ISLE OF ARRAN DISTILLERY
PROPOSED LONG SEA OUTFALL

Application to SEPA for a complex discharge license
(Supporting information)

Water Environment (Controlled Activities) (Scotland)
Regulations 2011 (CAR)

Arising from
European Union Water Framework
Directive (WFD)
**Isle of Arran Distillery and Visitor Centre, situated in the village of Lochranza, Isle of Arran**

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<td>Supporting information for SEPA discharge licence application</td>
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<td>Version:</td>
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<td>Date written:</td>
<td>Wednesday 8th February 2017</td>
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https://www.dropbox.com/sh/p7tmlo26wquxsrm/AABj0jlaCdyWp1PAGMifKXzga?dl=0

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Table 3. Data and media files associated with this application – various formats
1.0 EXECUTIVE SUMMARY

The Isle of Arran Distillery is a small whisky distillery located in the village of Lochranza, Isle of Arran. As a by-product of the whisky production process the distillery produces a cereal-based trade effluent at a rate currently averaging 34m³ per day. The current method for disposal of this effluent involves haulage of the effluent by road tanker to the south end of the island and disposal there by spreading on fields. This method has proved to be problematic and is becoming increasingly unsustainable. An alternative trade effluent disposal method for the Isle of Arran Distillery is required.

Alternative methods of effluent disposal were investigated in the period 2013 – 2015. These investigations focused on anaerobic digestion and microfiltration techniques, and installation of a long sea outfall. It was found that a long sea outfall was the only feasible option on grounds of cost, reliability and environmental impact. Using a long sea outfall to dispose of distillery trade effluent at sea is a long established and well studied method, and is the normal method of effluent disposal for coastal distilleries.

A suitable remote outfall site was identified at Rubh Airigh Bheirg, near Lennimore on the northwest coast of Arran, 4.7 miles south of the distillery by road. The site provides ready access to the deep open water and tidal flows of the Kilbrannan Sound. The site is classified as undeveloped coast, and is located in a National Scenic Area. No other special conservation, archaeological, or fisheries designations apply to the site. Planning permission to construct an outfall at the site has been received from North Ayrshire Council.

Investigative work including site surveys, effluent analysis, predictive dilution modelling, and outfall system design has demonstrated that installation of a long sea outfall at Rubh Airigh Bheirg is feasible. It will provide an effective means of trade effluent disposal for the Isle of Arran Distillery, with minimal and acceptable levels of environmental impact.

The siting and design of the proposed outfall system seeks to minimise the environmental impact of construction works, minimise aesthetic impact of the completed facility, and use best available technology/methodology to minimise the environmental impact of the discharged effluent. The proposed outfall system consists of the following five main elements:

Located within the existing distillery plant at Lochranza:

- **Effluent management system** – effluent formulation and storage system optimised to ensure the effluent is balanced, filtered, mixed, and volumetrically buffered against concentration spikes of environmentally significant constituents. This will ensure the effluent has a consistent composition and is environmentally benign.

- **Effluent tanker** – dedicated road tanker with 30,000 litre capacity, will transport trade effluent from the distillery in Lochranza to the outfall site and connect to the outfall headworks to discharge through the outfall. Between one and two effluent tanker loads will be discharged through the outfall system per distillery production day.

Located at the proposed Rubh Airigh Bheirg long sea outfall site:

- **Outfall headworks** – incorporating a screened tanker turning area and small, secure pump cabinet housing an effluent discharge management system. The discharge management system controls, monitors, records and samples each discharge. The system is automated, fail-safe, and is remotely monitored from the distillery in Lochranza via a GPRS internet data connection.

- **Outfall pipeline** – the 110mm diameter outfall pipeline extends 207m seaward from the pump cabinet, terminating on the seabed at a depth of 20m below chart datum. The onshore and foreshore crossing sections of the outfall pipeline will be contained within a buried duct, so will not be visible at any state of the tide. Where the pipeline crosses the seabed, it is secured in place by pre-cast concrete pipeline and terminal anchors.

- **Multiport outfall terminal** – the outfall outlet consists of 2No. outlet ports located on the seabed 25m apart, connected to a flow splitter on the seaward end of the main pipeline with 90mm diameter feeder pipes. The outlet ports are fitted with diffuser valves. These valves are operated
by the power of the discharge pump within the headworks. The power is transmitted to the valves hydraulically and actuates the valves, ‘power-mixing’ discharging effluent with ambient seawater to enhance initial dilution.

The location and design of the proposed outfall means effluent dilution standards, specified by SEPA, will be exceeded at all times. Specifically, the standard for the level of dilution the plume must receive as it rises from the seabed to the surface (initial dilution factor) will be exceeded by more than 13 times the required standard. The standard for the level of dilution the plume must achieve once it has traveled 100m from the surfacing position (secondary dilution) will be exceeded by more than 6 times the required standard.

Conservative methods were used in all calculations, analysis and dilution modelling work. Nonquantified factors such as the effect of installing diffuser valves will further enhance the environmental performance of the outfall, over and above the predicted levels.

The outfall will be operated on a ‘anytime’ discharge timing basis, with a ‘bleed-out’ discharge rate of 2.8 litres per second. A single full tanker-load of effluent will require 3 hours to discharge at this rate. A maximum of two tanker loads (60m³) will be discharged in any one 24hr day. The annual average discharge volume will be about 34m³ per day.

To safeguard the receiving environment and to monitor any impact from the outfall, the discharge effluent will be monitored and the outfall site will be surveyed and sampled on an ongoing basis. The main activities relating to this are summarised below:

- **Testing dilution predictions** - dilution and dispersal predictions will be checked under real operating conditions during outfall commissioning. Fluorescent dye tracing techniques will be used to map plume concentrations and extents in varying tidal conditions.

- **Effluent monitoring** - discharged effluent will be continuously sampled by a flow-proportionate autosampler, and daily composite samples stored for analysis. Measures allowing collection of occasional instantaneous samples of the discharge effluent will also be in place.

- **Seabed monitoring** - ongoing monitoring of the seabed and shoreline in the area of the outfall will be carried out on an annual basis. This will include visual seabed habitat dive surveys, and analysis of samples of sediment, flora and fauna for enrichment of copper and/or organic carbon.

The proposed long sea outfall is a necessary development which provides environmental advantages over the existing effluent disposal method, and will cause minimal and acceptable levels of environmental impact. This document, together with associated information, lays out the case for a SEPA discharge license to be granted under the Water Environment (Controlled Activities) (Scotland) Regulations 2011 (CAR).
2.0 PARTIES INVOLVED

2.1 APPLICANT
Applicant: Isle of Arran Distillers Ltd (IAD)
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Web: www.arranwhisky.com
Ref: Proposed long sea outfall

2.2 AGENT/CONTRACTOR
Agent/contractor: C D Campbell Marine Contracts (CMC)
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Email: info@campbellmarine.co.uk
Web: www.campbellmarine.co.uk
Ref: IAD-OUTFALL-2017-RPT-003

2.3 DILUTION MODELLING CONSULTANT
Modelling consultant: Partrac Ltd
Address: 440 Baltic Chambers
50 Wellington Street
Glasgow G2 6HJ
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Email: glasgow@partrac.com
Web: www.partrac.com
### CONSULTEES & CONTRIBUTORS

Parties who advised or contributed information during the development of this proposal are listed below in Table 4. Contribution of information in no way implies that consultees support the objectives or findings of this proposal.

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Table 4. Individuals and organisations who have contributed information to this report
3.0 INTRODUCTION

3.1 BACKGROUND

The Isle of Arran Distillery is a traditional small whisky distillery situated in the village of Lochranza on the northwest coast of the Isle of Arran. The distillery has produced Scotch whisky from raw natural ingredients since its establishment on the site in 1995.

The distillery is owned and operated by the Isle of Arran Distillers Ltd. It is a significant contributor to the fragile local economy, being the largest employer and one of the main tourist attractions on the island. The distillery is also of importance to the wider UK economy, due to the high-value duty paid on its products, much of which is exported to overseas markets.

An efficient operation with minimal and acceptable levels of environmental impact is important to the distillery in view of its remote location and spectacular environmental setting. Marketing of the distillery’s product also relies heavily on the consumer’s perception of a pristine natural environment in which the whisky is produced.

The distillery currently disposes of its cereal based trade effluent (approximately 34 m³/day) by hauling it to the south end of the island in road tankers where farmers spread it on their fields. This is carried out under Waste Management Licensing (Scotland) Regulations 2011, as an exempt activity; ‘Spreading of distillery waste for agricultural benefit’. Current farm licencing details are shown below in table 5.

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Table 5. Farms currently used for licenced disposal of effluent by spreading on land

This method of trade effluent disposal has proved to be problematic due to the following issues;

- **Weather dependence** - during wet weather farmers do not want heavy vehicles operating on their ground, subsequently causing shut-downs in distillery production and production targets not being met.

- **Damage to roads** - impact of the effluent tanker on local transport infrastructure, which was not designed or built to handle haulage on this scale.

- **Road safety** - road safety issues exist relating to use of the effluent tanker on some stretches of Arran’s roads, particularly during the busy tourist season.

- **Cost and environmental impact** - the cost and environmental impact of ‘long-haul’ road transport to the south of the island is high.

- **Limited capacity** - the distillery wishes to increase production, but cannot do so while using the current effluent disposal method which struggles to cope with current production levels.

A reliable alternative method of trade effluent disposal is required to ensure the safe operation and future viability of the Isle of Arran Distillery.
3.2 ALTERNATIVE EFFLUENT DISPOSAL OPTIONS

Alternative effluent disposal methods were investigated in 2013, individually and in combination, and are summarised below:

- **Anaerobic digestion** – in-plant biological treatment of effluent to produce bio-gas, with waste water discharged into a river outfall

- **Microfiltration** – in-plant mechanic treatment of effluent, with solid residue exported off the island for processing and waste water discharged to river outfall

- **Evaporation** – in-plant concentration of effluent by evaporation, with solid residue exported off the island for processing

- **Reed bed treatment** – Extensive reed beds created adjacent to the distillery as a physical and biological filter, with waste water discharged to river outfall

- **Direct long sea outfall** – discharge of trade effluent to sea from the distillery plant through a long sea outfall, with an outlet located in the Kilbrannan Sound off the entrance to Loch Ranza

- **Remote long sea outfall** – discharge of trade effluent to sea from the distillery effluent tanker through a remote long sea outfall, with the outlet located in the Kilbrannan Sound to the south of Loch Ranza

Initially, a combination of anaerobic digestion and microfiltration techniques was selected as the preferred option for disposing of the distillery’s trade effluent. After further investigation and laboratory trials, this in-plant processing option was proven not to be feasible. The main reasons for this are cost, and the difficulty of maintaining an AD plant which can reliably operate on the relatively low volume intermittent output from the distillery. Disposal of residues from the system was also problematic.

At the end of their investigations the Isle of Arran Distillers found that a remote long sea outfall, discharging into the Kilbrannan Sound, was the only feasible option on the grounds of cost, reliability and environmental impact.

Discharge to sea has been the normal method for coastal distilleries to dispose of their trade effluent for several hundred years. Prior to the 1990’s, this discharge was unregulated and usually was piped directly to the shore. There was little significant environmental impact from this method other than localised pooling of effluent on the foreshore between tides, and some very happy ducks!

Over the last 30 years, environmental impact assessment work has been undertaken by the distilling industry together with SEPA and its predecessors, cumulating in the Loch Harport Studies in 1999/2000. This work has informed development of SEPA technical guidelines for the design and operation of distillery trade effluent outfalls (2002). It has shown that with sufficient dilution, toxicity of distillery trade effluent can be avoided with the initial buoyant discharge plume.

Today, the discharge of distillery trade effluent to the sea is required to be through long sea outfalls, and discharges must meet stringent Environmental Quality Standards (EQS) and aesthetic conditions. Distillery trade effluent outfalls are regulated and monitored by SEPA under the Water Environment (Controlled Activities) (Scotland) Regulations 2011 (CAR), arising from the European Union Water Framework Directive (WFD).

3.3 SITE SELECTION

The site proposed for a remote long sea outfall is located at Rubh Airigh Bheirig on the northwest coast of Arran, 4.7 miles south of the distillery by road, see location drawing IAD-OUTFALL-2017-DRW-001. The main attributes of the site that make it suitable for construction and operation of a long sea outfall are summarised below;
• Availability of land & foreshore - the landowner has agreed to the use of the land and foreshore area required for the outfall headworks and road tanker access.

• Access - there is existing private road access to the shoreline off the seaward side of the A841, with sufficient visibility splay for safe road tanker access and egress from the site.

• Road safety - the section of road between the distillery in Lochranza and the outfall site is suitable for safely operating the distilleries’ effluent tanker.

• Screening - existing topography and vegetation affords the site partial screening from the road.

• Designations - there are no special nature conservation, archaeological, or fisheries designations at the site which would prevent its development.

• Conflict with fishermen - the site is located in an area of coastline which is not heavily dredged for scallops, whereas large portions of the west coast of Arran is heavily dredged. Scallop dredging would demolish an outfall pipeline if it occurs across the route of the pipeline.

• Coastal geomorphology - the site is located in an open coastal setting, away from embayments, coastal promontories, and river discharges, all of which can inhibit dilution and dispersal of effluent.

• Bathymetry/hyromorphology - the site is located on the edge of a very deep straight of the Kilbrannan Sound, which reaches depths of more than 150m, giving direct access to large volumes of tidal water. Deep water (50m depth contour) is closer to the shore at this site than at almost any other location within the Firth of Clyde region.

The proposed site compares favourably in terms of its dilution and dispersal potential to many existing distillery trade effluent outfalls on which the author has experience of working, and which have had a track record of trouble-free operation over many years.

3.4 OUTLINE DESIGN

The design of the proposed outfall system requires the improvement of existing road access to the site, and construction of a tanker turning area, pump cabinet, and a buried outfall pipeline crossing the foreshore and extending a further 115m offshore across the seabed to a depth of 20m below chart datum. See Figure 1 below.

The design seeks to minimise the environmental impact of construction works, minimise aesthetic impact of the completed facility and use the best available technology/methodology for minimising environmental impact of the discharged effluent. The proposed outfall system consists of the following six main elements;

Located within the existing distillery plant at Lochranza:

• Effluent management system - effluent formulation and storage system optimised to ensure the effluent is balanced, filtered, mixed, and volumetrically buffered against concentration spikes of environmentally significant constituents. This will ensure the effluent has a consistent composition and is environmentally benign.

• Effluent tanker - dedicated road tanker with 30,000 litre capacity, will transport trade effluent from the distillery in Lochranza to the outfall site and connect to the outfall headworks to discharge through the outfall. Between one and two effluent tanker loads will be discharged through the outfall system per distillery production day.

Located at the proposed Rubh Airigh Bheirg long sea outfall site:

• Outfall headworks - incorporates a screened tanker turning area and small, secure pump cabinet housing an effluent discharge management system. The discharge management system contols,
monitors, records and samples the discharge. The system is automated, failsafe, and is remotely monitored from the distillery in Lochranza via a GPRS internet data connection.

- **Outfall pipeline** – the 110mm diameter outfall pipeline extends 207m seaward from the pump cabinet, terminating on the seabed at a depth of 20m below chart datum. The onshore and foreshore crossing sections of the outfall pipeline will be contained within a buried duct, so will not be visible at any state of the tide. Where the pipeline crosses the seabed it is secured in place by pre-cast concrete pipeline and terminal anchors.

- **Multiport outfall terminal** – the outfall outlet consists of 2 No. outlet ports located on the seabed 25m apart and connected to a flow splitter on the seaward end of the main pipeline, branching into 90mm diameter feeder pipes. The outlet ports are fitted with diffuser valves. These valves are operated by the power of the discharge pump within the headworks. The power is transmitted to the valves hydraulically, actuating the valves and mixing discharging effluent with ambient seawater to enhance initial dilution.

- **Navigation marker buoy** – moored seaward of the multiport outfall terminal, will mark the position of the outfall to mininimise risk to the outfall from anchoring and fishing vessels.

### 3.5 PREPARATION OF THIS PROPOSAL

A summary of the timeline and method for the development of this proposal is set out below:

- **2013 – Investigation of alternative methods** – desk-based study of in-plant and sea outfall methods for disposal of trade effluent

- **2013 – Anaerobic digestion and microfiltration trials** – effluent processing trials and analysis

- **2014 – Baseline outfall site survey** – initial site investigation of proposed remote outfall site, including bathymetric and topographic surveys, sidescan sonar survey, and diver seabed transects

- **2014 – Effluent analysis** – composition and density analysis of trade effluent, distillery freshwater supply, and seawater, utilising 2 No. independent laboratories

- **2014 – Outfall site investigation & outfall design** – deployment of current tracking drogues, tide gauge, “tell-tale” buoys, diver video/photo seabed transects, onshore and seabed ecology surveys, onshore and seabed geotechnical investigation.

- **2015 – Dilution survey & modelling** – deployment of current tracking drogues, AWAC current meter, tide gauge, dilution modelling using USEPA Visual Plumes

- **2016 – Outfall system detail design & consent** – planning permission obtained in 2016, seabed and land leases secured, other consents pending

All spatial site information collated during the project has been input into a GIS file, see figure 1, 2 and 3 for examples of data managed within this system.

The main interested parties consulted in the course of developing this proposal are below shown in table 6. They include all governmental agencies responsible for enforcing regulations, UK acts and EC directives applicable to the proposed outfall.

<table>
<thead>
<tr>
<th>TYPE</th>
<th>PARTY</th>
<th>INTEREST</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regulating Agency</td>
<td>Marine Scotland</td>
<td>Environmental impact of outfall</td>
</tr>
<tr>
<td></td>
<td>Scottish Environment Protection Agency (SEPA)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Scottish Natural Heritage (SNH)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Northern Lighthouse Board (NLB)</td>
<td>Safety of navigation</td>
</tr>
<tr>
<td></td>
<td>Maritime and Coastguard Agency (MCA)</td>
<td></td>
</tr>
<tr>
<td>CONSENT</td>
<td>ORGANISATION</td>
<td>REFERENCE No.</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>-----------------------------</td>
<td>---------------</td>
</tr>
<tr>
<td>Planning permission</td>
<td>North Ayrshire Council</td>
<td>N/16/00117/PP</td>
</tr>
<tr>
<td>Marine Licence</td>
<td>Marine Scotland</td>
<td></td>
</tr>
<tr>
<td>Navigation sanction</td>
<td>Northern Lighthouse Board</td>
<td></td>
</tr>
<tr>
<td>Discharge licence</td>
<td>SEPA</td>
<td></td>
</tr>
<tr>
<td>Seabed lease</td>
<td>Crown Estate</td>
<td>Crown BU-30-14</td>
</tr>
<tr>
<td>Land &amp; foreshore lease</td>
<td>Dougarie Estates</td>
<td></td>
</tr>
<tr>
<td>Navigation chart update</td>
<td>UK Hydrographic Office</td>
<td></td>
</tr>
</tbody>
</table>

Table 6. Parties consulted in the course of preparing this proposal

Statutory sanctions and other permission required to develop the outfall which are in place or have applications pending are shown below in table 7.
Fig 1 3D visualisation of proposed outfall site topography/bathymetry, with tanker turning area outlined in red, and route of outfall pipeline and multiport outfall diffuser terminal shown in black.

Fig 2 Visualisation of current mapping drogue tracks made during initial hydrographic survey work to investigate dispersal of effluent.

Fig 3 Visualisation of dilution modelling output data, showing predicted locations of surface boils relative to outfall and shoreline.
4.0 TRADE EFFLUENT PRODUCTION

4.1 DISTILLERY PRODUCTION RATES

Scotch whisky industry-wide production rates vary according to market demand and investor confidence, cycling between periods of high and low production. Currently the whisky industry is benefitting from a period of high demand and consequently production rates at the Isle of Arran Distillery are relatively high when compared to long-term trends.

The proposed outfall system must have the capacity to accommodate the full range of production rates likely to be required. This includes temporary cessations in production, and maximum theoretical production rates for the plant. For the purposes of this application, two possible production rates are considered, as defined below:

- CURRENT\textsuperscript{p} - is the current and normal production rate for the distillery during a period of relatively high production.
- MAX\textsuperscript{p} - is the maximum production rate possible if the distillery was to operate at full capacity. This rate is unlikely to be achieved, or sustained for long periods of time due to practical limitations.

Only the MAX\textsuperscript{p} rate is required in calculating values for licensing purposes, ensuring that the licence can accommodate all possible production rates. However, both MAX\textsuperscript{p} and CURRENT\textsuperscript{p} rates are used in calculations throughout this report in order to provide a more representative picture of likely discharge scenarios.

<table>
<thead>
<tr>
<th>DISTILLERY PRODUCTION</th>
<th>PRODUCTION RATE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CURRENT\textsuperscript{p}</td>
</tr>
<tr>
<td>Washbacks per day</td>
<td>3</td>
</tr>
<tr>
<td>Production days per week</td>
<td>6</td>
</tr>
<tr>
<td>Production weeks per annum</td>
<td>46</td>
</tr>
<tr>
<td>Available discharge days per week</td>
<td>6</td>
</tr>
<tr>
<td>Available discharge days per annum</td>
<td>276</td>
</tr>
</tbody>
</table>

Table 8. Possible production scenarios for the Isle of Arran Distillery use in this study

Typical production rates for the distillery are shown in table 3. It should be noted that, historically, current production rates are relatively high, and due to likely future fluctuations in market demand, long-term mean production rates may be lower than the CURRENT\textsuperscript{p} figures.

4.2 TRADE EFFLUENT COMPONENTS

Whisky production is a batch process, with volumes of trade effluent produced being approximately proportionate to the number of production batches (washbacks) during any one period. Inputs to the process are malted barley, yeast and water, and outputs are spirit, draff (particulate grain residue), and trade effluent.

Trade effluent produced by the Isle of Arran Distillery consists of four influent streams emanating from different stages in the production process; pot ale, spent lees, washing water and draff run-off. The schematic drawing in figure 9 shows which stage in the production process each influent stream emanates from.

The nature and approximate proportions of influent streams which make up the final trade effluent are summarised below:

- **Pot ale (65%)** - Pot ale is the residue of the first distillation of fermented worts, to produce low wines. This contains high concentrations of particulate and dissolved organic material (malt and yeast residues). Dissolved metals are present in moderate concentrations as metals tend to bind to the particulate organic matter.
- **Spent lees (25%)** - Spent lees are the residues of the distillation of low wines (second distillation), producing spirit. Spent lees contain little particulate organic content and has a low pH, and as a consequence contains a relatively high concentration of dissolved metals.

- **Washing waters (10%)** - Washing waters are waste from periodic cleaning of distillery plant (production equipment and areas). pH may be high due to the use of a caustic cleaning materials (up to 4% Sodium hypochlorite), so washing waters may contain relatively high dissolved metal and particulate concentrations.

- **Draff run-off (<1%)** - Draff is the particulate cereal residue left over at the end of the fermentation process. Run-off is drained from the draff hopper and draff trailer loading bay, but may be diluted by a small amount of rainwater as surface water run-off from the loading bay. Draff run-off passes through a settlement tank and filter before being pumped to the effluent holding tanks. This liquid consists of malt residues, with very low dissolved metals content.

Figure 9. Schematic of trade effluent production for Isle of Arran Distillery. water inputs are not shown
4.3 FORMULATION OF TRADE EFFLUENT

Treatment of the four influent streams will be by mixing and volumetric balancing within the distillery plant and road tanker before discharge as final effluent. The main components of the effluent treatment system are listed below, see drawing DRW-007 for more detail;

- **Effluent mixing tank** – single 13,000 litre mixing tank receiving spent lees and pot ale prior to entering the heat recovery process

- **Holding tanks** – twin 25,000 litre interconnected effluent holding tanks, where a minimum volumetric buffering volume of 50% (25,000 litres) is maintained during normal production

- **Effluent tanker** – single 30,000 litre road tanker adds a further large volumetric buffer to the system, with active in-tank mixing of the effluent during tanker charging and transport to the outfall

Mixing and volumetric balancing of influent streams during formulation/treatment of the effluent reduces toxicity and buffers the effluent stream against toxicity spikes. The whole mixed and balanced final trade effluent created is referred to as ‘trade effluent’ throughout the rest of this report. Production rates for distillery trade effluent are summarised below in table 9.

<table>
<thead>
<tr>
<th>TRADE EFFLUENT PRODUCTION</th>
<th>PRODUCTION RATE (litres)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CURRENT</td>
</tr>
<tr>
<td>Per washback (maximum)</td>
<td>15,000</td>
</tr>
<tr>
<td>Per production day</td>
<td>45,000</td>
</tr>
<tr>
<td>Weekly</td>
<td>270,000</td>
</tr>
<tr>
<td>Annual</td>
<td>12,420,000</td>
</tr>
<tr>
<td>Per available discharge day</td>
<td>45,000</td>
</tr>
</tbody>
</table>

Table 9. Production rates of trade effluent for Isle of Arran Distillery

4.4 TIMING OF EFFLUENT DISCHARGE PERIODS

A maximum of two tanker loads will be discharged within any 24-hour period, starting and ending at midnight. Discharge of a partial or full tanker load through the outfall will take up to 3 hours and will be called a ‘discharge period’ throughout the remainder of this report.

Timing of discharge periods can be at any time, with the following provisions;

- No discharge period will run through midnight so daily licence conditions are easy to work with administer

- Due to the time required to refill the road tanker the shortest time gap between consecutive discharge periods is 2.5 hours

- Due to working practices within the distillery, discharge periods will normally start within the 0700hrs - 1800hrs working day
5.0 TRADE EFFLUENT PROPERTIES

5.1 CONCENTRATION OF DISCHARGE EFFLUENT CONSTITUENTS

Understanding the nature of the distillery's trade effluent is essential for the successful design and operation of the proposed outfall, minimising its environmental impact and ensuring that all regulatory requirements are met. Of particular importance is the concentration of constituents which may be of environmental significance.

The constituents of significance in distillery trade effluent are well known and have been documented in various studies (e.g. United Malt and Grain Distillers Ltd, 1999). They are also identified in SEPA Supporting Guidance (WAT-SG-05) - Point Source Discharge Constituents 2014.

Figure 4. Photos taken during analysis of unfiltered Pot ale, Spent lees, and on the right a sample of mixed and balanced trade effluent.

In order to determine the concentration of environmentally significant constituents in the Isle of Arran Distillery trade effluent a series of 12 No. duplicate samples were taken for analysis over the course of one week. Production, treatment and sampling conditions of the proposed final trade effluent to be discharged were replicated as closely as possible.

An additional 3 No. samples were taken from the freshwater source for the Distillery, the Easan Biorach burn which flows past the distillery and into Loch Ranza. This provided background concentrations and accurate calculation of distillery inputs/outputs.

An analysis of each sample was carried out independently by Glasgow Scientific Services (Glasgow City Council), and National Laboratory Services (Environment Agency) – both UKAS accredited to ISO 17025. The results of the sampling programme are summarised in table 10.

<table>
<thead>
<tr>
<th>TRADE EFFLUENT CONSTITUENT</th>
<th>Concentration in trade effluent (µg/l)</th>
<th>Concentration in freshwater (µg/l)</th>
<th>GROUP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dissolved Copper (Cu)</td>
<td>3,149</td>
<td>4,820</td>
<td>29</td>
</tr>
<tr>
<td>Dissolved Zinc (Zn)</td>
<td>629</td>
<td>740</td>
<td>7</td>
</tr>
<tr>
<td>Dissolved Lead (Pb)</td>
<td>8</td>
<td>14</td>
<td>1</td>
</tr>
<tr>
<td>Total Ammoniacal Nitrogen (NH₃N)</td>
<td>77,156</td>
<td>107,000</td>
<td>29</td>
</tr>
<tr>
<td>---------------------------------</td>
<td>--------</td>
<td>---------</td>
<td>----</td>
</tr>
<tr>
<td>Suspended Solids (SS)</td>
<td>3,622,555</td>
<td>14,500,000</td>
<td>&lt;200</td>
</tr>
<tr>
<td>Chemical Oxygen Demand (COD)</td>
<td>42,066,667</td>
<td>64,600,000</td>
<td>NA</td>
</tr>
<tr>
<td>Biochemical Oxygen Demand (BOD)</td>
<td>17,155,555</td>
<td>21,000,000</td>
<td>3800</td>
</tr>
<tr>
<td>pH</td>
<td>4.0</td>
<td>3.8 - 4.2</td>
<td>5.9</td>
</tr>
</tbody>
</table>

Table 10. Concentration of environmentally significant discharge effluent constituents, independent of rate of distillery production. Dissolved is defined as passing through 0.45μm membrane filter.

As a result of measures taken to mix and balance the individual influent streams, it is likely that almost all instantaneous samples (>80%) of the trade effluent flow will have concentrations very close to the mean values.

Transient peaks in constituent concentrations will occur due to occasional ‘worst case’ combinations of production and treatment factors. An example of this would be during distillery shut-down or start up, or during effluent tank cleaning when in-tank buffer volumes may not be maintained. These peaks will be rare, and are highly unlikely to exceed the peak concentration shown in the table 10.

When peaks in discharge effluent constituent concentrations do occur, they will consist of elevated concentrations of constituents in either group 1, 2, or 3. The nature of the distillery trade effluent influent streams and the design of the effluent management system ensures that significant peak concentrations from the different groups cannot occur at the same time.

Statutory Environmental Quality Standards (EQS) are based on annual average concentrations, meaning mean values would be used. However, in previous distillery outfall licencing work SEPA have specified that peak concentration levels should be used in calculations as a conservative measure and to minimise risk of toxicity. For that reason, peak concentrations are used in EQS calculations in this report.

5.2 DENSITY OF TRADE EFFLUENT

Density of trade effluent at various temperatures was analysed during the sampling program as density information is required for dilution modelling work. The density analysis was carried out by Chemtest Ltd - UKAS accredited to ISO 17025. See table 11 for the result of this work.

<table>
<thead>
<tr>
<th>TRADE EFFLUENT TEMPERATURE (°C)</th>
<th>DENSITY (kg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>1.017</td>
</tr>
<tr>
<td>30</td>
<td>1.010</td>
</tr>
<tr>
<td>50</td>
<td>1.009</td>
</tr>
<tr>
<td>70</td>
<td>1.006</td>
</tr>
</tbody>
</table>

Table 11. Results from density analysis of trade effluent at selected temperatures

5.3 TEMPERATURE OF TRADE EFFLUENT AT POINT OF DISCHARGE

During normal operation, the temperature of trade effluent where it enters the outfall discharge pump will be 41 °C - 45°C. When there has been a weekend (24 hour) shut down in production, trade effluent temperatures may drop as low as 25 °C.

The temperature of trade effluent as it is discharged from diffuser valves at the seaward end of the outfall will be lower than temperature at the pump. This is due to the cooling effect of ambient seawater surrounding the submerged portion of the outfall pipeline. A simplified method used to calculate the loss of heat over the length of the outfall pipeline has been taken from GPS PE Pipe System Technical Guidelines 2016. Main parameters used and results are summarised below;
Flow rate through pipeline 2.8 l/s⁻¹
Flow velocity 0.52 m/s⁻¹
Length of submerged portion of outfall 135m
Mean seawater temperature (ambient) 11 °C
Initial trade effluent temperature 43 °C
Pipe diameter OD/ID 110mm/89mm
HDPE thermal conductivity 0.44 W/m⁻¹/K⁻¹

Heat lost is calculated as 4.53 Kcal/litre⁻¹ during passage through the outfall pipeline, therefore the change in trade effluent temperature when discharging through the proposed outfall is 4.6 C°. Given the calculations above, 38.4 C° should be used as a typical 'end of pipe' discharge temperature for dilution modelling calculations.

5.4 MASS OF TRADE EFFLUENT CONSTITUENTS

The mass of discharged effluent constituents of particular environmental significance is largely dependent on distillery production rate. Calculation of discharge mass is not required for consent purposes, but is useful in visualising the nature of the discharge effluent, and the amount of material discharged into the marine environment. The average concentration of effluent constituents, minus background freshwater concentration, is used in calculation of the distillery process-derived discharge mass (table 12).

<table>
<thead>
<tr>
<th>TRADE EFFLUENT CONSTITUENT</th>
<th>Average mass per washback (kg)</th>
<th>Average mass per day (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dissolved Copper (Cu)</td>
<td>0.0468</td>
<td>0.1404</td>
</tr>
<tr>
<td>Dissolved Zinc (Zn)</td>
<td>0.0093</td>
<td>0.02799</td>
</tr>
<tr>
<td>Dissolved Lead (Pb)</td>
<td>0.000105</td>
<td>0.000315</td>
</tr>
<tr>
<td>Total Ammoniacal Nitrogen (NH₃N)</td>
<td>1.156905</td>
<td>3.470715</td>
</tr>
<tr>
<td>Suspended Solids (SS)</td>
<td>54.33</td>
<td>163.01</td>
</tr>
<tr>
<td>Chemical Oxygen Demand (COD)</td>
<td>631.00</td>
<td>1893.00</td>
</tr>
<tr>
<td>Biochemical Oxygen Demand (BOD)</td>
<td>257.61</td>
<td>771.83</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1029.11</td>
</tr>
</tbody>
</table>

Table 12. Mass of environmentally significant discharge effluent constituents to be released into the marine environment, dependent on distillery production rate.

As a point of interest, mass of copper discharged can be checked against actual loss of copper from the distillery's stills, which are the most significant source of copper in the trade effluent.

Calculation of total discharged copper (minus background copper) over lifetime of stills (1995 – 2016), calculated from mean effluent concentrations minus freshwater supply concentrations and total effluent production volumes;

Dissolved copper released into effluent = 237.7kg
Particulate copper released into effluent = 97.9kg

*Note - this value is likely to be less than the actual amount due to a proportion of large non-suspended granules of copper not being included in homogenised samples.

Total copper discharged over lifetime of stills = 335.6 kg

Approximate copper loss from stills, based on ultrasonic thickness measurements during lifetime estimated to be;

Wash still: approximately 8% of 2,400kg initial weight = 192kg loss
Spirit still: approximately 11% of 2,400kg initial weight = 264 kg loss

Total copper loss over 21 year lifetime of 2 No. stills = 456 kg

Accepting the limitations in the accurate measurement of loss of copper mass in the stills, and that larger particles of copper may not be measured in the discharge data, this exercise demonstrates that the dissolved copper values used in this application appear to be realistic.

5.5 POPULATION EQUIVALENT DISCHARGE

The mass of labile organic matter in the discharge can be quantified as a Population Equivalent (p.e.) discharge for the purposes of standardisation and regulatory requirements. The method used to calculate p.e. is found in the British Water Code of Practice: Flows and Loads – 4 Sizing Criteria, Treatment Capacity for Sewage Treatment Systems.

Population equivalent (p.e) of trade effluent: To calculate p.e. for trade effluent, multiply the daily flow of the discharge (in m³) by the mean BOD (in mg/l) and divide by 60 (60g is the mean BOD load for one person in one day.

\[
\text{Population equivalent discharge} = \frac{\text{Annual averaged daily discharge} \times \text{Mean BOD concentration}}{\text{Person equivalent (domestic) BOD}}
\]

Mean BOD concentration = 17,155.55 mg/l
CURRENT annual average daily discharge = 34.027 m³
Person equivalent (domestic) BOD = 60g

\[
\text{Population equivalent discharge} = \frac{34.027 \times 17,155.55}{60} = 9,729 \text{ p.e.}
\]

Annual average daily discharge BOD = 9,729 p.e.

5.6 MICROBIAL CONTENT

As the cereal-based trade effluent is largely produced in the stills or from caustic washing waters, there is little or no significant microbial content in the trade effluent to be discharged. The following points set out below show that the trade effluent presents no biological hazard to sea bathers or to the environment.

- **Residence time** - resident times within the trade effluent formulation and holding system is relatively low - normally less than 24 hrs – with the system drained down to empty for cleaning once per week.

- **Cleaning** - periodic cleaning of the production areas, lines and tanks with hot 4% caustic wash to sterilise.
- **Temperature** - effluent is produced and held in the storage tanks at a relatively high temperature which suppresses microbial growth.

- **pH** – the relatively low pH of the trade effluent due to mixing in of caustic washing waters during formulation suppresses microbial growth.

- **Filtration** – all influent streams are filtered before entering the effluent holding tanks, ensuring no unwanted debris can enter the system or large grain particles.

- **Contamination** – the effluent production system is closed and monitored, so no sewage or other non-trade waste can enter the system.
6.0 DILUTION REQUIRED

6.1 DISCHARGE CRITERIA

Statutory environmental quality standards (EQS) and general criteria for marine trade effluent discharges from distilleries have been prescribed by SEPA. These have been developed during extensive discussion and collaborative research between SEPA and the whisky industry. These standards are underpinned by a long history of distilleries discharging waste water to the marine environment – a history stretching back for up to 500 years. The main sources for the various EQS and general criteria to be met by the proposed outfall are listed below:


Table 13 summarises the general discharge criteria to be met by the proposed outfall system, and which have been taken into consideration during design of the outfall and preparation of this application.

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>LEVEL</th>
<th>CONDITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mixing zone extent</td>
<td>Area ≤ 100m from surface 'boil'</td>
<td>Not impinge on shoreline</td>
</tr>
<tr>
<td>Suspended solids</td>
<td>≤ 10,000 mg/l Suspended Solids</td>
<td>No aesthetic impact</td>
</tr>
<tr>
<td>Settlement of solids</td>
<td>Visual particles on seabed</td>
<td>Must not accumulate</td>
</tr>
<tr>
<td>Dissolved oxygen</td>
<td>Annual average &gt; 80% Saturation</td>
<td>Achieved within mixing zone</td>
</tr>
<tr>
<td>Organic carbon in sediment</td>
<td>≤ 2 gC/m²/day</td>
<td>Daily net accumulation</td>
</tr>
<tr>
<td>pH of discharge</td>
<td>3.0 - 10</td>
<td>Not exceeded outside surface boil</td>
</tr>
<tr>
<td>Initial dilution (Spent lees)</td>
<td>Minimum of 100 x</td>
<td>Mean lower 95%ile</td>
</tr>
<tr>
<td>Initial dilution (Pot ale)</td>
<td>Minimum of 200 x</td>
<td>Mean lower 95%ile</td>
</tr>
<tr>
<td>Initial dilution (Trade effluent)</td>
<td>Minimum of 150 x</td>
<td>Mean lower 95%ile</td>
</tr>
<tr>
<td>Secondary dilution</td>
<td>EQS achieved within mixing zone</td>
<td>Mean lower 95%ile</td>
</tr>
<tr>
<td>Toxicity of surface ‘boil’</td>
<td>0.1% v/v effluent/seawater</td>
<td>Not toxic to oyster embryo</td>
</tr>
<tr>
<td>Biology/Ecology</td>
<td>No deleterious impact on flora or fauna</td>
<td></td>
</tr>
</tbody>
</table>

Table 13. Parameters for general outfall performance, as specified by SEPA with specific reference to malt whisky distilleries.

In addition to criterial above, a series of aesthetic conditions have been set out by SEPA which also required to be met:

- **Hydrocarbons** - no significant visible impact on the surface waters due to the presence of oil and/or grease
- **Accumulation of particles** - no significant deposition of particles on the seabed or shore of the receiving waters
- **Visual plume** - no significant discoloration of the receiving waters
- **Foam/bubbles** - no significant increased foaming in the receiving waters
SEPA prescribed EQS for effluent constituents of environmental significance in distillery trade effluent are shown in table 14. These constituents are all measurable by sampling the trade effluent and the discharge plume. Dissolved copper is the constituent which requires the most dilution to meet EQS. Therefore, dissolved copper can be regarded as the prime environmental determinant for this application.

<table>
<thead>
<tr>
<th>CONSTITUENT</th>
<th>Annual average EQS:</th>
<th>MAC</th>
<th>CONDITIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dissolved copper*</td>
<td>5.09 µg/l⁻¹</td>
<td>NA</td>
<td>Achieved within mixing zone</td>
</tr>
<tr>
<td>Dissolved zinc</td>
<td>6.8 µg/l⁻¹</td>
<td>NA</td>
<td>Achieved within mixing zone</td>
</tr>
<tr>
<td>Dissolved lead</td>
<td>7.2 µg/l⁻¹</td>
<td>14 µg/l⁻¹</td>
<td>Achieved within mixing zone</td>
</tr>
<tr>
<td>Ammoniacal nitrogen**</td>
<td>600 µg/l⁻¹</td>
<td>NA</td>
<td>Achieved within mixing zone</td>
</tr>
<tr>
<td>Biological Oxygen Demand</td>
<td>&lt; 0.5 mg/l⁻¹ reduction of ambient DO</td>
<td>NA</td>
<td>Acceptable within mixing zone if ambient DO is &lt; 7 mg/l⁻¹</td>
</tr>
</tbody>
</table>

* A conservative value for dissolved copper EQS is used as dissolved organic carbon (DOC) concentrations in the discharge or receiving environment are not known so cannot be compensated for.

** Expresses unionised ‘free’ ammonia (EQS 21 µg/l⁻¹), which is assumed to be ~ 1/30 of total ammoniacal nitrogen.

Table 14. EQS which must be achieved within the mixing zone

6.2 BEHAVIOUR OF TRADE EFFLUENT CONSTITUENTS IN SEAWATER

For the purposes of licensing the outfall, behaviour of trade effluent constituents is assumed to be conservative and predictable when mixed with seawater over the temporal and spatial scales relative to EQS compliance. This is in accordance with SEPA’s guidelines, and is required to allow the use of workable methods in predicting the performance of the outfall and determining its discharge licencing requirements. Assumptions made for the behaviour of the main environmental determinants are summarised below;

- **Dissolved metals** – Dissolved metals are assumed to maintain conservative behaviour when mixed with seawater. Concentration of these effluent constituents in the discharge plume is determined by initial concentrations, physical dilution rates, and background concentrations, and are not affected by any biological or chemical interactions.

- **Ammoniacal nitrogen** – The behaviour of ammoniacal nitrogen is also assumed to be conservative when mixed with seawater. Ammoniacal nitrogen concentration is used to express the concentration of unionised ammonia, which is calculated as ~ 1/30 of total ammoniacal nitrogen.

- **Biological oxygen demand** - Assumed to have non-conservative behaviour, with biological interactions occurring in the discharge plume within the mixing zone. This may impact on oxygen saturation levels within the mixing zone.

It should be noted that the assumptions set out above are conservative assumptions in terms of EQS compliance and predicted toxicity within the discharge plume. In reality, the chemical behaviour of trade effluent constituents when discharged from the outfall terminal will be highly complex. Individual effluent constituents will react to changes in the diluted effluents properties and interaction with seawater constituents. Factors that will affect the main environmental determinants in the trade effluent when discharged, but are not accounted for by the assumptions outlined above, are summarised below;

- **Dissolved metals** - The equilibrium of speciation of metals between dissolved and particulate states in trade effluent is dynamic, and will change rapidly when forming a solution with seawater. On balance, precipitation of dissolved metals by complexation with and adsorption into seawater constituents will remove a significant portion of dissolved metals from solution within the first few dilutions of the effluent, i.e. almost instantaneously in the case of the proposed outfall.
- **Ammoniacal nitrogen** – Total ammoniacal nitrogen will behave in a relatively conservative way when diluted with seawater. However, the balance/speciation of unionised (free) ammonia and ionised ammonium within the total ammoniacal nitrogen content of the discharge effluent/plume is dependent on total concentration, pH, and temperature of the solution. This balance will change rapidly upon discharge of the effluent, with the overall effect being the reduction of the portion of total ammoniacal nitrogen which exists as unionised ammonia.

- **Biological oxygen demand (BOD)** – Though the BOD of the discharge effluent is high, it is unlikely to have a significant impact on dissolved oxygen levels or marine ecology within the mixing zone. This is due to the effluent being discharged into a well oxygenated, exposed open coastal site where the plume will be advected out of the mixing zone and dispersed within a large body of water. The timescale of this process will be in the order of a few minutes out-with brief slack water periods, so therefore does not give sufficient time for significant biological utilisation of organic material within the effluent plume.

The more labile portions of malted barley used within the distilling process is efficiently metabolised by yeast to create alcohol, leaving only less labile longer chain carbohydrates, proteins and lipids in the residual trade effluent. The high COD/BOD ratio observed in the trade effluent confirms this, so little of the organic content will be metabolised until well diluted and dispersed far and wide from the outfall location.

The assertions above are supported by empirical and anecdotal evidence from extensive laboratory and field studies. This work was carried out by SEPA, its predecessors, and the whisky industry, investigating the likely impact of distillery effluent on the marine environment. Particular emphasis is placed on the Loch Harport studies carried out in 1998/99 jointly by SEPA and the whisky industry, also work carried out by Water Framework Directive - United Kingdom Technical Advisory Group (WFD-UKTAG) on marine copper in 2011, and work carried out by SEPA’s marine chemistry unit looking at the impact of dissolved copper from distillery outfalls in 2005-2008.

In summary, when considering the formulation and content of the trade effluent, outfall system design, and nature of the receiving environment, it is evident that a reduction in the trade effluent’s toxicity and concentration of controlled substances will occur within the mixing zone over-and-above that due to physical dilution alone. However, only the effect of physical dilution is considered when determining compliance with EQS in this application. This is done for the sake of workability and as a conservative measure.

### 6.3 INITIAL DILUTION REQUIRED

Initial dilution refers to the degree of dilution achieved by discharged effluent by the time it rises from the outfall port on the seabed to the sea surface. Trade effluent exiting the diffuser valves on the outfall ports will initially take the form of a high velocity horizontal jet (initial velocity 2.7m/s). As the jets’ momentum is dissipated through turbulent mixing, the diluted discharge will become a buoyant plume, rising towards the sea surface. Where the plume first reaches the sea surface it is called a ‘surface boil’. In the case of the proposed outfall a ‘surface boil’ is a somewhat misleading term as the plume will be highly diffuse at this point due to the low discharge rate, action of diffuser valves, depth of the outfall ports, and therefore exceptionally high levels of initial dilution achieved.

The minimum level of initial dilution required to be achieved by the outfall is prescribed by SEPA. This condition must be met for at least 95% of the time. Where the discharge is intermittent, as in this case, this is assumed to be 95% of the time that the outfall is discharging. The purpose of this licence condition is to guard against acute toxicity out-with the ‘surface boil’ and minimises the aesthetic impact of the surfacing diffuse plume.

A trade-specific minimum initial dilution standard was agreed with the distilling industry during a meeting between the Malt Distillers Association Environment Committee and SEPA, held at Castle Business Park, Stirling on 10 August 2000. The levels agreed are set out below;

- **Pot ale** – minimum 95%ile dilution factor of 200x
6.4 SECONDARY DILUTION REQUIRED

The SEPA-prescribed mixing zone for the discharged trade effluent is an area within 100m radius of the 'surface boil'. This zone is sometimes called the Allowable Zone of Effect (AZE).

The amount of dilution an effluent plume receives by the time it is advected out of the mixing zone, including initial dilution, is termed secondary dilution for the purposes of this report. Secondary dilution must be sufficient to ensure that concentrations of environmentally significant effluent constituents meet SEPA-prescribed Environmental Quality Standard (EQS) concentrations within the mixing zone.

EQS are set by SEPA as annual average concentrations (EQS\textsuperscript{annual}). As the Isle of Arran Distillery does not operate continuously throughout the year and the maximum number of discharge days per annum are known, the EQS\textsuperscript{annual} may be used to derive a daily average standard (EQS\textsuperscript{daily}) for the days when there will be a discharge. The site/discharge specific EQS\textsuperscript{daily} is therefore dependent on the distillery production rates, and the background levels of the effluent components in seawater. The method used in this study to calculate EQS\textsuperscript{daily} is shown by the equation below:

\[
EQS^{\text{daily}} = \frac{(365 \times EQS^{\text{annual}}) - (\text{Non discharge days per year} \times \text{Background concentration}_{\text{seawater}})}{276}
\]

\[
\text{Discharge days per year}
\]

\[\text{i.e. for dissolved copper;}
\]

\[
EQS^{\text{daily}} = \frac{(365 \times 5.09^{\text{annual}}) - (89 \times 0.5^{\text{seawater}})}{276} = 6.57 \mu g/l
\]

\[
\text{MAX}^{\text{p}}
\]

\[
EQS^{\text{daily}} = \frac{(365 \times 5.09^{\text{annual}}) - (29 \times 0.5^{\text{seawater}})}{336} = 5.49 \mu g/l
\]

The parameters used in the calculation of EQS\textsuperscript{daily} concentrations can be found in tables 9 and 10 of this document. The results of these calculations are shown below in table 15.

<table>
<thead>
<tr>
<th>CONSTITUENT</th>
<th>Seawater background ((\mu g/l))</th>
<th>EQS\textsuperscript{annual} ((\mu g/l))</th>
<th>EQS\textsuperscript{daily} ((\mu g/l))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>CURRENT\textsuperscript{p}</td>
<td>MAX\textsuperscript{p}</td>
</tr>
<tr>
<td>Dissolved Copper (Cu)</td>
<td>0.50</td>
<td>5.09</td>
<td>6.57</td>
</tr>
<tr>
<td>Dissolved Zinc (Zn)</td>
<td>0.20</td>
<td>6.60</td>
<td>8.93</td>
</tr>
<tr>
<td>Dissolved Lead (Pb)</td>
<td>0.025</td>
<td>7.20</td>
<td>9.51</td>
</tr>
<tr>
<td>Ammoniacal Nitrogen (NH\textsubscript{3})</td>
<td>3.90</td>
<td>600.00</td>
<td>792.22</td>
</tr>
</tbody>
</table>

Table 15. Site/discharge-specific EQS\textsuperscript{daily} concentrations, dependent on number of discharge days per year and background seawater concentration. Values for background concentrations of trace metals in Kilbrannan Sound is from Balls (1987).
The EQS<sub>daily</sub> concentrations for each environmentally significant constituent can be used to calculate the level of secondary dilution required for each constituent to achieve the EQS<sub>daily</sub> concentration. Since EQS<sub>daily</sub> is a daily average standard, a mean discharge concentration value would generally be used in this calculation. As a conservative measure, SEPA have specified that the peak concentrations of effluent constituents are used to calculate secondary dilution requirements. The equation used is shown below;

\[
\text{Dilution required} = \frac{\text{Discharge concentration}_{\text{peak}}}{\text{EQS}_{\text{daily}} - \text{Background concentration}_{\text{seawater}}}
\]

i.e. for dissolved copper;

\[
\text{CURRENT}^\circ \quad \text{Dilution required} = \frac{4820_{\text{peak}}}{6.57_{\text{daily}} - 0.5_{\text{seawater}}} = 794x
\]

\[
\text{MAX}^\circ \quad \text{Dilution required} = \frac{4820_{\text{peak}}}{5.49_{\text{daily}} - 0.5_{\text{seawater}}} = 966x
\]

The parameters used in this calculation, and the results, are shown below in table 16.

<table>
<thead>
<tr>
<th>CONSTITUENT</th>
<th>Peak effluent conc. (µg/l&lt;sup&gt;1&lt;/sup&gt;)</th>
<th>Secondary Dilution Required Factor (x)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dissolved Copper (Cu)</td>
<td>4,820</td>
<td>794</td>
</tr>
<tr>
<td>Dissolved Zinc (Zn)</td>
<td>740</td>
<td>85</td>
</tr>
<tr>
<td>Dissolved Lead (Pb)</td>
<td>14</td>
<td>1</td>
</tr>
<tr>
<td>Ammoniacal Nitrogen (NH₄)</td>
<td>107,000</td>
<td>136</td>
</tr>
</tbody>
</table>

In summary, for the proposed outfall to comply with site-specific EQS<sub>daily</sub>, derived from the annual average EQS<sub>annual</sub>, the discharge effluent must achieve a mean secondary dilution rate of at least 966 x for more than 95% of the time. The secondary dilution value calculated contains a significant safety margin due to use of peak concentrations, maximum production rates, and not taking into account natural physiochemical processes which reduce constituent concentrations/toxicity over and above volumetric dilution alone.

Dissolved copper in the discharge effluent has the relatively highest dilution requirement in terms achieving EQS. Dissolved copper is therefore to be regarded as the prime environmental determinant. If dissolved copper in the discharge effluent is diluted sufficiently to comply with EQS conditions, then it can be assumed that other environmentally significant constituents in the discharge will also comply with their relevant EQS conditions.
7.0 SITE ENVIRONMENTAL PARAMETERS

7.1 SITE LOCATION & GENERAL ENVIRONMENTAL SETTING

The proposed outfall site is located in an open coastal marine setting at Rubh Airigh Bheirg, near Lennimore on the northwest coast of Arran. The site is on the seaward side of the A841, 4.7 miles by road south of the distillery in Lochranza. The nearest settlement is the hamlet of Cattacoil located 3.1km northeast along the coast. See drawing DRW-001 for location and general arrangement for the proposed outfall.

Figure 5. Oblique 3D view from the northeast

Figure 6. Oblique 3D view from the southeast

The onshore portion of the site where the headworks are to be located is on an area of gently sloping wave-cut platform, which extends inland to where a wooded hillside rises steeply into mountainous terrain. The platform is overlain with raised beach deposits of glaciofluvial origin, and shallow peaty soils supporting heathland habitat.

The site has existing road access, possibly associated with the now demolished Lennimore Church which once stood near the site. Currently, the site is used as road access to land and shoreline by the landowner. The topography of the site, sloping down seaward from the road, and surrounding vegetation (scrub), partially screens the site area from the road.

The foreshore which will be crossed by the buried outfall pipeline consists of mobile free-draining cobbles and gravel, supporting very little fauna or fauna. The profile of the foreshore is uniform along the length of the shoreline in the area of the outfall. The nearest shoreline outcrops of bedrock, a schistose grit, which break this profile are 150m to the southwest, and 470m to the northeast.

The foreshore is fringed by subtidal sand flats, extending approximately 50m seaward from the low tide contour. Beyond that, the seabed drops away steeply and uniformly into the depths of the Kilbrannan Sound, reaching 150m deep in places. The subsea portion of the outfall pipeline will cross the sandflats and extend down the steep sedimentary slope to a depth of 20m below chart datum. Locating the outfall terminal further offshore is not possible due to construction/diving limitations, and the activities of commercial fishing vessels.

The Kilbrannan Sound is a straight of deep tidal water separating the Isle of Arran from the Kintyre Peninsula. It forms the western arm of the Firth of Clyde, which is Scotland’s largest fjord system. The
average flushing time for the Firth of Clyde is 3-4 months, and it is likely that the flushing time of the Kilbrannan Sound is significantly shorter than that. The nature of large scale circulation in the Firth of Clyde minimises the amount of estuarine waters entering the Kilbrannan Sound from the north. Reduces stratification of the water column and isolation of deep (>100m) waters, leaving the whole water column susceptible to mixing by winds in the summer. In winter, the waters of the Kilbrannan Sound are well mixed through the water column (Midgely, et al., 2001).

Key positions identifying the site and outfall components are set out below in table 17.

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>POSITION OSGB36 (NR)</th>
<th>DEGREES (WGS84)</th>
<th>HEIGHT - CD (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roadside entrance</td>
<td>188591.5, 647874.6</td>
<td>5.364077425254</td>
<td>+8.24</td>
</tr>
<tr>
<td>Turning area (central)</td>
<td>188578.5, 647884.7</td>
<td>5.3642815778227</td>
<td>-6.77</td>
</tr>
<tr>
<td>Pump cabinet join in pit</td>
<td>188564.3, 647871.8</td>
<td>5.3645070532529</td>
<td>+7.41</td>
</tr>
<tr>
<td>Pipeline crosses +5m contour</td>
<td>188565.2, 647901.4</td>
<td>5.3645155807309</td>
<td>+5.00</td>
</tr>
<tr>
<td>Pipeline crosses MHWS</td>
<td>188557.8, 647918.8</td>
<td>5.364646464493</td>
<td>+3.00</td>
</tr>
<tr>
<td>Pipeline crosses MLWS</td>
<td>188543.2, 647941.8</td>
<td>5.3648959639606</td>
<td>+0.30</td>
</tr>
<tr>
<td>Pipeline crosses +0m contour</td>
<td>188541.6, 647944.5</td>
<td>5.364923448585</td>
<td>0.00</td>
</tr>
<tr>
<td>Seaward end of 180mm duct</td>
<td>188539.9, 647946.9</td>
<td>5.364952282</td>
<td>-0.24</td>
</tr>
<tr>
<td>Pipeline crosses -5m contour</td>
<td>188510.9, 647993.4</td>
<td>5.3654485003137</td>
<td>-5.00</td>
</tr>
<tr>
<td>Pipeline crosses -10m contour</td>
<td>188494.9, 648009.0</td>
<td>5.3657145271165</td>
<td>-10.00</td>
</tr>
<tr>
<td>Pipeline crosses -15m contour</td>
<td>188474.5, 648023.5</td>
<td>5.3660495574079</td>
<td>-15.00</td>
</tr>
<tr>
<td>Pipeline flow splitter</td>
<td>188468.9, 648027.3</td>
<td>5.3661413877534</td>
<td>-17.04</td>
</tr>
<tr>
<td>SW outfall diffuser port</td>
<td>188452.8, 648023.6</td>
<td>5.3663941215753</td>
<td>-20.00</td>
</tr>
<tr>
<td>NE outfall diffuser port</td>
<td>188469.8, 648042.7</td>
<td>5.3661389762791</td>
<td>-20.00</td>
</tr>
<tr>
<td>Outfall diffuser centre point</td>
<td>188461.8, 648033.5</td>
<td>5.3662588816299</td>
<td>-20.09</td>
</tr>
<tr>
<td>Navigation marker buoy</td>
<td>188449.7, 648043.8</td>
<td>5.3664689130917</td>
<td>-23.50</td>
</tr>
</tbody>
</table>

Table 17. Key positions

7.2 CLIMATE & RIVER DISCHARGE

Local climatic conditions, principally wind and river discharge, have potential to affect the site's hydrography and influence outfall discharge plume behaviour. Climate and river discharge relevant to the site is described below;

Rainfall on Arran's north and west coast is relatively high due to the island's mountainous interior. Weather station data from Dougarie Lodge (10.5km to the south of the site) recorded from 2003 – 2007 is shown in fig 6. The mean total annual rainfall during this measurement period was 1241mm. It is likely that rainfall on the outfall site will be slightly higher than this, due to local topographical effects.
Figure 6. Mean monthly total rainfall at Arran Dougarie Lodge 2003 - 2007

The main sources of freshwater to the sea area near the outfall site are from five named rivers and streams, set out below. River flow data is not available for these watercourses, but an estimation of mean annual river flow has been made from rainfall data and approximate catchment areas – figures are indicative only.

- **Lochranza River** – discharges into Loch Ranza, 5.7 km northeast of site. Lochranza River – a confluence of Easan Biorach and the Chalmadale burn. Estimated annual mean discharge rate; 0.3m³ per second.

- **Catacol River (Abhainn Mor)** – discharges into Catacol Bay, 2.6km northeast of the site. Estimated annual mean discharge rate; 0.5m³ per second.

- **Alt Mor** – discharges to open coast near Thundergay, 1.2km southwest of the site. Estimated annual mean discharge rate; 0.2m³ per second.

- **Alt Gobhlich** – discharges to open coast near Pirnmiil, 3.9km southwest of the site. Estimated annual mean discharge rate; >0.1m³ per second.

Due to the proximity, high relief and small size of the catchment areas, these rivers have highly irregular flows corresponding to rainfall.

Other freshwater sources in the area of the outfall site are intermittent streams running directly off the hills during periods of heavy, sustained rainfall.

Figure 7. 30-year averaged wind strength and direction data for North Arran from Met Office wind model
The wind climate for North Arran is shown in fig 7, using modelled forecast data. This data is more representative than using nearby weather station records, due to local topographic effects.

The prevailing winds tend to disperse the larger Catacol and Lochranza river discharge plumes away from the site when they occur during spate conditions. The volume of river discharge in the area is relatively low, with none of the rivers significantly impacting on the outfall site.

Observations while onsite during investigation work confirmed that there is little riverine influence at proposed outfall discharge site. CTD cast transects made during the dilution survey also confirmed this.

On one occasion during spate conditions, and with a light onshore wind, a very slight brackishness could be seen on the surface within the site and along the shoreline. This body of brackish surface water was restricted to within a few metres of the shore, and is thought to be the remnants of a Catacol River spate plume carried south by the tide and held against the shore by the wind.

7.3 CONSERVATION & FISHERIES DESIGNATIONS

The site is classified as Undeveloped Coast and is within a Sensitive Landscape Area and National Scenic Area (North Ayrshire Council - Local Development Plan 2014). There are no marine conservation, archaeological, or fisheries designations that apply to the site or its surrounding area.

The area of land on the landward side of the A841 is designated as a Local Nature Conservation Site – this is a non-statutory designation and the area is unaffected by the proposed development.

The Food Standards Agency Scotland Pinmill Shellfish Harvesting Area extending south of the outfall site was discontinued in 2015 due to lack of use. The nearest designated Shell Fish Harvesting Area is Machrie Bay, lying 13.7km south of the outfall site.

<table>
<thead>
<tr>
<th>REGULATING AUTHORITY</th>
<th>DESIGNATION</th>
<th>CONTAINS OUTFALL SITE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scottish Natural Heritage</td>
<td>North Arran National Scenic Area</td>
<td>Yes</td>
</tr>
<tr>
<td>North Ayrshire Council</td>
<td>Coastal Zone Categorisation: Undeveloped Coast</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Local Nature Conservation Area</td>
<td>No, but nearby</td>
</tr>
<tr>
<td></td>
<td>Sensitive Landscape Area</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Table 18. Site designations/categorisation

7.4 BUILT ENVIRONMENT & ACTIVITIES OF OTHER SITE USERS

Existing built environment in the area of the site is limited to the following infrastructure:

- **Public road** – the A841, a 2-lane road, is a ring-road which runs around the Island of Arran, mainly following the coast

- **Water mains** – Scottish Water 4" water main, buried in the verge on the east side of the road

- **Offroad parking & tracks** - The site has existing road access, possibly associated with the now demolished Lennimore Church which once stood near the site. Currently the site is used as track access to land and shoreline by the landowner.

Agricultural use of the adjacent land is limited. The land is classified as unimproved rough grazing, and may be frequented by cows and sheep from time to time.
The sea area offshore of the outfall site is fished by commercial fishing vessels, mainly from Troon, Carradale, Tarbert, Campbeltown and Arran ports. Fishing effort in the area is light, sporadic and weather dependant, with working vessels only occasionally seen during the survey period.

- **Scallop dredgers** - tow bottom dredges for scallops (*Pecten maximus*) working along the 12m - 25m contours to the north and south of the site. The area from approximately 0.9km south of the site to 2.8km north of the site is not fished regularly, due to lack of commercial quantities of scallops.

- **Prawn trawlers** - tow bottom trawl nets for Langoustines (*Nephrops norvegicus*) work offshore of the site, usually deeper than the 55m contour.

- **Prawn creel boats** - lay fleets of prawn creels for Langoustines, in the same areas as the prawn trawlers work during the weekends when trawlers are not permitted to work.

- **Crab creels** - creel boats lay fleets of crab creels to catch brown crab (*Cancer pagurus*), velvet crab (*Necora puber*) and occasional lobster (*Homarus gammarus*). These inshore boats may also lay fleets of buckie pots for whelks (*Buccinum undatum*) along the coast from depths of 15m - 40m.

- **Shellfish diving** - divers occasionally hand-pick and electrofish for razor shell (*Ensis siliqua* & *Ensis ensis*) from shallow subtidal sandy seabed areas along the coast, usually in water depths of between 2m and 10m.

Winkle pickers may also harvest the common periwinkle (*Littorina littorea*) at low tide from rocky shore areas along the coast to the north and south of the site.

Existing anthropogenic discharges to the Kilbrannan Sound in the area of the outfall are summarised below;
• Carradale North Marine Cage Fish Farm – a salmon farm located 9.5km to the southwest of the site and on the opposite side of the Kilbrannan Sound. This fish farm is isolated from the outfall site in terms of water movement, due to the dominant north-south tidal flows through the Sound. Discharge consent No: CAR/L/1131788.

• Sewage - Scottish Water waste water treatment (WWT) plants and domestic septic tank outfalls in Lochranza, Catacol, Pirnmill and outlying dwellings.

• Diffuse Inputs – these mainly consist of farm run-off from fertilisers or slurry.

7.5 SCOPE OF SITE INVESTIGATION WORK

Site investigation work was carried out in 4 phases, starting on 14th August 2013 and ending on 5th March 2014. Various boat, land, and diving-based survey activities were carried out, with a total of 18 days spent onsite over this period. The main activities undertaken during each site investigation phase are summarised below;

• **Phase 1: Initial site survey** - to identify an optimum location in terms of outfall construction and environmental performance, and to provide information for planning of main site investigation survey effort. Survey team onsite for 1 day on 14th August 2013. See drawing DRW-003 for extent of wider survey area. Main survey activities are as follows;
  - Onshore site walk-over
  - Bathymetric and topographic survey
  - Sidescan sonar survey seabed imaging
  - Diver seabed transects and photographing

• **Phase 2: Site Investigation** – to determine optimal location/route for outfall with regard to constructional and environmental considerations. Establish a survey transect and series of survey stations extending 187m seaward of MLWS. See DRW-006 for locations. Survey period covers 27th October 2013 – 26th November 2013. Survey effort concentrated on 2No. neap tide and 2No. spring tide periods. Main survey activities are as follows;
  - Establish tide gauge (14 days)
  - GPS current tracking drogue casts (169No. ~ 40min casts)
  - Tell-tail surface marker buoys moored onsite for time-lapse video
  - Seabed biotope mapping with diver belt transects and spot dives
  - Diver seabed video transect and photographing
  - Geotechnical investigation of seabed – water lance probing
  - Geotechnical investigation foreshore/onshore – excavated test pits

• **Phase 3: Dilution survey and modelling** – with the optimum outfall location identified, a dilution survey centred on the proposed discharge location was carried out. Survey period covers 17th December 2013 – 31st January 2014. Main survey activities are as follows;
  - Deploy acoustic wave and current meter (AWAC) on seabed (43 days)
  - Establish tide gauge (43 days)
  - GPS current tracking drogue casts (12No. long casts)
  - CTD cast transects (5No. casts)
  - Establish met station (43 days)

• **Phase 4: Onshore biotope mapping** – survey of foreshore and hinterland ecology. Onsite on 5th March 2014.

  Discontinuous band transec
<table>
<thead>
<tr>
<th>LOCATION</th>
<th>POSITION (OSGB36)</th>
<th>POSITION (WGS84)</th>
<th>HEIGHT - CD (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Survey station P1-5</td>
<td>188511 647997</td>
<td>N55 40.757 W5 21.926</td>
<td>-5.0</td>
</tr>
<tr>
<td>Survey station P2-13</td>
<td>188483 648020</td>
<td>N55 40.769 W5 21.953</td>
<td>-13.0</td>
</tr>
<tr>
<td>Survey station P3-25</td>
<td>188447 648050</td>
<td>N55 40.784 W5 21.989</td>
<td>-25.0</td>
</tr>
<tr>
<td>Survey station W1-1</td>
<td>188544 647971</td>
<td>N55 40.744 W5 21.893</td>
<td>-1.0</td>
</tr>
<tr>
<td>Survey station W2-35</td>
<td>188398 648089</td>
<td>N55 40.804 W5 22.038</td>
<td>-35.0</td>
</tr>
<tr>
<td>Survey station W3-55</td>
<td>188255 648205</td>
<td>N55 40.863 W5 22.179</td>
<td>-55.0</td>
</tr>
<tr>
<td>Survey transect A-B landward end (A)</td>
<td>188631 647907</td>
<td>N55 40.712 W5 21.807</td>
<td>+8.4</td>
</tr>
<tr>
<td>Survey transect A-B seaward end (B)</td>
<td>188388 648091</td>
<td>N55 40.805 W5 22.047</td>
<td>-35.0</td>
</tr>
<tr>
<td>Survey transect C-D landward end (C)</td>
<td>188609 647827</td>
<td>N55 40.668 W5 21.824</td>
<td>+13.2</td>
</tr>
<tr>
<td>Survey transect C-D seaward end (D)</td>
<td>188579 647858</td>
<td>N55 40.684 W5 21.855</td>
<td>+8.8</td>
</tr>
<tr>
<td>AWAC position</td>
<td>188462 648033</td>
<td>N55 40.775 W5 21.974</td>
<td>-19.89</td>
</tr>
<tr>
<td>SW outfall diffuser port</td>
<td>188453 648024</td>
<td>N55 40.770 W5 21.982</td>
<td>-20.00</td>
</tr>
<tr>
<td>NE outfall diffuser port</td>
<td>188470 648043</td>
<td>N55 40.781 W5 21.987</td>
<td>-20.00</td>
</tr>
<tr>
<td>Outfall diffuser centre point</td>
<td>188462 648034</td>
<td>N55 40.776 W5 21.974</td>
<td>-20.09</td>
</tr>
</tbody>
</table>

Table 19: key survey positions

7.6 BATHYMETRY & TOPOGRAPHY

A regional bathymetric chart has been produced, showing the location of the proposed outfall in relation to wider bathymetric features of Kilbrannan Sound. The data used for this was from Maritime and Coastguard Agency bathymetric surveys carried out in the 1984/5. See drawing DRW-002 for detail.

A more detailed bathymetric survey of the site was carried out and combined with detailed onshore topographic survey data in the area of the outfall headworks and nearby shoreline. Drawing DRW-003 shows the results of the bathymetric and topographic survey, with additional topographic data imported from NEXTMap2 DTM to represent the inland areas.

Figure 9 below shows the bathymetry for the whole Firth of Clyde area. It should be noted that deep water (i.e. the 50m depth contour) is closer to the shoreline at the outfall site than at almost anywhere else in the Firth of Clyde.
7.7 HYDROGRAPHY – AMBIDENT CURRENTS & FATE OF FLOW

Water movement in the Kilbrannan Sound is dominated by tidal flows, flooding northwards up the Sound with rising tides and ebbing southwards down the Sound on falling tides. An Admiralty hydrographic survey station shown as diamond ‘A’ on chart BA221 is located in the centre of the Sound 3.8km southwest offshore of the outfall site, see figure 10 and table 20. Further information on this station (SN040G) is provide in Admiralty TotalTide software. The tidal flows recorded here, which should be fairly characteristic of the main channel flow, are summarised below;

- Tide starts to ebb south 1.5 hours before high water at Loch Ranza
- Tide starts to flood north 1.1 hours before low water at Loch Ranza
- Typical spring tidal velocity is 0.17 m/s
Typical neap tidal velocity is 0.11 m/s

Residual tidal flow is clockwise around Arran, so northwards in the Kilbrannan Sound, drawing water in from the North Channel and minimising estuarine influences and stratification in the area (Midgley, et al., 2001).

Large areas of turbulent flow can be found to the northeast and southwest of the outfall site. 8.3km to the northwest is the north end of Arran, where flows from the Kilbrannan Sound meet the waters of Bute Sound off the Cock of Arran. Here the flows mix in a turbulent area well known to mariners. 6.8km to the southwest is Whitefarland Bank and Erins Bank, forming an area of shallow seabed extending 2.4km out from the Arran shore. Here overfalls can be seen at times, and are marked on Admiralty charts to warn mariners/small craft to keep clear of the area.

At the proposed outfall site, turbulence can also be seen on the surface during periods of strong tidal flow and calm weather. This takes the form of gentle boils and swirls on the surface and is particularly notable during the northeast flowing flood tide. This turbulence is set up by seabed roughness which can be observed in the sites bathymetric survey results.

<table>
<thead>
<tr>
<th>TIME (hrs from HW Greenock)</th>
<th>DIRECTION (degrees T)</th>
<th>SPRING RATE (m/s)</th>
<th>NEAP RATE (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-06</td>
<td>040</td>
<td>0.15</td>
<td>0.10</td>
</tr>
<tr>
<td>-05</td>
<td>030</td>
<td>0.15</td>
<td>0.10</td>
</tr>
<tr>
<td>-04</td>
<td>017</td>
<td>0.15</td>
<td>0.10</td>
</tr>
<tr>
<td>-03</td>
<td>330</td>
<td>0.15</td>
<td>0.10</td>
</tr>
<tr>
<td>-02</td>
<td>297</td>
<td>0.15</td>
<td>0.10</td>
</tr>
<tr>
<td>-01</td>
<td>243</td>
<td>0.15</td>
<td>0.10</td>
</tr>
<tr>
<td>HW</td>
<td>225</td>
<td>0.21</td>
<td>0.15</td>
</tr>
<tr>
<td>+01</td>
<td>215</td>
<td>0.26</td>
<td>0.15</td>
</tr>
<tr>
<td>+02</td>
<td>205</td>
<td>0.21</td>
<td>0.15</td>
</tr>
<tr>
<td>+03</td>
<td>194</td>
<td>0.15</td>
<td>0.10</td>
</tr>
<tr>
<td>+04</td>
<td>121</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>+05</td>
<td>062</td>
<td>0.10</td>
<td>0.05</td>
</tr>
<tr>
<td>+06</td>
<td>044</td>
<td>0.15</td>
<td>0.10</td>
</tr>
<tr>
<td>Means</td>
<td>156</td>
<td>016</td>
<td>0.11</td>
</tr>
</tbody>
</table>

Table 20. Mid-channel tidal current flow information from Admiralty survey station SN040G 55°39.90’N 5°25.27’W, tidal diamond ‘A’ on chart BA221 – Firth Of Clyde – Pladda to Inchnamnok.

The outfall site is located between two harbours for which the UK Hydrographic Office produce tidal predictions; Loch Ranza and Carradale (see fig 10). Deployment of a self-recording tide gauge onsite during site investigation work has shown that tidal levels are a best match with Loch Ranza in terms of levels and timing. See drawing DRW-004 plot 4 for an example of survey data overlain with tidal predictions; perturbations in this correspond to weather events seen in drawing DRW-004 plot 5.

Storm surge levels expected at the site are taken from the National Tide Gauge Network data for Millport on Cumbrae. This show that historical storm levels with 5-year return (skew) storm surge is +1.35m, a 20-year return (skew) storm surge is +1.48m.
Figure 10. Mid-channel tidal current flow information from Admiralty survey station SN040G 55°39.90'N 5°25.27'W, tidal diamond ‘A’ on chart BA221 – Firth Of Clyde – Pladda to Inchmarnock.

<table>
<thead>
<tr>
<th>TIDAL STATE</th>
<th>TIDAL HEIGHT ABOVE CHART DATUM (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CARRADALE</td>
</tr>
<tr>
<td>Highest Astronomical Tide (HAT)</td>
<td>3.5</td>
</tr>
<tr>
<td>Mean High Water Springs (MHWS)</td>
<td>3.1</td>
</tr>
<tr>
<td>Mean High Water Neaps (MHWN)</td>
<td>2.6</td>
</tr>
<tr>
<td>Mean Level (ML)</td>
<td>1.85</td>
</tr>
<tr>
<td>Mean Low Water Neaps (MLWN)</td>
<td>1.1</td>
</tr>
<tr>
<td>Mean Low Water Springs (MLWS)</td>
<td>0.4</td>
</tr>
<tr>
<td>Lowest Astronomical Tide (LAT)</td>
<td>-0.2</td>
</tr>
<tr>
<td>Mean Spring Tidal Range</td>
<td>2.7</td>
</tr>
<tr>
<td>Mean Neap Tidal Range</td>
<td>1.5</td>
</tr>
<tr>
<td>Ordinance Datum (Newlyn)</td>
<td>1.62</td>
</tr>
</tbody>
</table>

Table 21. Tide level information for nearby ports from chart BA221 – Firth Of Clyde – Pladda to Inchmarnock.

To determine the nature of tidal flows passing through the outfall site a comprehensive current tracking survey was carried out using a fleet of 4No. GPS equipped drogues. To prevent wind drift the drogues used 1m³ sea anchors set at a depth of 4 meters, or less if working in shallower water (fig 12). Lights and retro-reflective tape were fitted to the surface marker buoys for working a night. GPS receivers fitted to the drogues recorded position, speed, and direction, every 15 seconds while deployed.
The fleet of 4No. drogues were deployed quasi-simultaneously at different stations during each cast, and allowed to drift for set amounts of time before being recovered and returned to their start points to repeat the cycle. During each drogue survey this process was continued over 13 plus hours to cover the full flood and ebb tidal period. The survey stations from where the drogues were released are located along the survey transect. The surveys were carried out in still or light wind conditions, ensuring that the drogue tracks recorded were unaffected by wind acting on the surface markers. A total of 181 drogue casts were made, recording 159 hours of current tracking data.

The four main elements of the drogue surveys are set out below:

- **Initial casts** – 1-hour casts, survey carried out on 29 and 30 October 2013, releasing from survey stations P1, P2 & P3. To determine broad nature of current flows onsite at different tidal states to inform planning main drogue survey.

- **Spring tides** – 40 min casts, survey carried out on 4 November 2013, releasing from survey stations P1, P2, P3 & W2. To map spring tide flows through the site.

- **Neap tides** – 40 min casts, survey carried out on 25 November 2013, releasing from survey stations P1, P2, P3 & W2. To map neap tide flows through the site.

- **Intermediate tides** – 2hr casts, survey carried out on 30 January 2014, releasing from survey stations P1, W2 & W3. To map intermediate tidal flows on a broader scale, with longer casts used to show fate of flow as it travels further from the site.

Currents flowing through the site were found to be strong, quickly advecting the drogues away from the area survey. Typical current speeds are shown in the table 22 below:

<table>
<thead>
<tr>
<th>TIDAL CONDITION</th>
<th>MEAN SPEED (m/s)</th>
<th>MAXIMUM SPEED (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spring tide</td>
<td>0.15</td>
<td>0.41</td>
</tr>
<tr>
<td>Intermediate tide</td>
<td>0.17</td>
<td>0.33</td>
</tr>
<tr>
<td>Neap tide</td>
<td>0.13</td>
<td>0.22</td>
</tr>
</tbody>
</table>

Table 22. Typical current speeds recorded during the current mapping survey – mean speed includes slack water periods.
The current mapping survey results are summarised below and shown in drawing DRW-005:

- **Eddies** – no persistent back-eddies created by coastal morphology occur within the in the survey area which would restrict dispersal of effluent from the site.

- **Slack water** – slack water periods during the turning of the tide were short; usually the flows swirled around to change direction rather than stopping to change direction.

- **Current speeds** – were found to be slightly higher than would be expected from Admiralty predictions for the mid-channel flow. Current speeds were found to increase with the distance offshore.

- **Shore contact** – drogues released from the nearshore stations (P1) were swept into shallow water near the shoreline and grounded on the seabed on 3 occasions, at varying distances from the release point. No drogues released from the stations further seaward of the inshore station contacted the shore.

- **Timing** – tidal flows through the site are not simple bi-directional semi-diurnal flows, corresponding to rising and falling tides. It was found that during the neap tides the northeast-going ‘flood’ tide was dominant, with very little southwest flowing ‘ebb’. During the spring tides the opposite was true, and during the intermediate tides the ebb and flood tide were about balanced in strength and duration. See figure 15 & 16, and drawing DRW-005 for drogue track plots. The reason for this is hard to determine, but likely due to regional tidal effects, regional weather effects, and morphology of the Kilbrannan Sound as a whole.
Figure 15. 'flood' dominated neap tide drogue survey  
Figure 16. 'ebb' dominated spring tide survey

The drogue tracks from the intermediate tidal survey were plotted on Admiralty chart backdrop as the drogues travelled far outside the main survey area. Several drogues travelled in excess of 1.5km within the longer 2-hour cast duration.

Figure 17. Mid-channel tidal cu
Once the optimum position for an outfall terminal was determined, an instrument package (AWAC) within a shroud was placed on the seabed by divers at this location to record ambient currents, surface waves, and tidal heights. The seabed depth at this location was 19.89m below CD, and the position was OSGB 188462 648033. The AWAC was deployed on 18 December 2013 and recovered on the 30 January 2014, recording data for a period of 43 days, well in excess of the 14 days specified by SEPA for dilution modelling. A meteorological station was established onshore for the duration of the current survey period, and CTD casts were made along the survey transect to measure the density profile of the water column. The weather during the survey period was unsettled, and included several severe gales and local flooding events.

This current survey was primarily designed and carried out to provide hydrographic data for dilution modelling work carried out by Partrac Ltd – see report IAD-OUTFALL-2017-RPT-004-dilution modelling v1. The work is described in detail in Partrac’s report, but the survey data is also summarised below as it helps set the scene of the broader hydrographic nature of the site.

![Figure 18. AWAC in gimble frame deployed by divers on seabed at a location mid-way between the proposed outfall port locations. Deployed on seabed for 43 days.](image)

<table>
<thead>
<tr>
<th>DEPTH BELOW CD (m)</th>
<th>MINIMUM SPEED (m/s)</th>
<th>MEAN SPEED (m/s)</th>
<th>MAXIMUM SPEED (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth averaged</td>
<td>0.01</td>
<td>0.14</td>
<td>0.51</td>
</tr>
<tr>
<td>4</td>
<td>0.01</td>
<td>0.18</td>
<td>0.67</td>
</tr>
<tr>
<td>10</td>
<td>0.01</td>
<td>0.17</td>
<td>0.60</td>
</tr>
<tr>
<td>16</td>
<td>0.01</td>
<td>0.15</td>
<td>0.61</td>
</tr>
</tbody>
</table>

Table 23. Characteristic current flow data from AWAC survey

Table 23 shows characteristic current speed data from the dilution survey. Mean speeds are comparable to those recorded in the current mapping survey. The maximum speeds are higher, as they are taken from data averaged over shorter time periods. The depth averaged speed is lower than expected in relation to depth specific speeds. This is due to due to significant amounts of current shear found throughout the water column.

Drawing IAD-OUTFALL-DRW-004-hydrographic and meteorological survey shows a graphic representation of the current data, together with tidal height and met data. Key points to be noted from this data is that the tidal flows, though consistently strong, are not easily predictable in terms of timing and direction. One example this occurs on the 18 and 19 December 2013, where the tide flows constantly in a north-easterly ‘flood’ direction for approximately 24 hours, never dropping below 0.15 m/s. Another example is on the 8 and 9 January 2014, when the tide flows south westerly almost constantly for a 48-hour time period.

The pattern of a flood-dominated neap tides and ebb-dominated spring tides observed in the drogue survey was not observed in the AWAC data. There was, however, some correlation with directional dominance and weather conditions. During more settled weather, tidal flows tended to become more semi-diurnal,
with balanced ebb and flood flows, such as seen between the 17 and 24 January 2014. From this observation, it can be said that the tidal current flowing through the site are strongly affected by chaotic meteorological conditions in terms of direction and timing, and therefore difficult to predict.

7.8 SITE ECOLOGY

A survey of the site ecology has been carried out in order to identify species or habitats of conservation significance which may be affected by the proposed outfall. This information will also be used to help design a baseline ecology survey for ongoing outfall site monitoring. Ecological survey effort over the course of site investigation work involved the four main activities set out below. See drawing DRW-006 for locations.

- **Foreshore and seabed survey (transect A-B)** – carried out by diving marine biologists and geologists; on the 5th and 6th November 2013. Surveyed one belt transect aligned approximately along the subsea route of the proposed outfall pipeline, extending from CD+5.0m to CD-35.0m. Semi-quantitative recording of conspicuous epifauna and flora species present at 10m distance intervals was carried out to a depth of CD -30.6m. Subsea video, photo, and visual surveys along this transect were also made to maximum CD depths of -18.8, -30.1m and -35.6m respectively.

- **Wide area seabed survey (spot dives)** - carried out by diving marine biologists and geologists; on 7th November 2013. To investigate along-shore habitat variation a number of ‘spot dives’ were carried out at distances of 50m, 100m, 200m and 500m southwest and northeast of the proposed outfall. Most dives covered the seabed in the CD -20m to CD -3m depth range. Visual observations were made and photographs taken.

- **Hinterland and foreshore survey (transect C-D & A-B)** – carried out by Head of Biology at the Lochranza Field Centre, on 5th March 2014. An interrupted belt transect extending from the foot of the hill landward of the road (CD +13.2m), to the roadside (CD +8.6), then from the roadside (CD +8.4m) to MLWS level on the foreshore (CD +0.3). For the hinterland section a 1m² quadrat was placed every 2m distance along the transect and dominant flora species recorded. For the foreshore section a 1m² quadrat was placed every 0.25m increase in height and conspicuous epifauna and flora species recorded.

- **General observations** – various stages of site investigation works cover the time period of 14th August 2013 to 6th February 2014. Time spent on site during this period amounted to 18 days in varying tidal and weather conditions. Total number of dives undertaken during this time was 17. General observations on the sites ecology were made by the boat, shore and diving based survey teams through this period.

As habitat type is dependent on site geology/hydrography, other site investigation works carried out onsite assist with identifying likely biotope distribution in the wider survey area. Sources of broader site information relevant to the ecology survey include:

- **Geomorphology** - high resolution bathymetric/topographic survey, see drawing DRW-003

- **Seabed surface features** - high resolution seabed sidescan sonar survey (CHIRP 800kHz), see figure 19

- **Seabed sub-bottom hardness** – low frequency single beam sonar survey (50kHz), see figure 20

- **Seabed geotechnical investigation** - diver operated high-pressure water lance to probe sediments (drawing DRW-010)

- **Onshore/foreshore geotechnical investigation** – excavation of test pits (drawing DRW-010)
Sidescan sonar imaging of the seabed was particularly useful in understanding the nature and distribution of habitats. The high-resolution images allowed identification of small scale seabed features such as individual boulders, sand ripples, worm-cast mounds and kelp fronds. See figure 19 for an example of sidescan sonar data.

Fig 19. Sample of broad scale sidescan sonar seabed imaging data (sonograph) showing the seabed along transect (A-B) from a depth of CD -32m up to +1m.

Fig 20. Sample of bottom hardness mapping data – showing a SW-NE (along shore) transect across channels cut into the slope adjacent to the outfall site.

The results of the ecological survey are shown in the documents/media listed below.

- IAD-OUTFALL-2017-DRW-006-bioptope mapping v1 - drawing showing survey transect location/profile and bioptope mapping results
- IAD-OUTFALL-2017-MED-001 - photos of the seabed, foreshore and hinterland along the survey transects and in the general area can be found in this file. Please note that image editing software was used to improve definition of photos lit by natural light, and colour balance has been distorted in some photos as a result; 334 photos.
- IAD-OUTFALL-2017-MED-002 - HD underwater video footage of foreshore and seabed along survey transect A-B, 35min duration
- IAD-OUTFALL-2017-DAT-002 - species survey results and notes for hinterland and foreshore – MSexcel spreadsheet
- IAD-OUTFALL-2017-DAT-001 - species survey results and notes for foreshore and seabed – MSexcel spreadsheet
Data gathered from transect surveys, spot dives, and other site information was used to characterise the various habitats types found onsite. Substrate type and dominant conspicuous species were used to identify biotope zones using the JNCC classification system; Connor, et al (2004). The 12No. biotopes identified are described below in height descending order. The extent of each biotope is shown on DRW-006.

- Coastal hinterland (transect C-D) – peaty wet heath on wave-cut platform extending landward to wooded hillside rising steeply behind. Ground is poorly drained with springs and ephemeral streams common. Stream channels are aligned straight downslope and at semiregular intervals so may be the remnants of lazy-beds/field drains.

  Level range; CD +8.8m - +13.2m. Transect distance; 43.1m (full transect). Slope; 4.7°

  Photo file; 001-transect C-D (25 photos)

  Typical vegetation consisted of patches of grasses, common bracken (Pteridium aquilinum) and ling heather (Calluna vulgaris). The vegetation was dominated by bracken with feather moss (Eurhynchium praelongum) and a few herb species such wood sorrel (Oxalis acetosella), and brambles (Rubus fruticosus) mixed within. The percentage of grass coverage is low as due to bracken. Stalks of foxgloves (Digitalis purpurea) occur occasionally.

- Coastal hinterland (transect A-B – zone 1) – area of sloping heath on wave-cut platform extending back to the road, assumed to overlie raised beach deposits found in adjacent test pits.
Level range; CD +8.4m - +5.6m. Transect distance range; 2.0m – 25.0m. Slope; 6.4°

Photo file; 002-transect A-B zone1 (9 photos)

Vegetation dominated by common bracken (*Pteridium aquilinum*), though some brambles (*Rubus fruticosus*) mixed in at the roadside. Isolated small trees are found such as eared willow (*Salix aurita*) and downy birch (*Betula pubescens*). Feather moss (*Eurhynchemium praelongum*) is still abundant with some bog moss (*Sphagnum spp*) found. Heather species such as ling heather (*Calluna vulgaris*) and cross-leaved heath (*Erica tetralix*) appear occasionally. The percentage of grass coverage is very low as due to the bracken cover.

Fig 25 & 26. Typical vegetation in zone 2, transect A-B, see file for additional photos

- **Adlittoral (transect A-B – zone 2)** – undulating flat ground made up of a series of relic raised beach berms running parallel with the shoreline and covered with vegetation. The ground is well drained due to shallow soils and underlying raise beach deposits.

Level range; CD +5.6m - +4.9m. Transect distance range; 25.0m – 41.0m. Slope; 2.4°

Photo file; 003-transect A-B zone2 (10 photos)

Vegetation dominated by grasses, though some clumps of mixed heather species and gorse (*Ulex europaeus*) are present. Stalks of perennial plants such as ragwort (*Jacobaea vulgaris*) and docks (*Rumex obtusifolius*) are also common where the turf is less well developed. The shallow troughs between the berms contain bog moss (*Sphagnum spp*) and rushes (*Juncus spp*) in places.

Fig 27 & 28. Typical shore features in zone 3, transect A-B, see file for additional photos
- **Supralittoral (transect A-B – zone 3)** – Littoral sediment - backshore storm berm of mobile pebbles and cobbles. Beach profile in this zone subject to seasonal change. Thin strandlines of storm debris consisting of some plastic and wood flotsam and jetsam, but mostly decaying algae which is largely made up of mixed bladderwrack species (*Fucus spp*).

Level range; CD +4.9m - +3.5m. Transect distance range; 41m - 54m. Slope 6.2°

Characteristic JNCC biotope; LS.LCS.Sh.BarSh

Photo file; 004-transect A-B zone3 (35 photos)

Littoral sediment mobilised during winter storm surge events, subject to occasional wave overtopping and frequent spray. Freely draining substratum. Macrofaunal limited to insects and sand hoppers (*Gammarus spp*), which are common among dead algae and under cobbles. Growth of lichen and colonising plant species are limited by mobility of the substratum.

![Typical foreshore features in zone 4, transect A-B](image)

- **Eulittoral (transect A-B – zone 4)** – Littoral sediment - upper foreshore of highly mobile pebbles and cobbles. Prograding and retrograding tidal berm ridge at the upper tidal levels. Beach profile in this zone subject to seasonal change. Occasional single thin tidal strandlines of assorted bladder wrack species. Pebbles and cobbles frequently mobilised due to moderate wave action. Freely draining substratum.

Level range; CD +3.5m - +1.7m. Transect distance range; 54m - 70m. Slope; 8.1°

Characteristic JNCC biotope; LS.LCS.Sh.BarSh

Photo file; 005-transect A-B zone4 (65 photos)

Common macrofaunal species are limited to insects and sand hoppers (*Gammarus spp*), which are frequent found among dead algae and under cobbles. Occasional rough periwinkle (*Littorina saxatilis*) and barnacles (*Semibalanus spp*) occur towards the lower levels of this zone.

Red and green microalgae coatings also occur on the cobbles towards the lower levels of this zone. Growth of algae and epifauna is severely limited due to exposure and frequent tumbling of cobbles and pebbles.
- **Eulittoral (transect A-B – zone 5)** – Littoral rock – lower foreshore of cobbles with interstitial sand in places. Cobbles occasionally mobilised by moderate wave action – has some properties of a sedimentary substrate due to mobility of cobbles. Beach profile appears stable.

Level range; CD +1.7m - +0.2m. Transect distance range; 70m – 90m. Slope; 4.5°

Characteristic JNCC biotope; LR.HLR.MusB.Sem.LitX

Photo file; 006-transect A-B zone5 (49 photos)

Common macrofauna limited to hardy species as substrate is occasional mobile and cobbles overturned. Dominated by shelled organisms; common winkles (*Littorina littorea*), dog whelk (*Nucella lapillus*), and barnacle (*Semibalanus spp.*). Other species that occasionally occur include purple top shell (*Gibbula umbilicalis*), and under and between the larger cobbles; tube worm (*Serpula spp.*), beadlet anemone (*Actinia equina*), and sand hopper (*Gammarus spp.*) are common.

Some macroalgae species are starting to appear in the lower reached of this zone; occasional clumps of spiral wrack (*Fucus spiralis*) and sparse red algae species such as carrageen (*Chondrus crispus*) and pepper dulse (*Osmundea pinnatifida*). Red microalgae species coating cobbles dominate over green microagal species. Occasional encrusting calcareous algae (*Lithophyllum incrustans*) can be found on more stable cobbles.
• **Infra littoral (transect A-B – zone 6)** – Infra littoral rock – sublittoral fringe on shore rise of small boulders and cobbles, with interstitial sand in places, overlain subtidal sand flat of mobile medium sand to seaward. Cobbles occasionally mobilised by moderate wave action. Area heavily scoured by sand during storm events, and by moderate wave action during extreme low tides.

Level range; CD +0.2m - -0.6m. Transect distance range; 90m – 100m. Slope; 4.7°

Characteristic JNCC biotope: IR.HIR.KSed.Sac (not well represented in terms of species)

Photo file: 007-transect A-B zone6 (29 photos)

In the summer the seabed is dominated by opportunistic semi-annual macroalgal species such as furbelow kelp (*Saccorhiza polyschides*), sugar kelp (*Laminaria saccharina*), sea lettuce (*Ulva lactuca*) and bootlace weed (*Chorda filum*). In the winter the seabed is dominated by an understory of scour-resistant species such as the calcareous algae (*Corallina officinalis*) and carrageen (*Chondrus crispus*).

Macrofaunal community is diverse with a mixture of species common to the littoral and sublittoral zones. Dominated by common periwinkle (*Littorina littorea*), dog welk (*Nucella lapillus*), and tube worm (*Serpula spp.*). Anemone species include snakelocks anemone (*Anemonia viridis*), beadlet anemone (*Actinia equina*), and strawberry anemone (*Actinia fragacea*). Starfish species include spiny starfish (*Marthasterias glacialis*), seven-armed sea star (*Luidia ciliaris*) and common starfish (*Asterias rubens*). Occasional demersal fish species were also noted hiding among the boulders and cobbles, including sea scorpion (*Taurulus bubalis*) and common gobies (*Pomatoschistus microps*).

**Fig 33 & 34**. Typical seabed features in zone 7, transect A-B, see file for additional photos

• **Infra littoral (transect A-B – zone 7)** – shallow sublittoral sediment – subtidal sand flats extending seaward to drop-off. Sand is medium grained, bioturbated, with low mud content. Surface varies between rippled sand from wave generated currents to extensive diatom mats, dependant on the weather/season. Razor shell (*Ensis siliqua*) has been commercial fished from the transect area in the past using electrofishing techniques, though it is not thought to have greatly affect the observed community or substratum.

Level range; CD -0.6m - -3.0m. Transect distance range; 100m – 138m. Slope; 3.6°

Characteristic JNCC biotope; SS.SSa.IMuSa.EcorEns

Photo file: 008-transect A-B zone7 (51 photos)

Sediment dominated by conspicuous infauna species; straight razor clam (*Ensis siliqua*), otter shell (gaper) (*Lutraria lutraria*), and sea potato (*Echinocardium cordatum*), recognised from active feeding syphons, dead shells, and surface trails. Razor shell (*Ensis siliqua*) are quite dense in places >
8No./m². Occasional lugworm cast mounds (* Arenicola marina and smaller species *) in the lower levels of this zone.

Also common are epifauna species such as hermit crab (* Pagurus bernhardus *) in the upper levels of this zone. The Buckie (* Buccinum undatum *), and common starfish (* Asterias rubens *) are common in the lower levels of this zone.

Due to a lack of hard substrate the dominant flora is extensive microalgae diatom mats forming over the surface of the sand. These mats form during periods of settled weather in the spring/summer/autumn when sediment is not significantly disturbed by wave action. Where hard substrate does exist in the form of occasional large shells or small pebbles, opportunistic macro algae species such as sugar kelp (* Laminaria saccharina *), and bootlace weed (* Chorda filum *) colonise these surfaces. Along-shore tidal currents are too strong for rafts of free living algae such as sea lettuce (* Ulva lactuca *) to develop to any significant degree.

**Fig 35 & 36**  Typical seabed features in zone 8, transect A-B, see file for additional photos

- **Circalittoral (transect A-B – zone 8)** – Circalittoral muddy sand – shore rise of bioturbated muddy sand, occasional isolated boulders and patches of gravels on upper slopes. The slope in this zone has bisected by channels leaving significant cross-slope undulations. These notable seabed features are likely to be relic glacio-fluvial features. The slopes are stable and the processes that formed the seabed morphology are no longer active. Sediment in this zone varies from heavily bioturbated muddy sand in the upper levels, to moderately bioturbated muddy sand in the lower levels. Exposed gravel patches and isolated boulders are occasionally found on the crest of the lobes formed between the channels in the upper levels of the zone.

Level range; CD -3.0m - -15.0m. Transect distance range; 138m – 195m. Slope; 12°

Characteristic JNCC biotope; SS.Ssa.IMuSa.AreISa

Photo file; 009-transect A-B zone8 (81 photos)

Sediment is dominated by infauna species; lugworm (* Arenicola marina *), straight razor clam (* Ensis siliqua *), and sea potato (* Echinocardium cordatum *), recognised from active feeding syphons, dead shells, and surface trails. A very diverse and rich community of epifaunal species was also found, including king scallop (* Pecten maximus *), spiny starfish (* Martasterias glacialis *), edible crab (* Cancer pagurus *), and buckie (* Buccinum undatum *). Where isolated boulders occur, attached epifaunal species can be found, mainly plumose anemone (* Metridium senile *).

The intense feeding activity of lugworm (* Arenicola marina * ) in the upper levels of this zone was noted. This is stimulated by the deposition of decaying macroalgae debris on the slope below wave-base and subsequently entrapment between worm mounds. These macroalgae debris are
generated seasonally in the coastal zone in the shallower waters above by storm action, and 
autumn die-back of ephemeral and annual macroalgae species.

Macroalgal growth is limited in the upper levels of this zone by lack of hard substrate, and in the 
lower levels, by lack of light. Where macroalgae species do grow, they tend to be dominated by 
sugar kelp (*Laminaria saccharina*) or red algae species such as *Plocamium cartilagineum*.

*Fig 37 & 38*. Typical seabed features in zone 9, transect A-B, see file for additional photos

- **Circalittoral offshore (transect A-B – zone 9)** – Circalittoral tidal swept fine sand with shell 
  fragments. Bioturbation is less active in this zone. In places the seabed is mobile with patches of 
  sand ripples aligned along axis of along-shore tidal currents.

  Level range; CD -15.0m - -22.0m. Transect distance range; 195m – 219m. Slope; 16.1°

  Characteristic JNCC biotope; SS.SSa.CFiSa

  Photo file; 010-transect A-B zone9 (23 photos)

  This zone is dominated by epifauna which is diverse, but found at much lower densities relative to 
  zone 8. Conspicuous dominant species include King scallop (*Pecten maximus*), Hermit crab 
  (*Pagurus bernhardus*), Swimming crab (*Liocarcinus depurator*), and common starfish (*Asterias 
  rubens*). Occasional hard substrates such as pebbles are colonised by Plumose anemone 
  (*Metridium senile*), and seaboard (*Nemertesia antennina*).

  Conspicuous infauna species are limited to burrowing anemone (*Cerianthus lloydii*), burrowing 
  starfish (*Astropecten irregularis*), pullet carpet shell (*Venerupis senegalensis*), and other small 
  clam species.

  The lower levels of this zone lie below the photic zone. Occasional macroalgae species found in 
  the lower reaches of this zone are unattached and likely swept down from shallower areas.
- **Circalittoral offshore (transect A-B – zone 10)** – Circalittoral fine clean sand with shell fragments. Tidal swept rippled surface. Very little active bioturbation evident. This area may have been dredged for scallops (*Pecten maximus*) from time to time.

  Level range; CD -22.0m - -30.6m. Transect distance range; 219m – 266m. Slope; 10.4°

  Characteristic JNCC biotope; SS.SSa.CFiSa

  Photo file; 011-transect A-B zone10 (6 photos)

  This zone is dominated by epifauna which is diverse, but found at lower densities relative to zone 9 above. Dominant species include king scallop (*Pecten maximus*), hermit crab (*Pagurus bernhardus*), swimming crab (*Liocarcinus depurator*), and common starfish (*Asterias rubens*).

  Conspicuous infauna species are limited to burrowing anemone (*Cerianthus lloydii*), burrowing starfish (*Astropecten irregularis*), pullet carpet shell (*Venerupis senegalensis*), and other small clam species, possibly *Abra alba*.

  No algae in this zone.

- **Circalittoral offshore (transect A-B – zone 11)** – Circalittoral muddy non-cohesive sand with shell fragments. Tidal swept rippled surface. Very little bioturbation evident.

  Level range; CD 30.6m - > -35.0m. Transect distance range; > 266m. Slope; 5.4°

  Characteristic JNCC biotope; SS.SSa.CMuSa

  Photo file; no photos taken at this depth

  Limited diver observations but conspicuous epifauna species noted include; burrowing starfish (*Astropecten irregularis*), common starfish (*Asterias rubens*), serpent's table brittlestar (*Ophiura albida*), hermit crab (*Pagurus bernhardus*).

  No algae in this zone.
To investigate along-shore habitat variation a number of ‘spot dives’ were carried out at distances of; 50m, 100m, 200m and 500m to the southwest and northeast of the proposed outfall discharge point. Each dive covered the seabed in the CD -20m to CD -3m depth range (see fig 41).

<table>
<thead>
<tr>
<th>DIVE</th>
<th>DIRECTION</th>
<th>DISTANCE (m)</th>
<th>POSITION (BNG)</th>
<th>SEABED DEPTH RANGE SWAM (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>NE</td>
<td>50</td>
<td>188542, 648036</td>
<td>-20 - -3</td>
</tr>
<tr>
<td>2</td>
<td>NE</td>
<td>107</td>
<td>188590, 648068</td>
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<td>3</td>
<td>NE</td>
<td>206</td>
<td>188674, 648125</td>
<td>-15 - -3</td>
</tr>
<tr>
<td>4</td>
<td>NE</td>
<td>491</td>
<td>188928, 648259</td>
<td>-20 - -3</td>
</tr>
<tr>
<td>5</td>
<td>SW</td>
<td>53</td>
<td>188482, 647951</td>
<td>-20 - -3</td>
</tr>
<tr>
<td>6</td>
<td>SW</td>
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<td>7</td>
<td>SW</td>
<td>203</td>
<td>188335, 647888</td>
<td>-20 - -6</td>
</tr>
<tr>
<td>8</td>
<td>SW</td>
<td>505</td>
<td>188072, 647741</td>
<td>-20 - -3</td>
</tr>
</tbody>
</table>

Table 24. Location of ‘spot dive’ transects and distance to outfall

It was found that to the northeast of the outfall site the seabed is largely the same as at the outfall site in terms of seabed profile and habitat distribution. An exception to this was at NE4 there are no channels cut into the slope and the seabed was found to be much more uniform, and without isolated boulders and gravel patches in Zone 8.

To the southwest the seabed shows more variety in relation to outfall site. At SW6 and SW7 the slope was deeply cut by channels and very steep in places within Zone 8 (depth CD -3 to -15m). Gravel patches were
more common, though sand still dominated. In the shallower areas, Sugar kelp (*Laminaria saccharina*) grows on the gravel.

![Image](image_url)

**Fig 42.** Seabed at a depth of CD -16.7m at ‘spot dive’ site SW8 - showing barren stony slope and isolated boulders

At SW8 the seabed changes significantly in terms of profile and composition in relation to all other areas in the survey area. The seabed slopes down very gently between CD -3m and -7m, and the substrate here is composed of sand and gravel. Below CD -7m the seabed slopes down very steeply and the substrate is composed of cobbles and gravels with isolated boulders strewn about its surface. The upper reaches of the area are dominated by sugar kelp (*Laminaria saccharina*) growing on the smaller gravel, and stands of cuvie (*Laminaria hyperborea*) on the larger cobbles and boulders. In the lower levels, below 10m, the seabed is surprisingly barren. Occasional king scallop (*Pecten maximus*), spiny starfish (*Marthasterias glacialis*), common sea urchin (*Echinus esculentus*), and plumose anemone (*Metridium senile*) were seen.

Figure 43 shows the EUNIS seabed classification map for the area in the vicinity of the proposed outfall. Distribution of habitat types shown on this map is indicative only due to high levels of interpolation between sparse sample points. The distribution of habitat mapped during this survey broadly corresponds with EUNIS seabed classification map.

The patch of 'Deep circalittoral mixed sediment' shown offshore of the outfall site on the EUNIS seabed map is of interest. It is located below the channel cut section of slope, and potentially formed by the same process that created the distinctive channel cut features at the outfall site.
Habitats or species of conservation significance observed within the survey area are noted below. The survey period extended between 14 August 2013 and 6 February 2014, with 18 days spent onsite within that period in varying weather and tidal conditions, and often from dawn till dusk.

- **Otter (Lutra lutra)** - a solitary otter was observed swimming along the shore past the outfall site at low tide on two occasions, not milling about or feeding. No spraints, marks or feeding debris attributable to otters were seen onshore. Otters are common to the northwest Arran area. The outfall site is not particularly attractive to otters as generally they prefer to feed and rest on rocky shores with cover, and close to a source of freshwater for rinsing salt from their fur. Discussion with the SNH area officer in April 2014 indicated that due to the nature of the site and the proposed outfall design/construction plan a specific otter survey is not required.

Protected status: European Protected Species listed in Appendix 74 of the CRoW Act 2000 and protected under Section 5 of the Wildlife and Countryside Act 1981 (as amended). In addition, otters are also protected under the Conservation (Natural Habitats &c.)

- **Common seal (Phoca vitulina)** – solitary seals were observed passing through the site or just offshore of the site in November and December 2013 on 6 occasions, with no correlation between tidal state or weather noted. On 24 and 25 November 2013, a juvenile seal milled around the site for several hours each day and interacted playfully with divers working in the water.

Protected status: Classified as Least Concern (LC) on the IUCN Red List. Protected in Britain under the Conservation of Seals Act 1970 (closed season from 1 September until 31 December) and schedule 3 of the Conservation Regulations (1994). Listed as a protected species under Annex II and Annex V of the European Community's Habitats Directive.

- **Harbour porpoise (Phocoena phocoena)** – small pods of approximately 3-4 individuals were seen passing the site at a distance of approximately 300m offshore on two occasions during November 2013. On several calm quiet days, porpoise could frequently be heard breathing far out in the Kilbrannan sound, though not seen. They were possibly over a kilometre away from the site on those occasions.

Although not found living within or near the outfall site, seagrass (Zostera marina or Zostera noltii) debris were found among seaweed on the strandline, and decaying debris were found among seaweed debris on the seabed in November 2013. Seagrass beds are included as a Priority Habitat in the UK Biodiversity Action Plan 2011. Extensive seagrass beds are known to occur within the South Arran MPA (one of its designation characteristics), and beds are also known to occur off Pirnmill, 4.4km to the south of the outfall site, Binnie et al (2012). Seagrass leaves are buoyant when live and only sink after they have been decaying for some time. It therefore seems probable that prevailing tides and winds have carried the seagrass debris into the site from Pirnmill, and possibly from further afield.

The only invasive species observed onsite was ragwort (Jacobaea vulgaris), found onshore in transect A-B zone 2. No marine invasive species were noted.

7.9 GEOTECHNICAL INVESTIGATIONS

Geotechnical investigation of the ground/seabed conditions along the route of the outfall pipeline were carried out primarily to inform the construction design of the outfall. Useful environmental information was also obtained.

For the onshore/foreshore section a 5-tonne excavator was used to dig 4No. test pits across the foreshore and hinterland along the proposed outfall route. On the seabed a diver operated 1.5m long high-pressure water lance was used to probe the seabed at 10m intervals along the survey transect to a depth of 16m below CD. The result of the survey are shown in detail in drawing IAD-OUTFALL-2017-DRW-010-pipeline design, and photos from the test pit can be found in file 004-MEDIA. The results are summarised below;

- **Hinterland** – 2No. test pits found that the ground consisted of mixed raised beach deposits; lenses of cobbles and gravels down to a depth of 1.8m. No bedrock encountered. Surface is thin, poorly developed turf.

- **Foreshore** – 2No. test pits found that ground conditions consisted of free draining beach sediments to a depth of approximately 1m. On the upper foreshore, a depth of 1.8m was achieved with no bedrock found. On the lower foreshore, bedrock of schist was found at a depth of 1.4m. No manmade debris, or strata were found during the excavations that indicate the foreshore may be unstable or vulnerable to changes in profile.

- **Seabed** – diver probing found that seabed was sand with some gravel horizons. The probe penetrated to maximum depth at all stations except where the downward sloping cobble foreshore is overlain by sand at the subtidal fringe, and where a gravel parch occurs on the seabed at depths of about 8m below CD (biotope zone 8).
Fig 44 & 45 Forshore and hinterland pest pits
8.0 DILUTION & DISPERSAL AVAILABLE

8.1 DILUTION SURVEY and MODELLING RESULTS

Basic predictive dilution modelling was carried out as part of the initial site survey in order to identify the optimum location and design for the outfall. The method used was the Water Research Council's empirical initial dilution equations (WRC 1988 and 1990). A range of location, ambient flow conditions and discharge scenarios were modelled, allowing the development of an optimised outline design for the outfall system.

This design, together with background information was discussed with [REDACTED] from SEPA's hydrographic modelling group in 2013. The scope and methodology for a site specific hydrographic survey and dilution modelling for Arran was agreed.

Dilution survey and modelling work was subsequently carried out by Partrac Ltd in 2013/14 – see report 'IAD-OUTFALL-2017-RPT-004-dilution modelling'. Hydrographic data recorded during the survey can be found in file 'IAD-OUTFALL-2017-DAT-005-P1473'.

![CTD during deployment](image1)

![AWAC during recovery](image2)

Modelling results for predicted initial and secondary dilution values are shown in table 25. The figure for maximum secondary dilution is limited to 20000x due to an arbitrary maximum set for the model output.

The conservative nature of the predicted dilution results in the probability that these dilution values will be significantly exceeded at all times.

<table>
<thead>
<tr>
<th>DILUTION CONDITION</th>
<th>INITIAL DILUTION (x)</th>
<th>SECONDARY DILUTION (x)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum dilution</td>
<td>1242</td>
<td>3098</td>
</tr>
<tr>
<td>Minimum 95%ile dilution</td>
<td>1981</td>
<td>6079</td>
</tr>
<tr>
<td>Mean dilution</td>
<td>5748</td>
<td>13603</td>
</tr>
<tr>
<td>Maximum dilution</td>
<td>14281</td>
<td>20000*</td>
</tr>
</tbody>
</table>

Table 25. Predicted initial and secondary dilution of the discharge effluent, see SAMS survey report for more details.

The predicted initial dilution values indicate that minimum initial dilution requirements for the discharge effluent will be significantly exceeded at all times. The predicted secondary dilution values indicate that EQS\textsuperscript{daily} requirements will be significantly exceeded at all times.

The predicted secondary dilution values allow for back-calculation of the theoretical maximum concentrations of environmentally significant effluent constituents allowable in the discharge effluent while still complying with EQS\textsuperscript{daily} requirements. The equation used for this calculation is shown below.
Theoretical max discharge concentration = \( \text{Dilution}^{\text{secondary}} \times (\text{EQS}_{\text{daily}} - \text{Background concentration}_{\text{seawater}}) \)

The results of this calculation, worked out for varying dilution conditions and distillery production rates, are shown in table 26. They show that a theoretical allowable peak dissolved copper concentration in the effluent, while still meeting EQS requirements, is 30,334 µg/l⁻¹. The peak concentration in the proposed discharge effluent is 4,820 µg/l⁻¹.

<table>
<thead>
<tr>
<th>CONSTITUENT</th>
<th>Theoretical max discharge conc. (µg/l⁻¹) for EQS\text{daily} compliance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CURRENT\text{p}</td>
</tr>
<tr>
<td></td>
<td>min</td>
</tr>
<tr>
<td>Dissolved Copper</td>
<td>18,804</td>
</tr>
<tr>
<td>Dissolved Zinc</td>
<td></td>
</tr>
<tr>
<td>Dissolved Lead</td>
<td></td>
</tr>
<tr>
<td>Ammoniacal Nitrogen</td>
<td></td>
</tr>
</tbody>
</table>

Table 26. Maximum discharge concentrations theoretically allowable while still meeting EQS\text{daily} dilution requirements at the edge of the mixing zone. Dependent on distillery production rate and secondary dilution conditions.

Predicted secondary dilution values also allow for the calculation of predicted peak concentrations of environmentally significant effluent constituents at the edge of the mixing zone under the varying dilution conditions. These concentrations will not vary with distillery production rate. The equation used in this calculation is shown below:

\[
\text{Concentration in plume at edge of mixing zone} = \frac{\text{Effluent}_{\text{conc}} + (\text{Dilution} \times \text{Background}_{\text{conc}})}{\text{Dilution}}
\]

Table 27 contains the results of this calculation, with EQS\text{annual} and EQS\text{daily} also included for comparison. The results indicate that EQS\text{daily} concentrations will be met for all dilution conditions.

<table>
<thead>
<tr>
<th>CONSTITUENT</th>
<th>Conc. at edge of mixing zone (µg/l⁻¹)</th>
<th>EQS\text{annual} (µg/l⁻¹)</th>
<th>EQS\text{daily} (µg/l⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>min</td>
<td>95%ile</td>
<td>mean</td>
</tr>
<tr>
<td>Dissolved Copper</td>
<td>2.06</td>
<td>1.29</td>
<td>0.85</td>
</tr>
<tr>
<td>Dissolved Zinc</td>
<td>6.80</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dissolved Lead</td>
<td>7.20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ammoniacal Nitrogen</td>
<td>600.00</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 27. Concentration of environmentally significant discharge effluent constituents at the edge of the mixing zone. Based on peak discharge effluent concentrations, and dependent on secondary dilution conditions.

8.2 DILUTION FACTORS NOT ACCOUNTED FOR IN PREDICTIONS

Several factors which can significantly affect dilution rates within the mixing zone, but are not accounted for in the dilution prediction, or easily quantifiable, are set out below;

- Meteorological effects - predicted dilution rates do not take into account mixing of the surface plume by wind driven waves within the mixing zone. As the outfall site is exposed to prevailing winds, and a fetch of up to 10km, it is likely mixing of the surfaced plume by wind drive waves will provide significant additional dilution.
This point is particularly significant, as some of the periods of lowest current speeds recorded correspond to periods of high wind speeds. An example of this is on 26 December 2013 when the longest recorded period of low current flow during the survey corresponds with the strongest peak wind speed recorded during the survey. The predicted dilution rates for this period will be low, whereas due to mixing by wind driven storm waves a surfaced plume would receive a very high rate of dilution.

- **Turbulence** – visual observations of boils and swirls in the tidal flows passing through the outfall site were made during the site survey. Turbulence is caused by seabed roughness in the area and is particularly notable during the northeast-going ‘flood’ tide. The effect of the observed turbulence is evident in the small scale (sub-decimetre) ‘wiggling’ of some drogue tracks, and divergence of drogues released from the same survey station simultaneously. Turbulence has the ability to significantly enhance dilution and may not be sufficiently accounted for in the model.

- **Stratification** – formation of shallow diurnal thermoclines during hot calm days has the potential to suppress dilution within the mixing zone, though due to the depth available and turbulence observed onsite, this is not thought to be a significant factor.

- **Diffuser valves** – the dilution predictions are produced by a model which assumes the outfall discharge ports are round open-ended orifices. The ports on the proposed outfall will be fitted with Tideflex diffuser valves, manufactured to suit the outfall’s specific flow rates and line pressure requirements. These valves are tight ‘duck-bill’ valves made of rubber and require considerable line pressure to open – about 2.4bar. This pressure, generated by the discharge pump in the outfall headworks, is converted into kinetic energy by the valves and result in the effluent being discharged as a high velocity jet into the ambient current. The kinetic energy of the jet is then dissipated by turbulent mixing, as the jet breaks down in the ambient flow and starts to rise as a buoyant plume. So, in effect, the power of the discharge pump is hydraulically transmitted to the seaward end of the outfall to actively mix the effluent with seawater and enhance initial dilution.

Mixing is further enhanced by the diffuser valves due to the orientation and morphology of the discharge jet formed by the valves. The jet is injected into the ambient current as a thin vertical sheet of effluent, injected perpendicular to ambient current flow direction. The high surface area of the jet, coupled with its high velocity and orientation across the ambient flow, all combine to significantly improve initial dilution rates.

For a video of similar Tideflex diffuser valves in operation see Youtube video [https://youtu.be/zSboDo5EMvE](https://youtu.be/zSboDo5EMvE). Please note that the diffuser valves and pump pressure design for the proposed outfall will generate a discharge jet with 2.5x greater velocity and half the flow rate of the discharge featured in the video.

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### 8.3 DISPERSAL & FATE OF FLOW

Surface boil positions of the surfacing discharge plume calculated during predictive modelling are shown in drawing DRW-005, plot 6. The predicted surface boil positions, together with the current mapping survey using drogues (fig 48), show that the plume will not impinge on the shoreline. The plume will be advected out of the area on both the ‘flood’ and ‘ebb’ tide flows and dispersed in the deep tidal waters of the Kilbrannan Sound.

Further afield remnants of the plume may pass through areas of highly turbulent flow 8.3km to the south of the site at Whitefartland Bank, and 6.8km to the north off the Cock of Arran. By this stage however the plume will be diluted to below detection levels.
Figure 48. Drogue tracks from release stations closest to the proposed outfall discharge location.
9.0 DESIGN & CONSTRUCTION

9.1 SCOPE OF CONSTRUCTION WORK


Work within the distillery plant to enable operation of the outfall includes minor modifications to the existing effluent management system, and integration of the proposed remote outfall control and monitoring system with the distilleries existing in-plant control system. A minor modification to the distillery’s road tanker will also be required to enable secure connection to the headworks during discharge.

Construction work at the outfall site will involve improving existing road access, creating a tanker turning area, installation of a pump cabinet, 207m long outfall pipeline, multiport diffuser terminal, and a navigation marker buoy located off the end of the pipeline. The design for this facility aims to maintain an agricultural rather than industrial appearance, in better keeping with the surrounding undeveloped landscape. To further minimise visual impact, the low-profile pump cabinet will be tucked into the existing slope at the southern end of the site. Existing screening will be further augmented by planting additional native birch. A holding tank for effluent is not required onsite, as a dedicated road tanker will discharge direct to the outfall via an automated pump cabinet. The surface of the land area and foreshore crossed by the buried outfall pipeline will be returned to natural on completion of the works. The outfall pipeline will not be visible at any state of the tide.

9.2 DISTILLERY EFFLUENT MANAGEMENT SYSTEM

Effective and efficient operation of an in-plant effluent management system is vital in terms formation of an environmentally benign final effluent. The existing in-plant effluent tanks and road tanker provide a total effluent storage capacity of 95,000 litres. Minor modification to existing pipework and control systems will be made. This will enable the available storage volume to be optimally utilised in mixing, balancing and volumetrically buffering the effluent before being discharged to the outfall.

See drawing 'IAD-OUTFALL-2017-DRW-007-process engineering diagram' for detail of the proposed in-plant effluent management system.

9.3 ROAD TANKER

An existing 30,000 litre capacity road tanker will be used to transport the effluent from the distillery in Lochranza to the outfall location at Rubh Airigh Bheirg. The tanker will be dedicated to servicing the outfall and carry no materials other that the distillery trade effluent. The tanker will be fitted with a 4m flexible hose, armoured with stainless steel braiding. The hose will terminate with a dry-lock coupling for connecting to the pump cabinet inlet. This will ensure a secure and drip-free joining during connection, discharge and disconnection.

9.4 TANKER TURNING AREA

The design for the main elements of the proposed tanker turning area at Rubh Airigh Bheirg are summarised below, and, shown on drawing IAD-OUTFALL-2017-DRW-001-site plan, and IAD-OUTFALL-2017-DRW-008-headworks site plan.

- **Improved road access (53m²)** - new bellmouth entrance with a footprint inside the existing entrance. It is to be constructed so as to protect the edge of the public road. The bellmouth will be 24m wide where it meets the existing carriageway, with a concrete apron extending 2.5m into the bellmouth from the edge of the carriageway. The concrete apron will be constructed of a 300mm deep steel-reinforced concrete slab, incorporating a slot drain and anti-skid surface. A concrete apron extending further into the site is not required due to the entrance sloping down away from...
the road, and the need to minimise aesthetic impact. The entrance will be bordered by soft kerbs to minimise aesthetic impact.

- **Tanker turning area (639m²)** - this area will be surfaced with compacted type-1 stone to forestry road (Forestry Commission) specification. Any side slopes running off the surfaced area will gently taper back to natural ground level (<1:2 slope), dressed with turf scraped off from within the surfaced area during construction.

- **Drainage** - Surface water currently runs off the adjacent A841 road and un-drained slopes above the site and flows across the site during heavy rains. To protect the tanker turning area from surface water runoff, a discrete diversionary drain will be installed upslope. The drain will consist of a slot drain crossing the bellmouth entrance, connecting to French drains (buried perforated 80mm OD PVC pipe) bisecting the slopes above the turning area. The drains lead to outlets in the permeable cobble beach below the site and do not require SUDS due to their minor diversionary nature and discharge direct to coastal waters.

- **Screening (78m²)** - to improve natural screening of the facility from the road additional downy birch (*Betula pubescens*), and possibly eared willow (*Salix aurita*) will be planted in the area upslope of the pump cabinet. These species are native to the site and found in existing scrub already partially screening the pump cabinet area. During the summer months, dense bracken growth on the slopes between the road and the site provides significant additional screening. Specification for planting is based on guidelines found in; Scotland’s Native Trees and Shrubs - a designer’s guide to their selection, procurement and use in road landscape (2002), ISBN 325544-5-02.

- **Signage** - road safety signage and site safety signage is required. The road safety signage will take the form of a ‘lorries turning’ sign on the verge of the A841 to either side of the bellmouth entrance. Road signage detail is to be advised by North Ayrshire Council. A site safety sign will be mounted on the side of the pump cabinet.

### 9.5 HEADWORKS

The headworks for the outfall are contained in a small pump cabinet mounted on a concrete base on the site. Power from a diesel generator within the cabinet will run the discharge pump and various automated control, monitoring and sampling systems. See drawing IAD-OUTFALL-2017-DRW-009- for a schematic design of the pump cabinet and its contents.

- **Pump cabinet** - galvanised steel pump cabinet (1.2m wide, 4.0m long, 1.4m high) with a painted olive green matt surface finish. The removable cabinet is installed on a ground level concrete base (1.4m x 4.2m in plan) which also incorporates a joining in pit for the buried outfall pipeline. The cabinet is vandal-resistant and soundproofed, with lockable doors/hatches over all access points, and a lock-box to fit over the discharge hose connection when connected to the tanker. The cabinet contains three main compartments; 1) generator compartment, 2) fuel tank compartment, and 3) pump compartment.

- **Plant and equipment** – the pump compartment contains plant, equipment and pipework required to control, monitor and sample the discharge effluent. The system will incorporate a data logger, flowmeter, flow-proportionate auto-sampler, level sensor (dry pipe sensor), actuated valves, alarm system, 24v battery bank for UPS, etc...

- **Control system** - operation of the effluent outfall system will be controlled, monitored and recorded by a fully automated Programmable Logic Controller (PLC)-based management system. The system will be failsafe and automatically shut down the discharge in response to specific alarms. The PLC will be connected to the distillery in Lochranza via a GPRS internet data connection, so can be monitored and operated remotely in real time and any alarms responded to.
9.6 OUTFALL PIPELINE

The main outfall pipeline extends 190.5m from the headworks onshore to a multiport outfall terminal located on the seabed in the Kilbrannan Sound at a depth of 20m below chart datum. The onshore and foreshore crossing portion of the outfall pipeline is contained within a buried duct to shield it from overburden. The duct will also allow the future retrieval/replacement of the effluent outfall pipeline without any re-excavation work, should this be required for inspection or maintenance purposes.

Drawing IAD-OUTFALL-2017-DRW-001-site plan shows the layout and drawing 'IAD-OUTFALL-2017-DRW-010-pipeline design' shows the construction design for the pipeline. The main construction elements of the pipeline are summarised below.

- **Outfall pipeline duct (82.4m)** – the buried duct is constructed of 180mm diameter SDR17 HDPE pipe joined by electrofusion couplings. The duct extends 82m, from a join-in pit below the pump cabinet to the CD – 0.25m contour on the seabed below the low tide level. Minimum burial depth to crown of pipe on land is 0.9m, on upper foreshore is 1.8m, and on the lower foreshore is 1.2m. After installation of the duct, the land/foreshore surface will be reinstated to natural outwith the tanker turning area.

- **Outfall pipeline (190.5m)** – the outfall pressure line carrying the effluent is constructed of a 110mm diameter SDR11 HDPE pipe, 190.5m long. The pipeline extends from the pump cabinet, through the 82m buried duct, and a further 108m seaward across the seabed to a multiport diffuser terminal located at a depth of 20m below CD. The section crossing the seabed is anchored in place by 280kg precast concrete anchors spaced at 2.8m centres along the length of the pipeline (fig 48 & 49).

Figure 48. Outfall pipeline terminal connections  
Figure 48. Outfall pipeline precast concrete anchor blocks


Environmental protection standards for the outfall pipeline and terminal during the design and construction phase is the CIRIA 2015 Coastal and marine environmental site guide (second edition) (C744).

9.7 MULTIPORT OUTFALL TERMINAL

A multiport outfall terminal will be installed at the end of the main 110mm diameter outfall pipeline. A flow splitter will split the flow equally into two 16m long legs of 90mm SDR11 HDPE pipe. The seaward ends of these legs will be secured to 2No. 2250kg precast concrete terminal anchor blocks installed at a depth of 20m below CD and spaced 25m apart. The two legs will have identical length and depth change and will be geometrically symmetrical to ensure equal flow through both pipes.
The outlet ports at the end of the feeder legs will be fitted with Tideflex diffuser valves. The valves will have an elevation of 200mm off the seabed, orientated to discharge horizontally to ensure that the discharge jet has no upward momentum, and on a bearing of 323° which is perpendicular to the mean axis of ambient current flow.

Figure 50 & 51. Tideflex diffuser valve outlets fitted to 2250kg precast concrete outfall terminal anchor blocks.

The design of the feeder system will ensure identical internal flow resistance of each feeder route, e.g. same length, bend radii, elevations, etc.

The installation of a multiport diffuser array fitted with Tideflex diffuser valves will provide the outfall system with several environmental and operational performance advantages over a single outlet ‘open pipe’ outfall design. These advantages are set out below.

- **Enhanced initial dilution** – splitting the discharge flow between 2No. outlets spaced 25m apart significantly increase initial dilution rates by increasing jet/plume surface area.

- **Enhanced initial dilution** - fitting Tideflex diffuser valves will enhance initial dilution by generating a high-speed jet of effluent. This will be injected into the ambient current flow as a vertical sheet, orientated across the direction of ambient current flow.

- **Sealing end of outfall between discharges** - the valves are activated by line pressure, so will close and seal off the pipeline between discharge periods. This ensures that the performance of the outfall is not affected by internal marine biofouling, infiltration of marine debris, or propagation of pressure waves into the outfall system, all of which would affect the internal hydraulics of the outfall.

- **Flow equalisation** - the resistance to flow, or back-pressure from the valves can be adjusted to a fine degree. This allows for fine-tuning of flow equalisation between outfall ports, if required.

9.8 NAVIGATION BUOY

Navigation buoy. A ‘Special Mark’ navigation buoy will be installed offshore of the seaward end of the outfall to mark the location of the outfall for mariners, particularly scallop dredging vessels.

- **Buoy** – 1.8m hull diameter yellow buoy with SOLAD retroreflective pannels and fitted with internal radar reflector.
9.9 CONSTRUCTION METHOD

An outline construction method is listed below as an approximate timeline for the onsite works.

1. Access to the site from A841 is via the existing site entrance and track. Install a temporary contractors compound on the land immediately to the northeast of the site. The compound will contain welfare and storage units and space for parking and material storage.

2. Install any permanent road warning signage on the verge of the A841 as specified/required by North Ayrshire Council.

3. Carry out planting of additional screening trees upslope of the pump cabinet location.

4. Construct new concrete bellmouth entrance within footprint of existing entrance. Traffic management on A841 for the works is temporary warning signage and cones – traffic lights are not required. Edge of concrete slab joining the public road to be constructed at level suggested by North Ayrshire Council road engineer, then council is to make uneven road surface good and to level of concrete slab.

5. Install 82m long 180mm diameter HDPE duct extending from pump cabinet location to the seabed 0.25m below chart datum by burying and reinstating land and foreshore surface to natural.

6. Install French drains upslope of the tanker turning area, connected to slot drain across concrete bellmouth entrance, and discharging to the shore in free draining cobble foreshore.

7. Construct tanker turning area by surfacing with imported compacted stone to forest road (Forestry Commission) specification.


9. Install navigation buoy and mooring marking outfall terminal location, can be used to moor workboat during construction works.

10. Place outfall terminal anchor blocks on seabed at discharge positions, and pipeline anchor blocks on seabed along pipeline route, using workboat.

11. Main 110mm dia. pipeline is welded together onshore into single piece and pressure tested to 16bar before being floated out to sea for installation. 110mm pipeline drawn up through duct and into headworks join-in pit. The seaward section of 110mm pipeline is anchored to the seabed by placement of pipeline anchor blocks on the pipe by divers, progressively sinking the pipe in a seaward direction.

12. The multiport outfall terminal is assembled onshore, then floated out and sunk to be joined on the seabed to the end of the main 110mm dia. pipeline by bolted flange. Pipeline anchors placed over diffuser legs to secure. Seaward ends of diffuser legs and diffuser valves bolted to pre-laid terminal anchor blocks with pipe clamps to secure.

13. Install pre-assembled pump cabinet, bolt down to concrete plinth to secure, and connect outfall pipeline.
14. Final pressure testing of pipeline, commission facility and start operation.

15. Remove contractors compound and leave site safe and clean.

The duration of construction works onsite (onshore & offshore) is expected to take somewhere in the region of 4 weeks, subject to weather. Timing of works is dependent on consents being obtained, but it is likely the onsite work will be carried out during June 2017.

The main plant and equipment deployed for onshore works includes one 16tonne excavator, one roller/compacter, small plant and tools appropriate to concreting, groundwork and HDPE fabrication. The main plant and equipment deployed for offshore work includes one 20m workboat, one 6m workboat/launch/tender, and one surface supplied diving system.

The work will have minimal environmental impact as no construction materials or sediments will be released to the marine environment. Environmental precautions will include ensuring excavator uses a biodegradable hydraulic fluid in case of hose burst, no refuelling of plant carried out near the shoreline or at sea, and ensuring surface water runoff from groundwork areas will not carry silt into the sea by installing temporary settlement pits and filters. A floating debris/oil boom will be installed around the shore side works area for the duration of the works as a precaution – weather permitting. No concrete will be cast in situ below the high tide contour.
10.0 OPERATION & MANAGEMENT

10.1 COMMISSIONING

Commissioning of the outfall system at the end of the construction period and before discharge of effluent begins will involve the following steps:

- **Ecology survey** – Carry out a repeatable diver seafloor survey of conspicuous species by divers from Community of Arran Seabed Trust (COAST)/Seasearch. This is a baseline survey for planned ongoing annual site monitoring surveys.

- **Biochemistry and geochemistry surveys** – Carry out repeatable collection of sediment, fauna and flora samples by divers. These will be analysed for dissolved copper concentrations by the Scottish Association for Marine Science. This is a baseline survey/analysis for planned ongoing annual site monitoring surveys.

- **Pipeline leak test** – outfall pipeline will be blanked off and pressurised to 16bar to check for structural integrity and leaks.

- **Headworks function test** – test discharge management system with one tanker load of effluent (30m³) to check system works correctly and is fail-safe.

- **Dilution test** – discharge one tanker load of effluent (30m³) dosed with rhodamine florescent dye during median tidal and weather conditions and map the effluent plume using a vessel mounted fluorometer. Discharge carried out during mid-flood, mid-ebb and slackwater tidal conditions. This test is carried out to check the accuracy of predictive dilution modelling results.

10.2 OPERATION

The key outfall operational parameters proposed are as follows:

- **Maximum discharge flow rate** - is 2.8 l/s⁻¹ – this will be the nominal flow rate

- **Maximum discharge volume** - 60,000 litres (2No. tanker loads) per 24-hr day starting at midnight

- **Discharge timing** - Discharge can be made at any time, regardless of tidal or weather conditions

- **Maximum number of discharge days per year** – the maximum number of days per year a discharge may occur within is 336. A day is a 24-hour period starting at 0000hrs.

- **Information displayed during discharge** - information displayed on the headworks PLC display and transmitted to the distillery includes; instantaneous discharge rate, daily discharge volume, totalised cumulative discharge volume, outfall backpressure, system faults.

- **Information logged during discharge** - data logged by the headworks PLC includes; instantaneous discharge rate, daily discharge volume, totalised cumulative discharge volume, outfall backpressure, system faults. All logged data is available to download in a format compatible with MS Excel.

- **Continuous effluent sampling** – to ensure the effluent does not breach its licence conditions effluent samples will be taken by a flow-proportionate autosampler as fixed-time aliquots. This sampling system should take one sample of 250ml per 5000l discharged (TBC). The combined sample will be collected in a 4-litre bottle which will be manually changed on a daily basis. The sample will be stored in a fridge at the distillery at 4°C for a minimum period of 7 days.

- **Instantaneous effluent sampling** – there will be a provision for instantaneous sampling of the effluent, taken at any stage in the discharge period. This could be done either via overriding the automated flow proportionate sampler, or using a separate manual valve.
The normal operational sequence for the system discharging a tanker load of effluent (30m³) for the outfall is set out below as a timeline. Throughout this sequence, the operation of the discharge system within the headworks is monitored within the distillery in Lochranza via GPRS internet data connection.

1) Distillery effluent tanker loaded with trade effluent pulls into tanker turning area and reverses back alongside pump cabinet and parks.

2) Operator unlocks and opens engine vents, control panel door, and lockbox over tanker connection valve.

3) Operator connects tanker discharge hose to headworks inlet valve with dry-lock coupling and floods pipe by opening manual valve at base of tank.

4) Operator standing at headworks control panel turns on PLC and checks generator fuel gauges, etc

5) Operator starts automated discharge via SCADA start-up sequence

6) Discharge system powers up and begins automated discharge

7) Operator closes and locks door over control panel, closes and locks lock-box over hose connection, and leaves site

8) Discharge system discharges at 2.8 l/s until tanker is empty and inlet hose runs dry

9) Discharge effluent is sampled automatically for every 5000 litres discharged

10) When inlet pipe runs dry (tanker empty) the discharge system automatically shut down and inlet valve closes

11) Operator returns to tanker, disconnects tanker hose and stows on tanker rack

12) Operator accesses and changes effluent autosampler bottle if appropriate

13) Operator closes and locks and generator vents and lock-box over headworks inlet valve

14) Tanker leaves site

The discharge management system will shut automatically down upon any of the following events;

1) Level sensor detects empty inlet pipe
2) 30,000 litres discharged
3) Generator engine fault
4) Pump fault
5) Flowguage fault
6) Pump dry run sensor detects no fluid in pump
7) Outfall pipeline backpressure pressure sensor outside permitted pressure range
8) Emergency manual crash down button depressed
9) Instructed to shutdown via remote monitoring/internet

Normal operation of the outfall will see the full tanker discharged in just less than 3 hours, with the tanker visiting the site once per day on three days of the week, and twice per day on three days of the week
10.3 OUTFALL SYSTEM MONITORING & MAINTENANCE

In addition to continuous monitoring of the outfall by the PLC-based effluent management system, periodic inspection and maintenance of the headworks and outfall pipeline will also be carried out. The following activities will be undertaken on an annual basis, or as required.

- **Internal Inspection and cleaning** - should cleaning be required, provisions have been made to allow internal inspection and pigging/jetting of the outfall pipeline.

- **External Inspection and cleaning** - diver cleaning and visual inspection of the subsea outfall pipeline and multiport diffuser terminal during effluent discharge will confirm condition and environmental performance of the outfall.

- **Structural Integrity testing** - provisions have been made for pressure testing of the outfall pipeline to 16 bar to test the structural integrity of the pipeline.

- **Calibration of Instruments** - the accuracy of the effluent management systems sensory equipment, e.g. flowmeters, will be tested to relevant British Standards and a log of test results maintained.

- **Navigation buoy** - the navigation buoy and its mooring will need annual inspection and periodic maintenance, with the riser chain and solar lantern batteries expected to require renewal every 3-4 years.

10.4 ENVIRONMENTAL MONITORING

Ongoing monitoring of the receiving environment in the vicinity of the outfall will be carried out on an annual basis to help understand the impact of the discharge on the biochemistry, geochemistry, and flora and fauna of the site. The main elements of the planned monitoring program are set out below:

- **Ecology survey** - Engage with a local conservation group; Community of Arran Seabed Trust (COAST) to carry out an independent survey of conspicuous flora and fauna species in the area of the outfall on an annual basis. This will involve repeat surveys of seabed transects at varying distances from the outfall.

- **Biochemistry & geochemistry surveys** - Engage with the Scottish Association for Marine Science (SAMS) to collect samples of sediment, fauna and flora. All samples will be analysed for copper, and the sediment samples will also be analysed for total organic carbon (TOC) and dissolved organic carbon (DOC).
11.0 ENVIRONMENTAL IMPACT ASSESSMENT

11.1 OUTFALL CONSTRUCTION WORKS

The engineering design and construction method proposed for the outfall minimises the environmental impact of outfall construction works. The outfall pipeline is constructed of 110mm OD pipe, and the headworks are all contained in a small steel cabinet (W-1.2m, L-4.5m, H-1.4m), so it is a relatively minor development. The main measures taken to ensure the environment impact of the construction works and completed structure are minimal and acceptable are summarised below:

- **Site selection** – the site has existing road access and is naturally partially screened from the road at the pump cabinet location. Additional planting of native species found onsite will enhance natural screening.

- **General design aesthetics** – to maintain an ‘agricultural’ appearance to the facility, i.e. minimise use of concrete surfacing, signage, lighting, tanks, visible plant and pipework, etc, to be in keeping with the undeveloped rural nature of the area.

- **Prefabrication** – the headworks pump cabinet, precast concrete pipeline anchors, and navigation buoy and mooring are manufactured offsite, minimising construction work required onsite.

- **Delivery of materials to site** – pipeline anchors and navigation buoy and mooring will all be delivered to the site by sea and laid on the seabed by the delivery vessel, minimising requirement for road transport and shore-crossing works.

- **Float and sink** – the HDPE outfall pipeline and multiport diffuser will be fabricated and tested onshore, before being tidally lifted from the foreshore and floated out to be sunk in place. This minimises the amount of in-water construction work carried out.

- **Groundworks** – as the onshore/foreshore ground consists of raised beach deposits of cobbles and gravels, minimal fines will be released to the environment when trenching in of the onshore and foreshore crossing duct. All surface will be returned to natural on completion of trenching in the outfall pipeline. Debris/oil booms at sea and settlement traps ashore will be used during the construction period.

- **Subsea structure** – the pipeline and multiport outfall terminal will be laid across the seabed. The structure will add some biodiversity to the largely sedimentary environment by providing habitat for attached flora and fauna and associated species assemblages. The pipeline (but not the outlets) will naturally sink into the seabed over time due to the natural effects of bioturbation. The structure will not significantly impact on along-shore sediment movement in the area or affect seabed or foreshore geomorphology due to its minimal cross-sectional profile and nature of the site.

- **Materials** – materials used in intertidal/subsea construction are limited to; precast concrete, mild steel, 316-grade stainless steel, high density polypropylene (HDPE), nylon, and nitrile rubber. All materials are non-toxic and do not degrade in the marine environment. Mild steel will rust and is limited to use in the navigation buoy riser chain, which will be renewed approximately once every 4 years.

11.2 OPERATION & MAINTENANCE

The design of the outfall system uses best available technology and methodology to ensure minimal and acceptable levels of environmental performance. All statutory standards and industry norms are predicted to be significantly exceeded. The main parameters relating to environmental impact of the outfall operation are summarised below:

- **Effluent formulation and treatment** – influent streams from different stages of the production process, of varying composition, will be collected, balanced and volumetrically buffered within the
distillery effluent management system before being transported to the outfall site. The volumetric buffering capacity of the system is 95,000 litres, with minimum buffer volumes retained in various parts of the system. Mixing and balancing of effluent streams within the effluent management system reduces toxicity and buffers the effluent streams against peaks in effluent constituent concentrations and resultant toxicity spikes.

- **Organic content** - the trade effluent has a very low microbial content due to > 99% volume if being sterile still residues (boiled) or washing waters (caustic). The organic content (BOD/COD) is high but it should be noted that much of this content is not readily bioavailable/labile so will not cause localised eutrophication. This is due to yeast consuming the more easily digested materials such as sugars and short-chain carbohydrates and converted then to alcohol during the fermentation process, so only a residue of less labile organic materials (and dead yeast cells) remains. This material will be massively diluted and carried far from the discharge site by tidal flows before, in time, it is broken down and assimilated by the natural marine environment through chemical and/or biological processes.

- **Dissolved metals content** - the dissolved metals within distillery trade effluent flocculate and are complexed with tannins and ligands when discharged into seawater so tend to become particulate and non-toxic on discharge or immediately afterwards. The large buffering capacity of seawater means that the low pH of the effluent is quickly neutralised on discharge, further causing the dissolved metals to tend towards a non-toxic particulate speciation.

- **Discharge timing and rate** - trade effluent is to be discharged in up to 30,000l batches at a rate of 2.8 l/s (1.4 l/s per outlet port). Discharging a batch over 3 hours at a low ‘bleed-out’ rate greatly improved dilution rates. The timing of discharge periods is based on ‘anytime’ discharge, as long as the period does not extend through midnight for record keeping purposes. A tidally timed discharge for further enhancement of dilution is not proposed at this site as current flow timing was found not to be well correlated with predictable tidal height times.

- **Outfall depth** – the outfall will discharge at a depth of 20m below chart datum, which is 21.76m below mean sea level. This depth provides high levels of initial dilution to the rising buoyant plumes. Locating the outfall further offshore in deeper water is not possible due to constructional/maintenance related issues, and the activities of commercial fishing vessels in the area.

- **Multiport outlet** - the outfall discharge is evenly divide between 2No. outlets, spaced at 25 meters apart on the seabed. Installation of 2No. ports greatly enhances initial dilution rates by increasing the plume surface area of the discharge. Installation of a greater number of ports was not specified for constructional related issues.

- **Diffuser valves** – the outlet ports are fitted with Tidflex diffuser valves. These greatly enhance initial dilution by producing a high velocity, high surface area jet orientated perpendicular to the main axis of ambient tidal flows. The valves utilise the power of the high-pressure discharge pump, transmitted hydraulically to the valves, to actively mix the trade effluent with seawater at the seaward end of the outfall.

- **Predicted initial dilution** - the minimum level of initial dilution required for 95% of the time is 150x for distillery trade effluent. Dilution modelling using PLUMES has shown that this level of dilution will be greatly exceeded at all times. Predicted minimum initial dilution is 1,242x, lower 95%ile is 1,981x, mean is 5,748x and maximum is 14,281x. The initial dilution level requirement specified by SEPA is therefore exceeded by a factor of more than 13 times.

- **Predicted secondary dilution** – the minimum level of secondary dilution required for 95% of the time is set by the EQS for dissolved copper. It has been calculated that a secondary dilution level of 966x will required to meet the site specific EQS for dissolved copper. Dilution modelling using PLUMES has shown that the minimum level will be greatly exceeded at all times. Predicted minimum secondary dilution is 3,098x, lower 95%ile is 6,079x, mean is 13,603x and maximum is in excess of 20,000x. The secondary dilution level requirement specified by SEPA is therefore exceeded by a factor of more than 6 times.
- **Unquantified dilution factors** – predicted dilution factors are conservative, as are the calculations for the minimum dilution levels that need to be met. Factors such as the effect of diffuser vales, wave action, tidal flow turbulence, and chemical interactions within the discharge plume, cannot be easily quantified, but will all greatly increase the environmental performance of the outfall over and above the predicted dilution levels. Calculation of EQS are normally based on mean conditions, where as in this report worst case conditions have been used throughout. Examples of this is using peak effluent concentrations instead of mean effluent concentrations, and using minimum water depth rather than mean tidal water depth. A conservative approach has been used throughout this report.

- **Predicted dispersion** – a 43-day long duration current meter survey at the discharge location, CTD casts, and an extensive current tracking drogue survey over the wider site area has shown that tidal flows through the site are well mixed and strong, with current speeds averaging 0.15 m/s and reaching maximum speeds of 0.51 m/s. Slack water periods are relatively short and often don't occur as tidal flows often swirl to change direction rather than stopping. Timing of tidal flows changing direction do not correlate well with high and low tide timings, and at times may be strongly influenced by weather conditions. There are no eddy systems present in the area of the outfall that will hinder dispersal of effluent from the area, and the plume will not impinge upon the shoreline.

- **Testing predicted dilution and dispersion** – during commissioning of the outfall system, a dye tracing survey will be carried out to test dilution and dispersion predictions by mapping effluent plume concentrations under varying tidal conditions.

- **Species or habitats of conservation significance** – there are no habitats or endemic species of conservation significance found at the site. Species of conservation significance such as otters, common seals, and possibly porpoise, pass through the outfall site from time to time, but are not thought to be disturbed by the proposed low impact construction, operation or maintenance activities.

- **Habitat impact** – The sedimentary foreshore in the site area is largely barren mobile cobbles, with some resilient species such as periwinkles found at the lower levels. The subtidal zone is also sedimentary, but more diverse and featuring several distinct biotope zones typical of the sites coastal setting. The seabed in the nearshore shallower areas is heavily reworked by bioturbation. The seabed in the deeper offshore area, where the outfall discharges, is less heavily bioturbated and is dominated by current generated sand ripples. An extensive habitat monitoring program will be put in place as part of the operation plan for the outfall. This will involve dive surveys on an annual basis to monitor conspicuous species distribution, check for accumulation of discharged particulates, and taking samples of flora, fauna and sediment to analyse for copper concentrations and organic carbon enrichment indicators.

- **Maintenance considerations** – The outfall system is designed to be easily maintained with minimal impact on the environment. Maintenance of the outfall pipeline will involve a dive team opening the seaward end of the main pipeline at the flow-splitter before the multiport outfall diffuser. The outfall would then be jetted to clean the pipe internally, with discharged particulate debris collected in a mesh bag attached to the end of the pipe to prevent release to sea. Should the main pipeline need to be recovered to shore for maintenance or replacement purposes, the pipeline anchors can be left in situ and reused, and the buried land/foreshore crossing section withdrawn from the duct without disturbing the land/foreshore surface. The headworks are contained in a bunded pump cabinet, which can be removed from the site for maintenance as a single unit if required.

- **Discharge monitoring** – the discharged effluent is monitored to prevent discharge of any liquid other than distillery trade effluent, and ensure the concentrations of environmentally significant constituents in the effluent do not breach expected levels. This is done by a flow proportionate autosampler within the headworks enclosure, taking fixed-time aliquots of effluent to form a composite sample, removed, labelled and stored on a daily basis. Provisions are also made within the headworks enclosure for safely taking an instantaneous sample of discharge effluent at any time during discharge period.
• Spills – the outfall system is designed to be robust, automated, constantly monitored via
telemetry, and generally failsafe. The pipeline and headworks pipework will be pressure tested to
16bar (> 4x maximum working pressure), and inspected for deterioration or leaks regularly. The
tanker connection will normally be coupled and uncoupled when dry. If a wet coupling/uncoupling
is required due to a system fault, the hose be fitted with a dry-lock valve system which means even a
flooded pipe can be coupled or uncoupled with a maximum spillage of less than 10ml. Should a
spill occur at the tanker connection the environmental consequences are minimal due to the
beguine nature of the trade effluent – the effluent can be simply flushed away to sea with fresh
water. Should a spill within the headworks enclosure or along the buried land/foreshore crossing
section of the outfall pipeline occur, the effluent will drain down the buried duct into the sea below
CD level. Should a spill occur along the seabed crossing section of the outfall pipeline, the effluent
will be dispersed from the site by tidal currents. Any failure of the system causing a leak will be
detected by pressure sensors which are constantly monitored, and the system will automatically
shut down and alarms are activated.

• CO₂ Emissions - the proposed outfall system will provide an 83% reduction in CO₂ emissions (a
saving of 27.1 tonnes of CO₂ per annum) over the existing effluent disposal method. Existing
disposal method by spreading on fields, including road haulage and field spreading. This saving
totals 32.8 tonnes/annum at current production rates. The proposed outfall system, including road
haulage and headworks generator; will emit 5.7 tonnes/annum at current production rates.

11.3 DECOMMISSIONING

Should the proposed outfall need to be removed or replaced in the future, the design of the outfall allows it
to be removed from the site entirely in the course of one day's work. No debris would be generated during
dismantling, and no lasting impact on the foreshore or seabed would be left behind. Decommissioning plan
for the main elements of the outfall facility are set out below:

• **Tanker turning area** – bellmouth entrance and surfaced area retained for continued landowner
  access through the site as at present. Vegetation planted to enhance screening the site are
  species native to the site and would not be disturbed.

• **Headworks** – pump cabinet would be disconnected from pipeline and concrete base, and removed
  from site in single unit. Concrete base/JOIN-in pit would be demolished and removed from site, with
  ground surface made level and turfed over.

• **Land/foreshore crossing duct** – to remain in situ to avoid disturbing land/foreshore surface.
  Landward end blanked off and buried, seaward end excavated and cut back to 1.0m below shore
  level then buried.

• **Pipeline and multiport diffuser** – pipeline detached from pipeline anchors and terminal anchors
  by diver, withdrawn from duct, and cut into sections to be removed from site by workboat. Anchors
  stropped by divers and removed by workboat.

• **Navigation buoy and mooring** – buoy and mooring lifted onto deck of a workboat and removed
  from site.
12.0 REFERENCES & FURTHER READING


P. W. BALLS


The Malt Distillers Association of Scotland (?) The Relationship Between Copper and Toxicity in Discharges of Pot Ale and Spent Lees into Sea Water: A Kinetic Study.


Minute of meeting between representatives of the Malt Distillers Association Environment Committee and representatives of SEPA held at Castle Business Park, Stirling, on 10th August 2000.

North Ayrshire Council The Local Development Plan (2014) and associated map 4


SEPA Report Number ENC 2001/81 (2002). Direct Toxicity Assessment of Effluent Discharges From Bunnahabhain, Caol Ila and Laphroaig Distilleries, Islay

SEPA Regulatory Method (WAT-RM-05): Trade Effluent Discharges to Surface Waters v8.0 – 2016


Campbell Marine Contracts

Dilution Report:

Arran Distillery Outfall Predictive Modelling

March 2017
## DOCUMENT CONTROL

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EXECUTIVE SUMMARY

An Acoustic Wave and Current Doppler Profiler (AWAC) was deployed for 44 days at a potential trade effluent outfall site at near Lochranza on Arran for the isle of Arran Distillery. CTD casts were also recorded to determine salinity and temperature to define water density. The AWAC recorded data for two complete tidal cycles; the current flow was determined to be SW/NE flowing with an average current speed of 0.2 m s⁻¹. The data were used to inform a hydrodynamic model (Visual Plumes) in order to model the likely dilution rates of the effluent.

The model was run using ambient data conditions taken from the AWAC and CTD casts, whilst effluent discharge variables are defined in Campbell, 2004. The study focused on an anytime discharge during a neap slack tide to provide a worst-case scenario of dilution rates.

6049 discharge scenarios were made over 10 minute intervals. The results of the model confirmed that 95% dilution exceeded the SEPA EQS thresholds. Sensitivity analysis increasing the effluent flow rate and water density reduced the dilution. Results still significantly exceeded the SEPA EQS, suggesting that the effluent dilution rate will meet environment quality standards 95% of the time.
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6. APPENDIX
1. INTRODUCTION

Partrac were contracted by Campbell Marine Contracts to undertake a hydrographic survey at a proposed outfall on the Isle of Arran. The resultant data was used to hydrodynamically model particle dispersion away from the site. The survey consisted of a tidal gauge and Acoustic Doppler Current Profiler (AWAC) deployed for 43 days (covering two complete tidal cycles), and CTD casts to determine water density, salinity and temperature.

1.1 Background

The Isle of Arran distillery is a small-scale whisky distillery located in Lochranza. The distillation process produces a bi-product of cereal-based effluent which is currently transported to the south of the island by road tanker for farmers to spread on fields as fertiliser.

This disposal method is becoming increasingly unsustainable. As a result, the distillery have investigated alternative methods for the disposal of effluent and have opted to construct long sea outfall at Rubh Airigh Bheirg, 6.6km south of the distillery.

Site investigative work for this proposal was carried out in 2014, including topographic/bathymetric mapping, hydrographic surveys, diver surveys and biotope mapping. This report uses some of that data in order to hydrodynamically model the dilution of the effluent under a variety of scenarios and determine if there is sufficient flushing of the area to dispose of the effluent without impacting the local environment.

1.2 Survey Aim

This survey represents a portion of the environmental work principally carried out by Campbell Marine Contracts and covers the deployment of an acoustic Doppler current profiler (AWAC) and CTD casts for the calibration of a hydrodynamic model. The study aims to determine the dilution and pathway of any effluent particles if released at the proposed site.

1.3 Location

The proposed outfall site is located 6.6km to the south of Lochranza on the northwest coast of the Isle of Arran in the Firth of Clyde. The receiving waters is the Kilbrannan Sound; the strait of water separating the Isle of Arran and the Kintyre Peninsula.

Table 1 lists the positions of survey stations, AWAC deployment position, and proposed outfall ports. Figure 1 presents these on a map.

<table>
<thead>
<tr>
<th>WPT name</th>
<th>Position BNG</th>
<th>Position WGS84</th>
<th>Seabed depth below CD (m)</th>
</tr>
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<tr>
<td>P1 - 5m</td>
<td>NR 88511 47997</td>
<td>N55 40.757 W5 21.926</td>
<td>5.0</td>
</tr>
<tr>
<td>P2 - 13m</td>
<td>NR 88483 48020</td>
<td>N55 40.769 W5 21.953</td>
<td>13.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--------</td>
<td>--------</td>
<td>--------</td>
<td>--------</td>
</tr>
<tr>
<td>P3 – 25m</td>
<td>NR 88447 48050</td>
<td>N55 40.784 W5 21.989</td>
<td>25.0</td>
</tr>
<tr>
<td>W1 – 1m</td>
<td>NR 88544 47971</td>
<td>N55 40.744 W5 21.893</td>
<td>1.0</td>
</tr>
<tr>
<td>W2 – 35m</td>
<td>NR 88398 48089</td>
<td>N55 40.804 W5 22.038</td>
<td>35.0</td>
</tr>
<tr>
<td>W3 – 55m</td>
<td>NR 88255 48205</td>
<td>N55 40.863 W5 22.179</td>
<td>55.0</td>
</tr>
<tr>
<td>AWAC position</td>
<td>NR 88462 48033</td>
<td>N55 40.775 W5 21.974</td>
<td>19.89</td>
</tr>
<tr>
<td>Northeast port</td>
<td>NR 88470 48043</td>
<td>N55 40.781 W5 21.967</td>
<td>20.0</td>
</tr>
<tr>
<td>Southwest port</td>
<td>NR 88453 48024</td>
<td>N55 40.770 W5 21.982</td>
<td>20.0</td>
</tr>
</tbody>
</table>

Figure 1. Map of the proposed discharge site with the position of survey stations.
2. HYDROGRAPHIC SURVEY

2.1 AWAC

An Acoustic Wave And Current (AWAC) Doppler profiler was deployed at the site of interest (NR 88462 48033, N55 40.775 W5 21.974 at 19.89 m -CD) on 18th December 2013 until 30th January 2014 (43 days) using the following set up:

- Profile interval – 600 seconds
- Cell size – 1 m
- Average Interval – 60 seconds
- Blanking distance 0.5 m

Figure 2 shows the AWAC installed by divers on the seabed in a shielded, gimbaled frame.

Figure 2. The deployed AWAC showing its gimbaled frame.

Data were quality controlled to remove any cells that were recorded during deployment/recovery and those affected by side-lobe errors near to the sea surface. The instrument was deployed level with very little movement on tilt or roll, which means that the AWAC was optimally placed for high quality data acquisition (see Figure 3). The heading remained stable at 238° throughout the deployment. Despite this optimal deployment, there
appears to be an issue with the third beam which caused high echo reflections for the first two bins. No reason can be provided for this and affected the bins have been removed from the AWAC data used in modelling.

![Tilt and roll recorded by the AWAC.](image)

Figure 3. Tilt and roll recorded by the AWAC.

2.1.1 Currents

Figure 4 and Figure 5 respectively show a profile view of the current speed and direction. Generally, the current speed rarely exceeded 0.4 m s⁻¹, and averaged 0.17 m s⁻¹. The direction appears to show a change in peak direction with tidal cycle. The peak direction was ~45° in the first half of the deployment, but changed to ~225° in the second half of the deployment. The frame was stable during the whole deployment with no change in heading, making the likelihood of this pattern being an artefact of instrument error low. It would therefore appear that the current characteristics are quite changeable. Observations of changing flow dominancy have also been confirmed during independent drogue surveys in the area by Campbell Marine Contracts. During spring tides, the ebb tide was much stronger than the flood tide, but this affect was reversed during neap tides.

Figure 6 and Figure 7 show velocity frequency (magnitude and direction) for spring and neap tidal flows respectively. There does not appear to be a significant difference between the two suggesting that the effect seen during the drogue study maybe a localised affect. There is a slight dominance in the NE direction (flood) during both spring and neap tides.

Figure 8 shows velocity scatter plots at 4, 10 and 16 m above the bed; there is a distinct rectilinear tidal flow in a SW/NE direction. Figure 9 details the statistics of the flow at 10 m above the bed and reveals that the flood and ebb tide are highly similar, with an average current speed of 0.17 m s⁻¹.
Figure 4. Velocity magnitude as a time series profile. Water level from the AWAC pressure sensor is also shown.

Figure 5. Velocity direction as a time series profile. Water level from the AWAC pressure sensor is also shown.
Figure 6. Velocity magnitude and direction during spring tidal flow (across the water profile).

Figure 7. Velocity magnitude and direction during neap tidal flow (across the water profile).
Figure 8. Velocity scatter plots at 4, 10 and 16 m above bed for AWAC data used in the model.
Figure 9. Tidal axis for bin 9 (10 m above bed) at AWAC site.
2.1.2 Tidal level

The Matlab tidal analysis function, \( T_{\text{tide}} \), was used to create an astronomical prediction of the tide.

Figure 10 shows a 29 day analysis of the tide at Arran comparing this predicted (astronomical) tide against that recorded directly by the tidal gauge. In general, the match was good but the observed tide tended to be a bit stronger than predicted by an average of 0.1 m.
Figure 10. Predicted and observed tidal levels with residuals.
2.2 CTD Data

CTD (Conductivity, Temperature, Depth) casts were taken at the site during the AWAC deployment using a calibrated RDI Citadel CTD. The location and depths are given in Table 2. Figure 15 presents the deepest cast taken and shows that the site is moderately well mixed, with the profile indicating that water gets slightly warmer and more saline with depth. A modest thermos/haloocline occurs at approximately 40 m depth although the change in temperature and salinity is < 0.5 unit.

<table>
<thead>
<tr>
<th>WPT name</th>
<th>Position BNG</th>
<th>Position WGS84</th>
<th>Seabed depth below CD (m)</th>
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</thead>
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<tr>
<td>Cast 1 (W1)</td>
<td>NR 88544 47971</td>
<td>N55 40.744 W5 21.893</td>
<td>1.0</td>
</tr>
<tr>
<td>Cast 2 (P2)</td>
<td>NR 88483 48020</td>
<td>N55 40.769 W5 21.953</td>
<td>13.0</td>
</tr>
<tr>
<td>Cast 3 (P3)</td>
<td>NR 88447 48050</td>
<td>N55 40.784 W5 21.989</td>
<td>25.0</td>
</tr>
<tr>
<td>Cast 4 (W2)</td>
<td>NR 88398 48089</td>
<td>N55 40.804 W5 22.038</td>
<td>35.0</td>
</tr>
<tr>
<td>Cast 5 (W3)</td>
<td>NR 88255 48205</td>
<td>N55 40.863 W5 22.179</td>
<td>55.0</td>
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![Graph showing temperature and salinity profiles for casts 1 and 2.](image-url)
Figure 11. CTD cast of temperature and salinity at site 1.

Figure 12. CTD cast of temperature and salinity at site 2.
Figure 13. CTD cast of temperature and salinity at site 3.

Figure 14. CTD cast of temperature and salinity at site 4.
Figure 15. CTD cast of temperature and salinity at site 5.
3. MODELLING STUDY

3.1 Overview

Prior to the dilution modelling study both CORMIX and Visual Plumes (Frick et al., 2001) were evaluated for utility in the study. Due to limitations of CORMIX for time series runs Visual Plumes was selected for all modelling purposes. This model is recommended for dispersion modelling by SEPA (SEPA, 2013) and has previously been used for similar environmental impact assessments of distillery outfalls (SAMS, 2005).

The model was configured with ambient data conditions taken from the AWAC and CTD casts, and effluent discharge variables provided by Campbell Marine Contracts.

Dilution rates for the outfall based on SEPA’s Environmental Quality Standard (EQS) were defined as a minimum of 150x for initial dilution, and 966x for secondary within 100 m of the surface boil for 95% of discharge events.

3.2 Ambient Data and Discharge Variables for Model Input

Due to the unpredictable timing of current flows, the modelling study focused on an anytime discharge. This gave coverage of a ‘worst case scenario’ (neap slack water) and minimised responsibility of the distillery in timetabling specific discharge windows.

The model was driven through the current data presented in section 2.1.1: current velocity and direction at bins 4, 10 and 16 m above bed were used from 19/12/2013 00:00 to 29/01/2014 23:50, this resulted in 6049 scenarios (10 minute intervals). The data were then extrapolated within Plumes to the surface and bed to provide current data for the full water column. Due to limitations of the Visual Plumes software the directional data was transformed to a -180 to 180° directional angle based on the tidal axis (with 0° representing 53°)

Ambient salinity and temperature were taken from the CTD casts. The far-field diffusion coefficient was taken from Frick et al. (2001).

Table 3 presents a summary of the ambient data used in the model. Table 4 presents the effluent flow characteristics used for the near and far field models, the design and specification of these is covered in Campbell, 2004.
Table 3. Ambient input parameters for Plumes model.

<table>
<thead>
<tr>
<th>Data</th>
<th>Value/Source</th>
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<tr>
<td>Ambient Speed</td>
<td>AWAC height 4,10,16 m</td>
</tr>
<tr>
<td>Ambient direction</td>
<td>AWAC height 4,10,16 m</td>
</tr>
<tr>
<td>Depth/tidal signal (m)</td>
<td>AWAC pressure gauge</td>
</tr>
<tr>
<td>Ambient surface salinity (PSU)</td>
<td>32.2</td>
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<tr>
<td>Ambient bottom salinity (PSU)</td>
<td>32.7</td>
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<td>Ambient surface temperature (°C)</td>
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<td>Background pollutant (kg/kg)</td>
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<tr>
<td>Pollutant decay rate (s⁻¹)</td>
<td>0</td>
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<tr>
<td>Farfield diffusion coefficient (m⁰.⁵/s⁻²)</td>
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Table 4. Effluent flow characteristics.

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<tr>
<td>Port elevation above sea bed (m)</td>
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<tr>
<td>Port Depth (m)</td>
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<tr>
<td>Number of Ports</td>
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<td>Horizontal Port Spacing (m)</td>
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<tr>
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</tr>
<tr>
<td>Horizontal angle of port (*)</td>
<td>90° to ambient flow</td>
</tr>
<tr>
<td>Effluent density</td>
<td>1017 kg m³ at 15°C</td>
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<tr>
<td>Effluent salinity (PSU)</td>
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<tr>
<td>Effluent temperature (°C)</td>
<td>15</td>
</tr>
<tr>
<td>Effluent concentration (kg/kg)</td>
<td>100%</td>
</tr>
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<td>Northeast port (OSGB NE)</td>
<td>188470, 648043</td>
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<tr>
<td>Southwest port (OSGB NE)</td>
<td>188453, 648024</td>
</tr>
<tr>
<td>Total discharge flow rate (L s⁻¹)</td>
<td>2.80</td>
</tr>
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3.3 Model Results

Output statistics from the initial and far-field model are presented in Table 5. The statistics were extracted from the Plumes model output through a Matlab routine; this routine generated a number of outputs dependent on the result of each specific case.

In the event of a surface boil, the centre line dilution, position (x and y from the port) was extracted, for the far-field model the same parameters were then extracted for 100 m from the boil. If no boil occurred for a case the shallowest part of the effluent plume was extracted.

It was noted that the amount of surface boils occurring from the outfalls were less than 30%, this is primarily due to the depth at site and low flow rate of effluent from the ports, further enhanced by the tidal currents observed; this was confirmed through sensitivity analysis in Section 3.4.

<table>
<thead>
<tr>
<th>Percent of Surface Boils</th>
<th>Initial Dilution</th>
<th>Far-Field</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(Surface Boils)</td>
<td>(Surface Boil + 100 m)</td>
</tr>
<tr>
<td>Max. Dilution</td>
<td>14281</td>
<td>20000</td>
</tr>
<tr>
<td>Mean Dilution</td>
<td>5748</td>
<td>13603</td>
</tr>
<tr>
<td>Min. 95%ile Dilution</td>
<td>1981</td>
<td>6079</td>
</tr>
<tr>
<td>Min. Dilution</td>
<td>1242</td>
<td>3098</td>
</tr>
</tbody>
</table>

Figure 16 presents surface boil dilution and displacement from port, the movement of the plume is directly influenced by the tidal axis as expected. As the surface boils did not exceed 60 m towards the shore (suggesting there is little chance of shore impaction of the plume), the data are then transformed and presented with the coastal position (mean water level) in Figure 17, showing the parallel movement of the effluent plumes to the coast. Figure 17 presents far field output of the surface boil dilution and +100 m of the boil. As expected dilution increases but due to the high levels of dilution already occurring for surface boils it's expected to have little observable impact as the effluent has already exceeded recommended SEPA dilution rates. It was noted that merging of the plumes was common in the output (3815 cases/63% occurrence); Figure 18 presents the merge dilution point and distance from port, in all cases the dilution exceeded the SEPA EQS (minimum dilution at merge was 553) and so is expected to have no impact.
Figure 16. Surface boil positions with dilution defined by colour intensity from initial dilution model.
Figure 17. Surface boil dilution and position based on outfall, with coast indicated by blue.

Figure 18. Merge of plumes and dilution at merge for model output.

3.4 Sensitivity Testing

Due to the high dilution levels being returned by the model a number of sensitivity runs were made to judge if this was an error due to low discharge rates and high dilution rates, or an accurate representation of the outfall system. Table 6 presents four sensitivity run results:
- Sensitivity 1 lowered the water depth to a constant 10 m depth
- Sensitivity 2 increased the buoyancy of the outflow to 1000 kg m$^{-3}$
- Sensitivity 3 increased the outflow rate to 20 litres s$^{-1}$
- Sensitivity 4 increased outflow and buoyancy 20 litres s$^{-1}$ and 1000 kg m$^{-3}$

The results show that high dilution levels being observed, along with the low surface boil numbers, are a direct product of the depth of the site and the volume of outflow from the ports. Surface boil occurrence increased significantly with increased flow rate, but minimum dilution was still below the SEPA dilution thresholds.

Buoyancy of the effluent flow has been observed to have little effect on the likelihood of a surface boil occurring; this is reassuring for cases where the effluent is discharged warmer (and therefore more buoyant) than the 15°C ran through the model.

<table>
<thead>
<tr>
<th>Table 6. Sensitivity run outputs.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity Run</td>
</tr>
<tr>
<td>Percent of Surface Boils</td>
</tr>
<tr>
<td>Max. Dilution (Surface boils)</td>
</tr>
<tr>
<td>Mean Dilution (Surface boils)</td>
</tr>
<tr>
<td>Min. 95thile Dilution (Surface boils)</td>
</tr>
<tr>
<td>Min. Dilution (Surface boils)</td>
</tr>
</tbody>
</table>
4. FINAL REMARKS

- The proposed outfall site can be characterised as a well-mixed, but relatively low-flow speed water body.
  - Mean velocity 0.17 m s⁻¹.
  - SW (ebb) / NE (flood) flow
  - Salinity of ~32 PSU

- The predicted dilution rates using Visual Plumes model meet SEPA’s EQS requirements at the surface (150x in initial dilution, and 966x by 100 m from boil).

- 95%ile initial dilution was modelled to be 1981x, increasing to 6079x at 100 m.

- Reducing the water depth to 10 m reduced the initial dilution to 770x.

- Increasing the effluent buoyancy reduced the initial dilution to 1892x.

- Increasing the outflow rate reduced the initial dilution to 724x.

- Increasing both outflow and buoyancy reduced the dilution to 650x.

- None of these factors reduced the dilution below the SEPA EQS.

- The effluent is not expected to have a significant impact on the coastline.
5. REFERENCES


SEPA (2013), Supporting Guidance (WAT-SG-11), Modelling Coastal and Transitional Discharges