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South Atlantic Natural Capital Assessment: St Helena Cost Benefit Analysis, water security

South Atlantic Environmental Research Institute

Alistair McVittie,
Nicholas Conner,
Amanda Gregory,
Ness Smith.

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Review table

Name	Reviewed by	Date
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Version 4		

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For more information, please contact the South Atlantic Environmental Research Institute (SAERI) at info@saeri.ac.fk or visit http://south-atlantic-research.org
PO Box 609, Stanley Cottage Stanley
FIQQ 1ZZ
Falkland Islands
Tel: +500 27374
www.south-atlantic-research.org

1. Background

This study was commissioned by the South Atlantic Environmental Research Institute (SAERI) to assess water security options for St Helena. The findings contribute evidence to a programme of natural capital assessment (NCA) being implemented by the UK Joint Nature Conservation Committee (JNCC) and conducted by the South Atlantic Environmental Research Institute (SAERI) in the UK South Atlantic Overseas Territories. Funded by the Foreign and Commonwealth Office (FCO) managed Conflict, Stability and Security Fund (CSSF), the work sits under its Environmental Resilience programme which includes objectives to integrate natural capital considerations into economic and social development planning.

A consultation workshop held on St Helena in January 2018, followed by a smaller Advisory Group meeting, resulted in priority areas being identified by on-island key stakeholders for further study. One particular issue identified was water security following several years of near-drought conditions; i.e. what is the best approach to managing water capture and distribution which will ensure that St Helena residents and businesses have a safe and reliable supply of potable water for drinking, stock feed, irrigation, and other domestic and commercial needs into the future, even during period of low/ no rainfall and runoff.

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Introduction

The need for a water supply on St Helena has been exacerbated by drought conditions, most recently in 2016/17, which led to Connect St Helena, the supply authority, needing to truck water to individual communities, when their local reservoirs and boreholes were unable to meet their needs.

Predictions of increasing tourism[1], following the commencement of flights from Johannesburg to Jamestown are expected to lead to more people on the island, and increased overall [water] demand, and thus the need for appropriate water management measures to manage supply and demand. The new? St Helena agricultural development strategy is also likely to lead to greater demand for water for irrigation and food processing.

Economic assessment approaches can be used to evaluate the viability of management actions that may address St Helena's water security issues. Cost-benefit analysis (CBA) is one form of economic assessment that can be used to estimate changes to the economic wellbeing of local and wider communities in response to different management approaches.

CBA involves estimating and comparing the costs and benefits of implementing a proposed project or management activity, with the costs and benefits of a 'base case', which represents a continuation of current conditions under which the proposed project/ policy is not implemented. In the case of a CBA for water security options, the base case would represent a continuation of the current approach to water collection, storage and supply (i.e. a 'business as usual' situation). The costs and benefits of alternative management options are then compared with the costs and benefits of the base case to identify any incremental differences between the base case and the alternative approaches.

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[1] http://www.sainthelena.gov.sh/number-of-people-visiting-st-helena-at-a-record-high/

A simple cost benefit analysis for a project will usually consider the direct costs and benefits of a range of options which are likely to achieve a common objective. Costs and benefits over the life of a project, such as construction, maintenance and administration costs, and revenue received, are discounted to today's value and subtracted to give a net present value (NPV) and a benefit cost ratio (BCR). Options with a positive net present value and a benefit cost ratio greater than one are considered feasible, with the option with the highest positive NPV and BCR being the most preferred.

Ideally, government projects involving public expenditure should demonstrate that the expenditure incurred provide a net economic benefit to the community. In these cases, a more comprehensive assessment (social cost-benefit analysis) should be carried out to consider the potential impacts of the options in question on the wider community, or large parts of the community, and that the proposed activity represents the most economically efficient course of action. The basic concepts underpinning Social CBA come from a branch of economics known as 'welfare economics' which is concerned with the effect of making particular choices about how scarce resources such as time, labour and money can be allocated to increase the economic wellbeing of individuals and groups. These parties in aggregate can be defined as 'the community'. CBA is not concerned with the interactions that occur in the local, state or national economy between the different sectors of the economy (firms, households, government and financial institutions).

Social CBA (hereafter CBA) includes estimates of the indirect costs and benefits of proposed options, as well as the direct costs and benefits. Indirect costs ('negative externalities') occur when the full costs of an action are not borne by the main beneficiaries, but are imposed on a third party. e.g. a polluting industry is reducing its costs of operation by not paying for adequate pollution control of its emissions, but imposing costs on downstream communities who have to pay medical costs for treatment of the effects of this pollution on their health. In this case, the polluting industry is transferring a cost it should pay itself to a third party as a negative externality. Indirect benefits ('positive externalities') occur when third parties gain a benefit which they did not pay for, e.g. when renovation of one house in a street leads to an improvement of visual amenity, which increases the perceived market value of surrounding properties

It is often difficult for economists to estimate the monetary value of the indirect costs and benefits associated with proposed options (as well as in some cases, the direct benefits and direct costs). In such cases, it is acceptable to at least describe the impacts qualitatively, so that decision makers can be better informed about the range of impacts that a proposed option may cause, if implemented.

A CBA should also be accompanied by a distributional analysis, which considers how the direct and indirect costs and benefits of preferred options are distributed among different sections of the community. Although a particular option may have the highest NPV and benefit: cost ratio from a range of options being considered, particular groups may disproportionally benefit, or bear costs. For example, a particular option may produce high private benefits, but also high public costs for the community, and yet still have a positive NPV and benefit cost ratio. It is important that decision makers are aware of the distributional aspects of the costs and benefits of a project, as they may wish to take compensatory actions to mitigate some of the negative effects on specific groups, while continuing to implement a preferred option which has a high NPV and BCR (and thus provides an economic benefit to the community overall).

This report describes a CBA that has been carried out to identify appropriate water management options using CBA framework, and to assess the direct cost and benefits of a range of alternative options compared to the status quo (BAU). The report then ranks these options according to their ratio of benefits to costs and their net present value (i.e. the difference between the estimated costs and benefits of the options over the project's life, expressed in today's prices).

It is important to note that a base case is not the same as a 'do nothing' approach, as government agencies are already carrying out various management activities to address the issue of concern. A 'do nothing' approach would involve agencies ceasing all existing management activities, and so does not represent a continuation of the status quo, and does not represent an appropriate Base Case.

The water security options described below provide direct benefits to certain parties, such as security of water supply to businesses dependent on water, and may impose costs on other parties e.g. the government agency paying for the project. However, other groups who do not receive direct benefits or pay the above direct costs, may also be affected positively or negatively by the options. In the case of this project, it has not been possible to estimate the value for indirect costs and benefits, and so these have been expressed in qualitative terms, rather than quantitatively. Further, it has also not been possible to estimate the direct benefits of the options considered in monetary terms, and again, these have been described in qualitative terms.

It should be noted that CBA does not generally consider how the options being assessed may be funded or financed. These issues should be considered once a preferred option has been identified.

The following sections of the report describe the current water supply and distribution system, and a range of feasible options that may be able to address St Helena's water security issues, including continuing with current approach (the Base Case).

2. Water and wastewater services in St Helena

The current situation[2]

The St Helena water supply is based on a system of connected reservoirs, with a major reservoir at Harpers serving Redhill Treatment works , smaller reservoirs serving Levelwood and private reservoirs used on some rural properties for farming needs.

As well as surface flows to reservoirs (e.g. to Longwood reservoir from the Peaks National Park), and springs (e.g. to Jamestown) there are also bores supplying some locations, for example a series of bores serve the airport (including Borehole 5 which provides a reliable supply of good quality water). Some bores are connected to the public water supply distribution system, e.g. pressure-fed and pumped bore water is used for some locations e.g. Jamestown, which is also supplied by perennial springs.

Private bores supply some locations, but the number and location of these is not known. Apart from the private bores and storages, the system is managed by Connect, a St Helena Government (SHG) utility. Connect aims to cover the cost of services through rates, but needs Government approval to access funds from revenue for capital works.

The St Helena system supplies both treated and untreated water. Treated water is supplied from Redhill Water Treatment Works using supply from Scots Mill, Redhill and Harpers 1, 2, and 3 reservoirs, and from Hutts Gate Water Treatment Works using supply from Hutts Gate reservoirs. There are raw water storages at Red Hill, Hutts Gate. Levelwood, Grapevine Gut, and Longwood, which predominantly supply water for irrigation.

In general, the water sources are not notably contaminated by chemicals. However, chlorine dosing is used in some locations for microbial treatment. Acid runoff to a few storages is corrected by lime dosing, or dilution (e.g. Prosperous Bay). Many households in the west of St Helena rely on horizontal boreholes and therefore untreated water. Information on the public health impacts of consumption of untreated water were not available.

There are apparently high levels of water loss from the supply system, and Connect are running a loss reduction programme. A typical loss figure is 10%, however losses at Levelwood have been measured at 52% but then 14%. It is assumed that the first figure is a calibration issue due to use of new unfamiliar monitoring equipment. There have been some areas like Deadwood where water losses have been effectively alleviated by a reduction programme.

Water is taken from the most suitable reservoir according to levels and amount of sediment. Energy costs for moving water between reservoirs are 46p per kw/hr.; gravity transfer between most reservoirs is not possible due to terrain. Connect incurs high energy costs from pumping water (and wastewater) and chemical dosing. A proposal to increase renewables to 80% of electricity supply should help to reduce some of these system costs.

Connect also incurs routine operational costs for labour, planning and management, pumping water and wastewater, maintaining storages, reducing siltation, bank erosion, and disposal of silt. It is not known whether Connect includes decommissioning costs for infrastructure in its budgets. In the past,

[2] All information in this section is from personal communications with Connect St Helena.

storages that have become unusable through excess siltation, these required rehabilitation (see Option 4 for a discussion of rehabilitation).

Currently, the available public storages have a total capacity of 112,517m^3 of water. Water is supplied to customers at different rates i.e. the first 15m^3 (15,000 litres) is charged at £1.39 per m^3, and after that charges increase to £1.84 per m^3. The average amount used by residential consumers is 23m^3 per quarter per property for treated water. Businesses pay £3.61m^3 for their water supply. Untreated water is supplied at £0.92/(/) m^3 (mainly for agricultural purposes). The utility recently increased domestic water charges by 2% in 2018 and 20% for agricultural supplies.

A major concern for the water utility has been rainfall deficit conditions over the last six years; particularly in 2016/17 when rainfall and runoff were insufficient to recharge storages to meet demand. During this time, the water utility was forced to provide water trucks to service local communities. It has been estimated that this activity cost the utility £1K per week to service. A range of water restrictions were introduced by the water utility during this period including the need for residents to obtain permission for watering gardens.

Although water consumption fell during, and shortly after, the drought conditions of 2016, water consumption data indicates that demand increased by some 20% between 2017 to 2018. Reasons for this increase are not immediately obvious. Daily demand is now on average 1,100m^3. Some rainwater harvesting and water saving methods are helping to reduce demand.

Environmental issues

Rain-fed supplies depend on good tree coverage in upland catchments, and good soil coverage to reduce soil erosion and sediment filling reservoirs and reducing pump efficiency. Some of these catchments are under the ownership and management of the SHG and private owners, rather than Connect. This arrangement means that Connect has no ability to manage these catchments for upstream improvements to increase flows. It is believed that the (relatively) undisturbed nature of these catchments, and the small scale of earthworks cared out to create storages, has minimised releases of soil carbon over time.

Social aspects

There are no specific water restrictions in place on St Helena at present, but during the most recent drought in 2016/17 there was a more active campaign to conserve water. Connect provides regular advice to St Helena residents, via local newspapers, on how to conserve water but there does not appear to be an active, continuing programme to encourage tourists in Jamestown to think about ways of minimising water consumption, e.g. by asking tourists to use their towels for more than one day's use. Water supply charges, under instruction from the water regulator, were increased in 2018 which caused concern amongst civil society.

Waste water

Some brief information supplied by Connect St Helena about St Helena's wastewater management is given below for information.

Wastewater from properties is discharged through soakaways or septic tanks. When this is not possible it is discharged at Babylon Rocks in Jamestown Harbour without treatment. There is a standing charge for wastewater for Jamestown, Half Tree Hollow, Bottom Woods and Longwood, but the rest of the island uses private systems. Connect collects £70K per annum income from wastewater charges, at a loss of £20K.

There is a proposal for a wastewater scheme to link Half Tree hollow to Jamestown via a pipe which will run besides Jacob's Ladder. The treatment system will have a screen and screened effluent will be discharged via a pipe to 500m offshore[3].

Some residential development is encroaching on land currently being used for settlement ponds. These ponds will need to be relocated because of potential odour issues for the residences in question.

[3] http://www.sainthelena.gov.sh/combined-sewage-handling-and-treatment-facility/

3. Proposed options

Suitable options will be those that enable water security to be achieved in the near future, and provide a net economic benefit to the community; i.e. where the sum of the stream of discounted direct and indirect benefits is greater than the sum of the discounted direct and indirect costs of the project over its life, and is positive. The ratio of these benefits to these costs should be greater than one.

Four options have been developed to address St Helena's water security issues: i.e. a Base Case of 'business as usual' with no new developments beyond those already in place or confirmed (Option 1), a new reservoir at Fishers Valley (Option 2), a desalination plant (Option 3) and a package of mixed measures including reservoir extraction, use of fog/ mist nets and increasing the capacity of existing small storages (Option 4). Details of these options are given below.

It has not been possible to provide monetary values for the likely range of direct and indirect costs and benefits of the following options for businesses, government and the community. Instead, this assessment only quantifies the monetary values for the direct costs and the options where they are available, and describes their likely direct benefits and indirect costs and benefits.

This combination of quantitative and qualitative assessment enables a general comparison to be made between the proposed options and the continuation of status quo (i.e. business as usual); represented by the Base Case (Option 1).

As noted above, the Base Case is not the same as a do nothing at all scenarios, which might be developed as an option for some CBAs for illustrative purposes. The aim of the Base Case is to provide a counterfactual case against possible options can be compared.

Option 1: Base Case; business as usual

The Base Case represents the continuation of the current situation as described above for the timeframe chosen for the options i.e. 25 years.[4].

Under the Base Case we can expect that the water supply will continue to be provided under current arrangement of connected storages, and direct supply from boreholes and springs.

The advent of scheduled flights to St Helena is expected to lead to a significant increase in tourists staying on the island, and a consequential increased demand for potable, treated water, as will the implementation of initiatives proposed under the St Helena Agricultural Development Strategy. The scheduled air service may also lead to an increase in the population from expatriate Saints now able to return to St Helena more frequently.

Increasing demand for treated potable water supply is likely to put pressure on the current storage and distribution infrastructure in the medium term, or perhaps sooner. N.B. the estimated 2020 demand for water made by Fairhurst consultants in 2013 had already been reached by 2016.

[4] In the case of Option 2, a new reservoir, the life span of the earth walled dam may be closer to 40-45 years. However, if the dam has a clay lining, Connect has suggested that functioning life of the liner may be 25 years. Assuming that failure of the lining will lead to the need for significant remediation work and other economic and social costs from interference to supplies, a 25-year timeframe would seem to be a reasonable figure to use for comparing the different options discussed in this report.

Uncertain rainfall and reduced runoff will increase the vulnerability of the system to provide reticulated supplies.

Under the Base Case, it has been assumed that the current system will increasingly be unable to meet demand in normal rainfall conditions, as well as during droughts, and bowsers will need to be used on an increasingly regular basis. For the purposes of the Base Case it has been assumed that bowsers will need to be called upon at an average of 8 weeks at 5 yearly intervals (£8,000 per event) from years 5 to 30, and then annually from years 31-40.

Other expected costs under the Base Case are the cleaning out of sediment from existing reservoirs and previously abandoned silted up reservoirs. However, we do not have estimates of the costs. Some new reservoirs can be built, but it has been estimated that these reservoirs would only help increase water storage capacity by ¾ day's supply (see Option 4).

It is assumed that some hydrological surveying will be commissioned under the Base Case, with the intention of identifying new opportunities for accessing water from boreholes. The additional supply from these sources may make a minor addition to water supply capacity, as may a continuing program of reducing lost water from pipes and storages.

Technical aspects

The system will continue to use gravity surface fed storages, with inter-storage pumping when necessary to meet localised needs, and bore hole pressure-fed and pumped supplies for some locations e.g. Jamestown.

Some stream extraction will continue to be used for agriculture, and some farmers will receive subsidised water. Longwood reservoirs will mainly be used for agriculture, with runoff from peaks NP.

Under the Base Case, Jamestown will continue to rely on perennial springs but in the second half of the option time frame, the increased demand from an increasing number of tourists will lead to these springs beginning to be unable to meet demand.

Environmental aspects

As noted above, Connect does not currently own and manage the water supply catchments. and Connect has no ability to manage these catchments for upstream improvements to increase flows. It is assumed that this situation will continue under the Base Case.

Social aspects

There are currently no water restrictions in place in St Helena, and only voluntary measures during droughts. However, it is anticipated that under the Base Case, Connect (and the SHG) will need to bring in increasingly strict measures to enable water supplies to continue to be provided to the community at all.

Economic aspects

Under the Base Case, Connect will continue to incur operational costs for labour, planning and management, pumping water and wastewater, maintaining storages, reducing siltation, bank erosion, and disposal of silt. No decommissioning costs are expected to occur.

Connect will need to keep rates pegged to changes in the Consumer Price Index or another relevant indicator, and may need to increase rates routinely say every 5 years during the 25-year time frame of the options being considered in this report.

Risks and opportunities

It appears highly likely that maintaining the business as usual approach to water supply and management into the future will not provide an adequate solution to St Helena's water security issues, given the likelihood of future droughts, and the expected increase in demand from population growth, tourism and implementation of agricultural development initiatives proposed in the St Helena agricultural development strategy.

Although maintaining the status quo under the Base Case may defer the need for the capital expenditure required under the other options considered here, it is likely that the current system will need increasing expenditure on maintenance to ensure that it can perform as efficiently as possible.

Option 2: A New reservoir – Fisher's Valley, Prosperous Bay Plain

Option 2 consists of a major infrastructure development to create a new reservoir at Fisher's Valley, with an estimated storage capacity of 260,000m^3? The technical design of the reservoir is shown in Appendix 2.

This structure will involve earth removal to a depth of approximately xx, and a compacted earth bund to a height of approximately 17m (330m AOD)…It is estimated that some 61,000 m^3 of soil will be required. The reservoir bed is likely to be clay lined to prevent seepage.

The reservoir is expected to take to two to three years to build and would be expected to reach full capacity from streamflow in four to five years (assuming it was allowed to fill uninterrupted by offtakes in the meantime).

Technological aspects

As with the Base Case, under Option 2 the system will continue to be a mix of gravity rainwater-fed storages, and inter-storage pumping when necessary to meet localised needs, and public and private bore holes and springs.

The relatively high costs of energy consumption from pumping water and wastewater, and chemical use, will continue under this option, although, as mentioned for the Base Case, if new renewable energy sources come on stream these costs may decline.

Environmental aspects

The original location of the proposed reservoir was likely to have significantly affected a candidate RAMSAR wetland site. It is understood that the new proposed location of the reservoir will now be downstream of the wetland. Any impact of the reservoir on the wetland would be determined during the Environmental Impact Assessment (EIA) process.

Social aspects

It is anticipated that the extra storage capacity available with the new reservoir will reduce concerns over water availability from the public, businesses and public officials during drought periods, and reduce the need for water restrictions and water reduction campaigns.

Economic aspects

The additional storage from the reservoir will remove the need for water restrictions and loss of production for businesses during droughts. Additional capacity will also enable new economic activities to occur, and meet expected demand from increasing numbers of visitors arriving on flights and the agricultural developments proposed in the St Helena Agricultural Development Strategy.

The new reservoir will involve design, construction and pre-operational costs, including additional labour and capital costs, and transportation of construction machinery. Operational costs, including pumping costs, are expected to be higher than in the Base Case, although there is existing pumping from bore holes in Fisher's Valley to Hutts Gate reservoir.

No changes to water rates for business and household consumption are expected in the short term. However, it is assumed that Connect will need to recoup any additional operational costs incurred in managing an expanded system over time, as well as keeping rates pegged to changes in the Consumer Price Index or another relevant indicator.

Although the proposed Fisher's Valley Dam will be sited in a remote part of the island, some farmers will be affected, as the valley bed for the proposed reservoir is currently used for limited animal grazing. The remainder of the area that will be inundated by the dam comprises mostly near-barren land not currently used for farming or other human activity (see Fisher's Valley Dam Feasibility Study, Final report, January 2018)

Institutional aspects

The governance arrangements under the Base case are expected to continue under this option; i.e. that the system will continue to be the responsibility of Connect.

Risks and opportunities

A new reservoir will address St Helena's water security issues for the foreseeable future. However, significant capital investment (from DfID via SHG) will be needed, and the reservoir will take up to three years to construct and fill to the desired level to provide the required level of reserve storage. This time frame may not be a concern if there is sufficient rainfall and runoff to other storages to meet demand in the interim.

Nevertheless, if demand for water supplies continues to rise from increasing tourism, agricultural development and population growth, eventually there will be few suitable locations to build new storages to meet demand, and demand-side management will become needed.

Option 3: Desalination plant

Description of option

This option involves construction and operation of a reverse osmosis desalination plant to provide enough water on a continuous basis to meet St Helena's water requirements. Agricultural users would continue to use private on-farm dams and bores, and untreated water sources on their properties. Over the longer term, additional operating modules can be added to meet any significant growth in demand (e.g. from a rapid growth in tourist numbers to St Helena).

Desalination is utilised in many small islands, including volcanic islands in the Caribbean which have adopted desalination to meet increased potable water demand created by development objectives and reduced supply due to poor storage, or land use conflicts in watershed areas. For example, in St Lucia, desalination is used in some larger resort areas not serviced by the distribution system, or to satisfy upward fluctuations in demand (UNESCO, 2005).

The preferred technology for desalination is usually reverse osmosis (RO). Advantages of RO include that a plant can be built and operational in twelve months, and that it would take up less physical space than a fresh water distillation plant. RO uses relatively less energy than other traditional thermal desalination technologies such as MSFD, Multiple Effect Distillation (MED). The disadvantage includes the fact that this process, like distillation, is energy dependent and relatively expensive compared to conventional water production from ground and surface water sources. However, where energy supplies can be sourced from local renewable energy, the costs of imported energy will be a less significant issue (e.g. I00% of the energy requirements of the Kurnell Desalination Plant in South West Sydney is sourced from local renewable energy sources).

Sommariva et al. (2003) suggest a target of 40 years of economic life for desalination plants, assuming strategic replacement of parts. However, a proposed plant and supporting infrastructure in South Australia are being engineered to have be operational for 25 - 100 years. Civil assets such as the tunnels, shafts, buried pipelines and piles will need to be reconstructed or refurbished after approximately 100 years. Assets such as concrete structures, buildings, intake and outfall pipelines, and mechanical and electrical assets are expected to perform for approximately 20 to 50 years. These assets will be replaced during the life of the Desalination Plant as they become inoperable or as technologies advance.

Technical aspects of a desalination plant

A study[5] for a desalination plant in South Australia noted the following infrastructure requirements:

- Seawater intake structure and connecting tunnel/s or pipelines;
- Intake pumping station and screening system;
- Pre-treatment system and associated buildings;
- Reverse osmosis treatment system and associated buildings;
- Outfall structure with diffusers and connecting tunnel/s and pipelines;
- Post-treatment system and associated buildings; and
- Waste treatment area, including solids thickening and dewatering.

The proposed Desalination Plant will also need:

- A transfer pump station for pumping desalinated water to a water treatment plant.
- Hardstand areas for unloading and storage of chemicals associated with the Desalination Plant;
- An electrical substation, power cabling and switchgear for distributing power within the site;
  An energy recovery facility for the saline concentrate prior to its discharge to receiving waters;
- Site access roads, internal access roads and parking areas;
- Stormwater management infrastructure and other buried services across the site;
- Site offices and administration buildings, control rooms, laboratory, research and development test facility, and a visitor education/interpretive centre; and

[5] https://www.sa.gov.au/__data/assets/pdf_file/0014/21254/Desal_Environmental_Impact_StatState_Chapter_3.pdf

- Site landscaping, lighting and security fencing across the site.

Social aspects

Social aspects of construction and operation of a desalination plant may include the physical disturbance and noise from construction and operation activities, and impacts on visual amenity. Given that the plant will need to be sited in a coastal area to access seawater and dispose of brine, it is likely to be highly visible.

Environmental aspects

UNESCO (2005) notes that the environmental impacts of Caribbean desalination plants have so far been negligible. Other studies have noted some evidence of negative environmental impacts (Cooley et al., 2013). These impacts will depend on the characteristics of the brine, the method of discharge, the rate of dilution and dispersion and the sensitivity of organisms (Cooley et al., 2013) Given the small scale of a plant on St Helena, and sufficient currents to facilitate rapid dispersion over a short distance, there should be little impact on marine, coastal and benthic ecosystems. However, there may be odour issues from plant operation, and depending on the location chosen for the plant, impacts on native vegetation.

Economic aspects

According to Quora (2018) a typical large-scale desalination plant produces 100,000m^3 of water per day. Assuming a per capita consumption of 300 litres of water per day and a population of 4,500, and the same levels of efficiency, St Helena would require a plant with an output of 1,450m^3 a day (assuming that small desalination plants have the same efficiency as the larger ones Quora refers to).

Quora estimates that the installed cost of desalination plants is approximately US$1m (approx. £769,000)[6] for every 1,000m^3 per day of installed capacity; thus for St Helena, this gives a cost of US$1.45m (£1.12m) to install a suitable plant to meet a demand of 300 litres per day.

The cost of desalinated water, the majority of which is accounted for by plant capital costs and energy costs, is typically in the range of US$0.5 to US$3 (£0.38 - £2.31) per cubic meter of water (0.05-0.3 dollar cents, or 4 – 23 £ pence, per litre of water). The lower end of the scale corresponds to regions where electricity costs are low (e.g. Middle East) and the higher end to regions where electricity costs are high (e.g. Australia, where electricity is sometimes mandated to be from renewable energy). In St Helena, there may be opportunities to reduce these energy costs by using renewable energy sources. (NB. Ascension Island desalination costs are £25-30/m^{3,} plus pumping costs to distribute. The basis for estimating this figure is not known)

Because of the reliance on energy, desalination may not be as cost-effective as other alternatives, but the perceived advantages for each local situation where it has been implemented, have been determined to outweigh the cost (UNESCO, 2005). In various countries, the advantages include the reliability of this option, and the relatively short timeframe in which a RO plant can be erected and operational can also be a factor. A properly functioning desalination plant produces high quality water that is suitable for a wide range of functions including many industrial applications that require water that exceeds WHO drinking water guidelines.

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[6] We assume an exchange rate of £1 = $1.30 throughout the analysis

Institutional aspects

The RO plant proposed under this option may be constructed by external contractors, but operated by the public utility. However, many RO plants are constructed under Build-Own-Operate-Transfer (BOOT) schemes. Decisions about ownership, operation and maintenance will need to be made by SHG.

Risks and opportunities

One risk in using a desalination system is significantly higher cost of producing potable water, compared to traditional sources. As noted above this issue can be significantly reduced by using renewable energy supplies to replace the expensive sources of imported fuels. Also, skilled, trained operators are needed to ensure that an RO plant functions efficiently; UNESCO (2005) notes that this has not always been the case in the Caribbean, even when Build-Own Operate-Transfer (BOOT) schemes are used.

Operational difficulties have been reported such as voltage fluctuation, which has resulted in production capacity being reduced at times. Another operational problem related to sand passing through a filter and destroying the membrane in some units. Water pressure fluctuations have also resulted in filter damage, requiring new filters, of a different design, to replace those damaged. As plants will be close to the sea, they may experience general corrosion problems with metal parts and equipment, and need regular maintenance.

Perhaps the biggest issue for St Helena under this option is the shortage of suitable coastal sites big enough to build a plant and its associated physical infrastructure. However, should it be possible to construct and operate a RO desalination plant in St Helena, it should more than address water supply security issues well into the future in its own right. Sourcing energy from renewable sources on St Helena, instead of using imported fuel, will also reduce the running costs of the plant, and increase its relative attractiveness as an option. A desalination plant will not provide water supplies for all residents and businesses, due to the cost of providing distribution infrastructure and the water charges that will be incurred for many communities when the have alternative source of supply such as private bores and springs. Nevertheless, a desalination plant should be able to contribute significantly to water supply security as a whole.

Option 4: Investigation and implementation of Mixed Measures

This option involves a combination of an aquifer-fed water system, enhanced mist/fog capture, increasing the capacity of existing reservoirs, and building new small storages. There is little information available at the moment about the capacity and quality of aquifers, or the effectiveness of an aquifer-fed system, so this option would require a research, development and demonstration (R, D & D) phase to prove these technologies before they could be considered as feasible solutions to St Helena's water security issues. The potential for enhanced mist/fog capture from cloud forest restoration has been explored by a Darwin Plus project (DPLUS051, Sansom et al., 2018). We compare the costs of habitat restoration with the alternative of using mist/fog nets. These have been applied elsewhere, although planning restriction on man-made structures and biophysical constraints such as available space and existing land cover mean that their use on St Helena is probably infeasible.

The third component of this option, increasing the capacity of small reservoirs and constructing new storages, is a proven approach so will not need an R, D and D phase.

This option consists of:

- Phase 1 from Years 1 to 5: involving works to increase small storages and build new storages in available locations, and a RD and D program to investigate the feasibility of an aquifer fed water supply and mist/fog nets. While this activity is occurring, the conditions described above for Base Case would apply.
- Phase 2 from Years 5 to 10; involving the continuing development of new, and restoration of, small reservoirs, and based on the results of the RD and D process, introduction of aquifer-fed supplies and mist/fog nets where they are likely to be feasible. The remainder of supply needed would come from the arrangements described under the Base Case (i.e. a continuation of the business as usual approaches)
- Phase 3: From Years 10 to 25; the system applying under the Base Case will be increasingly replaced by aquifer supplies, supplemented by enhanced mist/fog capture, and continuing maintenance of the small storages already created or restored. Any shortfall in supplies would be made up from the existing rainfall, bore and spring system applying under the Base Case.

The potential of an aquifer-fed system to solve St Helena's water security concerns is not certain. Even if an aquifer-fed system was not able to make a major contribution to St Helena's water supply, at least the contribution of new/ restored small storages would add to the water supply system that would occur under the Base Case alone, and provide a greater level of security than would otherwise be the case.

Technical aspects

(i). Aquifer-fed water system

Although some deep boreholes were drilled in the last drought, there is a lack of information about the capacity of aquifers on St Helena, and poor understanding of recharge rates, water pressure and quality, infrastructure required for extraction, suitable bore locations, and connections to the existing distribution system. Further investigation is needed.

(ii) Mist/Fog capture

Full details of the potential for mist capture by native vegetation are provided by Sansom et al. (2018). This includes potential water yields and costs. Below we outline the available evidence for mist/fog nets that we use for comparison.

Mist/fog nets have been used in cloud forests and high-altitude areas exposed to sea fogs as a means of collecting fresh water for drinking, irrigation and restoring ground cover in eroded areas. The nets collect droplets from mist and fogs, which are channelled to fall on seedlings below them, which then have a sufficient water supply to become established. The growing plants in turn are able to capture mist for their own growth and allow water percolation into the soil and subsoil. This cycle encourages further plant growth moisture capture and continuing vegetation restoration.

Atmospheric water is generally clean, does not contain harmful micro-organisms and is suitable for irrigation purposes. The environmental impact of installing and maintaining the technology is minimal, the construction process is not labour intensive, and the system does not require any energy for operation.

Although mist/fog harvesting depends on a water source that is not always reliable, certain areas do have a propensity for fog development. According to ClimateTechWiki (2019), as well as the Pacific South America, the areas which would benefit from nets include the Atlantic coast of Southern Africa (Angola, Namibia), South Africa, and Cape Verde. St Helena would appear to fit this list geographically.

Mist/fog nets could provide a small scale, low cost technology to increase St Helena’s water supply, and transformation of airborne moisture into surface runoff to add to storages.

FogQuest (2019) notes that costs will vary with location, access and costs of labour. The small fog collectors they evaluated cost US$75 to US$200 each to build. The large 40m^2 mist/fog collectors cost about $1000 to $1500 US each and can last 10 years. A project producing about 2,000 litres a day could will cost about $15,000 US.

Typical water production rates from a mist/fog collector range from 200 to 1,000 litres per day, subject to daily and seasonal variations. Collection efficiency improves with larger water droplets, higher wind speeds, and narrower collection fibres/ mesh width. Some water collection rates from collectors cited by ClimateTechWiki (2019) are shown in Table 1.

Table 1 Example mist/fog collection case studies

Project	Total collecting surface (m^2)	Water collected (litres/day)
University of South Africa	70	3,800
Yemen	40	4,500
Cape Verde	200	4,000

Weather patterns, the potential performance of nets in drought conditions, and the expected role of nets in the water supply system at different times and under different conditions will need to be determined.

It is understood that Mist/fog nets have been tested at Hutts Gate, but planning limitations are restricting the availability of suitable sites. Much of the area suitable for mist collection is within the Peaks National Park or subject to other planning restrictions. As there is little information about the potential of this technology, more research would be needed, and involvement of parties other than Connect will need to be considered. Given the lack of knowledge on the potential for mist/fog nets on St Helena our analysis below is restricted to an example 40m^2 net area rather than a fully developed scheme.

(iii) Increasing the capacity of small storages and building new storages

Connect manages several smaller reservoirs which could potentially be enlarged through additional earthworks to increase water storage levels. There are also opportunities for constructing new storages. For example, there is potential for small new reservoirs at Levelwood (3,800m^3) or about 4 days’ supply for the Island; and at Rural Retreat. Harpers 2 also could be enlarged from 7,000m^3 to 25,000m^3 (6 days’ to 23 days’ supply). There is also scope for a small reservoir with treatment in western St Helena, where residents are currently using cheaper untreated water supplies. Other locations which could supplement existing storage capacity are new reservoirs at Redhill (20,000m^3), and at Hutts Gate (14,000m^3).

As mentioned above, Connect do not own the water supply catchments which feed their reservoirs, and so have limited opportunity for upstream improvements to increase flows to smaller reservoirs, or reduce the levels of sediment being carried into the reservoirs from soil erosion. Further work is needed to identify catchment management practices that could be used to reduce sedimentation, such as plantings of particular types of native vegetation to reduce erosion. It is understood that there a several reservoirs that have been abandoned due to siltation, which potentially could be restored to add to the overall storage capacity. The cost of and timescale of this work is not known at this stage.

Environmental aspects

Developing an aquifer-based supply is likely to involve significant geotechnical investigation with impacts on human and natural environments from drilling, blasting, excavation, earthworks and construction of headworks. Local residents are likely to incur direct and indirect costs from disturbance, pollution, loss of access to particular areas, loss of visual and public amenity, and loss of existence values from damage to the natural environment.

There are not expected to be significant economic costs associated with construction and operation of mist/fog nets, or the work involved in expanding storage capacity. Although new reservoirs may result in some loss of terrestrial habitat to open water bodies, these water bodies in turn may provide additional freshwater habitat. No notable direct or indirect costs or benefits from changes to habitats or loss of visual amenity would be likely here.

Institutional aspects

It is assumed that the investigations and works involved in developing an aquifer-based supply system, constructing and operating mist/fog nets, and expanding reservoir capacity, will either be funded and managed by Connect or through capital grants. Connect are also supporting cloud forest restoration (see discussion of habitat restoration in the following section). As well as these costs, there will need to be capital expenditure on infrastructure to connect aquifer sources and new and rehabilitated storages, to the existing water distribution system.

Risks and opportunities

As noted above, a research, development and demonstration programme is needed to assess the potential of aquifer-sourced water supplies for St Helena. If aquifer water was proven to be a suitable source of supply, it could make an important contribution to overall water security.

Mist/fog nets and rehabilitation and construction of small reservoirs have the advantage of being generally low-cost, and low technology approaches which are adaptable to local conditions, relatively cheap to fund can be implemented incrementally, or as part of a coordinated approach. Along with new and rehabilitated reservoirs, such small-scale additions can help to stretch the existing system, and can help to defer the need for the expensive capital expenditure required under Options 2 and 3, although expenditure will be incurred should the above-mentioned RD and D programme show that aquifer supplies can be a feasible solution to St Helena’s water security issues.

4. Cost-benefit assessment

In this section we present the analysis of available costs and benefits for each of the options. These will be based on the available data either from St Helena or from appropriate cases elsewhere. However, the analysis does remain partial across each of the options. Each of options is evaluated using a range of discount rates: 4%, 7% and 10%. Where there are differential flows of costs and benefits over time, the use of discounting allows those flows to be expressed in present value terms. The higher the discount rate the lower the value placed on flows that occur further into the future. This reflects both the concept of time preference where immediate returns are preferred, but can also account for future uncertainty. The use of multiple discount rates can test the robustness of the CBA.

Option 1: Base case, business as usual

Under the BAU option there is limited additional reservoir capacity added at Redhill (20,000m^3) and Hutts Gate (14,000m^3). The costs for these is not available, so we apply a per m^3 value estimated for option 2 (see below). Given the much larger size of the proposed Fisher's Valley reservoir and the associated economies of scale, the estimate per m^3 value of £14.10 is likely to be an underestimate. The BAU option also see increased use of bowsers to the respond to temporary supply shortages in some areas. The frequency and therefore cost of bowsers use is expected to increase over time.

Connect charges a variety of water tariffs for different users (domestic, agricultural, commercial) depending on volume supplied and whether the water has been treated. We use a value of £1.83/m^3 as the benefit (i.e. potential revenue) of different water supply options. This value reflect the price of treated water to domestic (after the first 15m^3 of supply) and agricultural users.

The benefits of the BAU option are estimated at £62,560 per annum reflecting the potential revenue from the additional reservoir supply at Redhill and Hutts Gate. The costs of installing this additional storage is £282,050 and £197,435 respectively, this cost is assumed to be incurred in year 0 of the analysis. In addition, the supply of water from bowsers is assumed to incur an average annual cost of £1,600 from year 5, no revenue is assumed for bowser supply.

Table 2 summarises the results of the CBA for the BAU option. The net benefits are positive for each discount rate analysed, although decline with higher rates, this reflects the balance between largely upfront costs and future revenue streams.

Table 2 Present value and benefit/cost ratios of BAU option

Present value	Discount rate		
	4%	7%	10%
Total benefits (£)	977,317	729,048	567,860
Total costs (£)	498,672	492,711	488,936
Net benefit (£)	478,645	236,337	78,923
Benefit-cost ratio	1.96	1.48	1.16

Option 2: A new reservoir – Fisher's Valley

There are detailed costings available for the new reservoir proposal for Fisher's Valley. The total being £3,666,652. It is expected that these costs could be met by a direct grant from the UK Government, but a CBA is nevertheless informative to allow comparison across alternative options. The proposed reservoir has a capacity of 260,000m^3 representing a considerable expansion of the existing reservoir capacity of 112,517m^3 on St Helena. This can be compared to estimated annual demand of 401,500m^3.

As with option 1 we assume that water from Fisher's Valley would be supplied for £1.84/m^3, this represents the benefits of the option. It is estimated that following completion it would take 4 years for the reservoir to fill, during this time no supply would be made or revenue generated. However, we do not have an estimate of the likely volume of supply from the reservoir once full. The combined capacity of Fisher's Valley and existing reservoirs is below total annual demand, and there is ongoing recharge and supply from other sources such as springs. We calculate two scenarios to test the sensitivity of the CBA outcomes to the volume supplied, in one we value the total volume of the new reservoir, in the second we assume that only 50% of the volume is supplied. However, a key objective of the Fisher's Valley reservoir proposal is to ensure security of supply, in particular during periods of drought. Under climate change it is expected that drought will become more frequent. The valuation of water where security of supply is an objective should therefore consider both actual supply and the option value of the normally unused reserve. Discussions with Connect indicate that they view the 'full supply' scenario as appropriate to capture the water security benefits of Fisher's Valley. A further benefit is that the additional capacity of Fisher's Valley could alleviate the need for abstractions elsewhere allowing groundwater/aquifer recharge and leaving water available for natural habitats.

The results of the CBA are summarised in Table 3. These indicate that the CBA is sensitive to the assumption about the volume water supplied and valued. If the total volume supplied and valued then there a positive net benefit at both the 4% and 7% discount rates, but not at 10%. If 50% of the volume is valued then the option does not provide a positive net benefit at any of the discount rates tested. Consequently, the assumptions made about the value of water are key for the economic case of this option.

Table 3 Present value and benefit/cost ratios of Fisher's Valley reservoir option

Present value	Discount rate		
	4%	7%	10%
Benefits (£)			
Full supply	5,737,061	3,954,632	2,825,992
50% supply	2,868,531	1,977,316	1,412,996
Costs (£)	3,666,652	3,666,652	3,666,652
Net benefit (£)			
Full supply	2,070,409	287,980	-840,660
50% supply	-798,122	-1,689,336	-2,253,656
Benefit-cost ratio			
Full supply	1.56	1.08	0.77
50% supply	0.78	0.54	0.39

Option 3: Desalination plant

We use two sets of the cost estimates for the desalination option. The necessary plant can either be costed on the basis of the initial capital cost plus ongoing operational costs (largely energy), or we can use lifecycle costs which incorporate capital and operating expenditure for a plant of given size. The costs of desalination plants are related to scale, with larger plants being more cost-effective. Our research found that a small desalination plant would have a capacity of 4,000m^3/day, this would be more than sufficient to supply existing demand on St Helena[7]. Furthermore, existing water supply

[7] 0.3m^3/person/day x 4,500 people = 1350m^3/day

options would remain, this would impact on both the cost-effectiveness of desalination and the revenue it could generate.

We evaluate a number of scenarios within this option. The desalination plant can either supply all of the St Helena's current water needs or 50% of the demand. The costs will either be based on lifecycle costs (including both capital and operating costs) or the unit cost for a desalination plant, plus operating costs. Estimates of operating costs ranged from £0.38 to £2.31 per m^3, thus a high and low scenario can be evaluated. The included costs are only partial. Given the topography of St Helena, there would also be significant costs in pumping either seawater to a desalination plant or from a desalination plant close to sea level.

Table 4 summarises the CBA for the different desalination options. The results show that only the scenario based on unit costs, with low operating costs, provides positive net benefits. The scenario aspects reflecting quantity of supply made no difference. This reflects the fact that the cost data were not sensitive enough to volume, we would expect lower volume plant to have higher cost per unit of volume. The life cycle cost and high unit cost scenarios produced very similar results, this might be indicative that these are the more robust scenarios.

Table 4 Present value and benefit/cost ratios of desalination option

	Present value	Discount rate		
		4%	7%	10%
Total benefits (£)				
	Full supply	11,540,968	8,609,201	6,705,754
	50% supply	5,770,484	4,304,601	3,352,877
Total costs (£)				
Life cycle	Full supply	15,429,772	11,510,128	8,965,302
	50% supply	7,714,886	5,755,064	4,482,651
Unit costs – low	Full supply	3,421,923	2,816,449	2,423,346
	50% supply	1,710,961	1,408,225	1,211,673
Unit costs – high	Full supply	15,530,206	11,848,850	9,458,733
	50% supply	7,765,103	5,924,425	4,729,366
Net benefits (£)				
Life cycle	Full supply	-3,888,804	-2,900,926	-2,259,548
	50% supply	-1,944,402	-1,450,463	-1,129,774
Unit costs – low	Full supply	8,119,045	5,792,752	4,282,408
	50% supply	4,059,523	2,896,376	2,141,204
Unit costs – high	Full supply	-3,989,239	-3,239,649	-2,752,979
	50% supply	-1,994,619	-1,619,825	-1,376,489
Benefit-cost ratios				
Life cycle	Full supply	0.75	0.75	0.75
	50% supply	0.75	0.75	0.75
Unit costs – low	Full supply	3.37	3.06	2.77
	50% supply	3.37	3.06	2.77
Unit costs – high	Full supply	0.74	0.73	0.71
	50% supply	0.74	0.73	0.71

Option 4: Investigation and implementation of mixed measures

This option involves the implementation of a mix of different approaches to enhancing water supply. As with option 1 there is some new storage capacity at Redhill and Hutts Gate with the addition of Harpers 2 and Levelwood, this would add a total of 55,800m^3 in new capacity. Under this option the new capacity would be in place in year 6 of the analysis. The other element of this option is increased use of mist capture from year 10. This would be through further restoration of St Helena's cloud forest, although we use mist nets as a comparison. The CBA in this instance considers the new storage and mist capture elements separately as they potentially form consecutive elements within the supply system rather than alternatives, i.e. mist capture feeds into, and may require, the additional reservoir capacity.

Estimates of the cost of cloud forest habitat restoration are provided by the DPLUS051 final report (Sansom et al., 2018). This involves 16 ha of habitat restoration, replacing invasive flax with propagated native species, above the 690 m contour in two catchments, Wells Gutt and Grapevine Gutt. This would represent a 40% increase in the cloud forest habitat (Sansom et al. 2018). The total cost is estimated at £18.6 million, based on the cost of previous habitat restoration, and the additional water yield is estimated at 146,886 m^3/annum (Sansom et al., 2018). This suggests that water yield would be 9.2m^3/annum/m^2 of restored habitat. Sansom et al. (2018) do not state how long the restoration of 16ha would take, there may be constraints based on the number of plants that can be propagated over a given time and the availability of labour to undertake the restoration activity. Furthermore, following restoration it may take a number of years for vegetation to produce the full yield of water from mist capture. For this analysis we assume that the costs of restoration occur in year 0, with the flow of benefits from year 10.

Comparison to estimated yields from mist netting (these range between 6.7 and 37.8 m^3/annum/m^2) may be problematic. The area of mist nets refers to the vertical surface of the nets; these should be placed in arrays with minimum horizontal and vertical distances between nets, so yield per unit area of ground space will be less than unit area of each net. Further information is needed on the area on St Helena that would be suitable for installing mist nets, and what overall volume of mist capture might be possible. A constraints mapping exercise could identify suitable areas. Consequently, our analysis is limited to estimating the costs and benefits of a 40 m^2 net area, this represents the size of a large single mist net that we compare to achieving the same net area using a number of smaller 1m^2 nets.

The CBA results for the additional storage are summarised in Table 5. These indicate that positive net benefits would be achieved across each of the discount rates evaluated.

Table 5 Present value and benefit/cost ratios of new storage in the mixed measures option

Present value (£)	Discount rate		
	4%	7%	10%
Total benefits (£)			
New storage	1,146,873	775,521	542,750
Total costs (£)			
New storage	621,914	524,358	444,196
Net benefits (£)			
New storage	524,958	251,163	98,554
Benefit-cost ratios			
New storage	1.84	1.48	1.22

Table 6 summarises the results of the CBA for the two mist collection approaches considered. The habitat restoration scenario resulted in considerable net losses and low BCR values when evaluated purely on the revenue generated from the water yield. However, this does not include the wider benefits of habitat restoration, these include safeguarding and enhancing St Helena's biodiversity and habitats, providing a cultural and recreational resource for residents and tourists, and through greater water retention and slowing of runoff a potential reduction in erosion and flood damage. The approaches to native plant propagation and restoration being developed on St Helena may also provide valuable experience that can be applied in habitat restoration projects elsewhere. This illustrates a common problem in the evaluation of 'nature-based solutions' that a holistic analysis across multiple benefits is often required. However, if that is possible, then demonstrating multiple benefits can also help to identify the potential for multiple funding sources where single objective CBA tests may not be passed.

For mist nets we evaluated a reference area of 40m^2 achieved through using either a single large net or 40 smaller 1m^2 nets. We also used low and high cost scenarios based on examples from FogQuest (2018). Evidence on yield per unit area indicates that a larger number of smaller nets will produce a higher yield, although that will be achieved at a higher installation cost. Regardless of the combination of size and cost, each of the mist net scenarios resulted in a positive net benefit and benefit-cost ratios of between 3.1 and 8.7 at a 4% discount rate.

Table 6 Present value and benefit/cost ratios of mist collection in the mixed measures option

Present value	Discount rate		
	4%	7%	10%
Total benefits (£)			
Habitat restoration	2,212,634	1,388,743	896,761
Mist nets (small)	22,764	14,288	9,226
Mist nets (large)	4,049	2,541	1,641
Total costs (£)			
Habitat restoration	15,695,115	13,983,142	18,606,400
Mist nets (40m^2 total, small nets, low cost £58)	2,626	1,779	1,239
Mist nets (40m^2 total, small nets, high cost £154)	6,973	4,723	3,291
Mist nets (40m^2 total, large nets, low cost £769)	872	590	411
Mist nets (40m^2 total, large nets, high cost £1,154)	1,302	882	614
Net benefits (£)			
Habitat restoration	-13,482,481	-12,594,398	-17,709,639
Mist nets (40m^2 total, small nets, low cost £58)	20,138	12,509	7,987
Mist nets (40m^2 total, small nets, high cost £154)	15,791	9,564	5,936
Mist nets (40m^2 total, large nets, low cost £769)	3,177	1,951	1,230
Mist nets (40m^2 total, large nets, high cost £1,154)	2,747	1,660	1,027
Benefit-cost ratios			
Habitat restoration	0.14	0.10	0.05
Mist nets (40m^2 total, small nets, low cost £58)	8.67	8.03	7.44
Mist nets (40m^2 total, small nets, high cost £154)	3.26	3.02	2.80
Mist nets (40m^2 total, large nets, low cost £769)	4.65	4.30	3.99
Mist nets (40m^2 total, large nets, high cost £1,154)	3.11	2.88	2.67

5. Summary

The CBA analysis across the four options indicates that small-scale expansion of reservoir capacity is cost-effective, with positive net benefits. The analysis does not include the cost of water pumping, however, as the potential expansion sites in options 1 and 4 are close to existing infrastructure additional distribution costs may be minimal.

The proposed new reservoir at Fisher's Valley would ensure security of supply due to the large increase in overall capacity. However, the benefit-cost estimation was sensitive to the assumptions of how the benefits of the additional supply were valued (based on potential revenues). Given the water security objective of this option, then valuing total capacity rather than just volume supplied would be reasonable. Distribution costs were also not included. Although the cost of Fisher's Valley would need to be met be a UK Government grant, it remains reasonable to apply CBA given the potential opportunity costs, or more cost-effective alternatives.

The desalination option, did not have positive net benefits except under assumptions of the lowest cost. Given the scale of current desalination plants, it is likely that any plant would be underutilised. The CBA remains partial as it does not fully account for economies of scale, or the likely distribution costs from the sea level.

Option 4 considered mixed approaches, these were analysed separately they could either be used in combination or individually. Restoration of native cloud forest habitats were also evaluated. Sansom et al. (2018) estimate that 16ha of cloud forest restoration could contribute an additional 33% to treated water supply. Based on the potential revenue of that water supply alone, restoration would incur a significant net loss. However, the CBA does not include the wider ecosystem service benefits of habitat restoration, in particular with respect to biodiversity, culture including tourism, and reduced flood and erosion damage. Further information is also needed on the capacity and resources (propagation and labour supply) and the time taken for mist capture benefits to be realised.

Mist nets were found to have potentially the highest net benefits per unit of water collected, although this did vary considerably depending on assumption of net size and installation cost. But, the potential use of mist nets is likely to be infeasible due to planning restrictions and existing land cover. It was also not possible within the scope of this analysis to determine the scale of mist net installation that could be applied on St Helena, and whether a meaningful contribution to water supply could be achieved.

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Appendix 1: Estimating net present values and benefit-cost ratios

Net present value (NPV) is the sum of the discounted project benefits less the sum of the discounted project costs. The benefit-cost ratio (BCR) is the ratio of the present value of benefits to the present value of costs. In algebraic terms NPV and BCR can be expressed as follows: NPV = $\sum N$ n=0 $Bn-Cn$ (1+r) BCR = $\sum N$ n=0 Bn (1+r) n / $\sum N$ n=0 Cn (1+r) n Where: Bn = benefits in year n expressed in constant dollars Cn = costs in year n expressed in constant dollars r = real discount rate N = number of years that costs and/or benefits are produced.

A project is potentially worthwhile if the NPV is positive and the BCR is greater than one, i.e. the present value of benefits exceeds the present value of costs. If projects are mutually exclusive, this rule would indicate that the project with the highest BCR should be chosen.

Appendix 2: Proposed Fisher's Valley Reservoir costs and technical details

FISHERS VALLEY DAM: Full supply level 330 m amsl
BILL OF QUANTITIES FOR EARTHFILL DAM

ITEM NO	PAYMENT CLAUSE	DESCRIPTION	UNIT	QTY	RATE GBP	AMOUNT GBP
1		**SITE CLEARANCE**				
1.1		River	Ha	0.4	5,714.29	2,457.14
1.2		Bush	Ha	0.7	7,142.86	4,714.29
2		**RIVER DIVERSIONS**	Sum	1.0	2,857.14	2,857.14
3		**EXCAVATION (Embankment)**				
3.1		**Bulk**				
3.1.1		All Materials	m^3	3,600	4.57	16,457.14
3.1.2		Extra-Over for rock	m^3	360	17.14	6,171.43
3.2		**Confined**				
3.2.1		All Materials	m^3	4,850	6.00	29,100.00
3.2.1		Extra-Over for rock	m^3	1,455	17.14	24,942.86
4		**EXCAVATION (Spillway)**				
4.1		**Bulk**				
4.1.1		All Materials	m^3	69,500	4.57	317,714.29
4.1.2		Extra-Over for rock	m^3	45,175	17.14	774,428.57
4.2		**Confined**				
4.2.1		All Materials	m^3	-	6.00	0.00
4.2.2		Extra-Over for rock	m^3	-	17.14	0.00
5		**PREPARATION OF SOLUM (Embankment)**				
5.1		All Materials	m^2	11,000	2.29	25,142.86
5.2		Extra-Over for rock	m^2	1,100	4.57	5,028.57
6		**DRILLING AND GROUTING**				
6.1		**Curtain Grouting**				
6.1.1		Setups	No	103	149.05	15,351.89
6.1.2		Drilling	m Drill	541	42.31	22,892.03
6.1.2		Water Pressure Test	No	206	177.14	36,491.43
6.1.3		Grouting	ton	13	84.54	1,056.80
6.2		**Consolidation Grouting**				
6.2.1		Setups	No	-	149.05	0.00
6.2.2		Drilling	m Drill	-	42.31	0.00
6.2.3		Water Pressure Test	No	-	177.14	0.00
6.2.4		Grouting	ton	-	84.54	0.00
7		**EMBANKMENT**				
7.1		Earth Fill	m^3	53,250	6.86	365,142.86
7.2		Filters	m^3	2,020	22.86	46,171.43
7.3		Rip-Rap	m^3	3,250	25.71	83,571.43

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7.4		Drain	m^3	2,825	22.86	64,571.43
7.5		Overhall beyond 5 km	m^3/km	-		Included above
8		**OUTLET WORKS (Civil works)**				
8.1		Intake structure and access bridge	Sum	1.00	54,285.71	54,285.71
8.2		Pressure conduit to outlet structure	Sum	1.00	9,714.29	9,714.29
8.3		Outlet structure	Sum	1.00	8,571.43	8,571.43
9		**CONCRETE WORKS (Spillway control weir)**				
9.1		**Formwork**				
9.1.1		Gang Formed	m^2	-	22.86	0.00
9.1.2		Intricate	m^2	235	25.71	6,042.86
9.2		**Concrete**				
9.2.1		Mass	m^3	-	102.86	0.00
9.2.2		Structural	m^3	142	114.29	16,228.57
9.3		**Reinforcing**	t	13	800.00	10,400.00
10		**GABION WORKS**				
10.1		Gabion boxes	m^3	200.00	75.00	15,000.00
10.2		Gabion matresses	m^3	750.00	75.00	56,250.00
11		**MECHANICAL EQUIPMENT**				
11.1		Valves, gates & screens	Sum	1	17,142.86	17,142.86
11.2		Cranes and hoists	Sum	1	8,571.43	8,571.43
11.3		Pipework	t	1.0	8,571.43	8,571.43
12		**FENCING**	m	1,500.0	12.00	18,000.00
13		**ACCESS ROAD**	km	0.5	28,571.43	14,285.71
20		**SUB TOTAL A (Items 1 - 13)**	Sum			2,087,327.86
21		**LANDSCAPING (% of Item 20)**	%	5%		104,366.39
22		**MISCELLANEOUS (% of Item 20)**	%	10%		208,732.79
23		**SUB TOTAL B (Items 20 - 22)**	Sum			2,400,427.04
24		**PRELIMINARY & GENERAL (% of Sub Total B)**	%	30%		720,128.11
25		**SUB TOTAL C (Items 23 - 24)**	Sum			3,120,555.15
26		**CONTINGENCIES (% of Sub-Total D)**	%	17.5%		546,097.15
27		**TOTAL CONSTRUCTION COST**				3,666,652.30
28		**ANCILLARY WORKS**				
28.1		Relocate farmsteads	No	-	0.00	0.00
28.2		Relocate access roads	km	-	14,285.71	0.00
28.3		Provide electricity to site	Sum	-	0.00	0.00
28.4		Water to site for construction	Sum	-	0.00	0.00
28.5		Cost of land acquisition	Sum	1	0.00	0.00
29		**TOTAL PROJECT COST**	Sum			3,666,652.30

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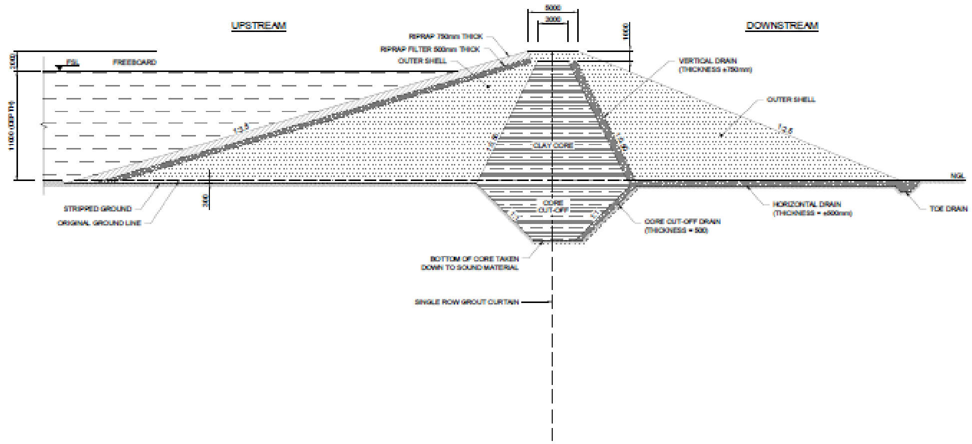
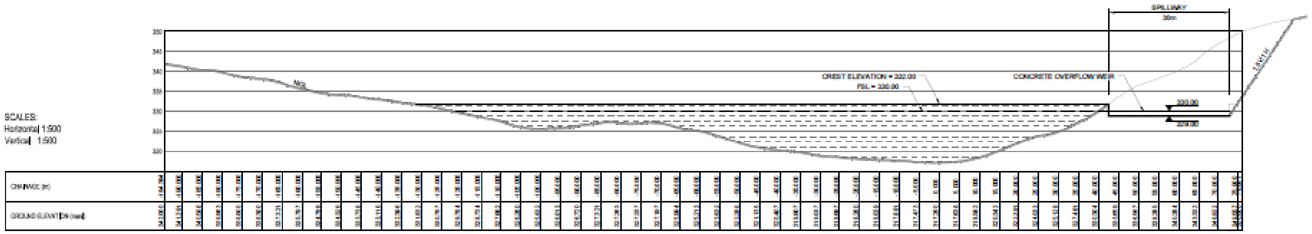


TYPICAL CROSS SECTION OF
ZONED EMBANKMENT WITH
VERTICAL AND HORIZONTAL DRAINS



SECTION ALONG
DAM CENTERLINE

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ST HELENA WATER DEVELOPMENT PROJECT

FISHERS VALLEY EARTH DAM
GENERAL SECTIONS
OF PROPOSED DAM

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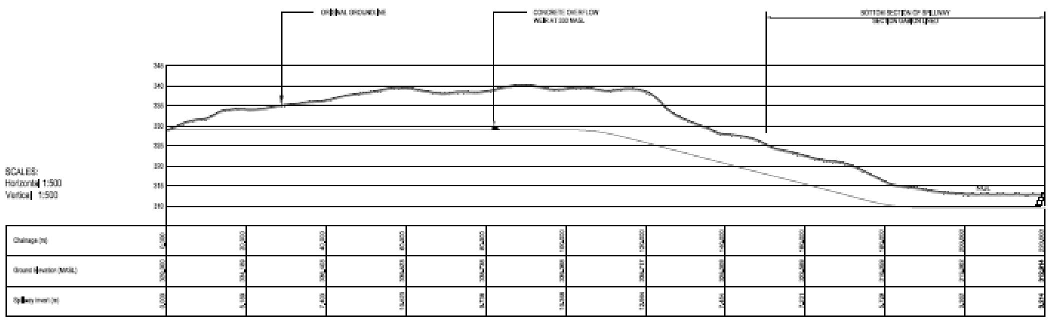
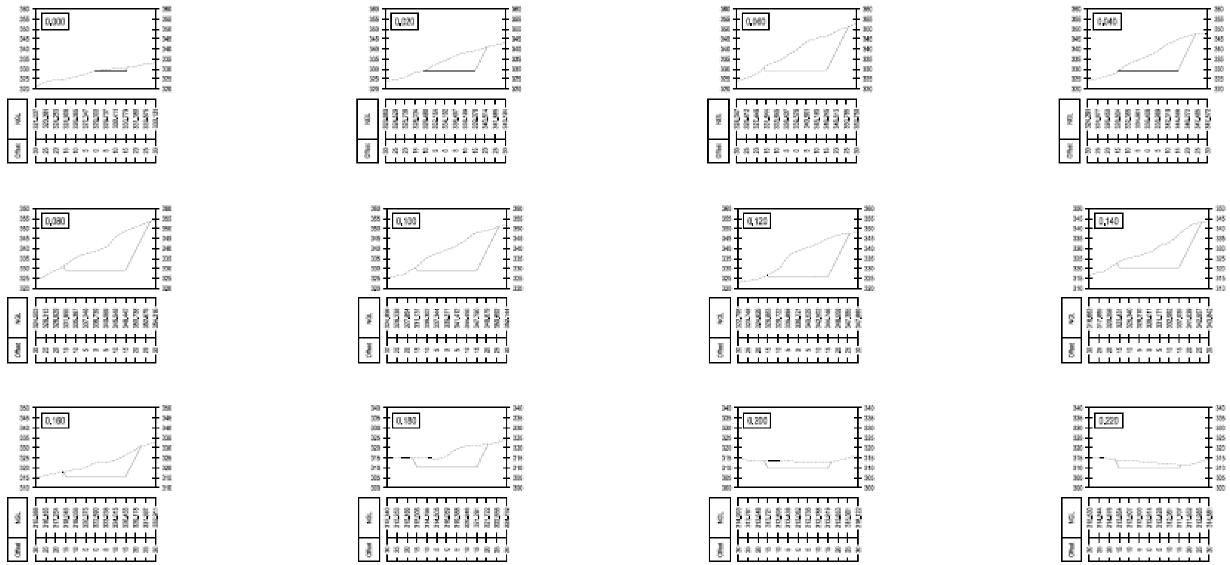


SECTION ALONG CENTERLINE OF SPILLWAY



CROSS SECTIONS ALONG CENTERLINE OF SPILLWAY

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FISHERS VALLEY EARTH DAM SPILLWAY PROFILE AND SECTIONS

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GENERAL LAYOUT
1:1000
NOV 2018
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