# A630 Deephams Sewage Works Upgrade

# Treatment Options Assessment

# Stage 2b Report

## Public consultation version

Deephams
Sewage Works Upgrade
Creating a cleaner, healthier River Lee

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# 1 Executive summary

1.1.1 Deephams Sewage Works, located in Enfield in north east London, is the ninth largest sewage works in England. It treats sewage collected from within its catchment and discharges treated effluent that flows into the Salmon's Brook, a tributary of the River Lee, in accordance with a discharge consent set by the Environment Agency.

1.1.2 The Environment Agency has issued a new discharge consent that requires us to make improvements to the quality of the discharge. The Deephams Sewage Works Upgrade (the upgrade) will improve the quality of effluent (treated wastewater) discharged from the Deephams Sewage Works into the Salmon's Brook. It will accommodate growth within the catchment to at least 2031, and improve infrastructure at the sewage works, much of which is now over 50 years old.

1.1.3 The upgrade has to be delivered whilst the existing sewage works remains operational to treat the sewage to the existing consent levels. This places significant engineering constraints on our ability to implement the upgrade within the boundaries of the existing sewage works site.

1.1.4 This report documents how we have undertaken an engineering assessment of potentially viable treatment options to ensure that there is a viable treatment solution for the site that is to be selected for the upgrade. This includes an assessment of options for treatment at different stages of the sewage treatment process.

1.1.5 The assessment considers potential treatment process plant and not a full replacement of the whole Deephams site infrastructure as concluded in the "strategic options review stage 1 report". The Deephams Sewage Works inlet pumping stations, preliminary treatment works, sludge treatment and storm tanks will remain on the current site irrespective of the option selected for the upgrade.

1.1.6 This report considers treatment options at all stages of the sewage treatment process – primary, secondary and tertiary treatment. The secondary treatment stage was identified as the area where the greatest number and variation in available treatment process technologies are found. Nine secondary treatment option solutions were subjected to a preliminary assessment, with four subject to more detailed assessment:

- Conventional Activated Sludge (CAS)
- Biological Aerated Flooded Filters (BAFF)
- Integrated Fixed-film Activated Sludge (IFAS)
- Membrane Bio Reactor (MBR)

1.1.7 The conclusions of the assessment are taken forward to inform the work to identify the preferred site for the upgrade, reported in the separate "Identification of the preferred site stage 3 report". No decisions have been taken on treatment options at this stage. The selection of the treatment technology for the upgrade will be informed by feedback from the phase 1 public consultation and from our ongoing scheme design development work.

# 2 Introduction

## 2.1 Section objectives

2.1.1 This introduction explains the background to the Deephams Sewage Works and the need for the upgrade, provides an overview of the assessment methodology process, and explains the purpose and structure of this report.

## 2.2 Background to Deephams Sewage Works

2.2.1 Deephams Sewage Works is one of our six main sewage works that serve London. It is located off Picketts Lock Lane in Edmonton, as shown in Figure 1 below. It is the ninth largest sewage works in England and serves a population equivalent of 885,000 people (as of 2010). The catchment that Deephams Sewage Works serves extends over large parts of north east London, and northwards beyond the M25.

**Figure 1: Plan showing location of Deephams Sewage Works**

2.2.2 Sewage treatment has been undertaken in this part of Edmonton since the 1870s when the first Edmonton sewage farm was developed on adjoining land. The sewage treatment works was largely constructed on the current site in the 1950s and 1960s.

2.2.3 Despite the various improvements over the last 30 to 40 years, and those under construction, the current sewage works is predominately the works that was first constructed in the 1950s and 1960s. The ageing plant is under increasing pressure to meet and maintain treatment standards.

## 2.3 Summary of the need for the upgrade

2.3.1 The need for the upgrade is set out in the National Policy Statement for Waste Water, and can be summarised as the requirement to respond to:

- an increase in the discharge consent requirements
- an increase in flow to the works:
  - a requirement to provide sufficient treatment capacity to meet population growth within the catchment already served by the works.
  - a requirement to respond and adapt to the challenges of climate change.
- ageing infrastructure under pressure to meet and maintain treatment standards

2.3.2 The upgrade will also deliver wider social or environmental benefits, for example reduced odour emissions and, depending on the option selected for implementation, increased renewable energy generation.

## 2.4 Summary of the Assessment Methodology

2.4.1 We have developed an assessment methodology for selecting the most appropriate option for delivering the upgrade, including the assessment of site and treatment technology options.

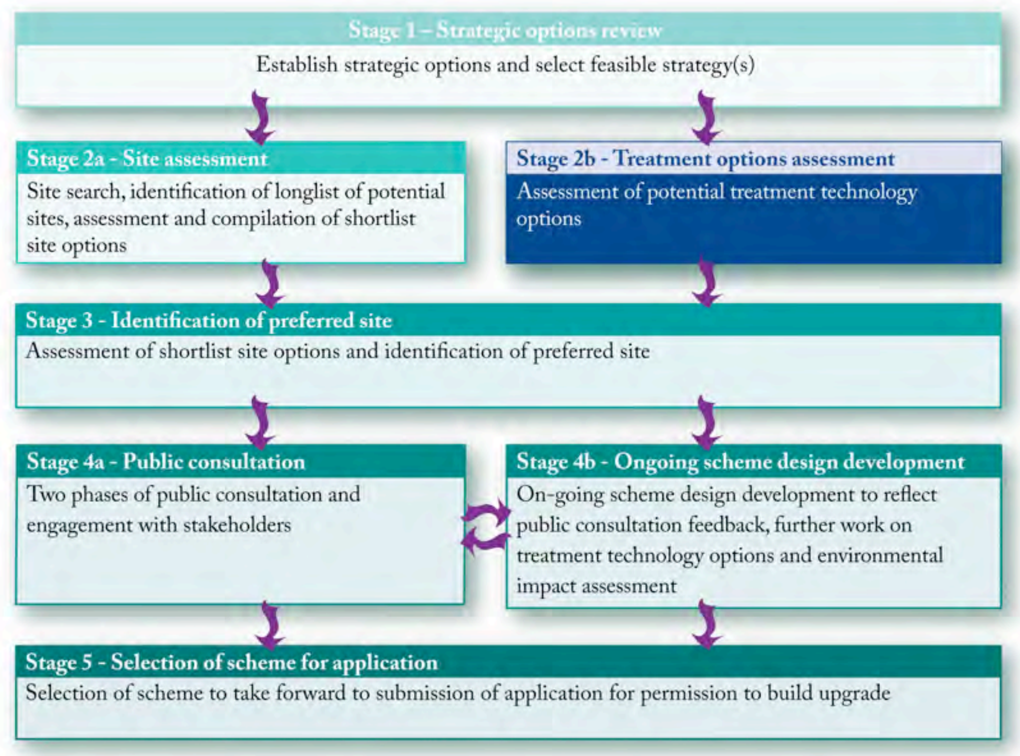
2.4.2 The methodology allows for the assessment of a range of strategies for meeting the need for the upgrade. It allows for the consideration of potential locations for new sewage treatment infrastructure. The construction of the upgrade could be on the existing site, although the site would have to remain operational throughout the upgrade, or it could be on a new site nearby. A suitable treatment technology option has to be selected, to meet the treatment requirements of the new discharge consent within funding, programme, treatment technology and physical site constraints.

2.4.3 The proposed methodology is a multi-stage process, with stages undertaken both in parallel and sequentially. Figure 2 below illustrates this process diagrammatically.

2.4.4 The assessment process firstly allows an initial review of strategic options for meeting the need for the upgrade to be undertaken. From this, an assessment of treatment options is undertaken, alongside an assessment of potential development sites. A more detailed assessment of a shortlist of sites is then undertaken to enable a preferred site to be identified. The preferred site is then published for a first phase of public consultation and stakeholder engagement.

2.4.5 Alongside, and following on from, the first phase of consultation we will undertake scheme design development work and further work on treatment options. This will confirm the feasibility of our preferred site and treatment technology options for delivering the upgrade. A second phase of public consultation will then be held on our proposals and designs for the upgrade and information on the potential environmental impacts of the upgrade and our plans for mitigating them. An application for permission to build the upgrade will then be submitted.

**Figure 2: The assessment methodology**




2.4.6 An essential part of the methodology is an ongoing process of review and checking the validity of previous assessments through feedback loops at all stages of the process. This enables the assessment of sites and options to remain valid as information changes and new information is obtained. Thus, where necessary, stages in the process may be repeated (or 'back-checked') in order to take account of new information or other changes of circumstance.

## 2.5 Structure of this report

2.5.1 This report summarises the outcomes of the treatment options assessment. Section 3 of the report provides background context for the assessment. Section 4 describes the preliminary assessment of treatment options, with section 5 explaining the further assessment of secondary treatment options that was undertaken. Finally, section 6 outlines the next steps in the assessment of treatment options.

# 3 Background context

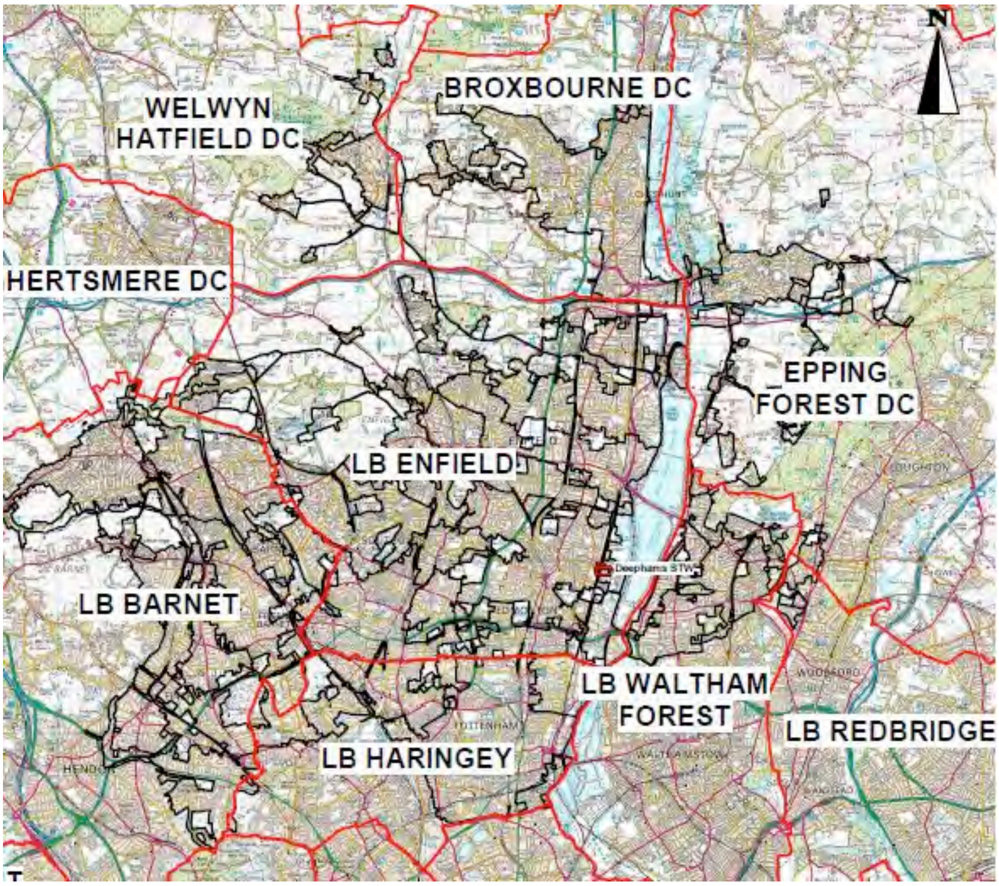
## 3.1 Section objectives

3.1.1 This section provides a brief explanation of sewage treatment processes at Deephams and how a typical sewage treatment works operate, as background context for the subsequent sections of the report.

## 3.2 The Deephams Sewage Works catchment

3.2.1 The catchment which Deephams Sewage Works serves extends over large parts of north east London and northwards beyond the M25, as indicated in Figure 3 below.

**Figure 3: Plan of Deephams catchment**




3.2.2 We have an obligation to take away used water from domestic and commercial premises within the catchment. This includes discharges from toilets, wash hand basins, baths, washing and dish washing machines. These discharges are termed ‘sewage’ or ‘wastewater’ and are conveyed from their source to a site for treatment in pipes called ‘sewers’. We also take away some discharges from industrial premises, though these flows may require specialist pre-treatment at source prior to discharge to a sewer.

3.2.3 In some areas, rainwater falling on roofs, roads and pavements is collected in surface water sewers which discharge directly to local watercourses. However, in some areas, including in parts of the Deephams Sewage Works catchment, surface water and sewage are mixed together in the sewers before flowing to the treatment works. These date from before 1936 and are called combined sewers. Many of them were originally watercourses that were turned into pipes or culverts and incorporated into the sewerage system.

3.2.4 When a toilet is flushed or a sink emptied, the wastewater goes down the drain and into a pipe which takes it to a larger sewer under the road. This sewer then joins our network of other sewers that take the wastewater to the sewage treatment works. Usually this involves pumping.

3.2.5 At the treatment works the sewage is treated in a variety of cleaning processes to remove the solids and treat the sewage so that the effluent can be put safely back into the river system.

3.2.6 Raw sewage arising in the Deephams sewerage catchment arrives at the sewage works via three main gravity trunk sewers. The Lee Valley Sewer (serving Waltham Abbey, Cheshunt, Cuffley and north east Enfield), the Barnet High Level Sewer (serving east Barnet and south and west Enfield) and the Tottenham Low Level Sewer (serving Tottenham, Wood Green and south east Enfield). There is a further Chingford Branch Sewer serving the western side of the London Borough of Waltham Forest that connects into the Tottenham Low Level Sewer south of Deephams.

## 3.3 Overview of the Deephams Sewage Works treatment processes

3.3.1 The Deephams Sewage Works is a conventional sewage treatment works. Sewage enters the works through an inlet works, where rags and grit are removed from the incoming sewage, followed by Primary Settlement Tanks (PSTs), where solids are settled out and sent to the sludge treatment plant.

3.3.2 The remaining sewage is then treated using a Conventional Activated Sludge process. This is a suspended-growth system where the biomass (activated sludge) is mixed with the sewage and then dissolved oxygen is used to promote the growth of bacteria that substantially removes organic pollution. This process takes place in aeration tanks, followed by Final Settlement Tanks (FSTs). The treated effluent from the FSTs is then discharged to the final effluent channel and the Salmon's Brook. Figure 4 below identifies the main processes on the Deephams Sewage Works site.

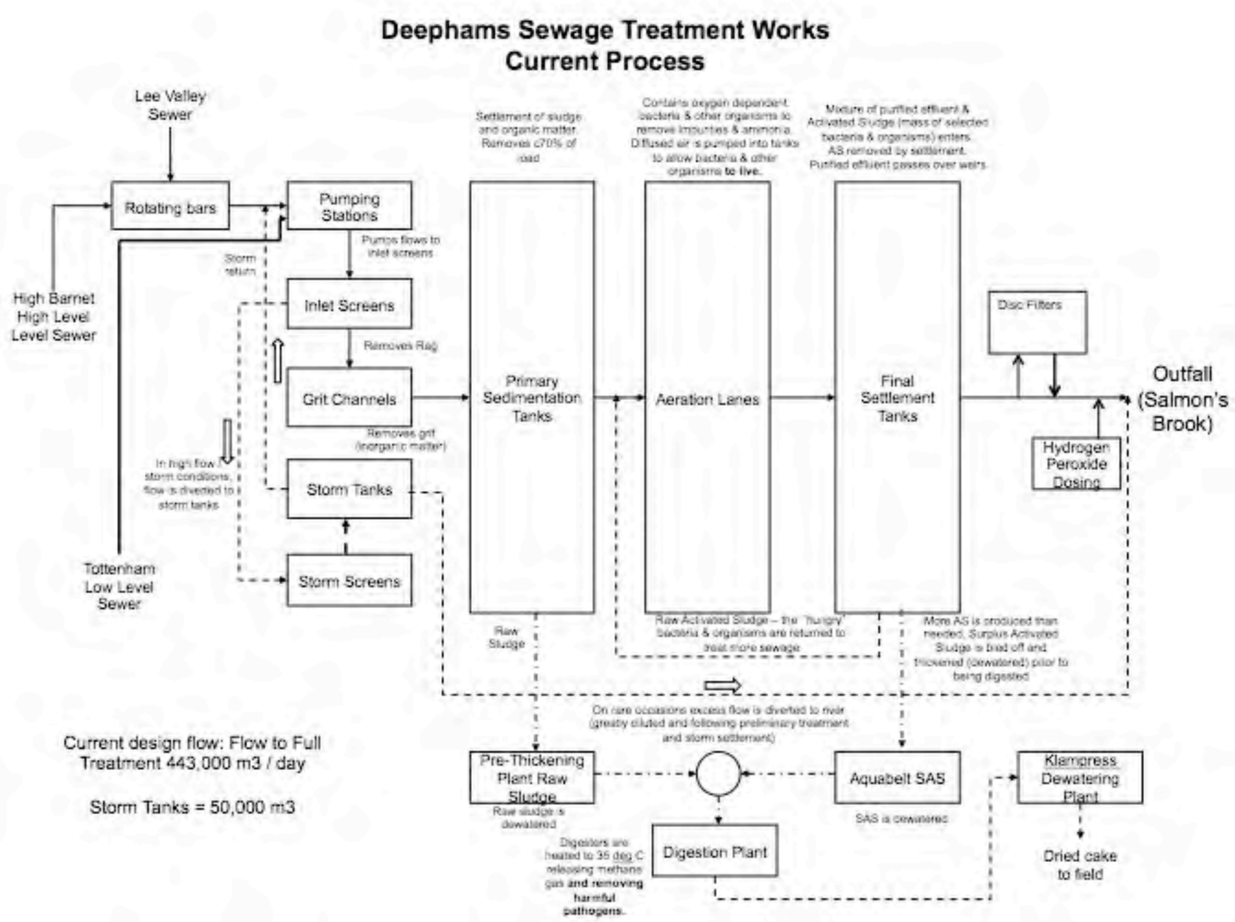
**Figure 4: Existing Deephams Sewage Works (at March 2010)**

3.3.3 At Deephams, primary and secondary treatment takes place in three separate and independent process streams. Streams A and B each consists of six PSTs, four aeration lanes and sixteen FSTs. Stream C consists of four PSTs, four aeration lanes and sixteen FSTs. Stream 'A' was installed in the early/mid 1950s and extended in the 1960's, Stream 'B' was installed in 1956 and extended in 1966, Stream 'C' was installed from 1966. A disc filter tertiary treatment plant is currently under construction to improve effluent quality, and will be completed in 2012.

3.3.4 Solids from the primary and final settlement tanks are pumped to the sludge treatment plant, where they are treated by anaerobic digestion (broken down by bacteria which live without oxygen) in digestor tanks. After further treatment and removal of water from the sludge, the treated sludge solids are recycled as fertiliser on agricultural land and the methane produced during the digestion process is reused as a renewable energy source on site, as fuel in Combined Heat and Power (CHP) engines.

3.3.5 The following text and Figure 5 (below) explain the treatment processes at the Deephams Sewage Works.

**Figure 5: Deephams Sewage Works processes**



**Inlet works and screening**

3.3.6 The three main sewers arriving at the site are located deep underground so the flows need to be pumped up to the inlet works. The inlet works provide screens to remove coarse and finer debris including paper, plastics, cloth and larger items from the incoming raw sewage. These large objects are removed as they might otherwise block or damage equipment or be unsightly if allowed back into the watercourse. Materials removed by screening are washed to remove faecal matter and discharged into skips for disposal to a landfill site.

3.3.7 Sewage flows into the works normally contain a lot of grit, especially in areas with combined sewers that receive rainwater flows from roads. Grit is removed in a specialist physical treatment process and then washed to remove faecal matter and the grit is then either recycled for use as building material or sent to a landfill site. The screened and degritted sewage is then passed into the works for treatment.

**Storm storage**

3.3.8 The amount of sewage arriving at a treatment plant increases significantly during periods of wet weather as it includes rainwater. During storms or at times of high flow when the capacity of the treatment works is exceeded the excess storm sewage flows are separated upstream of the inlet works screens and a proportion passes through dedicated storm screens prior to flowing into storm tanks. Once the flows in the incoming sewer have reduced to normal levels, the content of the storm tanks is returned to the inlet works, and is then treated.

3.3.9 Should the storm continue such that the storm tanks become full, they are then permitted to discharge an overflow of partially treated (screened, degritted and settled) sewage via a culvert to the Salmon's Brook. Whilst these flows are not fully treated, they are significantly diluted by the high volumes of rainwater that enter the sewage works during storm events. Hydrogen peroxide dosing is also used to ensure that the overflow is well-oxygenated and so does not have a significant effect on Salmon's Brook. The discharge of these storm flows to the Salmon's Brook is regulated by the Environment Agency under the terms of the discharge consent for the sewage works.

**Primary treatment**

3.3.10 At the primary treatment stage the sewage receives physical treatment to remove organic solid matter or human waste. This is achieved by passing the flow into large tanks where the solid material is allowed to settle to the floor of the tanks. This settled material is called 'sludge'. Chemicals may be added to encourage the sludge to settle quickly. The sludge is collected from the floor of the tanks by mechanical scrapers which travel along the base of the tank to push the sludge into hoppers set into the floor where it is stored prior to transfer to the sludge treatment plant.

3.3.11 Fats and greases, which float in the sewage, collect on the surface of these tanks. This material, which is termed 'scum' is removed by skimming it from the surface of the tank. After an appropriate period of storage, to allow the majority of the organic solids to settle to the tank floor, treated sewage is discharged over a weir at the outlet end of the tank and is taken to the next stage of the treatment process.

### Secondary treatment

3.3.12 The primary treatment stage removes most of the larger solid organic material from the flow, however there will still be an amount of fine suspended and some dissolved solid material. This material is broken down and removed by biological action in the secondary treatment stage.

3.3.13 Bacteria which break down the organic material in the incoming flow are grown in tanks which are called 'aeration lanes'. These tanks have air pumped through them to encourage the bacteria to grow and consume the organic material. The aeration lanes are sized such that the bacteria have sufficient time to consume the organic material before flows are passed to the next treatment stage.

3.3.14 Following treatment in the aeration tanks the biomass mixed with the partially treated sewage is discharged into the Final Settlement Tanks (FSTs) There the activated sludge is settled out for recycling to the head of the aeration tanks leaving the liquid fraction of the flow to be discharged over weirs around the tank perimeter. This treated effluent is then discharged to the final effluent channel and into the Salmon's Brook. Periodically, part of the biomass from the FSTs is drawn off as surplus activated sludge which is dewatered and treated with the rest of the sewage sludge.

### Tertiary treatment

3.3.15 Where a high quality of treatment is required before effluent can be discharged to a watercourse or river, it is necessary to provide additional treatment to the flow, known as tertiary treatment. This involves filtration of the flow to remove fine particles using either sand filters or a membrane with a fine woven mesh. Effluent passing through the sand filter or membrane is discharged to the river. Periodically the sand filter or membrane is taken out of service and washed to remove accumulations of sediment which has been collected. A tertiary treatment plant to treat 50% of the flow through the Deephams Sewage Works is currently under construction.

### Sludge treatment

3.3.16 Sludge and scum removed from the primary treatment stage is processed to remove water and stored on site in tanks to allow bacteria and pathogen levels to reduce naturally to acceptable levels. This process is accelerated by the digestion of sludge in heated tanks, which uses bacteria to break down the cell structure of the sludge. This helps to remove water from the sludge, increasing the rate at which bacteria and pathogens are destroyed and producing sludge gas, which can be collected for use as a fuel.  The 'biogas' recovered and used on site at Deephams in a Combined Heat and Power (CHP) plant generates approximately 2.5MW of renewable energy.

3.3.17 Sludge from secondary treatment processes is collected in the final settlement tanks and recycled back into the aeration lanes to maintain a healthy level of bacteria. Periodically it is necessary to remove a proportion of these bacteria to prevent bacteria concentrations rising too much. These surplus bacteria are thickened in a similar manner to that used for sludge arising from primary treatment stages further treatment (digestion).

3.3.18 Following treatment, the resulting sludge is transported to farmland where it is recycled as a nutrient-rich fertiliser - known as biosolids.

# 4 Preliminary engineering assessment of options

## 4.1 Section objectives

4.1.1 This section outlines the preliminary engineering assessment of treatment options.

## 4.2 Potential treatment options

4.2.1 We have assumed that, consistent with the conclusions of the strategic options review, the inlet works, screening and sludge treatment facilities will remain on the existing Deephams Sewage Works site.

4.2.2 We undertook a preliminary engineering assessment of potentially viable treatment options to identify those considered to have potential for the upgrade. The purpose of the assessment was to consider sewage treatment options against consistent factors that will affect their suitability for the upgrade. Table 1 shows the technologies potentially available to meet the new discharge consent standards for the upgrade.

**Table 1: Potential treatment technology options available**

| Primary Treatment Options | Secondary Treatment Options | Secondary Settlement Options | Tertiary Treatment Options | Phosphorus Removal Options |
|---|---|---|---|---|
| Do Nothing | Conv AS (Conventional Activated Sludge) | Do nothing (unless in combination with MBR or Reed Bed or Bio-tower) | Do nothing (unless in combination with MBR or Reed Bed) | Biological Removal |
| Conventional Primary Sedimentation | IFAS (Integrated Fixed-film Activated Sludge) | Conventional Final Settlement Tanks | Disc Filters | Chemical Dose (AS Lane) |
| FOG Removal & Lamella Primary Sedimentation | BAFF (Biological Aerated Flooded Filter) | | Rapid Gravity Sand filters (RGF) | Chemical Dose (Primary) |
| | SBR (Sequencing Batch Reactors) | | | |
| | MBR (Membrane Bioreactors) | | | |
| | AS + N-SAF (Conventional AS with Nitrifying Submerged Aerated Filter) | | | |
| | Biotower + N-SAF (Filter works + N-SAF) | | | |
| | Reed Bed (2 Stages of Reed Bed - horizontal flow then vertical flow) | | | |
| | Other Systems e.g. RBC, oxidation ditches | | | |

4.2.3 We undertook a high level engineering assessment of potential treatment options, to enable conclusions to be drawn on which of the treatment technologies had potential for use as part of the Deephams Sewage Works Upgrade project. The outcomes are reported below.

## 4.3 Primary treatment options

4.3.1 In the primary treatment stage, sewage flows through large tanks, commonly called primary sedimentation or settlement tanks (PSTs). The tanks are used to settle out organic solids/sludge whilst fats, oils and grease (floatables) rise to the surface and are skimmed off. PSTs are usually equipped with mechanically driven scrapers that continually drive the collected sludge towards a hopper in the base of the tank, from where it is pumped to sludge treatment facilities. The tank should be designed for the removal of a high percentage of the floatables and settleable solids as a waste sludge. A typical tank may remove from 50 to 60 per cent of suspended solids, and from 30 to 40 per cent of Biochemical Oxygen Demand (BOD) from the sewage. These figures assume that the performance of the PSTs is not enhanced by chemical dosing. If settlement characteristics are improved by chemical dosing the above figures change to 65% to 75% removal of suspended solids and 45% to 55% removal of BOD.

4.3.2 Primary treatment can take place in conventional radial or horizontal flow PSTs, or PSTs fitted with lamellas. Lamella PSTs use inclined plates to reduce the footprint area needed to settle solids from the sewage. Lamella based primary treatment is considered less reliable than conventional PST as they are prone to loss of performance if they become partially blocked by accumulations of fat, oil and grease, however their more compact nature warrants inclusion. Lamella based primary tanks will require an upstream Fats, Oil and Grease (FOG) plant to protect the lamella plates by prior removal of material which may stick to the plates. Tanks will need to be able to be removed from service for regular pressure washing of the lamella plates to remove any accumulations of fat, oil and grease.

## 4.4 Secondary treatment options

4.4.1 Secondary treatment is designed to substantially remove the biological pollution content of the sewage. The majority of municipal sewage works undertake secondary treatment by treating the settled sewage which exits from the primary treatment stage using aerobic biological processes. The secondary treatment stage has the greatest number of potential alternative process technologies. The conclusions of the assessment of all of the secondary treatment options considered are reported below. The outcome of the assessment was that some of these options were not considered appropriate for the upgrade.

**Preferred secondary treatment options**

4.4.2 The following secondary treatment options have been identified as meriting assessment:

4.4.3 **Conventional Activated Sludge (CAS):** CAS is a suspended-growth system where a biomass (called 'activated sludge') is mixed with the settled sewage (sewage following treatment in the PSTs) to accelerate natural degradation of the organic material load. CAS uses dissolved oxygen to promote the selective growth of particular types of bacteria in the aeration tanks that substantially removes the organic material. Upon exiting the aeration tanks, these bacteria are settled out of the flow in final settlement tanks (FSTs) and collected for return to the head of the aeration tanks as the 'activated sludge'. Periodically the concentration of biomass rises above the level required for efficient operation of the process and the excess biomass is drawn off as 'surplus activated sludge' which is thickened and treated along with the sludge from the Primary Treatment stage. The liquid fraction of flows entering the FSTs exits these tanks over weirs constructed around the tank perimeters.

4.4.4 This technology offers space savings when compared to the traditional fixed film growth systems such as trickling filters. CAS provides a well understood process, having a high confidence in its capability of achieving the effluent quality required for the Deephams upgrade. Most of the largest sewage works in the world are CAS plants and we have significant experience with operating large CAS plants. The conventional activated sludge process is currently used at Deephams Sewage Works, however this existing plant does not have capacity to meet the new consent.

4.4.5 **Integrated Fixed-film Activated Sludge (IFAS):** IFAS includes a fixed-film or attached growth system suspended within the activated sludge process. The objective is to increase the concentration of biomass activity within the aeration tank by maximising the correct type of biomass growth. This greatly enhances the tank performance and increases the purification capabilities and capacity.

4.4.6 IFAS technology allows for a smaller activated sludge plant, otherwise it is similar to CAS. This technology provides some confidence in meeting the Deephams upgrade consent, although it is not widely used on scales comparable to Deephams Sewage Works. There are only a limited number of suppliers who provide systems of a suitably reliable nature to guarantee meeting the future consent, which may restrict any competitive tender process.

4.4.7 **Membrane Bio Reactor (MBR):** MBR combines activated sludge treatment with a membrane liquid-solid separation process. The membrane component uses low pressure microfilter or ultrafiltration membranes and eliminates the need for subsequent clarification and tertiary filtration stages. The membranes are typically immersed in the aeration tank, however, some applications utilise a separate membrane tank. One of the key benefits of an MBR system is that it effectively overcomes the limitations associated with poor settling of sludge in conventional activated sludge processes.

4.4.8 The technology permits bioreactor operation with considerably higher biomass concentrations. These elevated concentrations allow for very effective removal of both soluble and particulate biodegradable materials and increased sludge retention times. Over time, membrane filters can become clogged with grease or abraded by suspended grit. MBRs typically require more electrical energy than conventional systems and have a limited membrane filter life span (7-10 years). This increases the cost of MBR plants.

4.4.9 The technology has become increasingly popular for reliably pre-treated waste streams. The small area of land needed of MBR systems and the high quality effluent produced, make them particularly useful for wastewater recycling applications or meeting tight effluent standards such as those needed for the Deephams upgrade. The MBR process needs fine screens to protect the membranes, but offers a very compact treatment process requiring a small area of land. This technology provides good confidence of meeting the Deephams upgrade consent. However, the technology is not widely used on scales comparable to Deephams Sewage Works.

4.4.10 **Biological Aerated Flooded Filter (BAFF):** BAFF plants comprise a reactor filled with an inert granular material (filter media). The media is either buoyant and retained in place by a suitable grid at the top of the filter or submerged and supported by a gravel layer at the bottom of the filter. The dual purpose of this media is to provide a surface upon which a highly active biomass can adhere and grow, and to physically filter suspended solids from the flow. BAFF systems are very compact when compared to conventional activated sludge.

4.4.11 To meet the Deephams upgrade consent a two-stage BAFF process is envisaged as a minimum. The first stage is for Biological Oxygen Demand removal, with the second stage being required to achieve the ammonia standard. A two stage BAFF system provides only some confidence of meeting the Deephams upgrade consent. It is likely that a three stage system would be required. The technology is not widely used on scales comparable to Deephams Sewage Works in the configuration required.

**Secondary treatment options considered, but not preferred**

4.4.12 The following secondary treatment options have been identified as unsuitable and will not be taken forwards for further assessment

4.4.13 **Reed beds/wetlands:** Constructed wetlands or engineered reed beds can provide a high degree of biological improvement and depending on design, act as a primary, secondary and sometimes tertiary treatment systems. The use of two stages of reed beds following primary treatment could be appropriate for a small works to meet the upgrade consent, however, the size required for the flow treated by Deephams flow would be vast (over 1,100 hectares). There would not be sufficient land within or close to the Deephams Sewage Works catchment to facilitate this. For these reasons, Reed beds or wetland treatment is not a preferred treatment technology at this stage of the assessment process.

4.4.14 **Trickling filter technology (or biotowers):** In this process the settled sewage is distributed via small holes in continuously moving arms over beds containing live bacteria and other micro-organisms. These remove the dissolved organic material as the settled sewage trickles downward. Although biotowers are used widely for wastewater treatment, they are less common where there is a need to meet the discharged standards required for the upgrade. To meet the new Deephams effluent ammonia standard the biotower system would need to be supplemented by a further process stage, termed Nitrifying Submerged Aerated Filter (N-SAF). Biotowers at Deephams would require a large area of land, a N-SAF plant to achieve the required ammonia standard, and would tend to release higher levels of odour than activated sludge processes. For these reasons, biotowers is not a preferred treatment technology at this stage of the assessment process.

4.4.15 **Sequencing Batch Reactors (SBRs):** SBRs combine secondary treatment and settlement, equivalent to activated sludge processes, although a single tank stage is used to perform both the bio-reaction phase and settlement phases. The processes tend to be more difficult to control than conventional activated sludge processes, since they are reliant on mechanically induced processing stages. SBRs also require a larger area of land for a single storey installation and would require a larger odour control system. For these reasons, SBR is not a preferred treatment technology at this stage of the assessment process.

4.4.16 **Conventional activated sludge followed by N-SAF:** This solution represents a hybrid of a high rate activated sludge process followed by nitrification through a submerged aerated filter (N-SAF). This process is commonly used for extension of existing activated sludge plants where improved ammonia removal is required to meet a tightening consent. Applying the technology to a new treatment works does not provide a significant saving in area of land needed relative to conventional activated sludge (estimated to be 0.5 hectares) and would be more complex to operate. For these reasons, this is not a preferred treatment technology at this stage of the assessment process.

4.4.17 **Rotating Biological Contactors (RBCs):** This technology is not appropriate for large sewage treatment plants as it requires a large area of land. As an example, an area of 16 hectares would be required to achieve approximately 3 mgl/ ammonia, eight times the area taken by a conventional activated sludge plant. Furthermore the RBC option would require more than one stage to achieve the new Deephams ammonia consent (1mg/l). For these reasons, RBCs is not a preferred treatment technology at this stage of the assessment process.

4.4.18 **Oxidation ditches:** These are shallow aeration tanks with long retention times and would require a large area of land to treat the flows at Deephams. Oxidation ditches are generally used for the treatment of raw sewage on small works and have high aeration/mixing energy requirement. For these reasons, this is not a preferred treatment technology at this stage of the assessment process.

## 4.5 Tertiary treatment options

4.5.1 Where very high quality final effluent is required, additional filtration processes are used to reduce the amount of fine suspended solid material in the effluent. This also reduces the BOD levels. These filtration stages include sand or gravel filters and natural systems such as ponds or wetlands. The two-stage reed bed and MBR processes described above already incorporate effective solids removal processes and therefore do not require a separate tertiary treatment stage for enhanced solids capture.

4.5.2 Where needed following the secondary treatment stage, tertiary treatment, is assumed to require additional filtration in deep bed sand filters. These are called Rapid Gravity Filters (RGFs) and are normally arranged as a series of filters which operate together to treat the flow. RGFs operate by trapping fine suspended solid particles within the depth of the sand filter bed.

4.5.3 Ongoing experience with disc filters currently being installed at Deephams Sewage Works may provide evidence that the future suspended solids and Biological Oxygen Demand discharge standards could be met with more compact disc filter technology, especially where part of the flow is being treated in an MBR treatment plant (The MBR process will produce a very high quality of effluent which could be blended with effluent from a disc filter plant to achieve the discharge consent standard). However, until this is demonstrated, it is assumed that only RGF provides a robust enough tertiary treatment solution to meet the future Deephams consent. RGFs must therefore be included (when required) as part of the treatment solution.

## 4.6 Phosphorous removal options

4.6.1 Phosphorous from the wastewater can be removed either biologically in a process called enhanced biological phosphorous removal or through chemical precipitation, usually with salts of iron, or aluminium. The chemical phosphorous removal process requires a significantly smaller equipment footprint, is easier to operate and often more reliable than biological phosphorous removal. In addition, from our experience, biological phosphorous removal processes generally need chemical dosing support.

4.6.2 Two chemical options are available, either dosing chemicals into the primary tanks (termed pre-dosing) or dosing different chemicals into the aeration plant (termed simultaneous dosing). Chemical dosing into primary treatment was chosen as the common basis for evaluating the different secondary treatment options that passed the screening exercise. This decision was based on: the presumption that the greater quantity of chemical needed would be more than offset by the reduction in activated sludge plant sizing; a reduced blower size needed in secondary treatment stages; and a greater volume of biogas generated from sludge digestion processes resulting in greater energy generation from the CHP engines.

## 4.7 Conclusions of preliminary engineering assessment

4.7.1 The results of the assessment are illustrated in Table 2 below.

4.7.2 Technologies shaded green denotes technologies that were assessed as having most potential for use in the upgrade. These are the technologies that we then used in later stages of our assessment, including in the assessment of shortlist sites (see our separate Identification Site Assessment (Shortlist) Report) for details.

4.7.3 Technologies shaded in orange are considered to have less potential than the preferred technologies. These have not been used as part of our further assessment work, however they could be re-introduced into the assessment process at a later date, should new information suggest that these are appropriate processes for use in the upgrade. This could be as a result of the feedback from the phase 1 public consultation process, or from our ongoing scheme design development work.

4.7.4 Technologies shaded in red are considered to not have potential for use in the upgrade. These have not been used as part of our further assessment work. We think it is unlikely that these would be re-introduced into the assessment process at a later date. However, should new information suggest that these are appropriate processes for use in the upgrade, we would revisit our assessment of these options as a result. This could be as a result of the feedback from the phase 1 public consultation process, or from our ongoing scheme design development work.

**Table 2: Preliminary engineering assessment of treatment options**

| Primary Treatment Options | Secondary Treatment Options | Secondary Settlement Options | Tertiary Treatment | Phosphorus Removal Options |
|---|---|---|---|---|
| Conventional Primary Sedimentation | **Conv AS** Conventional Activated Sludge | Do nothing (unless in combination with MBR or Reed Bed or Bio-tower) | Do nothing (unless in combination with MBR or Reed Bed) | Biological Removal |
| FOG Removal & Lamella Primary Sedimentation | **IFAS** Integrated Fixed-film Activated Sludge | Conventional Final Settlement Tanks | Disc Filters | Chemical Dose (AS Lane) |
| | **BAFF** Biological Aerated Flooded Filter | | Rapid Gravity Sand filters (RGF) | Chemical Dose (Primary) |
| | **SBR** Sequencing Batch Reactors | | | |
| | **MBR** Membrane Bioreactors | | | |
| | **AS + N-SAF** Conventional AS with Nitrifying Submerged Filter | | | |
| | **Biotower + N-SAF** (Filter works + N-SAF) | | | |
| | **Reed Bed** 2 Stages of Reed Bed (horizontal flow then vertical flow | | | |
| | **Other Systems** e.g. RBC, oxidation ditches | | | |

4.7.5 For the primary stage treatment both conventional and lamella primary tanks were considered to have potential for use as part of the upgrade.

4.7.6 The secondary stage of treatment has the greatest range of potential treatment technologies. We subjected the preferred technologies to further assessment on a comparative basis. The outcomes from this are reported in section 5 of this report.

4.7.7 Tertiary and phosphorous removal options are selected as part of the overall treatment process design to meet the discharge consent.

# 5 Further assessment of secondary treatment technologies

## 5.1 Section objectives

5.1.1 This section outlines the further assessment of secondary treatment options.

## 5.2 Basis for assessment

5.2.1 The four secondary treatment process technologies were identified as technologies that could meet the new discharge consent limit within appropriate constraints for the Deephams Sewage Works upgrade were paired with an appropriate primary treatment configuration and assessed. Chemical dosing into the primary treatment system for phosphorus removal was common to all options. Furthermore conventional final settlement and sand filter tertiary treatment (where needed) were also applied.

5.2.2 Each combined technology option was developed into a conceptual generic layout to facilitate capital costs, operating costs and outline construction programmes to be estimated. These layouts, costs and programmes were then evaluated for each of the four technologies against a standard set of criteria, as explained below.

5.2.3 The relevant advantages and disadvantages of each treatment technology were recorded in a matrix, enabling comparative assessments to be undertaken. The criteria that each treatment types was assessed against are set out in Table 3. As each criterion was considered, a grade was attributed to the performance of that technology against that criterion. The grade was indicative, as opposed to absolute or numerical. As such, the purpose of the grade was to record areas of interest in the performance of the technology, whether these are potentially positive or negative.

**Table 3: Secondary treatment assessment criteria**

| **CRITERION** | | | |
|---|---|---|---|
| | **Red** | **Amber** | **Green** |
| **Engineering Criteria** | | | |
| **Technology appropriate for consent?**<br><br>Review of experience in meeting Deephams equivalent consent limits reliably | Poor confidence<br><br>Technology not appropriate for 10/5/1/1 consent or unacceptable risk retained | Some confidence<br><br>Technology could meet 10/5/1/1 consent but some limited risk retained | Good confidence<br><br>Technology proven to meet 10/5/1/1 consent, no residual process risk |
| **Technology applied on Deephams scale?**<br><br>Number of reference sites at comparable scale to Deephams (500.000 – 900,000 PE) operating for a minimum 2 years | No or very limited experience<br><br>< 2 examples | Limited experience<br><br>2 to 5 examples | Good Experience<br><br>> 5 examples |
| **Speed of construction**<br><br>Build duration for each process option (off site build) | Long<br><br>> 4 years | Medium<br><br>3 to 4 years | Short<br><br>< 3 years |

| CRITERION | | | |
|---|---|---|---|
| | Red | Amber | Green |
| **Engineering Criteria** | | | |
| **High level Whole Life Cost (WLC) evaluation**<br><br>Relative WLC compared to the conventional activated sludge baseline previously accepted by Ofwat | High<br><br>WLC greater than 110% of the baseline case | Medium<br><br>WLC between 90% and 110% of the baseline case | Low<br><br>WLC less than 90% of the baseline case |
| **WwTW Sustainability**<br><br>Power consumption (kWh/m3) relative to Conventional AS baseline | Low<br><br>Power greater than 110% of the baseline case | Medium<br><br>Power between 90% and 110% of the baseline case | High<br><br>Power WLC less than 90% of the baseline case |
| **Odour**<br><br>Odour generation potential and ease of mitigation | High<br><br>High odour generation and/or only poor mitigation possible | Medium<br><br>Medium odour generation, mitigation possible | Low<br><br>Low odour generation, mitigation possible |
| **Competition**<br><br>Evaluation of how competitive any tender process would be. Value for money for TW and customers | Poor<br><br>Highly supplier patented specific technology in solution. Likely only single practical tenderer. | Acceptable<br><br>Some supplier patented specific technology in solution. Likely multiple (> 2) tenderers. | Good<br><br>Little supplier patented specific technology in solution. Multiple tenderers (>3). |

5.2.4 The four secondary treatment process technologies that were identified as preferred technologies in preliminary engineering assessment were Conventional Activated Sludge, BAFF, IFAS and MBR. The following sections of the report explain and assess these secondary treatment options in more detail.

## 5.3 Conventional Activated Sludge (Conv AS)

5.3.1 Conventional activated sludge is a suspended-growth system where the biomass (activated sludge) is mixed with the sewage and uses dissolved oxygen to promote the growth of a biological floc that substantially removes organic material. The treated water is then drawn separated from the activated sludge in final settlement tanks. The excess biomass is periodically drawn off as surplus activated sludge which is treated with the rest of the sewage sludge.

5.3.2 This technology offers space savings when compared to the traditional fixed film growth systems such as trickling filters. Conventional AS provides a well understood process, having a high confidence in its capability of achieving the effluent quality required for the Deephams upgrade. Most of the largest sewage works in the world are conventional AS plants and we have significant experience with operating large conventional AS plants. The conventional activated sludge process is currently used at Deephams Sewage Works, however much of this existing plant is 50 years old and does not have the capacity to meet the new consent.

5.3.3 Our assessment of layouts and construction programmes identifies that a minimum site area of 24 hectares would be required for a treatment technology option based on conventional AS plant. We assessed that on a cleared site a typical construction programme would be 3-4 years at a medium range of cost.

**Figure 6: Conventional AS plant illustration**

## 5.4 Biological Aerated Flooded Filter (BAFF)

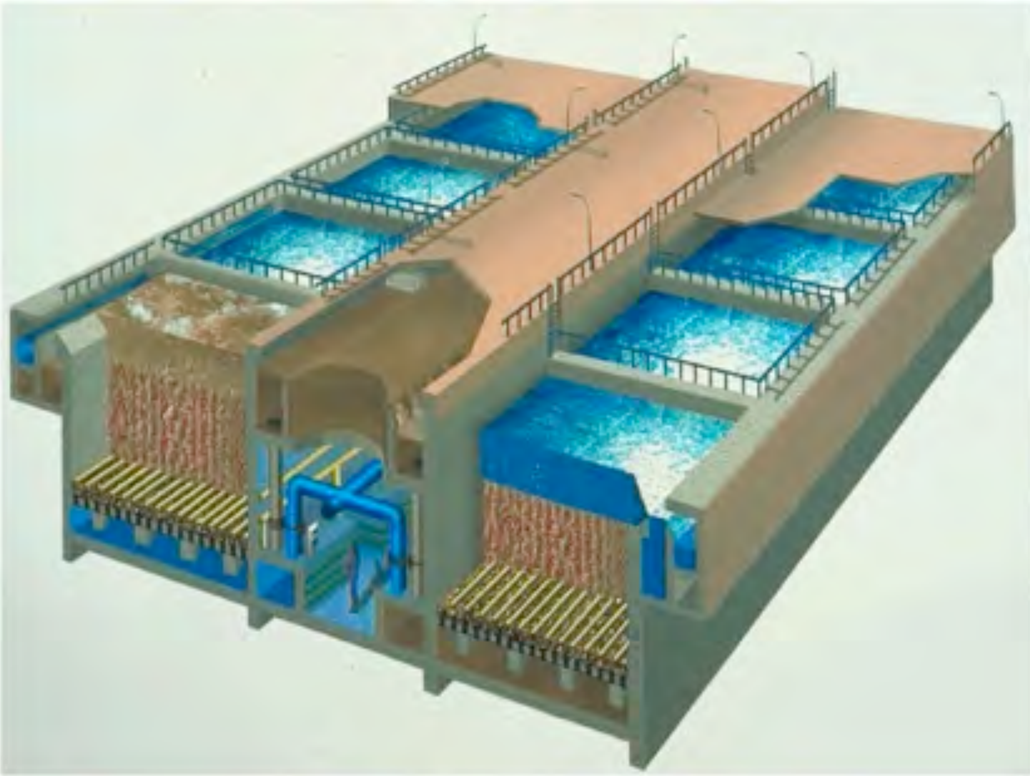
5.4.1 Biological Aerated Flooded Filters (BAFF) combine filtration with biological carbon reduction, nitrification or denitrification. BAFF plants comprise a reactor filled with a filter media. The media is either in suspension or supported by a gravel layer at the foot of the filter. The dual purpose of this media is to support highly active biomass that is attached to it and to filter suspended solids. BAFF systems are very compact when compared to Conventional AS.

5.4.2 To meet the Deephams upgrade consent a two stage biological aerated flooded filter (BAFF) process is envisaged as a minimum. The first stage is for BOD removal, with the second stage being required to achieve the ammonia standard.

5.4.3 A two stage BAFF system provides only some confidence of meeting the Deephams upgrade consent and it is possible that a 3 stage system would be required. The technology is not widely used on scales comparable to Deephams Sewage Works in the configuration required.

5.4.4 Our assessment of layouts and construction programmes identifies that a minimum site area of 20 hectares would be required for a treatment technology option based on a BAFF plant. We assessed that on a cleared site a typical construction programme would be 3-4 years at a medium range of cost.

**Figure 7: BAFF plant illustration**



## 5.5 Integrated Fixed-film Activated Sludge (IFAS)

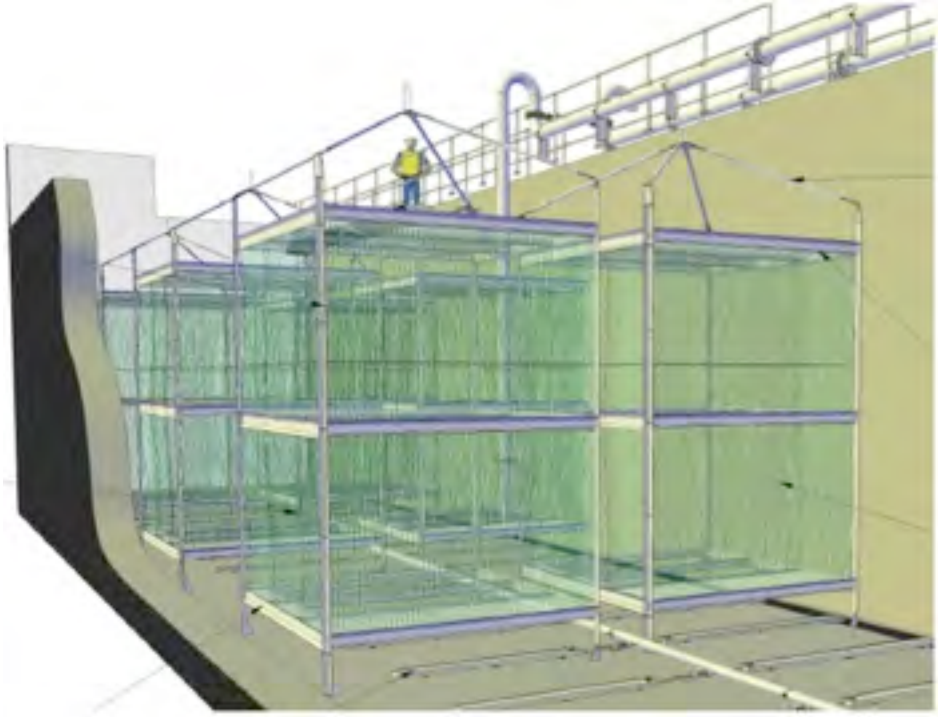
5.5.1 IFAS includes a fixed-film or attached growth system suspended within the activated sludge process. The biomass either grows on media and the sewage passes over its surface, or the biomass grows on media which is free to move around in the IFAS reactor tank.

5.5.2 The objective is to increase the concentration of biomass activity within the aeration tank by maximising the correct type of biomass growth. This greatly enhances the tank performance and increases the purification capabilities and capacity.

5.5.3 IFAS technology allows for a smaller activated sludge plant, otherwise it is similar in concept to Conventional AS. This technology provides some confidence in meeting the Deephams upgrade consent. However, the technology is not widely used on scales comparable to Deephams Sewage Works. There are a limited number of suppliers who provide systems of a suitably robust nature to guarantee meeting the future consent which may restrict any competitive tender process.

5.5.4 Our assessment of layouts and construction programmes identifies that a minimum site area of 13 hectares would be required for a treatment technology option based on IFAS plant. We assessed that on a cleared site a typical construction programme would be 3-4 years at a medium range of cost.

**Figure 8: IFAS plant illustration**



## 5.6 Membrane Bio Reactors (MBR)

5.6.1 MBR combine activated sludge treatment with a membrane liquid-solid separation process. The membrane component uses low pressure microfilter or ultrafiltration membranes and eliminates the need for downstream clarification and tertiary filtration stages. The membranes are typically immersed in the aeration tank, however, some applications utilise a separate membrane tank. One of the key benefits of an MBR system is that it effectively overcomes the limitations associated with poor settling of sludge in Conventional AS processes.

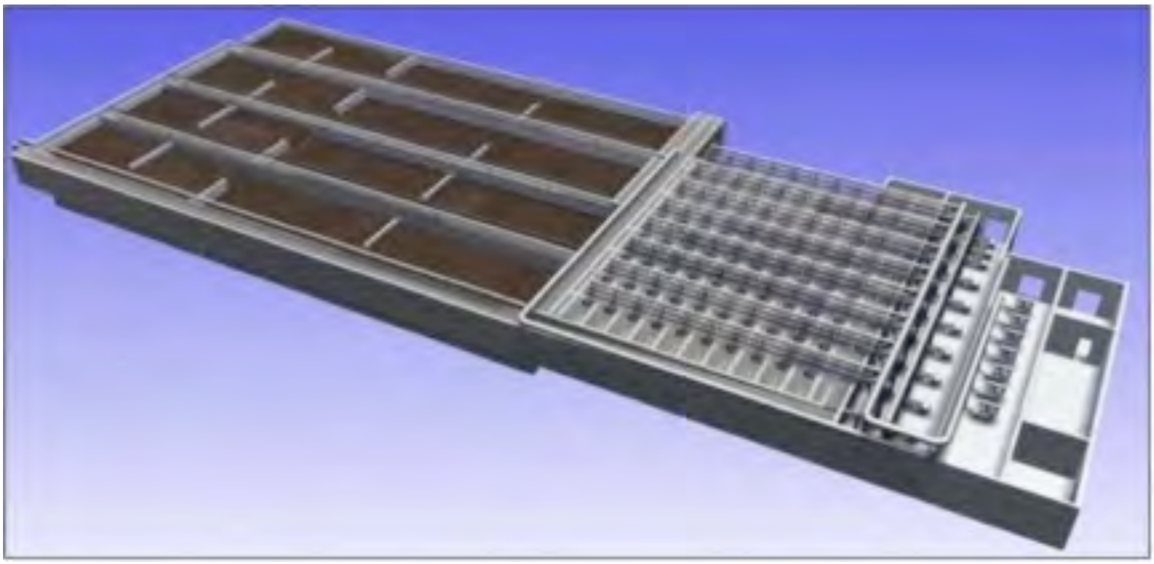
5.6.2 The technology permits bioreactor operation with considerably higher biomass concentrations. These elevated concentrations allow for very effective removal of both soluble and particulate biodegradable materials and increased sludge retention times. However, MBRs typically require more electrical energy than conventional systems and may be additionally penalised on whole life cost terms by the limited membrane filter life span (7-10 years). Over time, membrane filters can become blinded with grease or abraded by suspended grit.

5.6.3 The technology has become increasingly popular for reliably pre-treated waste streams. The small footprint of MBR systems and the high quality effluent produced, make them particularly useful for water reuse or recycling applications or meeting tight effluent standards such as those needed for the Deephams upgrade, and where space is a limiting factor. The MBR process should be supplemented by upstream fine screens and will offer a very compact treatment process requiring a small footprint area.

5.6.4 This technology provides good confidence of meeting the Deephams upgrade consent. The technology is not widely used on scales comparable to Deephams STW.

5.6.5 Our assessment of layouts and construction programmes identifies that a minimum site area of 8 hectares would be required for a treatment technology option based on MBR plant. We assessed that on a cleared site a typical construction programme would be 3-4 years at a high range of cost.

**Figure 9: MBR plant illustration**



## 5.7 Site size conclusions

5.7.1 The evaluation of generic solution layouts performed as part of the Treatment technology assessment process has informed an analysis of the minimum size of site area that could be used to treat flows for Deephams STW using different treatment technologies.

5.7.2 The analysis is summarised in Table 4 below.

**Table 4: Treatment technology site size comparison**

| | Conv. AS | IFAS | BAFF | MBR |
|---|---|---|---|---|
| Site size (hectares) | 24 | 20 | 13 | 8 |

5.7.3 This confirms the minimum site area of 8 hectares for use in the site assessment process. This minimum area is based on an optimum layout on a regular shaped site. It does not include space for future expansion, future consent changes or flood mitigation.

## 5.8 Conclusions on secondary treatment options

5.8.1 The further assessment of secondary treatment options is outlined in the following matrix on a comparative basis.

**Table 5: Secondary treatment technology options comparative matrix**

| Evaluation Criteria | CAS | IFAS | BAFF | MBR |
|---|---|---|---|---|
| Confidence in technology meeting new discharge consent? | Good confidence | Some confidence | Some confidence | Good confidence |
| Experience of technology on Deephams scale? | Good experience | No or very limited experience | Limited experience | No or very limited experience |
| Speed of construction on a cleared site | Medium<br><br>3 – 4 years | Medium<br><br>3 – 4 years | Medium<br><br>3 – 4 years | Medium<br><br>3 – 4 years |
| Comparison of Whole Life Costs | Medium | Medium | Medium | High |
| Comparison of power consumption | Medium | Medium | High | Medium |
| Competition in Construction Tenders | Good competition | Acceptable competition | Poor competition | Good competition |
| Comparison of odour generation | Medium odour generation, mitigation possible | Medium odour generation, mitigation possible | Medium odour generation, mitigation possible | Medium odour generation, mitigation possible |

5.8.2 As a result of the assessment, the secondary treatment options were taken forward to be used as part of the process to identify the preferred site.

- Conventional Activated Sludge (CAS) for the treatment of the entire flow
- Integrated Fixed-film Activated Sludge (IFAS) for the treatment of the entire flow, or parts of the flow (IFAS could reduce the required footprint when compared to CAS treatment)
- Membrane Bio Reactor (MBR) for the treatment of parts of the flow (there are concerns over MBR experience on a Deephams Sewage Works scale, and on energy and cost grounds, however the use of MBR could reduce the area of land required when compared to CAS treatment)

5.8.3 Our conclusion at this stage was that the BAFF system would not be taken forward to be used as part of the shortlist site assessment process.

5.8.4 Whilst these treatment technologies are assessed as having potential as part of the upgrade, these and other treatment technologies will be further assessed and considered as part of the process of identifying the preferred option for delivering the upgrade. The process of selecting the final option will include consideration of feedback from the phase 1 public consultation and from our ongoing scheme design development work.

# 6 Next steps

6.1.1 The assessment of treatment options has identified that we have a number of potential treatment technologies that could be used as part of the upgrade. Some stages of treatment have more treatment options than others, with the secondary stage having the greatest number of potential technologies to consider.

6.1.2 The assessment of treatment options undertaken to date, documented in this report, will help inform our assessment of the shortlist sites. This work is reported separately in the “Identification of preferred site stage 3 report”.

6.1.3 No decisions have been taken on the treatment options at this stage. We will use feedback from the phase 1 public consultation, and from our ongoing scheme design development work, to inform our decisions on treatment technologies to be used for the upgrade.

6.1.4 The final treatment option could be one of those identified as preferred within this report, or potentially one of the non-preferred options if our further assessment demonstrates it to be the most appropriate treatment process for the upgrade.