Geological Society - Hydrogeology Group

Groundwater Asset Management
Shropshire Groundwater Scheme

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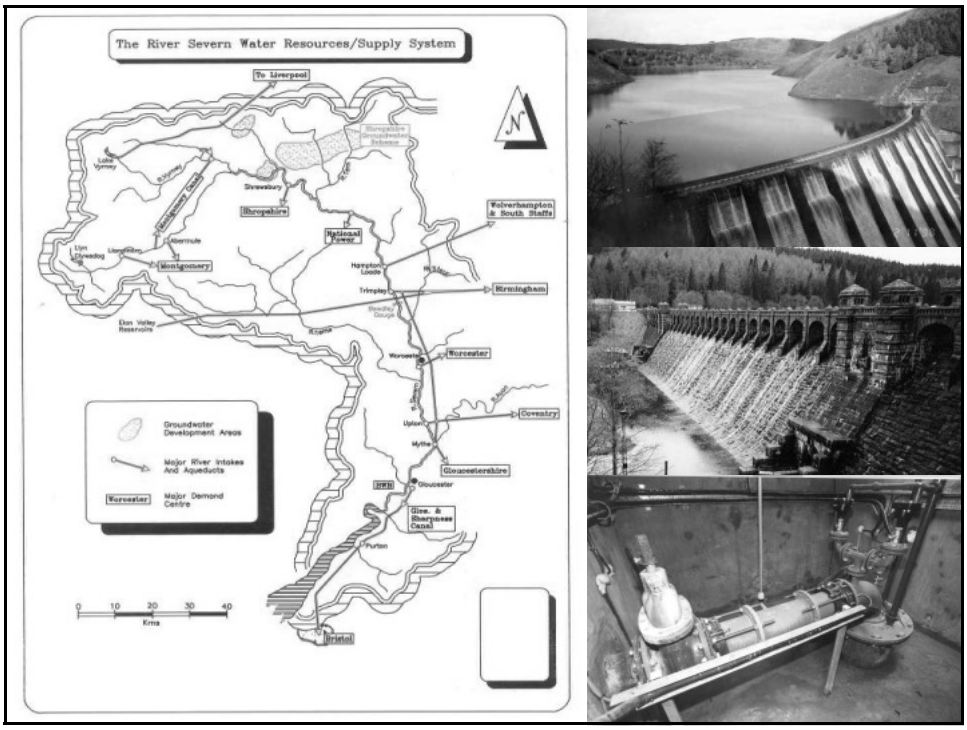
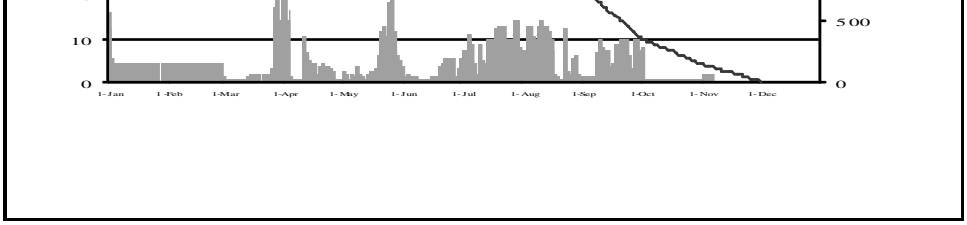
Hydrogeologist

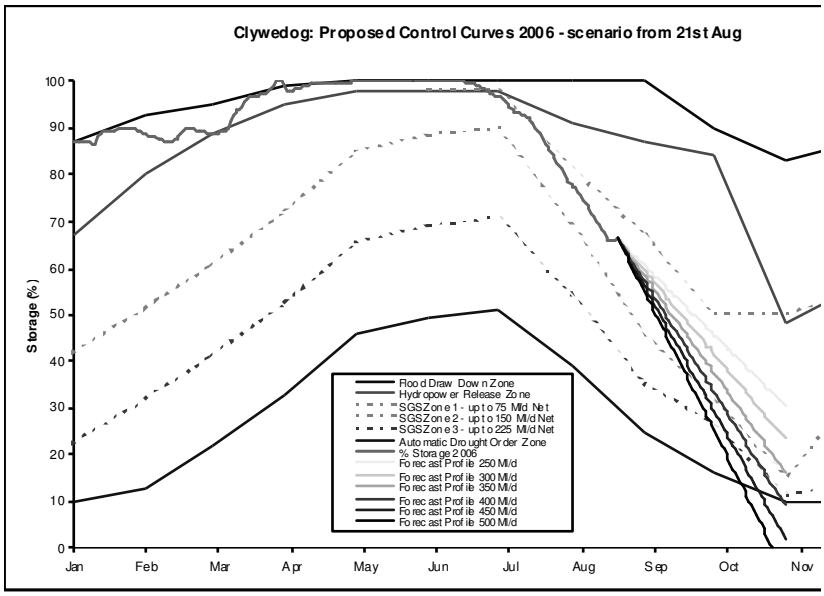
Midlands Region
Groundwater & Contaminated Land Team
10 September 2008

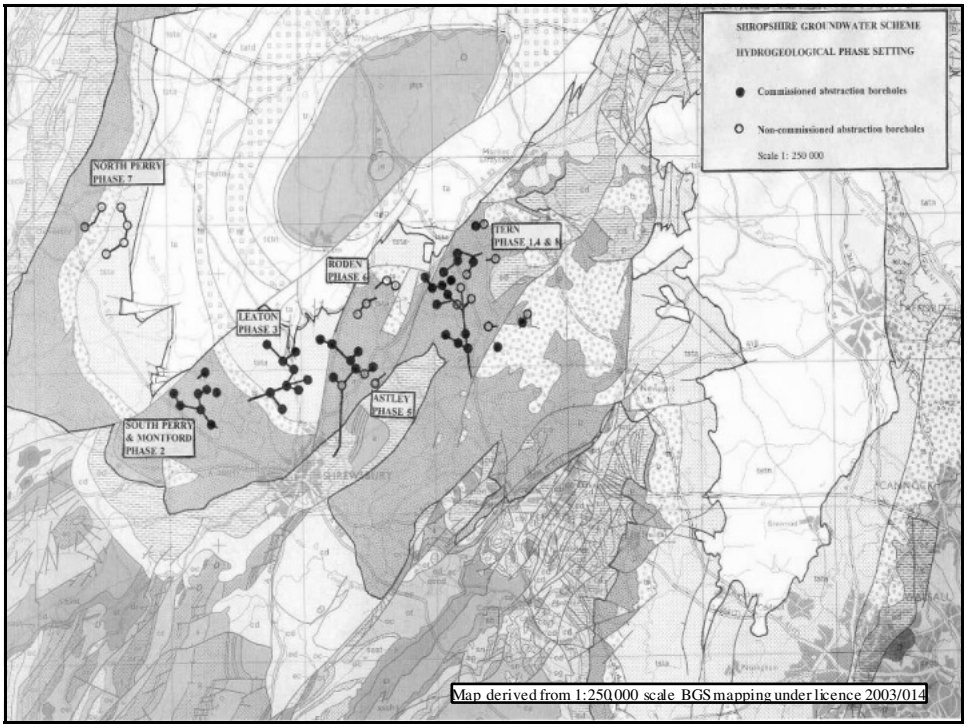
Presentation

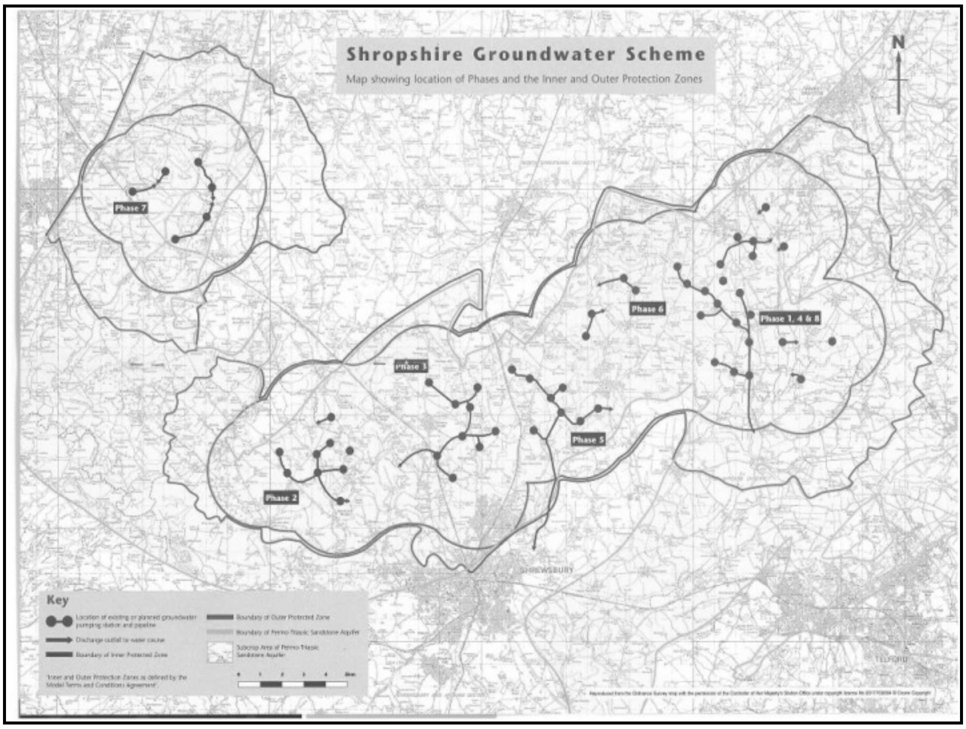
- SGS Role in Strategic Water Resource Planning & Operations – River Severn Regulation
- Development of the Scheme to date
- Environmental Management
- System Management

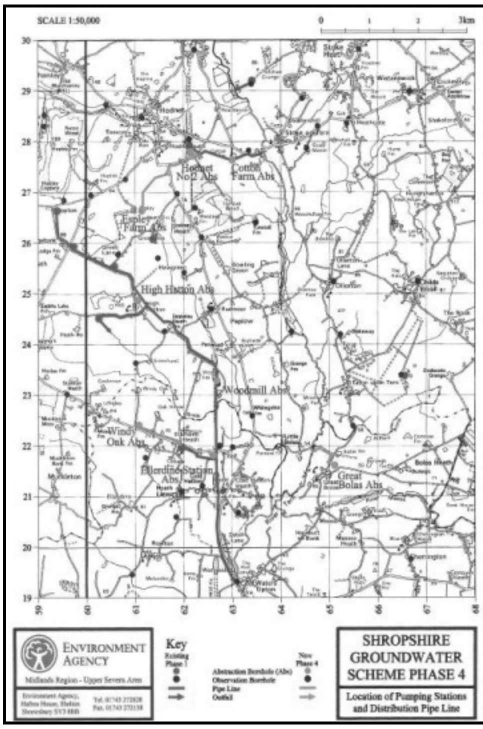

The River Severn Water Resources/Supply System
To Liverpool
Shrewsbury
Shropshire
Wolverhampton & South Staffs
National Power
Montgomery
Hampton Loade
Trimpley
Birmingham
Elan Valley Reservoirs
Worcester
Coventry
Gloucestershire
Gloucester
Glos. & Sharpness Canal
Purton
Bristol
Groundwater Development Areas
Major River Intakes And Aqueducts
Major Demand Centre
0 10 20 30 40
Kms

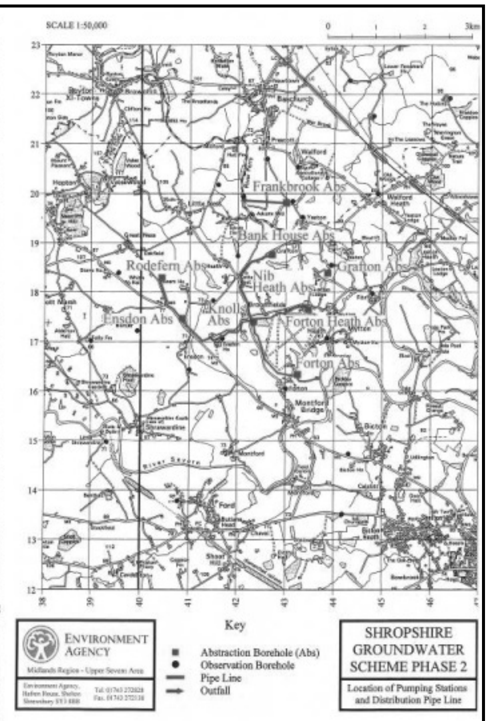

LLYN CLYWEDOG OPERATIONS 2006
2006 %Storage
Flood Drawdown
Temporary Flood Drawdown
Seek Drought Order
Drought Order In Force
Release or Overflow
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
1-Oct
1-Nov
1-Dec


Clywedog: Proposed Control Curves 2006 - scenario from 21st Aug
Storage (%)
100
90
80
70
60
50
40
30
20
10
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Flood Draw Down Zone
Hydropower Release Zone
SGS Zone 1 - up to 75 Mld Net
SGS Zone 2 - up to 150 Mld Net
SGS Zone 3 - up to 225 Mld Net
Automatic Drought Order Zone
% Storage 2006
Forecast Profile 250 Ml/d
Forecast Profile 300 Ml/d
Forecast Profile 350 Ml/d
Forecast Profile 400 Ml/d
Forecast Profile 450 Ml/d
Forecast Profile 500 Ml/d


SHROPSHIRE GROUNDWATER SCHEME
HYDROGEOLOGICAL PHASE SETTING
Commissioned abstraction boreholes
Non-commissioned abstraction boreholes
Scale 1: 250 000
NORTH PERRY PHASE 7
TERN PHASE 1,4 & 8
RODEN PHASE 6
LEATON PHASE 3
ASTLEY PHASE 5
SOUTH PERRY & MONTFORD PHASE 2
Map derived from 1:250,000 scale BGS mapping under licence 2003/014


Shropshire Groundwater Scheme
Map showing location of Phases and the Inner and Outer Protection Zones
N
Phase 7
Phase 6
Phase 1, 4 & 8
Phase 3
Phase 5
Phase 2
SHREWSBURY
Key
Location of existing or planned groundwater pumping station and pipeline
Discharge outfall to water course
Boundary of Inner Protected Zone
Boundary of Outer Protected Zone
Boundary of Permo-Triassic Sandstone Aquifer
Subcrop Area of Permo-Triassic Sandstone Aquifer
'Inner and Outer Protection Zones as defined by the Model Terms and Conditions Agreement'.


SCALE 1:50,000
0 1 2 3km
Hodnet Abs
Combe Farm Abs
High Hatton Abs
Woodmill Abs
Wine Oak Abs
Ellerdine Station Abs
Great Bolas Abs
ENVIRONMENT AGENCY
Midlands Region - Upper Severn Area
Key
Existing Phase 1
New Phase 4
Abstraction Borehole (Abs)
Observation Borehole
Pipe Line
Outfall
SHROPSHIRE GROUNDWATER SCHEME PHASE 4
Location of Pumping Stations and Distribution Pipe Line

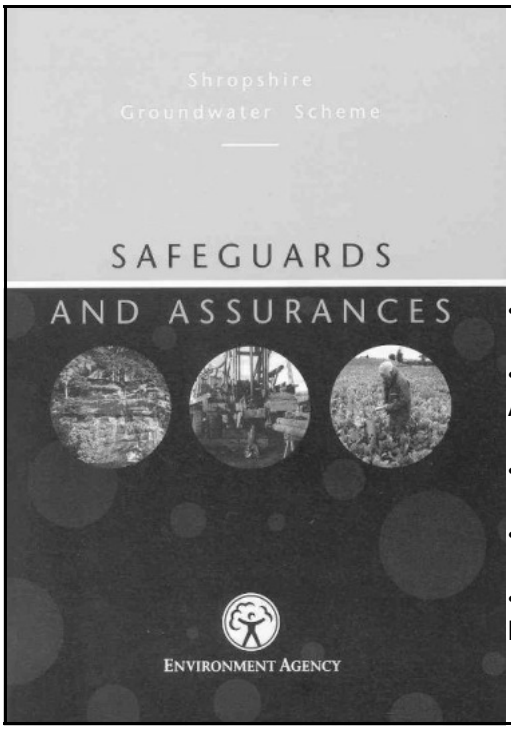

SCALE 1:50,000
0 1 2 3km
Frankbrook Abs
Bank House Abs
Rodefern Abs
Nib Heath Abs
Grafton Abs
Ensdon Abs
Knolls Abs
Forton Heath Abs
Forton Abs
River Severn
ENVIRONMENT AGENCY
Key
Abstraction Borehole (Abs)
Observation Borehole
Pipe Line
Outfall
SHROPSHIRE GROUNDWATER SCHEME PHASE 2
Location of Pumping Stations and Distribution Pipe Line

Shropshire Groundwater Scheme –
Gross Deployable Yields and Operational Years

Phase	Gross Yield	Regulation Seasons Requiring SGS Support
Phase 1 (commissioned 1984/85)	45Ml/d	1984, 1989, 1995, 1996, 2006
Phase 2 (commissioned 1991)	50Ml/d	1995, 1996, 2006
Phase 3 (commissioned 1999)	50Ml/d	2006
Phase 4 (commissioned 2005)	45-50Ml/d	2006
Phase 5	60-65Ml/d est.	Underdevelopment
Phase 6	20-25Ml/d est.	Not developed
Phase 7	35-40Ml/d est.	Not developed
Phase 8	40-45Ml/d est.	Not developed
TOTAL SCHEME	(max 330Ml/d)	

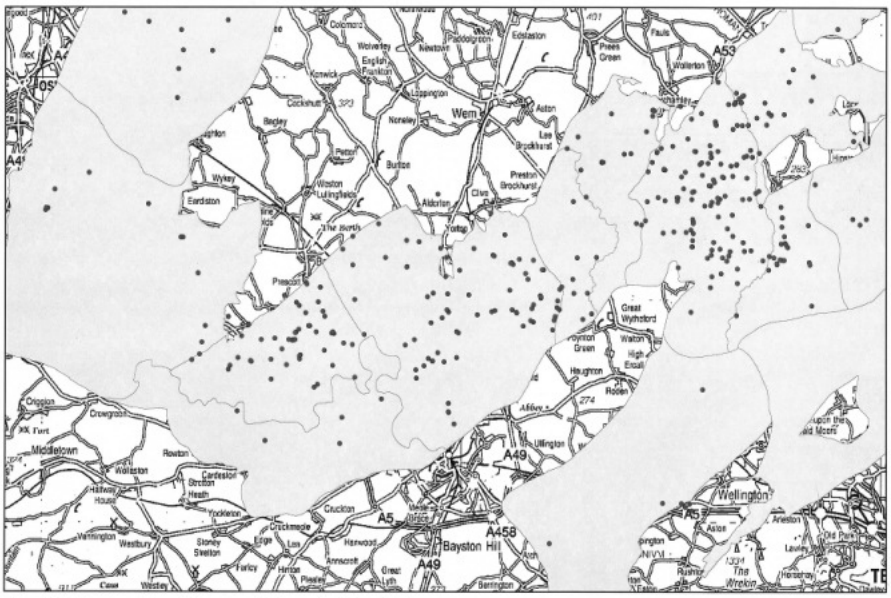
Environmental Management

- Groundwater level monitoring & resources assessment
- Crop vulnerability mapping
- Ecological monitoring
- Hydro-chemical monitoring & assessment



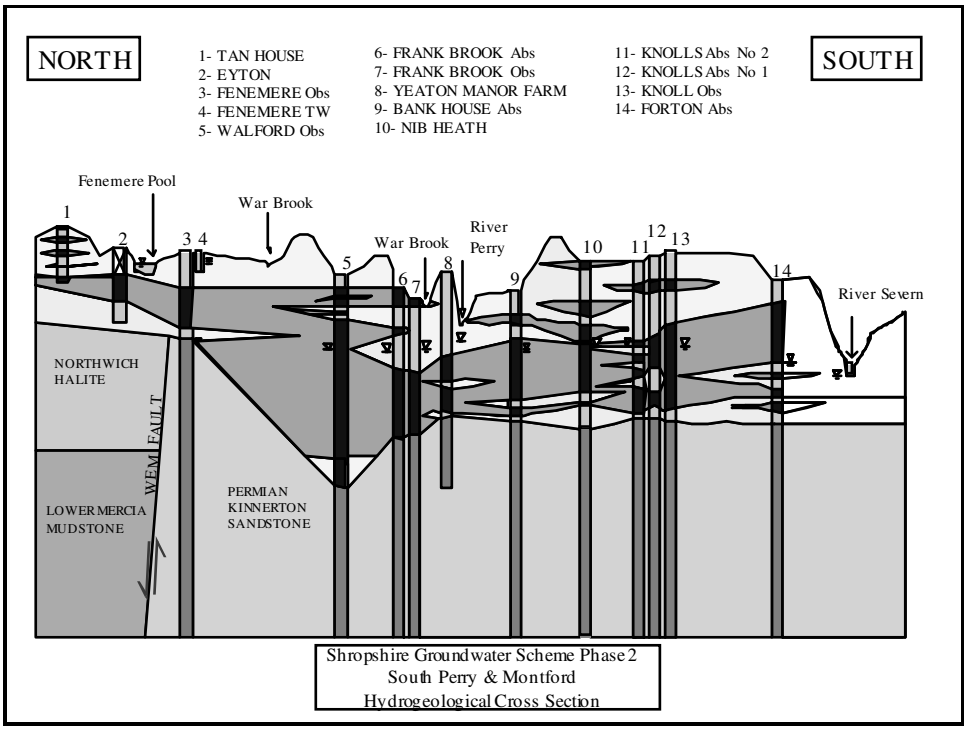
Legislative Drivers

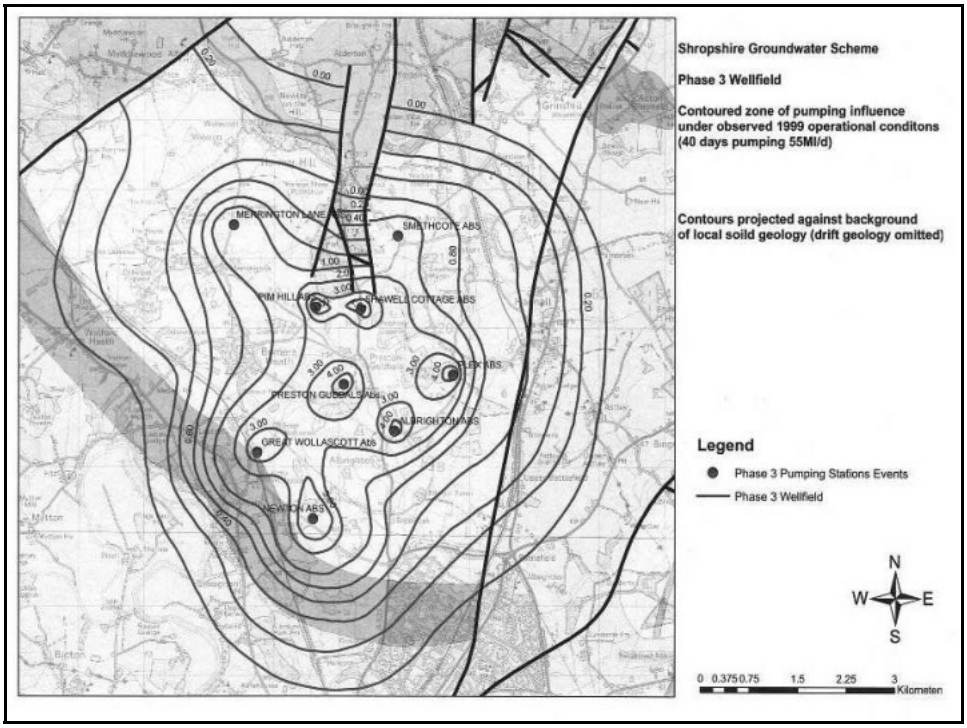
- 1979 SGS Public Inquiry
- Model Terms & Conditions Agreement
- 1981 SGS Abstraction Licence
- Water Resources Act 2003
- CAMS - Catchment Abstraction Management Strategies

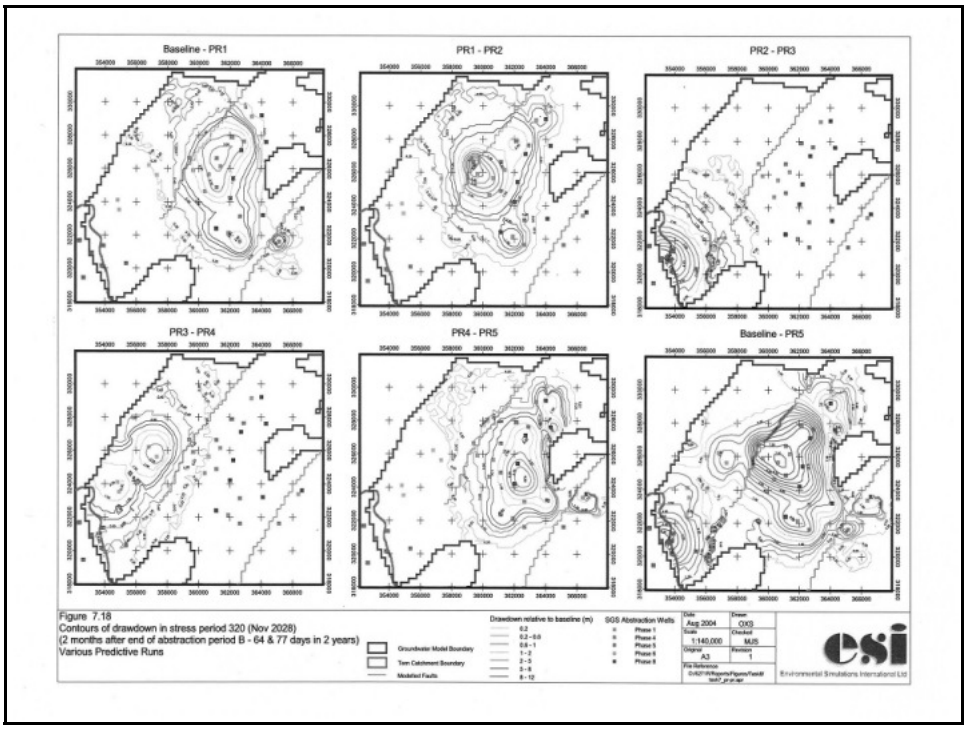


North Shropshire Permo-Triassic Sandstone

Groundwater Monitoring Network


NORTH
SOUTH
1- TAN HOUSE
2- EYTON
3- FENEMERE Obs
4- FENEMERE TW
5- WALFORD Obs
6- FRANK BROOK Abs
7- FRANK BROOK Obs
8- YEATON MANOR FARM
9- BANK HOUSE Abs
10- NIB HEATH
11- KNOLLS Abs No 2
12- KNOLLS Abs No 1
13- KNOLL Obs
14- FORTON Abs
Fenemere Pool
War Brook
War Brook
River Perry
River Severn
NORTHWICH HALITE
WEM FAULT
LOWER MERCIA MUDSTONE
PERMIAN KINNERTON SANDSTONE
Shropshire Groundwater Scheme Phase 2
South Perry & Montford
Hydrogeological Cross Section


Shropshire Groundwater Scheme
Phase 3 Wellfield
Contoured zone of pumping influence under observed 1999 operational conditons (40 days pumping 55Ml/d)
Contours projected against background of local soild geology (drift geology omitted)
Legend
Phase 3 Pumping Stations Events
Phase 3 Wellfield
N
W
E
S
0 0.375 0.75 1.5 2.25 3
Kilometers


Baseline - PR1
PR1 - PR2
PR2 - PR3
PR3 - PR4
PR4 - PR5
Baseline - PR5
Figure 7.18
Contours of drawdown in stress period 320 (Nov 2028)
(2 months after end of abstraction period B - 64 & 77 days in 2 years)
Various Predictive Runs
Drawdown relative to baseline (m)
SGS Abstraction Wells
Groundwater Model Boundary
Tern Catchment Boundary
Modelled Faults
Environmental Simulations International Ltd

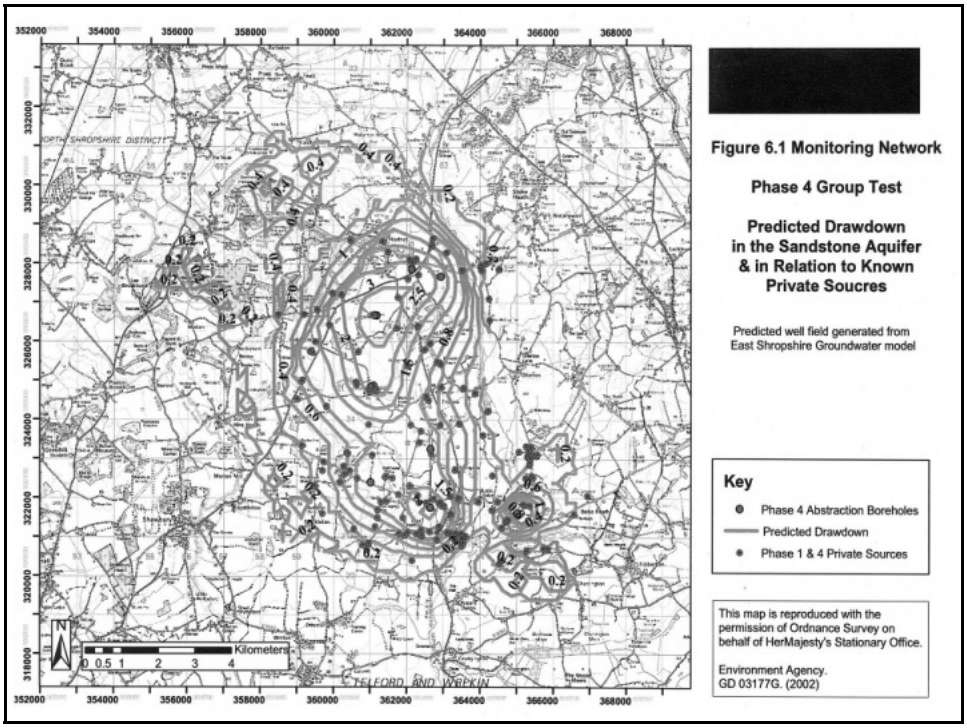
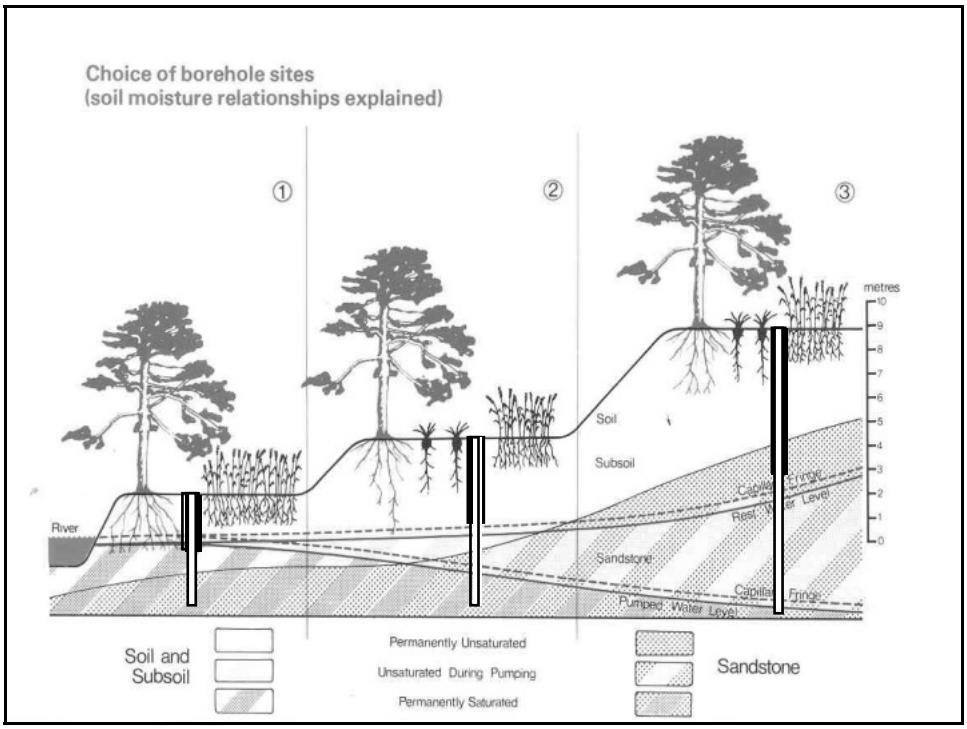
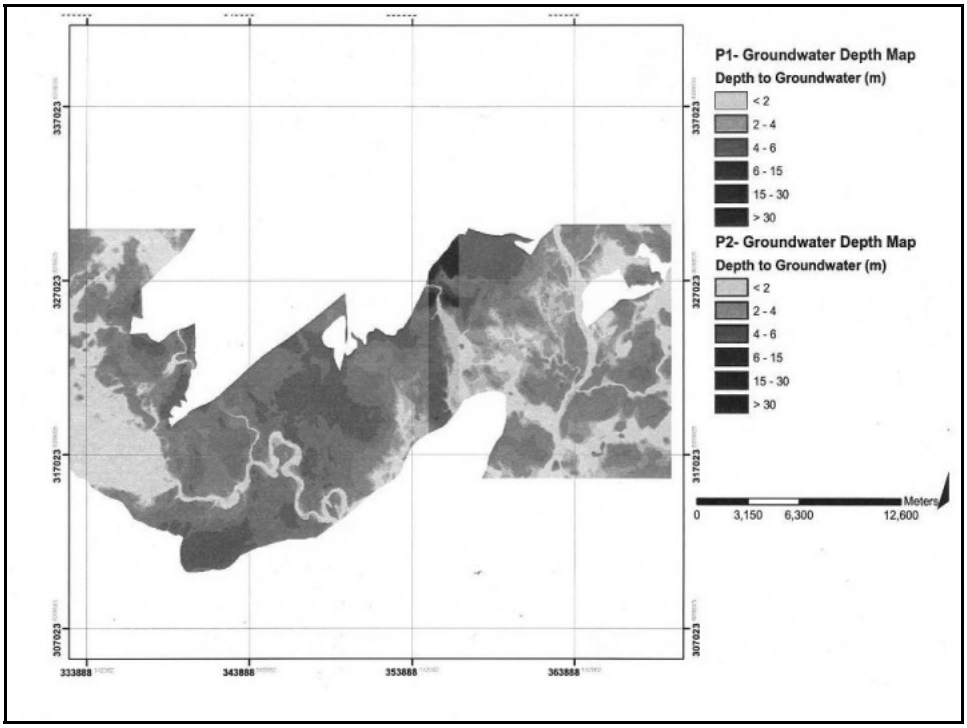
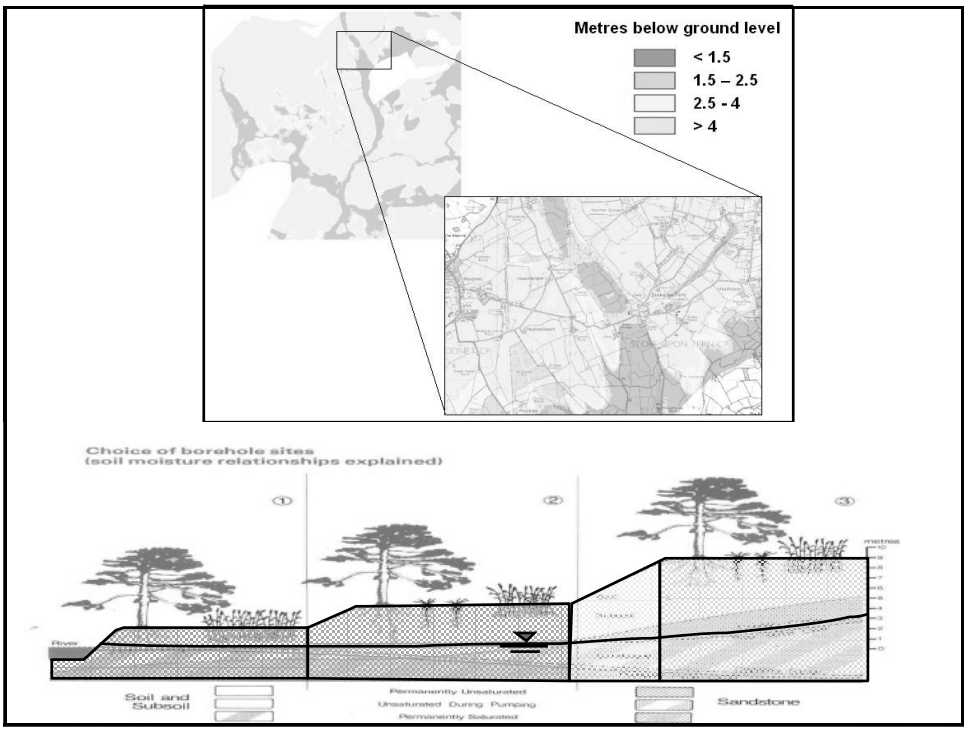
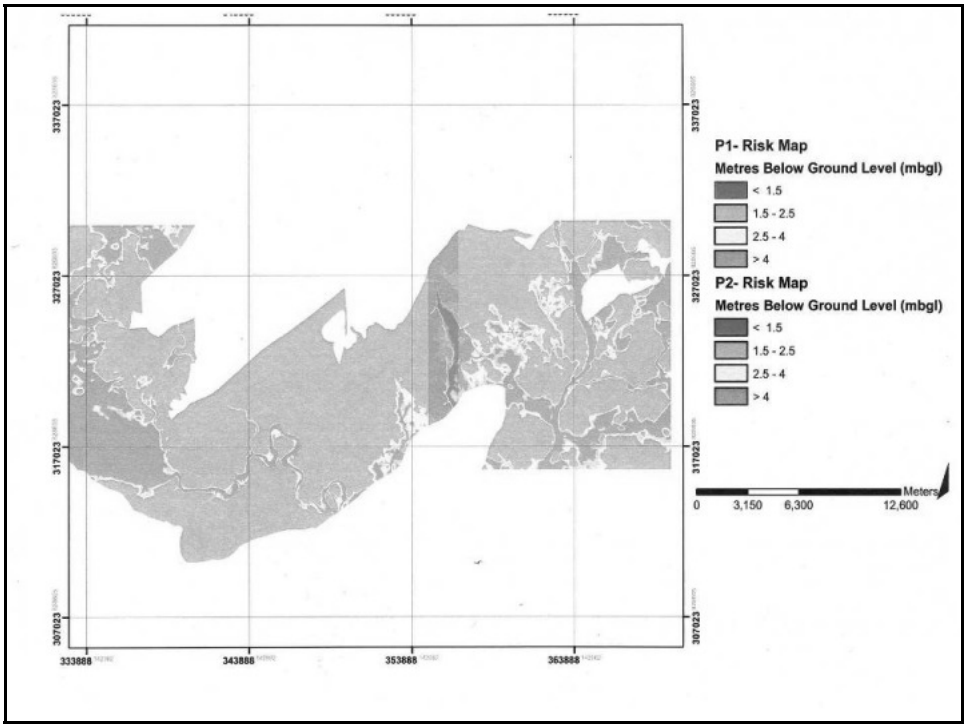


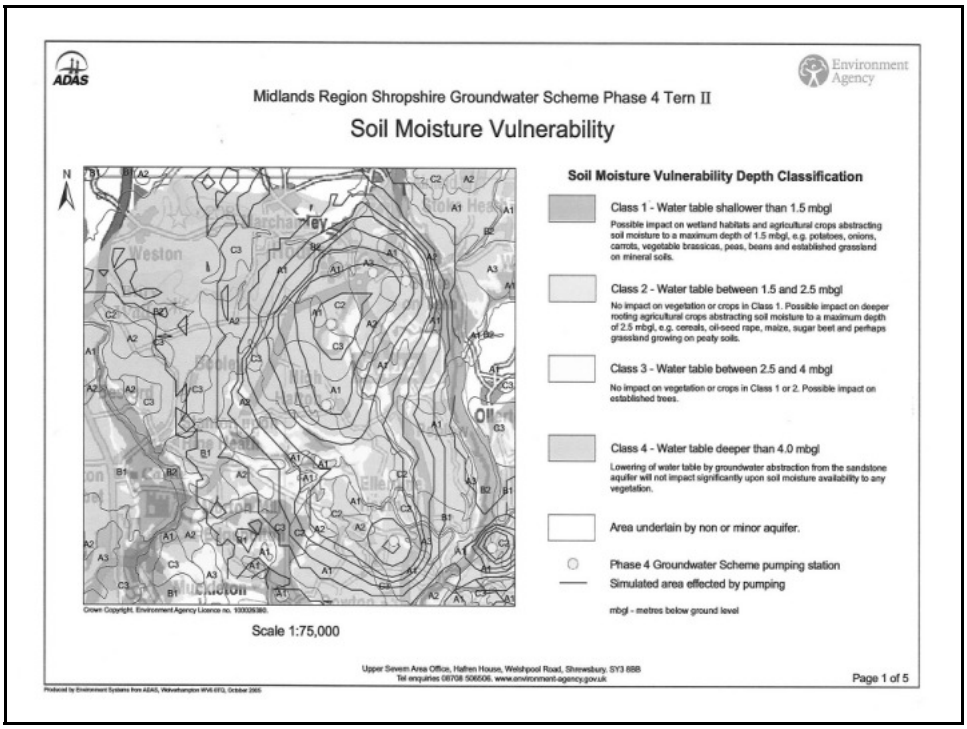
Figure 6.1 Monitoring Network
Phase 4 Group Test
Predicted Drawdown
in the Sandstone Aquifer
& in Relation to Known
Private Soucres
Predicted well field generated from
East Shropshire Groundwater model
Key
Phase 4 Abstraction Boreholes
Predicted Drawdown
Phase 1 & 4 Private Sources
This map is reproduced with the permission of Ordnance Survey on behalf of HerMajesty's Stationary Office.
Environment Agency.
GD 03177G. (2002)
Kilometers
0 0.5 1 2 3 4
NORTH SHROPSHIRE DISTRICT
TELFORD AND WREKIN

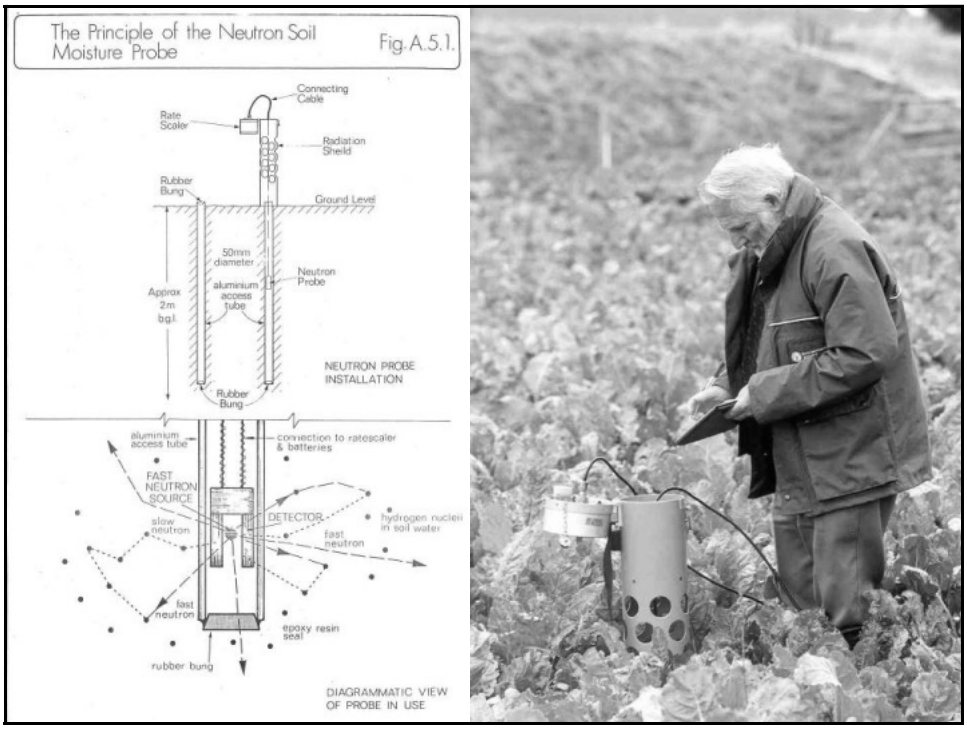

Choice of borehole sites
(soil moisture relationships explained)
①
②
③
metres
10
9
8
7
6
5
4
3
2
1
0
Soil
Subsoil
River
Sandstone
Pumped Water Level
Soil and Subsoil
Permanently Unsaturated
Unsaturated During Pumping
Permanently Saturated
Sandstone

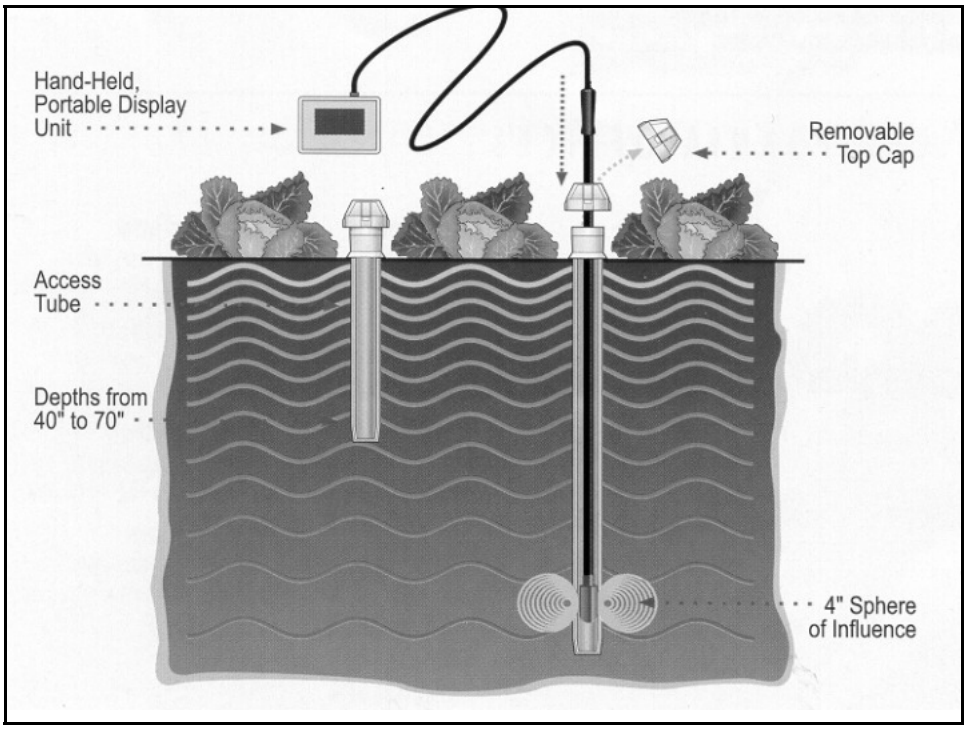

P1- Groundwater Depth Map
Depth to Groundwater (m)
< 2
2 - 4
4 - 6
6 - 15
15 - 30
> 30
P2- Groundwater Depth Map
Depth to Groundwater (m)
< 2
2 - 4
4 - 6
6 - 15
15 - 30
> 30
Meters
0
3,150
6,300
12,600
337023
327023
317023
307023
333888
343888
353888
363888

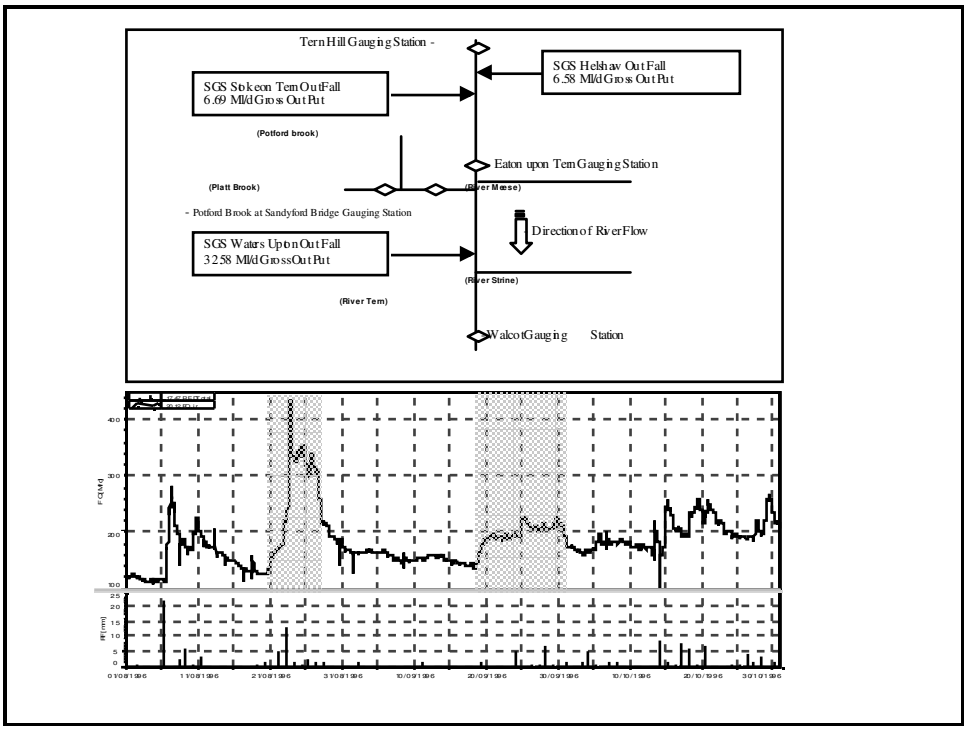

Metres below ground level
< 1.5
1.5 – 2.5
2.5 - 4
> 4
Choice of borehole sites
(soil moisture relationships explained)
①
②
③
River
Soil and Subsoil
Permanently Unsaturated
Unsaturated During Pumping
Permanently Saturated
Sandstone

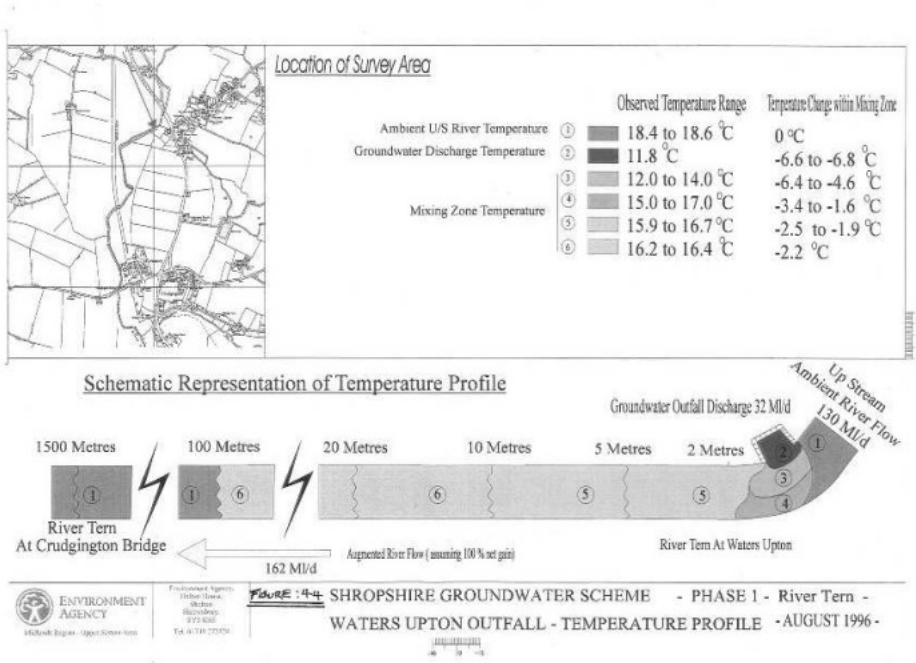

P1- Risk Map
Metres Below Ground Level (mbgl)
< 1.5
1.5 - 2.5
2.5 - 4
> 4
P2- Risk Map
Metres Below Ground Level (mbgl)
< 1.5
1.5 - 2.5
2.5 - 4
> 4
Meters
0
3,150
6,300
12,600
337023
327023
317023
307023
333888
343888
353888
363888

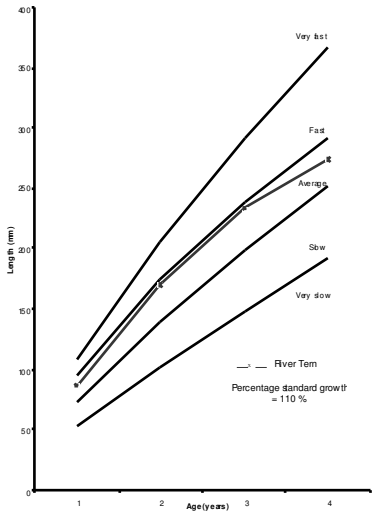

ADAS
Environment Agency
Midlands Region Shropshire Groundwater Scheme Phase 4 Tern II
Soil Moisture Vulnerability
N
Soil Moisture Vulnerability Depth Classification
Class 1 - Water table shallower than 1.5 mbgl
Possible impact on wetland habitats and agricultural crops abstracting soil moisture to a maximum depth of 1.5 mbgl, e.g. potatoes, onions, carrots, vegetable brassicas, peas, beans and established grassland on mineral soils.
Class 2 - Water table between 1.5 and 2.5 mbgl
No impact on vegetation or crops in Class 1. Possible impact on deeper rooting agricultural crops abstracting soil moisture to a maximum depth of 2.5 mbgl, e.g. cereals, oil-seed rape, maize, sugar beet and perhaps grassland growing on peaty soils.
Class 3 - Water table between 2.5 and 4 mbgl
No impact on vegetation or crops in Class 1 or 2. Possible impact on established trees.
Class 4 - Water table deeper than 4.0 mbgl
Lowering of water table by groundwater abstraction from the sandstone aquifer will not impact significantly upon soil moisture availability to any vegetation.
Area underlain by non or minor aquifer.
Phase 4 Groundwater Scheme pumping station
Simulated area effected by pumping
mbgl - metres below ground level
Crown Copyright. Environment Agency Licence no. 100026380.
Scale 1:75,000
Upper Severn Area Office, Hafren House, Welshpool Road, Shrewsbury, SY3 8BB
Tel enquiries 08708 506506. www.environment-agency.gov.uk
Page 1 of 5


The Principle of the Neutron Soil Moisture Probe
Fig. A.5.1.
Connecting Cable
Rate Scaler
Radiation Shield
Rubber Bung
Ground Level
50mm diameter
aluminium access tube
Neutron Probe
Approx 2m b.g.l.
NEUTRON PROBE INSTALLATION
Rubber Bung
aluminium access tube
connection to ratescaler & batteries
FAST NEUTRON SOURCE
DETECTOR
slow neutron
fast neutron
hydrogen nuclei in soil water
fast neutron
epoxy resin seal
rubber bung
DIAGRAMMATIC VIEW OF PROBE IN USE

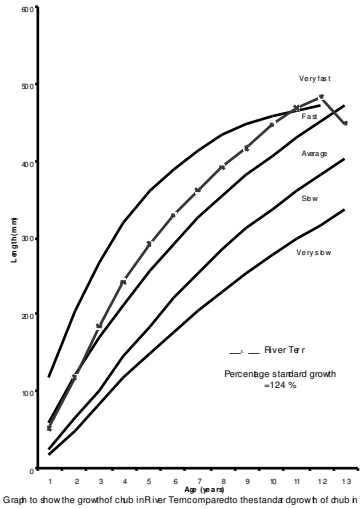

Hand-Held,
Portable Display
Unit
Removable
Top Cap
Access
Tube
Depths from
40" to 70"
4" Sphere
of Influence


Tern Hill Gauging Station -
SGS Stokeon Tern OutFall
6.69 Ml/d Gross Out Put
SGS Helshaw Out Fall
6.58 Ml/d Gross Out Put
(Potford brook)
Eaton upon Tern Gauging Station
(Platt Brook)
(River Meese)
- Potford Brook at Sandyford Bridge Gauging Station
Direction of River Flow
SGS Waters Upton Out Fall
3.258 Ml/d Gross Out Put
(River Strine)
(River Tern)
Walcot Gauging Station





Graph to show the growth of brown trout in River Tern compared to the standard growth of brown trout in rivers (National Fisheries Laboratory unpublished data)



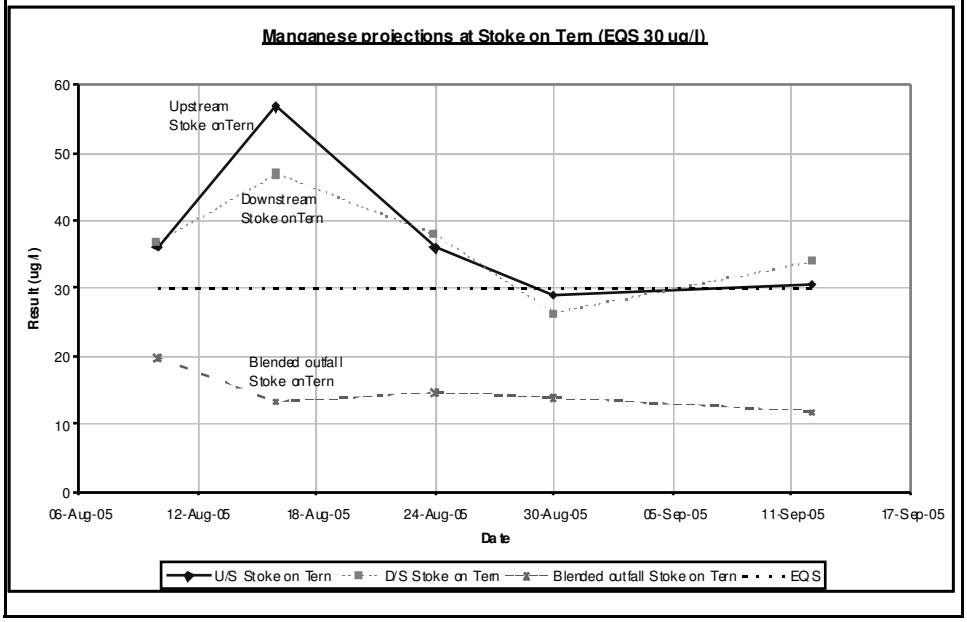
Graph to show the growth of club in River Tern compared to the standard growth of club in southern rivers (National Fisheries Laboratory unpublished data)

Brown Trout

Club

Hydro-chemical Monitoring

- Baseline (non-operational) & Operational sampling regimes
- Early analysis - nutrients, metals, & major ion chemistry
- Organic chemistry - Pesticides, Herbicides & Hydrocarbons
- Gas Chromatography Mass Spectrometry (GCMS)

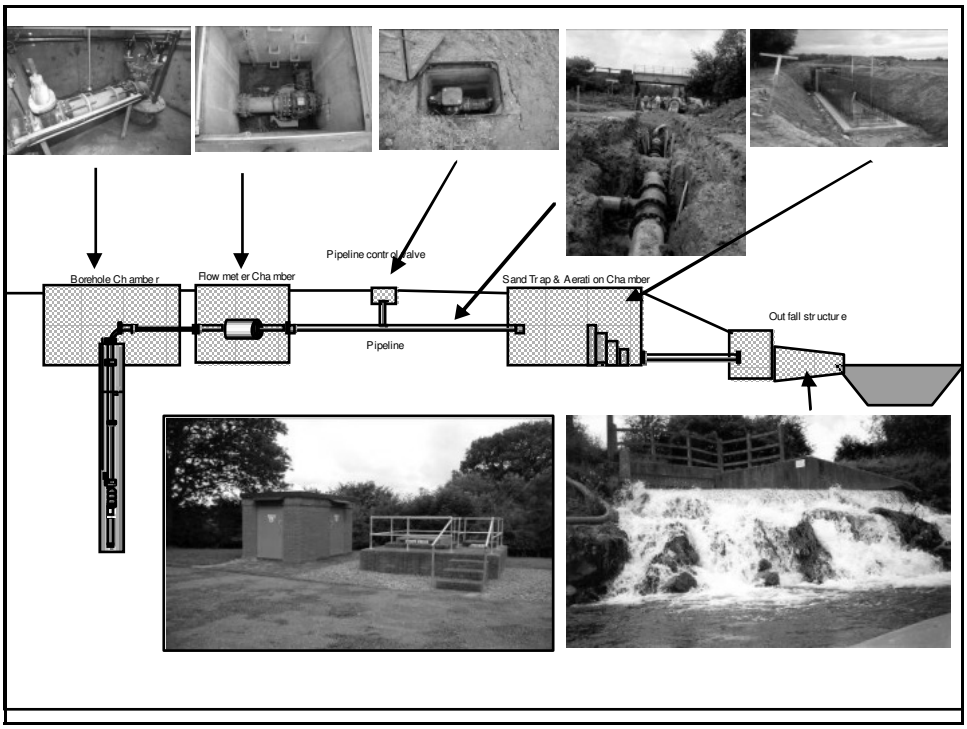


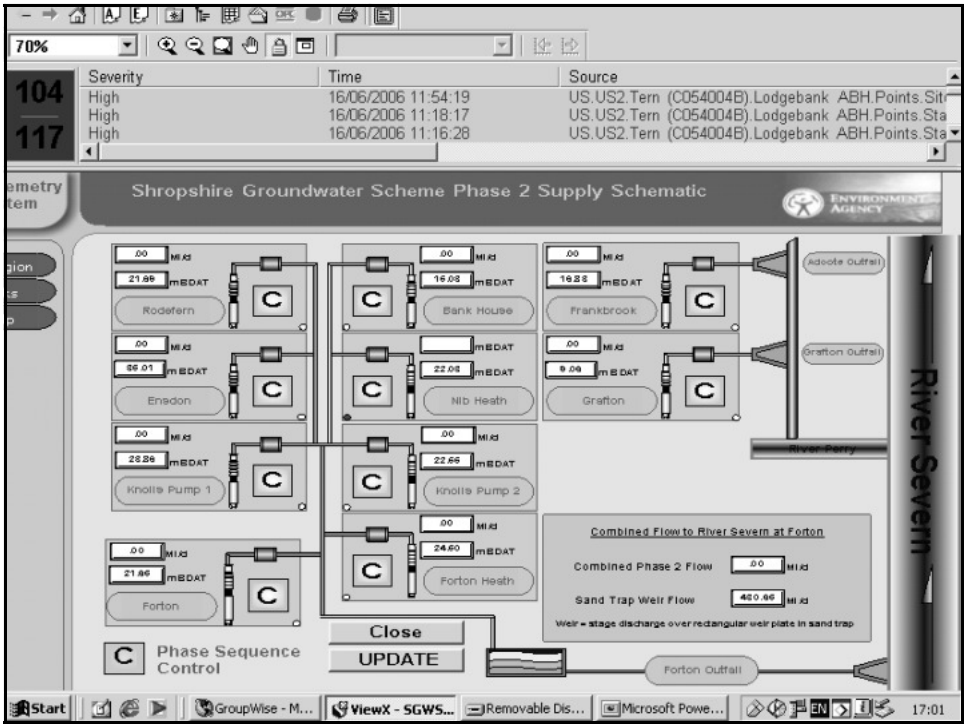
Borehole Yield - MSc Study

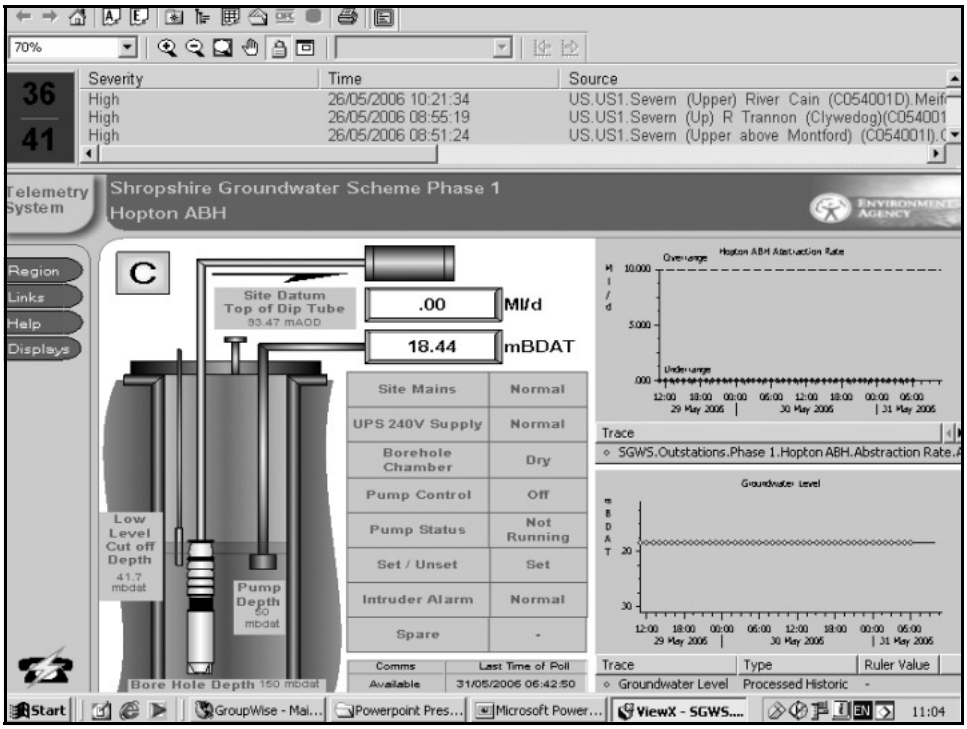
- **Comparison of operational yields and repeat step test v baseline specific capacity**
- **Hydro-chemical modelling showed water to be supersaturated with iron species haematite, magnetite, geothite & ferrihydrite**
- **Microbial testing confirmed presence of iron & sulphur reducing bacteria and slime forming bacteria**
  - **Iron reducing bacteria (greater mobility)**
  - **Slime forming bacteria (catalyst to encourage Fe & Mn precipitation)**
- **6 out 42 boreholes proven to have >5% yield loss. Coincide with areas of localised confined aquifer (thick drift) giving rise to reducing conditions (Phase 2 & 5) low DO & elevated Fe & Mn**

System Management

- Asset management plans
- Routine turnover of pumps & scheduled maintenance
- Telemetry monitoring, interrogation & operation
- System performance

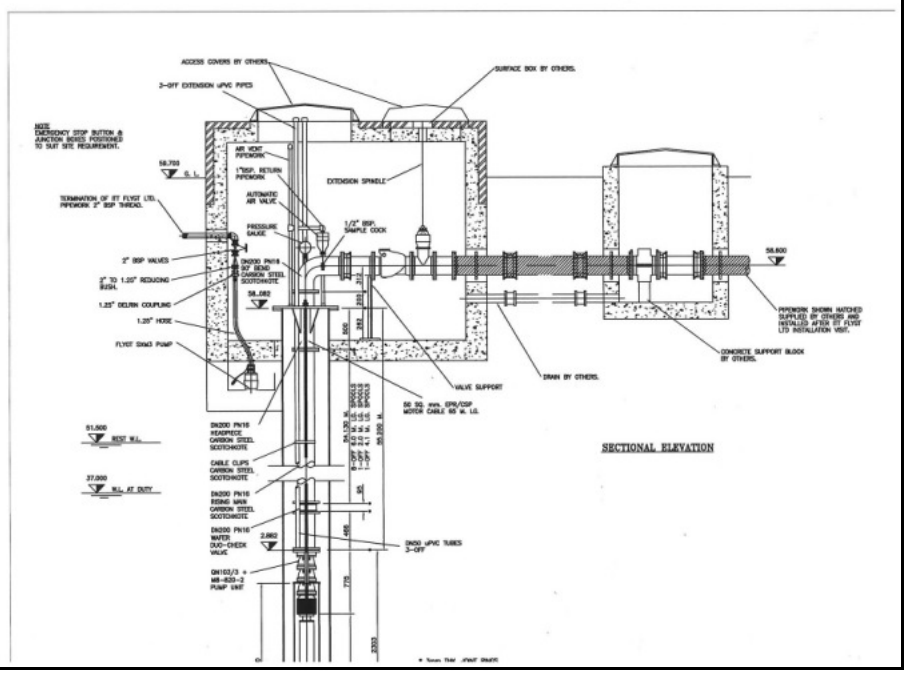

Borehole Chamber
Flow meter Chamber
Pipeline control valve
Pipeline
Sand Trap & Aeration Chamber
Out fall structure


Severity
Time
Source
High 16/06/2006 11:54:19 US.US2.Tern (C054004B).Lodgebank ABH.Points.Sit
High 16/06/2006 11:18:17 US.US2.Tern (C054004B).Lodgebank ABH.Points.Sta
High 16/06/2006 11:16:28 US.US2.Tern (C054004B).Lodgebank ABH.Points.Sta
Shropshire Groundwater Scheme Phase 2 Supply Schematic
Rodefern
Bank House
Frankbrook
Ensdon
Nib Heath
Grafton
Knolls Pump 1
Knolls Pump 2
Forton
Forton Heath
Adcote Outfall
Grafton Outfall
River Perry
River Severn
Combined Flow to River Severn at Forton
Combined Phase 2 Flow
Sand Trap Weir Flow
Weir = stage discharge over rectangular weir plate in sand trap
Phase Sequence Control
Close
UPDATE
Forton Outfall



Energy Consumption 2006

- **Combination of up to 4 Phases**
- **Target Daily Yield 100Ml/d**
- **Total Vol Pumped 4,752 Ml**
- **Total Energy units 1,211,012 kWh**
- **Electricity Cost £66,989**



Energy Performance Evaluation

- **Hodnet Abstraction Pump**
- **Operating Flow 6.02 Ml/d**
- **Head 44m**
- **Energy & Carbon Emission Savings**

  Annual kWh Savings = 7,230.65 (£557.12)

  kWh/Ml Savings = 9.872

  $kgCO_2$/kWhr = 0.43

  Estimated Annual CO_2 Savings (tonne) = 3.11

Concluding points

- Shropshire Groundwater Scheme - Role in Strategic Water Resource Planning & Operations
- Environmental Management
- System Management