A RESEARCH PROJECT SUPPORTED BY THE EUROPEAN COMMISSION UNDER THE FIFTH FRAMEWORK PROGRAMME
AND CONTRIBUTING TO THE IMPLEMENT OF THE KEY ACTION "SUSTAINABLE MANAGEMENT AND QUALITY OF WATER"
WITHIN THE ENERGY, ENVIRONMENT AND SUSTAINABLE DEVELOPMENT

EVK1-CT-2002-00106

REPORT

No 7.1 - April 2004

WP 7, Deliverable D20
The CARE-S Procedure

Joanne Hulance, Project Manager, WRc
Roger Hurley, Senior Consultant, WRc
Mark Kowalski, Consultant Engineer, WRc
Nick Orman, Senior Consultant, WRc

CARE

CARE-S - Computer Aided REhabilitation of Sewer networks

COMPUTER AIDED REHABILITATION OF SEWER NETWORKS

RESEARCH AND TECHNOLOGICAL DEVELOPMENT PROJECT OF EUROPEAN COMMUNITY

Water Research Centre plc, Frankland Road, Blagrove, Swindon, SN5 8YF

Phone: +44 1793 865 038 / 068 Fax: +44 1793 865 001

CARE – S

Computer Aided REhabilitation of Sewer networks.
Decision Support Tools for Sustainable Sewer Network Management

WP7 – Wastewater Network Rehabilitation Manager

Report D20

THE CARE-S PROCEDURE

Joanne Hulance
Project Manager, WRc plc

Nick Orman
Senior Consultant, WRc plc

Roger Hurley
Senior Consultant, WRc plc

Mark Kowalski
Consultant Engineer, WRc plc

Swindon, April 2004

CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. SUMMARY

The overall aim of the CARE-S project is to develop methods and software that will enable engineers to define and implement effective management of their sewer networks, rehabilitating the right pipe lengths at the right time. The CARE-S project is a large project formed from various elements which will produce specific methods and tools to assist in the decision making process. The results of these various elements will be brought together in the Wastewater Network Rehabilitation Manager, the output from WP7.

The first step in the process to integrate the CARE-S project has been to develop a procedure which can be adopted by a wastewater network manager to develop effective rehabilitation plans. The next step has been to identify and define the methods or software tools which can be used to develop these plans. These methods have then been applied to the generic planning procedure to develop the CARE-S procedure for rehabilitation planning.

The benefits of the various applications being developed under CARE-S have been assessed and a procedure for integration has also been presented in terms of a step-by-step guide. This step-by-step guide identified the relationship of the tools in terms of the flow of data and also highlighted the reports that would be required to assist in the development of a rehabilitation plan. This integrated procedure will form the blueprint for the Wastewater Network Rehabilitation Manager.

The Wastewater Network Rehabilitation Manager will be more than a software application linking a collection of analysis tools. It will be a versatile and powerful application, facilitating the efficient use of the CARE-S tool-kit. At its simplest level it will provide a central storage area for appropriate asset data and analysis results. The Rehabilitation Manager will also facilitate the manipulation of this data, allowing the user to view it both geospatailly and in tabular form. It will manage data interaction with all of the CARE-S tools and produce appropriate reports to facilitate the development of a rehabilitation plan. Finally, the Rehabilitation Manager will provide interactive guidance for the selection of the appropriate analysis method, in accordance with the CARE-S procedure.

This report provides an introduction to the concepts on which the design of the Rehabilitation Manager has been based, presenting the architecture of the software.

The next deliverable for WP7 is D21 (due in March 2004) which will present the results of Task 7.2. The aim of Task 7.2 is to define the user interface for the Rehabilitation Manager. The user interface can be defined as any element of the Rehabilitation Manager with which the user will interact. This would include the following functions:

- Creating projects;
- Importing data;
- Manipulating data;
- Accessing tools;
- Editing data;
- Displaying data and reporting the results of analyses;
- Interactive guidance, and;
- Help facility.

These aspects are dealt with in report D21.

2. INTRODUCTION

2.1 CARE-S Aims

The CARE-S project aims to develop methods and software that will enable sewerage engineers to define and implement an effective management of their sewer networks, rehabilitating the right pipe lengths at the right time. The results will be disseminated as a Manual of Best Practice[1] for sewer network rehabilitation.

This project is organised in the following Work Packages (WP):

- WP1 : Construction of a control panel of Performance Indicators for Rehabilitation
- WP2 : Description and validation of structural condition
- WP3 : Description and validation of hydraulic performance
- WP4 : Rehabilitation technology information system
- WP5 : Socio-economic consequences
- WP6 : Multi-criteria decision support
- WP7 : Wastewater network rehabilitation manager
- WP8 : Testing and validation
- WP9 : Result presentation and dissemination
- WP10 : Project management

WRc is responsible for WP7, which is divided into three tasks. This report deals with the work undertaken for the first of these, viz.

"Task 7.1 Develop the CARE-S procedure for optimising rehabilitation planning: The individual CARE-S tools will be thoroughly evaluated in terms of their benefits, data requirements and inter-relationships (there will be some overlap of functionality and differences of approach due to local application). Some rationalisation or development may take place. The application benefits will be mapped and a procedure for optimum integration developed. It will be made clear, how to utilise the toolbox most efficiently in order to address a given problem or circumstance."

[1] The project proposal refers to a manual on 'Best Management Practice (BMP)'. This term is commonly used to describe more sustainable methods for managing urban run-off (e.g. the use of swales or permeable pavements). It is therefore suggested that the term 'Best Management Practice' be replaced by 'Manual of Best Practice' in CARE-S.

The other two tasks will be the subject of future reports. For information, these tasks are described below.

"Task 7.2 Define the User Interface for the CARE-S suite: The CARE-S software will include the link to a standard GIS based tool to be used as the user interface. The user shall be able to map the existing wastewater system and the consequences of probable failures, as well as describe scenarios with connecting consequence. The aim of this task is to select an appropriate GIS system for the user interface of CARE-S."

"Task 7.3 Create the prototype (software, manual and website): A database will be developed that will support the integration and data flows between the CARE-S component software. This will support automatic and manual data input. The database will store information (results of analysis) that can, for example, enable write back to electronic corporate data storage systems, such as GIS (geographic information system). A manual will be developed to support the use of the software. This will be used to generate an on-line help system. A working demo of the software will be accessible via the CARE-S Web site.

2.2 WP7 objectives

WP7 will produce the software application enabling a range of tools (identified and developed under work packages 1 to 6) to be applied methodically to the rehabilitation planning process. The specific objectives of WP7 are as follows:

- Specify the data input/output and storage requirements for the integrated CARE-S package;
- Produce a specification for software that will optimally integrate the use of the tools defined in CARE-S;
- Deliver working prototype software that will manage the information needed and results generated from the tools defined in CARE-S, enabling the integrated CARE-S package to identify optimum rehabilitation strategies.

2.3 Scope of this report

This report aims to present a rehabilitation planning procedure concordant with use of the CARE-S prototype (hereafter referred to as 'the prototype') and demonstrate how CARE-S may assist in this process.

This document (D20a) describes the procedure in general terms, describing the current understanding of the tools proposed in each work package, their data requirements and how they function together. It replaces the earlier report, D20, which was produced at month 6 (March 2003) and discussed at the Ferrara Workshop (end-March 2003). The step-by-step guide described in Section 3 constitutes our understanding of the data requirements of the CARE-S tool-kit. This report does not give details of the data items needed by each tool as most of these details are still awaited from tool developers.

The structure of this report is as follows:

Section 1: Summary

Section 2: Introduction

Section 3: Describes the generic rehabilitation planning procedure contained in the CEN standard, which is applicable in most instances, regardless of the analysis tools available.

Section 4: Describes how CARE-S may be applied to the procedure outlined in Section 2, and provides a list of possible tools which may be included in the project.

Section 5: Describes a step-by-step guide to the development of a rehabilitation plan using the CARE-S tool-kit within the CEN procedure.

Section 6: Provides an overview of the software.

NOTE: The key performance indicators and data flows must be developed and specified as a prerequisite to developing the prototype software under work package WP7. It is essential *at the earliest possible stage* to specify thoroughly the data outputs and reports that are required by users and generated by the CARE-S tools.

3. A GENERIC REHABILITATION PLANNING PROCESS

3.1 Rehabilitation planning: An engineering perspective

Efficient planning requires the rehabilitation engineer or planner to be in possession of a substantial amount of background knowledge and experience on the types of problems faced, current performance and possible effective solutions. The engineer must be aware of the objectives of rehabilitation for each problem, and apply sound judgement using all the tools available in an appropriate manner. This places a huge burden on the engineer when many rehabilitation methods are feasible and there are many solutions to improve service delivery to customers. The engineer can narrow the search for an acceptable solution by using strategic level data and knowledge of historical performance. However, scheduling rehabilitation over, say, a 5-year planning horizon is a complex multivariate problem and the engineer must be guided by a suite of useful analysis tools to help choose the most cost-effective rehabilitation options from those available.

Figure 3.1 summarises a generic sewer rehabilitation process in accordance with EN752-5:1997.

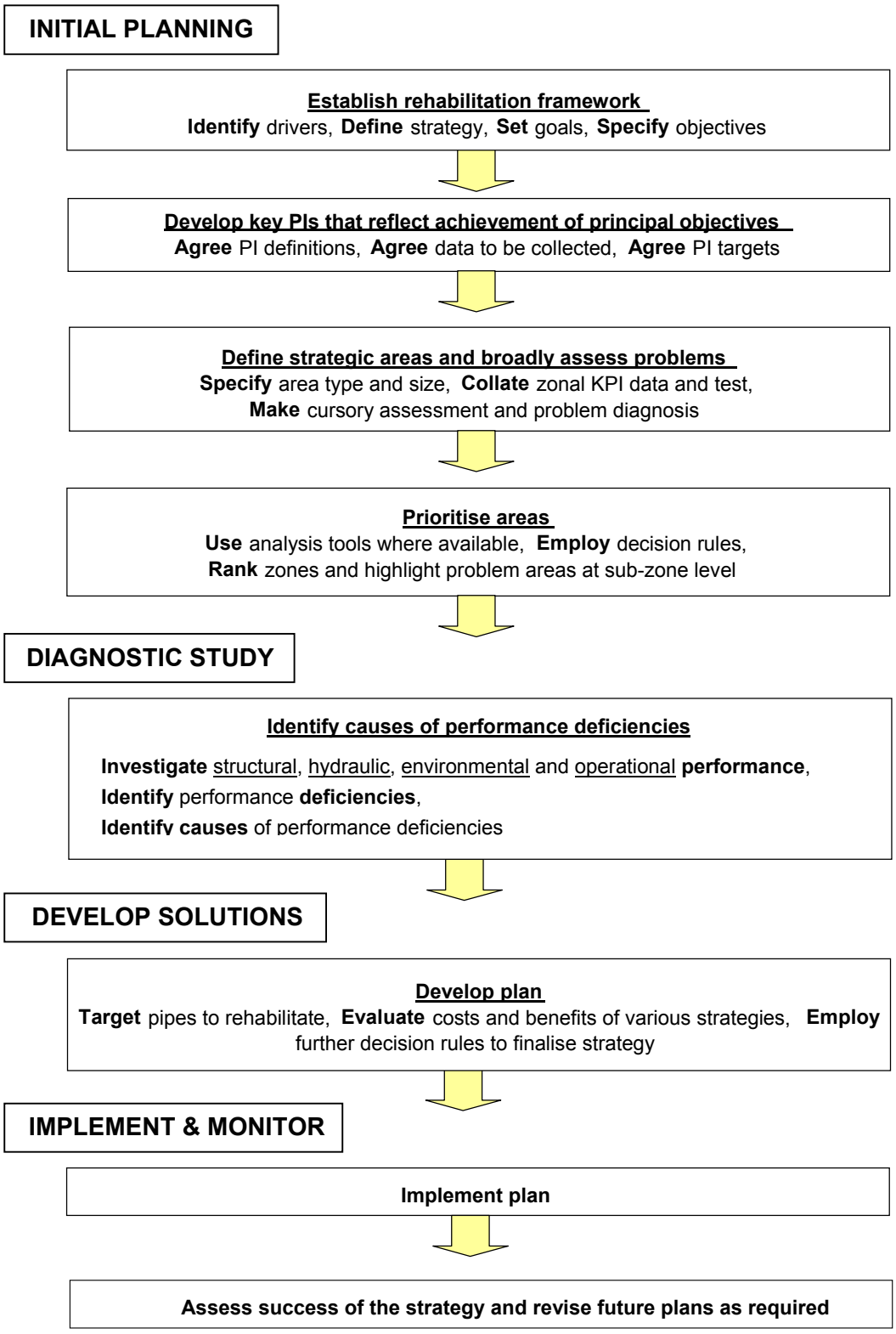


Figure 3.1 Generic rehabilitation planning process

EN752-5 describes four stages of this process. They are described in the following sections.

- Initial planning;
- Diagnostic study;
- Develop solutions;
- Implement and monitor.

3.2 Stage 1 - Initial planning

In the initial planning stage, 'ground rules' for the rehabilitation study are established and knowledge about the current performance is collected, so that the detailed studies can be carried out accordance with a defined programme. This stage is shown diagrammatically in Figure 3.2 and described in the following sections.

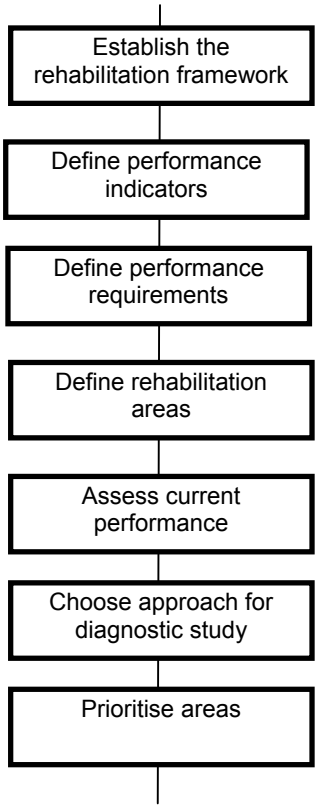


Figure 3.2 Flowchart for the initial planning stage

3.2.1 Establish the rehabilitation framework

The first step is to establish the overall framework for managing the rehabilitation process. This would involve identifying the drivers which influence rehabilitation and, perhaps, assessing their relative importance. The drivers which are important will naturally vary from region to region, and country to country. For instance, flooding from sewers, pollution of the aquatic environment, sewer blockage rates, collapse rates, pipe condition and cross-utility co-ordination are all drivers which influence perceived asset serviceability (and, hence, rehabilitation needs) in most European countries. These drivers will determine the objectives of the rehabilitation work, which will in turn influence the overall rehabilitation strategy. The timescale over which the work needs to be carried out (the *planning horizon*) must be decided at this stage.

3.2.2 Define performance indicators

Once the framework of the rehabilitation plan has been decided upon, key performance indicators (KPIs) can be defined. Targets for the KPIs would also be defined at this stage. These must reflect the current and predicted future drivers for the water company or municipality. In other words, one needs to ***measure to manage***. For example, if customer complaints of localised flooding are high and this is a key concern of the sewerage undertaker, it makes sense to define, record and analyse performance data (e.g. number of complaints of flooding and sewer blockages/collapses). The sewerage undertaker can then keep a close watch on the problem and monitor the efficacy of any remedial action taken, over a period of time.

This is also the correct time to assess data needs and validate all sources of data. Some KPIs will need data from a number of different and possibly disparate sources. Whilst it is important to ensure KPIs can be calculated from data available, a lack of data should not preclude the development of a particular performance measure if it addresses an important business or service issue. Instead, a way must be found to collect this information in order that the KPI may be validated and its use tested.

3.2.3 Determine performance requirements

The performance requirements should be clearly specified on a regional basis and should cover:

- Hydraulic performance;
- Environmental protection;
- Structural integrity; and,
- Operational performance.

For each aspect of performance two levels may be required:

- Trigger levels which justify early upgrading action;
- Target levels to aim for when upgrading.

The performance requirements will also be used to evaluate potential solutions against the relevant standards. In this case it is important that ***all*** rehabilitation needs (hydraulic, environmental, structural and operational) are considered together. This is because integrated solutions are the most cost-effective.

3.2.4 Define rehabilitation areas

The next step is to define the size of the areas to which the rehabilitation framework will be applied. These catchments or drainage areas should be defined by the rehabilitation engineer or planner. A drainage area could be an area that drains to a specific watercourse, an area that drains to single treatment works or a part of one of these areas, such as an area draining to a pumping station which, in turn, pumps to a treatment works. Working on small areas will be data-intensive but will provide highly specific solutions. Working on larger areas will require less data but will produce more general solutions, which will require further development before they can be implemented. The engineer or planner must decide on the appropriate balance. However these drainage areas are decided upon, they need to be specified and the KPI information for each area collated and used to develop an initial view of the performance of each area.

3.2.5 Assess current performance

This should be a rudimentary exercise with the aim of gaining an appreciation of the nature and scale of the problems in each drainage area so that:

a. The precise scope of the diagnostic study can be determined; and

b. A programme for completion of all drainage area studies can be produced and priorities assigned against each study.

An initial assessment of the performance of the systems should be made using performance indicators. Where PI's are not yet available, the current performance should be assessed using reports of incidents such as sewer collapses, flooding or pollution of watercourses. Records of past incidents together with any other relevant local knowledge of the system (e.g. recurring maintenance problems) should be collated, and an initial assessment should be carried out to compare current performance with the performance criteria specified.

It is recommended that this stage is completed for ***all*** drainage areas, so that a programme of investigation can be drawn up, with priorities which are based on some knowledge of the problems in each of the drainage areas.

3.2.6 Choose approach for diagnostic study

Following the initial assessment of the current performance of the system, it will be necessary to decide on the level of investigation that will be required.

In the majority of drainage areas it is likely that a detailed diagnostic study, including a degree of environmental assessment, will be necessary. In drainage areas where there has been a previous drainage area study or where few problems exist, an abbreviated investigation may be sufficient. Similarly in small, rural catchments it may be unnecessary to undertake a detailed diagnostic study and an abbreviated study, concentrating upon known or suspected problems may be appropriate.

When there are a large number of drainage areas requiring detailed investigation, the areas with the most serious problems should be considered first. The programme should take into account that some environmental investigations will need to be undertaken on a wider area reflecting, for example, river catchments.

3.2.7 Prioritise areas

Significant resources of experienced staff are likely to be required for detailed investigations. It is unlikely that any Sewerage Undertaker will be able to provide sufficient resources to allow this work to proceed immediately in every system. It will therefore be necessary to set priorities. The aim should be to deal with systems on a "worst first" basis and this will require a regional allocation of resources.

The prioritisation may depend largely on outside pressures, for example from the environmental (or other) regulator. Where this is not the case, decisions will have to be taken with regard to the relative severity of the problems in each drainage area. Insofar as the problems are structural, the total length of critical sewer in the drainage area, or the collapse rate, can be useful measures of the cumulative risk of collapse in a catchment.

3.3 Stage 2 - Diagnostic study[2]

3.3.1 Identify causes of performance deficiencies

Areas requiring detailed investigation must be chosen to assist in meeting the business objectives of the sewerage provider. In terms of the customer, these must include maintaining existing service provision or, if the level of service is deemed unacceptable, improving service to customers. The steps in the process of investigations will naturally be guided by the nature of the problem(s) to be solved, the policy of the sewerage undertaker, industry regulation and available data. However there are four aspects of performance which are inter-related and which the investigations should address: *structural, hydraulic, environmental and operational* performance. Because each aspect of performance affects the others, the investigations should be carried out together, as shown in Figure 3.3:

[2] Further information on the diagnostic study is contained in prEN13508-1

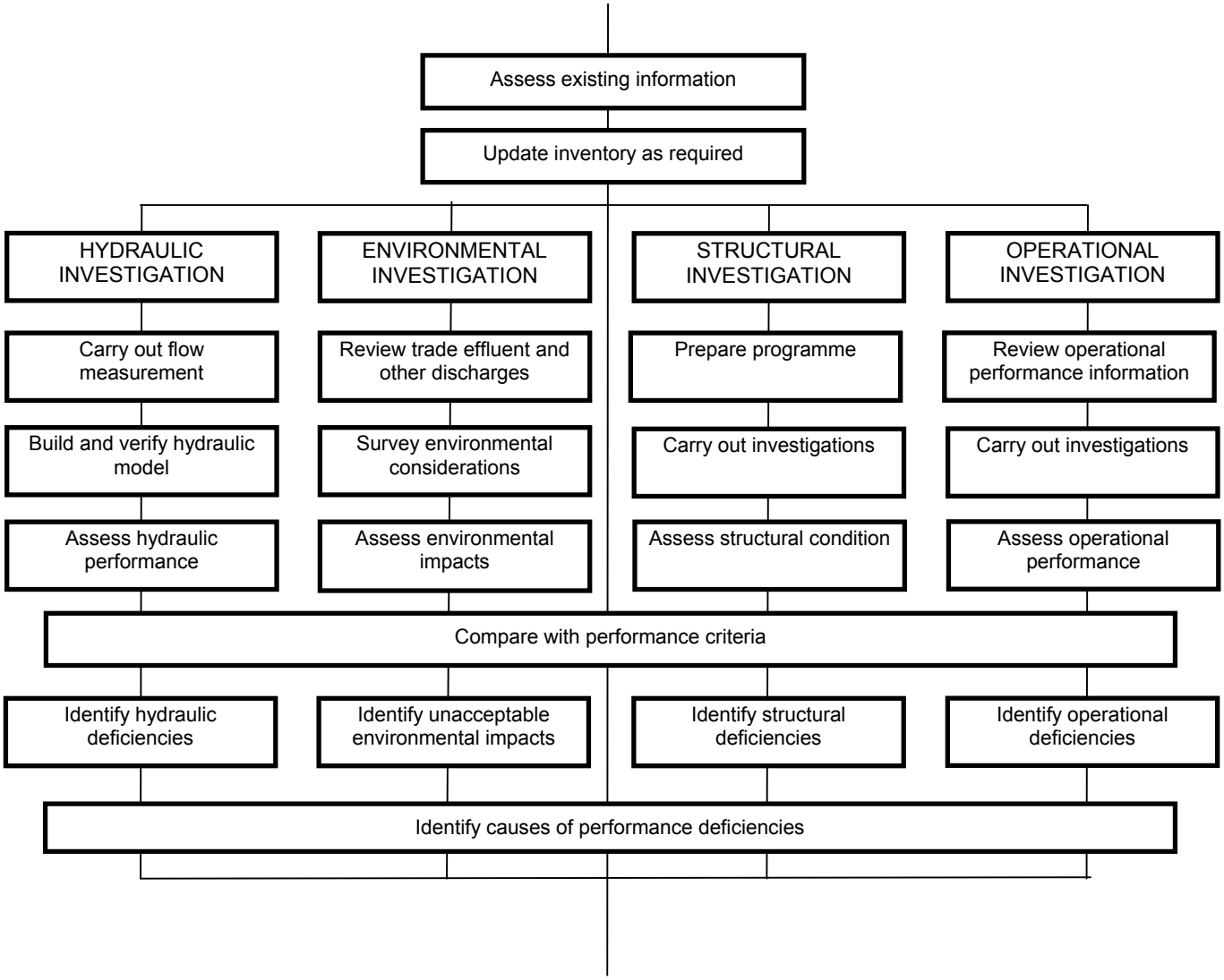


Figure 3.3 Flowchart for the diagnostic study

3.3.2 Hydraulic investigation

This consists of three initial activities:

- Carry out flow measurement;
- Build and verify hydraulic model;
- Assess hydraulic performance.

Flow measurement

A flow survey is necessary for two reasons:

- To ensure that existing flows are understood (dry weather and storm flows, infiltration, exfiltration, unauthorised connections, etc.); and

- to provide information with which to verify the hydraulic model (see below).

The survey should include the measurement of 'contributing areas' (measuring surface areas and allocating them to specific sewer entry-points), rainfall and the corresponding sewer flows, and the measurement of groundwater levels.

Build and verify hydraulic model

A flow simulation model may be needed to understand the hydraulics of the sewer system and to enable the rehabilitation engineer make predictions for future 'what-if' scenarios. If the hydraulic situation is relatively simple a model may not be necessary (e.g. there are no known hydraulic problems, there are no combined sewer overflows (CSOs), or any structural problems can be solved using techniques which do not affect the hydraulic capacity).

The model must represent the system as shown on the sewer records. Some interpretation and simplification will normally be required, so it is necessary to validate the model to ensure its accuracy and to provide confidence when using it as a predictive tool.

Assess hydraulic performance

The results of the hydraulic surveys and the verified flow simulation model are used to assess the hydraulic performance of the system for a range of rainfall conditions, in order to identify aspects of performance which are unsatisfactory.

3.3.3 Environmental investigation

This consists of three initial activities:

- Review trade effluent and other discharges;

- Survey environmental considerations;

- Assess environmental impact.

Trade effluents and other discharges

The location of trade effluent sources should be identified and the nature, quality, quantity and the potential environmental hazards should be assessed.

Survey environmental considerations

Watertightness

Investigations may be required to locate leakage from the sewers (exfiltration). This is particularly important if the sewers pass through aquifer protection zones or if they carry hazardous substances.

Receiving water quality

The quality of all receiving waters should be assessed to see whether it meets the required standards. If not, investigations will be necessary to determine whether the sewers contribute to the problems.

Other environmental impacts

Consideration should be given to other environmental factors such as noise, odour and visual intrusion.

Assess environmental impact

The frequencies, durations and volumes of discharges to receiving waters should be estimated using the verified flow simulation model (if available). This information enables the rehabilitation engineer to assess the environmental impacts of the sewer system (including impact on soil and groundwater).

The structural condition of the sewers may have an impact on the environmental impact, so the results of the structural investigation (see below), the trade effluent survey and the other environmental considerations should be examined to identify:

- Sources of hazardous effluents;
- Exceedence of permissible concentrations and discharges;
- Other deviations from permits.

3.3.4 Structural investigation

This consists of three initial activities:

- Prepare programme;
- Carry out investigations;
- Assess structural condition.

Prepare programme

The structural investigations may include either a complete condition survey of the sewer system (or sub-system) or a partial survey. A partial survey may concentrate on those sewers

which have not previously been inspected, ignoring those which have been inspected in the recent past, or may concentrate on a representative sample of the sewers or a stratified sample, concentrating on potentially high cost sewers.

Carry out investigations

The recording of sewer condition can be carried out directly by walking through or indirectly with the aid of closed circuit television equipment (CCTV). The objective is to record the defects in the sewers and, from this record, to assess the structural condition. Where appropriate, other investigation techniques may be used (e.g. sonar, radar, etc.).

As explained above, the results of the structural investigations can also be relevant to the assessments of the hydraulic performance and environmental impact.

Assess structural condition

Once the sewer system has been inspected, the next stage is to examine the results in order to identify those areas requiring action. Sewer condition can be expressed in terms of *condition* or *performance grades* with 'grade 1' representing as-new condition/performance and 'grade 5' representing an urgent need for attention. A prioritised action list can then be prepared.

3.3.5 Operational investigation

Many problems that become apparent through operational incidents cause poor hydraulic or environmental performance. Such incidents are frequently caused by structural problems in the sewer system (e.g. collapse or lack of hydraulic capacity), however they can also be caused by operational or maintenance problems. The operational investigation involves a review of current planned maintenance activities and past incidents. This will enable the engineer of planner to identify the causes of these problems and assess the effectiveness of the existing operations and maintenance regimes (in accordance with EN752-7 Clause 6.2).

Some of the tools used in the operational investigation can also be used for other parts of the study. For example, a hydraulic model may be used to establish the cause of sedimentation in a sewer, and a visual inspection using CCTV may be used to identify the cause of repeated blockages in sewers. The operations and maintenance investigation will therefore need to be co-ordinated closely with the hydraulic, environmental and structural investigations.

The investigation consists of three initial activities:

- Review operational performance information;
- Carry out investigations;
- Assess operational performance.

Review operational performance information

The operational data considered in the initial investigation (Stage 1) should be reviewed to identify any activities or locations which may require more detailed investigation. The justification for investigation should be whether there are problems which could be resolved cost-effectively by rehabilitation or changes in operation & maintenance procedures. Areas which should be considered include the following:

- Sewer collapses and rising mains bursts
  Are collapse rates excessively high or concentrated in local areas?

- Sewer blockages
  Where are the blockages concentrated? Do they cause flooding or pollution?

- Pumping Stations
  Are failure rates acceptable? Are the reactive and planned maintenance policies effective?

- Combined Sewer Overflows
  Are there frequent discharges in dry weather? Do they cause pollution problems?

- Odour complaints
  Are there concentrations of complaints in local areas?

- Rat complaints
  Are there high levels of rat sightings? Are they associated with the sewer system?

- Planned sewer cleaning
  Why are planned sewer cleaning activities being carried out? Are they effective?

Carry out investigations

Once areas with operational problems have been identified, the detailed investigations of the underlying causes can be carried out. The most common types of investigations are:

- CCTV inspection of sewers;

- Further analysis of causes from existing records;

- Collection of additional operational data for short periods;

- Inspection of electrical and mechanical plant;

- Test baiting for rats;

- Hydrogen sulphide testing.

It should be noted that, in many cases, the operational information will be material to another investigation. For example, where the risk of collapse is considered excessive, this should be addressed during the structural investigation; and where excess flows are the cause of incidents at sewage pumping stations, this should be included in the hydraulic investigation.

Investigations in connection with planned sewer cleaning (sediment removal) activities should be carried out in conjunction with the hydraulic investigation.

Assess operational performance

The results of the investigations should be used to assess the operational performance of the system. This should be reported using the performance indicators chosen in the initial planning stage (Stage 1).

3.3.6 Compare with performance criteria

Having assessed the hydraulic, environmental, structural and operational performance of the sewer system, it should be compared with the required performance levels to identify performance deficiencies. This provides the rehabilitation engineer with an overall view of the sewer system's current performance.

3.3.7 Identify causes of performance deficiencies

The causes of the performance deficiencies should then be determined by reference to the three strands of the investigation. The relative impact of each cause should be assessed in order to develop appropriate solutions and to set priorities for action in the next stage of the rehabilitation study.

3.4 Stage 3 - Develop solutions

As explained above, the four aspects of performance are inter-related. A structural defect in a sewer can give rise to debris which, in turn, causes hydraulic problems (loss of capacity) which might cause flooding or pollution. Similarly, hydraulic problems can cause surcharging of the sewer, and the flow of sewage or groundwater through cracks in the structure can promote structural problems. It is important to consider the four sets of problems *together* when developing the solutions, because a single solution can affect more than one aspect of performance.

The process of developing the rehabilitation plan therefore involves identifying *integrated solutions* to the problems, as shown in Figure 3.4:

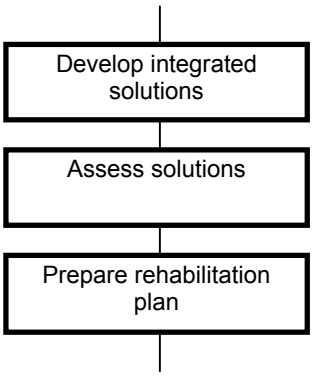


Figure 3.4 Flowchart for developing solutions

Broadly speaking, in identifying and assessing the solutions, the following questions should be asked:

- Is the proposed action feasible?
  - Is the work practically possible? Are there engineering problems?
  - Does the material, diameter and condition of the existing sewer allow the rehabilitation technique of choice to be used?
- What effect does the proposed action have on other parts of the network (what is the action's *sphere of* influence)?
- Does the proposed action impact on other performance measures other than the target performance measure (are there *secondary benefits* which should be acknowledged)?
- Are there other grounds on which the decision should be based (*'tertiary' decision rules*)?
  - Can the proposed actions be co-ordinated with other work, or can additional work be conducted at that location?
  - Are there additional practical or financial obstacles (e.g. the action requires an unrealistic proportion of the available budget or resources; or there are a number of sensitive and/or key customers in the area affected by the works)?

Preferred options can then be chosen for inclusion in the rehabilitation plan based on considerations of cost-benefit, cost-effectiveness, risk management and so on. In addition to the capital works thus identified, the process will identify operational activities which should be implemented alongside the rehabilitation plan in a corresponding *operations & maintenance plan*.

If the plan is being developed at the strategic (long-term) level, the various drainage areas should themselves be prioritised on the basis of the cost-effectiveness of their individual rehabilitation plans. This will enable the strategic plan to be optimised to deliver improvements at the earliest opportunity and at least cost.

3.5 Stage 4 - Implement and monitor results

The final stage in the process, shown in Figure 3.5, is to implement the plan and monitor the results:

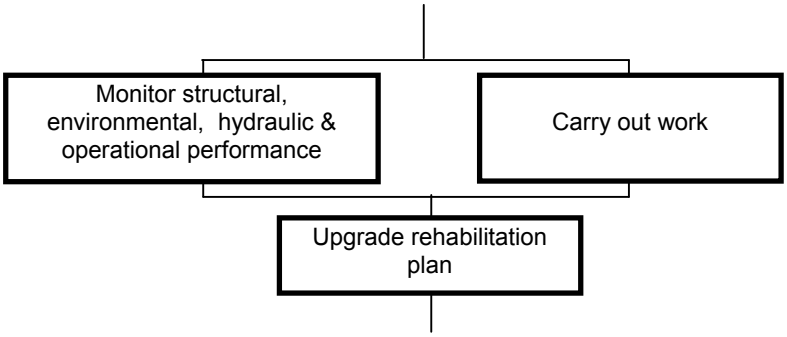


Figure 3.5 Flowchart for implementation and monitoring

3.5.1 Implement the rehabilitation plan

As mentioned above, the works included in the rehabilitation plan should be undertaken as part of a structured programme which ensures that significant benefits are delivered as soon as it is feasible and cost-efficient to do so.

The success of the rehabilitation plan should be monitored throughout the implementation process and modifications made as necessary.

3.5.2 Assess success of the strategy and revise future plans as necessary

Conditions in the sewer networks are constantly changing as the structures deteriorate and required levels of service change. Monitoring should therefore continue after completion to confirm that the expected benefits have been achieved and to identify problems which may develop over time for which additional rehabilitation works may be required.

4. APPLYING CARE-S TO REHABILITATION PLANNING

4.1 Relationships between work package elements

The various CARE-S work package elements will provide assistance in the rehabilitation planning process described in Section 2. The principal functions of the work package elements are described below:

WP1 (performance indicators) will provide definitions of the performance indicators together with algorithms for calculating them from the performance data provided by users.

WP2 (structural performance assessment) will provide the suite of structural assessment tools which can be used in the planning process.

WP3 (hydraulic & environmental performance assessment) will provide the suite of hydraulic assessment tools which can be used.

WP4 (rehabilitation technology database) will provide information on possible rehabilitation techniques, including a description of each technique, its strengths and weaknesses, availability in each country/territory, contractors who can undertake the work and cost data to enable budget prices to be estimated. The WP4 rehabilitation technology database will provide information for the WP6 decision support system, which will guide users to appropriate techniques to suit their specific needs.

WP5 (Socio-economic consequences) will provide a 'guidebook' containing information on the indirect (external to utility budget) costs of sewerage network failures and rehabilitation works. These indirect or 'social' costs will include costs of disruption to daily life and loss of amenity. The WP5 guidebook will provide a panel of socio-economic cost indicators and guidance for users on the method of quantifying these indicators in specific circumstances. WP5 will also provide a spreadsheet-type software tool which users can populate with details of the failure event or rehabilitation works, together with the corresponding costs or cost indicators, calculated after referring to the guidebook. The software tool will then pass the data to the WP7 Rehabilitation Manager for use by the WP6 Multi-criterion Decision Support tool and other tools as necessary.

WP6 (multi-criterion decision support) will provide the essential link between WPs 1 to 5. As explained in Section 2, rehabilitation planning is an iterative process involving:

- The assessment of structural/operational, hydraulic/environmental performance;
- Costs and technical aspects of rehabilitation techniques and
- Socio-economic costs.

WP6 will provide the functionality required to evaluate the possible rehabilitation options with respect to these issues.

The conceptual links between work packages are shown in **Figure 4.1** and described in the following paragraphs:

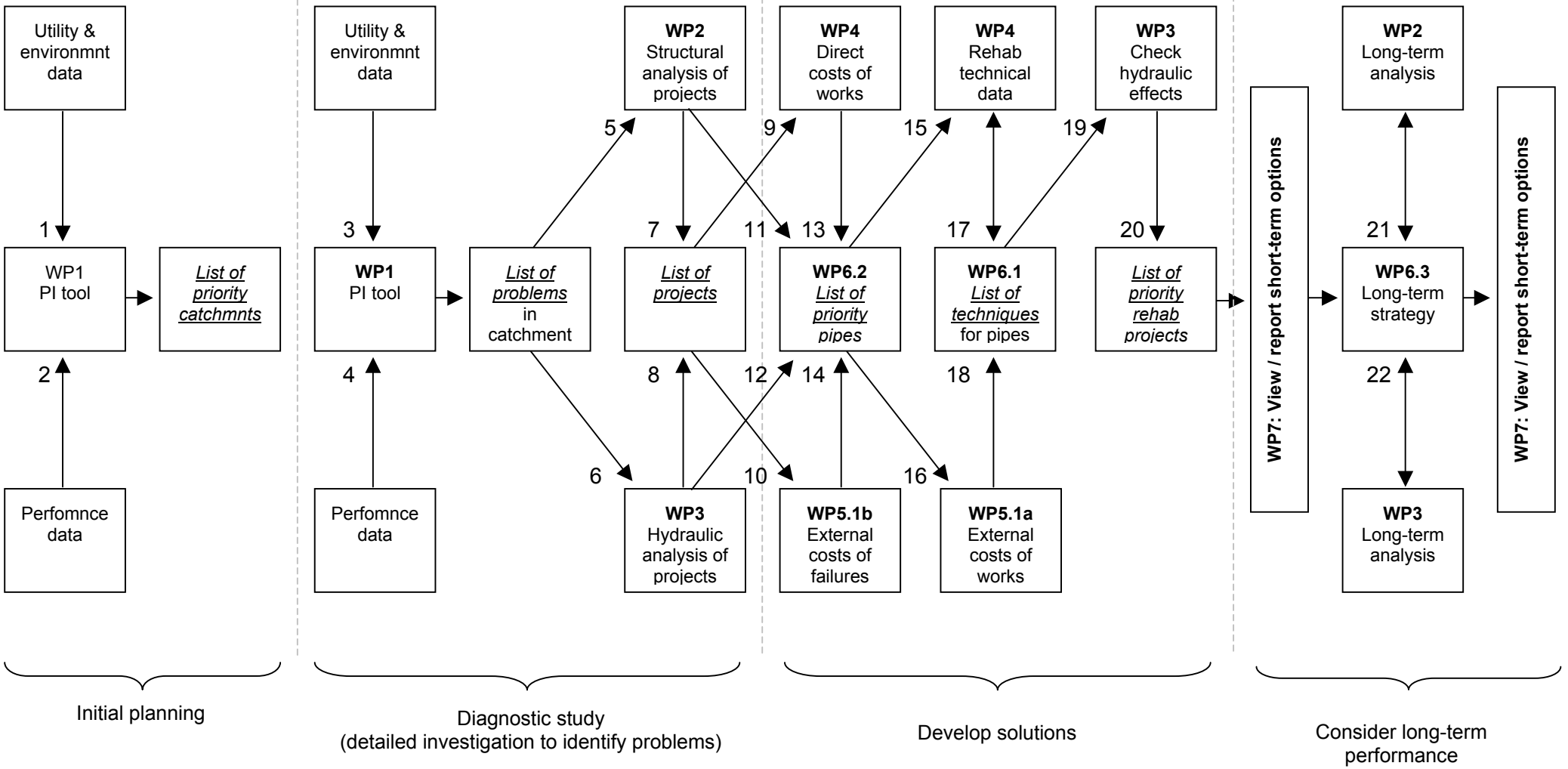


Figure 4.1 Conceptual links between work packages

Initial planning

At the initial planning stage the objective is to identify problem catchments (or sub-catchments). This is achieved by analysing overall system performance (i.e. at company or regional level) using the WP1 PI tool. It requires inputs of the basic utility and environment data plus performance data (see links 1 and 2 in **Figure 4.1**). The result is a general understanding of the nature and severity of the problems, so that planners can generate a list of priority catchments/subcatchments for attention.

Diagnostic study

The first catchment/subcatchment is then selected for investigation. The WP1 PI tool is used at a more detailed level than before to identify problems within the area under investigation. The result is a list of performance problems in the area (links 3 and 4).

The WP2 and WP3 tools are then used to analyse the structural/operational and hydraulic/environmental performance of the sewer system, to understand the causes of the problems identified (links 5 and 6). This produces a list of problems to be solved by rehab projects (links 7 and 8).

Develop solutions

The proposed projects are then analysed by the WP6.2 project selection tool to produce a list of priority pipes for the area. WP6.2 requires inputs from WP2 (structural performance), WP3 (hydraulic performance), WP4 (direct costs of possible rehab techniques) and WP5.1b (external costs of the failures) (see links 11, 12, 13 and 14). This list is passed to WP4 and WP5.1a (links 15 and 16).

Rehabilitation techniques for the priority pipes are then identified by the WP6.1 technology selection tool. This tool requires information from WP4, for the pre-elimination of rehab techniques, and WP5.1a (which will be integrated within WP6.1) to assess the external costs of the works (links 17 and 18).

Finally, the hydraulic effects of the proposed rehab works are checked using the WP3 tools (links 19 and 20).

The list of priority projects and recommended rehabilitation options will support the rehabilitation engineer in developing the short-term rehabilitation plan, enabling urgent works to be set in progress at the earliest opportunity.

Consider long-term performance

Further evaluation of the proposed solutions, to identify their long-term effectiveness, is then undertaken by WP6.3 in conjunction with WP2 (structural tools) and WP3 (hydraulic tools) (links 21 and 22). This generates a second prioritised list of solutions to support the rehabilitation engineer in developing the long-term rehabilitation plan.

4.2 Data flows

In practice, data will not flow directly between work packages, but will pass through the rehabilitation manager (WP7), which provides the principal user interface and data handling functionality for CARE-S.

WP7 will link to the other elements as shown in Figure 4.2 below.

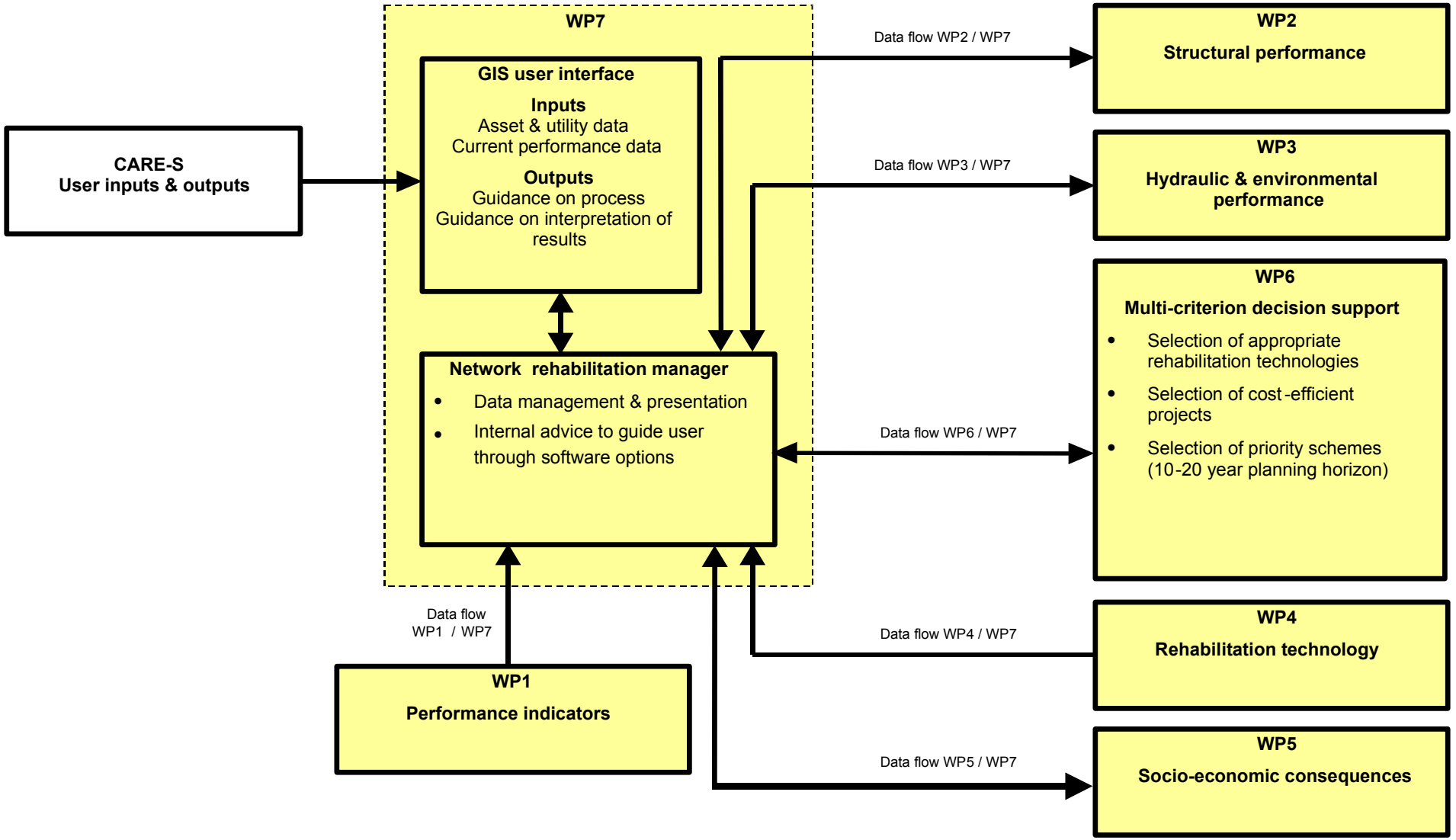


Figure 4.2 Data flows between work package elements

The data flows managed by the Network Rehabilitation Manager (WP7) are explained below:

WP1 (performance indicators)

Performance data are provided by users and entered via the WP7 user interface. WP7 will provide the data to the WP1 PI tool and the PI tool will, in turn, return PI values to WP7.

WP2 (structural performance assessment)

WP7 will advise users on the collection and interpretation of condition inspection data and will inform users of possible tools to suit the circumstances observed. When the user decides to run a tool, WP7 will provide the data required by the tool and, upon completion of the run, the tool will return output data to WP7.

WP3 (hydraulic & environmental performance assessment)

WP7 will inform users of possible tools and, when the user decides to run a tool, WP7 will provide the data required and receive the outputs.

WP4 (rehab. technology database)

WP4 provides a catalogue of rehabilitation technique data. WP7 will interrogate this database and provide information to WP2 and WP3 (for the structural and hydraulic analysis of possible rehabilitation techniques) and WP6 (for support in the decision-making process when selecting options).

WP5 (Socio-economic consequences)

WP5 provides a catalogue of socio-economic cost data (the indirect costs of sewer rehabilitation). WP7 will provide this information to WP6 for the economic analysis of possible techniques; (note: It is likely that some elements of WP5 will be embedded into the WP6 tools).

It is anticipated that users will select appropriate indicators from the WP5 catalogue and calculate values for their site-specific circumstances using a spreadsheet-type software tool developed under WP5. WP7 will interrogate this spreadsheet tool and pass the information to the other work packages as necessary.

WP6 (multi-criterion decision support)

WP6 provides decision-making support at various stages in the rehabilitation planning process. WP7 will provide WP6 with information from WP1, 2, 3, 4 and 5 and will return information on the selected rehabilitation techniques to WP2 and 3 for the structural and hydraulic analysis of possible options.

WP7 (prototype network rehabilitation manager)

In addition to the data flows described above, WP7 will provide the user GIS interface. This will facilitate the manual input of utility and environment data plus the input of data required by the various tools. The interface will also provide outputs (in electronic form) to the various tools, and standardised outputs (electronic and hard-copy) for audit and reporting purposes.

4.3 Possible CARE-S tools

A wide range of tools can be used for wastewater network rehabilitation planning. Some are already available and others are being developed under CARE-S work packages. The partners have provided initial details of possible tools, with general descriptions of the tools and some information on their input/output requirements.

Following discussion at the CARE-S meeting in Ferrara during April 2003, a shortlist of tools for inclusion in CARE-S was developed. This shortlist is given in Table 4.1. This list is now considered final and the tools included in CARE-S will not be changed except under extreme circumstances.

Partners are required to supply WRc with *full input/output file specifications* for the tools selected (including those tools currently being developed under CARE-S work packages) as soon as such data are available.

If a 'first release' of the software is to be available for testing by October 2004, then first versions of tools, with input and output specifications defined, *must be provided to WRc by the end of June 2004*.

Table 4.1 Tools proposed for inclusion in CARE-S

Note: Work package references (e.g.WP2.2) indicate that the tool is being developed under CARE-S

Work Package	Purpose of tool / Name of tool
WP1	**Identify and calculate values for performance indicators**
	PI WW tool (WP1)
WP2	**Structural condition analysis**
	Sewer Condition Classification and conversion to CEN coding (WP2.1)
	'Survival function based probability of failure' (WP2.2)
	DeForm (condition & trend based probability of failure) (WP2.2)
	'CCTV based probability of failure' (WP2.2) a. Structural failure b. Infiltration c. Exfiltration d. Roots / blockages
	WATS 2.0 'Internal bio-chemical deterioration' (WP2.3)
	'External deterioration' (WP2.3)
	'Physical processes and loading' (WP2.3)
WP3	**Hydraulic and environmental analysis**
	MOUSE HD (flow simulation)
	Infoworks (sewer hydraulic flow simulation)
	EPA SWMM (Storm Water Management Model)
WP4	**Identification of possible rehabilitation strategies**
	Rehabilitation technologies database (WP4)
WP5	**Identification of socio-economic constraints**
	Socio-economic spreadsheet calculator (WP5)
WP6	**Selection of rehabilitation technologies and projects**
	CARE-S - SRT (selection of projects based on technical criteria - WP6.1)
	CARE-S - SRP (multi-criterion decision support – WP6.2)
	Development of inspection and rehabilitation strategies - WP6.3

5. STEP-BY-STEP GUIDE TO USING THE CARE-S TOOL-KIT

The following tables and dataflow diagrams explain how the CARE-S tools will be used in conjunction with the CARE-S database and Rehabilitation Manager to assist End Users in developing a rehabilitation plan in accordance with the EN752-5 procedure.

One table and associated dataflow diagram is provided for each principal stage in the rehabilitation planning procedure:

Table 5.1 Stage 1 - Initial Planning: Figure 5.1

Table 5.2 Stage 2.1 - Detailed investigation (structural): Figure 5.2

Table 5.3 Stage 2.2 - Detailed investigation (hydraulic): Figure 5.3

Table 5.4 Stage 2.3 - Detailed investigation (environmental): Figure 5.4

Table 5.5 Stage 2.4 - Detailed investigation (operational): Figure 5.5

Table 5.6 Stage 3 - Develop solutions: Figure 5.6

Table 5.7 Stage 4 - Implementation

Details of dataflows between the WP7 database and the tools are given. These represent WRc's current understanding of the requirements of each tool. The details must be confirmed and data format specifications must be provided by the tool developers to enable WRc to make appropriate provision for data management under WP7.

A number of reports are referred to in this step-by-step guide. These reports will be available either via the GIS viewer or as tabular (Excel) based reports. It is not intended to present the details of these reports in this document. Further details will be presented in deliverable D21 Defining the User Interface for the CARE-S Suite.

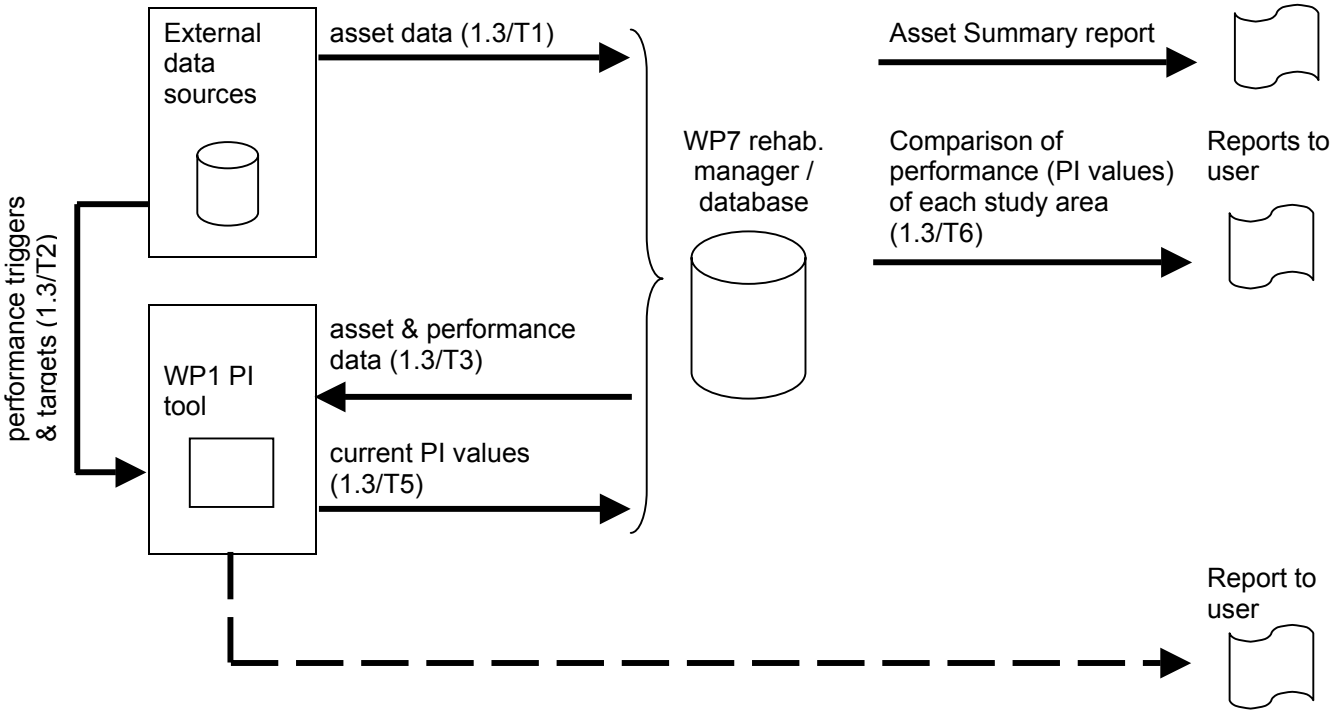
Table 5.1 Stage 1 – Initial Planning

EN752-5 Stage	*CARE-S task*	***Description of task and dataflows***	**CARE-S Tasks**	**Comments**
1		***STAGE 1 – INITIAL PLANNING***		Stage 1 is undertaken at a high level (e.g. the entire WSP area) to set the ground-rules for the rehab studies and establish priorities between individual catchments and sub-catchments for the studies.
1.1		**Establish the framework**		
1.1.1		Identify reasons why rehabilitation is being considered (flooding, pollution, blockages, etc.) and rank them in order of importance.		This is obtained from the End Users' general knowledge of his sewer systems
1.1.2		Identify PIs which relate to these identified reasons for rehabilitation.		CARE-S will have no direct input here, but the WP1 list of PIs may be a useful reference of possible Pis
1.1.3		Agree planning horizon of rehab plan		
1.2		**Define PIs**		
1.2.1		Set triggers & targets for PIs (structural, hydraulic, environmental & operational, as relevant)		
1.2.2		Establish robust data sources		

EN752-5 Stage	*CARE-S task*	***Description of task and dataflows***	**CARE-S Tasks**	**Comments**
1.3		**Define the extent of the area to be assessed and make a broad assessment of the problems**		
1.3.1		Catchment or sub-catchment studies? Users must choose between a data-intensive detailed study of a small area or a more general study of a large area.		The decision between investigations at catchment or sub-catchment level can be done by the WP1 PI tool, but in reality is more likely to be done outside CARE-S, based on user's knowledge.
	1.3/T1		Establish a CARE-S 'project' for the entire area and divide into catchments or sub-catchments for comparison of high level performance indicators. *Import asset data from external sources* to WP7 database (these may be GIS, or CSV files, or files already created for any of the CARE-S tools).	At this stage, a single 'project' will be created for the entire company area. The catchments (or sub-catchments) will form datasets within the projects. When carrying out the detailed rehab studies (that is, EN752-5 'detailed investigations') on the catchments, a separate 'project' will be created for each catchment.
	1.3/T2		*Import trigger and target values for each PI from external sources* to WP1 PI tool.	Many PI's are area-specific (not pipe-specific) so the areas must be defined before the PI's are calculated.
1.3.2	1.3/T3	Assess current performance in order to define precise scope of study and set overall programme including other studies.	*Export asset and performance data from WP7 database* to WP1 PI tool.	The WP7 Rehab Manager will produce an asset summary report at this stage. The WP1 PI tool will be an Access database, which is linked to the WP7 database. The movement of data between WP7 and the WP1 PI tool will be done by directly querying tables within both databases.
	1.3/T4		*Run WP1 PI tool*	

EN752-5 Stage	*CARE-S task*	***Description of task and dataflows***	**CARE-S Tasks**	**Comments**
	1.3/T5		*Import PI values for each catchment or sub-catchment from WP1 PI tool* to WP7 database.	The PI tool will save results directly to the WP7 database.
1.3.2	1.3/T6	Decide on level of detail of study (simple, structural only, hydraulic/environmental only, etc).	WP7 Rehab Manager generates reports on performance for each catchment or sub-catchment.	Users must review the PI data and decide on the level of study required in each sub-catchment. This decision is taken outside of CARE-S.
1.4		**Prioritise areas**		
1.4.1		Assess the PI data for all catchments and sub-catchments under consideration and set priorities & programmes for each study.		Users must review the PI data and decide on priorities for rehab studies. This decision is taken outside of CARE-S. WRc to consider the types of report which would be most useful to users for deciding on study details and priorities.

Figure 5.1 Dataflows for Stage 1: Initial Planning



Note: the figures in brackets after the data descriptions (e.g. 1.3/T1, etc.) are the references to the CARE-S tasks in the preceding table.

Table 5.2 Stage 2.1 - Detailed investigation (structural)

EN752-5 Stage	*CARE-S task*	**Description of task and dataflows**	**CARE-S Tasks**	**Comments**
2		***STAGE 2 – DIAGNOSTIC STUDY*** ***Identify causes of performance deficiencies***		A NOTE ON DATASETS: Many different sets of information can comprise a dataset. Examples: The assets in a catchment or sub-catchment and the associated performance data; a sub-set of these assets (e.g. pipes by material); the assets and performance for a particular set of upgrading options; the assets and performance at given times, etc.
	2/T1		Select first catchment (or sub-catchment) as the 'project' in the WP7 Rehab Manager. *Import (or update) asset data to the WP7 database*. (e.g. manhole and pipe records; ground levels; invert levels; pipe lengths; diameters (or heights & widths); materials; dates constructed, repaired or renovated; etc.).	A rehab study is now undertaken for the first catchment (or sub-catchment). The four aspects of performance should be considered in parallel (structural, hydraulic, environmental and operational) but, depending on the nature of the catchment and its problems, it may not be necessary to investigate all four in every study. The WP7 Rehab Manager will produce an asset summary report for the catchment.
2.1		**Investigate structural performance**		
2.1.1		Identify priority sewers for inspection		The identification of priority sewers is done outside of CARE-S. It enables investigations to be undertaken selectively, i.e. not on every sewer in the system.

EN752-5 Stage	*CARE-S task*	**Description of task and dataflows**	**CARE-S Tasks**	**Comments**
	2.1/T1		*Import priority sewer identifications (and categories if appropriate) and existing condition inspection data* to WP7 database.	
	2.1/T2		WP7 Rehab Manager advises user to carry out condition inspections, calculate internal condition grades (ICGs) and import the results (defect codes and ICGs) into WP7 database.	The WP7 Rehab Manager provides guidance on condition inspections and the translation of coded condition data from National systems to the CEN system.
	2.1/T3		WP7 Rehab Manager produces reports to help users prepare the condition inspection survey programme.	
2.1.2	2.1/T4	Carry out condition inspections and allocate Internal Condition Grades to each sewer inspected	*Import survey details and condition data* from external data source to WP7 database.	End Users will convert defect data produced under National coding systems to the CEN coding system before adding the data to the WP7 database.
	2.1/T5		*Add ICG's to WP7 database*.	The allocation of Internal Condition Grades is done outside of CARE-S. It may be done manually or automatically, using a proprietary CCTV software package. Some software packages (e.g. Examiner) have the facility to export data in a specified format which the WP7 database will accept, otherwise it may be necessary to import the data manually.
	2.1/T6		*Add SPGs to WP7 database*.	Allocate Structural Performance Grades to each sewer (by considering environment, etc.). This is done outside of CARE-S and the results are added to the WP7 database. This is not a compulsory step, as the user may prefer to use the predicted failure times and modes determined by the WP2 tools.

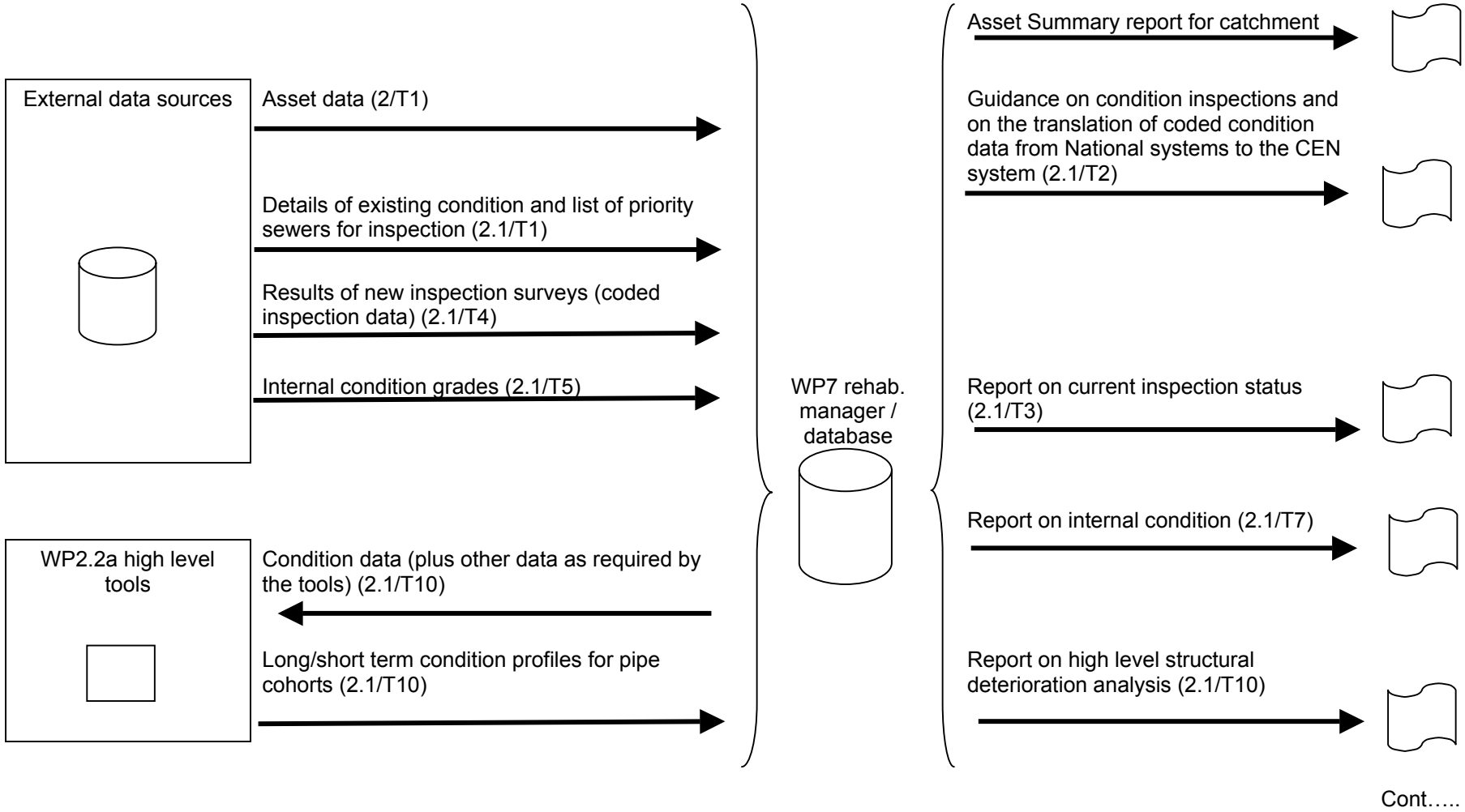
EN752-5 Stage	*CARE-S task*	**Description of task and dataflows**	**CARE-S Tasks**	**Comments**
2.1.3	2.1/T7	Identify structural deficiencies	Identify problem sewers using internal condition data. WP7 Rehab Manager produces reports to help the user identify sewers with structural problems and the types of problems.	
	2.1/T8	Identify problem sewers using WP2.2 and WP2.3 models.	*Export condition data (ICG's)* from WP7 database to WP2.2a[3] high level models.	
	2.1/T9		*Run WP2.2a high level model(s)* to identify the probability of failure within a given time frame for each group of sewers.	
	2.1/T10		*Import results from high level models* to WP7 database.	The results produced by the WP2.1a tools will be: i. Probability of survival of pipe cohort in each condition class; ii. Transition functions between condition classes; iii. Probable time of residence in each failure/condition class. The WP7 Rehabilitation Manager will produce reports detailing the results of the high level analysis.
	2.1/T11		*Export condition data (defect codes & ICG's)* from WP7 database to WP2.2b and WP2.3 detailed models.	

[3] The WP2.2a 'high level models' are DeForm, KANEW and the Cemagref structural deterioration model; the WP2.2b 'detailed models' are the, infiltration, exfiltration and roots/blockages models

EN752-5 Stage	*CARE-S task*	**Description of task and dataflows**	**CARE-S Tasks**	**Comments**
	2.1/T12		*Export hydraulic data produced by WP3.1 tools if available (flows, frequency of surcharging, etc.)* from WP7 database to WP2.2b and WP2.3 detailed models.	If hydraulic data are not available at this stage, the WP2.2 & WP2.3 models must be run after the hydraulic model has been built.
	2.1/T13		*Run WP2.2b and WP2.3a/b detailed models* to identify the type of failure and time to failure for each sewer.	
	2.1/T14		*Import results of structural analyses* to WP7 database.	The results produced by the WP2.2b and WP2.3a/b models will be: i. Probability of chokes/blockages for each pipe; ii. Volumes of infiltration over an area at specified times; iii. Volumes of exfiltration over an area at specified times; iv. Extent of internal corrosion for each pipe at specified times; iv. Extent of external corrosion for each pipe at specified times; v. Safety factors against structural failure at specified times (based on loading and residual strength). The WP7 database will store the results produced by each of the WP2.2a and WP2.3 models.
	2.1/T15		*Run the WP2.4 routine* to compare the outputs from the 2.1, 2.2 and 2.3 tools This tool will be developed under WP2.4 and incorporated into the WP7 Rehab Manager.	Interpretation of the individual results from the WP2.2b and WP2.3 tools is required to identify which pipes have structural deficiencies, the nature of the deficiencies and their severity. The Rehab Manager will use the results of the WP2.4 routine to produce a report identifying the most significant structural failure mode for each pipe.

EN752-5 Stage	*CARE-S task*	**Description of task and dataflows**	**CARE-S Tasks**	**Comments**
2.1.4		Identify causes of deficiencies		Users will review the results of the condition inspections and structural models to identify the causes of the structural problems. Causes might be installation, operation or design factors (soils/groundwater/loading), etc. They may be exacerbated by hydraulic or operational deficiencies, so users should also refer to the results of the hydraulic and operational analyses at this stage.

Figure 5.2 Dataflows for Stage 2.1: Detailed Investigation (Structural)



Stage 2.1 (structural) continued

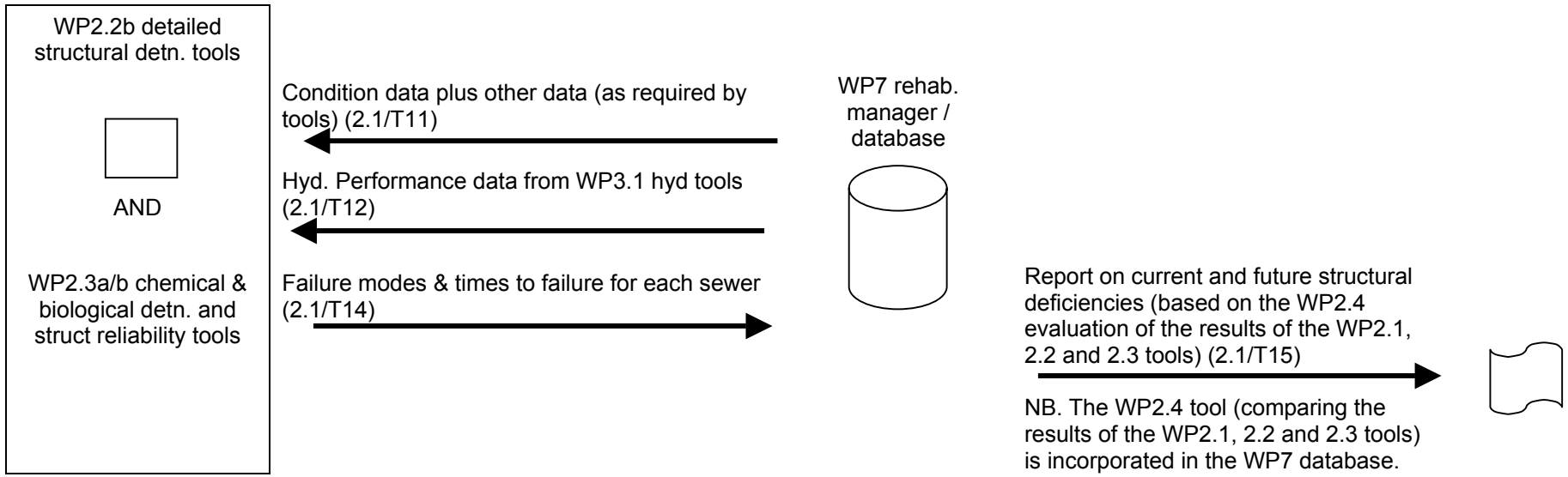


Table 5.3 Stage 2.2 - Detailed investigation (hydraulic)

EN752-5 Stage	*CARE-S task*	**Description of task and dataflows**	**CARE-S Tasks**	**Comments**
2.2	2.2/T1	**Investigate hydraulic performance**	*Export asset data* for the catchment or sub-catchment from the WP7 database to the WP3.1 hydraulic modelling tool. Export hydrological data from external data source to the WP3.1 modelling tool.	The WP7 Rehab Manager will provide brief guidance on hydraulic modelling. The WP3.1 hydraulic modelling tool will be either MOUSE, SWMM or Infoworks (these are flow models, not quality models). The hydrological data required by the WP3.1 tools will be supplied by an external source and will not be stored within the WP7 database.
	2.2/T2		*Run the WP3.1 tool*	The hydraulic model of the sewer network will be built and verified outside of CARE-S. The model may be a simplified representation and *need not include every sewer in the network*. A flow survey must be undertaken to verify the model and the model is then run with a range of rainfall events to produce 'surcharge-flooding' diagrams for trigger and target rainfall events.
	2.2/T3		*Import results* to WP7 database (or establish links to reports generated by the hydraulic modelling tools, see 'identify hydraulic deficiencies', below).	The WP7 Rehab Manager will provide a report summarising the results of the hydraulic analysis. This report will, in fact, display the combined hydraulic and structural status of the catchment or sub-catchment. The structural data will be the ICGs. And the hydraulic results will be the return period of the rainfall event which causes the on-set of surcharging and flooding at the upstream node of a sewer.

EN752-5 Stage	*CARE-S task*	**Description of task and dataflows**	**CARE-S Tasks**	**Comments**
	2.2/T4		*Export results of WP3.1 analyses* from WP7 database to the WP2.2b and WP 2.3 tools (as required by the tools).	It may be necessary to run the WP2.2b and 2.3 tools at this stage to provide data for the WP3.2 (hydraulic deterioration) tools (see 2.1/T12).
	2.2/T5		*Export results of WP2 analyses (WP2.1 (ICG data) and WP2.4 (predicted failures) models) from the WP7 database* to the WP3.2 hydraulic deterioration ('degraded systems') model.	
	2.2/T6		*Run the WP3.2 hydraulic deterioration ('degradation') tool*	WP3.2 ('FLUENT' model) is used to assess the effect of future structural deterioration on hydraulic performance.
	2.2/T7		*Import results* to WP7 database	The WP7 Rehab Manager will provide a report summarising the results of the hydraulic analysis of the degraded system. This report will be similar to that produced for the WP3.1 tools, but will relate to future conditions rather than the current situation.
	2.2/T8		*Export results of WP3.1 (hydraulic performance of current system), WP3.2 (hydraulic performance of degraded system) and WP3.3a/b (environmental impact tools from WP7 database* to WP3.4 hydraulic reliability tool.	It may be necessary to run the WP3.3a/b tools at this stage (see 2.3/T1-T4) to provide data for the WP3.4 hydraulic reliability tool.
	2.2/T9		*Run WP3.4 hydraulic reliability too*l.	
	2.2/T10		*Import results* from the WP3.4 hydraulic reliability tool to the WP7 database.	Results produced by the WP3.4 tool will be 'at risk' maps for hydraulic, environmental and operational failures. The WP7 Rehabilitation Manager will present these results via the User Interface.

EN752-5 Stage	*CARE-S task*	**Description of task and dataflows**	**CARE-S Tasks**	**Comments**
2.2.1		Identify hydraulic deficiencies		The WP7 Rehab Manager will produce reports to assist the user to identify sewers with existing hydraulic problems and predicted problems. The database will contain links to the results files and reports produced by the hydraulic modelling tools. WRc will consider the outputs produced by the three modelling tools (Mouse, SWMM and Infoworks) and the WP3.4 hydraulic reliability tool. If the tools do not produce suitable reports, the Rehab Manager will generate them.
		Identify causes of deficiencies		Users will review the results of the hydraulic modelling to identify the causes of the hydraulic problems. Problems may be exacerbated by structural/operational deficiencies, so users should also refer to the results of the structural and operational analyses at this stage.

Figure 5.3 Dataflows for Stage 2.2: Detailed Investigation (Hydraulic)

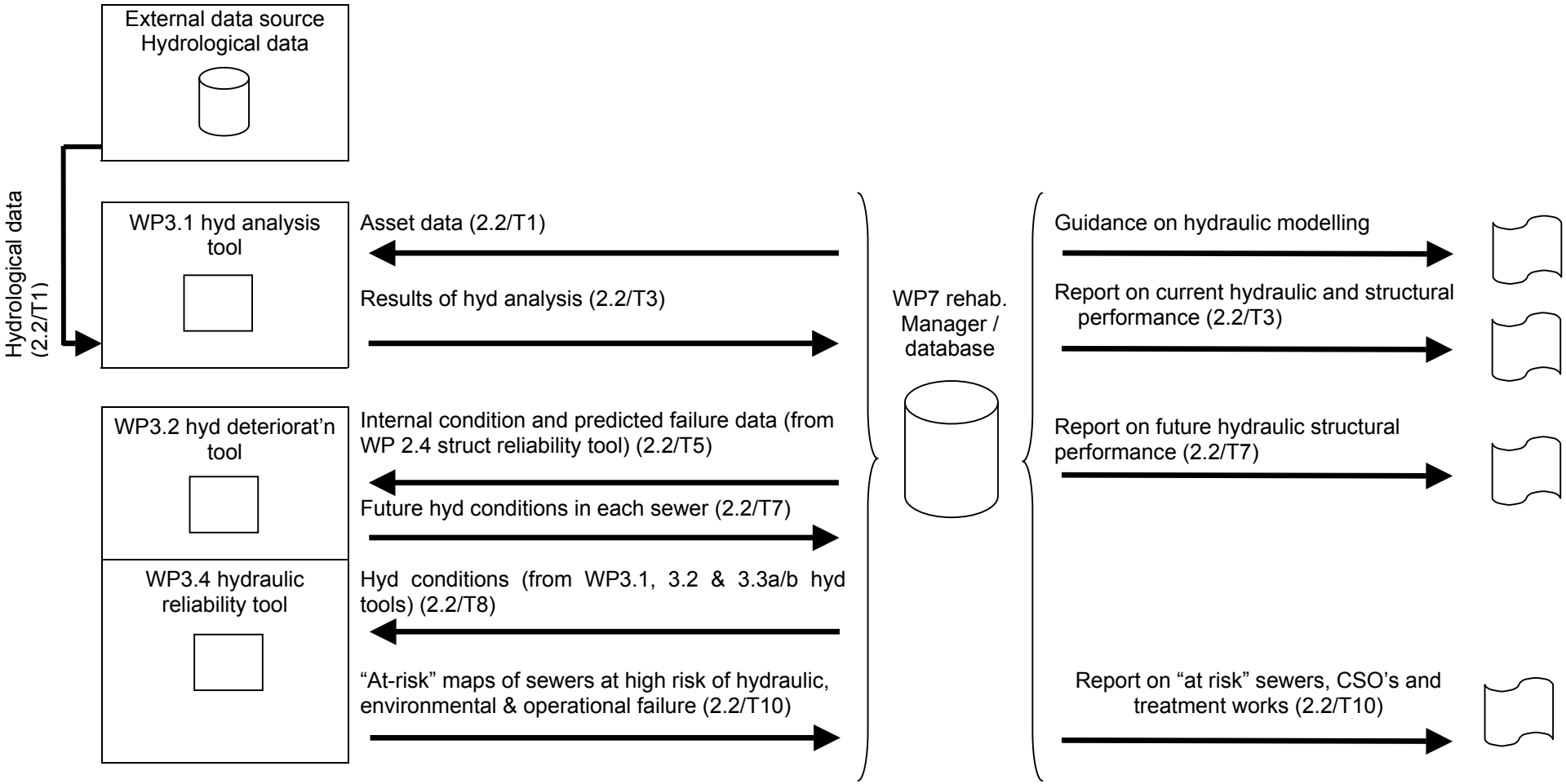


Table 5.4 Stage 2.3 - Detailed investigation (environmental)

EN752-5 Stage	*CARE-S task*	*Description of task and dataflows*	**CARE-S Tasks**	**Comments**
2.3		**Investigate environmental performance**		This stage of the EN752-5 procedure involves the building, calibration and validation of hydraulic quality models of the sewer/watercourse network and groundwater. This detailed analysis is beyond the scope of CARE-S but users must be aware of the implications of significant sewer exfiltration and sewage discharges to watercourses. A high-level view of environmental problems will be provided by the WP3.3 environmental impact tools. These tools will provide solutions to simple problems and guidance on which locations require more detailed analysis. The WP7 Rehab Manager will provide basic information on the external tools available for detailed environmental analysis and references to sources of further guidance.
	2.3/T1		*Export infiltration and exfiltration rates from the WP7 database to the WP3.3a hydraulic impact tool.*	
	2.3/T2		*Run the WP3.3a hydraulic impact tool and import results to the WP7 database.*	Results will be total infltration/exfiltration over the area, comparison with benchmark values, list of problem locations and advice on the need for further environmental analysis.
	2.3/T3		*Export details of flows at CSO's and WWTP's from WP7 database to WP3.3b environmental impact tool.*	

EN752-5 Stage	*CARE-S task*	***Description of task and dataflows***	**CARE-S Tasks**	**Comments**
	2.3/T4		*Run the WP3.3b environmental impact tool and import results* to the WP7 database	Results will be a list of problem locations (CSO's and WWTP's) and advice on the need for further environmental analysis.
	2.3/T5		*Carry out more detailed environmental investigations if necessary (outside of CARE-S) and import results* to the WP7 database.	The results produced by the detailed environmental quality models will be lists of overflows which exceed the permitted discharge limits and the rainfall events responsible. NB. The CARE-S database will only store information if it is required by CARE-S tools or if it is useful for generating reports. It is likely that some of the results of detailed environmental investigations will not need to be stored in the WP7 database.
2.3.1		Identify deficiencies		
	2.3/T6		*Export data to the WP3.4 'probability of hydraulic failure' tool, run tool and import results* to the WP7 database.	The WP3.4 tool will produce reports on environmental problems to help the user identify the locations of these problems.
2.3.2		Identify causes of deficiencies		Users will review the results of the environmental modelling to identify the causes of the problems. This must be undertaken in conjunction with the hydraulic and structural modelling.

Figure 5.4 Dataflows for Stage 2.3: Detailed Investigation (Environmental)

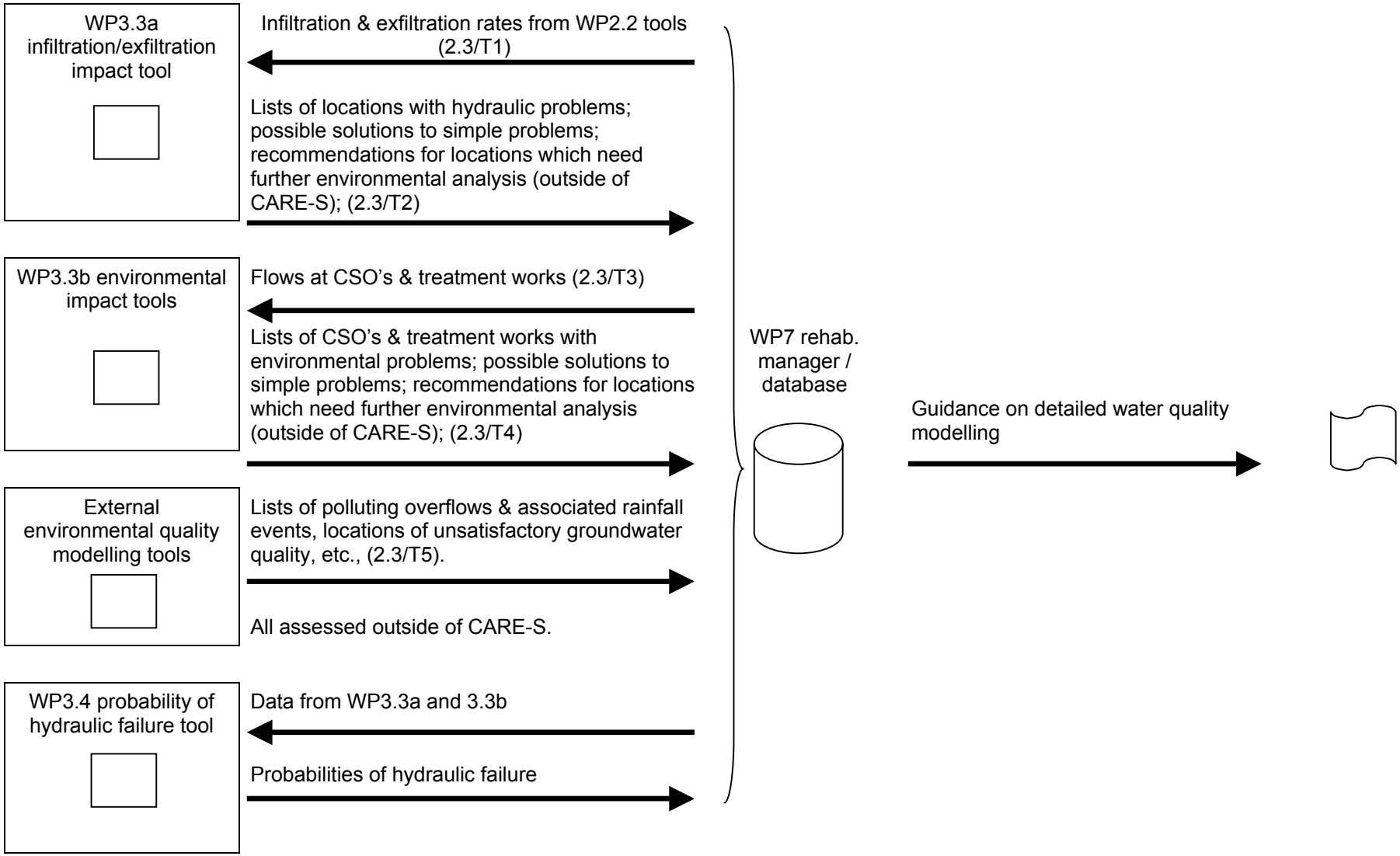


Table 5.5 Stage 2.4 - Detailed investigation (operational)

EN752-5 Stage	CARE-S task	*Description of task and dataflows*	CARE-S Tasks	Comments
2.4	2.4/T1	**Investigate operational performance**	Export defect codes and position of defects from the WP7 database. This will be used in the external operational assessment process. Import incident data from utility operational records to external operational assessment process.	The operational investigation is all done outside of CARE-S. The work involves reviewing operational data (planned and unplanned maintenance, sewer blockages, CSO spills, pumping station failures, customer complaints (e.g. odour, rats), etc.) and identifying areas with operational problems. Reference should also be made to data collected for the structural and hydraulic investigations. The WP7 Rehab Manager will provide a guidance note on this work, but will provide no assistance with the investigation.
	2.4/T2		*Import results of operational investigation* to the WP7 database (if required by other CARE-S tools).	The results of the operational investigation will be a list of sewers subject to the types of problems mentioned above.
2.4.1		Identify operational deficiencies		The WP7 Rehab Manager will not produce reports on operational deficiencies.
2.4.2		Identify causes of deficiencies		Users will review the results of the operational investigation to assess whether the operational problems are best addressed by changes in operational practice or by rehabilitation works. Reference will need to be made to the results of the structural, hydraulic & environmental investigations at this stage. If it is decided that rehabilitation is the best option, the operational problems should be addressed in Stage 3 ('develop solutions'), if not, then they should be addressed by a new Operational Plan.

Figure 5.5 Dataflows for Stage 2.4: Detailed Investigation (Operational)

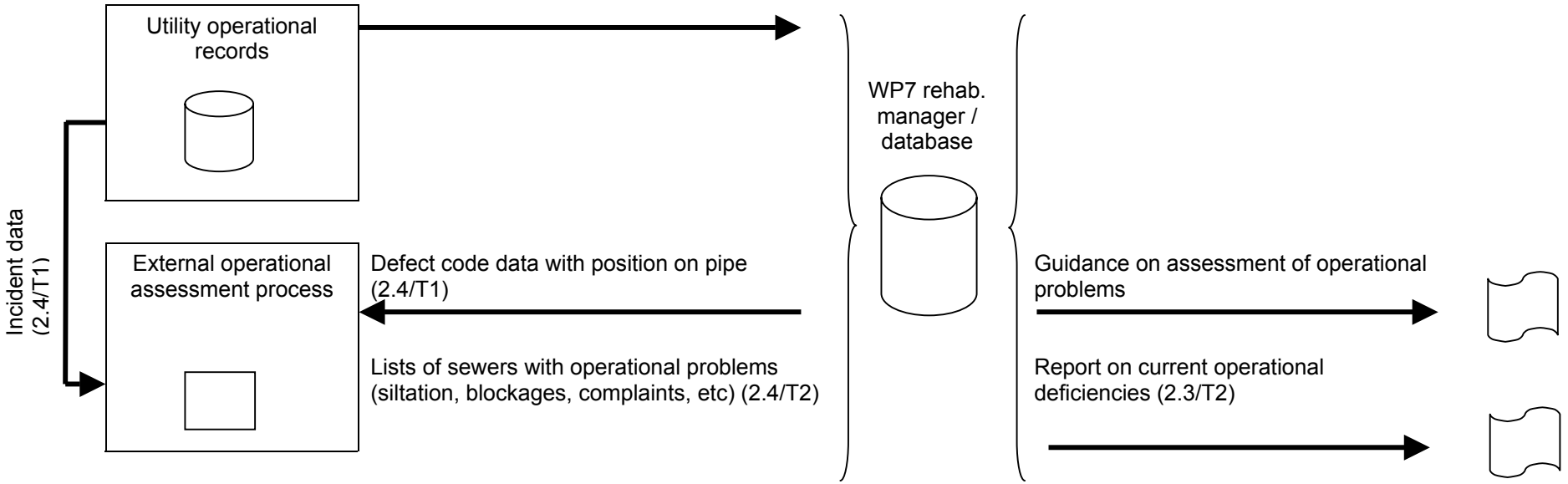


Table 5.6 Stage 3 – Develop solutions

EN752-5 Stage	*CARE-S task*	*Description of task and dataflows*	CARE-S Tasks	Comments
3		***STAGE 3 – DEVELOP SOLUTIONS***		
3.1		**Develop integrated solutions**		
		The EN752-5 procedure is summarised below: 1 Set problems in order of significance 2 Consider solutions to each problem 2.1 Consider <u>structural problems first</u> 2.1.1 Sub-divide into local damage, recurrent local damage & extensive damage; 2.1.2 Consider local repair wherever possible; 2.1.3 If local repair is not feasible, consider renovation;		The WP7 Rehab Manager will provide a brief guidance note on the procedure for developing solutions.

EN752-5 Stage	*CARE-S task*	***Description of task and dataflows***	**CARE-S Tasks**	**Comments**
		2.1.4 If renovation is not feasible, consider replacement. 2.2 Consider <u>hydraulic/environmental and operational</u> problems 3 Consider if they can be solved in conjunction with structural solutions; 4 Test possible solutions by running hydraulic flow (& quality) models.		
			<u>Step 1 of the EN752-5 procedure</u> (set problems in order of significance)	
	3.1/T1		*<u>Export details of sewers with problems from WP7 database</u>* to the WP4 (rehab costs) and WP5.1b (failure costs) tools.	
	3.1/T2		Run WP4 and WP5.1b tools to estimate direct costs of rehabilitation options and external costs of failures.	
	3.1/T3		*<u>Import costs from WP4 and WP5.1b tools</u>* to WP7 database.	

EN752-5 Stage	*CARE-S task*	*Description of task and dataflows*	**CARE-S Tasks**	**Comments**
	3.1/T4		*Export the following from the WP7 database* to the WP6.2 (SRP project selection) tool: Structural deficiencies (from WP2.1, 2.2b & 2.3) Hydraulic deficiencies (from WP3.1, 3.2, 3.3 & 3.4) Direct costs of rehab works (from WP4) Socio-economic costs of failures (from WP5.1b)	There is no input from detailed environmental quality models or operational investigations, which may be carried out outside of CARE-S.
	3.1/T5		*Run WP6.2 tool* to identify priority pipes ("projects")	
	3.1/T6		*Import results from WP6.2 tool* to WP7 database	Results will be priority pipes. The WP7 Rehab Manager will produce a report on project priorities. It will be necessary to refer to the reports on the environmental and operational deficiencies (produced by the WP7 Rehab Manager) to check that the priorities produced by the WP6.2 tool are compatible with environmental and operational problems and priorities.
			Step 2 of the EN752-5 procedure (consider structural and hydraulic, environmental & operational solutions to each problem)	
	3.1/T7		*Interrogate WP4 spreadsheet tool to identify a "first estimate" of possible rehab techniques for each pipe* (the WP4 spreadsheet will be 'hard-wire' linked to the WP7 Rehab Manager).	

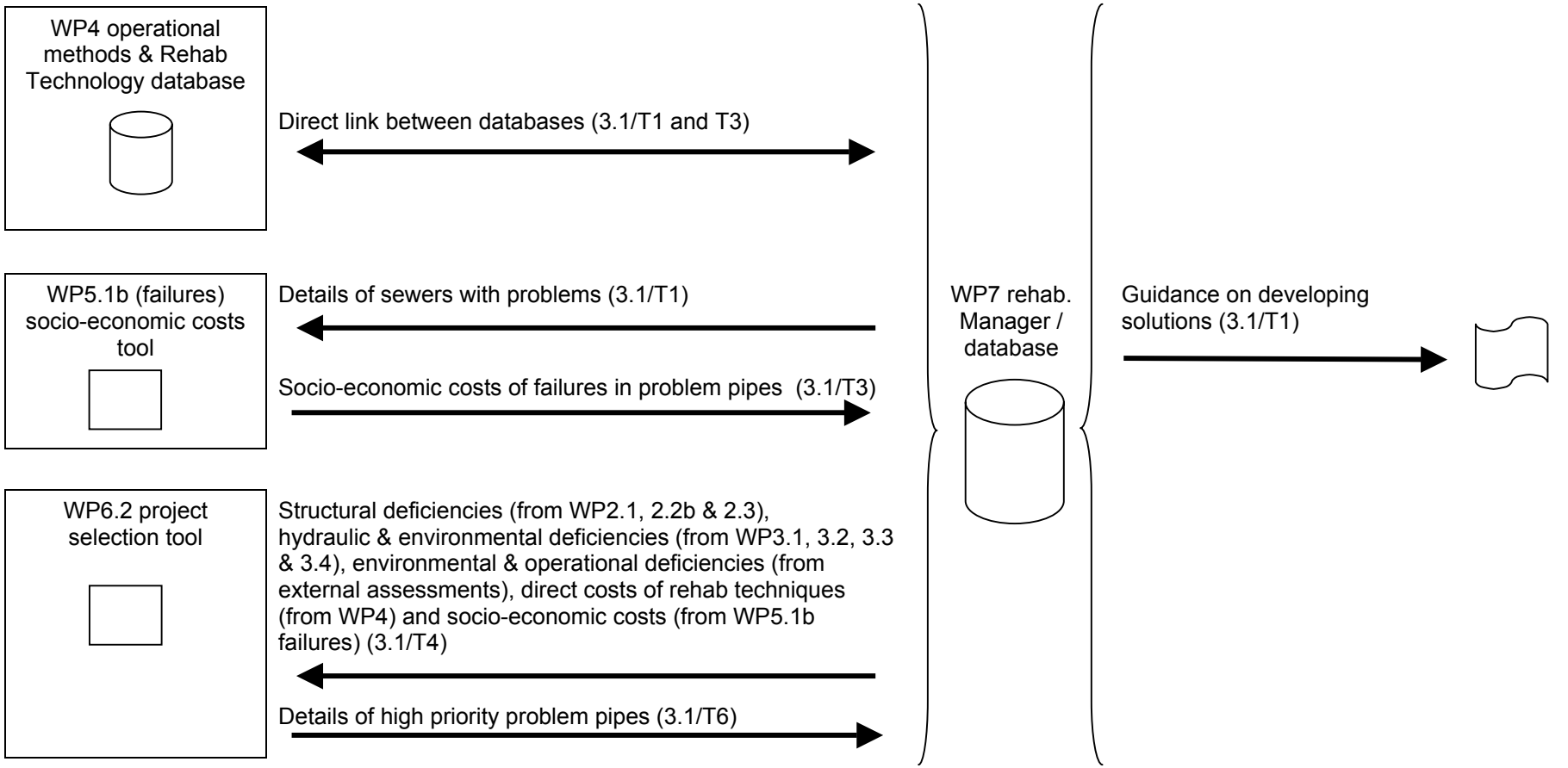
EN752-5 Stage	*CARE-S task*	*Description of task and dataflows*	**CARE-S Tasks**	**Comments**
	3.1/T8		*Run pre-elimination module of the WP6.1 tool* to refine the list of possible rehab techniques for each pipe.	
	3.1/T9		*Import possible rehab techniques for each pipe from WP6.1* to the WP7 database.	
	3.1/T10		*Export details of possible rehab techniques from WP7 to WP5.1a*	
	3.1/T11		*Run the WP5.1a tool to assess the external socio-economic costs of the possible rehab works at each pipe*	
	3.1/T12		*Import results from WP5.1a* to the WP7 database	
	3.1/T13		*Export the following from the WP7 database* to the WP6.1 tool (SRT technology selection tool): Priority pipes (WP6.2) Current sewer condition (WP2.1) Rehabilitation options & costs (WP4) Socio-economic costs (WP5.1)	Note: The WP5.1a tool is likely to be integrated into the WP6.1 tool. In this case it will not be necessary to run WP5.1 independently of WP6.1 and export the results to WP6.1 via the WP7 database.
	3.1/T14		*Run the project ranking module of the WP6.1 tool* to identify the most appropriate rehabilitation technique for each sewer.	The WP6.1 tool addresses step 2.1, structural solutions.

EN752-5 Stage	*CARE-S task*	*Description of task and dataflows*	**CARE-S Tasks**	**Comments**
	3.1/T15		*Import results from WP6.1 tool to WP7 database*	Results will be lists of the sewers in the areas under consideration with the most appropriate rehab technology for each. At this point users must address Step 2.2 of the procedure by referring to the reports on hydraulic, environmental and operational deficiencies produced by the WP7 Rehab Manager. The current problems (WP3.1) and future problems (WP3.2) should be considered and appropriate solutions identified (e.g. flow diversions, attenuation, upsizing, etc.).
			Step 3 of the EN752-5 procedure (consider if hydraulic problems can be solved in conjunction with structural solutions)	Users must assess the proposals developed in step 2 and decide on integrated solutions to the various problems.
3.2	**3.2**	**Assess solutions**	**Step 4 of the EN752-5 procedure** (test possible solutions)	
	3.2/T1		*Modify asset data in WP7 database* to reflect the proposed changes to the sewer system.	A new dataset will be generated in the WP7 database and the amended asset details will be entered manually.
	3.2/T2		*Export revised asset data from the WP7* database to the WP3.1 hydraulic model.	
	3.2/T3		Run WP3.1 tool	As with the previous analysis using the WP3.1 tool, this is done outside of CARE-S. The results will be water levels in each sewer generated by the trigger and target rainfall events for the system after the proposed rehabilitation works have been implemented.

EN752-5 Stage	*CARE-S task*	*Description of task and dataflows*	**CARE-S Tasks**	**Comments**
	3.2/T4		Run WP3.3a/b tools to check the environmental effects of proposed changes to the sewer system.	
	3.2/T5		Review the effects of the proposed rehabilitation works; select an alternative option; revise asset data in WP7 database to reflect the new option; and re-run tasks 3.2/T1–T4 until the optimal solution is determined.	Developing the optimal integrated solution is an iterative task, which will involve developing and testing several alternative rehab proposals. This work is all done outside of CARE-S.
	3.2/T6		*Import results for the* optimal rehab solution *from WP3.1 tool* to the WP7 database.	The WP7 Rehab Manager will produce reports showing the works proposed in the optimal solution for each problem. Audit trail WRc will consider whether the WP7 database needs to be able to store details and results of each modelling run for audit-trail purposes. It may be preferable for this functionality to be provided by the hydraulic modelling applications (MOUSE, etc.).
3.3		**Prepare rehabilitation plan**		
3.3.1		Short-term rehabilitation plan		The works identified in task 3.2/T6 will constitute the short-term rehabilitation plan. The WP7 Rehab Manager will produce reports showing details of the short-term plan, based on the solutions identified in task 3.2/T6 and the priority pipes identified by the WP6.2 tool.
3.3.2		Operational plan.		An operational plan must also be produced, showing any changes to operational practice which will be implemented to solve the problems

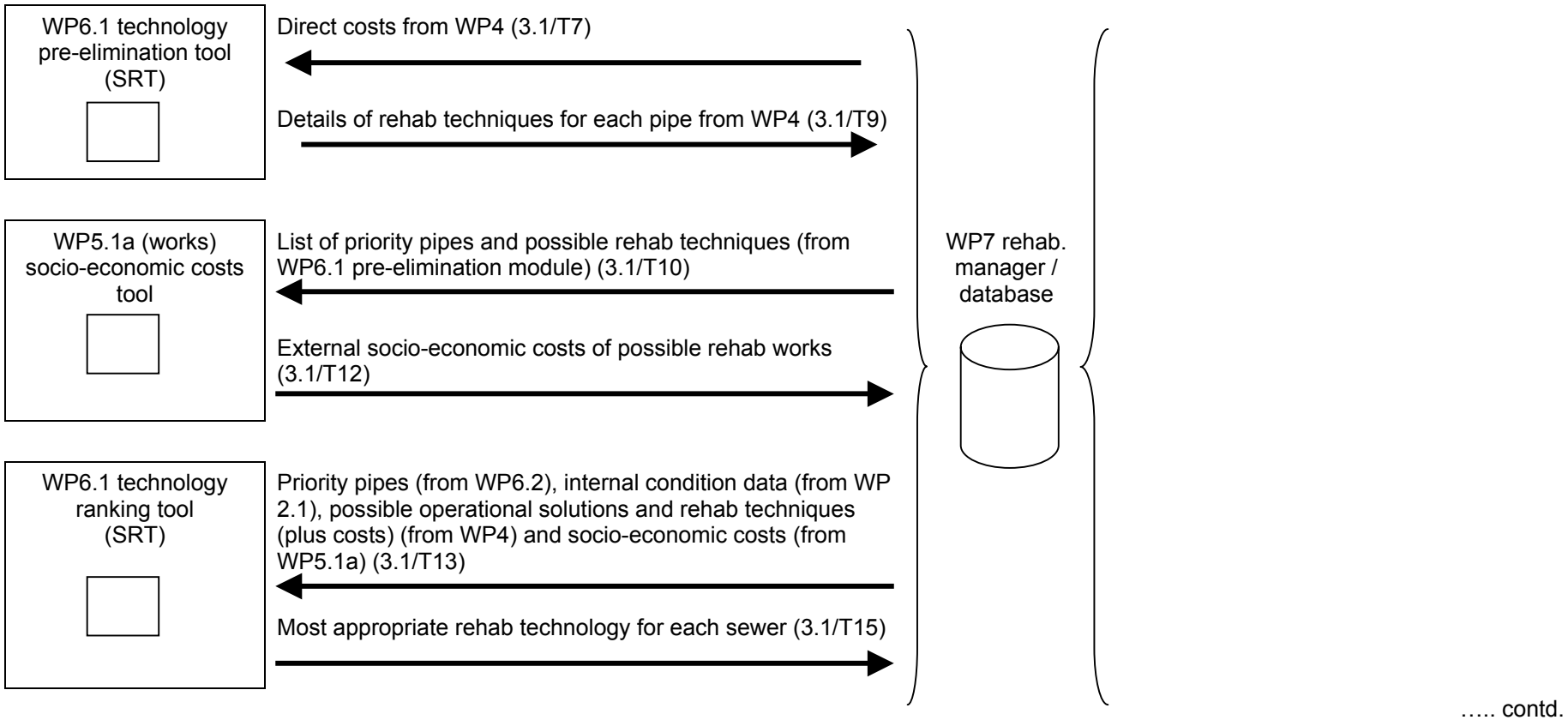
EN752-5 Stage	*CARE-S task*	*Description of task and dataflows*	**CARE-S Tasks**	**Comments**
				identified in the rehab study. This is done outside of CARE-S.
3.3.3		Long-term rehabilitation plan		
	3.3/T1		*Export the following from the WP7 database* to the WP6.3 (long-term strategy) tool: List of possible PI's (WP1); Details of possible rehab techniques (WP4); Costs of possible rehab options (WP4 & 5).	
	3.3/T2		*Run the WP6.3* tool to investigate long-term (10–30yrs) strategies & budgets.	This will be an iterative process in which the user reviews the costs and benefits of different strategies and compares them with available budgets and performance targets before arriving at the preferred strategy and associated budget requirement.
	3.3/T3		*Import results for the optimal long-term plan from the WP6.3 tool* to the WP7 database.	The WP7 Rehab Manager will produce a report containing details of the selected long-term rehab plan.

Figure 5.6 Dataflows for Stage 3: Develop Solutions



….. contd.

Stage 3 (contd.)



….. contd.

Stage 3 (contd.)

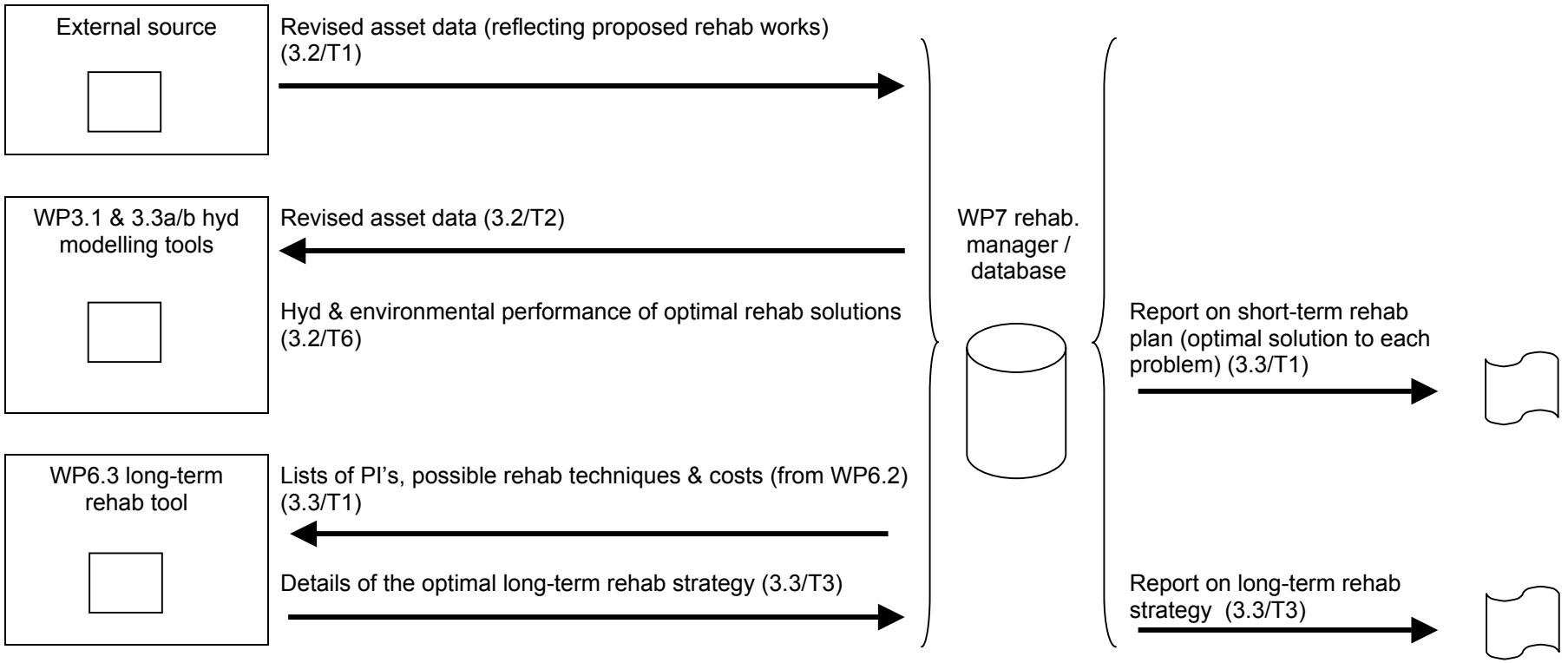


Table 5.7 Stage 4 - Implementation

EN752-5 Stage	*CARE-S task*	***Description of task and dataflows***	**CARE-S Tasks**	**Comments**
4		**STAGE 4 – IMPLEMENT & MONITOR RESULTS**		The following tasks are undertaken outside of CARE-S. The WP7 Rehab Manager will provide no more than general guidance on them.
4.1		Carry out rehab works		
4.2		Implement operational plan		
4.3		Revise hydraulic & environmental models		
4.4		Monitor KPIs		
4.5		Continue condition inspection programme.		
4.6		Review success of rehab plan.		
4.7		Revise plan as necessary.		

EN752-5 Stage	*CARE-S task*	***Description of task and dataflows***	**CARE-S Tasks**	**Comments**
		Daily management of the sewer system The CARE-S database will form a valuable information source for the continuing (day-to-day) management of the system. Data on the system configuration, sewer condition and performance indicators should be kept up-to-date. It is not anticipated that rainfall and sewer flow data, collected for hydraulic modelling, will be permanently stored in the CARE-S database, these will be stored elsewhere.		

6. OVERVIEW OF THE CARE-S SOFTWARE ARCHITECTURE

6.1 Introduction

The following sections provide a brief overview of the rehabilitation manager software, which is discussed in detail in Report D21, "User Interface for the CARE-S wastewater rehabilitation manager software", published in April 2004.

6.2 Scope

The Rehabilitation Manager will be a versatile and powerful application, incorporating a variety of rehabilitation planning tools. It will have the flexibility to allow the rehabilitation of networks to be planned at both strategic and tactical levels, or in other words, at various levels of complexity (network, catchment/sub-catchment, drainage area/sub-area or sewer) and timescale (short- or long-term). This flexibility is possible because of the nature of the tools that form the Prototype. It should be noted that the CARE-S software is a tool to *help* an engineer devise annual and strategic rehabilitation plans; it will assist the engineer in developing a rehabilitation plan based on the integrated analysis of the relevant issues but **it does not, and is not intended to** produce the plan itself.

6.3 Datasets and projects

The unit of currency in CARE-S will be the **dataset**, which may be one of the following types: network, sector, or cluster. All datasets will belong to one or more **projects**. A project is merely a convenient grouping for working with, and maintaining, multiple datasets and model runs. *In practice, the user will import his project data to a CARE-S project database*.

A **sector** is defined as a collection of sewers which have been grouped under a reference name, typically an area draining to a single treatment works or outfall, e.g. a drainage area or sub-area. A **cluster** is defined as a grouping of sewers with one or more common attributes which may or may not lie within one sector (e.g. sewers of a specific material or size range). A **network** is defined as the largest grouping of sewers, typically a collection of sectors of a company or municipality, which would normally comprise a catchment or a sub-catchment.

It is important to maintain and cross-reference general dataset information with information relating to the sewers which constitute that dataset. This allows reports to be produced consistently and efficiently.

6.4 Software architecture

The prototype software will consist of a central MS Access 2000 (Visual Basic 6.0) database application with the following attributes:

- It will provide a central storage area and reference point for essential CARE-S data;

- It will accept **user-validated** input data in a pre-defined format. Data source fields will be mapped to fields within the CARE-S database according to the specification of the declared input data source;

- It will provide automatic conversion of data item units to standard CARE-S convention;

- It will perform rudimentary data validation including duplication, data type and range checking;

- It will allow user interaction with a pre-determined range of tools under the CARE-S umbrella;

- It will interact with a pre-determined range of tools at the user's request by:

  (a) Creating the necessary input file(s) from the data stored in the CARE-S database to enable the tool to be run; and

  (b) Accepting and storing necessary output data on completion of tool use.

The general architecture of the CARE-S prototype software is shown in Figure 6.1.

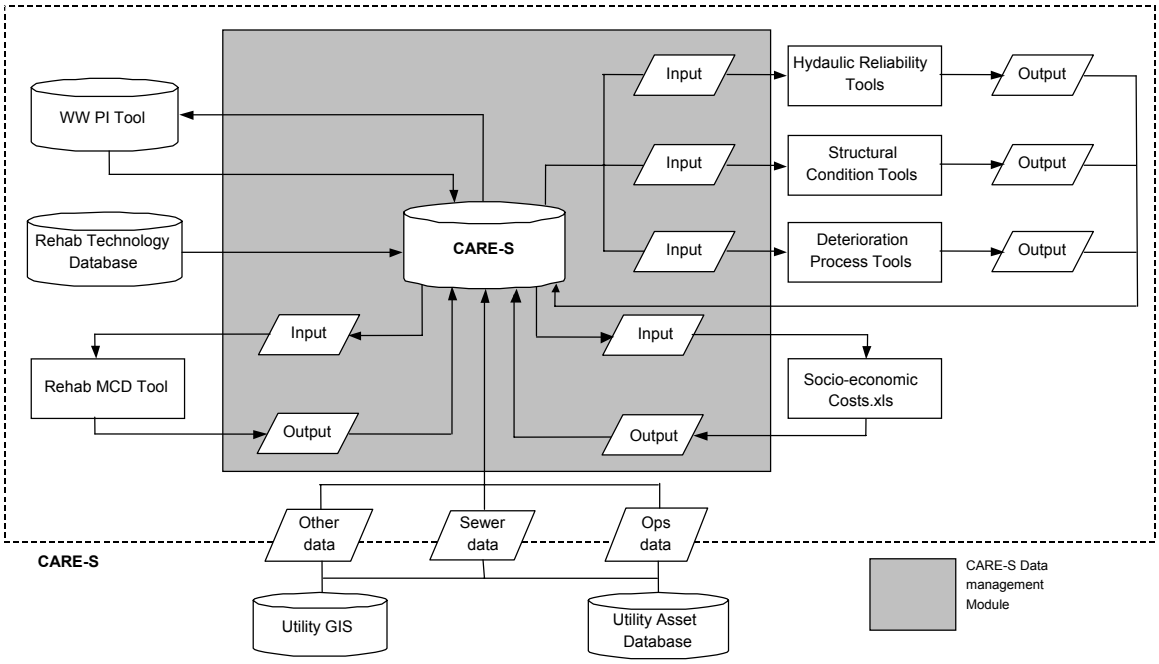


Figure 6.1 Overview of the CARE-S software architecture

6.5 The central database

The heart of the software will be a database containing a series of tables which are used to store information from a number of different input sources. The CARE-S software will manage the import of data to these tables through the user interface. Information will be stored once only and only information required for further analysis by CARE-S tools will be stored in the central database. Geospatial elements, pipe-based information and catchment information will be recorded in individual tables under suitable references. Other tables will record utility, operating environment and performance data and, of course, will also hold relevant results for use by the tools and for reporting to the user.

6.6 Data flow and tools interaction

All external tools will be referenced by the CARE-S database according to a series of input and output protocols written by WRc in close consultation with the tool developer. On user request, the central software package will produce the necessary input and output files which must be read and interpreted correctly by each of the tools in order that information may be passed back and forth between the CARE-S database and the external tool currently in use.

CARE-S is not intended to bind together the external tools produced as part of WP1, WP2, WP3, WP4, WP5 and WP6 in a fixed and constraining way, but rather to allow the user to use them individually or in a sequence appropriate to the data available for analysis.

6.7 The user interface

It is anticipated that the GIS user interface will be constructed using Visual Basic 6.0, with a standard Windows-style menu structure to provide access to the various functions and forms. The development of the GIS interface is the subject of a later stage of this work package (WP7.2), so it is not discussed further in this report.

6.8 Help

The CARE-S software will contain both passive and active help facilities. The passive help will act as a reference guide for the more experienced or general interest user. Given sufficient information on the user's objectives in working with CARE-S and the data available, the active help facility will guide the new user in how to use CARE-S most effectively.

The CARE-S Partners

SINTEF, Trondheim, Norway
NTNU, Trondheim, Norway
CLABSA, Barcelona, Spain
University of Ferrara, Ferrara, Italy
Cemagref, Bordeaux, France
Engees, Strasbourg, France
CSIRO, Australia
University of Bologna, Bologna, Italy
University of Palermo, Palermo, Italy
Aalborg University, Aalborg, Danmark
Technical University of Budapest, Budapest, Hungary
Brno University of Technology, Brno, Czech Republic
Dresden University of Technology, Dresden, Germany
Laboratório Nacional Engenharia Civil, Lisboa, Portugal
WRC plc, Swindon, United Kingdom

Partner name: WRc plc
Contact person: Mr Will Williams
E-mail: williams_wd@wrcplc.co.uk
WWW.WRcplc.co.uk

Address: Frankland Road, Blagrove, Swindon, Wilts, UK
Phone: + 44 1793 865000
Fax: + 44 1793 865001

http://care-s.unife.it/