The Design of Small Sewage Pump Stations

This is a relatively simple task for an experienced drainage engineer but one which is fraught with misunderstandings involving the need to iterate to a solution, and the relative responsibilities of civil and mechanical engineers. A simple process consisting of seven stages is given along with some supporting advice of a more general nature. The documentation required is a pump catalogue from a supplier of submersible sewage pumps and a copy of the ‘Colebrook White’ tables. It is assumed that the application is of a size which is suitable for the use of submersible pumps. The seven stages may be easily remembered by the mnemonic:

Local Flygt Man Has Pump With Seals

1) Location

The first step in the process is to determine the location of the station. Normally it will be constructed at the lowest point of the site to be served so that all of the properties served can drain to it by gravity. The site will normally be in the same ownership as the development which it serves. The location, which can be confirmed later, at the stage when the layout is being considered, needs to be marked on a contour map of the site so that its availability to serve the site can be checked.

2) Flow

There are three main types of flow which need to be considered: domestic industrial and storm. In the case of industrial flows it is a matter of getting information from the client to cover the maximum, minimum and average flows. In the case of storm flows this will normally involve the use of a model such as (for small areas) ‘The Rational Method’. Let’s proceed on the basis of a small domestic development. It is presumed that, at this stage, we know what the development will look like. Assuming that the purpose is for domestic property it is a simple matter to count the houses and multiply by the assumed occupancy rate to determine the population which we need to calculate as a normal dry weather flow and a peak. The normal formula for the average flow is:

\[ \text{DWF} = \text{PG} + \text{I} + \text{E} \]

Were ‘P’ is the population; ‘G’ is the usage per day; ‘I’ is infiltration and ‘E’ is for trade flows. The usual figure for ‘G’ in the UK is 135 l/c/d and unless ‘I’ is significant we can ignore it (see flow multiple later). ‘E’ in this instance is zero. It is normal to take the average calculated and multiply the figure by a factor of six to allow for infiltration, wrongly connected storm flows and the need to allow for a peak which could be as much as three times the average. Whilst crude, this generally provides a satisfactory result and includes an allowance for
growth; however, it is necessary to warn against further increasing the design flow as this can lead to a badly over-designed station.

Let’s assume we have 100 houses and an average occupancy of three giving a served population of 300 then the average flow will be $100 \times 3 \times 0.135 = 40.5 \text{ m}^3 \text{ per day}$ or $0.469 \text{ l/s}$ which multiplied by six gives a design flow of let’ say ‘$F$’ = $2.8 \text{ l/s}$.

3) Main

We now have to design the size of the main. The normal requirement for the main is that the velocity in the main should not be so great as to involve excessive power consumption and not so low as to result in septicity in the main. The normal target is not to exceed $0.8 \text{ m/s}$. We can calculate the required diameter or use the ‘Colebrook White’ tables:

$$F = Av \text{ and } A = \frac{pd^2}{4}$$

Where $A$ is the cross sectional area of the pipe and ‘$v$’ the velocity in the main, ‘$p$’ is pi and ‘$d$’ the pipe diameter thus, for our design flow of $2.8 \text{ l/s}$ and a velocity of $0.6 \text{ m/s}$ the required diameter would be 77 mm say 75 mm (a 3” dia pipe).

4) Head

We can now calculate the head as we know the diameter of the main and (presumably) the route so the length can be measured from the site plan. The head requirement consists of the ‘static head’ plus the friction losses which come in two parts: the station losses and head loss in the pressure main.

The static head is measured from the height where the pump body will be positioned (about 3 m below ground level at the site of the station) to the point of delivery from the main. Let’s say this is 9.5 m.

Losses in the pipes and valves at the station are very difficult to calculate and not usually that great compared to the other losses so we will assume a loss of 1.0 m.

To calculate the friction losses in the main you can use equations such a Darcy Weisbach but it is much easier to use the ‘Colebrook White’ tables with a ‘$ks$’ value (0.015) appropriate for sewage. On page 16 of my copy I find in Table 2 that a 75mm pipe with 2.897 l/s discharge and 0.656 m/s velocity gives a gradient of 1/154. If the length of the main is 300 m then the friction loss in the main will be $300/154 = 1.95\text{ m}$.

Thus the total losses will be $9.5 + 1.0 + 1.95 = 12.45 \text{ m}$.

5) Pump

As we now have the flow and the head we can now assess which pump is most suitable for the required duty. Sewage is not a homogenous liquid like potable water so we need to
have an impellor which will not clog. If the impellor will pass a cricket ball, it is unlikely to clog except in the most extreme conditions. Thus we can choose a pump with a ‘thoughlet’ of around the range 70-100 mm. This is now a matter of looking at the manufacturers’ catalogues to get the best fit. In my old Flygt catalogue, I find that I could get a 100 mm, CP3102, with a 435 impellor with a 76 mm throughlet and 3.1 kW motor. Other submersible manufacturers have similar pumps and the actual choice is often made at the tendering stage.

6) Well

I have assumed that the station will be a normal single wet well design though the principles are the same for a dual well station. One of the biggest mistakes in station design is to neglect the required fall into the wet well. In some countries the well is almost non-existent and the station performance is, as a result very poor. If a dimension of 1.0 m is used for the incoming pipe invert to the top of the pump volute then the station will generally perform without surcharge and the incoming pipe will flow freely.

The diameter of the sump is calculated using a figure of six starts per hour for the pump based on the average flow thus ‘T’, the maximum cycle time to pump the well down will be 10 minute. It can be shown that the pump will start most frequently when the incoming flow rate is exactly half the pump rate (2.8 l/s).

\[ V = \frac{60TQ}{4} \]

Where V is the pumped volume; T is the cycle time and Q half the inflow. Thus the required volume is only 0.42 m³ which is much smaller than that required to house the pumps.

7) Site

The detailed station layout is drawn up by virtually copying those contained in the pump manufacturers’ catalogues but adapted to the site. The minimum requirement is for two pumps, so that one can act as standby in the case of breakdown and still cope with the design requirements.

In addition to the station details, the valve chamber must be included and a detailed layout of the station compound must be shown including vehicle access, installed lifting gear, covers and security fencing.

Further Considerations

Most submersible stations have two identical pumps and this follows from the requirement that there must be a standby pump which is able to handle the design flow. It is, however, relatively easy to show that a station with three smaller pumps is a better design than two bigger ones.
Over-design is common feature in many stations due to the conservative nature of design engineers who over-egg each of the figures – “just to be on the safe side”. This is a mistake as it leads to the installed equipment being too large and never operating efficiently. As the average life of electrical equipment is only about fifteen years, it may be better to under-design and replace it when it becomes too small. Obviously the civils structures need to be properly sized from the outset.

Saving on the depth of the wet well is a frequent mistake especially where the station is built in bad ground especially water logged conditions. This is done to save on the construction cost but leads to problems when the station is in operation.

Septicity may be a problem when the pressure main is over-sized, usually due to over provision for future flows. The retention time (the volume of the main divided by the average flow) should be calculated based on initial flows so that it can be ascertained whether the main may suffer from septic conditions. Odour control measures may be necessary in hotter climates.

Some pump manufacturers have their own patent additions such as ‘autoclens’ which should be considered as they may reduce maintenance requirements and septicity problems.

Most modern pump stations have a breakdown system installed which will give warning of pump malfunction, high level in well and intruder alarm.

The requirements for ‘adoption’ of a sewage pumping station will be available from the adopting body.