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WATER RESOURCES PLANNING

HYSIM MODEL:
MODELLING THE FLOWS OF THE RIVER DEBEN

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September 1995

DOCUMENT CONTROL SHEET

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CONTENTS

1 Summary 1

2 HYSIM 1

3 Data Requirements 1

3.1 Actual Abstraction Data 2
- 3.1.1 Identification of Licences 2
- 3.1.2 Data Quality 2
- 3.1.3 Future Abstractions 3

3.2 Effluent Return Data 3
- 3.2.1 The Dry Weather Flow Approach 3
- 3.2.2 The Population Approach 4
- 3.2.3 The Approach Used for the Deben 6

3.3 Rainfall Data 6

3.4 Potential Evapotranspiration 7

3.5 Gauged Flows 7

4 Changing to HYSIM Data Format 7

5 Modelling 7
- 5.1 Calibration and Validation of HYSIM 7
- 5.2 Simulation of 'Natural Flows' 8
- 5.3 Simulation Results 8

6 Determination of Environmental Allocation 8

7 Application to Deben Study 8

8 Conclusion 9

Appendices:-

I Licence data, effluent data and actual abstraction data.
II Final parameters defined from calibration exercise.
III Simulation results
IV NRA Interim Refinement of Naturalised Flow Record

MEMORANDUM

NRA

To: see distribution list

From: Andy Turner, Assistant Engineer (Water Resources)

Our Ref: 656/3/6
Your Ref:

Date: 4 September, 1995

Deben Rainfall Runoff Modelling Exercise

Please find the attached modelling report which details the exercise undertaken to refine the naturalisation work carried out by Southern Science in 1994. The work has 3 main outputs:-

- A refined **minimum environmental allocation of 0.084 cumecs** (7.1 Ml/d) which equates to the natural 98th percentile flow.
- Confirmation that spray irrigation abstractions reduce a naturally low flow by a further 33% (at Q95).
- A naturalised flow record.

If you have any queries on the work, or would like further information please feel free to get in touch.

Andy

Andy Turner
Assistant Engineer (Water Resources)

Encs: Modelling Report

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1 Summary

The need to refine the environmental flow requirement of the River Deben was highlighted in the Deben Groundwater Unit Water Resources Management Plan[1]. This had previously been identified by Southern Science[2] as 0.076 cumecs (6.57 Ml/d) based on the velocity and level requirements of key indicator species at three representative locations upstream of the reaches suffering from low flows during dry periods. However, as part of the naturalisation process, spray irrigation abstractions had been distributed evenly over a six month period and groundwater abstractions had not been taken into account at all. The Quality Review Panel of the Southern Science work, recommended that refinements were made to the allocation. Interim refinements[3&4] (see Appendix IV) using monthly abstraction returns for spray irrigation resulted in a reassessed value of 0.088 cumecs (7.6 Ml/d).

This modelling work takes account of the groundwater abstraction in the catchment, and arrives at a minimum environmental allocation of **0.084 cumecs** (7.1 Ml/d). This value is equivalent to the 98th percentile of natural flow at Naunton Hall. It is considered that this is the best current estimate of the flow requirements of the River Deben.

The modelling exercise has also been of use in a) determination of the human impact upon the flows of the Deben (33% of Q95 natural); and b) provision of a naturalised flow record.

This report identifies how HYSIM has been applied to the River Deben, presents the results from modelling and lists the input data utilised.

2 HYSIM

HYSIM is a rainfall/runoff model which uses precipitation and climate data to simulate the movement of moisture both above and below ground. Internally, the model simulates interception storage, runoff from impermeable areas, overland flow, interflow from the upper and lower soil horizons, rapid and slow response from groundwater and the hydraulics of flow in river channels. More detailed descriptions of the model and its application are given by Manley[5 & 6].

3 Data Requirements

In order to simulate the flows of a river, HYSIM has a requirement for several forms of data, these are:-

Groundwater abstractions
Surface water abstractions }
Effluent discharges } Combined to produce net surface water abstraction.
Rainfall
Potential Evapotranspiration
Gauged flows

These are discussed in turn:-

3.1 **Actual Abstraction Data**

The actual abstraction data (and effluent data) used in HYSIM and collated using the following processes are illustrated in Appendix I.

3.1.1 **Identification of Licences**

Actual abstraction returns are provided under Section 201 of the Water Resources Act 1991. Investigation of the actual abstraction data for the Deben highlighted that not all data was present. Further investigation showed that not all licensed abstractors are required to provide the information in a monthly format, not all monthly returns are stored on the abstraction licence database, and most of those falling under these categories are licensed for small quantities only.

A major exercise to put all the historical monthly abstraction data onto the computer mainframe was undertaken in conjunction with the licensing sections at Ipswich and Peterborough and the Data Input section at Peterborough. This involved collating, entering and checking around 20 years worth of data for approximately 60 licences.

All licences within the identified area of study were used in the modelling exercise (previous studies[7] have used the top 95 or 98% of licensed volume).

3.1.2 **Data Quality**

For those licences still not having monthly return data on the abstraction licence database one of the following procedures was followed, in order of preference:

- Monthly returns were entered onto the abstraction licence database if they existed.

or • If monthly returns did not exist, annual returns were used and factored into monthly quantities by using the distribution factors identified in Table 1.

Table 1: Seasonal Distribution Factors Used for Annual Abstraction Data.

Use	J	F	M	A	M	J	J	A	S	O	N	D
P.W.S.	0.8	0.9	1.0	1.1	1.1	1.2	1.2	1.1	1.0	0.9	0.9	0.8
S.Irr.	0.0	0.0	0.0	0.0	2.4	4.0	4.0	1.6	0.0	0.0	0.0	0.0
Agric.	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Domest.	0.8	0.9	1.0	1.1	1.1	1.2	1.2	1.1	1.0	0.9	0.9	0.8
P.W.U.	0.8	0.9	1.0	1.1	1.1	1.2	1.2	1.1	1.0	0.9	0.9	0.8
Indust.	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Source: NRA (1992), Orton Flow Naturalisation[4].

or • For licences without monthly or annual returns, but where data existed for a similar sized licence having the same category of use and source, the following applied:-

The similar licence was examined to determine the percentage of licensed quantity it abstracted (year or month specific, not on average). The same percentage was then applied to the licence quantity (and then the same distribution factors as identified in Table 1 if using annual return data).

The same procedures were applied to any licence having partial information ie., if monthly abstraction return data existed, but a particular year was missing.

Appendix I shows the licences used, and the type of data used for each individual year.

3.1.3 Future Abstractions

The actual abstractions determined for each component of use could be used in conjunction with demand forecasts taken from the Anglian Region Water Resources Strategy, 1994[9] to estimate future actual abstractions within the Deben. However, care should be taken when doing this as year to year variations in actual abstraction would not be shown, when in reality they are of major significance.

The relevant demand forecast can be applied to each component of use, within each subcatchment.

3.2 Effluent Return Data

There are several approaches to the derivation of effluent return data. Two were considered in detail:-

3.2.1 The Dry Weather Flow Approach

This uses dry weather flows (dwf's) from discharge consents multiplied by 0.75 to reflect actual reliable quantities, but will only provide a snapshot. Dry weather flows provide an indication of the reliable flow in "dry weather" (rainfall < 5 mm over a 24 hr period) and do not reflect the short term variations of quantities of effluent returned under actual conditions.

Furthermore, many discharge consents are descriptive (there is no numerical dwf value) where the dwf will be < 0.25 tcmd.

3.2.2 The Population Approach

This approach accounts for the PWS component of effluent returns only and should be used in conjunction with proportions of actual abstraction returned (Table 2).

The population perceived to be in areas contributing effluent to the area of study can be identified from census information on a parish level (used in conjunction with maps of discharge points).

Table 2: Proportion of Abstraction Returned as Effluent

Use	Proportion Returned
Private Water Undertakings/ Domestic	0.90
Industry (General)	0.90
Cooling (Non Consumptive)	0.95
Mineral Washing	0.95
General Agriculture	0.90
Spray Irrigation	0.00

Source: NRA, (1994) Groundwater Balances Review, 1994 Edition.

The population through time is required, therefore parish population such as those contained in Demographic Information Note 5/93[10] (1971,1981 and 1991 parish populations for Norfolk) can be utilised.

The proportion of the population connected to sewage treatment works should be considered if the information is available, and the initial population reduced accordingly.

Per capita consumption figures (Table 3) can then be applied to the population to determine how much water is supplied to the area. Care should be taken to break down gross consumption figures into their components so that leakage or industry can be omitted if required.

The value derived is then factored by 0.9 (Table 2) to allow for PWS and metered industrial consumption, and monthly distribution factors are applied.

Table 3: Per Capita Consumption Figures (l/h/d)

Component of Indigenous Demand	Year									
	1971	1981	1986	1992	1994	1999	2004	2009	2014	2021
Leakage Component	59.1	64.6	64.0	57.0	58.0	56.0	55.0	53.0	51.0	50.0
Metered (Industrial)	76.9	83.9	88.7	96.0	86.0	79.0	77.0	76.0	77.0	78.0
Unmeasured (ie. Domestic)	128.0	139.4	146.3	144.0	149.0	151.0	154.0	158.0	161.0	165.0
Total Per Capita Consumption	264.0	288.0	299.0	297.0	293.0	286.0	286.0	287.0	289.0	293.0

Sources: A.Turner (NRA) Jun,1994; 1992-2021 derived from Regional Water Resources Strategy, 1994.
F.Howard (NRA) Sep,1993; 1971-1986 proportions based on 1983 actuals, ex. Camb Water Plan 1985.

3.2.3 The Approach Used for the Deben

In order to estimate the spatial distribution of effluent returns through time, the parish population approach was adopted for the public water supply component (sewage connection data was unavailable). This was coupled with consumption factors of actual abstraction for other uses as identified in Table 2.

The industrial component in the case of the Deben has been omitted as the catchment has little or no industry. Leakage has not been taken into account either.

3.3 Rainfall Data

Rainfall records from the following stations were used for the periods indicated. Some stations used data from other stations which were linked together to provide a complete record for the period required.

Charsfield	(220391)	1961-1991
Kettleburgh	(220313)	1961-1991
Helmingham Hall	(220022)	1968-1991
Melton St Audry's	(220579)	1961-1991
Kenton	(220165)	1966-1988

Some records were incomplete and required 'infilling' a process whereby a relationship is identified between two rainfall stations and applied to produce generated values.

The relationships identified are stated below:-

Charsfield	1:0.989	Melton
Charsfield	1:1.009	Kenton
Charsfield	1:1.027	Helmingham
Helmingham	1:0.969	Kettleburgh
Charsfield	1:1.238	Kettleburgh

(NB. Differences in ratios are due to non common periods of comparison)

The individual rainfall files were then merged to produce a catchment rainfall file using the weighted average method. The weightings applied were:-

Charsfield	0.1574
Kettleburgh	0.2329
Helmingham	0.2619
Melton	0.0613
Kenton	0.2864

The catchment rainfall file was then compared against the record for Sandringham (201056) in a double mass plot (Figure 1) to assess the consistency of the record through time. No changes or adjustments were considered necessary.

3.4 Potential Evapotranspiration

The potential evapotranspiration for the period 1961 to 1990 for grass was estimated from the Meteorological Office Rainfall and Evaporation Calculating System (MORECS) for square number 142.

3.5 Gauged Flows

The gauged flows for the River Deben at Naunton Hall gauging station (No. 034002) were downloaded from the NRA flow processing system for the period 1961-1990.

4 Changing to HYSIM Data Format

In order to convert the collated data into a format suitable for use within HYSIM, a facility exists within the model whereby a template can be constructed to 'filter' any unwanted headings, footers and summary values. A file can then be converted. Options exist for using daily, weekly or monthly data. This offers extreme flexibility in the modelling process and dispenses with the requirement to write data conversion programs (although the option to use these still exists).

Templates can be saved to aid the user in future modelling exercises. For example, rainfall data comes in a standard structure from NRA archives which can then be converted into HYSIM format by using a pre-prepared template.

Once all the files containing the relevant hydrological and abstraction/effluent data have been generated they are combined within HYSIM to form one catchment data file.

5 Modelling

5.1 Calibration and Validation of HYSIM

The model was calibrated to the 1980-1985 period using all the optimization routines within HYSIM, plus 'tweaking' individual parameter values. Around 30 model runs were undertaken before the point of diminishing returns was reached, and a further 15 runs taken to fine tune the model, and validate it. Validation was undertaken on several periods (1971-90, 1971-80 and 1980-90). The final parameter values are listed in Appendix II.

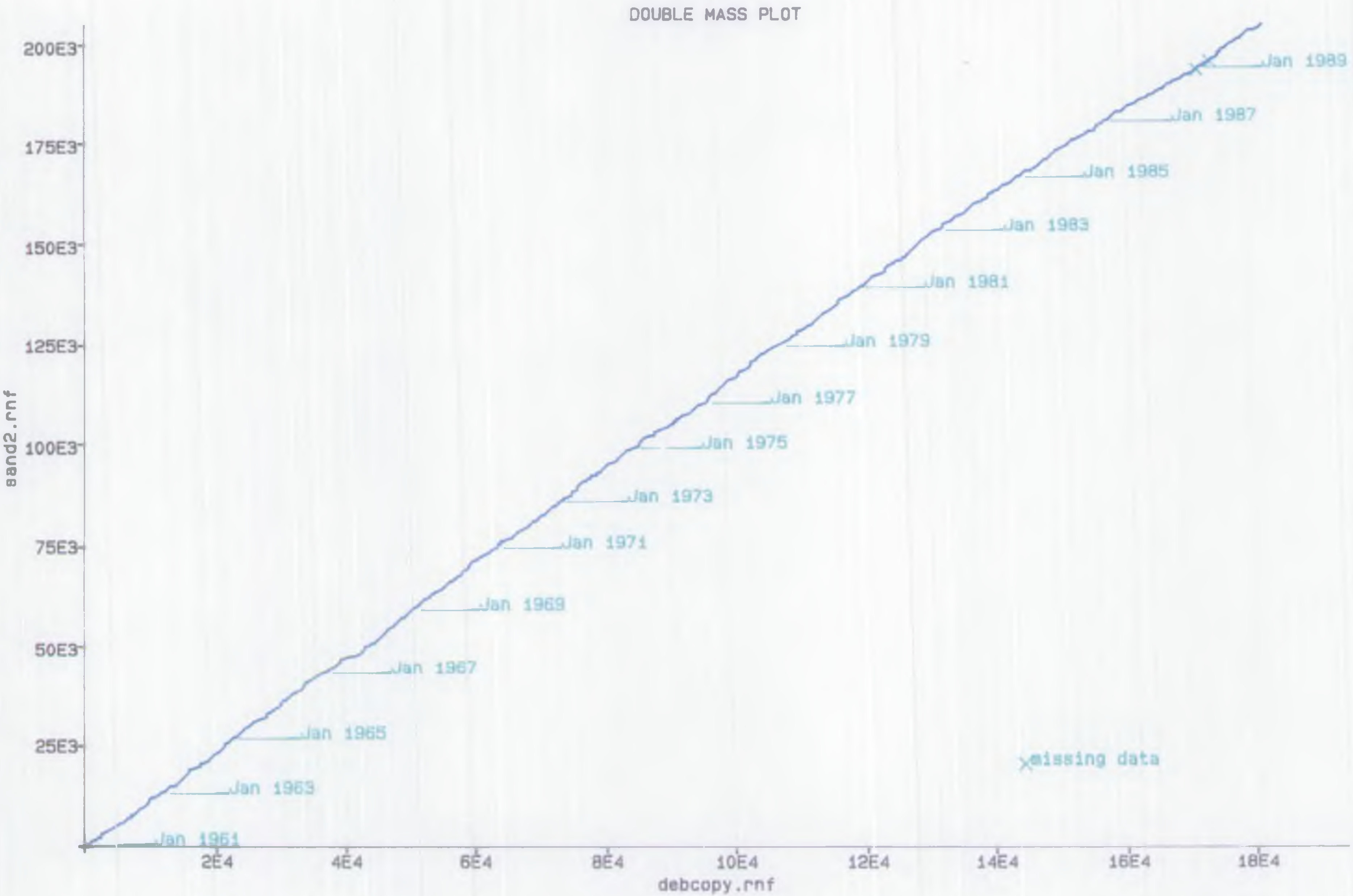
DOUBLE MASS PLOT
200E3
175E3
150E3
125E3
100E3
75E3
50E3
25E3
sand2.rnf
2E4
4E4
6E4
8E4
10E4
12E4
14E4
16E4
18E4
debcopy.rnf
Jan 1961
Jan 1963
Jan 1965
Jan 1967
Jan 1969
Jan 1971
Jan 1973
Jan 1975
Jan 1977
Jan 1979
Jan 1981
Jan 1983
Jan 1985
Jan 1987
Jan 1989
missing data

Figure 1

5.2 Simulation of 'Natural Flows'

Simulation of the natural flows for the period 1971-1990 was undertaken by modelling flows with the abstraction and effluent data sets removed, therefore calculating so called 'natural conditions'.

5.3 Simulation Results

Flow duration curves of simulated historical, simulated natural and gauged flows were plotted and tabulated (Appendix III) in order to assess the effectiveness of the modelling exercise.

The simulated historical and gauged flows were similar to a reasonable degree. This is backed up by the statistical evidence presented in Appendix II.

6 Determination of Environmental Allocation

The minimum environmental requirement of the River Deben has been calculated to be the 98th percentile of the naturalised flow at Naunton Hall (Q98 nat), following the work undertaken by Southern Science, and the NRA refinement to that work (Appendix IV). This report enables the identification of Q98 natural at Naunton Hall following the modelling exercise. The new minimum environmental requirement to be identified as **0.084 cumecs** (7.1 tcmd).

7 Application to Deben Study

HYSIM was used to refine the minimum volume of water to be allocated to the River Deben for environmental purposes as calculated by Southern Science This value will also be of use for the following:-

- refining the environmental allocation in the future as an understanding of the flow requirements of rivers is developed.
- refinement of the groundwater resource balance of the Deben, and hence licensing policy in the catchment.
- determination of control rules for river augmentation of the Deben from the Earl Soham borehole.
- post project appraisal of the Deben ALF scheme
- future environmental assessment studies.

8 Conclusion

The modelling exercise supports the view that ground and surface water abstractions within the catchment have a significant effect on low flows in the Deben, with a 33% reduction of natural 95 percentile flows due to human influences for the period 1970-1990. This does not necessarily reflect the peak impacts of abstraction on a daily basis, which are likely to be much higher.

This work represents the best current estimate of the effect of abstractions and effluents on the flows of the River Deben at Naunton Hall. However, a degree of caution should be exercised due to the following:

- The data collection and modelling exercise has utilised all existing actual abstraction data for the Deben and therefore high confidence levels exist for both gross groundwater and gross surface water abstractions. However, there may be inaccuracies with effluent data as sewage connections, the leakage component to groundwater and the metered industrial per capita consumption components have not been taken into account.

- HYSIM is a lumped model and as such has inherent drawbacks in that the whole of the catchment is assumed to behave in a uniform manner. The Deben is complex hydrogeologically and this may be an over simplification. Furthermore, because of the calibration process involved, it is possible to simulate flows satisfactorily for differing data sets by "tweaking" different parameters.

- Catchment characteristics can change with time (eg land use), whereas the calibration settings once chosen are static, this adds to potential error in results.

Nevertheless, with the limitations of both HYSIM and the data it uses, HYSIM produces a reasonable estimate of the human impact on flows in the Deben.

REFERENCES

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5. Manley, R.E. (1993). HYSIM - User Guide.

6. Manley, R.E. (1993) HYSIM - Reference Manual

7. Hillier,R.J. & Turner,A.P., NRA (Anglian Region) Hysim Model: Modelling the Flows of the River Nar.

8. NRA (1992) Orton Flow Naturalisation.

9. NRA (1994). Water Resources in Anglia. Anglian Region Water Resources Strategy.

10. Norfolk County Council (1993) Demographic Information Note 5/93.

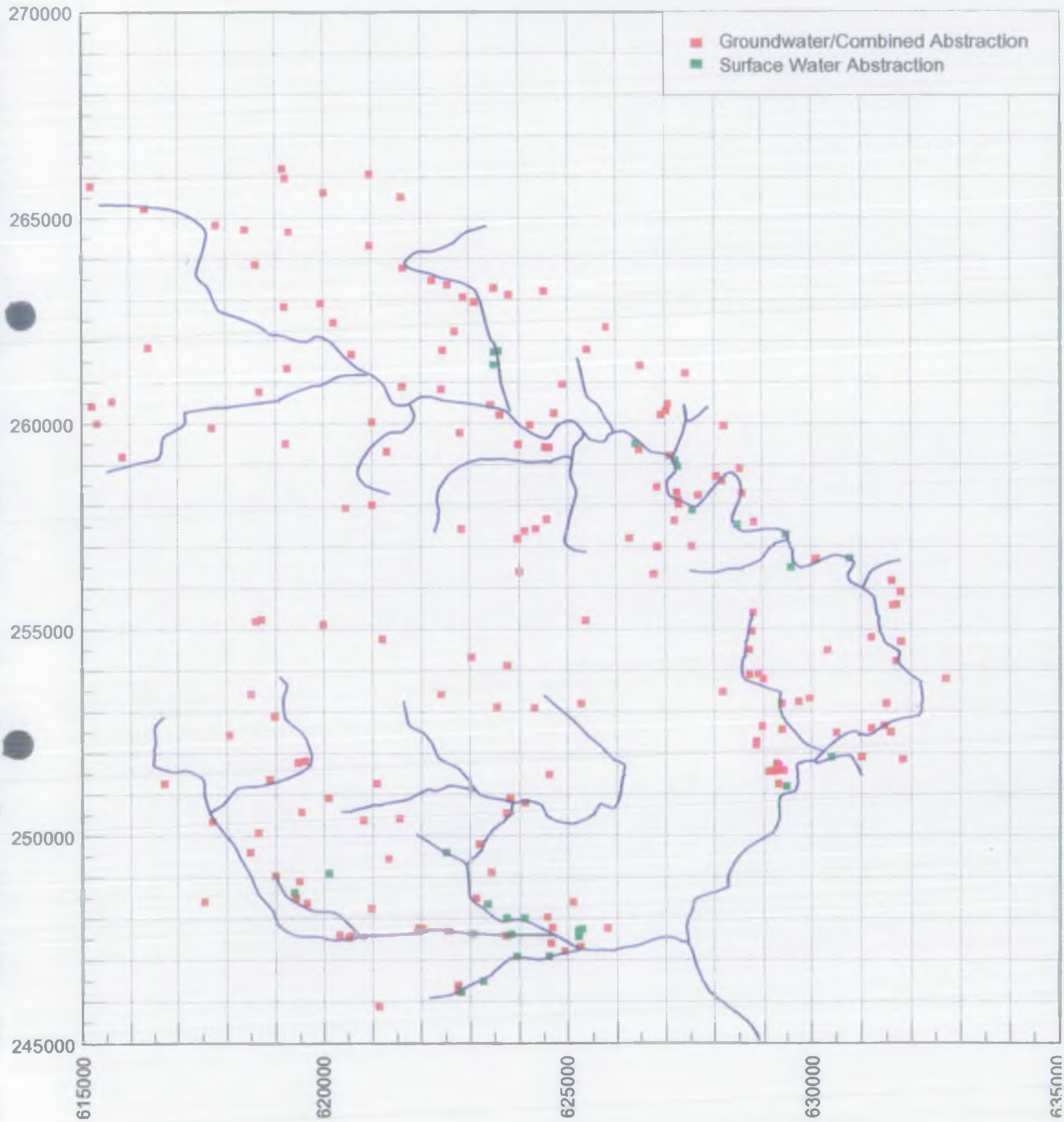
APPENDIX I

Licence Data
Abstraction & Effluent Data

APPENDIX II

Final parameters defined from calibration exercise.

Location of Abstraction Licences in the Deben Groundwater Unit



DEBEN RAINFALL RUNOFF MODELLING: DATA PREPARATION PHASE - ACTUAL ABSTRACTIONS

Licence no. & Site		tcma	Use	Source	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93
7/35/06/*g/001	1	4.90	AG	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
7/35/06/*g/002	1	68.10	SI	G	M	M	M	M	M	M	M	M	M	A	M	M	M	M	M	M	M	M	A	M	M	M	M	M
7/35/06/*g/003	1	8.30	AG	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	‖‖‖	‖‖‖	‖‖‖	‖‖‖
7/35/06/*g/004	1	1.60	AG	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
7/35/06/*g/005	1	9.00	PWU	G	G	G	G	G	G	G	G	G	G	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
7/35/06/*g/006	1	5.80	AG	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
7/35/06/*g/007	1	1.40	AG	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
7/35/06/*g/008	2	4.50	AG	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
7/35/06/*g/009	1	1.40	AG	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
7/35/06/*g/010	1	.80	AG	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
7/35/06/*g/011	1	2.20	AG	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
7/35/06/*g/012	1	3.30	AG	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
7/35/06/*g/013	1	4.50	AG	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
7/35/06/*g/014	1	.90	AG	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
7/35/06/*g/015	1	3.40	AG	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
7/35/06/*g/016	1	3.30	AG	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
7/35/06/*g/017	1	3.30	AG	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
7/35/06/*g/018	1	2.40	AG	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
7/35/06/*g/019	1	.40	AG	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
7/35/06/*g/020	1	.80	AG	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
7/35/06/*g/021	WL	4.55	AG	G	G	G	G	G	G	G	G	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
7/35/06/*g/022	1	1.60	AG	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
7/35/06/*g/023	1	5.60	AG	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
7/35/06/*g/024	1	4.10	AG	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
7/35/06/*g/025	1	1.60	AG	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
7/35/06/*g/026	1	1.60	AG	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
7/35/06/*g/027	1	1.60	AG	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
7/35/06/*g/028	1	1.60	AG	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
7/35/06/*g/029	1	.40	AG	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G

‖‖‖ Non current licence
AAAAAAAAA Annual returns exist
MMMMMMMMM Monthly returns exist
GGGGGGGGG Generated data required

Licence no. & Site		tcma	Use	Source	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93
7/35/06/*g/030	1	1.10	AG	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
7/35/06/*g/032	1	.30	AG	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
7/35/06/*g/033	1	3.30	AG	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
7/35/06/*g/034	1	.80	AG	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
7/35/06/*g/035	1	.60	AG	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
7/35/06/*g/036	1	.80	AG	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
7/35/06/*g/037	1	3.30	AG	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
7/35/06/*g/038	1	1.60	AG	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
7/35/06/*g/039	1	1.60	AG	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
7/35/06/*g/040	1	1.60	AG	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
7/35/06/*g/041	1	4.50	AG	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
7/35/06/*g/042	1	.80	AG	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
7/35/06/**/043	WL	22.70	SI	G	M	M	M	M	M	M	M	M	M	M	M	M	G	M	M	M	M	M	M	M	M	M	M	M
7/35/06/*g/044	1	5.70	SI	G	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
7/35/06/*g/045	1	.80	AG	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
7/35/06/*g/046	2	18.10	ASI	G	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
7/35/06/*g/046	3	50.00	SI	G	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
7/35/06/*g/047	1	2.20	AG	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
7/35/06/*g/048	2	4.30	PWU	G	G	G	G	G	G	G	G	G	G	G														
7/35/06/*g/048	3	9.30	AG	G	G	G	G	G	G	G	G	G	G	G														
7/35/06/*g/049	1	2.70	AG	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
7/35/06/*g/050	1	2.70	AG	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
7/35/06/*g/051	1	1.80	AG	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
7/35/06/*g/052	1	.60	AG	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
7/35/06/*g/054	1	22.70	SI	G	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
7/35/06/*g/055	1	1.60	AG	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
7/35/06/*g/056	1	61.80	SI	G	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
7/35/06/*g/057	1	5.50	AG	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G					
7/35/06/*g/057	2	27.30	SI	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G					

Non current licence
AAAAAAAAA Annual returns exist
MMMMMMMMM Monthly returns exist
GGGGGGGGG Generated data required

Licence no. & Sito		tcma	Use	Source	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93
7/35/06/*g/058	1	2.27	AG	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
7/35/06/*g/059	1	4.60	SI	G																								
7/35/06/**/060	1	69.90	SI	S	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
7/35/06/**/061	WL	38.10	SI	S	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
7/35/06/*s/062	1	150.00	SI	S	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
7/35/06/*s/063	1	7.20	SI	S	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	G	M	M
7/35/06/*s/064	1	36.30	SI	S	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
7/35/06/**/065	1	2.70	SI	S	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
7/35/06/*s/066	1	31.70	SI	S	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
7/35/06/**/067	WL	125.00	SI	S	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
7/35/06/**/068	WL	113.60	SI		EXCLUDE																							
7/35/06/*g/069	1	2.70	AG	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
7/35/06/*g/070	1	3.30	AG	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
7/35/06/*g/071	1	.80	AG	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
7/35/06/*g/072	1	8.10	AG	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G			
7/35/06/*g/072	2	8.10	AG	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G			
7/35/06/**/073	1	4.10	AG	S	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
7/35/06/**/073	2	45.00	SI	S	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
7/35/06/*g/074	2	20.40	SI	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
7/35/06/*g/074	1	2.20	AG	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
7/35/06/*s/075	WL	2.20	SI	S	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
7/35/06/*g/076	1	36.30	SI	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
7/35/06/*g/077	1	9.00	SI	G		G	G	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	M	M	M
7/35/06/*g/078	1	163.60	SI	G		M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	A	M	M	M	M	M	M
7/35/06/*g/079	WL	124.13	SI	G	Exclude																							
7/35/06/*g/080	1	4.50	AG	G					G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
7/35/06/*g/081	1	4.50	ASI	G					G	G	G	G	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
7/35/06/*g/081	2	40.90	SI	G					G	G	G	G	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M

	Non current licence
AAAAAAAAA	Annual returns exist
MMMMMMMMM	Monthly returns exist
GGGGGGGGG	Generated data required

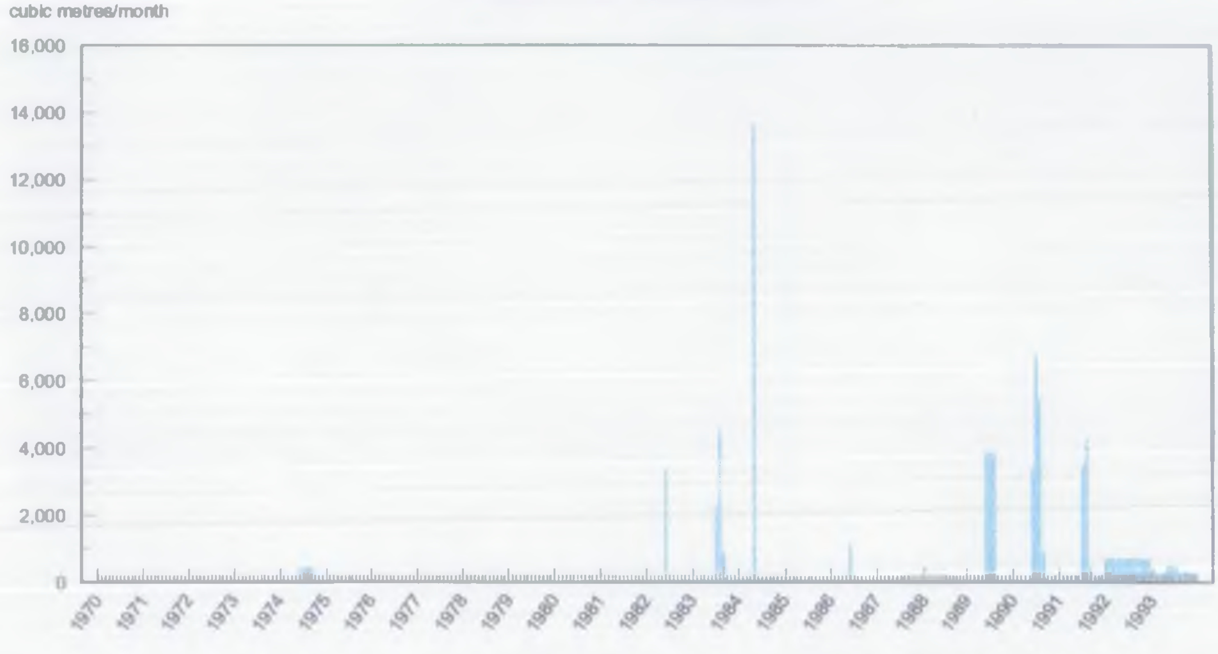
DEBEN RAINFALL RUNOFF MODELLING: DATA PREPARATION PHASE - ACTUAL ABSTRACTIONS

Licence no. & Site		tcma	Use	Source	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93
7/35/06/*g/082	1	3.30	AG	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
7/35/06/*g/083	1	9.00	SI	G						G	G	A	G	G	G	G	G	G	M	M	M	M	M	M	M	M	M	M
7/35/06/*g/084	1	2.60	SI	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
7/35/06/*s/085	1	24.00	SI	S										M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
7/35/06/*g/086	1	1.80	AG	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
7/35/06/*g/087	1	.90	AG	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
7/35/06/*g/088	1	72.70	SI	G										M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
7/35/06/*g/089	WL	45.40	SI	G													M	M	M	M	M	M	M	M	M	M	M	M
7/35/06/*g/090	1	2.30	SI	G														M	M	M	M	M	M	M	M	M	M	M
7/35/06/*g/091	1	68.20	SI	G															M	M	M	M	M	M	M	M	M	M
7/35/06/*g/092	1	23.00	SI	G																	M	M	M	M	M	M	M	M
7/35/06/*g/093	1	90.70	SI	G																		A	M	M	M	M	M	M
7/35/06/*g/094	1	20.50	SI	G																		A	M	M	M	M	M	M
7/35/06/*s/095	WL	45.50	SI	S																				M	M	M	M	M
7/35/06/*g/096	1	.50	PWU	G.																				G	G	G	G	G
7/35/06/*g/097	1	64.32	SI	G																					M	M	M	M
7/35/06/**/098	4	2.70	SI	S																						M	M	M
7/35/06/*g/099	1	7.32	PWU	G																						G	G	G
7/35/06/*g/100	1	7.32	AG	G																			G	G	G	G	G	M
7/35/06/*g/101	1	7.32	AG	G																			G	G	G	M	M	M
7/35/06/*g/102	1	60.00	SI	G																							M	M
7/35/06/*g/103	1	7.30	AG	G																							M	A
7/35/06/*g/106	1	18.18	SI	G																								
7/35/06/*g/107	1	27.27	SI	G																								M

	Non current licence
AAAAAAAAA	Annual returns exist
MMMMMMMMM	Monthly returns exist
GGGGGGGGG	Generated data required

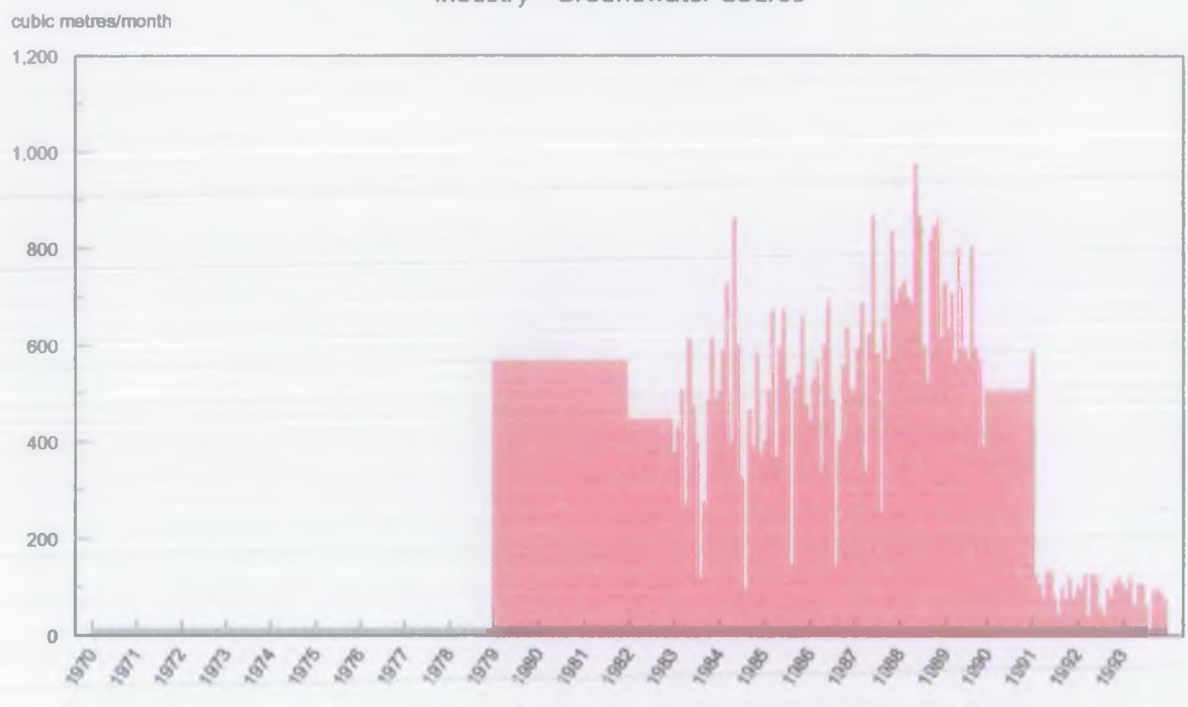
Actual Abstraction Data:

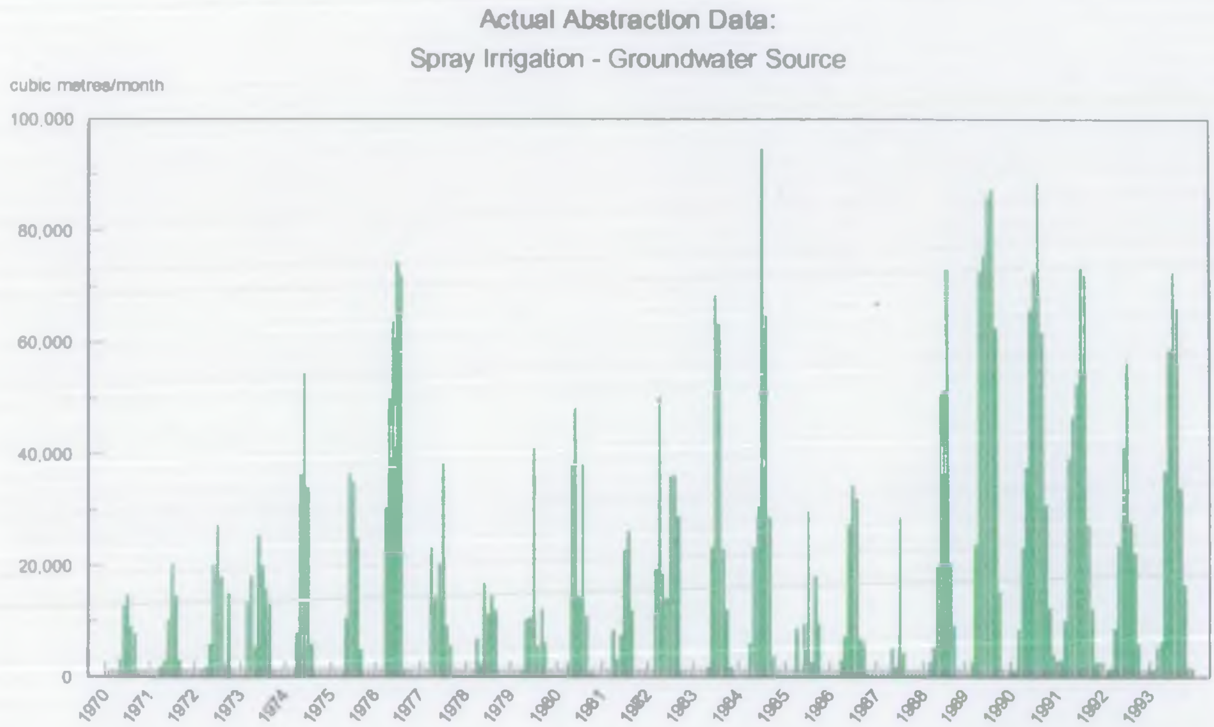
Agriculture - Groundwater Source

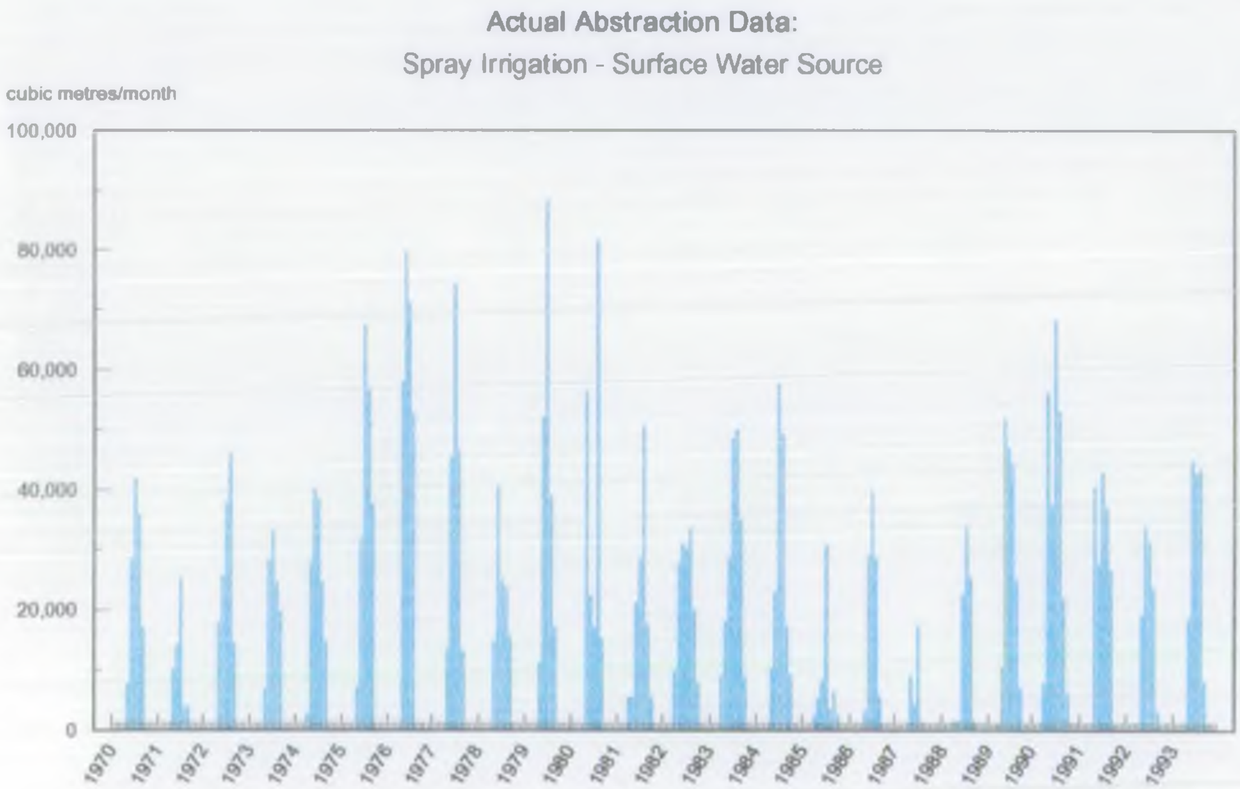


Actual Abstraction Data:

Industry - Groundwater Source

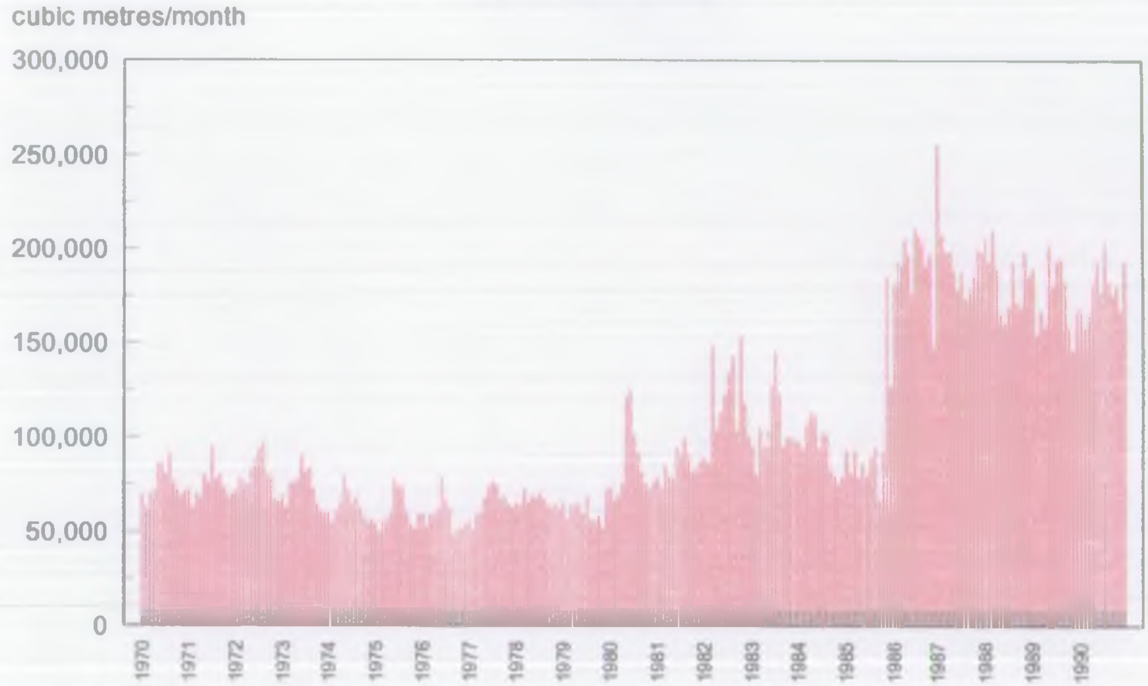


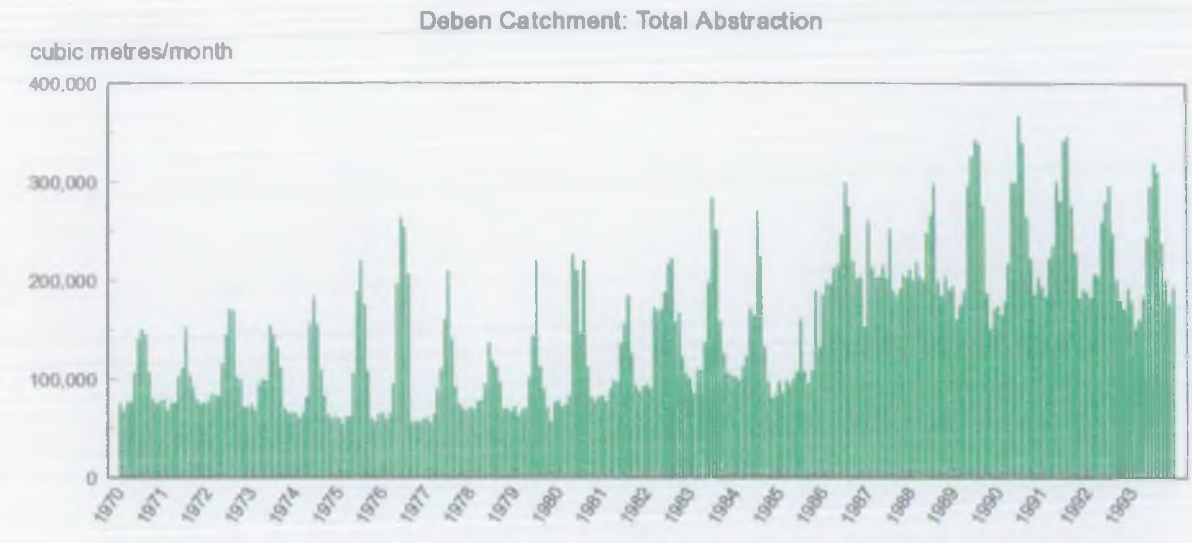

Actual Abstraction Data:
Spray Irrigation - Groundwater Source
cubic metres/month
100,000
80,000
60,000
40,000
20,000
0
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993

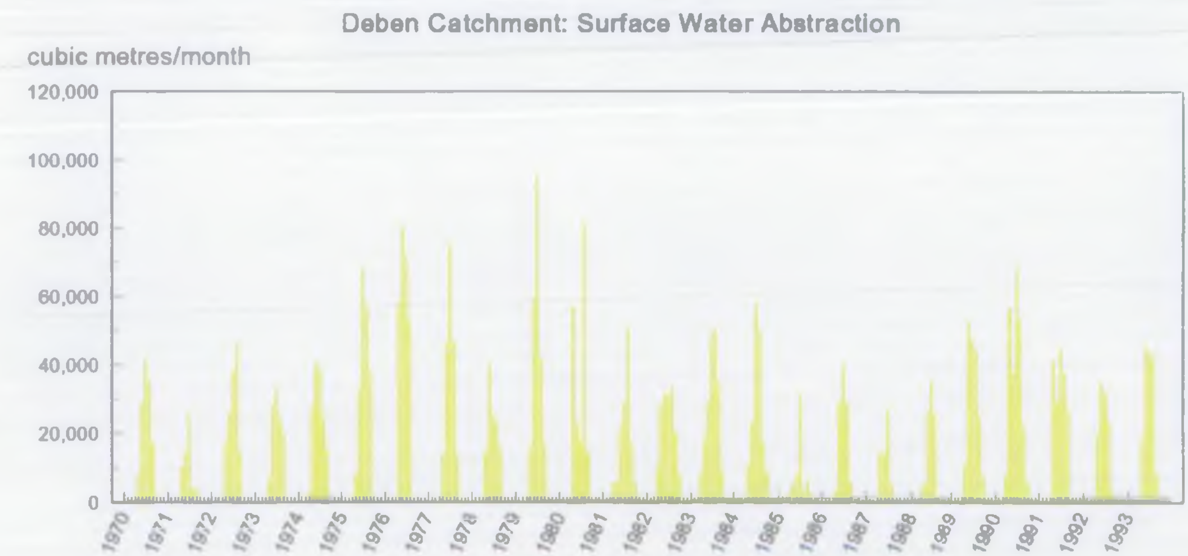

Actual Abstraction Data:
Spray Irrigation - Surface Water Source
cubic metres/month
100,000
80,000
60,000
40,000
20,000
0
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993

Actual Abstraction Data:

Public Water Supply




Deben Catchment: Total Abstraction
cubic metres/month
400,000
300,000
200,000
100,000
0
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993


Deben Catchment: Surface Water Abstraction
cubic metres/month
120,000
100,000
80,000
60,000
40,000
20,000
0
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
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1984
1985
1986
1987
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1989
1990
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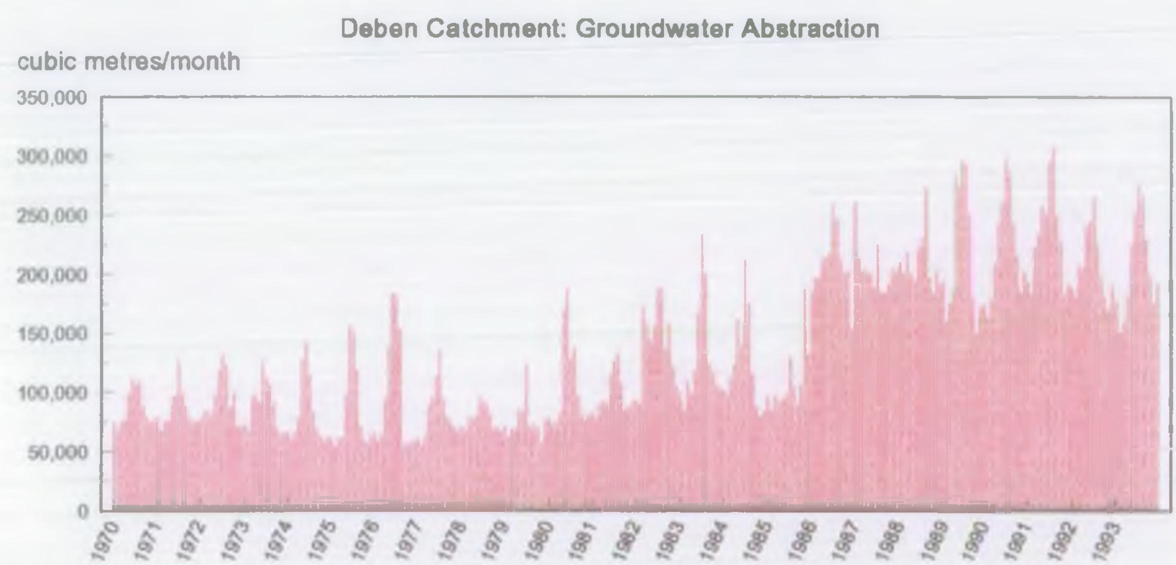
Deben Catchment: Groundwater Abstraction
cubic metres/month
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
1970
1971
1972
1973
1974
1975
1976
1977
1978
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1980
1981
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1984
1985
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1987
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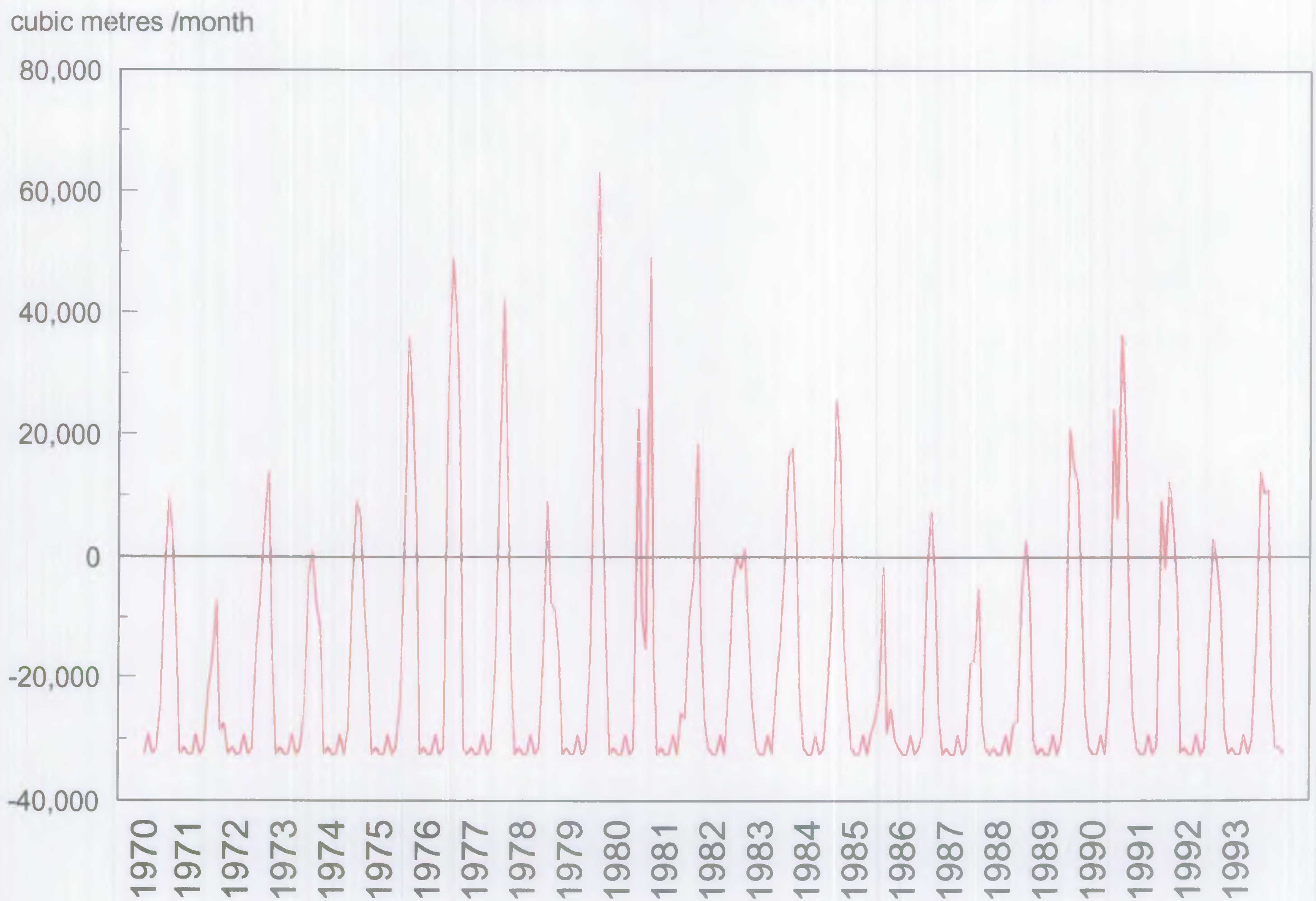
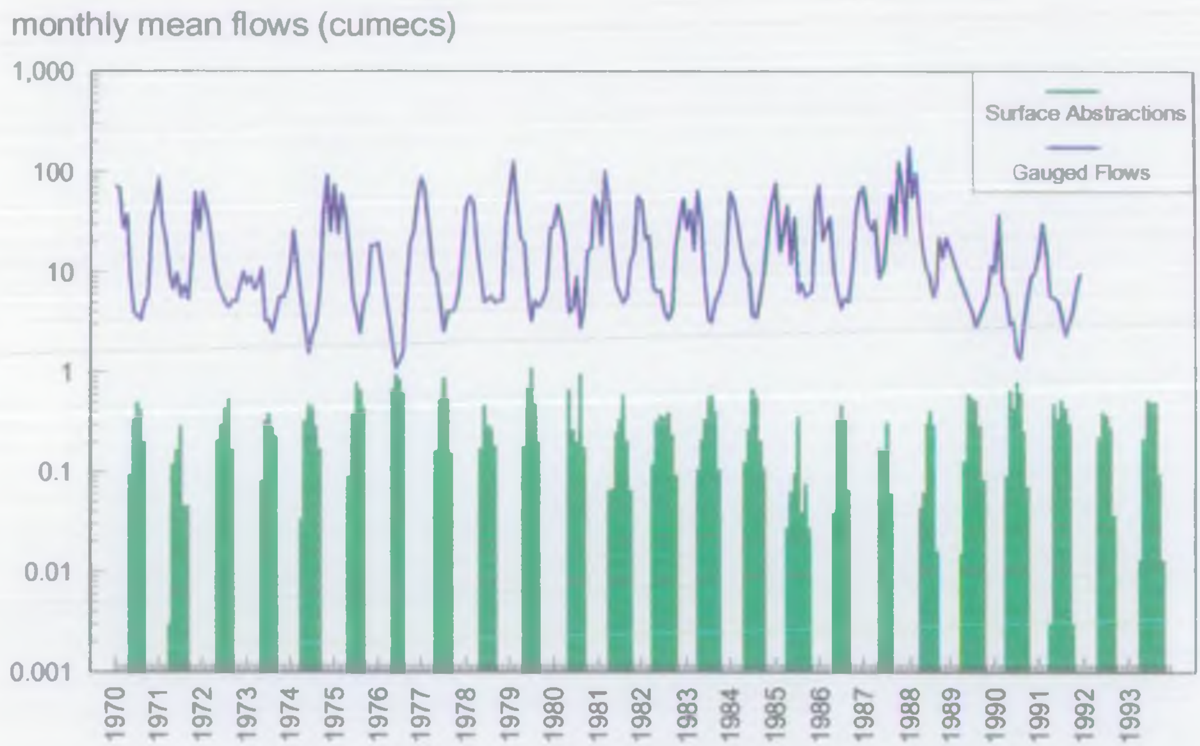
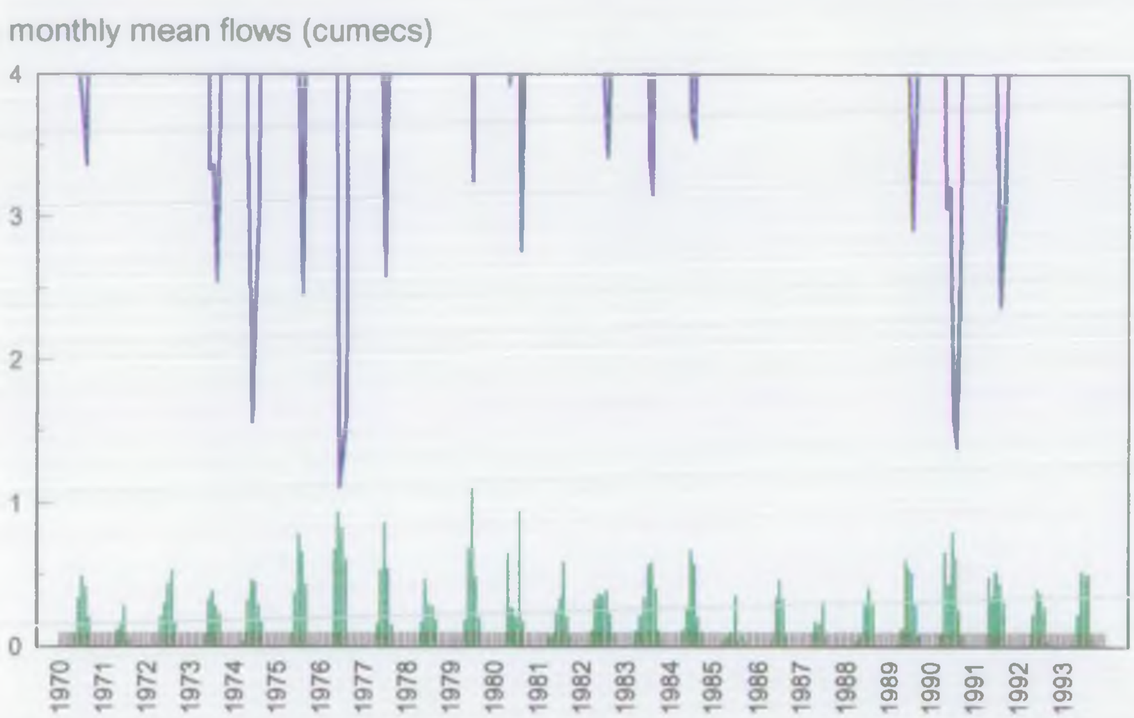
1989
1990
1991
1992
1993

River Deben Modelling: Net Surface Abstractions



Deben Catchment:
Comparison of Gauged Flows and Surface Abstractions





Appendix II ~~and~~.
Final parameters defined from calibration exercise
and.

APPENDIX III

Simulation Results

Final parameters for model run 35; statistics based on 1980-85 period; validation against 1971-90, 1971-80 and 1980-90 periods respectively.

Parameter	*Final Value*	*Parameter*	*Final Value*
Interception storage (mm)	1	Pore size distribution index	0.1
Impermeable proportion	0.04	Interflow - upper horizon	22.6
Time to peak (hrs)	9	Interflow - lower horizon	3.9
Total soil moisture (mm)	300	Precipitation correction factor	1.05
Proportion - upper horizon	0.52	PET correction factor	0.9
Porosity	0.5	PET factor from interception storage.	1
Permeability - top of upper horizon (mm/hr)	1000	Snow correction factor	1.5
Permeability - base of lower horizon (mm/hr)	5.2	Catchment area	163.1
Permeability - horizon boundary (mm/hr)	20	Ratio of groundwater to surface water area	1
Bubbling pressure (mm)	200	Proportion of catchment with no groundwater	0
Transitional groundwater recession ratio	0.26	Proportion of runoff from transitional groundwater	0
Groundwater recession ratio	0.99		

Gauged Values		*Simulated Values*	
Daily Values:		*Daily Values:*	
mean flow (cumecs)	0.727	mean flow (cumecs)	0.759
standard deviation	1.507	standard deviation	1.292
Monthly Values:		*Monthly Values:*	
mean flow (cumecs)	0.734	mean flow (cumecs)	0.767
standard deviation	0.856	standard deviation	0.845

Statistical Comparisons			
Daily correlation coefficient.	0.843	Daily "efficiency"	80 %
Monthly correlation coefficient.	0.943	Monthly "efficiency"	89 %

Simulated historic flows

flow(cumecs)	perc > flow	num in class	cum total
17.630	.000	0	0
14.499	.026	2	2
11.924	.104	6	8
9.807	.300	15	23
8.065	.482	14	37
6.633	.834	27	64
5.455	1.356	40	104
4.486	1.943	45	149
3.690	3.090	88	237
3.034	4.563	113	350
2.496	6.584	155	505
2.052	8.905	178	683
1.688	11.904	230	913
1.388	15.137	248	1161
1.142	18.814	282	1443
.939	22.973	319	1762
.772	26.897	301	2063
.635	31.525	355	2418
.522	35.867	333	2751
.430	40.978	392	3143
.353	45.111	317	3460
.291	49.374	327	3787
.239	53.990	354	4141
.196	58.214	324	4465
.162	61.851	279	4744
.133	66.023	320	5064
.109	73.664	586	5650
.090	82.477	676	6326
.074	88.344	450	6776
.061	94.993	510	7286
.050	98.383	260	7546
<= .050	100.000	124	7670

Analysis from 1 1970 to 12 1990
used 7670 values (of which 0 missing, 0 above upper limit).
Complete year used

Mean flow = .745 cumecs

Q 5. percentile = 2.918 cumecs
Q10. percentile = 1.919 cumecs
Q20. percentile = 1.084 cumecs
Q25. percentile = .853 cumecs
Q30. percentile = .680 cumecs
Q40. percentile = .447 cumecs
Q50. percentile = .284 cumecs
Q60. percentile = .179 cumecs
Q70. percentile = .121 cumecs
Q75. percentile = .106 cumecs
Q80. percentile = .095 cumecs
Q90. percentile = .071 cumecs
Q95. percentile = .061 cumecs

Minimum flow: .050
Maximum flow: 17.630

Simulated natural flows

flow(cumecs)	perc > flow	num in class	cum total
17.660	.000	0	0
14.752	.026	2	2
12.323	.104	6	8
10.294	.222	9	17
8.599	.443	17	34
7.184	.704	20	54
6.001	1.056	27	81
5.013	1.578	40	121
4.187	2.229	50	171
3.498	3.481	96	267
2.922	5.033	119	386
2.441	6.871	141	527
2.039	9.192	178	705
1.703	11.877	206	911
1.423	14.824	226	1137
1.189	18.240	262	1399
.993	22.138	299	1698
.829	26.141	307	2005
.693	30.000	296	2301
.579	34.576	351	2652
.483	38.748	320	2972
.404	43.286	348	3320
.337	47.888	353	3673
.282	51.799	300	3973
.235	56.010	323	4296
.197	60.508	345	4641
.164	64.472	304	4945
.137	70.404	455	5400
.115	76.258	449	5849
.096	92.881	1275	7124
.080	99.713	524	7648
<= .080	100.000	22	7670

Analysis from 1 1970 to 12 1990
used 7670 values (of which 0 missing, 0 above upper limit).
Complete year used

Mean flow = .764 cumecs

Q 5. percentile = 2.934 cumecs
Q10. percentile = 1.938 cumecs
Q20. percentile = 1.100 cumecs
Q25. percentile = .876 cumecs
Q30. percentile = .693 cumecs
Q40. percentile = .462 cumecs
Q50. percentile = .307 cumecs
Q60. percentile = .201 cumecs
Q70. percentile = .139 cumecs
Q75. percentile = .120 cumecs
Q80. percentile = .110 cumecs
Q90. percentile = .099 cumecs
Q95. percentile = .091 cumecs

Minimum flow: .080
Maximum flow: 17.660

gauged flows.

GD NAUNTON HALL 035002 TM3220 5340

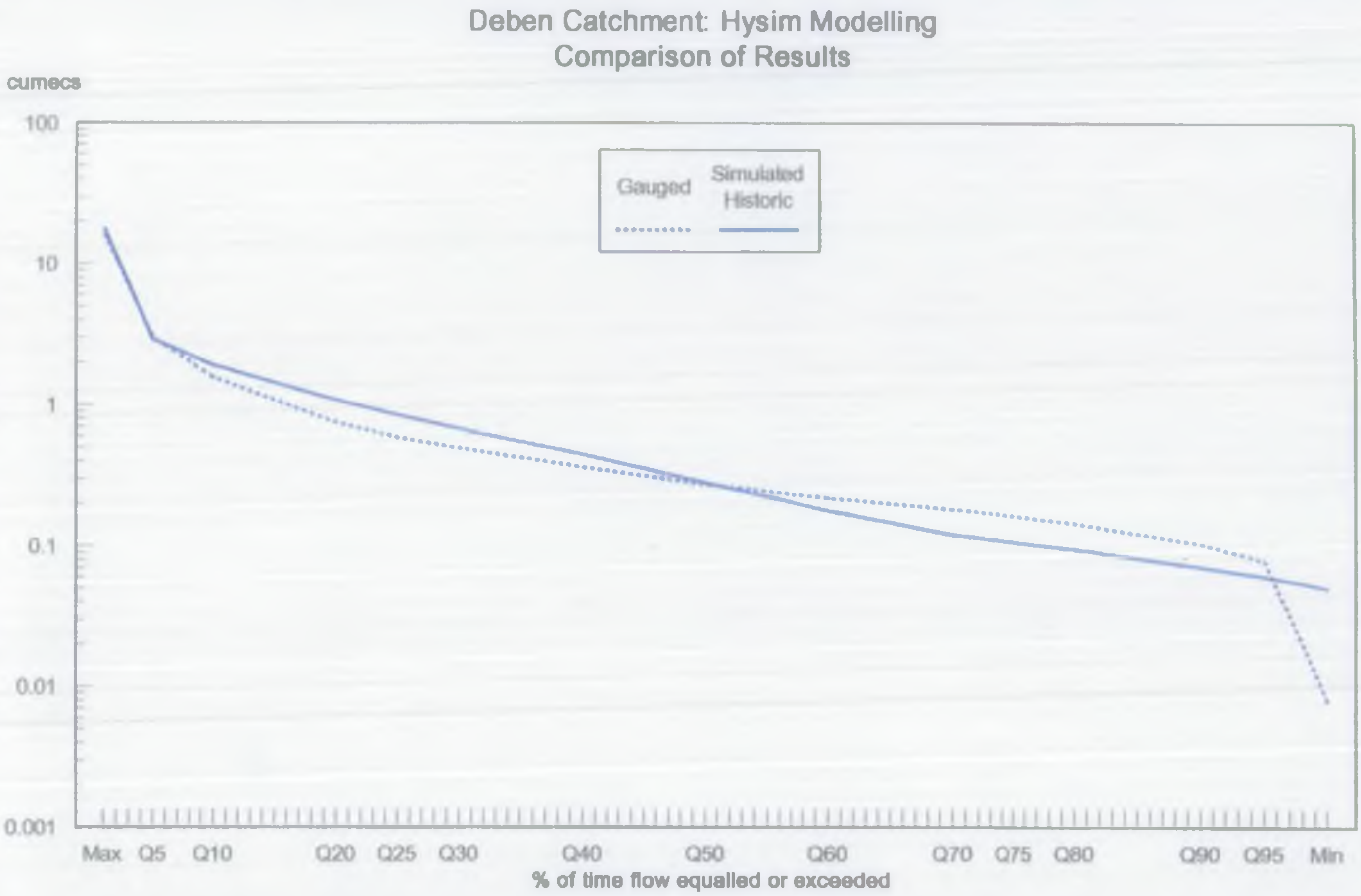
flow(cumecs)	perc > flow	num in class	cum total
16.403	.000	0	0
12.721	.311	23	23
9.866	.541	17	40
7.651	1.231	51	91
5.934	1.989	56	147
4.602	2.991	74	221
3.569	4.087	81	302
2.768	5.386	96	398
2.147	7.199	134	532
1.665	9.269	153	685
1.291	12.179	215	900
1.001	15.142	219	1119
.777	19.310	308	1427
.602	24.290	368	1795
.467	31.380	524	2319
.362	40.176	650	2969
.281	48.931	647	3616
.218	60.162	830	4446
.169	73.681	999	5445
.131	83.532	728	6173
.102	90.257	497	6670
.079	95.020	352	7022
.061	97.442	179	7201
.047	98.349	67	7268
.037	98.904	41	7309
.029	99.256	26	7335
.022	99.445	14	7349
.017	99.729	21	7370
.013	99.811	6	7376
.010	99.919	8	7384
.008	99.959	3	7387
<= .008	100.000	3	7390

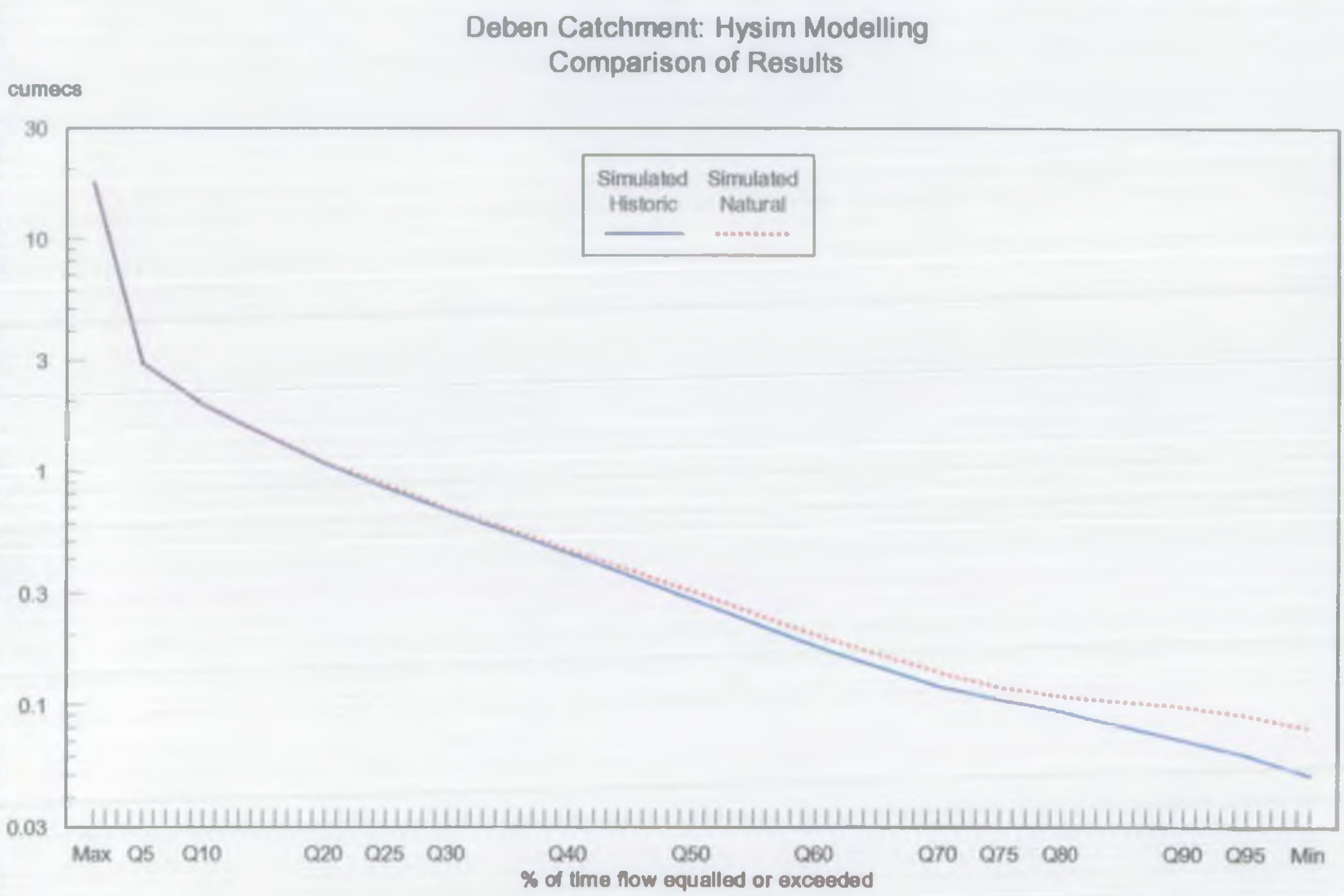
Analysis from 1 1970 to 12 1990
used 7670 values (of which 280 missing, 0 above upper limit).
Complete year used

Mean flow = .734 cumecs

Q 5. percentile = 3.006 cumecs
Q10. percentile = 1.571 cumecs
Q20. percentile = .752 cumecs
Q25. percentile = .589 cumecs
Q30. percentile = .493 cumecs
Q40. percentile = .364 cumecs
Q50. percentile = .275 cumecs
Q60. percentile = .219 cumecs
Q70. percentile = .182 cumecs
Q75. percentile = .164 cumecs
Q80. percentile = .145 cumecs
Q90. percentile = .103 cumecs
Q95. percentile = .079 cumecs

Minimum flow: .008
Maximum flow: 16.403


Deben Catchment: Hysim Modelling
Comparison of Results
cumecs
100
10
1
0.1
0.01
0.001
Gauged
Simulated Historic
Max
Q5
Q10
Q20
Q25
Q30
Q40
Q50
Q60
Q70
Q75
Q80
Q90
Q95
Min
% of time flow equalled or exceeded


Deben Catchment: Hysim Modelling
Comparison of Results
cumecs
30
10
3
1
0.3
0.1
0.03
Simulated Historic
Simulated Natural
Max
Q5
Q10
Q20
Q25
Q30
Q40
Q50
Q60
Q70
Q75
Q80
Q90
Q95
Min
% of time flow equalled or exceeded

APPENDIX IV

NRA Interim Refinement of Naturalised Flow Record, December 1994

River Deben ALF, Environmental Appraisal
Quality Review Action Point No. 3

"Other detailed comments form QRP members to be reviewed and included where relevant as part of the Water Resources Management Plan."

This note summarises the work undertaken under point 3, and details the re-assessment of the minimum required flows of the River Deben and the naturalisation process.

Outline of Southern Science Approach

The approach adopted by Southern Science to calculate minimum flow requirements for the River Deben was as follows:

- Survey 3 sites at Brandeston, Winston Grange and King's Hill (Earl Soham).
- Identify key indicator species at each site and determine the minimum depth and velocity requirements of each.
- Through channel surveys, identify a relationship between discharge, velocity and depth at each site.
- Express the minimum required flow at each site as a naturalised flow at Naunton Hall.

However, concern over the following points has been expressed by QRP members over the approach taken to naturalise the flows of the Deben at Naunton Hall.

1) The spray irrigation actual abstraction data (provided as annual values) were averaged out over the six 'summer months' (April-September), rather than proportioned using monthly distribution factors.

2) Test pumping abstractions and discharges were not been considered as part of the Southern Science naturalisation exercise.

3) Southern Science proportioned gauged flows at Naunton Hall by catchment area and then accounted for intervening abstractions to determine 'calculated actual flows' at the 3 sites where surveys were undertaken. The QRP considered that naturalised flows should have been proportioned and any effluents or abstractions above the ungauged location should have added back or subtracted respectively.

The calculations on the following pages have incorporated the above points.

4) The Southern Science 'naturalisation' is not a full naturalisation as groundwater abstractions have not been considered.

The Deben Water Resources Management Plan recommends that modelling of surface flows (which include consideration of groundwater abstraction) is undertaken. However, for the purposes of providing a working value, an interim refinement which does not include groundwater is considered appropriate.

Initial NRA Refinement

The in-house exercise to refine the Southern Science work is summarised below:-

- Naunton Hall gauged flows from 1971-1991 were retrieved from the flow processing system.

- Spray irrigation abstraction returns (shown in Appendix G of the Southern Science report) were proportioned using the following factors.

January	0.0
February	0.0
March	0.0
April	0.0
May	2.4
June	4.0
July	4.0
August	1.6
September	0.0
October	0.0
November	0.0
December	0.0

(Source: NRA, 1992 Orton Flow Naturalisation.)

- Discharges from pump tests and effluent dwf values were subtracted from the abstraction data to derive net abstractions.

- Net abstractions were added back to gauged flows to arrive at a part naturalised value.

- The part naturalised record was converted into 10 day mean flows to enable comparison with Southern Science data.

- The part naturalised record for Naunton Hall was proportioned by using catchment area (see APT file note 18/11/94 on sensitivity of hydro(geo)logical assumptions) to determine naturalised flows for the 3 survey sites.

- Effluents upstream of the ungauged locations were added, and abstractions upstream of the ungauged locations were subtracted from the proportioned flows to derive calculated actual flows.

- Flow duration curves were produced:

  Naunton Hall - 'naturalised'
  Brandeston - 'calculated actual flows'
  Winston Grange - 'calculated actual flows'
  King's Hill (Earl Soham) - 'calculated actual flows'

- The minimum flow required as identified from surveys of key indicator species at the 3 survey sites (0.01 cumecs) was quoted as a percentile flow for each of the sites.

  Brandeston - (not identified, 0.02 cumecs is lowest calculated flow)
  Winston Grange - (99.48 percentile flow)
  King's Hill - (98.52 percentile flow)

- Following the precautionary principle, the lowest percentile was taken (ie Q98.52) and a corresponding percentile flow was identified from the Naunton Hall 'naturalised' record (Q98.52 = 0.088 cumecs).

- **0.088 cumecs (7.6 tcmd) is taken as the refined value.**

Further NRA Refinement

It is recommended in the "Deben Groundwater Unit: Water Resources Management Plan", that further work is undertaken to refine the minimum required flow after taking groundwater abstractions into account. This could be achieved by using a rainfall runoff model such as HYSIM, GORM or similar.

A.Turner 7/12/94

Naunton Hall 'Naturalised' 1971-1991
(10 day mean flows)

	flow(cumecs)	perc > flow	num in class	cum total
	11.000	.000	0	0
	8.913	.258	2	2
	7.223	.515	2	4
	5.853	.773	2	6
	4.743	1.289	4	10
	3.843	2.835	12	22
	3.114	3.479	5	27
	2.523	5.541	16	43
	2.045	7.990	19	62
	1.657	10.696	21	83
	1.343	13.273	20	103
	1.088	15.851	20	123
	.882	20.876	39	162
	.714	31.701	84	246
	.579	43.428	91	337
	.469	52.577	71	408
	.380	61.082	66	474
	.308	68.943	61	535
	.250	77.062	63	598
	.202	82.474	42	640
	.164	87.887	42	682
	.133	93.041	40	722
	.108	97.423	34	756
	.087	98.582	9	765
	.071	98.969	3	768
	.057	99.485	4	772
	.046	99.613	1	773
	.038	99.613	0	773
	.030	99.613	0	773
	.025	99.742	1	774
	.020	99.742	0	774
<=	.020	100.000	2	776

Analysis from 1 1971 to 12 1991
used 790 values (of which 14 missing, 0 above upper limit).
Complete year used

Mean flow = .785 cumecs

Q 5. percentile = 2.678 cumecs
Q10. percentile = 1.757 cumecs
Q20. percentile = .918 cumecs
Q25. percentile = .818 cumecs
Q30. percentile = .741 cumecs
Q40. percentile = .618 cumecs
Q50. percentile = .500 cumecs
Q60. percentile = .391 cumecs
Q70. percentile = .300 cumecs
Q75. percentile = .264 cumecs
Q80. percentile = .224 cumecs
Q90. percentile = .151 cumecs
Q95. percentile = .122 cumecs

Minimum flow: .020
Maximum flow: 11.000

Brandeston Calculated Actual Flows 1971-1991
(10 day mean flows)

flow(cumecs)	perc > flow	num in class	cum total
6.940	.000	0	0
5.711	.258	2	2
4.699	.387	1	3
3.867	.644	2	5
3.182	.902	2	7
2.618	1.933	8	15
2.154	3.222	10	25
1.773	4.381	9	34
1.459	6.314	15	49
1.200	8.763	19	68
.988	11.082	18	86
.813	13.660	20	106
.669	17.010	26	132
.550	21.521	35	167
.453	31.701	79	246
.373	41.881	79	325
.307	52.062	79	404
.252	59.536	58	462
.208	68.299	68	530
.171	74.356	47	577
.141	80.026	44	621
.116	86.211	48	669
.095	91.237	39	708
.078	95.747	35	743
.064	98.325	20	763
.053	98.969	5	768
.044	99.356	3	771
.036	99.613	2	773
.030	99.613	0	773
.024	99.613	0	773
.020	99.613	0	773
<= .020	100.000	3	776

Analysis from 1 1971 to 12 1991
used 790 values (of which 14 missing, 0 above upper limit).
Complete year used

Mean flow = .500 cumecs

Q 5. percentile = 1.672 cumecs
Q10. percentile = 1.087 cumecs
Q20. percentile = .590 cumecs
Q25. percentile = .517 cumecs
Q30. percentile = .469 cumecs
Q40. percentile = .387 cumecs
Q50. percentile = .320 cumecs
Q60. percentile = .250 cumecs
Q70. percentile = .197 cumecs
Q75. percentile = .167 cumecs
Q80. percentile = .141 cumecs
Q90. percentile = .100 cumecs
Q95. percentile = .081 cumecs

Minimum flow: .020
Maximum flow: 6.940

Winston Grange Calculated Actual Flows 1971-1991
(10 day mean flows)

flow(cumecs)	perc > flow	num in class	cum total
2.310	.000	0	0
1.927	.258	2	2
1.607	.387	1	3
1.340	.515	1	4
1.118	.773	2	6
.933	1.546	6	12
.778	2.835	10	22
.649	3.479	5	27
.541	5.412	15	42
.451	7.603	17	59
.376	9.794	17	76
.314	11.985	17	93
.262	14.175	17	110
.218	17.784	28	138
.182	21.907	32	170
.152	31.701	76	246
.127	43.428	91	337
.106	51.546	63	400
.088	61.082	74	474
.074	66.495	42	516
.061	69.716	25	541
.051	77.062	57	598
.043	83.634	51	649
.036	91.237	59	708
.030	98.325	55	763
.025	98.325	0	763
.021	98.325	0	763
.017	99.485	9	772
.014	99.485	0	772
.012	99.485	0	772
.010	99.485	0	772
<= .010	100.000	4	776

Analysis from 1 1971 to 12 1991
used 790 values (of which 14 missing, 0 above upper limit).
Complete year used

Mean flow = .169 cumecs

Q 5. percentile = .564 cumecs
Q10. percentile = .371 cumecs
Q20. percentile = .199 cumecs
Q25. percentile = .173 cumecs
Q30. percentile = .157 cumecs
Q40. percentile = .134 cumecs
Q50. percentile = .110 cumecs
Q60. percentile = .090 cumecs
Q70. percentile = .061 cumecs
Q75. percentile = .054 cumecs
Q80. percentile = .047 cumecs
Q90. percentile = .037 cumecs
Q95. percentile = .032 cumecs

Minimum flow: .010
Maximum flow: 2.310

Earl Soham calculated actual flows 1971-1991
(10 day mean flows)

flow(cumecs)	perc > flow	num in class	cum total
1.430	.000	0	0
1.122	.258	2	2
.881	.515	2	4
.692	.773	2	6
.543	1.804	8	14
.426	3.351	12	26
.334	5.541	17	43
.262	7.990	19	62
.206	11.082	24	86
.162	13.918	22	108
.127	19.072	40	148
.100	31.186	94	242
.078	44.072	100	342
.061	50.515	50	392
.048	66.495	124	516
.038	74.356	61	577
.030	85.309	85	662
.023	85.309	0	662
.018	97.423	94	756
.014	97.423	0	756
.011	97.423	0	756
.009	99.613	17	773
.007	99.613	0	773
.005	99.613	0	773
.004	99.613	0	773
.003	99.613	0	773
.003	99.613	0	773
.002	99.613	0	773
.002	99.613	0	773
.001	99.613	0	773
.000	99.613	0	773
<= .000	100.000	3	776

Analysis from 1 1971 to 12 1991
used 790 values (of which 14 missing, 0 above upper limit).
Complete year used .

Mean flow = .103 cumecs

Q 5. percentile = .357 cumecs
Q10. percentile = .226 cumecs
Q20. percentile = .125 cumecs
Q25. percentile = .114 cumecs
Q30. percentile = .102 cumecs
Q40. percentile = .085 cumecs
Q50. percentile = .063 cumecs
Q60. percentile = .054 cumecs
Q70. percentile = .044 cumecs
Q75. percentile = .037 cumecs
Q80. percentile = .034 cumecs
Q90. percentile = .021 cumecs
Q95. percentile = .019 cumecs

Minimum flow: .000
Maximum flow: 1.430