Climate Change and Potential Effects on Sewerage Systems

Paul Hurcombe, Severn Trent Water Limited.

Introduction

Climate change is a subject which has been talked about for many years and has been the subject of many research projects to try and assess how this is likely to effect the future weather patterns across the world. More recently this work has concentrated on refining predictions for how climate change will impact on the United Kingdom and is now able to make predictions for individual regions.

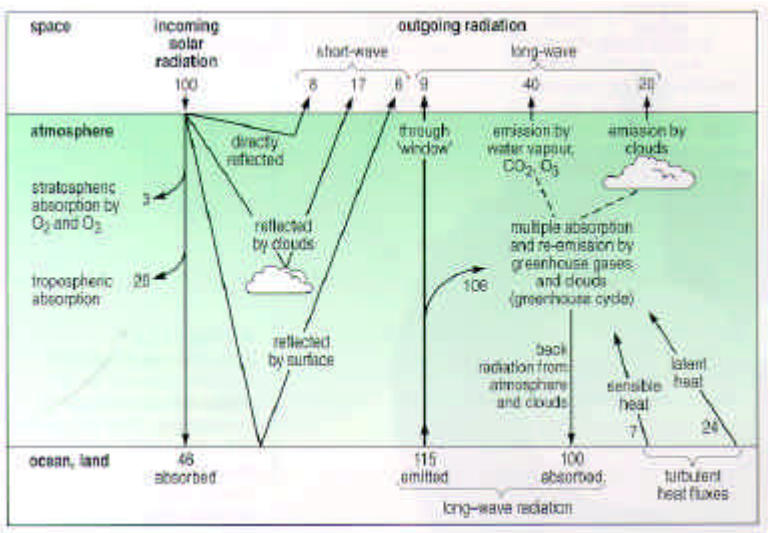
Research has concentrated on what climatic changes are likely to occur but to date there has been little work to look at how this will effect the operation and performance of sewerage systems. This paper identifies the potential effects of climate change on the sewerage system and how these will manifest themselves.

Climate Change

So, what is climate change and what does research suggest will happen?

In brief, the main reason for global climate change is attributed to the 'greenhouse effect'. Greenhouse gases occur naturally (primarily from water vapour, carbon dioxide, methane and nitrous oxide), as well as from industrial chemicals such as CFC's (Chloroflurocarbons). These gases are transparent to incoming short-wave solar radiation, allowing the sun's energy to pass through the atmosphere and warm the earth. They also absorb some of the long-wave radiation and reflect back a proportion of the heat coming from the earth. Without these gases the Earth's temperature would be –18^{o}C but in excess they will not allow excess heat to escape from the atmosphere, resulting in higher temperatures. This process is illustrated in figure 1 below:

Figure 1: The 'Greenhouse Effect' [1]



Climate change is something which has always taken place, it occurs naturally due to the complex interaction of a variety of factors e.g. volcanic activity, solar variations. However, the current increased rate of change is for the most part due to human actions. Since the start of

the Industrial Revolution over 200 years ago the atmospheric concentration of greenhouse gases has risen by 50%.

Work undertaken by the West Midlands Climate Change Impacts Study (WMCCIS), based on UKCIP (UK Climate Impacts Programme) climate scenarios (medium-high) and regional climate model for the West Midlands, indicates that:

- Annual mean temperatures will rise +0.5^{o}C to +1.3^{o}C by the 2020's, +0.8^{o}C to +2.2^{o}C by the 2050's and +1.1^{o}C to +3.0^{o}C by the 2080's.
- There will be more frequent very hot summers but fewer very cold winters.
- Overall the climate will become wetter, although whilst winters will become wetter, summer rainfall will reduce. Annual precipitation is due to increase by 2 to 5% by the 2020's, by 3 to 5% in the 2050's and by 2 to 9% by the 2080's. Winter rainfall is predicted to increase by up to 24% by the 2080's, whilst summer rainfall will reduce by 7 to 14% by the 2080's.
- The type of precipitation is predicted to change towards an increase in both frequency and intensity of short-duration, extreme rainfall events.
- For the West Midlands there will be a trend towards milder, wetter winters and hotter, drier summers.

Mitigate or Adapt?

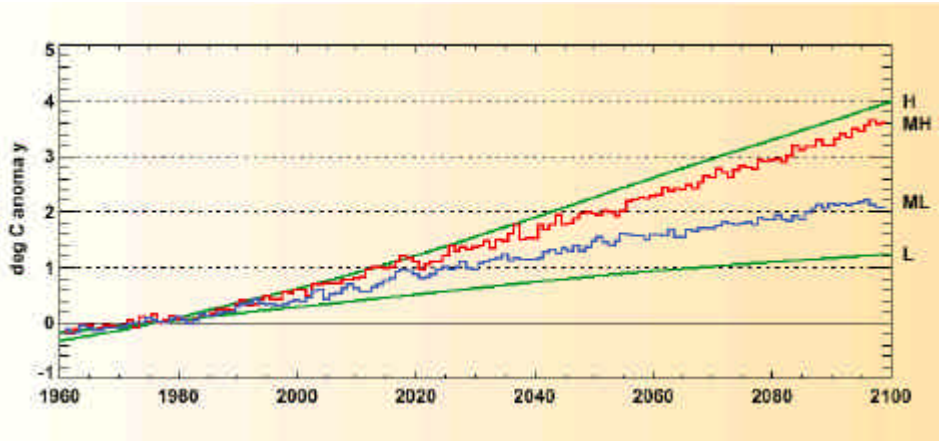
Although there is continued argument and debate on whether or not climate change is an issue, it is something which should not be ignored. Policy forms the basis of 'Mitigation Strategies' which, on a global and national level, aim to reduce the emissions of gases into the atmosphere which are generally accelerating climate change.

The United Nations Conference on Environment and Development (UNCED) (known as The Earth Summit) was held in Rio, Brazil in 1992. The conference resulted in the Framework Convention on Climate Change (Climate Treaty), which intended to stabilise greenhouse gas concentrations at a level which would allow ecosystems to adapt naturally to climate change. During December 1997, more that 160 nations met at Kyoto in Japan to set targets for reducing greenhouse gas emissions. The outcome of this summit was the Kyoto Protocol, in which the developed nations agreed a legally binding commitment to reduce their greenhouse gas emissions, relative to the levels emitted in 1990. The UK's target is to cut its greenhouse gas emissions by 12.5%, although the UK has set a separate goal of cutting carbon dioxide emissions to 20% below 1990 levels by 2010. With this objective, Government policies have been introduced (e.g. energy efficiency schemes, integrated transport policy and integrated pollution prevention and control). The Government's commitment to this aim is also reflected in the introduction of the Climate Change Levy.

Whilst mitigation is the favoured solution, there will still be a need to adapt. Although Kyoto aims to stabilise greenhouse gas concentrations, climate change is still expected to continue, so it will still be necessary to plan ahead and look at adapting to future weather patterns. This is the approach being taken by Severn Trent Water.

The UK Climate Impact programme (UKCIP) was established by the Government in 1997 to assess the likely impact of climate change on the UK to provide stake-holders with the information they require to adapt to climate change. From this work four scenarios have been devised by UKCIP to take into account differing natural climate change scenarios and hence the rate of global warming. These scenarios are labelled Low, Medium-Low, Medium-High, and High and are based on the global warming curves shown in Figure 2:

Figure 2: Global warming curves for the four UKCIP98 scenarios, identified by the letters. The temperature increases are shown with respect to the 1961-90 average. [2]



The global sea level changes and carbon dioxide concentrations predicted for the 2050's is shown in Table 1.

Table 1: Global climate change estimates for the period centred around the 2050's for the four UKCIP98 scenarios. Changes in global temperature and sea level are calculated with respect to the 1961-90 average. [2]

	Temperature Increase (degC)	*Sea-level Rise (cm)*	*CO_2 Convention (ppmv)*
Low	*0.9*	*12*	*467*
Medium-Low	*1.5*	*18*	*443*
Medium-High	*2.1*	*25*	*554*
High	*2.4*	*67*	*528*

Based on this work Severn Trent have undertaken further work in association with the Hadley Centre to concentrate specifically on the potential impacts of climate change on Severn Trent region. As a consequence of this Severn Trent consider the Medium-High scenario to be somewhat more likely than the others.

Hydraulic Impacts

This is the area which will clearly be affected by changes in rainfall patterns – but to what extent?

There are two scenarios which need to be considered.

Summer Rainfall Events

It is predicted that changes in summer rainfall profiles will result in more frequent short-duration but higher intensity storms. These storms will overwhelm drainage systems and smaller watercourses. It is also more likely that drier summers will bake the surface of the ground - converting otherwise permeable areas into impermeable surfaces and thereby increasing both the rate of rainfall run off and volume. The combined effect of these will result in more flash floods. These types of storm have in the past been categorised and being 'exceptional' storms but in more recent years are starting to become the norm.

There is also an issue over responsibility for flooding. It is likely that these sort of events will result in flooding not only from public sewerage systems but also from third party inlet restrictions such as highway gullies or domestic yard or rainwater gullies. It is therefore vital that future investigations address inlet restrictions and the fact that flooding caused by rainwater which cannot get into the public sewerage system, due to third party inlet restrictions, are not the sewerage undertakers responsibility. However, in these cases it is

vital that everyone works together so that remedial actions taken by a third party do not have a detrimental effect on the public sewerage system.

Winter Rainfall Events

Winter storms are likely to result in longer duration yet less intense storm events which pose different problems. Longer duration storms are likely to fill the whole sewerage system before flooding occurs. This is compounded by the fact that wetter winters will result in saturated ground and higher ground water levels which reduces the soils ability to absorb rainfall and therefore increasing run off. This is further compounded by higher river levels which drown public sewer outfalls reducing hydraulic capacity and potential problems with sewer overflows.

These events are likely to result in longer duration flooding events. There is an issue that such events may hide the cause of the problem. River flooding can mask hydraulic problems with public sewers and the interaction between the two needs to be considered.

It is also necessary to consider the potential problems of more frequent high intensity storms coming back-to-back, thus not giving the sewerage system (and in particular tanks) time to drain down before the next storm occurs. This has issues relating to modelling and need to be addressed though revised time series rainfall events updated to take account of climatic changes.

Pollution

Sewer Overflows

Following on from the hydraulic flooding performance of the sewerage systems is the operation of sewer overflows. Higher intensity rainfall will result in overflows operating more frequently and in greater volumes. This is likely to have a greater impact on watercourses in dry summers and possibly aesthetic problems leading to more complaints.

Surface Water Sewer Outfalls

During prolonged dry summer periods there will be an increase in pollutant levels, both on the surface and in sewer silts, which will have a greater pollutant impact on receiving watercourses at a time when their flows are low.

Watercourse Impacts

Low summer flows in watercourses will make them more susceptible to pollution. This is expected to influence surface water discharges as prolonged dry periods will allow sediment concentration to build up. Conversely, higher winter flows and water levels will drown outfalls, fill sewers and therefore reduce hydraulic capacity.

Asset Condition

Although not an immediate thought, the effects of climate change could effect the structural integrity of assets.

Wetter winters will result in higher winter ground water levels leading to potential increases in infiltration. This will result in more 'clean' water flow in sewers therefore reducing the available capacity for storm flows and increasing flow (and sewage concentration) to sewage treatment works. Fine soil particles can also be washed into the sewer, thereby increasing risk of collapse and siltation in the sewer.

Drier summers will have the opposite effect with lower summer ground water levels leading to potential sewage leakage into surrounding ground.

The issue is also affected by changes in the sewer surcharge cycle. Whereby higher intensity and more frequent storms will result in increase frequency and depth of pipe surcharge causing potential localised exfiltration/infiltration through defective pipework thereby increasing fine soil particles washing into sewer and thus increasing the risk of sewer collapse.

Operational Impacts

Whilst more flooding is the obvious effect of climate change there are other potential implications.

Pumping Stations

Clearly if it rains more then pumping stations are going to have to pump more. This will impact on increased electricity consumption as well as higher maintenance costs. There will also be an impact on asset life being shortened due to higher usage

It is also likely that prolonged dry summer periods will result in increased septicity problems resulting in greater chemical dosing costs in an attempt to avoid odour complaints. When it does rain it is more likely that pumps will be overwhelmed resulting in flooding and/or more frequent operation of emergency overflows.

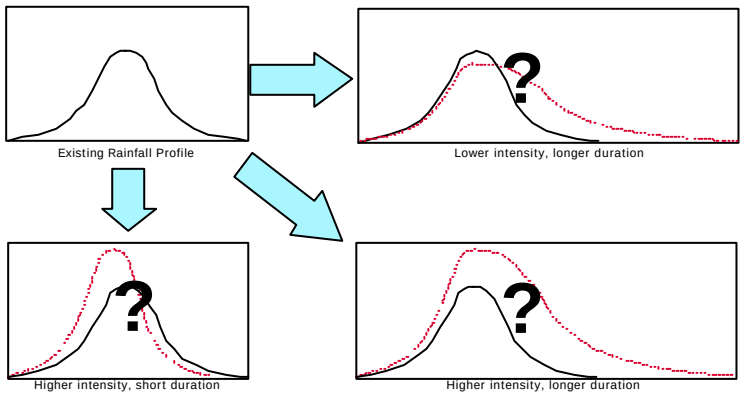
Sewers

Warmer, dryer summer months are likely to place greater demands on water supplies, leading to incentives to reduce water consumption. Reduced water consumption together with prolonged dry periods could potentially increase siltation in combined foul water sewers. This will increase the risk of blockages and therefore possible flooding and an increase in odour complaints. To address this there will be a requirement to increase sewer jetting and blockage clearance, hence higher maintenance costs.

Rainfall profiles

The key to evaluating and being able to quantify the potential effects of climate change on sewerage systems is to determine future rainfall profiles. The graphs below (Figure 3) demonstrate what could happen to rainfall profiles as a result of climate change - but which one is likely to be the correct one?

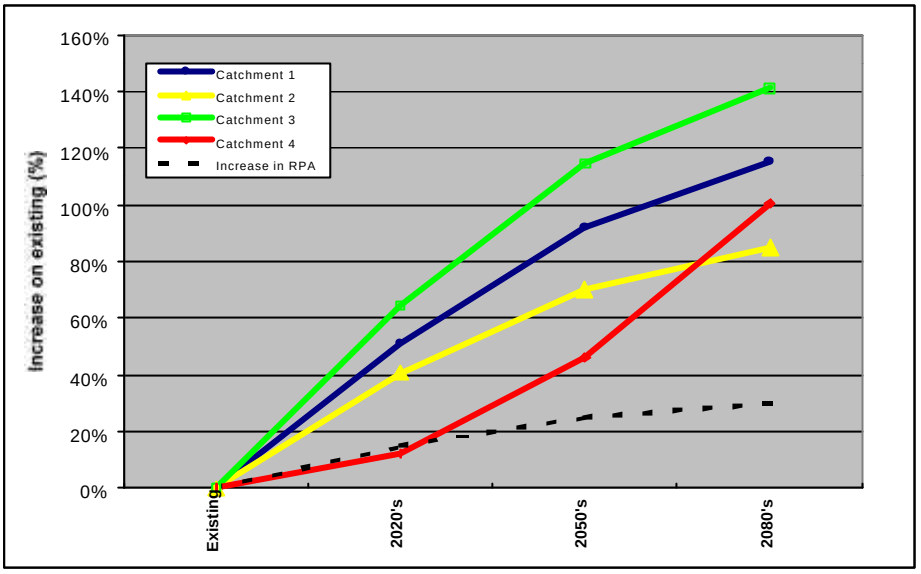
Figure 3: Potential Rainfall Profiles



The problem is trying to determine the profiles for future storms but there is likely to be a more pronounced difference between winter and summer storm profiles. Whilst more detailed work is required on this subject, some simple assumptions have been made to try and assess the

potential impact on sewer flooding. Assuming that future rainfall profiles will remain the traditional 'bell shape', each incremental rainfall intensity time step was increased by a percentage to represent predicted increases in return period amounts (RPA) to produce revised storm profiles. These new rainfall profiles for existing, 2020's, 2050's and 2080's scenarios were then run through four hydraulic model case studies to try and gauge the potential impacts. The findings are shown in Figure 4:

Figure 4: Potential effects of revised rainfall profiles of sewer flood volumes (based on 2 year 90 minute duration storm profiles)



Whilst this is only a simplistic analysis making simple assumptions the exercise has highlighted that catchments are likely to respond in different ways.

How should we deal with it?

Modelling Tools

Design tools need to be updated to take account of new rainfall profiles. Existing profiles have been determined from historically rainfall events and whilst this has proved effective until now, the profiles need to be updated to take account of predicted future rainfall events. This is where the difficulties begin. What do you design for and how do you do so?

Reviewed Design Standards

Hydraulic design standards need to be reviewed to ensure that capital investment not only meets today's requirements but will also allow tomorrows needs to be met. Improvements to rehabilitate a hydraulically deficient sewerage system need to be adaptable. Most sewer pipes have an asset life of 60 years or more so it is essential that big enough pipes are laid. The majority of the costs are incurred in excavating the trench, so increasing a pipe size by one increment will usually have a minimal effect on cost but will offer a greater return for future pipe full capacity or storage. The sewerage industry needs to consider the long term adaptability of the sewerage systems and not just today's.

Sustainable Urban Drainage Systems (SUDS)

Sustainable urban drainage systems have a part to play but they do have their limitations and associated problems, primarily future ownership and maintenance responsibilities. They should not be discounted and need to be considered as part of the overall plan.

Research

Further work is needed to look more closely at climate change in terms of quantifying what the impacts will be, particularly in terms of cost implications which need to be substantiated for AMP4.

Conclusion

Whilst this paper has identified the potential effects climate change will have on the sewerage system, the difficulty arises when you try to quantify the size of the problem and more importantly the cost implications to the water industry for AMP4 and the forthcoming negotiations with OFWAT.

It is expected that these questions will be answered in more detail by a forthcoming UKWIR project entitled “Climate Change and the Design of Sewerage Systems” (UKWIR Project CL10). Tenders for this project are currently being evaluated for this three year study to look at potential changes in rainfall profiles and its likely effects.

References

[1] Global Environmental Issues: Blackmore and Reddish (1996)

[2] Climate change scenarios for the United Kingdom, Summary Report: UKCIP (1998)

West Midlands Climate Change Impacts Study (WMCCIS)

UKCIP (UK Climate Impacts Programme)

UKWIR (www.ukwir.org.uk)

Paul Hurcombe
Severn Trent Water
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