Development of guidance for sewerage undertakers on the implementation of drainage standards

June 2008

Plan Design Enable

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Final report

June 2008

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Executive Summary

Atkins Ltd (Atkins) was commissioned by Ofwat to undertake a short study in respect of drainage standards to support the development of guidance from Ofwat to sewerage undertakers for the PR09 process. The objective was stated as:

"to inform [Ofwat's] decision on what guidance it should provide to sewerage undertakers to aid them to implement appropriate risk based cost beneficial drainage design, such that the benefits of reduced flooding risk are balanced with the costs of providing a higher standard of flood protection. This guidance will need to be based on the current state of knowledge regarding climate change impacts".

In addition to this over-arching objective there were some outputs also required:

> "• *Recommendations of best practice in the level of flood protection that should be assumed when designing or renewing combined or surface water drainage systems, including pumping equipment where relevant.*
>
> • *Recommendations of possible minimum standards for drainage design in terms of protection from flooding including views on whether this is likely to be beneficial or not.*
>
> • *Recommendations on how companies should factor in the risks of climate change.*
>
> • *An evaluation of the extent that sewerage undertakers' current practice is in line with these recommendations, highlighting if there is a substantial difference in the level of protection from flooding that consumers receive from different sewerage undertakers."*

Current practice was examined through the sewerage undertakers' responses to an Ofwat questionnaire, which were of variable quality.

Current drainage standards adopted by undertakers do vary depending on circumstances. For the design of new sewerage systems, accepted practice is to design sewers for a 1 in 30 year rainfall return period as set out in Sewers for Adoption 6 (SfA6). Common industry practice for minimum design standards for sewer flooding schemes can be summarised as:

Internal property	30 years
External property	20 years
Other areas	10 years

Companies' standards tend to be based on Sewers for Adoption 6, the latest version of the Sewer Rehabilitation Manual and design rainfalls, without climate change, are taken from the Floods Estimation Handbook (FEH). In our opinion these are the current state of the art for design parameters, without climate change.

Network models, taking guidance from the WaPUG industry group, are routinely used for new systems and upgrades to produce designs. Small, simple systems may still be designed by hand where risk is deemed low.

For some drainage elements identified as being of particular sensitivity the return period is reportedly varied up to 1:100 years. There were no data from the questionnaire regarding the role of CBA in setting such standards, so there are no primary data to suggest that CBA has been used for this purpose. Our experience of working with sewerage undertakers is that explicit CBA is not usually undertaken for setting design standards, although it is implicit in judgements of different return periods for particularly sensitive areas or items of equipment; different risk levels are thereby accorded different return periods. Whilst we cannot state from the evidence the extent to which such standards may be cost beneficial the fact that they have been workable for many years but may now through population growth and possible climate change be in places performing less well suggests that they may have been conservatively designed in the past.

Other points that can be made from companies' responses are:

- Generally companies adopt similar baseline return period standards of protection for new and upgraded systems as listed above.
- Some companies provide higher or lower levels of protection for particular areas or particular items based on a qualitative risk assessment
- Climate change is generally not addressed by the undertakers with only 2 companies noting that they make adjustments, with one making reference to Defra's guidance and the other adopting longer return periods as a utilitarian route to providing headroom. Neither refer to CBA.

We are also aware that many of the companies use the UKWIR guidance "The Role and Application of Cost Benefit Analysis - Volume II: Sewer Flooding Guidance (07/RG/07/10)" to some extent. This may be considered best practice and the development of the guidance is an indication of the general acceptance by the industry of the need to move towards more explicit forms of CBA in drainage as for other areas of their business.

Possible minimum standards for drainage design which are cost beneficial are difficult to establish in light of the fact that CBA is not generally undertaken. We propose that as a baseline from which to move forward the above list of minimum standards could be taken, with deviations justified by CBA.

Climate change risks are currently reported by the sewerage undertakers to be: not included; or a nominal rainfall intensity increase allowed; or a longer return period allowed. Neither of the adjustment types noted were reportedly supported by CBA. The sewerage undertakers felt inadequately informed on this issue.

We recommend that the Defra FCDPAG indicative sensitivity ranges are used as a starting point for incorporating climate change into sewerage asset design, with deviations away from these figures justified by companies with supporting evidence.

A precautionary allowance should be made for those assets which have a long-life and which are difficult to adapt (e.g. some tunnelled or deep sewers). It may also be prudent to increase the flexibility of such assets where possible.

An adaptive management approach is recommended where asset life is short, or for longer-life assets where flexibility is or can be incorporated (e.g. pump capacity). Under this approach the 'without climate change' design should be tested against the full range of climate change sensitivity ranges over the expected asset lifetime to identify the scale and need for any precautionary allowance or enhanced flexibility for adaptation.

SUMMARY

Risk based cost beneficial drainage design is in its early stages in the water industry in England & Wales, and is patchy in its application, although the UKWIR report referenced above provides the current benchmark. Our review, backed up by our experience of working in the field, indicates that the sewerage undertakers require further guidance to press them along a path already started on.

We have reviewed ways in which Ofwat might wish to provide such guidance. We suggest there are two stages to this, firstly for the PR09 process where many companies have already completed the vast majority of the work they considered necessary and secondly for future Periodic Reviews.

PR09

Given the short timescales available, it is not considered feasible to require companies to carry out full cost-benefit analysis to determine design standards for PR09. Instead, we recommend that Ofwat ask companies to set out a risk-based approach to design standard setting for PR09. The investments concerned will nonetheless be subject to CBA as part of the justification of the PR09 investment programmes and projects, and cost effectiveness analysis (CEA) should be used to define least cost solutions.

Risk based approaches are well embedded in water industry planning processes, through the application of the common framework for capital maintenance planning and the use of CBA for investment justification. Of particular relevance to the risks relating to drainage design, there is a requirement on all companies to justify PR09 sewer flooding schemes using CBA, which attempts to put a monetary value on the benefits of risk reduction.

It would appear both feasible and consistent with the approaches taken to other capital investments for Ofwat to require companies to set out how they will take risk into account in the selection of design standards.

Water industry planners already use a variety of techniques to quantify risk, and others exist outside the water industry. As is already the case for other regulatory requirements, it is not considered necessary for Ofwat to specify the exact method which companies should use to assess risk.

Nonetheless, as a minimum, it would appear reasonable for design standards to take into account the vulnerability or criticality of the receptors (assets, properties or areas) of flood risk. This means that higher standards may be applied to designs affecting hospitals and environmentally sensitive sites than ‘ordinary’ domestic sub-catchments, whereas design standards relating to external domestic flooding may be lower. More detailed risk-based differentiation than this may not be feasible within PR09 timescales.

Companies would also be expected to explain how they propose to take climate change into account, in particular, how they propose to determine in which circumstances a precautionary allowance or adaptive management approach is appropriate.

Future Price Reviews

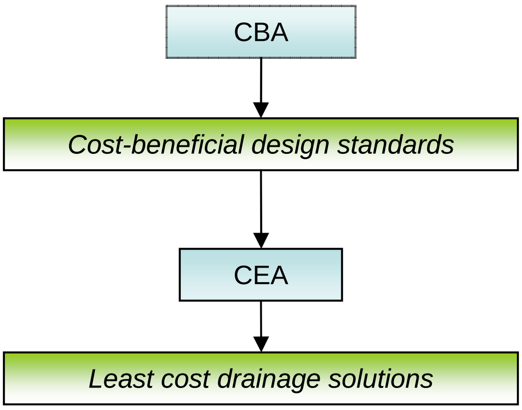
In future price reviews (i.e. by PR14), we believe that it should be feasible to move towards design standards justified, at least partly, using CBA. This will provide consistency with sewer flooding scheme justification and other levels of service (e.g. CBA for water resource demand restriction frequency).

We believe that there are two main options which may be appropriate:

1. CBA to justify changes from historic company design standards. This would have the advantage of being a relatively light touch form of regulation, but may serve to entrench current standards irrespective of their justification.
2. CBA to justify departures from industry design standards. This option would set a common starting point for all companies but would require definition of industry design standards, either by Ofwat or an industry research body.

The overall process is summarised in high level form below:

Figure 1.1 Economic framework for drainage design



The application of CBA to changes or departures in standards would be consistent with the approach taken for other levels of service (e.g. water resources demand restriction frequency) and less effort-intensive than carrying out CBA for all potential design situations individually.

Much of the information necessary to carry out CBA for design standard setting is already available. In particular, the UKWIR *Role and Application of CBA* study and Defra’s FCDPAG set out methods for benefits assessments and project appraisal for changes to flood risk standards. To complete a robust CBA it will also be necessary to gain a good understanding of how costs vary with design standards. The definition of these cost curves may be usefully carried out at industry level for different design scenarios (e.g. small versus large catchments, pumped versus gravity).

If uncertainties in climate change impacts are set aside, CBA can be applied in a relatively straightforward manner to drainage designs where precautionary allowances are being used.

Because adaptive management requires a series of decisions and interventions over time, CBA becomes more complex. This is further complicated by the fact that it is not possible to assign a robust probability to the various climate change scenarios. Despite these challenges, a more nuanced approach to CBA, identified through further research, may be possible.

For either method, the emphasis of both the CBA and cost effectiveness analysis (CEA) will be to identify an approach which is robust in the face of climate change and other uncertainties, remembering that other uncertainties, such as the scale and rate of future growth, may be even more significant than the potential impact of climate change.

Abbreviations

Abbreviation	Description
ABI	Association of British Insurers
AMP	Asset Management Plan
CBA	Cost Benefit Analysis
CEA	Cost Effectiveness Analysis
CoP	Code of Practice
CSO	Combined Sewer Overflow
EA	Environment Agency
EU	European Union
FCDPAG	Flood and Coastal Defence Project Appraisal Guidance
FEH	Flood Estimation Handbook, 1999
FIS/ %ile	Fundamental Intermittent Standards/ Percentile Standards
FSR	Flood Studies Report, 1975-88
GCM	General Circulation Model
IUD	Integrated Urban Drainage
IWCS	InfoWorks Collection Systems (sewer simulation software)
PET	Potential Evapotranspiration
PPS25	Planning Policy Statement 25
PR09/PR14	Periodic Review 2009/2014
SfA/ SfA6	Sewers for Adoption / 6th Edition,
SRM/ SRM 4	Sewerage Rehabilitation Manual / 4th Edition
Stormpac	Stochastic rainfall generator program developed by WRc
SUDS	Sustainable Urban Drainage Systems
SWMP	Surface Water Management Plan
TSRSim	Stochastic rainfall generator program developed by HR Wallingford
UKCIP08	UK Climate Impacts Programme 08
UKWIR	UK Water Industry Research Limited
UPM	Urban Pollution Management
WaPUG	Wastewater Planning Users Group
WaSC	Water and Sewerage Company
WIA	Water Industry Act 1991
WinDes	MicroDrainage

1. Introduction

1.1 Objectives

Atkins was engaged by Ofwat to inform its review of possible guidance for sewerage undertakers on the implementation of drainage standards. Details of this work were set out in Atkins' final proposal to Ofwat of 11 March 2008.

The objective of the consultancy services is:

"to inform [Ofwat's] decision on what guidance it should provide to sewerage undertakers to aid them to implement appropriate risk based cost beneficial drainage design, such that the benefits of reduced flooding risk are balance with the costs of providing a higher standard of flood protection. This guidance will need to be based on the current state of knowledge regarding climate change impacts".

The terms of reference for this review are included in Appendix A.

1.2 Approach

Atkins approach to this review has been to:

- Review responses to Ofwat's questionnaire to water and sewerage companies about their drainage standards;
- Identify and recommend best practice from the companies' responses and experience within the industry;
- Review how climate change could be incorporated into design standards;
- Identify other constraints and uncertainties, particularly within the current regulatory context;
- Recommend possible minimum design standards and an approach to dealing with climate change;
- Discuss this in relation to water companies' responses.

Because many water companies will have substantially completed their work for the Draft Business Plans at this time, our recommendations are limited to practicable options for the short term, with a discussion of possible future developments.

1.3 Structure of this report

This report is structured in the following manner:

- Section 1 – this introduction, setting out the objectives of this review and Atkins' methodology;
- Section 2 – provides a summary of water companies' responses to Ofwat's Questions in relation to the design of drainage. It also provides an initial review of these responses;
- Section 3 – summarises current best practice;
- Section 4 – this discussion section provides a context for the provision of guidance and Atkins recommendations. This includes a discussion of climate change;
- Section 5 – presents possible minimum standards that could be considered;
- Section 6 – summarises Atkins' recommendations and future work; and
- Section 7 – concludes.

2. Questions and responses

2.1 Questions

In preparation for this project, Ofwat issued a series of eleven questions to all ten sewerage undertakers, as reproduced in Appendix B. These aimed to elicit the necessary information on the standards and approaches currently applied to sewer flooding.

2.2 Summary of Responses

This section aims to discuss the key points arising from the responses, with comments on the responses provided in Section 2.3 below. Many of the points made are relevant to or were raised by the companies under several of the questions.

2.2.1 Question 1: What is the standard?

Designs seek to protect property and other areas from repeated flooding. Current design standards (return period for flooding) reported vary as follows:

Internal property	20 – 50 years
External property	10 – 30 years
Other areas	10 – 30 years

Standards are reportedly not generally affected by location or scheme driver. There are exceptions in particularly sensitive or critical locations, or where large numbers of properties are at risk.

2.2.2 Question 2: Is current guidance satisfactory?

There is no clear consensus on whether existing guidance is satisfactory. Views ranged from:

"General guidance is satisfactory. WaSCs [water and sewerage companies] *should have flexibility to set individual design standards for protection against flooding, rather than having rigid national standards imposed on them"*

to

"Apart from Sewers for Adoption[1] *there is very little if any guidance on the design of sewers and therefore the current guidance does not seem to be satisfactory".*

The use of risk (probability and consequence) rather than simply return period (probability) was mentioned by a number of respondents, but no detailed suggestions were made..

2.2.3 Questions 3, 4 and 5: Modelling and rainfall

Hydraulic models are reportedly used for all but the simplest of schemes. The sources of information mentioned were broadly the same, but more details were given in some responses than others. The use of the Wastewater Planning Users Group (WaPUG) Code of Practice was only mentioned once.

As far as rainfall is concerned, the Flood Estimation Handbook (FEH, 1999)[2] method appears to be taking over from the Flood Studies Report (FSR, 1975-88)[3] method, which has been the standard for many years. Stormpac and TSRSim (stochastic rainfall generator programs

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[1] Sewers For Adoption, 6th Edition (SfA6), WRc, 2006

[2] Flood Estimation Handbook, Centre for Ecology and Hydrology, 1999

[3] Flood Studies Report with supplements, Natural Environment Research Council and Centre for Ecology and Hydrology, 1975-1988

developed by WRc and HR Wallingford respectively) are often used to generate time series rainfall, and the use of site-specific Met Office data was mentioned.

Storms in excess of the design standards are not modelled or investigated as a matter of course, but this appears to be changing gradually for AMP5 and in particular cases. It was mentioned by six respondents in the context of adoptions, and the practice appears to be spreading slowly to capital schemes now that modelling tools are more readily available. Higher return periods (1:100 and 1:200 years) were mentioned in the context of resilience of major assets such as treatment works, but are reportedly not applied to the network in general.

2.2.4 Questions 6, 7 and 8: Taking account of Climate change

Climate change is not generally taken into account at present although there is evidence that it may be incorporated into decision making for major schemes.

One Company has commented on the need to account for increasing sea level rise prediction on certain tide locked schemes. One company states it has increased its design target for solutions for external flooding from 1 in 20 years to 1 in 30 years and for internal flooding from 1 in 30 years to 1 in 50 years. It estimates this to be roughly equivalent to around a 10% increase in peak storm intensity.

Looking forward, companies recognise that the impacts of climate change will have to be taken into account but there is not yet a consistent approach to this. Allowances of between 5 and 30% on peak rainfall intensity were mentioned, depending on planning horizon, but there is very little consistency. Variation in projected changes in rainfall patterns between and within regions was mentioned as adding uncertainty to the projections. The results of the UKWIR CL/10 “Climate Change Modelling for Sewerage Networks” project and UKCIP08 are awaited by most respondents. However, the latter will not report until Spring 2009, too late for inclusion in the Final Business Plan. It was also pointed out that the climate models predict the changes to be “significant” only from 2030 onwards, which is beyond the planning horizon for most PR09 schemes.

One response included the statement

“we believe that it is more important to adapt to climate change rather than keep trying to accommodate increasing flows. We agree that sewerage assets should be more resilient and that this primarily means protecting them from inappropriate inflows. Highway drainage in particular represents a major input of non-sewage flow”.

This illustrates that looking and planning forward is about a lot more than just revising rainfall predictions and then inserting new targets into models. The impact must be considered in terms of predicting and controlling water into the sewerage system, through the system and the impact of flows once they have left the system. The modelling tools for this type of integrated catchment management and flood routing are now becoming available, are being piloted by some companies and it is expected they will be used more in future. They are capable of providing a more realistic assessment of catchment risk than existing pipe only models.

Most companies do not appear to be explicitly considering the effects of events more onerous than 1 in 30 years. They do have to consider some of their schemes in the context of Environment Agency (EA) floodplain fluvial flooding standards of 1 in 100 years but do not generally propose such standards for sewerage flooding. However, many companies suggest that future risk based approaches may include consideration of more extreme events in tandem with flow routing.

The possible options identified by respondents for responding to climate change (compared to current practice) may be summarised as:

1. Do nothing, and accept that there is a risk of deteriorating service, but that current uncertainty is too great to form the basis of increased investment (current approach by some companies)
2. Build bigger sewers to store and convey away more intense rainfall events with an expectation of maintaining the same service level as present (Based on new climate and hydrology tools)

3. Modify catchments to limit stormwater inflow to the sewer system or better direct surface flow floods away from and manage overflows out of the system in order to maintain the same level of risk of larger storms impacting on customers properties. SUDS and overland flow routing, changes to Section 106 and Section 115 of the Water Industry Act (1991), which refer to the right to connect to the sewerage system, were mentioned by respondents.
4. A combination of the above within a risk based approach considering revised design tools predicting changes in rainfall and utilising integrated catchment management solutions to control risk to the customers' property and level of service (may include increased flood resilience and insurance / compensation solutions)

2.2.5 Question 9: Difficulties in applying the standards

The respondents did not generally identify difficulties with applying the standards as such, although the mismatch between highway drainage and sewerage 'probability' based design standards was mentioned under this heading. Difficulties were identified with buildability and space issues, and with other utilities diversion costs. On rare occasions, these have led to schemes being completed to a lower standard of protection (when expressed as a probability standard) than desired. Mitigation measures (to reduce the impact of flooding) were mentioned as an option where alleviation costs are excessive.

2.2.6 Question 10: Other cost benefit analysis

Cost Benefit Analysis (CBA) does not appear to be used to affect the design standards applied, other than in exceptional cases. Companies may use CBA to select where work is required to remove existing problems, but it is rare to use it to alter the design standard.

2.2.7 Question 11: Other comments

Under "any other views", concerns are mentioned that can be summarised under the heading of Integrated Urban Drainage, i.e. the relationship between sewerage, highway drainage and open watercourses, the different standards applied to them and the fragmented responsibilities. The funding mechanisms needed are also mentioned. The SWMP approach appears to have general support.

Cases where different standards could be applied (e.g. hospitals or schools) are suggested, and the applicability of standards to foul and storm systems is raised. The use of depth of flooding as an indicator of severity is mentioned.

Also mentioned were:

- ABI's current 75 year target for fluvial flooding.
- The fact that new combined sewer overflow (CSO) structures are not currently practicable as part of a solution. They can represent a cost effective and reliable means of dealing with extreme events but approval for construction is virtually impossible to obtain.

2.3 Comments on responses

The responses varied greatly in the amount of detail provided and in the emphasis on particular questions. This no doubt reflects the differing priorities, experience and backgrounds of individuals who contributed to the responses, as well as to different views held corporately by the companies. However, common themes and concerns did emerge, as summarised above. It is worth making some comments on these in the light of Atkins' experience of working with the companies.

2.3.1 Design standards

2.3.1.1 Sewers

Neither the design standards applied nor the rainfall used are currently consistent across sewerage undertakers, and there is no clear or consistent view as to how the impacts of climate change should be addressed. All design standards are expressed as "return periods", i.e. a frequency only or probability standard for flooding. Many customers experience far better than the minimum, while a small number experience a lower standard and become drivers for investment in upgrading the system. However, the trigger for investment is often the sewer flooding risk registers (properties flooded twice or once respectively in ten years), which represent a significantly lower standard of service than the design standard. When a scheme is implemented, the same standards are applied to the existing system as to new developments in all but exceptional cases.

When considering sewer flooding, higher design standards (expressed as 'probability of flooding') are generally applied to protection from internal than to external flooding Also, where sites are sensitive, e.g. hospitals, a higher level of protection may be provided. Adopting the definition of risk as the 'probability of a hazard or event occurring multiplied by the consequence of that occurrence', current practice could be regarded as a limited risk-based approach, even if it is not an explicit one. The standards differ in the return periods or probabilities applied, reflect assessments made in the past of the seriousness of flooding from the various systems. The standards have been based on empirical assessments of what frequencies of flooding are “acceptable”, rather than a rigorous risk assessment procedure.

2.3.1.2 Highway drains

Rainwater running across and along roads is inevitable and acceptable, provided it is not to a depth that causes discomfort or danger to pedestrians, excessive spray from vehicles or a danger to occupants of vehicles (and from vehicles to pedestrians). Provided gullies are clean and operational and the underground drains are clear and have a free outfall, the current standards seem generally to be felt to provide an acceptable level of risk. Traditional roads with kerbs and footpaths with a cross-fall are expected to be wet in the rain, and complaints arise when poor detailing or deterioration of the surfacing lead to large puddles or deep flows. This, however, is not generally seen as flooding, which only arises when the water cannot enter or be adequately removed by the piped system.

Reflecting the greater damage (and potential health impacts) associated with the flooding of properties, the design return periods for combined sewers are higher than for highway drains.

2.3.1.3 Rivers and watercourses

There is no absolute requirement that river defences should provide any given standard of protection. Instead, the EA applies cost-benefit analysis to determine the optimal level of protection. This applies to Main Rivers and Critical Ordinary Watercourses, but there are many other watercourses for which the EA are not responsible, for which no standards may have been set and which may not be protected in any way. Public surface water sewers and highway drains often discharge to these watercourses, and their performance may be affected by the water levels in them.

2.3.1.4 Comparison of standards

100-year protection against fluvial flooding is commonly aimed for in urban areas. This appears to be inconsistent with the targets commonly used for sewers. The main reason for the higher standard for fluvial flooding is that, for a given flood probability, the consequences of the flood are more severe i.e. generally more properties are involved, and the flooding is generally deeper and of longer duration, sometimes lasting for several days, (i.e. the impact is very high, including in terms of pollution). Also, and importantly, flow taken into sewers can in many cases escape overland to a water course, whereas when a river floods the flow has nowhere else to go. With notable exceptions, sewer flooding tends to be localised, fairly shallow and short duration, usually measured in minutes or hours, meaning that the impact of flooding from sewers is less. Although the standards are not expressed as such, they attempt to reflect the risks (frequency and impact) to the properties concerned, and to implicitly define the risks that are “acceptable”.

In practice, most sewers designed in the past to probability standards nominally lower than 30 years have never caused flooding to the majority of customers. This may simply be good fortune, but it is more likely that the combination of simple manual calculations, design processes which seek to make pipe sizes consistent rather than optimal and worst case scenarios used have led to a high factor of safety being incorporated.

Modern methods of designing sewers could reduce the level of protection against flooding by not assuming that all worst case scenarios will occur simultaneously. In practice, sewer models often allow for factors other than rainfall, such as worst case river levels at an outfall, and so introduce combined probabilities of flooding less than those represented by the rainfall alone. However, this may not affect the performance in all parts of a catchment, so it is very difficult to quantify such effects. Another common practice is to allow for high antecedent rainfall before a design storm, so that the catchment is modelled as saturated at the start of the storm, leading to increased runoff. As a rough estimate, based on experience, a 10% increase in peak runoff equates to a “step” in return period from 30 to around 40 or 50 years: the relationship is not linear.

In summary, it is not readily possible to say whether fluvial and pluvial 'probability' standards are equivalent in terms of risk. What is clear is that there are subjective, or even unacknowledged, risk assessments involved in the different standards that have evolved. A more rigorous and explicit approach to these assessments could be beneficial.

2.3.2 Planning horizons

Planning horizons were only mentioned by a minority of respondents, although this is a crucial factor in determining the extent of climate change to be allowed for. Planning horizons are generally determined by the timescale of local plans, i.e. up to around 15 years. Projected developments beyond this timescale are generally not allowed for, even though the lifetime of a sewer is likely to be in excess of 100 years, based on past experience and current renewal rates. While this can be seen as inconsistent, it is also difficult to see what meaningful projections can be made beyond this. It can be expensive to provide spare capacity in a sewer for possible developments, in contrast to a treatment works site, where space can more readily be allocated for future expansion. The difficulty is compounded by any uncertainty over the location of future developments: spare capacity in the wrong location is an expensive mistake.

We do not, therefore, propose to make any recommendations to change the current approach to planning horizons. In particular cases, sewerage undertakers may wish to include longer term projections in their appraisals, and would justify this. We do refer later to the potential for including adaptive management approaches, where justified by CBA, to help deal with uncertainties due to climate change and flow growth.

2.3.3 Modelling and rainfall

Hydraulic modelling (see Appendix C) is used to represent the performance of the sewer system for all but the simplest of flooding studies. InfoWorks CS (Collection Systems) (IWCS) is used by most sewerage undertakers to model existing systems and enhancements, while MicroDrainage (WinDes) is generally used for design of new systems for adoption. The WaPUG (Wastewater Planners User Group) Code of Practice is universally used by urban drainage modellers, although it was only mentioned by three respondents. The responses on model inputs, while not uniformly detailed, also showed consistent approaches, and it is clear that there is a high degree of consistency in modelling practice.

Two dimensional (2D) overland flow modelling is now increasingly being used. This allows the surface route of floodwater that is unable to enter or has escaped from surcharged sewers to be simulated, in some cases explaining why particular properties may be affected by surface flows although they are remote from manholes which flood[4] [5]. It also opens up the possibility of directing floodwater along relatively low-impact routes to mitigate the impact of flooding. WinDes has had

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[4] (WaPUG Spring conference 2007 see www.wapug.org.uk) Urban flood modelling – a hierarchy of modelling and data collection methodologies, Barry Hankin, JBA Consulting et al

[5] (WaPUG Autumn conference 2007) A comparison of 1D and 2D flooding analysis from the Brechin case study - Juan Gutierrez Andres, HR Wallingford and Claire Rayner, Wallingford Software

an analogous capability for some time, aimed at meeting the “design for exceedance” requirement in the Sewers for Adoption manual (SfA) and now includes a specific 2D module.

River and sewer models can be linked so that the interaction between the two can be studied in detail, as needed for Integrated Urban Drainage design. This will allow, for example, the root causes of some of the 2007 flooding to be determined and economical alleviation measures to be identified.

Such tools will not need to be used in all cases, but are under constant development by the software houses concerned, and will allow the responses to heavy rainfall to be more comprehensively modelled, including the overland flow routes of water that flood from or cannot enter the sewer system. While the sewerage undertakers and their consultants have the expertise to take advantage of these models, the sewerage undertakers only control some of the assets concerned, and implementing integrated solutions will call for new relationships between the bodies concerned, as discussed in Sir Michael Pitt’s draft report and in Defra’s consultation paper “Future Water”[6].

Concern was expressed at the poor state of records of highway drainage, as well as the lower standards applied. From the writers’ experience, this is a very real concern and the presence or otherwise of highway drains complicates the analysis of flooding problems on many occasions. The liability for alleviating the problems can also be unclear.

2.3.4 Pumping stations and rising mains

Increasingly solutions to flooding include active mechanical and electrical systems such as pumps and screens. The centralisation of wastewater treatment to attain higher standards of effluent has also led to the increased construction of pumped transfers between previously unconnected sewer systems. The response of such mechanical systems to storm events can have a major impact on service, and should form part of the risk assessment in scheme appraisal.

2.3.5 Other issues

Although PPS25[7] was referenced, no mention was made of the role of land use planning in preventing development in flood plains and other flood-prone areas. WaSCs presumably feel that they have no choice but to accept such developments do occur, and factor the results into their business plans. However, Future Water suggests that the automatic right to connect may be rescinded.

2.3.6 Risk based approach

There is a general consensus for a move towards a risk based approach. The exact approach to be taken was not mentioned. A standard approach, so far as is possible, would be beneficial.

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[6] Future Water Strategy, Defra, 2007

[7] Planning Policy Statement 25, Development and Flood Risk (PPS25), HMSO, 2006

3. Current practice

For PR09 Ofwat has set out its requirements that companies manage their assets in a manner that is risk-based and cost beneficial. It is against this background that “best practice” drainage design standards ought to be defined.

It is considered that “best practice” is a difficult term to define precisely in the context of drainage standards, particularly as the current “probability” based standards are founded on assessments of acceptable risks that are themselves not rigorously derived. In this report, we have instead identified the consensus derived from the responses received and the authors’ own experience. Cost data are not available to quantitatively assess whether the standards identified are cost-beneficial.

Assets

For the design of new sewerage systems, common practice is to design sewers for a 1 in 30 year rainfall return period as set out in Sewers for Adoption 6 (SfA6).

Design standards for solutions to sites that experience flooding from sewers are more varied. Ignoring “outliers”, the current practice for rainfall design return periods for sewer flooding schemes can be summarised as:

Internal property	30 years
External property	20 years
Other areas	10 years

Rainfall

Flood Estimation Handbook (FEH)[8] based rainfall estimates are taking over from the Flood Studies report (FSR)[9] traditionally used, and can be regarded as good current practice. FEH is based on more extensive and more recent rainfall records, and is therefore more representative of current conditions.

River and tide tailwater levels

As far as the influence of river or tide levels on sewer performance is concerned, best practice is to use “worst case” scenarios in most cases. The effect of using design rainfall with “worst case” scenarios is to increase the actual standard of protection in areas where the boundary conditions affect floodwater levels. There are cases in which time series rainfall is used for integrated catchment models, and the resulting frequency of flooding is derived, but these are exceptional.

Climate change

Best practice (in the sense referred to) in allowing for climate change has yet to emerge. An allowance of up to 30% is sometimes made, based on Defra FCDPAG3[10] Indicative Sensitivity Ranges for Climate Change, but this is not widespread or sophisticated enough to qualify as meaningful “best practice”. In particular, it is not very location-specific, gives no guidance on antecedent conditions and may not reflect the “shape” of future storms, which can have a significant effect on the performance of the sewers, especially at the outer reaches of the networks.

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[8] Flood Estimation Handbook, Centre for Ecology and Hydrology, 1999

[9] Flood Studies Report with supplements, Natural Environment Research Council and Centre for Ecology and Hydrology, 1975-1988

[10] Project Appraisal Guidance 3 - Economic Appraisal, Defra, 2000

3.1 Existing guidance

The relevant national standards are:

- BS/EN 752[11]
- Sewers for Adoption 6 (SfA) [12]
- The Sewerage Rehabilitation Manual (SRM)[13]
- DG5 and other sewer flooding registers held by water companies

The CIRIA designing for exceedance[14] and Defra Making Space for Water consultation[15] documents both include useful summaries of design 'probability' standards. Of these, the respondents only consistently referred to the DG5 and other sewer flooding registers and SfA6 as being actually used for guidance, generally in creating their own internal documents.

The current SRM4 does not itself set performance standards for flooding from sewers. It states that they should be "*clearly specified on a regional basis and … may be due to a variety of sources including:*

(i) statutory requirements

(ii) the requirements of the economic and environmental regulators; and,

(iii) the company's or the authority's internal policy."

It shows a table (Table 2.1) of examples of performance criteria, but makes a point of highlighting that these are intended as a guide, not as recommendations. The relevant extract is reproduced in Table 3.1 below.

Aspect	**Level**		
	Trigger for early rehabilitation	**Target for upgrading (see note (c))**	**New Design**
PUBLIC HEALTH Flooding Frequency (see note (a))			
- inside occupied premises	Twice in 10 years	1 in 30 years	1 in 50 years
- streets	Twice per year	1 in 20 years	1 in 25 years

Table 3.1 Extract from SRM4 Table 2.1

It should be noted that this differs from the requirements of SfA6, which requires a 1 in 30 year design standard for new design.

3.1.1 SRM update

The 5th Edition of SRM is expected to take a similar approach to the current edition of not making its own recommendations. A summary of the approach has been provided to Ofwat by WRc for this study:

"The approach will be covered in Steps 3 (Assess Risk) and 6 (Information Gathering) of the SRM Procedure. The main effect of climate change is likely to be on the rainfall producing runoff to surface water and combined sewer systems. The assessment of the likelihood of hydraulic overload is a key part of the risk assessment and we are proposing a simplified and detailed

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[11] BS EN 752: 2008, Drain and sewer systems outside buildings, BSI, 2008
[12] Sewers For Adoption, 6th Edition (SfA6), WRc, 2006
[13] Sewerage Rehabilitation Manual 4th Edition (SRM4), WRc, 2001
[14] Designing for exceedance in urban drainage - good practice (C635), CIRIA, 2006
[15] Making Space for Water, Defra, 2005

methodology, further sub divided to assess the likelihood of overload under both current state and future catchment conditions.

The simplified method is basically an assessment based on historic records and therefore will not cover climate or other change for future likelihood assessment. Hydraulic modelling is the way forward to correctly assess the impact of climate change on the future catchment conditions (i.e. changes due to planning developments, "urban creep" as people pave drives etc.)

The applied rainfalls should be adjusted based on the latest studies available at the time from the meteorological community / Defra, and I think some utilities have worked already with the Met. Office to do some work on this to obtain figures appropriate to their own patch.

We are also moving towards using time series of rainfall to assess likelihood rather than the use of just a single design storm. The hydraulic modelling community is familiar with time series rainfalls and lack of computer power is no longer an issue."

4. Potential approaches to design standard setting

The purpose of this section is to identify and evaluate options for design standard setting. The options have been grouped into three approach types:

- Traditional “return period” approaches (i.e. probability of flooding);
- Risk-based approaches (i.e. methods which also take account of the consequences of flooding); and
- Cost-benefit approaches (in which monetary values are placed on the costs and benefits of different levels of flooding risk).

No distinction is made between the standards applicable to the existing system, to new developments, or to their impact on the existing system.

Climate change is discussed separately in Section 5 below. Other issues affecting the selection of design standards for AMP5 are discussed here, including regulatory and practicality constraints.

4.1 Options for design standard setting

4.1.1 Traditional return period standards

Option 1 No change

The water companies would each continue to set their own standards. The discrepancies between company areas and sources of flooding (highway drains, public sewers, rivers and streams, groundwater) would remain. The advantage would be that nobody would have to change their approaches but the inconsistencies between the different standards would remain.

This approach does not reflect the need for risk based and cost beneficial approaches and is not taken forward.

Option 2 Same return period for all flooding sources and locations

The target standard of protection could be raised to the greater return period provided against fluvial flooding, where this is known. The option of reducing all standards to current highway drainage or sewerage standards levels has been discounted.

This option has the advantage of being a simple concept, but does not reflect the need for risk based and cost beneficial approaches and is not taken forward.

Option 3 Spatially varying standards

This option would seek the same target probability standard of protection at any given location, whether due to river, sewer or highway drainage or to groundwater. However, not all locations of a similar type would have the same protection when measured as a return period.

This would nominally remove the situation where properties are protected from river flooding, but are overwhelmed by sewer flooding instead, or where the protection provided by sewers is reduced by backing-up from a river. Customer perception is a major advantage of this option.

A disadvantage would appear to be that different customers would visibly be receiving a different standard of service expressed as 'risk'. This approach does not reflect the need for risk based and cost beneficial approaches and is not taken forward.

4.1.2 Risk based standards

Option 4 Risk based standards

Whereas traditional return period approaches focus on the probability of flooding, risk-based standards also take the consequences of flooding into account.

These consequences are typically characterised by severity, location and duration but can also include factors such as vulnerability (elderly and infirm) and criticality of the services or assets at flood risk.

Risk-based approaches are well embedded in the industry, through the application of the common framework for capital maintenance planning and the use of CBA for capital project and programme justification. Of particular relevance to the risks relating to drainage design, there is a requirement on all companies to justify PR09 sewer flooding schemes using CBA, which attempts to puts a monetary value on the benefits of risk reduction.

It would appear both feasible and consistent with the approaches taken to other capital investments for Ofwat to require companies to set out how they will take risk into account in the selection of design standards.

Water industry planners already use a variety of techniques to quantify risk, and others exist outside the water industry (e.g. the Defra FCDPAG3 approach). As is already the case for other regulatory requirements, it is not considered necessary for Ofwat to specify the exact method which companies should use to assess risk.

As a minimum, it would appear reasonable for design standards to take into account the qualitative vulnerability or criticality of the assets, properties or areas at flood risk. This means that higher standards may be applied to designs affecting hospitals and environmentally sensitive sites than ‘ordinary’ domestic sub-catchments, whereas design standards relating to external domestic flooding may be lower. More detailed risk-based differentiation than this may not be feasible within PR09 timescales.

4.1.3 Standards derived using cost benefit analysis

Cost-benefit analysis is a means of comparing the costs and benefits of a potential investment, to ensure that it is economically “worthwhile”. It is a widely used technique, which is already in common use in the water industry and for which significant guidance exists. Two main CBA options have been identified.

Option 5 CBA to justify all design standards

Under this option all design standards would be set using CBA. In most cases, the benefits could be valued using existing approaches, most notably the UKWIR *Role and Application of CBA* sewer flooding methodology and the FCDPAG. It is nonetheless likely that a risk based approach may still be required for designs affecting some sensitive installations (such as hospitals), for which it may be difficult to derive meaningful monetary values for risk reduction.

Given that it is likely to be impractical to carry out designs and costings for each investment for a range of design standards, standard cost curves are likely to be necessary to determine the costs and benefits for different standards.

This option has the drawback of being relatively effort-intensive, more so than for most other levels of service.

Option 6 CBA used to justify changes to design standards

An alternative approach, consistent with that taken for other levels of service (e.g. water resources demand restriction frequency) and less effort-intensive, would be to require companies to use CBA only to justify departures from a set of standards.

At the present time, it may be difficult to apply CBA in a meaningful way to responses to climate change, given the lack of probability data to apply to rainfall impacts. However, climate change is only one of the uncertainties faced in drainage design, and the existence of this uncertainty does not mean that cost benefit analysis cannot have a role to play in determining overall drainage design standards. Instead the focus should be on identification of cost-beneficial drainage standards which are robust in the face of these uncertainties.

4.2 Regulatory considerations

In the past Ofwat has focused on the DG5 register of properties at risk in 1 in 10 or 2 in 10 year storm events. There is now an increased focus on a further risk register (1 in 20 year event) and an external flooding register. Any future changes to the focus on these registers will change the companies' investment in these areas and may influence their choice of design standard.

There are a number of recent and current reviews of surface water drainage that will influence companies in AMP5.

The EU Floods Directive[16] on the assessment and management of flood risks requires improved mapping of flood risk, including surface water flood risk. It is intended that this will be managed through the development of Surface Water Management Plans, managed by the EA or Local Authorities. Water companies can expect to have to provide information for the development of these plans and the plans may provide information they can use to apply a risk based approach to surface water design.

The Pitt Review[17] could result in wider organisational changes to the management of surface water In the UK. At either extreme, water companies may no longer be responsible for surface water drainage or they may become fully responsible for all drainage up to the main river. In reality, a more moderate approach involving all key stakeholders is likely.

At present water companies are not statutory consultees within the planning system. However, new developments have a right to connect to the public sewerage system. Also, property owners can pave over their land or convert their basements to habitable areas, or add extensions (some under "permissible development"). Some, but not all, of these actions require planning permission but all of them can affect the volume of water entering into the sewerage system or the impact of a flood event. Future changes to planning could include opportunities for water companies to influence the affect of developers and land owners on their assets.

There is an overall move towards a more integrated approach to managing drainage and flood risk. For water companies this may mean that they will need to design and own new types of assets (for example SUDS) or to design their assets to a new standards. Certain types of SUDS are included in the SfA6 guidance and the Interim Code of Practice for SUDS[18] provides a framework for the adoption of SUDS. It is likely that they will need to co-ordinate their schemes with other surface water managers. This could result in both some increased and some reduced cost pressures.

4.3 Practicality, cost and related issues

A new approach to standards would not necessarily increase cost. For example, the existing design storm plus worst case approach may provide a higher level of service in some cases than intended because of the combined probability of the rainfall and boundary conditions. A rigorous risk-based approach may offer a more focused and economic solution.

The practicality of imposing new guidance at this stage of the PR09 business plan development process should be considered. Atkins experience suggests that many companies have substantially completed the preparatory work for the draft business plans and work is proceeding apace for the final business plans. If the proposed standards are different to those currently being used, it would introduce a degree of uncertainty into the costing of schemes. Atkins informal contact with water company sources suggests that there would inevitably be delays and abortive

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[16] Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007
[17] Learning lessons from the 2007 floods, Pitt Review, 2007
[18] Interim Code of Practice for SUDS, CIRIA, 2004

costs as feasibility and design work would need to be repeated to take account of the new standards. This could in turn affect the cost-benefit of particular schemes and their place in the capital programme, with potential impacts on customer service.

4.3.1 Feasible solutions

At a practical level, the space available in highways for traditional piped solutions is becoming highly restricted in many locations, not just in cities. Increasingly, options such as tunnelling are having to be considered, which are expensive and highly sensitive to local conditions. They often involve pumping, which in turn raises issues of long term financial and carbon cost, reliability and sustainability.

Other than pipe capacity or storage within the sewer system, options for dealing with increased rainfall are either to reduce the amount that is converted to runoff, or to allow more of it to flow across or accumulate on the surface; in other words, SUDS or IUD/ overland flow. Where traditional protection methods are not feasible for one reason or another, low cost, low benefit palliative mitigation measures should be considered; examples might include purchase of affected properties or resilience measures.

4.3.2 Hydraulic modelling

Hydraulic modelling should continue to be used in the vast majority of cases. The type of models to be used in particular cases should in general be left to the interested parties to determine, recognising that the cost of the final scheme may depend in part on the level of sophistication of the models used.

Integrated Urban Drainage and Surface Water Management Plans (SWMPs)[19] [20] [21] [22] will, however, almost always call for integrated drainage models, and any consideration of overland flow routing will require 2D models.

4.3.3 Public relations

Flooding is a highly sensitive issue, particularly for those at risk of flooding. It is difficult enough to communicate the meaning of an x-year return period when someone has been flooded, and to tell them that they could still flood again even after a scheme is completed. The more complex the design standard of that scheme, or of a risk evaluation that determined whether a scheme is implemented or not, the harder it will be to explain. The EA is reported to be considering a study into these and related issues, and it may be worthwhile for Ofwat to be included in the study.

Even if a clear explanation is given and accepted, the result needs to be seen to be reasonable and equitable, both in terms of the standards applied and the prioritisation of a particular flooding problem. Whatever option is chosen, effort will need to be put into preparing to explain it in general terms, and its outcomes in particular cases. The importance of this should not be under-estimated.

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[19] Integrated Urban Drainage Pilots, Scoping Study, Defra, 2006

[20] May 2006 CIWEM IUD conference, see www.coastms.co.uk: Developing policy on Integrated Urban Drainage through Pilot Studies, David Richardson, Defra; Drainage exceedance – going with the flow, Paul Shaffer, CIRIA; An integrated solution for wastewater drainage, Peter Myerscough, WaPUG; and others, including conference outputs report highlighting unclear legislation

[21] May 2007 CIWEM IUD conference, see www.coastms.co.uk: INTERREG III Urban Water Projects, John Blanksby, University of Sheffield; IUD – Making it happen, Sandy Gillon, Glasgow City Council; and others, including conference outputs report highlighting leadership and funding issues

[22] WaPUG Autumn conference 2007, A Surface Water Management Plan for Glasgow's Clyde Gateway, Harry Adshead, Hyder Consulting

5. Climate change

Climate change is a risk facing all companies. In terms of drainage design, the frequency, duration and magnitude of intense rainfall events are particularly relevant

5.1 Current of state of science

5.1.1 Climate change impacts on rainfall, river levels and tides in the UK

Projections for UK rainfall under climate change are currently based on those produced by the United Kingdom Climate Impacts Programme 2002 (UKCIP02). UKCIP02 provides predictions of climate change impacts across the UK in 50km grid squares for three future 30-year time slices: the 2020s (2011 to 2040), the 2050s (2041 to 2070) and the 2080s (2071 to 2100)[23]. Maps are available that show the impact of climate change according to four emissions scenarios (low, medium-low, medium-high and high) on a seasonal and annual basis. These maps can be used to interpret the varying impacts across the UK for a number of climatic variables, including rainfall. UKCIP02 is due to be replaced later in 2008 by UKCIP08 which will provide probabilistic climate scenarios on 25 by 25 km grid squares over the UK land area (see 4.1.2).

UKCIP02 shows a general increase in rainfall in winter, with the largest changes in southern and eastern parts of the UK. Observational records for winter between 1961 and 1995 have shown an increasing contribution to seasonal rainfall by heavy rainfall events over that of light and medium events[24]. This is particularly true for eastern UK, where it is driven entirely by an increase in rainfall amount, with either no change or a decrease in the number of wet days. This suggests that when rainfall events occur in the winter, they are becoming increasingly heavy. This would be expected to increase further under climate change, as mid-latitude events become increasingly driven by convective mechanisms[25].

The impact on summer is less well defined. Under climate change, UKCIP02 projections show an overall decrease in summer rainfall amount – most severely in the southeast – with associated decrease in inter-annual variability, suggesting a trend towards more consistently dry summers.

For summer intensive (peak) rainfall, intuition would suggest that increasing summer temperatures and associated evapotranspiration would result in an increasing number of large convective rainfall events. UKCIP02 shows a slight reduction in the number of intense rainfall days during summer across most of England and Wales. However, a recent Met Office study concluded that, while overall rainfall totals in summer would decrease under climate change, it is likely that when rainfall events do occur, that they will be more intense, as warmer air is capable of holding more moisture[26]. Research by Osborn *et al*. (2000) has shown that, over the period 1961-95, summer rainfall events have had a declining influence on the overall seasonal rainfall totals. During this period, the summer season has seen a slight decline in seasonal mean rainfall, and an associated decrease in the number of wet days.

As summer convective rainfall events tend to be local, they are not modelled well by General Circulation Models (GCMs). Therefore, future changes and likelihood of intense rainfall are rather uncertain; while a reduction in mean summer rainfall is most likely, this won't necessarily prevent

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[23] Hulme, M., Jenkins, G. J., Lu X., Turnpenny, J. R., Mitchell, T. D., Jones, R. G., Lowe, J., Murphy, J. M., Hassell, D., Boorman, P., MacDonald, J. M. and Hill, S. 2002. *Climate Change Scenarios for the United Kingdom: The UKCIP02 Scientific Report*. Tyndall Centre for Climate Change Research, School of Environmental Sciences, University of East Anglia, Norwich.

[24] Osborn, T.J., Hulme, M., Jones, P.D. and Basnett, T.A. 2000. Observed trends in the daily intensity of United Kingdom precipitation, *Int. J. Climatol*. 20: 347-365.

[25] Dale, M (2005), Impact of climate change on UK flooding and future predictions, Proceedings of the Institute of Civil Engineers: Water Management, 158, 135-140.

[26] Pope, V. 2008. *What can climate scientists tell us about the future?* Available at http://www.metoffice.gov.uk/research/hadleycentre/future/ [Accessed 4/5/08].

occasional extreme rainfall events. Any changes to such events are likely to depend on spatial scale, perhaps becoming more localised, and temporal scale, perhaps hourly intensity might change differently from daily extremes, and differently from accumulations over a few days[27].

The impact on spring and autumn shows both increases and decreases in different regions of the UK. On an annual scale, UKCIP02 shows that most areas of the UK will experience a slight decrease in mean rainfall.

In general, the impact of climate change on river flows closely follows the impact on rainfall. UKWIR[28] conducted a study in 2006 that used rainfall-runoff modelling for 27 catchments across the UK to assess the impact of climate change characterised by six GCMs. The results found that winter rainfall increase in almost all of the catchments studied, with a maximum increase of 9 percent. The impact was found to be more substantial on summer flows, with decreases of up to 32 percent found. Flows during spring and autumn seasons were found to be a mix of increases and decreases; with spring increases primarily in groundwater-dominated catchments and autumn flows divided by increases in the west and decreases in the east of the UK.

As part of the same UKWIR project described above, guidelines were produced for assessing climate change impacts on average monthly flows and recharge in UK catchments for the 2020s[29]. Based on the same six GCMs, plus three scenarios of the UKCIP02 Regional Climate Model (RCM), monthly change factors were produced for rainfall and potential evapotranspiration (PET). Guidance is given on how these factors can be used to perturb historic daily rainfall and PET records to give a future climate series. The resulting series can then be used in a number of ways depending on the methodology selected. A limitation of this method is that it does not provide for different sequencing of events or for changes in natural variability caused by climate change. These problems could be overcome using more advanced methods, such as statistical downscaling, stochastic weather generation or resampling of the historic meteorological series.

UKCIP02 also provides scenarios for the impact of climate change on sea level rise and storm surge frequency. Indirectly, this gives an indication to the impact on tidal levels around the UK. The impacts of sea-level rise will be most substantial in southeast England, which will be affected by both rising sea levels and isostatic rebound. UKCIP08 will provide information on similar variables as UKCIP02, but give probabilistic projections of sea-level rise and storm surge frequency for seven 30-year time slices during the 21st century.

5.1.2 UKCIP08

The UK Climate Impacts Programme 21st Century Climate Scenarios, or UKCIP08, are expected to be released in November 2008, and represent the fifth set of climate scenarios for the UK, replacing UKCIP02. UKCIP08 is based on an ensemble of over 300 model projections from the Hadley Centre climate model HadCM3. It will provide probabilistic climate scenarios on 25 by 25 km grid squares over the UK land area.

UKCIP08 projections will cover similar climate variables to those used in UKCIP02 (for example temperature, precipitation, humidity, wind speed, cloud cover and mean sea level pressure) for three future scenarios of greenhouse gas emissions (Low, Medium and High). These projections, both as climate change relative to 1961-90 and as absolute future climate values, will be available for seven over-lapping 30-year time slices, moving forward in decadal steps (i.e. 2010–2039, 2020–2049, etc. until 2070–2099).

These projection data will only be available at monthly timescales and longer. However, the probabilistic information produced will be available to drive a weather generator, created by

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[27] Osborn, T.J. Personal communication, May 13, 2008.

[28] UKWIR. 2006. *Effect of Climate Change on River Flows and Groundwater Recharge: A Practical Methodology – Interim report on rainfall-runoff modelling.* UKWIR Report 06/CL/04/7. United Kingdom Water Industry Research, London.

[29] UKWIR. 2007. *Effect of Climate Change on River Flows and Groundwater Recharge: Guidelines for Resource Assessment and UKWIR06 Scenarios*. UKWIR Report 06/CL/04/8. United Kingdom Water Industry Research, London.

Newcastle University and the Climatic Research Unit at the University of East Anglia. This will provide a statistical representation of future daily and hourly weather conditions, consistent with a future 30-year time-slice, for any 5 x 5 km land grid square.

The probabilistic projections of climate change will help decision makers to carry out sensitivity analyses to make more informed, risk-based decisions with direct reference to varying severity and uncertainty of climate impacts. The weather generator in particular will be a very useful tool for the water industry. It will provide time series of data that can be used, for example, in hydrological models to assess climate change impacts on individual catchments.

The UKCIP08 projections will provide updated climate change information required for wastewater planning. However, further work will still be required to provide a straightforward and practical means for sewer modellers and engineers to generate the design storms and/ or time series rainfall that they need.

5.1.3 UKWIR CL10: Climate Change and the Performance of Sewerage Systems (2003)

The UKWIR CL10 programme made significant advances in the application of climate change modelling to sewerage design and performance assessment. However, one of the key challenges faced by the project was timing and available data; the project was conceived at a time when only the UKCIP98 data was available, but its publication overlapped with the release of UKCIP02. Although some further work was carried out to assess the implications of the new UKCIP02 scenario data, full allowance would have required much of the project to be repeated, at significant cost.

The impact of the different climate scenarios was assessed as part of the CL10 outputs. The affect emphasises the uncertainties that still remain in using climate model data, particularly in this instance in downscaling to very fine temporal and spatial resolutions. Nevertheless, CL10 provides a good overall approach based on best available evidence at the time to assess sensitivity in the performance of wastewater systems to climate change.

There remain uncertainties in the factors derived in CL10 which need to be borne in mind in any assessment of implications for wastewater planning; principally:

- Large variation in seasonal factors between UKCIP98 and UKCIP02 scenarios; although the overall trend on average remains broadly consistent. UKCIP02 showed a mean increase in extreme rainfall over the autumn, winter and spring of 17% compared to 28% under UKCIP98, but a significant reduction in summer rainfall.
- Increasing uncertainty in predictions of future precipitation extremes. Ensemble approaches such as those provided by UKCIP08 will, however, provide a more robust basis for the assessment of uncertainty.
- Uncertainties created in downscaling climate model data, which is already inherently uncertain, particularly downscaling to provide estimates of extreme rainfall at 5 minute intervals.

The main findings of CL10 point to very significant implications for future planning of wastewater systems, namely:

- Small increases in rainfall will drive significant investment to maintain current levels of service.
- As rainfall depths predicted for future larger events are significantly greater than those currently experienced, considerable additional storage would be required at CSOs to maintain current levels of service.
- The change in the general impact of stormwater runoff on rivers is not significant in spite of the predicted longer dry periods in summer.
- The total runoff delivered by sewerage systems to WwTWs will be slightly increased, but the pollution load is unlikely to change significantly due to climate change effects.

- However, summer flows are likely to decrease significantly throughout the UK with potential impacts on water quality in receiving waters. River water quality downstream of CSO discharges in particular, is likely to decrease unless steps are taken to reduce pollutant loads.
- Percentage runoff from catchments with large proportions of pervious area will significantly increase in winter.
- Given the uncertainty in predicting future rainfall, sewer design should move towards a risk based approach rather than meeting design standards.

Since CL10, considerable improvements have been made to our understanding of climate change and its representation in models. As a result, UKWIR is currently tendering for a follow-on project which is expected to review and update CL10, incorporating new data, tools and approaches from UKCIP08. This work will focus on the UKCIP08 High and Medium Emission Scenarios to assess impact on a selection of catchments across the UK.

5.2 Design and the risk of climate change

Ofwat has encouraged companies to manage their assets in a framework of risk based, cost beneficial assessments. The aim of this approach is to ensure appropriate stewardship of and investment in water and sewerage assets. Options for designing sewerage assets in the face of risks due to climate change are considered within this risk based, cost beneficial framework.

A risk based management framework is discussion in Section 5.2.1. Design options that could be incorporated within this management framework are, in general terms, a “Do-Nothing” option, a precautionary approach and an adaptive management approach.

Further discussion on considering climate change within a risk based framework can be found in the Ofwat commissioned work, carried out by Halcrow, “*Asset resilience to flood hazards: Development of an analytical framework*.[30]”

5.2.1 Risk based management framework

A true risk based approach requires an assessment of the frequency or likelihood of an event, combined with an assessment of the impact of that event. As discussed in Section 5.1 above, there are issues in extending the analysis of current climate change science to provide reliable information on the likelihood of any one emissions scenario outcome and hence on how the likelihood or frequency of a given event may change in the future.

However, it is possible to focus on the possible impact of differing events. The responses to the Ofwat questionnaire for this study indicate that companies currently make some assessment of impact, if subjectively, by considering different design standards for different sewer flooding interventions.

A more formal framework can be termed a “vulnerability” based approach. This would be based on an assessment of sensitivity to climate, exposure and the capacity (and cost) to adapt. This approach is an alternative to a fully quantitative risk-based approach; it explicitly recognises that climate change will be experienced very differently depending on the characteristics of the asset or receptor, and therefore that adaptation requirements will vary.

It is important that companies understand vulnerability or criticality of the assets, properties or areas at flood risk and focus responses accordingly.

This should start with an assessment of existing vulnerability, including an understanding of where capacity is limited but not yet exceeded, from which an evaluation of future change can be made. In this way the approach is less dependent, in the short-term, on climate change scenarios and associated uncertainties.

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[30] http://www.ofwat.gov.uk/aptrix/ofwat/publish.nsf/Content/ltr_pr0912_resilfloodhaz

This approach is equally valid for sewerage system asset management planning and for designing new assets or assets that are being renewed.

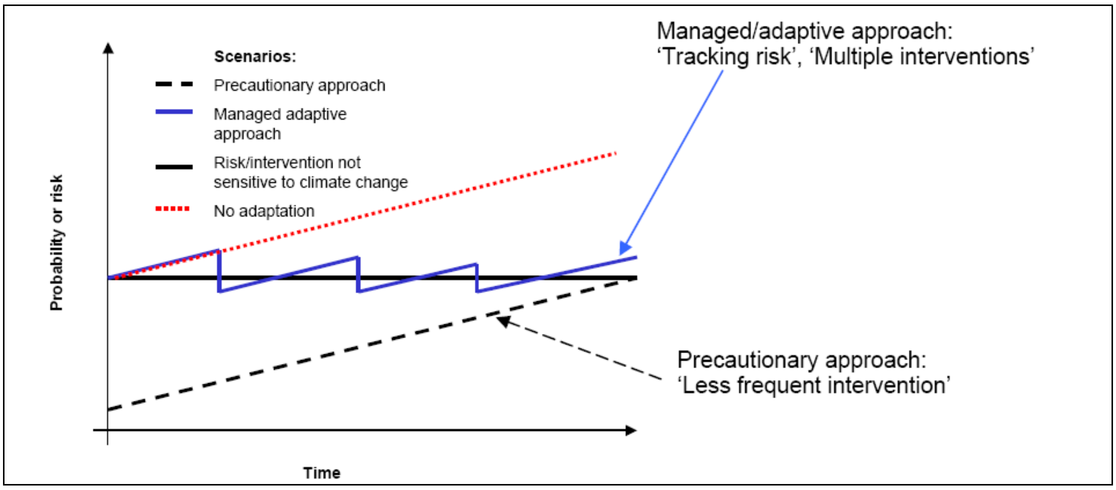
5.2.2 Options

Three main approaches to sewerage asset management in the face of risks arising from climate change can be considered by water companies:

1. Continued research and no further investment or intervention at this time;
2. Adoption of a precautionary approach;
3. Adoption of an adaptive management approach.

These approaches are usefully summarised in Figure 5.1, and each option is discussed in further detail below.

Figure 5.1 Comparison of approaches to managing climate change impacts[31]



Option 1 – Continued research and no further investment or intervention

Further research in climate science and impact assessment is required and will help better define risk and quantify uncertainties.

The UKCIP08 projections will be probabilistic in relation to specific emissions scenarios, so a definitive assessment of risk will remain somewhat elusive. Given that climate change projections are only scenarios, contingent upon particular emissions pathways, and are unverifiable, a 'wait and see' approach may seem appealing.

Whilst this may be sensible where future risks, costs of inaction and costs of adaptation are low and hence there is no incentive to avoid these costs, it is less prudent where the future risks and costs are high, and where adaptation will be expensive.

In terms of drainage design, where the expected increase in rainfall intensity could significantly increase risk and incur large costs, and where future adaptation costs are large, a ubiquitous 'wait and see' approach seems imprudent.

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[31] Defra, Flood and Coastal Defence Appraisal Guidance FCDPAG3 Economic Appraisal Supplementary Note to Operating Authorities – Climate Change Impacts October 2006

Option 2 – Precautionary approach

A precautionary approach would make an allowance for climate change, based on a review of the accepted scientific consensus of impacts. The FCDPAG values discussed in Section 5.2.4 would provide an appropriate starting point. This would result, for example, in sewerage assets that are designed and constructed to convey forecast future flows.

Although there remains uncertainty about the magnitude of change, there is a high level of confidence that rainfall intensities will increase. A fully precautionary approach may result in over-investment, but where assets cannot be adapted over time, it may be the optimal option.

If uncertainties in climate change impacts are set aside, CBA can be applied in a relatively straightforward manner to drainage designs where precautionary allowances are being used.

Option 3 – Adaptive management

An alternative approach is adaptive management, where either no allowance or a smaller precautionary allowance is initially made and then reviewed as the climate changes, with further adjustment(s) then made.

An adaptive management approach reduces potential over or under investment associated with options 1 and 2 and is particularly suited to assets which have a short life or which can readily be altered to accommodate future evidence . It is also an appropriate approach for sewerage asset management planning.

The uncertainties regarding climate change – both scientific uncertainties and those associated with future emissions – mean that assessing impacts and making decisions about the level of adaptation is complex, but taking an adaptive management approach would allow companies to take a strategic and long term view of risks and measures required to adapt to those risks. This would allow a pragmatic response to risks that are identifiable within the next 30-50 years, and which can be responded to with confidence, and to identify those longer term issues which may (in the case of socio-economic scenarios) infer a fundamental review of approach and response.

It is difficult to accurately identify and quantify the net benefits of investment to offset risks due to climate change so applying CBA to adaptive management is impractical. The costs of providing adaptation measures to meet an absolute standard (e.g. provision of a pipe to deal with flows of 10 litres per second) is relatively straight-forward, although the costs of delivering relative standards (e.g. a 1 in 10 year event, or an annual probability of exceedence of 10%) will alter over time in a way that is not fully predictable. Benefits of adaptation are particularly problematic to evaluate over long periods of time, as true benefit will depend on the actual level of damage avoided (which is uncertain). Furthermore the ‘unit value’ of benefit will change significantly over time in response to socio-economic change.

Examples of adaptive management options include purchasing land to accommodate future expansion of CSOs, wider easements to allow future duplication of sewers, building pump wet and dry wells to accommodate future flows.

To provide an economic framework for this approach, the ‘without climate change’ design should be tested against the full suite of climate change sensitivity ranges over the expected asset lifetime to identify the scale and need for any precautionary allowance or enhanced flexibility for adaptation.

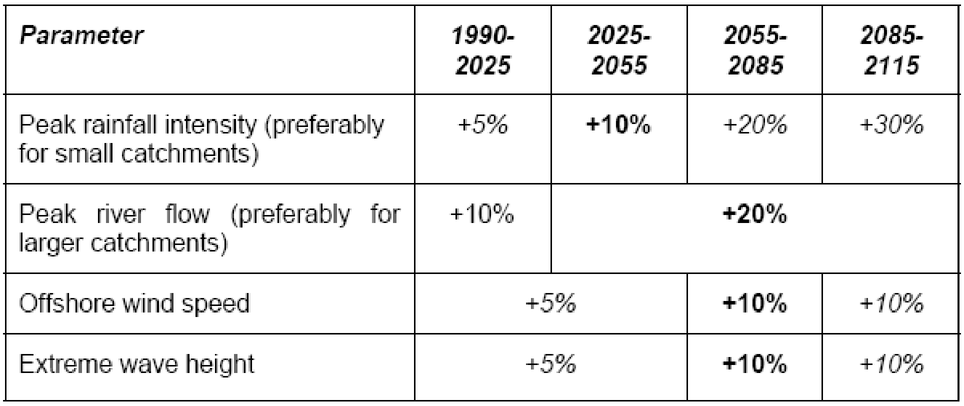
5.2.3 Drainage design standards

The above discussion of risk and vulnerability focuses on specific assets or interventions. Risk based design standards are discussed in detail in earlier sections of this report.

Climate change could be implicitly incorporated into these standards, which would be the case for a precautionary approach. Alternatively, a design standard could be justified on cost-beneficial grounds, then the cost or difficulty of adapting to climate change considered on a site by site basis.

5.2.4 Practical guidance

The UK Government, in setting guidance for flood and coastal erosion risk management appraisal, plans and strategies, has provided indicative sensitivity ranges for a range of variables including peak rainfall intensity as shown in Table 5.1. The figures are based on scientific evidence and scaled into the future.



Parameter	***1990-2025***	***2025-2055***	***2055-2085***	***2085-2115***
Peak rainfall intensity (preferably for small catchments)	*+5%*	**+10%**	*+20%*	*+30%*
Peak river flow (preferably for larger catchments)	+10%	**+20%**		
Offshore wind speed	*+5%*		**+10%**	*+10%*
Extreme wave height	*+5%*		**+10%**	*+10%*

Table 5.1 Defra FCDPAG3 Indicative Sensitivity Ranges for Climate Change[32]

The figures would form a useful and consistent starting point for water companies in considering the potential implications of climate change for drainage design. The decision of which approach to use should depend on the asset life, future adaptability and the local setting (risks can be distributed).

Once published, CL10 (updated), along with improvements in climate scenario tools and data from UKCIP08, should provide a useful framework to develop risk based management of sewerage design.

5.2.5 Summary

The UKCIP02 climate change scenarios suggest that winter rainfall intensities will increase, and a high degree of confidence is attached to this, although the amount of change is uncertain. The convective processes which cause intense summer rainfall events are not well represented in climate models and therefore projections of intense summer rainfall in the UKCIP02 scenarios are only provided with low confidence. Understanding of physical processes suggests that such events may increase, although moisture may be a limiting factor.

The analytical framework for asset resilience to flood hazards, commissioned by Ofwat, provides guidance on how climate change can be considered within a risk based framework.

We recommend that the Defra FCDPAG indicative sensitivity ranges are used as a starting point for quantifying the impact of climate change, with deviations away from these figures justified by companies with supporting evidence.

A precautionary allowance should be made for those assets which have a long-life **and** which are difficult to adapt (e.g. some tunnelled or deep sewers).

An adaptive management approach is recommended where asset life is short, or for longer-life assets where flexibility is or can be incorporated (e.g. pump capacity or small, high level sewers). This approach should also be applied to sewerage system asset management planning. Under this approach the ‘without climate change’ design is tested against the full range of climate change sensitivity ranges over the expected asset lifetime to identify the scale and need for any precautionary allowance or enhanced flexibility for adaptation.

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[32] Defra FCDPAG3 Supplementary Guidance Note 2006.

If uncertainties in climate change impacts are set aside, CBA can be applied in a relatively straightforward manner to drainage designs where precautionary allowances are being used.

Because adaptive management requires a series of decisions and interventions over time, CBA becomes more complex. This is further complicated by the fact that it is not possible to assign a robust probability to the various climate change scenarios. Despite these challenges, a more nuanced approach to CBA, identified through further research, may be possible.

For either method, the emphasis of both the CBA and cost effectiveness analysis (CEA) will be to identify an approach which is robust in the face of climate change and other uncertainties, remembering that other uncertainties, such as the scale and rate of future growth, may be even more significant than the potential impact of climate change.

6. Recommendations

Our recommendations are set out below. Firstly, we address the overall framework for taking climate change into account in drainage design. We then go on to make recommendations for approaches to drainage standard setting for PR09, and then for future price reviews. Finally, areas for further development and consideration are set out.

6.1 Taking climate change into account

The UK Government, in setting guidance for flood and coastal erosion risk management appraisal, plans and strategies, has provided indicative sensitivity ranges for a range of variables including peak rainfall intensity. The figures are based on scientific evidence and scaled into the future. The figures would form a useful and consistent starting point for water companies in considering the potential implications of climate change for drainage design.

The decision of whether to use a precautionary approach or an adaptive management approach should depend on the asset life, future adaptability and the local setting because risks can be distributed. It is recommended that the Defra FCDPAG indicative sensitivity ranges are used as a starting point, with deviations away from these figures justified by companies with supporting evidence.

It is recommended that a precautionary allowance is made for those assets which have a long-life and which are difficult to adapt (e.g. some tunnelled or deep sewers). It may be prudent to increase the flexibility of such assets where possible.

An adaptive management approach is recommended where asset life is short, or for longer-life assets where flexibility is or can be incorporated (e.g. pump capacity). Under this approach the ‘without climate change’ design is tested against the full range of climate change sensitivity ranges over the expected asset lifetime to identify the scale and need for any precautionary allowance or enhanced flexibility for adaptation. For example, a pumping station may be designed so that it can be easily adapted (i.e. upgraded) yet with pumps initially sized without a climate change allowance.

6.2 Periodic Review of Prices 2009

Ofwat is seeking to promote risk-based cost-beneficial drainage design. Given the short timescales available, it is not considered feasible to require companies to carry out cost-benefit analysis to determine design standards for PR09. Instead, we recommend that Ofwat ask companies to set out a risk-based approach to design standard setting for PR09. The investments concerned will nonetheless be subject to CBA as part of the justification of the PR09 investment programmes and projects, and cost effectiveness analysis (CEA) should be used to define least cost solutions.

Risk based approaches are well embedded in water industry planning processes, through the application of the common framework for capital maintenance planning and the use of CBA for investment justification. Of particular relevance to the risks relating to drainage design, there is a requirement on all companies to justify PR09 sewer flooding schemes using CBA, which attempts to put a monetary value on the benefits of risk reduction.

It would appear both feasible and consistent with the approaches taken to other capital investments for Ofwat to require companies to set out how they will take risk into account in the selection of design standards.

Water industry planners already use a variety of techniques to quantify risk, and others exist outside the water industry. As is already the case for other regulatory requirements, it is not considered necessary for Ofwat to specify the exact method which companies should use to assess risk.

Nonetheless, as a minimum, it would appear reasonable for design standards to take into account the vulnerability or criticality of the receptors (assets, properties or areas) of flood risk. This means that higher standards may be applied to designs affecting hospitals and environmentally sensitive sites than ‘ordinary’ domestic sub-catchments, whereas design standards relating to external domestic flooding may be lower. More detailed risk-based differentiation than this may not be feasible within PR09 timescales.

Companies would also be expected to explain how they propose to take climate change into account, in particular, how they propose to determine in which circumstances a precautionary allowance or adaptive management approach is appropriate.

6.3 Future Price Reviews

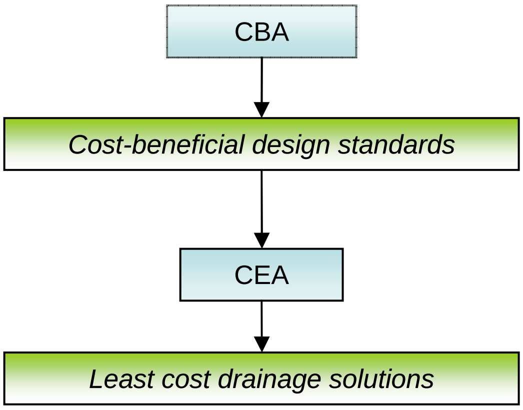
In future price reviews (i.e. by PR14), we believe that it should be feasible to move towards design standards justified, at least partly, using CBA. This will provide consistency with sewer flooding scheme justification and other levels of service (e.g. CBA for water resource demand restriction frequency).

We believe that there are two main options which may be appropriate:

1. CBA to justify changes from historic company design standards. This would have the advantage of being a relatively light touch form of regulation, but may serve to entrench current standards irrespective of their justification.
2. CBA to justify departures from industry design standards. This option would set a common starting point for all companies but would require definition of industry design standards, either by Ofwat or an industry research body.

The overall process is summarised in high level form below:

Figure 6.1: Economic framework for drainage design



The application of CBA to changes or departures in standards would be consistent with the approach taken for other levels of service (e.g. water resources demand restriction frequency) and less effort-intensive than carrying out CBA for all potential design situations individually.

Much of the information necessary to carry out CBA for design standard setting is already available. In particular, the UKWIR *Role and Application of CBA* study and Defra’s FCDPAG set out methods for benefits assessments and project appraisal for changes to flood risk standards. To complete a robust CBA it will also be necessary to gain a good understanding of how costs vary with design standards. The definition of these cost curves may be usefully carried out at industry level for different design scenarios (e.g. small versus large catchments, pumped versus gravity).

If uncertainties in climate change impacts are set aside, CBA can be applied in a relatively straightforward manner to drainage designs where precautionary allowances are being used.

Because adaptive management requires a series of decisions and interventions over time, CBA becomes more complex. This is further complicated by the fact that it is not possible to assign a robust probability to the various climate change scenarios. Despite these challenges, a more nuanced approach to CBA, identified through further research, may be possible.

For either method, the emphasis of both the CBA and cost effectiveness analysis (CEA) will be to identify an approach which is robust in the face of climate change and other uncertainties, remembering that other uncertainties, such as the scale and rate of future growth, may be even more significant than the potential impact of climate change.

6.4 Further development

The key areas for further development and consideration are:

- Decision framework/guidance for selection of either a precautionary allowance or adaptive management approach.
- Implications of new climate models (e.g. UKCIP08) for drainage design. This is likely to be led by companies themselves (e.g. UKWIR).
- The extent to which Ofwat wishes to be prescriptive in what should or should not be included in definitions of risk.
- If Ofwat chooses to ask companies to justify departure from ‘industry standards’, definition of appropriate standards on which to base this judgement.
- Details of acceptable methods for assessment of costs and benefits` of differing design standards, taking account of the heterogeneity of catchments and the opportunities to characterise drainage design scenarios.

7. Conclusions

The key conclusions of the study are set out below.

Current practice: Current drainage standards adopted by undertakers do vary depending on circumstances. For the design of new sewerage systems, accepted practice is to design sewers for a 1 in 30 year rainfall return period as set out in Sewers for Adoption 6 (SfA6). Common industry practice for minimum design standards for sewer flooding schemes can be summarised as:

Internal property	30 years
External property	20 years
Other areas	10 years

Companies' standards are based on Sewers for Adoption 6, the latest version of the Sewer Rehabilitation Manual and design rainfalls, without climate change, are taken from the Floods Estimation Handbook (FEH). In our opinion these are the current state of the art for design parameters, without climate change.

Network models, taking guidance from the WaPUG industry group, are routinely used for new systems and upgrades to produce designs. Small, simple systems may still be designed by hand where risk is deemed low.

For some drainage elements identified as being of particular sensitivity the return period is reportedly varied up to 1:100 years. There were no data from the questionnaire regarding the role of CBA in setting such standards, so there are no primary data to suggest that CBA has been used for this purpose. Our experience of working with sewerage undertakers is that explicit CBA is not usually undertaken for setting design standards, although it is implicit in judgements of different return periods for particularly sensitive areas or items of equipment; different risk levels are thereby accorded different return periods. Whilst we cannot state from the evidence the extent to which such standards may be cost beneficial the fact that they have been workable for many years suggests that they may have been conservatively designed in the past.

Other points that can be made from companies' responses are:

- Generally companies adopt similar baseline return period standards of protection for new and upgraded systems as listed above.
- Some companies provide higher or lower levels of protection for particular areas or particular items based on a qualitative risk assessment
- Climate change is generally not addressed by the undertakers with only 2 companies noting that they make adjustments, with one making reference to Defra's guidance and the other adopting longer return periods as a utilitarian route to providing headroom. Neither refer to CBA.

We are also aware that many of the companies use the UKWIR guidance "The Role and Application of Cost Benefit Analysis - Volume II: Sewer Flooding Guidance (07/RG/07/10)" to some extent. This may be considered best practice and the development of the guidance is an indication of the general acceptance by the industry of the need to move towards more explicit forms of CBA in drainage as for other areas of their business.

Possible minimum standards for drainage design which are cost beneficial are difficult to establish in light of the fact that CBA is not generally undertaken. We propose that as a baseline from which to move forward the above list of minimum standards could be taken, with deviations justified by CBA.

Climate change risks are currently reported by the sewerage undertakers to be: not included; or a nominal rainfall intensity increase allowed; or a longer return period allowed. Neither of the adjustment types noted were reportedly supported by CBA. The sewerage undertakers felt inadequately informed on this issue.

We recommend that the Defra FCDPAG indicative sensitivity ranges are used as a starting point, with deviations away from these figures justified by companies.

A precautionary allowance should be made for those assets which have a long-life and which are difficult to adapt (e.g. some tunnelled or deep sewers). It may also be prudent to increase the flexibility of such assets where possible.

An adaptive management approach is recommended where asset life is short, or for longer-life assets where flexibility is or can be incorporated (e.g. pump capacity). Under this approach the 'without climate change' design should be tested against the full range of climate change sensitivity ranges over the expected asset lifetime to identify the scale and need for any precautionary allowance or enhanced flexibility for adaptation.

Summary

In summary, risk based cost beneficial drainage design is in its early stages in the water industry in England & Wales, and is patchy in its application, although the UKWIR CBA report provides the current benchmark. Our review, backed up by our experience of working in the field, indicates that the sewerage undertakers require further guidance to press them along a path already started on.

We have reviewed ways in which Ofwat might wish to provide such guidance. We suggest there are two stages to this, firstly for the PR09 process where many companies have already completed the vast majority of the work they considered necessary and secondly for future Periodic Reviews. These recommendations have been set out in Section 6.

Appendix A Terms of Reference

The overall purpose of this project is to assimilate and review information provided by the sewerage undertakers and further investigate the need for revision of drainage standards for consideration by Ofwat, for possible issue to sewerage undertakers as part of guidance in respect of their planning for drainage design and management.

The key items in the Terms of reference for this project are as follows:

"4.2 In terms of climate change the Contractor should focus on general issues of how climate change should be taken into account based on current knowledge, rather than attempt to incorporate the latest expectations of the likely impact. UK Climate Impacts Programme 08 (UKCIP08) may materially change expectations.

4.3 The Contactor will be required to recommend to the Client what practical guidance Ofwat should provide to sewerage undertakers to aid them to implement appropriate risk based cost beneficial drainage design such that the benefits of reduced flooding risk are balanced with the costs of providing a higher standard of flood protection. Assessments should be viewed in the long term, for example over one hundred years, factor in the risks from climate change and take into account the values that consumers place on social and environmental factors. Guidance will need to be pragmatic and practicable for the purpose of PR09 business planning, taking account of current knowledge, tools and best practice in drainage design. It will also need to be consistent with the Client's wider stance on asset management, as set out in its PR09 methodology, and with the principles of risk based business planning embodied in the capital maintenance planning common framework

5.1 In order to meet the Client's objective(s) it is expected that the project will involve the Contractor performing the following tasks:

- *Evaluate company responses to the Clients request for information to compare consistency and identify best practice. A copy of the letter sent to sewerage undertakers is attached at Appendix B.*

- *Recommend best practice drawing from the companies' responses, expert knowledge and latest literature.*

- *Recommend possible minimum standards for drainage design in terms of protection from flooding and comment on them in terms of whether they would be cost beneficial and practicable. This should relate to all relevant asset types including gravity sewers and pumping assets.*

- *Recommend how it would be best for companies to factor in the risks from climate change. For example, should rainfall data be adjusted or companies assume that return periods of rainfall events should change*

- *Re-evaluate company responses against these recommendations.*

8.1 The key Deliverables of the project will be a report detailing its findings: The key Deliverables of the study will be a report outlining:

- *Recommendations of best practice in the level of flood protection that should be assumed when designing or renewing combined or surface water drainage systems, including pumping equipment where relevant.*

- *Recommendations of possible minimum standards for drainage design in terms of protection from flooding including views on whether this is likely to be beneficial or not.*

- *Recommendations on how companies should factor in the risks of climate change.*

- *An evaluation of the extent that sewerage undertakers' current practice is in line with these recommendations, highlighting if there is a substantial difference in the level of protection from flooding that consumers receive from different sewerage undertakers."*

A.1 Additional guidance

The e-mail from Peter Jordan 28 March 2008 included the following:

“The guidance needs to focus on standards in 2010-15. The long term framework only looks at projects that need to start in this period anyway. It is most important that the investment that is made now factors in climate change appropriately.

The guidance will need to take a view of the dividing line between what water companies can feasibly be expected to consider and what is outside their responsibility and influence. In line with this it will be helpful if the guidance was devised in such a way that it could be relevant/helpful to the development of surface water management plans.

In case you are not aware, what was the sewerage rehabilitation manual, now the sewerage risk manual, is due for another release in mid May. This edition attempts to be in line with the common framework. It will be important that any guidance also ties up with this. The edition is not likely to be finalised until after this project finishes, but I think the broad approach that it sets out will be more important than the fine detail still to be resolved. It would be worth you having a look at a latest draft. In the first instance please talk to John Wood who is directing the project at WRc about having sight of the latest draft. If there is any problem with this let me know and I will try and arrange access.”

Appendix B Questions to companies

(007-Letter to Companies - Annex A - questions Feb 08.doc)

1 Explain the risk or frequency standard (for flooding) you use when planning sewerage schemes. Please cover:
- **a What is the standard?**
- **b Is the standard based on published guidance, if so what?**
- **c Is your chosen standard affected by location?**
- **d Is your chosen standard affected by the driver of the scheme, ie new development, growth, sewer flooding, maintenance etc?**

Commentators suggest guidance is unclear. The following might be used to define standards:-

a. Ofwat sewer flooding registers with 2 in 10, 1 in 10 events, and with 1 in 20 events under development.
b. BS EN 752 which recommends that, in the absence of other guidance, that for smaller schemes sewers are designed to run full, without surcharge from the following storms:

Rural areas	1 in 1
Residential areas	1 in 2
City centre/industrial/commercial – with below flooding check	1 in 2
City centre/industrial/commercial – without below flooding check	1 in 5
Underground railway / Underpass	1 in 10

For other schemes a further step is recommended that the level of flooding protection be directly assessed by sewer flow simulation model to check the level of flood protection for the following standards:

Rural areas	1 in 10
Residential areas	1 in 20
City centre/industrial/commercial	1 in 30
Underpass	1 in 10

c. Developers are instructed to design systems not to flood any part of the site and to run full in a 1 in 30 storm event (Sewers for Adoption, 6th edition, WRc).
d. The Sewerage Rehabilitation Manual, Sewerage Rehabilitation Manual 4th Edition, WRc

2 With the exception of climate change which is covered below, do you consider that current 'guidance' on design of sewers is satisfactory? If not what changes should be made eg more emphasis on risk from flooding or more definitive frequency standards.

We want companies to deliver a level of service that its consumers desire. At the moment there is a lack of clarity of the standards that companies are working to. We hope that an outcome of our work is that we are able to better articulate companies' current practice and highlight best practice. We may decide that we should issue high level guidance for companies in order to protect consumers and safeguard the future.

Current guidance tends to be related to probabilistic events, most notably that companies design for a 1 in 30 event. In an ideal world companies would implement appropriate risk based cost beneficial drainage design such that the benefits of reduced flooding risk are balanced with the costs of providing a higher standard of flood protection. This would be viewed in the long term and take into account the values that consumers place on social and environmental factors.

The costs of flooding may need overland flow modelling in certain circumstances to more accurately evaluate the ‘consequence’ part of risk. At present, the vast majority of hydraulic models only include the underground piped system, and only look at the ‘probability’ element of risk. They are thus able to predict where flood waters will arise and the likely frequency, but this does not give a true reflection of risk.

However, there is a cost to carrying out detailed CBA, especially overland flow modelling, and a probabilistic standard such as a 1 in 30 year event might therefore be appropriate, especially for small projects. Whatever standard is used in the future it will need to fit into the wider management of surface water flooding that is envisioned by Surface Water Management Plans.

It is unlikely that any guidance we provide in the context of PR09 will be dramatically different to current practice. It is more likely that any conclusions will feed into the wider work and reviews on drainage design and surface water management.

3 For capital schemes, whether additions or improvements, outline when you employ hydraulic network modelling to assess the flood risk

Noting the BS EN 752 guidance, it may not be feasible or economic to use hydraulic network models for every small extension or renewal of the sewerage system. Please summarise the circumstances where such modelling is not used to design schemes. Possible criteria may be the length of new sewers, the size of sewers or the absence of known pinch points in the network.

4 Please outline how you derive material assumptions that you use in conducting hydraulic network modelling.

There are a number of assumptions that need to be made in hydraulic network modelling, possible examples are:

- Area that could potentially contribute to run off
- Percentage of impermeable surface, including what allowance is made for ‘urban creep’ in models in assessing future probability of flooding
- Assumptions of changes
- Surface retention
- Saturation of permeable land
- Infiltration into sewer network.
- Water levels in other systems, such as rivers.
- Loads from sewers which are not adopted but connect into the public sewer network.

The choice of particular assumptions will impact the level of flood protection that consumers actually experience

5 Please explain how you derive rainfall data for different return periods. To what extent do you include local data?

6 Please explain how you currently take climate change into account (including how climate change affects what you have set out in questions 1 and/or 5).

7 Do you have views on how climate change should be taken into account going forwards (including how it should affect questions 1, 2 and/or 5)?

8 Do you look at the consequences of storms that are greater than the normal design standards that you implement and if so how, for example modelling of surface water flooding and flow paths? What would lead to you making changes?

For instance in Sewers for Scotland developers are recommended to consider whether households will flood from 1 in 100 or 1 in 200 events. Designing for exceedance in urban drainage – good practice, CIRIA, 2006 outlines how to reduce problems which arise from flows that exceed sewerage and drainage systems.

9 What difficulties do you find in applying the standard you described in response to question 1 and are there circumstances in which you are unable to complete the design in the way that you would desire.

It would be helpful to know the kinds of problems that occur in the course of designing new systems which may include:

a Lack of relevant rainfall data
b Constrain in building in locality
c Lack of information of network

10 If not covered already above, please explain whether cost benefit analysis that considers wider environmental or social factors leads to changes to the design of schemes that either reduces or increases the frequency of flooding.

11 We welcome any other views you may have on standards relating to flooding from sewers.

Appendix C Hydraulic models

C.1 Integrated river and sewer models

It has been a practice in the past to use the phrase “integrated modelling” to describe a process of running both river and sewer models for a given catchment, usually so that the impact of CSO spills on the river can be assessed. It has also been used for models in which both rivers and sewers are represented in the same model, typically and IWCS model. More recently, it has become possible to link river and sewer (and, potentially, groundwater or marine) models so that they can interact at the time step level, taking advantage of the particular strengths of each type of model.

OpenMI is the current industry leader in integrated modelling. Essentially, the OpenMI standard is a software component interface definition for the computational core (the engine) of the computational models in the water domain. Model components that comply with this standard can, without any programming, be configured to exchange data during computation (at run-time). This means that combined systems can be created, based on OpenMI-compliant models from different providers, thus enabling the modeller to use those models that are best suited to a particular project. The standard supports two-way links where the involved models mutually depend on calculation results from each other. Linked models may run asynchronously with respect to time steps, and data represented on different geometries (grids) can be exchanged seamlessly.

The OpenMI standard is defined by a set of software interfaces that a compliant model or component must implement. These interfaces are available both in C# and Java.

InfoWorks CS – the current industry standard sewer modelling package is OpenMI compliant (from version 7 onwards), as is InfoWorks RS. Many other river modelling packages are also OpenMI compliant. Hence, sewer models can be integrated with existing river models in many different formats.

C.2 Overland flow modelling

Overland flood modelling requires 2D flood routing. There are a number of models which offer 2D modelling capabilities including both InfoWorks CS and RS. Other commercially available 2D models include, JFLOW, TuFLOW, Mike 21, Hydro-2D, HydroF (Atkins internal), DIVAST, DelftFLS, SMS, Telemac, Sobek and others.

The advantage of using overland flow modelling, compared with traditional node flooding, is that actual flooding can be more accurately modelled. Flooding at a particular property may be due to water escaping at a manhole remote from the property and flowing along roads or through gardens to a low spot. A 2D overland flow model will simulate this without the need for a modeller to understand and conceptualise the flooding mechanism in advance.

A further advantage is in developing solutions, particularly when “designing for exceedance”. It can then be checked or ensured that flooding beyond the standard of protection designed for can flow along relatively harmless routes, minimising the overall risk to the public. Integrated Urban Drainage schemes will need to use this capability to achieve their objectives.

C.3 Design storms and time series rainfall

The use of time series rainfall as opposed to traditional design storms has grown in recent years, partly driven by CSO spill frequency standards.

Design storms are a straightforward concept, and easy to apply. They are idealised storms of defined durations which, on the basis of analysis of historical data, are likely to occur at given return periods (frequencies). They are used to test the performance of the system under stress conditions, and to determine the standard of protection at particular locations. However, being idealised, they are not necessarily representative of actual conditions. In particular, the antecedent conditions used

The advantage if using time series rainfall is that, assuming the time series is representative of the area concerned, a more realistic picture of the behaviour of the system is obtained. If detailed historic records at a suitable timestep are available, it is possible to reproduce specific flooding events, and devise an alleviation scheme that would have prevented them. In a sewerage context, the timestep needs to be of the order of 5 minutes to be meaningful, while the generally slower response of rivers means that hourly or even daily totals are sufficient. Unfortunately, rainfall records at such small timesteps and at the spatial resolution of small urban catchments are not generally available, so it is usually necessary to disaggregate hourly or even daily totals, inevitably introducing errors.

There are two commercially available programs for this purpose. Stormpac is produced by WRc and TSRSim by HR Wallingford. They have similar functions, but “TSRSim arises from the UKWIR Project CL10, Climate Change and the Hydraulic Design of Sewerage Systems (2004) undertaken by HR Wallingford, the Met Office, MWH and Imperial College. The software generates long time series stochastic rainfall, calibrated for a specific rain gauge location using observed data and therefore addresses some of the limitations of other rainfall software.” (Jody Cockcroft, 4D, WaPUG Nov 2006). However, both programs are under ongoing development in response to customer needs. It will be essential for any software used to be able to produce time series rainfall that takes account of climate change.

Using a sufficiently long time series of rainfall and other associated time-varying data such as tide levels as appropriate in a given situation, it is possible to explicitly identify the actual *frequency* of flooding and/ or other performance measures such as CSO spill frequency. This is not the same as a traditional return period, which is usually defined in terms of the return period storm, but ignoring the influence of other factors on the combined frequency that this represents. Where there is time-varying data that is independent of the rainfall, such as when the time of concentration of a river differs from that of the sewer network, multiple scenarios can be run and an average frequency derived – this is the process used in UPM studies.

Longer model run times are involved, and more data is generated, so the most appropriate approach needs to be chosen for each case.

C.4 Overland flood routing and integrated catchment management

Integrated modelling and overland flood routing are complementary developments within hydraulic modelling which will enable a better understanding of the whole drainage system, thus enabling a more feasible and holistic way of setting and enforcing drainage standards.

Integrated modelling allows all sources of flooding to be modelled in the same environment, and enables the representation of feedback between different sources. This is an important issue when dealing with some of the problems faced by sewerage undertakers such as the presence of systems with lower drainage standards upstream such as Highway drainage, thus forcing the sewer system to accommodate the overland flow from these systems in addition to rainfall input to the system. It also enables a feedback between the various systems. Of particular importance is the feedback between the river system and the sewer outfalls. Using integrated modelling to represent this dynamic feedback eliminates the need to model the very worst case of a completely restricted outfall, thus enabling more realistic assessments of sewer capacities.

Overland flood routing is particularly important to the definition of drainage standards, as it provides a means of defining flood flow paths from all sources of flooding modelled within the system. This enables the correct identification of the sources of flooding which can then be dealt with in an integrated manner. It is often the case that the flooding produced by lower capacity systems further upstream within the catchment, could end up at the bottom of the drainage system following overland flow possibly over considerable distances. Thus the receptor of flooding can be geographically distant from the source.

Integrated modelling and overland flow routing therefore provide a means of assessing all components of the source – pathway – receptor systems and provides a framework within which to address them in an integrated manner. This can only be of benefit to the definition of drainage standards which have previously been set in isolation from the rest of the system within which the drainage system sits. It also allows for a full assessment of the risk of flooding from all sources at any given location, which is essential to any proposed new risk-based standards.

Overland flow and integrated modelling will be essential tools for the integrated catchment management envisaged in Making Space for Water. Pilot schemes are in hand, and can be expected to highlight the need for tools that enable all sources of flooding to be taken account of.

C.5 Modelling software and climate change

For modellers to be able to determine the effects of climate change on sewer networks, they need to be able to generate plausible “future” rainfall that is specific to the locations concerned. As mentioned above, there are simple uplift factors available in the design storm generators in IWCS, which is an adequate approach provided suitable external guidance is available on the factor to apply. There is currently no corresponding capability for time series rainfall. Without this, risk-based methods cannot realistically be applied.

In generating TSR data, the proprietary packages are Stormpac and TSRSim. Stormpac currently has no facility at all for projecting climate change. TSRSim has a limited capability, based on a selection of seven sites that have been studied. The validity of extrapolating from these, and the methods of doing so, is insufficiently clear for modellers to produce consistent or reliable results without input from climate change specialists.

The UKWIR CL/10 project is intended to build on the results of UKCIP08 to develop tools for assessing the impact of climate change on the sewer system. Integral to this will be useable guidelines on changes in rainfall intensities. Until this is complete, we do not consider that suitable tools are available for general use by sewer modellers.

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