Understanding and managing the environmental effects of waste water discharges to the marine environment

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ABSTRACT

South West Water is working to enhance the coastal environment of the Devon and Cornwall region of the United Kingdom through a massive programme of engineering marine improvement schemes for waste water treatment and discharge. The Company's marine improvement programme is the largest of its type in Europe. The programme seeks to address the growing requirements of environment legislation combined with increasing public awareness of environment issues. The objective is to achieve the best practical approach in solving the existing problems of waste water disposal coupled with minimising overall environmental impact. The paper considers the challenge of achieving the necessary understanding of coastal processes and the way in which this understanding is used as an input to the identification of optimum engineering solutions and the implementation of effective waste water management practice.

INTRODUCTION

For many decades the coastal waters of the United Kingdom have traditionally been used for the disposal of domestic and industrial waste water. Until recently, coastal waters were merely used as a dumping ground for discharges of untreated waste water on the premise that the sea would act as a sink for the biodegradation of the discharge. Recent increase in global environmental awareness and concurrent legislative controls have provided the foundation for widespread improvement measures within the newly privatised water industry of England and Wales. This includes a £3.5 billion investment programme to bring most of the UK's 473 identified bathing waters up to the EC Bathing Waters Directive standard by the mid 1990's. Recent government statistics indicate that there are 605 coastal marine discharges of which 253 serve summer populations of more than ten thousand, 151 of these discharge into the particularly sensitive waters of estuaries or tidal rivers. There is considerable variation in the levels of treatment prior to discharge to estuarine and to coastal waters with many outfalls continuing to input untreated waste water.

The problem of waste water management is most apparent within the popular South West Region as there is a natural dependence on the extensive coastal waters of this region for waste water disposal from the coastally based centres of population. Significant increases in population occur during the summer months because of the region's attraction as a tourist destination and this serves to further increase waste water discharges. Both residents and visitors expect recreational waters to be aesthetically clean, as well as free from contamination by invisible pollutants such as potentially harmful micro organisms. This regional perspective which is fully recognised by the regulatory bodies in enforcement of environmental control measures.
Figure 1 identifies the extensive designation of European Community (EC) bathing beaches throughout the region which have received a particular emphasis on environmental protection measures. There are currently 134 designated bathing waters in the South West, 30 percent of the UK total of 455.

Figure 1 - EC Bathing Waters compliance situation and South West Waters related Marine Improvement Programme including completion dates.

South West Water is charged with the responsibility of managing the public waste water disposal for the majority of the regions resident population of 1.5 million and summer population of up to 12 million. A proportion of industrial discharges which enter the sewerage networks around the region, for which the Company has the ultimate responsibility for disposal following discharge from sewer into the environment. As with many UK coastal regions, the South-West has a legacy of poorly maintained sea outfalls with currently some 40% of the region’s waste water is discharged without treatment.

The former public utility and predecessor authorities were constrained for many years in progressing much needed improvement schemes by the limitations of public sector spending. The event of privatisation in 1989 revitalised the opportunity to enhance the local environment. At that time the Company announced a marine improvement programme of £435 million for coastal discharges which impact upon bathing water quality. The programme involved a total of 33 major schemes throughout the region, 29 of which require completion by the end of 1995. This challenging programme will result in water quality improvements at 81 EC identified bathing beaches upon completion.
Following UK Government commitment to the provision of improved waste water treatment standards during 1991 in line with the EC Urban Waste Water Treatment Directive, and the acceleration of Bathing Waters compliance programme a successful application for additional funding to a total of £900 million for marine improvements was secured. This was awarded in recognition of the unique circumstances of the South West Peninsula, and constitutes the major part of a £2 Billion investment programme for the provision of improved waste water services to the region.

One of the largest improvement schemes of South West Waters improvement is the Plymouth catchment area, located within a complex system of four estuaries. The City of Plymouth has a population of 254 000 and is the largest urban settlement in the South West. The Plymouth area is a renowned centre of maritime activity and is an area of high recreational use. It includes four EC identified bathing waters which have failed on occasions to meet the required standards. The large population contributes a significant waste water loading to the local marine environment.

The existing facilities for waste water disposal are currently inadequate. The Company is challenged with the responsibility to ensure improved standards are achieved. The strategic approach needed to achieve this is considered within the paper.

**WASTEWATER MANAGEMENT PRACTISE AND ENVIRONMENTAL LEGISLATION**

During the last few years there has been an unprecedented increase in environmental awareness and concern. The problem being caused by the large number of untreated coastal discharges is reflected in the complex requirements and demanding programme of an ever growing range of national and international legislation. For untreated discharges, the UK philosophy at the time of the marine programmes inception was the provision of fine screening and long outfall dispersion for discharges contributing to or likely to cause EC Bathing Water failure. Other discharges were to await the setting of new consents following review by the UK National Rivers Authority (NRA) of 'deemed' discharge permissions which typically applied a flow condition, only. The decision of the UK Government to apply the emission standards principles of the EC Urban Waste Water Treatment Directive promoted a radical change in philosophy with a need to provide and fund additional treatment for coastal discharges. These developments have increased emphasis on the use of disinfection process technology, particularly ultra violet irradiation, as a means of reducing coliform loadings to achieve bathing waters compliance objectives.

EC and UK Government legislation, Quality Regulation Policy decisions (both national/ regional) and traditional practices combine to influence the design objectives and timescales for any marine discharge improvement scheme. Of central importance are:

**The EC Bathing Waters Directive** which remains the cornerstone objective for the marine programme; it requires that designated bathing waters as delineated by the NRA meet the mandatory limit values for coliform bacteria. In response to increasing public pressure the UK and European legislative bodies are considering the use of more stringent guideline limit values for coliform bacteria together with other standards such as better indicators of health risk and year round sampling. This situation has been anticipated within the European Blue Flag scheme awarded for 'clean beaches' now requiring the achievement of guideline standards, other criteria are also considered. The present position is further complicated by the uncertainties over health related effects of sea bathing and waste water pollution together
with the sensitive issues of what constitutes 'acceptable risk' and affordability.

In May 1991 a new EC Directive for the control of urban waste water disposal was agreed. It requires a minimum level of treatment for industrial and urban waste water discharges according to the population served and the characteristics of the receiving waters. The timetable for implementation of the Directive falls between the next 8-12 years. The designation of receiving water status will be decided by the NRA in conjunction with water users. Under this directive the majority of significant discharges to coastal waters will require a minimum of secondary treatment. Higher levels of treatment will be required for sensitive waters such as enclosed bays or upper reaches of estuaries subject to limited water movement. The directive requires the provision of alternatives to disposal of sludge to sea to be achieved by the end of 1998. This will necessitate careful consideration of sludge disposal strategy given increased sludge production associated with provision of additional treatment.

South West Water has responsibility under UK Law to meet standards for waste water disposal as required by the NRA and other statutory consultees. The NRA consent 11,000 discharges in the South West for both the nature and position of discharge such that no deterioration in existing water conditions is permitted. Consents are issued for both continuous (e.g. treatment works) discharges and intermittent (e.g. storm) discharges. Discharge Consents have regard to the following;

The establishment of Water Quality Objectives, based on a three element system taking account of legitimate water use, classification criteria, and the achievement of relating EC legislation.

Regulation of Dangerous Substances is applied through the imposition of trade effluent controls for discharge to and from sewer for prescribed substances from the EC list.

The NRA are also empowered to protect EC designated shellfisheries under the Shellfish Waters Directive. There are only 3 such waters identified at present within the South West region. The implementation of the EC Shellfish Hygiene Directive which classifies shellfish harvesting areas on the basis of suitability for consumption, are also of importance.

In addition the NRA have developed a series of policies which are applied as part of consenting practise;

Coastal Storm Overflow Policy identifies spill frequency and screening requirements having regard to the sensitivity of the receiving water course and the risk of compromising environmental quality objectives, particularly bathing waters compliance.

Initial Dilution Policy - stipulates the minimum dilution to be afforded to a waste water discharge.

Disinfection Policy - The adoption of emission standards under the Urban Wastewater Directive, together with increasing confidence in process technology and capital expenditure constraints has led to increased reliance on disinfection techniques.
NRA policy requirements identify the need to provide an equivalent level of protection to that afforded by a long outfall schemes including treatment of robust, potentially harmful micro-organisms - a situation which requires careful evaluation of plant performance and operational costs in evaluating improvement scheme options.

There are other significant areas of environmental legislation including the EC diffuse substances directive controls for discharge of nitrates (primarily agricultural), sludge disposal legislation and perhaps most importantly the implications of the Environmental Protection Act. This Act came into effect under UK Government policy in 1990 and it draws together most of the predecessor legislation with respect to nuisance controls (atmosphere, noise, odour etc) together with the control of prescribed processes liable to cause pollution. The philosophy of approach is based on the achievement of integrated pollution control having regard to all environmental considerations in achieving protection measures.

The progression of each improvement schemes must take account of all the factors influencing the decision to ensure a balanced approach in achieving the best practical environmental option (BPEO).

Ultimately the 'BPEO' decision is influenced by a broad range of issues including local considerations. Decisions on scheme options must be based on an integrated approach with careful evaluation of engineering feasibility (outfall location, process selection) sewerage infrastructure requirements, trade inputs, environmental impacts (aquatic and terrestrial) and regulatory compliance. The recent introduction of integrated pollution control measures to regulate all aspects of environmental impact reinforces this concept. Whilst recognising the current emphasis on the "polluter pays" principle with respect to environmental protection concerns all best endeavours must be made to ensure affordability i.e. the "BATNEEC" approach (Best Available Technology Not Entailing Excessive Cost) which is favoured in Europe.

Figure 2 illustrates the range of environmental and engineering considerations which relate to a variety of discharge scenarios. The following aspects are of particular importance:-

1. **Siting of the outfall** to take account of the environmental implications of discharging to riverine, estuary or coastal waters with respect to assimilative capacity, amenity use, and environmental quality objectives which apply.

2. **The appropriate level of treatment (process technology)** to be used as influenced by available land, planning constraints, visual intrusion of new works, design horizons for population served, and the nature of incoming waste water. Sewage sludge production and related atmospheric odour emissions require consideration if integrated pollution control is to be achieved. The balance between dilution and dispersion of the discharge and levels of treatment applied determines the pollutant load. This is of particular importance in controlling the levels of coliform bacteria to ensure bathing waters compliance as shown in Figure 2.

3. **The sewerage network** may require renovation and uprating. Storm flow containment for combined sewers must be considered. There is a need to consider the balance between continuous (treatment works) and intermittent (storm) point source discharges together with diffuse loads (e.g. agricultural run off to streams) in evaluating environmental impact and achievement of compliance objectives.
4. **Understanding the sources, fate and effects of waste water entering the environment** is of fundamental importance if realistic objectives are to be met in minimising environmental impact. A wide variety of pollutant sources exist which must be considered when making value judgements for schemes.

5. **Risk Assessment** - there is a need to consider the risks of non compliance with environmental quality and compliance objectives taking account of worst case environmental conditions, plant performance, and discharge location variables. Great care must be taken to avoid over 'conservatism' and thereby over design with resulting cost penalties.

![Diagram of effluent plume behaviour](image)

**Figure 2** - The "Best Practical Environmental Option" (BPEO) the need for integrated environmental engineering approach.

**UNDERSTANDING THE ENVIRONMENT**

All engineering schemes have some impact on the environment and the treatment and disposal of waste water effluent is no exception. The importance of establishing appropriate and achievable environmental objectives based upon an appropriate level of environmental understanding to protect legitimate water use is fully recognised. No matter what method of treatment is selected, ultimately, waste water must enter the sea. It may do so by direct discharge or via rivers or estuaries (see Figure 2).
The coastal environment is a complex one and the importance of understanding the fate and effects of any discharge within its local situation cannot be overstated. It is only through a thorough understanding of the physics, chemistry and biology of coastal waters receiving such discharges that schemes can be designed which optimise the protection of the coastal environment. The effects of tides combined with effects of variable wind speed and direction, produce a dynamic and ever changing pattern of water movement in coastal waters. In addition the interaction between discrete bodies of coastal, estuarine and riverine waters of differing density and temperature creates discontinuities within the structure of the water column. Understanding water movement and structure is essential to the design of waste water disposal schemes, since it is the pattern of water movement which dictates the way in which a waste water discharge is diluted and dispersed.

Understanding of the coastal water environment is achieved through a combination of measurement and the use of predictive tools such as mathematical models. Measurement of the processes taking place naturally allows the building of models to predict behaviour. These models can then be used alongside the understanding gained through measurement and observation to predict the effects of different options and to examine whether or not these will achieve the required environmental objectives. Figure 3 provides an outline approach to environmental appraisal for an engineering problem. In approaching the problem of appraising the environmental impact of an engineering scheme, it is important to select an approach which is appropriate to the local environment being considered.

![Figure 3 - The Environmental Approach to Appraisal of the Engineered 'Solution' for a Marine Improvement Scheme.](image-url)
All approaches, whether they involve physical measurement or predictive numerical modelling, have limitations which must be recognised and understood. Coastal Models provide valuable design tools and enable evaluation of different discharge scenarios. The important limitations of dimensionality (i.e. the averaging across and through the water column) restricts the representation of near field site specific behaviour, and this together with the quality of theoretically assigned values, defines the utility of models. Equally the limitations of accuracy in spatial and temporal coverage which are achievable using measurement techniques must be recognised. Ultimately observations, measurement and modelling are complementary.

In recognition of the need for environmental information and understanding to ensure an objective and integrated appraisal of engineering solutions South West Water has commissioned extensive work to support the coastal improvement schemes. Typically this work comprises comprehensive multidisciplinary baseline studies. These have been undertaken during the summer period to evaluate the existing environmental situation under conditions of peak waste water loading. The baseline studies examine various environmental features including physical water movements and structure, water and sediment quality in conjunction with measurement of existing pollutant inputs. These are used to assess current status and to establish and verify mathematical models for use in the evaluation of various engineering improvement options. Having identified the best practical option through integrated environmental and engineering appraisal further targeted site specific studies are then undertaken in support of the selected options. These provide a further level of confidence in the efficacy of selected schemes through the use of tracer studies to define discharge behaviour for comparison with predictive model output.

The last decade has seen many advances in the ability to measure and model the coastal environment. Some of these new techniques have found practical application in improving the ability to measure and predict the fate of coastal waste water discharges.

Two recent techniques which have greatly improved our ability to understand coastal water movement and the fate of coastal discharges are the use of radar for large scale detailed measurement of surface currents and the use of novel acoustic techniques for mapping vertical water improvements.

The application of these techniques to the coastal waters adjacent to Plymouth is shown diagrammatically in Figure 4.

Ocean Surface Current radar (OSCR) permits the measurement of surface currents at a grid of up to 700 points regularly distributed over a body of coastal water. This is achieved using two shore based radar installations.

The use of vessel mounted Acoustic Doppler Current Meters allows the OSCR data to be supplemented by a very detailed knowledge of the vertical structure of the water column in areas of particular interest.

By combining these two techniques a detailed three dimensional knowledge of water movements is obtained. This is invaluable in understanding the fate of coastal discharges and, used in conjunction with coastal water quality models, allows accurate determination of optimum sites for environmentally acceptable waste water discharge.
Figure 4 - The use of High Resolution Data Gathering Techniques (ADCP / OSCR II) in achieving environmental understanding of the Plymouth Catchment Area.

South West Water Services and Wimpey Environmental have pioneered the application of these and other techniques for the evaluation of Waste Water discharge schemes. The Plymouth catchment area management plan provides a good example. Extensive measurement and modelling has been undertaken to support local improvement schemes. Figure 5 shows the modelling approach together with an indication of the programme of environmental investigation. The mathematical model provides a high resolution output covering the area of complex circulation and stratification.

The 1990 field survey achieved a synoptic description of waste water pollution loading and of the resulting water quality and associated hydrodynamic conditions. Extensive use of Acoustic Doppler Current Profiling together with Ocean Surface Current Radar Measurements allowed definition of the complex water exchange which occurs between the estuaries and the waters of the Inner and Outer Sound as separated by the Plymouth Breakwater. All of the information obtained through the measurement and modelling studies is used to support the selection and design of waste water schemes which will provide a comprehensive improvement in waste water management practise for the entire catchment area.
CONCLUDING REMARKS

South West Water Services seek to realise the benefits of an integrated approach to waste water management based on selection of the best practical environmental option. This selection depends on achieving a close link between consideration of political and economic constraints, of engineering feasibility and the evaluation of environmental acceptability measured against legislative requirements.

In recognition of the likelihood of the implementation of ever more stringent environmental standards and improvements in available treatment technologies it is important to consider a phased approach to the solution of waste water management problems. This is particularly the case for large population centres such as Plymouth where the scale and complexity of the improvements required is such that full implementation takes a considerable time period. Selection of the best practicable environmental option should take account of the possible need for future enhancements either to achieve compliance with new legislation or to permit the adoption of more cost effective treatment technologies.

South West Water is committed to achieving cost effective and timely implementation of improvements to waste water treatment throughout the South West region. By investing in thorough and systematic evaluation of available options and realising the benefits of strategic flexibility, the Company is ensuring the achievement of legislative and relating environmental benefit now, whilst preserving the potential for yet further improvements in the future.