

Water management

Water is perhaps our most valuable natural resource. Climate change, increasing desire for environmental protection and continuing development place ever greater demands on this fragile asset.

Regulators and planners are tasked with implementing new legislation. Attention is also focused on the reduction of environmental impact and the remediation of existing environmental damage.

When proposing a new scheme which interacts with the water environment, the developer must ensure that any impact will be managed in a way that is acceptable to the environment and is both affordable and manageable to the developer.

Furthermore, in assessing a proposal, the regulator must be confident that it is based on sound science and engineering, such that the impact and proposed mitigation can be reviewed fairly and objectively, thereby often requiring a multi-disciplinary integrated approach. The regulator also has a requirement to manage water resources and water quality. This may require R&D, assistance with the preparation of operational guidance, and the provision of data and systems to enable permitting decisions to be made.

The ability to call on an experienced strategic partner can be essential in meeting the challenges that water management presents.



Capability statement

Entec

Entec is one of the UK's largest environmental and engineering consultancies and forms part of AMEC's Earth & Environmental division. Our technical and business skills are dedicated to delivering strategic, technical and engineering solutions which bring commercial benefit to customers at home and overseas. This know-how is based on over 60 years' consulting experience in the public and private sectors.



Certificate No. FS 13881

Certificate No. EMS 69090

Entec operates a Quality Management System in accordance with the latest requirements of the international standard BS EN ISO 9001 and an Environmental Management System compliant with BS EN ISO 14001. Both are audited by BSI Management Systems.



Water management



Entec's approach

In delivering your project we create and work in integrated teams so we can meet the unique demands of each project. By doing this we are able to support our customers' objectives and ensure the best possible skills match to meet the required project outcomes.

We concentrate on establishing relationships with our customers who value service delivery based on partnership. That is why we spend time ensuring that our people demonstrate the right qualities and we help them to develop personally.

Communication is extremely important to our business strategy: we listen to our customers and we act on their opinions and ideas. We provide information at the point of need, and we are open and honest in what we say and do.

Flexibility means different things to different people and we appreciate this. As a customer, you have access to all of our resources, not just our project dedicated team members and managers. Our breadth of skills and experience creates a comprehensive matrix of support to enable us to respond to your changing needs.

Entec's experience and knowledge of water management has been built upon delivering our knowledge to our customers: regulators, operators and contractors.



The service

Water Management

Entec understands all aspects of the hydrological cycle and the impacts of human activities upon it. Our staff are at the forefront of water resources management, with specialists in:-

- hydrogeology
- groundwater modelling
- river and coastal modelling
- water resource planning
- flood risk assessment and management
- drainage assessment and design
- water quality modelling
- catchment management and pollution prevention
- water sustainability and efficiency
- well drilling, testing and rehabilitation
- contaminated groundwater investigation
- groundwater remediation
- hydroecology
- waste disposal
- GIS and information management
- economic assessment

We offer the breadth of expertise necessary to tackle all projects related to the water environment. Working in integrated teams to apply these capabilities appropriately, enables us to provide innovative and cost effective solutions that are always focussed on the customer's needs.

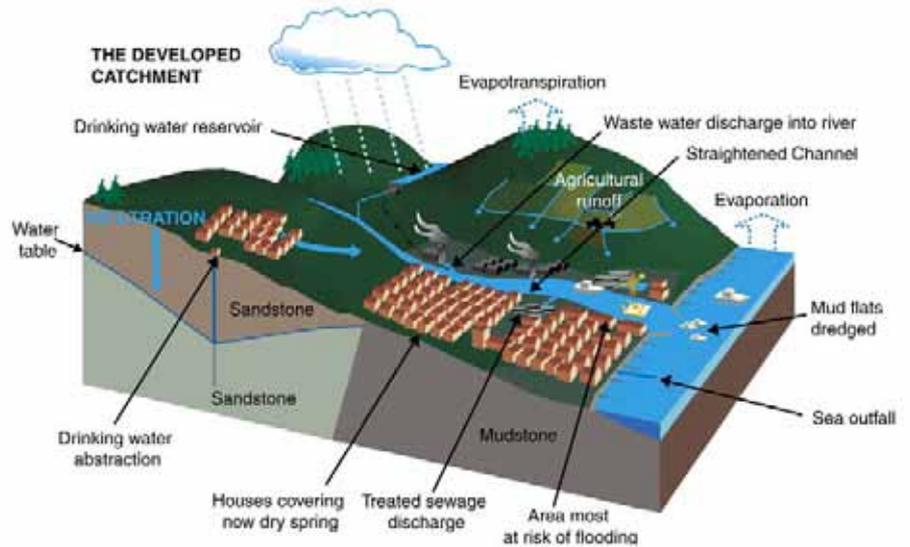
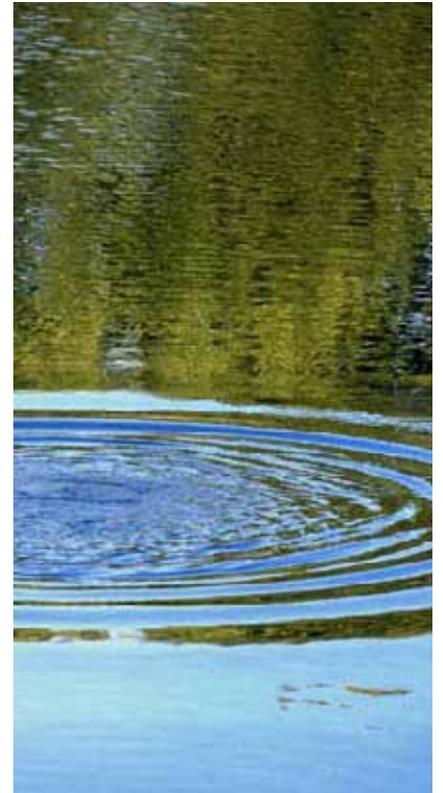


Image from *Urban Rivers: Our Inheritance and Future* (ISBN 1900222221), co-edited by John Heathcote of Entec.

Key Sectors

- Central Government and Agencies
- Water Companies
- Power
- Nuclear
- Property
- Regional and Local Government
- Industry and Oil and Gas
- Minerals and Mining
- Waste
- Agriculture



Water management

Service Areas and Business Drivers

UK and European environmental directives increasingly focus on protecting and enhancing our natural resources in the context of growing pressures from development and climate change. DEFRA's recent publication 'Future Water: The Government's water strategy for England' builds on European directives for 'sustainable delivery of secure water supplies and an improved and protected water environment' - principles that apply to the whole of the UK. Our services to water companies include water resource planning, supply and demand forecasting, and water quality and climate change modelling. We have experience in improving water efficiency, asset management, cost-benefit analysis and strategic environmental assessment, which all lead to increased profitability. By conducting catchment risk assessments, Entec helps the water industry to improve the quality of raw water and hence reduce the cost of water treatment.

The quantity and quality of our water resources are vital indicators of the overall state of the environment. The Water Framework Directive (WFD) is the

principal driver to assess and improve all inland and coastal waters. At Entec, we have used our knowledge of water and ecology, and our skills in modelling and GIS, to help implement Catchment Abstraction Management Strategies (CAMS) and the WFD, working on characterisation, risk assessment, development of environmental standards, classification and objective setting. Further, the Habitats Directive protects designated species and water-dependent ecologically sensitive sites through initiatives such as the Restoring Sustainable Abstraction and Streamlining Abstractions programmes. Here, Entec's ability to provide teams of groundwater modellers, ecologists and hydrologists has been fundamental to our success in delivering these national programmes.

The Groundwater Daughter Directive (GDD) extends the WFD in protecting of our vital groundwater resources. Entec has an unsurpassed record in groundwater modelling, having produced some of the UK's largest groundwater models, allowing us to assess resource availability and the relationships between abstraction and ecologically sensitive sites, and to predict the impact of drought scenarios - skills that are crucial to the water industry.

The GDD puts greater emphasis on the quality of groundwater, though preventing pollution, reversing deteriorating trends, and restoring aquifers to good chemical status. Implementing these policies has led us to undertake a wide variety of proactive and retroactive projects. We carry out catchment risk assessments to identify and control hazards, predictive modelling of agricultural nitrate, and research to improve source protection zones and groundwater vulnerability mapping. Where groundwater has already been polluted, we conduct site investigations, fate and transport modelling, and risk assessments to determine the most appropriate means of remediation. We also carry out remediation, using both conventional surface treatment and innovative in-situ and ex-situ technologies to find the optimum solution for each site. Entec's staff have considerable experience of developing groundwater supplies to meet the needs of our clients, whether they be potable, industrial or agricultural; guiding developments through all stages from investigation, legislative issues, design and engineering, to installation, commissioning and operation. In addition, our hydrogeologists apply the same skills to service the needs of landfill and mining operators.



Water management



In response to climate change and increased flooding and drought, new developments must consider the impact on the environment more than ever. Our work includes hydrological and hydrogeological assessments for Environmental Impact Assessments, Flood Risk Assessments and Water Cycle Studies. Entec has an established reputation in EIAs and FRAs for all scale of developments, that range from individual sites to regional assessments, through the work of our *Intelligent-GIS* and river and coastal modelling teams. We have worked with central and local government to deliver sustainable development programmes, embracing our expertise in drainage impact assessment, and integrated and sustainable urban drainage. Concerns over the impact of induced climate changes influenced the UK governments 2007 Energy White Paper to promote renewed investment in nuclear energy. Entec's experience and links with the nuclear industry places us in a strong position to deliver the services required by the nuclear industry in decommissioning and deep disposal of nuclear waste.

Modern water management generates huge volumes of information, and consequently the need to analyse, integrate and display this information. Our team of GIS and database specialists has expanded rapidly, and those skills now permeate the business, allowing us to provide the most efficient and state-of-the-art services to our clients. We have a comprehensive capability to produce small and large scale drawings, to develop customised GIS and database applications, manage monitoring programmes, and maintain and process the resulting information according to the clients needs, including web-based solutions where required.



Case studies

The following pages demonstrate Entec's capabilities in the area of Water management, using case study examples. ►



Anglian Framework Contract Environment Agency, Anglian Region

Entec has been awarded a framework contract to provide consultancy services to the Anglian Region of the Environment Agency, in order for them to deliver their programme for groundwater resources assessment. Entec is the sole provider under this five-year contract that began in 1999, and has grown to more than £1 million / year of fee work under this contract.

The nature of the framework is providing technical expertise with around 10-20 individual assignments running at any one time. The client actively promotes a team-working approach that allows Environment Agency staff and other stakeholders to contribute actively to deliverables. Emphasis is also placed upon reporting, programme planning and resourcing to ensure that current progress is monitored, and that new assignments can be planned and delivered in an efficient manner.

The Environment Agency Anglian Region's programme for groundwater resources assessment is aimed at providing the Agency with the tools and information to make groundwater resource decisions based on sound science and good technical practice. The programme identifies the need for collation of existing data and information, together with collection of additional data if required, leading to the development of distributed groundwater flow models, which will underpin decision-making on water resources management. Delivery of GIS products also forms an important part of the strategy, to permit maximum benefit to be derived from the interpretation of information.

Projects within the programme will technically underpin decision-making for Catchment Abstraction Management Strategies (CAMS), which address both water resource management plans and licensing policy, the Habitats Directive Review of Consents and the Restoring Sustainable Abstraction Programme.

The groundwater programme covers the main aquifer units of the Anglian region, and splits these into nine project areas. Four of these are currently being investigated: Ely Ouse; Yare and North Norfolk; Essex; and Cam-Bedford Ouse.

Stakeholder involvement and external technical review are both important features of the studies. A number of stakeholders were involved in consultations during the scoping studies, to ensure that water interests in the project areas are understood by the project teams.



Stakeholders represented include Environment Agency regional staff; other central government agencies (such as English Nature); local and county councils; internal drainage boards; and abstraction licence holders including water companies and farmers.

As well as stakeholder input to the project programme, technical review of project output has been undertaken by internal, external peer and stakeholder review groups.



Providing technical expertise to deliver major water resources strategy



Coastal Flood Risk Research and Development – GIS Association of British Insurers

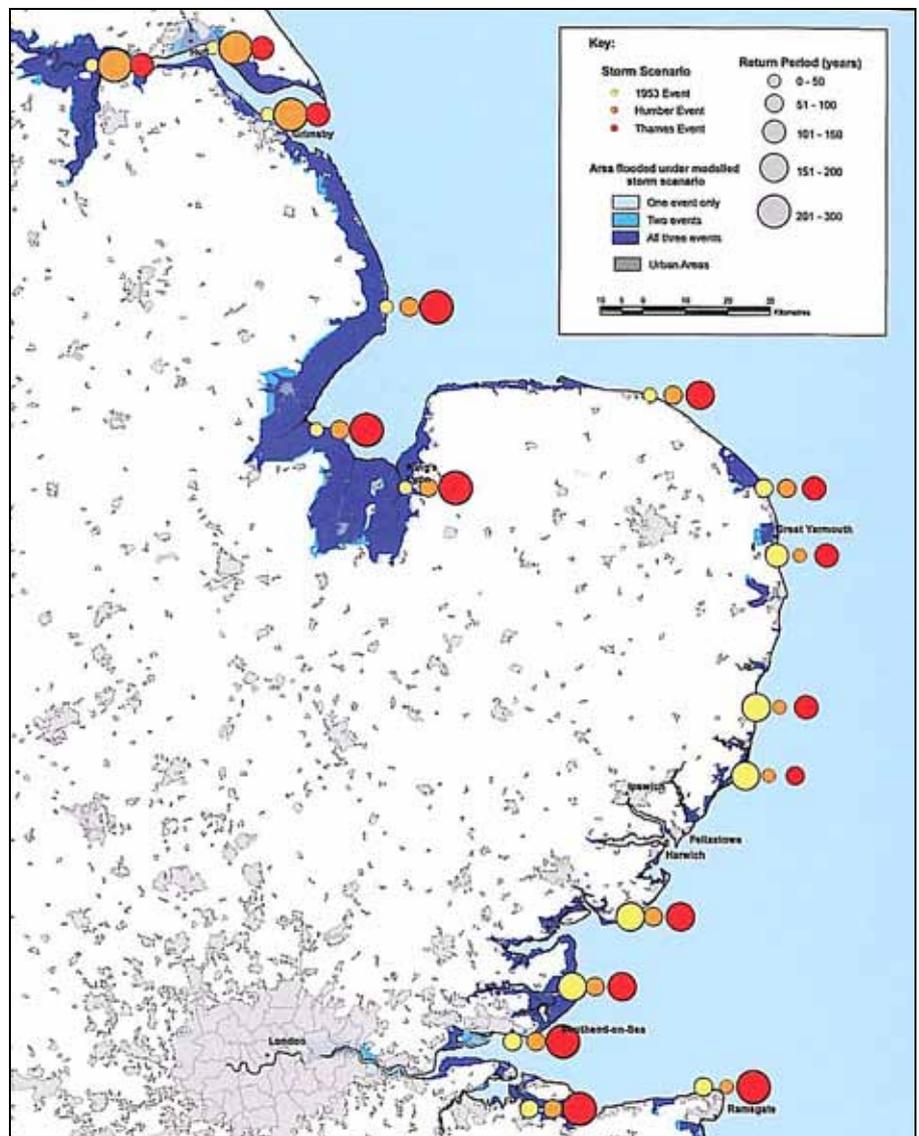
In May 2006, Entec (in association with Risk Management Solutions and Risk & Policy Analysts) were commissioned by the Association of British Insurers to undertake a study to assess the current and future risks posed by extreme storm surge events along the East Coast of England.

This work concentrated on assessing levels of flood risk using a number of indicators including residential and commercial property losses and vulnerable sites (e.g. schools, ambulance/fire services, hospitals). The analysis conducted in the study indicated that the financial damages from a major coastal flood affecting Eastern England are likely to increase fourfold up to £16 billion, following a sea level rise of just 0.4m. This increase could happen as early as 2040, taking account of climate change pressures, and is relatively certain by 2080.

The damage values reported are considered to be lower than total costs, as only physical damage and immediate response costs are included. The evidence from New Orleans shows that communities recover very slowly when whole regions suffer widespread damage. Financial and social costs escalate quickly as a consequence – for example, it is estimated that up to 12% of health services in coastal communities of Eastern England could be affected in a future major storm surge event.

More detailed analysis was also conducted within a series of case studies (Kingston-upon-Hull, Great Yarmouth/Lowestoft, South Essex and East London) to evaluate the likely consequences of coastal flooding upon property damages, business and transport disruption, social impacts and environmental consequences. The analysis highlighted that socio-economic effects including population movements, increased development and rising asset values could add substantially to future damage costs.

In addition, the final study report highlighted the likely requirement of future management policies, i.e. investment requirements for coastal and flood management spending, regional planning policy and local planning system (PPS25) which will be necessary to limit the impacts of future coastal flooding.



*Assessing current and
future flood risks
along the
East Coast of England*



Ashley Road Remediation Total UK Ltd

Entec was commissioned by Total UK Ltd (Total) to assess the risks arising from a spill of unleaded petrol from a fuel filling station in St Albans. The assessment identified that 'monitored natural attenuation' (MNA) was an appropriate remedial solution, but that additional information was required to better understand the behaviour of the fuel in the sub-surface.

Entec recommended a scope of additional work including further site investigation boreholes, a programme of groundwater quality monitoring from existing and additional borehole installations, and further research on the degradation of organic compounds in the sub-surface, including MTBE.

Entec was retained by Total to implement and manage the overall scheme, including borehole installation, groundwater quality monitoring and assessment of remedial options. The University of Sheffield's Groundwater Protection and Restoration Group was commissioned to undertake the research project, which was partially funded under CL:AIRE.

A total of 18 monitoring boreholes were constructed within and down-gradient of the filling station, including several with multi-level monitoring installations. In addition, soil core and groundwater samples were obtained during construction for microbiological studies. The boreholes were monitored over several months for key contaminants. The results supported the MNA approach.

Entec's commission was extended to include the decommissioning of the filling station. Entec produced a specification for the works, procured a specialist contractor, provided full-time site supervision and also acted as 'planning supervisor'. The works involved the removal of the forecourt canopy; eight underground storage tanks and their associated pipelines; and localised zones of contaminated soil; plus backfilling of the excavations and reinstatement of tarmac surfaces.

In addition, a soil vapour extraction system was operated during the works and for a period after completion, using boreholes located within the forecourt of the filling station. This was undertaken as a contingency measure in the event of further contaminant mobilisation; however, none was observed.

A programme of groundwater quality monitoring during and following the decommissioning works showed no significant change in contaminant concentrations compared to the results

from the long-term monitoring, indicating that the works did not have a detrimental impact on groundwater quality.

Following completion of the works programme, Entec prepared a detailed validation report, which described the works carried out and the condition of the site upon completion. This report was presented to the Environment Agency and has subsequently been accepted by the Agency as evidence of the satisfactory completion of the decommissioning works.

Contaminated land expertise for fuel filling station



Towards Water Neutrality in the Thames Gateway Environment Agency

*Water efficiency in a
high growth area*



In December 2006 Entec was commissioned by the Environment Agency on behalf of the Agency, Communities and Local Government and the Department for Environment, Food and Rural Affairs to undertake a study investigating the feasibility of achieving water neutrality within the Thames Gateway.

The Thames Gateway is an area characterised by low rainfall and high water use and lies within an area classified as 'seriously water stressed'. The Government has outlined plans for the construction of two million new homes by 2016, with at least 160,000 of these houses to be constructed within the Thames Gateway. The Thames Gateway development presents the opportunity for the area to be an exemplar for sustainable development and encourage ambitious levels of water efficiency.

For this study it was considered that water neutrality would be achieved 'if the total water used after new development is equal

to or less than total water use in the Thames Gateway before the development'.

Entec developed a scenario based approach to modelling water demand in the Thames Gateway, which explored the feasibility of water neutrality by:

- making new developments more water efficient;
- offsetting new demand in the Thames Gateway by retrofitting existing homes and other buildings with more efficient fixtures and fittings; and
- increasing domestic metering and introducing innovative tariffs for water use which encourage households to use water more efficiently.

The project found that achieving water neutrality within the Thames Gateway by 2016 is technically feasible, but is a challenging target for policymakers, consumers and those involved in delivery.

There are a number of ways in which neutrality could be achieved using different combinations of the uptake of water efficient devices in new buildings, retrofitting existing properties with more water efficient fixtures and fittings and through the use of other demand management mechanisms such as domestic metering and variable tariffs.

The study showed that it may be possible to go 'beyond neutrality' with a high level of water efficiency in new buildings and an extensive retrofitting programme. The study also showed that the costs of achieving neutrality are comparable with those of other options such as leakage reduction.

This project will be used by Government to inform policy around the concept of water neutrality. The issues explored in this study are readily transferable to other regions where substantial growth is planned.



Dounreay Contamination Barrier Consultancy Support UKAEA

The United Kingdom Atomic Energy Authority (UKAEA) is responsible for managing the decommissioning of the nuclear reactors and other radioactive facilities used for the UK's nuclear research and development programme, in a safe and environmentally sensitive manner.

Within the Dounreay site a number of areas, presently grass-covered, have radiation levels at ground surface sufficiently high that they are designated 'controlled' under the Ionising Radiation Regulations. The radiation flux at surface is believed to be the consequence of radioactively contaminated soil at depth, and there is the possibility of rainwater infiltration causing this contamination to spread. Therefore, regulators have asked UKAEA to demonstrate control by preventing water infiltration.

Entec has been appointed to design works to place impermeable covers on the barriered areas and remove surface water run-off, via the site drainage system or other routes as necessary, appropriate and practicable. The design for the cover needed to consider the following requirements:

- minimisation of ground intrusion;
- minimisation of new material being contaminated;
- for it to be easily removable, if required;
- acceptable to be left in place;
- repairable;
- resistant to local wildlife, such as rabbits and unattractive to ground nesting seabirds; and
- light plant should be able to traverse the cover.

The project's unique nature requires Entec to develop innovative solutions to seemingly straightforward issues. Our proposed solution involves:



Designing new surface coverings to minimise potential contamination migration

- a four-layered, impermeable barrier system which is repairable and resistant to wildlife;
- a smooth graded surface built up using imported fill, laid on a separation membrane, with channels created across service ducts to allow routine maintenance to take place;
- areas bounded with concrete retaining structures to provide retention of surface water during periods of heavy rainfall; and
- having a control system to limit discharge to the local drainage system during heavy rainfall, in order to prevent localised flooding.

The solution has a number of benefits to UKAEA, as it can be sized to accommodate

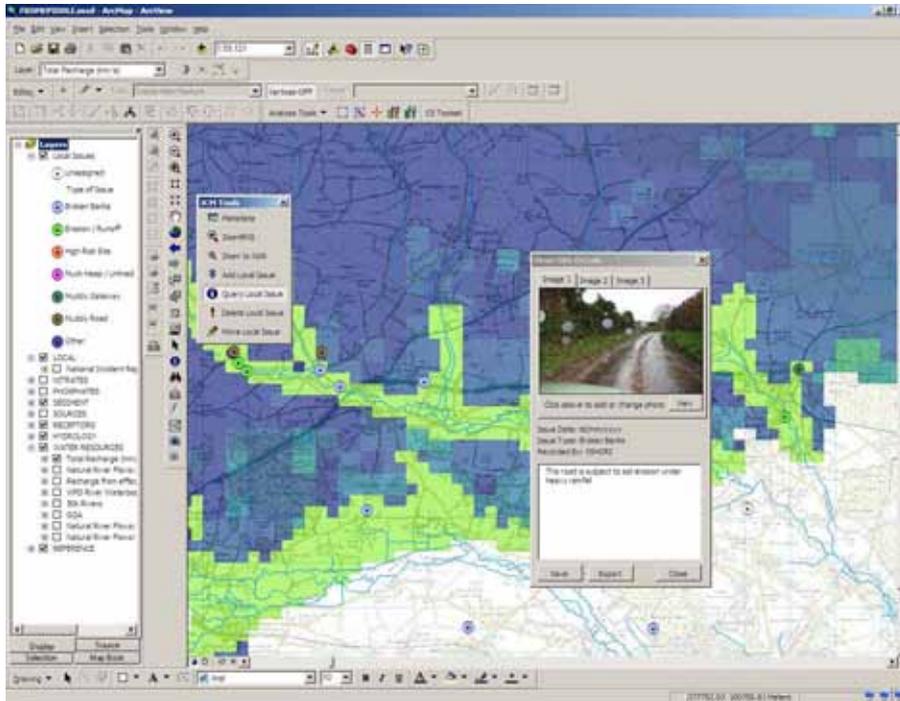
any barriered area; can be tailored to the unique environment; optimally exploits the capacity of the connecting drainage system; maximises the amount of work outside the radiological areas and minimises work inside; minimises the amount of material contaminated; and relies on construction techniques/materials commonly available on site.

This project aims to reduce the movement of the contaminants within the barriered areas through the percolation of ground water, until a time when permanent remediation is appropriate as part of overall decommissioning. As part of the works, Entec will be looking to minimise both the liabilities associated with the barriered sites and the overall costs of the works.



Making Information Available for Integrated Catchment Management Environment Agency

*Using GIS to gather
and manage geographic
data in the Frome-
Piddle catchments*



This project was undertaken for the Science division of the Environment Agency (EA), focusing on the Frome-Piddle catchments in Dorset. The overall aim was to explore the use of GIS as a tool for gathering and managing geographic data, related to diffuse pollution in catchments. Entec's GIS team collected over 150 layers of GIS data from within the EA and third party suppliers, consisting of base maps, pollution sources and sensitive receptors, water resources data, measured, observed and modelled pollution layers. These were organised in to a number of GIS projects, and 'metadata' (information about the data layers) was also gathered, to aid with the understanding of the information for all those involved in catchment management.

A geographic information 'portal' was created using MS Excel, to indicate which geographic layers are available, and detailing the source, coverage, resolution,

file locations, suitability and format of the data. Hyperlinks from within this document link to ancillary reports, supporting information and to full metadata records of the GIS layers. Metadata records contain full information about the ownership and copyright of the data, any access and distribution restrictions, detailed information about the derivation of the data, GIS processing steps and methods which have been applied to the data, and some interpretation about the reliability and suitability of modelled data for various purposes. The spreadsheet was also customised to allow users to open ArcGIS directly from Excel, to load pre-defined or user defined projects.

Customised ArcGIS tools were also developed to enable the local catchment staff to easily and quickly capture local knowledge about diffuse pollution.

A toolbar was developed to enable the user to enter a location on the map, and to record issues related to nitrate, phosphate and sediment pollution. Notes and photographs can be added to the point on the map, and a report generated in Word to show a location map and include the notes and photographs.

Other methods for sharing of spatial information were also explored, especially for non-GIS users who don't have access to specialist ArcGIS software. Selected layers were published to an Internet Explorer free map viewer in SVG format, and the local knowledge layer was exported to Google Earth format, so it could be viewed against a detailed aerial photography backdrop.



Cardiff Bay Barrage - Drainage and Groundwater Control Cardiff Bay Development Corporation

The construction of a tidal exclusion barrage across the mouth of Cardiff Bay creates a freshwater lake with a water level close to 4.5m OD in place of a tidal estuary with diurnal water level fluctuations between -2 and 6m OD. This change has a significant impact on the drainage and quality of groundwater in the low-lying areas of South Cardiff which surround the Bay.

Since 1990 Entec has been the principal hydrogeological consultant to the Cardiff Bay Development Corporation on all aspects of the hydrogeology and groundwater estuary interaction in the area. This work has included:

- detailed data synthesis, conceptual understanding and predictive digital modelling to support the Barrage Act;
- design and installation of an extensive (250 piezometer) groundwater surface water and climate monitoring system;
- analysis and interpretation of monitoring data;
- design of 'groundwater control system' including long horizontal boreholes, for installation in South Cardiff;
- participation (jointly with Hyder Consulting) in the supervision of the installation and commissioning of the 'groundwater control system'; and
- analysis and reporting of the impact of impounding and the effectiveness of control pumping on the multilayered groundwater system of the South Cardiff area.

Throughout the work Entec has participated extensively in public consultation activities both with the regulatory and local authorities and with opponents of the Barrage Scheme.



Hydrogeological advice for one of Europe's largest investment and engineering projects



River Basin Characterisation for the Water Framework Directive Environment Agency

Entec was commissioned by the Environment Agency to assess groundwater pollution and abstraction risks and to carry out flow risk screening for rivers, lakes and estuaries across England and Wales as part of the Initial Characterisation phase for implementing the EU Water Framework Directive (WFD) [See Box 1]. The initial characterisation risk assessment included a number of elements as follows:

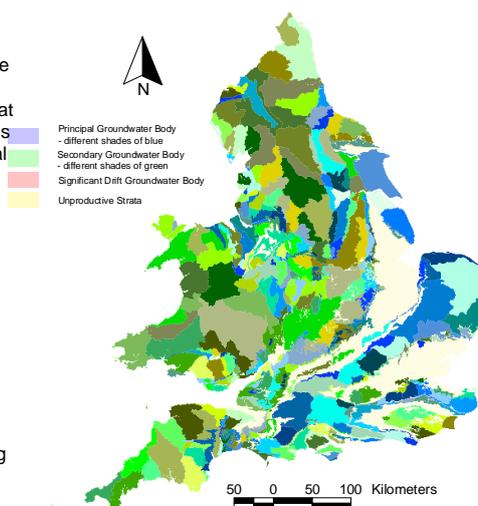
- Development and review of guidance** in support of the UK Technical Advisory Group (UKTAG) for both groundwater and rivers. UKTAG includes representatives from EA, SEPA, NI-EHS, GSI and Eire EPA.
- Development of risk assessment methodologies** jointly with the EA under the direction of the EA River Basin Characterisation Project. Method development was undertaken with steer and input from the EA Groundwater and Water Resources group, EA Science Group, plus input and review from the wider EA. These methods were developed to undertake risk assessments at a national scale. A key requirement was the use of available datasets with national coverage to allow a consistent approach to be used across the country.
- Delineation of groundwater bodies** - the areas for which risks are assessed and reported to Europe. Groundwater bodies are the units for which groundwater status will be reported to Europe as part of the Water Framework Directive. These bodies needed to be hydrogeologically coherent units so that water balance calculations can be used to determine their quantitative status, where possible within boundaries comparable with existing resource management units. Groundwater bodies across England and Wales were initially based on an assessment of their water resources potential (aquifer type – see figure). Aquifer boundaries simplified using GIS were then divided using the Agency's Catchment Abstraction Management Strategy (CAMS) surface water or groundwater catchments.
- Assessment of pressures and impact evidence** to determine the risk of groundwater bodies failing to meet their environmental objectives, as defined in the WFD, by 2015. Initial characterisation focussed on the following main pressures:
 - Groundwater abstraction:** Is groundwater abstraction likely to be a high proportion of the aquifer recharge, and what impact is this abstraction likely to have on groundwater dependent lakes, Protected Areas (i.e. protected ecological habitats) and flows in surface water bodies (rivers and lakes)?
 - Chemical risks to groundwater:** Are chemical impacts from diffuse and point sources of pollution likely to cause groundwater quality to fail meet its objectives? The risk was assessed for both individual parameters including nitrate, phosphate, pesticides, and activities such as mining and urban development.
 - Regional Workshops** were run in each of the Agency's 8 Regions where the Initial Characterisation process was reviewed with Agency staff including hydrogeologists, hydrologists and CAMS officers. The workshops were also used as a forum to collect additional information from local staff on known pressures and impacts to supplement the national datasets.

Box 1: WFD Initial Characterisation of Groundwater Bodies

As part of the timetable for implementation of the Water Framework Directive the Environment Agency is required by the end of 2004 to have delineated groundwater bodies within England and Wales and to have identified those at risk of failing to meet their environmental objectives by 2015. This process is referred to as Initial Characterisation. The WFD defines three environmental objectives for groundwater bodies:

- To prevent or limit input of pollutants;
- To achieve "good groundwater status", which includes both good quantitative status i.e. a balance between recharge and abstraction, and good chemical status i.e. quality standards are met and not derogate the ecological status of dependent surface water bodies or dependent ecosystems;
- Reversal of significant upward trends in pollution concentration.

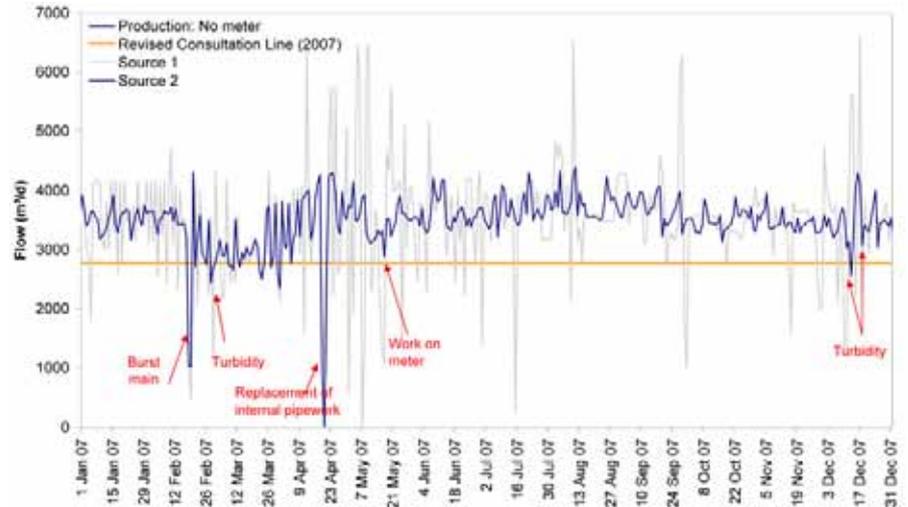
Initial characterisation is viewed as a "fit for purpose" risk assessment focussing on the major pressures likely to impact groundwater bodies e.g. groundwater abstraction or agricultural use of fertilisers. The process has provided an indication of the number of groundwater bodies viewed as being "at risk" of failing to meet the environmental objectives. It will also help prioritise more detailed risk assessment and monitoring to be undertaken before the status of groundwater bodies is first classified in 2009.



Assessing the risk of failure of groundwater to meet its environmental objectives in 2015



Outage Data Collection Dŵr Cymru-Welsh Water



Integrating asset operations and water resources planning

Following the submission of the Water Resources Plan for the 2004 Periodic Review, Dŵr Cymru-Welsh Water (DCWW) commissioned Entec to help improve the assessment of outage levels at water treatment works (WTW) for future regulatory submissions. Outage is an allowance in the supply-demand assessment representing a temporary loss of deployable output and can be caused by factors such as pollution, raw water turbidity, algae, planned and unplanned asset maintenance.

Our approach to improving the knowledge of outage involved developing a consultation process with operations managers to discuss how outage information is currently collated, and how a regular and efficient process of reporting could help establish a database of outage events. This would ultimately deliver benefits in:

- efficiency through having information centrally stored and processed for future submissions;
- helping improve the awareness of outage issues across the business; and

- specifically ensuring future Water Resources Plan submissions used a more robust evidence base.

Since 2005, Entec has implemented a routine monthly process of outage data collection at approximately 85 WTW in DCWW covering the 24 Water Resources Zones. The process involves the production of monthly reports on outages and annual reports which summarise key trends and impacts of outages on normal water production levels.

In addition to providing a more robust outage dataset, the process has helped engage operations and water resources planners in the business on a regular basis, which has delivered wider awareness of key asset risks for investment planning. The collection of outage data has also been used to validate the modelling of outages using the Environment Agency/UKWIR guidance on Outage Allowances for Water Resources Planning, and the DCWW process has been commended by the regulator as an example of good working practice



Brogborough Landfill Hydrogeological Risk Assessment and Hydraulic Containment Shanks

Brogborough Landfill is one of the largest landfills in the UK. It is situated within low permeability Oxford clay, infilling a former brick-pit in Bedfordshire. Its base is below the natural water table (piezometric level) within the clay and underlying poorly productive limestones.

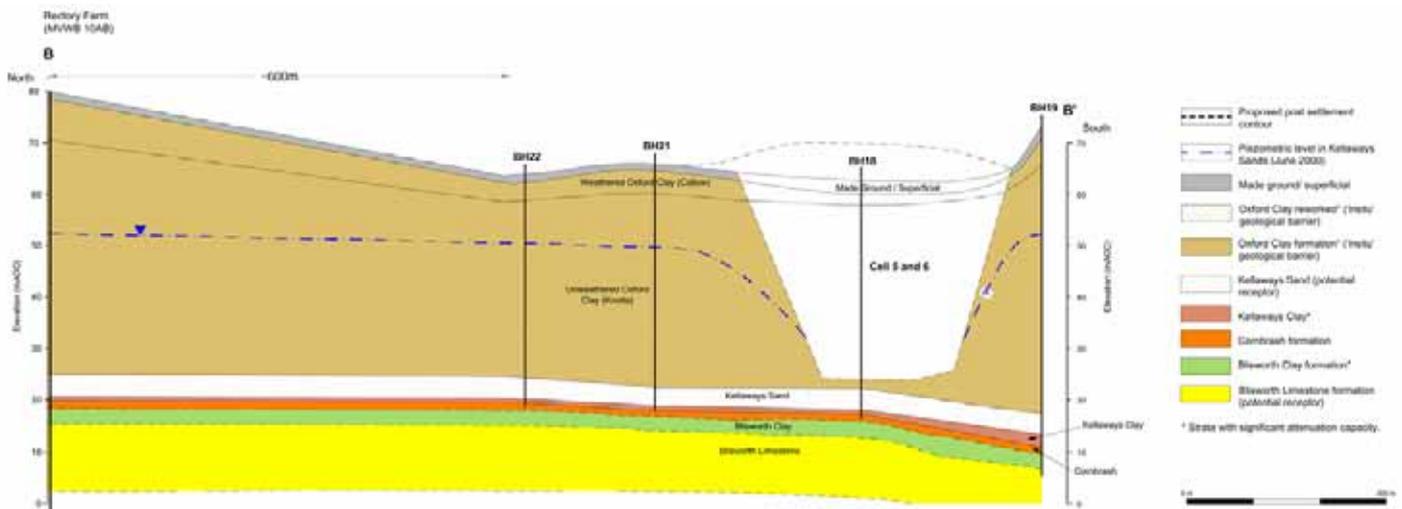
In late 2001, Shanks and the Environment Agency were unable to agree on the level of leachate control needed at the site. Shanks were basing their requested control levels on groundwater risk assessments prepared by Entec in 1997 and 1998. The Entec risk assessments recommended that leachate levels be maintained below piezometric levels in underlying strata so as to promote groundwater movement into the site; a principle called hydraulic containment. The Environment Agency were reluctant to accept this approach and were looking towards much lower levels of leachate level control, which would have required the removal of significant volumes of leachate.

In 2002, through providing an updated groundwater risk assessment, Shanks showing commitment to a leachate management plan, liaising closely with Environment Agency staff in the local office as well as inviting national centre staff to help arbitrate, Entec was able to help both parties avoid the pending Waste Management Licence appeal inquiry.

A key part of the risk assessment was putting the case for hydraulically containing the waste and leachate and demonstrating this to be the 'best practical environmental option' (BPEO). Various technical issues were considered including groundwater protection, gas generation and waste stabilisation.

Entec has subsequently carried out the hydrogeological risk assessment, part of the site's PPC application, and has also been successful in gaining landfill tax credit funding to undertake research into hydraulic containment at landfill sites.

Appeal inquiry avoided through sound risk assessment and proactive liaison with statutory authority



Analysis of Family Level Macroinvertebrate Data Against Flow Statistics for Suitability as Drought Triggers Environment Agency

*Assessing the
relationship between
varying flows and
Family LIFE Scores as
a suitable drought
trigger*



Following the Water Summit in 1997, all water companies are required to produce a Drought Plan detailing their management approach in the event of a drought. The Environment Agency is closely involved in this process, and each Agency region is responsible for producing its own drought plan. A drought plan identifies how a drought status will be recognised and the key actions to be taken during a drought. Various triggers are used to indicate the onset of a drought situation, such as river flow and groundwater levels.

Entec was commissioned to investigate the suitability of macroinvertebrate Family LIFE (Lotic Invertebrate Index for Flow Evaluation) scores as a trigger for indicating the onset of a drought situation in the North East and South East areas of the Environment Agency Thames Region. 10 biology monitoring sites were chosen from each area, representing chalk, sandstone, clay and urban rivers. Flow time series were derived at each site using regression analysis to determine the

relationship between gauged flows and spot flow data. Where no suitable regression existed, CATCHMOD rainfall-runoff modelling was used to derive a flow time series.

Flow statistics were next calculated at each site, and each flow statistic regressed against LIFE score to determine the optimum flow statistic. Observed:Expected (O:E) LIFE score ratios for each site were also calculated and analysed comparing them to flows time series. Finally, LIFE scores were compared with groundwater levels as measured in each area.

The optimum flow statistic was found to vary from site to site, and no one method of

calculation generated consistently better results. The correlation between LIFE score and flows for almost all sites was poor, suggesting that LIFE score is not an appropriate drought trigger in this region.

A lag time of approximately 12 months was seen between a change in river flow and a corresponding change in O:E LIFE score ratio. LIFE scores show a similar lag time when responding to changes in groundwater levels. Therefore, macroinvertebrate abundance does not appear to respond quickly to the onset of a drought situation, and family LIFE scores are not an appropriate trigger for indicating the onset of a drought situation.



Slade Heath Pumping Station South Staffordshire Water

*Supervising the
drilling and testing of
a new production
borehole*

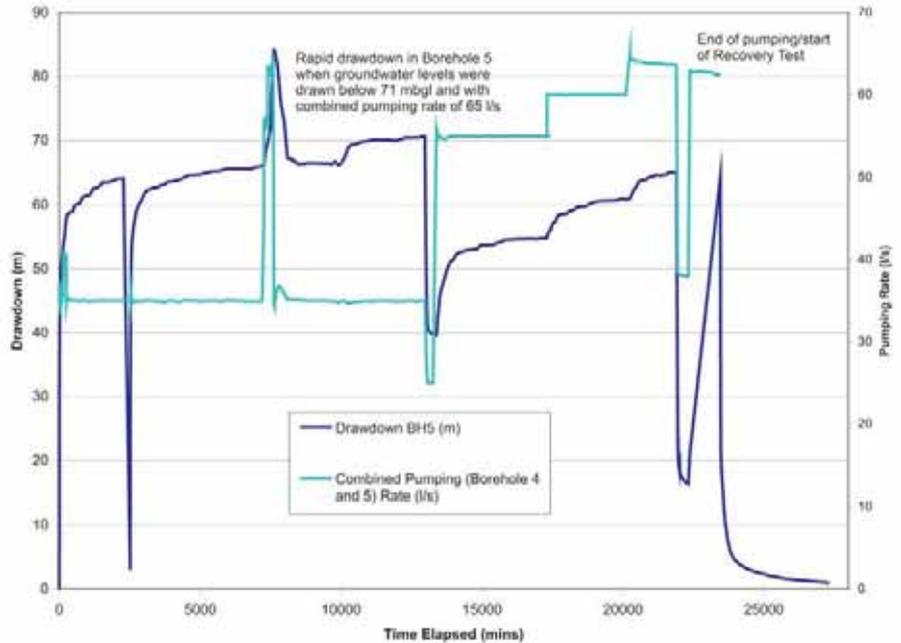
Following a review of options for combating declining yields at Slade Heath Pumping Station, South Staffordshire Water commissioned Entec to design, procure contractor services and supervise drilling and testing of a new production well at the site. Entec staff also acted as CDM Coordinator throughout the site works.

This well was completed at 570mm diameter and 150m depth through the Wildmoor and Kidderminster Formations of the Sherwood Sandstone Group into the top of the Enville Beds.

Drilling was by rotary reverse circulation and development by airlift pumping and surging.

Test pumping was carried out over a one month period and involved both conventional step and constant rate testing of the new well and combined operation with other wells on the site to establish optimum site pumping procedures. As water from Slade Heath is blended with other sources, water quality was rigorously assessed to determine appropriate abstraction volumes.

Detailed completion and test analysis reports were prepared, including recommendations of operational procedures.



Strategic Flood Risk Assessment Charnwood Borough Council



*Supporting future
development through
flood risk management*



Charnwood Borough is located north of the City of Leicester, where the River Wreake, Rothley Brook and Black Brook join the River Soar before it flows north to the River Trent. A large corridor of the Borough is located in Flood Zone 3, with development in places encroaching on the floodplain. The Rivers Soar and Wreake have a history of flooding throughout Leicestershire, with severe flooding occurring in the winter of 1998.

In April 2007, Charnwood Borough Council commissioned Entec to undertake a Strategic Flood Risk Assessment (SFRA) to inform the Council's emerging Local Development Framework (LDF). The SFRA was undertaken in line with the guidance set out in Planning Policy Statement 25 Development and Flood Risk and the accompanying PPS25 Practice Guide. Entec ensured the SFRA was tailored to the specific flooding and development issues facing Charnwood Borough, to ensure a SFRA relevant to the Council's needs. The SFRA alongside other technical studies will underpin decisions on

the choice of locations for future development and in support of regeneration in the Borough.

The Environment Agency flood zones and hydraulic models were used to assess the flood risks posed by the main rivers in the Borough. Hydraulic modelling was used to delineate the Flood Zone 3b (the Functional Floodplain) and potential future increases in the extent of Flood Zone 3a due to climate change. In addition, a large number of watercourses across the Borough have recently been enained as these watercourses potentially pose a significant flood risk to nearby people and property. Two of these water courses, the Wood Brook and Burleigh Brook pass through Loughborough near the town centre, adjacent to key regeneration sites, flood risk being a significant constraint on their redevelopment. Recommendations were provided on flood risks issues specific to these areas to inform the planning and design process, and to inform more detailed Flood Risk Assessments (FRAs) of any sites selected for redevelopment.

In addition to watercourses, other sources of flooding were also considered, including sewer flooding, overland flow, runoff control and groundwater. The SFRA provided a collated source of all flood risk information presently available from the Environment Agency, Charnwood Borough Council, Severn Trent Water, British Waterways and the Leicester County Council Highways Department. This included consideration of planning policy as well as Catchment Flood Management Plans and Flood Risk Strategies relevant to the Borough. During the development of the SFRA, all digital information was compiled into a GIS (Geographical Information System) and detailed graphical outputs were included in the final report. GIS data was supplied to the council in a format compatible with their systems.



Research Project into Recommendations for Groundwater Vulnerability Assessment and Associated Tools Environment Agency

Entec was commissioned by the Environment Agency's National Groundwater and Contaminated Land Centre to develop a new framework for groundwater vulnerability assessment to potentially replace the existing system that is based on 53 Groundwater Vulnerability Maps published for England and Wales. The current groundwater vulnerability tool, which has been in existence for nearly 10 years, does not address new legislation e.g. the Water Framework Directive.

The key objectives for the new framework were:

- to be consistent with the Agency's risk-based approach to groundwater protection;
- to meet the requirements of various EC directives, including the Water Framework Directive and the Groundwater Directive;

- to allow a broad range of activities to be assessed from potential point sources of pollution such as septic tanks, to assessment of diffuse pollutants such as the application of pesticides; and
- that the vulnerability assessment could be easily updated to reflect monitoring data.

The project reviewed the different approaches to assessing groundwater vulnerability which have been developed elsewhere in the world and concluded that none of the existing techniques fully met the Agency's requirements.

The new framework has been developed so vulnerability can be evaluated on the basis of predicted concentrations and travel times. The framework allows a range of tools or algorithms to enumerate data held as a series of GIS layers. The tools / algorithms and data layers used for an

activity will be selected on the basis of the properties of specific contaminants and the nature of the activity. Outputs will be produced as GIS layers that will be assessed against assessment criteria to determine groundwater vulnerability and will also be linked to appropriate planning responses, e.g. codes of practice.

Two case studies have been carried out within GIS using data available for an area of North Norfolk. The case studies have identified a number of technical, logistical and computational requirements, but none that cannot be met reasonably.

A number of work elements have been identified which would allow significant development of the proposed framework. The main development work could be progressed over a period of one to two years, with further development over a subsequent two to five year period.

The Concept of Groundwater Vulnerability

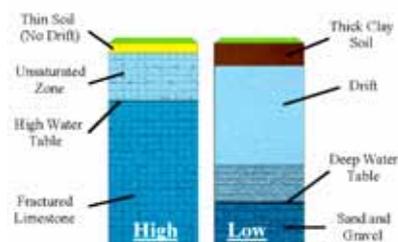
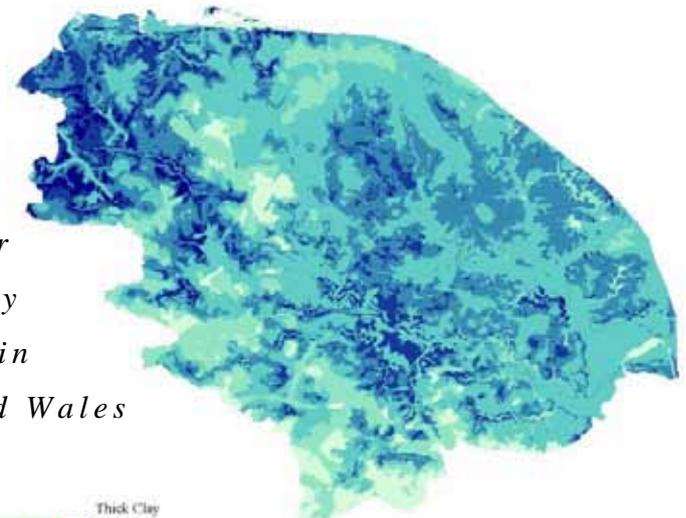
Groundwater vulnerability is the susceptibility of underground water resources to pollution by various activities and contaminants.

This vulnerability tends to be lower where soils and substrata are thicker and more organic and clay-rich, where there is a general absence of fissures, and where the water table is deeper (see illustration).

These factors reduce and / or slow the amount of water moving downwards and are also important in stopping a wide range of contaminants reaching the water table.

There are a large number of activities with a potential to contaminate groundwater. Examples include use of pesticides and fertilisers in agriculture, septic tank discharge, sludge spreading and landfills. A technique that can appropriately subdivide land areas into areas of high and low groundwater vulnerability to a range of activities is therefore a useful tool in identifying locations where such activities have a higher risk of contaminating groundwater. Once identified, different areas of vulnerability can then be subjected to use restrictions, codes of practice or targeted for more detailed assessment.

Developing a new framework for groundwater vulnerability assessment in England and Wales



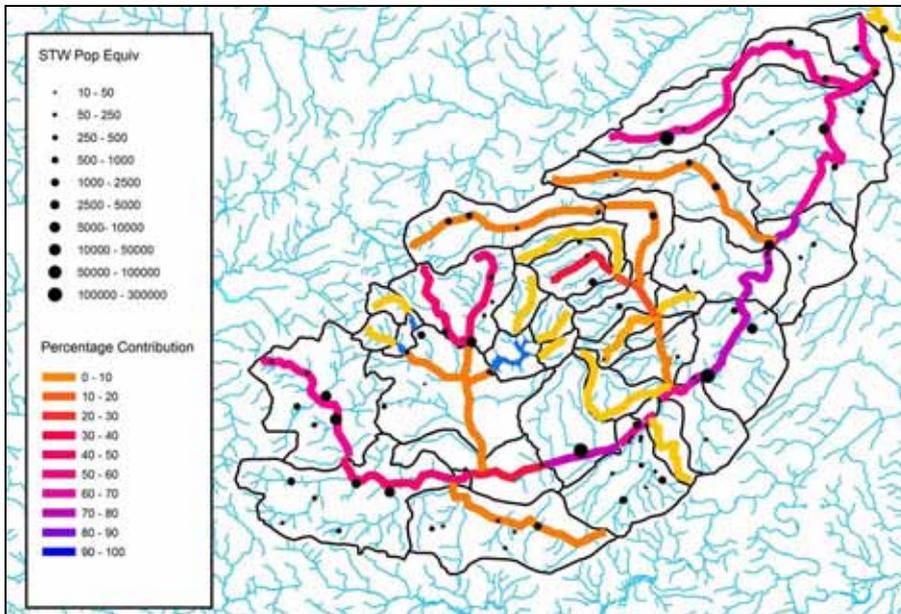
Above:
The North Norfolk case study area:
example travel time map

Left:
Vulnerability illustrated



Implications of the Water Framework Directive - River Nene Pilot Study Anglian Water Services

*Pilot study of water
quality in the
River Nene*



Anglian Water commissioned Entec to carry out a pilot study to model the impacts of water company assets (sewage works, storm overflows and abstractions) on water quality in the River Nene catchment to provide a basis to assess Anglian Water's future investment programme to meet the requirements of the Water Framework Directive (WFD). The analysis also provided a means to assess the validity of the Environment Agency's River Basin Characterisation and Programme of Measures (PoM).

An Integrated Lake and Catchment (ILC) model was developed to simulate phosphorus, nitrogen, ammonia, BOD, dissolved oxygen, chlorophyll-a, copper, zinc, cadmium, mercury and lead concentrations in the river and connected reservoirs (Rutland Water, Pitsford Reservoir, Hollowell Reservoir and Ravensthorpe Reservoir). Model output was compared to UK TAG standards to assess potential future expenditure that may form part of Water Framework Directive programme of measures. The output was also compared to WFD risk

maps (RBC1) to indicate areas where the less detailed Environment Agency models may have overestimated the impact of water company assets (compared to other sources of pollution including diffuse sources). The model provides a tool to assess management options and engage with the regulators (DEFRA, OFWAT, Environment Agency) on River Basin Management Plans.

Model build and calibration were presented and a range of scenarios and outputs were compared to current UK and UKTAG (WFD) standards (for Phosphorus, TON, Ammonia, BOD, Dissolved Oxygen, Copper, Zinc, Mercury, Lead, Cadmium and Suspended Solids). The outputs are also compared to the results of the River Basin Characterisation RBC1. Source apportionment estimates based on the model output are also derived.

Achievement of Water Framework Directive environmental objectives (i.e. good ecological status) is likely to require measures to reduce the impacts of intermittent discharges as well as continuous discharges. Intermittent

discharges were not simulated by the original version of the model so Anglian Water commissioned Entec to increase the capability of the model to simulate impacts of intermittent discharges. Impacts are reported as 99% values and compliance with Fundamental Intermittent Standards (FIS) following the standard approach adopted in Urban Pollution Management Studies.



Test and Itchen Groundwater Modelling Study and River Itchen Support Scheme Investigation Environment Agency (Southern Region) and Southern Water

*Examining the impact
of water company
operations on the
Test and Itchen SSSIs*



The Test and Itchen are large chalk spring-fed rivers in Hampshire flowing through Southampton and Winchester respectively, before discharging into Southampton Water. Both are designated as Sites of Special Scientific Interest (SSSI) and the Itchen further classified as a Special Area of Conservation (SAC). The water resources within and close to the catchment are also important for public water supply, dilution of treated sewage effluent and a range of agricultural and recreational activities. The Environment Agency is responsible for developing and applying a sustainable management strategy for these rivers and their tributaries. In addition, the agency operates a pair of river support schemes in the upper Itchen to maintain river flows and to allow continuing public water supply abstraction direct from the river further downstream.

Entec was commissioned to carry out this modelling study to aid the examination of the impact of water company operations on the Test and Itchen SSSIs. The influence of significant but non-consumptive abstraction on river flows and groundwater levels were

also considered. The overall goal was to identify a target flow regime to maintain a sustainable balance between the stresses on the river (e.g. public water supply), flood defence considerations, provision of recreation and a healthy ecosystem.

A wide range of information was collated and analysed in order to develop an integrated conceptual understanding of the recharge, runoff and groundwater flow processes upon which the numerical model of the catchments is based.

The numerical model (comprising a runoff and recharge model and a groundwater model) was built to represent the conceptual understanding and hence to simulate river flows and groundwater levels in response to meteorological, abstraction and discharge stresses over a 38 year period, from 1965 to 2002. The runoff and recharge model uses soil moisture budgeting algorithm based upon the FAO Penman-Monteith method and the groundwater model has been built using a version of the USGS MODFLOW code that incorporates the concept of variable

hydraulic conductivity with depth (VKD). Successful representation of the natural processes saw the model considered as 'fit for purpose', and following this it was used to investigate various water management scenarios.

The river support schemes, managed by the agency to allow continued public water supply abstraction from the lower Itchen, source water from the chalk aquifer and discharge to the Alre and Candover during periods of low flow. The success of the Test and Itchen modelling study led to Southern Water employing Entec to develop a new MODFLOW module to more realistically model the operation of these augmentation boreholes and discharges.

The model and the new river support module have been handed over to the Environment Agency and water companies for further sustainability studies, particularly Stage 4 of the Habitats Directive review of consents and for informing the Test and Itchen CAMS ledger.



Water Resource Assessment and Management (RAM) Framework Environment Agency

In this project, Entec worked with Halcrow and the Environment Agency to develop a new Resource Assessment and Management (RAM) Framework for application by the Agency in the development of Catchment Abstraction Management Strategies (CAMS) across England and Wales. The RAM Framework will also be used by the Agency for the subsequent management and licensing of water resources.

The Framework provides an integrated approach to resource assessment and management for both rivers and groundwater in a practical, flexible and widely applicable manner. By focusing attention at an early stage on the river flow regime that the Agency is seeking to protect, the RAM Framework will help in prioritising more detailed investigations

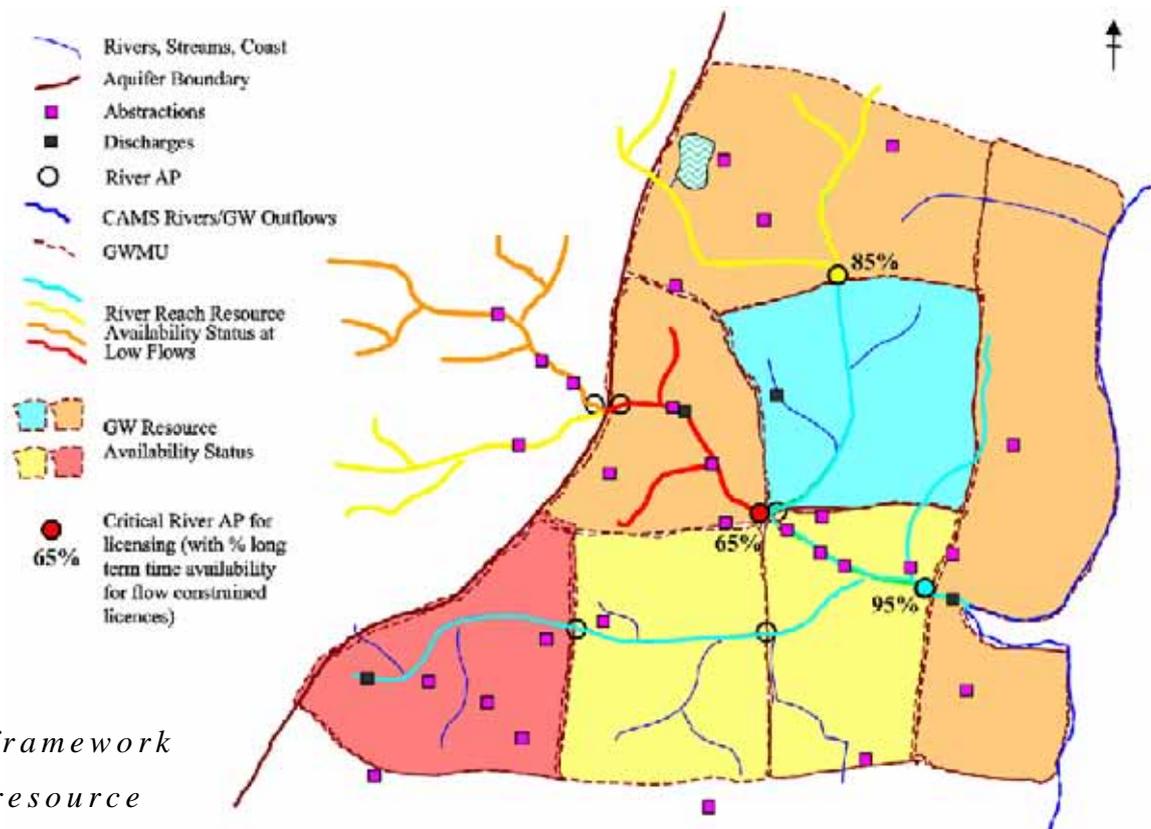
that might lead to future resource recovery schemes in a technically consistent and robust manner. It requires assessments to start with a conceptual understanding of how the hydrology and management of the catchment work which includes a clear and open account of uncertainty.

A key task is then to establish river flow objectives based on the hydro-ecological sensitivity of the rivers to the impacts of water abstraction. This requires close working between staff from different backgrounds within the Agency including water resources, quality, fisheries, ecology and recreation. The RAM Framework thereby represents a significant step towards the integrated approach to water resources management advocated by the EU Water Framework Directive.

Spreadsheet software has been designed to support the Framework. This combines data storage with an auditable trail of assumptions and calculations and generates graphical output in a variety of standard formats which help to facilitate comparisons between catchments.

The project ran intensively over an 18 month period delivering an interim and final version user manual, software, user training and ongoing close support for Agency teams working on their first CAMS. Entec have continued to support this process with the development and delivery of a standard RAM Framework training package and responses to user queries through the Agency's National Help Desk.

RAM Framework map of river and groundwater resource availability status for catchment abstraction management strategies



*A unified framework
for water resource
assessment and management*



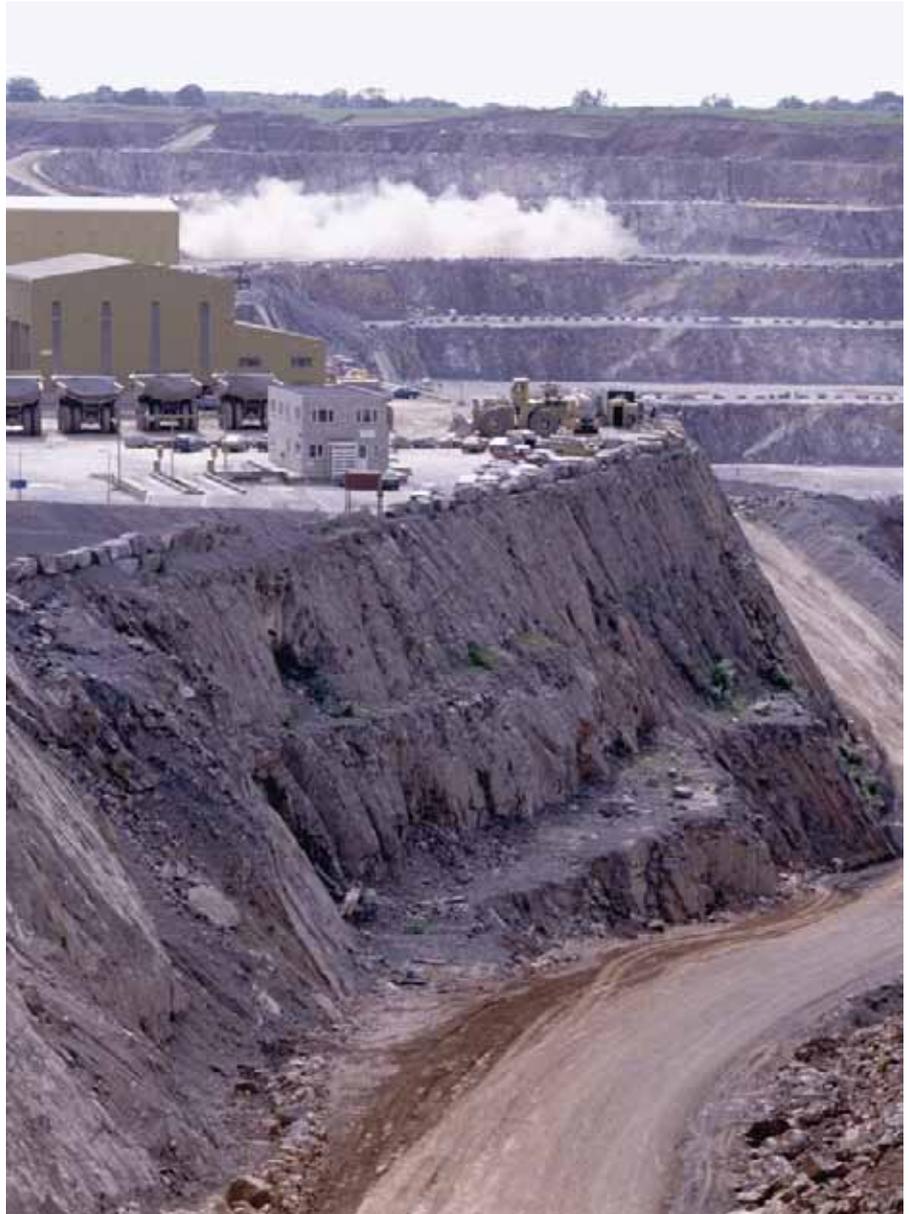
Whatley Quarry ARC (Now Hanson)

Hanson's super-quarry at Whatley, Somerset works the Carboniferous Limestone and is one of the largest quarries in the UK. Entec has been retained as consultants to Hanson since 1989 advising on many aspects of the water management of the quarry. Initially Entec was commissioned to produce the hydrological / hydrogeological component of the environmental assessment prepared in support of a planning application for an extension to the quarry.

Entec carried out investigations into the claimed derogation of river flows, groundwater abstractions and local springs due to historic dewatering associated with the quarry. The results of these investigations were presented as evidence at a public inquiry in 1992 for which Entec provided a number of expert witnesses. Hanson challenged the Secretary of State's decision against the application and Entec prepared a supporting submission for a High Court hearing although the decision was withdrawn by the Secretary of State before the case went to court. Hanson submitted a modified planning application in 1995 for which Entec prepared a second environmental statement. Following this application Entec was involved in extensive negotiations with the Environment Agency and others to agree the technical basis for a series of Section 106 Agreements to support the application and ensure protection of local hydrogeological features.

The Section 106 Agreements were signed and planning permission was granted in July 1996.

Extensive investigations and negotiations lead to planning permission for super-quarry extension



Water management

Sample client list

Essex & Suffolk Water
Welsh Water/Dwr Cymru
Environment Agency
Mid Kent Water
Severn Trent Water
Yorkshire Water
Cargill
Danone
Highland Spring
Nestlé
Princes
British Airports Authority
English Partnerships
Cardiff Bay Development Corporation
West Lothian Council
British Gas
Hanson
Tarmac
Celtic Energy
Caird
Railtrack
Nirex
Samsung
R J B Mining
Suffolk Wildlife Trust
Waste Recycling Group
Shanks
Coal Authority
Ministry of Defence
Lattice Properties/SecondSiteProperties
SNIFFER



Water management

Entec

*For further details on
Entec's full range of environmental and engineering services:*

Telephone

0800 371733 (UK)
+44 (0) 191 272 6100 (Overseas)

Fax

0191 272 6592 (UK)
+44 (0) 191 272 6592 (Overseas)

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