

Wastewater pumping station design—experiences of West of Scotland Water: project definition and development

Bill Martin

ABSTRACT

Many wastewater pumping stations ranging in size and purpose currently operate in West of Scotland Water (WoSW). In recent years substantial investment in large-capacity coastal pumping stations has been undertaken to transfer domestic sewage to treatment, limit storm spillage and hence comply with the Urban Wastewater Treatment Directive (UWWTD) in terms of frequency of storm sewage discharge. In addition the requirement of the UWWTD to cease dumping of sludge at sea from December 1998 has meant transfer of sludge produced in the Glasgow area to a single sludge treatment centre located to the east of the city. This has meant the design and construction of a network of pumping mains and pumping stations across the city.

The author has been responsible for the project management of several of the above schemes. This paper highlights and discusses some of the key areas of wastewater pumping station project definition and development, utilising experience gained from those projects.

The paper initially discusses some of the factors influencing the development of a wastewater pumping station design. Then, using a case study, it gives examples of how these have been catered for.

Key words | critical factors, environmental impact, project development, pumping station design, pumping station layout

Bill Martin

West of Scotland Water,
John MacDonald House,
296 Vincent Street,
Glasgow G2 5RU,
UK
Tel: +44 (0)141 227 6656
Fax: +44 (0)141 227 6577
E-mail: bill.martin@westscotlandwater.org.uk

PROJECT DEFINITION AND DEVELOPMENT

In any project, whether large or small, clear definition at the outset is crucial to its future success. This is particularly true in pumping station design. As the project develops other factors may be introduced, or the importance of factors already identified may vary.

At an early stage the main influencing factors should be identified and clearly understood. These can be referred to as the *critical factors*. The critical factors will be an integral part of the project development, with the significance of each factor varying according to each particular project and its requirements.

A brief description of typical factors is as follows.

Incoming flow

Assessment of the incoming flow in terms of volume and composition will need to be done.

Domestic sewage

Volume is normally assessed in terms of population equivalent, with effects due to storms being removed using storage or a storm overflow arrangements. For composition, in practical terms most wastewater pumps will deal with solids content of normal domestic sewage; however,

consideration should be given to changes in composition that may influence septicity. This is especially the case in long pumping mains where over certain periods flows may be low and therefore sewage will be retained within the pipeline for a longer period of time. Careful consideration should be given in coastal environments where an increased level of salinity is likely to cause septicity at an earlier stage.

Storm pump rating should be determined after catchment modelling, using historical rainfall data. This is an important part in the development of a project and therefore adequate time and resources must be allowed.

Sludge

In a sludge pumping station the incoming flow can be controlled and the solids content of the material to be pumped can be assessed. The removal of screenings before pumping is beneficial in reducing risk of blockages, especially as periods of low or no flow will be encountered. Hence settlement of solids may occur. Alternatively the installation of macerators just upstream of the pumps will also reduce the risk of blockages. The consistency of sludge to be transferred will be variable and experience has shown that the possible effect of solids content on friction head can be considerable. Increased solids content can also lead to higher surge pressures as illustrated in Figure 1, which relates to the Dalmarnock to Daldowie Sludge Pipeline project recently completed by WoSW.

To produce an appropriate design, if possible adequate time should again be given to assessing the likely solids content. The greater the solids content, the greater the total head generated. This has impact on both capital and running costs. Therefore the solids content used in any modelling exercise should be given careful consideration. A decision on whether to choose an average value, a maximum value or even model a range will be required. The basis on which the value adopted is identified should be looked at in terms of its reliability. In addition possible future variations due to sludge treatment or a change in sludge source, i.e. increased septic tank input, should be taken into account.

In event of a sludge pumping station being used for the transfer of imported septic tank sludge then consideration

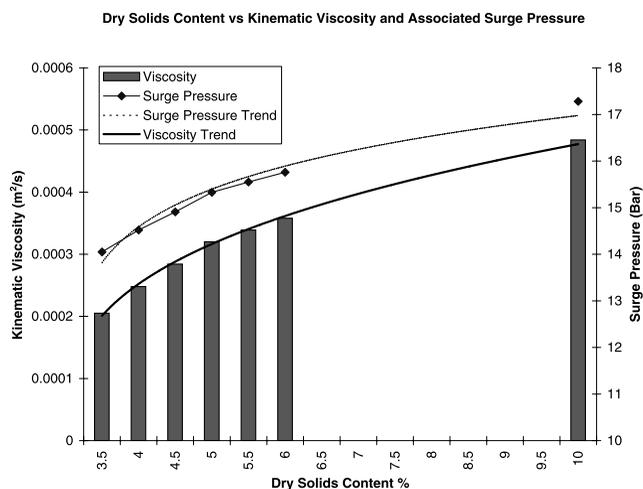


Figure 1 | The pipeline from Dalmarnock Wastewater Treatment Works (WWTW) to Daldowie WWTW is required to transfer sludge for treatment. It is 400 mm in diameter and has a maximum pressure of 25 bar. The sludge to be transferred varies in solids content and therefore it was required that the effect of this be investigated in terms of friction head produced. The chart illustrates the impact of dry solids content.

should be given to mixing with other sludge types before reaching the pumps. This can be done mechanically but preference should be given to mixing using a baffled contact tank.

Static head

Generally the static head is relatively simple to calculate and is based on a known delivery level. However, in a coastal pumping station where storm pumps are being utilised to discharge storm flows to a tidal area, then a view on the possible static head must be taken.

The minimum static head will be experienced in low tide conditions whereas at high tide a much greater head will have to be overcome. The effect of exceptionally high water levels must also be considered: i.e. highest astronomical tide or even highest recorded wave height.

A decision must be made based on the effect of pumps being unable to cope in the event of high tidal/wave events and high rainfall occurring simultaneously, and the consequences of this. Storage, pump rates, risk of occurrence and impact will require consideration. Cost implications may be considerable and should also be examined.

It may be possible to construct two discharge outfalls of varying lengths. Design would be such that operation of the longer outfall would occur at the middle to lower end of tidal range, whereas the shorter outfall would operate at the higher, less frequent values. The minimum distance of the shorter outfall would be determined through modelling and discussion with the regulating authority.

Delivery pipework

The possibility of blockages must be allowed for within the pumping station design, and pumps should be fitted with protection from overload to avoid damage. To minimise the risk of blockages, if possible screening or maceration should be done before pumping, and pipe size should not be less than 150 mm. Minimum flow velocities to prevent settlement should be achieved when pumps are in operation.

To minimise 'down time' as a result of pipe blockage, consideration should be given to the doubling-up of areas of pipework with difficult access. For example, in the event of a blockage under a river considerable time may be required to locate and remove it. In addition, as the crossing is likely to be in the vicinity of a low point then the likelihood of blockage is increased. A standby/bypass pipe in this area may be justified, depending on the storage available at the pumping station.

The early location of bursts is vital and so consideration must be given to minimising the time taken to locate and repair them. It is assumed that in event of pressure drop the pumps will automatically shut down. If the burst is not obvious at ground level then a procedure must be put in place to allow it to be located.

The inclusion of isolation valves at regular locations along the pumping main will allow sections of the pipeline to be inspected for signs of leakage in a controlled manner. It is important in this respect that accurate records are kept and are readily available when required. In addition sufficient fittings and lengths of pipework should be stored at the pumping station to allow repairs to be carried out.

Physical modelling

The need for detailed modelling of the pumping station sump and associated chambers cannot be underestimated.

The effect on flows of standby requirements, screening arrangements and bypass channels, etc. should be physically modelled.

Coastal pumping stations are often used as a means of separating storm flows from foul: the storm flows being spilled to the adjacent coastal receiving waters. Before spillage screening (6 mm or 10 mm) will be required and therefore consideration must be given to the flow characteristics at the screens. For the screens to act efficiently a uniform flow will be required and hence pump delivery in terms of forwarding foul flow to adjacent facilities must be given due consideration. Therefore as well as modelling of the pump well, the effect of flows downstream of the pumps should be assessed. The cost of modelling is usually small compared with overall project cost but can be of considerable benefit both in capital and operational costs.

The effect of the discharge being prevented should be identified. Normally a pumping station will include an emergency overflow, and in terms of the discharge consent this will generally mean operation in the event of power failure to the pumping station. Operation at other times would be unacceptable. A view has therefore to be taken, with the regulating authority, about the level to be adopted.

Environmental impact

In the development of a pumping station project, environmental impact needs to be given due consideration. It is often the case that the successful development of a project to completion is dependent on obtaining approval from affected statutory consultees.

Visual impact, odour and noise are normally of concern to planning officials or nearest residents. However, these concerns can be designed out. Odour control is an area in itself and this paper limits comment to the case study described. Noise should not normally be a problem but should be considered especially if motors are to be above ground. Visual impact can be minimised by good architectural practice and this part of the project can easily be underestimated both in terms of cost and importance to final success of the overall project. As demonstrated in the case study the pump design adopted may

have a considerable effect on the visual impact of the project.

It is apparent that whenever possible the pumping station should be sited away from residential properties or regularly populated areas. However, it is the nature of the facility that its position is often dictated by the location and depth of existing sewers or available land areas. In this regard operational requirements such as working areas, welfare facilities, pump removal/maintenance requirements, ventilation, security, etc. must all be given due consideration. Therefore an important member of the project team will be the operational representative.

General

In the development of any project the knowledge/experience of the project team will, if given adequate opportunity, play a vital role. It is important to utilise the views of the team to ensure all possible scenarios are identified and discussed. For example, possibility of pump breakdown or power failure must be investigated. Dependent on implication, a decision on the need for standby pumps or alternative power supplies will be required.

With regard to the power supply the frequency of previous failures and length of failure should be established. The impact of failure will also be assessed in terms of its acceptability. Alternative supplies may be considered if impact was unacceptable e.g. flooding public areas. A 'firm' supply may be available (i.e. the station being served from two different networks) or a 'looped' supply might be considered sufficient (i.e. two supply lines from same network). Provision of a firm power supply may be expensive and should be considered carefully before installation. In any event, as a minimum requirement a 'hook-up' socket for a portable generator should be provided. Consideration may also be given to the permanent installation of a standby generator. The maintenance issues relating to the permanent installation of a standby generator should be identified and dependent on response time it may be preferable to hire when required.

An uninterrupted power supply (UPS system) may be required to give immediate back-up to telemetry facilities.

This will maintain signals until a generator is operational. If a standby generator is provided UPS will only be required for a few minutes until power is restored. However, if a generator has to be brought to site then a UPS of several hours should be provided. The cost and space required for battery storage increases considerably as more time is required; therefore the reasons for provision should be justifiable. In all circumstances a minimum amount of storage will be required before operation of an emergency overflow.

Pipework layout in terms of access, ability to remove/replace, and flexibility of pump operation is important and should be discussed in detail as the project develops.

CASE STUDY: AYR WASTEWATER PUMPING STATION

Background

The town of Ayr is located on the Ayrshire coast, approximately 40 miles south-west of Glasgow. The town has traditionally been a tourist resort, and its beach is a designated bathing beach under European Legislation. The population of Ayr is around 50,000 with accommodation available for up to 5,000 visitors. In the summer period there can also be many day visitors. As a temporary measure, limited treatment by way of screening and disinfection is currently provided. However, under the Urban Wastewater and Bathing Waters Directives, discharge of raw sewage had to cease by December 2000, and faecal coliform levels in the bathing area and on the beach must not exceed those given in the Bathing Waters Directive.

The proposal for Ayr was to intercept the coastal discharges and gravitate to a site to the north of the town. At this location a pumping station would be constructed to pump foul flows to Meadowhead Sewage Treatment Works, approximately 13 km to the north of the town.

In accordance with the UWWTD storm flows will be spilled to sea following screening to 6 mm. The total estimated cost of the scheme is £45 million, with a programmed completion date of December 2000.

Pumping station development

Incoming flow

As discussed earlier, adequate time should be allowed to collate flow data and assess incoming flow.

For the Ayr sewerage catchment, rainfall data for the previous 10 years was analysed and from this the 40 worst storm events identified for volume, intensity and duration. The new system was then designed to contain the thirtieth worst of these and hence limit spill frequency from the system to three per bathing season. The design flow values were therefore determined as follows:

- maximum foul flow: 565 l/s (three dry weather flows);
- maximum storm flow: 6,000 l/s.

The design philosophy of the scheme required that the foul pumps would operate and when storage within a large tank sewer was used up the storm pumps would start. Storage was calculated to limit storm pump operation to three per bathing season. The storage required was approximately 28,000 m³ and calculations indicated a maximum storage time of 12 h. This would occur in the event of flow exceeding the capacity of the foul pumps but not starting the storm pumps.

To minimise the risk of septicity several cascades were constructed to introduce oxygen where possible.

Layout

The contract was to be issued under the Institution of Civil Engineers Conditions of Contract and therefore detailed design work was carried out pre-tender. However, after receipt of tenders several alternative bids were submitted and it was the alternative bid submitted by Miller Water that was accepted. Therefore the layout of the pumping station changed significantly pre-tender to post-tender, illustrating the change in importance of the *critical factors* referred to earlier. For example greater emphasis was given to cost savings rather than operational factors and this led to a much-simplified final layout.

Pre-tender layout

During this stage of the project development, as stated above, discussion centred on operational requirements and in particular pump removal and maintenance. Foul

flows would be transferred using four No close-coupled centrifugal pumps (two duty/one assist/one standby) situated within a dry well. The pump layout was designed to optimise pump use in terms of starts per hour and minimise standing time within the pumping main. In addition account had to be taken of the possible considerable static head exerted on the pumps (up to 20 m). The motors being positioned within a dry well would allow maintenance without the need to remove the pumps, although provision for this was also made.

As regards the storm pumps several options were again considered but in terms of operational requirements a preference for screw pumps to lift the flow and allow it to gravitate through the outfall was stated.

The use of submersible pumps was considered for both situations but was ruled out by the operations function on the basis that they would be susceptible to blockage, and difficult to remove. As well as the excessive weight of the pumps, the depth of well (20 m) and corresponding length of cable/lifting chain had to be taken into account. Although an overhead crane was to be provided the need to lift and lock the chain and at the same time deal with approximately 20 m of cable proved unattractive.

The size of screw pumps required was 3.0 m dia × 9.5 m, which meant that a large building in terms of area and height was necessary to allow for possible future removal and space for maintenance. The approximate building size was 70 m long × 30 m wide × 15 m high.

The requirement for a larger building had several other impacts including:

- Increased cost.
- Greater visual impact.
- Greater volume of air within the building to be treated via the odour control unit before discharge. Hence a considerably larger odour control facility.
- Increased construction time. This was of particular importance, as completion was required to meet the December 2000 deadline.

This clearly illustrates the effect of critical decisions on other factors affecting the project development. In addition, time was becoming more critical as the December 2000 compliance date drew closer.

The estimated cost pre-tender was £7.2 million.

Final layout

On receipt of tenders compliant bids ranged from £7.2 million to £8.9 million. Of particular interest, however, was an alternative bid submitted by Miller Water, which offered a substantial financial saving and reduction in programmed completion.

As was expected the proposal was to use both submersible pumps for foul and storm flows. The benefits of this included:

- a smaller building (55 m long × 25 m wide × 15 m high);
- reduced odour control requirement;
- reduced timescale: a saving of 8 weeks on construction programme;
- a cost saving of approximately £700,000.

As previously stated the use of submersible pumps was considered unattractive owing to the anticipated problems associated with blockage and removal. However, further consideration had to be given to their use in light of the substantial savings of both cost and programme if they were to be used.

For pump removal, safety as well as operational suitability was assessed. After discussion with operational personnel it was agreed that as long as a safe system of pump removal could be established then submersible

pumps would be acceptable. A system known as the Dock Lock System, utilising a guide wire rather than a slide rail, was identified and adopted. This arrangement allowed the pump lifting bracket to be located without the crane being positioned directly above, and also facilitated the lifting of the pump in one uninterrupted lift.

CONCLUSION

In general two distinct phases exist in a project. Firstly, the initial definition phase during which the critical factors and objectives of the project will be established, and secondly the development stage where as the project progresses the critical factors may vary in importance or nature.

Early in the project influencing factors that cannot alter should be defined, e.g. location, environmental considerations, flow characteristics. Other factors that will impact on the development of the project should be prioritised, e.g. pump type, programme, operational/maintenance issues, cost. As has been illustrated, it is the influence of these factors that may change as the project develops. Therefore at regular intervals the *critical factors* should be re-assessed.