



Development of Enhanced Serviceability Indicators For Sewerage Assets

Final Report

October 2001



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Foreword

We are pleased to publish this report of the jointly commissioned work on serviceability in relation to sewerage by Ewan Associates and Mott MacDonald. It covers the environmental aspects of serviceability. The objectives of the work were to develop an improved package of indicators to reflect more closely the serviceability status of sewerage and sewage treatment systems.

Trends in serviceability indicators over time inform our judgement of maintenance of the asset systems for the medium and long term. Technology is helping companies improve their data recording and analysis on the performance and operation of their assets. We want the extended suite of serviceability indicators to reflect the best data available.

The focus of the work was to develop indicators in time for use in the next Periodic Review in 2004. Over the summer months a number of water and sewerage companies have worked with us on the development of promising approaches, using real asset performance and operational data.

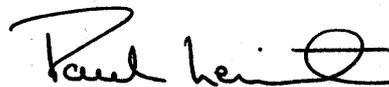
We will now consider the Ewan/MottMacDonald proposals and comments from other stakeholders. We wish the process to be open and welcome constructive input. We will require water and sewerage companies to report first on the agreed new indicators in the 2002 June Returns and provide feedback particularly on data handling.

We are also pleased to be involved in the separate study by the water companies through UKWIR. We see that approach as complementary to this project.

We will both continue to work together on these issues to inform the next and future periodic reviews.



Bill Emery
Director of Costs & Performance
and Chief Engineer
OFWAT



Paul Leinster
Director of Environmental
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EXECUTIVE SUMMARY

Background

This document is the Final Report on a project carried out jointly by Ewan Associates Ltd and Mott MacDonald Ltd for Ofwat and the Environment Agency. The project has sought to develop an improved package of indicators to reflect more closely the serviceability status of sewage collection, treatment and disposal systems. The approach adopted has been to develop existing indicators through alternative data analysis and to add new indicators from non-statutory data. A key objective for new indicators has been that they should inform a forward-looking assessment of asset serviceability. The project has included a review of complementary studies and where appropriate has incorporated some of the ideas and concepts from these works. The Project has been conducted with the participation of four volunteer Water and Sewerage Companies (W&SCs):

Anglian Water, Southern Water, Thames Water and Yorkshire Water

who have provided data and other invaluable inputs to the study.

It should be noted that all Indicator information submitted to the Director will be subject to detailed scrutiny and challenge by the company's Reporters who will give their opinion on it to the Director.

Asset Categorisation

The wastewater asset base has been sub-divided according to the Ofwat classification for assessing capital maintenance needs into:

- infrastructure (below ground assets including the sewerage system and combined sewer overflows) and
- non-infrastructure (above ground assets including pumping stations, treatment works and sludge disposal systems).

Development Framework

For the purposes of this project Asset Serviceability has been defined as:

The ability of an asset to deliver a defined service to customers and safeguard the environment.

This has led naturally to the concept of using a Failure ~ Consequence (Risk) approach to the development of serviceability indicators where "failures" are related to asset state and "consequences" are related to customer service impacts. A pragmatic approach has been adopted for the development of indicators for JR02 which recognises the need to produce significant enhancements to existing indicators in the short term whilst working towards more sophisticated indicators that will incorporate information that is not yet available.

Candidate Indicators

A preliminary list of indicators was developed during Stage 1 of the project. Some of these indicators have subsequently not been recommended for adoption, either because of a perceived lack of available information or because of doubts or concerns about the validity of the resulting test and the cost and time implications associated with collection of the required data. Figure 1 illustrates how the two areas of infrastructure and non-infrastructure are divided in terms of associated assets and the indicators proposed for development. Indicators are 'flagged' as red, yellow and green:

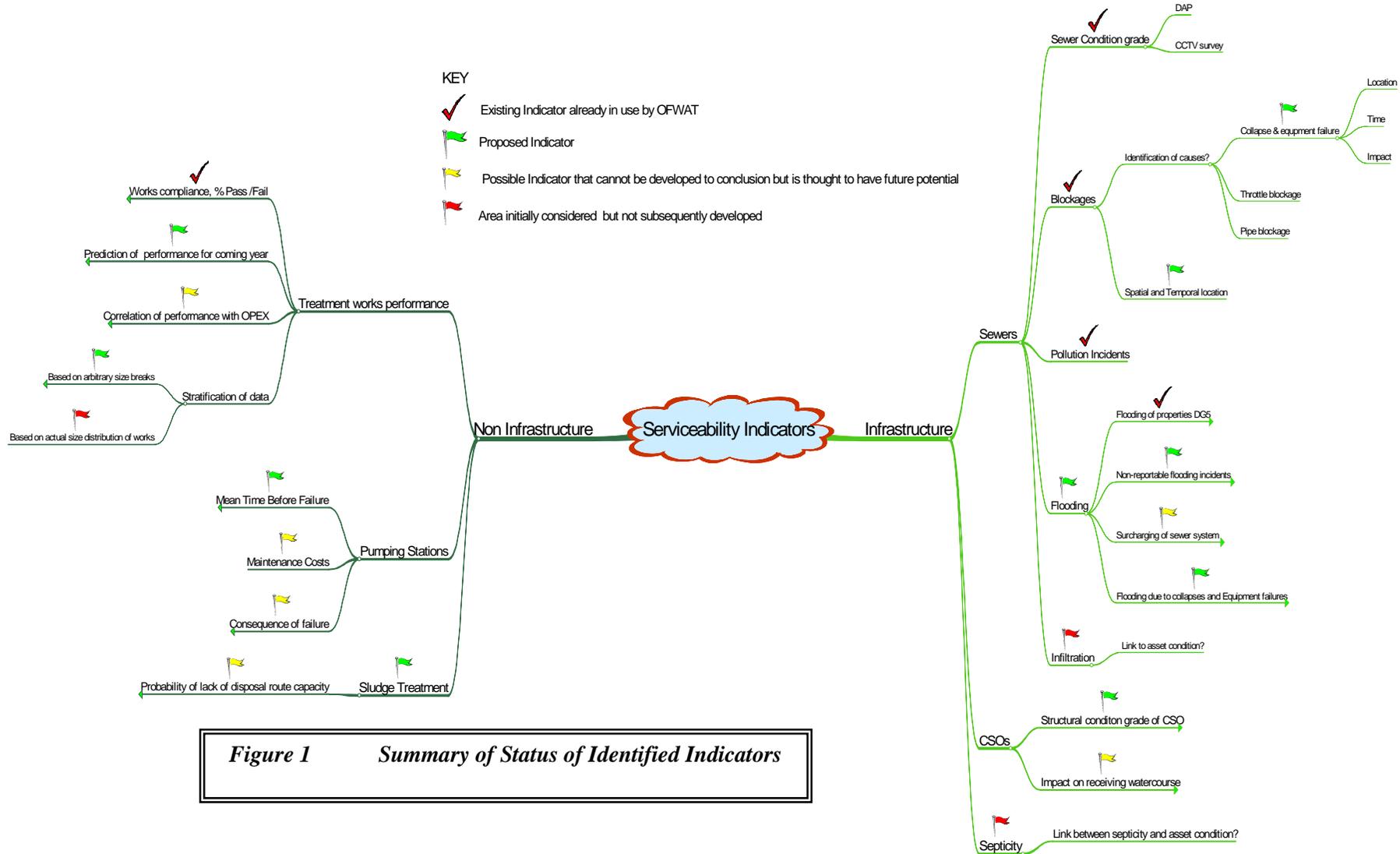


Figure 1 Summary of Status of Identified Indicators



Green flagged asset groups or indicators are those where a potential indicator was identified, the data was thought to be available to validate the proposed test and the assessment was continued through the project.



Yellow flagged asset groups or indicators represent those where there was thought to be the potential to develop an indicator but it became apparent that there was insufficient supporting data to enable its current development to conclusion. Yellow flagged indicators have been discussed within the report and the reasoning given for not taking the development further.



Red flags have been assigned to potential indicators or asset groups identified at the start of the project which were not developed further.

Staged Development

A framework for the development of indicators is proposed which enables the level of analysis applied to each asset type to be progressively developed and reflect the available information. Use of this layered approach will allow the current indicators to be built upon and developed to provide additional information without making the current indicators redundant. Four 'levels' of indicator are proposed:

LEVEL 1 INDICATOR (L1)	'First Process' Presentation of Base Data	Level 1 indicators are 'first process' indicators. They are a simple report of base data which reflect asset state or customer / environmental impact. This may be in relation to defined targets (e.g. works compliance) or a report of event occurrence (e.g. number of collapses per length of sewer).
LEVEL 2 INDICATOR (L2)	Multi-component Analysis (to enable assessment of trends)	Level 2 indicators require the analysis or combination of two or more base data to enable an identification of underlying change in asset state or customer service levels which may therefore inform an assessment of trends in serviceability. This may include spatial and probability analysis.
LEVEL 3 INDICATOR (L3)	Risk Indicator	Level 3 indicators are developments of Level 2 and incorporate the concept of Risk i.e. combine measures of both asset state and customer service.
LEVEL 4 INDICATOR (L4)	Local effects and detailed analysis	Level 4 indicators are those measures developed by W&SCs for internal management purposes and are not intended for reporting to Ofwat. They may provide for example a better understanding of local effects that may explain variations in performance or operating costs of individual assets.

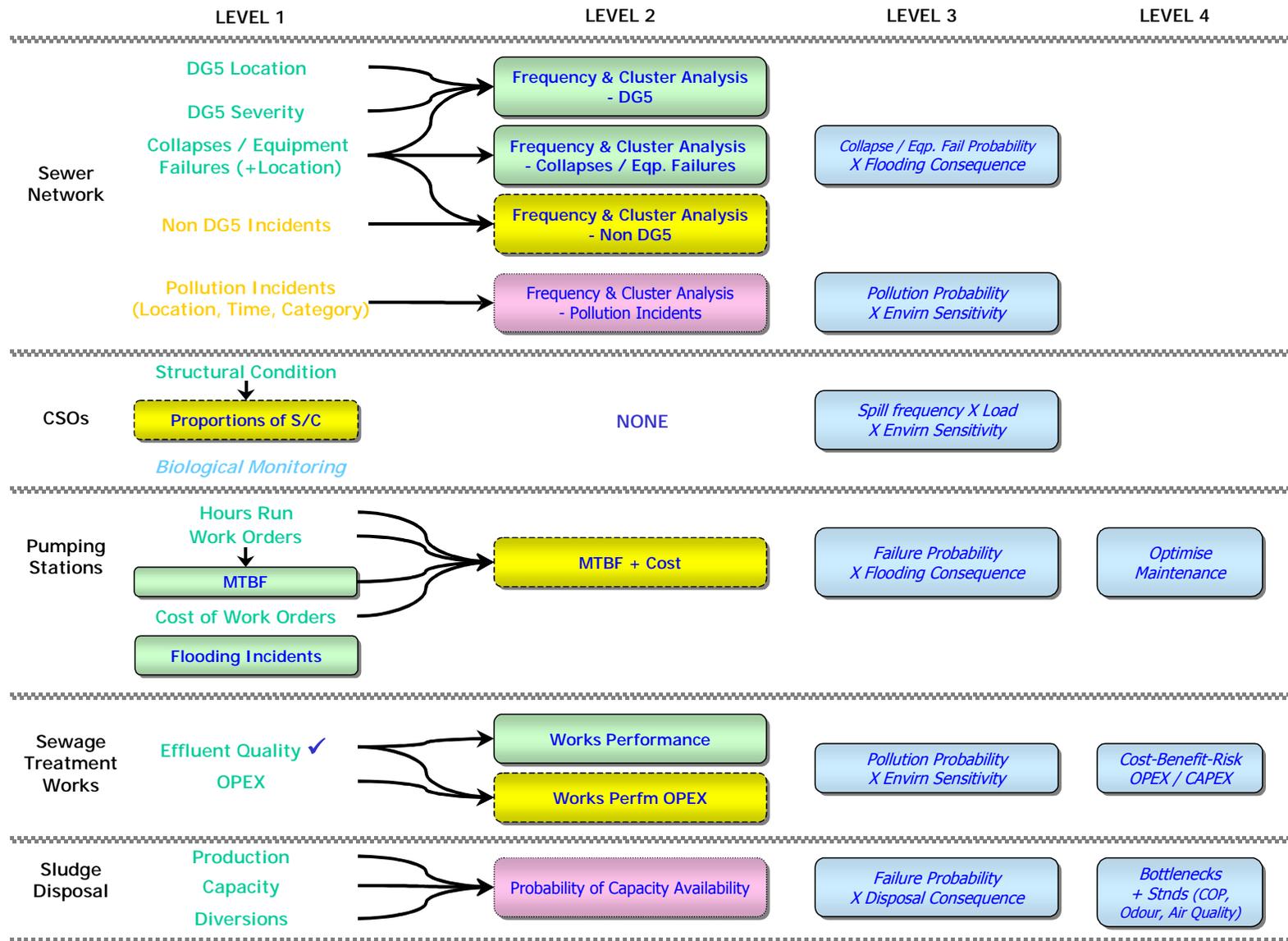
Proposed JR02 Indicators

Table 5.1 is a summary of the recommended new serviceability indicators together with the additional data requirements. Figure 5.1 illustrates the relationships between the indicators and data and the time schedule for reporting. Appendix C of the Report provides Guidance Notes to companies for the calculations necessary to produce the proposed new indicators for reporting at JR02 and Appendix D provides guidance notes to reporters.

ASSET GROUP	No	INDICATOR PROPOSED	NEW INFORMATION REQUIRED	PRESENTATION OF INDICATOR	INDICATOR LEVEL AND REPORTING DEADLINE
SEWERS	1a 1b	<ul style="list-style-type: none"> • Clustering of collapses • Clustering of equipment failure 	Location and time / date of collapse or equipment failure events	Number and degree of clustering of incidents within network	Plan Data – JR02 L2 - JR03
	2a 2b	<ul style="list-style-type: none"> • Severity of DG5 flooding incidents caused by sewer collapse • Ditto for equipment failure 	Location and time / date of collapse Eqp failure events. Numbers of properties flooded	Degree of clustering and impact severity of event	Plan Data – JR02 L2 - JR03
	i	Clustering of all flooding events (to include DG5 and non-DG5) caused by collapses or Eqp. failure	Location and time / date of collapse or Eqp. failure events. Impact severity	Degree of cluster and impact severity of incidents within network	Plan Data – JR02 L2 - Future
	ii	Distribution of pollution incidents	Location, time / date and category of pollution incident	Degree of cluster of incidents in network. By pollution category	Plan Data – JR02 L2 - Future
CSOs	3	Condition Grade of structure	Structural condition grade of overflow as for SCG. Assess 1/3 of total per 5yr period	Proportion of structures of grades 1 to 5	Plan Data – JR02 L1 – PR04
	iii	Biological Impact	RIVPACs assessment for impact on receiving watercourse	Number of CSOs having a negative impact on receiving watercourse	L1 - Future
PUMPING STATIONS	4a	Mean Time Between Failures	Total Hours run Work orders issued	Mean Time Between Failures (MTBF) for each size band of PS	L1 – JR02
	4b	Flooding caused by PS failure	Location and time of PS failure. number of properties affected	Number of incidents and impacts by size band	L1 – JR02
	iv	Incorporation of maintenance cost	Cost resolving work orders	To be developed	L2 – PR04
TREATMENT WORKS	v	Operational Cost: Performance indicator	Operational cost at works level	To be developed	Plan Data – JR02 L2 – PR04
	5a 5b 5c	Performance Predictor	No new information (although the indicator will be more valuable with greater consistency in data collected for comparable classes of works)	Proportion of works for which a defined 'event' is predicted in the coming year based on performance over past 3 years. 4 Size classes	L2 – JR02
	vi	Probability of non-availability of disposal route	Total sludge production rate. Aggregated capacity of disposal system at intervals	Probability of non-availability of disposal route based on 3 years records	Plan Data – JR02 L1 – PR04 L2 - Future

Table 5.1 Proposed JR02 Indicators and required data
(Indicators for future development numbered in roman numerals)

Figure 5.1 – Proposed Indicators



Key to Figure 5.1

Data Already Available ✓

Recommended Data Collection
for JR02

Plan of Data Collection Programme
to be demonstrated for JR02

*Data Collection Requiring
More Planning*

Indicator for JR02

Indicator for PR04

Indicator when Data Available

*Indicator
for Future Development*

Glossary

Base Data	Information that is directly recorded about the condition or performance of an asset and is not manipulated in any way. E.g a suspended solids measurement.
Capital Maintenance	The capital investment required to enable assets to continue to deliver a specified base level of service to customers and the environment.
Clustering	An aggregation of 'events' at a concentration higher than would be expected were the events randomly distributed.
CSO	Combined Sewer Overflow
Flooding Impact Severity	Number of properties affected by flooding.
Infrastructure	Underground sewerage system assets. These include the pipe network and CSOs but do not include pumping stations.
Non-infrastructure	Above ground assets. These include treatment works, sludge disposal systems, and pumping stations.
JR02	June Return 2002. Information provided by the companies to Ofwat.
JR03	June Return 2003.
Level 1 Indicator	A 'first process' indicator that is a report of base data relative to some objective standard that provides a measure of asset performance or condition.
Level 2 Indicator	A multi-component indicator that requires the analysis or combination of two or more base data to enable identification of underlying change in asset state or customer service levels which may therefore inform an assessment of trends in serviceability.
Level 3 Indicator	A multi-component indicator that incorporates Risk.
Level 4 Indicator	Indicators developed by the companies for internal management purposes and are not intended for reporting to the regulator. They may provide for example a better understanding of local effects that may explain variations in performance or operating costs of individual assets.
pe	Population equivalent

Poisson Distribution	A probability distribution that is based on a theoretical formula representing a random process operating in a defined manner.
PR04	Periodic Review 2004
Risk	The probability of a failure event occurring combined with a measure of the resulting consequences.
Serviceability (in the context of capital maintenance and as applied in this project)	The ability of an asset to deliver a defined service to customers and safeguard the environment.
W&SCs	Water and Sewerage Companies

CONTENTS

Foreword

Executive Summary

Glossary

1.0	INTRODUCTION	1
1.1	Background and Objectives	1
1.2	Asset Categorisation	2
1.3	Existing Serviceability Indicators	3
1.4	Stage 1 Report	4
2.0	DEVELOPMENT FRAMEWORK	6
2.1	Introduction	6
2.2	Failure ~ Consequence Model	7
2.3	Staged Approach	9
3.0	INFRASTRUCTURE SERVICEABILITY	10
3.1	Introduction	10
3.2	Sewer Network	13
3.3	Combined Sewer Overflows	19
4.0	NON-INFRASTRUCTURE SERVICEABILITY	23
4.1	Sewage Treatment Works	23
4.2	Pumping Stations	28
4.3	Sludge Treatment and Disposal Systems	32
5.0	SUMMARY OF INDICATORS AND RECOMMENDATIONS	38
5.1	Summary of Proposed Indicators	38
5.2	Sewers	39
5.3	Combined Sewer Overflows	40
5.4	Pumping Stations	40
5.5	Treatment Works	41
5.6	Sludge Disposal	42

Appendix A Cell Cluster Analysis Methodology

Appendix B Treatment Works Serviceability – Analysis Methodology

Appendix C Guidelines for JR02 Reporting

Appendix D Guidelines for Reporters

Appendix E Participating Company Comments

ACKNOWLEDGEMENT

The authors would like to acknowledge the assistance provided by Anglian, Southern, Thames and Yorkshire Water over the course of this study.

1.0 INTRODUCTION

1.1 Background and Objectives

1.1.1 Over the last ten years Ofwat has developed a staged framework to assist it in reaching an overall judgement of likely *Capital Maintenance* needs for the next price limit period. One of the stages in this process is the assessment of *Serviceability* to customers and to the environment. This comprises a review of trends in serviceability indicators that aid assessment of the continuing fitness for purpose of the asset systems [Ofwat Information Notes 35A and 35B]¹.

1.1.2 Ofwat, the Drinking Water Inspectorate (DWI) and the Environment Agency (EA) are working together to enhance existing indicators and develop additional indicators which improve the robustness of asset state assessments and which in addition reflect service to customers and the environment. The overall aim of this project may be summarised as follows:

To develop a package of improved indicators which reflect more closely the serviceability of the sewerage and sewage treatment and disposal systems.

The co-sponsor of this project is the Environment Agency. A parallel study which has similar aims but addresses the serviceability aspects of the water supply and distribution system is being co-sponsored by the DWI.

1.1.3 In the lead-in to this current study, both the EA and Ofwat have commissioned feasibility studies^{2,3}. These studies have provided a foundation for this project and where appropriate some of the ideas and concepts have been further developed. In addition UKWIR have commissioned a complementary project “*Capital Maintenance Planning: A Common Framework*” which commenced in April 2001 and is due to be completed by April 2002. The objectives of this project are to develop a common framework for estimating W&SC capital maintenance expenditure requirements. Regular consultation between the three project teams has taken place to ensure that there is a consistency between the projects.

1.1.4 The tender for undertaking this project was awarded on 9th July 2001 to a joint Ewan Associates Ltd / Mott MacDonald team. The project has been conducted over a 14 week timescale in the following stages:

Stage 1A	Review of previous and on-going complementary studies; Identification of the candidate parameters most likely to impact on sewerage serviceability
Stage 1B	Investigation of available data; Trial analyses; Recommendation of final candidate parameters and preliminary serviceability indicators; Interim Report
Stage 2	Detailed data analysis; Development of enhanced and new serviceability indicators; Draft Final Report.

Table 1.1 Project Stages

¹ Information note No 35A and 35B – March 2000. Serviceability in the Water Main and Sewer Networks in England and Wales up to March 1999. Serviceability of water treatment works, water storage, water pumping stations and sludge treatment facilities in England and Wales up to March 1999. Ofwat

² DWI / Ofwat Joint serviceability study. Review of drinking water quality aspects of serviceability relating to infrastructure and non-infrastructure assets Phase 2 Report, May 2001. W S Atkins

³ Improved performance measures for wastewater treatment. 2001. Tynemarch Systems Engineering

1.1.5 The Project has been conducted with the participation of four volunteer Water and Sewerage Companies (W&SCs): Anglian Water, Southern Water, Thames Water and Yorkshire Water.

Representatives from the companies have been consulted at regular intervals throughout and in addition to data they and other staff members have provided valuable ideas and suggestions. The enthusiastic co-operation of the companies is acknowledged.

1.1.6 An Interim Report was presented to Ofwat and the EA on 7th August 2001 summarising the outcome of stages 1A and 1B and outlining the general approach for the remainder of the work in Stage 2. This Final Report is intended as a basis for consultation with W&SCs and with project teams conducting complementary studies.

1.2 Asset Categorisation

The Ofwat framework for assessing water company capital maintenance needs sub-divides the asset systems by service (water/sewerage) and by infrastructure and non-infrastructure. Whilst ideally it would have been attractive to consider the serviceability of the wastewater systems as one integrated whole we have followed the Ofwat model and categorised the wastewater system into infrastructure and non-infrastructure assets as follows:

Infrastructure	Non-infrastructure
The sewerage network comprising sewers, manholes, valves	Pumping Stations
Combined Sewer Overflows (CSOs)	Sewage Treatment Works
	Sludge Treatment and Disposal systems

Table 1.2 Asset Categories

This inter-relationship between these assets is shown in Figure 1.1

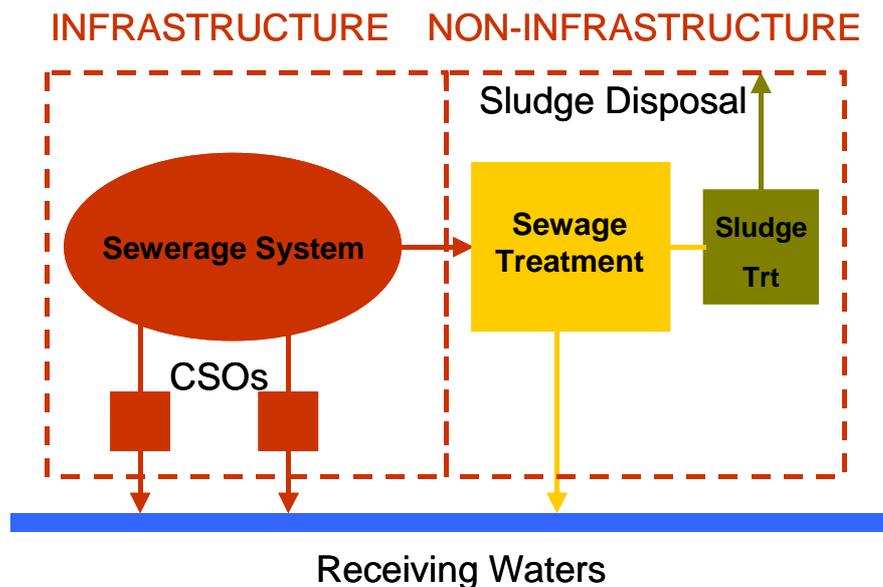


Figure 1.1 The Wastewater System

Conceptually the project may be considered as an investigation into the inter-relationship between Asset condition, historical and future performance and the impacts on customers (where the customer in this context is the population at large and the environment).

1.3 Existing Serviceability Indicators

1.3.1 Existing key serviceability indicators associated with the above asset categories are as follows:

Infrastructure	Non-infrastructure		
Sewerage System	Sewage Treatment	Sludge Treatment and Disposal	Pumping Stations
Internal flooding of properties (DG5)	% of works failing numeric consents	No indicator	No indicator
Sewer Collapses	% of equivalent population served by non-compliant works failing "look-up" table consents		
Pollution Incidents (CSOs / Sewers)			

1.3.2 The general shortcomings of the existing indicators include the following:

- In their present form they may not be good indicators of Serviceability eg because they are measures of Impacts on Customers (Service Levels) i.e. historical performance, and may not adequately reflect the capital maintenance aspects of assets.
- The converse of the above i.e. they may not be good indicators of Serviceability e.g. because they are measures only of Asset State which may not adequately reflect impacts on customer service.
- Restricted in scope e.g. DG5 is limited to internal flooding of properties.
- Some asset categories are not represented i.e. Sludge Treatment and Disposal, Pumping Stations.
- Not forward looking i.e. inability to give a future indication of improving or worsening serviceability.
- Based on Pass / Fail criteria which give poor indications of asset degradation and tendency to failure.

1.3.3 Issues Addressed in Project

In addition to the development of enhanced or additional indicators that attempt to overcome the above shortcomings the project has included considerations of:

- The spatial nature of serviceability i.e. is there a tendency to geographic clustering of particular "problems" within a company?

- The distribution of a given serviceability indicator measure across the asset base ie what proportion of problems are associated with a given proportion of the asset?
- What is the appropriate level in a company at which to assess serviceability for a given asset category and how can these be aggregated to give a company value?

1.4 Stage 1 Report

- 1.4.1 This report represents the results from Stage 1 of a two stage investigation by Ewan Associates and Mott MacDonald to identify enhancements to existing serviceability indicators and new indicators on behalf of Ofwat and the Environment Agency. With the collaboration of four volunteer water companies, Anglian, Southern, Thames and Yorkshire, the report examines a range of possible indicators relevant to Infrastructure and Non-infrastructure assets.
- 1.4.2 Following discussions held with the companies, those indicators that appeared most likely to be predictive, relatively easy to compile and with the greatest ability to indicate the condition of the asset were identified for further investigation in the second stage of the project. Indicators that show potential but either for reasons of current lack of data or the likely time required to develop them to a useable stage within the project timeframe were identified and 'parked' for possible future development.
- 1.4.3 A summary of the indicators considered and the actions to be taken with respect to their future development is shown diagrammatically in Figure 1.2. Existing indicators are shown with a 'tick'. Possible new indicators which showed potential for development within the project timescale were marked with a green flag. Potential indicators for which no data is or will be available either now or within the short term are marked with a yellow flag. These are discussed within the body of the final report however do not currently have the potential for development as indicators. Indicators considered or proposed during the initial phase but since rejected are marked with a red flag.
- 1.4.4 In summary, 10 potential indicators were highlighted for further development in Stage 2 of the project in the following key areas: These are identified in Figure 1.2

Infrastructure indicators:

- Enhancement of flooding indicators (1 indicator)
- Pumping station performance (2 indicators)

Non-infrastructure indicators:

- Treatment works performance (5 indicators)
- Sludge treatment (2 indicators)

Figure 1.2 illustrates the indicators that were proposed for further development during Stage 2 and those which were 'parked' following initial assessment in the first phase.

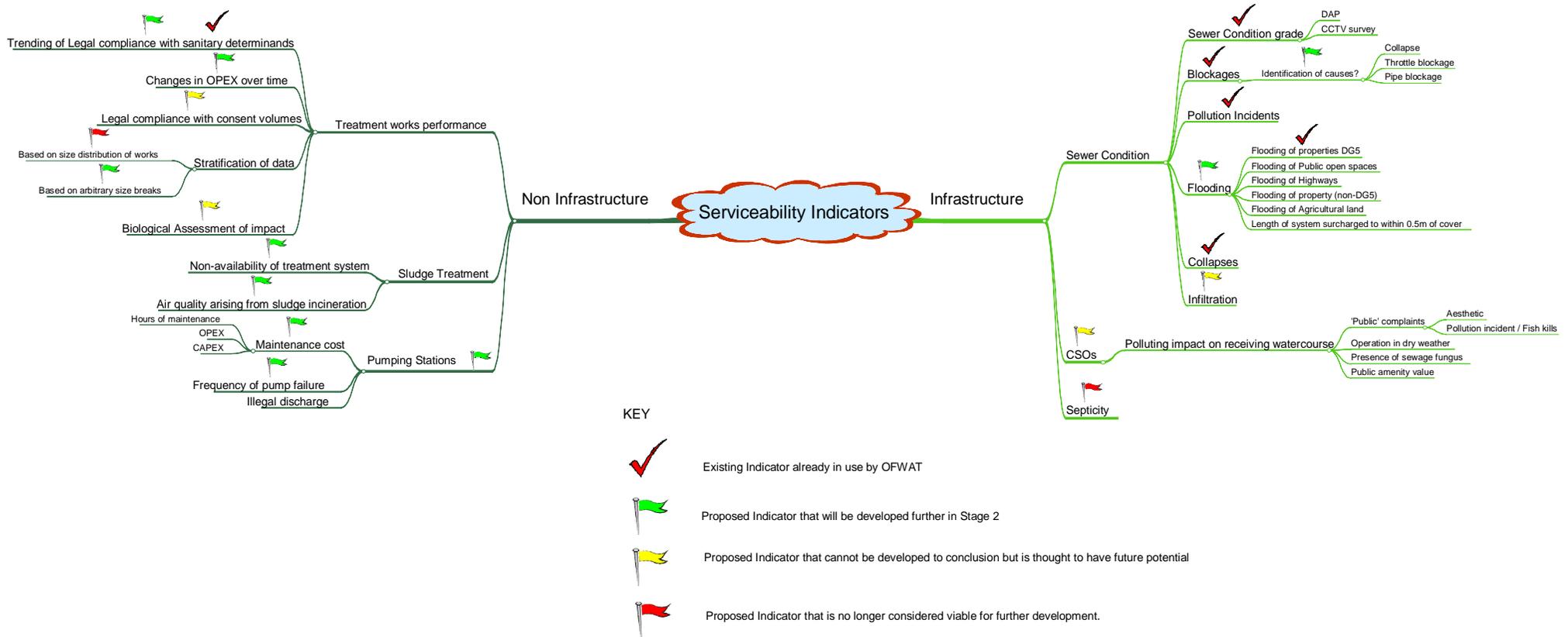


Figure 1.2 Proposed Indicators and their Status at Completion of Stage 1

2.0 DEVELOPMENT FRAMEWORK

2.1 Introduction

- 2.1.1 A draft version of the UKWIR document *Capital Maintenance Planning: A Common Framework* (31 July 2001) has been made available to the project team and has provided a useful background to the thinking behind that study. It has also enabled us to consider the overall direction of this project in the context of the *Common Framework* approach.
- 2.1.2 Whilst there are a number of aspects of the UKWIR draft report which we may take issue with (and have discussed separately with the UKWIR team) overall, we support the general thrust of the study that a risk-based framework for Capital Maintenance Planning is one which the industry should work towards.
- 2.1.3 It is clear from the draft UKWIR report and complementary studies (including this project) that there is a common need to agree a number of definitions. Not least is the need to clearly define the terms *Capital Maintenance* and *Serviceability*. For the purpose of this project we have used the following working definitions:

Capital Maintenance:

The capital investment required to enable assets to continue to deliver a specified base level of service to customers and the environment.

By definition, capital maintenance excludes operational expenditure and excludes investment on assets which may be required to deliver an enhanced level of service (above base service) and which may be required to meet growth.

Serviceability:

In the context of capital maintenance we have defined *Asset Serviceability* simply as:

The ability of an asset to deliver a defined service to customers and safeguard the environment.

The above definition should not be confused with *Serviceability to Customers* which as illustrated by the following quotation from the August 1998 Submission H Reporting Requirements:

“To avoid confusion of the concept of serviceability to customers with the concept of serviceability of individual asset groups, the Director will use serviceability to refer to a company’s performance as perceived by customers and will describe the assessed operational capability of a group of assets as performance.” (PR99 Information Requirement H, Asset Inventory and System Performance Submission, August 1998, Page 4.

We consider that an emphasis purely on *service received by customers* as a measure of asset serviceability (for the purposes of assessing capital maintenance needs) would tend over time to hide the general condition of the assets, the degradation over time of these assets and the consequential increased tendency to fail.

- 2.1.4 Clearly there would appear to be a general need to clarify terminology across the industry. However, taking the above working definition of asset serviceability it follows that the principal requirement of a *Serviceability Indicator* is that it should consider both the *state of the asset* and the *service delivered*. This leads naturally to a Risk (failure and consequence) model for the development of serviceability indicators.

2.2 Failure ~ Consequence Model

- 2.2.1 Quantification of Risk is commonly defined as:

$$\text{The probability of a "failure" event occurring} \times \text{Consequences of failure event}$$

In order to adopt this model for asset serviceability, *Failure* is taken to mean “inability to deliver service” and *Consequence* is taken to mean the severity of the resulting impact on customers and the environment. It would seem logical therefore to consider the concept of a *Risk Indicator* as the serviceability indicator. For example, a risk indicator for the sewerage network might be:

$$[\text{probability of a sewer collapse}] \times [\text{number of properties likely to be flooded}]$$

The change in the reported value of a given risk indicator year on year (or rolling period) would be used as a measure of changing asset serviceability.

- 2.2.2 Within this approach we recognise that it will also be important to report both components of the indicator (the asset “failure” component and the service impact component) in order to not lose sight independently of the asset state changes and the customer service changes.
- 2.2.3 For a given asset type there may be one or more risk indicators because of the integrated nature of the system and the multiple impacts on customer service that a given asset “failure” may have. For example, a Pumping Station “failure” may result in both flooding and pollution incidents. An illustration of a Risk Framework for the wastewater system is shown in Figure 2.1.
- 2.2.4 Within this model it is convenient to consider the asset types within the wastewater system as having differences in their mode of failure. For example for capital maintenance purposes the significant measure for sewers is *collapse* (as a particular subdivision of *blockage*) whereas for Pumping Stations we have considered periods of *non-availability* to be the failure measure.
- 2.2.5 Where there is a failure ~ consequence effect, the “stars” represent serviceability measured in the form of a risk indicator. So for example in the case of Pumping Stations we could envisage two risk indicators:
- $$RI_{AF} = [\text{Probability of non-availability}] \times [\text{Numbers of properties flooded}]$$
- $$RI_{AP} = [\text{Probability of non-availability}] \times [\text{Numbers of pollution incidents}]$$
- 2.2.6 Sewage Treatment Works assets do not conveniently fit into this traditional failure ~ consequence model. In this case “probability of failure” could be regarded as the probability of an effluent quality parameter eg. BOD, exceeding the River Needs Consent level. The consent in this case may be considered to be a surrogate for the consequential effect on the receiving watercourse.

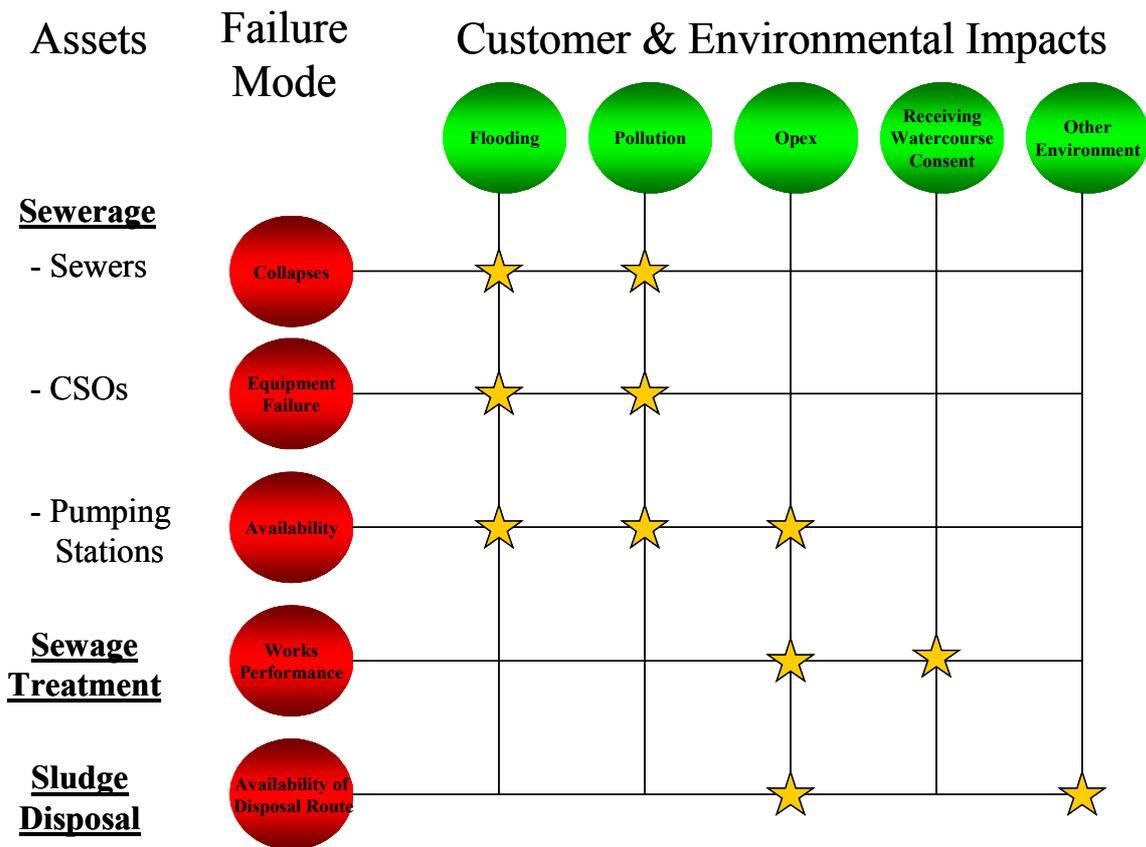


Figure 2.1 Risk Indicator Framework

- 2.2.7 We would not envisage that indicators for all asset categories are in some way aggregated to produce a single indicator at the Company level. However, for each RI there is a need to consider its spatial distribution across the company and aggregation to company level.
- 2.2.8 Despite the possible differences in failure mode, where appropriate we have considered failure events to be Poisson processes.
- 2.2.9 As an alternative to this we have also considered the related measure “Mean Time Between Failures” (MTBF). This term is in common use within the industry when referring to plant failure.
- 2.2.10 There is also a wide range of possible measures for *customer impacts* as illustrated in Figure 2.1. These include direct impacts on customers (e.g. numbers of properties affected), impacts on the environment (eg pollution incidents) but might also include indirect effects on W&S Company Operating Expenditure (OPEX).

2.3 Staged Approach

- 2.3.1 We have concluded that the failure ~ consequence model for assessing asset serviceability in the context of capital maintenance is an ideal which companies should seek to adopt. Some W&S Companies are already working to this end. However, to meet the requirements of this project and provide realistic expectations for JR02 we have proposed a staged approach which will over time lead companies towards risk based serviceability indicators. This will allow time for systems to be put in place for the collection of data which is not currently being collected by all companies and for inconsistencies to be resolved.
- 2.3.2 We have developed a layered approach to the development of new and enhanced serviceability indicators which will provide logical interim steps on the route to the proposed full risk based approach described above and beyond:

LEVEL 1 INDICATOR (L1)	'First Process' Presentation of Base Data	Level 1 indicators are 'first process' indicators. They are a simple report of base data which reflect asset state or customer / environmental impact. This may be in relation to defined targets (e.g. works compliance) or a report of event occurrence (e.g. number of collapses per length of sewer).
LEVEL 2 INDICATOR (L2)	Multi-Component Analysis (to enable assessment of trends)	Level 2 indicators require the analysis or combination of two or more base data to enable an identification of underlying change in asset state or customer service levels which may therefore inform an assessment of trends in serviceability. This may include spatial and probability analysis.
LEVEL 3 INDICATOR (L3)	Risk Indicator	Level 3 indicators are developments of Level 2 and incorporate the concept of Risk i.e. combine measures of both asset state and customer service.
LEVEL 4 INDICATOR (L4)	Local effects and detailed analysis	Level 4 indicators are those measures developed by W&SCs for internal management purposes and are not intended for reporting to Ofwat. They may provide for example a better understanding of local effects that may explain variations in performance or operating costs of individual assets.

Table 2.1 ***Layered Approach to the Development of Serviceability Indicators***

3.0 INFRASTRUCTURE SERVICEABILITY

3.1 Introduction

- 3.1.1 The sewerage system comprises the pipe network, combined sewer overflows, pumping stations and the associated ancillaries such as valves, flow controls and storage tanks. For accounting purposes the sewer pipes, ancillary equipment and overflows are considered by Ofwat as *Infrastructure* whilst pumping stations are termed above ground assets and therefore fall into the *Non-infrastructure* category.
- 3.1.2 In attempting to develop new or enhanced serviceability indicators it is considered that there are benefits in assessing the performance of the sewer network as an integrated system since it is common that a failure of one component affects the performance of another. It is the ability of the group of assets that make up the system as a whole to deliver service to the customer that is of primary importance. This argument is particularly valid if a Risk Based approach is applied where the consequences (customer impacts) as well as probability of asset failure are considered.
- 3.1.3 However the approach adopted in this study to the development of indicators has been to consider the principal elements of the sewer system and how an indicator might be developed or enhanced to provide a more complete picture of system serviceability. Although the focus of this study is on indicators that can be related to capital maintenance requirements, some of the existing and potential indicators are linked to asset serviceability through a surrogate measure such as a flooding or pollution incident; these are direct indicators of the performance delivered to customers but not necessarily of the asset state. Comment is made where appropriate to reflect this and how the capital maintenance element might be identified. In some areas the reverse is true (for example pumping stations) and the indicators proposed directly reflect the asset performance but only indirectly reflect the service provided to customers. The indicators considered for further development are illustrated in Figure 3.1.

3.1.4 Spatial Issues and Cluster Analysis

The spatial distribution of incidents is considered to be of importance as there are related cost implications for capital maintenance. If, for example, the collapses are highly localised this may be indicative of a more advanced deterioration in one network which could be resolved by focusing expenditure in this area. This is likely to be less expensive than resolving incidents that are evenly spread throughout the asset base. However, spatial distribution of incidents must be considered in conjunction with the total number of events and the change in event frequency: a general increase in incidents spread over the entire network with little clustering for example paints a different picture to a similar total number of incidents focused in a small proportion of the overall network asset base.

A cluster analysis is concerned with where the greatest concentration of 'events' lies and whether the observed distribution is more or less aggregated than would be expected at random. There are various techniques available which highlight the spatial relationship between events in adjoining cells. Also of interest is the persistence of clustering events through time. A combined spatial and temporal analysis is therefore recommended.

The study of spatial analysis is highly complex and there are various techniques available which use varying degrees of sophistication and complexity. Which technique is most appropriate depends to some extent on the quality and reliability of the data. A detailed investigation into spatial analysis of network performance is outside the scope of this project

however an example has been given in Appendix A to demonstrate how a simple spatial analysis might be undertaken and reported.

A more detailed examination of cluster analysis for events occurring within both potable water and wastewater networks is recommended as being of significant value for network performance analysis.

For demonstration purposes three options for splitting a company into discrete areas or cells have been considered:

- *Drainage Area*
Different drainage areas perform differently and have catchment-specific characteristics. This model has not been pursued because of the difficulty in obtaining a complete set of drainage area plans or models for an area or company. Although production of models is progressing these are by no means complete yet and the work required to compile a database representative of the whole company's sewer networks by drainage area would be significant.
- *Postcode*
The whole of the UK is divided into unique postcode areas which could be used as the geographic reference zone for a network associated indicator. The postcode has the advantage of reflecting to a limited extent where people are living and therefore where there is likely to be a sewer system however it has an associated drawback of being variable in size.
- *Geographical grid system*
A grid is overlaid on to the network with a unique identifier for each cell. The National Grid system is an easily applied and widely accepted system that can very easily be superimposed over existing digitised network information (both for wastewater and clean water systems). GIS systems can be used to interrogate each cell for the presence and extent of an asset and its attributes.

A 1km square geographical grid has been used within Appendix A for demonstration purposes at this stage in the development of the indicator. GIS systems can be adapted to interrogate cell contents making data extraction relatively straightforward and a high degree of sophistication can be applied to these processes. The Reporting Guidelines in Appendix C are based on the assumption that a 1km grid system is adopted and that the cluster analysis method in Appendix A is followed.

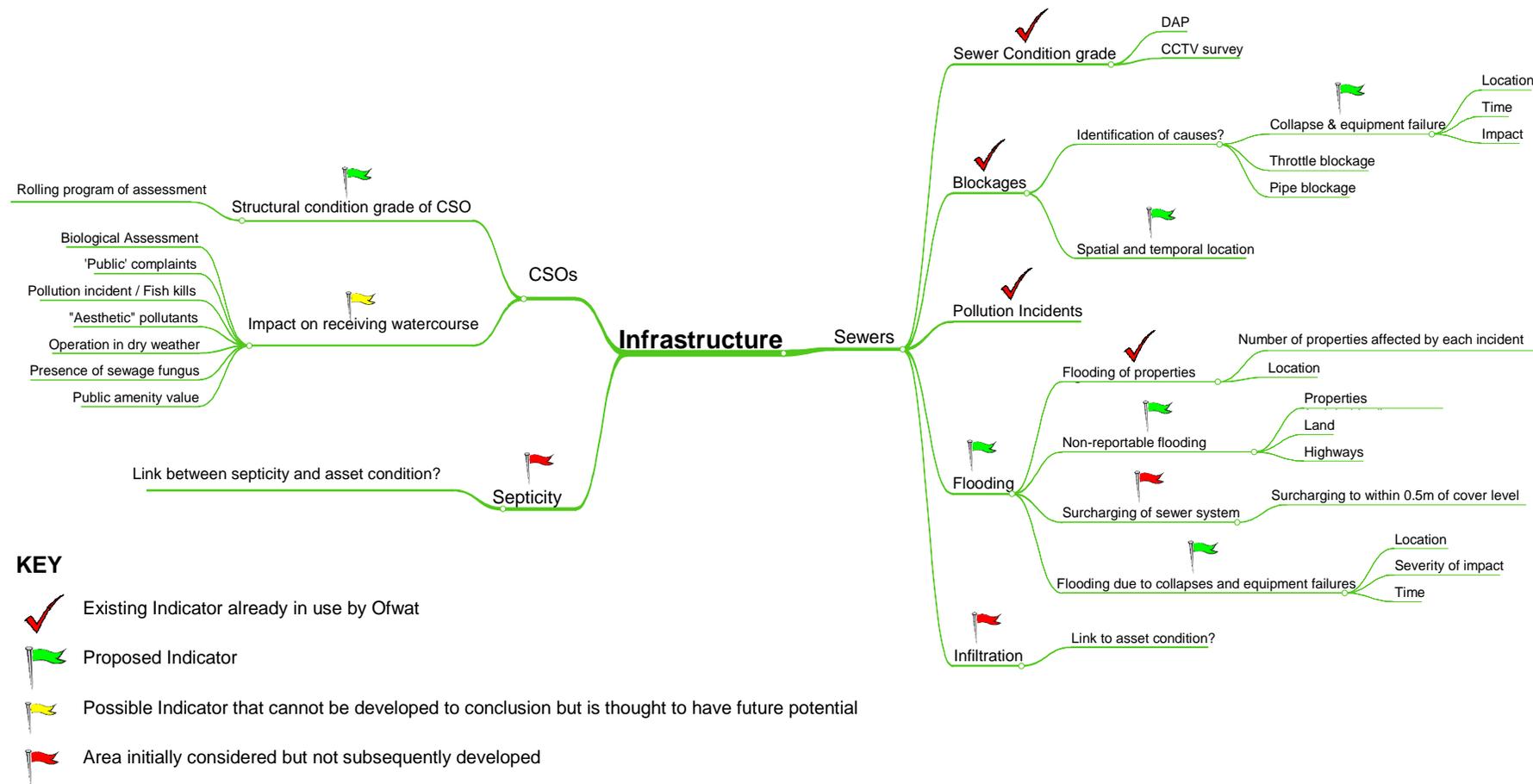


Figure 3.1 Summary of the status of indicators considered for infrastructure assets

3.2 Sewer Network

3.2.1 Background – Existing Indicators

Many factors contribute to the overall performance of the sewerage system. The key indicators that Ofwat currently use to determine whether a company is maintaining serviceability within the sewer network are:

- The number of properties flooded because of insufficient sewer capacity (DG5)
- The number of sewer collapses
and more recently
- The number of pollution incidents occurring at combined sewer overflows and sewers.

Within the adopted definition of “serviceability” (para 2.1.3) sewer collapses would fall into the category of *asset failure* and flooding and pollution incidents into the *customer impacts* category. None of the existing three indicators completely fulfils the requirements of a predictive risk based indicator and they are considered to be Level 1 indicators since they are little more than counts of events.

Within the proposed framework for the development of serviceability indicators we have stated that ideally there should be a transition towards risk-based (Level 3) indicators which encompass both asset state and service to customers. In the case of the sewer network and the existing indicators this would lead naturally towards new indicators which link *Asset State* (measured in terms of collapses and equipment failure) and *Impact on Customers* (measured in terms of flooding and pollution incidents).

Since the full development of risk-based Level 3 indicators will require additional data and analysis and may take some time to gain acceptance we have proposed an interim step (to Level 2) which requires development of the existing three indicators.

The current DG5 flooding indicator requires the reporting of information in a number of categories relating to the internal flooding of properties. The causes of a flooding incident are requested in three classes: blockages, collapses and equipment failure. Of these, collapses and equipment failure are the most directly attributable to a requirement for capital maintenance expenditure. Blockages, where not caused by collapsed sewers, are generally transient obstructions and may be unrelated to asset condition and have little direct impact on the requirement for capital maintenance.

3.2.2 Indicators 1a and 1b. Distribution of sewer collapses and equipment failure

The proposed indicators are primarily concerned with identifying the condition of the network as reflected by the occurrence of sewer collapses and equipment failures (measured separately) since these most directly reflect the capital maintenance requirement across the network. These indicators are only concerned with the asset performance in terms of event frequency and distribution and not the resulting service delivered to customers which are incorporated in Indicators 2a and 2b.

The total numbers of collapses and equipment failure events are currently reported as part of the existing June Return to Ofwat. The proposed enhancement will indicate how clustered these events are within the network. When viewed alongside the number of events and over

time it is hoped that changes in the distribution of events within the network will provide a better picture of how the sewer system is performing as a whole.

- **New information required (as part of JR02) will be the location and time at which a sewer collapsed and equipment failure occurred. For the purposes of these indicators the definition of a sewer collapse is taken to include a partial collapse which prevents the sewer from carrying the design flow of that part of the system.**

An example spatial analysis is given in Appendix A and the reporting methodology to be used is detailed in Appendix C.

3.2.3 **Indicators 2a and 2b. Distribution and severity of DG5 flooding incidents caused by sewer collapses and equipment failure.**

The number of properties flooded is currently recorded as part of the DG5 reporting requirements. However, for capital maintenance purposes it is important to identify those incidents that are attributable to collapses and equipment failure and the scale or severity of the resulting incident. Indicators 1a and 1b will identify the distribution of ALL sewer collapses and equipment failure throughout the network. In order to provide a more complete picture of the scale or severity of impact of a collapse or equipment failure it is proposed to record the number of properties affected (and reported under DG5) and their distribution across the network. The proposed report to Ofwat will be a pair of numbers that gives the total number of properties affected in each case and a measure of how clustered these events are within the network. The proposed reporting methodology is detailed in Appendix C in C1.2.

3.2.4 **Customer Impact Indicators for Future Development**

Indicator (i) - Spatial analysis of general flooding incidents resulting from collapses and equipment failure

Experience of carrying out drainage area plans has shown that in some networks the ratio of non-reportable flooding incidents to DG5 reportable incidents may be as high as 4:1. Even where the number is much lower, incorporation of non-reportable flooding incidents into an indicator would provide a more complete picture of the performance of the sewer asset base as it impacts customers. Categories of currently non-reportable flooding for incorporation within such an indicator are currently the subject of an ongoing study by Ofwat but may include categories such as:

- Open spaces
- Agricultural land
- Uninhabited property
- Highways.

It is proposed that a future indicator would record the location and time of the event and in addition, its severity. It is envisaged that reporting of this indicator would require a more complex presentation format since it is a 'three dimensional' indicator that is seeking to illustrate how many events are occurring, where in the system they are occurring and the resulting severity of impact on customers. It will be necessary to objectively compare the impact of flooding of different property and land types in order to be able to produce a 'severity' rating that enables a generic report to be produced.

Pollution Incidents

The number of Pollution Incidents occurring at combined sewer overflows and sewers has been introduced to provide a more complete picture of service. Pollution Incidents *per se* are recorded and reported by the Environment Agency. Pollution incidents are split into 4 categories with Category 1 being the most serious and Category 4 the least. There are many potential reasons for an incident and some may be unrelated to the water company. Farming for example remains the largest single cause with both point and diffuse discharges. The Agency notifies the Water Company if the incident is attributable to a failure of its assets.

The Pollution Incident (when attributed to the sewer network) may be regarded as a consequence arising from an asset failure within the sewer system. Pollution Incidents in themselves are not necessarily justification for Capital Maintenance expenditure and are not therefore direct serviceability indicators by the definition used within this project unless it can be identified that the incident can be directly attributable to a failure of asset performance.



Indicator (ii)- Location and distribution of Pollution Incidents

Existing information regarding pollution incidents is reported to the companies by the Environment Agency. This report attributes the incident to one of a range of different defined causes. Where the pollution incident is attributable to a failure at a treatment works or intermittent discharge within the network this will subsequently be reported by the company in its annual June return to Ofwat. For most companies the frequency of Category 1 and 2 incidents is typically less than 20 per year. Inclusion of Category 3 events would provide a more complete picture however concern has been voiced over ensuring consistency in reporting if these were to become reportable events.

It is recommended that the grid reference and date / time of category 1, 2 and 3 pollution incidents are recorded to enable future spatial analysis to be investigated.

At present the location of pollution incidents is not reported or directly analysed by the company or Ofwat. The event frequencies for the various categories are however relatively low and it is doubtful whether there is any additional value in taking the analysis to a spatial or predictive level: Category 1 and Category 2 events are so rare that if a repeat event occurred at the same location the type of spatial analysis proposed for network flooding events would not be required for the problem to be resolved. In addition a predictive statistic is likely to be inaccurate since once a Pollution Incident has occurred resources are more likely to be allocated to preventing its reoccurrence. At present it is therefore not proposed to develop further the Pollution Incident Indicator although it is recommended that the grid reference of pollution incidents is recorded to enable a future analysis if required.



3.2.5 **Surcharge of Sewer System**

Surcharging of the sewer system to a specified level can be predicted from a hydraulic model, built for a particular network from flow survey information. The proportion of a network that is subject to a given level of surcharge is a characteristic of its hydraulic performance and could be used to contribute to the wider picture of the overall network performance.

The use of sewer surcharge as an integral part of a network performance indicator for capital maintenance planning purposes has been discounted at this stage for the following reasons:

- Existing network performance indicators such as flooding incidents and sewer collapses are reported for a company's entire sewer asset base. Sewer surcharge is calculated theoretically once a hydraulic model has been constructed. However, many smaller rural catchments do not currently have a hydraulic model so it would not be possible to provide a figure for surcharge over the whole of a company's asset base.
- Current network performance indicators are reported on an annual basis. A hydraulic model can only be updated when new flow survey information is available. This is unlikely to happen more often than once in ten years.

3.2.6



Infiltration as a Potential Indicator

Infiltration was proposed as a potential serviceability indicator at the outset of the project. Superficially infiltration appears to be the wastewater equivalent of leakage within potable water distribution systems and to offer a surrogate indicator for the sewer network condition. This is on the basis that as the condition of the pipes deteriorates, joints open up, cracks and partial collapses appear and the amount of infiltration will increase. Indeed in many systems infiltration accounts for a significant proportion of the dry weather flow. The proposed indicator was to measure changes in infiltration and use the results as evidence for changes in the asset condition.

A number of concerns and difficulties associated with the practical viability of such an indicator were raised during the initial discussion phase of the project. The most significant difficulty is that the figure for infiltration *per se* for any given network does not provide a direct indication of the asset condition. Many other factors need to be taken into account such as:

1. Illegal connection of downpipes from roofs and drainage from paved areas occur in virtually every network and contribute to the infiltration figure. A gradual increase in the paved surface area connected to the combined or foul sewers will lead to an increase in infiltration that is unrelated to the condition of the asset.
2. Deterioration in the pipelines normally occurs at specific points or short runs of pipe. Any increase in infiltration will be small relative to the total flow through the network. Flow is only likely to be measured at the inlet to the treatment works (at best).
3. Variations in the local geology have a dramatic impact on infiltration rates. Where a network crosses two or more fundamentally different areas of geology this would make interpretation of data difficult to relate back to the condition of the pipes.
4. Infiltration rates will be significantly affected by the level of the watertable with respect to the sewer network being studied and this will be affected by, *inter alia*, the recent weather pattern, soil type and catchment runoff characteristics.
5. Attempting to reduce infiltration by pipe lining and other remediation techniques has been shown to be unsuccessful. The condition of the pipes themselves may therefore be satisfactory and not contributing to a high infiltration figure which, if used as a performance indicator in the same way as leakage rates, might suggest that the asset base was deteriorating at a significant rate when it was not.
6. When making an assessment of dry weather base flow it would be difficult to differentiate between infiltration and flows from new developments (growth) and illegal connections.
7. The impact of variations in rainfall on measured flows needs to be taken into account for each catchment area and network. This would impose a significant burden of data collection and analysis.

8. Impact of metering on changing apparent infiltration due to changes in water consumption.
9. Where widespread, chronic infiltration results in service failures caused by overloading of downstream pipes, the most economic solution is often to replace the overloaded pipes rather than to attempt to stop the infiltration. If a company adopted this approach then, following capital investment, the rate of infiltration would remain at the previous level and continue to increase as before. An infiltration indicator would suggest that further investment is required after the problem, in this case lack of hydraulic capacity, had been satisfactorily resolved.
10. Sewer systems might be expected to have a life in excess of 300 years and therefore the rate of year on year deterioration is likely to be relatively small. The errors inherent in relating infiltration to sewer system condition are likely to be larger than the rate of deterioration.
11. Although the intention would be for change in infiltration to act as an indicator of sewer condition and be correlated with other existing condition indicator information such as Structural Condition Grades, Sewer Collapses and blockages it was felt that absolute rate of infiltration could be seen as a driver in its own right rather than an indicator of deterioration in the sewerage asset. Experience indicated that efforts to reduce measured levels of infiltration by remedial sewer repair work were largely unsuccessful.

From a philosophical perspective the use of infiltration as an indicator of the condition of the sewer system is appealing. At first sight it appears to represent a direct measure of the physical condition of the sewer pipes and therefore to be ideal as a serviceability indicator. When examined in greater depth however, the difficulties and errors associated in producing the indicator are severe.

Technically it would be possible to remove or reduce most of the difficulties described such that an indicator could be created however the practicalities in terms of the time, cost and effort required to produce an indicator which could be used with any degree of confidence would be prohibitive. ***Taken as a whole it is felt that infiltration should not be developed as a potential serviceability indicator at this stage.***

3.2.7 Septicity as a Potential Indicator

The presence of septicity (manifested as hydrogen sulphide gas) is important because of the highly corrosive impact of hydrogen sulphide on sewers, in particular concrete sewers and its high nuisance rating giving rise to complaints even at concentrations in the low parts per million range. Its value as a serviceability indicator is low however since it is not possible to link a high level of sulphide with an asset condition beyond acknowledging that an ongoing high concentration of hydrogen sulphide will lead to a premature degradation of the system.

The use of septicity as a potential indicator has been discussed with the volunteer companies and all have indicated that although this is an issue of importance in its own right because of the customer service aspect, it is not perceived to be of any value as a serviceability indicator. ***Due to there being no demonstrable link between asset condition or serviceability and septicity no indicator has been proposed.***

3.2.8  **Potential ‘Level 3’ Sewer Serviceability Indicators**

Critical Sewers as defined in the Sewer Rehabilitation Manual are identified in current returns to Ofwat and reflect assets that are expensive to repair and cause major disruption in the event of failure. Most companies however have several thousand kilometres of Critical Sewers making it impractical to routinely monitor the condition of all of these assets. The production of a probability of failure (collapse) within a particular cell, when correlated with the presence of ‘Critical’ sewers could be used to generate a Level 3 risk indicator which implicitly takes account of the consequence of failure through the prior categorisation of the assets as ‘Critical’.

Alternatively (or in addition) to the above a risk based serviceability indicator could be developed which combines the proposed Level 2 indicators: *Asset State* in terms of sewer collapse probability and *Customer Impacts* in terms of severity of a range of flooding categories (possibly including pollution incidents). The form of the indicator would be as follows:

$$\text{Risk Indicator} = [\text{Probability of Sewer Collapse}] \times [f (\text{flooding incidents, pollution incidents})]$$

(where *f* = ‘some function of’)

This is closely related to a similar indicator for pumping stations (see sect. 4.2.3 below). In order to sum the different categories of flooding some degree of common ‘valuation’ will be necessary. As an interim step this risk indicator could use only DG5 flooding incidents where the cause has been identified as sewer collapse.

3.2.9 Summary

LEVEL 1	<ul style="list-style-type: none"> • Data requirement only. No Level 1 Indicator proposed
LEVEL 2	<ul style="list-style-type: none"> • Indicator 1. Spatial indicator of sewer collapses and equipment failure.  • Indicator 2. Severity rating and spatial indicator of DG5 flooding events caused by sewer collapse and equipment failure.  • Spatial and severity analysis of combined DG5 Non-DG5 flooding incidents to be developed  • Spatial analysis of pollution incidents   Proportion of sewer system surcharged.
LEVEL 3	<ul style="list-style-type: none">  Future consideration of the following:  RI₁ linking Probability of sewer collapse to Critical Sewers.  RI₂ linking Probability of sewer collapse to Flooding (and Pollution) severity.

Table 3.1 Summary of Sewer Serviceability Indicators

3.3 Combined Sewer Overflows

3.3.1 Background

Following the improvement in the standard of effluent discharged from treatment works resulting from the Quality Programme within AMP1 and 2, attention in AMP3 has shifted to intermittent discharges of which combined sewer overflows make up the majority. Around 5500 unsatisfactory Combined Sewer Overflows (uCSOs) remain following the AMP2 programme of which the government has asked that 4,682 are improved during AMP3. This constitutes the largest single area of investment within the AMP3 programme and has a projected cost of £1,700 million over the 5-year period out of a total sewerage capital expenditure budget of £5,120million³.

At present the water companies receive notification from the Environment Agency if an overflow is judged 'unsatisfactory' or in breach of consent. Factors contributing to the classification of a CSO as 'unsatisfactory' are listed within the AMP2 and AMP3 Guidelines and within FR0466, *User Guide for Assessing the Impact of CSOs (1994)*. These include:

- Operation of the overflow in dry weather.
- The presence of sewer related litter.
- The presence of sewage fungus.
- The occurrence of a pollution incident attributable to the operation of the overflow.
- Assessment of the amenity value of the receiving watercourse, current access and related impact of discharges.
- History of justified public complaints.

By and large this information is obtained on an ad hoc basis resulting from a combination of public complaints, pollution incidents and inspections. As part of the AMP3 programme the Water Companies informed the Agency of known problem outfalls which were assessed against the criteria described in the AMP2 and AMP3 Guidance notes. If these resulted in an 'unsatisfactory' rating by the Agency, the overflow was added to the Company's Quality Programme. At this stage it was in the Company's interest to notify the Agency of 'unsatisfactory' overflows since provision for funding the required improvement was made within Ofwat's AMP2 and AMP3 determinations. No systematic assessment programme for checking the performance of all overflows against these criteria has been implemented.

As part of the 1999 Periodic Review (PR99), the Agency proposed as national policy that all intermittent discharges found to be deficient after April 1999 would be regarded as new deficiencies resulting from growth/new development, deterioration through lack of maintenance, or possibly through indirect effects of addressing levels of service such as DG5 property flooding.

Consequently these unsatisfactory intermittent discharges would not be eligible for funding under a Quality driver, but would be remedied under Base Maintenance, Supply/Demand or Levels of Service. This has significant implications for the industry, due to the impact this would have on customers' bills.

³ Periodic Review Determination, 2000. Ofwat

3.3.2 Development of a Potential CSO Serviceability Indicator

Deterioration in Asset Condition of Satisfactory CSOs

At present both the total number of intermittent discharges and the number of unsatisfactory intermittent discharges as notified to the companies by the Environment Agency is reported in the June returns to Ofwat. There is however currently no programme in place for the routine inspection of CSOs. In addition there is no planned appraisal or assessment of the effectiveness of the investment programme carried out within the AMP2 and AMP3 periods. The Agency is not resourced to carry out this work and it is not in the Water Company's interest to undertake this unilaterally since no further funding from the Quality Programme is available. *This situation is unlikely to change until there is a business driver in place to provide an incentive for routine assessment.*

The link between asset condition and asset performance for CSOs is by no means clear. The majority are simple overflow weirs with little or no capability for retaining pollutants within the system. This is overwhelmingly the case for the CSOs not rated as unsatisfactory. For these assets, deterioration in condition is not likely to be manifested by a measurable reduction in performance unless there is a major structural failure. Structural deterioration may be little or no slower than that of the sewers themselves with maintenance or upgrading driven by failure or the requirement for additional quality investment on a site-by-site basis.

For the 25,000 CSOs not rated as 'unsatisfactory' there are a number of scenarios:

1. Little or no impact on receiving watercourse with no upgrading required in the medium to long term. Maintenance is provided on an as needed basis.
2. The impact of the overflow has not previously been recognised. Assessment of the overflow shows that it has a demonstrable negative impact on the receiving water fulfilling the classification of 'unsatisfactory' and requires a quality improvement to be made.
3. An improvement in the quality of the receiving watercourse makes the impact of the overflow 'unsatisfactory' and therefore investment to improve the quality of the discharge is required. A tightening of consent would be required with 'Q' funding provided for the CSO upgrading.

None of these three scenarios however present a significant Capital Maintenance requirement.

Within Table 16 of the water company's June returns to Ofwat there is the requirement to report the number of intermittent discharge structures, the number of intermittent discharges considered unsatisfactory by the EA and the number of other unsatisfactory intermittent discharges.



Proposed Level 1 Indicator - CSOs

For the purposes of Capital Maintenance planning, the point at which a CSO becomes or is likely to become unsatisfactory as a result of general deterioration must be identified. If this process is to be predictive this judgement can only be made if there is an ongoing assessment programme that allows the rate of deterioration in performance and / or asset condition to be made. The rate of asset deterioration is likely to be slow for the reasons outlined, particularly in CSOs not fitted with mechanical components such as screens.

It is proposed that the routine reporting of the structural condition grade of CSOs at Periodic Reviews be introduced utilising the same criteria currently used for the sewer pipe infrastructure. If the entire CSO asset base is assessed on a rolling basis this will allow a

picture of changes in the asset base condition to be built up. Given the expected slow rate of deterioration following an initial assessment of the entire asset base, subsequent reporting of a proportion of the assets at each Periodic Review is likely to be sufficient. This information will provide a dedicated Serviceability Indicator that will directly relate to Capital Maintenance requirements. It is therefore proposed that the condition grade of a proportion of the CSO asset base be reported at each Periodic Review. For initial consultation purposes a figure of 1/3 of each company's CSOs is proposed with the assets being subdivided by area to avoid the possibility of 'cherry picking'.

Biological Monitoring

The only practical way that we have identified of monitoring the performance of CSOs on a wide scale is to use the FR0466 type procedures together with biological monitoring. The outputs from biological sampling are not always clear-cut but are capable in many cases of providing results to which a high degree of confidence can be attributed. The methodology adopted for assessment within the Yorkshire Water area is based on the RIVPACS II procedure that is in general use by the Agency.

It is anticipated that in the longer term the requirements of the Water Framework Directive will drive the need for the assessment of impact of point discharges such as from CSOs. At present there is no such requirement and routine biological monitoring is carried out 'only' for 3000 river reaches on a minimum frequency of once in 5 years. The results cannot usually be directly related to the impact of a particular discharge. The cost implication of routine biological monitoring for all CSOs is significant. Typically a minimum of two samples taken over two seasons, at least two months apart and not during the winter is required. Analysis of the macro invertebrates obtained typically takes a trained biologist 1 to 2 days. Since discharges are deemed to be 'innocent until proven guilty' however it is likely that there are many having a negative impact on the receiving water course that are currently not identified as unsatisfactory.

Any requirement by the regulator for the companies to demonstrate the effectiveness of the investment solution will impose an additional element of risk as well as the cost of the appraisal itself. The argument has been put forward that if a UPM approach has been adopted and correctly implemented for a particular scheme then the solution should *de facto* be satisfactory. Auditing of some schemes via post project appraisal would however validate not just the impact of a particular overflow on a watercourse but the adopted design approach.

This is likely to be of particular significance where a Risk Based approach as promulgated in the UPM Manual is adopted as an alternative to the emission standard. Evidence from studies using this approach have shown spill frequencies from 5 to 30 per bathing season to be acceptable with considerable savings in terms of reduced stormwater storage and pumping costs compared with schemes which are designed to ensure an absolute emission standard of no more than 3 spills per bathing season⁴.

Techniques for assessing CSO performance have been developed. Yorkshire Water are currently employing a combination of the methodology prescribed in FR0466 (FWR Report: *User guide for assessing the impact of CSOs, 1994*) together with biological monitoring of macro-invertebrates upstream and downstream of discharge points. This has then been

⁴ Hutchings. C. Bathing Beaches – Three spills too few? Conference on UPM, AMP3, CSOs and Consents, May 2000. HR Wallingford.

compared with the predictions from UPM studies for the particular discharge and watercourse. The motivation for this has been that a number of their overflows have previously been flagged as requiring upgrading but it was not clear whether a 'Quality' related upgrade or purely aesthetic upgrade was required. Survey work has been used to confirm the assumptions as to which CSOs fall into which category and to obtain funding for remedial work under the Quality programme.



Proposed Future Level 1 Indicator – Biological Impact

To supplement the proposed Asset Condition Grade Indicator for CSO structures it is proposed that a biological impact indicator be introduced. In common with the condition grade indicator this is viewed as a long term indicator for which information is collected on a rolling basis covering at least two Periodic Reviews.

A representative proportion of discharges should be assessed, this information will be used to predict the likely performance of the remaining assets. The production of a simple headline (Level 1) indicator 'Number of intermittent discharges demonstrated to have a negative impact on the receiving water course' would be used as a baseline. An increase would clearly be unacceptable. Target reductions over a defined time period would be agreed with the regulator. This would enable the success of an investment programme to meet the objectives to be clearly demonstrated.

3.3.3 Summary

LEVEL 1	 Structural condition grade of CSO. – Proportion of structures in each condition grade.  Biological monitoring of impact of discharges. – Numbers of CSOs giving rise to a significant deterioration in receiving water quality.
LEVEL 2	None currently proposed
LEVEL 3	None currently proposed

Table 3.2 Summary of CSO Serviceability Indicators

4.0 NON-INFRASTRUCTURE SERVICEABILITY

Figure 4.1 provides a summary of existing and proposed indicators relating to non-infrastructure at the conclusion of the project.

4.1 Sewage Treatment Works

4.1.1 Background - Existing Indicators

The two current serviceability indicators for sewage treatment facilities are based on a pass or fail of statutory sanitary determinand consent criteria. These relate to the percentage of works meeting their numeric consents and the percentage of the population served by works that are within consent. These measures are not able to take into account the reasons for failure or the extent by which a works has passed or failed its consent. General changes in performance are therefore not recorded if this does not result in a change in the pass / fail status of the works. There is therefore no mechanism in place that will pick up a gradual deterioration in performance until the works is legally 'non-compliant'.

Consents issued for sewage treatment works can include a large number of criteria, some of which are listed below:

- Look-up table and upper tier limits for sanitary determinands such as BOD, suspended solids, ammonia, nitrates and phosphorus
- Maximum volume discharged per day
- Percentage removal of sanitary determinand (UWWTD)
- Max rate of discharge
- Dry weather flow discharge volume per day
- Unauthorised discharges
- Substantial change to the discharge such that it results in a significant increase in the polluting effects of the discharge
- Degree of retention and treatment for discharge of storm sewage from storm tanks including possible provision of recording systems.

4.1.2 General Approach

A multi-stage approach to the design of treatment works serviceability indicators is proposed based on the current need to enhance the existing indicators and recognition that an 'ideal' indicator will require a level of information that is currently not available.

It is proposed that two long-term objectives in the development of indicators for treatment works are to assess:

1. Whether there is a correlation between the performance of the treatment works and the operational cost incurred.
2. Whether there is a direct relationship between the performance of the asset and the asset condition.

Intuitively both of these hypotheses would appear to be true however the link between asset performance and asset condition is difficult to prove unequivocally without good quality supporting data. Even if the link can be established it may be that the asset condition has deteriorated quite markedly before it impacts performance and this in itself will be of significance when planning capital maintenance requirements. If the asset failure mode is one of rapid deterioration following a prolonged period of stable operation, identifying the start of this phase is of great significance for economic asset maintenance.

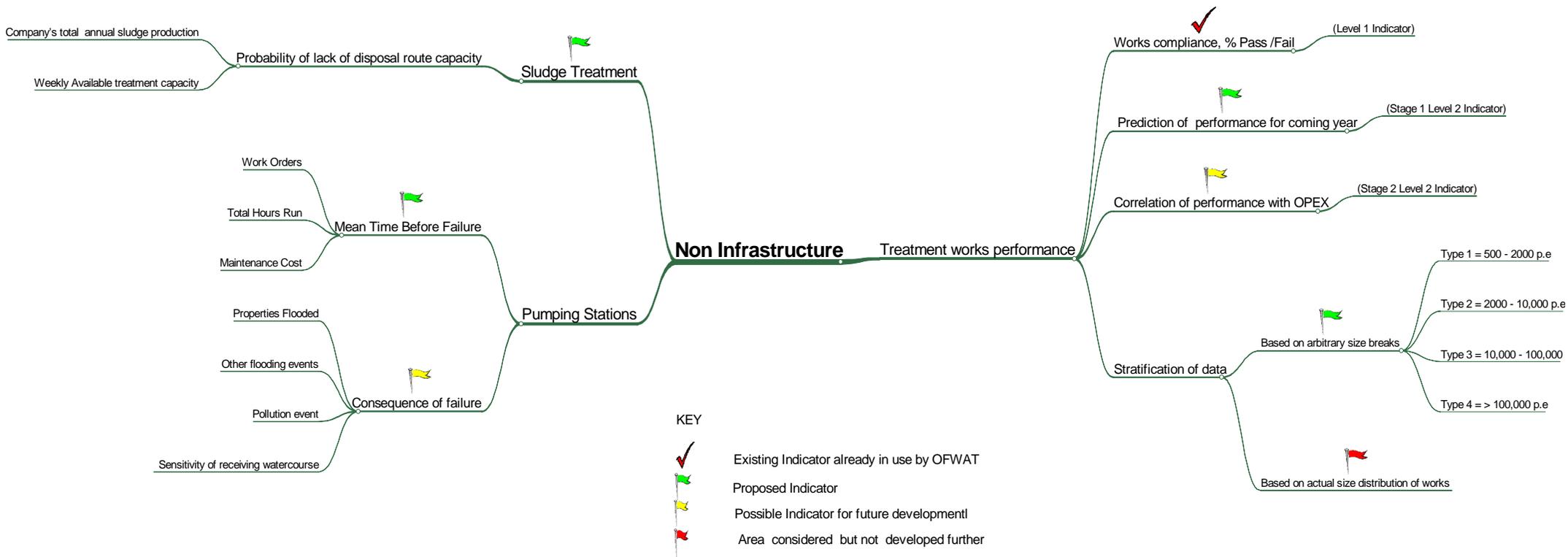


Figure 4.1 Status of Proposed Non- infrastructure Indicators

4.1.3 Development of a Level 2 Treatment Works Serviceability Indicator

The objective of the first stage in this process has been the development of a *forward looking* ‘Level 2’ indicator derived from an analysis of existing treatment works sanitary determinand compliance data. In addition to being forward looking the indicator is required to provide an assessment of the level of performance relative to a given standard, i.e. How good or bad was the performance not just did it pass or fail relative to a particular consent standard.

A detailed description and comments on the analysis methodology and the development of the indicator is given in Appendix B. However the following table summarises the rationale behind the proposed process.

<ul style="list-style-type: none"> The measurements of BOD and Suspended Solids have been used in the analyses to provide general indicators of asset performance. Values for ammonia, nitrate and phosphate could also be used to provide indicators for the performance of these stages of the treatment process. Consent values for these determinands are not currently as widely imposed as for BOD and SS and it would not therefore be possible to aggregate results to the same extent across a company as for BOD and SS.
<ul style="list-style-type: none"> The compliance values for an individual determinand (BOD and SS) are divided by the prevailing consent condition to provide a scale-free quantity. This enables any changes in the consent to be taken into account as well as permitting aggregation across Treatment Works to provide regional and company level indicators of performance as required. It should be noted that the prevailing look-up table consent value may be substituted for any indicator value required, for example the statutory consent value may be substituted for the river needs consent, a maximum value etc.
<ul style="list-style-type: none"> The consent adjusted values will have a distribution of positive values ranging from <1 where the performance betters the consent value, to > 1 where the consent value has been exceeded. The value 1 indicates equality of measurement and consent value.
<ul style="list-style-type: none"> The assessment of the Treatment Works performance can be made using defined characteristics of the distribution, e.g. the mean value of the distribution or the 95%tile value of the distribution. Given such a characteristic an ‘event’ can be defined as occurring when some characteristic of the distribution breaks some threshold value.
<ul style="list-style-type: none"> Values for 3 years of data are assessed and using the Poisson process a probability of one of the prescribed ‘events’ occurring in the coming 12-month period is generated.
<ul style="list-style-type: none"> As data for another year becomes available the oldest year of the previous 3 years’ ‘drops off’ and is replaced by the most recent year generating a new predicted performance for the next year.
<ul style="list-style-type: none"> The statistic is thereby forward looking and indicates the proportion of works in which a particular event would be expected to occur. Data can be looked at for a single works and aggregated upwards to any degree to company or national level.

Table 4.1 Rationale for Level 2 Works Performance Indicator

The constraints, assumptions and limitations of the proposed test are considered more fully in Appendix B.

4.1.4 Future Development of 'Level 2' Serviceability Indicator

It has not been possible to develop the works performance indicator to the point of correlating works performance with operational cost. This has been due to a lack of available cost data. A detailed examination of costs is required to identify which of these relate solely to process and works performance to ensure that other masking costs are not included.

It is strongly recommended that the second stage of this Level 2 indicator should be developed to incorporate costs as it will more clearly show those areas where investment in capital maintenance is required. Although the first stage Level 2 indicator represents a significant step, its use for Capital Maintenance planning purposes will be significantly enhanced by the addition of operational cost information.

At present different companies capture cost information to widely differing degrees and in different ways. It is proposed that a consistent cost reporting structure should be developed by consultation with the water companies and the regulator.

Although it is unlikely that Ofwat would be interested in the operating cost for individual works it is only if information is ultimately available at the asset level that the companies themselves will be best able to ensure that the requirement to “*demonstrate how the flow services to customers can be maintained at least cost in terms of both capital maintenance and operating expenditure ..*” outlined in MD 161 can be met. The process of developing the second stage of this performance indicator is likely to take some time: It is expected that 3 – 5 years of operational cost data will be required before a useful analysis can be undertaken.

4.1.5 Potential for Development of a 'Level 3' Treatment Works Serviceability Indicator

The proposed Level 2 indicator described in 4.1.3 above provides the proportion of works within which an “event” is predicted to occur in the following year where the events are expressed in terms of performance relative to the consent value. We have defined this as a ‘Level 2’ indicator since it does not fully meet the requirements at Level 3 which is to incorporate both *Asset Performance* and *Customer Impact*.

Assessment of failure-consequence for treatment works is dependent on the degree of failure which is highly variable. A tanker load of contaminated effluent may knock out an activated sludge based works and lead to a significant breaching of consent whereas a more minor breach as a result of flooding may have far less significant effects. The quality and size of the receiving watercourse will also play an important part in determining the consequence of any failure.

A stratification of the degree of failure and the related impact would represent a significant and onerous workload and one that presents little obvious benefit over the current system of prosecuting non-compliance and resulting pollution events according to their severity. For these reasons we do not consider that there will be any significant benefit in developing an indicator for works performance that incorporates the varying consequences of different degrees of failure.

There may in the future be merit in examining how the risk of volumetric consent failure might be incorporated into a Level 3 indicator when determining the acceptable volumetric ‘headroom’ that needs to be allowed for prior to new investment.

4.1.6 Development of 'Level 4' Treatment Works Serviceability Indicators

There is significant potential to develop detailed works performance analyses by the companies that will provide better management information. They could, for example, be used to demonstrate the most cost effective processes and optimisation techniques or operating differences between regions. The full potential will only become available once operating cost information to the level of detail described becomes available.

4.1.7 Development of Other Treatment Works Serviceability Indicators

In addition to the existing and proposed serviceability indicators the issue of performance with respect to non-sanitary determinands, particularly volumetric consent criteria is of note. Many works have historically not recorded the volumes treated however most will be fitted with flow meters during the AMP3 period. Where there is no evidence to the contrary the Environment Agency has typically assumed that works are operating within volumetric consent, however, some water companies have expressed concern at Periodic Reviews and in June Return submissions that some works have been operating outside of their volumetric consents. This will particularly apply to works which suffer a high degree of infiltration in the associated networks.

From the perspective of ongoing capital maintenance requirements, new or refurbished works are designed for a future flow rate that allows for an element of anticipated growth. If a works is refurbished or rebuilt without checking the flows to treatment there would seem little ground for subsequent compensation through increased capital maintenance in the event that assumptions regarding flows were shown to be too low. Since growth is perceived to be self-funding, capital maintenance could not be used to fund any subsequent requirement for increased capacity.

For works that have been operating outside of their volumetric consent for some years and have not been refurbished there may be an argument on a case by case basis that the company 'inherited' the problem at privatisation and some allowance should be made for whatever additional capital expenditure would be incurred in meeting a new consent issued to reflect the new conditions or redirecting flows to meet the existing consent.

It is not recommended that *volumetric consent compliance* is developed as a general indicator of treatment works serviceability.

4.1.8 Summary

 <p>LEVEL 1</p>	<p>No additional data is required for the proposed Level 2 indicator that is not already collected for statutory works compliance purposes.</p> <p>Collection of operating costs at works level is recommended for further development of this indicator.</p>
 <p>LEVEL 2</p>	<p>Three indicators giving the proportion of works for which an event is predicted in the next year where 'events' are described in terms of the BOD and SS consent values:</p> <p style="margin-left: 40px;"> I_1 Extreme Event: Max value > 2.0 consent I_2 Borderline: 95%ile > 1.0 consent I_3 Poor performance: Mean value > 0.5 consent </p> <p>Further development is recommended to relate the above indicators to operating cost. </p>
 <p>LEVEL 3</p>	<p>Development not recommended.</p>
 <p>LEVEL 4</p>	<p>Development recommended after further development of Level 2 indicator to incorporate operating costs for the purpose of local cost/performance optimisation.</p>

Table 4.2 *Summary of Treatment Works Serviceability Indicators*

4.2 Pumping Stations

4.2.1 Background

Pumping stations represent a significant proportion of the sewerage asset base with most companies operating and maintaining several hundred spread throughout their areas. At present there is no serviceability indicator to reflect pumping station serviceability although if a pollution incident is caused by a pumping station failure this is reported by the Environment Agency. In practice this represents an extreme and rare event. Most pumping stations are linked to a telemetry system and the failure of a pump or a sustained high-level alarm within a wet well is reported and used to instigate the appropriate response such as a repair team and a tanker to empty the well and prevent a polluting spill from occurring.

Different companies operate different maintenance and replacement strategies. Any serviceability indicator should therefore reflect the service provided by the asset and make no comment on the operation and maintenance regime of the individual company.

4.2.2 Proposed 'Level 1' Pumping Station Serviceability Indicators

Mean Time Between Failures

The proposed pumping station serviceability indicator is based on Mean Time Between Failures (MTBF) for all pumping stations within each of the standard 5 size bands agreed by Ofwat. The MTBF is calculated from total hours run for the station divided by number of Work Orders issued:

$$\text{MTBF} = \frac{\text{Total hours run}}{\text{Number of Work Orders}}$$

The standard pumping station size bands are shown below:

Pumping station capacity including standby	Band 1	Band 2	Band 3	Band 4	Band 5
	<= 5 kW	6 – 20 kW	21 – 100 kW	101 – 500 kW	> 500 kW

Table 4.3 Pumping Station Size Bands

For the purposes of this indicator the Ofwat definition of a pumping station is used i.e. it is defined as an individual site (not an individual pump) and includes both foul, combined and stormwater pumping stations but excludes terminal pumping stations situated at treatment works and excludes inter-stage pumping.

There has been some discussion of the merit of excluding Work Orders that do not relate directly to the ability of the asset to deliver service to the customer, e.g. repairs to compound and building, replacement of hand railings etc. However it is considered that any repairs made are likely to be directly related to what is required to operate the pumping station to the required standard which will include the appropriate level of site security and take into account the requirements of Health and Safety at work. Work Orders not related directly to the performance of the pumping station itself are therefore still considered to be valid.

It is important that each company reports the generation of Work Orders in a similar way to ensure that the figure provided for MTBF can be compared between companies. For the purposes of the indicator all visits to a pumping station that are not a routine inspection and are to carry out some form of maintenance may be considered to be as a result of a Work Order.

The proposed indicator will provide a measure of the reliability of each pumping station and thereby its ability to deliver service to customers. When aggregated over different company areas it will provide a means for companies to check the reliability between these areas and when assessed over a number of years the indicator should show whether the pumping stations within each size group of a company are becoming more or less reliable.

Flooding caused by pumping station failures

Whereas the above MTBF indicator is a measure of asset state this second indicator measures the impact on customers of a pumping station failure in terms of internal flooding to property. This can be regarded as a further enhancement of the existing DG5 flooding indicator discussed in 3.2.3 above in the context of sewer collapses and equipment failures.

It is proposed that the indicator be reported as the pair of values:

- Number of pumping station failures causing flooding, and
- Number of properties flooded

in each of the above pumping station size bands.

For the purposes of future development of this indicator the wider flooding and pollution impacts of pumping station failures will also need to be gathered in common with the same information for sewer collapses and equipment failures. This is discussed further in 4.2.4 below.

4.2.3 Future Development of a 'Level 2' Pumping Station Indicator

A further level of refinement to the MTBF indicator is to include the cost associated with each Work Order (as has been done by one of the volunteer companies in the study) so that the total maintenance cost of each pumping station can be calculated. Changes in maintenance costs can then be demonstrated in order to maintain a stable level of asset performance.

4.2.4 Future Development of a 'Level 3' Pumping Station Indicator

It is recommended that the development of a Level 3 risk based indicator should be considered by incorporating an assessment of the consequence of pumping station failure. This has not been feasible within the current study owing to lack of data.

The following are likely to amongst those areas considered in this type of assessment: the number of properties flooded, gardens, highways and other non-reportable areas flooded, sensitivity of water course receiving untreated sewage in the event of a discharge etc.

The recommended enhancement of the sewerage flooding indicator suggests that additional data concerning flooding incidents is collected, including the above categories, and also requests identification of cause e.g.. sewer collapse, pumping station failure etc. This additional data once collected will enable the feasibility of a Level 3 indicator to be considered. The possible form of a risk based serviceability indicator could be as follows:

Risk Indicator = [probability of failure] x [*f* (flooding incidents, water course sensitivity)]

Assuming that pumping station failures are Poisson events the probability of failure in this case may be calculated from the MTBF. The consequences function is likely to be more complex and implies that some degree of common 'valuation' will be necessary in order to sum the different flooding categories. As an interim step this risk indicator could use only DG5 flooding incidents where cause has been identified as pumping station failure.

4.2.5 Summary

 <p>LEVEL 1</p>	<p>Total hours run in year for all pumping stations. Numbers of Works Orders generated for all pumping stations.</p> <p>Number of pumping station failures causing flooding and numbers of properties flooded.</p> <p>Flooding incidents in range of categories arising from failure (this is common with the sewerage indicator, see sect 3.2.).</p> <p>Mean Time Before Failure (MTBF).</p>
 <p>LEVEL 2</p>	<p>Incorporation of cost into MTBF indicator.</p>
 <p>LEVEL 3</p>	<p>Feasibility to be considered following collection of Level 1 measures and assessment of 'subjectivity' in assessment protocol.</p>
 <p>LEVEL 4</p>	<p>Development by companies as required.</p>

Table 4.4 *Summary of Pumping Station Serviceability Indicators*

4.3 Sludge Treatment and Disposal Systems

4.3.1 Introduction

A serviceability indicator for sludge disposal should be a tool that assists Ofwat in assessing the W&SCs' requirement for capital maintenance spend on sludge disposal equipment. The indicator should also act as a tool that assists the W&SCs in running their sludge disposal facilities efficiently and assist the planning of infrastructure that can be relied upon to securely meet the loads placed upon it. We have set out an outline methodology for achieving these aims. However, no data has been available for the testing of this methodology and considerable further development and consultation will be required.

The route of sewage sludge from production in the STW to satisfactory disposal generally involves several stages some of which are operated on a continuous basis and some of which are operated only intermittently (e.g. only during the hours of the working day). There are many different ways to organise the sludge treatment and disposal route. The processes selected will vary on a site specific basis but will have to meet the requirement that the process must be able to convert the raw sludge to a sludge product that meets a specification acceptable at the disposal site. Figure 4.2 illustrates some major treatment stages in the sludge disposal process.

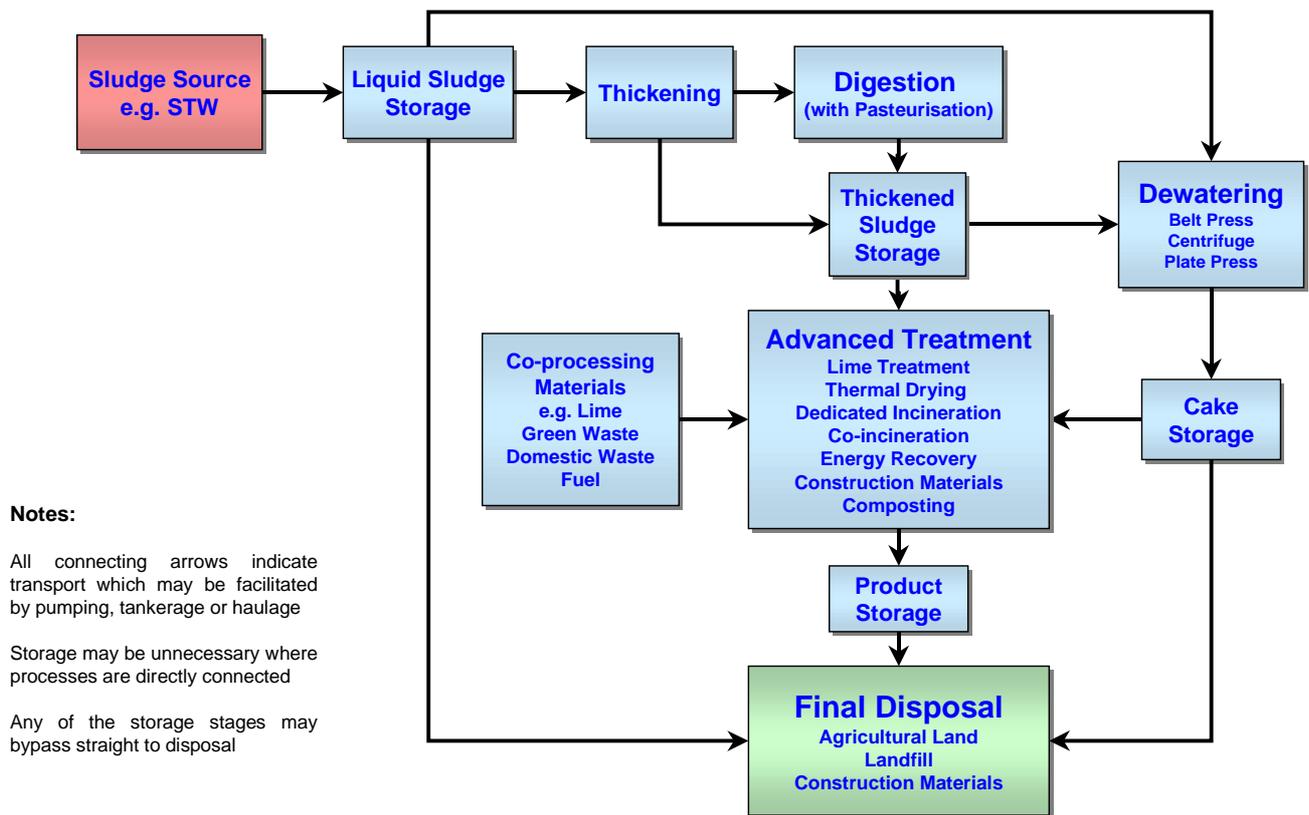


Figure 4.2 Simplified Sludge Production ~ Disposal Routes

For any given route the non-availability of any one treatment stage on that route may render the entire process stream ineffective. For example sludge disposal will fail if the disposal site specifies a dried digested sludge but the required drying equipment is unserviceable, or, if a lime stabilised sludge cake is being produced but there is insufficient storage to hold the product until fields in the land bank are in the correct stage of the crop cycle for the application of the sludge. For the assessment of the serviceability of facilities it will be necessary to identify the primary routes through the system.

4.3.2 Approach to Serviceability Indicator Development

There are no existing serviceability indicators for the sludge treatment and disposal system. At present the regulatory standards applied to sludge disposal facilities are largely descriptive so it is not practical to attempt to derive an indicator based on performance against a quality standard. However, the quality requirements for sludge products should become more clearly defined next year following agreement of an updated Code of Practice for Sludge Disposal (COP), it may then be possible to derive quality related indicators.

It is proposed that the serviceability indicator for sludge disposal should be based on a comparison of the available capacity of a sludge disposal route and the load being placed upon it.

Any sludge producer should assess their capacity to satisfactorily dispose of their sludge on a periodic basis. Managers of sludge treatment centres should complete an assessment of their capacity to collect, store, treat and dispose of sludge in the context of the sludge disposal route in which they operate.

When treatment stages are unavailable there should be, and usually are, alternative routes available. However, the use of these alternative routes may have cost and capacity implications, e.g. using up transport capacity or overloading a particular final disposal site. Ultimately the alternative routes may become saturated and no longer available.

A manager of sludge disposal at company level will want to know which sludge disposal routes are unavailable for any reason. However, for the purposes of assessing capital maintenance investment the indicator should be calculated to reflect unavailability due to reasons directly related to the condition of the assets and excluding growth or changes in the standards for disposal sites.

Development of Serviceability Indicators for the Sludge Disposal Process

To assess the capacity of a sludge disposal route, data regarding the performance of each treatment stage and inter-stage conveyance must be assessed in the context of the whole sludge disposal route. Indicators may be developed in accordance with the proposed “Staged Development” framework. The following sections describe an outline of possible procedures for each stage of this framework.

4.3.3 Base Data Requirement and Level 1 Indicator

The information required for periodically assessing the condition of sludge disposal facilities should be as follows:

- a) Quantity of raw sludge requiring processing
- b) Rated capacity of treatment stages when in full working order
- c) Rated capacity of treatment stages as available
- d) Normal operating hours of treatment stages
- e) Potential maximum operating hours of treatment stages (utilising overtime)
- f) Periods of time for which treatment stages were not available
- g) Reasons for non availability of capacity or availability of sludge disposal route
- h) Actual capacity of sludge disposal route utilised (i.e. quantity of sludge processed)
- i) Degree and consequence of using alternative treatments or routes
- j) Specific quality information, e.g., incinerator flue-gas air quality, odour control equipment performance, microbiological pathogen content or relative reduction, heavy metals content of sludge applied to land compared with heavy metals content of soil
- k) Sustainability of disposal site (Number years site will be able to accept sludge before becoming full).

Some of this data may be obtainable at present but other items may require the installation of additional monitoring equipment or periodic testing of asset performance (e.g. pump efficiency). A management system would have to be put in place to ensure that the data are collected at works level and returned to an appropriate central database.

Initially this may appear to be a lot of information requiring collection and processing but in fact it need not be overly onerous. An initial assessment of each treatment stage's capacity needs to be made (data items b), c), d), e) above). Information required regularly is a record of the amount of sludge to be processed and actually processed (a) and h) above). Other information need be recorded only when there is an event leading to a change in performance. And in most cases only:

- Changes in treatment stage capacity, c)
- Treatment stages being unavailable for a period of time, f), g)
- Treatment stages being run for additional hours, from h)
- Sludge being diverted to other disposal routes, i)

The manager of each works should keep records of sludge quantities through the works and events leading to changes from normal operation at a resolution of days or weeks. For the purposes of assessing availability estimates of sludge flows should be sufficient. It is not proposed that exact measurements of sludge volumes and %dry solids be taken on a continuous basis. The data need only be collated and reported on a quarterly or annual basis.

This information may be used to calculate an indicator of the spare capacity in the system. The exact procedures for carrying out such an analysis would require very careful consideration but the following is an outline of possible procedures for each reporting period:

1. **Identify the Rated Capacity of Each Treatment Stage.** Assuming that stages are in full working order. Throughput would be expressed as a volumetric or mass flow rate as appropriate.
2. **Potential Capacity Available.** Multiply the rated capacity of the stages by the number of normal working hours or days in the reporting period.

3. **Actual Normal Capacity Available.** Calculated as for 2. but taking account of treatment stages that are known not to be performing to their full capacity and subtracting any time the stages have been unavailable due to repairs or maintenance.
4. **Utilised Capacity.** Based on measurements of the actual throughput of sludge. Noting peaks and minima in the quantities held in storage stages.
5. **Extra Capacity Utilised.** Capacity provided by running systems outside of normal working hours.
6. **Use of Alternative Disposal Routes Due to Process Stream Non-Availability.** Quantity of sludge disposed of by extraordinary measures, with reasons for doing so and additional costs incurred and impact on disposal site sustainability.
7. **Calculate Indicator for Stages.** For each treatment stage the indicator would be “Actual Normal Capacity Available” divided by “Utilised Capacity”. If this factor is less than one then this would indicate that the process has been unable to cope with the load placed upon it. The extra capacity required must have been provided by utilising storage, running the plant for longer than normal hours or diverting sludge to an alternative disposal route.
8. **Calculate Indicator for Sludge Disposal Route.** This is taken to be the minimum of the indicators for the individual stages. Thus the indicator will reflect the condition of the sludge disposal route as follows.

Table 4.5 Meaning of Calculated Values of Sludge Disposal Indicator

Value of indicator	Situation described by indicator
>2	Plenty of spare capacity in the system, any system downtime is not impacting on ability to provide service.
1 to 2	Some spare capacity in the system. System downtime may require short periods of running at overtime to catch up.
0 to 1	No spare capacity. Part or all of the route is having to run during overtime to cope with load. This may be due to general overload, downtime or difficulties with disposal sites. Any further mechanical problems likely to have serious consequences.

9. **Record Diversions to Alternative Routes.** Where sludge has been diverted to alternative routes this should be reported as a percentage of total sludge requiring processing and as a volume, Approximate % dry solids and type (e.g. raw sludge, digested liquor or dried cake).

4.3.4 Development of a ‘Level 2’ Spare Sludge Disposal Capacity Indicator

A water company will have available more than one disposal route for any sludge source and the capacity of the whole sludge disposal system can only really be assessed at the company level. A probability based Level 2 indicator is proposed to do this. This indicator will be calculated as follows:

- Define a threshold for the level 1 indicator that is deemed to represent a “Failure Event”, these events will be defined at a range of degrees of severity.
- Trends over a number of years used to develop a forward looking indicator using Poisson techniques similar to those described for the wastewater treatment works indicators.

Thus the Level 2 indicators would be the probable percentage of sludge disposal routes in the company that in the next year will have sufficient capacity to dispose of the sludge load placed upon them with 4 levels of severity:

- 1) *Under normal operating hours,*
- 2) *Utilising available overtime,*
- 3) *Utilising spare capacity in other disposal routes.*
- 4) *Not able to dispose of sludge.*

A differentiation may be made at this stage between failure brought on by growth, serviceability failures and general service failures. Serviceability failures would be when the service capacity is insufficient to meet demand due to mechanical or structural failure of the process equipment. Service failures would be when disposal capacity is insufficient to meet demand for any reason, be that growth, mechanical failure, operational mismanagement or political change resulting in particular disposal routes becoming non-viable.

OPEX data for sludge disposal systems may be included as a co-variant in the calculation of the Level 2 indicator in order to give a greater insight to the condition and operation of the assets.

4.3.5 Potential Development of 'Level 3' Risk Indicator

No risk indicator is currently proposed for development.

4.3.6 Development of 'Level 4' Local Effects

The information may also be used by the Water Company to identify problems and failure risks in particular areas and process units. Of particular importance at this level would be an analysis of the "Bottlenecks" in the sludge disposal system which give rise to the greatest risk of failure to deliver required service by a whole disposal route or region. At this level indicators could be derived for specific processes which have to meet performance targets against quality objectives, e.g. COP for sludge to land, odour emissions, air quality from incinerators.

4.3.7 Summary

 LEVEL 1	<ul style="list-style-type: none"> • Sludge quantities required to be processed and actually processed • Process capacities and 'quality' information • Normal and maximum operating hours • Hours not available • Impacts of using alternative disposal routes • Process operating costs
 LEVEL 2	I ₁ : Actual capacity / Utilised capacity (and range of severity levels) I ₂ : Incorporation of OPEX.
 LEVEL 3	Risk Indicator incorporating probability of inadequate capacity and quality implications of failure.
 LEVEL 4	Analysis of 'bottlenecks' by companies and process failure risks. Performance against product or emissions quality standards.

Table 4.6 Summary of Sludge Disposal Serviceability Indicators

The implementation of this type of systematic sludge disposal analysis system would place some financial and organisational burdens on the W&SCs. However, there would be clear benefits that could be derived in terms of potential for more efficient operation and minimisation of risks. It is likely that these benefits would outweigh the implementation costs.

5.0 SUMMARY OF INDICATORS AND RECOMMENDATIONS

5.1 Summary of Proposed Indicators

5.1.1 Potential new serviceability indicators identified during the study are summarised in Table 5.1 together with the information that will be required to support them. A number of areas for further investigation and development have been identified and recommendations for supporting work are summarised in the asset categories to which they apply and in figure 5.1.

ASSET GROUP	No	INDICATOR PROPOSED	NEW INFORMATION REQUIRED	PRESENTATION OF INDICATOR	INDICATOR LEVEL AND REPORTING DEADLINE
SEWERS	1a 1b	<ul style="list-style-type: none"> Clustering of collapses Clustering of equipment failure 	Location and time / date of collapse or equipment failure events	Number and degree of clustering of incidents within network	Plan Data – JR02 L2 - JR03
	2a 2b	<ul style="list-style-type: none"> Severity of DG5 flooding incidents caused by sewer collapse Ditto for equipment failure 	Location and time / date of collapse Eqp failure events. Numbers of properties flooded	Degree of clustering and impact severity of event	Plan Data – JR02 L2 - JR03
	i	Clustering of all flooding events (to include DG5 and non-DG5) caused by collapses or Eqp. failure	Location and time / date of collapse or Eqp. failure events. Impact severity	Degree of cluster and impact severity of incidents within network	Plan Data – JR02 L2 - Future
	ii	Distribution of pollution incidents	Location, time / date and category of pollution incident	Degree of cluster of incidents in network. By pollution category	Plan Data – JR02 L2 - Future
CSOs	3	Condition Grade of structure	Structural condition grade of overflow as for SCG. Assess 1/3 of total per 5yr period	Proportion of structures of grades 1 to 5	Plan Data – JR02 L1 – PR04
	iii	Biological Impact	RIVPACs assessment for impact on receiving watercourse	Number of CSOs having a negative impact on receiving watercourse	L1 - Future
PUMPING STATIONS	4a	Mean Time Between Failures	Total Hours run Work orders issued	Mean Time Between Failures (MTBF) for each size band of PS	L1 – JR02
	4b	Flooding caused by PS failure	Location and time of PS failure. number of properties affected	Number of incidents and impacts by size band	L1 – JR02
	iv	Incorporation of maintenance cost	Cost resolving work orders	To be developed	L2 – PR04
TREATMENT WORKS	v	Operational Cost:Performance indicator	Operational cost at works level	To be developed	Plan Data – JR02 L2 – PR04
	5a 5b 5c	Performance Predictor	No new information (although the indicator will be more valuable with greater consistency in data collected for comparable classes of works)	Proportion of works for which a defined 'event' is predicted in the coming year based on performance over past 3 years. 4 Size classes	L2 – JR02
	vi	Probability of non-availability of disposal route	Total sludge production rate. Aggregated capacity of disposal system at intervals	Probability of non-availability of disposal route based on 3 years records	Plan Data – JR02 L1 – PR04 L2 - Future

**Table 5.1 Proposed JR02 Indicators and required data
(Indicators for future development numbered in roman numerals)**

5.2 Sewers



5.2.1 Indicators 1a and 1b:

Degree of clustering of sewer collapses and equipment failure

- Spatial and temporal location of sewer collapses and equipment failures

Information required to provide a more complete picture of network. Further work is recommended to identify the most appropriate form of spatial analysis. The work undertaken within this project identifies the degree of clustering within individual cells but does not consider the spatial relationship of clustering that occurs between ‘near neighbours’ or the issue of persistence.



5.2.2 Indicators 2a and 2b:

Flooding severity due to sewer collapses and equipment failure

- Spatial and temporal analysis of reportable flooding incidents caused by sewer collapses and equipment failure

- Severity of impact in terms of number of properties affected by incident

Analysis to indicate severity of impacts caused by collapses and equipment failure. Longer term analysis of trends will indicate whether impact is increasing or decreasing and can be used to predict future impact.



5.2.3 Potential Future Indicator (i): Clustering of all flooding events

– reportable and non-reportable including incorporation of impact severity

It is proposed that a capital maintenance focused indicator should be developed that incorporates an assessment of customer impact caused by reportable and (currently) non-reportable flooding incidents. This indicator should incorporate an assessment of the severity of flooding impact of both currently reportable and non reportable events. The indicator should record location, time and severity of impact to best reflect how sewer network performance as directly impacted by capital maintenance is changing.



5.2.4 Potential Future Indicator (ii): Spatial distribution of pollution incidents

It is proposed that the existing pollution incident report be enhanced to include the location of pollution incidents to enable a subsequent cluster analysis and the possible incorporation at a future date of pollution incidents into an integrated network performance indicator. It is proposed that category 3 events are also recorded.



5.2.5 Septicity Indicator – Not recommended for further development

- No demonstrated link between septicity and asset condition

-  **5.2.6 Infiltration Indicator – Not recommended for further development**
- Difficulties associated with demonstrating a link between infiltration and changes in asset condition

5.3 Combined Sewer Overflows

-  **5.3.1 Indicator 3:**
CSO Indicator – Physical Condition Grade of Overflow Structures

In line with current sewer condition grade system and reporting systems the condition grade system will provide a check on the deterioration of intermittent discharges that are not considered to currently have a negative impact on the receiving water.

-  **5.3.2 Level 1 Indicator – Biological Impact of Discharge on Ecology of Receiving Water**
Biological impact assessment of discharge of intermittent discharges on receiving water course combined with assessment of physical characteristics. To provide a baseline against which future changes in receiving water course quality can be assessed. Physical characteristics which may be considered together with biological impact include operation in dry weather conditions, physical evidence of pollution in receiving water course, justified complaints arising from the operation of the overflow, presence of sewage fungus as prescribed in FR 0466 and AMP3 Guidelines.

-  **5.3.3 Level 2 CSO Indicator**

-  **5.3.4 Level 3 CSO Indicator**

5.4 Pumping Stations

-  **5.4.1 Indicators 4a and 4b:**
Pumping Station Failure Indicator – Mean Time Between Failures
Consequences of Failure Indicator – Numbers of properties flooded

It is proposed that base data for total hours run and Work Orders issued is collected to enable the calculation of 'Mean Time Between Failures'. This simple index reflects the reliability of the asset base. It does not however reflect the cost of interventions generated by the Work Orders. For Level 2 the cost associated with each Work Order will be required.

It is proposed that the numbers of pumping station failures causing internal flooding of properties are recorded together with the consequences of failure measured in terms of the numbers of properties flooded. Future enhancement of this Indicator is proposed by recording the wider flooding impacts of pumping station failures.

Results should be reported within size bands agreed by Ofwat as shown below:

Pumping station capacity including standby	Band 1	Band 2	Band 3	Band 4	Band 5
	< = 5 kW	6 – 20 kW	21 – 100 kW	101 – 500 kW	> 500 kW



5.4.2 **Level 2 Pumping Station Indicator** - **Inclusion of Cost in Mean Time Between Failure Indicator**

It is proposed to incorporate the cost of Work Orders into the indicator to reflect a combination of reliability and maintenance costs. Without this information it might appear that one company has twice the Mean Time Between Failure for its assets compared with another whereas the reality might be that on the occasions when visits are made to the ‘more reliable assets’ three times as much is spent as on them. In order to give as unbiased a picture as possible these potential variations in management practices should be accounted for.



5.4.3 **Level 3 Pumping Station Indicator** – **Incorporation of consequence of pumping station failure**

Further work is required to define how risk should best be judged and incorporated into this proposed indicator.

5.5 **Treatment Works**



5.5.1 **Level 1 Indicator – OPEX information at individual works level** • **Further work required to define how and what costs are collected and reported**

Detailed operational cost data at the individual treatment works level is essential if the true whole life cost of the works is to be assessed. This information will enable comparisons to be made between similar works by companies identifying those that are particularly good as well as those that are poor. At the Level 1 indicator level this information can be used to provide a simple cost per head for works of given size. Although this information may not be required in its own right as a lead indicator of asset serviceability it is important information to tie in with works performance data for this purpose. If cost information is to be reported (either directly or in relation to performance) it is important that there is consistency in the way that this information is collected. It is recommended that the information to be collected and the manner in which it is collected and reported is determined through a consultation exercise between Ofwat and volunteer companies to ensure that any proposals are workable and do not result in an undue additional reporting burden and that the data collected has the widest possible use to the companies themselves.

5.5.2 **Indicator 5a, b, c - Predictive works performance indicator**

It is proposed to supplement the existing pass or fail indicators of Treatment Works compliance with a forward looking Level 2 indicator that provides a prediction of the proportion of works for which 3 characteristic events are likely to occur in the coming year based on the previous 3 years of data. Three 'events' are proposed as when considered together they are considered to best 'capture' the overall performance of the works and any underlying trends.

5.5.3 **Level 2 - Future correlation of performance with OPEX**

The next stage is developing a more informative indicator that is better able to account for the effect of interventions to relate the operational costs with the observed performance level. This will require operational cost data to be collected in a consistent format by each water company. It is proposed that this is best accomplished by conducting a consultation exercise with the water companies.

5.5.4 **Level 3 – Development of risk based Treatment Works Indicator**

There is a high degree of complexity and variability associated with ascribing a consequence of failure of a treatment works. A large number of variables would need to be accounted for. The benefit of doing this does not currently appear to justify the effort that would be involved. The development of a Level 3 Treatment Works indicator is not recommended.

5.6 **Sludge Disposal**

5.6.1 **Level 1 Sludge Disposal Data required**

- Total sludge produced within the company per year
- Sludge disposal route capacity (various levels of information required)

Sludge disposal capacity is required on a regular basis (e.g. monthly or quarterly) in order to calculate the proposed Level 2 indicator.

5.6.2 **Level 2 Sludge Disposal Indicator**

- Calculation of probability of lack of disposal route capacity

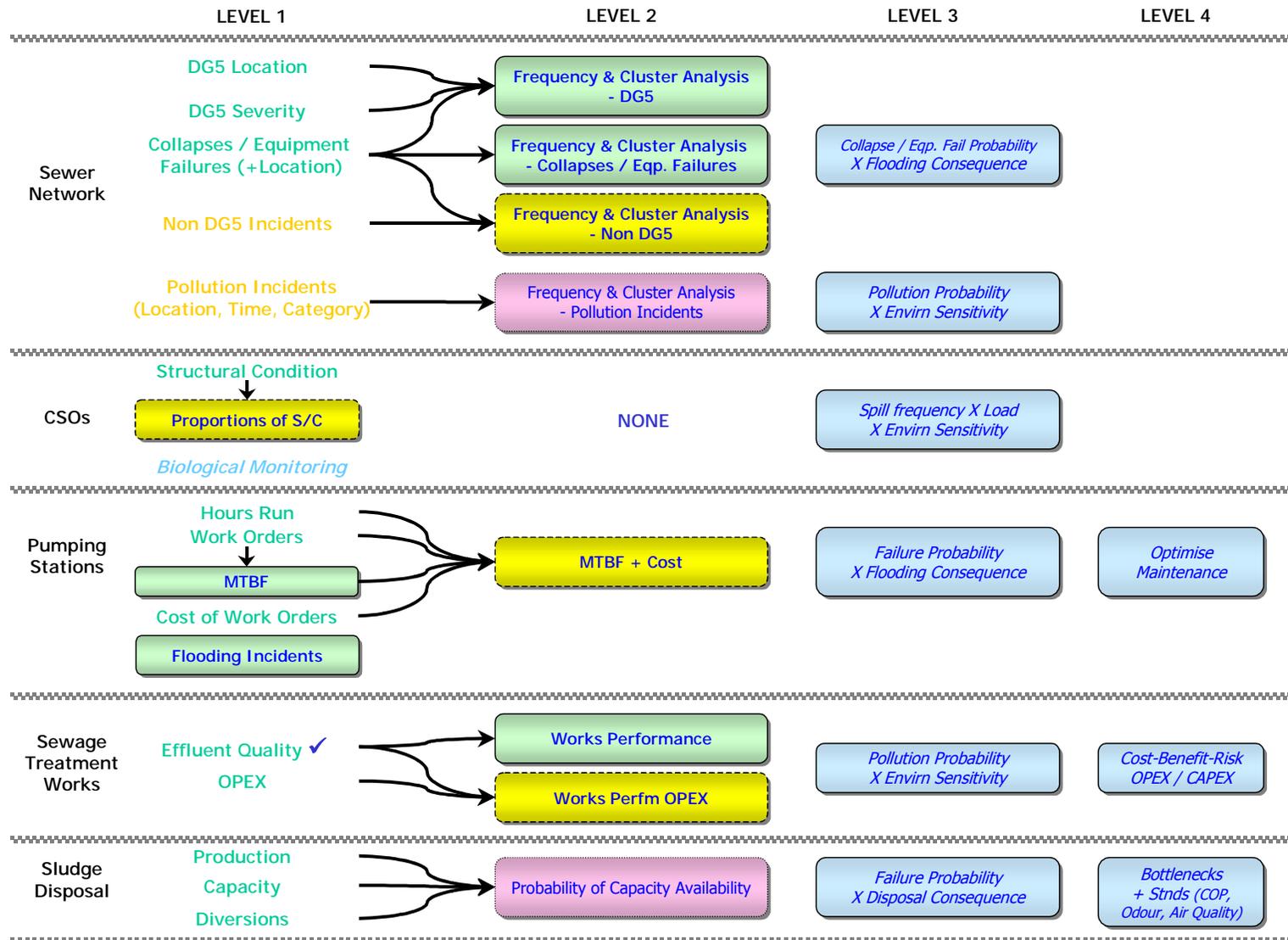
Information provided for Level 1 indicator used to generate a probability of lack of disposal route capacity.

5.6.3 **Level 3 Sludge Disposal Indicator**

- None Recommended

No recommendations are made for the development of an indicator to incorporate risk at this stage. This may develop on publication of the new Code of Practice.

Figure 5.1 – Proposed Indicators



Key to Figure 5.1

Data Already Available ✓

Recommended Data Collection
for JR02

Plan of Data Collection Programme
to be demonstrated for JR02

*Data Collection Requiring
More Planning*

Indicator for JR02

Indicator for PR04

Indicator when Data Available

*Indicator
for Future Development*

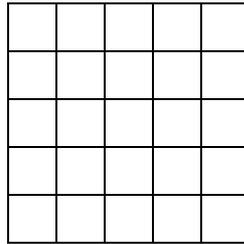
APPENDIX A

CELL CLUSTER ANALYSIS

POSSIBLE METHODOLOGY

A. POSSIBLE METHOD FOR CELL CLUSTER ANALYSIS

- A.1 The following description represents an example of how a simple cluster analysis might be undertaken on events distributed within a particular asset set.
- A.2 Suppose that a company area is 'covered' by a grid of 'N' cells. These need not necessarily be square or rectangular – more sophisticated structures could be used in more detailed *spatial* analysis were the data available to warrant the additional complexity associated with assessing the spatial distribution of incidents. However, a simple grid is suitable for our purposes in discussing a possible approach.



- A.3 The simplest measure – Indicator 2a in Summary Table 5.1, involves the determination of the *proportion of cells* that contains a *proportion of incidents*. For company A, the number of incidents are shown in Figure A1 for years 1998, 1999 and 2000, for flooding incident type 'non-reportable'.

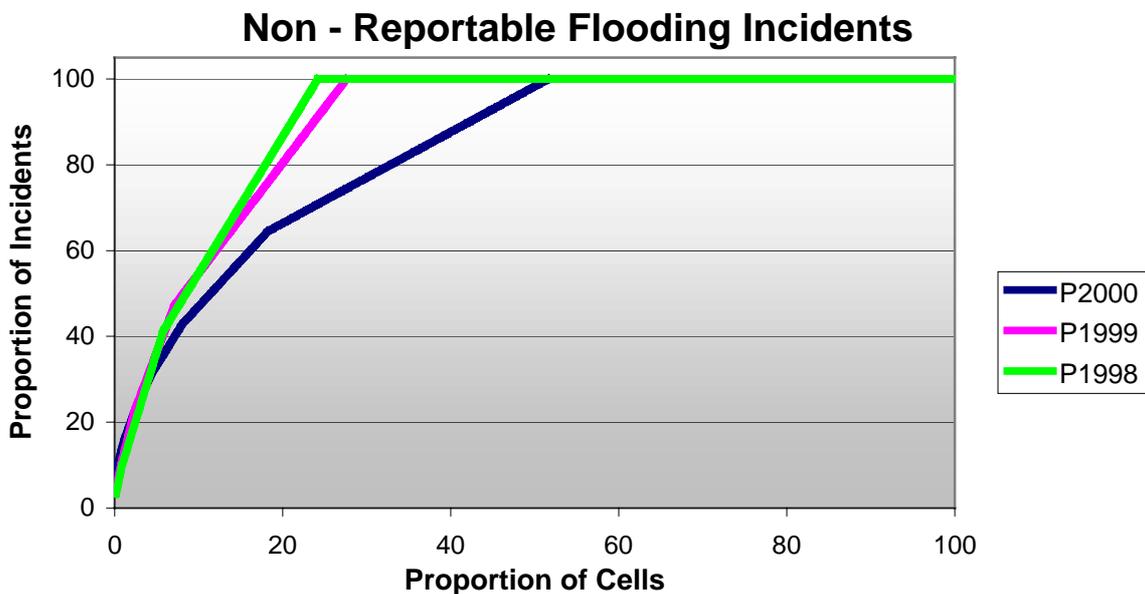


Figure A1

- A.4 This indicator does not capture in a direct way some of the *spatial* features of incidents that might be important to a proper understanding of the nature of the performance of a set of assets.

- A.5 As a first step to do this we might consider the following: the number of incidents of type C is noted within each of the N cells, each year. Under a hypothesis of ‘complete spatial randomness’ we might expect the distribution of cell-counts to follow a Poisson distribution, i.e.

$$\text{Pr ob}[Count = c] = \frac{a^c e^{-a}}{c!}$$

If we let \bar{c} and s_c^2 denote the sample mean and variance of the set of counts (from a grid), then

$$R = \frac{s_c^2}{\bar{c}} \text{ should be } \sim 1;$$

if $R < 1$ the incidents are *more spread out than expected*;

and if $R \gg 1$ the incidents are *more clustered than expected*.

- A.6 The quantity R (Indicator 2 b) can therefore be used as a broad measure to *capture* the extent to which the incidents are clustered or spread out over the network. The results of these calculations using data from Company B are given below:

Table A.1 *Estimated Values of Indicator 2(b) - by Incident Type, within Year*

Year	Non Reportable		Other Causes		Other Causes Blockages		Other Causes Collapses		Other Causes Equipment Failures		Overloaded Sewers	
	No	R	No	R	No	R	No	R	No	R	No	R
1995	3	1.0	616	3.5	4	1.0						
1996	6	1.0	968	4.0	5	1.0					3	1.7
1997	187	1.7	569	3.5	4	1.0	1	1.0	1	1.0	177	3.1
1998	184	1.5	122	1.6	261	1.8	100	1.5	10	1.9	201	11.0
1999	228	1.9			391	2.7	90	2.7	23	4.0	193	7.4
2000	552	5.6			397	4.2	56	2.4	21	7.7	190	5.0

- A.7 Neither of these indicators properly captures the spatial nature of such events – nor are they able to take any account of *space-time* interaction. For example, it may be important to summarise in some way the extent to which problems persist – through time – at the same locations. Also, it may be important to take account of covariate information (e.g. the amount of asset within the cell) in assessing the spatial distribution.
- A.8 It would be possible to construct further indicators, but these would require much fuller documentation of events. Care needs to be taken that proposed methodology is not *over-kill* in terms of the data that can reasonably be collected.

APPENDIX B

TREATMENT WORKS SERVICEABILITY

ANALYSIS METHODOLOGY

B. TREATMENT WORKS SERVICEABILITY

Introduction

It is proposed that a statistical analysis of STW effluent data be used to characterise the performance of the treatment works and that changes in the performance of the works will indicate changes in the condition of the STW asset. This section presents an analysis of data to support the hypothesis that statistical analysis of effluent data can be used to identify trends in treatment works performance. Having proved this it describes the full method used to derive a forward-looking indicator of STW serviceability and presents example results from the analysis of data provided by the volunteer water companies.

B1 Proof of Concept

- B1.1 The primary statistic of works performance is the comparison of effluent quality with discharge consent. Samples of effluent are collected at each STW at least once per month and analysed for a range of determinands. Discharge consents are set at levels deemed appropriate for the nature of the works and the receiving waters with prescribed concentrations of BOD and SS at all works, and also for ammonia at some works and for total oxidised nitrogen (TON) and total phosphorous at a few works.
- B1.2 Compliance with the consent is determined on an annual basis by counting the number of times one or more of the measured determinands exceeds the consent value. A works will be deemed to have failed its consent if more than 5% of the samples contain a determinand which exceeds the consent value. However, the number of samples collected in a year and analysed for the consent compliance is often fewer than the number samples that are required to directly calculate 95 percentile values with a high degree of confidence. The works may only be considered to have failed its consent if there can be 95% confidence that the 95 percentile value exceeds the consent. There are several methods for determining this confidence using parametric fits to the data, the most common method uses look-up tables for the number of samples taken and the required number exceeding consents to determine failure.
- B1.3 The first phase of this project involved testing the hypothesis that changes in the condition of the works will be reflected by changes in the characteristics of the statistical distribution of the effluent data and that trends in these changes may be used to identify works that are deteriorating and headed towards failure and works that are improving their performance.
- B1.4 The first stage of the proof of concept was to examine the shapes of the statistical distributions and see how they changed over time with regard to the Legal and River Needs Consents. The frequency / value histograms of a rolling three years of data were calculated, percentiles were calculated and some possible parametric distributions were compared to the data and measured for “goodness of fit”. Three examples illustrating this analysis are presented below.

Example 1

B1.5 Works A, an example of a works that has improved significantly and steadily over the last 10 years as illustrated by the statistical analysis.

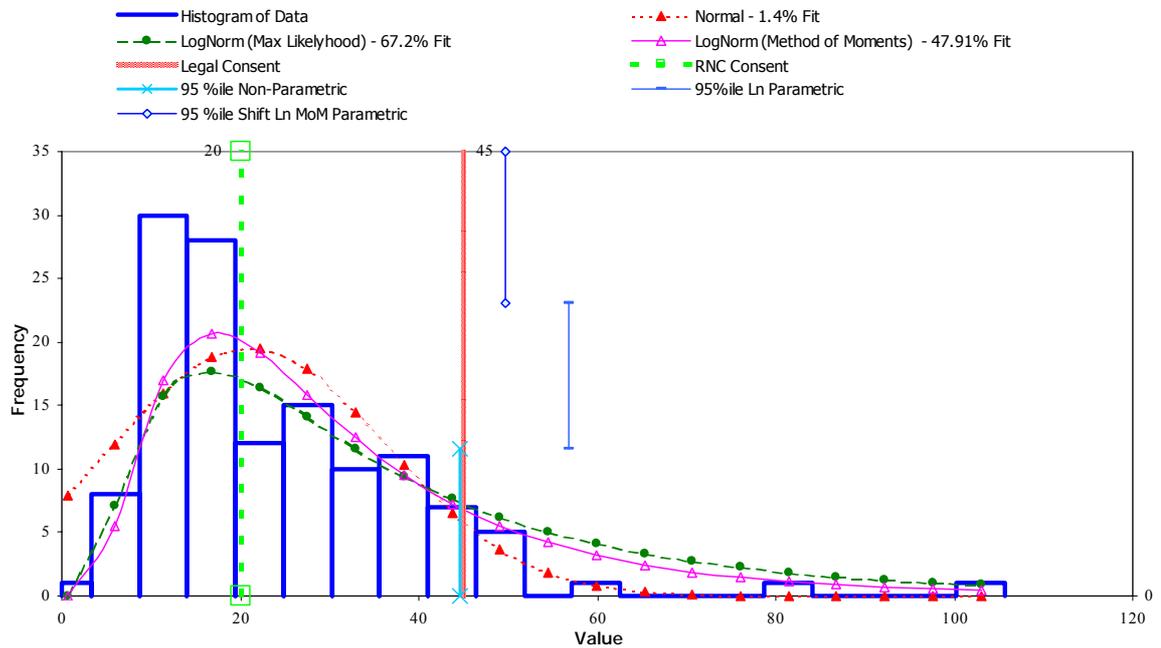


Figure B1.1 – Statistical Histogram of Data from 1990, 91 and 92 from Measurements of Suspended Solids in Works A STW Effluent

Parametric models of the data are compared with the data distribution, the consent 95 percentile limits are shown, as are estimates of the 95 percentile of the data to demonstrate the degree of compliance. It may be seen in Figure B1.1 that this works is just failing, or close to failing its legal consent and is severely failing its River Needs consent during the time period shown.

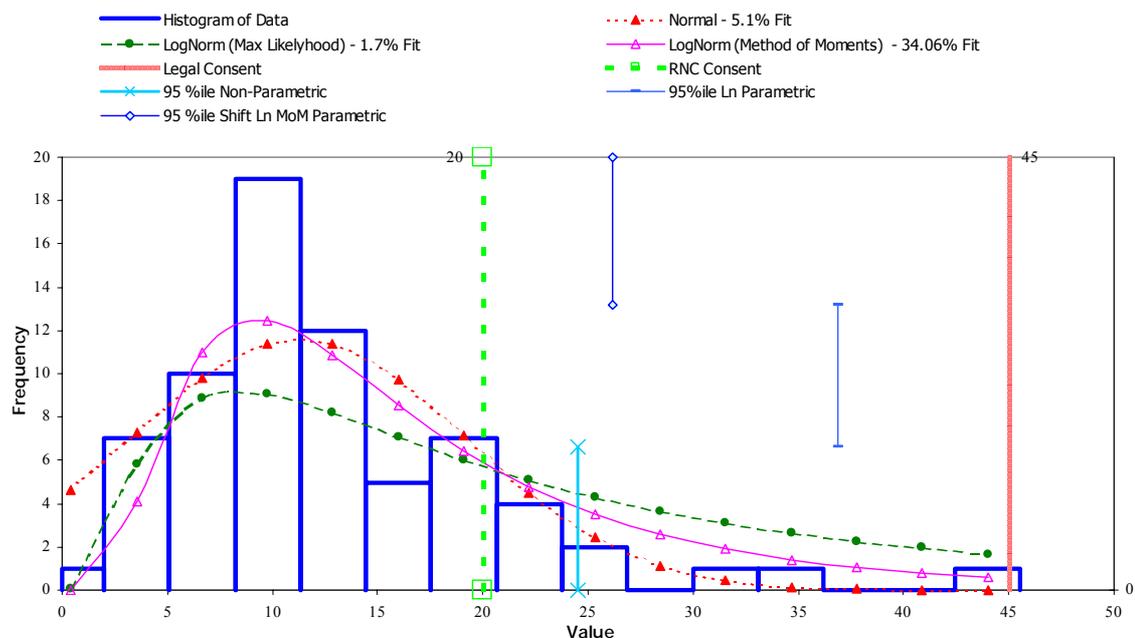


Figure B1.2 – As Figure B1.1 but now for the 1994, 95, 96 Data for the Same Site and Determinand.

Note that in Figure B.2 the effluent quality is well within its legal consent but still fails the River Needs consent.

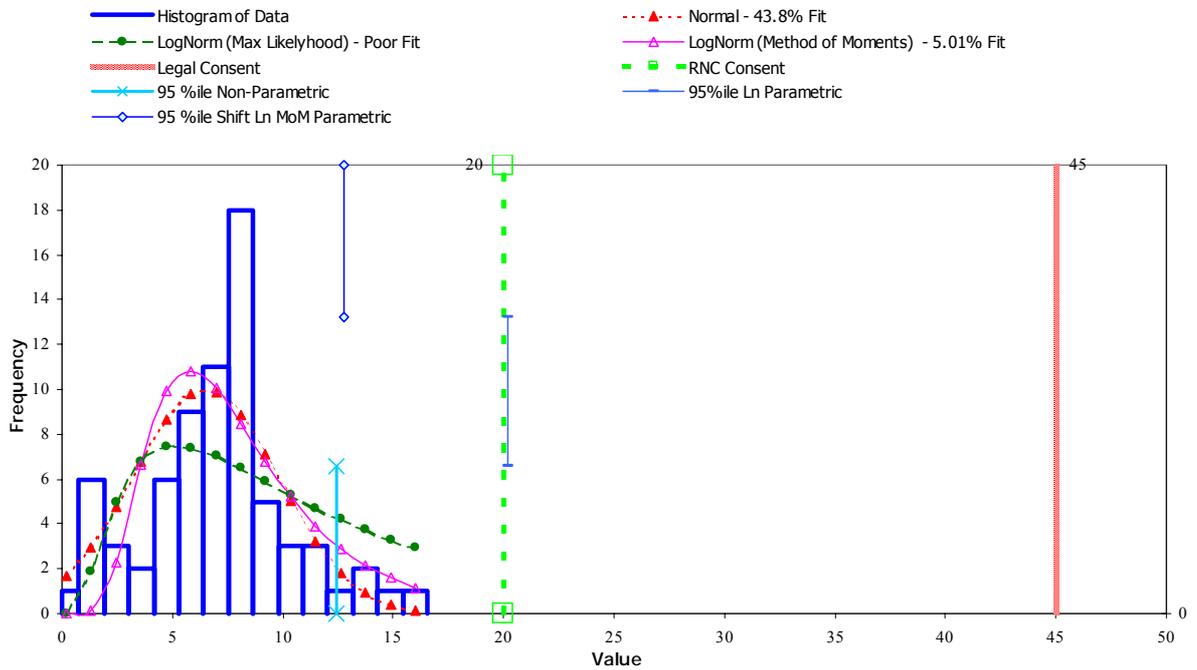


Figure B1.3 – As Figure B1.2 above but for 1998, 99, 2000 Data

In Figure B1.3 it may be seen that the effluent is now within the river needs consent. This behaviour of the change in works performance over time may be quantified by calculating the linear regression through a statistic of the effluent quality distribution. Figure B1.4 shows such a regression. In this case the statistic selected is the index of river needs consent failure.

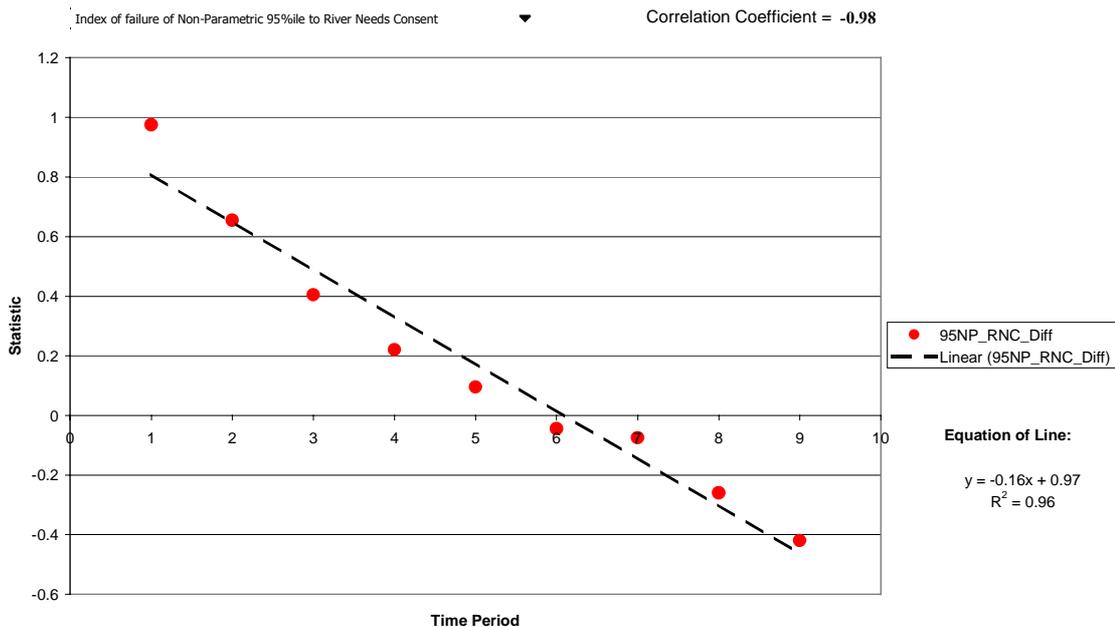


Figure B1.4 – Linear regression through Change in River Needs Consent Index for Works A

This statistic is calculated as the 95 percentile of the data (in this case the non-parametric percentile) minus the consent value and then normalised by dividing by the consent value, a positive number will result where the consent is exceeded and a negative value where the effluent is compliant. Because the statistic is normalised it is possible to combine the results from all three determinands, either by averaging or by taking the highest value of the three.

The same principle may be applied to the plotting of the movement in normalised medians, means or 95 percentiles in order to detect significant changes in the works performance. Figure B1.5 shows how the overall distribution of effluent quality has shifted with time for Works A.

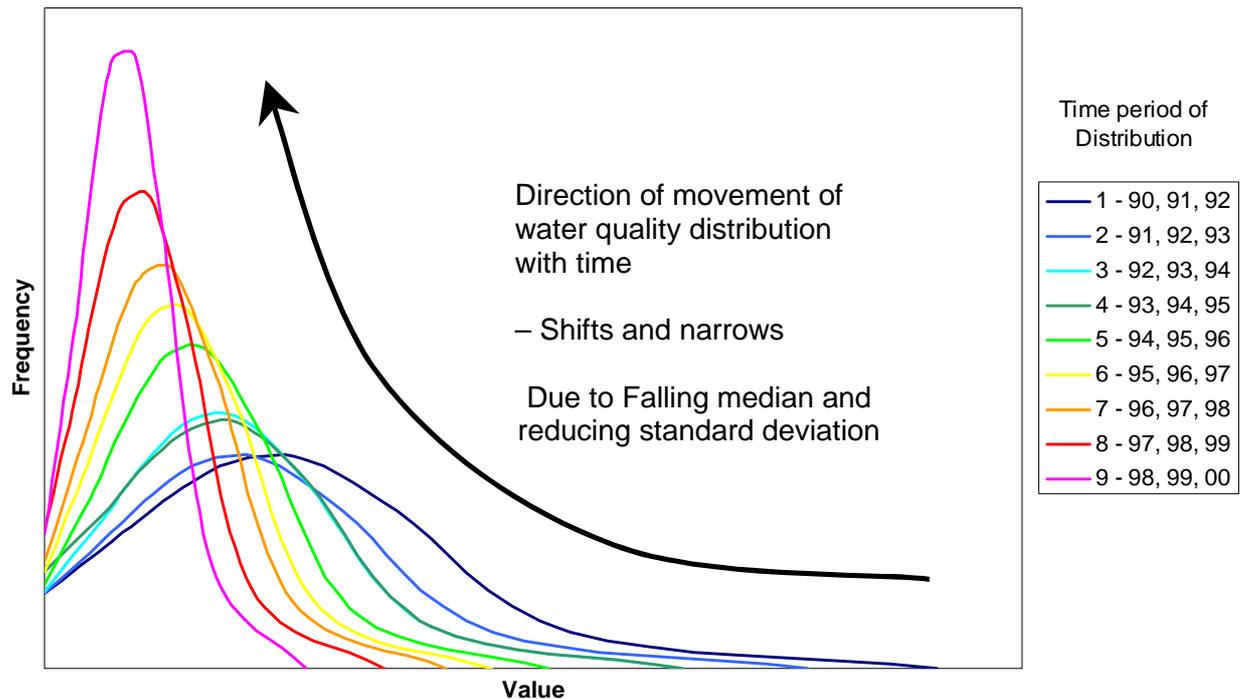


Figure B1.5 – Change in Position and Shape of Composite (SS, BOD, Ammonia) Works Effluent for Works A over A 10 Year Period, Parametric Fitted Distribution Using Method of Moments.

Example 2

B1.6 Example of a deteriorating effluent quality, Works B

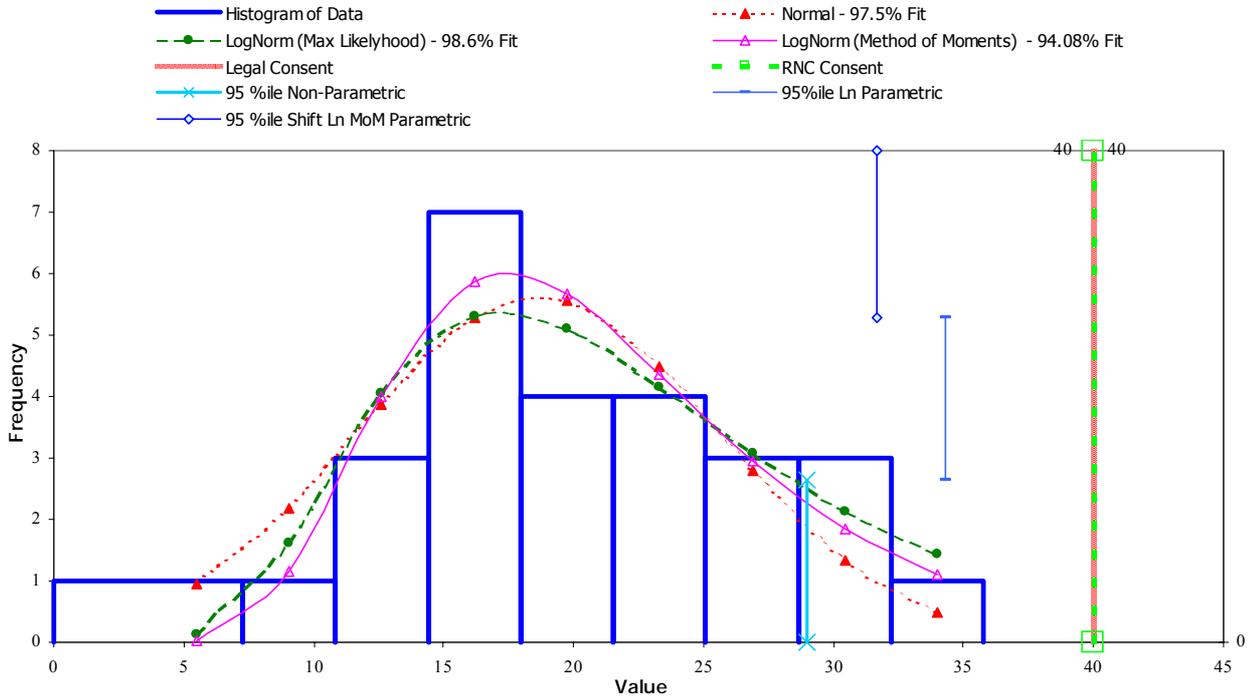


Figure B1.6 - Suspended Solids Data, Works B Effluent, Period 1 – Start 1990 to End 1992

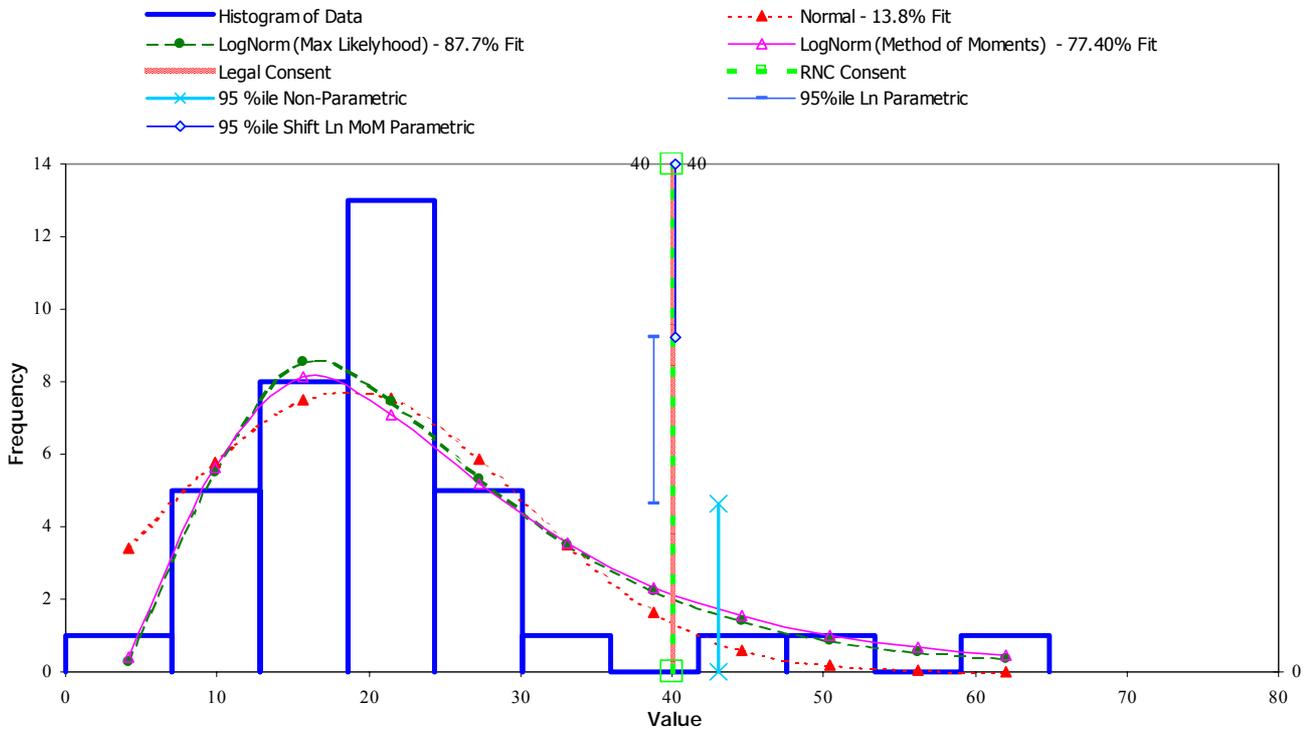


Figure B1.7 - Suspended Solids Data, Works B Effluent - Start 1998 to End 2000

From the Figures B1.6 and B1.7 it may be seen that the effluent quality has moved from secure compliance to likely failure over the 10 year period. Figure B1.8 below shows that trend in the compliance index and Figure B1.9 shows the change in shape of the distributions that characterises the trend at this works (the median remains static but standard deviation increases).

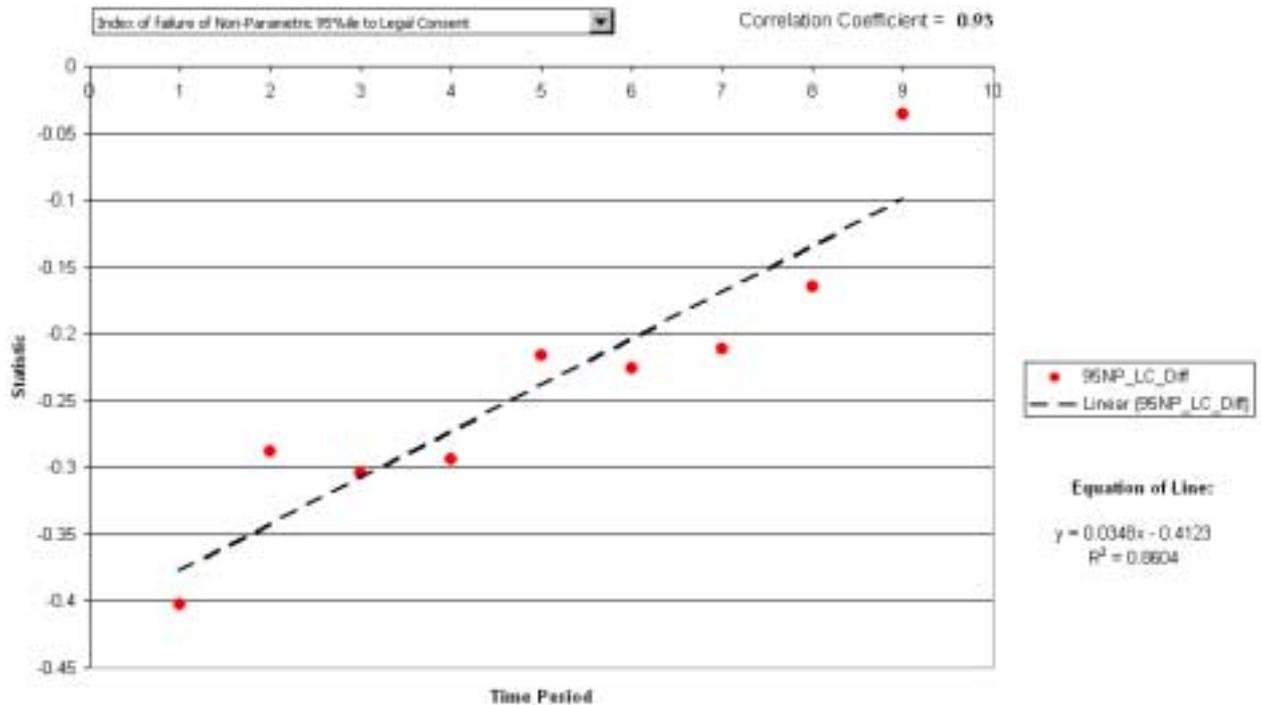


Figure B1.8 – Linear Regression through the Change in Legal Consent Compliance Index for Works B

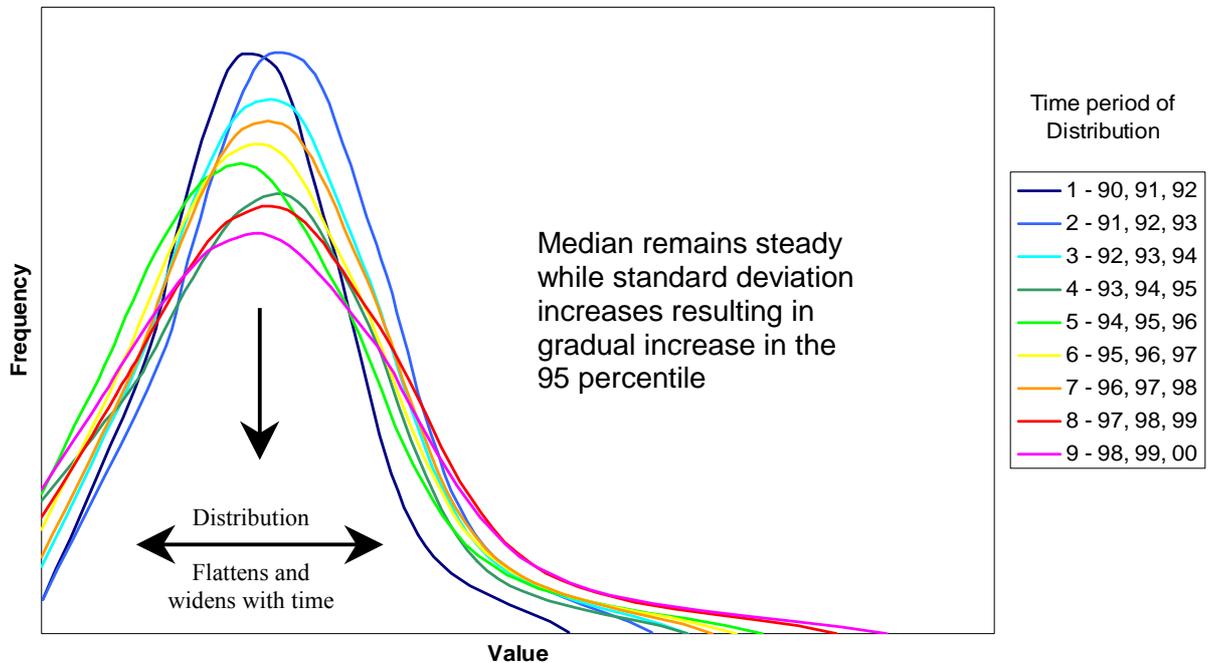


Figure B1.9 – Change in Position and Shape of Composite (SS, BOD, Ammonia) Works Effluent for Works B over a 10 year Period, Parametric Fitted Distribution Using Method of Moments.

Example 3

B1.7 A deteriorating works where the median of the distribution shifts as well as the standard deviation.

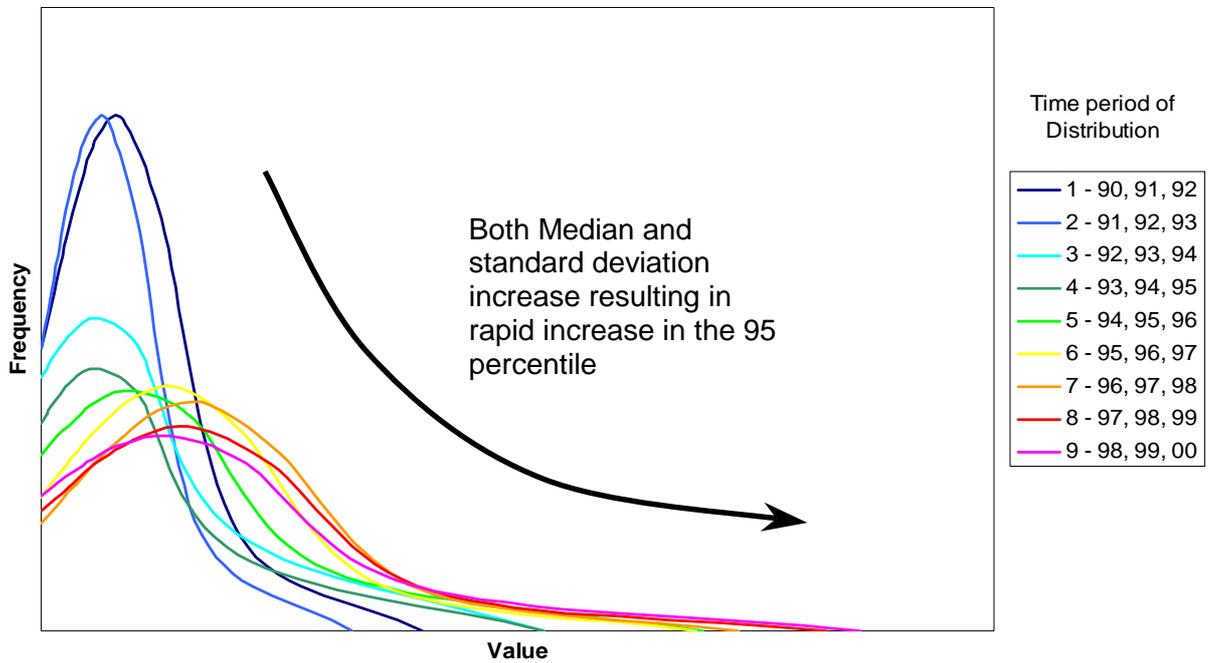


Figure B1.10 – Change in Position and Shape of Composite (SS, BOD, Ammonia) Works Effluent for Works C over a 10 year Period, Parametric Fitted Distribution Using Method of Moments.

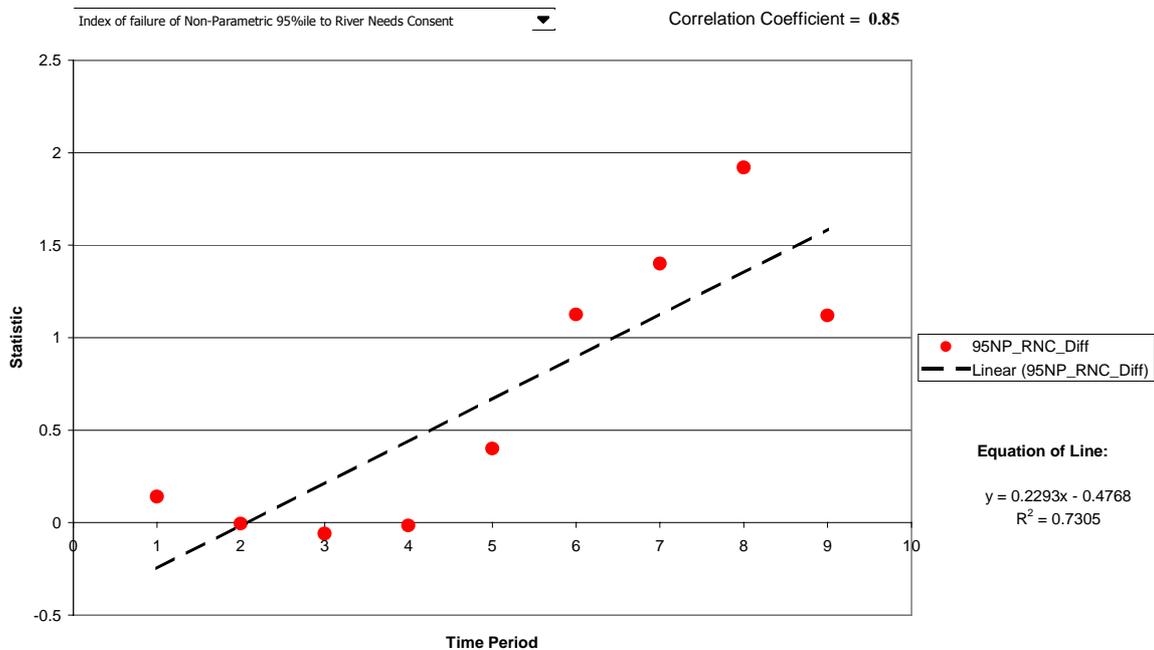


Figure B1.11 – Linear Regression through the Change in River Needs Consent Compliance Index for Works C

In the above examples it may be seen that the distribution has shifted, mostly as a result of one major step in the mid nineties, and that this has brought the site into the area of failure against river needs consent. In this instance the median shifts at the same time as the standard deviation increases.

Summary of Results

B1.8 If the above statistics are calculated for all the works in a company it is possible to differentiate between those works that show a significant improvement over time, those that are deteriorating and those that are remaining roughly constant or are varying from year to year such that a trend may not be determined. Table B1.2 summarises these results for one of the sets of effluent data submitted representing all of that company's works over 500 PE. The results have been divided into stratified groups based on PE of Works. The improvement or deterioration is deemed significant if the correlation coefficient (PMCC) is greater than 0.8 or less than -0.8.

Table B1.2 – Summary of Changes in Works Performance for a Company, Illustrated by Significant Temporal Changes in Index of Non-Parametric 95%ile to Legal Consent, over 10 year Period of Available Data.

Stratification By Population Equivalent		STWs Showing Change in performance				Total Nr Works
		Worse	Better	Worse	Better	
500	2,000	2	272	0.5%	72.1%	377
2,000	10,000	1	134	0.5%	72.4%	185
10,000	100,000	1	52	1.3%	68.4%	76
100,000	1,000,000	0	8	0.0%	57.1%	14
TOTAL		4	466	0.6%	71.5%	652

The above method of analysis appears to be a good long-term measure of trends in the past performance of a company's STWs. However it is not possible to justifiably extend such a linear regression into the future in order to predict the future performance of the works, also this analysis does not differentiate between works that are close to failure and works that are well within their consent. Such a linear regression requires 5 to 10 years data to be significant, an alternative method is required which can make a reasonable prediction based upon a shorter historical period.

It is therefore proposed that rather than a linear regression on trends a Poisson distribution be used for the calculation of a forward looking statistic indicating the probability of defined "Failure" events.

B2 Introduction to Proposed Indicator

- B2.1 This Level 2 indicator has been developed with the intention of providing a more complete picture of trends in the performance of Sewage Treatment Works and to enable a prediction of the likely performance in the coming year based on 3 years of historical data.
- B2.2 The approach adopted has been to assume that the distribution of determinand values is characterised by the Poisson Process. This is used to describe random phenomena that have a low probability of occurrence. A Poisson random variable has an infinite number of possible values, namely all non-negative integers. The distribution thereby allows extreme outliers to be included (rather than discarded) which is of importance when attempting to predict the occurrence of extreme (but rare) events. The statistical process itself is generic and may be used for similar analysis of any data that might be considered to follow a Poisson process.

B3 Works Size Categories

- B3.1 Measurements of effluent quality were provided for a selection of Treatment Works taken from each of 4 size categories of works. These size groups were:

Category	Population Equivalent (pe)
1	500 - 2,000
2	2,000 - 10,000
3	10,000 - 100,000
4	> 100,000

- B3.2 These size categories were arbitrarily selected for this study. A 500 pe works was selected as a minimum since below this some works have descriptive consents. 2,000 and 10,000 pe works represented natural size breaks described in the Urban Wastewater Treatment Directive. A 100,000 pe works was selected as being representative of a 'large' works but a size which each of the volunteer water companies would have examples of.

B4 Method

- B4.1 The measurements of BOD and SS have been used in the analyses to provide general indicators of asset/service performance. These indicators have been developed to be *forward* looking. However, it must be noted that in any forecasting exercise, care should be taken that the forecasting-period is *short-term* rather than *long-term*, unless there is sufficient and sustained constancy in the underlying processes. In the context of STW performance it is not unreasonable to make *one-year ahead* forecasts. This is consistent with the pattern of monthly measurements of various determinands that are taken at STWs.
- B4.2 Each measurement (m) was *divided* by its prevailing consent condition (c) to provide a scale-free quantity ($m^* = \frac{m}{c}$) which *not only* takes account of changes in consent through time *but also* permits aggregation across STWs to provide category, regional, and company indicators of performance.
- B4.3 The consent adjusted values $\{m^*\}$ will have a distribution of possible values ranging from '0' to ' ∞ ' - the value '1' indicating equality of measurement and consent value. It is this

distribution, at each STW and for each determinand (BOD, SS, etc.) that is characterised by the appropriate set of yearly measurements.

- B4.4 The assessment of STW performance can then be made using defined characteristics of this distribution. Given such a characteristic (e.g. the median value of the distribution) it is possible to define an ‘*event*’ as occurring when the characteristic of the sample breaks some threshold (e.g. sample median > 0.4).
- B4.5 The choice of *both* distribution characteristics *and* threshold values have been made to provide indicators that are able to reflect STW performance. It is also important to use a characteristic combined with a threshold value that is able to ‘capture’ *changes* in the underlying distribution of the determinand. A number of candidate indicators were considered including those in the table below:

Event No	Distribution characteristic	Event <i>if</i>
1	Maximum value	> 2.0
2	95%tile (Normal)	> 1.0
3	Mean value	> 0.5

where:

Event [V₁]	Maximum value > 2.0	indicates an extreme event
Event [V₂]	95%tile (Normal) > 1.0	indicates what might be judged a ‘ <i>borderline</i> ’ event
Event [V₃]	Mean value > 0.5	indicates <i>possible</i> poor underlying performance with some <i>potential</i> for an event

These were chosen with a view *not only* to reflect changes that may occur in the distribution of an effluent parameter *but also* to avoid events that are happening either *all-of-the-time* or *none-of-the-time*. Although such events would still represent valid features of the effluent distribution, they would not be useful in monitoring change through time.

- B4.6 Each ‘characteristic-threshold’ combination gives rise to a series of annual events (*compliant or non-compliant*). If the assumption is made that the events are a Poisson process then we can use a simple formula for determining, at each year-end, the probability of failure in the next year. A Poisson process is characterised by a *rate constant*. At each year-end we can use the previous, say, 3-years event data to estimate the rate constant. This has the important advantage that as data for another year becomes available, the oldest of the three years event data ‘*drops-off*’ and is replaced by it.
- B4.7 Indicators **5a**, **5b**, and **5c** are defined for each of V₁, V₂, and V₃ as the *expected* proportion (%) of no event STWs within categories of works type, or region, or for the company as a whole. The values of each indicator are calculated each year as a new set of data becomes available.
- B4.8 The methodology is applied at the level of an individual works and estimated quantities aggregated upwards to categories of works, and to regional or company level as required.

B.5 Examples

B5.1 It should be remembered that the following company comparisons are not made using the same sized random samples of STWs from the works categories. The examples are only illustrative of the kinds of results that might be expected.

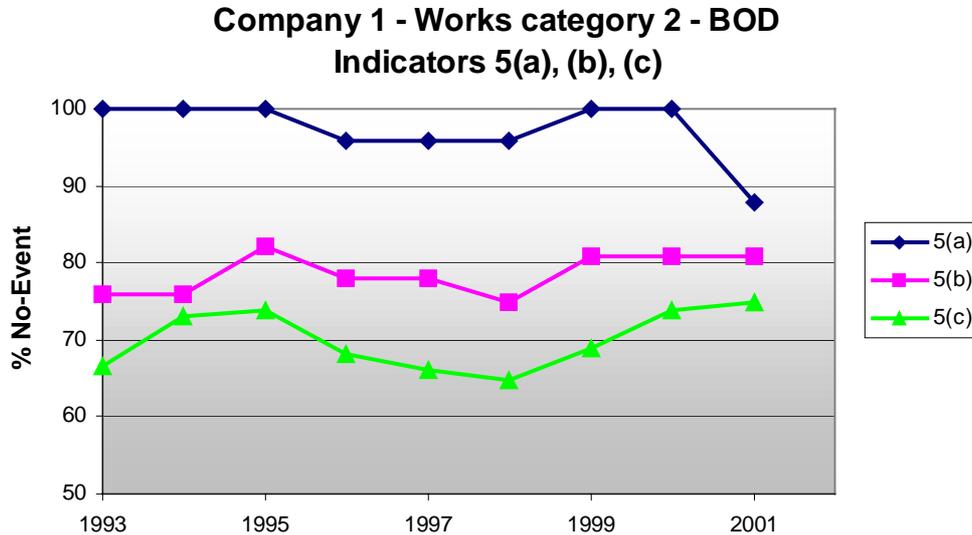


Figure B5.1

B5.2 Figure B5.1 shows that although *borderline* events – as summarised in 5(b) – have remained reasonably stable over the past few years, there appears to have been some improvement in the underlying performance of the STWs – reflected in 5(c).

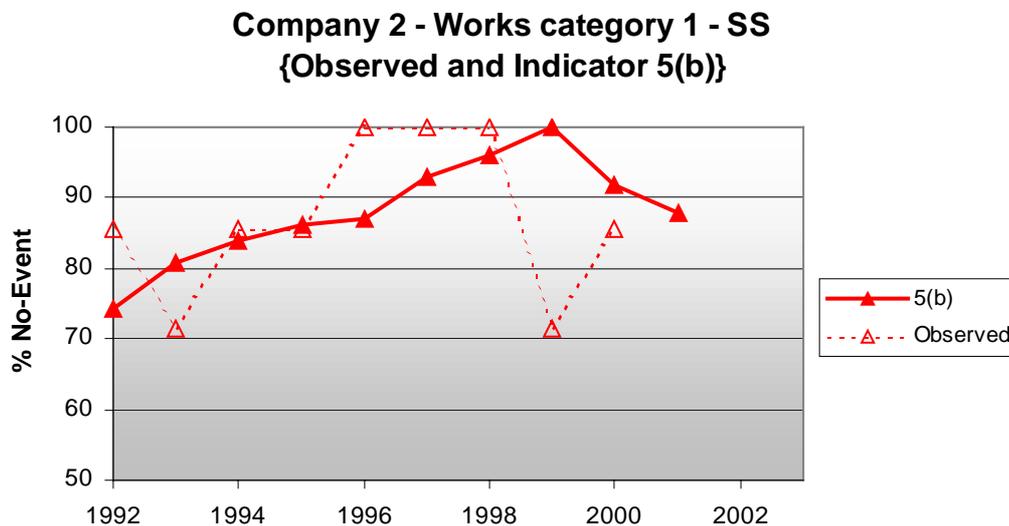


Figure B5.2

B5.3 Figure B5.2 illustrates - for SS - how the Indicator 5(b) reflects the past *observed* event pattern. It needs to be remembered that the events are defined on an individual STW basis and then aggregated for the whole works type.

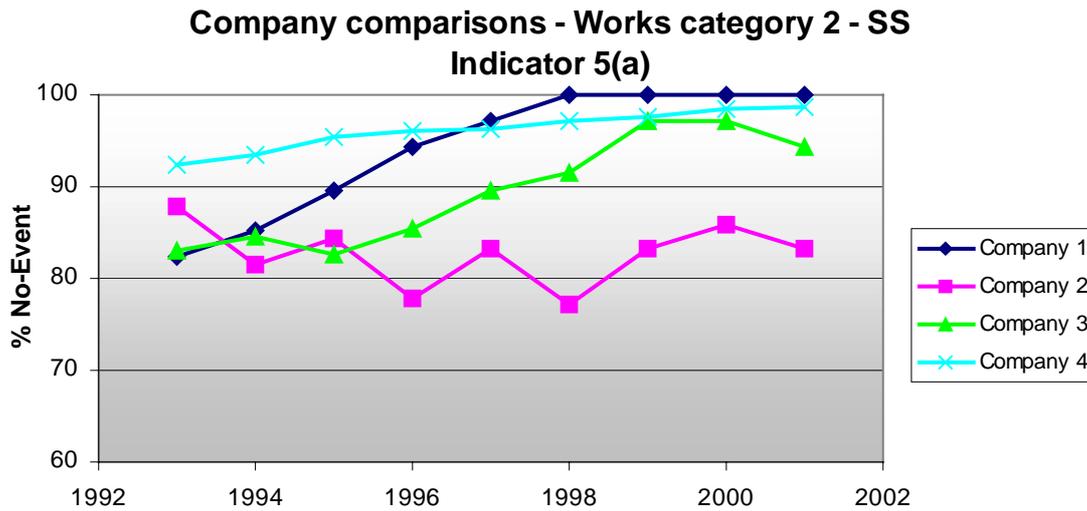


Figure B5.3.1

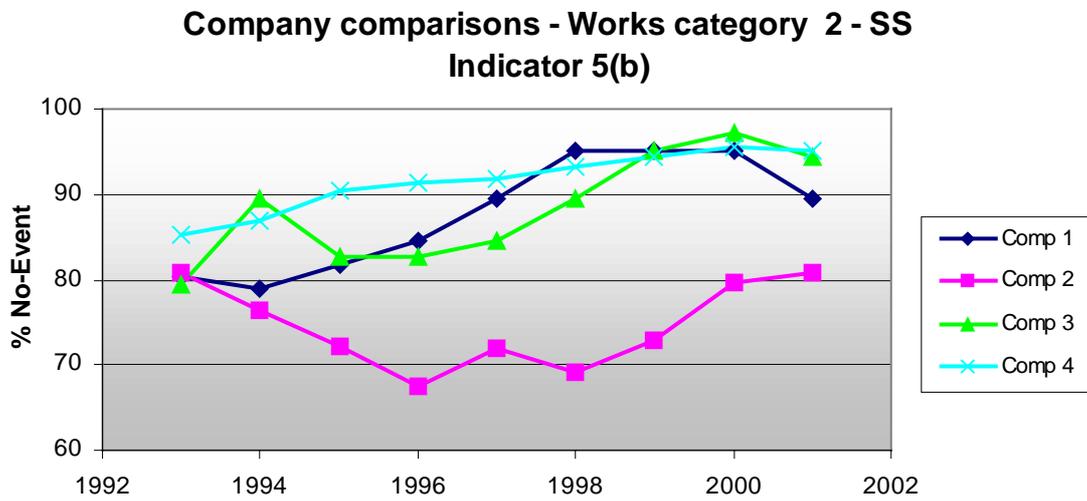


Figure B5.3.2

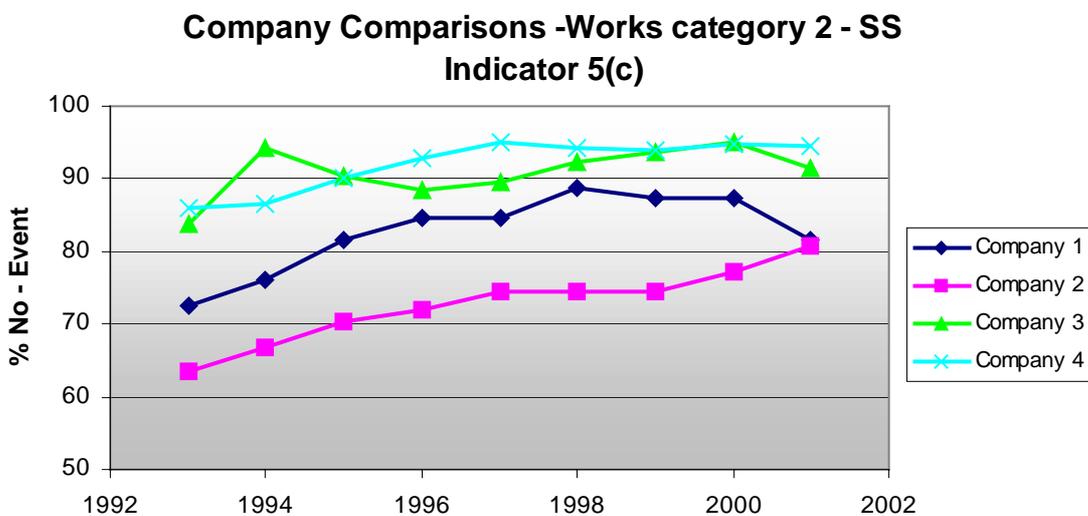


Figure B5.3.3

B5.4 Figures B5.3.1, B5.3.2 and B5.3.3 provide company comparisons for the Indicators 5(a), (b) and (c) respectively, within a particular works type. Clearly companies operate with different historical bases. In some cases improvements have occurred, but not necessarily in a uniform way. A general feature is that there is some evidence of recent deterioration for two of the companies – it remains to be seen if this picture is consolidated by 2001 data.

**Company Comparisons - All works - SS
Indicator 5(a)**

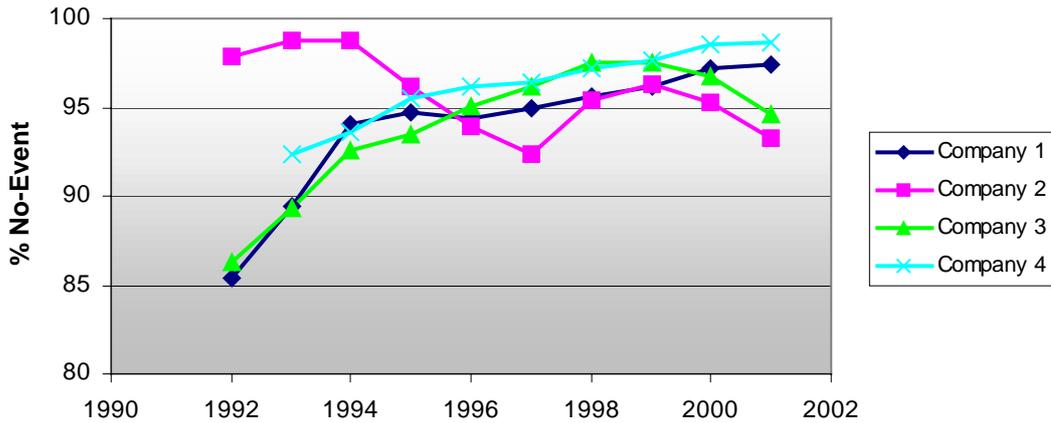


Figure B5.4.1

**Company Comparisons - All works - SS -
Indicator 5(b)**

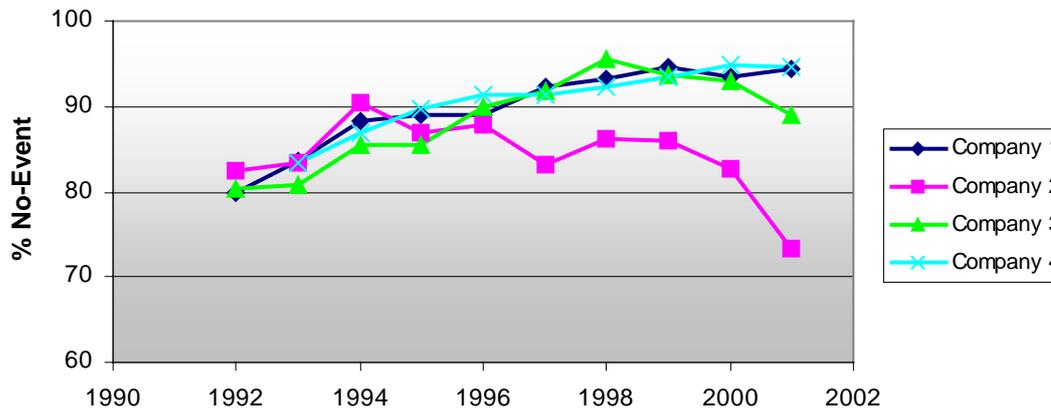


Figure B5.4.2

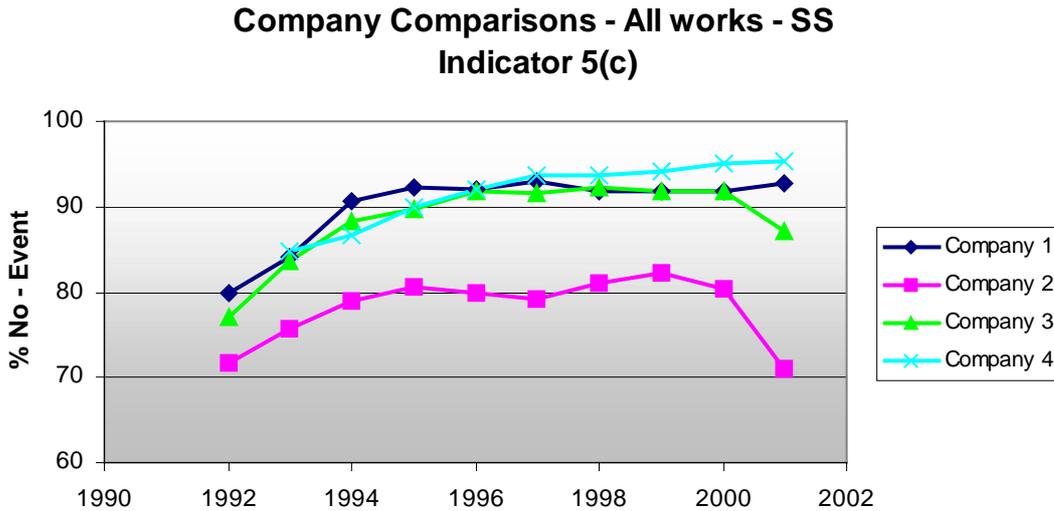


Figure B5.4.3

B5.5 Figures B5.4.1, 4.2 and 4.3 provide company comparisons for the Indicators 5(a), (b) and (c) respectively, at a company (all works) level. Again there are obvious differences in company performances, and still the evidence of recent deterioration in the performance characteristics.

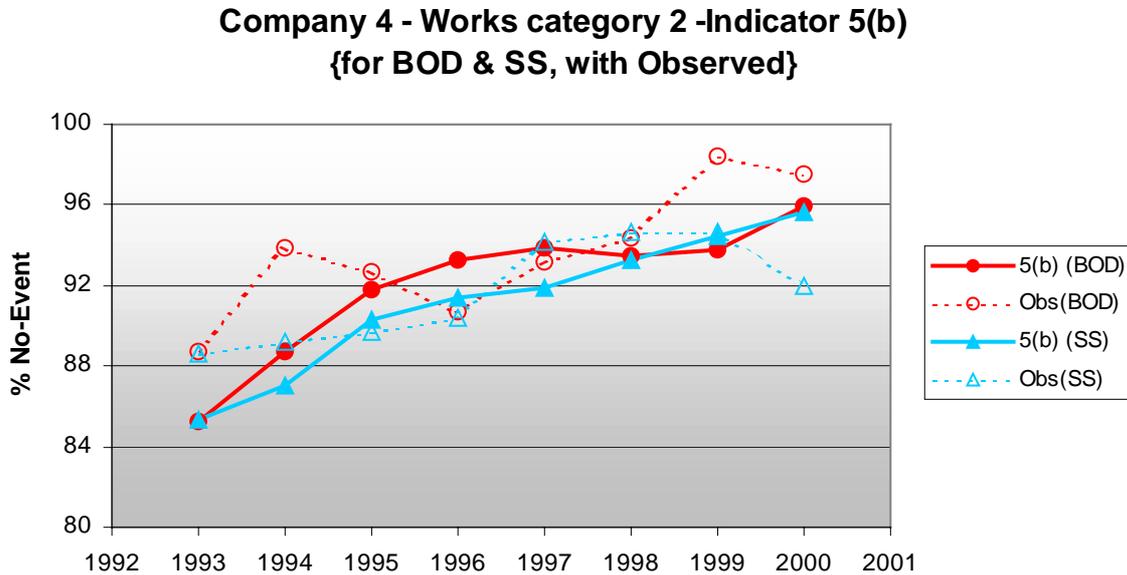


Figure B5.5

B5.6 Figure B5.5 provides a comparison, within a works type within a single company, between observed and Indicator 5(b) values for BOD and SS. As we would expect the indicator values tend to *smooth-out* the observed values and in this way reflect more of an *underlying trend*.

B.6 Issues

B6.1 Sampling Plans

a. Variation in sample sizes:

The sample size (in a year) varied *both* from company to company *and* from year to year. The sample size per year ranged from 0 to 72. Such variation could upset the validity of company comparisons. For paper comparison, it is important that a *standard* sampling scheme is used so that any data presented arises from a uniform pattern of sampling activity at all (or at least *most*) STWs.

b. Missing data:

Whatever the context and whenever data is collected, certain items will inevitably be *missing*. The effect of such omissions depends upon a number of factors including: the proportion of missing values; the location of them within the overall data matrix (i.e. Are they *sprinkled* about in the data set? Or, are they concentrated in certain parts?); the extent to which the occurrence of a missing value is correlated with other important factors in the study. Consideration of these possibilities may not be *just an academic exercise* for STW effluent data, where the absence of information needs to be properly explained before it can be assumed to have occurred by chance.

c. ‘Outliers’:

Data supplied to us has been assumed free of erroneous outliers. The data has been used for statutory compliance purposes and analysed by nationally accredited laboratories and therefore there is a degree of confidence in the accuracy of the results. If the process were to be employed for raw data that had been less rigorously checked it would seem sensible that raw data should be subject to some kind of documented *cleaning* process before it enters appropriate databases for subsequent use. The *arbitrary* removal of suspicious values can be a potentially dangerous activity, especially in this context. Of course, any cleaning process would need to identify any obviously wrong values (e.g. mis-recordings, etc.).

B6.2 Intervention

The proposed methodology has tried to allow for the fact that the effluent data arises from processes that are likely to be subject to both *documented* and *undocumented* sources of intervention by utilising a rolling assessment of data over a 3 year period that smoothes out these short-term effects. Some might well be a natural function of the operation of an STW.

B6.3 Time Dependency

Preliminary analysis of the data indicated that ‘*challenges*’ to an STW’s systems, as reflected in (a) *high* determinand value(s), are not always randomly occurring in the calendar year. In fact, many of the time series of data exhibit repeating patterns from year to year. If sufficient samples were available on a monthly basis then it would be possible to use monthly samples rather than annual samples to define appropriate indicators. The methodology, although it may well need to be augmented with some form of ‘*seasonal*’ adjustment, might be better linked to *expenditure* than an analysis based on a year’s collection of samples.

B6.4 Distribution Characteristics

There are a large number of distribution characteristics to choose from. The choice made reflected the need to try to capture the *main* features and to choose that which might have potential to differentiate *good* and *bad* performance.

B6.5 Event-defining Break-points

The choices of break points to define the events were made to reflect current features of the assessment of STWs – namely at 2 x, 1 x, and 0.5 x prevailing consent value.

B6.6 Use of ‘Rolling’ Sets of 3 Years

The choice of using three years is the minimum necessary to underpin several of the assumptions made to produce the various estimates. Ideally we would like to be using an underlying process that could be assumed stable for a much longer period!

B7. General Comments

- B7.1 It must be recognised that important assumptions have had to be made to arrive at the proposed methodology. Although it is possible to make a strictly statistical judgment about them, their usefulness as an approximate summary description will be significantly enhanced by combining relevant expenditure data. Such information is essential to validate the relationship between performance and operational expenditure but would, if proven to be of great significance both to the companies and to Ofwat.
- B7.2 The processes underlying the measurements are undoubtedly non-stationary (as many are in practical contexts). To take better account of this, than has been done in the proposed methodology, would require a level of complex modelling not likely to be justified by available data.

APPENDIX C

GUIDELINES FOR

JR02 REPORTING

C. REPORTING GUIDELINES

C.1 SEWERS

C1.1 Indicators 1a and 1b: Clustering of Collapses and Equipment Failures.

Summary of Reporting Requirements

Indicator	For JR02	For JR03 and beyond
1a	Total number of collapses for the company [N_{CTOT}]* Progress towards recording collapse locations and time/date.	Total number of collapses for the company [N_{CTOT}]* Cluster analysis of collapses [R_{SC}]
1b	Total number of equipment failures for the company [N_{FTOT}] Progress towards recording equipment failure locations and time/date.	Total number of equipment failures for the company [N_{FTOT}] Cluster analysis of equipment failures [R_{EF}]
Future	Progress towards recording specified wider flooding and pollution impacts of collapses. Progress towards recording specified wider flooding and pollution impacts of equipment failures	Reporting of specified wider flooding and pollution impacts arising from collapses and equipment failures

* as used in the currently reported figure collapses / 1000km

The indicators 1a and 1b should be reported from JR03 as the pairs of numbers:

$$\{N_{CTOT}, R_{SC}\} \text{ and } \{N_{FTOT}, R_{EF}\}$$

Description

These are Level 2 indicators of *asset state* which extend existing reported information for ALL sewer collapses and equipment failures by reporting total numbers of each incident in the year, their degree of clustering across the company network and their impacts on service.

For the purposes of spatial analysis of DG5 Flooding Impacts (Indicators 2a and 2b) and proposed future spatial analysis from JR03 of other impacts resulting from these incidents (Indicators i and ii) it will be necessary to separately identify those incidents which result in:

- internal flooding of properties
- other categories of flooding
- pollution events

Sewer collapses are defined as “full” or “partial” and include fractures and deformations in line with current reporting requirements.

Sewerage equipment includes all ancillary devices such as valves, flow controls and storage tanks but in this context excludes Pumping Stations which are reported separately.

Data Recording

- For every Collapse and Equipment Failure incident in the report year record separately the corresponding service impacts ie. each incident may result in one or more of the following impacts:

Service Impacts:

- None
 - Numbers of properties flooded (see also Indicators 2a and b)
 - Other categories of flooding (for future indicator i):
 - gardens, car-parks, driveways, uninhabited property
 - agricultural land, parks and recreational spaces
 - highways
 - Pollution incidents (categories 1, 2 and 3) (for future indicator ii)
 - Other impacts.
- Record the date and time of each collapse and equipment failure.
 - NGR of each collapse and equipment failure.

Procedure for cluster analysis of collapses and equipment failure

Step 1:

The spatial analysis specified below is well suited to automatic processing via a GIS. The basis of the analysis is the construction of a square-grid pattern – side of each square 1 kilometre - covering the company's operational sewered area – the *same* grid pattern to be used each year. Note: only cells containing sewers are to be included in the analysis.

This gives N_c columns x N_r rows cells e.g.

	1	2	...	N_c
1				
2				
...				
N_r				

Step 2:

Determine which of the $N_c \times N_r$ cells include some sewerage network asset – denoted by 'M', where $M \leq N_c \times N_r$.

E.g. $M = 20$

Step 3:

Using the geo-referenced data collected for collapse and equipment failure incidents determine the total number of sewer collapses $\{N_{SC}\}$ and the total number of equipment failure incidents $\{N_{EF}\}$ which have occurred in each of the M cells in the year.

Step 4:

Record the total number of collapses for the company:

$$N_{CTOT} = \Sigma \{N_{SC}\}$$

and the total number of equipment failures for the company:

$$N_{FTOT} = \Sigma \{N_{EF}\}$$

Step 5:

Put the M values of $\{N_{SC}\}$ and $\{N_{EF}\}$ into rank-order (largest down to smallest).

E.g. with $M = 20$, we might have a set of cell counts for $\{N_{SC}\}$ as follows:

Cell	5.7 $\{N_{SC}\}$
1	7
2	4
3	4
4	3
5	2
6	0
...	0
M=20	0

Total number of collapses over the year, $N_{CTOT} = 20$ (including repeat incidents).

Step 6:

Calculate the sample mean (denoted 'm') and the sample variance (denoted 'v') for each of the set of counts $\{N_{SC}\}$ and $\{N_{EF}\}$ to give m_{SC} , m_{EF} , v_{SC} and v_{EF} :

E.g. for the example data for collapses we have:

$$\text{sample mean, } m_{SC} = N_{CTOT} / M = 20 / 20 = 1.0$$

and

$$\text{sample variance, } v_{SC} = (1/M-1) \cdot \Sigma (N_{SC} - m_{SC})^2 = 3.9$$

Step 7:

Calculate the value of the cluster statistics R_{SC} and R_{EF} for each of collapses and equipment failures,

$$R_{SC} = v_{SC} / m_{SC}$$

and

$$R_{EF} = v_{EF} / m_{EF}$$

E.g. for the example data above $R_{SC} = 3.9 / 1.0 = 3.9$.

C1.2 Indicators 2a and 2b: Severity and Clustering of DG5 Flooding Events

Summary of Reporting Requirements

Indicator	For JR02	For JR03 and beyond
2a	Total number of properties flooded caused by collapses [N_{CPROP}] Progress towards recording locations and time/date of collapses causing flooding*	Total number of properties flooded caused by collapses [N_{CPROP}] Cluster analysis of collapses causing flooding [R'_{SC}]
2b	Total number of properties flooded caused by equipment failures [N_{FPROP}] Progress towards recording locations and time/date of equipment failures causing flooding*	Total number of properties flooded caused by equipment failures [N_{FPROP}] Cluster analysis of equipment failures causing flooding [R'_{EF}]

* Note that these will be sub-sets of the data required for Indicators 1a and 1b.

The indicators 2a and 2b should be reported from JR03 as the pairs of numbers:

$$\{N_{CPROP}, R'_{SC}\} \text{ and } \{N_{FPROP}, R'_{EF}\}$$

Description

These are Level 2 *customer service* indicators which extend the existing DG5 indicator by reporting the total numbers of properties affected in the year by internal flooding and their degree of clustering across the company network. However, note that these are restricted to those flooding events which have been caused by sewer collapses or equipment failures ie a subset of the collapses and equipment failures used for indicators 1a and 1b.

For the purposes of spatial analysis it is also necessary to record (but not report) the National Grid Reference (NGR) of each event cause (collapse or equipment failure, see Indicators 1a and 1b).

The spatial analysis process is identical to that required for Indicators 1a and 1b but is repeated here for completeness.

Data Recording

1. For every sewer collapse or equipment failure event in the report year which results in internal flooding of properties, record:
 - a. where cause is *sewer collapse*:

The total numbers of properties flooded	
Date and time of incident	} sub-set of
The NGR of the collapse	} Indicator 1a data

- b. where cause is *equipment failure*:
- | | |
|---|---------------------|
| The total numbers of properties flooded | |
| Date and time of incident | } sub-set of |
| The NGR of the failure | } Indicator 1b data |
2. For the company as a whole, record the total numbers of properties affected in the year for each cause:
- Total Properties flooded (caused by collapses): N_{CPROP}
- Total Properties flooded (caused by equipment failures): N_{FPROP}

Note: This is an enhancement of existing reported information Table 3, Lines 7 and 9 which asks for numbers of flooding incidents.

Procedure for cluster analysis of collapses and equipment failures causing flooding

Step 1:

The following spatial analysis is well suited to automatic processing via a GIS. The basis of the analysis is the construction of a square-grid pattern – side of each square 1 kilometre - covering the company’s operational sewered area – the *same* grid pattern to be used each year.

This gives N_c columns x N_r rows cells e.g.

	1	2	...		N_c
1					
2					
...					
N_r					

Step 2:

Determine which of the $N_c \times N_r$ cells include some sewerage network asset – denoted by ‘M’, where $M \leq N_c \times N_r$.

E.g. $M = 20$

Step 3:

Using the geo-referenced data collected for DG5 incidents (restricted to those caused by collapses and equipment failures) determine the total number of collapses which have resulted in flooding $\{N_{SC}\}$ and the total number equipment failures which have resulted in flooding $\{N_{EF}\}$ over the year in each of the M cells. Note that these will be sub-sets of the Indicator 1a and 1b data sets.

Step 4:

Record the total number of collapses for the company which have resulted in flooding:

$$N'_{CTOT} = \Sigma \{N'_{SC}\}$$

and the total number of equipment failures for the company which have resulted in flooding:

$$N'_{FTOT} = \Sigma \{N'_{EF}\}$$

Step 5:

Put the M values of $\{N'_{SC}\}$ and $\{N'_{EF}\}$ into rank-order (largest down to smallest).

E.g. with $M = 20$, we might have a set of cell counts for $\{N'_{SC}\}$ as follows:

Square	5.8	$\{N'_{SC}\}$
1		5
2		3
3		2
4		2
5		1
6		0
...		0
M=20		0

Total number of events over the year, $N'_{CTOT} = 13$ (including repeat events)

Step 6:

Calculate the sample mean (denoted 'm') and the sample variance (denoted 'v') for each of the set of counts $\{N'_{SC}\}$ and $\{N'_{EF}\}$ to give m'_{SC} , m'_{EF} , v'_{SC} and v'_{EF} :

E.g. for the example data for collapses we have:

$$\text{sample mean, } m'_{SC} = N'_{CTOT} / M = 13 / 20 = 0.65$$

and

$$\text{sample variance, } v'_{SC} = (1/M-1) \cdot \Sigma (N'_{SC} - m'_{SC})^2 = 1.8$$

Step 7:

Calculate the value of the cluster statistics R'_{SC} and R'_{EF} for each of collapses and equipment failures,

$$R'_{SC} = v'_{SC} / m'_{SC}$$

and

$$R'_{EF} = v'_{EF} / m'_{EF}$$

E.g. for the example data above $R'_{SC} = 1.8 / 0.65 = 2.8$.

C.2 COMBINED SEWER OVERFLOWS

C.2.1 Indicator 3: Condition Grade of Combined Sewer Overflows

Summary of Reporting Requirements

Indicator	For JR02	For PR04
3	Total number of CSOs in the company [N_{CSO}]. Action Plan for the sampling and auditing of the company's CSO stock in order to achieve the PR04 objectives.	Condition Grade of $\{N_{CSO} / 3\}$ CSOs segregated into each of 5 asset condition grades* Percentage of CSOs in each Condition Grade*

* This information will be reported at PR04 as follows:

Asset Condition Grade	1	2	3	4	5
Number of CSOs in each category	N^1_{CSO}	N^2_{CSO}	N^3_{CSO}	N^4_{CSO}	N^5_{CSO}
% in Grade	P^1_{CSO}	P^2_{CSO}	P^3_{CSO}	P^4_{CSO}	P^5_{CSO}

where $P^1_{CSO} = 100 \cdot N^1_{CSO} / N_{CSO}$ etc.

At each subsequent Periodic Review (PR09 and PR14) the Condition Grade of the next 1/3 of assets is to be reported.

Description

This is a Level 1 indicator which provides an assessment of the structural condition of all CSOs for a company in 5 condition grades.

Data Recording

1. Establish the total number of CSOs in the company [N_{CSO}].
2. Prepare an Action Plan for the sampling and auditing of the company's CSO stock.
3. Undertake site inspections of a random one-third sample of the company's total CSO asset stock by PR04.

Procedure for selection and Condition Grading

Step 1:

Select a random sample of one-third of the asset stock. Assets should not be 'cherry-picked' from an area to give a distorted picture of overall condition.

Step 2:

Undertake a condition assessment of each CSO applying a similar methodology to that used for sewer condition⁶. There is currently no universal methodology for assessing the Condition Grading of CSOs. It is anticipated that a methodology will be agreed through a process of consultation between OFWAT and the companies.

⁶ *Sewerage Rehabilitation Manual*, Edition 4, 2001, WRc

C.3 PUMPING STATIONS

C.3.1 Indicators 4a and 4b: Pumping Station Mean Time Between Failures and Flooding caused by Pumping Station Failures

Summary of Reporting Requirements

Indicator	For JR02	For JR03 and beyond
4a	Allocation of pumping stations into 5 power bands*. Estimated values of Mean Time Between Failure for pumping stations in each power band*. Progress towards collection of Hours Run and Work Order numbers at PS level.	Robust values of Mean Time Between Failure for pumping stations in each power band*.
4b	Total number of pumping station failures causing flooding [N_{PF}] Total number of properties flooded caused by pumping station failures [N_{PPROP}] Progress towards allocation of N_{PPROP} to pumping station power bands.	Total number of pumping station failures causing flooding [N_{PF}] allocated to size bands*. Total number of properties flooded caused by pumping station failures [N_{PPROP}] allocated to pumping station power bands*
Future	Progress towards collection of Maintenance Cost data at PS level. Progress towards recording wider flooding and pollution impacts of pumping station failures.	Maintenance Cost data at PS level. Reporting of wider flooding and pollution impacts arising from pumping station failures

*The format of the information to be reported is as follows:

	Band 1	Band 2	Band 3	Band 4	Band 5	Company
Number in band	N^1_{PU}	N^2_{PU}	N^3_{PU}	N^4_{PU}	N^5_{PU}	N_{PU}
Mean Hours Run	m^1_H	m^2_H	m^3_H	m^4_H	m^5_H	m_H
Mean MTBF	m^1_{MTBF}	m^2_{MTBF}	m^3_{MTBF}	m^4_{MTBF}	m^5_{MTBF}	m_{MTBF}
Pumping Station failures	N^1_{PF}	N^2_{PF}	N^3_{PF}	N^4_{PF}	N^5_{PF}	N_{PF}
Properties flooded	N^1_{PPROP}	N^2_{PPROP}	N^3_{PPROP}	N^4_{PPROP}	N^5_{PPROP}	N_{PPROP}

Description

These are Level 1 indicators which report:

- the Hours Run and Mean Time Between Failures (MTBF) for all sewerage pumping stations for a company within 5 size bands, and
- the numbers of pumping station failures and properties flooded arising from pumping station failures in each size band.

The wider flooding and pollution impacts of pumping station failures are as specified for Indicators 1a and 1b.

Pumping stations are defined as an individual site (not an individual pump) and include foul, combined and stormwater pumping stations but exclude terminal pumping stations situated at treatment works and inter-stage pumping.

Data Recording

1. Determine the total power rating of each pumping station and segregate the installations into 5 bands as follows:

Pumping station capacity including standby	Band 1	Band 2	Band 3	Band 4	Band 5
	≤ 5 kW	6 – 20 kW	21 – 100 kW	101 – 500 kW	> 500 kW

2. Record the number of pumping stations N_{PU}^B in each size band:

$$N_{PU}^1, N_{PU}^2, N_{PU}^3, N_{PU}^4 \text{ and } N_{PU}^5$$

3. For each pumping station in each band record the *total* hours run for the year $\{H\}$. This is to be defined as the aggregated time for which the station is pumping ie. not the sum of the run times of the individual pumps.
4. For each pumping station in each band compile the total number of work orders issued $\{N_{WO}\}$. Work orders are to be defined as *the total number of visits required for maintenance and non-routine inspections*.
5. For the purposes of future analysis a system should be put in place (where none currently exists) and data collection progressed to record the cost of resolving each work order. Capital and Operating expenditure should be recorded separately.
6. Where pumping station failures have occurred and have resulted in internal flooding of properties, record the numbers of pumping station failures $\{N_{PF}\}$ and the numbers of properties $\{N_{PPROP}\}$ which have been affected and allocate these to the pumping station size bands.

Procedure for calculating Mean Time Between Failure

Calculate the Mean Time Between Failure (MTBF) for each station within each size band from:

$$\{MTBF\} = H / N_{WO}$$

Calculate the Arithmetic Mean, m_{MTBF}^B , of the MTBF values for the pumping stations in each size band:

$$m_{MTBF}^B = (1 / N_{PU}^B) \cdot \Sigma \{MTBF\}$$

C.4 SEWAGE TREATMENT WORKS

C.4.1 Indicators 5a, 5b and 5c: Works Performance

Summary of Reporting Requirements

Indicator	For JR02	For JR03 and beyond
5a, b, c	Numbers of works in 4 size bands*. Performance Statistics for BOD and SS and each size band*. Performance Statistics for BOD and SS at company level*.	Performance Statistics for BOD and SS and each size band*. Performance Statistics for BOD and SS at company level*.
Future	Progress towards the collection of individual works operating costs.	Works operating costs.

* The format for reporting is as follows:

		Determinand BOD			Determinand SS				
		No of STWs used:	Indicators			No of STWs used:	Indicators		
			5a	5b	5c		5a	5(b)	5(c)
STW Band	1								
	2								
	3								
	4								
Company level									

Description

Three indicator values are to be reported at company level for works in 4 size bands. The indicators provide a prediction of the proportion of works for which a defined “event” will occur in the coming year based on works performance over the previous 3 years. Three “events” are specified.

Event	Distribution characteristic of m / c
a	Maximum value > 2.0
b	95%tile (Normal) > 1.0
c	Mean value > 0.5

where ‘m’ is a determinand measurement and ‘c’ is the prevailing consent for that determinand.

Data Recording

1. The total asset stock of sewage treatment works is to be segregated into 4 bands according to the population equivalent served. Record the number of works in each band:

	Band 1	Band 2	Band 3	Band 4
Population equivalent served	500 to 2,000	2,000 to 10,000	10,000 to 100,000	> 100,000

2. Record the legal consent value for each works and any changes throughout the year.
3. Record sanitary determinand compliance data (BOD and SS) for all works. This is no more than is currently required under current reporting requirements.
4. For the purposes of future analysis an accounting system should be put in place (where none currently exists) and data collection progressed to record the operating costs associated with the management of each of the company's works.

Procedure for calculating Works Performance Statistics

The calculation process follows a nested looped procedure as follows:

Step 1:

Loop Steps 2 to 9 then 10, 11, and 12 for each size band of works 'B' (\equiv 1, 2, 3, and 4)

└ Step 2:

Loop Steps 3 to 9 for each determinand D (\equiv BOD, SS) and for each Treatment Works within the works-band 'B'

└ Step 3:

Assemble the set of yearly measurements (at least one measurement from each month) made of each determinand D.

This gives a set of 'n (≥ 12)' values $\{m_1..m_n\}$.

└ Step 4:

Divide each sample value by its prevailing *consent* value to give $\{m_1^*..m_n^*\}$.

└ Step 5:

For the set of values $\{m_1^*..m_n^*\}$ calculate:

$$\text{a. Sample maximum: } \max = \max(m_1^* \dots m_n^*)$$

b. **Sample mean:** $\bar{m} = \frac{1}{n} \sum_{i=1}^n m_i^*$

c. **Sample standard deviation:** $s = \sqrt{\frac{1}{n} \sum_{i=1}^n (m_i^* - \bar{m})^2}$

d. **Sample 95%tile** = $\bar{m} + 1.64485 \times s$

┆ **Step 6:**

For current year (y) data,

let $V_1(y) = 1$ if sample max > 2.0 and $V_1(y) = 0$ otherwise;
 let $V_2(y) = 1$ if sample 95%tile > 1.0 and $V_2(y) = 0$ otherwise;
 let $V_3(y) = 1$ if sample $\bar{m} > 0.5$ and $V_3(y) = 0$ otherwise.

┆ **Step 7:**

Calculate $r_{V_1} = \frac{V_1(y) + V_1(y-1) + V_1(y-2)}{3}$

and $p(\text{no event in } (y+1); V_1 = 0) = \exp(-r_{V_1})$.

┆ **Step 8:**

Repeat Step 6 with V_2 to give

$$p(\text{no event in } (y+1); V_2 = 0) = \exp(-r_{V_2})$$

┆ **Step 9:**

Repeat Step 6 with V_3 to give

$$p(\text{no event in } (y+1); V_3 = 0) = \exp(-r_{V_3})$$

┆ **Step 10:**

Indicator 5a is defined as the expected percentage of ‘no events’ of V_1 for the group of ‘J’ STWs within the Works-Band:

$$I_{5a} = 100 \times [\text{sum of the ‘J’ values of } p(\text{no event in } (y+1); V_1 = 0)] / J$$

┆ **Step 11:**

Indicator 5b is defined as the expected percentage of ‘no events’ of V_2 for the group of ‘J’ STWs within the Works-Band

$$I_{5b} = 100 \times [\text{sum of the ‘J’ values of } p(\text{no event in } (y+1); V_2 = 0)] / J$$

┆ **Step 12:**

Indicator 5c is defined as the expected percentage of ‘no events’ of V_3 for the group of ‘J’ STWs within the Works-Band

$$I_{5c} = 100 \times [\text{sum of the 'J' values of } p(\text{no event in } (y+1); V_3 = 0)] / J$$

Company Level Statistics:

Loop Steps 13, 14 and 15 for each determinand BOD and SS:

┌ Step 13:

Indicator 5a for the company is defined as the expected percentage of 'no events' of V_1 for all STWs:

$$I_{5a} = 100 \times [\text{sum of all values of } p(\text{no event in } (y+1); V_1 = 0)] / N_{\text{works}}$$

└ Step 14:

Indicator 5b for the company is defined as the expected percentage of 'no events' of V_2 for all STWs:

$$I_{5b} = 100 \times [\text{sum of all values of } p(\text{no event in } (y+1); V_2 = 0)] / N_{\text{works}}$$

└ Step 15:

Indicator 5c for the company is defined as the expected percentage of 'no events' of V_3 for all STWs :

$$I_{5c} = 100 \times [\text{sum of all values of } p(\text{no event in } (y+1); V_3 = 0)] / N_{\text{works}}$$

Note that the company level statistics are NOT the sum of the individual works band values and need to be computed separately (steps 13, 14 and 15).

C.5 SLUDGE TREATMENT AND DISPOSAL SYSTEMS

C.5.1 Availability of Disposal Route

Summary of Reporting Requirements

Indicator	For JR02	For JR03	For PR04 and beyond
Future L1	Programme that will enable all data to be available by PR04. Progress towards collecting data.	Example pilot calculations for selected disposal routes. Progress towards collecting data.	Percent sludge disposal routes available: <ul style="list-style-type: none"> • Under Normal Operation • Utilising Overtime Routes Diverting Sludge: <ul style="list-style-type: none"> • Percentage of production diverted due to non-availability of primary disposal route • Quantity diverted
Future L2	Programme that will enable all data to be available by PR04. Progress towards collecting data.	Progress towards collecting data.	Probable percent sludge disposal routes available: <ul style="list-style-type: none"> • Under Normal Operation • Utilising Overtime

The above should be subdivided by cause of non-availability due to:

- General service failure
- Equipment serviceability failure

At JR02 companies should also submit their comments and suggestions for the efficient implementation of the Indicator.

Description

These are entirely new Indicators and comments and suggestions are welcomed on the methods proposed. It is intended to come to a consensus on an agreed final methodology for reporting and indicator calculation in PR04.

At this stage it is considered that the requirements for reporting of serviceability of sludge disposal systems should be limited to a data collection exercise. Once data are available it will be possible to test and refine the procedures for calculating the indicators. It is proposed that for JR02 reporting be limited to reporting on progress in setting up the data collection exercise. It should be demonstrated that plans are being implemented which will allow full data collection to commence for PR04.

Data Recording

1. A water company will have access to many sludge treatment facilities and disposal sites with sludge taking a variety of routes through the system. For the assessment of

the serviceability of facilities it will be necessary to identify the primary routes through the system.

2. Data needs to be collected for each treatment stage, where a treatment stage is any element on the route of sludge from source to disposal which is critical to the ability of that route to dispose of the sludge. For example:
 - A conveyance of sludge – pumps, tankers, conveyor belts.
 - A storage vessel
 - A process unit – e.g. Thickener, press, digester, dryer.
 - A Disposal Site – e.g. Land bank, Landfill.
3. The following information should be collected regularly and summarised into quarterly reports:
 - a) Quantity of raw sludge requiring processing
 - b) Rated capacity of treatment stages when in full working order
 - c) Rated capacity of treatment stages as available
 - d) Normal operating hours of treatment stages
 - e) Potential maximum operating hours of treatment stages (utilising overtime)
 - f) Periods of time for which treatment stages were not available.
 - g) Reasons for non availability of capacity or availability of sludge disposal route
 - h) Actual capacity of sludge disposal route utilised (i.e. Quantity of sludge processed)
 - i) Degree and consequence of using alternative treatments or routes
4. Produce an initial assessment of each treatment stage's capacity (data items b), c), d), e) above). Information required regularly is a record of the amount of sludge to be processed and actually processed (a) and h) above). Other information need be recorded only when there is an event leading to a change in performance. And in most cases only:
 - Changes in treatment stage capacity, c)
 - Treatment stages being unavailable for a period of time, f), g)
 - Treatment stages being run for additional hours, from h)
 - Sludge being diverted to other disposal routes, i)
5. The manager of each works should keep records of sludge quantities through the works and events leading to changes from normal operation at a resolution of days or weeks. For the purposes of assessing availability estimates of sludge flows should be sufficient. It is not proposed that exact measurements of sludge volumes and %dry solids be taken on a continuous basis. The data need only be collated and reported on a quarterly or annual basis.

Procedures for calculating future Indicators

Level 1 Indicator

Once sufficient data has been collected it is proposed that the data should be analysed to derive a Level 1 indicator for each sludge disposal route, using methods based on the following procedures.

Step 1:

Identify the **Rated capacity of each treatment stage**. Assuming that stages are in full working order. Throughput would be expressed as a volumetric or mass flow rate as appropriate.

Step 2:

Determine the **Potential Capacity Available**. Multiply the rated capacity of the stages by the number of normal working hours or days in the reporting period.

Step 3:

Determine the **Actual Normal Capacity Available**. Calculated as for 2. but taking account of treatment stages that are known not to be performing to their full capacity and subtracting any time the stages have been unavailable due to repairs or maintenance.

Step 4:

Determine the **Utilised capacity**. Based on measurements of the actual throughput of sludge. Noting peaks and minima in the quantities held in storage stages.

Step 5:

Determine the **Extra Capacity Utilised**. Capacity provided by running systems outside of normal working hours.

Step 6:

Assess the **Use of alternative disposal routes due to process stream non-availability**. Quantity of sludge disposed of by extraordinary measures, with reasons for doing so and additional costs incurred and impact on disposal site sustainability.

Step 7:

Calculate Indicator for stages. For each treatment stage the indicator would be "Actual Normal Capacity Available" divided by "Utilised Capacity". If this factor is less than one then this would indicate that the process has been unable to cope with the load placed upon it. The extra capacity required must have been provided by utilising storage, running the plant for longer than normal hours or diverting sludge to an alternative disposal route.

Step 8:

Calculate Indicator for Sludge Disposal Route. This is taken to be the minimum of the indicators for the individual stages. Thus the indicator will reflect the condition of the sludge disposal route as in Table C5.1.

5.9 *Table C5.1 Meaning of values of sludge disposal indicator for a sludge treatment route*

Value of indicator	Situation described by indicator
>2	Plenty of spare capacity in the system, any system downtime is not impacting on ability to provide service.
1 to 2	Some spare capacity in the system. System downtime may require short periods of running at overtime to catch up.
0 to 1	No spare capacity. Part or all of the route is having to run during overtime to cope with load. This may be due to general overload, downtime or difficulties with disposal sites. Any further mechanical problems likely to have serious consequences.

Step 9:

Record **Diversions to Alternative Routes**. Where sludge has been diverted to alternative routes this should be reported as a percentage of total sludge requiring processing and as a volume, % dry solids and type (e.g. raw sludge, digested liquor or dried cake).

Level 2 Indicator

A water company will have available more than one disposal route for any sludge source and the capacity of the whole sludge disposal system can only really be assessed at the company level. A probability based Level 2 indicator is proposed to do this. This indicator would be calculated as follows:

Step 1:

Define a threshold for the Level 1 indicator that is deemed to represent a "Failure Event", these events should be defined for a range of degrees of severity.

Step 2:

Using the Poisson distribution function develop forward looking Indicators similar to those described for the sewage treatment works Indicators (5a, b and c).

Thus the Level 2 Indicators would be the probable percentage of sludge disposal routes in the company that in the next year will be have sufficient capacity to dispose of the sludge load placed upon them with 4 levels of severity:

- 1) *Under normal operating hours,*
- 2) *Utilising available overtime,*
- 3) *Utilising spare capacity in other disposal routes*
- 4) *Not able to dispose of sludge*

A differentiation would be made at this stage between failure brought on by growth, serviceability failures and general service failures. Serviceability failures would be when the service capacity is insufficient to meet demand due to mechanical or structural failure of the process equipment. Service failures would be when disposal capacity is insufficient to meet demand for any reason, be that growth, mechanical failure, operational mismanagement or political change resulting in particular disposal routes becoming non-viable.

APPENDIX D

GUIDELINES FOR REPORTERS

D. GUIDELINES FOR REPORTERS

D.1 BACKGROUND

- D.1.1 A framework for the continuing enhancement of Serviceability Indicators for sewerage assets has been developed. The aim of the “new” Indicators is to inform a forward looking assessment of the capital maintenance requirements of sewerage assets. Assets are categorised into Infrastructure (Sewers and Combined Sewer Overflows) and Non-infrastructure (Pumping Stations, Sewage Treatment Works and Sludge Disposal Systems). Indicators exist for Sewers, CSOs and Treatment Works but there are currently no Indicators for Pumping Stations or Sludge Disposal.
- D.1.2 The framework for the development of new Indicators has been structured to provide a staged development towards “risk-based” measures. The goal is to develop Indicators which fit into a “failure ~ consequence” model ie. where changes in asset state and changes in service to customers and environmental impacts are taken into account. Some Water and & Sewerage Companies are already working to this end
- D.1.3 However, to provide realistic expectations for JR02, JR03 and beyond we have proposed a staged approach which will over time lead companies towards risk-based serviceability indicators. This will allow time for systems to be put in place for the collection of data which is not currently being collected by all companies and for inconsistencies to be resolved.
- D.1.4 The following layered approach to the development of new and enhanced serviceability indicators is proposed (Table D.1) which will provide logical interim steps on the route to risk-based serviceability indicators.

LEVEL 1 INDICATOR	'First Process' Presentation of Base Data	Level 1 indicators are 'first process' indicators. They are a simple report of base data which reflect asset state or customer / environmental impact. This may be in relation to defined targets (e.g. works compliance) or a report of event occurrence (e.g. number of collapses per length of sewer).
LEVEL 2 INDICATOR	Multi-Component Analysis (to enable assessment of trends).	Level 2 indicators require the analysis or combination of two or more base data to enable an identification of underlying change in asset state or customer service levels which may therefore inform an assessment of trends in serviceability. This may include spatial and probability analysis.
LEVEL 3 INDICATOR	Risk Indicator	Level 3 indicators are developments of Level 2 and incorporate the concept of Risk i.e. combine measures of both asset state and customer service.
LEVEL 4 INDICATOR	Local effects and detailed analysis	Level 4 indicators are those measures developed by W&SCs for internal management purposes and are not intended for reporting to Ofwat. They may provide for example a better understanding of local effects that may explain variations in performance or operating costs of individual assets.

Table D.1 Layered Approach to the Development of Serviceability Indicators

D.1.5 A set of objectives has been established for W&SC reporting at JR02 and JR03 and Guidelines have been produced (Appendix C) which specify the data requirements and analytical processes required to achieve these objectives. These *Guidelines for Reporters* are a supplement to Appendix C and provide supporting information to Reporters about the JR02 and JR03 objectives and beyond and highlight specific auditing requirements.

D.2 SEWERS

D.2.1 Indicators 1a and 1b: Clustering of Collapses and Equipment Failures.

Summary of Reporting Requirements

Indicator	For JR02	For JR03 and beyond
1a	Total number of collapses for the company [N_{CTOT}] Progress towards recording collapse locations and time/date.	Total number of collapses for the company [N_{CTOT}] Cluster analysis of collapses [R_{SC}]
1b	Total number of equipment failures for the company [N_{FTOT}] Progress towards recording equipment failure locations and time/date.	Total number of equipment failures for the company [N_{FTOT}] Cluster analysis of equipment failures [R_{EF}]
Future	Progress towards recording specified wider flooding and pollution impacts of collapses. Progress towards recording specified wider flooding and pollution impacts of equipment failures	Reporting of specified wider flooding and pollution impacts arising from collapses and equipment failures

Objectives

Indicators 1a and 1b

The objective is that by JR03 companies will report two Indicators (1a and 1b) which measure the serviceability of the sewer network in terms of numbers of collapses and equipment failures and their degree of clustering across the network. The indicators are to be reported from JR03 as the pairs of numbers:

$$\{N_{CTOT}, R_{SC}\} \text{ and } \{N_{FTOT}, R_{EF}\}$$

At JR02 all companies will be able to report the total numbers of collapses N_{CTOT} for the company since it is used to calculate the currently reported figure for collapses / 1000km. However the spatial data necessary to calculate the cluster statistics $\{R\}$ is unlikely to be available. At JR02 companies should have put the necessary systems and procedures in place to collect this data so that R can be calculated at JR03. The method for calculating the cluster statistic R in each case is specified in Appendix C.

Future Indicators

A longer term objective is for companies to work towards the production of a “failure ~ consequence” matrix which identifies the consequential effects of each sewer collapse and each equipment failure measured in terms of their impacts on customer service and the environment (flooding and pollution incidents). It is intended that in time this will lead to the development of a Risk Indicator for sewers which incorporates probability of asset failure and service impacts.

It is unlikely that companies will be in a position to report the full set of consequential effects of collapse and equipment failure events specified in the Data Requirements section in Appendix C until JR03. However for JR02 all companies are required to have in place systems and procedures for the collection of this information and be able to demonstrate significant progress towards data collection and analysis to enable reporting of these measures at JR03.

Auditing Requirements JR02

For Indicators 1a and 1b:

- inspect and comment on the systems which are in place to capture the specified spatial data for collapses and equipment failures with respect to "fitness for purpose".
- verify that the definitions of sewer collapse and equipment are understood by the company and have been consistently followed.
- comment on the rate of progress of spatial data collection.
- where companies have sufficient data and have calculated the R statistic, verify that the calculation methodology has been correctly followed

For Future Indicators:

- verify that systems and procedures are in place for the collection and recording the specified data and are "fit for purpose"
- inspect a sample of data for any collapse and equipment failure events which may have occurred and for which consequence data has been collected.
- comment on the degree of progress towards comprehensive company wide data collection.

D.2.2 Indicators 2a and 2b: Severity and Clustering of DG5 Flooding Events

Summary of Reporting Requirements

Indicator	For JR02	For JR03 and beyond
2a	Total number of properties flooded caused by collapses [N_{CPROP}] Progress towards recording locations and time/date of collapses causing flooding*	Total number of properties flooded caused by collapses [N_{CPROP}] Cluster analysis of collapses causing flooding [R'_{SC}]
2b	Total number of properties flooded caused by equipment failures [N_{FPROP}] Progress towards recording locations and time/date of equipment failures causing flooding*	Total number of properties flooded caused by equipment failures [N_{FPROP}] Cluster analysis of equipment failures causing flooding [R'_{EF}]

* Note that these will be sub-sets of the data required for Indicators 1a and 1b.

Objectives

Indicators 2a and 2b

In the same way that Indicators 1a and 1b provide measures of *asset state*, Indicators 2a and 2b provide measures of *service impact* by concentrating initially on internal flooding of properties (DG5) where this has been the result of collapse or equipment failure incidents. The objective is that by JR03 companies will report the total numbers of properties affected in the year by internal flooding and the degree of clustering of the sewer collapses or equipment failures which have caused these events. The Indicators are to be reported as the pairs of numbers:

$$\{N_{CPROP}, R'_{SC}\} \text{ and } \{N_{FPROP}, R'_{EF}\}$$

At JR02 it is anticipated that as a minimum all companies will be able to provide estimates of the total numbers of properties flooded in the year (N_{CPROP} and N_{FPROP}) resulting from each event type. However the spatial data necessary to calculate the cluster statistics $\{R'\}$ is unlikely to be available. There is clearly a relationship with the data required for Indicators 1a and 1b insofar as the incidents which give rise to internal flooding will be a sub-set of the full population of collapses and equipment failures recorded for Indicators 1a and 1b. At JR02 companies should have put the necessary systems and procedures in place to collect this data and be able to demonstrate significant progress towards data collection and analysis so that R' can be calculated at JR03. The method for calculating the cluster statistic R' is identical to that for Indicators 1a and 1b and is specified in Appendix C.

Auditing Requirements JR02

- inspect and comment on the systems and procedures which are in place to capture the specified spatial and other information, with respect to "fitness for purpose".
- verify that the flood event data has a 1:1 relationship with the collapse and equipment failure incident data
- confirm that "equipment" has not included Pumping Stations (these are reported separately under Indicator 4).

- comment on the method for identifying or estimating the numbers of properties flooded
- inspect a sample of data for any collapse and equipment failure events which may have occurred and for which internal property flooding has resulted.
- comment on the degree of progress towards comprehensive company wide data collection.
- where companies have sufficient data and have calculated the R' statistic, verify that the calculation methodology has been correctly followed.

(It should be noted that in this case the cluster statistic R' is based on the collapse and equipment failure locations which have resulted in property flooding and NOT the property locations themselves.)

D.3 COMBINED SEWER OVERFLOWS

D.3.1 Indicator 3: Condition Grade of Combined Sewer Overflows

Summary of Reporting Requirements

Indicator	For JR02	For PR04
3	Total number of CSOs in the company [N_{CSO}]. Action Plan for the sampling and auditing of the company's CSO stock in order to achieve the PR04 objectives.	Condition Grade of $\{N_{CSO} / 3\}$ CSOs segregated into each of 5 asset condition grades Percentage of CSOs in each Condition Grade

Objective

Indicator 3

The long-term objective is that companies will inspect and assess on a continuing basis the asset condition of their stock of CSOs where this affects performance. It is recognised that this assessment work is likely to be a substantial task for most companies and an approach has been put forward which requires the work to be phased over 3 periodic review periods with the first phase reported at PR04. At each periodic review the asset condition of a total of one third of the company's CSO stock is to be reported. The sample for reporting by PR04 is to be a random one-third of the total asset stock.

A universal method for assessing the condition grade of CSOs does not currently exist although some companies have developed and are applying their own methods. A method similar to that used for grading sewers, *Sewerage Rehabilitation Manual*, Edition 4, 2001, WRc., which allocates assets into 5 condition grades is recommended for development and adoption. It is anticipated that the methodology will be developed and agreed by JR02 through a process of consultation between OFWAT and the companies.

The information to be reported at each periodic review is as follows:

Asset Condition Grade	1	2	3	4	5
Number of CSOs in each category	N^1_{CSO}	N^2_{CSO}	N^3_{CSO}	N^4_{CSO}	N^5_{CSO}
% in Grade	P^1_{CSO}	P^2_{CSO}	P^3_{CSO}	P^4_{CSO}	P^5_{CSO}

where $P^1_{CSO} = 100 \cdot N^1_{CSO} / N_{CSO}$ etc.

For JR02 companies will be expected to have put in place a comprehensive *Action Plan* for the sampling and auditing of the company's CSO stock in order to achieve the PR04 objectives and have established Procedures for undertaking CSO site inspections. Included in each Asset Plan will be a report of the total number of CSOs in the company, how the one-third sample has been selected and a programme outlining how the structural assessments will be achieved.

Future Indicator

A further long-term objective is for companies to report on the biological impacts of CSO discharges on the receiving watercourse. Issues regarding biological sampling will be the subject of ongoing debate and consultation and need not be considered further in the context of these reporting requirements.

Auditing Requirements JR02

Reporters will be required to examine each company's Action Plan and:

- Comment on the method and procedures for site inspections and Condition Grade assessment.
- Comment on the company's programme to achieve the PR04 objectives.
- Verify that the one-third sample for reporting at PR04 is random and will not represent a distorted view of the company's CSO asset stock.

D.4 PUMPING STATIONS

D.4.1 Indicators 4a and 4b: Pumping Station Mean Time Between Failures and Flooding caused by Pumping Station Failures

Summary of Reporting Requirements

Indicator	For JR02	For JR03 and beyond
4a	Allocation of pumping stations into 5 power bands. Estimated values of Mean Time Between Failure for pumping stations in each power band. Progress towards collection of Hours Run and Work Order numbers at PS level.	Robust values of Mean Time Between Failure for pumping stations in each power band.
4b	Total number of pumping station failures causing flooding [N_{PF}] Total number of properties flooded caused by pumping station failures [N_{PPROP}] Progress towards allocation of N_{PPROP} to pumping station power bands.	Total number of pumping station failures causing flooding [N_{PF}] allocated to power bands. Total number of properties flooded caused by pumping station failures [N_{PPROP}] allocated to pumping station power bands.
Future	Progress towards collection of Maintenance Cost data at PS level. Progress towards recording wider flooding and pollution impacts of pumping station failures.	Maintenance Cost data at PS level. Reporting of wider flooding and pollution impacts arising from pumping station failures

Objectives

Indicators 4a and 4b

There are currently no Serviceability Indicators for sewage pumping stations. The long-term objective is to establish a risk-based Indicator which combines the probability of a pumping station failure with the consequences of that failure measured in terms of flooding and pollution incidents.

As a logical step forward companies are required to calculate and report by JR03 two Indicators:

Indicator 4a: the *Hours Run* and *Mean Time Between Failures* (MTBF) for all sewage pumping stations for the company within 5 size bands.

Indicator 4b: {the number of pumping stations which have failed and caused internal flooding of properties, and the numbers of properties flooded} in 5 size bands.

(Size bands are based on the power rating of the pumping stations and are specified in Appendix C).

Most companies should be in a position to provide estimates of the MTBF Indicator values in each power band for JR02. As a minimum, the numbers of pumping stations in each power band should be reported. Where insufficient information is available to provide MTBF estimates, companies will be required to demonstrate at JR02 that systems have been put in place for the collection of the information necessary to calculate MTBF. Companies will also be required to demonstrate significant progress towards data collection and analysis to enable robust Indicator values to be evaluated for JR03.

For pumping station failures and consequential flooding (Indicator 4b) it is expected that as a minimum the total numbers of pumping station failures causing flooding will be available or can be estimated for JR02. Similarly it is expected that the total numbers of properties flooded will be available or can be estimated for JR02. Where insufficient information is available to provide reliable estimates, companies will be required to demonstrate at JR02 that systems have been put in place for the collection of the information necessary and will be required to demonstrate significant progress towards data collection and analysis to enable robust Indicator values to be evaluated for JR03.

Future Indicators

The next phase of development of these Indicators will be to incorporate maintenance costs and to broaden the consequence effects of pumping station failures to include wider flooding and pollution impacts as for sewer collapses and equipment failures (see Indicators 1a and 1b).

For JR02 all companies are required to have in place systems and procedures for the collection of this information and be able to demonstrate significant progress towards data collection and analysis to enable reporting of these measures at JR03.

Auditing Requirements JR02

Reporters should be satisfied that the correct interpretation has been made of the following:

Definitions:

Pumping Stations are defined as an individual site (not an individual pump) and include foul, combined and storm-water pumping stations but exclude terminal pumping stations situated at treatment works and inter-stage pumping. The power rating for the station is the sum of the ratings of the individual pumps.

Mean Time Between Failures is defined as Hours Run / Number of Work Orders.

Hours Run is the aggregation of the times in the year when the **station** has been pumping ie. not the sum of the individual pump run times.

Work Orders are defined as the total number of visits required for maintenance and non-routine inspections.

Reporters should also:

For Indicator 4a:

- verify the allocation of the company's sewage pumping stations into the 5 power bands.
- inspect and comment on the company's systems for determining station-specific Hours Run and Work Orders and verify that they are "fit for purpose".

- comment on the rate of progress towards establishing MTBF for all pumping stations to enable full reporting at JR03.
- where it has been possible to calculate or estimate MTBF values, check a sample of the calculations and verify that they have been based on the correct assumptions for Hours Run and Work Orders.
- comment on the company's maintenance strategy and any differences between one area to another which might give rise to a skew in the Indicator results.

For Indicator 4b:

- comment on the method for determining the numbers of pumping stations which have failed and caused flooding.
- comment on the method for identifying or estimating the numbers of properties flooded from pumping station failures.
- inspect a sample of data for any pumping station failure event which may have occurred and for which internal property flooding has resulted.

For Future Indicators:

- verify that systems and procedures are in place for the collection and recording the specified maintenance cost and wider flooding data and are "fit for purpose"
- inspect a sample of data for any pumping station failure events which may have occurred and for which consequence data has been collected.
- comment on the degree of progress towards comprehensive company wide data collection.

D.5 SEWAGE TREATMENT WORKS

D.5.1 Indicators 5a, 5b and 5c: Works Performance

Summary of Reporting Requirements

Indicator	For JR02	For JR03 and beyond
5a, b, c	Numbers of works in 4 size bands. Performance Statistics for BOD and SS and each size band. Performance Statistics for BOD and SS at company level.	Performance Statistics for BOD and SS and each size band. Performance Statistics for BOD and SS at company level.
Future	Progress towards the collection of individual works operating costs.	Works operating costs.

Objectives

Indicators 5a, 5b and 5c

Three new indicators have been developed which together overcome the shortcomings of the existing “pass ~ fail” indicator for sewage treatment works by providing a measure of works performance measured in terms of the prevailing works consent values. Since there is no additional determinand data required than is already being collected, companies will be expected to report a full set of Indicator values at JR02. The requirement is to report the three indicator values for each of two determinands (BOD and SS) in each of four works size bands. The report is of the form:

STW Band (pop equiv)	Determinand BOD				Determinand SS			
	Nr works in band	Indicators			Nr works in band	Indicators		
		5a	5b	5c		5a	5b	5c
500 to 2,000		x	x	x		x	x	x
2,000 to 10,000		x	x	x		x	x	x
10,000 to 100,000		x	x	x		x	x	x
> 100,000		x	x	x		x	x	x
Company		x	x	x		x	x	x

Each indicator value **x** is calculated as the *proportion of works for which a defined event is predicted in the coming year* and is based on the works performance over the previous 3 years. Three “event” types are used:

Event	Distribution characteristic of m / c
a	Maximum value > 2.0
b	95%tile (Normal) > 1.0
c	Mean value > 0.5

where ‘m’ is a determinand measurement and ‘c’ is the prevailing consent for that determinand. The analysis method is detailed in Appendix C.

Future Indicators

Further development of these Indicators is planned which relates them to works operating costs. To enable this future development to take place companies are asked to collect operating cost data at a works level. For JR02 companies are required to demonstrate that systems are in place for the collection of the specified works cost information and be able to demonstrate significant progress towards data collection.

Auditing Requirements JR02

- Verify that the company's sewage treatment works have been correctly assigned to the 4 size bands.
- For a sample of works covering each size band, inspect and verify that the methodology for the calculation of each of the six Performance Statistics (3 for BOD and 3 for SS) has been correctly followed. Take particular note that consent value changes have been applied correctly.
- Verify that the procedure for calculating the Performance Statistics at company level has been correctly followed.
- Verify that systems and procedures are in place for the collection and recording of works operating costs at works level and are "fit for purpose".
- Comment on progress towards collection and recording of works operating costs to enable full reporting at JR03.

D.6 SLUDGE TREATMENT AND DISPOSAL SYSTEMS

D.6.1 Availability of Disposal Route

Summary of Reporting Requirements

Indicator	For JR02	For JR03	For PR04 and beyond
Future L1	Programme that will enable all data to be available by PR04. Progress towards collecting data.	Example pilot calculations for selected disposal routes. Progress towards collecting data.	Percent sludge disposal routes available: <ul style="list-style-type: none"> Under Normal Operation Utilising Overtime Routes Diverting Sludge: <ul style="list-style-type: none"> Percentage of production diverted due to non-availability of primary disposal route Quantity diverted
Future L2	Programme that will enable all data to be available by PR04. Progress towards collecting data.	Progress towards collecting data.	Probable percent sludge disposal routes available: <ul style="list-style-type: none"> Under Normal Operation Utilising Overtime

Objectives

There are currently no serviceability indicators for sludge treatment and disposal systems and the method for calculation of the proposed future indicators has not been tested owing to lack of data. It is intended to come to a consensus on an agreed final methodology for reporting and indicator calculation by PR04.

For JR02 reporting is to be limited to a demonstration of progress on setting up the data collection exercise and that plans are being implemented which will allow full data collection to be complete for PR04.

For JR03 further progress on data collection should be demonstrated and a pilot study undertaken which applies the proposed methodology to a selection of sludge disposal routes.

Auditing Requirements JR02

- Collate comments on the proposed methodology and any alternative approaches that the company may wish to be considered.
- Inspect and comment on the company's data collection programme and procedures to achieve the PR04 objectives. In particular ensure that the programme includes the full list of data specified in Appendix C.

APPENDIX E

PARTICIPATING COMPANY COMMENTS

These are initial thoughts from working level contacts with participating companies. They are included here to inform consultation, and do not necessarily represent the companies' corporate views.

ANGLIAN

Anglian Water have welcomed the opportunity to be involved in the review of existing wastewater serviceability measures and the development of new measures which will aid the definition of future performance standards and associated investment levels.

We have recognised that the existing measures do not provide sufficient indicators or detail to aid the development of forward looking investment plans relating to the capital maintenance needs of the existing asset base to give a sustained level of performance. This study has gone some way to addressing these concerns and promoting additional indicators. However, it is inevitable, within the timescale constraints imposed on the study, that much work remains to be done in validating the use of the proposed indicators to deliver the objectives.

The requirements for data collection and the quality of the collected data are causes for concern. It is our view that this will take a number of regulatory cycles (JR Returns) before there is any consistency of approach (or indeed interpretation of reporting requirements) across the industry. For this reason we have concerns regarding the usage of the new and revised indicators in any performance "league table" approach until this bedding in process has been allowed to come to fruition.

There will need to be a period of review when the adequacy of current data and the improved systems required to collect new data can be assessed. It is critical that confidence in the effectiveness of the new and improved indicators to achieve an improved measure of sustained performance is established. The need for effective GIS systems which have the functionality to identify "clusters" for sewer collapses and flooding events in the forms proposed and the use of work planning information for the mean time between failures in the pumping station indicators are areas of concern.

The review of potential indicators has been wide and there has been robust debate over the validity and effectiveness of a number of the measures. There is now a need to review the proposed indicators and their associated data requirements across the industry and to comment constructively on their applicability.

As previously stated we have welcomed the opportunity to be involved in the development of these new indicators. We intend to comment in detail on them and on the reporting requirements proposed in the report during the consultation period.

In a general sense we believe that the report provides a significant step forward in the relationship between the Regulators and the water industry. Taken in conjunction with other reports on potable water indicators and the industry sponsored work on capital maintenance, it will provide a sound basis for moving into the PR04 reporting cycle.

SOUTHERN

Southern Water (SW) has welcomed the opportunity to participate in this important study. In common with many of the Water and Sewerage companies SW has major concerns regarding the provision for asset maintenance made in the K3 settlement and the methods that Ofwat has used to arrive at its decisions. This study on serviceability measures makes a step forward on the path to a more complete assessment of asset performance. Of particular concern to SW has been Ofwat's reliance to date on historic performance assessment only and the limited range of performance indicators used. Despite the very short time scale afforded to them Ofwat's consultants have developed a sensible approach to the enhancement of serviceability measures that ultimately seeks to develop forward looking indicators which will include an assessment of risk of failure. The consultants have also proposed measures to cover assets whose performance have not previously been assessed by performance indicators.

SW believes that an open and transparent process for assessment of asset maintenance requirements is to the benefit of all parties and is pleased that an improved spirit of co-operation seems to have been manifest with this study.

The aspiration has been to develop enhanced and additional indicators of asset performance in time for inclusion in the 2002 June Return. The consultants report recognises that this can only be realistically achieved for a small number of measures and acknowledges the time it will take for Companies to put new data collection procedures and modified systems in place to allow the new measures to be evaluated.

Even though there are practical limitations on collecting information for the proposed new measures we should ensure that AMP 4 heralds a step change in addressing the problems that exist whilst building a sound basis for the future. The short time scale of this exercise appears to have led to rejection of a number of important measures such as those related to STW volumetric compliance. We believe that it should be possible to develop an understanding of this and certain other measures and we look to the complimentary UKWIR report on Capital Maintenance Planning to explore this.

In conclusion, we welcome the attempt to develop an improved package of indicators designed to reflect the serviceability status of sewage disposal and treatment systems. It is an essential next step to make clear how these might fit into a periodic review process for setting forward asset maintenance budgets. In this way we can ensure that maintenance levels are properly set in relation to the impact on customers and the environment of operational and asset performance.

THAMES

The report is a substantial contribution to the debate and will require significant study. We do not think it is therefore appropriate to provide detailed comments on the proposed measures at this stage, particularly for the public domain, as this may prejudice the subsequent consultation. We do offer some general views.

Criteria

In order to assess the suitability of the proposed measures as monitors of current maintenance activity and drivers of future activity and expenditure, we propose to use the following criteria.

- Is the indicator significantly influenced by the level of capital maintenance expenditure?
Were capital maintenance to be stepped up or down, would the indicator change in the corresponding direction?
- Is the indicator also affected by other types of expenditure?
For example, has the indicator improved due to the quality programme or to service enhancements.
- If so, is it possible to determine the underlying trend after the effects of the improvement programme?
If not, it may be necessary to conclude that the indicator tells us nothing about maintenance activity until the improvement programmes are complete.
- Can the indicator be forecast over the next 5 – 15 years?
This is critical to using the indicator as a driver of future maintenance activity and expenditure.
- Has the data been recorded in the past or, if not, is it practical and cost effective to start recording it now?
Where the new data requirements are onerous an assessment of the cost and benefits should be undertaken before inclusion in June Returns.

Preliminary Views

- 1) We support the proposal to consider measures for each major asset group rather than a simple infra and non-infra split.
- 2) We also support the development of indicators of both asset performance and of serviceability to customers and the environment. We prefer these terms to those of “probability of failure event” and “consequence of failure event” used in the report.
- 3) We are concerned about the proposals for spatial data. Data collection will be onerous and the measures are of dubious value as serviceability indicators.
- 4) We do not support the proposals for a structural condition grade survey of a 1/3rd of CSOs. This will be expensive and condition assessments do not provide a good guide to asset performance. Survey costs may therefore outweigh capital maintenance benefits.

- 5) The proposals for sludge disposal are untested and have little to do with maintenance as they relate to the capacity of the assets, or disposal routes, not maintenance of the assets.

YORKSHIRE

Yorkshire Water welcomes the opportunity to be involved in the review of OFWAT's existing wastewater serviceability measures.

We have long since recognised that the existing measures do not provide sufficient, relevant indicators, to inform the development of robust forward investment plans aimed at sustaining existing levels of service and compliance from our asset base. Our AMP3 base maintenance submission was in fact based upon a leading-edge, risk-based approach to identifying serviceability failure – an approach which we are keen to develop further for PR'04.

This study has taken a step forward in addressing the weaknesses of the existing serviceability indicators. Additional indicators are being promoted for above ground assets and a start has been made on recognising the importance of establishing 'lead' (rather than 'lag') indicators. In addition, effort has been made to include the more challenging aspect of assessing risks of loss of service from underground assets. The latest CSC reports show that customers' priorities relate to this latter group of assets.

It is also reassuring to note that this study, and report, acknowledges that there is a fundamental requirement to move to risk-based approaches to asset management, with impacts expressed in terms of loss of service to customers and the environment. This view is shared by Yorkshire Water and also reinforced by the ongoing UKWIR (UK Water Industry Research) Capital Maintenance Framework study which is co-sponsored by OFWAT, DWI, EA and the water industry.

Our prime concern centres around how the output of this project and that of the UKWIR study will be dovetailed. This project is being driven to conclude in sufficient time so as to allow revised data collection requirements to be incorporated into the 2002 June Return. The UKWIR project continues beyond that cut-off, but is endeavouring to establish a more holistic Capital Maintenance Framework, linking serviceability measures with risk of failure and, potentially, customers' willingness to pay. This work is being further supplemented in Yorkshire Water. As a minimum it is not clear how the outcome of the UKWIR project (assuming the need to further refine data collection around serviceability measures) would be merged into OFWAT's timetable for data collection around June Returns. Neither is it clear, without the benefit of the UKWIR work how, for example, the indicators as proposed fulfil the need to move to a set of risk-based leading indicators, since, as proposed, they largely relate to information about the fabric of assets.

We view this report as being an important platform for further debate on base service provision. As indicated, the proposals converge on approaches already being undertaken or developed within this company. For example, we agree with the comment that to combine different flooding categories would require a common degree of valuation - Yorkshire Water is looking to apply this principle across all measures of service to derive an economic level of investment. The next steps to agree such common currencies, and how these fit into a risk-based approach to asset management, are where regulators and the industry need to engage next

In conclusion, we believe we need the output of the UKWIR Capital Maintenance Framework prior to finalising the serviceability indicators to be used in PR'04 and therefore would strongly suggest a further review of measures and data collection requirements during the Autumn of 2002.

We also believe that the report provides a significant step forward in the relationship between the Regulators and the water industry. Taken in conjunction with other reports on potable water indicators and the jointly sponsored work on capital maintenance, it will provide a sound basis for moving into the PR04 reporting cycle.

