Coastal communities - Group B
The Challenge of Storm Water Management

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INTRODUCTION

West of Scotland Water (WoSW) have identified a number of Coastal Communities as requiring new or upgraded waste water collection and treatment facilities in order to comply with the Urban Waste Water Treatment (Scotland) Regulations 1994. WoSW require these works to be completed by December 2004 and will provide treatment to a standard not less than secondary treatment.

Hyder Consulting Ltd (HCL) were awarded the commission to provide preliminary design for sewage collection and disposal at nine communities in Mid Argyll, Kintyre and Islay. The nine sites are shown in Figure 1 and summarised in below.

Community	Estimated Population*	Estimated Average DWF* (l/s)	Estimated %age of Properties Connected
Inveraray	690	6	90
Furnace	210	1	60
Lochgilphead and Ardrishaig	3740	30	95
Tarbert	1350	11	95
Macrihanish and Drumlemble	480	2.3	95
Carradale and Port Righ	560	4.5	75
Tayvallich	250	1	30
Bowmore	610	10	95
Port Ellen	920	9	90

*Population and DWF values are current estimates and are subject to change as designs progresses.

HCL's Commission for the Preliminary Design includes:

Drainage Area Studies – Initial Planning, Model Build, Verification and Optioneering

Marine Surveys and Investigations - bathymetric, geophysical and hydrographic surveys

Marine Dispersion Modelling - outfall initial dilution and dispersion studies

Since HCL's award of Preliminary Design works WoSW have commissioned a Joint Venture consortium of Biwater and George Leslie to identify strategic options for the Coastal Communities that includes design of new treatment facilities. HCL are now working with the Biwater Leslie consortium to provide options which comply with hydraulic and environmental, flood and spill parameters respectively.

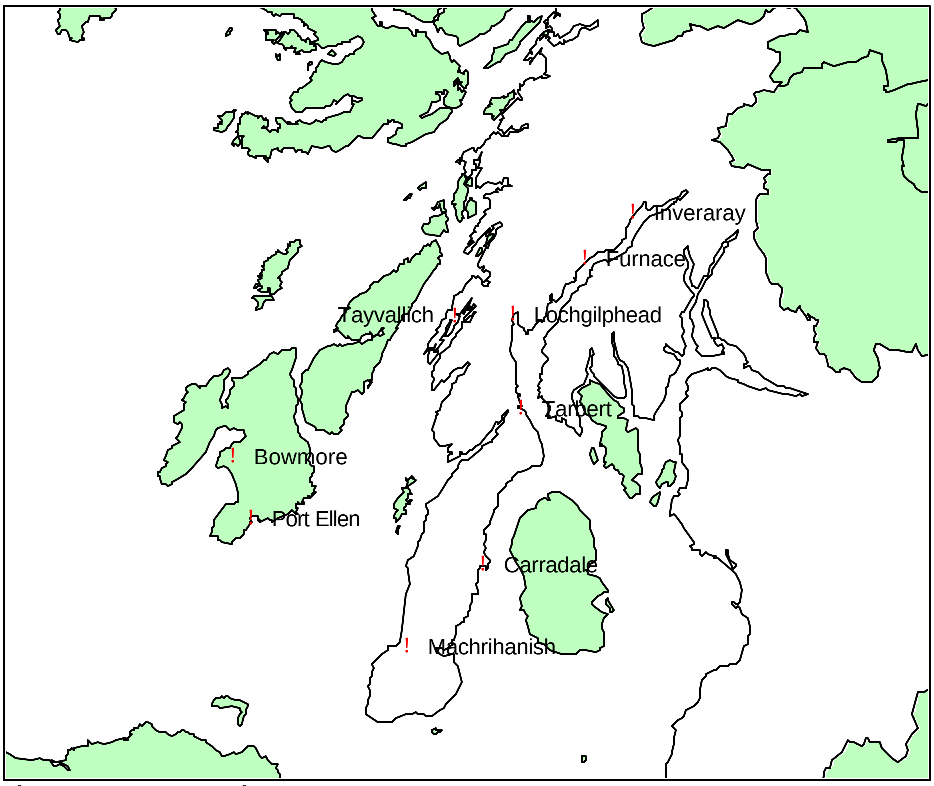

Figure 1 Location Map

RECEIVING WATER STANDARDS

The receiving water designations for the Coastal Communities range from Shellfish Waters to Bathing Waters, Recreational Waters and Shoreline Waters as described in

The EU Bathing Water Directive (76/160/EC) / Bathing Waters (Classification) (Scotland) Regulations 1991,

SEPA Policy Statements No.28 (Initial Dilution and Mixing Zones for Discharges from Coastal and Estuarine Outfalls), and

SEPA Policy Statement No27 (Microbiological Standards in Marine Waters (excluding Shellfish Waters) in Relation to Design Criteria for Discharges).

Shellfish Standards have been determined in discussion with SEPA.

The standards to be applied for the Coastal Communities are as follows:

Designation	Standard (fc/100ml)	No. Storm Spills	Communities
Bathing Waters	M 2000 G 100	3 per Bathing Season	Macrahanish
Shellfish Waters	M 100	10 per annum	Loch Fyne to 100m from MLWS
Recreational Waters	M 2000	10 per annum	Port Ellen, Macrahanish, Carradale, Tarbert, Lochgilphead
Shoreline Waters	M 2000	10 per annum	All

DRAINAGE AREA STUDIES

Scope of Studies

Study Outline

Phase 1 – Initial Planning Study

Phase 2 – Model Build and Verification

Phase 3 – Development of Catchment Strategy

Identify and recommend the most viable wastewater outfall/storage design solution for compliance with the legislation using integrated catchment and coastal modelling approach.

Study Location

The studies are located on the West Coast of Scotland in the regions of Mid Argyll, Kintyre, and Islay.

Of the nine studies to be undertaken four lie along the shores of Loch Fyne and two are based on the Island of Islay. The small community of Tayvallich lies on the shores of the Sound of Jura, the Carradale catchment discharges to the Kilbrannan Sound and Machrihanish sits on the Atlantic coastline.

The catchments have a very varied topography with ground conditions ranging from relatively impermeable soils with boulders/sedimentary clays to areas of bare rock and shallow permeable rocky soils on steep slopes.

All of the study locations are exposed and are therefore subject to extreme weather conditions with Standard Average Annual Rainfall (SAAR) variations of between 1300 and 2100 recorded.

Initial Planning Study

There were several surveys carried out as part of the Phase 1 – Initial Planning Study to obtain network and catchment data and these included the following:

Manhole surveys – STC25 and SUS databases

Flow surveys – where flows were able to be measured accurately

Combined Sewer Overflow (CSO) and Pumping Station (PS) surveys

Impermeable Area surveys – These were conducted in areas where the flows were too low to measure accurately and where greater area runoff detail was required.

Other data sources included the Met office, SEPA, Council departments, WoSW operations, Census data and Ordinance Survey data.

Hydraulic Model Build and Verification

The models built for the DAS's are of Type II construction (WaPUG, 1998) and are suitable for use as drainage area planning tools.

Through agreement with WoSW, and by following the WoSW Drainage Area Planning Specification, it was agreed to construct the coastal community models using the New UK runoff model and to verify the model against the full flow survey data.

The above approach to the verification was considered advantageous as;

1) The New UK runoff model will better represent the changing catchment wetness within the study area with consideration to the high level of rainfall experienced in the region.

2) Rather than just give a 'snapshot' view of how the model responds to particular storm events, a greater understanding of the model performance and flexibility can be obtained.

3) The prolonged rainfall experienced in the flow survey resulted in a lack of dry days and the sewerage system often did not return to normal conditions before the onset of the subsequent event. Assessment of the full period data makes the greatest use of any inter-event dry period data available.

Verification over the full flow survey period is an innovative approach and one that in this particular case is practical to perform, due largely to the small nature of the individual catchments. This approach also provides greater accuracy and confidence in model predictions (Figure 2).

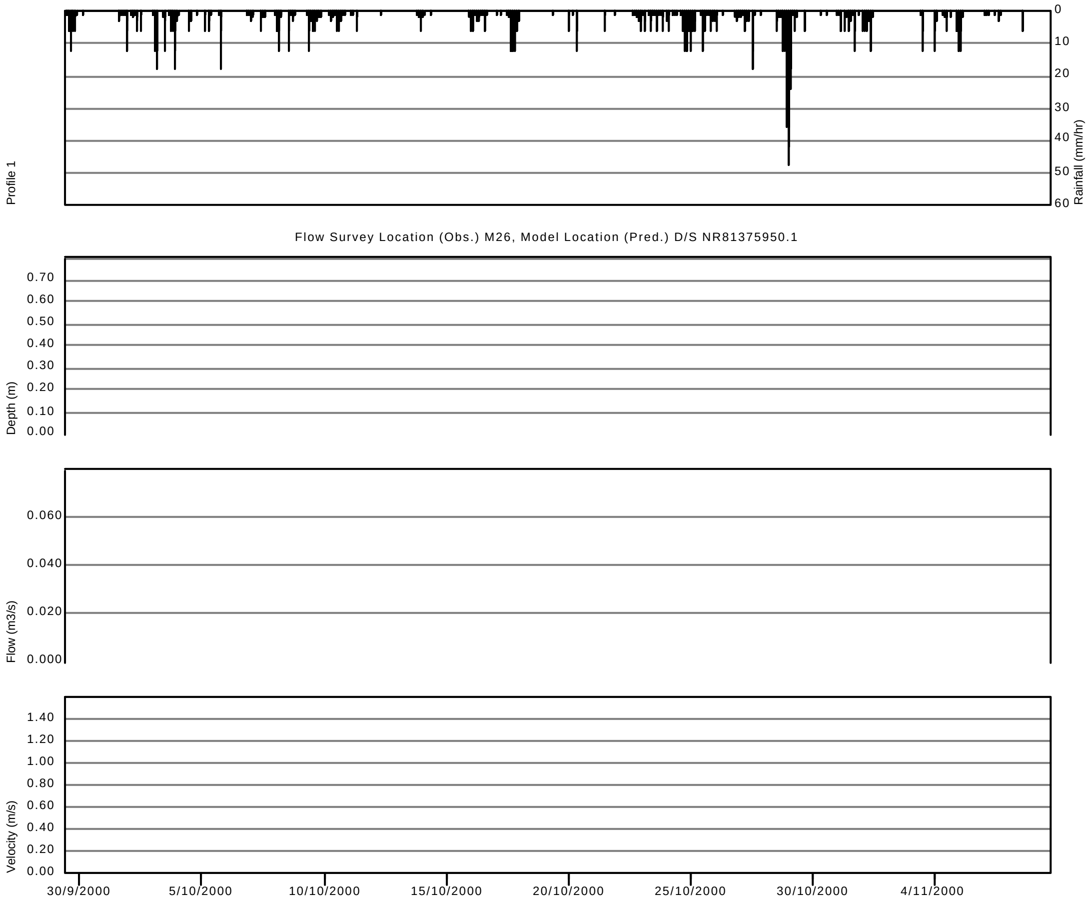

Figure 2 Typical Verification Graph

Development of Catchment Strategy

The Biwater Leslie consortium identified a number of options for the transfer and treatment of foul/storm flows for each of the catchments and Value Management Workshops were held on a regular basis, whereby a variety of options would be investigated during a live demonstration of the hydraulic model. This enabled a preferred option to be further refined and all the risks associated with not meeting the water quality objectives to be identified and quantified.

SIMPOL models of the sewer networks (Figure 3) were built and calibrated against the detailed InfoWorks models in accordance with recommendations given in the UPM2 Manual and were used to assess;

the amount of flow to be transferred to the wastewater treatment plant, the size of any storm tanks required to achieve the number of spills for compliance throughout Loch Fyne and surrounding coastline, and the frequency and volume of spills at each of the interception points.

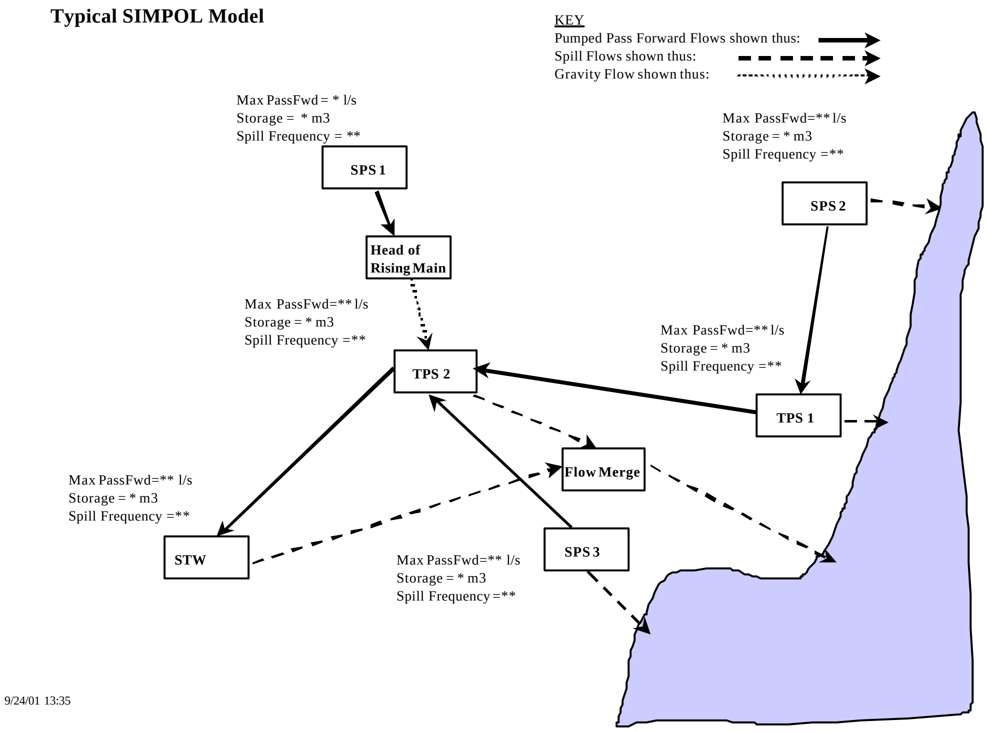

Figure 3 Typical SIMPOL Model

SIMPOL proved to be very effective in quickly arriving at a particular transfer and storage combination which could be investigated further using the detailed hydraulic model together with the marine model. Both SIMPOL and the detailed hydraulic model were used live at the workshops.

The final spill assessment/ storm tank sizing was undertaken through running a 10 year series of rainfall through the hydraulic models for each of the catchments.

MARINE SURVEYS AND INVESTIGATIONS

Marine surveys were carried out on behalf of HCL by EMU Environmental during the late summer of 2000, these comprised:

- Bathymetric and geophysical surveys along the proposed outfall corridor with bathymetry extended over a larger area to support model construction where required.
- Hydrographic surveys including the deployment of tide gauges and bed mounted ADCP current meters and CTD recorders along the proposed outfall route. Dye and drogue releases were also undertaken at the proposed outfall location on spring and neap tides.

MARINE MODELLING

To assess the impacts of treated and storm discharge upon the receiving waters, dispersion models were constructed for each site. The extent of modelling was determined according to SEPA classifications of Basic, Intermediate and Detailed, depending on the local oceanography and the sensitivity of the receiving waters.

Detailed Model Sites - Loch Fyne

Four of the Communities (Inveraray, Furnace, Ardrishaig and Lochgilphead and Tarbert) lie within Loch Fyne, the largest sea loch in Scotland; length 61km, maximum depth 185m. The loch has a steeply shelving bathymetry, in places depths exceed 50m within 100-200m of the shoreline. Tidal velocities are low, typically below 0.1 ms^{-1}, but are strongly influenced by wind giving rise to complex flow patterns and velocities in excess of 0.3 ms^{-1}.

The low tidal velocities and reduced flushing required that Detailed modelling be undertaken. HCL constructed and verified a 2D hydrodynamic and particle tracking model (Delft3D) of Loch Fyne. The curvilinear grid was constructed to provide a resolution of 50 to 100m at each of the communities.

Intermediate Model Sites

The remaining sites are located in relatively open coastal waters where tidal velocities are generally stronger, approximately 0.1 to 0.2 m/s as a tidal average. The bathymetry tends to be steeply shelving, generally to 30m depth within 500m or less of the shoreline.

As Intermediate sites a spreading disc model was used to assess effluent dispersion. In this case USEPA CORMIX models, a simple steady state model for the assessment of near and mid field dispersion, were constructed and verified using data collected during the Marine Surveys and Investigations.

Effluent Disposal Options

Treated Effluent

Treated effluent discharges are generally small and are diluted and dispersed reasonably rapidly in the receiving waters. Significantly long outfalls are not required to reach the required Water Quality Standards. However the steep topography means that outfalls will be constructed in water depths of between 10 and 30m.

Storm Spills

The management and disposal of storm water present greater challenges. There are a number of possible storm water management options ranging from storage to increased flow to treatment to extended CSO outfalls, and in some cases the possibility of separating parts of the system. The range of potential options and the relative advantages and limitations of each are summarised in Table 1.

The most significant issue is the volume of storage required at each pumping station to meet a 10 spills per annum requirement. The practicality of providing high levels of storage must be considered on both cost and feasibility grounds. Large storage volumes are costly to construct and with a low FFT transfer there is a risk that storage cannot be drained down at a sufficiently high rate to avoid septicity or additional spills from subsequent storms.

Increasing FFT transfer may reduce these risks but often requires large or dual rising mains and associated pumps that increase both capital and revenue costs. Larger pipes will also be at risk of siltation problems. Also associated with increased FFT will be a larger and more costly Waste Water Treatment works which may not operate efficiently over the range of flows and loads from DWF to FFT.

Table 1 Storm Flow Disposal Options

Option	Advantages / Limitations
Storage Limit spills to 10 per annum or equivalent	***Advantages*** Smaller works, pumps and mains Short Outfalls ***Limitations*** Limit space for large storage volumes Disproportionate spend for the size of catchment. Inefficient drain down, septicity Risk of increased spills for successive storms.
Greater FFT A greater proportion of flow could be passed to treatment.	***Advantages*** Reduced storage requirements Reduced cost Greater volume of effluent treated ***Limitations*** Dual pumps / mains High capital and revenue cost Risk of excessive siltation in large mains. Disproportionately large treatment facilities required. Weaker effluent - inefficient treatment.
More Frequent Spills Long Outfalls at CSO's Spill at >10 per annum providing sensitive waters meet Standards	***Advantages*** Reduced storage volumes and associated problems Reduced main and pump size Reduced pumping costs Environmental solution ***Limitations*** Long outfalls Bathymetry limits outfall length Receiving water Standards Construction cost v storage cost balance Negotiation with SEPA for number of spills More detailed coastal modelling required Plume merging may be an issue for multiple CSO's May be perceived as providing no significant improvement as large volumes of untreated effluent still entering receiving waters.
Separation and Infiltration Reduction Reduce infiltration levels and fully or partially separate runoff from domestic effluent.	***Advantages*** Reduced storm flows in system Reduced storage volumes and associated problems Reduced main and pump size Reduced pumping costs ***Limitations*** Infiltration small compared to storm runoff Practicality and cost of separated systems

Base Infiltration reduction strategies may reduce storm storage requirements, however this is considered to be of limited value as the base infiltration is low when compared to storm runoff. Surface water separation would provide a solution but can be costly and is in many cases impractical. The removal of rainfall induced infiltration will provide a definite benefit to helping reduce the storm storage required however, this may lead to further flow monitoring costs and as with separation may prove difficult to achieve.

In many instances extending CSO outfalls into deeper water provides a viable solution, by moving from an emission based standard of 10 spills per annum to an environmental standard of 95% compliance, i.e. ensuring 10 or fewer spill events lead to compliance of the designated receiving water. The principal limitation of this approach is the relatively steep bathymetry which significantly limits outfall length and means that in most cases outfalls will discharge close to the designated waters. Furthermore the reduction in storage that can be gained by this approach may be limited as a significant increase in the number of spills could be perceived as providing no significant improvement, i.e. the volume of untreated effluent entering the receiving water remains high.

Figure 4 presents a typical example of storm flow distribution in one of the catchments. To meet a 10 spills per annum Standard approximately 4000 m^3 of storage is required. Increasing the number of storm spills to 15 reduces the storage by 50%, increasing to 30 spills per annum reduces the storage by 75%. In this particular case it was found that extending storm outfalls to 200m offshore would mean fewer than 10 spills per annum failing the Water Quality Standard with no storage provided at the pumping station.

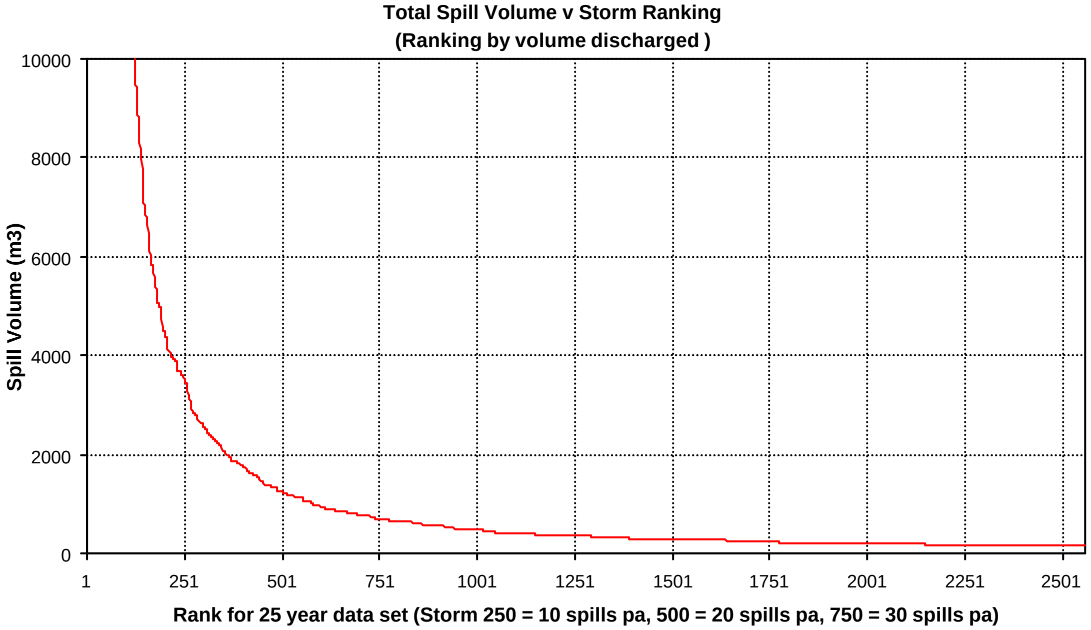

Figure 4 Typical Storm Spill Distribution

To effectively manage storm water in these catchments will require optimisation of FFT, storm storage and outfall length to achieve minimum impact on the receiving water whilst reducing FFT, storage volume and outfall length to practicable levels. Optimisation has been undertaken by the use of catchment and coastal models in an integrated approach. Catchment models are initially applied with no storage and the results input to the coastal models. Coastal models are then applied to a range of outfall lengths and storage scenarios, with storage represented by a modification of the basic no storage hydrograph. Once optimisation is complete the catchment models are re-applied with storage added and the results input to a final coastal model to demonstrate compliance of the preferred option with Water Quality Standards.

CONCLUSIONS

In each of the Coastal Community Catchments the most feasible storm water management option will depend upon a combination of the relative magnitude of dry weather to storm flows, ground conditions, available space, and the nature of the catchment and receiving water. Available options therefore need to be considered on a case by case basis and in negotiation with SEPA.

Established modelling techniques as described in the UPM2 have been used to good effect on this project and this in conjunction with detailed modelling of the marine environment has resulted in cost effective solutions that will ensure that WoSW will achieve legislative targets