Saline intrusion, groundwater and coastal habitat: impacts of sea level rise

A report by Debbie Putt, NERC Intern to RCEP, Jan-Apr 2009

Introduction

A rise in sea level has many implications for the natural environment. As well as accelerating coastal erosion, there are impacts on groundwater quality and coastal habitat. In the south east these problems are exacerbated as the ground level is also sinking at the same time as the sea level is rising. This, combined with changes in rainfall patterns and increased demand for water, will increase the risk to coastal aquifers of saline intrusion.

Groundwater quality is monitored by the Environment Agency under the Water Framework Directive (WFD). The high degree of complexity in addressing groundwater issues has led to a 'daughter directive' of the WFD aimed specifically at protecting groundwater. It has recently been adopted at European level and will operate alongside the 1980 Groundwater Directive (80/68/EEC) until December 2013, when the latter will be repealed. According to Defra, the new directive takes a more comprehensive and more risk-based approach to pollution prevention and control than the 1980 Directive. Transposition in England and Wales is subject to the parliamentary timetable, but is expected to be complete some time during the spring.

The status of a groundwater body depends on the outcome of five chemical and four quantitative status tests. If any one of the tests results in poor status, then the overall classification of the body will be poor. Testing for saline intrusions occurs under both the quantitative and chemical regimes, as evidence that level changes have led to increased saline intrusion would lead to poor quantitative status, just as high levels of chloride would lead to poor chemical status.

The age of groundwater is measured in decades so pollution problems can be long-lasting, and its underground nature makes groundwater pollution very difficult to treat. The UK Groundwater Forum is a body that aims to promote awareness of groundwater issues amongst decision makers, with a steering committee comprised of representatives of the water industry, research, academia, consultancies and the regulatory bodies. They made the following comment in 2003[1]:

> " ...the implications of meeting the requirements of the WFD are wide ranging for the UK. The capacity of those responsible will be severely challenged, both in terms of financial and human resources. Further, the scientific understanding may not presently exist to underpin the management decisions required. The potential impacts of the WFD have yet to be fully appreciated by the water industry and regulators, let alone the general public. The requirement for increased knowledge and research is high and the number of people adequately trained is falling year by year, as the number of students graduating with the appropriate skills declines."

When asked about the progress made over the last 6 years, Mark Morton, Policy Advisor on Groundwater Protection at the Environment Agency (co-writer of the original article) sent the following reply:

[1] http://www.groundwateruk.org/html/forum/groundwater_challenging-times.pdf, accessed 11/03/2009.

"The Environment Agency has made significant progress with the WFD in the last six years. There is a consultation ongoing on the draft River Basin Management Plans. A large amount of information has been collated and all water bodies have been characterised. There is also a healthy strategic groundwater quality monitoring network allied to improved analysis. The understanding for the WFD requirements is now well made in parts of the Environment Agency and the water companies.

Challenges still remain. The process of informing the public and bringing professionals and some regulators and officers up to speed continues. The WFD is complicated. To assume everyone who needs to will understand it and its requirements and obligations is risky. However, good progress has been made and new process and techniques to implement the directives are in development. For example government are looking at a streamlined method for defining Water Protection Zones, where additional statutory measures can be applied to tackle pollution of drinking water supplies and water features.

In relation to the availability of suitably experienced/trained personnel to carry out the work required to implement the Directive, the Agency relies on a small group of dedicated experienced professionals who carry the project and there is little resilience in the system. The Agency has a reasonable number of more junior staff but there is rapid turnover and some concerns about the availability of 'mentors' to develop practical skills. A review published by the UK Groundwater Forum in 2007 (http://www.groundwateruk.org/html/careers5.htm) highlighted the difficulties in recruiting trained groundwater specialists at all levels of experience in the UK.

In relation to the requirement for increased knowledge and research, at present, there is a reasonable understanding but it is based on a lot of assumptions and in places limited data. Further work is ongoing and more will start soon but we aren't there yet."

This report presents the evidence given to the Royal Commission on Environmental Pollution about the impact of saline intrusion on coastal aquifers in the context of adaptation to climate change and sea level rise. Some evidence surrounding the impact of sea level rise on coastal habitat is also presented.

Groundwater modelling and research

In coastal regions, fresh water from rainfall flows out into the sea via rivers and aquifers, while seawater also penetrates some way inland. The Ghyben-Hertzberg relationship determines the theoretical shape of the interface between fresh and saline groundwater, as illustrated in figure 1, based on the difference in density between the two. In reality the situation is more complicated, with geologic variability, tidal fluctuations and abstraction and pumping regimes creating a dynamic equilibrium. This leads to a transition zone of mixed salinity rather than an interface. Even so, the height of sea level will have an influence on the depth of the water table below ground level, and the depth of freshwater in the aquifer.

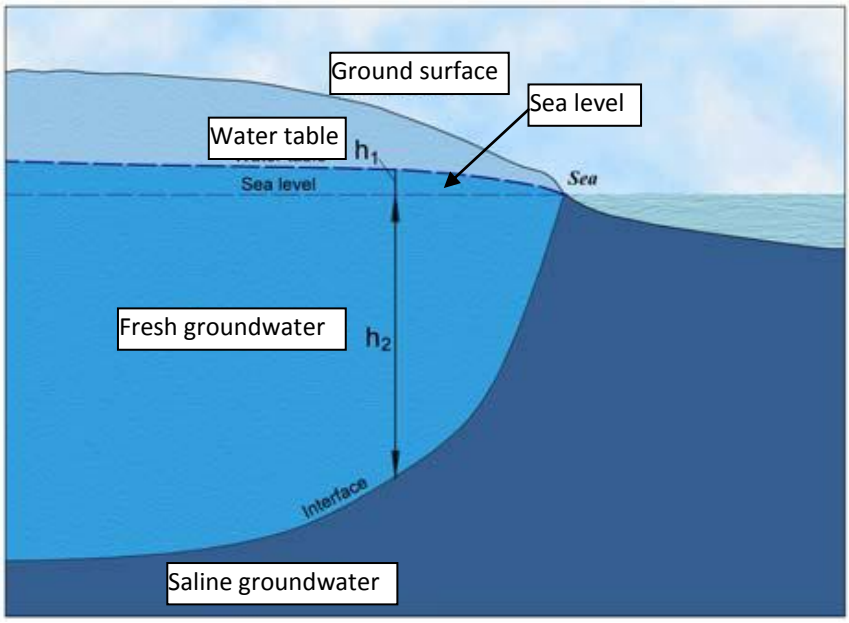

Figure 1, after UK Groundwater Forum. The interface between fresh and saline groundwater in a coastal aquifer, as predicted by the Ghyben-Hertzberg relationship. The depth of the interface below sea level is about 40 times the height offresh-water above sea level. That is h2 = 40h1.

A paper by Derek Clarke at Southampton[2] describes the use of a groundwater model to predict changes in water table height from various forcings at a coastal site aquifer in Sefton, NW England. The results from the following changes in model forcing are investigated:

- Changes in meteorological driving variables with climate change (data supplied by UKCIP02)
- Changes in land use, specifically clearing of pine trees
- Changes due to coastal erosion and sea level rise.

The relative impact of these different forcings were estimated over a "near future" period – 25 to 50 years ahead. Changes in rainfall patterns were predicted to have the largest impact on groundwater levels, and the results were particularly sensitive to rainfall timing and distribution. Coastal erosion and accretion, land use change, sea level rise and temperature changes were shown to have much smaller relative impacts, though the authors point out that the climate change factors may have much larger cumulative impacts over longer time periods. It is also noted that at this site, a greater concern from climate change is that of increased storminess which may result in severe erosion of the coast dunes in this area, leaving farmland at risk of flooding by the sea. The impact of sea level rise on farmland was addressed as part of a Defra report, 'Climate change and agriculture in the United Kingdom'. The extract referring to sea level rise, box 4.1, is attached as Annex A[3].

Groundwater modelling was referred to in the Environment Agency submission to the Commission (RCP(08)324). They predict a general lowering of groundwater levels by 2025, though they note the hydrogeologic differences between aquifers, and the impact this should have on adaptation strategies:

[2] Clarke D., Sanitwong Na Ayuttaya S, (2007). "A Probabilistic Assessment of Future Coastal Groundwater Levels in a Dune System In England." International Conference on Dune Restoration, Santander, 2007

[3] http://www.defra.gov.uk/farm/environment/climate-change/pdf/climate-ag.pdf, "Climate change and agriculture in the United Kingdom", 2000.

> "The biggest reductions in river flows occur in heavily stressed aquifers such as in the west midlands, where sandstone is prominent. However, the large storage capacity of the sandstone means that this aquifer will respond relatively slowly to climate change. There is therefore scope to adapt management practices to help to cope with climate change impacts, for example by better use of aquifer storage to offset seasonal low flows. In chalk areas, overall reductions are smaller, however river flows and groundwater levels show increased seasonal variability. The relatively small storage availability of the chalk means that it will respond more quickly than the sandstone, and some of the simple adaptation management practices used in sandstone areas will not have the same impact in chalk areas."

The impact of rising sea levels would therefore differ depending on the particular aquifer. Ian Gale, a hydrogeologist with the British Geological Survey, has provided the following information:

> "1. Where coastal aquifers are covered by an impermeable confining layer - no interaction with fresh water aquifer so no change.
>
> 2. Where the saline interface in an aquifer in contact with the sea is controlled by the flux of fresh groundwater then the base discharge level changes with the rising average sea level and a new equilibrium is established. Pumping regimes will need to be managed to suit the specific hydrogeological situation. For example, saline intrusion is kept at bay along the Dutch coast by infiltrating water in the sand dunes to maintain a hydraulic groundwater barrier as the landscape is below sea level - hence the natural equilibrium hydraulic gradient is inland.
>
> 3. Where stretches of coast are returned to the sea to provide the coastal defence afforded by wide saline marshland then the impacts on groundwater quality would need to be assessed on a case by case basis."

Further modelling has been done by Kevin Hiscock at the University of East Anglia, as part of a paper discussing the impact of climate change on saline intrusion to groundwater[4]. Hiscock uses a groundwater flow model to investigate saline intrusion into a Norfolk aquifer for the 1970s baseline and the 2080s medium-high emissions scenario. After 100 years the saline interface is simulated to move 500m from the coastline, at a depth of about 30m below the ground. This would threaten the inland drainage areas. The author writes:

> "The mitigation and avoidance of saline intrusion problems necessitates, as for groundwater resources protection in general, better database management and dissemination, the engagement of local communities in solving local problems and the development of sustainable groundwater abstraction policies at regional and national levels. The longer term adaptation to the loss of freshwater resources in coastal aquifers will include the abandonment of wells and boreholes in favour of alternative, inland water sources. Given the large urban populations living in coastal areas this will

[4] 'Climate change, saline intrusion and impacts on groundwater'. Prepared 25 February 2009 by Dr Kevin Hiscock, School of Environmental Sciences, University of East Anglia, Norwich, NR4 7TJ, UK, for the Royal Commission on Environmental Pollution

> require careful planning to achieve sustainable water supplies but is probably desirable in comparison to alternative, energy-intensive engineering solutions to prevent saline intrusion and/or supply desalinated water. In terms of research requirements, a systematic survey of coastal aquifers is required to identify those groundwater resources and groundwater-dependent habitats at risk from sea-level rise."

This last point is echoed by Ian Gale of the British Geological Survey, who suggests that "It would be a valuable exercise to scope and model the likely scale of the impacts of sea level rise on groundwater quality, and to estimate the cost of likely interventions."

Anglian Water is the only water company researching saline intrusion, according to Bruce Horton at Water UK. Anglian Water are using the Environment Agency's groundwater model to evaluate future risks of saline intrusion into the North Lincolnshire Chalk aquifer from the Humber Estuary. The current model dates back to work in the late 1970s by Birmingham University, however it is being refined to be able to provide further information on the potential long-term impact of climate change on aquifer resources (Dave Harker, Regulatory Water Resources Manager at Anglian Water). This kind of detailed, case-by-case approach is the preferred way of predicting and responding to changes in such a complex hydrogeological system. Keith Seymour, Hydrogeology Team Leader at the Environment Agency, is confident that the local knowledge of the water companies means they are best placed to implement strategies that protect their water resources successfully.

Andy Turner, the Water Resource Policy Manager at the Environment Agency, says the following about saline intrusion:

> "We are aware that rising sea levels could cause increased levels of saline ingress to rivers and saline intrusion to aquifers. We are in the process of formulating our research needs for the coming years, in order to support policy development in water resources (including land use and water quality aspects which could safeguard water resources). Saline intrusion is one area in which we are interested in finding more about the risks to abstractors and to the environment."

Saline intrusion is a problem across the Mediterranean where water resources are particularly scarce. The situation in the UK however is more similar to that of the Netherlands. Remco van Ek, of Deltares, outlined an assessment of the development of the fresh groundwater reservoir that concluded that on the national scale no major changes are to be expected. Most changes are in the lower western part of the Netherlands, bordering the North Sea.

Managing saline intrusion

Saline intrusion is not a new threat, and has been managed for decades. Figure 2 shows locations of previous saline intrusions, which historically have occurred following the pumping of large volumes of water from coastal aquifers, often for industrial use. In all these instances the problem was managed by the alteration of pumping regimes, or the abandonment of boreholes if they became too salty. The loss of large scale heavy industry in many parts of the UK at the end of the twentieth century also contributed to a reversal of the problem.

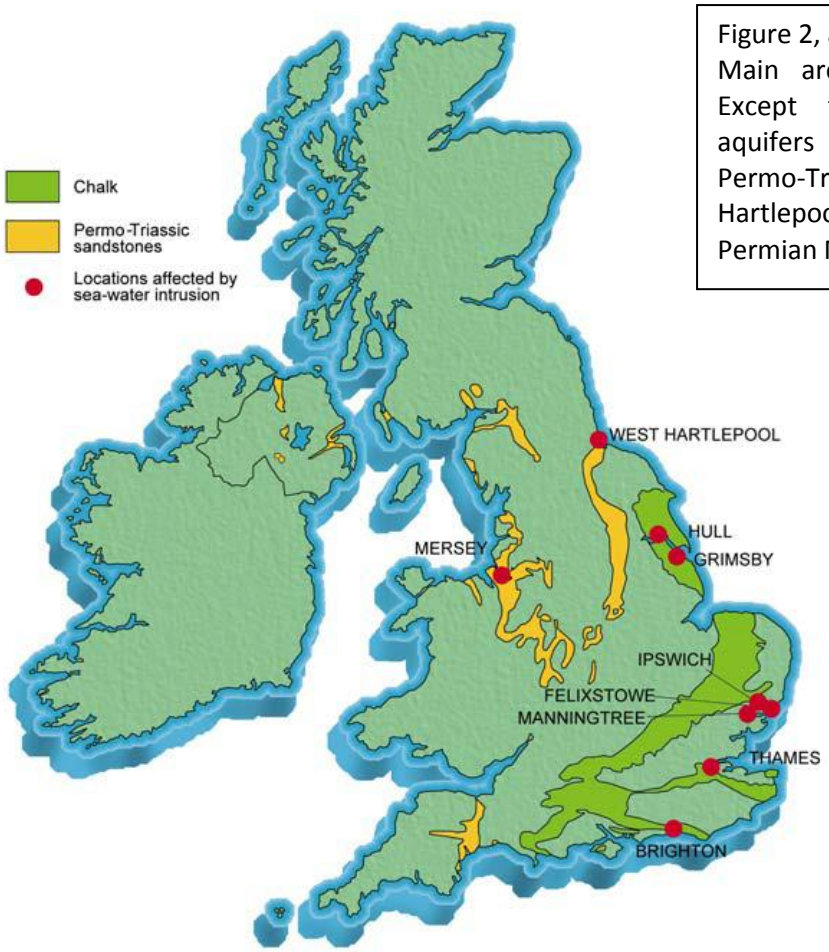

Figure 2, after UK Groundwater Forum. Main areas of sea-water intrusion. Except for West Hartlepool, the aquifers affected are the Chalk and Permo-Triassic sandstones. At West Hartlepool the aquifer affected is the Permian Magnesian Limestone.

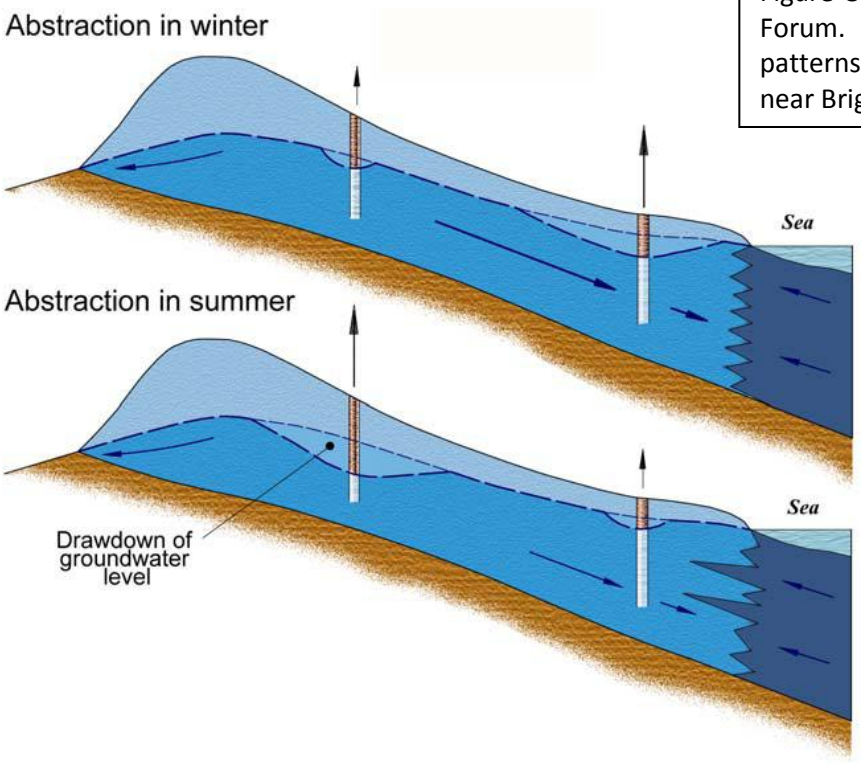

Figure 3, after UK Groundwater Forum. Seasonal abstraction patterns in the Chalk aquifers near Brighton.

A skilful balancing of abstraction to match recharge is ongoing in areas vulnerable to saline intrusion. An illustration of an abstraction management strategy is shown in figure 3. In Brighton, saline intrusion is managed by preferentially extracting water from the inland boreholes during summer and the coastal ones over winter, to maintain a hydraulic gradient from the aquifer to the sea.

These management practices have been successful in dealing with saline intrusion thus far, though rising sea levels coupled with increased demand for water from a growing population will put aquifers under more pressure. Nevertheless, Trevor Tanton, Professor of Civil Engineering at Southampton University, says the following:

> "As we are expected to get slighter wetter winters we will only get intrusion if the aquifers are over-pumped to meet summer demand. It is not generally seen as a researchable issue but will become an aquifer management issue."

The Environment Agency agrees that the most important pressures on available groundwater resources (quantitative rather than chemical quality) are from abstraction patterns (due to demand) and recharge patterns (due to natural variability in rainfall). The latter is particularly challenging, with the very wet and very dry spells in the last ten years requiring very careful resource management by the water companies. It is felt that these factors will have a much larger impact on water resources in the coming decades than the predicted sea level rise, and over much larger regions of the UK.

Nevertheless, the Water Framework Directive obliges the Environment Agency to control saline intrusion. The EA limit abstraction through catchment abstraction management strategies (CAMS) and the individual abstraction licences. Many licences are already controlled through chloride limits. It is also important to note that abstraction licences do not legally guarantee the quality of water for abstraction; abstractors do not necessarily need high quality water for the purpose of their abstraction (e.g. some industrial processes and cooling processes have lower quality requirements than say a farmer who wants to irrigate salad crops).

Currently only 20% of abstraction licences are time-limited, and the EA are pushing for legislation to make this apply to all licences. This is part of Defra's strategy 'Future Water' which was launched on 7th February 2008. For non-time-limited licences, the EA does have legal powers to change a licence, but this requires an application to be made to the Secretary of State and is a lengthy process. The holder of the licence may also be entitled to compensation if the abstraction limits are reduced.

Time-limited licences are usually granted for a 12-year period, with an assumption of renewal subject to certain tests that the holder must meet: the need must still be justified, the water must be available and there must be no new environmental problems discovered that were caused by the abstraction. In some areas climate change may lead to a shortage of available water whereupon the licence could be revoked through a failure of the second test, however a failure of the third test would require proof that the environmental problem (such as saline intrusion) was caused by the abstraction and not by climate change (or any other external factor out of the licensee's control); EA policy is that conditions on licences will not be used as a tool to alleviate climate change impacts.

If a borehole were becoming more saline, and sea level rise was believed to be the cause, it appears unlikely that the EA would change the abstraction limit in the licence. It would be the water company's decision whether to move abstraction to a different borehole (if available), to reduce demand or to bear the cost of additional treatment (depending on the water quality required for the end use). However it is more likely that the problem had been caused by either a lack of recharge or a change in abstraction, and either of these could lead to the licence being altered on a 'water availability' basis. The EA would also not be issuing further licences in areas already over-abstracted.

The Environment Agency implements the WFD by producing River Basin Management Plans for the 11 river basin management districts of England and Wales (a map of the districts is attached at Annex B). These plans, which are currently published as drafts for public consultation, are to be reviewed every six years, with the first compliance point being 2015. The Anglian region was the only region identified by the EA as part of the process as having significant pressure coming from salinity, although more localised problems were also noted in other areas, such as the Mersey and Romney Marsh. No strategies other than abstraction management are suggested. This is echoed by Dave Harker, Regulatory Water Resources Manager at Anglian Water:

> "There is a formal 'water resource management agreement' between Anglian Water and the EA that mitigates against the risk of saline intrusion by reducing abstraction when groundwater levels are low. I would expect the future abstraction regime to be adapted in the light of projections for sea level rise and any reduction in recharge to protect the aquifer and maintain the availability of water resources. This can be done by moving abstractions to existing or new boreholes further from the coast."

In general the Environment Agency says[5]:

> "In the longer term, there is little we will be able to do to avoid sea level rise having an impact on coastal aquifers. In future planning cycles of Water Framework Directive implementation it may be necessary, therefore, to redefine reference conditions. The implications of salinisation of coastal aquifers on increasing demands on alternative water resources will need to be considered."

Complication arises in the coastal regions because of the diverse group of bodies with different responsibilities. Defra noted the following concerns with respect to the Water Framework Directive[6]:

> "While the Environment Agency is the competent authority for implementation of the WFD in transitional and coastal waters, the Environment Agency does not have the same overarching regulatory responsibilities in relation to these waters, and so a much higher proportion of the measures in these areas will need to be implemented by other regulators. Ensuring two-way links between RBMPs and other transitional and coastal

[5] http://wfdconsultation.environment-agency.gov.uk/wfdcms/en/anglian/Intro.aspx, Draft River Basin Management Plan for the Anglian region, Annex H – Climate Change, published Dec 2008, accessed 11/03/2009

[6] http://www.defra.gov.uk/environment/water/wfd/pdf/riverbasinguidance.pdf, Volume 1 of Defra's River Basin Planning Guidance, published in 2006, accessed 11/03/2009.

plans will be particularly important, and may be challenging as management arrangements and responsibilities are complex in transitional and coastal waters."

In addition to the management plans of the EA, the water companies also publish strategic plans and risk assessments. Anglian Water do not consider the risk of impacts on water resources from sea level rise to be sufficient to require investment through adaptation or mitigation during the next 5 year planning period (2010-15).

In the Anglian region, 32% of groundwater bodies have poor quantitative status and 35% have poor chemical status[7] (information on how much these groundwater bodies with poor status overlap is not provided). The predictions for chemical status for 2015 are for this to worsen, however most of the failures are to due to nitrate or phosphate pollution. The EA judge the increase in pressure from salinity with climate change in the Anglian region as 'medium', whereas nutrient pressure increases are judged as 'high'[8]. Anglian Water agree that the main concerns for groundwater pollution are from agricultural and industrial activities, and that flooding from fluvial or sea water sources is a more pressing climate change impact. The EA also judge the increase in abstraction pressures with climate change in the region as 'high'[9], with concerns for water resources of greater concern than the impact of lower river flows on water quality (Andy Turner, pers comm).

Pesticide pollution of groundwater is also a concern. The British Geological Survey has undertaken an assessment for Defra of the impacts of climate change on the fate and behaviour of pesticides in the environment (summary attached as Annex C). The study concluded that, in the long term, land-use change driven by changes in climate may have a more significant effect on pesticides in the environment than the direct impacts on pesticide fate and transport.

In general, the impact of sea level rise on groundwater quality is not a priority concern for any of the bodies that have provided evidence for the Commission. The threat is recognised and may assume more importance as the sea level rises further over the coming decades, however the pressures from agricultural and industrial pollution, along with changes in rainfall patterns, are greater. The feeling is that the strategies to manage water resources to face these more pressing problems will absorb any impact of sea level rise on groundwater quality.

[7] http://wfdconsultation.environment-agency.gov.uk/wfdcms/en/anglian/Intro.aspx, Draft River Basin Management Plan for the Anglian region, Consultation Main Document, published Dec 2008, accessed 16/03/2009

[8] http://wfdconsultation.environment-agency.gov.uk/wfdcms/en/anglian/Intro.aspx, Draft River Basin Management Plan for the Anglian region, Annex H – Climate Change, published Dec 2008, accessed 11/03/2009

[9] Ibid.

Effect of saline intrusion on coastal habitats and biodiversity

As sea level rises, tidal habitats such as saltmarsh and mudflats would naturally extend inland. However, where hard coastal defences exist this natural migration of habitat is prevented; this is often termed 'coastal squeeze'. In contrast to the impact on groundwater, the impact of saline intrusion on coastal habitat and biodiversity was highlighted in many of the submissions to the Commission, and on several of the visits. In particular it was discussed by the Natural England submission (RCP(08)324) and in the annexes to the CEH submission (RCP(09)303, Annex B 'England Biodiversity Strategy – towards adaptation to climate change') and that of the Wildlife Trusts (RCP(09)306, Annex B 'A living landscape' and Annex C 'Conserving biodiversity in a changing climate').

Many research papers have been published on this topic, such as Mark Lee's 2001 paper 'Coastal Defence and the Habitats Directive: Predictions of Habitat Change in England and Wales'[10]. Lee identifies the conflict between maintaining the favourable conservation status of intertidal areas and avoiding the degradation and loss of freshwater areas. A 'stark choice' is presented between protecting freshwater sites and accelerating coastal squeeze, or the realignment of existing defences and 'replacement' of freshwater habitat by intertidal and brackish habitats. Freshwater habitats could be the loser in these cases as the intertidal areas provide the added value of being flood defences. Lee predicts a loss of 4000ha of freshwater and brackish habitat over 50 years, and presents a likely cost of £3 million per year over a ten year period for hectare-for-hectare replacement. The author suggests that there is a need for a legal and administrative framework to deliver integrated coastal defence and habitat replacement at a strategic as well as local level.

Stewart Clarke of Natural England, speaking at a conference on 'Climate Change and Aquatic Systems in the UK', emphasises the link between freshwater habitat and decisions made at the coast[11]:

> "There is no easy solution. Our coastal colleagues in Natural England are quite keen on allowing sustainable naturally functioning coasts to develop and DEFRA are keen on not spending large amounts of money on repairing sea defences that have to be ever higher and ever more robust. So the danger is we will lose those freshwater habitats completely, unless we can improve lateral connectivity within floodplains at a greater distance from the coast."

These 'stark choices' between freshwater and coastal habitat protection bring together coastal management with regional and perhaps even national planning strategies. The Living with the Sea project, funded by the European Union, brought together English Nature, the EA, NERC and Defra to create Coastal Habitat Management Plans (CHaMPS) to provide guidance on the long-term impacts of coastal management plans on the obligations under the Habitats Directive. Tim Collins of Natural

[10] Lee, M.2001. 'Coastal Defence and the Habitats Directive: Predictions of Habitat Change in England and Wales', *The Geographical Journal*, 167(1):39-56.

[11] http://www.eurolimpacs.ucl.ac.uk/oldsite/docstore/Climatechange&aquaticecosystems.pdf, proceedings volume from the Euro-limpacs conference 'Climate Change and Aquatic Systems in the UK: science, policy and management', accessed 11/03/2009.

England suggests that much of the work from this has already been embraced by Defra Flood Management in its policy approaches. The CHaMPS introductory leaflet has been attached as Annex D.

Long term consideration of habitat provision and replacement was also part of the Thames 2100 project, as discussed during the Commission's visit to the Thames Barrier in January. The opinion of Rachael Hill, the Technical Strategy Manager for the project, was that coastal freshwater habitats would have to make way for the creation of new saltwater habitats, as there would be opportunities to recreate freshwater reserves further inland. Remco van Ek, of Deltares, provides a similar viewpoint from the Netherlands:

> "Also it is important to notice that in the Netherlands most areas (including nature reserves) have become more influenced by fresh water, due to water management practices. Although brackish ecosystems mostly harbour less species, these type of ecosystems have become more rare. There is even an ecological programme from the ministry of water management that advocates restoration of fresh water - salt water transition zones. In the future we expect more influence of brackish water and according to several ecologists, from the ecological point of view, this does not need to be a bad thing."

However, work led by White Young Green Environmental and Natural England on sea level rise impacts on the Suffolk coast suggests that moving the freshwater habitats inland is not necessarily the best option[12]:

> "Although not established conclusively in this study, it is believed that the maintenance of the coastal context is of importance when considering the strategy for replacement sites ... Hence the study has highlighted the importance and significance of the coastal Biodiversity Action Plan resource, emphasising the need for a planned strategy as sea levels rise."

The deliberate abandonment of particular sites will always be contentious. A good example of such a decision being made currently is the management of Cemlyn lagoon in Anglesey. Cemlyn Bay is protected at European level as a Natura2000 site: a Special Area of Conservation for its lagoon and shingle ridge vegetation and a Special Protected Area for its nesting terns. The site is owned by the National Trust, and leased to the North Wales Wildlife Trust who manage the site, and would like to preserve the tern colony for as long as possible. The shingle ridge and hence the lagoon are at risk from rising sea levels and increased storminess along the coast. The National Trust's position is that natural processes have to be allowed to occur, so the lagoon must be allowed to become much more saline, losing the tern community as well. This is likely to happen within 5 years, making it quite possibly the first site where this sort of decision is made. Although the National Trust as landowner has the authority to make this decision, they are consulting with the NWWT and Countryside Council for Wales (CCW). John Ratcliffe, the CCW Team Leader for Ynys Mon describes the situation as follows:

[12] Humphries, R.N., N.J.K. Howden, C.E.L. Humphries, R. Meade and R. Morris,2007. 'Coastal Squeeze: a pilot study of potential climate change impacts on groundwater-dependent coastal ecosystems in Suffolk, UK.'

> “The site was (mainly) saltmarsh situated behind the shingle ridge until the 1930s when a weir was constructed to create a shallow lagoon with low islands on which sandwich, arctic and common tern breed (though not for the past 2 disastrous years due to predation) ... If the ridge is breached it would lead to the loss of the lagoon - it is already saline from leakage through the ridge and through the weir at high tide (indeed much of its biological value emanates from its brackish nature), but would drain out from about mid tide onwards so would revert to saltmarsh for a period. However, I would expect the ridge to re-form at some stage - perhaps to landward - given the continuance of a supply of pebbles and building waves.
>
> I am not sure that the legal implications of a loss of N2K habitat to sea level rise have been worked out as yet. My inclination would be to assign this to "natural" causes (even though we know it isn't) because we cannot control it in any real sense and because, in other circumstances, it might be entirely natural. However I assume that there would be an obligation to select alternative N2K representation of lagoon and shingle habitats to replace the loss. Furthermore there would be a BAP obligation to "contribute to maintaining the coastal lagoon and saline pond resource, despite losses due to sea level rise". Clearly any analysis of the likely implications of coastal change presupposes a particular timescale and assumptions about climate change within that time. These comments are predicated on the medium term (2070) projection of the Welsh Assembly Government.”

The immediacy of the impact of sea level rise on coastal habitat means decisions are being taken now and in the coming years that will have long term impacts on the coastal zone, and further inland. Accommodating change and building resilience for both biodiversity and people is a challenge, particularly in these vulnerable and rapidly-changing environments.