Ireland at Risk

Water

The Irish Academy of Engineering

Ireland at Risk

No.1

The impact of climate change on the water environment

Supported by:

Arup Consulting Engineers, Cork County Council, Department of Communications, Marine & Natural Resources, Department of the Environment, Heritage & Local Government, Dublin City Council, Environmental Protection Agency (EPA), Office of Public Works (OPW)

September, 2007

Acknowledgement

This report is based on presentations and discussions convened by the Irish Academy of Engineering in Dublin in May 2007. It is the first in a series of 'Ireland at Risk' reports being prepared by the academy, exploring areas of risk that may impact significantly on Ireland's future social and economic development. The aim is to ensure that the engineering profession contributes fully in formulating policy and planning to mitigate and deal with potentially dramatic developments over the coming century.

The Irish Academy of Engineering wishes to acknowledge the work of Mary Mulvihill in finalising the report.

The Irish Academy of Engineering thanks the many agencies, organisations and individuals that supported this project.

The views and opinions expressed here are those arising from the workshop, and do not necessarily reflect the views of the various bodies that supported this project.

ISBN No.: 1898 012 938

This report, and the full text of the papers presented at the symposium, are available online at www.iae.ie

Contents

Foreword 4

The way forward – Summary and recommendations 5

Why we should worry – Introduction 7

What we should know – Keynote summaries

1. Climate change scenarios and challenges for the water environment 9
   John Sweeney, Conor Murphy, Rowan Fealy, Ro Charlton
   Irish Climate Analysis and Research Units (ICARUS), NUI Maynooth

2. Impact on Coastal Areas 12
   Gerard Farrell, Chief Engineer, Department of Communications,
   Marine & Natural Resources

3. Impact on inland flooding 14
   Tony Smyth, Director of Engineering Services, OPW

4. Impact on water supply 17
   Michael Phillips, Dublin City Engineer

5. Impact on groundwater supplies 20
   Natalya Hunter Williams and Monica Lee, Geological Survey of Ireland

6. Conclusions 24

What we must do – Recommendations 26

References 32

Appendices 33
Workshop rationale
List of participants

Foreword

"Water, water, everywhere,
Nor any drop to drink"

Samuel Taylor Coleridge

Ireland is already starting to experience the impact of climate change. Over the coming decades, we can expect that change to accelerate. For Ireland, one of the most important factors will be changing rainfall patterns and rising sea levels; this will affect our water supply, ecosystems and agriculture, and put us at greater risk of flooding and coastal erosion.

This report identifies the measures that we in Ireland must take to address the challenge of climate change and its effect on our water environment. The recommendations here are the result of deliberations and discussions from the combined expertise of over 40 experts from various disciplines and organisations across the island of Ireland.

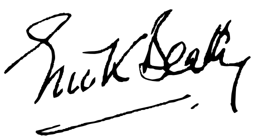
It is the first in a series of studies which the Irish Academy of Engineering is undertaking, under the title ‘Ireland at Risk’, and exploring potential threats to our social and economic development. We want to ensure that the engineering profession plays its proper part in formulating long-term policy and planning, and in how we deal with potentially dramatic developments over the coming century.

The Academy’s membership identified several challenges, and future reports in the series will look at topics such as energy and telecommunications. But we begin the series with what we believe is the greatest problem facing us - the impact of climate change on Ireland’s water environment, in particular: flood control and protection; rising sea levels and coastal erosion; and water sourcing, management and supply.

This broad and complex topic spans the remit of many agencies, and calls for wide-ranging expertise. Accordingly, we invited 40 relevant experts from various vocations and professions, from State, semi-State and local administration, from the Republic of Ireland and Northern Ireland, and from the third-level and private sectors, to participate in an in-depth, one-day workshop in Dublin in May, 2007. This report is based on their deliberations.

Four discussion documents were invited from national experts – on climate change, water supply, flood protection and coastal erosion – and these were circulated to participants in advance. A further paper on groundwater was prepared by the Geological Survey of Ireland after the workshop. Summaries of all five papers are presented here; the full texts are available online (www.iae.ie).

The Irish Academy of Engineering thanks the many agencies, organisations and individuals who contributed to this report, including the workshop facilitators and rapporteurs, and those who supported the project. The views and opinions expressed here are those arising from the workshop, and do not necessarily reflect the views of the Irish Academy of Engineering, nor the various bodies that supported this project.



Eric K Beatty
President, Irish Academy of Engineering

The Way Forward

Summary and key recommendations

Ireland faces a future of continued economic development, a growing population – that could reach 8 million by 2100 – and climate change. These changes will put increased pressure on our existing water supplies. The impacts of economic and population growth on communities, infrastructure and resources are reasonably predictable, but there remains uncertainty as to the specific impacts of climate change. The past is no longer the key to the future. This report focuses on the additional impacts likely to arise from climate change and to affect the water environment, and what we must do to minimise the impact.

Adaptation: We must begin immediately to adapt to the inevitable consequences of climate change. The scientific community has reached consensus on the likely impacts, and the 'do nothing' approach is not viable. Greenhouse gases already emitted will take decades to fully impact on the atmosphere, climate change and the water environment, not to mention future emissions.
Recommendation: The Governments of the Republic of Ireland and Northern Ireland must act now and develop co-ordinated adaptation strategies for the water sector.

Mainstreaming: A high-level strategic group is required in each jurisdiction to take an overarching view on the impact of climate change on the water environment, and to recommend actions to their respective Governments. Climate change will affect the island of Ireland as a whole, and appropriate cross-border collaboration is essential.
Recommendation: Establish high-level strategic climate change bodies in both jurisdictions with full collaboration.

National planning: Spatial strategies and infrastructure investment plans should be urgently reviewed to ensure that all programmes and projects take full account of potential climate change impacts. Ensuring the optimum use of the available water supply, and properly managing flood risks when deciding where significant growth in population can take place, will require strong leadership, especially in preparing plans from national through to county level.
Recommendation: Ensure spatial strategies and infrastructure plans are climate proofed.

Critical infrastructure: Power generation and transmission facilities, water supply and treatment facilities, and other critical infrastructure should be reviewed for climate proofing, and adapted where necessary as a matter of urgency, so as to avoid potential catastrophic breakdown in services during extreme climate events, such as storms or flooding.
Recommendation: critical infrastructure should be reviewed for climate proofing and adapted where necessary.

Independent assessment: All statutory development plans should be independently assessed, prior to adoption, for completeness, complementarity with neighbouring authorities, and consistency with Government policies, particularly in respect of climate change.
Recommendation: Statutory development plans should be independently audited and monitored regularly.

Delineating flood plains: We need a robust methodology for delineating flood plain areas that takes account of climate change. Inappropriate development should be prohibited in high risk areas, and suitable guidance provided for other areas at risk.
Recommendation: Develop a methodology for delineating flood plains, and plan development accordingly.

Coastal erosion and flooding: We urgently need to identify areas at risk from coastal erosion or flooding, and implement coastal management plans for those areas. Surge forecasting and a coastal flood warning system should be put in place where appropriate, along with a tide gauge network to monitor sea level changes.

Recommendation: Identify areas at risk from coastal erosion or flooding, and install surge forecasting, a coastal flood warning system and tide gauges.

Planning for uncertainty: Climate change makes the future uncertain and yet we must plan for it. New flood protection schemes and projects must be flexible so that they can be adapted in the future as more information becomes available. We must adopt a risk assessment/risk management approach for all water infrastructure projects, including the design of flood defences, as fixed design standards are no longer relevant.
Recommendation: Water infrastructure schemes must be flexible, adaptable and subject to rigorous risk assessment.

Water conservation: Water usage in Ireland is significantly higher than elsewhere in Europe, and this, coupled with climate change and a growing population, could lead to significant water shortages in the medium and long term. We need regulations and incentives to manage demand.
Recommendation: Introduce new measures to reduce water usage and improve water conservation.

Competing demands: Climate change will alter the needs and demands of water users in Ireland, and could generate a serious imbalance between areas where rainfall will be most plentiful, and areas of greatest need.
Recommendation: Prepare a long-term national plan to provide the necessary infrastructure in a timely and appropriate way, and ensure sustainable water supplies, both surface and groundwater, across the country.

Network maintenance: Increased investment in detecting water losses, accompanied by major network improvements, should be extended nationwide and sustained, to reduce leakages to acceptable levels and manage demand efficiently.
Recommendation: All water authorities should set maintenance and leakage targets to be achieved in specified time periods.

Climate change research: We need greater research into the relationship between the built environment and the natural environment, including climate change. Current climate change scenarios involve considerable uncertainty in relation to the changes that may materialise. Research is needed to reduce these uncertainties, and to allow us to develop more accurate methodologies and calculations so that we can accommodate the emerging changes.
Recommendation: The Governments should fund further research in the area of climate change and its impact on the water environment.

Public information: A major information programme is required to convince the public of the reality of climate change and its likely impacts. The water environment should be dealt with as a specific topic, and initiatives developed with a view to changing culture and behaviour, perhaps similar to the 'Power of One' campaign to reduce energy use.
Recommendation: Begin a public information and awareness campaign to change people's attitudes and behaviour with regard to water use and the water environment.

'The key is adaptation to a warmer, changed world'

Why we should worry

Introduction

The evidence for global warming over the past century is now overwhelming, and Ireland is already experiencing the start of climate change. The latest climate change report from the Environmental Protection Agency (EPA), reveals that our climate is now warmer on average than a century ago, with less frost, and with more rain in the north and west of the country, but drier weather in the south and east. This global warming and climate change is very likely due to human activities, notably the release of greenhouse gases and the burning of fossil fuels, according to the most recent report from the Intergovernmental Panel on Climate Change (IPCC, February 2007). A rising population, and on-going economic development will compound these changes.

The EPA report on Key Meteorological Indicators of Climate Change in Ireland (August 2007), prepared by the Irish Climate Analysis and Research UnitS (ICARUS), at NUI Maynooth, concludes that:

- Ireland is now on average 0.7°C warmer than a century ago.
- Our climate is warming at a rate of 0.42°C per decade since 1980.
- Six of the 10 warmest years have occurred since 1995.
- We now have fewer frost days, and a shorter frost season.
- The rain in the north and west is now heavier and more persistent, 'precipitation events' bringing over 10mm of rain are now more common and, as a result, conditions there are wetter.
- Conditions in the south and east of the country are on average drier than in the past.

Perhaps the biggest impact of climate change in Ireland will be changes in rainfall pattern. In other research by ICARUS, summarised here (see page 9), it now seems that Ireland can expect more seasonal rainfall, with wetter winters and drier summers on average, the wet summer of 2007 notwithstanding. There will also be a greater difference between the north and west of the island, which can expect even wetter conditions, and the south and east, where conditions on average will be drier. Extreme events, such as floods, are also more likely, while rising sea levels and more frequent storms will increase the likelihood of coastal erosion and flooding.

These changes will have major and long-term implications for our water supply, and thus for water for drinking and domestic use, for industry and farming, crop irrigation and industrial development, as well as the ecology of rivers and lakes, pollution and the spread of water-borne diseases, even hydro-electricity generation. Floods, droughts and coastal erosion will have major social, economic and ecological consequences, including for example, landslides and soil erosion, limiting the land available for agriculture and development, damage to property and the environment, and risks to human health.

Even if we could stabilise emissions of greenhouse gases at current levels, the Earth would continue to warm and climatic change would continue over the coming century, fuelled by the greenhouse gases we have already emitted, but which have yet to fully impact on the atmosphere. Thus, even the 'best case' scenario presents us with serious challenges in the medium and longer term.

Rapid economic and population growth, in Ireland and globally, means however, that we are unlikely to be able to stabilise, never mind reduce our greenhouse gas emissions.

The population of Ireland is projected to rise to 5.3 million by 2020, and possibly 8 million by 2100, a level not seen since before the Great Famine of the 1840s. This, coupled with economic growth, will mean greater demand for water, and at a time when water is likely to become more scarce.

Clearly, we need to plan for this future, and this planning needs to take a long-term horizon,

Image: Dublin City Council

Dublin, 2005: the River Tolka breaks its banks. Climate change, rising sea levels and changing rainfall mean that by 2100 floods such as this, currently expected once every 50 years, might happen every three years.

'The past is no longer the key to the future, and the future is uncertain'

of at least 50 years. As the latest report from the IPCC puts it, the focus now must be on 'adaptation' to a warmer world. Unfortunately, the past is no longer the key to the future. The future is uncertain, and this uncertainty makes long-term planning difficult, and all the more urgent. The flooding experienced in Britain in summer 2007 highlights the vulnerability of key infrastructure and flood defences.

For Ireland, this planning must be on an all-Ireland basis, as climate change knows no political borders or geographical boundaries. We must plan for coastal erosion and inundation, and for inland flooding; for how we manage our water resources, and water demand and supply; for both surface water and groundwater, and for water quality and quantity. All planning for infrastructure and development will need to be 'climate proofed', and flexible enough to accommodate the uncertain future.

Climate change is now firmly on the Governments' agenda and the establishment in the Republic of the new Cabinet subcommittee on climate change is a welcome first move. The key recommendations of this report, produced by a panel of engineering and scientific experts, outline the initiatives that must be taken if we are to protect Ireland's water resources and environment, and meet the challenge of preparing for climate change in Ireland.

What we should know

1. Climate change scenarios and challenges for the water environment*

John Sweeney, Conor Murphy, Rowan Fealy, Ro Charlton
Irish Climate Analysis and Research UnitS (ICARUS), Department of Geography, NUI Maynooth

Evidence for global warming over the last century is now overwhelming. All the emissions scenarios examined by the Intergovernmental Panel on Climate Change (IPCC) project that globally averaged surface temperatures will increase this century as a consequence of increases in atmospheric carbon dioxide concentrations. There is broad agreement that such human-induced climate change is likely to have a large impact on water resources, with concerns arising over the availability of water to meet future demands and the increased risks posed by more frequent and severe extreme events.

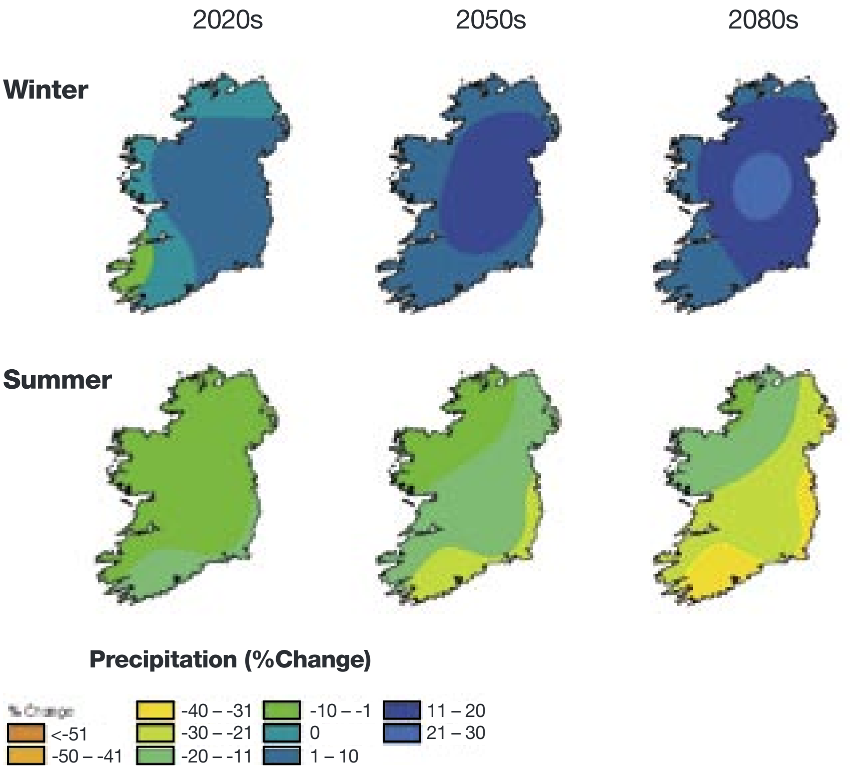
Future climate scenarios for Ireland: Global climate models (GCMs) have greatly improved in reliability and resolution as computing power has increased and as better inputs from Earth observation have become available. Despite this, their grid size remains too coarse to enable future climate scenarios at the scale necessary for impact analysis. Our study employs statistical downscaling to overcome these difficulties (see the full paper for details), and the results presented here are derived from three different GCMs downscaled to the Irish synoptic station network. Future changes in temperature and precipitation for Ireland over the coming century are highlighted.

Temperature: Mean annual temperatures in Ireland rose by 0.5°C over the past century. Over the coming century mean temperatures in Ireland relative to the 1961-90 averages are likely to rise by 1.4-1.8°C by the 2050s, and by more than 2°C by the end of the century.

Precipitation: this is likely to be the most important aspect of future climate change for Ireland. By the 2050s, winter rainfall in Ireland is projected to increase by approximately 10%, and summer rainfall to reduce by 12-17%. By the 2080s, winter rainfall will have increased by 11-17% and summer rainfall will have reduced by 14-25%. The largest percentage winter increases are expected in the midlands. By the 2050s, southern and eastern coasts could have 20-28% less rain in summer and 30-40% less by the 2080s.

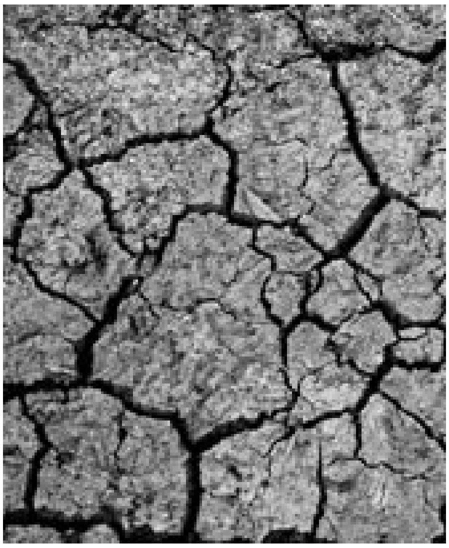
Extreme events: Changes in the frequency of extreme events will accompany these climate changes. Longer heatwaves, lengthier rainfall events in winter and more intense downpours in summer are all projected. At the same time, we could see more summer droughts, especially in eastern and southern parts of Ireland.

Impacts on the water sector: As part of an EPA-funded project, Climate Change: refining the impacts, hydrological modelling based on nine key catchments throughout Ireland was undertaken using the future scenarios



Changes in rainfall based on an ensemble of several global climate models (GCMs) and emissions scenarios, down-scaled for Ireland (Source: Fealy, R. and Sweeney, J. Statistical downscaling of precipitation for a selection of sites in Ireland employing a generalised linear modelling approach. International Journal of Climatology. Published online: 29 May 2007, DOI:10.1002/joc.1506.)

*The full text of all five keynote papers is available online at www.iae.ie



developed above to assess future changes in the water environment (Murphy and Charlton, 2007). Results show that the ability to adapt our water management systems will be critical to ensuring the wellbeing of future generations in Ireland.

Surface water: All catchments show increases in winter and spring flows and decreases in late summer and autumn. In winter, increases of 12-15% in the amount of water flowing in rivers are expected in the majority of catchments by mid-to-late century. Such increases would have major implications for flooding, with greatest increases in the west. The most notable reductions in surface water are simulated for the Ryewater and Boyne. These catchments are the most heavily populated in the country and comprise a substantial proportion of the greater Dublin area (GDA). Significant reductions in the Boyne are suggested by the 2020s in early summer and autumn with reductions becoming more pronounced as the century progresses. By the end of the century reductions of up to 70% are simulated in August. Such reductions in surface water availability would have substantial implications for the entire water environment – from water supply to quality issues to loss of habitat.

Water supply: Summer and autumn, when demand is greatest, are also when the greatest reductions in surface water resources are likely, and when increased evaporation is likely to result in greater losses from storage reservoirs. The domestic sector is not the only one likely to put increased pressure on supplies: agricultural demand is also particularly sensitive to climate change, and therefore increased competition between sectors for declining resources is likely. Water provision could become an ever more complex task. Even under current climate conditions, demand is projected to be at the limit of projected supply capacity in the GDA by 2015. Serious and ambitious long-term plans need to be initiated for the sustainable development of water supply within all regions.

Soil moisture and groundwater:
Our results predict less soil moisture for all catchments and this will have huge implications for agricultural practices. Soil moisture deficits will become more pronounced, begin earlier and extend later in the year than currently experienced. Such projected changes in soil moisture storage may affect key soil and ecosystem functions.

Over the coming century all catchments show longer, sustained periods of low groundwater levels. Under current conditions the late autumn and winter recharge period is critical to sustaining groundwater levels throughout the year. By mid-to-late century, significant reductions in storage during this time will increase the risk of severe drought, as the occurrence of a dry winter may result in prolonged drought periods where the groundwater system is unable to recover. In Ireland groundwater is an important resource for drinking water supply. Moreover, the areas likely to experience the most significant reductions in groundwater storage are also where future demand for water is likely to be greatest.

Flooding: One of the most high-profile impacts of climate change is on flood

'The flood we now expect once every 50 years, could occur once every three years'

'Changing rainfall pattern is likely to be the most important aspect of climate change for Ireland'

frequency, with major areas of concern relating to the integrity of flood defences, planning and development control, urban storm drainage and the implications for the insurance industry. Results suggest that large flood events will become much more frequent. In the Boyne catchment by the end of the century the flood we now expect to occur once every 50 years could occur once every three years. Similar trends are expected in all catchments. Such changes would have significant impacts for property and flood plain development, the reliability of flood defences, water quality and insurance costs.

The way forward

Modern approaches to water management have been founded on the ability to react and adapt to changing pressures and demands with adaptation historically based on reactive measures that are triggered by past or current events, or anticipatory measures where decisions are based on assessment of future conditions. Traditionally such anticipatory measures have been built on the premise that the past is the key to the future, but this is no longer the case. Therefore adaptation to climate change presents new challenges to water resources management, requiring innovative approaches to complex environmental and social problems.

In relation to climate change impacts, considerable uncertainty remains in several areas and further research into these is highly desirable to increase confidence for policymakers. This is not however a justification for not accelerating measures to promote adaptation. In light of these uncertainties it is bad practice to base adaptation options on output from a single GCM or scenario. In such cases there is a significant risk of over- or underestimating impacts, with substantial societal, environmental and economic consequences. Rather, we need to use multi-model ensembles that provide representative uncertainty ranges for impacts, as we have done here. To confront uncertainty we need to begin the task of identifying potentially successful adaptation options that are robust to uncertainty, equitable and cost effective.

While climate change poses many challenges for the water environment, early action to reduce impacts through adaptation measures will avoid damages and the need for increased expenditure at a later date. From a societal, institutional and operational perspective we need anticipatory action now. We cannot suddenly start adapting to climate change in 30 years time. The successful management of future water resources and the capacity to adapt to a changing climate will depend on our ability to incorporate both technological and scientific advances into decision-making processes in an integrated and environmentally sustainable fashion. With this in mind, adaptation should be focused on reducing the sensitivity, increasing the resilience and altering the exposure, through preparedness, of both society and our water management systems to the effects of climate change. Therefore decisions we make today need to ensure that we are on the right adaptation, technological and policy development pathways.■

What we should know

2. Impact on Coastal Areas

Gerard Farrell, Chief Engineer
Department of Communications, Marine & Natural Resources

Coastal erosion and coastal flooding cause significant economic and social disruption and pose serious threats to the coast of Ireland. The climate change scenarios outlined in the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2007), predict rising sea levels and more frequent and more severe coastal storms. These consequences of climate change will significantly increase the risks posed by coastal erosion and coastal flooding.

Coastal erosion occurs when the sea progressively encroaches upon the land. The extent and causes of coastal erosion in Ireland have been documented in several studies over the last century and these studies all converge to the same general conclusion: that about 20% of Ireland's coastline is at risk from erosion, with erosion rates varying from a maximum of about 2 m per annum on parts of the east coast to near zero at sheltered locations.

Coastal flooding occurs when high tides, surges and 'wave overtopping' combine to inundate coastal areas. Normally, tides do not give rise to coastal flooding concerns but tide levels are rarely exactly as predicted. The difference between a higher than expected sea level and the predicted normal tide level is referred to as a surge. Surges of varying magnitudes occur frequently around our coasts and generally pass unnoticed. They come to attention only in the rare event that they coincide with a high spring tide. This happened on the east coast in February 2002, when a surge of about 1 m coincided with one of the highest spring tides of the year. Many of the large urban centres in Ireland such as Dublin, Cork, Waterford and Wexford are built on the coast and are currently at serious risk of surge-based coastal flooding.

In the climate change scenarios outlined in the IPCC's 2007 report, mean sea level is predicted to rise by up to 0.59 m over the next century, about three to four times the current globally averaged rate of mean sea level rise. This, coupled with more frequent and more severe coastal storms, will significantly increase the risks of coastal erosion and coastal flooding.

The relationship between the rate of sea level rise and the rate of coastal erosion is complex but for the purposes of national overview, it can reasonably be taken that they are linearly related. Thus the current rate of coastal erosion and the current economic impact can be expected to treble or quadruple over the next one hundred years.

In the case of coastal flooding, adding the predicted increase in mean sea level to a high spring tide will show little inundation on the Irish coast. But, simple static analysis is highly misleading, as it fails to take into account the impact of mean sea level rise on extreme events. These will change in a number ways but most significantly, the frequency of flooding at a particular depth will increase dramatically. Thus even with a modest 0.4 m rise in mean sea level, the flooding that occurred in Dublin in February 2002, currently expected to occur about once a century, will occur at least every five years, if not more often.

The increased rates of coastal erosion and coastal flooding driven by climate change have serious economic implications for Ireland and steps need to be taken now to prepare for the threats to our coast that may emerge in the decades ahead.

The first step in preparing for climate change lies in identifying and quantifying the threats. This entails down-scaling global analyses and converting the downscaled data into specific impacts on Ireland. This work is ongoing, but perhaps needs to be put on a more formal cross-sectoral footing. The single most important step to prepare for the threats posed by climate change to the Irish coast is to integrate the risk data into the planning and development and National Spatial Strategy systems.

'We can defend, accommo-date or re-align the coast'

Image: Department of Communications, Marine & Natural Resources

Coastal erosion is already a serious problem along the sandy Blackwater coast of Co Wexford. But by 2100, the rate of coastal erosion around Ireland could be three or even four times faster than today.

'Ireland has no system for surge forecasting or coastal flood warnings'

In relation to developed areas, there are essentially three approaches to responding to erosion and flooding threats: defend, accommodate or re-align the coast. The decision on which approach to adopt will have to be taken on a case by case basis with sustainability and economic considerations to the fore, and issues such as social cohesion also given serious weight. With limited funding, difficult decisions may arise and it will be important that objective and transparent procedures are in place at a national level for scheme prioritisation.

Ireland does not yet have a system for surge forecasting and for disseminating coastal flood warnings. Such a forecasting system needs to be put in place. Computer models are now available that, when combined with the good quality meteorological forecasts computed by Met Éireann, can give two to three days' advance warning of coastal flooding. These warnings can allow emergency responses to be initiated and help significantly to reduce the flood damage and social disruption.

Finally, a reliable, quality controlled tide-gauge network with a quality controlled data processing and archiving system needs to be established in Ireland. This is required to monitor sea level changes and provide data for numerical model calibration and real time feedback to a coastal flood warning system.

What we should know

3. Impact on inland flooding

Tony Smyth,
Director of Engineering Services, OPW

The biggest challenge that arises as we examine the question of inland and estuarine flooding, is the uncertainty associated with the climate change scenarios being developed by climate scientists. If we knew with confidence what was going to happen, it would be far easier to make the economic and other decisions related to investment in, for example, flood protection and risk management works, and development planning. The uncertainty requires policies to be implemented that are based on emerging scientific data and general assumptions about its impacts.

Adaptability is another key challenge that is intimately linked to uncertainty. We have to design flood defences based on current estimates of flows, and make provision for the anticipated impact of climate change, if this approach is acceptable when measured against the various cost or environmental assessment criteria (the 'precautionary' approach). We must ensure also that the construction works we carry out are, as far as possible, adaptable at a future date to cater for the anticipated changes, as and when they materialise. The degree, cost and acceptability of this adaptability are now criteria against which the OPW assesses flood relief scheme options. The challenge is how to apply this new approach – risk management – and to assess economic viability of defence schemes in face of the uncertainty.

The issue of design standards is related to the issue of uncertainty. For example, the recently-completed Kilkenny flood relief scheme was designed to provide protection against the 1% flood. We don't know however, what level of protection the scheme will provide in 50 years, and hence what works need to be planned and financed to maintain the design standard, and indeed whether it is economically viable to maintain this standard.

This topic is tied also into the concept of risk management (as opposed to protection measures) and to adaptability. As we move to a risk management approach, in which the risk is most economically reduced and with a strong emphasis on adaptability of the constructed scheme to meet future change as it emerges, the concept of fixed design standards is no longer relevant.

Flood policy

The Government's adoption of the Flood Policy Review Group report (2004) provides the framework for the OPW to change in a fundamental way how we approach the issue of flood protection. That report changed how we deal with flooding issues in Ireland. The focus for the future is now:

To minimise the national level of flood risk to people, businesses, infrastructure and the environment, through the identification and management of existing, and particularly potential future, flood risks in an integrated, proactive and catchment-based manner.

The policy introduced a shift by the State away from structural or constructed flood defence measures to non-structural measures; it emphasises a risk management approach to the problem of flooding, and in particular to the management of future risks that may arise from development or climate change.

While much has changed in the State's approach to dealing with the issue of flooding, there remains more to do to face the many challenges presented by the climate change scenarios, at both official level and for the public at large.

Planning and development: Existing and likely future flood risk will be identified and should be used by planning authorities in preparing development plans, local area plans, and deciding on individual planning permissions in their areas. The catchment flood risk assessment and management (CFRAM) process, initiated by the OPW will, when

'How do we delineate a flood plain?'

Current flood prediction methods are based on historic data, but climate change means that the past is no longer a guide to the future. Flood protection measures we build today will have to be flexible to cope with this uncertainty.

implemented, provide a risk management approach to development in a catchment. The issue then is to build public support and confidence in the decision-making process and in the outputs from the CFRAMs.

This awareness of the flood risk, and the potential future increases in risk due to climate change are important issues in the planning and development process. However, an important (and difficult) task is to ensure that potential impacts of climate change on flooding are significant considerations in policy and decision-making. This applies at all levels, from central Government (including policies, such as planning guidance, and financing), through local authorities (e.g., planning and permitting or refusing development) to the developers and the public (e.g. should they pursue a course of action in face of potential future threat?)

There are a number of policy issues in the area of planning and development control to be discussed and decided, and related to the uncertainty challenge discussed above. For instance, how do we delineate flood plain areas? How do we enforce a 'no development' policy in flood plain areas of very high risk? To base the delineation of flood plain areas on historic records of river flows is to ignore the climate changes predicted. However, to base them on the worst climate change scenarios may be difficult to justify and could fail to win support at a local level. Adaptability is likely to be key to managing this issue.

Flood prediction and drainage design: At present flood prediction methodologies are based on, where possible, a historic record of flows from a river gauging site, calibrated from flood events that have occurred over the period of the hydrometric record. The process assumes that records are a sample from a statistically stationary population of flood events and that, in effect, the future will be statistically similar to the past. Clearly in the climate change scenarios emerging, this assumption is invalid. New methodologies will have to be developed to allow engineering calculations and estimates to be made of flood levels for particular probabilities.

This area of work is an important one when the estimates are used in conjunction with flood maps to delineate flood plain areas, particularly when the issue of restricting classes of development in areas at risk of flooding is under consideration.

Mitigating climate change impact: Several methods can be utilised to mitigate the impact of climate change, such as incorporating 'sustainable drainage systems' (SuDS) into new developments to limit discharges into streams and rivers to the pre-developed level of flow. This would have the dual effect of limiting the flood potential of the development and protecting ground water levels.

Second, is the use of catchment-wide land-use planning to reduce flood risk in centres of population. The use of wetlands, of bog restoration or of setting aside upstream areas of land to act as flood storage would also have the effect, while reducing flood levels, of improving the wildlife and biodiversity of a river catchment. Such solutions have the benefit that even with increased rainfalls the flood peak may be kept at or below its present level and the risk to populated areas reduced.

There are, of course, a range of issues to be examined before bringing forward such options. We need to research and demonstrate the effectiveness of the various options. Also, the farming community may take issue with the idea of using farmlands to protect urban areas. Landowner agreement, land purchase or compensation for the use of the lands may likewise be contentious.

A third approach to mitigating the impact of flooding is to improve the flood resilience of building design and construction. This may overlap with our building regulations and merit further investigation.

Adequacy of existing defences: Significant flood defences exist in various parts of the country. Where the OPW has carried out a capital works scheme these assets are known and maintained, but this is not the case everywhere. To record such assets, as part of the CFRAM process, the OPW intends to develop a flood asset register, identifying those walls, embankments, etc., that provide some level of flood protection. The task then will be assessing the level of protection the assets provide and how they will perform in the light of predicted changes.


Image: Dublin City Council

Engineering skills: Specialist engineering skills in hydrology and river engineering will be required, and their development has already been identified by the Institution of Civil Engineers (ICE) in the UK as a critical issue in meeting future needs.

In conclusion, the recent review of flood policy and the implementation plan developed on foot of Government approval of that review have put our approach to dealing with flood risk in line with the latest developments across Europe. It has also set a framework for dealing with future impacts as they emerge from climate change. There is however, much still to be done.

What we should know

4. Impact on water supply

Michael Phillips
Dublin City Engineer

'The mere presence of people near a water body has a detrimental effect on its quality'

Water is the key to the survival of all human, animal and plant life on this planet. It has the ability to mix with some substances, to corrode others, to operate as a vapour, liquid or solid, and at the same time has extraordinary self-cleaning properties, yet we in Ireland usually take water for granted. That situation will alter, however, as climate change takes effect, and we come to recognise water for the liquid gold it is.

The impact of climate change on water resources will become critical for people's lives and economies. Even if CO_2 emissions were stabilised today, the temperature increases and consequent impact on water availability would continue for some decades. The latest assessment report of the Intergovernmental Panel on Climate Change (IPCC, 2007) projects that global average temperatures in 2100 will be 1.8-4°C higher than the 1980-2000 average. Meanwhile, the world's population is expected to increase from the current 6.5 billion to 8 billion in 2020, and hit 13 billion by 2100. While the rate of increase of greenhouse gas emissions depends on global population, and on economic, technological and social trends, the link to population is clearest: the more people there are, the higher emissions are likely to be. The rate of climate change will be determined largely by the USA and the emerging economies of China and India, and what happens in Ireland will have little net effect. Nevertheless, these global trends will affect us and it is prudent that we should plan for the expected changes.

As outlined in the other summary papers here, global climate models are used to forecast the expected climate change and, to predict for Ireland, these models have to be downscaled. The predicted outcome for Ireland for the present century is a temperature rise in excess of 2°C, coupled with 11% more rainfall in winter, but 25-40% less rainfall in summer and early autumn. Sea levels are predicted to rise 0.59 m over the next century, along with an increase in the frequency and severity of coastal storms.

The impact of changing farming patterns, possible changes in the hydrological cycle or failure of the North Atlantic Drift ('gulfstream current'), whether due to natural phenomena or human interference, and the arrival of alien flora or fauna, imported accidentally or otherwise into the country, pose additional threats. Thus climate change will, directly and indirectly, impact on every aspect of our daily life, and we will have to adapt over time to these changes. For this long-term adaptation to be sustainable, we need long-term planning of our water resources.

Current status

Ireland is fortunate in that it is well endowed with water resources, having one of the highest rates of water availability in Europe. Unfortunately, the places where water availability is greatest and where water is most needed tend to be at opposite ends of the country. It is predicted that there will be 5.3 million people in Ireland by 2020, and perhaps 8 million by 2100, with the east of the country being the more densely populated.

Most of the eastern half of the country has 750-1,000 mm of rainfall a year, compared with 1,000-1,300 mm in the west, and over 2,000 mm per year in many mountainous districts. When evaporative and plant transpiration losses are taken into account, annual *effective* rainfall is approximately 350-550 mm in the east, 620-820 mm in the west, and more than 1,500 mm in mountainous areas.

Over 70% of the population draws its water supply from freshwater lakes, reservoirs and rivers (surface water abstraction). About 30% of water supply sources that abstract more than 10 m^3/day are derived from groundwater, and many private domestic and agricultural users also depend on groundwater sources. This is considerably less than in other countries (e.g. North America 51%, European average 75%). Groundwater in Ireland is generally of

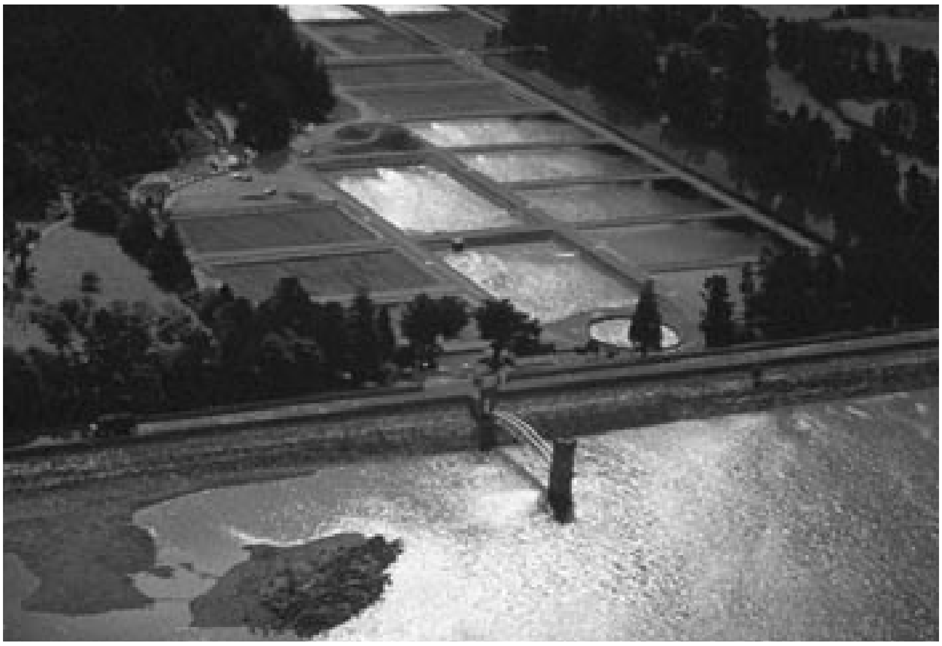


Image: Dublin City Council

Drinking water treatment plant at Roundwood, Co Wicklow. Currently, 70% of Ireland's water supply comes from such surface water, but where will we get our water when climate change takes effect?

good quality, requires less treatment, and is cheaper to develop and distribute than surface abstraction. The proportion of water supplied from groundwater is likely to grow as development increases. (For more on groundwater, see page 20.)

The part of the effective rainfall that percolates into the ground to reach the water table is called groundwater recharge. This varies depending on the effective rainfall available, and the geological conditions. Recent research indicates that less than 5% of annual effective rainfall becomes groundwater recharge where subsoils comprise thick clay, but can be over 80% where gravels occur. In many areas, particularly the uplands, the bedrock that transmits the groundwater (the aquifer) cannot accept significant quantities of recharging waters due to its poorly transmissive nature. Deeper aquifers are largely unexplored.

In recent years the demands on and threats to rivers and other surface water bodies have grown dramatically, fuelled by the competing interests of urban dwellers, farming and tourism. Intensive farming has the potential for pollution as a result of nutrient run-off; the demands of urban dwellers and industry for a clean water supply and the disposal of wastewater present a potential threat to the water body. The growth in affluence in recent years has also put greater demands on water bodies to provide a source for active leisure time. In fact, the mere presence of people near a water body has a detrimental effect on its quality resulting from waste and other forms of pollution.

EU Directives have focused attention on setting standards and minimising damage to the environment and Ireland is endeavouring to comply with them. Current work for the Water Framework Directive is establishing links between groundwater and associated surface water and ecological receptors, which will enhance our knowledge of the quantities of available water.

Pollution of groundwater in Ireland tends to be microbiological rather than chemical. Levels of chemicals exceeding the EU MAC are less widespread, and the main contaminants are generally nitrates, ammonia, potassium, chloride, iron and manganese. (Some constituents, for example iron and manganese, occur naturally at high concentrations in certain rock types.)

Adapting to the future

For the foreseeable future, water will continue to be abstracted from surface and groundwater sources, with salt or brackish water providing an additional supply in some circumstances. The protection of surface water sources and the increasing demands present challenges. In particular, the growth of 'water thirsty' crops, and crops grown as biomass or as a biofuel, may increase irrigation needs.

While groundwater currently provides only 30% of Ireland's water supplies, it is important to note that 70% of Ireland is underlain by 'poorly productive' bedrock aquifers – bedrock which is limited in its ability to accept recharge and transmit groundwater laterally. It is critical, therefore, that we continue to research the recharge acceptance, storage, capacity, movement and quality of groundwater resources.

Demand is often highest when water is most scarce, so with changing rainfall patterns we may have to investigate the possibility of storing water in times of plenty to meet future demand. Aquifer storage and recovery (ASR) is a technology that may help in some areas to bridge the gap between supply and demand.

Some 70% of the planet is covered by the oceans, yet deriving potable water from sea water on a commercial basis is relatively recent. As an island, Ireland is ideally located to use such a source and availability and quality are not an issue. Membrane technology and the process of reverse osmosis (RO) have dramatically changed the market, and the price of desalination has significantly reduced in recent years. The main difficulty with membrane technology is the energy required to operate it, and disposal of the brine residue.

The perception of the availability of water is based on the demands for it at a particular time. These demands may originate from a global or national perspective. One such demand is the fact that Ireland, because of its size, must economically be export-orientated in order to ensure economic growth. With a possible population of 8 million by 2100, this means that the demand on available water resources will have to include sufficient flexibility to cater for the uncertainty that global trade introduces to the situation.

Internationally, Ireland will also be viewed as 'water rich' compared with 'water poor' developing countries. This could result in increased inward migration and encourage the growth here of 'water hungry' crops, such as wheat, world production of which is decreasing due to water shortages elsewhere.

Providing water for Ireland's future population and economic growth will present many challenges. It is not known if there will be adequate water to meet demand, and hence it is critical that we reduce demand in the future. This can be achieved through conservation and alternative or even multiple re-uses of non-potable water.

The issues going forward are, therefore: Where will the significant water resources be located? How can the resources be quantified and protected for future use in the most sustainable manner? How can we develop an effective education programme on demand and re-use for such a long timescale when the majority of people operate on short- to medium medium-term plans and have entrenched views on issues such as the re-use of treated effluent? And finally, how can the present institutions be utilised or modified to prepare a strategy to reduce uncertainty, and integrate the outcome into medium-term strategies for the future?■

What we should know

5. Impact on groundwater supplies

Natalya Hunter Williams and Monica Lee,
Groundwater Section, Geological Survey of Ireland

Changes in climate could potentially alter each hydrological element within the catchment water balance, and have a significant impact on both surface and groundwater resources. These changes will be compounded by increased demands on supply as our population increases and our climate becomes hotter. Significantly, the greatest demand is likely to be in areas that will experience the greatest changes in climate.

Groundwater supplies

Groundwater is water located beneath the surface in pore spaces and fractures of geologic formations, with the term 'aquifer' used for deposits that yield water in useful quantities. In most Irish bedrock aquifers, groundwater flows through fissures, fractures and faults, and the volume that can flow through a bedrock aquifer depends on the number, size and connectivity of the fissures. Groundwater is also found in deposits of sand and gravel overlying the bedrock. The aquifer classification system used in Ireland, developed by the Geological Survey of Ireland (GSI), reflects the groundwater flow type (through fissures, karst systems, or gravels) and describes the resource potential (e.g., regionally important, locally important, poor).

A combination of climatic and geologic factors determines the amount of groundwater recharge, and thus the volume that a groundwater system can supply to surface waters or ecosystems, and also the volume potentially available for sustainable abstraction. Recharge depends broadly on the amount of rainfall, and the subsoil and aquifer properties. The amount of water potentially available to become groundwater recharge depends on *effective* rainfall, namely the total rainfall less the amount taken up by plants (transpiration) and the amount lost directly to the atmosphere (evaporation).

Prolonged rainfall is more efficient at recharging groundwater since short, intense periods of rain often cannot percolate through the soils and subsoils, but instead become surface run-off. Permeability is the principal subsoil factor controlling recharge: where subsoils are thick clay, less than 5% of annual effective rainfall becomes groundwater recharge, whereas over 80% of effective rainfall can percolate through highly permeable gravels. The nature of the aquifer also determines its 'recharge acceptance': highly fissured aquifers can, in general, accept more recharge than poorly fissured ones; sand and gravel aquifers typically accept the most recharge. Where the water table is close to the ground surface, high groundwater levels limit groundwater recharge.

Groundwater is an integral part of the hydrological cycle: rain falling on the ground surface can either run off to surface waters, or percolate into the subsurface. Aquifers discharge groundwater on land and at sea as springs and seeps, and provide baseflow and solutes to wetlands and rivers, thereby influencing the flow regime and water quality, and maintaining surface-water ecosystems during dry months. Some wetlands, such as turloughs, are highly dependent on groundwater, while others are dependent to some degree. Whilst there are seasonal variations in groundwater levels and flows to the surface, there is a long-term balance between recharge and outflows.

Groundwater use

Groundwater plays a critical role in the natural environment and in sustaining surface water flows and ecosystems but, abstracted from wells and springs, it is also exploited to provide drinking water, and water for farming and industry. Current groundwater abstraction for public, group and industrial water supplies is about 200 million m^3. Nationally, almost 30% of water supplies (abstracting more than 10m^3/day) come from groundwater, rising to more than 50% of public water supplies in some counties (e.g. Roscommon, Offaly). Taking into account the widespread use of groundwater

'Almost 30% of our water supplies come from ground-water'

As climate change takes effect, we will probably be forced to draw more of our water supply from groundwater sources, but we need to know more about the capacity, flow, quantity and quality of our groundwater resources.

'Groundwater plays a critical ecological role by sustaining surface water flows'

for domestic and agricultural supplies in rural areas, at least 100,000 wells and springs are in use nationally.

Groundwater quantity and quality in Ireland are generally good. Over-abstraction is rare, and risk assessments indicate that there is sufficient groundwater to satisfy the current usage sustainably (i.e. without impacting on ecological receptors) over most of the country. While quality overall is good, there are widespread issues of poor microbiological quality, and elevated nitrate concentrations occur in certain areas, particularly the southeast.

Groundwater use, whether for drinking water, industry or agriculture, depends on several factors, in addition to the primary geological factors of aquifer type and subsoil. There may not be sufficient suitable land for well head protection and pump control housing. Strategic environmental assessments (SEAs) are now important when considering groundwater abstraction, and development of groundwater supplies that abstract more than 5,500 m^3/day requires an environmental impact statement (EIS).

While available resources vary across the country, there is a growing use of groundwater, fuelled by a bigger urban population, the housing boom in commuter belt and rural areas, and industrial growth. Local authorities now often meet growing water demands with groundwater. Since existing local authority supply systems are often near capacity, new housing developments are often required as part of their planning permission to ensure that there is an independent water supply; this is frequently met with groundwater

Climate change

The effect of climate change on a groundwater system will depend on the often complex interactions of subsoil properties, aquifer properties, effective rainfall amount and rainfall timing. We expect groundwater levels, volumes and quality to be affected, which in turn will affect drinking water resources, rivers and ecosystems.

In productive fissured aquifers and diffusely karstified aquifers, for example, recharge volumes could increase if there is greater effective rainfall (provided subsoil permeability is not a limiting factor). But these types of aquifer are mainly located in the south and east of the country, where we expect drier summers. For sand and gravel aquifers, in areas where effective rainfall increases, recharge volumes will generally increase, although, where effective rainfall decreases, recharge volumes will also decrease. Poorly productive aquifers, in contrast, generally have a limited ability to accept recharge, and so wetter winters will not contribute to greater recharge, since these aquifers cannot accept the extra rain. Even current annual rainfall amounts in the west (up to 2,000 mm) mainly run off, rather than recharge poorly productive aquifers, and these 'poorly productive' aquifers underlie 70% of the country.

The late autumn and winter recharge period is critical to sustaining groundwater levels throughout the year. By mid-to-late century, however, the failure of winter or spring rains could result in prolonged drought, leaving the groundwater system unable to recover from previous dry spells. Reduced levels and flows in all types of aquifers will be bad for supply. A lowering of the water table will further reduce the summer resource potential of poorly productive aquifers, because of their low storage capacity and the fact that flow is predominantly in the upper, more fractured part of these aquifers. This is already seen in dry years at existing sources.

Where recharge decreases, then the catchment area or 'zone of contribution' to a borehole or spring must increase in order to meet the same demand. If there are limits to the possible expansion, or potentially polluting activities occur within the expanded catchment area, then demand may not be met.

Springs, which occur where the groundwater table intersects the ground surface, are susceptible to changes in water table levels. Reduced groundwater levels could cause the flow at a spring to drop or dry up, either seasonally or permanently. Springs often provide a significant volume of water to rivers, lakes and particular ecosystems, and springs of all sizes are frequently tapped for public or private drinking water or for farm animals. The loss of spring water will therefore affect ecosystems, people and farming.

Groundwater flow to rivers (baseflow) provides much of a river's summer flow (and during drought periods, all of the flow). Baseflow can drop, however, particularly at certain times of the year, and the reduced flow means lower dilution rates, which can mean poorer river water quality. If the water table falls below the river bed, then some river reaches may dry up entirely.

If there is less groundwater recharge, then the concentrations of contaminants in groundwater could increase, even if the amount of contamination remains the same, because there will be less water to dilute it. Higher rainfall, and particularly more intense rain, could adversely affect water quality in karst aquifers. Pulses of turbid and poor quality water are already seen in these systems following intense rain, particularly at the onset of the autumn/winter recharge period.

The effect of changing rainfall patterns on groundwater could make floods more likely. In theory, wetter winters should increase groundwater recharge, but if aquifers are saturated, any further rainfall will become 'rejected recharge', in other words, run-off. Even in the current climatic conditions, the 70% of the country that is underlain by

'Some 100,000 wells and springs are in use in Ireland'

poorly productive aquifers cannot accept the amounts of rain falling in winter. Flooding also becomes more likely in areas underlain by low permeability subsoils, which prevent the water percolating down. In very karstified limestone aquifers, greater effective rainfall may lead to greater recharge amounts. However, much of the recharge will not be 'retained' by the system, but will flow rapidly out to springs and rivers, increasing the chance of flooding in low-lying karst areas.

Overall, however, the greater storage capacity of aquifers means that climate change is likely to have less impact on groundwater than on surface water. Consequently, we are likely to look to ground water to supply more of our drinking and other water needs, and increasingly more of our water supply will come from groundwater. Irrigation may be required for crops, and groundwater will probably be targeted to supply that. The direct and indirect impacts of climate change on groundwater – respectively, decreased recharge and increased demand – will put groundwater sources at increasing risk of over-abstraction. This could impact on rivers and other ecosystems that depend on groundwater, and shape future water consumption and settlement patterns.

Adapting to future changes

Climate change will significantly affect both fresh surface and groundwater supplies. Groundwater recharge may increase in some areas, and decrease in others. A key challenge will be adapting to meet those changes, whilst maintaining supply for an increasing population that is becoming more urbanised, and simultaneously maintaining the ecological requirements for water quantity and quality of river systems, lakes and groundwater-dependent ecosystems.

The current under-utilisation of groundwater to meet domestic, agricultural and industrial requirements puts Ireland in a relatively good position, since the 'slack' could be taken up to adapt to changing water availabilities and demands. In some areas, groundwater will become an increasingly important part of the water supply equation. In others, possibly those not hydro-geologically capable of providing sufficient supplies, surface water preservation and/or storage solutions will be needed. Groundwater could be used as a store through artificial recharge of 'productive' aquifers. The current trend for large single abstractions for public water supplies may have to be modified where aquifers cannot sustain single large abstractions, but instead can yield smaller volumes from multiple abstraction points. A significant water supply strategy is likely to be one of conjunctive use within the 'river basin management plans' (RBMPs), determined for the Water Framework Directive.

Notwithstanding uncertainties in climate change predictions, we need quantitative estimates of how climate change will affect the groundwater environment and its dependent ecosystems so that we can forward plan. Rapid assessments could be made on the basis of current understanding and existing mapping, but to improve the calculations, we need further research in key areas, especially physically-based research into recharge mechanisms to verify and improve current mapping and understanding. The complex and variable interaction between groundwater and surface waters and ecosystems is still not understood sufficiently and likewise requires further research.■

What we should know

6. Conclusions

Climate change can affect Ireland's water sector through changes in rainfall, rising temperatures and also, because of our island nature, sea level rises. Increases in temperature are likely to be significant, but the greatest threat from climate change will be from changes in precipitation. Rainfall drives our hydrological cycle, so any change in this primary input will have significant knock-on effects for the rest of the system. Climate scenarios produced by ICARUS, NUI Maynooth, show a more seasonal rainfall over the coming century, with wetter winters and drier summers (see page 9). Warmer temperatures will likely lead to more intense rainfall, and this will also affect the hydrological cycle. Meanwhile, a growing population and continued economic and industrial development will increase demand for water, and strain our existing supplies and resources. The successful management of future water resources and the capacity to adapt to a changing climate will depend on our ability to incorporate both technological and scientific advances into decision-making processes in an integrated and environmentally sustainable fashion. Decisions we make today need to ensure that we are on the right adaptation, technological and policy development pathways.

Surface and groundwaters: All areas will probably experience less summer run-off, especially in the east of the country. Winter run-off, however, is likely to increase, particularly in the west.

- Soil-moisture deficits are likely during summer and autumn, with serious implications for agricultural practices. The lower the capacity of soils to hold moisture, the greater is their sensitivity to climate change.

- If groundwater recharge drops and groundwater levels fall during critical times of the year, this could alter the nature of groundwater-surface water dynamics for entire river systems and other ecosystems.

- A dry winter could leave groundwater systems unable to recharge fully and recover for the subsequent summer; this would be exacerbated by the severe droughts, predicted for mid-to-late century.

- Water flow in the majority of Irish streams and rivers could drop dramatically in summer and autumn months, but in winter flows could increase.

- The catchments most susceptible to climate change are those dominated by surface run-off; those with a sizeable groundwater flow component are less at risk.

- Floods are likely to become more severe and more frequent, with implications for property, flood plain development, the reliability of flood defences, water quality and insurance costs.

- Water quality is likely to be affected by climate change both directly and indirectly. Direct effects include warmer water temperatures and the contamination of coastal aquifers by salt water; indirect effects relate to increasing demands placed on limited resources, especially during times of low flow when water will be scarce.

- Climate change, coupled with a growing population and greater commercial demands will put a continuous strain on the quality of our water resources. This will be particularly so during periods of drought (when assimilative capacity is down), and periods of flooding (resulting from overflowing networks and treatment facilities). Mitigation measures will be needed to protect ecosystems and biodiversity.

Sea levels and the Irish coast: Global sea level is projected to rise by up to 0.59 metres by the end of the century, due to warming and expansion of the ocean water body, and water flowing in from melting glaciers and ice masses. In Ireland this will mean:

- A 'higher platform' for wave attack, and greater erosion of soft coastlines (those formed of glacial drift and unconsolidated materials).
- Sandy coastlines will 'retreat' or lose about 1 m for every 1 cm rise in sea level.
- Coastal flooding will become more frequent.
- Rising sea levels, coupled with more frequent winter flooding, will pose major problems for coastal cities.

Water Resources: Over 70% of our water supply comes from freshwater lakes, reservoirs and rivers, and the remaining 30% or so from groundwater. In recent years, the demands on and threats to both surface-water and groundwater resources have grown dramatically, fuelled by the competing interests of urbanisation, agriculture, industrial development and tourism.

- The impact of climate change on water resources will become critical for people's lives, economies and ecosystems worldwide. These global trends will affect Ireland and it is essential to plan now for the expected changes.
- Protecting surface and ground waterwater sources, while meeting the increasing demands for water, presents significant challenges. Groundwater currently provides only 30% of Ireland's water supplies, but it is critical that we continue to research the recharge acceptance, capacity, flow and quality of groundwater sources.
- Ireland is ideally located to derive potable water from the desalination of sea water. Even with new technologies, however, this option remains expensive and energy intensive and produces a brine residue that must be disposed of.
- We must quantify our water resources and protect them for future use in the most sustainable manner. We urgently need an effective public information campaign on conservation and demand reduction, and we must continue the intensive ongoing work of rehabilitating our water networks to reduce leakages.

Image: Dept. of Communications, Marine & Natural Resources

Raven Point, Co Wexford: soft coastlines are particularly vulnerable to erosion, and that's likely to be exacerbated in the future by rising sea levels, more frequent severe storms and climate change.

What we must do

Recommendations

1. General

Adaptation: We must begin immediately to adapt to the inevitable consequences of climate change. The scientific community has reached consensus on the likely impacts, and the 'do nothing' approach is not viable. Greenhouse gases already emitted will take decades to fully impact on the atmosphere, climate change and the water environment, not to mention future emissions. The Governments of the Republic of Ireland and Northern Ireland must act now and develop co-ordinated adaptation strategies for the water sector.

Mainstreaming: Climate change must be mainstreamed across all areas of planning and development, and future infrastructural and housing developments must be 'climate proofed'.

Strategic planning: Each jurisdiction, north and south of the border, should establish a high-level strategic group to take an 'overarching view' of the impact of climate change on the water environment over the next 50 years, and make recommendations to Government. Cross-border collaboration will be essential, as climate change will affect the island of Ireland as a whole. These strategic groups should comprise politicians, engineers, environmental and social scientists, economists and business leaders, with a focus on ensuring the sustainable and timely development of the necessary infrastructure. The new Cabinet subcommittee on climate change, in the Republic of Ireland, and chaired by the Taoiseach, is a welcome first move.

Government: Successful adaptation to climate change will require effective communication and implementation across the entire public and private sectors. Strong leadership will be required from Government, especially where hard decisions have to be made. The responsibilities and decision-making functions of Government, local authorities and relevant agencies may need to be streamlined and coordinated to ensure effective implementation.

Climate proofing: Infrastructure investment plans and spatial strategies should be urgently reviewed, to ensure that all programmes and projects are 'climate proofed' and take full account of the potential impact of climate change. Risk assessment and management should be an integral part of all design and environmental assessments, with climate change proofing requiring specific assessment.

Critical infrastructure: Power generation and transmission facilities, and water supply and treatment facilities, and other critical infrastructure should be reviewed for climate proofing, and adapted as necessary so as to avoid potential catastrophic breakdown in services during extreme climate events, such as storms or flooding.

2. Planning and sustainable development

Spatial strategies: Existing spatial strategies deal mainly with population distributions and, to an extent, the infrastructure required to support them, but they do not currently take account of climate change. Spatial strategies need to be upgraded to include climate change and its impact on both urban and rural communities, in particular the long-term scenario and a likely population of 8 million by 2100. These strategies should be updated regularly as new information becomes available. Cross-border co-operation will be critical to achieving an optimal all-island approach.

Infrastructure planning: In preparing development plans, there is insufficient pre-development planning of associated infrastructure. Often, infrastructure, including water resources, is provided retroactively rather than proactively. This needs to change. Infrastructure, and in particular water resources, need to be planned and provided for in advance.

'Strong leadership is needed from Govern-ment, especially where hard decisions have to be made'

Catchment-based planning: Planning for the water environment must go beyond the 'county model' currently used for development plans, and function instead at a regional or national level as appropriate (e.g. catchment-based). Local authorities should have input to these plans, and then be governed by them in preparing county plans. Using management units of surface- and ground-water bodies, as per the Water Framework Directive, will help in assessing water resources holistically.

Leadership: Ensuring the optimum use of the available water supply, and properly managing flood risks when deciding where significant growth in population can take place, will require strong leadership, especially in preparing plans from national through to county level. Flood risk maps should be used in the planning process, and updated as new information becomes available.

Independent assessment: All statutory development plans should be independently assessed, prior to adoption, for completeness, complementarity with adjacent authorities, and consistency with Government policies, particularly in respect of climate change. Their implementation should be audited and monitored regularly.

Planning controls: Development planning and control should ensure that all future developments are sustainable, and take into account:

- The impacts of climate change, such as increased drought and flood risks.
- Catchment management plans.
- Future availability of water resources.
- The impact of climate change on coastal zones.

Where appropriate, planning applicants should be required to undertake a risk assessment and demonstrate that the proposed development has been climate proofed.

Building regulations: Those responsible for preparing and approving major building and infrastructural projects should be given general and technical guidance to ensure adequate consideration is given to all aspects of climate change, including the water environment. A revised set of building regulations could form part of this guidance. Emphasis should be placed on risk-based design, on a 'no regrets' basis, and on developing adaptable solutions that are both beneficial today and can respond as new information on climate change becomes available.

3. Coastal erosion and flooding

Climate change is expected to increase the rate of coastal erosion and coastal flooding, and this will have serious economic implications for Ireland. Steps must be taken now to prepare for the threats to our coastline that may emerge in the decades ahead.

Mapping areas at risk: The first step is to map the areas at risk from erosion or flooding, and identify and quantify the threats. The Governments of Northern Ireland and the Republic need to develop and implement coastal management plans for all coastal areas at risk from erosion or flooding. The risk data in these plans must be integrated into the next phase of the spatial strategies and of regional and county development plans.

Coastal protection: Various approaches and techniques can be used to tackle the threats of coastal erosion and flooding. To optimise the use of available funding, the coastal management plans should provide objective and transparent procedures for deciding on which approach to adopt in areas at risk, and how to prioritise competing schemes.

Flood forecasting and warning: A system for surge forecasting and for disseminating coastal flood warnings should be urgently put in place where appropriate, to mitigate the impact of the increased frequency of floods.

Tide gauge network: A reliable tide gauge network with a quality-controlled data processing and archiving system needs to be established in the Republic of Ireland to monitor sea level changes, and provide data for numerical model calibration and for real-time feedback to a coastal warning system.

4. Inland flooding

One of the most serious challenges in planning for the future is the uncertainty associated with the climate change scenarios being developed by climate scientists. We expect more flooding, and more severe floods, but we cannot yet predict with certainty what the increased frequency and degree of flooding will be. Many flood defences are expensive, and if they fail, the consequences can be catastrophic and costly, in terms of loss of life, economic setback and damage to property. Policies and plans must be based on the best scientific data available and on the predicted impacts of climate change. Adaptive responses must be assessed for their robustness to the uncertainty.

Following the report of the Flood Management Review Group (2004), the approach to flooding issues in the Republic of Ireland is now to "... minimise the national level of flood risk to people, businesses, infrastructure and the environment, through the identification and management of existing, and particularly future potential, flood risks in an integrated, proactive and catchment-based manner."
If this commendable objective is to be achieved, several challenges must be met.

Adaptable flood protection: In planning and building new flood protection schemes and projects, we must ensure they can be adapted to this uncertain future. The protection provided by the schemes should be maintained to

'We expect more flooding, and more severe floods'

an appropriate level, while making provision for anticipated climate change impacts as they emerge over the life of the schemes. We must now adopt a risk assessment/risk management approach to designing flood defences, as the long-held concept of fixed design standards is no longer relevant. This new design approach is being adopted by the Office of Public Works (RoI) and by the Rivers Agency (NI), in assessing flood relief scheme options. The challenge is to implement an appropriate risk management approach that also addresses the uncertainty.

Flood risk assessment and management: National plans, county development plans and local plans must fully embrace the 'catchment flood risk assessment and management' (CFRAM) process initiated by the OPW. Local consultation and involvement is imperative at all stages of the development of those catchment plans, to ensure the necessary support for and confidence in the process and decision making.

Delineating flood plains: A robust and acceptable methodology needs to be developed on which to base the delineation of flood plain areas. This should take account of the effects of climate change, based on current estimates, by prohibiting development in high risk areas, and providing suitable guidance for other areas at risk. The guidelines should be revised as new information becomes available on climate change effects.

Flood prediction: Current flood prediction methodologies are based on historical records, and assume that future events will be statistically similar to past events. With climate change, this assumption is no longer valid, and new methodologies are needed to allow engineering calculations and estimates of flood levels for particular probabilities.

Minimising flood risks: To minimise the effects of climate change on flood risks to vulnerable areas, it is essential to put in place cost-effective and environmentally sound mitigation measures at national and local levels. These could include:

- Incorporating measures in new developments to limit the discharge to streams and rivers to the pre-developed level of flow, while protecting groundwater quality, e.g. sustainable drainage systems (SuDS).
- Use of catchment-wide land-use planning to reduce flood risk in centres of population.
- Use of wetlands, bog restoration, or setting aside upstream areas of land to act as flood storage so that, even with increased rainfall, the flood peak may be kept at or below its present level, thus reducing the risk to populated areas downstream.

Public awareness: A necessary first step in optimising the use of long-term resources, is to develop and publicise information relating to flood risk. This could include the OPW's flood mapping programme, and the Flood Asset Register being developed in both jurisdictions. The register identifies walls, embankments, etc, that currently provide a level of flood protection. This information will be essential, especially in improving the quality of decision-making in planning and development, and reducing the existing level of flood risk.

5. Water resources

Water can be supplied from three sources: surface freshwater, groundwater, and salt water. Approximately 70% of Ireland's present needs are abstracted from surface freshwater, but this reliance on one source leaves us vulnerable to the changing rainfall patterns predicted for climate change. The potential contribution of all three sources should be urgently and fully investigated and considered for all future major water schemes.

Groundwater sources: Groundwater sources could be further developed. However, we need more detailed information on the quality, quantity and potential yields of aquifers, to ensure the optimal use of groundwater resources. Approximately 70% of Ireland is underlain by 'poorly productive' aquifers, most of which are at their recharge acceptance limit. Most of the north and west of Ireland is underlain by these aquifers, so increased winter rainfall there cannot be captured for additional groundwater resources.

Competing demands: Climate change will alter the needs and demands of water users in Ireland, particularly where irrigation will be required. We will need new policies to establish priorities to deal equitably with competing demands for scarce water resources. Climate change and demographic projections predict a serious imbalance between areas where rainfall will be most plentiful (west and northwest), and areas of greatest need (east and southeast). A long-term national plan is needed to ensure the necessary infrastructure is provided in a timely and appropriate way. This plan should ensure that sustainable water supplies, both surface and groundwater, are available across the country, while recognising the needs of individual stakeholders and protecting the quality of all sources.

Desalination option: Salt water is virtually limitless, but desalination is expensive – although membrane technology has reduced the price significantly – and it can be difficult to produce palatable water. Any comparison between desalination and other options must take account of the environmental impacts such as greater energy use and the disposal of the brine residue.

Network maintenance: Increased investment in detecting water losses, accompanied by major network improvements, should be extended nationwide and sustained in order to reduce leakage to acceptable levels and manage demand efficiently. All water authorities should set targets to be achieved in specified time periods.

Water conservation: Water usage in Ireland is significantly higher than elsewhere in Europe, and this, coupled with climate change and a growing population, could lead to significant water shortages in Ireland in the medium and long term. We need a fresh approach if scarce supplies are to be conserved. Measures to improve demand management should include regulation and incentives.

Sustainability of supply: the long-term sustainability of current surface and groundwater abstraction schemes needs to be fully investigated, to consider the impact of changing rainfall patterns and low flows on the quantity and quality of water availability, the increased risk for pollution, and the potential impact on surface water and groundwater-dependent ecosystems.

6. Research, education and information

Current climate change scenarios involve uncertainty in relation to the changes that may materialise, and the impacts of those changes on society and infrastructure. Research is needed to reduce these uncertainties, and to allow us to develop more accurate methodologies and calculations so that we can accommodate the emerging changes.

Research organisations in Ireland should be mandated to develop and deliver cutting-edge climate change scenarios, impact assessments and the evaluation of adaptation measures. International co-operation is essential to ensure best possible practice given the magnitude of the risk associated with decision making on climate change.

Public information: A major and sustained information programme is required at national level to convince the public of the reality of climate change and its likely impacts.

'Approximately 70% of Ireland's present needs are abstracted from surface freshwater'

The water environment should be dealt with as a specific topic, and initiatives developed with a view to changing culture and behaviour, perhaps similar to the 'Power of One' campaign to reduce energy use.

The concepts of risk and uncertainty should be explained, together with the need for adaptable solutions for significant developments and infrastructure projects. These concepts should be introduced at secondary level, and embedded in all relevant third-level courses, particularly in engineering and the sciences. The first step should be to educate the educators.

Submissions should be sought from relevant professional institutions on proposals for providing guidance to their members and the public at large on the need for new approaches to design and practice to deal with the impacts of climate change. The water environment should be addressed as a key sector.

Climate change research: We need greater research into the relationship between the built environment and the natural environment, including climate change. Research into climate change and its impacts on the water environment should be planned and co-ordinated on an all-island basis, to ensure that the latest information is available to decision-makers, infrastructure providers and designers, and that the research effort is focused on priority areas.

Research priorities: Specific research is needed to address information gaps and technical shortcomings in areas such as:

- Flood risk assessment: methodologies for assessing flood magnitude; the potential to mitigate flooding by water retention and storage, e.g. in reclaimed bogs.
- Planning and development risk assessment.
- Water supply options and requirements: reconciling various and competing demands for water; aquifer characterisation.
- New methods for advance communication of flood risk to the public.
- Tide and coastal issues: coastal sediment use and preservation.
- Ecological issues arising from climate change: the sensitivity of surface- and groundwater-dependent ecosystems and biodiversity to climate change; vegetation and soil moisture deficit changes.

Specialist skills: We need to ensure that we have the necessary skill sets to meet the challenges ahead, and avoid a skills shortage in the key specialist areas of engineering, hydrology and hydrogeology. An assessment of the requirements should be made, and action taken to ensure that graduates with the appropriate skills are available.

References

Fealy, R. and J. Sweeney. 'Climate Scenarios for Ireland'. In: Sweeney, J. *et al.* (ed) *Climate Change: Refining the Impacts*, Environmental Protection Agency, Ireland, Government Publications, in press, 2007.

Institution of Civil Engineers. *Engineering Skills for Flood Risk Management: a report by the Institution of Civil Engineers Task Team on Skills Shortages*, ICE (UK) 2004.

Intergovernmental Panel on Climate Change. *Climate Change 2007: The Physical Science Basis, Summary for Policymakers*, IPCC, 2007

Murphy, C. and R. Charlton. 'Climate Change and Water Resources in Ireland'. In: Sweeney, J. *et al*. (ed) *Climate Change: Refining the Impacts*, Environmental Protection Agency, Ireland, Government Publications, in press, 2007.

Office of Public Works. *Report of the Flood Policy Review Group* OPW, Dublin, 2005
http://www.opw.ie/whatsnew/PDF/Published%20Report.pdf

Appendix 1: Workshop rationale

Experts from across the island of Ireland were brought together for in-depth discussions to identify the key actions and initiatives needed in planning for how climate change will impact on Ireland's water environment. Some 40 participants were invited to the one-day workshop, and four keynote papers were circulated in advance. The keynote speakers also made presentations on the morning of the workshop, and these were followed by a short discussion.

For the detailed afternoon discussions, participants were assigned in advance to one of five groups, each with a convenor and rapporteur. To provide some focus for the discussions, the groups were asked to address a number of questions:

- How do we ensure that the necessary infrastructure is planned and implemented in time to mitigate the impact of climate change on the water environment?
- How should the impact of climate change on the water environment influence the next phase of the National Spatial Strategy?
- How do we ensure that a satisfactory framework is in place to guide and regulate developers of all new projects, including rigorous enforcement arrangements?
- How do we best inform engineering design in the face of the risk and uncertainty associated with climate change?
- Can we develop a set of key principles for climate-proofing, that would form the basis for the development of policies and plans?
- What must be done to ensure satisfactory demand management is in place to provide for the greater good in prioritising and allocating our limited water resources in the future?
- What research should Ireland do to best utilise our resources? Are there any specific areas where Ireland can become a leader rather than a follower?

The groups were invited "to provide a range of recommendations for action", having discussed the matters arising from the four keynote presentations, together with any other aspects raised in their group.

The workshop concluded with an open forum discussion at which the rapporteurs presented their group's findings and opinions. This report is based on those findings.

Appendix 2: List of participants

Adamson, Mark	Office of Public Works (OPW)
Bell, Adrian	RPS Group
Brick, Tim	Dublin City Council
Bruen, Michael	University College Dublin
Callanan, Finbar	Irish Academy of Engineering
Callery, Phil	Irish Academy of Engineering
Carey, Tom	Clare County Council
Casey, Jim	Department of Communications, Marine & Natural Resources
Charlton, Ro	ICARUS, NUI Maynooth
Clarke, John	Northern Ireland Rivers Agency
Cooper, Andrew	University of Ulster
Cunnane, Con	NUI Galway
Cunningham, Don	Irish Rail
Doyle, Aileen	Department of Environment, Heritage & Local Government
Farrell, Gerard	Department of Communications, Marine & Natural Resources
Foster, Dave	Environment & Heritage Service, DOE NI
Healy, Denis	Port of Cork Company
Hunt, Brian	An Bord Pleanála
Langford, Peter	Arup Consulting Engineers
Larkin, Padraic	Environmental Protection Agency (EPA)
Lavelle, Michael	Cork County Council
Lynch, Patrick	Irish Academy of Engineering
McArdle, Peadar	Geological Survey of Ireland (GSI)
McGrath, Ray	Met Éireann
Menzies, Don	Arup Consulting Engineers
Murphy, Conor	ICARUS, NUI Maynooth
O'Kane, Philip	University College Cork
O'Mahony, Brian	Electricity Supply Board (ESB)
Phelan, Pat	Office of Emergency Planning, Department of Defence
Phillips, Michael	Dublin City Council
Scott, Sue	Economic and Social Research Institute (ESRI)
Smyth, Tony	Office of Public Works (OPW)
Stewart, Roisin	Northern Ireland Water Service
Sweeney, John	ICARUS, NUI Maynooth
Terry, Kevin	Cork City Council
van der Kamp, Henk	Irish Planning Institute
Waldron, Eamon	Association of Consulting Engineers of Ireland

Notes

The Irish Academy of Engineering

IAE members are Irish engineers of distinction, including those resident in other countries. Membership is drawn from a wide range of disciplines, and currently stands at 120 members.

The Academy focuses on long-term issues where the engineering profession can make a unique contribution to Ireland's economic, social and technological development. Drawing on the experience and knowledge of its distinguished members, it works to facilitate communication and dialogue on engineering-related matters. It publishes reports, some jointly with other learned and professional bodies, including Engineers Ireland. Recent publications include:

- Future Energy Policy in Ireland
- Engineering a Knowledge Island
- A Vision of Transport in 2050
- Ireland's Environment
- The Government's Technology Investment Fund
- Spatial Development for an Island of 6 Million
- Creating Europe's Most Attractive Environment for Intellectual Property

The Irish Academy of Engineering is an all-Ireland body

The Irish Academy of Engineering, c/o Director's Office, Faculty of Engineering, DIT, Bolton Street, Dublin 1.
Tel: **+353 (1) 402 4058** Email: **iae@dit.ie** Web: **www.iae.ie**
This report is available online at **www.iae.ie**

ISBN: 1-898012-93-8