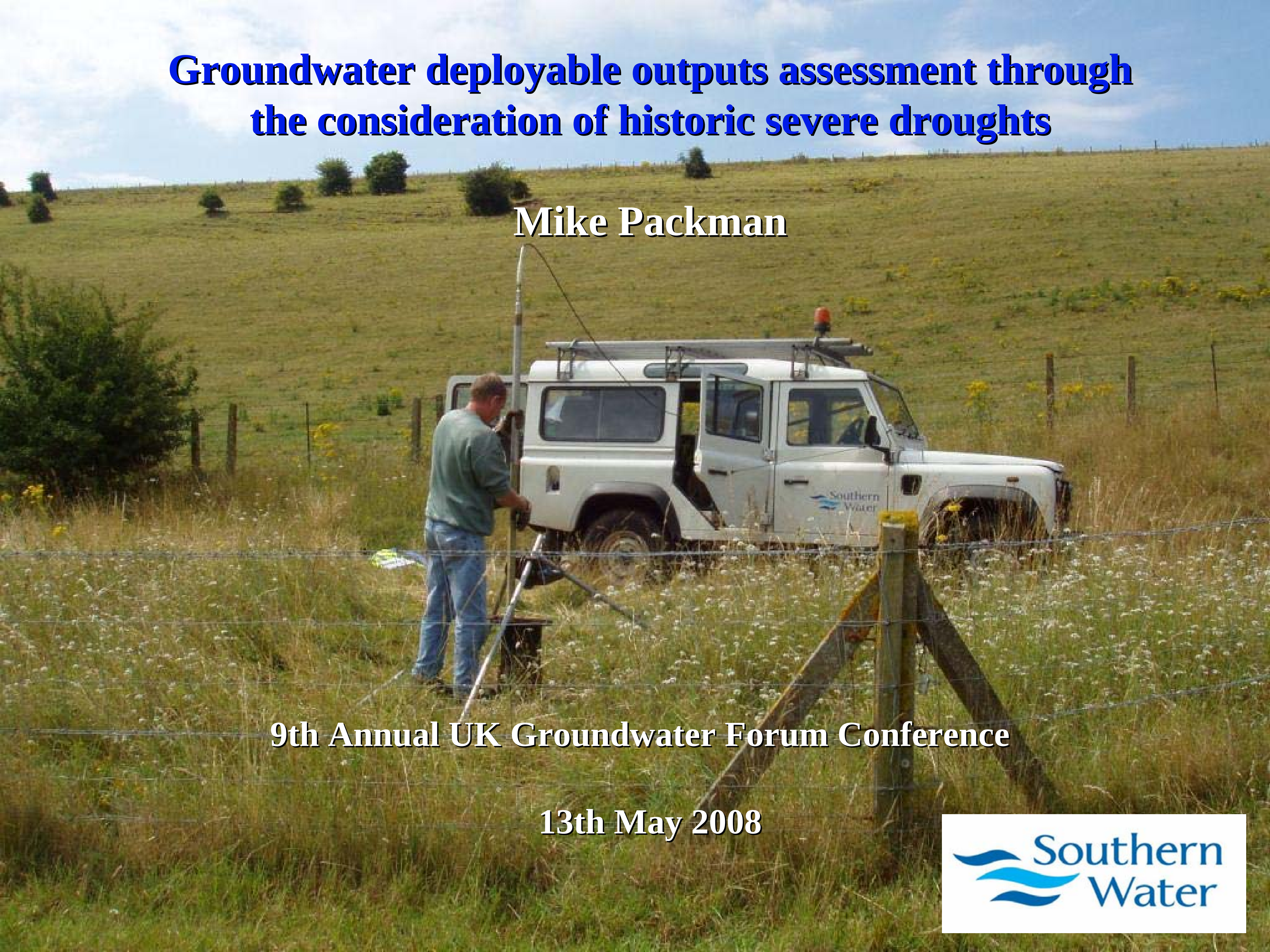
Groundwater deployable outputs assessment through the consideration of historic severe droughts

Mike Packman



9th Annual UK Groundwater Forum Conference

13th May 2008

Southern Water

Southern Water DO Assessments: Key Issues

- SW have completed DO assessments for most GW sources using some historic data from 1989, but mostly telemetry data from 1996.
- This excludes the droughts of 1973, 1976 and droughts in the 1900s, 1920s to 1940s. Surface water drought assessments usually include these droughts.
- The groundwater level return period for the 2005-2006 drought has been estimated to vary between 1:20 to 1:50 years across the SW area.
- This compares to a return period of 1:100 years typically used for surface water assessments.
- This suggests that the groundwater DOs currently used are an overestimate compared to surface water DOs.

Southern Water

Southern Water Severe Drought Groundwater Deployable Output Assessment Brainstorming Workshop - June 2007

- Consultants working directly or indirectly for Southern Water on projects involving DO assessments were invited
- Atkins as SW Water Resource Frameworkers hosted and co-ordinated the workshop
- Each consultant presented their ideas on severe drought DO assessment
- I would therefore like to thank the following participants:
- Atkins: Doug Hunt, Lesley McWilliam, Ben Piper, Simon Wood, Jon Reed
- Aquaterra: Andy Ball, Adam Taylor
- Entec: Rob Soley, Tim Power
- Mott McDonald: Jane Dottridge, Jan Van Wonderen
- Scott Wilson: Jane Sladen, Stephen Cox, Tom Hargreaves

Southern Water

Southern Water

- 70% of the average daily quantity of water supplied by Southern Water comes from groundwater
- 109 groundwater sources
- 85% of groundwater sources are Chalk/Upper Greensand

Southern Water

Aquifers utilised by Groundwater Sources

- Chalk - 86
- Lower Greensand - 10
- Upper Greensand - 7
- Ashdown Beds - 5
- Barton Sand (Tertiary) - 1

Southern Water

Groundwater Source Types

- Wells & adits plus boreholes – 6
- Wells & adits – 33
- Multiple boreholes – 39
- Single borehole – 27
- Springs - 4

Southern Water

Do we have sufficient water?

- Sprinkler/ hosepipe bans
  - target: 1 in 8/10 years
  - actual: Zero to 1 in 3 years

    Varies across area

- Drought Permits/Orders
  - target: 1 in 20 years
  - actual: 40 granted (since 1989)

Southern Water

Deployable Outputs

Surface Water sources

- few, relatively large and simple with deployable outputs estimated from generated long term historic drought sequences

Groundwater sources

- many, relatively small and complex with deployable output estimated from operational data and statistical analysis

Southern Water

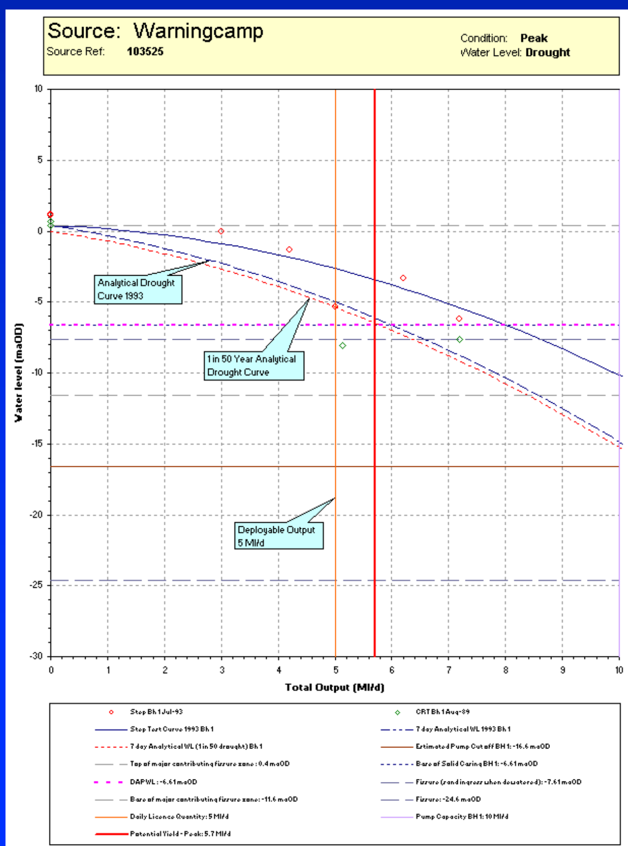
Groundwater Deployable Outputs

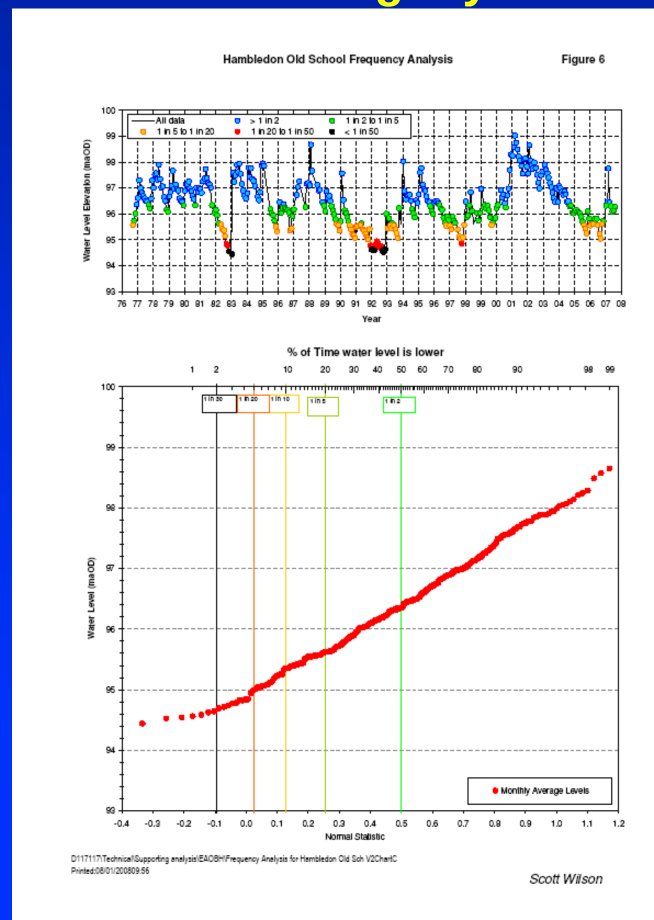
- Some water resource zones that are dependant solely on groundwater are vulnerable, being poorly connected to other WRZs with few interventions possible
- Better telemetry from recent droughts has highlighted DO constraint problems, resulting in DOs being revised, often downwards but also upwards
- Difficult to combine the SW and GW DO approaches
- The operation of GW – river augmentation and conjunctive use schemes is triggered by monitoring based rules which depends on the drought severity
- Usually little or no monitored information for the most severe historic droughts

Southern Water

2005/6 – Southern Water DO Assessments

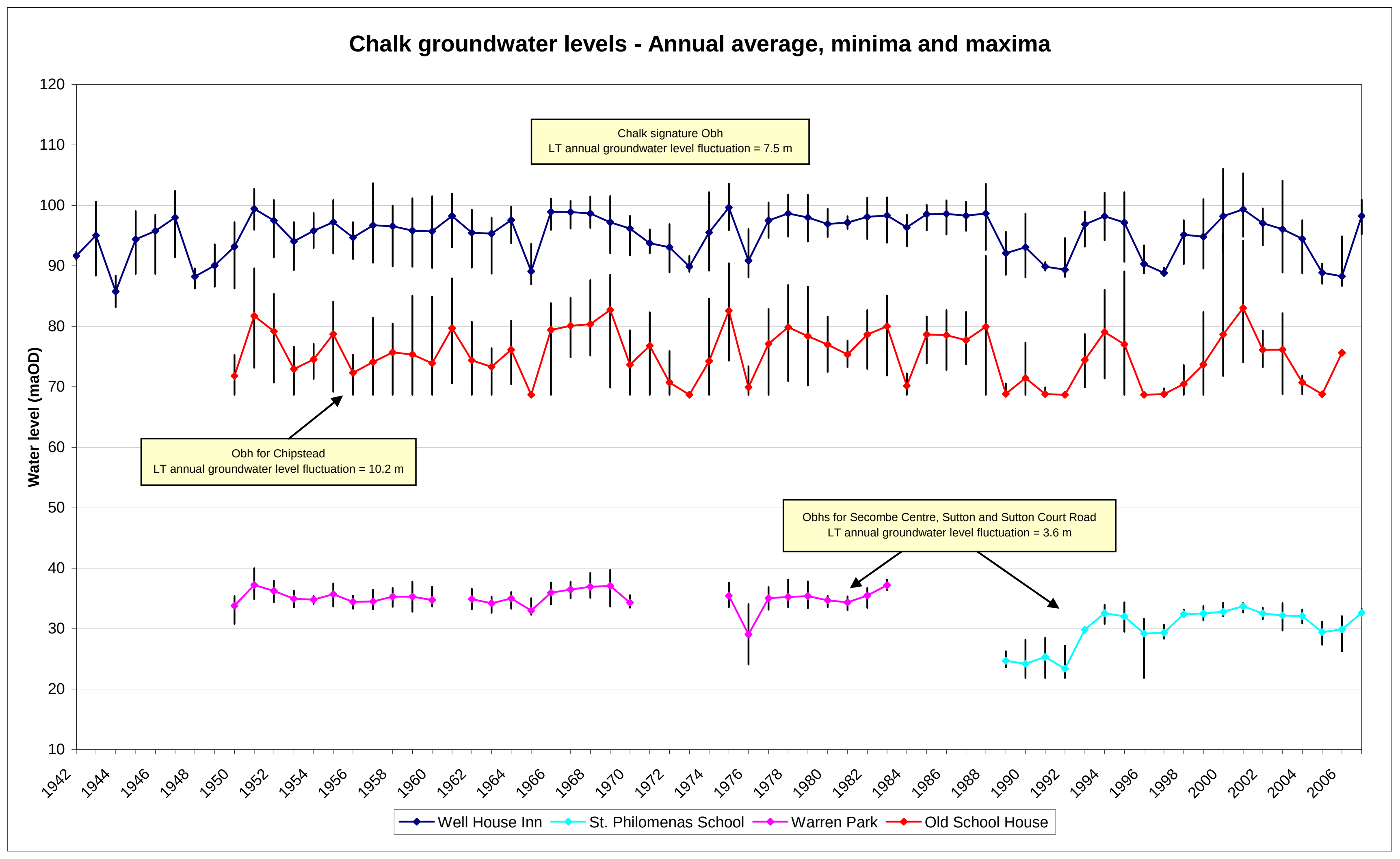
- Signature observation boreholes selected
- Water level probability calculated using the entire data set
- Return period hydrographs used to select drought years and make a 1 in 50 year drought correction (curve shift)



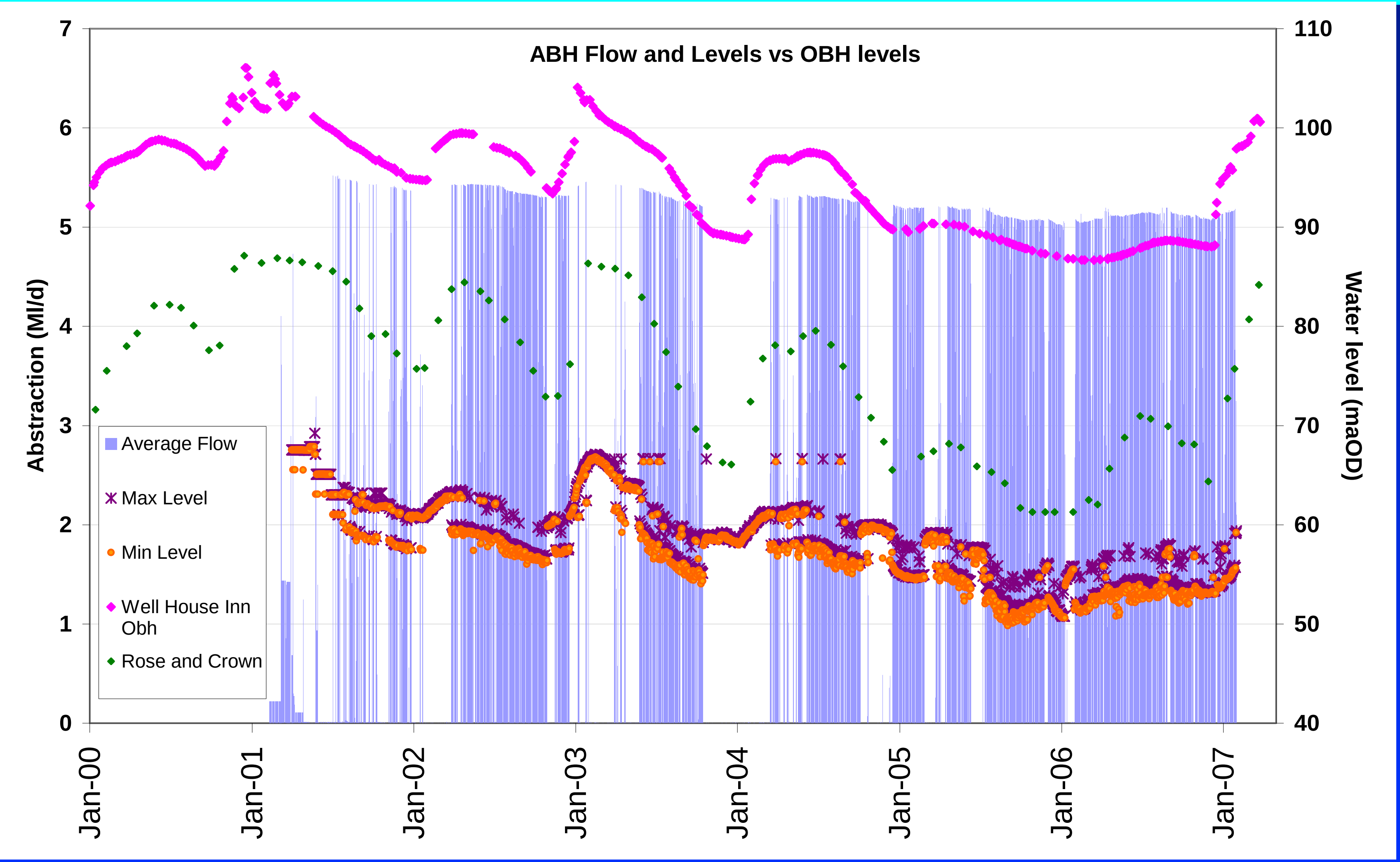


Southern Water

Scaling index OBH with local OBH



Comparison of index OBH with local OBH & source GWLs



Southern Water

Limitations of the curve shift approach

- Relies on a long enough groundwater level record to allow an appropriate drought water level to be determined
- Scaling
- Often don't know shape of drought curve in the zone defining the DO
- Don't know whether water quality (particularly turbidity) issues will become a constraint at water levels lower than had previously been recorded
- Don't know hydraulic characteristics of source at lower water levels

Southern Water

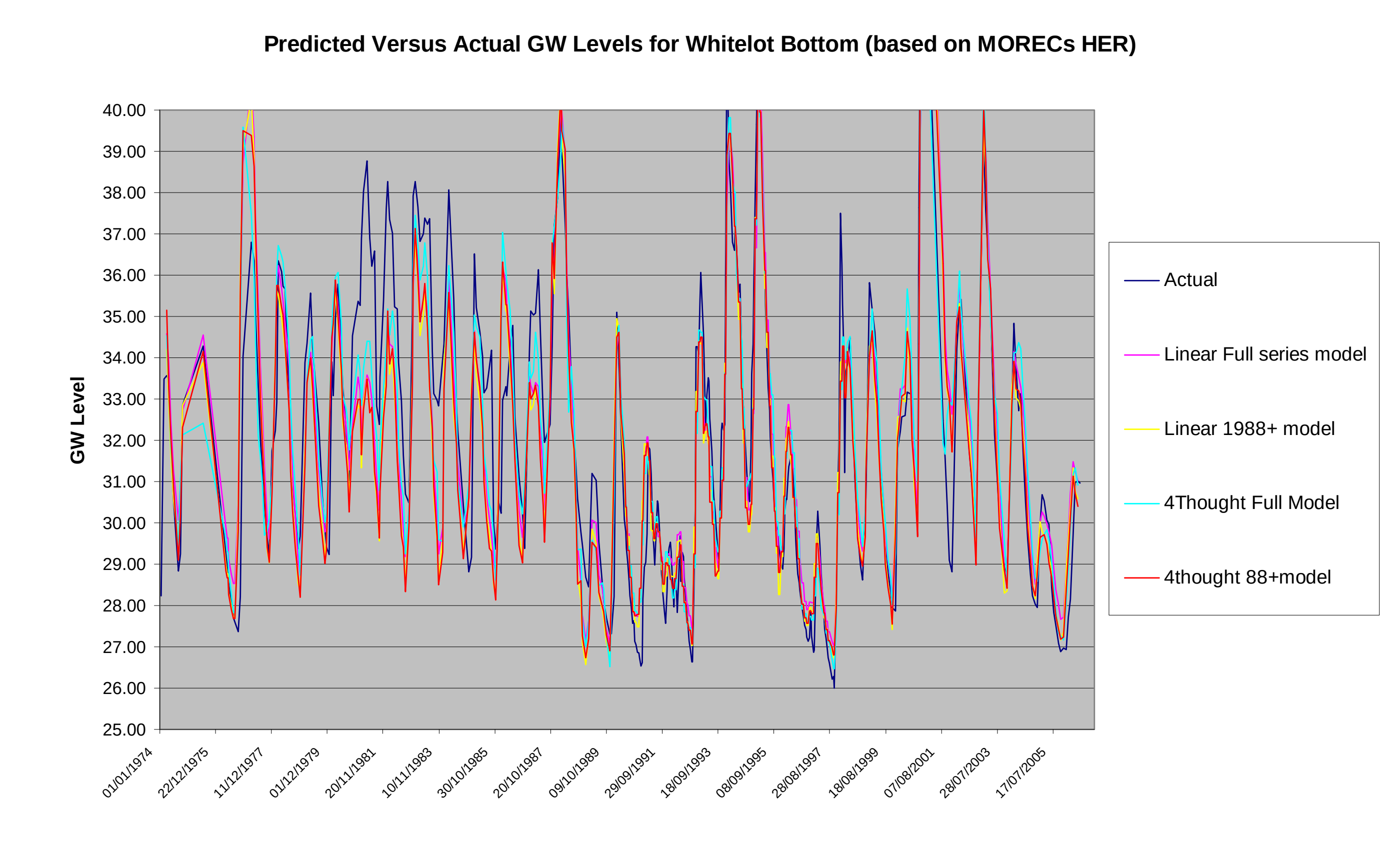
Sussex Coast severe drought DO assessment

- Clear and significant risk to DO during severe droughts
- Level of Service relied on critical droughts, which were much more severe than 1990's and 2005-06
- Long record OBs remote from abstractions (e.g. Chilgrove) not representative of the hydrogeological nature of the productive aquifer, particularly for the Chalk
- Started with assessment of available OBHs:
  - Must reflect the productive aquifer
  - Long enough record (include 1970s as more severe than more recent droughts)
- Groundwater level regression models based on MORECs, 4R and Catchmod outputs for monthly recharge plus abstraction
- All relationships other than abstraction and 12-24 month recharge were linear

Southern Water

Regression analysis: good results for abstraction affected OB

Recharge Data Used	Linear Model		Non-Linear Model	
	Full Time Series	1988+	Full Time Series	1988+
4R	83.4%	90.3%	84.81%	89.6%
MORECS	78.1%	88.3%	84.17%	89.29%
Rother Catchmod	75.6%	82.6%	75.6%	Not assessed



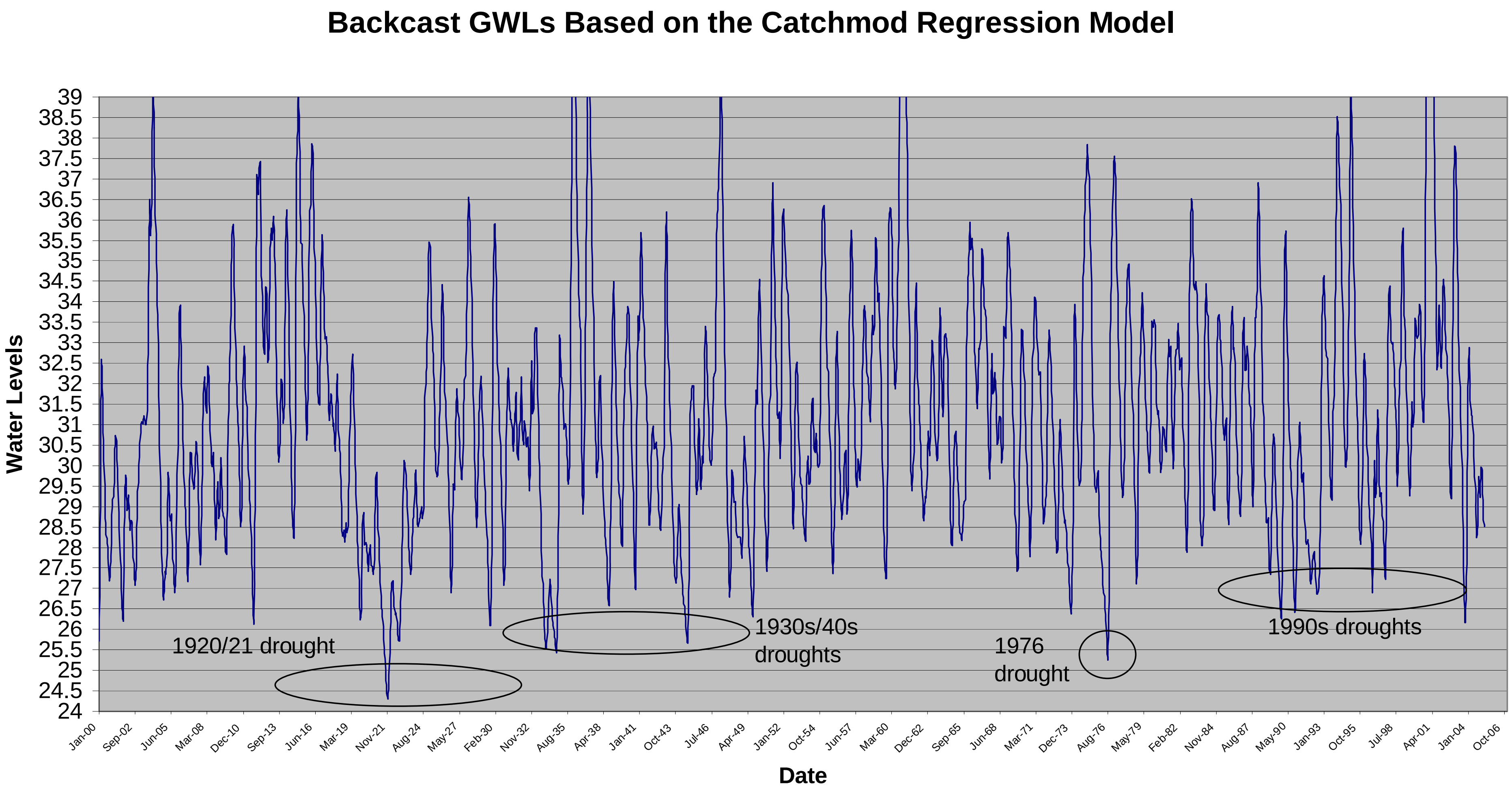
Southern Water

Sussex Coast Drought Analysis 1960 - 2005

Hydrological Year	Autumn Affected	AR	HER	Winter HER	2 W HER
1972	1973	637.8	89.8	74.9	219.9
1975	1976	449.4	98.8	98.8	607.6
1988	1989	550.6	118.3	118.3	665.3
1996	1997	741.1	130.2	130.2	334.1
1991	1992	684.9	130.9	130.9	347.9
2004	2005	666.7	138.1	138.1	415.1
1971	1972	613.2	145	145	410.3
1964	1965	821.4	214.9	161.2	533
1960	1961	508.2	210.5	193.9	387.8
1973	1974	873.9	275.8	203.3	278.2
1995	1996	651	203.9	203.9	670.1
1990	1991	865.4	272.6	217	507.9
1978	1979	773	276.1	251.3	578.6
1962	1963	795.5	255.6	253.1	510.7
1961	1962	839.6	257.6	257.6	451.5
1970	1971	849	327.6	265.3	544.1
2003	2004	891	297	277	710.2
1969	1970	828.3	278.8	278.8	587
1980	1981	797.3	324.2	279	617.7
1998	1999	898.8	286.9	286.9	623.3
1989	1990	744.8	290.9	290.9	409.2
1967	1968	966.1	380.7	294.3	647.7
1999	2000	917.3	342.9	295.1	582
1983	1984	812.7	302.7	302.7	737.8
1981	1982	726.3	303.3	303.3	582.3
1986	1987	899.5	304.8	304.8	659.6
2001	2002	854.3	349.3	305.9	1181
1968	1969	724.2	308.2	308.2	602.5
1992	1993	899.4	320.4	320.4	451.3
1984	1985	931.1	332	321.9	624.6
1977	1978	814.2	364	327.3	914.1
1997	1998	947.1	336.4	336.4	466.6
1979	1980	928.1	364.2	338.7	590
1966	1967	950.1	377.5	353.4	773
1985	1986	795.8	354.8	354.8	676.7
1963	1964	816.3	422.7	371.8	624.9
1965	1966	900.7	422.7	419.6	580.8
2002	2003	805.8	433.2	433.2	739.1

Southern Water

Drought backcasting results



Southern Water

Drought backcasting conclusions

- **Analysis back to 1970 very useful:**
  - **MORECs and 4R gave similar impacts from 1972/73 droughts (clearly worse than 2005-06)**
  - **Gave useful information about the impact of 2 year versus 1 year droughts (1976 not the most severe)**
- **Analysis back to 1900 more challenging because of lack of recharge data**
- **The ‘curve shifting’ approach contained in the Unified Methodology was of use, <u>but</u> with allowances for borehole specific issues**

Southern Water

Backcasting regional models – first approach

- Can backcast groundwater levels at sources using daily rainfall and PE data for the drought periods of interest
- Find relationship between simulated water levels and measured RWLs at sources
- Use relationship to extrapolate to RWLs during each drought, where possible
- Estimates of RWLs can be made for:
  - operational conditions of the day (if abstraction records can be reconstructed)
  - current operational conditions (perhaps more useful)
  - hypothetical drought situations, such as 2-3 consecutive dry winters, etc.

Southern Water

Summary of first regional modelling approach

Determine if model can be used to reliably predict RWLs at sources

Determine recharge scenarios required and Levels of Service

Update existing model with recharge and abstraction scenarios

Produce groundwater hydrographs for abstraction bhs

Determine appropriate DO assessment method

Calculate DO using either analytical or operational approach

Second regional modelling approach

- Requires a distributed MODFLOW time variant numerical GW model - calibrated/accepted over a recent period
- Few but long term historic rainfall and PE records required
- Use of modified MODFLOW module for groundwater abstraction - river augmentation
  - developed for Southern Water & published in MODFLOW 2006
  - modelled flow at trigger point in previous stress period controls rate of GW abstraction & associated SW discharge
- Groundwater abstraction rate controlled by modelled river flow or modelled river flows in previous stress period (psp)
- Surface water abstraction rate could also be controlled or varied by modelled river flows in psp?
- Groundwater abstraction rate could also be dependent on intercell groundwater flows in psp? (e.g. to control saline intrusion)

Southern Water

Outline methodology (1)

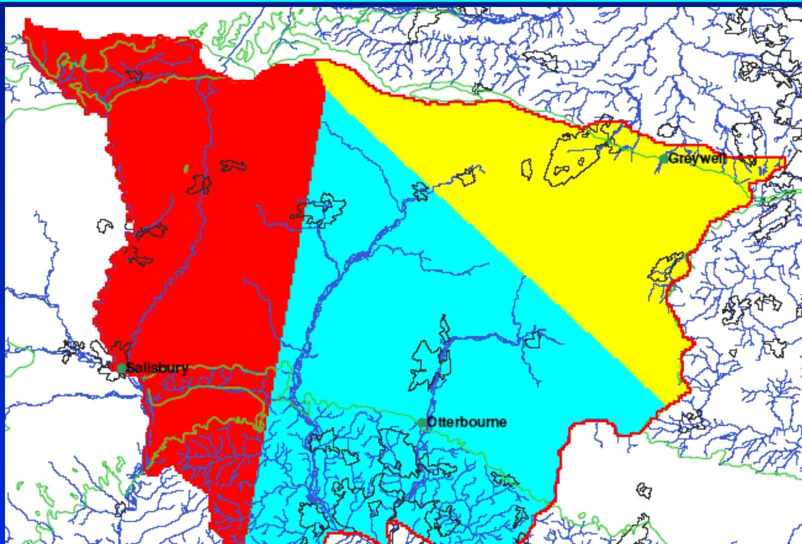
- Develop an appropriate long term historic drought climate sequence
  - simpler/fewer input gauge rainfall & PE correlated/adjusted in relation to detailed recent period models
  - stress period length appropriate for peak demand
  - enough wet period recovery in between the historic droughts
  - including recent period to allow recent model & data comparisons
- Run through recharge model & groundwater model
- Check/adjust calibration in relation to recent modelled/monitored period flows, levels etc

Outline methodology (2)

- Develop max. DO scenario abstraction rates, (NOT the historic, or recent actual or full licensed), but with DO constraints
- Consider source-by-source DO influences during the recent monitored critical drought DO periods and develop relationships with MODELLED flows or heads
- Develop the maximum desired demand profile for each source, build in any preferred source resting strategy
- Run/refine the historic severe droughts simulation with the max DO scenario so that the new model module calculates the achievable DO

Southern Water

Developing historic severe droughts recharge & groundwater models



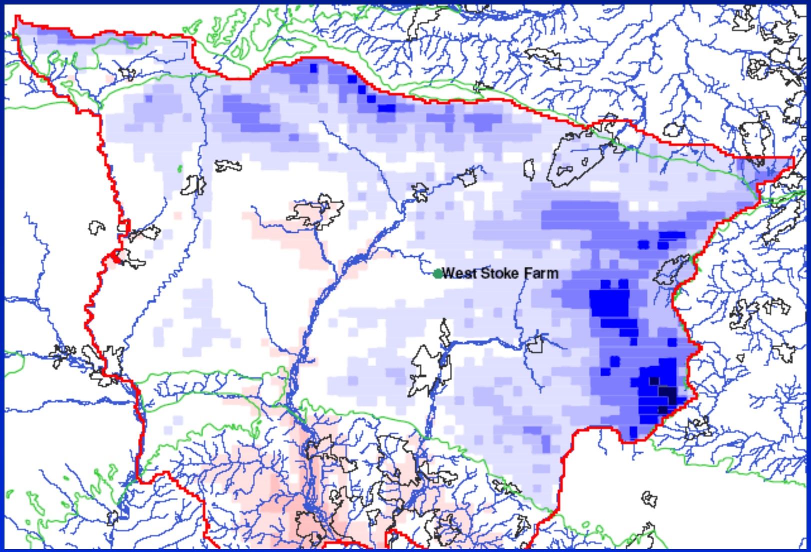


Figure 4.2: Rainfall and Evaporation Rates per Stress Period for the Itchen Groundwater Catchment, 1988-1997, Runs 56 and 65

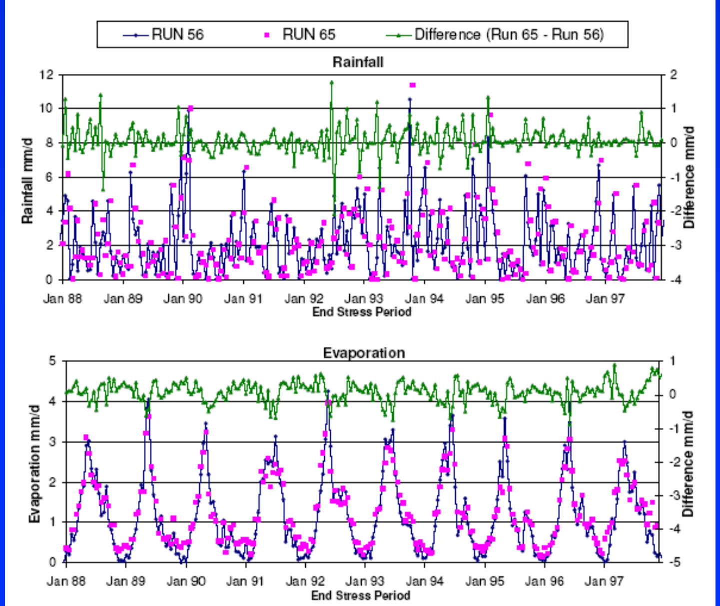
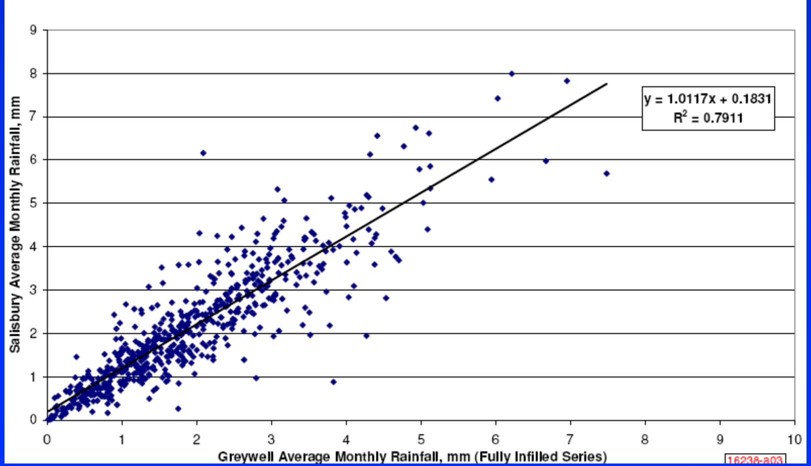


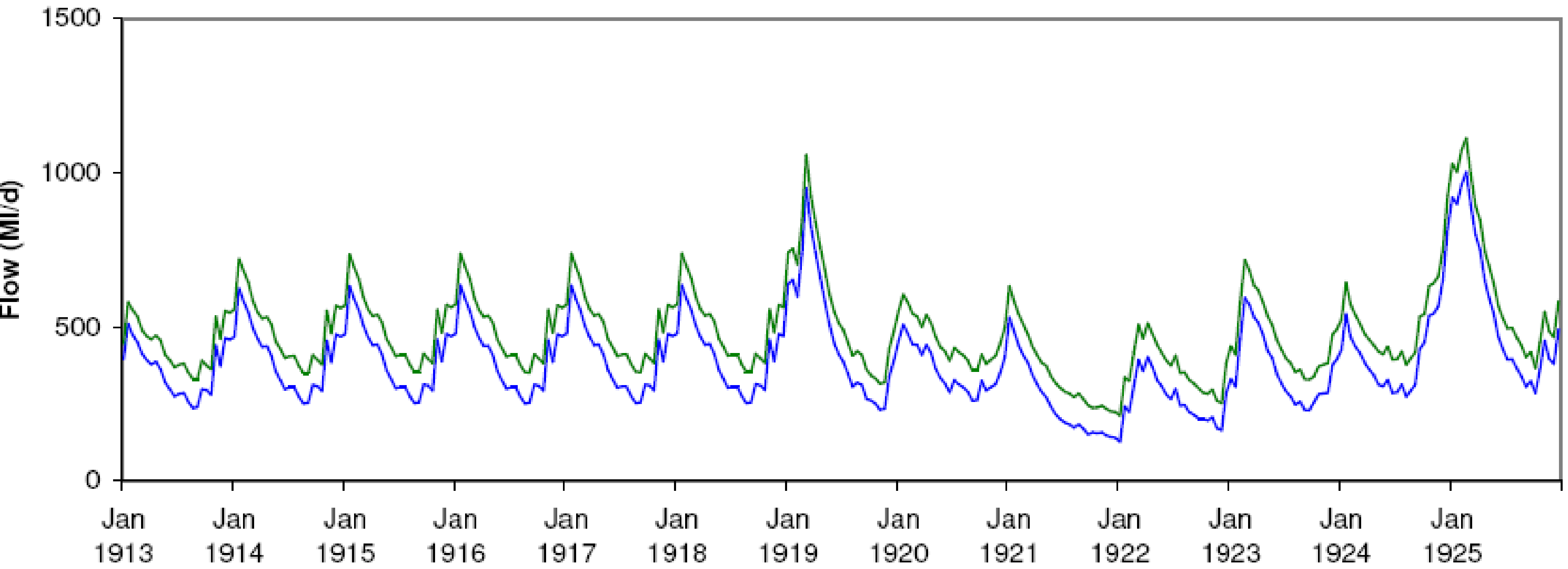
Figure 2.3: Average Monthly Rainfall at Salisbury & Greywell (Infilled Series)



Developing the long term rainfall and PE inputs

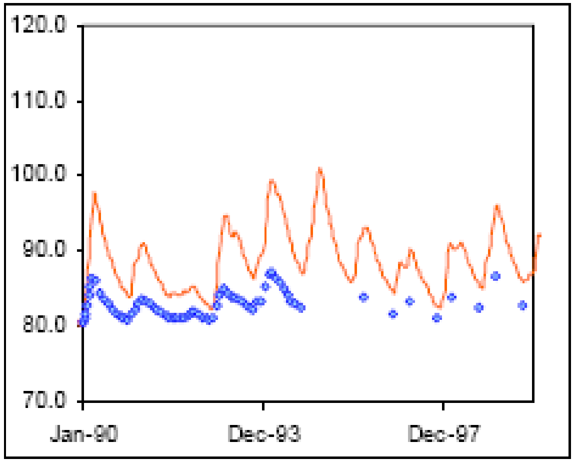
Southern Water

First pass historic drought runs

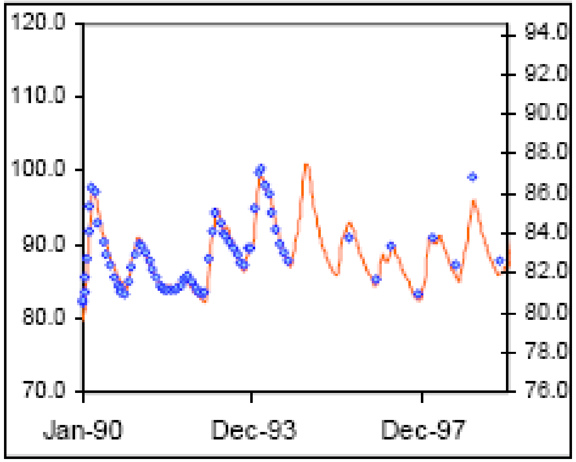


Southern Water

BUT can GW models simulate observed GW levels well enough for DO predictions?



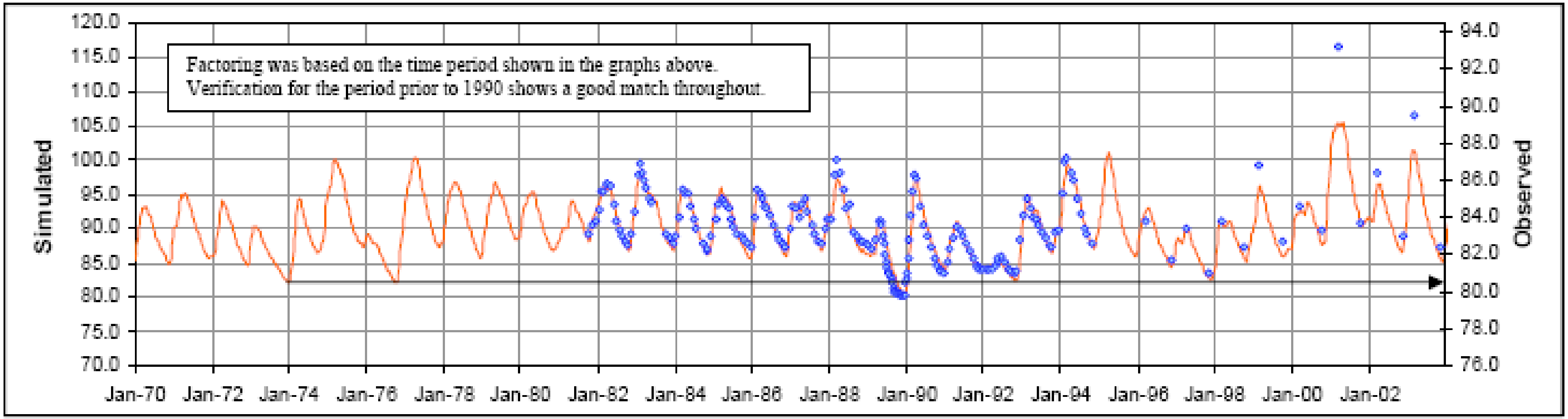
Un-factored



Factored

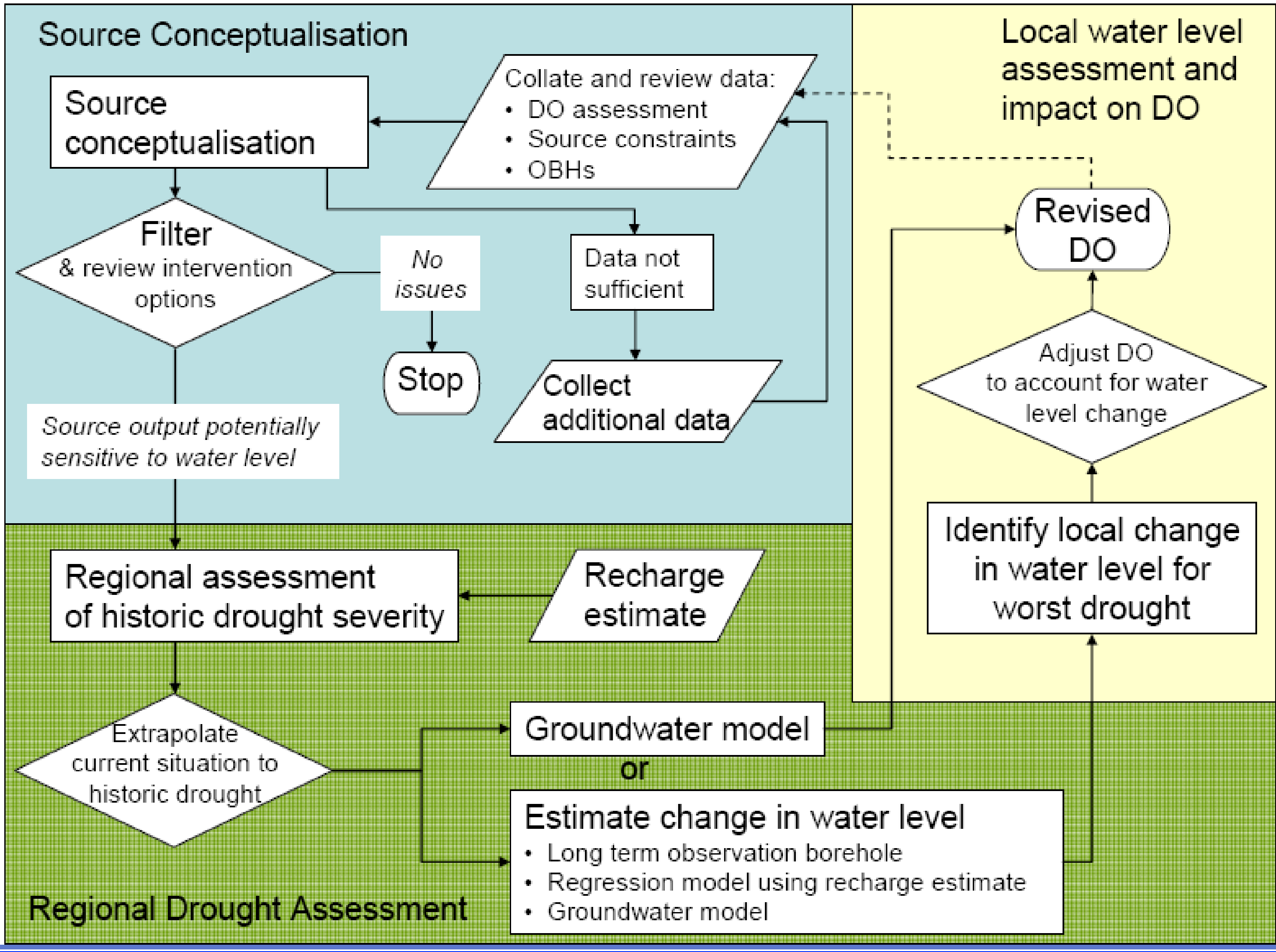
The answer is probably yes as careful factoring <u>is</u> possible

Actual lowest groundwater level at end of 1973 would have been ~ 80.5 m
The accuracy of the estimate would be high given the good factored match.



Southern Water

Workshop conclusions



Southern Water