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Report

Gairloch Wastewater Treatment Works

Technical Review

August 2018

Stantec and Mott MacDonald working with Scottish Water

Report

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EXECUTIVE SUMMARY

Background

The existing membrane bioreactor (MBR) at Gairloch wastewater treatment works is in need of major capital maintenance investment (extensive membrane replacement) to keep it operational and to lower the risk to the nearby Bathing Waters. Scottish Water has opted to change the treatment process due to the unexpectedly high degree of ongoing operational and maintenance input that the MBR requires and concerns over its ability to treat all flows during maintenance activity. This is in line with Scottish Water's practice elsewhere with a number of MBRs having been decommissioned and replaced with alternatives in recent years. Indeed, Scottish Water has indicated to m^2 that it has given a commitment to SEPA to exit this technology at the earliest suitable point as these become due for major investment.

The alternative that Scottish Water has proposed comprises septic tanks for settlement and anaerobic treatment followed by filtration and seasonal ultraviolet (UV) disinfection. This has been designed to meet the Bathing Water standards required for Loch Gairloch. The community expressed concerns regarding the potential impact of the perceived reduced treatment on water users and the environment. In response to these concerns, Scottish Water instructed m^2 to carry out an independent technical review of the decisions and options considered.

Current issues

As well as requiring investment in the membranes, the existing MBR suffers from ongoing operational issues that affects its ability to treat the required flow thus increasing the risk of non-compliant sewer network overflows including

- high incoming flows that mean that the WwTW is hydraulically constrained and cannot pass all flows during membrane maintenance periods
- ragging and fouling of the membranes reducing the achievable throughput.

While there are options to reduce the impact of these risks, such as improving waste water screening, investigating and implementing reductions in ground water infiltration and sea water ingress into the sewerage network, and increasing the available membrane capacity, these would at best only marginally reduce the frequency of significant maintenance interventions and at worst may create conditions that introduce additional risks of non-compliance due to the nature of the incoming wastewater and the conditions needed for successful operation of the MBR.

In particular we have noted that the incoming flows are particularly high with the amount of infiltration being more than double the amount of wastewater produced. While there may be some point sources of infiltration that can easily be isolated Scottish Water has already investigated this and it is more likely that substantial investment in rehabilitation of the sewerage network would be required to make a significant difference to performance overall.

Review of proposed solution and potential alternatives

We reviewed the proposed solution and concluded that it is designed to meet the effluent quality requirements and ensure “excellent” bathing water quality at the designated beaches given that the processes perform as designed and the required feed quality to meet the process guarantees can be achieved. The design uses components that are commonly used and are backed up by Process Guarantees from the suppliers. The combination of process components is an innovation as the arrangement proposed is unusual it does carry some technical risks. As part of this review, the suppliers have confirmed that the process as designed is able to meet the discharge license. Mitigations against any risks have been explored and we are confident the risks are manageable.

A range of alternative technologies were compared against the proposed solution. An optimally functioning MBR would undoubtedly produce much better effluent quality than the proposed process but there is significant risk of untreated sewage overflows from the network during maintenance. Modifications to the MBR were considered but the risk during maintenance remained. Taking this into consideration, continuing with an MBR plant would mean the overall discharge to Loch Gairloch would likely be poorer due to spillages elsewhere from emergency outfalls in the sewer network. None of the other options considered was identified as preferable to the proposed option. Two options (enhanced settlement and fixed film roughing filters, such as trickling filters) were identified as potential future upgrades that could be retrofitted relatively easily should the influent to the disc filters or UV system under perform against the process guarantees.

GLOSSARY

Abbreviation	Description
BOD	Biochemical oxygen demand
CAR	Controlled Activities Regulations
cfu/100mL	Colony forming units per 100mL of sample
COD	Chemical oxygen demand
CSO	Combined sewer overflow
CVS	Customer value system
DP	Differential pressure
DSEAR	Dangerous and Explosive Atmosphere Regulations (2002)
E. coli	*Escherichia coli* - an indicator organism of faecal contamination
EPS	Extracellular polysaccharides
FST	Final settlement tank
HSE	Health, Safety and the Environment
L/s	litres per second
m^2	An engineering consultancy collaboration of Stantec (formerly MWH) and Mott MacDonald
m^3	cubic metre
MBR	Membrane bioreactor
mg/L	milligrams per litre
MLSS	Mixed liquor suspended solids; the solids suspended in a biological reactor
OPEX	Operational expense
P&ID	Process and instrumentation diagram
PE	Population equivalents
pH	A measure of hydrogen ion concentration; a measure of acid / alkaline balance
SAF	Submerged aerated filter - a type of fixed film biological treatment
SCADA	System control and data acquisition (a control system).
SEPA	Scottish Environmental Protection Agency
SMP	Soluble microbial products

Abbreviation	Description
SRT	Sludge retention time
SW	Scottish Water
TF	Trickling filter - a type of fixed film biological treatment
TMP	Trans-membrane pressure
UV	Ultraviolet
UVT	Ultraviolet transmissivity
WwTW	Wastewater treatment works; also known as a sewage treatment plant

1 INTRODUCTION

1.1 Background

Scottish Water installed a membrane bioreactor (MBR) at Gairloch wastewater treatment works (WwTW) in 2002. At the time, MBR technology was new and the site offered an opportunity to use the latest technology. Subsequent operational experience at this site and others in Scottish Water led to a review of the technology and its removal from Scottish Water's process selection through its specifications and standards. The site has a history of problems primarily related to limitations on its hydraulic capacity, which deteriorates as the membranes age, thus Scottish Water identified concerns regarding the long-term viability of the treatment process. As part of a capital maintenance exercise, Scottish Water identified that a better whole life cost solution would be to replace the MBR with an alternative treatment solution that has more flexibility to accommodate growth. Later additional quality drivers were introduced with the beaches at Gairloch and Big Sand being designated Bathing Waters so, from starting as solely a septic tank process, the proposal has developed additional treatment stages to ensure Bathing Water standards are not compromised.

The local community has concerns about the proposed new treatment process as it is perceived that it will lead to a deterioration in the quality of the receiving water. The hydraulic capacity of the site is currently reduced due to the membrane performance and the network is reported to overflow at times, through emergency outfalls, due to this constraint. The proposed solution overcomes the hydraulic constraint and thus a greater proportion of the sewage will be treated. The quality of the discharge from WwTW is therefore only part of the picture when considering the environmental impact.

1.2 Purpose of report

This report provides analysis of the existing situation and reviews the option Scottish Water is proposing. It compares this with potential alternatives taking into consideration the concerns of the local community and technological features to identify the preferred way forward, thus allowing Scottish Water to progress a suitable project to meet the discharge licence at Gairloch.

2 CURRENT ISSUES

Through this review, m^2 has identified and reviewed two issues namely:

- The current performance of the network and the impact this has on treatment and the receiving water.
- The problems that the existing works experiences and whether these could be mitigated.

These are considered in more detail in the following sections.

2.1 Network performance

Three potential sewer network performance issues have been identified namely network infiltration, saline intrusion and premature spillage of storm water.

2.1.1 Network infiltration

Based on analysis of the inlet flow to the WwTW, the average flow to Gairloch WwTW in 2017 was 623m^3/d (equivalent to approximately 560 l/PE/d or 7.2 L/s). SEPA assesses the dry weather flow to a WwTW as being the total daily flow that is exceeded 80% of the time (in other words on 20% of days the total daily flow will be less than this and on 80% of days the total daily flow will be above this value) [1]. Based on this criterion, the dry weather flow in 2017 was around 517m^3/d. This is equivalent to 470 l/PE/d which is much higher than the licensed dry weather flow of 230m^3/d. The variation in influent flows over the course of 2017 is shown in Figure 2-1.

There are no trade effluent flows to the WwTW and hence the dry weather flow, by standard definitions, comprises the domestic foul flow and infiltration. Domestic foul flow is generated at approximately 150 l/PE/d hence the residual network infiltration is around 350m^3/d (320 l/PE/d). While infiltration rates vary from catchment to catchment, the infiltration in the Gairloch catchment implied by the measured dry weather flow is at the high end of the normal range.

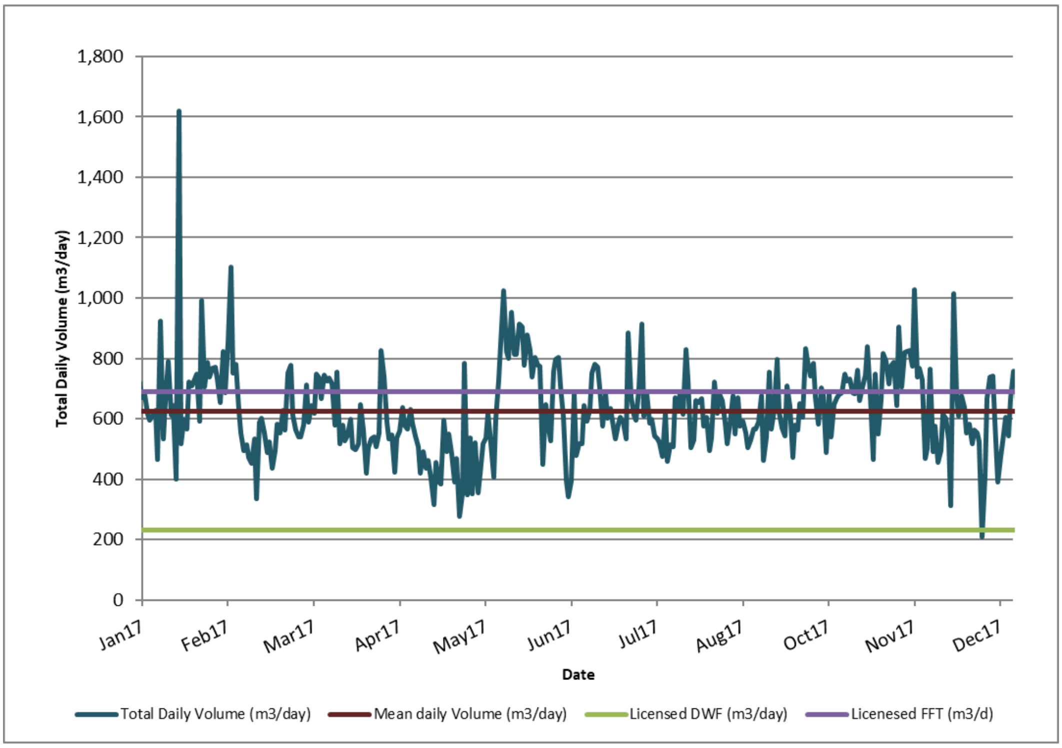
There are a number of consequences of the high infiltration:

- There is little scope for the network to buffer storm flows
- Larger volumes are pumped to the WwTW meaning higher operating costs are incurred
- The wastewater is relatively dilute making it less ideal for treatment in an MBR
- Process units need to be larger to accommodate the higher flows.

We understand that while the sewerage networks around the pumping mains were installed around the time of the WwTW, other parts of the network are likely to be older and constructed around the same time as the houses they serve and therefore may be suffering from age related deterioration. There would be merit in Scottish Water investigating the network further for any significant sources of infiltration with a view to isolating these. We note that some infiltration may be from the private drainage pipes that feed into the sewers which Scottish Water has less control over.

[1] For compliance assessment SEPA compares the flow exceeded 90% of the time to allow for any particularly wet years. The flow exceeded 90% of the time in 2017 was 467m^3/d, which is still much higher than the licensed dry weather flow.

Figure 2-1: Treatment works inlet flow 2017



Based on Scottish Water flow data the higher dry weather flow means that the currently licensed flow to full treatment of 8 L/s is less than would be required if the normal assessment method of flow to full treatment is used (3x foul flow + infiltration which would be 10 L/s).

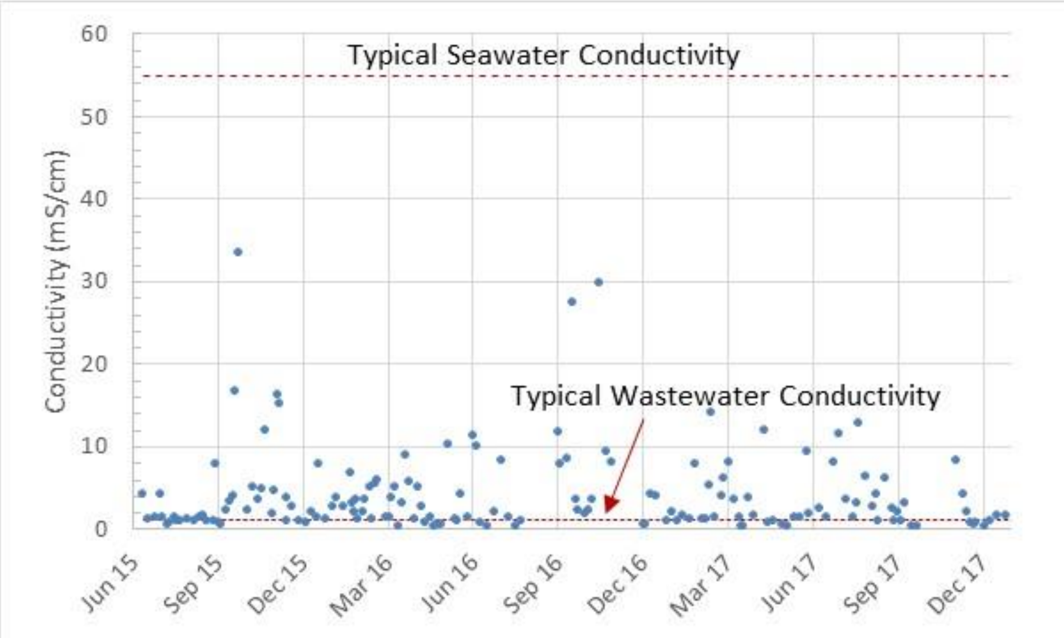
It also appears from Figure 2-1 that the WwTW does, at times, treat significantly more flow than the current license requirement. This may indicate pump control issues or inaccuracies in the inlet flow measurement.

Reviewing the veracity of the flow information will confirm any impacts upon licencing, the current design or the proposed design.

2.1.2 Saline intrusion

Variable, and sometimes high, conductivity measurements have been observed at the treatment works suggestive of saline intrusion into the sewer network. Conductivity measurements from June 2015 to February 2018 are shown in Figure 2-2. At the highest conductivities it is estimated that 60% of the flow is sea water. Scottish Water has undertaken a programme of measures to reduce saline intrusion and it is believed that this is one reason that the significant conductivity peaks shown in autumn 2015 and autumn 2016 were not repeated in autumn 2017; however, it is clear that there are still periods where the conductivity is high suggesting that saline intrusion still occurs albeit to a lesser degree.

Figure 2-2: Treatment works conductivity measurements



Saline intrusion can result in a number of issues including:

- Inhibition of biological treatment processes
- Microbial fouling of membranes
- Increased pumping costs due to additional flow into network
- Storm spillage in dry weather as network becomes overwhelmed
- Greater septicity potential and subsequent damage to structures and equipment from hydrogen sulphide

We note that Scottish Water continues to seek opportunities to identify point sources of infiltration to reduce saline intrusion to limit these effects.

2.1.3 Storm Spillage

During periods where there are capacity restrictions at the WwTW, the required treatment flow of 8 l/s cannot be maintained. Inspection of telemetry data for the WwTW and the final pumping station indicates that, when one of the two membrane trains is out of service, the permeate rate is approximately half the required treatment flow and this can lead to the storm tanks filling up rapidly, spilling to the environment, through licenced outfalls, and remaining full for extended periods, which will in turn cause immediate spillage to the environment during future storm events.

As noted in section 2.1.1 the average flow of 7.2 L/s is also very close to the required flow to full treatment of 8 L/s meaning there is little headroom to empty the stored storm water through the WwTW. Thus, there is an ongoing risk that premature spillage of storm water occurs due to the flow to full treatment being too low for the current infiltration levels. It should be noted that this review has not identified any periods where spillage to the environment has occurred due to flow to full treatment being too low. Environmental spillages have only been identified when there has been either saline intrusion or a reduced pass forward to the WwTW due to maintenance or operational problems.

2.2 Existing process

2.2.1 Symptoms

Scottish Water described the following symptoms for Gairloch WwTW:

- The WwTW has experienced periods of diminishing hydraulic throughput, requiring one or both membrane trains to be taken offline for maintenance resulting in:
  - The potential to breach the SEPA discharge consent requirement which stipulates that no discharge of overflow to the environment is allowed at flows to treatment below 8L/s;
  - The potential to discharge untreated (or minimally treated) wastewater to the environment through emergency outfalls.
- Scottish Water has invested significant funds into reducing sewer network inflow and infiltration in the catchment to reduce the hydraulic load to the plant. It anticipates that these improvements will only provide temporary relief and will require ongoing investment due to the low lying and coastal nature of the network. In our experience the two main management techniques are either: network rehabilitation (by identifying the salinity sources, identifying solutions, prioritising works, and methodically implementing them in an ongoing program of works) or accept a reasonable level of infiltration and provide salinity resilience in the downstream processes. In practice, the latter is usually more cost effective across the industry, unless obvious point source infiltration is identified.
- The membrane plant has incurred greater operational expense than was originally anticipated based on the tender response for the MBR plant. Some of these additional expenses may be attributable to the hydraulic reductions that have been experienced, such as the additional manhours required to conduct physical break-down and cleaning of the membranes and the increased level of network maintenance to reduce the inflow and infiltration flows to the plant.

The WwTW is currently due for an age-related replacement of the plant's membrane sheets. This represents a significant capital maintenance expenditure and provides Scottish Water with an opportunity to review the effectiveness of the MBR plant in addition to reviewing the long term whole life cost and resilience of operating and maintaining this plant.

2.2.2 Information considered

- Spreadsheet of Gairloch WwTW site record sheet data for the period Jun 2015 – Feb 2018
- Spreadsheet of MBR permeate flow data at 15min intervals for the period 5 Jan – 1 Mar 2016
- Assorted plant construction drawings
- Process & Instrumentation Diagram (P&ID; drawing CX305/G101/1 rev B)
- SEPA discharge license CAR/L/1002928/VN03
- Assorted telephone conversations and emails with Scottish Water operational staff
- Gairloch WwTW options workshop (held in Inverness on 31 May 2018)
- Report J110, Gairloch WwTW appraisal (ver. Draft final report) by Professor S. Judd
- MBR refurbishment report (Project number PJ20298) by Jacopa (dated 3 Apr 2017)

2.2.3 Hydraulic capacity findings

The MBR was originally designed to treat a peak flow of 22 L/s. This was then varied down to a peak flow of 16L/s for an anticipated population equivalent (PE) of 2,200, but the plant was incapable of reliably achieving this. The licence was reviewed again, and the peak flow revised down to 8L/s based on a catchment population of 1,100PE.

We reviewed the design for the MBR. In our opinion the plant has sufficient hydraulic capacity to meet SEPA licence conditions (8L/s of throughput) only with all trains online and operating at full capacity. Based on experience with other similar plants, the plant should be capable of temporarily treating a peak flow capacity of approximately 16L/s which is likely to be appropriate for treating Gairloch's peak diurnal flows (daily flow variations) and non-storm-related peak day flows (day to day variation). However, there is minimal safety factor in the design, little or no capacity for catchment growth, little or no capacity to accept increased infiltration of groundwater or seawater into the system, and insufficient hydraulic capacity when one process train is taken offline for necessary maintenance.

Scottish Water has indicated that stripping and cleaning one membrane train takes approximately one working week to complete. This reduces, by half, the average hydraulic throughput of the treatment system during this period (maintenance flow capacity: average = 4L/s; peak = 8L/s). This is insufficient capacity to treat all of the average flows (~7.2L/s) at a sustainable membrane flux rate. This means that the train in service would need to overproduce on a continuous basis, increasing its fouling rate, reducing its throughput and risking permanent membrane damage. If the plant was designed to current practice, it would be considered too small for its purpose, as it lacks sufficient standby capacity to allow for necessary offline maintenance while maintaining the design flows.

Scottish Water has also indicated that sometimes the actual hydraulic capacity has been less than the hydraulic capacity assessed here. In membrane systems, hydraulic capacity restrictions are typically associated with fouling of the membranes (increasing filtration resistance). The causes and management of fouling are considered further later in this report.

2.2.4 Effluent quality findings

No issues have been noted with the MBR effluent quality. The effluent quality discharged from the WwTW remains better than the SEPA discharge licence requirements, even when accounting for some membrane damage. However, this effluent evaluation is only based on the water treated through the MBR system. It does not consider environmental discharges of untreated (or minimally treated) wastewater if (or when) the membrane plant is hydraulically constrained. Nor does it consider other septic tank discharges from communities within the loch's catchment that are not connected to the public sewerage system.

2.2.5 Fouling findings

2.2.5.1 Types of fouling

Fouling is when the ability to filter through the membranes is compromised. In the case of the Gairloch MBR this decreases the membranes' hydraulic throughput. Fouling is considered to occur in three main forms termed:

- reversible,
- irreversible,
- irrecoverable.

Reversible fouling tends to be biological in nature and is managed by relaxation and backwashing the membranes. Irreversible fouling tends to be due to chemical precipitation and fine particle blockage of the membrane pores and is reversible using chemical cleaning. Irrecoverable fouling has been associated with caking of the membrane surfaces, requiring drainage of the reactors, physical disassembly of the membrane cartridges and pressure washing of the membrane surfaces.

Differential pressure sensors are typically used to monitor the fouling rates and can be used to assess the fouling type. The MBR plant uses differential pressure readings within its control system, but it is understood that these data are not trended in the SCADA system. Therefore, our assessment of the predominate fouling type/s is primarily based Scottish Water's description of the fouling events and the flow improvements experienced after physical membrane cleaning.

Note - without differential pressure data it is difficult to estimate the rates of the fouling types and the likely quantitative effects of any interventions.

2.2.5.2 Sources of fouling considered

The following sources of fouling have been considered and are described in order of the likelihood of these being responsible for the issues experienced.

Braiding (also known as Ragging)

Fibres and microfibres mesh together in the reactors, forming rope or braid like materials which snag on reactor components and continue to grow. In membrane reactors these braids can reduce the effectiveness of air scour cleaning, resulting in the accumulation of solids on the membrane surfaces (irrecoverable fouling). Potential causes of this are:

- Ineffective inlet screens

The WwTW's influent is screened by two screens in series: 1x 6mm followed by 1x 3mm screen. A 3mm screen size was the original minimum size specified upstream of membrane systems and was considered suitable at the time it was installed. Based on world-wide experience, the standard advice is now to install a one-dimensional screen size of no greater than 1 – 2mm with a 90° flow direction change, such as can be achieved with an inclined drum screen. The WwTW's screening is therefore now considered insufficient for an MBR process, which will contribute to more frequent braiding issues.

- Scour air rate

A minimum air scour rate is recommended to enable intermembrane cleaning. Gairloch WwTW's stated installed air scour flow rate conforms to best practice recommendations. We recommend that the actual air scour flow rate is confirmed in the field to confirm that the originally installed rate is still maintained.

Solids management

MBRs work most effectively over a relatively small range of solids concentration. With insufficient solids they are prone to blockage due to micro-particles or poor filterability due to microbial produced substances. Too many solids increase the resistance of the membrane and decrease the throughput. If the solids are too old, then their average particle size reduces which can foul the membranes. Potential issues identified are:

- MLSS concentrations

The average mixed liquor suspended solids (MLSS) concentration reported for the WwTW is 14 – 17g/L of MLSS, which is at the high end of typical recommendations. This is likely to increase the risk and rate of irrecoverable fouling. The MLSS concentration can be managed by reducing the solids retention time (SRT) within the reactors (wasting more sludge). Based on experience the typical operating advice is to achieve MLSS concentrations of 10 – 12g/L of MLSS leading to longer periods between cleans.

- MLSS gradients

The solids concentrate along the length of reactor as water is removed. This creates a concentration gradient from dilute MLSS at the front of the reactor to concentrated MLSS solids at the end of the reactor. This may result in some of the membranes operating outside of the advised operating range. This concentration effect is usually managed by recycling sludge from the downstream end of the membranes to the upstream end. Currently this recycle rate appears to be 50 – 90% lower than typically recommended and is likely to result in uneven solids concentrations along the length of the membranes.

- Relaxation periods

Relaxation is when filtration is paused while air scour continues or is enhanced. This is intended to remove concentrated solids from the membrane surfaces. The MBR relaxation frequency is lower than typically recommended (Gairloch = 2 per hour vs. typical 3.5 – 6 per hour) and shorter than typically recommended (Gairloch = five minutes per hour vs. seven to twelve minutes per hour). This may cause less effective cleaning of the membranes. Caking (irrecoverable fouling) of the membranes tends to positively feedback with the presence of cake making cleaning less effective which encourages more caking to occur.

Other foulants

In our opinion the most probable causes for the fouling experienced at the WwTW are excessive braiding and suspended solids; however, there may be other causes of fouling. Reviewing and eliminating these potential causes would require further investigation and may require field studies, such as in collaboration with a local university. Some of the other foulants considered are:

- Enhanced microbial fouling through conditions such as excess salinity, low pH, and high dissolved oxygen concentrations.

The microbes within the sludge can produce increased amounts of cellular secretions (EPS and SMP) under certain conditions. These products can decrease the filterability of the suspended solids. The plant data suggests that the MBR is subjected to fluctuating salinity concentrations and low pH. Variable salinity has been demonstrated to increases the amount of cellular secretions and low pH has been demonstrated to reduce the filterability of these secretions.

- Enhanced particle fouling through conditions such as excessive sludge retention time (SRT; the average time that solids are retained within the treatment system) and applying inadequately blended wastewater to the membranes.

Some conditions, such as those listed, can increase the fraction of fine particles within the suspended solids. Fine particles can foul the membranes faster than usual.

- Unknown foulants

There is a chance that the WwTW is experiencing atypical fouling due to something unusual in its wastewater. This is considered unlikely based on our understanding of the catchment and the fact the fouling appears to be recoverable when the membranes are stripped down. A membrane autopsy may identify the predominant foulant, if it is not simply due to excessive solids concentration at membrane surface.

2.2.6 Fouling conclusions

Based on our review the main foulants, and hence cause of reduced throughput, at the WwTW are likely to be:

- Braiding – worsened by inadequate screening
- Excessive suspended solids concentrations within the reactors

With secondary contributions from:

- Salinity of the feed effluent

2.3 Summary of technical issues

The MBR system appears to have sufficient hydraulic capacity to meet the SEPA 8L/s requirement when unfouled and with both trains online. However, there is insufficient safety factor in the design, little or no capacity for catchment growth or to accept increased infiltration of groundwater or seawater into the system, and insufficient capacity when one process trains is taken offline for necessary maintenance.

The MBR system appears to be suffering excessive membrane fouling. The high rate of fouling is most likely attributable to irrecoverable fouling resulting from insufficient screening of influent wastewater, excess braiding/ragging and high concentrations of suspended solids within the plant. The high rate of fouling is expected to decrease the allowable time between offline membrane cleaning activities. However, reducing the high fouling rate is only forecast to increase the allowable time between cleaning, it will not eliminate the need for offline cleaning entirely. In addition, some of the techniques discussed later to increase the period between cleans, such as increasing the duration of the relaxation periods or flushing with permeate will decrease the average hydraulic throughput – reducing safety margins further but extending the time between shut-downs.

3 PROPOSED PROCESS

Scottish Water has proposed to replace the existing MBR with an entirely new system comprising:

- Septic tanks
- Disc filter
- Ultraviolet (UV) light disinfection

The proposal is to be backed up by Process Guarantees from the suppliers indicating they are satisfied the process will perform as designed. While our review has recognised this, to our knowledge, this is not a tried and tested combination of processes, so we note the following potential risks:

- The ability of the proposed disc filter to handle the level of solids likely to be present in septic tank effluent.
- The ability of a UV disinfection system to operate successfully in wastewater that has not been biologically treated due to poor UV transmissivity.

These items are considered further below.

3.1 Septic tank review

Septic tanks are Scottish Water's standard process to achieve the licensed effluent quality (excluding the bacteriological standards anticipated) and if sized, operated and maintained properly are readily able to achieve this through settlement and anaerobic breakdown of the settled matter. The addition of disc filters will act to reduce suspended solids further.

3.2 Disc filter review

Disc filters are typically used as a polishing stage to remove low concentrations of solids from biologically treated wastewater. As the filter sections become blocked with solids they are rotated out of the wastewater and washed clean, typically using the filtered effluent.

The proposed disc filter in the design prepared for Scottish Water is an Ultrascreen Disk Filter by Xylem, which is also supplying the proposed UV system. This particular type of disc filter is designed to be able to handle peaks in incoming solids up to 150mg/l, which will be sufficient to handle septic tank effluent. It is not known how well the proposed unit performs when exposed to an influent containing a continually high solids concentration as the filter sections will block more quickly and will therefore require more frequent cleaning. If the filter was on a tertiary system, the effluent is normally suitable for use for cleaning the filters. As the filter follows a primary process, the effluent may not be clean enough to use as a wash water; it may require further treatment before being used or potable water may be required instead.

Scottish Water has operated disc filters on primary settled wastewater at Lochgilphead for more than 15 years and has not reported any significant issues indicating that these could be operated successfully at Gairloch. The supplier was approached for evidence of a track record of their disc filters in this application but has not responded during the preparation of this report. It is important to understand the opex impact if the disc filter is exposed to a continually high incoming solids concentration.

3.3 UV disinfection review

As with disc filters, UV is more typically used on effluent that has been aerobically treated and possibly also a tertiary solids removal process. Aerobic treatment removes dissolved and colloidal organic matter from wastewater which improves transmittance of UV through the water and allows more effective disinfection. The lower effluent solids concentration also helps prevent bacteria from hiding behind particles thus ensuring that the UV reaches them. The suppliers process guarantee for the disc filter performance shows confidence that it will remove the effluent solids to a level that reduces the possibility of the bacteria hiding from the UV.

In recent years, UV disinfection has been used on combined sewer overflows (CSOs) where the initial discharges could be similar in composition to crude sewage. The systems used for these tend to have higher numbers of lamps, more closely spaced and with turbulence inducing features to ensure that all the flow is presented to the lamps.

Scottish Water has undertaken various dispersion modelling studies to understand the impact of the discharge on bathing water quality in the area. These studies identified that, due to dilution and dispersion at the outfall, 'excellent' bathing water quality would be achieved within 100m of the outfall provided the faecal coliforms were brought to below 1×10^4 colony forming units (cfu)/100ml in the effluent from the WWTW. Discharge directly from a septic tank which typically contains around 1×10^6 cfu faecal coliforms/100ml would not achieve 'sufficient' bathing water standard until nearly 5000m from the outfall. The closest point of the nearest bathing water is approximately 1500m from the current discharge location.

It should be noted that since this exercise was undertaken, the monitoring parameters for bathing water quality have changed from faecal coliforms to intestinal enterococci and *E. coli.* The principle is the same however in that discharge directly from a septic tank would adversely affect bathing water quality but reducing the licensed species to 1×10^4 cfu/100ml by either disinfection or providing a barrier to their discharge would result in excellent bathing water quality within a short distance of the outfall.

The system proposed in the design prepared for Scottish Water is the Wedeco TAK 55 system by Xylem. The supplier has been approached for evidence of a track record of UV in this application. It has noted that UV disinfection of septic tank effluent is unusual so could not provide specific site references but has based its recommendations and process guarantee on a bank of bioassay data collected over many years and from many other applications in other scenarios.

The supplier has offered to guarantee an *E. coli* target of 1×10^4 cfu/100ml provided that (among other things):

- the incoming *E. coli* does not exceed 1 x 10^7 cfu/100ml,
- the suspended solids in the feed does not exceed 200mg/l,
- the particle size of the suspended solids does not exceed 3mm and
- the UV transmittance (UVT) is not less than 40%.

As noted previously the incoming *E. coli* concentrations are likely to be much less than 1 x 10^7 cfu/100ml and the suspended solids target will be readily achievable if the upstream processes are working as designed. Scottish Water has undertaken particle size analysis at other sites in the area and has found that typically the particles are less than 0.1mm and all were below 0.5mm. It is not clear what the UVT of the septic tank effluent will be but based on standard literature values for primary tank effluent there is a risk that the UVT may not be sufficiently high to meet the process guarantee.

A number of safeguards have been built into the design that will reduce the risk of the process not achieving the required standards.

- The UV supplier has noted that the UV system has been designed to meet the guaranteed effluent quality based on presenting it with effluent directly from the septic tank and the inclusion of the disc filter should result in a bacteriological quality better than that guaranteed.
- The disc filter should provide some improvement on UVT over septic tank effluent alone although there is a risk that it does not meet the minimum requirement of the guarantee. Measuring the UVT from a range of other SW septic tank effluents would confirm if the expected UVT is within the guarantee range.
- Scottish Water has indicated that SEPA has recommended bacteriological standards of 3.5 x 10^4 cfu/100ml *E. coli* and 3.5 x 10^4 cfu/100ml intestinal enterococci both of which are less stringent than the supplier has indicated it is prepared to guarantee and should readily achieve the discharge requirements and hence ensure excellent bathing water quality.

The supplier's quality requirements make no mention of the salinity of the influent. In general salinity itself does not cause issues with UV disinfection but special consideration will need to be given to the materials of construction.

3.4 Process risk mitigation

Given that there are some uncertainties when working with a new process and, should the process not produce the required effluent standard, we have examined what 'bolt-on' process could be added to bring the performance to the standard required.

A SAF process unit could be installed between the septic tank and the disc filter. There is space available in what will be the redundant MBR tanks to install this unit along with inter-stage pumps required to forward the flow. The power supply to the site is unlikely to be compromised as the overall power consumption of the new process is less than that required for the MBR.

4 REVIEW OF OPTIONS

Scottish Water is funded through customer charges and is required to ensure best value from its investment programme. Scottish Water uses a hierarchy of interventions in its planning process to consider how to achieve required objectives at the lowest whole life cost and carbon. The hierarchy is:

- Accept
  - Doing nothing (or very little) and continuing with the status quo. Scottish Water considers both the current and future risks associated with the existing assets.
- Operate
  - Introducing operational changes to the existing assets. Scottish Water considers the risks associated with proposed changes and how sustainable the operation is for the future.
- Innovate
  - Implementing innovative solutions. Innovative solutions typically are new to market or new to Scottish Water. These offer the potential for cost savings or improved performance but are not widely tested. In these cases, Scottish Water considers the opportunity offered and the risks involved with using new technologies.
- Excavate
  - Constructing conventional tried and trusted solutions in line with its company specifications and standards policy. This sets out the types of assets that are proven to be appropriate under different circumstances.

4.1 Accept

For the previous year (May 2017 – May 2018), the MBR is meeting its hydraulic discharge licence requirements, in that 8 L/s is being passed forward for treatment; however, based on the average flow data provided, Scottish Water would have difficulty complying with this condition when a membrane train is offline for maintenance. We have identified operational changes which are likely to reduce the rate of membrane fouling (potentially only marginally) and increase the time between train shut-downs. However, the forecast maintenance duration period is longer than the allowable membrane peak flow operating period, so non-storm overflows are likely to occur (SEPA non-compliance).

The current compliance has been achieved with significant investment to manage network inflow and infiltration reduction works. Due to Gairloch's sewer network properties (low lying, coastal, and old) it is expected that any inflow/infiltration mitigation works will only have a temporary effect. Continued management is likely to involve significant ongoing investment to maintain the inflow/infiltration at current levels. There is currently no hydraulic capacity to accept additional connections or businesses within the catchment.

Membrane performance deteriorates over time and membrane replacement is an ongoing and periodic requirement of any membrane plant. It involves significant capital maintenance investment. Membrane bioreactor reactor plants were a relatively new technology when they were introduced at Gairloch. Experience has shown that they have limitations, such as rigid effluent flow rates and high operating costs. They continue to be successfully used around the world where their limits are offset by their advantages, such as a small footprint, rigid effluent quality, and the ability to retain bacterial contaminants. However, in our opinion (and with hindsight) an MBR system is not the appropriate technology for Gairloch – a catchment with relatively dilute and variable wastewater flows and discharge licence conditions that are not particularly onerous.

4.2 Operate

Some operational improvements have been identified which may increase the time period between maintenance shut-downs; however, these will not eliminate the need for offline maintenance. The main interventions (the numbered elements) are listed in order of likelihood of positive effects.

4.2.1 Braid management

- Install a 1mm one dimensional screen with a 90° flow change, such as an inclined drum screen
- Schedule regular mechanical drawdowns and membrane cleans triggered on DP trends or review of the scour air bubble patterns
- Reconfigure the coarse air pipework for periodic permeate flushes
- Return a fraction of the recycled sludge flowrate through the inlet screen
- Promote braiding on removable and cleanable surfaces, such as on CopaSacs and mesh structures

4.2.2 Solids management

- Maintain the suspended solids at between 10,000 - 12,000mgMLSS/L (the target concentration should be adjusted to reflect the sampling location: 10,000mg/L at the inlet end of the MBR and 12,000mg/L at the downstream end of the MBR).
- Increase the sludge recycle from approximately 0.5 – 1 times the inlet flow to 2 – 4 times the influent flow. We expect that currently some of the membranes will be operating outside of their optimal solids range due to a high solids concentration gradient along the tank.
- Optimise the relaxation phases based on differential pressure (DP) trends. Increasing the relaxation periods and frequencies generally decreases the rate of fouling; however, this is done at the expense of hydraulic throughput, as water cannot be produced during relaxation. Optimal relaxation is a balance of fouling vs. throughput.

4.2.3 Other foulants

- Trend the DP sensors on SCADA to allow the reversible and irreversible fouling rates to be identified and tracked. The DP deterioration can then be compared against the following data:
  - Conductivity to determine salinity effects
  - SRT/MLSS concentration to identify the optimal summer and winter operating zones

- Compare influent flow rates against fouling to test for potential unbound influent particle fouling or to identify specific fouling events

- Unbound influent particles
  - Increase sludge recycle to provide more sludge blending
  - Include an anoxic zone for blending and pH management
  - Conduct bench scale testing to determine the potential effects of unbound particle fouling effects
- Unknown foulants
  - Perform membrane autopsies. Unknown foulants are considered unlikely due to the nature of the wastewater catchment.

The MBR system lacks sufficient standby capacity for the membrane system. Typically, this would be mitigated by providing an additional membrane train (increasing the number of membrane trains from two trains to three trains); however, the WwTW appears to suffer from two conflicting constraints due to its relatively dilute influent water. It has insufficient hydraulic capacity to maintain the flow throughput and insufficient influent load to maintain the mixed liquor concentration within the desired range without excessively long sludge ages.

Adding a third reactor would satisfy the hydraulic constraint but increase the sludge age by 50% (assuming the same mixed liquor concentration is maintained). The sludge age is already excessive in winter. Increasing the sludge age further may significantly increase the fouling rate of the membranes and increase by 50% the already high running and capital maintenance costs (in comparison to other technologies available to meet the discharge licence conditions). The conflicting constraints (hydraulic and load) therefore make the addition of a third train technically unsuitable.

4.3 Innovate

At the time the existing MBR was constructed it would have been considered an innovative centralised treatment solution. Operational experience across the water industry over time has uncovered many of the treatment issues with membrane plants that were not apparent in the early days of operation. We have not identified any alternative market ready single treatment process that has emerged since that would give the same benefits as an MBR in terms of providing a high level of treatment and a bacteriological barrier in a single unit. Typically, where a low bacteriological content is required in WwTW effluent (e.g. for Bathing Waters) this would be achieved through multi-stage treatment to progressively improve quality, normally culminating in UV disinfection.

While Scottish Water has been considering innovative options for rural communities these are also only at the early stages of development or trialling and are not market ready hence cannot be considered for implementation at this stage. If the trials are unsuccessful then these may never be suitable.

4.4 Excavate

Several potential "Excavate" options have been identified that were evaluated against the existing process at a workshop with Scottish Water stakeholders. These are shown in Table 4-1.

Table 4-1: Excavate options considered

Option	Description
Septic Tank/Disc Filter / UV (seasonal)	The current proposal.
Septic Tank/Disc Filter / UV (all year)	The current proposal but providing year-round disinfection to give bacteriological quality in the receiving water in line with the existing MBR process.
Current proposal plus secondary treatment e.g. SAF, trickling filter, reed bed/wetland before disc filter and UV (seasonal UV operated seasonally or all year)	Addition of secondary treatment to make overall effluent quality closer to that provided by existing MBR process and to improve UVT with sub-options of providing disinfection only during the bathing season or year-round as is the case with the existing MBR.
Oxidation Ditch/Final Settlement Tank (FST)/UV (operated seasonally or all year)	Provision of secondary treatment with fewer stages than the option highlighted above.
Extend outfall	Relocate discharge to a location where septic tank treatment alone is suitable without needing to disinfect.
Enhanced settlement as an alternative to septic tanks in the current proposal	Provision of an enhanced settlement process to improve effluent quality prior to UV disinfection to improve the chance of success.
An alternative disinfectant to UV in the current proposal	Chemical disinfection (e.g. chlorination or peracetic acid) or ozonation.

4.5 Discussion and workshop review

A workshop was held between Scottish Water and m^2 to discuss the technical findings of the MBR review and to compare Scottish Water's proposed solution (septic tanks → disc filtration → seasonal UV disinfection) with the other potential approaches or technologies outlined in Table 4-1.

The options were discussed and rated by group consensus as to whether they were potentially better or worse than the current proposal for eleven scoring criteria (based on Scottish Water's Customer Value System (CVS) decision maker).

The net result was that one option was recommended for further consideration (current proposal with seasonal disinfection) and two options (enhanced settlement and fixed film roughing filters) were recommended as risk management options, should the disc filter and UV disinfection systems under-achieve against their performance guarantees or the current influent sewage properties change.

A summary of the criteria findings is outlined in Table 4-2. The criteria are clarified below, along with more detail regarding the options considered.

4.5.1 CVS criteria

The CVS criteria considered are outlined below. These were discussed and applied during the workshop as high-level screening criteria to trigger discussion and debate. The CVS criteria were assessed using the following summary key:

- = Similar to current proposal

✓ = Better than current proposal

X = Worse than current proposal

✓✓/XX = Much better/worse than current proposal

Customers

Are Scottish Water's customers likely to consider this option as better or worse than what is proposed? The primary customers are those within Gairloch's potential sewer catchment. The workshop also considered Scottish Water's wider customer base whose projects and wastewater bills may be affected by the chosen option. It is understood that the community's lead concern is maintaining the perceived pristine nature of the water around Gairloch.

Reputation

Is Scottish Water's reputation likely to be damaged or enhanced by the option proposed? This is Scottish Water's reputation with its customers, its stakeholders, other water authorities, the governing bodies

Construction

Is the option easier or harder to construct than what is currently proposed? Constructability may be influenced by factors such as the available land area and ease of construction around, and then tying to, the existing infrastructure.

Timing

Is the option likely to be constructed faster or slower than the current proposed solution? Will the option have the potential to be constructed and commissioned prior to the next bathing season?

Maintenance

How much maintenance is likely to be required compared with the current proposal, both in terms of cost and personnel hours? How often are personnel required to undertake potentially hazardous maintenance activities? How reliable is the technology? How many parts are installed and how frequently are they expected to fail or require maintenance?

Operability

How difficult is it to optimise the compliant operation of the treatment system? Does the option require significant instrumentation and automation? Is frequent internal sampling and lab testing required? How much process scientist and operator time is required to adjust for daily and seasonal variability.

Flexibility

How flexible is the option in terms of changing flows/pollutant loads or tightened SEPA discharge limits?

Performance Certainty

How certain are we, compared to the current proposal, that the option will be able to meet the SEPA discharge licence limits under a range of conditions?

Sustainability

How do the options compare in terms of sustainability? This covers a wide range of sustainability criteria, such as embodied carbon, operational carbon footprint, the environment cost of treatment versus the cost to the environment of under-treatment.

Power

Is the option likely to be less or more power intensive than the current proposal? Power use is a key factor in sustainability, but it also directly impacts the local power infrastructure. A large power demand from the wastewater treatment plant may restrict power availability elsewhere, whether that is for existing services or proposed development.

4.5.2 Discussion of alternative treatment options

This technical review was primarily driven by the SEPA discharge requirements and the community's concerns regarding the degree of wastewater treatment provided. It is understood that:

- Technology is not the constraining factor for the WwTW. The technologies exist to meet the SEPA discharge requirements. The technologies also exist to meet the community's apparent quality goals.
- The primary treatment driver for SEPA and the community appears to be the management of microbial contamination.
- The key technical risks to be addressed for the current proposal are: will the disc filter be capable of filtering septic tank effluent without excessive backwashing and will the UV system be able to achieve the disinfection targets. Although the processes are not widely used in this combination, Scottish Water has significant experience of operating a disc filter on primary settled sewage and the UV supplier has extensive research experience of wastewater disinfection and the equipment suppliers intend to provide process guarantees.
- Seasonal or year-round disinfection is a separate discussion, as the SEPA requirements only stipulate bathing season disinfection limits. Technically all solutions are capable of being extended to year-round disinfection. However, year-round disinfection may result in additional equipment standby requirements, operating time/cost and additional carbon use that is not required to meet the environmental permit. Note - the extended outfall option is intrinsically a year-round solution, as, while not disinfecting, it aims to separate the wastewater derived microbes from special interest zones at all times. The technical review is primarily based on meeting Scottish Water's legal requirements. However, it is acknowledged that there is still an ongoing discussion between Scottish Water and the community between seasonal or year-round disinfection.

The basis of the consideration of alternative treatment technologies to address potential technical and community concerns regarding the current proposed solution (septic tank, filtration, then seasonal UV disinfection). The question considered was: are there treatment technologies which will better satisfy the constraints associated with the WwTW? The alternative technologies considered are discussed in greater detail below.

An assessment of the relative solids and bacterial loads to the environment for each option was made. These are described in Figure 4-1 and Figure 4-2. These show that Scottish Water's proposed option (septic tank, disc filter, UV disinfection) will significantly exceed the requirements of the consent. The current MBR effluent quality is better than the proposed solution but during maintenance there is a significant deterioration in the overall load to the environment.

Figure 4-1: Solids loads to the environment for the options reviewed

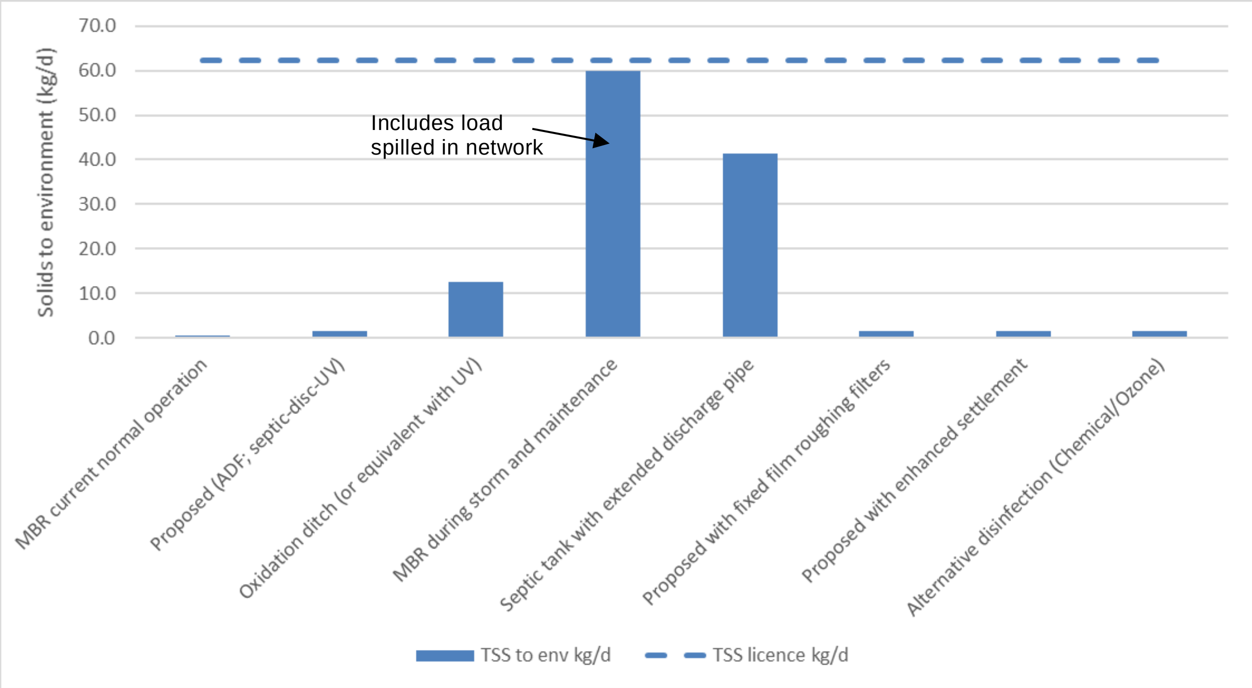
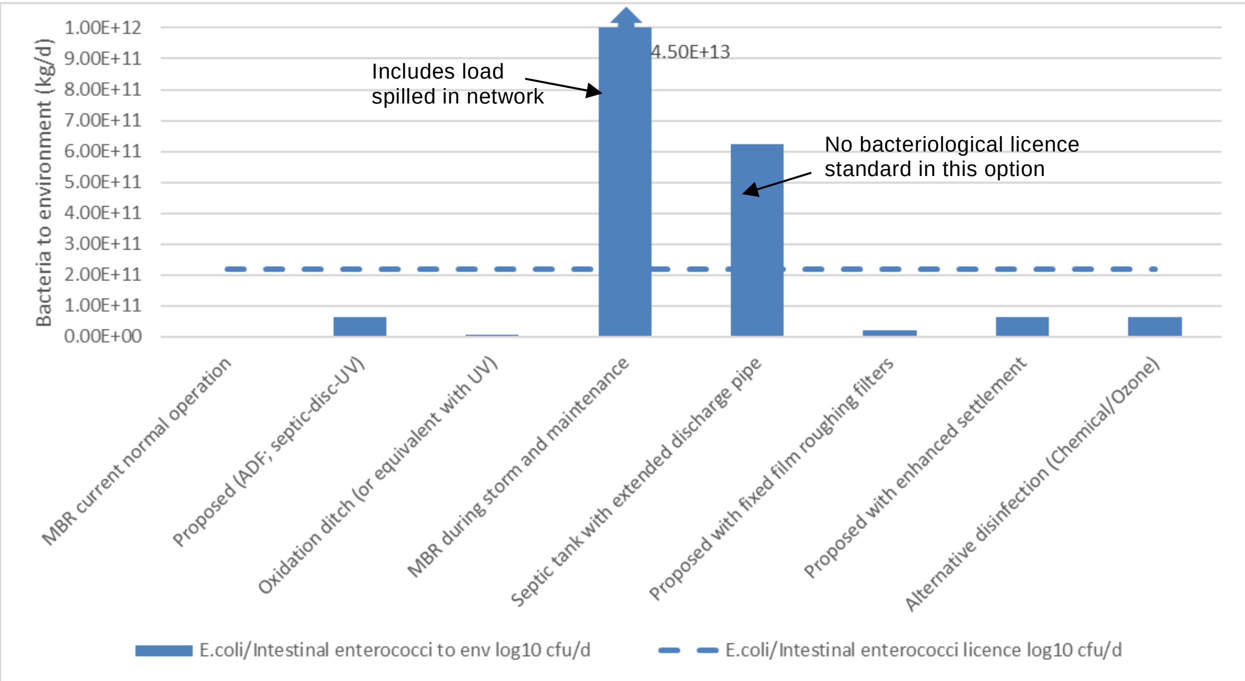


Figure 4-2: Bacterial loads to the environment for the options reviewed



4.5.2.1 UV disinfection (year-round)

Proposed process flow = Septic tanks → Disc filtration → UV disinfection (year-round)

Description of treatment system – The current proposal is for UV disinfection only during the bathing season (as per the SEPA licence conditions). The community has raised concerns that the waters around Gairloch are used year-round. This option proposes to provide year-round disinfection.

Advantages

- It addresses the community's concern regarding year-round bathing.
- It preserves Scottish Waters external reputation in terms of community engagement

Disadvantages

- It increases the annual operational period and therefore the maintenance requirements. It may require the installation of standby units, as originally routine maintenance was planned outside of the bathing season, when the disinfection was offline.
- It increases the annual operational period and therefore the monitoring, operating, and compliance obligations.
- It increases the power use and shortens the bulb life of the UV system (increased bulb replacement frequency). The carbon footprint is greater for this option.

Risks

- This option has the same risks as the proposed option described in Section 3. Operating the UV year round does not change these risks.
- During winter there are likely to be more frequent network overflows due to more frequent storm conditions. These are part of the normal operation of the network during prolonged rainfall and may be the dominant impact on the bacteriological quality of the bathing water. This may mean that the additional disinfection provides no material environmental benefit.

Verdict

- Technically feasible though not a regulatory requirement and may not provide a material benefit to the environment.
- Additional CAPEX may be required depending on Scottish Water's standby requirements.
- Not recommended for Scottish Water's consideration unless Scottish Water can offset the additional carbon and cost. The local community benefit case would have to be justified to Scottish Water's wider customer base, the WICS and the Scottish Ministers.

4.5.2.2 Activated sludge with UV

Proposed process flow = Septic Tank → Oxidation ditch (or similar activated-sludge-type plant) → Final settling tank → UV disinfection (seasonal)

Description of treatment system – Traditional secondary treatment process in which microbes are grown in the wastewater under aerobic conditions to convert wastewater pollutants into more benign by-products. This removes dissolved pollutants, improving the water clarity and the reliability of UV disinfection.

Advantages

- Traditional, well understood process. It is likely to be accepted by the community and to enhance Scottish Water's external reputation through the application of a widely accepted treatment technology.
- Generally produces a reliable effluent quality in terms of UV transmissivity (which would improve UV disinfection performance / reliability). It also removes organic load and water-borne solids.
- The activated sludge process typically removes 90% of the influent indicator microbes (a one log reduction) during the secondary process
- Activated sludge has the flexibility to meet tightening discharge conditions, such as nutrient limits

Disadvantages

- Difficult to construct around the existing plant. Activated sludge has a larger site footprint requirement than the current proposal.
- An activated sludge plant is considerably more complex than the current proposal and has increased maintenance and operation requirements. The treatment complexity tends to require standby units which further increases the maintenance requirements, footprint, operational complexity, and monitoring / testing requirements.
- An activated sludge plant is slower to build that the proposed solution and is highly unlikely to be installed prior to the 2019 bathing season leading to increased risk of overflows from the network due to reduced hydraulic capacity of the MBR.
- The sustainability is negative as an activated sludge plant would have a greatly increased carbon / energy footprint (in comparison to the current proposal), along with an increased sludge load to the nearest landfill or sludge treatment centre. This would increase the number of tanker movements to and from the WwTW.
- The local community may not welcome the presence of a larger site with a more wastewater treatment plant appearance, particularly on a site that is visible from the coast.
- This option would require ongoing network maintenance to minimise saline intrusion.

Risks

- Variable salinity could have a negative impact on settlement performance which would in turn either
  - disrupt the treatment performance of the ditch through loss of solids,
  - create a visible plume at the discharge point and/or
  - lead to failure of the UV disinfection process due to the concentration of solids passed to the UV system exceeding what it can tolerate.

Verdict

- This technology tends to be the current standard practice. It removes a number of other pollutants other than microbial contamination. However, it has a large footprint, is complex to maintain and operate, is vulnerable to salinity variations and has a high energy footprint in comparison to the current proposal.
- It is not considered appropriate for further consideration under the current discharge requirements.

4.5.2.3 Extend outfall

Proposed process flow = Septic tanks → Extended outfall pipe discharging further out into the loch

Description of treatment system – The influent wastewater would be settled and anaerobically treated in septic tanks. The effluent would then be discharged to the environment via an extended outfall pipe. The outfall pipe length and discharge location would be set to minimise the risk of bacterial contamination of the bathing waters. Essentially it would aim to replicate the current proposal by providing less treatment but more separation distance. The environment would be providing the necessary dilution and disinfection; however, the bacterial contamination would be greater at the point of discharge.

Advantages

- Once constructed it requires the least human intervention.
- Very low operation and maintenance requirements.
- It is the most sustainable solution provided that the environment has sufficient carrying capacity to absorb the pollutant loads without degrading the water quality.

Disadvantages

- Likely to degrade Scottish Water's external standing and further degrade its apparent standing with the local community.
- Not likely to be acceptable to the community, as a less-treated wastewater would be discharged into the loch. The discharge may have the same net effect on the bathing beaches but is likely to be perceived as more damaging in terms of the overall loch health.

- Modelling of optimum location and construction is likely to be slower to complete that the current proposed solution.

Risks

- A suitable location may not be identified without incurring excessive construction costs.
- There is a risk that additional treatment processes would still be required to achieve the required bathing water quality if this is not successful as it may be difficult to extend the outfall further.

Verdict

- Not recommended as it is likely to be unpalatable to customers and to Scottish Water.

4.5.2.4 Enhanced settlement

Proposed process flow = Enhanced settlement in septic tanks → Disc filtration → UV disinfection (seasonal or year-round)

Description of treatment system – Essentially the same as the current proposal but chemicals (such as ferric sulphate or poly aluminium chloride) would be dosed into the feed to the septic tanks to promote solids capture and settlement. This would reduce the solids load on to the disc filters and improve the water clarity for UV disinfection and address technical risks around the current proposed solution.

Advantages

- It reduces the technical risk around the performance of the disc filters and UV disinfection within the current proposal.
- It allows optimisation of the dosing to improve future performance.

Disadvantages

- It requires additional equipment which must be operated and maintained.
- It reduces the overall sustainability due to the ongoing consumption of chemicals
- It will lead to an overall increase in the amount of sludge produced which needs tankered away.

Risks

- Enhanced settlement does not reduce dissolved and colloidal organic matter sufficiently to increase UVT to a level adequate for disinfection.

Verdict

- It is not recommended now, as it effectively achieves the same net result, but with an improved performance reliability. However, it represents a relatively easy upgrade which could be implemented later should the suppliers be unable to meet their performance guarantees.

4.5.2.5 Fixed film roughing filters

Proposed process flow = Septic tanks → Fixed film with or without settling tank → UV disinfection (seasonal or year-round)

Description of treatment system – a fixed film process such as a trickling filter – where wastewater is trickled over media such as rocks – or a Submerged Aerated Filter (SAF) – where media is submerged in aerated wastewater – is installed downstream of the septic tanks to convert some of the dissolved pollutants into biomass which can then be settled or filtered out of the wastewater. This is intended to increase the performance of both the disc filter and the UV disinfection. The fixed film processes could potentially be operated with or without a final settlement tank.

Advantages

- It would reduce the technical risk of the proposed solution. It would improve the average effluent quality particularly through reduction of dissolved and colloidal substances that reduce UVT.
- It is less complex and less energy intensive than activated sludge
- It is more robust to salinity and flow variations than activated sludge
- This would be expected to reduce the microbial contamination by 0.5 – 1.0 log (30 – 90% reduction) within the fixed film process.
- It is likely to be acceptable to the community.
- It is likely to enhance Scottish Water's reputation.

Disadvantages

- This option will take longer to construct than the current proposed option.
- The addition of a fixed film process will increase the operation and maintenance requirements.
- It will decrease the sustainability due to the additional embodied carbon and the ongoing power costs (though these would be less than for an activated sludge plant).

Risks

- Wastewater salinity reduces effectiveness of biological treatment
- Seasonal sloughing of biomass creates intermittent high solids loads on downstream processes which reduces their effectiveness with a consequent impact on quality of water presented to UV disinfection

Verdict

- It is not recommended now, as it effectively achieves the same net result with improved reliability. However, it represents a relatively easy further upgrade should the suppliers be unable to achieve their warranty guarantees.

4.5.2.6 Chemical disinfection

Proposed process flow = Septic tanks → Chemical disinfection → Discharge

Description of treatment system – Dose the septic tank effluent with a chemical disinfectant such as chlorine or peracetic acid.

Advantages

- Achieves the disinfection target and is easily tuned

Disadvantages

- Unlikely to be acceptable to SEPA, as the industry has moved away from chemical disinfection of environmental discharges due to the discharge of potential disinfection by-products to the environment and potential disinfection of the wider environment due to residual disinfection power
- High chlorine dose is likely to be required to overcome the breakpoint chlorination of ammonia
- High potential environmental by-kill may result from peracetic acid discharge to the environment (peracetic acid residue may partially disinfect the receiving waters).
- Both chemicals have health, safety and environmental issues, particularly peracetic acid.
- Peracetic acid would require further DSEAR mitigations to enable safe operation.

Risks

- Disinfection by-products create greater environmental problems than the bacteria being targeted.
- Spillage and/or other uncontrolled release of chemicals during delivery and operation
- Health and safety risks to site operators through exposure or handling

Verdict

- Likely to be unpalatable to SEPA as less environmentally friendly and possibly the community.
- Not recommended for further consideration.

4.5.2.7 Ozone disinfection

Proposed process flow = Septic tanks → Disc filtration → Ozone disinfection (seasonal or year-round)

Description of treatment system – The septic tank discharge is disinfected by ozonation. The ozone is generated by the application of high voltages to oxygen. The ozone then is mixed with the water to be disinfected. Ozone tends to be consumed immediately and doesn't have a disinfection residue, so doesn't create environmental by-kill.

Advantages

- Immediate disinfection without residue
- It isn't affected by water transmissivity

Disadvantages

- It has a high-power demand.
- The wastewater may have a high ozone demand due to the presence of other contaminants.
- It is likely to require large and expensive ozone generators. Ozone generators tend to look industrial in style and may not be in keeping with Gairloch's landscape.
- It is not considered sustainable due to the high energy demand.
- Possible community concern regarding the risk of ozone escape.
- HSE obligations and DSEAR implications around ozone generators.

Risks

- Potential for ozone release to the atmosphere
- Health and safety risks to site operators through exposure

Verdict

- Not recommended due to the site aesthetics, health and safety risks, high-power demand, and high running costs.

4.5.3 Workshop technical summary

The workshop took the current proposal as a base (septic tank, disc filter and UV). Eight alternative treatment approaches were considered during the workshop discussions. Six of the alternative approaches were found not to be suitable for further consideration for reasons, such as technical infeasibility or the lack of competitive advantages. Two options, enhanced settlement and fixed film secondary treatment, were recommended as add-on corrective options should the disc filters and UV disinfection fail to meet the suppliers' performance guarantees.

A summary of the options considered is presented in Table 4-2

Table 4-2 Workshop option summary

Options	Septic Tank/ Disc Filter/ UV (all year)	Oxidation Ditch/ FST/ UV (seasonal)	Extend discharge pipe	Enhanced Settlement	Fixed film roughing filter	Chemical Disinfection	Ozonation
Option reference	1	2	4	5	6	7	8
Customers	✓	✓	X	-	✓	X	Uncertain
Reputation	✓	✓	- X	-	✓	X	-
Construction	-	X	-	-	-		-
Timing	-	X	X	-	X		-
Maintenance	X	X	✓	X	X		X H&S
Operability	X	X	✓	X	X	X Dangerous Chemical PAA	X H&S
Flexibility	-	✓	✓	✓	-		-
Performance Certainty	-	✓	✓	✓	✓		-
Sustainability	X	-	✓	X	X	X	-
Power							X
Verdict	Not recommended w/o carbon offset	Reject	Reject	Monitor	Monitor	Reject	Reject

Key	✓	Better than current proposal	Worse than current proposal	-	Similar to current proposal	✓✓/XX	Much better/ worse than current proposal

5 CONCLUSIONS

Following our review, we have concluded the following:

- The existing MBR appears to have sufficient capacity to treat the current flows when both trains were online and the membranes were unfouled; however the existing plant is suffering from braiding and fouling and non-optimal solids management that leads to an increased maintenance requirement. There is minimal safety factor in the design, little or no capacity for catchment growth, little or no capacity to accept increased infiltration of groundwater or seawater into the system, and insufficient hydraulic capacity when one process train is taken offline for necessary maintenance.
- Opportunities were identified, involving both operational and equipment changes, to gain a marginal performance improvement through the optimisation of solids management. However, it was noted that these actions would only (potentially marginally) extend the time between offline maintenance events, it would not eliminate the need entirely, leaving Scottish Water exposed to the risks of untreated sewage overflows from the network during maintenance periods.
- Despite efforts by Scottish Water to remove saline intrusion the network is subject to saline intrusion particularly during high tides which may be having a negative impact on the performance of the MBR and increase the likelihood of spillage from the network in dry weather.
- The proposed replacement process of septic tanks, disc filter and UV disinfection has been designed to achieve the required effluent quality, which in turn will be capable of ensuring “excellent” bathing water quality at the designated beaches. The proposed system should achieve an effluent quality much better than required by the license. As this process combination is unusual, there is a risk that the requirements of the process guarantees will not be met in which case it would be relatively straightforward to retrofit additional processes to improve treatment prior to disinfection.