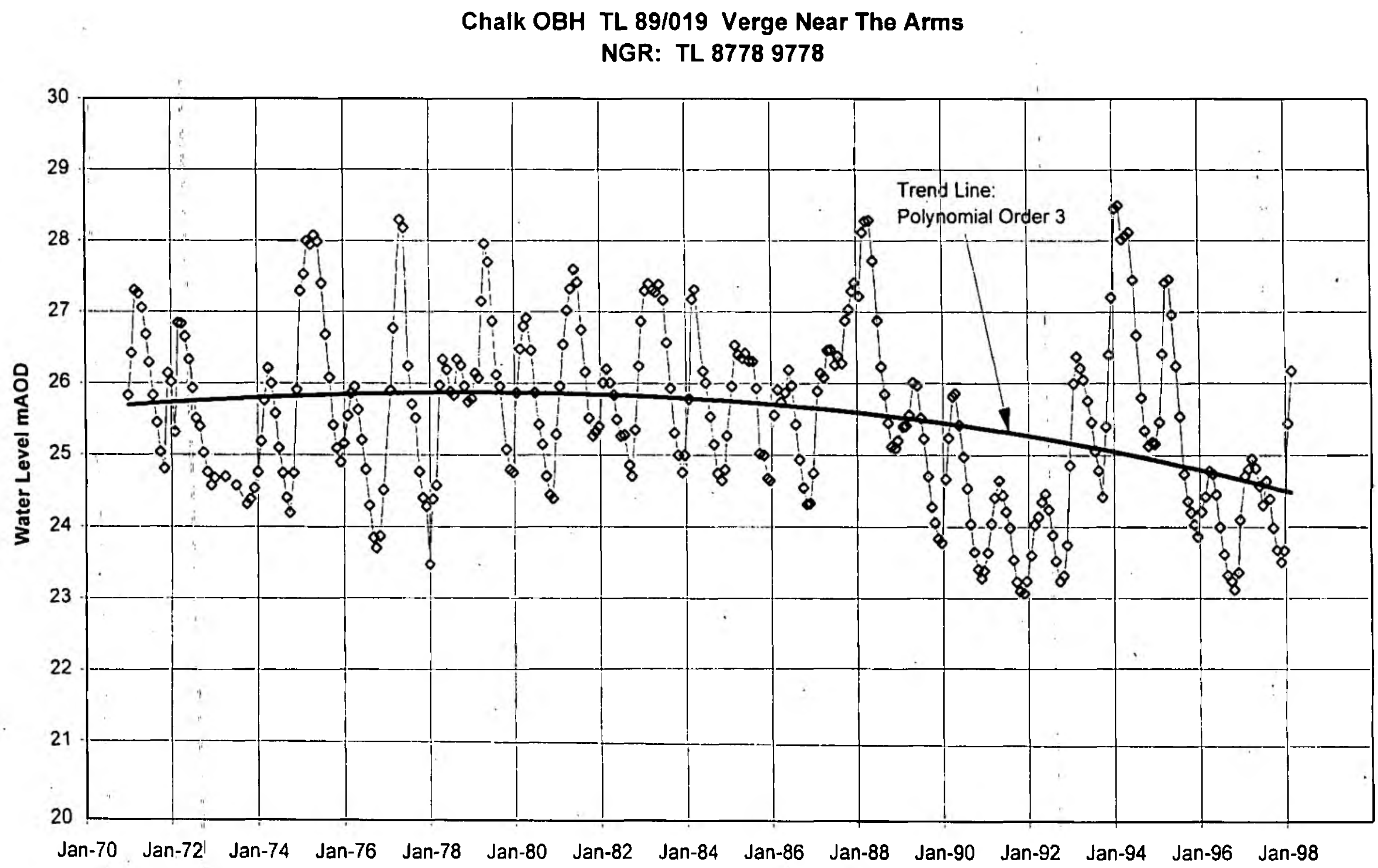
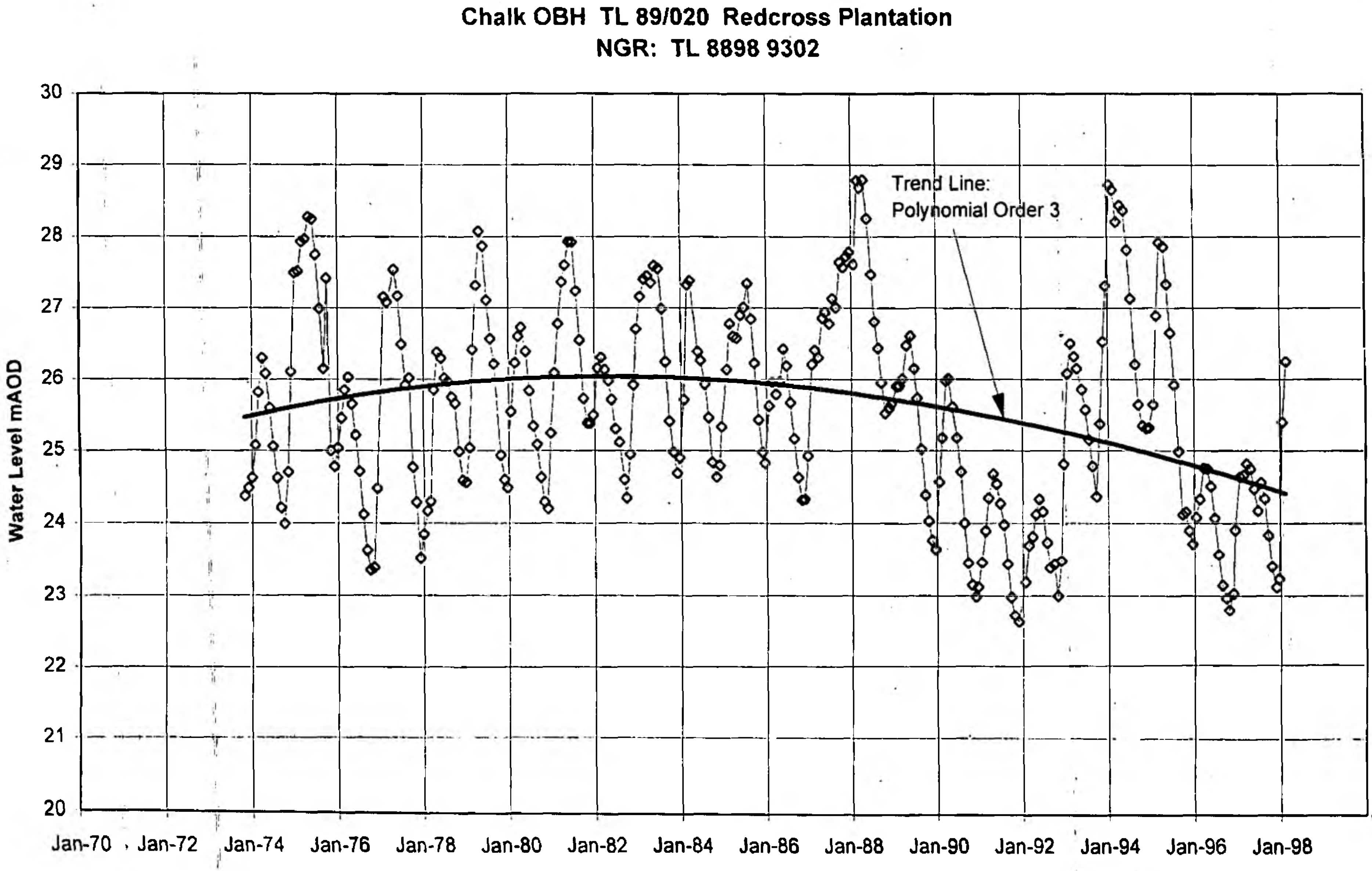

Chalk OBH TL 89/019 Verge Near The Arms
NGR: TL 8778 9778
Trend Line:
Polynomial Order 3
Water Level mAOD
30
29
28
27
26
25
24
23
22
21
20
Jan-70
Jan-72
Jan-74
Jan-76
Jan-78
Jan-80
Jan-82
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98

Fig. 4.12



Chalk OBH TL 89/020 Redcross Plantation
NGR: TL 8898 9302
Trend Line:
Polynomial Order 3
Water Level mAOD
30
29
28
27
26
25
24
23
22
21
20
Jan-70
Jan-72
Jan-74
Jan-76
Jan-78
Jan-80
Jan-82
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98

Figure 5.1 Wissey Groundwater Sub Units

Fig 5.1

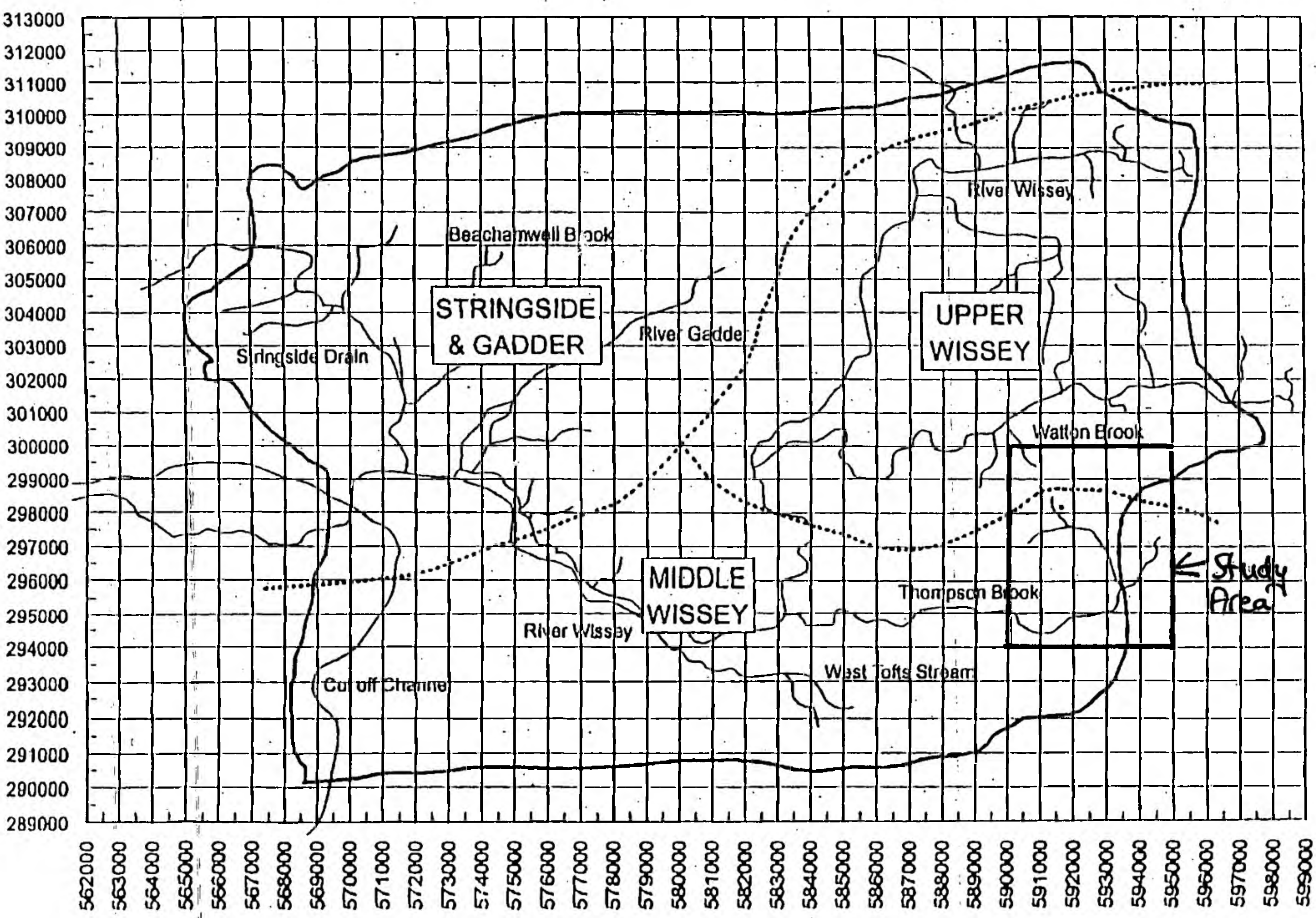
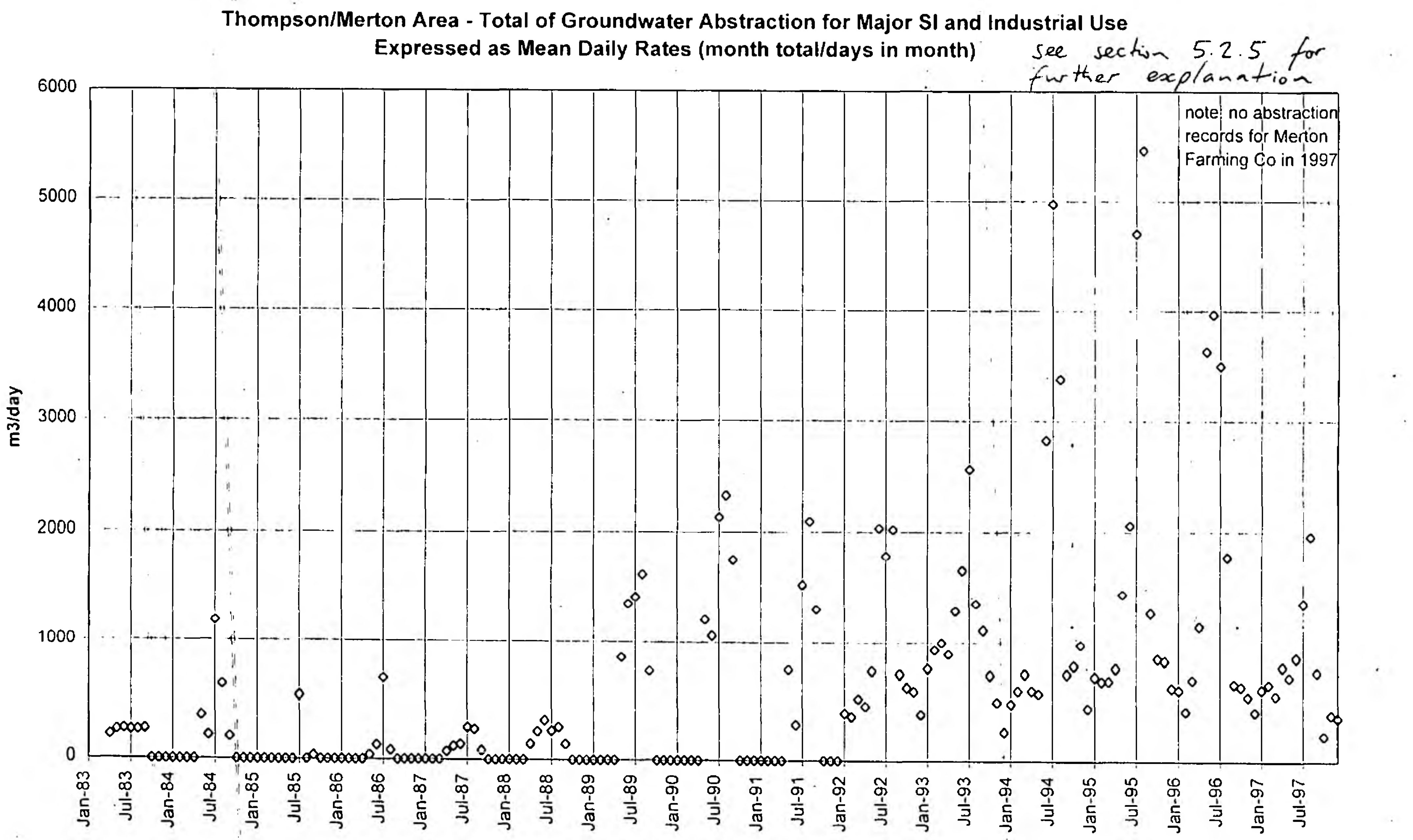
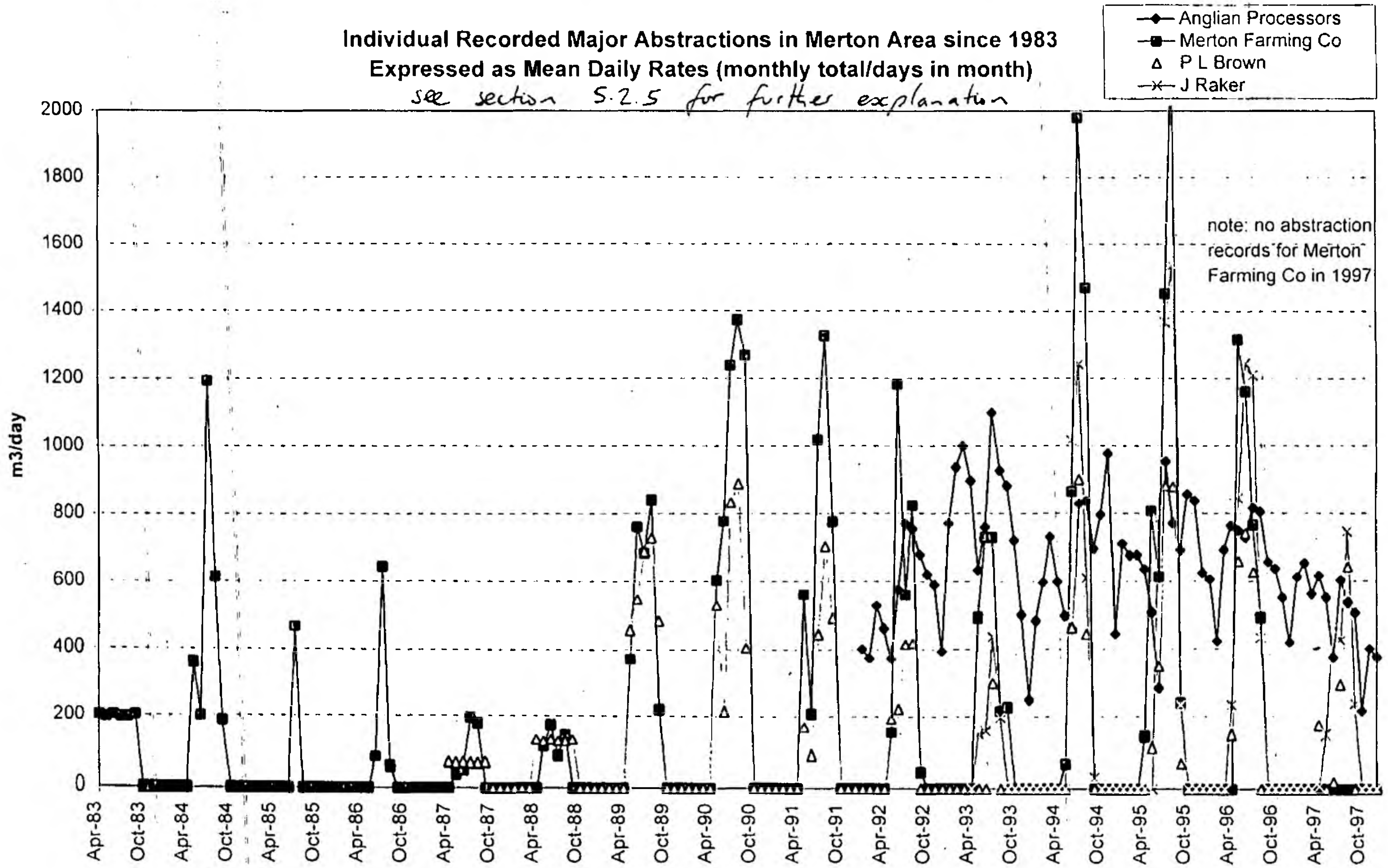


Fig 5.2



Thompson/Merton Area - Total of Groundwater Abstraction for Major SI and Industrial Use
Expressed as Mean Daily Rates (month total/days in month)
see section 5.2.5 for further explanation
note: no abstraction records for Merton Farming Co in 1997
m3/day
6000
5000
4000
3000
2000
1000
0
Jan-83
Jul-83
Jan-84
Jul-84
Jan-85
Jul-85
Jan-86
Jul-86
Jan-87
Jul-87
Jan-88
Jul-88
Jan-89
Jul-89
Jan-90
Jul-90
Jan-91
Jul-91
Jan-92
Jul-92
Jan-93
Jul-93
Jan-94
Jul-94
Jan-95
Jul-95
Jan-96
Jul-96
Jan-97
Jul-97

Fig 5.3



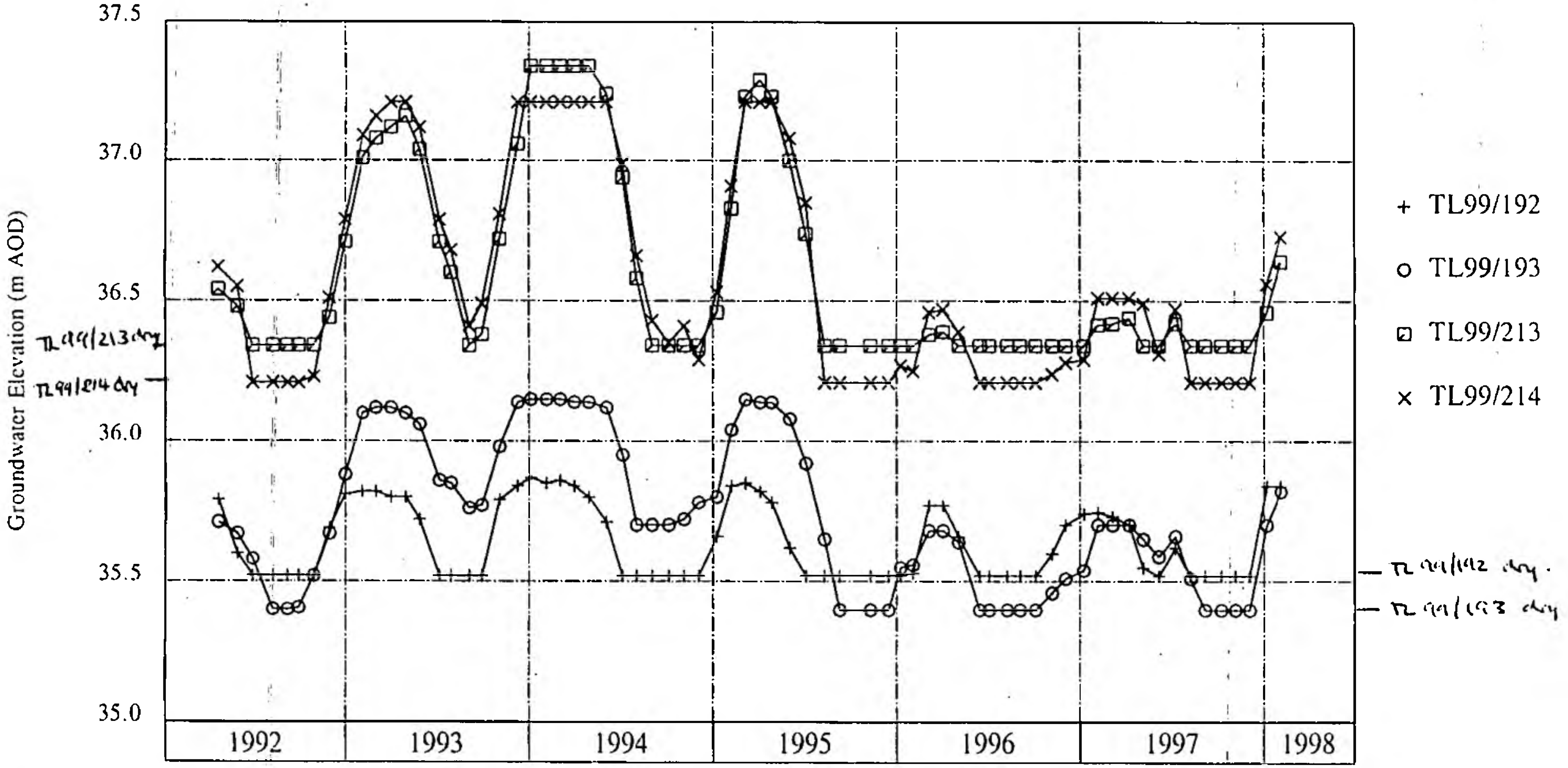
Individual Recorded Major Abstractions in Merton Area since 1983
Expressed as Mean Daily Rates (monthly total/days in month)
see section 5.2.5 for further explanation
Anglian Processors
Merton Farming Co
P L Brown
J Raker
note: no abstraction records for Merton Farming Co in 1997
m3/day
2000
1800
1600
1400
1200
1000
800
600
400
200
0
Apr-83
Oct-83
Apr-84
Oct-84
Apr-85
Oct-85
Apr-86
Oct-86
Apr-87
Oct-87
Apr-88
Oct-88
Apr-89
Oct-89
Apr-90
Oct-90
Apr-91
Oct-91
Apr-92
Oct-92
Apr-93
Oct-93
Apr-94
Oct-94
Apr-95
Oct-95
Apr-96
Oct-96
Apr-97
Oct-97

Fig. 6.1 — Boundary of SSSI Thompson Water Carr & Common.
— Main watercourses


Figure 6.2 showing locations of gaugeboards and boreholes on Thompson Common (presently monitored as a condition of licence 6/33/48/G/197
⊙ Borehole (drift) ● Borehole into Chalk
+ Gaugeboard
A TL99/192
B TL99/193
C TL99/194 now 213
D TL99/195 now 214
E TL99/196
F TL99/197
G TL99/198
H TL99/199 now 99/215
I TL99/200
Installed in 1997:
new TL99/194, 195 & 199
+ TL 99/203 gaugeboard
⊙ TL 99/201 & 202 boreholes
Existing Boreholes:
● TL99/008 & 034 (chalk OBH)
THOMPSON CP
Thompson
Pockthorpe
Thompson Common
Stow Heath
Thompson Water
ROMAN ROAD
92
93
94
97
96
95
91
99/173
99/169
99/167
99/168
99/008
99/201
& 99/202
99/170
99/171
99/203
99/172
99/034

Fig. 6.3

Gauge Boards: Thompson Common (N)

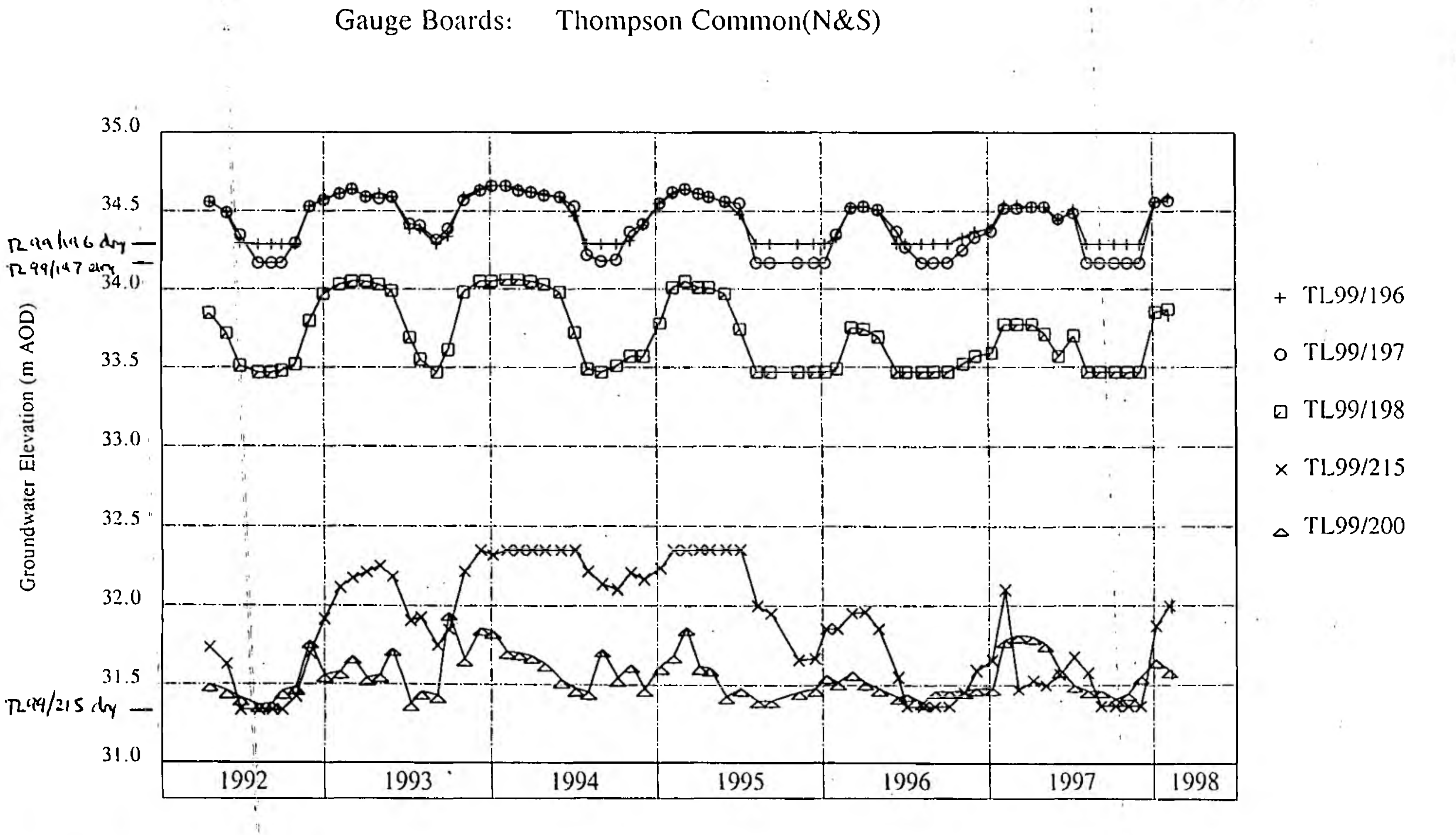


Environment Agency

Anglian Region

Legend

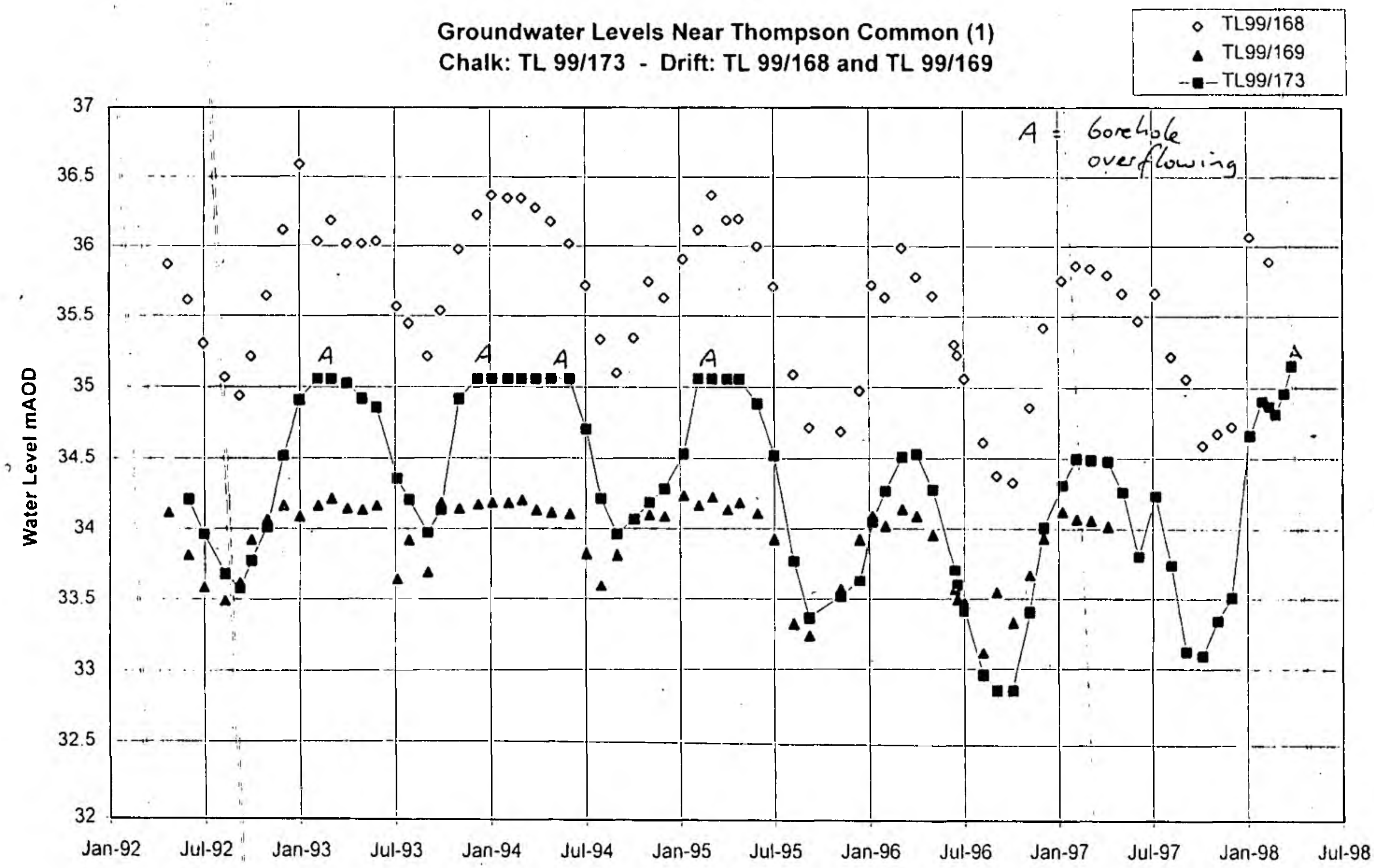
Fig 6.4



Environment Agency
Anglian Region

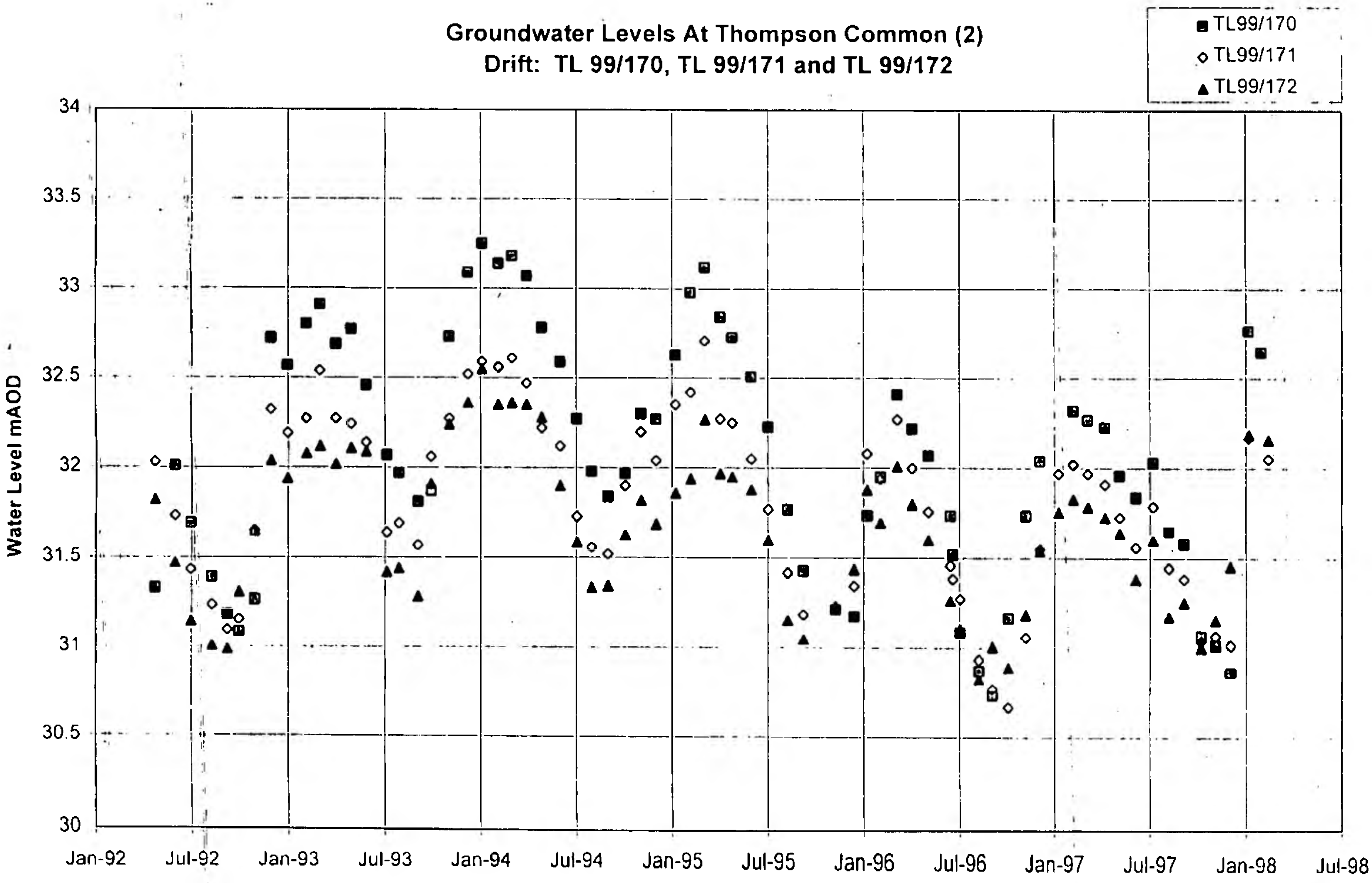
Legend

Fig 6.5



Groundwater Levels Near Thompson Common (1)
Chalk: TL 99/173 - Drift: TL 99/168 and TL 99/169
TL99/168
TL99/169
TL99/173
A = borehole overflowing
A
Water Level mAOD
37
36.5
36
35.5
35
34.5
34
33.5
33
32.5
32
Jan-92
Jul-92
Jan-93
Jul-93
Jan-94
Jul-94
Jan-95
Jul-95
Jan-96
Jul-96
Jan-97
Jul-97
Jan-98
Jul-98

Fig 6.6



Groundwater Levels At Thompson Common (2)
Drift: TL 99/170, TL 99/171 and TL 99/172
TL99/170
TL99/171
TL99/172
Water Level mAOD
34
33.5
33
32.5
32
31.5
31
30.5
30
Jan-92
Jul-92
Jan-93
Jul-93
Jan-94
Jul-94
Jan-95
Jul-95
Jan-96
Jul-96
Jan-97
Jul-97
Jan-98
Jul-98

Fig. 67

Environment Agency Anglian Region HYDROLOG Archive Report

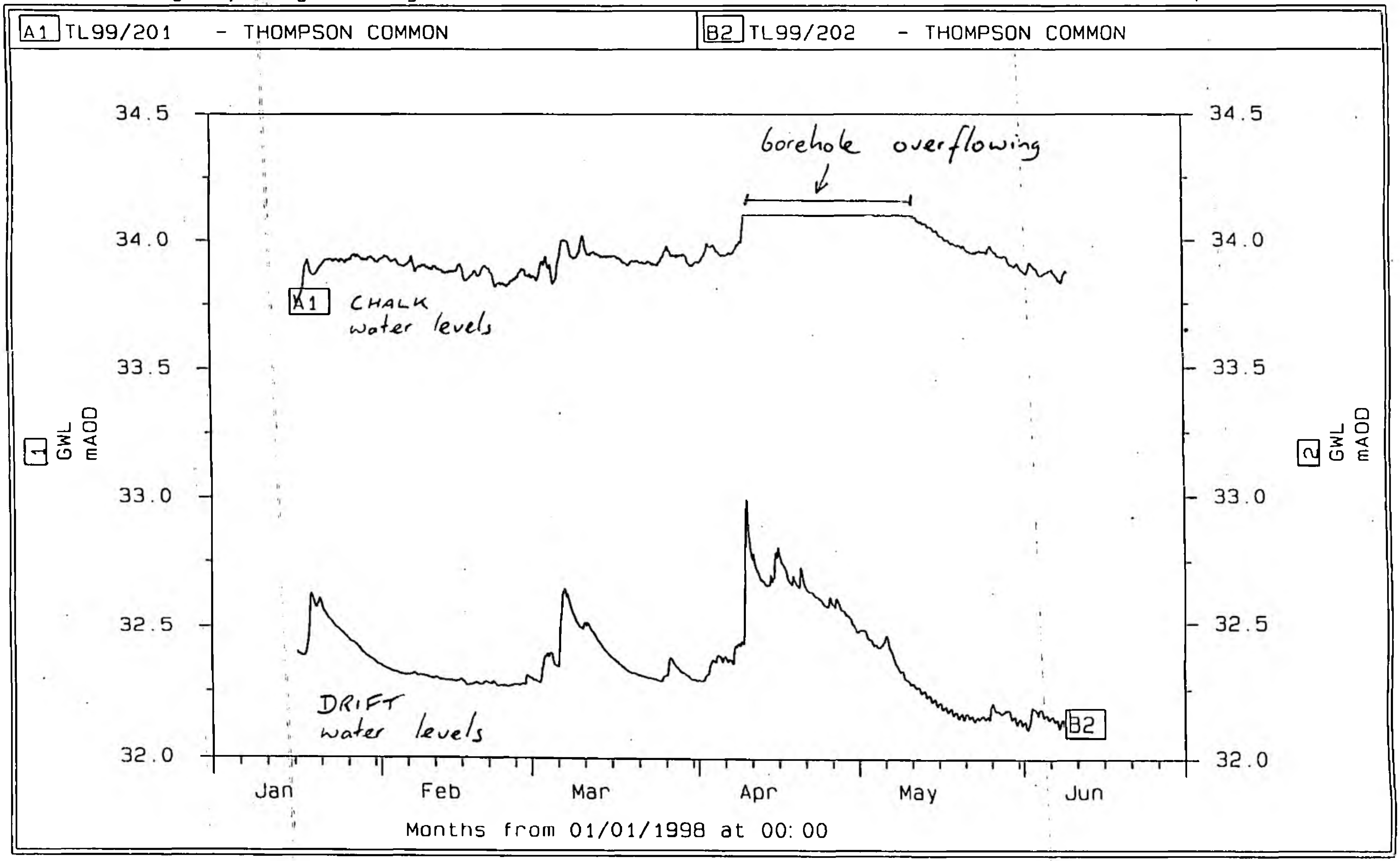
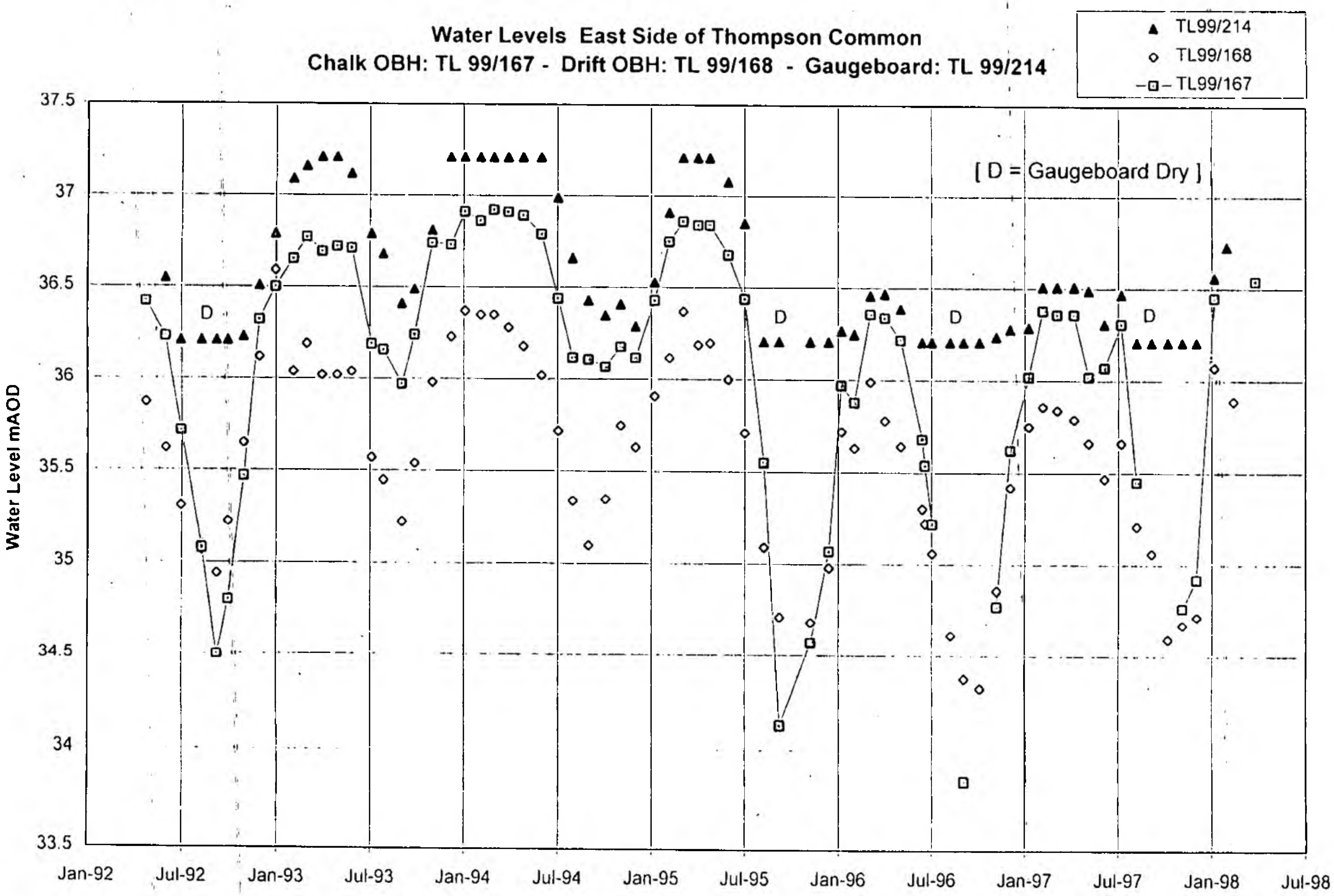


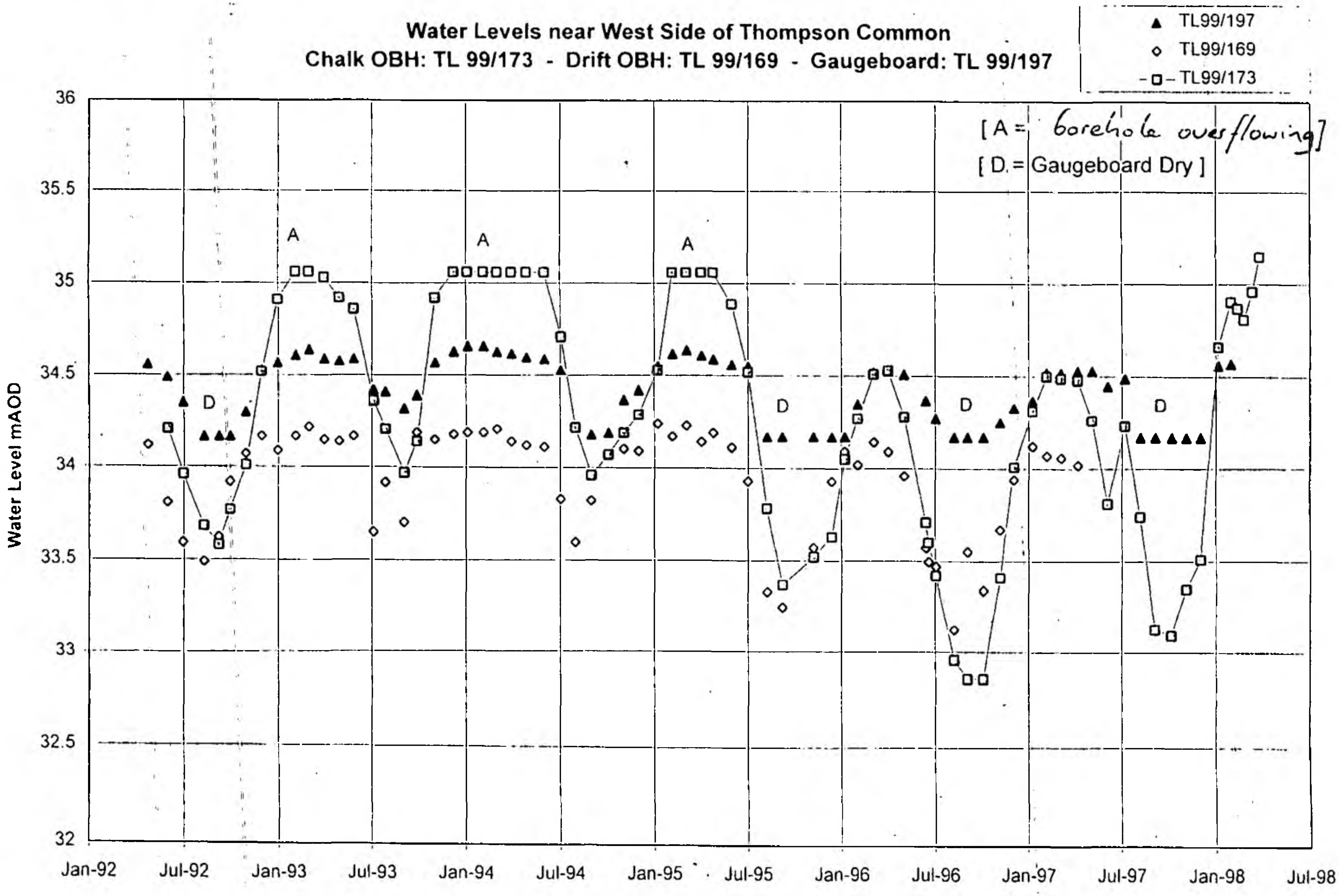
Fig 6.8



Water Levels East Side of Thompson Common
Chalk OBH: TL 99/167 - Drift OBH: TL 99/168 - Gaugeboard: TL 99/214
TL99/214
TL99/168
TL99/167
[D = Gaugeboard Dry]
D
Water Level mAOD
37.5
37
36.5
36
35.5
35
34.5
34
33.5
Jan-92
Jul-92
Jan-93
Jul-93
Jan-94
Jul-94
Jan-95
Jul-95
Jan-96
Jul-96
Jan-97
Jul-97
Jan-98
Jul-98

Fig 6.9.

Fig. 6.9



Water Levels near West Side of Thompson Common
Chalk OBH: TL 99/173 - Drift OBH: TL 99/169 - Gaugeboard: TL 99/197
TL99/197
TL99/169
TL99/173
[A = borehole overflowing]
[D = Gaugeboard Dry]
A
A
A
D
D
D
D
Water Level mAOD
36
35.5
35
34.5
34
33.5
33
32.5
32
Jan-92
Jul-92
Jan-93
Jul-93
Jan-94
Jul-94
Jan-95
Jul-95
Jan-96
Jul-96
Jan-97
Jul-97
Jan-98
Jul-98

Fig 6.10

Cross Plot 1 : TL 99/169 Drift levels and TL 99/197 Gauge board levels plotted against TL 99/173 Chalk levels (1992-1998)

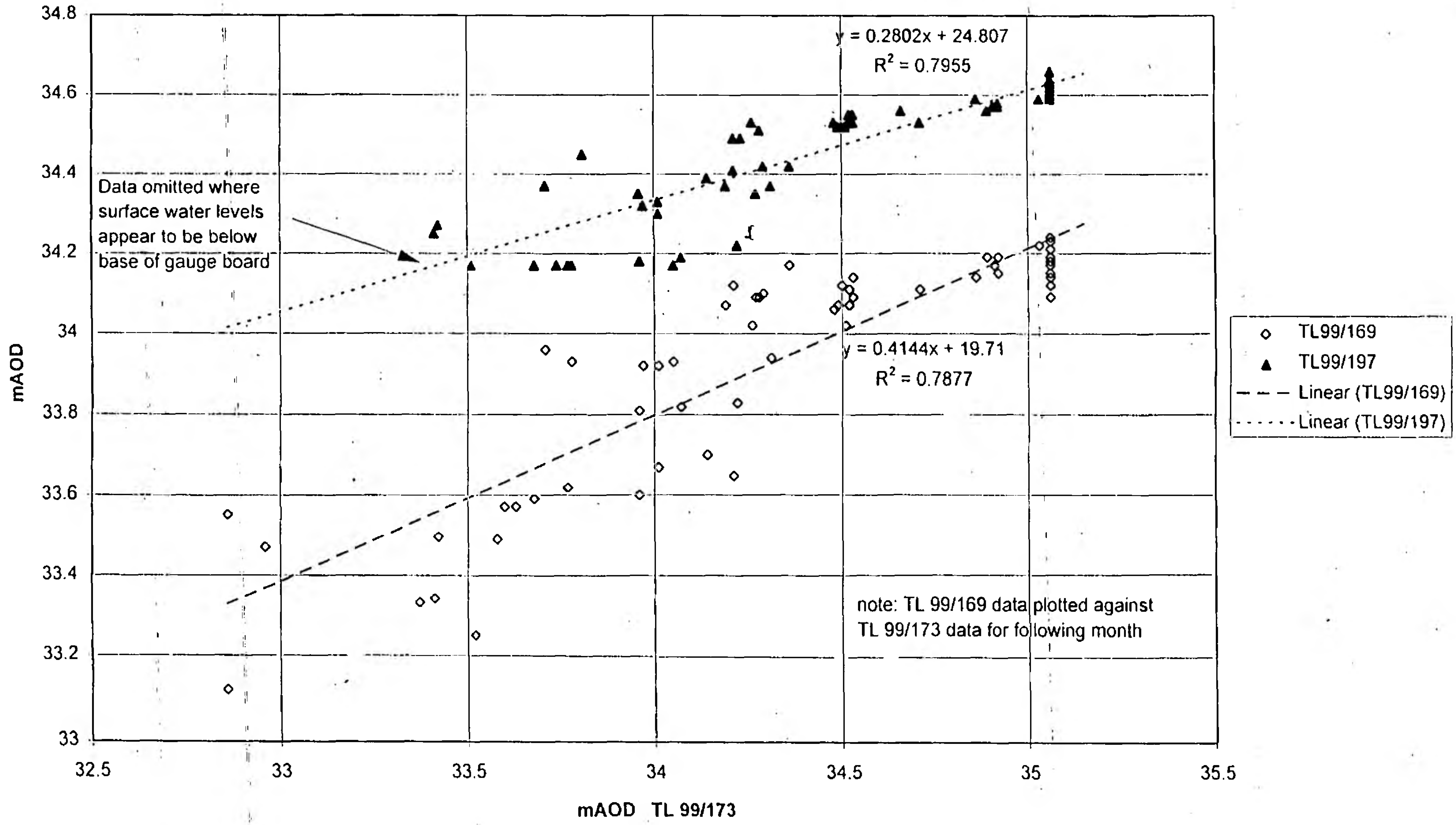
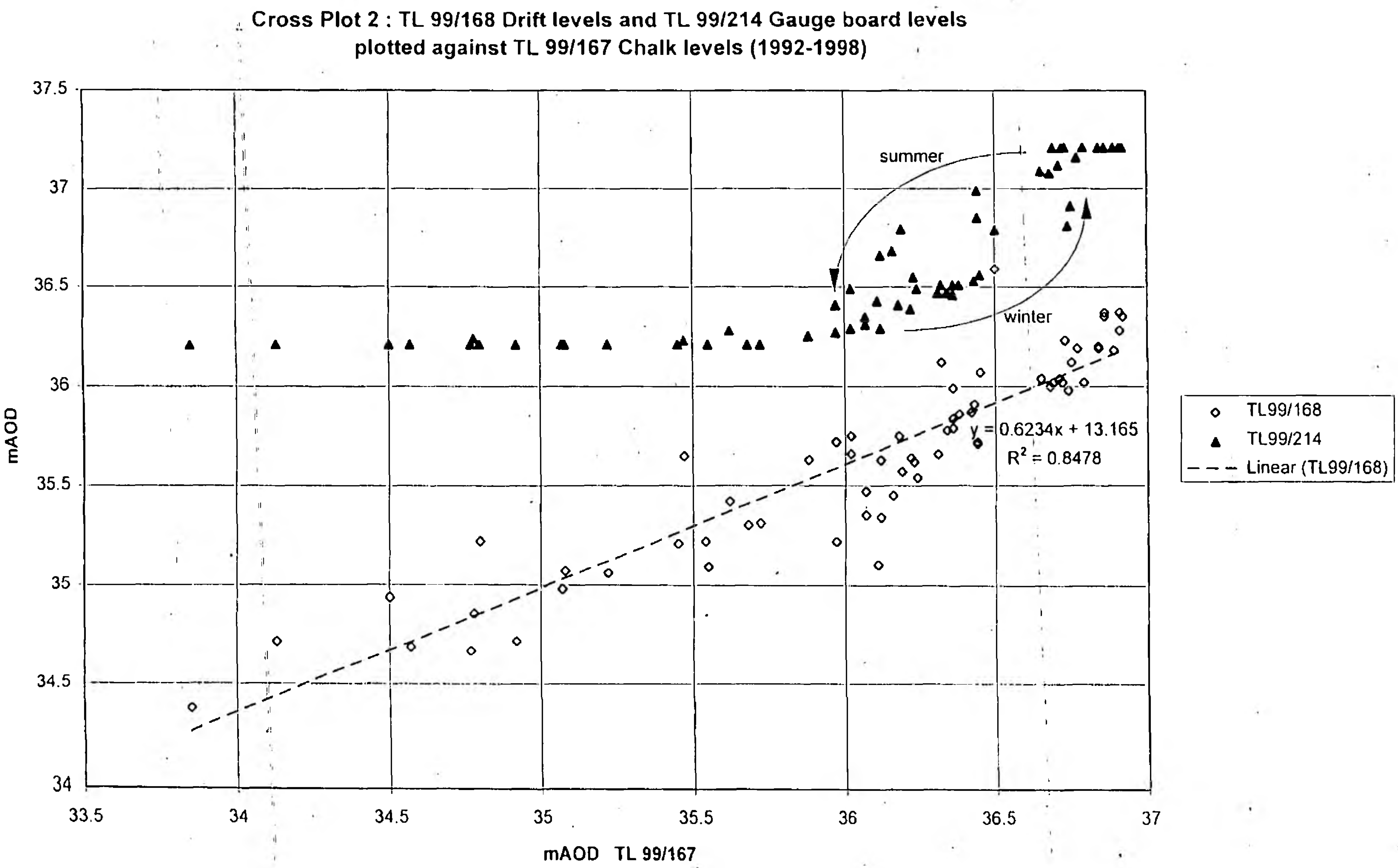


Fig 6.11



Cross Plot 2 : TL 99/168 Drift levels and TL 99/214 Gauge board levels plotted against TL 99/167 Chalk levels (1992-1998)
summer
winter
y = 0.6234x + 13.165
R² = 0.8478
mAOD
mAOD TL 99/167
37.5
37
36.5
36
35.5
35
34.5
34
33.5
34
34.5
35
35.5
36
36.5
37
TL99/168
TL99/214
Linear (TL99/168)

Fig 6.12

Cross Plot 3 : TL 99/168 Drift water levels and TL 99/214 Gauge board levels plotted against TL 99/173 Chalk water levels (1992-1998)

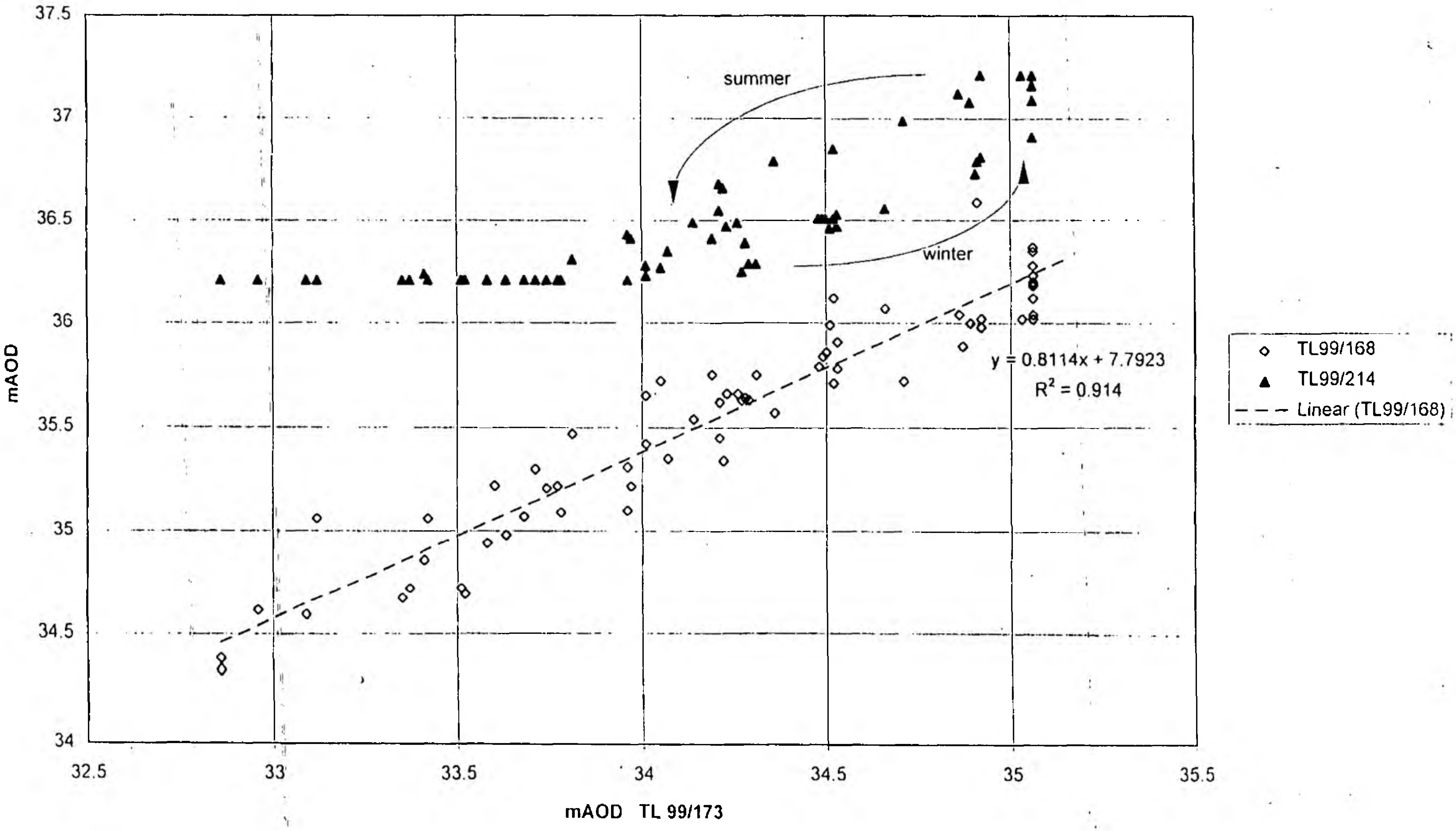


Fig 6.13

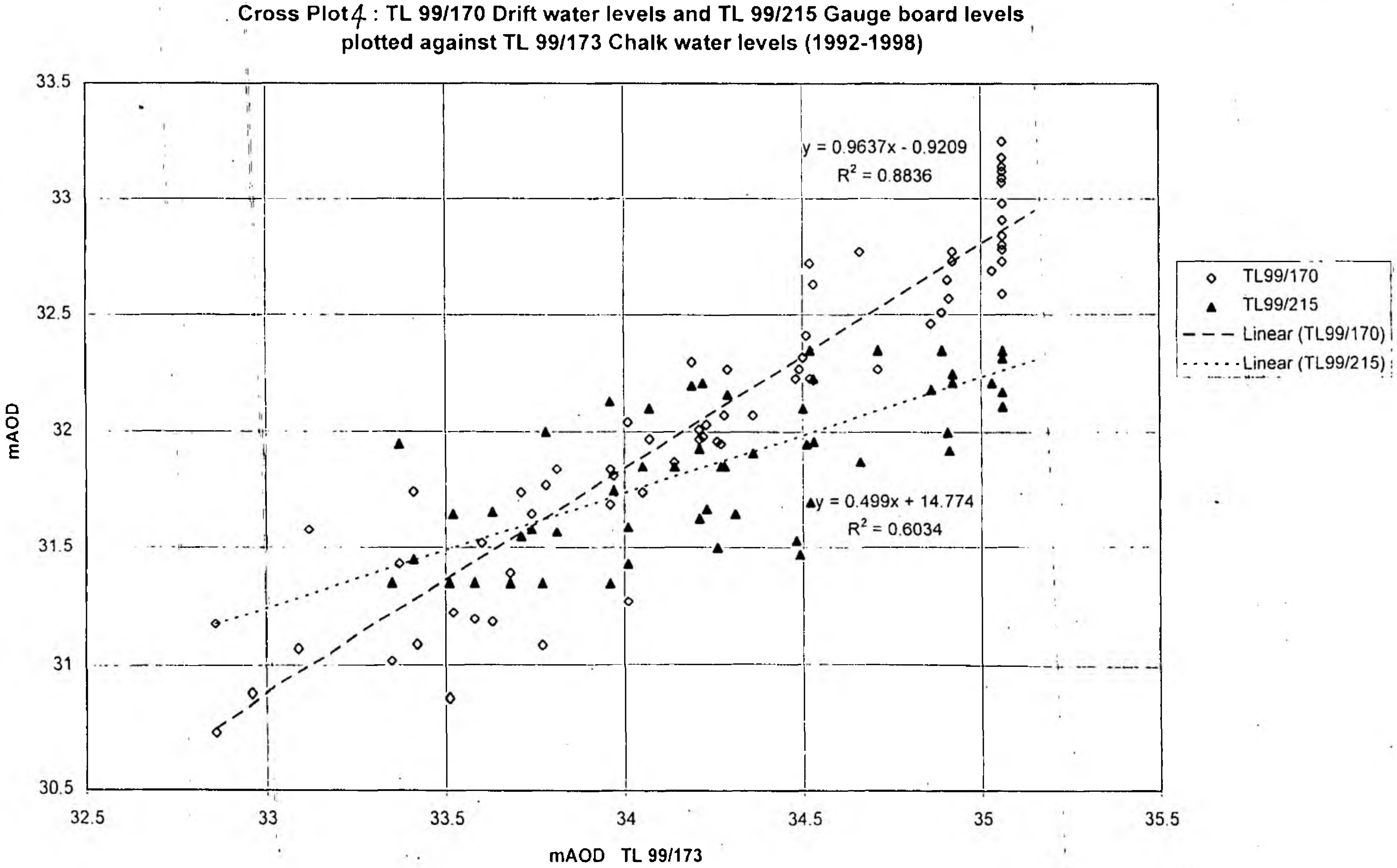
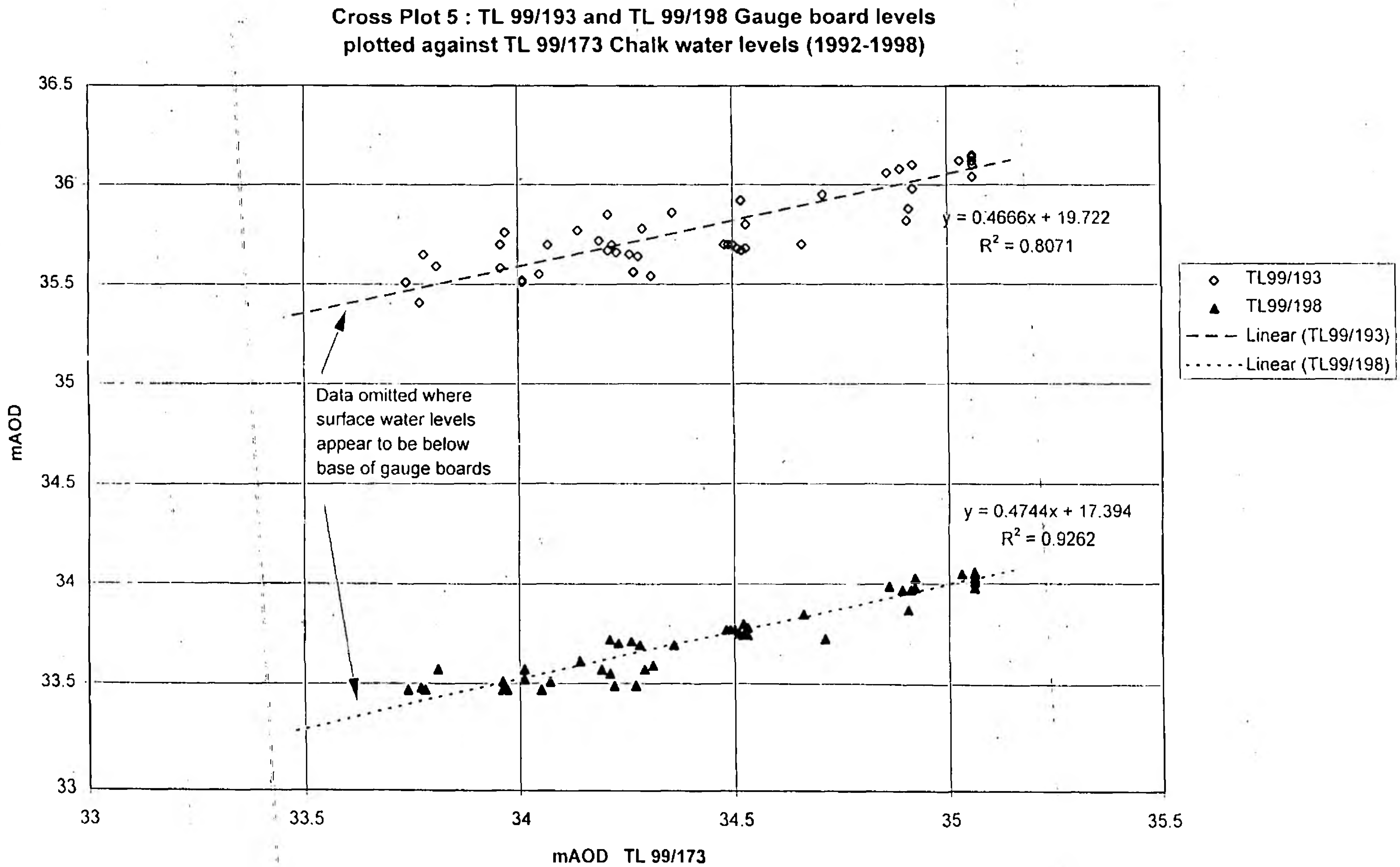

Cross Plot 4 : TL 99/170 Drift water levels and TL 99/215 Gauge board levels plotted against TL 99/173 Chalk water levels (1992-1998)
y = 0.9637x - 0.9209
R² = 0.8836
y = 0.499x + 14.774
R² = 0.6034
TL99/170
TL99/215
Linear (TL99/170)
Linear (TL99/215)
mAOD
33.5
33
32.5
32
31.5
31
30.5
32.5
33
33.5
34
34.5
35
35.5
mAOD TL 99/173

Fig 6.14


Cross Plot 5 : TL 99/193 and TL 99/198 Gauge board levels plotted against TL 99/173 Chalk water levels (1992-1998)
mAOD
mAOD TL 99/173
36.5
36
35.5
35
34.5
34
33.5
33
33
33.5
34
34.5
35
35.5
y = 0.4666x + 19.722
R2 = 0.8071
y = 0.4744x + 17.394
R2 = 0.9262
Data omitted where surface water levels appear to be below base of gauge boards
TL99/193
TL99/198
Linear (TL99/193)
Linear (TL99/198)

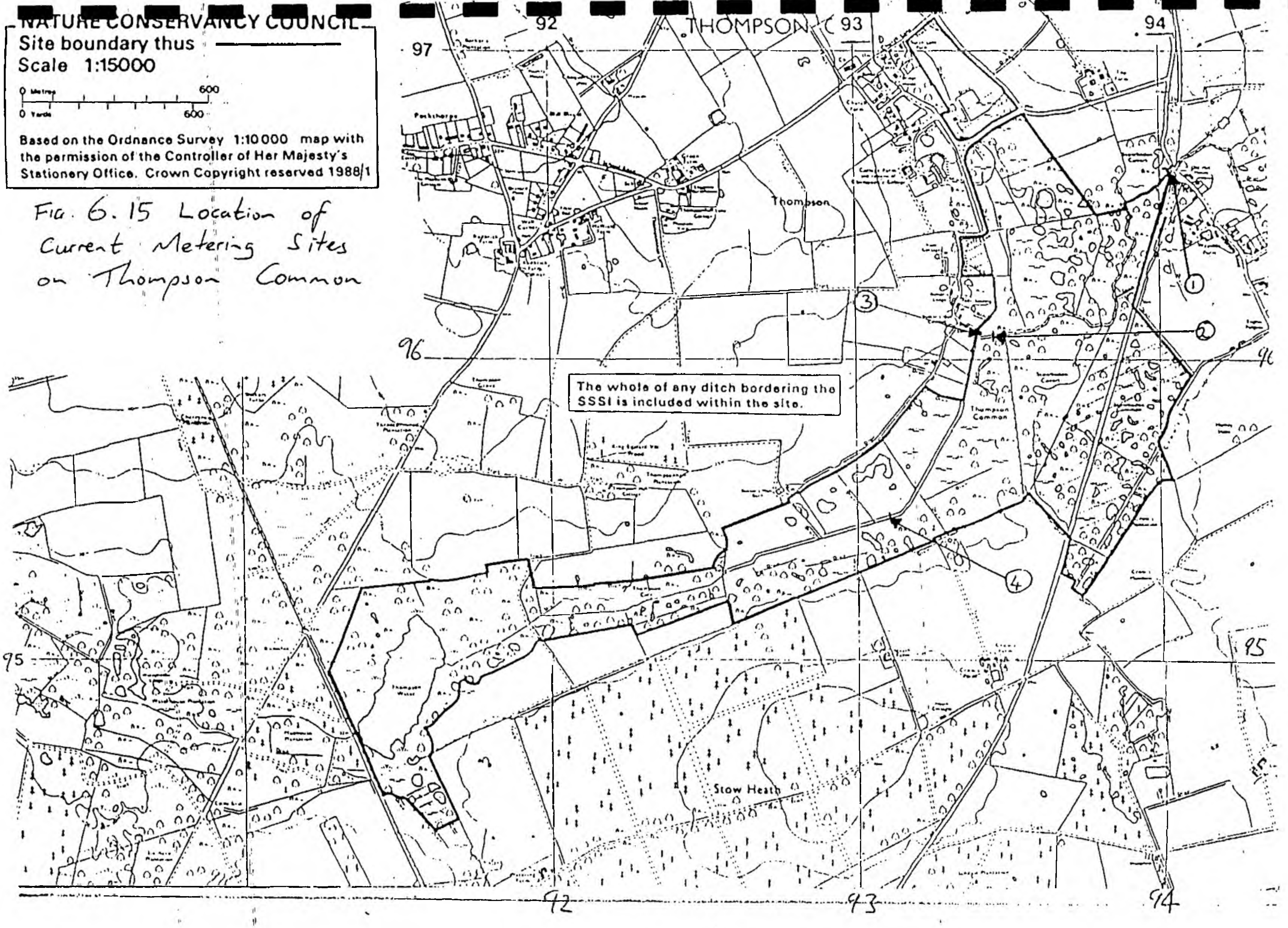
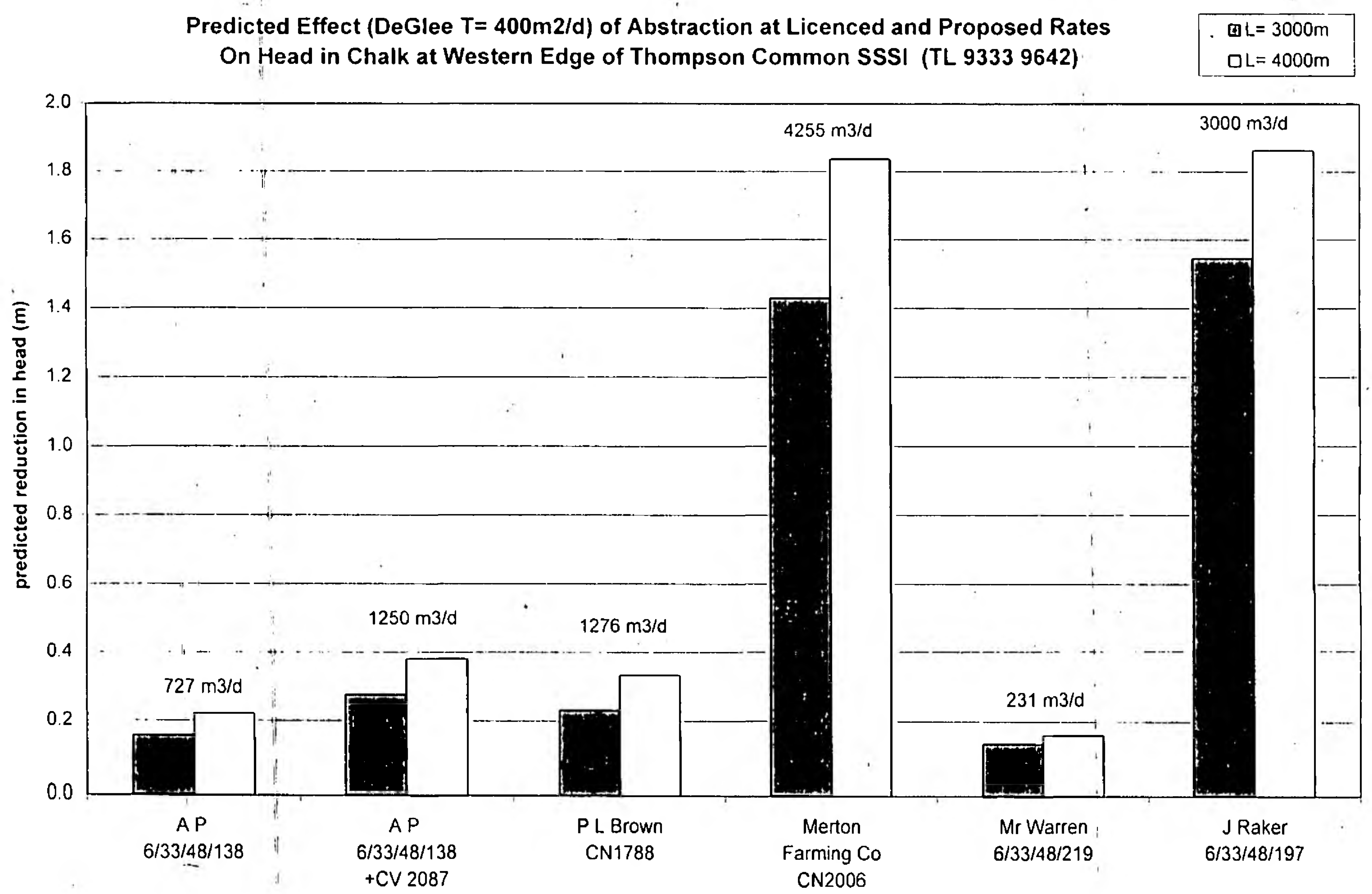


Fig. 6.15 Location of Current Metering Sites on Thompson Common

Fig. 7.1

Fig 7.1


Predicted Effect (DeGlee T= 400m2/d) of Abstraction at Licenced and Proposed Rates
On Head in Chalk at Western Edge of Thompson Common SSSI (TL 9333 9642)
L= 3000m
L= 4000m
predicted reduction in head (m)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
727 m3/d
1250 m3/d
1276 m3/d
4255 m3/d
231 m3/d
3000 m3/d
A P
6/33/48/138
A P
6/33/48/138
+CV 2087
P L Brown
CN1788
Merton
Farming Co
CN2006
Mr Warren
6/33/48/219
J Raker
6/33/48/197

Appendix A
Borehole Geological Information Summary

Thompson/Merton Area: Borehole Geological Information					Data summarised from strata records on Agency BH Archives					
		NGR	NGR		- approximate thickness of layers -			TK1+TK2+TK3		
Well Ref	BH type	Easting	Northing	GL mAOD	TK1 Sand m	TK2 Clay m	TK3 Sand m	Total Drift m	Top of Chalk mAOD	BH Total Depth m
TL 99/004	obhC	9176	9678	**51.85**	7.6	12.2	0	19.8	32.1	42.70
TL 99/005	obhC	9236	9941	**54.91**	0.6	14.6	0	15.2	39.7	41.10
TL 99/007A	obhC	9369	9828	**49.23**	3.4	10.6	0	14.0	35.2	29.60
TL 99/016A	obhC	9230	9270	**48.08**	22.9	6.1	0	29.0	19.1	45.70
TL 99/017A	obhC	9150	9755	**51.72**	19.8	16.8	0	36.6	15.1	45.70
TL 99/027	obhC	9158	9729	**52.29**	1.5	22.9	0	24.4	27.9	39.60
TL 99/031	obhC	9372	9310	**34.47**	1.5	12.2	10.7	24.4	10.1	39.60
TL 99/032	obhC	9395	9442	**36.27**	1.5	25.9	12.2	39.6	-3.3	54.90
TL 99/034	obhC	9144	9457	**31.15**	4.6	21	0	25.6	5.6	46.60
TL 99/167	obhC	9374	9648	**36.98**	0.4	0	0	0.4	36.6	3.36
TL 99/173	obhC	9333	9642	**35.06**	3	4	0	7.0	28.1	15.00
TL 99/036	bhC	9010	9580	36.6	5.5	6.1	0	11.6	25.0	39.60
TL 99/037	bhC	9060	9912	47.6	0	8.2	0	8.2	39.4	25.90
TL 99/040	bhC	9108	9770	48.8	0	4.6	0	4.6	44.2	35.00
TL 99/041	bhC	9112	9714	57.6	10.4	29	0	39.4	18.2	50.30
TL 99/042	bhC	9115	9751	51.8	8.5	19.5	0	28.0	23.8	44.20
TL 99/043	bhC	9115	9760	51.8	12.8	9.1	0	21.9	29.9	62.20
TL 99/044	bhC	9115	9775	48.8	1.4	3.7	0	5.1	43.7	30.10
TL 99/046	bhC	9164	9815	51.8	4.6	4.8	0	9.4	42.4	60.00
TL 99/047	bhC	9194	9654	50.0	6.7	7	0	13.7	36.3	36.60
TL 99/050	bhC	9242	9662	48.8	4.2	7.6	0	11.8	37.0	37.18
TL 99/051	bhC	9269	9794	43.3	6.1	19.5	0	25.6	17.7	33.22
TL 99/052	bhC	9315	9673	38.1	3.9	0.9	0	4.8	33.3	28.60
TL 99/076	bhC	9327	9481	42.4	10	9.1	0	19.1	23.3	45.41
TL 99/084	bhC	9306	9498	45.1	4.57	3.05	0	7.6	37.5	39.62
TL 99/126	abhC	9410	9650	39.0	1.8	6.3	0	8.1	30.9	45.00
TL 99/154	bhC	9230	9660	50.0	2.75	12.8	0	15.6	34.5	91.00
TL 99/156	bhC	9320	9601	34.0	3.4	3.7	0	7.1	26.9	45.70
TL 99/157	bhC	9317	9599	34.0	3.7	3.4	0	7.1	26.9	45.70
TL 99/201	obhC	9328	9570	**33.274**	3.7	3.3	0	7.0	26.3	12.00
TL 99/053	bhC	9419	9911	52.7				18.3	34.4	30.78
TL 99/054	bhC	9432	9956	56.7				11.9	44.8	38.70
TL 99/125	bhC	9421	9897	51.8				18.3	33.5	25.91
TL 99/007B	obhD	9369	9828	**49.23**	3.4	10.6	0	14.0	35.2	29.6
TL 99/016B	obhD	9230	9270	**48.08**	22.9	6.1	0	29.0	19.1	45.7
TL 99/017B	obhD	9150	9760	**51.72**	19.8	16.8	0	36.6	15.1	45.7
TL 99/166	bhD	9393	9625	**35.66**	> 4.1				??	4.1
TL 99/168	obhD	9365	9644	**36.93**	0.5	> 2.44			??	2.94
TL 99/169	obhD	9346	9643	34.6	> 3.98				??	3.98
TL 99/170	obhD	9296	9561	**33.76**	> 3.54				??	3.54
TL 99/171	obhD	9301	9557	**33.02**	> 3.6				??	3.6
TL 99/172	obhD	9308	9543	**32.74**	> 3.51				??	3.51

Thompson/Merton Area: Borehole Geological Information					Data summarised from strata records on Agency BH Archives					
		NGR	NGR		- approximate thickness of layers -			TK1+TK2+TK3		
Well Ref	BH type	Easting	Northing	GL mAOD	TK1 Sand m	TK2 Clay m	TK3 Sand m	Total Drift m	Top of Chalk mAOD	BH Total Depth m
TL 99/004	obhC	9176	9678	51.85	7.6	12.2	0	19.8	32.1	42.70
TL 99/005	obhC	9236	9941	54.91	0.6	14.6	0	15.2	39.7	41.10
TL 99/007A	obhC	9369	9828	49.23	3.4	10.6	0	14.0	35.2	29.60
TL 99/016A	obhC	9230	9270	48.08	22.9	6.1	0	29.0	19.1	45.70
TL 99/017A	obhC	9150	9755	51.72	19.8	16.8	0	36.6	15.1	45.70
TL 99/027	obhC	9158	9729	52.29	1.5	22.9	0	24.4	27.9	39.60
TL 99/031	obhC	9372	9310	34.47	1.5	12.2	10.7	24.4	10.1	39.60
TL 99/032	obhC	9395	9442	36.27	1.5	25.9	12.2	39.6	-3.3	54.90
TL 99/034	obhC	9144	9457	31.15	4.6	21	0	25.6	5.6	46.60
TL 99/167	obhC	9374	9648	36.98	0.4	0	0	0.4	36.6	3.36
TL 99/173	obhC	9333	9642	35.06	3	4	0	7.0	28.1	15.00
TL 99/036	bhC	9010	9580	36.6	5.5	6.1	0	11.6	25.0	39.60
TL 99/037	bhC	9060	9912	47.6	0	8.2	0	8.2	39.4	25.90
TL 99/040	bhC	9108	9770	48.8	0	4.6	0	4.6	44.2	35.00
TL 99/041	bhC	9112	9714	57.6	10.4	29	0	39.4	18.2	50.30
TL 99/042	bhC	9115	9751	51.8	8.5	19.5	0	28.0	23.8	44.20
TL 99/043	bhC	9115	9760	51.8	12.8	9.1	0	21.9	29.9	62.20
TL 99/044	bhC	9115	9775	48.8	1.4	3.7	0	5.1	43.7	30.10
TL 99/046	bhC	9164	9815	51.8	4.6	4.8	0	9.4	42.4	60.00
TL 99/047	bhC	9194	9654	50.0	6.7	7	0	13.7	36.3	36.60
TL 99/050	bhC	9242	9662	48.8	4.2	7.6	0	11.8	37.0	37.18
TL 99/051	bhC	9269	9794	43.3	6.1	19.5	0	25.6	17.7	33.22
TL 99/052	bhC	9315	9673	38.1	3.9	0.9	0	4.8	33.3	28.60
TL 99/076	bhC	9327	9481	42.4	10	9.1	0	19.1	23.3	45.41
TL 99/084	bhC	9306	9498	45.1	4.57	3.05	0	7.6	37.5	39.62
TL 99/126	abhC	9410	9650	39.0	1.8	6.3	0	8.1	30.9	45.00
TL 99/154	bhC	9230	9660	50.0	2.75	12.8	0	15.6	34.5	91.00
TL 99/156	bhC	9320	9601	34.0	3.4	3.7	0	7.1	26.9	45.70
TL 99/157	bhC	9317	9599	34.0	3.7	3.4	0	7.1	26.9	45.70
TL 99/201	obhC	9328	9570	33.274	3.7	3.3	0	7.0	26.3	12.00
TL 99/053	bhC	9419	9911	52.7				18.3	34.4	30.78
TL 99/054	bhC	9432	9956	56.7				11.9	44.8	38.70
TL 99/125	bhC	9421	9897	51.8				18.3	33.5	25.91
TL 99/007B	obhD	9369	9828	49.23	3.4	10.6	0	14.0	35.2	29.6
TL 99/016B	obhD	9230	9270	48.08	22.9	6.1	0	29.0	19.1	45.7
TL 99/017B	obhD	9150	9760	51.72	19.8	16.8	0	36.6	15.1	45.7
TL 99/166	bhD	9393	9625	35.66	> 4.1				??	4.1
TL 99/168	obhD	9365	9644	36.93	0.5	> 2.44			??	2.94
TL 99/169	obhD	9346	9643	34.6	> 3.98				??	3.98
TL 99/170	obhD	9296	9561	33.76	> 3.54				??	3.54
TL 99/171	obhD	9301	9557	33.02	> 3.6				??	3.6
TL 99/172	obhD	9308	9543	32.74	> 3.51				??	3.51

APPENDIX A

Borehole Geological Information Summary

APPENDIX A

Thompson/Merton Area: Borehole Geological Information					Data summarised from strata records on Agency BH Archives					
		NGR	NGR		- approximate thickness of layers -			TK1+TK2+TK3		
Well Ref	BH type	Easting	Northing	GL mAOD	TK1 Sand m	TK2 Clay m	TK3 Sand m	Total Drift m	Top of Chalk mAOD	BH Total Depth m
TL 99/004	obhC	9176	9678	**51.85**	7.6	12.2	0	19.8	32.1	42.70
TL 99/005	obhC	9236	9941	**54.91**	0.6	14.6	0	15.2	39.7	41.10
TL 99/007A	obhC	9369	9828	**49.23**	3.4	10.6	0	14.0	35.2	29.60
TL 99/016A	obhC	9230	9270	**48.08**	22.9	6.1	0	29.0	19.1	45.70
TL 99/017A	obhC	9150	9755	**51.72**	19.8	16.8	0	36.6	15.1	45.70
TL 99/027	obhC	9158	9729	**52.29**	1.5	22.9	0	24.4	27.9	39.60
TL 99/031	obhC	9372	9310	**34.47**	1.5	12.2	10.7	24.4	10.1	39.60
TL 99/032	obhC	9395	9442	**36.27**	1.5	25.9	12.2	39.6	-3.3	54.90
TL 99/034	obhC	9144	9457	**31.15**	4.6	21	0	25.6	5.6	46.60
TL 99/167	obhC	9374	9648	**36.98**	0.4	0	0	0.4	36.6	3.36
TL 99/173	obhC	9333	9642	**35.08**	3	4	0	7.0	28.1	15.00
TL 99/036	bhC	9010	9580	36.6	5.5	6.1	0	11.6	25.0	39.60
TL 99/037	bhC	9060	9912	47.6	0	8.2	0	8.2	39.4	25.90
TL 99/040	bhC	9108	9770	48.8	0	4.6	0	4.6	44.2	35.00
TL 99/041	bhC	9112	9714	57.6	10.4	29	0	39.4	18.2	50.30
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TL 99/044	bhC	9115	9775	48.8	1.4	3.7	0	5.1	43.7	30.10
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TL 99/084	bhC	9306	9498	45.1	4.57	3.05	0	7.6	37.5	39.62
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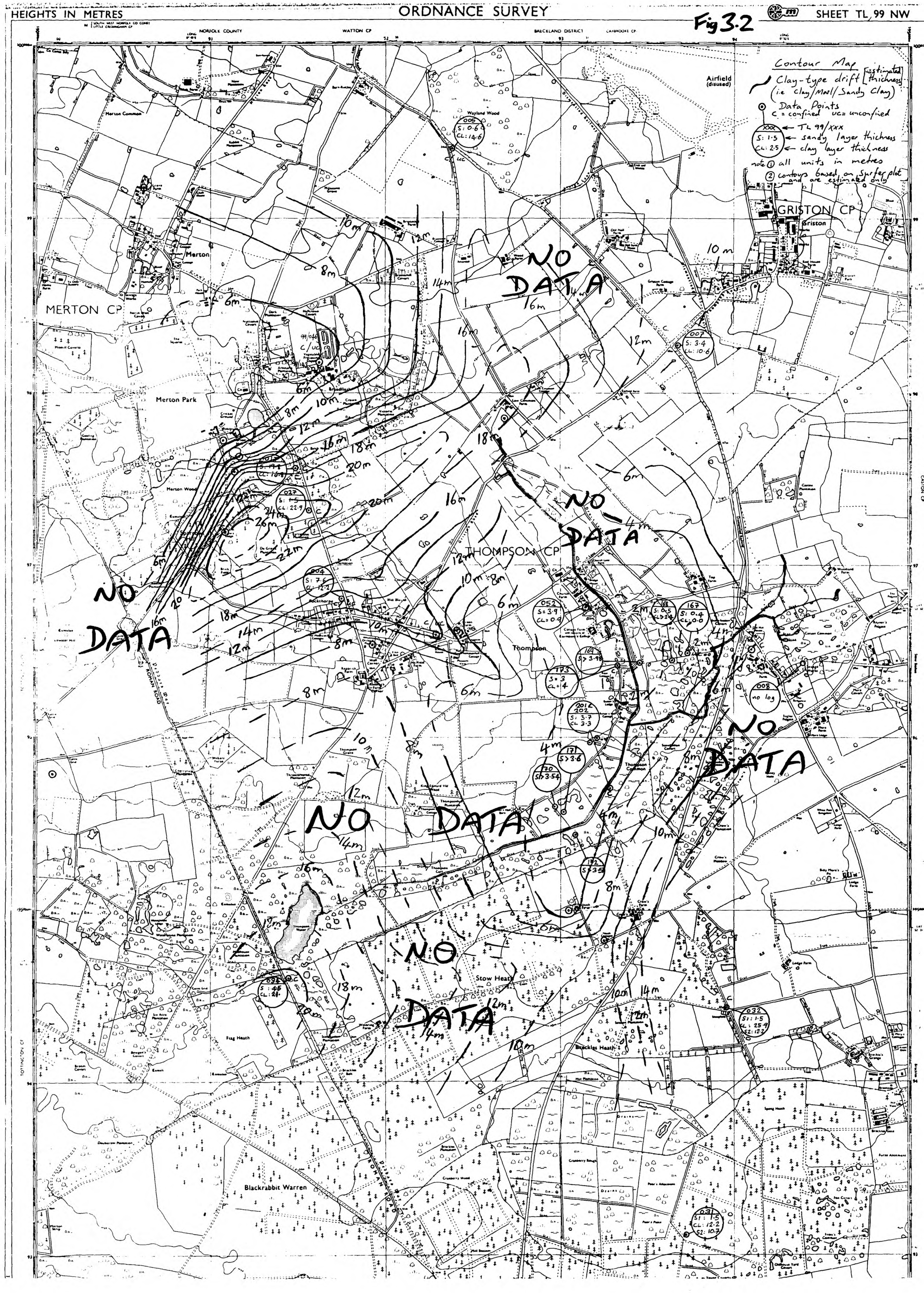
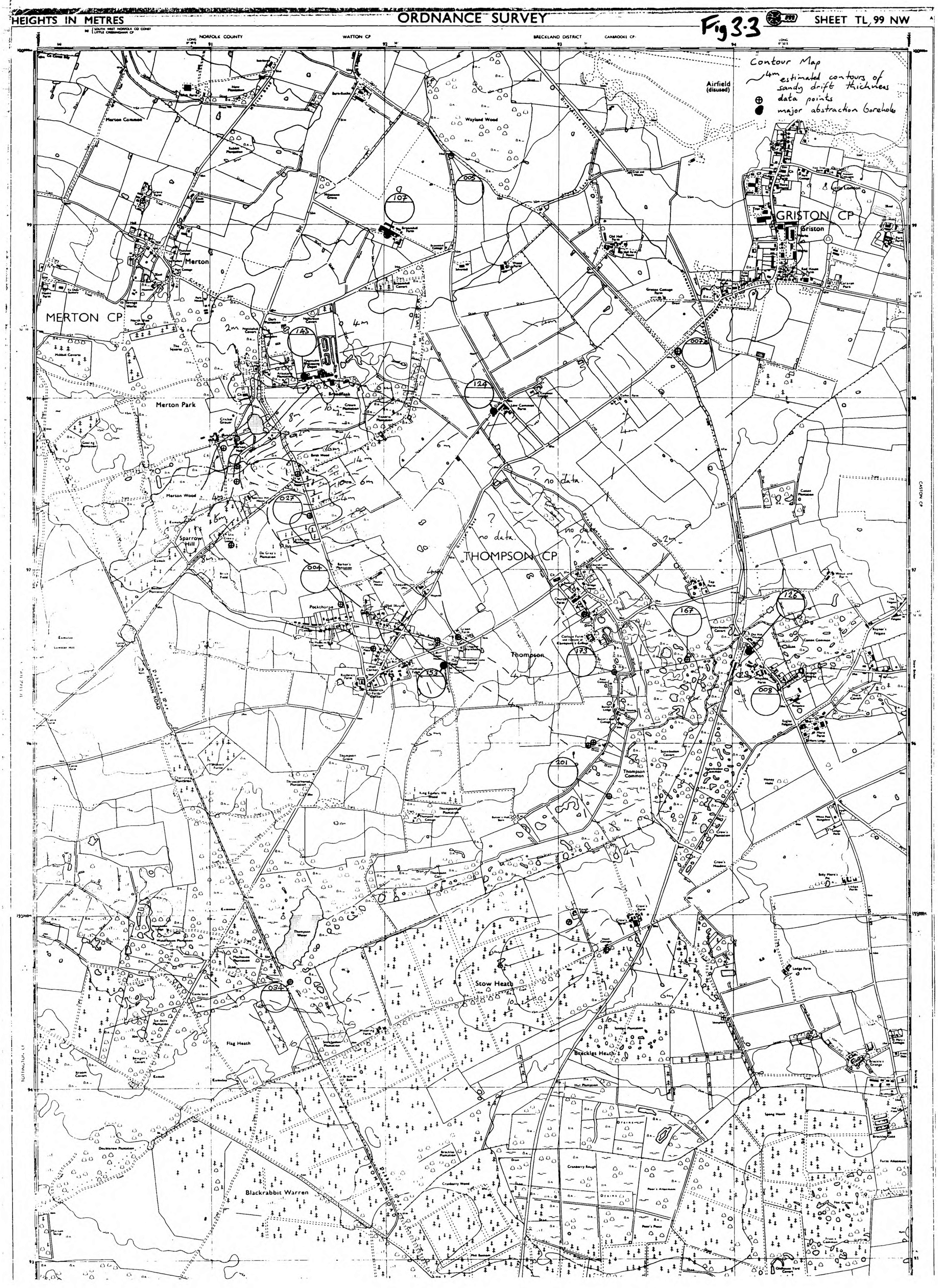
TL 99/166	bhD	9393	9625	**35.66**	> 4.1				??	4.1
TL 99/168	obhD	9365	9644	**36.93**	0.5	> 2.44			??	2.94
TL 99/169	obhD	9346	9643	34.6	> 3.98				??	3.98
TL 99/170	obhD	9296	9561	**33.76**	> 3.54				??	3.54
TL 99/171	obhD	9301	9557	**33.02**	> 3.6				??	3.6
TL 99/172	obhD	9308	9543	**32.74**	> 3.51				??	3.51

Fig 3.2


HEIGHTS IN METRES
ORDNANCE SURVEY
SHEET TL 99 NW
Contour Map
Clay-type drift [estimated thickness]
(ie clay/Marl/Sandy Clay)
Data Points
c = confined uc = unconfined
TL 99/xxx
sandy layer thickness
clay layer thickness
note: ① all units in metres
② contours based on Surfer plot and are estimated only
NORFOLK COUNTY
WATTON CP
BRECKLAND DISTRICT
MERTON CP
GRISTON CP
THOMPSON CP
Merton
Merton Park
Merton Common
Wayland Wood
Griston
Airfield (disused)
Thompson
Stow Heath
Frog Heath
Breckles Heath
Blackrabbit Warren
ROMAN ROAD
NO DATA
NO DATA
NO DATA
NO DATA
NO DATA
NO DATA
005 S: 0.6 CL: 14.6
007 S: 3.4 CL: 10.6
027 S: 1.5 CL: 22.9
004 S: 7.6 CL: 7.2
052 S: 3.9 CL: 0.9
167 S: 0.4 CL: 0.0
173 S: 3 CL: 4
171 S > 3.6
170 S > 3.54
008 no log
032 S1: 1.5 CL: 25.9 S2: 12.2
031 S1: 1.5 CL: 12.2 S2: 10.7
6m
8m
10m
12m
14m
16m
18m
20m
22m
24m
26m


HEIGHTS IN METRES
ORDNANCE SURVEY
Fig 3.3
SHEET TL 99 NW
Contour Map
4m estimated contours of sandy drift thickness
data points
major abstraction boreholes
Airfield (disused)
Merton Common
Wayland Wood
GRISTON CP
Griston
Merton
MERTON CP
Merton Park
Merton Wood
Sparrow Hill
THOMPSON CP
Thompson
Pockthorpe
Thompson Common
Stow Heath
Flag Heath
Breckles Heath
Blackrabbit Warren
Cranberry Wood
no data
005
107
143
124
007
027
004
126
167
173
153
008
201
034
2m
4m
6m
8m
10m
14m
16m