Glasgow Strategic Drainage Plan – Stage 2

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1 Introduction

In June 2003, Hyder Consulting (UK) Limited (HCL) was appointed by Scottish Water (SW) as Lead Consultant to undertake masterplanning of the sewerage and drainage infrastructure of Greater Glasgow through the Glasgow Strategic Drainage Plan (GSDP). The GSDP is being undertaken in recognition of the need for an integrated and sustainable approach to address the city's problems.

In July 2002, the City of Glasgow suffered severe flooding due to rainfall estimated as a 1 in 100 year storm event. This resulted in flooding of over 500 properties with sewage and floodwater, with consequent misery for the occupants, and claims for compensation. Although Glasgow was known to be flood-prone, the extent of flooding and damage experienced was a setback for the City and its plans for extensive redevelopment. Both SW and Glasgow City Council (GCC) found themselves under considerable pressure from residents, planners, councillors and politicians to identify solutions to this major threat to the city. More recently, Glasgow's bid for the 2014 Commonwealth Games has brought further focus to the problems.

There are also serious water quality problems associated with the River Clyde and its tributaries with classifications of mainly 'poor' and 'seriously polluted'. Existing water quality is also a major constraint to redevelopment. Current water quality is generally well below the Scottish Environment Protection Agency (SEPA) existing and future Water Framework Directive (WFD) target classifications. The WFD requires all water bodies to achieve 'good ecological status' by 2015.

In addition, the latest global warning research predicts that Glasgow is particularly vulnerable to climate change which will further increase flooding risk and water quality problems.

The GSDP encompasses the catchment areas served by the Dalmuir, Dalmarnock, Daldowie and Shieldhall Waste Water Treatment Works (WwTWs). Between them, these catchments serve over a million people and include all of Glasgow City plus parts of West Dunbartonshire, East Dunbartonshire, North Lanarkshire, South Lanarkshire and East Renfrewshire. The GSDP catchment area is shown in Figure 1-1 below:

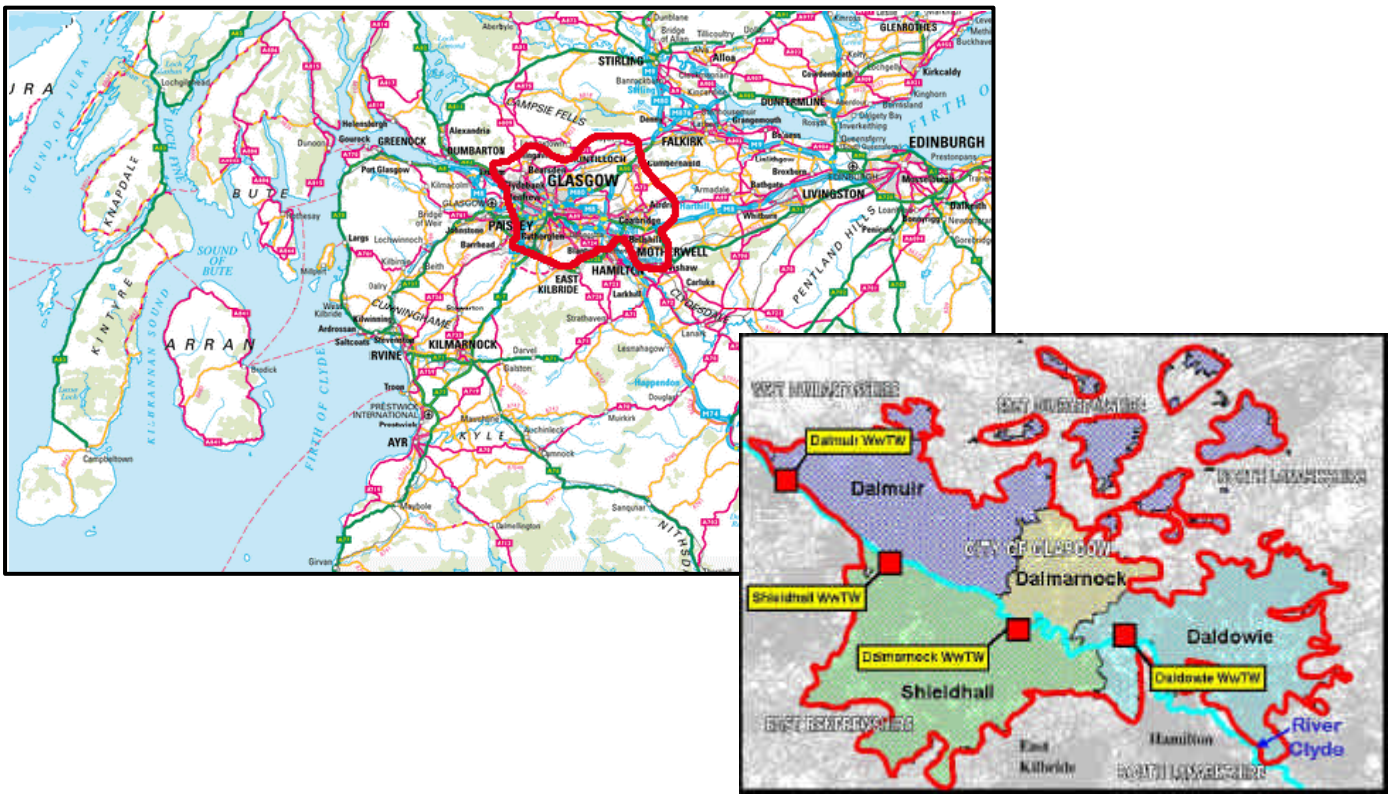

Figure 1-1 -GSDP Catchment Area

Responsibilities for stormwater management in Scotland are divided between numerous parties. Since the 2002 flooding event, it was recognised that a joint strategy was required to address the drainage problems in Glasgow and the needs of all stakeholders.

The GSDP is thus being promoted and guided by a Steering Group comprising SW, GCC, SEPA and Scottish Enterprise Glasgow (SEG). Both HCL and Scottish Water Solutions (SWS) report to the Steering Group.

The key objectives of the GSDP are as follows:

- **Flood Risk Reduction:** the flood risk from both sewers and watercourses is unacceptable in many areas. The flood event of 30 July 2002 affected hundreds of families and businesses and caused damage estimated at £100m. Climate change will increase the frequency of such events.
- **Water Quality Improvement:** many of Glasgow's urban watercourses have been heavily modified over the years with culverts replacing open channels. Whilst the performance of the sewerage system is dependent on the hydraulic relief provided by numerous Combined Sewer Overflows (CSOs) discharging surplus stormwater to watercourses, existing water quality is unacceptable and needs to be improved to meet increasingly stringent legislative requirements.
- **Removal of Development Constraints:** the lack of capacity and other deficiencies with the drainage infrastructure is now hampering regeneration efforts and much needed economic development. The benefits of other major infrastructure investment, such as the M74 extension and the East End Regeneration Route, will not be realised if development is restricted.
- **Habitat Improvement:** urban regeneration should provide opportunities for improving the environment and open watercourses should be considered in this regard. A further objective is therefore to explore the possible opportunities for "de-culverting" of watercourses. Along with other measures such as provision of attenuation ponds, this could provide valuable habitat and amenity enhancement in an area where it is much needed.
- **Integrated Investment Planning:** the likely level of investment required to address development constraints, flooding and water quality needs to be understood. A business case needs to be made to allow each stakeholder to secure the necessary funding support. In particular, it is considered that European Regional Development Fund (ERDF) funding should be pursued before this becomes more difficult to obtain due to expansion of the European Union.

Such is the extent of the legacy position of the sewerage and drainage infrastructure, it was clear that major rehabilitation and investment would be required to address the problems. Although numerous drainage area studies were ongoing at a local catchment level, it is was evident that a more holistic approach was required to cost-effectively address this legacy position and define a blue-print for the long term needs of Glasgow's sewerage and drainage infrastructure.

2 Masterplanning

Masterplanning provides a cross catchment holistic approach to deliver a strategic plan for the overall region. A masterplan addresses all the performance drivers, including cumulative future land use and development requirements to agreed longer term planning and design horizons.

At the core of the masterplanning process are the Wastewater Treatment Works (WwTW) flow/loading assessments and the definition of future treatment strategy requirements. If the existing WwTW cannot accept the increased flows or loads, then the need and feasibility of future phased expansion must be identified. If existing WwTW footprints are insufficient to accept all the future flows then consideration is required of the need for additional treatment facilities. Masterplanning also allows environmental impact to be addressed at a regional level and encompass all storm water/river interactions.

Due to the scale of the legacy problems in Glasgow, local catchment drainage area planning was increasingly recognised as a too narrow an approach as this only reviews and defines local catchment requirements and solutions. This approach often purely results in the transfer of hydraulic and environmental problems to another point in the WwTW network. In addition, local drainage area plans are also normally based on fairly short term local development plans.

Originally, SW had broken down the GSDP catchment area into 120 individual local drainage areas. These were subsequently rationalised into some 27 hydraulically discrete catchments for the purposes of progressing combined drainage area plans. These combined drainage area plans have been progressed by a number of consultants of the last few years, principally HCL, Montgomery Watson Harza (MWH) and Ewan Associates (EA). Whilst some of the plans had been completed, many were only partially complete and/or still ongoing or at the commencement of the GSDP.

For the masterplanning approach, amalgamated network models were required for each complete WwTW catchment and potentially a single regional model or a combined WwTW model analysis to investigate the potential of cross catchment solutions. Figure 2-1 overleaf shows the amalgamation process.

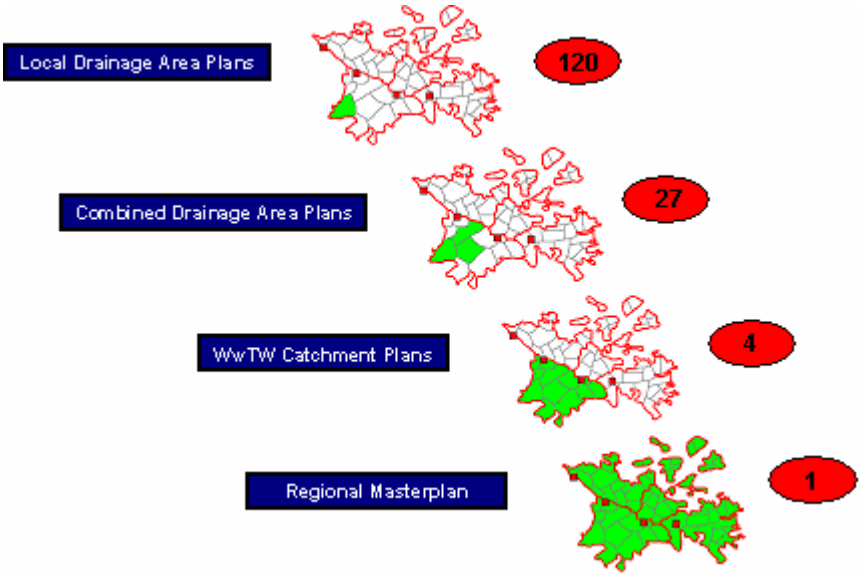

Figure 2-1 Model Amalgamation

Attempting to address the problems at a local level in a more piecemeal manner risks being unviable and uneconomic. Numerous local solutions may perhaps be individually robust, but are unlikely to be sustainable collectively, particularly in addressing overall water quality requirements. The lowest cost local solutions are often attenuation based, and even if they could collectively address the strategic hydraulic and environmental requirements, the total storage involved would be impracticable. There were therefore significant risks associated in not adopting the holistic masterplanning approach.

A masterplanning approach defines the total catchment solution and enables overall costs, benefits and investment requirements to be understood by the stakeholders. Within the overall masterplan, solutions and schemes can be broken down and prioritised for phased implementation.

In addition to the overall masterplanning philosophy, an integrated approach to both the sewerage and drainage infrastructure was also recommended with the aim to develop cost effective integrated solutions with the right balance between conventional 'hard' engineering solutions and 'soft' solutions such as watercourse improvements and Sustainable Urban Drainage Systems (SUDS) for example.

The GSDP Steering Group agreed the benefits of an integrated masterplanning approach which are summarised as follows:

- Flooding is occurring from both sewers and watercourses. Where this occurs together, it is necessary to understand the hydraulic performance and interaction of both systems.
- There can be considerable physical interaction between combined sewer systems and watercourses, e.g. via combined sewer overflows. Assessing both systems together permits a full understanding of the performance of both systems under potential loading conditions.
- Sewer systems, watercourses and treatment works, and the continuous and intermittent discharges there from, are subject to constantly changing loading due to urban development and regeneration. An assessment of population and land use will provide an understanding of short, medium and long term loads.
- Assessment of wastewater treatment capacities, together with an understanding of the assimilative capacity of receiving waters, will allow consideration of potential transfer / treatment options.
- A review of drainage policy will allow appropriate design criteria to be identified and consistently applied in order to provide an acceptable level of service.
- The River Clyde Catchment Study is looking at options to address the risk of flooding (tidal and fluvial) in the Clyde corridor. Appreciation of the behaviour of urban watercourses (and potential improvement solutions) will inform the design of any solutions for the River Clyde.

It was agreed that the actions described above would permit development of best value strategic drainage options to address the backlog of investment and deliver the Vision of Sustainable Urban Drainage for Glasgow.

In broad terms, a strategy was required to bring stakeholders together and to step-elevate the infrastructure to a steady-state standard which is then sustainable. The concept of the GSDP adopting a masterplanning approach was agreed as the best means of achieving this aim.

The overall need for the GSDP is to promote further economic development and hence provide an improved quality of life for the population of Glasgow. This is best done through the provision of a sustainable drainage system. The elements needed to do this are summarised in Figure 2-2 overleaf:
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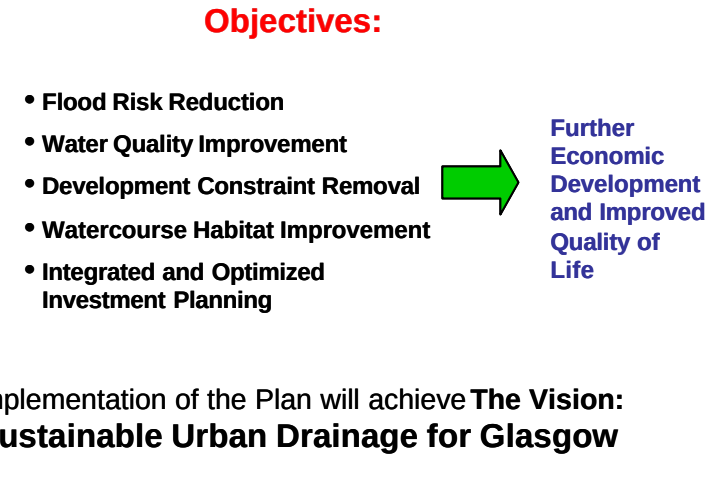

Figure 2-2 - GSDP Objectives and Vision

A staged approach was agreed and adopted to the masterplanning process as shown in Figure 2-3 below:

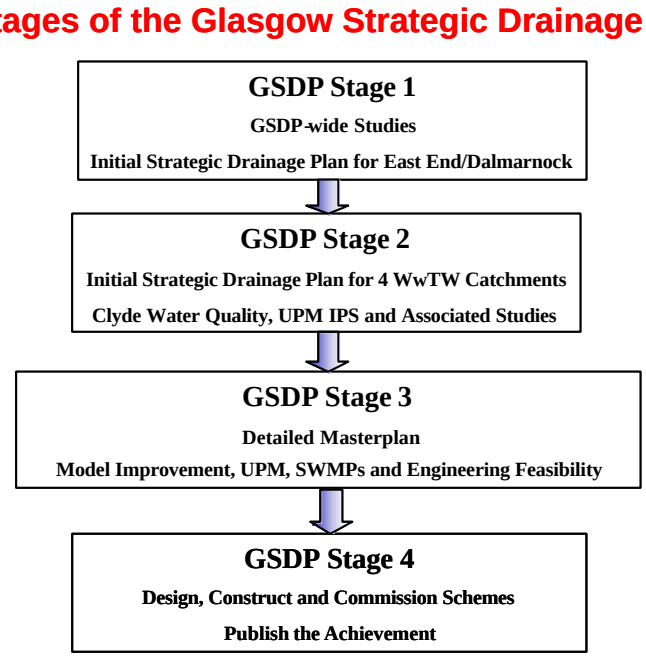

Figure 2-3 GSDP Stages

3 GSDP Stage 1

Stage 1 of the study initially investigated overall drainage and flooding issues affecting the whole of Glasgow, while at the same time concentrating in particular on the Dalmarnock catchment, which suffered worst from the July 2002 flooding. The primary objective of Stage 1 was to provide the stakeholders with an initial assessment of the problem and further facilitate debate as to how to best address the situation. Stage 1 was completed in April 2004.

The following reports were produced:

- Catchment Hydrology Report.
- Wastewater Treatment Works Assessment Report.
- Land Use and Development Report.
- The Initial Strategic Drainage Plan (ISDP) for the East End/Dalmarnock

These full area studies provided the context for development of the overall Strategic Drainage Plan for Glasgow.

The Initial Strategic Drainage Plan (ISDP) for the East End/Dalmarnock catchment utilised an integrated hydraulic model of both the sewerage and drainage systems to identify the scope of conventional engineering solutions to address the deficiencies identified. The integrated model was developed by Montgomery Watson Harza (MWH) and although not verified at the time, it was sufficient to broadly replicate the existing system performance and identify the nature and scale of initial solutions.

In addition to the more traditional 'hard' engineering solutions, the potential for 'soft' engineering solutions such as SUDS retrofit and watercourse solutions were also initially assessed.

4 GSDP Stage 2

Although the stakeholders understood the potential magnitude of the challenge and investment ahead, this needed to be more refined in terms of scope, complexity, costs and programme. It was important that the stakeholders had something more tangible to engage debate as quickly as possible balanced against the need for sufficient accuracy.

The basic philosophy of Stage 2 was to make best use of all existing information to define an initial understanding of the potential scope and cost effectiveness of a strategic masterplan to achieve the GSDP objectives prior to defining and embarking on more detailed studies. Although existing model coverage and understanding was incomplete, it was considered that there was sufficient information to define the outline of an initial masterplan. The initial masterplan would allow future work to define the detailed masterplan to be more cost effectively understood and targeted. HCL continued the lead consultant role for Stage 2 under the management by SWS. Stage 2 was completed in August 2005.

Of particular importance was the need for an initial understanding of the water quality of the River Clyde particularly with respect to the relative impacts of continuous WwTW discharges, intermittent CSO spills and background diffuse pollution. Preparation of a Clyde River/Estuary model was therefore deemed necessary .

Additionally, it was considered important to gain an initial understanding of the level of UPM/water quality analysis that would be appropriate to the Clyde's tributaries to understand both existing and future target water quality compliance. Indeed, an overriding consideration is fundamentally whether future target water compliance is achievable both in the tidal and non-tidal waters. The tangible cost benefit of potential improvements needs to be considered against the other GSDP drivers such as flood risk reduction and the removal of development constraint.

For the purpose of the initial masterplan, bearing in mind the use of an un-calibrated river model together with some unverified catchment sewerage models, it was considered appropriate and sufficient to define water quality requirements on the basis of minimum Formula A standards. However more rigorous and conservative 'surrogate' standards were agreed by the stakeholders and adopted for many of the receiving watercourses, mainly the minor burns and watercourses due to the obvious low flows and lack of available dilution.

A fully integrated sewerage and drainage approach had already been adopted for the Dalmarnock catchment with associated integrated modelling. It was considered important to initially understand via the means of an initial masterplan whether this approach was applicable and justifiable to the wider GSDP catchment area. The requirements for integrated modelling needed to be considered at two levels: to enhance the analysis and delivery of a sewerage masterplan and/or; to facilitate a combined sewerage/drainage masterplan via the mechanism of Surface Water Management Plans (SWMP's). Rather than embarking on wholesale integrated modelling, it was considered that an initial assessment would define the need for only targeted catchment areas. Catchment wide integrated modelling would have significant implications on future GSDP costs and programme and therefore compromise the shorter term definition and removal of development constraint.

The definition of the Stage 2 Initial Masterplan has provided the stakeholders with the basis to refine their understanding of the challenge of the GSDP and facilitate discussion and agreement on the most appropriate way forward to reach the declared objectives.

The main Stage 2 workstreams and deliverables are more specifically summarised below:

4.1 Initial GSDP Masterplan

The work involved the extension of the Stage 1 process to produce an Initial Masterplan for all four Glasgow WwTW catchments. This involved the development of initial costed strategic solutions and recommendations for the Shieldhall, Dalmuir, Daldowie and Dalmarnock WwTW catchments with particular emphasis in evaluating cost effective 'cross catchment' options in terms of sewerage and treatment.

Work included producing amalgamated sewerage catchment models of Dalmuir, Daldowie and Shieldhall. The integrated catchment model produced by MWH was used for the Dalmarnock catchment. Hydraulic and environmental (spill volume and frequency) analysis of all catchments was undertaken for both the existing and agreed future design horizons.

A number of existing sub-catchment models were incomplete and not verified with work ongoing by the existing catchment consultants during the Stage 2 programme. Best use was therefore made of the existing models at the time of amalgamation with the identification of all key issues and constraints as to their accuracy. The available models are summarised in Figure 4-1 overleaf:

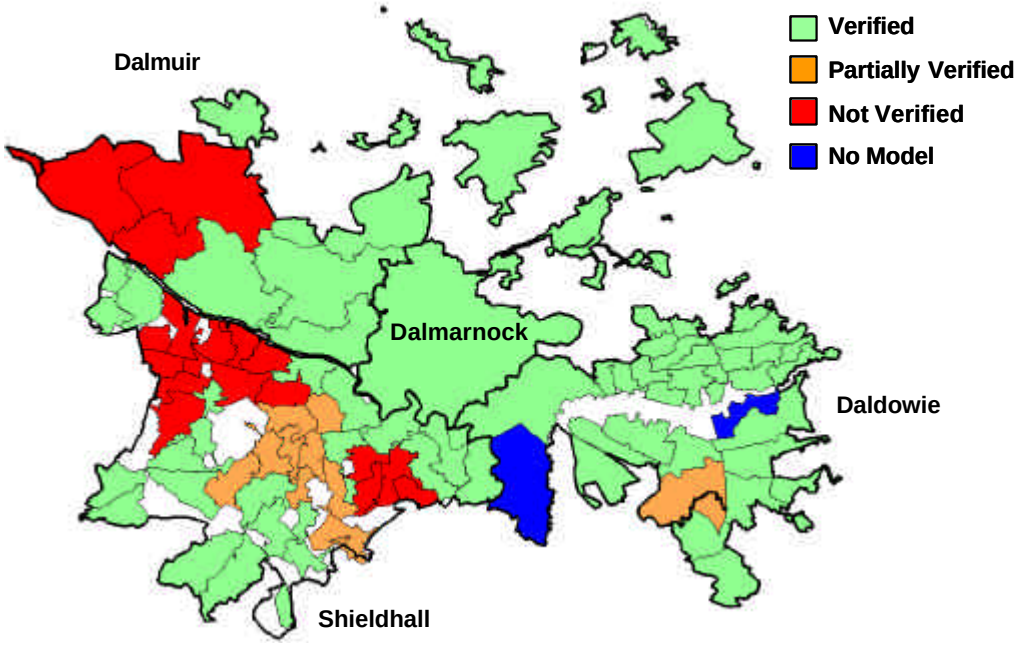

Figure 4-1 Existing Model Coverage

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Model statistics are summarised in Figure 4-2 below:

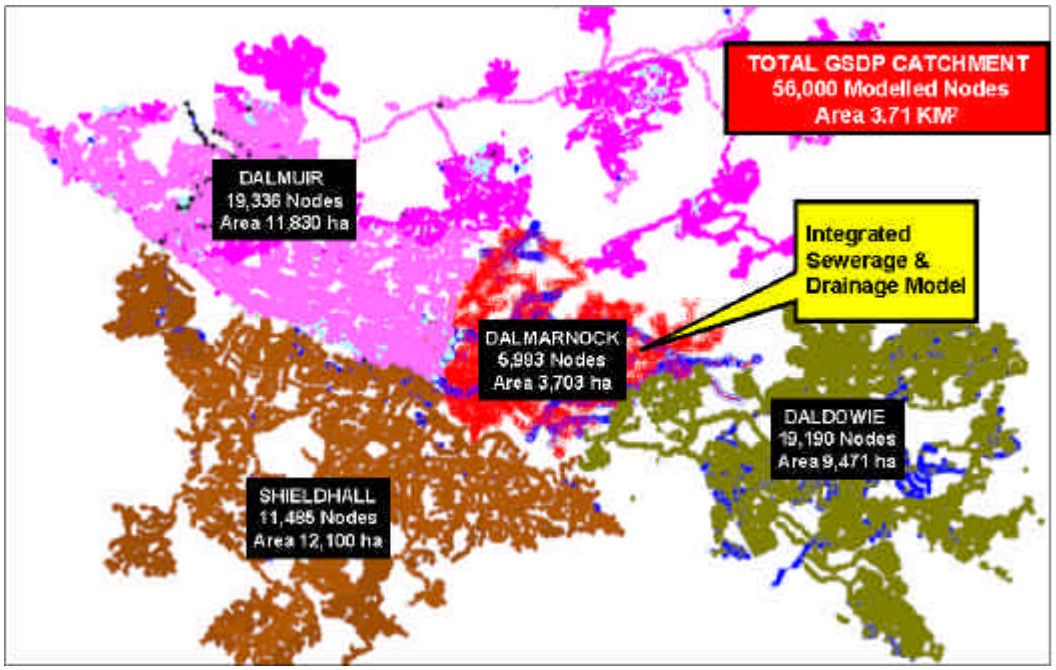

Figure 4-2 Model Statistics

Models were run with synthetic 'design' rainfall events covering a range of return periods and durations to provide a baseline understanding of how the existing system performs thus defining the existing 'legacy' position. Testing of CSO performance (annual spill frequency and volume) has been undertaken by simulating the model with an annual time series of stochastically generated rainfall events for a typical year.

The models were updated using the development database from the Land Use and Development study undertaken for Stage 1 and used to assess the impact of the agreed 2020 development horizon. The models were also update to include all completed and ongoing Quality and Standards II (Q&SII) schemes. The models were also used to assess the effects of climate change.

The results from model runs were then used to define and test more conventional strategic engineering options at WwTW catchment level and to understand potential 'cross catchment' solutions. The initial coarse river and estuary models were used to assess the water quality impact of the potential solutions against baseline conditions and future water quality objectives.

Both 'strategic' and 'local' solutions were developed. 'Local' solutions are defined as schemes that address catchment deficiencies that are more cost effectively remedied at a local level rather than at a strategic level. Although, the main focus of Stage 2 was the development of strategic solutions, it was necessary to define outline solutions to local needs so as to ensure that the downstream strategic options accounted for any increase in pass forward flows from these local solutions. The definition of 'local' solutions was also needed to understand overall costs.

It should be noted that t he terminology of 'local' solutions does not necessarily imply that they can be progressed in isolation from the 'strategic' solutions. If downstream strategic options are not initially progressed, the scope of 'local' solutions may increase for them to become 'stand alone'.

Two broad strategic approaches were developed:

Strategy Approach 1 (Conveyance) – Figure 4-3:

Maximise conveyance of flows to the wastewater treatment works, with corresponding provision of treatment capacity.

Strategy Approach 2 (Interception and/or Transfer) – Figure 4-4:

Minimise conveyance of flows to the wastewater treatment works by intercepting storm flows or transferring foul flows in the trunk sewers to adjacent WwTWs.

Both approaches can use local storage to reduce pipeline sizes or to reduce lengths of upgraded pipeline.

Both strategic approaches are supported by 'local solutions' as shown in Figure 4-5.

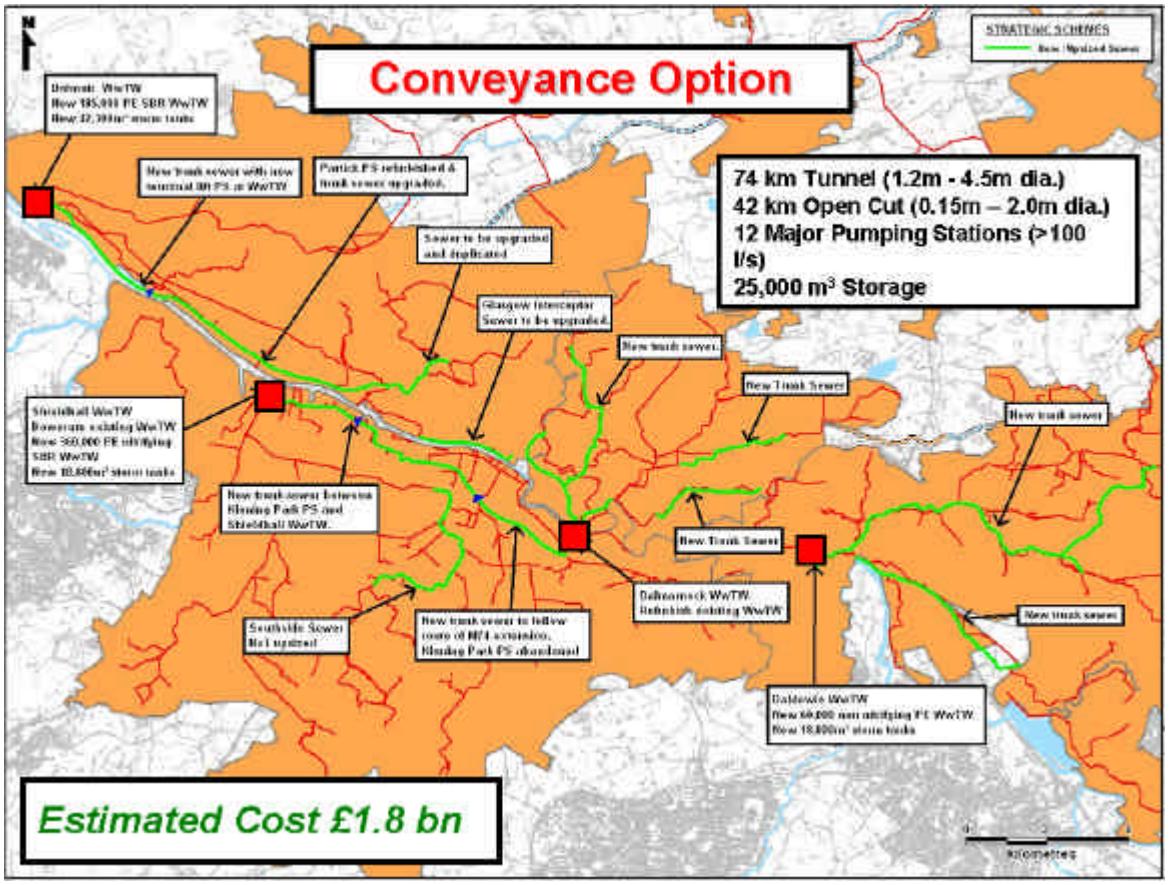

Figure 4-3 Conveyance Option

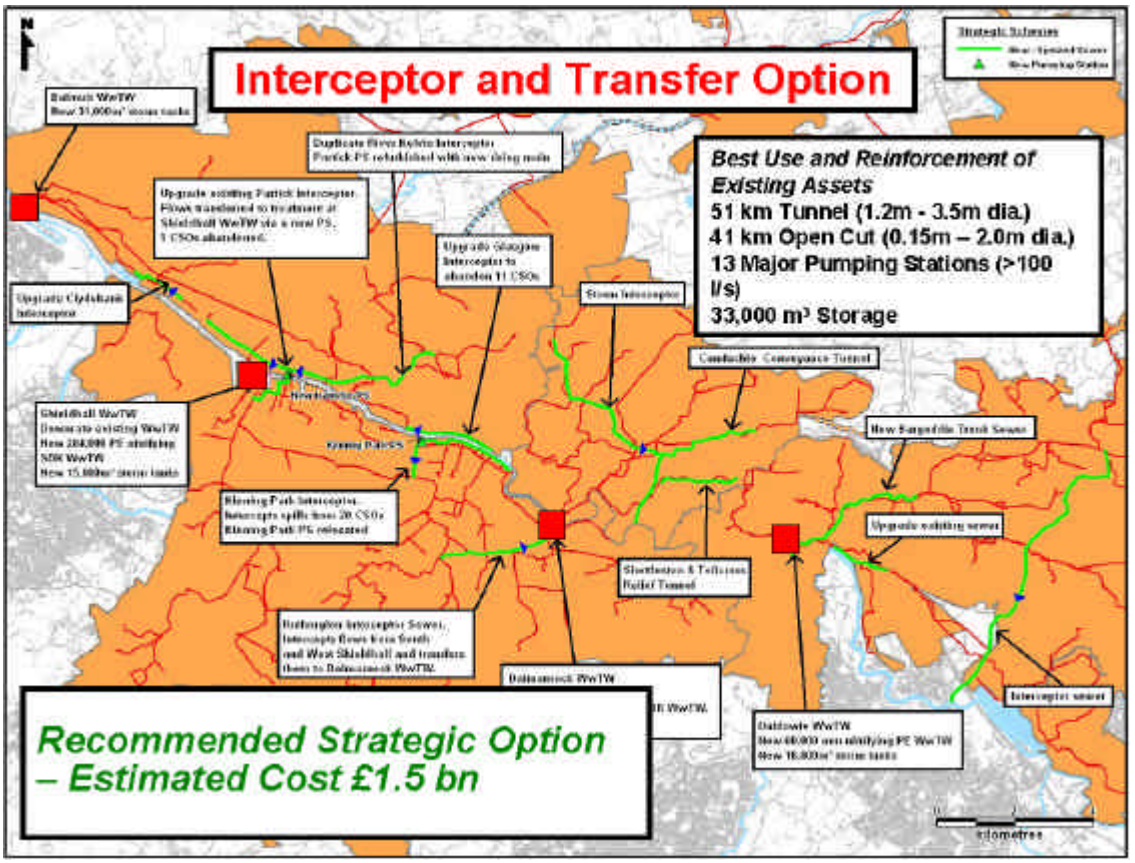

Figure 4-4 Interceptor and Transfer Option

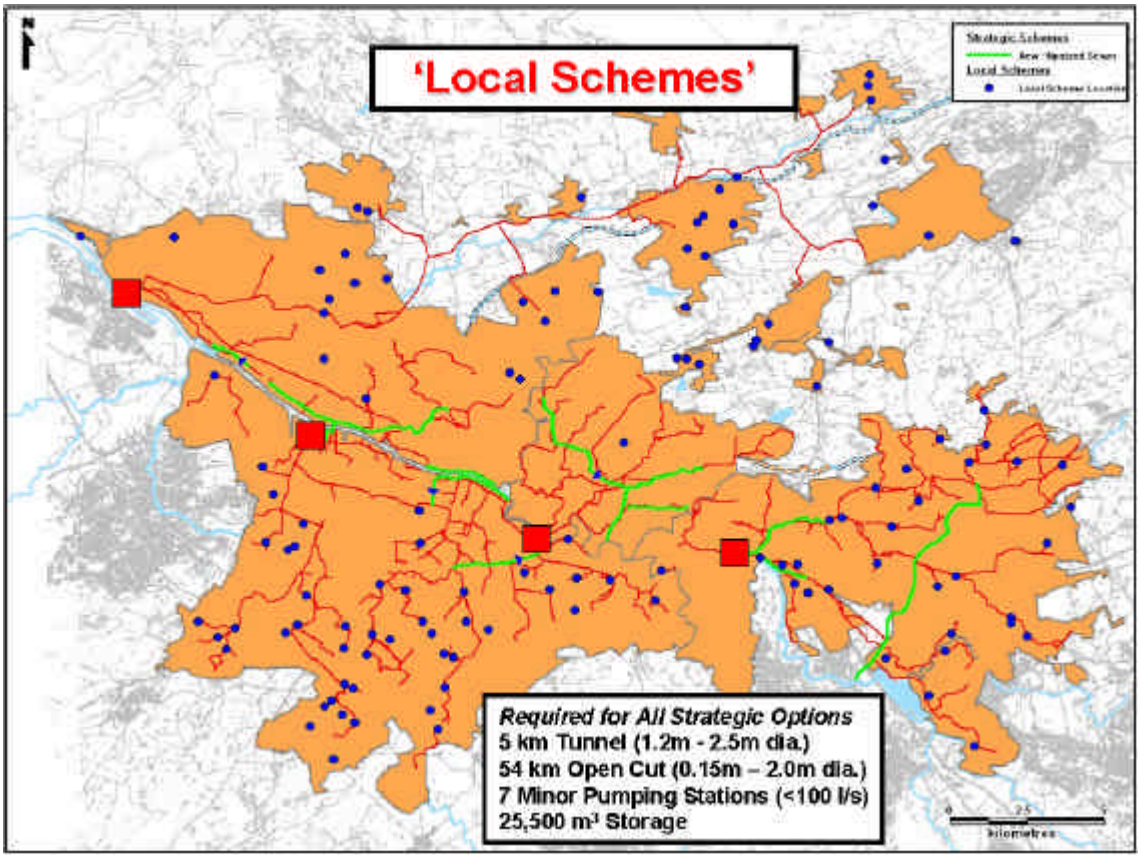

Figure 4-5 Local Schemes

All potential options were evaluated and costed in outline to enable discussion and recommendation of the preferred solutions.

The preferred solution is Strategy Approach 2 - Interception and Transfer. This approach utilises cross-catchment solutions that maximise the use of existing assets including the potential treatment capacity at Dalmarnock WwTW. This preferred solution also most cost effectively embraces all the work needed across the four catchments to serve existing and future development, in an environmentally sustainable manner.

The Initial GSDP Masterplan has identified upgrading works with estimated costs of **£1.5 billion**, which updated previous cost estimates and formed the basis for ongoing financial discussions. The estimated costs include all overheads and risk, but do not include other potential stakeholder costs.

The proposed works address:

- All at-risk 584 properties in the study catchment, defined as suffering from recurrent internal and external flooding.
- Water quality driven and aesthetic performance requirements for the 540 CSOs located in the catchment.
- Growth to the 2020 design horizon.

The preferred option has concentrated on optimising Glasgow's existing sewerage and wastewater treatment facilities. However, it is evident from the initial water quality investigation that a much more radical approach would be needed to provide any significant improvement to the water quality of the River Clyde. The most effective way of reducing pollutant loads and stormwater inputs to the River Clyde would be to intercept Formula A flows at each existing treatment works and carry this flow to a new WwTW further along the Firth of Clyde. This option is shown in Figure 4-6 below:

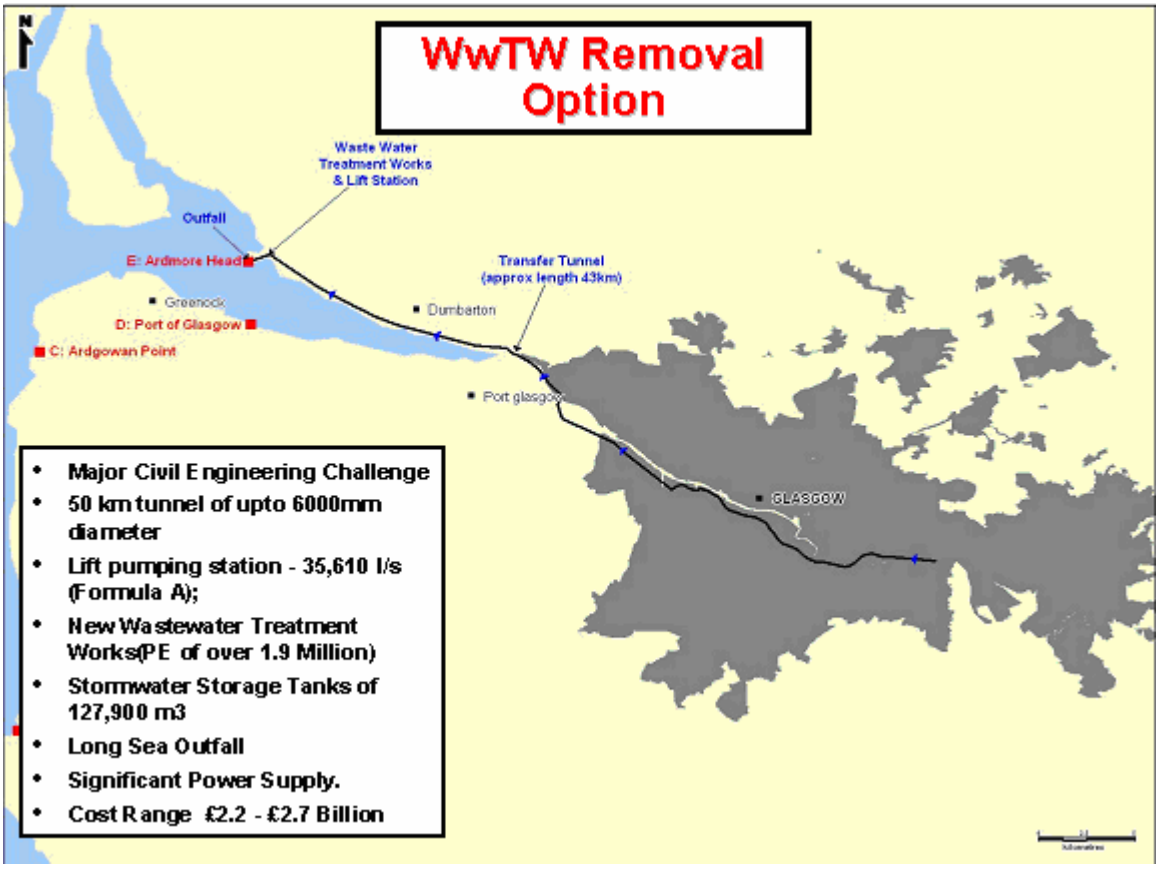

Figure 4-6 WwTW Removal Option

This option would be a significant engineering project and has been developed to determine and understand the implications of a 'worst case' scenario. The capital cost of a scheme of this nature would be immense and require significant planning, funding and justification. The estimated cost of this option is £2.7 billion including overheads and risk.

4.2 Wastewater Treatment

Understanding existing WwTW performance and future treatment requirements was essential to develop a robust masterplan.

An assessment was undertaken on the current performance of the four WwTWs serving the GSDP catchment area with a particular emphasis on their process capability and potential for future extension as part of the overall masterplan.

Stage 2 has involved much more detailed work by process specialists to assess the existing and potential performance of each Works. This has included site visits, assessment of further flow and load information, and preparation of process calculations for existing and possible future works.

4.3 Water Quality Modelling of the River Clyde and Clyde Estuary

An initial simplified Mike11 hydrodynamic and water quality model of the River Clyde was constructed to assist with the development of the initial masterplanning options. The model comprises a hydrodynamic model, an advective-dispersion model and a water quality model.

Coarse model verification and calibration has been undertaken using existing available data, and in the absence of such data, default values and sensitivity testing has been adopted. The model provides an initial understanding of water quality issues in the Clyde, in particular the existing impact from the main tributaries and CSOs and the implications of transferring existing catchment CSO spills directly to the Clyde. The Mike 11 model was developed from existing ISIS hydraulic models developed by Halcrow Consultants on behalf of GCC. SEPA have also provided data to support the water quality modelling.

Key features and discharges are shown in Figure 4-7 below:

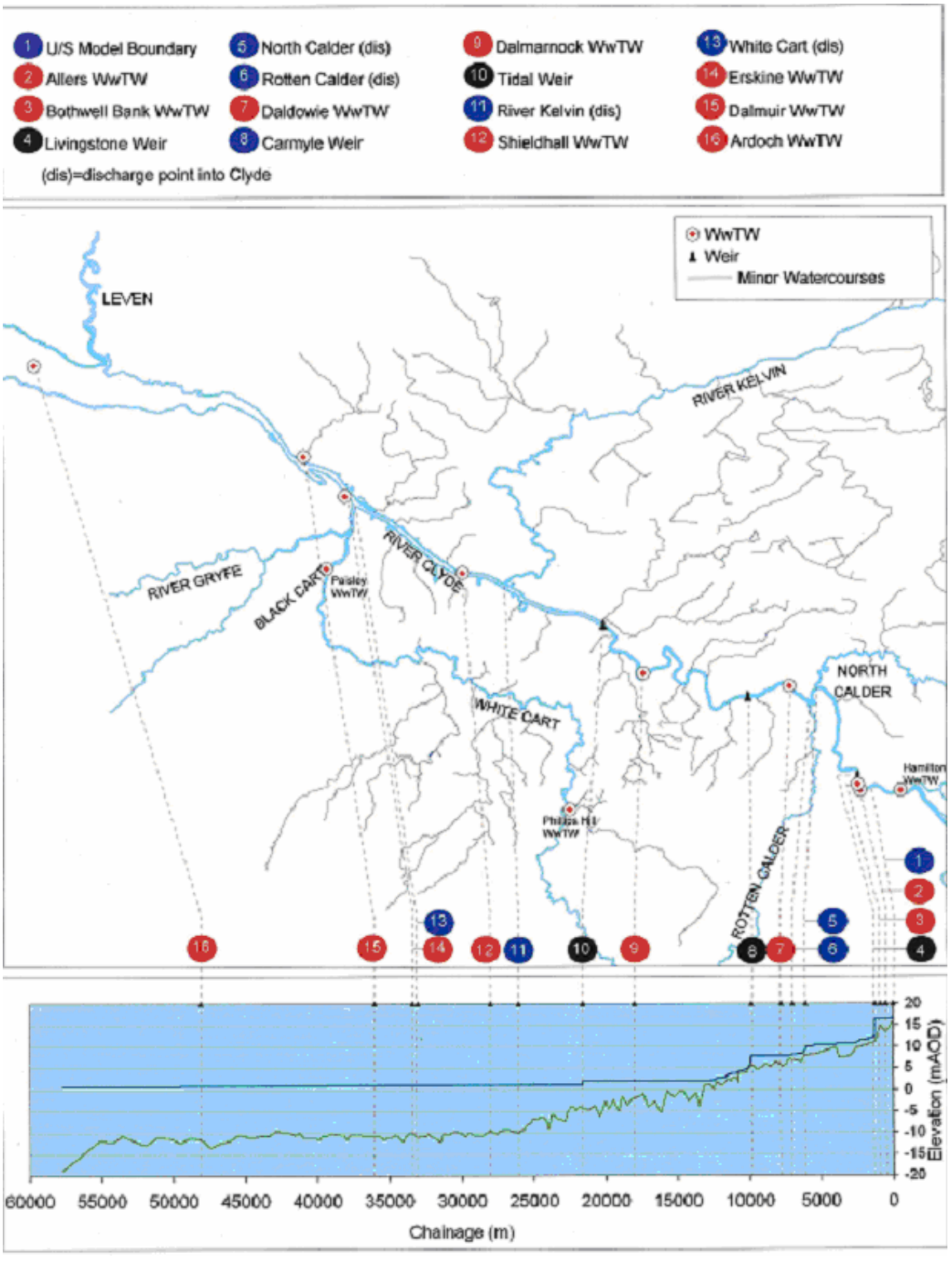

Figure 4-7 River Clyde Water Quality Model

The key finding of the initial water quality modelling of the Clyde is that if the significant pollutant inputs to the Clyde were removed, DO concentrations downstream of the tidal weir increase but still remain relatively low (<4 mg/l) and would be expected to be only water quality Class C. This phenomenon can be attributed to upstream DO sinks, low aeration rates, and the poor flushing of the estuary with the Firth of Clyde. Given the results of the flushing assessment it would appear that the DO sag observed downstream of the tidal weir is largely a natural phenomenon and even with all potential pollution sources to the Clyde removed, low DO would be expected downstream of the weir.

Poor flushing and the DO sink may be attributed, in part, to the general morphology of the estuary, but is likely to have been compounded by heavy modification of the watercourse; particularly dredging, which may have artificially deepened the channel, and the construction of the tidal weir. Flushing could be improved by natural siltation of the channel, although this could take a significant time to occur naturally. The DO sink effect upstream of the tidal weir could potentially be reduced by removal of the weir. However this may have impacts on upstream flood risk and ground stability resulting from a lowering of the water table and drying of soils close to the riverbank.

Under future baseline and future design options, the concentration of DO, BOD and ammonia does not significantly change in the Clyde. The comparison between masterplanning options for conveyance and interception has indicated that by redistributing discharge locations in the Clyde River and estuary, there is no significant benefit or detriment in terms of water quality.

In order to see an improvement in water quality of the Clyde river and estuary the load of BOD and ammonia entering the watercourse would have to be reduced by improved treatment at the WwTWs, greater treatment capacity at the WwTWs, and a reduction in storm water inputs and infiltration. Alternatively pollutant inputs could be moved further downstream, away from areas of poor flushing by passing treated loads downstream of Glasgow towards the Firth of Clyde.

An alternative approach would be to improve the DO of the river by injecting oxygen and hydrogen peroxide at times of low DO. Such measures are in use on the River Thames in the form of oxygen barges which move along the river following the low DO stretches, together with fixed hydrogen peroxide injection points for known problem areas. Cardiff Bay also uses oxygen barges to improve water quality conditions. These measures will improve DO, but do not address the underlying reasons for the low DO conditions.

4.4 Urban Pollution Management (UPM) Initial Planning Study

A UPM Initial Planning Study of the GSDP area has been completed in accordance with the procedures outlined in the UPM Manual (Second Edition). The study area includes the River Clyde and its major tributaries the Kelvin, the White Cart, the Black Cart, the North Calder, the South Calder, the Rotten Calder and some 100 minor watercourses.

The Initial Planning Study Report presented the findings of the UPM data collection and initial analysis to facilitate consultation with SEPA and the other key stakeholders.

The Initial Planning Study has identified that the majority of watercourses within the UPM study areas currently fail to achieve their perceived long-term target river class of A2. In addition, as described above, initial water quality modelling has demonstrated that the River Clyde will also fail both target river and estuarial water standards.

Water quality is a major influence on the scale of the initial masterplanning options compared with the other study drivers to reduce flood risk and remove development constraint.

The initial masterplan has been based on a minimum Formula A standard with a conservative surrogate standard adopted where there is clearly a lack of available dilution in the receiving watercourses. It is believed that the implementation of the masterplan would significantly improve the water quality of the Clyde's tributaries. However, only by adopting an appropriate level of future UPM study can it be confirmed whether the improvements would be sufficient to meet the target river standards

Although the initial masterplanning options may significantly improve the water quality of the Clyde's tributaries, this is considered unlikely to be the case for the River Clyde itself.

Therefore a key consideration for the GSDP is what future target standards are realistically achievable for the River Clyde and the cost benefit of moving towards these standards. A detailed UPM modelling approach during Stage 3 is required to properly address these issues.

4.5 Cardowan Surface Water Management Plan Case Study

One of the key findings/recommendations of the Stage 1 study was to undertake a pilot Surface Water Management Plan (SWMP) case study of a specific area with particular emphasis on looking in more detail at the viability, benefits and relative costs of 'soft' sustainable options, such as SUDS retrofit and watercourse improvements etc. in comparison with the more conventional 'hard' engineering' solutions.

The implementation of 'soft' solutions has the potential to mitigate the scale of the sewerage schemes due to the disconnection and/or attenuation of storm flows currently connected to the foul/combined systems.

The Cardowan Link Sewer sub-catchment was chosen as the case study area so that direct comparisons could be made with the proposed Cardowan Link Sewer which is being progressed as a 'hard' engineering solution by SW and GCC.

The results show that the Cardowan Link Sewer is necessary to eliminate flooding and improve water quality to the agreed performance standards. In this case, the adoption of purely 'soft' engineering solutions would not negate the need for a 'hard' engineering solution. However, SWMP's would 'buy time' while the 'hard' engineering solutions are being implemented.

However, it should be noted that this case study has been undertaken over a relatively small area and it is believed that in other targeted areas there would be greater potential for 'soft' engineering alternatives to be more cost-effective, particular on a strategic level. SWMP's targeted at 'corridor's of opportunity' will be beneficial to achieve the correct and most cost-effective balance between 'hard' and 'soft' engineering solutions, including watercourse solutions. SWMP's should be targeted where there is the greatest potential to mitigate or negate the need for hard engineering solutions and/or achieve habitat/amenity improvements. SWMP's should also be targeted where there is significant new development or re-development.

The case study embraced some very innovative work in terms of defining methodologies to define and understand the cost effectiveness of a 'soft' engineering approach at a catchment level. Cost benefit and ranking indices were derived which offer a useful starting point of where best to target future SWMP's. In simple terms, future SWMP's should be most cost effective where there are large potential development areas upstream of existing flooding water quality problems and where there are areas with high densities of surface water runoff such as industrial areas.

4.6 Overland Flow Routing – Numerical Modelling

HCL was separately commissioned by GCC to undertake a pilot study of the application of two-dimensional hydrodynamic modelling to Urban Flood Routing in Glasgow. The results from this pilot study were presented to the WaPUG Spring Conference in May 2005. Three sites which suffered flooding in the July 2002 storm within the Glasgow catchment were chosen for this study:

- Cardowan Road, and Shettleston Road, part of the Dalmarnock WwTW Catchment.
- Elmvale Row within the Dalmuir WwTW Catchment.

The pilot study assessed the use of 2D hydrodynamic models in determining flood routes in the three catchments and developed a common approach that can be used when assessing flooding in other catchments.

The Pilot Study has identified the ability of the MIKE21 system to model overland flows and provide robust predictions of flood routes and flooding (area and depth).

The overland flood routing models provide a valuable design tool as part of Surface Water Management Plans (SWMP's) and can be used to:

- Assess existing flow paths and risk.
- Test mitigation options and design scenarios.
- Assess the impacts of new development – existing models can be quickly modified and re-run.
- Support a flood warning system.

It is becoming increasingly recognised in the industry that in sewerage and drainage design there is a need to consider and assess safe flood routes for design rainfall exceedance and to mitigate climate change. This is very relevant to the GSDP and the Mike 11 application will be an invaluable tool to undertake such assessment during Stage 3. The definition and creation of safe flood routes will be of benefit to Scottish Water to mitigate existing flooding problems and the upsizing of sewers to cope with increased run-off resulting from climate change.

4.7 Infiltration and Leakage Assessment Desktop Study

This study addressed the specific requirement identified during Stage 1 to assess existing infiltration affecting the sewerage systems and Wastewater Treatments Works in the four Glasgow catchments, and to produce an initial strategy for dealing with such infiltration flows. The study assessment embraced reference to existing hydraulic models and flow measurement data and identifying any correlation with current water pressure reduction and leakage.

Infiltration is very significant across all four GSDP catchments and varies between 60% and 85% of DWF. It is clear that much of this infiltration is due to the general deterioration in the fabric of the sewerage system.

However, 'hot spots' have been identified where there is substantial more localised infiltration. Further investigation of these 'Hot Spots' could be justified where potential reductions could be attainable to reduce flows in sufficient volumes as to mitigate the extent of the overall masterplanning solutions.

In order to further evaluate the extent of infiltration within Glasgow, more detailed survey work will be required on a 'region by region' basis. The Stage 2 'desktop' study began this process with the collection of catchment wide flow survey data and modelled baseflows to help focus the perceived problems and best way forward. More detailed work is to be undertaken during the next stage of the GSDP.

4.8 Watercourse, SUDS Retrofit and Alternative SUDS Solutions

The watercourse solutions review involved extending the investigations carried out on the East End/Dalmarnock catchment to the full GCC area. The GIS database was extended and assessed to provide:

- Identification of watercourses with potential for improvement, especially de-culverting.
- Identification of potential attenuation areas along the watercourses.
- Potential improvements to the Stage 2 optioneering process.

Similarly, the desktop SUDS retrofit work undertaken during Stage 1 was extended to the full GCC area. The aspects considered included:

- Constraints on infiltration from clay soils and contaminated land.
- Feasibility of retrofitting in high density development.
- Public perception of Health and Safety of SUDS facilities.
- Availability and shape of vacant and derelict land.
- Land use and potential for regional or district schemes.

Alternative national and international SUDS approaches were also investigated.

The work confirmed the potential in Glasgow for watercourse solutions and SUDS retrofit to form part of SWMP's targeted at 'corridors of opportunity'. SWMP's should be targeted where there is the greatest potential to mitigate or negate the need for hard engineering solutions and/or achieve habitat/amenity improvements.

4.9 The GSDP Toolbox

Under the masterplanning process, the GSDP has collected many disparate sources of information, models, databases, etc. The masterplanning process has applied this information to give an overall understanding of the sewerage, wastewater treatment works (WwTWs) and watercourse systems of Glasgow.

The GSDP "Toolbox" is thus a range of study results, information, utilities and techniques that have been derived and promoted under Stages 1 and 2. The intention is that the Toolbox continues to be used for the following stages of the GSDP, and for other external investigations and operational issues.

The toolbox contents include:

- Amalgamated sewerage models of Dalmuir, Daldowie and Shieldhall catchments.
- Integrated sewerage and watercourse model of Dalmarnock catchment.
- Future models of all WwTW catchments, including Q&S2 upgrading works.
- Process assessment of existing and future potential for Glasgow WwTWs.
- Water quality model of River Clyde integrated with WwTWs and catchment models.
- UPM Initial Planning Study for River Clyde tributaries.
- Infiltration mapping and "hot spots" for reduction strategy.
- Stormwater Management Plan based on Cardowan case study.
- Overland flood routing techniques based on case study.
- Catchment Hydrology and design and time series rainfall.
- Watercourse assessment for future improvement.
- Sites for potential future SUDS retrofit.
- Population and Land Use Maps and GIS databases of existing and future development.
- Review of drainage policy.

5 The Way Forward

5.1 Stage 2 Conclusions

The main conclusions of the Stage 2 Initial Masterplan are summarised below:

- The Initial Masterplan has identified upgrading works with estimated costs of **£1,422.5 million**, which updates previous cost estimates, and form the basis for ongoing financial discussions. Financing for the GSDP masterplan works will need to be agreed with relevant stakeholders, in particular the Water Industry Commissioner, Scottish Water and the local Councils.
- GSDP needs to be urgently progressed to implementation stage to meet stakeholder aspirations. The Initial Masterplan provides the blueprint for Glasgow's drainage, and therefore needs to be advanced to feasibility and implementation stages, if the current legacy failures are not to be worsened.
- Special funding is required for the following reasons:
    - Scottish Water funding for sewers does not cover the level of strategic stormwater infrastructure investment needed.
    - Glasgow City Council can only procure improvements to watercourses through a Flood Prevention Order.
    - Developers cannot be expected to fund rectification of historical deficiencies.

5.2 Stage 2 Recommendations

Stage 3 – Detailed Masterplan

- Detailed Masterplan of GSDP Catchment
- Extend Study Area to Greater Glasgow ?
- Agree Stakeholder Requirements and Funding
- Finalise Hydraulic and Water Quality Modelling (Agreed UPM Approach)
- Development Scenario Extended to 2025
- Targeted Storm & Surface Water Management Plans (GSDP Wide)
- Preliminary Designs

Stage 4 – Design, Construct and Commission Schemes

- Tender and Contract Arrangements
- Utility Diversion and Co-ordination
- Construction and Commissioning

Scottish Water's current proposed forward 8 year investment plan (Q&SIII) for Glasgow from April 2006 would be far from sufficient to fund their obligations with respect to the implementation of the masterplan. The current Q&SIII represents a 'tactical' approach embracing targeted isolated works within the GSDP catchment based on the funds that are perceived as currently available. Such a 'tactical' approach would not address the fundamental legacy position and deliver the stakeholders objectives of a sustainable urban drainage for Glasgow.

A high level forum is being held with all the key stakeholders to discuss the findings of Stage 2 with a view to presenting a united case to the Scottish Executive with respect to seeking special 'ring fenced' funding to address Glasgow's legacy sewerage and drainage infrastructure legacy. In the mean time, work remains ongoing to define and facilitate the more precise requirements for Stage 3 and determine and agree priorities within the overall masterplan.