CREW CENTRE OF EXPERTISE FOR WATERS

A review of investment decisions at small drinking water supply systems with declining water quality issues

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Contents

Abreviations

ARCS: Asset Risk Customer Score

DOC: Dissolved organic compounds

DWI: Drinking Water Inspectorate

DWSP: Drinking Water Safety Plan

DWQR: Drinking Water Quality Regulator for Scotland

Fe: Iron

H&S: Health and Safety

IDP: Intervention definition process

MF: Microfiltration

Mn: Manganese

NF: Nanofiltration

O&M: Operation and Maintenance

p.e.: Population equivalent

RO: Reverse osmosis

RSPB: Royal Society for the Protection of Birds

SCSP: Strategic Customer Services Planning

SEPA: Scottish Environment Protection Agency

SG: Scottish Government

SSSI: Site of special scientific interest

SW: Scottish Water

TDR: Technical design review

THM: Trihalomethane

TTU: Transportable treatment unit

UF: Ultrafiltration

UPS: uninterruptible power supply

UV: Ultraviolet radiation

WICS: Water Industry Commissioner for Scotland

WLC: Whole life cost

WTW: Water treatment works

Executive Summary

Aim of the Project

This project seeks to review the challenges in delivering drinking water compliance, with a focus on the quality and quantity of investment drivers, and to assess the proposed or deployed solutions against these criteria. These outputs will assist in identifying value for money criteria for investment; identify how the policy and regulatory framework includes water treatment choices, risk appetite and costs; identify how changes to the policy framework could improve value for money and sustainability and inform policy on drinking water treatment based on economics and quality enhancement.

Research Undertaken

The reviewed investment processes related to existing water supply schemes that are in the process of undergoing improvement or have already undergone improvements to meet appropriate qualitative and quantitative standards. The methodology adopted was as follows:

- Identification of three case study sites in collaboration with the CREW Protecting Drinking Water theme steering group and Scottish Water (SW): Fair Isle WTW, North Hoy WTW, Yarrowfeus WTW.
- Review of drinking water treatment systems performance relative to the drinking water regulatory requirements, and the legislative framework that defines the requirements to supply safe and wholesome water.
- Assessment of capital investment plans to improve compliance at the case study sites and investigation of the effectiveness of the decisions in relation to the supplies, interventions and cost effectiveness of the interventions proposed.

The review of case study sites included consideration of the precursor or antecedent factors that can affect compliance and confirmed the investment drivers and environmental, operational and other concerns related to achieving compliance at each of these sites.

Key findings and recommendations

The review has revealed that the decision-making processes employed by SW to address declining water quality issues in small supplies are underpinned by the need to ensure overall cost effectiveness, sustainability and provision of a reliable and wholesome water supply. It has been found that SW procedures are generally effective and informed by stringent application of internal procedures underpinned by the relevant regulatory and policy framework.

The current intervention definition process appeared to be robust, seeking to improve cost benefit analysis and value management while involving a wide range of stakeholders. The process is well aligned with drinking water safety plans and seeks a high level of protection for water consumers, regardless of the size of the supply. The study has also identified several challenges in capital investment process for small systems and suggests that the current robust nature of the Intervention Definition Process (IDP) process makes it lengthy, and potentially complex. The requirements of regulations limit the level of risk that SW is able to take when considering treatment options as all products and materials used in provision of drinking water need to be on an industry approved list[1]. Risk appetite influences the scope of decisions made by SW when considering new innovative treatments rather than tried and tested alternatives. Consideration of risk also appears to involve further iterations in internal process that involve additional time and cost which may not result in increased value for the customer. The study suggests that an opportunity exists for further enhancing the IDP process for small systems through improved engagement with academic and professional specialist support and harnessing the technical capacity and innovation where available within SW operations across all regions, whilst still balancing risk and the need for a secure provision of service. The latter will ensure cross functional learning within SW and ensure that regional differences and technology preferences for these systems are better understood and aligned. SW may also consider providing the optimised internal processes available to private water suppliers.

Key words

Drinking Water Supply, Compliance, Investment Drivers, Cost Effectiveness, Sustainability

[1] http://www.dwi.gov.uk/drinking-water-products/approved-products/soslistcurrent.pdf

1.0 INTRODUCTION

Scottish Water (SW), supported by the Scottish Government (SG), has been delivering a capital investment programme since 2002 that has led to measurable improvements in drinking water quality and service levels across Scotland to comply with The Water (Scotland) Act 1980. A number of drinking water treatment works (WTW) across Scotland are still facing compliance challenges related to either deterioration in drinking water quality or facing risks to achieving compliance in the future, particularly small rural WTW. Challenges in these locations may be related to both raw water quantity and quality. For example, these challenges include increases in water demand due to population growth, seasonal impacts on water sources, compliance with regulatory limits for dissolved organic compounds (DOC), iron (Fe), manganese (Mn), turbidity, *Cryptosporidium* and disinfection control, etc. To address these challenges, intensive capital investment may be required to reduce risks to achieving compliance.

This project seeks to review the challenges in delivering drinking water compliance, with a focus on the quality and quantity of investment drivers, and to assess the proposed or deployed solutions against these criteria. These outputs will assist in identifying value for money criteria for investment; identify how the policy and regulatory framework includes water treatment choices, risk appetite and costs; identify how changes to the policy framework could improve value for money and sustainability and inform policy on drinking water treatment based on economics and quality enhancement.

2.0 AIM AND OBJECTIVES

The overall aim of this research is to assess the appropriateness and effectiveness of the SW processes and adopted technical solutions in providing potable water to small communities. The specific objectives include:

1. Evaluation of the interventions undertaken, and how the decisions made have been influenced by the regulatory and policy framework

2. Assessment of the chosen solution in terms of the following criteria:
    a. Value for money
    b. Sustainability
    c. Improvement to public health, and social justice aspects

3.0 APPROACH

This project has been based on a review of investment processes related to existing water supply schemes that are in the process of undergoing improvement or have already undergone improvements to meet appropriate qualitative and quantitative standards. The methodology adopted was as follows:

1. Identification of three case study sites in collaboration with the CREW Protecting Drinking Water theme steering group and SW.
2. Review of drinking water treatment systems performance relative to the drinking water regulatory requirements, and the legislative framework that defines the requirements to supply safe and wholesome water.
3. Assessment of capital investment plans to improve compliance at the case study sites and investigation of the effectiveness of the decisions in relation to the supplies, interventions and cost effectiveness of the interventions proposed.

The review of case study sites includes consideration of the precursor or antecedent factors that can affect compliance and confirms the investment drivers and environmental, operational and other concerns related to achieving compliance at each of these sites.

A start-up meeting was held with representatives of SW and the CREW Protecting Drinking Water theme steering group, consisting of representatives of the SG, Water Industry Commission for Scotland (WICS), and Drinking Water Quality Regulator (DWQR). The criteria for selection of case study sites were defined at the meeting as follows:

- The sites need to be "in design" phase
- The sites need to be in SR15 (investment period since 2015) programme
- The sites need to have defined treatment systems
- The sites need to have specified operation and maintenance plan

Based on these criteria, the following case study projects were proposed by SW:

1. Fair Isle WTW
2. North Hoy WTW
3. Yarrowfeus WTW

The case study projects enable assessment of WTW requirements and solutions in rural Scottish mainland and island communities, where there are no connection options to other water supply systems.

Once the case study sites were agreed, a workshop session was held with the National and East Regional Team

Leaders for Strategic Customer Services Planning (SCSP), who oversee decision making processes for drinking water investment decisions for SW. The workshop was used to identify the key regulatory drivers that influence drinking water investment decisions and the general decision-making process applied to drinking water investments within SW. This workshop was followed by meetings with their Intervention Managers, Water Asset Planners, and operatives of the case study sites to examine the drivers and decision-making processes in greater detail.

4.0 CAPITAL INVESTMENT PROCESS

4.1 Legislative framework

SW is obliged under The Public Water Supplies (Scotland) Regulations 2014 to ensure water provided in public water supplies is regarded to be wholesome (e.g. that the water does not contain microorganisms, or exceed concentrations or values listed in the Regulations for specific microbiological or chemical parameters and satisfies formula for nitrate and nitrite concentrations). In addition, before providing a supply of water for human consumption, SW must ensure that the water has undergone sufficient preliminary treatment, disinfection, and adequate treatment to produce wholesome water. To achieve this, SW must design, operate and maintain disinfection and treatment processes to keep disinfection and treatment by-products as low as possible without compromising the effectiveness of the disinfection or treatment.

To assess the potential for water contamination or interruption of supply, there is a regulatory requirement for SW to produce a drinking water safety plan (DWSP) for each operational water supply system operated by SW (this requirement is not applicable to private supplies). The DWSP provides a comprehensive review of the water supply system to identify key risks and the most effective control points. The DWSP establishes management systems to mitigate risk and verify that controls are effective in mitigating risk. DWSPs are based around key nodes in the supply system which include:

- Source and catchment
- Raw water mains
- Treatment
- Trunk mains
- Service reservoirs and pumping station
- Distribution
- Customer premises.

Capital investment processes are driven by capital maintenance requirements, a funded and regular programme of improvements to existing assets, or by enhancement requirements. In previous years, investment decisions were typically driven by water quality failures. The current approach to enhancement is now typically driven by risks identified in the DWSP. This risk is defined by both water quality data, as well as other factors such as quantity of supply, which collectively contribute to an overall risk scoring. Issues are usually identified from the outcomes of regulatory and operational sampling programmes, audits or investigatory processes that may be based on understanding of the asset or regulatory investigations. Priority is given based on the nature of the risk and the potential impact on customers. DWQR must provide agreement on the actions taken with regards to failures of drinking water quality.

Enhancement, or improvement plans are developed to address key risks for drinking water assets, which contribute to the definition of projects implemented by SW in an intervention definition process (IDP).

4.2 Identifying investment options

The intervention definition process (IDP) seeks to identify the need, present the intervention options, assess the options and then conclude on the preferred intervention. Figure 1 describes the IDP approach.

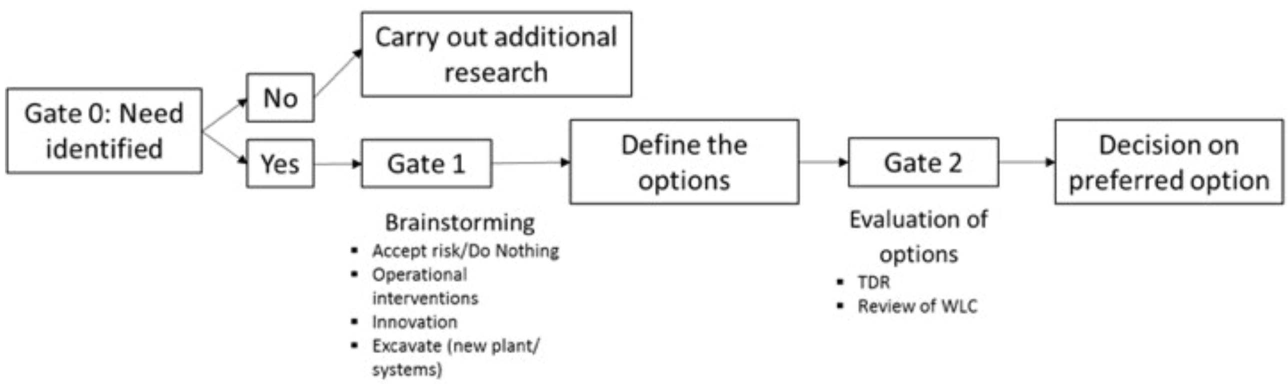

Figure 1. Intervention Definition Process (IDP)

The Gate 0 stage is intended to establish if there is an investment need, and this is supported by evidence. This stage is followed by a process of identifying credible interventions for further investigation to address the site enhancement need (Gate 1). The Gate 1 process involves contributors from across SW including business and technical development teams, process scientists, operators and asset planners. The brainstorming session undertaken at this stage can refer to an existing SW matrix of standard techniques and systems, but also allows for innovative solutions to be considered, including considerations of global solutions or grouping of technologies. Participants in the brainstorming sessions are also required to ensure compliance of options with SW 'Specifications and Standards' requirements. While brainstorming sessions in practice are open to all potential solutions including "blue-sky" thinking, constraints exist on the solutions that may be implemented in practice, particularly for the use of systems or products that are not present on the Drinking Water Inspectorate (DWI) list of approved systems[2]. Although innovations and global solutions may be referred to, only those approved by the DWI will be approved for use. Given the limitations on timescales to investment, only approved, tried and tested technologies are used unless they are unlikely to meet specific technical requirements. Scottish Water's Research & Development programme continuously examines and evaluates new and emerging treatment processes and technologies that can be considered in the investment process. Therefore, a matrix of currently approved standard techniques and systems may be referred to within the brainstorming session. A value management study may follow to further assist in evaluating options resulting from the brainstorming sessions and discarding those that are unlikely to be viable.

While regulatory factors are the primary influence on the capital investment decisions taken, additional factors related to Customers, Technical issues, Cost and Environmental impact (Figure 2) are also taken into consideration, with Customer related factors being of primary importance.

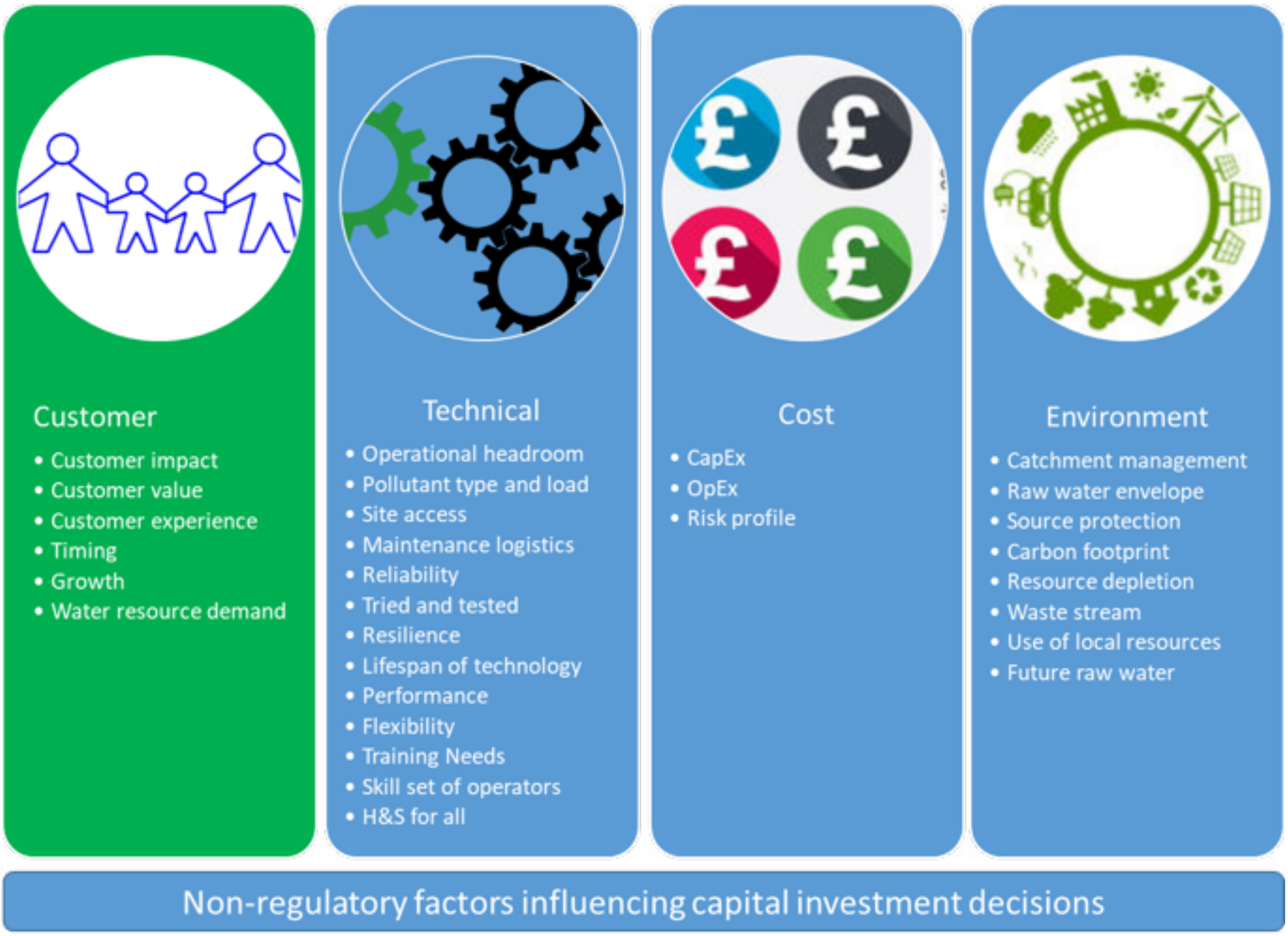

Figure 2. Non-regulatory factors influencing capital investment decisions as identified at SCSP workshop held at Abertay University during the study

[2] DWI, on behalf of DWQR, will normally test products or systems coming into contact with drinking water against Regulation 27 (in Scotland). A full list of Regulation 27 compliant materials is publicly available.

At Gate 2 stage, the options are evaluated and an agreed solution, scope and acceptance criteria confirmed. The full specification for the identified options is then prepared along with the whole life cost of these options. The options are then reviewed by managers during a technical design review (TDR) stage, where costs are presented and a preferred option is selected. Depending on the size and cost of the solution proposed, review by higher levels of management may be required. During this process, innovative solutions may be presented, or specifications may be amended by considering other options, their performance and costs. The final decision for small systems may be approved at a regional level, but depending on cost, higher levels of approval are required at national or senior management level, and for projects above £10m, board approval is required.

5.0 CASE STUDIES

The SR15 (Scottish Water Delivery Plan 2015-21), and in particular Appendix 5: *Improving drinking Water Quality* sets out a planned investment programme to provide customers with a safe and reliable supply of drinking water.

This strategy underpinned Scottish Ministers objectives (2015-2027) in relation to:

Drinking Water Quality

- Ensure full compliance (where there are still non-compliances) with the Drinking Water Directive 98/83/EC, the Water Supply (Water Quality) (Scotland) Regulations 2001 and the Cryptosporidium (Scottish Water) Directions 2003; and
- Reduce the risk of non-compliance with the Drinking Water Directive 98/83/EC, the Water Supply (Water Quality) (Scotland) Regulations 2001 and the Cryptosporidium (Scottish Water) Directions 2003, by improving the resilience to risks as identified in its Drinking Water Safety Plans.

Rural Communities Objective

- Assist the Drinking Water Quality Regulator and SEPA with the assessment of the sustainable and cost-effective options to address the public health risks, limitations to sustainable economic growth and customer willingness to connect to public water and sewerage services associated with community private water supplies and sewerage provision; and
- In light of studies undertaken for the point above, connect to appropriate public water and/or wastewater services as approved by Ministers.

In particular, the SR15 plan introduced the provision for new treatment or alternative supplies to address non-compliance issues and improve the reliability of drinking water quality, through a programme of planned investment.

5.1 Case Study 1: Fair Isle Water Treatment Works

5.1.1 Introduction

Fair Isle is a remote Shetland island community, located between mainland Shetland and Orkney. Fair Isle WTW serves a population of about 70 persons, with the population remaining relatively stable all year round. The treatment works supplies 23 domestic and 10 non-domestic properties. Two 60 m deep boreholes located in the centre of the island are the main sources of water supply for a design flow of 30 m3 per day. The possibility of abstraction from a nearby burn is retained in emergency, although use of this source has not occurred in recent times due to concerns over the quality. The island does not have a continuous 24-hr power supply which a challenge for water supply. The community has a cooperative power supply scheme generated by a wind turbine and SW contributes to the scheme to enable sufficient supply to operate the water treatment plant. An uninterruptible power supply (UPS) system is needed to guarantee water treatment processes are continuous as regular losses in supply cause equipment breakdowns and thus require the presence of emergency generators. A community group, the Fair Isle Electricity Company, is currently working towards a new electricity scheme to provide a 24-hr UPS on the island comprised of additional wind turbine and solar panels along with battery storage and extension of a high voltage network across the island.

Historically, water treatment at the site has consisted of slow sand filtration and chlorine dosing for disinfection as shown in Figure 3. Recently, only the borehole source has been used, with exclusion of the surface water from the supply. The use of the surface water source would increase the possibility of colour, turbidly and *Cryptosporidium* failures and of increased levels of trihalomethane (THM) disinfection by-products. Recent water quality monitoring has shown no microbiological failures, with manganese (Mn) levels being the only failures reported.

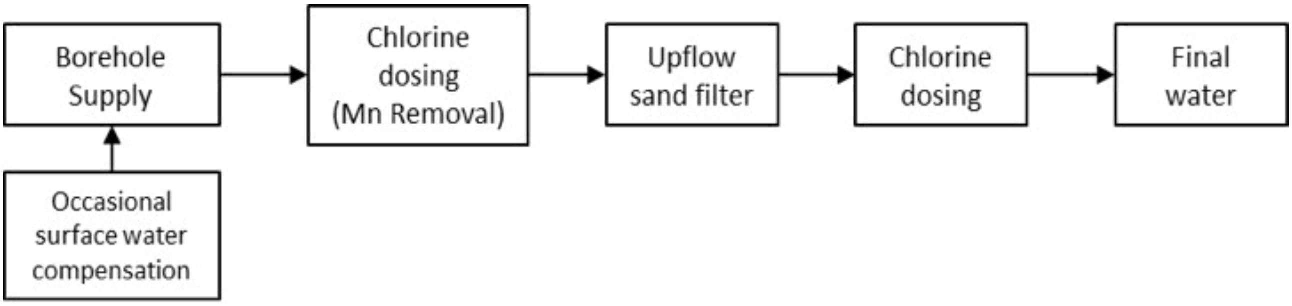

Figure 3. Existing treatment plant configuration at Fair Isle

5.1.2 Drivers and objectives for the intervention

The DWSP for Fair Isle lists the key risks to provision of potable water supply. The plan identifies potential hazards across the various nodes listed in section 4.1, particularly "Source and Catchment", "Treatment" and "Distribution". The DWSP notes that very limited raw water sampling has been undertaken for the analysis of microbiological hazards, and limited water sampling has been undertaken for the analysis of chloride, THMs, manganese and turbidity.

Despite an extensive list of hazards identified, a selection were presented for the technical design review (TDR) as drivers for the current intervention. These included:

- Risk of deterioration of raw water quality as a result of heavy rain. Deterioration of raw water quality as a result of heavy rain as although the borehole source is not affected by heavy rain, the Vaadal burn is susceptible to highly coloured and turbid water during heavy rainfall and wet weather.
- Non-compliance. Cryptosporidium detections. Inadequate treatment for identified risks in catchment. There were 2 Cryptosporidium detections in the first 8 months of 2012. Colour does not cause failure but the works struggles when colours get high. There have been manganese failures before 2010 and manganese causes other issues on the works. There have been sample failures in the past in raw water for pesticides and hydrocarbons. Treatment is not provided for pesticides or hydrocarbons.
- Risk of non-compliant water entering supply due to failure or absence of treatment. Non-compliant water enters supply due to failure of treatment due to poor condition of filters which are not able to be backwashed effectively. Media requires replacement. Non-compliant water entering supply as a result.

A summary of the above and other drivers for intervention are as follows:

- Ability to always meet peak demand of 30 m^3/day from the borehole sources only, and eliminate the potential use of surface water to compensate supply and consequently reduce the risk of THM, colour, *Cryptosporidium* and turbidity failures
- Reduce the risk incidence of *Cryptosporidium* and Mn failures
- Optimise existing chlorination unit
- Address power availability constraints.

5.1.3 Process for undertaking the intervention

The intervention process used at Fair Isle has followed the IDP process (Figure 1). The DWSP identifies the need to provide a potable water supply for Fair Isle and to remove existing risks. Benefits are identified as improving security of supply to customers while removing and reducing key DWSP risks.

The process of identifying the investment options for Fair Isle began in 2012 as part of the development of Scottish Waters regulatory business planning. Risks were identified and a solution proposed for inclusion within Scottish Waters regulatory business pan following the timeline set out by WICS. This was submitted in 2013, with regulatory approval granted in 2014 as part of the 2015-21 business plan. The initial IDP process identified a new reverse osmosis (RO) plant with a standalone power generation scheme as the preferred option to go before the technical design review (TDR). This option was presented to TDR in June 2016 but was rejected due to high costs. A revised scope following TDR included a new storage tank, two new boreholes, a new generator, additional and existing filters, refurbishment of the disinfection unit and provision of a new welfare facility. The option of identifying an improved source was excluded as new test boreholes drilled in 2016 were found to be of poor quality. In 2017, additional work was carried out to look for low-tech and traditional approaches.

Further consideration of the possible treatment options was carried out, and a revised set of options was presented for review and approval. Gate 0 and Gate 1 processes (Figure 1) were undertaken at the same time. Initial evaluation of the primary water source and treatment provision was carried out. This process considered whether the burn supply was viable as a primary source and whether new sources were possible, or if additional treatment of the existing source would be preferred. At Gate 1, no value management study was carried out as the full project scope was not understood at the time.

The revised intervention identified the following improvements of the existing works to achieve the required outcomes:

- Refurbishment of boreholes to improve borehole yield
- Addition of raw and treated water storage tanks (2 x 15 m^3) to meet peak demands. Water storage will also buffer against any disruptions that may result from technical failures since technical support may not be readily available given the island's geographical isolation and sometimes challenging weather conditions
- Optimisation of the existing pre-filtration chlorination unit to improve Mn precipitation
- Addition of pressurised filters to enhance Mn removal
- Refurbishment of the existing sand filter
- Optimisation of the final chlorination unit (with a new chlorine dosing) to ensure effective disinfection at all times

The revised system configuration presented to TDR in September 2017 is shown in Figure 4. The enhanced technical specification of the refurbished plant requires one part-time SW staff to operate.

This proposed solution allows the plant to avoid the use of the surface water source, addresses supply-demand balance issues and addresses key water quality concerns. Following a risk/cost-benefit assessment, Scottish Water issued a THM waiver for the site since it does not include specific provisions to eliminate the risk of THM. While THM fall well below regulatory limits, there have been cases of exceedances of internal SW water quality standards. Consequently, a waiver of internal quality standards for THM was requested for the site.

5.1.4 Discussions and Conclusion

The proposed solution for Fair Isle was based upon risks identified in 2012, with the approved solution decided in 2018 for subsequent implementation, however it must be recognised that this is strongly influenced by the investment framework as highlighted earlier. The timeline between identification of the problem and provision of a full operational solution in this case is about eight years, although from the approval of the SW business plan the full operational solution was delivered in 3 years.

The key water quality issue at Fair Isle relates to the occasional use of the Vaadal Burn to supplement supply, or provide emergency capacity. The exclusion of this source from the supply addresses several of the potential water quality issues particularly the risk of non-compliance due to *Cryptosporidium* detections caused by increased source turbidity brought about by catchment rainfall events. However, removal of the Vaadal Burn from the supply node does not eliminate the potential for manganese failures, or address the water supply capacity of the existing boreholes.

A summary of considerations and actions for Fair Isle WTW is as follows:

- Marginal population growth
- Boreholes are the only source of water supply for the community, e.g., increased future demand will be met by drilling extra borehole(s) rather than use of surface water (i.e., from the Vaadal Burn)
- Additional treatment of borehole water for Mn removal

A key consideration for the choice technology is operations, and how technology is supported. As one of the most rural inhabited islands in Scotland, access is limited at times due to poor weather conditions. Hence, the system in place must be a tried and tested technology which is reliable and easily operated and maintained by local resource. Trialling a new or complex technology will be difficult to support and sustain with the low level of technical manpower that will be obtainable locally. The proposed solution incorporates additional raw and treated water storage capacity, and seeks to incorporate operational controls that limit the occurrence and duration of potential breakdowns. The additional capacity also provides for a longer time-buffer for technical support to reach the island, particularly where adverse weather conditions can cause delays in returning systems to function, thereby reducing the need to supplement supply with alternative sources.

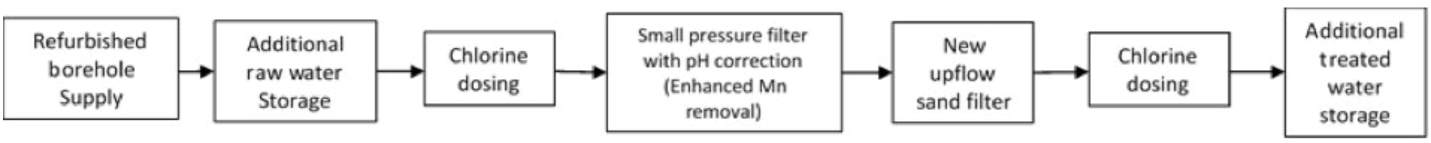

Figure 4. Proposed treatment plant configuration at Fair Isle

Another concern for the treatment works is the unreliability of frequent power supply. Any technology being proposed at the site must be less reliant on frequent power supply, and adaptable to power outages. Ongoing work by the community-led energy scheme to install a UPS on the island will reduce the potential for plant shutdowns and the need for emergency power generators, and back-up storage capacity.

The proposed solution also provides additional capacity for Mn removal in an additional small pressure filter and refurbished sand filter. Manganese removal is typically achieved by any of the following methods:

- Oxidation and filtration

  Oxidation of manganese causes it to precipitate, followed by removal of the precipitated material by filtration using sand filters or more expensive (and lower foot-print) pressurised filtration systems. Commonly used oxidising agents are oxygen (through aeration) and chlorine. Other oxidants include ozone, chlorine dioxide and potassium permanganate. Oxidation by oxygen is a slow process and can be enhanced by adding chemical oxidants, normally chlorine.

- Ion exchange

  This method does not require oxidation of the manganese prior to removal. Ion exchange media, or resin, exchanges one type of ion for the contaminant of interest. The treatment results in the production of a concentrated waste stream containing targeted contaminants, which must be safely disposed of. It also requires the ion exchange media to be regenerated periodically.

The most proven and cost effective option, considering existing assets, is the oxidation process followed by filtration. This is also the option selected by SW for Fair Isle. In this case, chlorine is the chosen oxidant since oxygen (aeration) alone is a slow process, and chlorine is already in use at the site for disinfection. The use of chlorine as oxidant, however, will be effective inasmuch as surface water continues to be excluded from the supply. The surface water has been shown to increase the risk of *Cryptosporidium* and other organics contamination (e.g. peat); chlorination of water containing these contaminants will result in high risk of producing THM. Should SW consider supplementing the supply with surface water, other oxidants should be considered, notably ozone, which can oxidise both Mn and organics, and is also a disinfectant. Combining ozone treatment (or ozonation) with hydrogen peroxide dosing can enhance the oxidation of organics. Ozonation does not involve chemical handling and storage (but does require power, dedicated storage and venting), however, it can produce bromate (a potential carcinogen) if the water being treated contains bromide, which is likely given the influence of sea water.

Additionally, UV treatment rather than chlorine disinfection can further reduce the risk of occurrence of THM. Since the flow is reasonably low, and turbidity and hence microbiological load also low, UV could be an effective disinfectant. Only UV disinfection could increase the risk of contamination of the water during transmission since UV (like ozonation) does not provide a residual disinfectant to protect the water when it leaves the treatment plant. Optimised levels of chlorine dosing may accompany UV treatment if this risk is deemed high, but in all, this approach has the potential of bringing about lower THM risk than the proposed system.

In conclusion, the preferred solution seems appropriate and suitable for the site, although, incorporation of UV treatment could ensure lower THM risk as explained above. The selection processes took into account cost effectiveness, sustainability and the need to provide the public with clean and reliable wholesome supply water at all times.

The length of time take for full implementation reflects both the nature of the investment cycle, and the significant technical challenges faced by the project. Local issues such as water quality data availability, chemical processes (bromide), sufficient and reliable power supply, and the needs to consider other sources of supply (from boreholes) all contributed to the complexity of the challenge. This study provides valuable insight into how to address such complex locations in the future, and how to develop a more streamlined version of the implementation process.

5.2 Case Study 2: North Hoy Water Treatment Works

5.2.1 Introduction

The North Hoy WTW serves the islands of Hoy and Graemsay in Orkney, supplying a population of about 56 persons. This includes 23 domestic and 5 non-domestic properties on North Hoy, and 15 domestic and 3 non-domestic properties on Graemsay. The source of the supply is Sandy Loch, a shallow but protected loch, with varying levels of colour and turbidity, which are highest in winter months. Raw water quality fluctuates throughout the year. The yield is adequate for year round supply, including during peak demand. The island is a Royal Society for the Protection of Birds (RSPB) reserve and site of special scientific interest (SSSI).

The loch experiences seasonal variation in turbidity and colour (e.g. 30 mg/l Pt/Co in summer vs. 80 mg/l Pt/Co in autumn), which are associated with fluctuations in metal concentrations (e.g. Fe, Mn). Water pH has a reasonable buffering capacity and averages pH 7.4 but can also fluctuate (e.g. 6.8 – 9.3). Monitoring results from 2010 to 2016 have also detected *E. coli* (0 – 100 cfu per 100 ml) and coliforms (0 – 1400 cfu per 100 ml). Monitoring data for the final water produced by the treatment plant shows a number of failures for THM concentrations, with 88% of samples over a 6-year dataset indicating THM concentrations above the internal SW limit value of 40 µg/l.

Historically, disinfection was the only treatment provided before distribution. In 2000 a filtration unit was installed for the reduction of turbidity and organic matter prior to disinfection. The filter was a first generation ceramic membrane filtration system, which was an innovative technology at the time. Figure 5 shows the layout of the treatment plant. This configuration has been in place to present day, but has proved problematic in many ways, including:

- Low output: The design output was 40 m3 per day, but has only ever produced 25 m3 per day due mainly to poor raw water quality in terms of organics, colour and turbidity. Due to the low output of the plant, at times fresh water is transported via tanker from a neighbouring island (South Hoy) to meet demand. This requires costly truck journeys.
- High operational costs: Frequent need for membrane cleaning (every six days), and costly replacement of membranes. There have been three membrane replacements over a 20 year period. This was not envisaged in the original plant specification. There is now difficulty in procuring approved replacement membranes due to lack of approved suppliers able to provide these.
- The disinfection system is rudimentary; it has no chlorine contact pipe/tank and is not equipped with automatic shutdown if chlorine dosing fails.

5.2.2 Drivers for the intervention

North Hoy was identified along with 34 other sites serving 1.3M customers as part of a £331.6M investment to improve existing treatment processes. In particular, the concern was around bacteriological contamination because of filter overloading which was resulting in failures. The objective was also to increase capacity and restore the supply:demand balance concomitant with decreased risk of non-compliance. In order to achieve these headline drivers, the aims for intervention were specified as follows:

- Increase output to greater than 50 m3/day to meet the WG4 supply/demand requirement
- Reduce filter replacement frequency and maintenance cost
- Reduce need to supplement supply from external sources, and hence, reduce transportation costs, road traffic impacts and reputational damage to SW.
- Reduce overall production costs.

5.2.3 Process for undertaking the intervention

The North Hoy intervention IDP process initiated with definition of the need. The need was stated as a "water supply deficit issues… unable to meet current demand". An extended process of optioneering was carried out with multiple options considered. The intervention options, as shown in Table 1, were initially presented to TDR in January 2016.

Table 1 Intervention options considered for North Hoy, presented to TDR January 2016

Intervention type	Description
Eliminate	Do nothing.
Operate	Unable to operate and maintain redundant equipment.
Innovate	Provision of ion exchange ceramic membrane process.
Excavate – Option 1	Mains supply from South Hoy WTW – discounted on cost.
Excavate – Option 2	Mains supply from Mainland Orkney WTW – discounted on cost.
Excavate – Option 3	Upgrade existing plant – redundant technology; upgrade is not possible.
Excavate – Option 4	New WTW - discounted on cost.
Excavate – Option 5	Provision of a borehole.
Excavate – Option 6	Innovative ceramic membranes.
Excavate – Option 7	Transportable Treatment Unit (TTU) incorporating membrane filtration.

Several of the options presented in Table 1 above were discounted either on their inability to achieve the needs of the project, or due to cost. The outcome of the initial TDR was to develop Option 7. The TTU was selected as the preferred option on the basis of cost effectiveness,

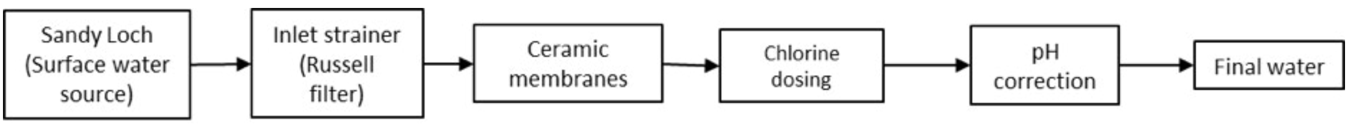

Figure 5. Current treatment plant configuration at North Hoy

ability to achieve the desired water supply and quality improvements, and the configuration was already in use elsewhere. SW decided in February 2017 to design a "Small Community" TTU in partnership with an identified contractor (Ross-shire Engineering). The working principles of the system design were to:

- Incorporate membrane technology
- Ensure health and safety and water quality would not be compromised
- Ensure the system was functional and operable for remote rural communities
- Allow for additional storage

An outline design was agreed, and SW carried out additional engagement with key internal stakeholders (Technical Support and Assurance, Capital Liaison, Standards and Specifications, H&S, Public Health Team) to review the design and establish costs for the project. The finalised design was presented to TDR in March 2017. A Latest Best Estimate (LBE) was presented comparing an SR15 compliant TTU option with a paired down "Small Community" option, which provided an estimated saving of £700k for the North Hoy project. The "paired-down" option achieved savings by adapting the specification to common parts (e.g. pumps and valves allowing for savings in procurement, and operation and maintenance (O&M)) and adjusting some controls from automatic to manual (e.g. cleaning process). In all, this option required 169 specification waivers from the Standards and Specifications team. The final proposed TTU design allows for replacement of the existing ceramic membrane filtration system with a more durable and robust, and cheaper system, that can continue to produce high quality water but with increased output. Increased output will allow for sufficient capacity to supply current demand, hence, no additional storage is needed. A refurbished chlorine disinfection unit will ensure correct chlorine dosing and reduce risks associated with microbiological contamination. Figure 6 shows an overview of the proposed treatment system. The scope of the works includes:

- construction of site welfare facilities,
- provision of power to existing site building which will be used for storage and to existing radio links to Graemsay tank,
- provision of site drainage, and
- works external to the TTU to allow connections from raw water source and to the existing Clear Water Tank, which is to be retained.

5.2.4 Discussions and Conclusion

The new treatment system proposed in North Hoy is similar to the existing plant with the key intervention being the replacement of an ineffective and expensive ceramic filtration unit with a new nanomembrane filtration (NF) unit. In assessing the suitability of this proposed solution for North Hoy, a review of this technology in light of the water quality challenges present at the site is necessary. NF systems are commonly used for the following applications in water treatment:

- Softening hard water
- Nitrate removal from groundwater
- Colour removal
- Organic matter removal.

Figure 7 shows the relationship between particle sizes of some water contaminants and filtration processes and pressures. The figure shows that for the removal of organic pollutants (similar to those present in the North Hoy raw water supply source), nano-filtration is more effective than conventional (e.g. slow and rapid sand filtration), microfiltration (MF) and ultrafiltration (UF) processes. Reverse osmosis (RO) can remove smaller sized particles than NF, however RO operates at higher pressures. RO can also separate ions, hence it is more commonly used in the treatment of brackish water for potable water supply. The target pollutant in the North Hoy water supply source is organic matter, therefore, NF is more than adequate to meet the quality requirements. Although MF and UF systems may also be suitable for the site, the use of NF provides additional efficiency guarantee as it can remove a greater range of organic particles.

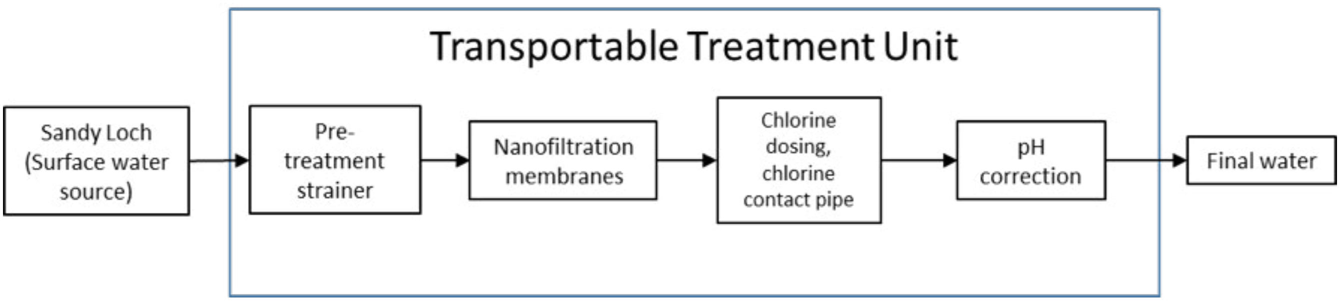

Figure 6. Proposed treatment plant configuration at North Hoy

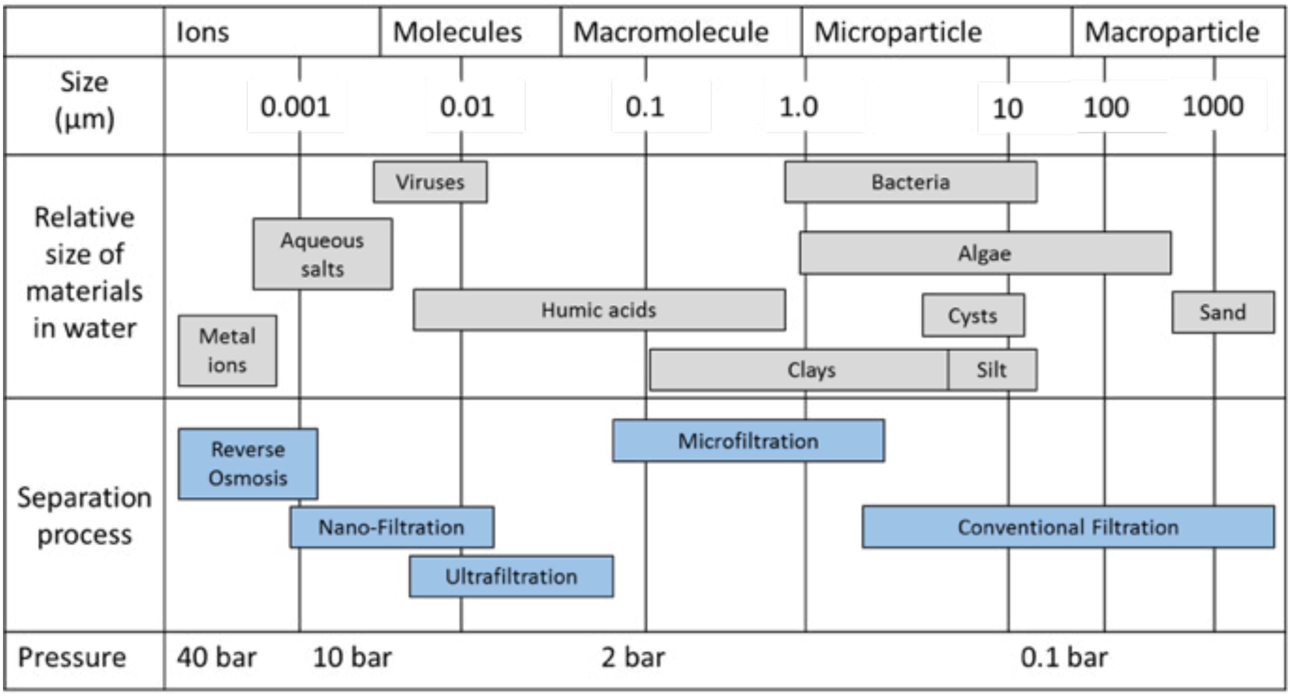

Figure 7. Pollutant characteristics with applicable filtration processes (*Source: adapted from DWI 2016*)

Choosing a suitable filtration system also requires consideration of both capital and maintenance costs. Due to the remoteness of the location, existing assets are deemed unsuitable. Meeting the water supply needs of the location thus requires a detailed study, covering the following:

- Market survey to identify available systems
- Collection of full-scale performance data of selected systems
- Field trials to determine performance and operational requirements
- Economic analysis

Conducting such a study is both expensive and time-consuming. In addition, the previous intervention that resulted in the adoption of "innovative" ceramic membranes resulted in a system that did not perform to the predicted specification, hence there is a reluctance to adopt relatively less tried and tested technologies in this rural location. Where solutions being considered are not on the DWI approved products list (Regulation 27 (in Scotland) as mentioned above) the time, cost and risk of obtaining approval must also be considered.

As in the previous case study, the problem on this site is relatively simple and straightforward, e.g. the existing filtration unit is incapable and needed to be replaced with capable and reliable cost-effective filters. In arriving at the preferred solution, cost effectiveness, sustainability and the need to provide the public with clean and reliable wholesome supply water at all times were all sufficiently taken into account. However, as in the previous case study, the path to arriving at the suitable solution involved a full application of SW internal processes for process selection.

5.3 Case Study 3: Yarrowfeus Water Treatment Works

5.3.1 Introduction

The Yarrowfeus WTW serves a population equivalent (p.e.) of approximately 76 consisting of 32 domestic and 5 non-domestic properties. The population is relatively stable throughout the year, with few tourists or holiday homes within the catchment. The source of supply is two relatively shallow boreholes sourced from a shallow gravel aquifer with a yield of about 1.5 litres per second, located at close proximity to the Yarrow Burn. Activity in the catchment includes limited grazing and small plantations.

The current treatment comprises of disinfection by chlorination using sodium hypochlorite followed by pH correction by caustic dosing as shown in Figure 8. A treated water storage tank provides 30 m3 storage capacity, which can provide approximately 12 hours of supply.

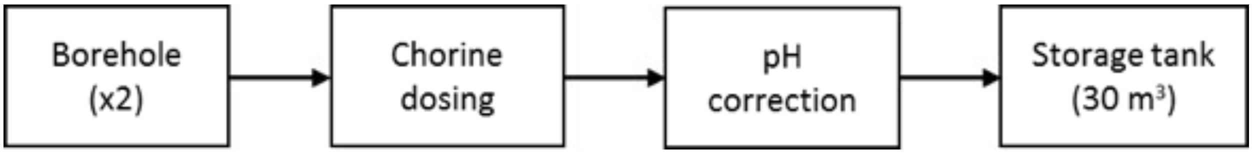

Figure 8. Current treatment plant configuration at Yarrowfeus

The main quality issue at Yarrowfeus is an increase in raw water turbidity and the associated risks of *Cryptosporidium* contamination, during rainfall events. Between 2005 and February 2017, a total of 22 *Cryptosporidium* failures were recorded from 587 regulatory samples. The failures occurred during and after heavy rainfall events when the river levels and turbidity were relatively high. The shallow borehole is thus most likely affected by infiltration from the nearby Yarrow Burn. The current treatment system provides no turbidity reduction and is unable to ensure that treated water is free from the risk of *Cryptosporidium* contamination. Although there have been no reported impacts on customers in terms of illness, one count of oocyst constitutes as a drinking water quality regulatory failure. The source of *Cryptosporidium* in the raw water is likely due to agricultural runoff when the Yarrow burn is in spate. There was a loss in confidence in the supply by the DWQR therefore requiring improvements to be initiated.

5.3.2 Drivers for the intervention

The DWSP for Yarrowfeus lists the key risks to provision of potable water supply. The plan identifies potential hazards across the various nodes listed in section 4.1, particularly "Source and Catchment", and "Treatment". These include for example a Source risk of "Deterioration of observed raw water quality" and a Treatment risk of "Inadequate treatment for identified risks in catchment".

The key drivers for the intervention include:

- Risks of microbiological contamination of raw water
- Risk of deterioration of raw water quality as a result of heavy rain
- Risk of contamination of raw water following borehole pump start-up

The risk of Cryptosporidium contamination has been identified to increase during heavy rainfall/flooding, when there is increased raw water turbidity. Customers in the local area may receive a public health notice, or a 'boil' notice during high rainfall events. However, issuing such notices can impact negatively on SW's reputation. SW are legally required to effectively manage the risks to ensure that no 'boil' notices are issued.

Another area of concern is the location of the existing water treatment works in the floodplain of the Yarrow Burn. There is a risk of flooding of the WTW during high water levels. This can bring about interruption of supply. During a flooding event, access to the site may be restricted due to road closures, which can result in inability of operations and maintenance teams to reach the site for up to 36 hours. This can prevent emergency action being taken during times of greatest risk to water quality. In addition, due to the fine nature of the particles causing the turbidity, the turbidity alarms typically do not capture high turbidity events. Therefore, an additional driver to water quality and reputational drivers is reducing the risk associated with high river water levels and flooding of the treatment plant.

5.3.3 Process for undertaking the intervention

The initial requirement for investment was identified in 2013 as part of needs identification for SR15 business plan. As specifically identified in SR15 the parameters at risk of non-compliance were cryptosporidium and turbidity, with a proposed solution of the installation of cartridge filters and UV disinfection. Connecting the community to a mains water supply was initially considered to be the preferred option for this site and other similar small sites. For example, a nearby site at Yarrowford had previously been connected to the mains water supply at Howdens (Selkirk) with sufficient pipe size and extra capacity in mind for future connection of Yarrowfeus. When the connection at Yarrowford was made, the DWQR acceptance criteria for reducing risk required total removal of *Cryptosporidium* whereas this has recently been updated, following DWI guidance, to include "inactivation" of *Cryptosporidium* as sufficient. While removal is still a preferred option, inactivation is now accepted as an effective method of reducing risk. This allows for the use of cartridge filters which provides microfiltration (MF), which can remove 1-10 μm particles, including some *Cryptosporidium* cysts as shown in Figure 7, followed by ultraviolet radiation (UV) to inactivate cysts that are not filtered out. A combined MF/UV option was considered at TDR in February 2016, raising several actions to be addressed including assessing the risk of UV only, the evidence of *Cryptosporidium* risk at the site, and to consider other options to reduce risk (not eradicate).

The Yarrowfeus intervention process (IDP) continued with a value engineering workshop in 2017 that confirmed the drivers for the intervention, set out the options in an extended brainstorming session and determined the preferred option. The workshop followed a value management process using multiple subject matter experts to share opinions and allow for a group decision to be made. Attendees included the following SW staff: Intervention Manager, Asset Planner, SCSP Team Leader, Water Team Leader, Water Operations Manager, Public Health Team Manager, Intervention Coordinator, Process Scientist, Process Science Team leader, Technical Specialist and Senior Treatment Operator. The value management process consisted of the following stages:

- Information phase (review history, discuss route cause of issues and customer impact)
- Idea generation (review current proposed options as a group; generate new ideas as a group)
- Evaluation phase (discuss risks/benefits of previous proposed options and new ideas, assess functionality, suitability, feasibility of each; use Customer Value System matrix to rank options)
    - o Possible; Functionally Suitable; Technically Feasible; Economically Viable, Client Acceptable.
- Decision making phase to discuss outcomes of matrix and consider options that should be progressed
- Action planning and next steps

The options identified and evaluated at the workshop are presented in Table 2.

Following the review of options, two selected options (i.e. connection-to-mains and MF/UV) were taken through a facilitated exercise to complete the Customer Value System to rank options according to SW's Vision. The MF/UV option provided a lower whole life cost (WLC), however the connections-to-mains option scored better for reduction in risks. The process resulted in the MF/UV option being selected as the preferred option. Additional actions were identified to confirm some unknown information regarding the MF/UV option before proceeding to preliminary design.

The subsequent proposed solution for Yarrowfeus is described in Figure 9. The project is likely to be delivered as a transportable treatment unit (TTU), but provision is now through a mains supply from Howden.

Table 2 Intervention options considered for Yarrowfeus in Value Management Process

Intervention Title	Reason for exclusion/inclusion
Do nothing.	Not viable as Boil Notice is not considered to be a solution but a last resort.
New borehole	Not enough known about local geology, may cause delays and high costs.
Buy farm land and move farm	Not confirmed that the *Cryptosporidium* risk is coming from the livestock; Too costly as 40 miles of riverbank fields would be required.
Run a pilot plant to test UV option	Considered to be too costly and time consuming.
Increase storage	Visual impact of tank in a field. Requires approval by the Scottish Environment Protection Agency (SEPA). Cost of buying land and placing the tank. Considered to be part of the evaluation of the UV option.
Back washing	Considered not relevant for the cartridge filters; would need a discharge licence for the backwash water and SEPA approval. Could reduce operation and maintenance, and considered to be valid as part of evaluation of the UV option.
Tankering	Whole life costs too high; part of emergency action plan. Considered to be unsuitable standalone option, high O&M costs and need to build lay-by, difficult to access site in storm and health and safety (H&S) issues around access.
Connection to mains	**Selected option**: Sent to TDR February 2016. Adds additional risks/considerations of age of water, THM, operational requirements and costs (pumping and secondary dosing)
UV plus MF cartridge filter treatment	**Selected option**: Sent to TDR February 2016. Provides buffer against storm events

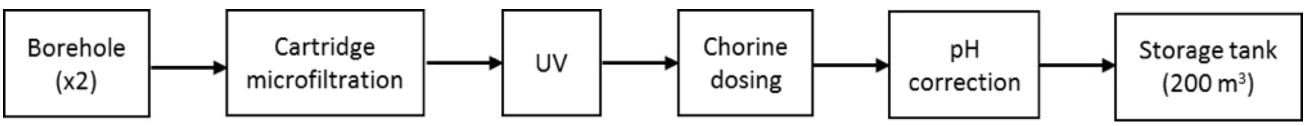

Figure 9. Proposed treatment plant configuration at Yarrowfeus

The proposed solution incorporates refurbished disinfection and pH correction units along with a storage tank with increased capacity allowing for between three and four days storage capacity to buffer against potential lack of access incidences caused by adverse weather conditions or flooding. There has also been an effort to relocate the plant further from the river to protect against potential flooding events.

5.3.4 Discussion and Conclusion

The primary driver for the intervention at Yarrowfeus is improvement of water quality, particularly a reduction in the risk of *Cryptosporidium* contamination. While connection-to-mains water supply would have been sufficient to address the supply needs of Yarrowfeus and would be viable in respect to both treatment capability with similar costs, a change in regulation resulted in the MF plus UV being proposed as a viable alternative. There are some advantages with regards to this option. Firstly it has a reduced capital cost compared to the connection-to-mains option. Additionally, not all water quality indicators would necessarily be improved with a connection to mains. For instance, supplying the Yarrowfeus community by mains from Howdens could increase the age of the water, requiring additional disinfection residual and increased risk of formation of THM.

The relaxation of the regulations to consider inactivation technology such as UV as suitable for risk reduction from *Cryptosporidium* allows for a greater number of remote sites with similar water quality challenges to consider this treatment option over more expensive UF or NF systems. UV treatment is a relatively new technology for SW water treatment operatives working in locations where this technology is not in use. SW could use more experienced operators to train staff that are using this treatment for the first time. There might be a side benefit here for SW in terms of cross-geography working and cross functional working within its workforce. The addition of a new storage capacity provides an additional flexibility in the system to allow for maintenance or plant shutdowns, as well as an option for supplementing supply during periods of high source turbidity and increased contamination risk. The new plant provides improved safety and usability by moving further away from the river, reducing the risk of flooding.

As with the previous case studies above, the final preferred solution was made on the basis of cost effectiveness, sustainability and the need to provide the public with clean and reliable wholesome supply water at all times. The solution also provides a useful test case for other small rural treatment works facing *Cryptosporidium* contamination risks, where it is now possible to consider *Cryptosporidium* 'inactivation' as equivalent to 'removal', thereby paving the way for its treatment using UV. The process that led to the final option, although lengthy and time consuming, seems necessary and appropriate as the final result will have a great impact on SW practices in the management of risks posed by *Cryptosporidium* contamination of water supply sources.

6.0 DISCUSSIONS

The review of the three case study sites has revealed that processes employed by SW in making investment decisions at small drinking water supply systems with declining water quality issues have at the core, the need to ensure overall cost effectiveness, sustainability and provision of fresh, reliable and wholesome water supply that is locally sourced and treated.

The study has also identified some challenges in the application of the processes, and these are discussed below.

<u>Low population size</u>

A major challenge in the optioneering of suitable treatment systems is the size of population and hence the amount of water needing treatment. Although many technologies can be scaled, they tend to become more expensive to operationalise on small scales when balanced by demand. Options available to SW process engineers are either to build bespoke systems, e.g. the TTU (polymer membrane technology being the option of choice due to its reliability, robustness, and relative cost), or utilise systems more suitable for private individual supplies. Either option involves both high capital and operational costs. Furthermore, these systems are usually manned by one person who also will be potentially responsible for several other facilities. The key is therefore to ensure that isolated rural provision facilities are robust and easy to get back into operation following failure. In order to mitigate the difficulties of accessibility (particularly because of remote location and seasonal weather constraints) additional storage capacity is generally built into the design to ensure short term continuity of supply.

<u>Geographical constraints</u>

Remote and rural locations such as those reviewed in this study suffer from typical remote access constraints. Operational and maintenance considerations are therefore exceedingly important in investment decisions, considering the additional time and cost required for operatives to reach sites in adverse weather conditions or emergency situations. Contingency planning for these sites is therefore critical. In the case of Fair Isle and Yarrowfeus, the provision of additional storage capacity presents an opportunity to increase the resilience of the system to some potential water quality failures. In such circumstances the additional resilience will reduce the urgency of quick access by site operatives, or the need for urgent corrective actions. There are potential shortcomings in relying on storage capacity. Treated water storage is often "wasted" where it is not used, therefore considerable materials and cost may be required to continually refresh stored water supplies. In the event of failure of automatic detection or switching systems, there are additional risks that alternative supply will not be put into use when needed.

For island sites, the connection to mains water supplies is often not a viable consideration, thus investment options for these sites are typically different from mainland sites where many small rural supplies are being considered for connection to mains.

Another important consideration is the unavailability of a reliable and sufficient power supply in some of these remote locations, particularly in island sites. In these cases, process selection must take into account potential for plant shutdowns and the need for emergency power generators, and back-up storage capacity. During certain periods of the year, when the weather conditions are very challenging, restoring power supply after a breakdown may take a longer time due to difficulties in sourcing technical assistance and spare parts from the mainland.

<u>Technological constraints</u>

The SW Specifications and Standards team set out the required materials, components and controls for each site. Sites will apply for waivers for some of these where deemed to be achievable in a more cost-effective manner for example the use of manual versus automated controls, or the use of common pumps or values to achieve savings on procurement. It is likely that not all Specifications and Standards provisions are appropriate for small rural works. For example, Specifications and Standards may specify a standard large pump, which may be suitable in a large WTW but provides challenges in smaller systems. This can include the additional energy requirement, but also the quantity of water being pumped. In the case of automatic pump control, this may result in more treated water being pumped to waste than is realistically needed.

Complexity of systems can provide some constraints, however the move towards automation can also introduce some inefficiencies into the system. For example, at the Fair Isle site, additional automated controls for the cleaning process had initially been specified in the design. This activity only takes place when an operative is onsite, and hence there is no real need for the process to be automated. In this example, cost savings were made by replacing automatic controls with manual ones and developing a cleaning process for operatives to follow.

<u>Regulatory constraints</u>

Standards and regulations have a significant influence on technologies that are adopted and changes in regulations can affect the decisions taken. For example, at Yarrowfeus, a relaxation of rules to accept a reduction in risk, as opposed to eradication of risk led to a different decision to be taken compared to other similar sites. This outcome only arose as a result of the lengthy decision-making process overlapping with regulatory changes. This highlights a key role for the water strategy team to ensure teams involved in capital decision making processes are made aware of upcoming changes that may affect the decision making process, and raising awareness widely when new regulation and standards are applied.

<u>Innovation</u>

Although the IDP makes provision for brainstorming and considerations of "blue-skies" thinking for identifying treatment solutions, a matrix of standard techniques and technologies that are available to those involved in the decision-making process, limits the scope of available or feasible techniques and technologies. In addition, the process recognises that although delivering improvements to the customer is key there can be delays associated with getting approval for alternative technologies which has to be factored into potential solutions. This provides a substantial hurdle in the evaluation of potential solutions. Some examples identified in the review process included the case where a technology itself was approved when put into beneficial use, but when it was due to be replaced it could not be as the supplier had voluntarily remove the product from the Regulation 27 approved list. Issues with approvals going out of date were also noted. Where a manufacturer only has a limited market for a specific filter product for example, it may not be worthwhile maintaining regulatory approval, and hence the product may be excluded from future use. This then presents inefficiencies in the system, for operatives to source alternative products (which may be more expensive), or where no replacements are available, to consider replacement of the entire system.

While the regulatory approvals process (delivered through DWI) provides an element of risk reduction for SW on product selection, it may in some cases appear to impact on the flexibility and adaptability of systems. A more collaborative working relationship between the water companies and the regulators may be one of the ways

[3] Where special dispensation has been granted, SW must identify potential capital interventions in future investment programmes to address the water quality issue. Ongoing none-compliance may result in fines being applied.

that can be employed to fast-track the acceptance and adoption of innovation within the sector. Consideration of a more collaborative, evidence based alternative means of assessing product suitability for small scale applications could also assist in reducing this barrier.

Challenges to innovation were also noted in the TDR for North Hoy as a reluctance to move from the status quo, inconsistent appetites for change and risk, and personal and geographical preferences for various technology types. This further highlighted the low risk appetite within SW and the need for a more robust evidence-based assessment processes for new innovations. Additional constraints on innovation may come from the pace in which regulatory changes or changes in guidance are disseminated to, and adopted by, actors involved in the IDP process.

Challenges in the decision making process

The IDP process is a detailed and comprehensive process, and as such can be a lengthy process. This can result in the final interventions to be based on issues identified in drinking water safety plans that take several years. As highlighted earlier, this in part reflects the difference between the regulatory planning process and the investment cycle which is used to deliver the required improvements. There is a degree of temporal de-coupling between identified need, regulatory prioritisation and the investment.

Additional limitations of the decision-making process include some decisions being made on historic water quality data, as opposed to up-to-date data. In the case of Fair Isle, the intervention was based on the 2012 drinking water safety plan, when many of the water quality issues were as a result of supplementing supply with surface water from the Vaadal burn. Since the exclusion of this source from the supply (which required an analysis of the supply:demand balance to be evaluated), many of the water quality issues were eliminated, yet still form part of the decision-making process.

The study noted that there are clear opportunities for standardisation of basic layout of small community systems that can be adapted for specific water quality issues. There are also opportunities for sharing of operational best practice amongst SW staff to streamline the decision-making process. It was observed that flexibility is needed in providing options for rural community systems. Not all challenges are identical, and the ability to adapt to changing conditions, source water quality or customer demand is essential. Working with contractors to design adaptable systems can assist in building this flexibility into the decision-making process.

7.0 CONCLUSION

The overall aim of this research report was to assess the appropriateness and effectiveness of the SW processes and adopted technical solutions in providing potable water to small communities. The research sought to evaluate the effectiveness of the interventions and assess how the decisions made have been influenced by the regulatory and policy framework. In addition, the project sought to assess each chosen solution in terms of value for money, sustainability, improvement to public health and improvement to social justice aspects. Based on the three case studies, it have been found that SW procedures are generally effective and informed by stringent application of internal procedures informed by the relevant regulatory and policy framework.

The current intervention definition process appears robust, and seeks to improve cost benefit analysis and value management while involving a wide range of stakeholders within SW. The process is well aligned with drinking water safety plans and seeks a high level of protection for water consumers, regardless of the size of the supply.

The study has also identified several challenges in capital investment process for small systems and suggests that the current robust nature of the IDP process makes it lengthy, and complex. The constraints of regulations and standards seem to influence the levels of risk and scope of decisions SW are willing consider and, in the end, some of these constraints are often relaxed in the form of specification waivers, some of which may be time limited. In general, SW operate in a regulatory environment (driven by legal duties and public health considerations), that can potentially constrain innovation and limit value to customers. The risk appetite for adopting innovation appears to add additional levels of decision making and thus inefficiency to the process, that involves additional time and cost. The study therefore finds that the application of internal processes can be improved by a greater use of technical experts early in the process, to advise on feasible options, assessment of new technologies and the value they can add for customers. Hence, it is proposed that an opportunity exists for further enhancing the IDP process for small systems through improved engagement with academic and professional specialist support and harnessing the technical capacity and innovation where available within SW operations across all regions, whilst still balancing risk and the need for a secure provision of service.. The latter will ensure continued cross functional learning within SW and ensure that regional differences and technology preferences for these systems are better aligned. SW may also consider making an optimised internal process available to private water suppliers.

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