The Irish Academy of Engineering

Critical Infrastructure - Water Supply

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Workshop on:

Critical Infrastructure - Adaptation for Climate Change

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Climate Change and Water

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. As a result, the conservation, use, demand and treatment of water have to be given the most careful consideration in order to ensure a sustainable environment.

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 (1) projects that global average temperatures in 2010 will be 1.8^{o}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^{o}, coupled with 11% more rainfall in winter, but 25-40% less rainfall in summer and early autumn. While IPCC scenarios suggest sea levels to rise between 0.28 - 0.43m over the next century (relative to1980 – 1999), recent thinking suggests this may be too conservative with the potential for a one meter rise possible, along with an increase in the frequency and severity of coastal storms (2,3). In addition more frequent and severe droughts, flooding and weather events are to be expected.

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 and to have systems in place to recognise when, where and by how much the change is occurring.

Water Supply Availability

Ireland is fortunate 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 (4)

Most of the eastern half of the country has 750 to1,000 mm of rainfall a year, compared with 1,000 to1,300 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 to 550mm in the east, 620 to 820mm in the west, and more than 1,500mm in mountainous areas.

The rain profile and the abundance of surface sources has resulted in over 70% of the population being able to draw its water supply from freshwater lakes, reservoirs and rivers (surface water abstraction). About 30% of water supply sources that abstract more than $10m^3$/day are derived from groundwater, and many private and agricultural users also depend on groundwater sources (4). This is considerably less than in other countries (e.g. North America 51%, European average75%). Groundwater in Ireland is generally of 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.

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 in Ireland 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. Climate Change will also affect the intensity of the precipitation and this could be critical to the balancing of what is required for groundwater recharge and what runs off into the nearest watercourse

Pollution of groundwater in Ireland tends to be microbiological rather than chemical.

The oceans cover some 70% of the planet; yet deriving potable water from seawater 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

Adapting to the Future

The most current census gives a population of 5.9 million for the Island of Ireland (5). .It is forecast that there will be 7.8 million people in Ireland by 2026 (6), with the east of the country being the more densely populated. The increase in population together with societies' increasing dependency on essential services ("always-on" availability) highlights the need to minimise any disruption. This can be achieved through emergency preparedness, contingency planning and investment in critical infrastructure.

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 (7)

To date the supply of water in Ireland has been fairly resilient but this cannot be taken for granted. The impact of climate change on weather events, as experienced with floods in recent years, has demonstrated the fragility of the existing infrastructure. Maintaining a specified level of resilience into the future will be complicated by the tendency of the hazard, vulnerabilities and consequences to change over time.

The 2007 floods in the UK had a dramatic effect on electricity power substations, water and wastewater treatment works, and road and rail network. People in recent years have become accustomed to a reliable supply of water and energy and were left feeling exposed and unprepared for the situation when they ceased to function. In total in the UK there were five water and 322 wastewater treatment works affected by the floods. The loss of the Mythe water treatment works deprived 350,000 people of water for up to 17 days. However, it was the "near misses" at various power sub stations, which would have cut off over one million people, that brought home the vulnerabilities of the infrastructural assets (8).

This highlights that there is a need for a more systematic approach into the vulnerability of critical infrastructure and a coordinated approach to improving its resilience. Resilience is considered as the ability of a system or organisation to withstand or recover from adversity, i.e. it is possible to achieve the core activities in the face of adversity through a combination of measures (8).

Demand

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 2026 on the island of Ireland, 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.

In general terms, the population distribution would indicate that approximately 5 million would be along the eastern seaboard and 3 million along the western seaboard (9). At present the population for the Dublin Region is 1.2 million and the daily production of water is 550 Mega litres per day. Assuming adequate sources are available this would mean that facilities would have to double to meet the demand. It is for such a scenario that the design of critical infrastructure would have to cater. Consequently, the loss of an essential service, such as water supply, has the potential to cause greater disruption, economic and social, than might have occurred in the past.

Internationally, Ireland will also be viewed as ‘water rich’ compared with ‘water poor’ developing countries. This could result in increasing inward migration of people and encourage the growth here of ‘water hungry’ crops, such as wheat, the world production of which is decreasing due to water shortages elsewhere. The production of one kilogram of wheat requires 1000 litres of water (10).

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 pricing policies, conservation, harvesting and alternative or even multiple re-uses of non-potable water.

Source

Going forward the resilience of the existing systems need to be proven, as without a water supply the rules of behaviour of society become untenable. Increasing pressure on water sources due to population growth, increase in demand and pollution threats means that a clearly defined approach to protecting future needs is essential. Strategies focused on managing and conserving water, land and biological resources to maintain and restore healthy, effectively functioning and climate change-resilient ecosystems are one way to deal with the impact.

The most critical part of the water supply system is the source. This can be affected in two ways, namely, the quantity and the quality. The changing weather patterns will have a major impact in the medium to long term. On a macro scale more precipitation will occur in the west than in the east of the Country and the more intense storms may have a detrimental effect on storage and soakage due to the speed of run off. The other threat to the availability of water will be the abstraction of it – the volume, location, by whom and for what purpose. Increasing use of irrigation systems in agriculture, if it should occur, will present problems so prioritisation will become an issue.

The quality of Irish Rivers is reported on by the Environmental Protection Agency (EPA). The Water Quality Report 2004 – 2006 (11) states that while pollution in the Eastern half of the country has been substantially reduced it has remained the same in comparison with the previous period. Increases in pollution have occurred in the North Western, Shannon and Neagh Bann River Basin Districts. This report may give cause for concern with the increase in pollution in some locations but the work by the EPA has highlighted that the general deterioration of river quality in Ireland has been arrested and that the sources of pollution are being identified. In the period from 1998 to 2006, the source of pollution for 50% of the rivers was as a result of municipal wastewater discharges. The remaining sources were ascribed mainly to agriculture, forestry and industry.

The implementation of the EU Water Framework Directive, the Flood Directive and the creation of River Basin Management Plans have resulted in an integrated approach to managing the quality of the river catchments (12). This approach will greatly assist in defining acceptable limits and reducing threats to the catchments. In ensuring that the quality of drinking water sources is preserved the competing needs of the towns, in relation to abstraction and wastewater discharges and the agricultural sector in relation to disperse pollution and irrigation will have to be finely balanced. Increasing pressure on future sources from all activities of society heightens the risk of pollution incidents. As a result bankside storage i.e. reservoirs alongside the river will become essential in order to ensure clean raw water while the incident passes the inlet pipe.

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 term plans and have entrenched views on issues such as the re-use of treated effluent? How can the current institutions be utilised or modified to prepare a strategy to reduce uncertainty, and integrate the outcome into medium-term strategies for the future?

Infrastructure

The majority of water supply systems in Ireland are, with the exception of the very large urban areas, small and discrete. The treatment of water to current standards throughout the country has only commenced since joining the EU in 1973. Prior to this time while a supply system existed for many towns there was a very basic treatment available and no treatment where group water schemes existed. As a result infrastructure in the form of integrated treatment works, large pipelines, storage reservoirs are only located close to the large urban areas. There is no interconnection between these networks e.g. Dublin is not connected to Waterford or Cork to Limerick.

The infrastructure for a water supply system generally consists of a treatment works, large water carrying (arterial) mains to convey the water to the town or city, storage reservoirs on the perimeter of the urban area and then distribution mains to deliver to the houses. Pumping stations may or may not be required depending on the contours of the supply area.

In an ideal situation every location in a town or city should be capable of being supplied from more than one source The Dublin region, at present, does not have the interconnecting pipework to ensure continuous supply when watermain bursts occur. Moreover, in the Dublin Region production and demand are, and have been for many years, finely balanced. While storage reservoirs that can provide from 24 hours to potentially three days storage do exist in the Dublin area it has been necessary to carry out a strategic storage study in order to cater for increased demand in recent years. It has identified the need for additional storage capacity in the region.

Connections are provided to towns on route from the raw water reservoir/treatment works to the large urban area e.g. Bray is connected to the Dublin City supply as it is located on the route from Roundwood Treatment Works to the City.

Ireland is a small country in infrastructural terms, when you consider that gas pipelines originating in Siberia transfer gas throughout Europe. Thus a decision on the necessity of transporting water around the country in order to ensure continuity of supply is not technically difficult but it would be costly and is it sustainable? In recent years in order to conserve water a programme of leakage reduction through the rehabilitation of water mains has been implemented. In the Dublin area an investment of €10 million will replace approximately 10 kilometres of pipeline however it is estimated that 800 kilometres of watermains are over 80 years old. This gives an indication of the scale of investment that is required when infrastructure needs are considered on a national basis. The availability of finance for investing in critical infrastructure is recognised as an issue in other countries as well (13).

The factor that all treatment works and pipelines have in common is an energy requirement. While some of the plants have generating units (e.g. hydro) the majority have a single source of energy from the national grid. Levels of back up from standby generators would only exist on plants close to the large urban areas. While Dublin City is fortunate, in so far, that 80% of its water is transported by gravity from the treatment works in Kildare and Wicklow the majority of other areas require pumps at source and sometimes in-line to ensure adequate pressures and flows. Thus the availability of adequate energy sources is probably the most critical element after source protection in ensuring the delivery of potable water. In smaller areas the availability of mobile generators may be more feasible. These issues would be included in current risk registers for all plants

In modern times the treatment of water has become quite sophisticated and the resources needed to man it require detailed training. While the large urban areas, due to their scale, can afford to have adequate resources to enable a treatment works to continue operating if subjected to damage from a disaster the availability of personnel in less densely populated areas may present difficulties if it is necessary to maintain a supply. It is essential therefore that such risks are mitigated against and that those personnel have the best available skillsets to manage the situation.

The following are some of the other factors that will impact on the infrastructure:

- Pipe systems will be more prone to cracking due to greater soil movement from wetting and drying cycles
- Assets on flood plains will be at increased risk from flooding, storm damage, coastal erosion and rises in sea level.
- Existing sewerage was not designed to cater for the expected more intense rainfall which is likely to exceed the capacity of parts of the network and cause local flooding.

- Dams will be more prone to siltation resulting from increased soil erosion or overtopping due to storms.
- Bankside storage required to ensure continuity of raw water supply

International Situation

The EU Commission has also published a green paper on Critical Infrastructure Protection, (14,15,16,17) which outlines the options on what would enhance prevention, preparedness and response to the Union's critical infrastructure protection. It states that the effective protection of critical infrastructure requires communication, coordination, and cooperation nationally and at EU level among all interested parties – the owners and operators of infrastructure, regulators, professional bodies and industry associations in cooperation with all levels of government and the public.

The destruction or disruption of infrastructure providing key services could entail the loss of lives, the loss of property, a collapse of public confidence and morale in the EU. Any such disruptions or manipulations of critical infrastructure should to the extent possible, be brief, infrequent, manageable, geographically isolated and minimally detrimental to the welfare of the Member States, their citizens and the European Union (18).

The EU has also produced a white paper in 2009 –"Adapting to climate change: Towards a European framework for action"(12,19) The EU's objective is to improve resilience to deal with the impact of climate change. It also adopts a phased approach. The intention is that Phase 1 (2009 – 2012) will lay the groundwork for preparing a comprehensive adaptation strategy to be implemented during phase 2 in 2013.

One of the proposals in the paper is to establish a "Clearing House Mechanism" as an IT tool and database. This database would capture the considerable amount of information and research, which already exists, but is not shared across Member States. Such a database could be crucial in developing critical infrastructure strategies and improving its resilience.

The EU recognises that due to the variability and severity of climate impact most adaptation measures will be taken at national, regional and local level. However these measures can be supported and strengthened by an integrated and coordinated approach at EU level (18). For this reason the EU seeks to reduce the impact of disasters within the EU by:

- The development of knowledge based disaster prevention policies at all levels of government
- Linking relevant actors and policies throughout the disaster management cycle
- Improving the effectiveness of existing policy instruments with regard to disaster prevention.

The UK published a National Security Strategy in 2008, which covers not only security threats but also transnational crime, pandemics and flooding. The strategy includes the compilation of a national-level risk register setting out its assessment of the likelihood and potential impact of the range of different risks that may affect the

UK. It is the intention that prompt action and improved prevention will be achieved through partnership between the public and private sectors (8).

Water UK, the association of water companies in the UK, commissioned its own report on the floods of 2007 in order to ensure that climate change and extreme events are taken into consideration in their flood risk management and in the protection of critical water infrastructure (20).

The United States launched a National Infrastructure Protection Plan (NIPP) in 2006 This provides for a coordinated approach to critical infrastructure protection, setting out national priorities, goals and requirements for effective distribution of funding and resources to ensure continuity in the event of an attack or disaster (8).

In addition the various water associations have implemented amongst the utilities the concept of "Utilities Helping Utilities". This proposal encourages utilities and local/state governments to establish intrastate mutual aid and assistance networks. The concept is about creating an opportunity to enhance water and wastewater utility resilience in response to disasters during the response and the recovery phases. An agreement is designed to provide a mechanism whereby water/wastewater utilities that have sustained damages from natural or man-made events could obtain emergency assistance in the form of personnel, equipment, materials and other associated services as necessary, from other water/wastewater utilities (21).

The Netherlands has also taken a systematic and coordinated approach to tackling potential disruption to critical infrastructure. They have established a project, Protection of Vital Infrastructure, which aims to develop an integrated package of measures to protect infrastructure in both the private and public sectors from security threats, accidents, and extreme natural phenomena (8).

Conclusion

This highlights the fact that the identification and role of critical infrastructure is given serious consideration in most developed economies today. In the current environment of uncertainty, how can we assess decisions across a 20,30, or even 40-year time horizon? At present when we make a decision in relation to infrastructure in Ireland, it may take up to 10 years to implement. How can we create more certainty? Is this a situation of creating scenarios, which would illustrate the potential political and societal situation in 50 years and then test our decisions against those scenarios? (22). The challenge is not only to develop a better understanding of the known hazards but also the changing and newly emerging vulnerabilities and consequences of loss as well as their interrelationships (8). Whatever decision is arrived at in relation to the role of critical infrastructure and drinking water it might behove us to remember

An ounce of prevention is worth a pound of cure.
- Benjamin Franklin.

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