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South East Strategic Reservoir Option Gate 1 submission – Technical Annex B1

Appendix A9 INNS

Thames Water Utilities Ltd.

14 May 2021

5201137-014

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Document history

Document title: Appendix A9 INNS

Document reference: 5201137-014

Revision	Purpose description	Origin-ated	Checked	Reviewed	Author-ised	Date
Rev 1.0	Supporting information for Annex B1 Environmental Assessment Report	PS	JJ	PM	BA	22/02/21
Rev 2.0	Final update following assurance	PS	JJ	PM	BA	14/05/2021

Client signoff

Client	Thames Water Utilities Ltd.
Project	South East Reservoir Strategic Option (SESRO)
Job number	5201137
Client signature/date	

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Contents

Appendix A9.1 Mitigation Measures Options Appraisal

A9.1. Potential mitigations and INNS prevention strategies

A major advantage of considering biosecurity at this stage of the planning process is that it can be incorporated into the initial design and operation of the site. If biosecurity processes are integrated with the initial site development, then less retrospective action will be needed in the future. This not only ensures that good biosecurity practices become an integrated feature of the site but will further decrease the risk of INNS establishment at the site. General site biosecurity measures provided herein are considered fundamental aspects of biosecurity which will help reduce the overall risk of INNS transfer to site, and in the event of an establishment of INNS on site, to reduce the risk of further transfer off site. Unlike other options provided in this section, these general site biosecurity measures have not been scored as they are to be viewed as required to manage INNS risk at the site. Other measures that have been related to the various risk assessment scenarios detailed in the main EAR (Technical Annex B1) Sections 9.3.2 and 9.3.3 are scored. All measures should be viewed as risk reduction or biosecurity measures, because even with a high level of implementation, no measure can provide full mitigation for the risk of the INNS introduction via an RWT. An overview of the most effective biosecurity options is provided in Table A9.1-1, Table A9.1-2, Table A9.1-3, Table A9.1-4 and Table A9.1-5.

A9.1.1. General site biosecurity

As a minimum precaution to reduce the risk of INNS transfer to the reservoir via the pathways identified, the site should instigate basic biosecurity practices and a biosecurity management plan. Both New Zealand and Australia are forerunners in biosecurity, following the invasion of the diatom *Didymosphenia geminata.* New Zealand's Biosecurity Act of 1993 is considered the most comprehensive biosecurity approach as it revolves around a central coordinating body, provides economic strength in pest-free exports, has successfully resulted in the eradication of INNS such as the white spotted tussock moth, and is as such regarded a success internationally[1]. It was New Zealand that instigated the Check Clean Dry campaign (discussed herein) in 2004 to raise public awareness and reduce further invasions of other INNS[2].

A review of New Zealand's biosecurity system found weaknesses that can be used to help improve other biosecurity plans, including for SESRO. One limitation is the inability to quickly predict new invaders[1]. This project's investigation into INNS that already have a reported presence in the local area provides some insight into the INNS that are likely to be at risk of introduction, but continuous monitoring of the site would need to take place to accurately identify new introductions. Rapid identification of new introductions is key to facilitate a rapid response approach to either quickly eradicate a species before it spreads or to contain it at the site. Financial constraints are also a key limitation to New Zealand's biosecurity system, as biosecurity is still generally not considered a top priority politically[1]. However, the importance of implementing good biosecurity practices alongside initial site development will provide cost savings in the future with regard to INNS control and eradication. Integrated biosecurity in SESRO can be used as an education tool for the general public and an example for other site development plans.

A9.1.1.1. Biosecurity management

It is recommended that a biosecurity manager should be appointed for the site and their role would include developing and regularly reviewing the site's biosecurity plan[3]. The role would include being responsible for:

- Conducting (or arranging) and logging the results of INNS surveys. Surveys of all land types on site should be conducted e.g. woodland, reservoir, beaches and angling pond. Specialised fish stock health checks should also be conducted to assess whether any INNS fish pathogens are present[3].
- Investigating any reports of INNS sightings on site made my members of the public or staff.
- Reporting all confirmed INNS sightings to GB NNSS.
- Creating and implementing a species-specific action plan if an INNS does become established on site.

[1] Meyerson, L.A. & Reaser, J.K. (2002). Biosecurity: Moving toward a Comprehensive Approach: A comprehensive approach to biosecurity is necessary to minimize the risk of harm caused by non-native organisms to agriculture, the economy, the environment, and human health. BioScience, 52, 593–600.
[2] Kilroy, C. and Unwin, M. (2011). The arrival and spread of the bloom-forming, freshwater diatom, Didymosphenia geminata, in New Zealand. Aquatic Invasions, 6, 249–262.
[3] Cefas (2019). Finfish Biosecurity Measures Plan. Fish Health Inspectorate. Centre for Environment, Fisheries & Aquaculture Science.

- Ensuring all staff are well-trained in INNS identification and management, with particular focus on the high priority species identified in the 2.5 km radius of the site and the Oxford to Culham reach of the River Thames[3].
- Training staff to recognise symptoms of poor fish health that may indicate pathogenic INNS.
- Making visitors aware of their role in upholding good biosecurity practices by signposting, proving educational materials such as leaflets and hosting short talks before high risk activates commence, such as boating, water sports or angling events[3].
- Checking and maintaining all biosecurity related activities and infrastructure. For example, if tyre troughs are implemented, these must be checked on a regular basis and replenished as often as is necessary to ensure their effectiveness is upheld.

Since 2019 in Australia, people entering an area with a biosecurity management plan in place must comply with the rules set out, and refusal to comply can result in fines[4]. Distributing fines is unlikely to be a viable option in the case of SESRO as it would require much greater staff resources, however, access to facilities could be denied by offenders. The Australian government website provides information on how best to create a biosecurity plan[5]. The essential elements to consider are:

- Inputs and outputs on site that may facilitate INNS introduction and establishment.
- People, vehicles and equipment entering and leaving site pose as potential vectors for INNS.
- On-site activities such as recreational anglers and walkers may increase the risk of contamination and introduction of INNS.
- Ferals and weeds that may naturally disperse onto site from elsewhere in the local area.
- Training, planning and recording. All biosecurity related matters must be recorded and managed and all staff on site must be appropriately trained to uphold biosecurity practices.

Biosecurity planning is about prioritising biosecurity actions and checking progress towards success implementation. Short-term actions may be implemented within 12 months, be financially feasible and help the site achieve its basic biosecurity goals[5]. Whereas long-term actions may take over 12 months to implement, require additional funding and enhance the site above and beyond its requirements[5].

A9.1.1.2. Check Clean Dry

After its success in New Zealand, the Check Clean Dry campaign was launched in the UK in 2011. It was aimed at anglers and other users of the water to raise awareness of INNS and how stakeholders can act to reduce the risk of spread between waterbodies[6]. The simple three step instructions are easy to follow:

1. Check – your equipment for mud, plants and animals and leave any attached organisms on site.
2. Clean – your equipment thoroughly, paying particular attention to hard to access crevices, nets and waders.
3. Dry – your equipment and clothing for as long as possible before it is used again. Some aquatic INNS can survive for up to two weeks in damp conditions, so this step is especially important.

Free ‘Check Clean Dry’ merchandise can be ordered from the Angling Trust and/or the GB NNSS to display on site. This includes signposts, posters, leaflets and stickers[7]. Distributing these materials on site, with leaflets available to visitors in the visitor centre and signposts at every access point to the reservoir and angling pond are a good way to reinforce biosecurity awareness, and therefore increase up-take of biosecurity actions[8]. As part of this process the most suitable locations for signposting, for example, at entrances to buildings, car parks, delivery pick up and drop off points, wash down areas and roads entering the site[5] should be considered.

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[4] NSW (n.d.). Biosecurity Management Plan. Department of Primary Industries. Available at: [Biosecurity Management Plan (nsw.gov.au)] [Accessed on: 03/12/2020].
[5] Farm Biosecurity (n.d.). Farm Biosecurity Action Planner. Available at: [Farm Biosecurity Action Planner - Farm Biosecurity] . [Accessed on: 03/12/2020].
[6] Angling Trust (n.d.). Invasive Non-Native Species. Available at: https://anglingtrust.net/invasive-non-native-species/ . [Accessed on: 03/12/2020].
[7] GB NNSS (2020). Biosecurity and Prevention. GB non-native species secretariat. Available at: http://www.nonnativespecies.org/index.cfm?sectionid=58 . [Accessed on: 03/12/2020].
[8] Anderson LG., Rocliffe S., Stebbing PD. And Dunn AM. (2014a). Aquatic biosecurity best practice: lessons learned from New Zealand. University of Leeds, University of York and Cefas.

Online biosecurity information and materials should also be made available to the general public. The GB NNSS offers a free e-learning course[9] on INNS identification, reporting and biosecurity[7]. This may be of interest to many visitors and education in biosecurity should be encouraged, possibly being an integral element of the visitors centre and the site experience. Biosecurity information can also be displayed on the site's website and in magazines/bulletins[6].

A9.1.1.3. Staff of site

All staff on site, including contractors should familiarise themselves with the INNS species that have been identified in the 2.5 km radius of the site. These are the INNS most likely to be found on site in the future. Any INNS sighted on site by staff and visitors alike are to be reported to the site biosecurity manager for further investigation.

If an invasive crab or crayfish is accidently caught and the member of staff is able to humanely kill it, they should do so[10].

Staff should actively engage with relevant campaigns and guidance such as Check Clean Dry, setting an example for visitors on site.

Free e-learning courses are available on the GB NNSS and Leeds University website, teaching identification and control of INNS. Courses such as these should be a part of, and not limited to, the mandatory staff biosecurity training. Further biosecurity training and fish disease recognition and management should be continuously provided to keep staff up to date with biosecurity measures and wary of INNS threat at all times[3].

A9.1.1.4. Visitors on site

Visitors should be encouraged to engage in the site's basic biosecurity plan and facilities. Their engagement in any biosecurity activities or measures is optional and should only be undertaken if safe to do so. The primary aim for all visitors is to have an enjoyable experience in a safe manner. By providing information about biosecurity and those INNS that have been identified in the local area, visitors are likely to become more wary of good biosecurity practice on site. The Check Clean Dry campaign should be used to educate the public, campaign resources (e.g. signposts, posters and leaflets) can be ordered free of charge from the Angling Trust. Site staff should also help educate visitors through word of mouth.

Any INNS sightings on site, must be reported to:

- A member of staff, who will pass this information onto the site biosecurity manager to investigate further.

Provision of photographic evidence and location details should be encouraged, so that any INNS reports can be investigated.

Visitors should be encouraged to arrive and leave site with clean footwear, pets and vehicles. A simple check of clothing, footwear, tyre treads and domestic animals' fur is an easy way of identifying and removing attached plant fragments or animals. If cleaning facilities are made available on site, visitors should have access to them, to clean boots thoroughly, should they wish to do so.

It is against the law to take an INNS, found in the wild, home[10].

A9.1.2. Cleaning options

A9.1.2.1. Biosecurity check points and cleaning facilities

A cleaning station should be made available for anglers, boaters and other users of the reservoir and angling pond. This should be a designated area, away from the water's edge so that any INNS washed out of the equipment do not re-enter the water. Depending on the level of investment and activity planned for the site, different options are available for implementation. All cleaning options and scores assume that the individual cleaning does so to the best of their ability and that cleaning equipment is maintained to a good standard.

A **purpose-built wash-down wet room** with integrated taps and a hose should be available for all recreational users of the reservoir. Cleaning equipment and protective wear should be provided, such as brushes, gloves and goggles. The floor should be built with a grating or gradient centred towards the drainage point, where all washed dirt, animal and plant matter collects and is disposed of.

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[9] GB NNSS free e-learning course can be accessed online here: http://www.nonnativespecies.org/index.cfm?sectionid=123
[10] Gov.uk (2020). Invasive non-native (alien) animal species: rules in England and Wales. Defra [online]. Available at: https://www.gov.uk/guidance/invasive-non-native-alien-animal-species-rules-in-england-and-wales [Accessed on: 07/12/2020].

A **separate dry room** for all cleaned equipment should be built, with hooks and bars attached to the walls from which to hang waders, nets etc. Floor drainage in the dry room should also be installed. It is important that the dry room and equipment storage facility is kept separate from the wet room to avoid re-contamination of clean equipment.

The wash down and drying rooms are intended for removable personal protective clothing (e.g. life jackets, waders, wet suits) and smaller equipment that can be brought indoors (e.g. nets, kayaks etc.). For larger equipment that cannot be brought indoors, such as small inflatable boats an alternative wash down method should be available. An external wall mounted **pressure washing hose** at the boat club could be available to water users to clean their equipment before and after entering the water. This would be an open-air facility so consideration must be given to appropriate placement and waste disposal, as it would be of little benefit if potentially INNS contaminated water were to run-off into the reservoir. In the event that no aquatic recreational activities were to take place in the reservoir, pressure washing hoses should still be available for maintenance staff in order for them to clean down their equipment and small boats used to access and maintain the draw off towers.

Boat wash down units are units designed for the cleaning of boats with hot, pressurised water hoses and a containment mat. They can be mounted on a trailer and mobilised, or a permanent boat washing facility could be built. The containment mat is emptied via a pumped hose system and the collected wastewater can then be disposed of appropriately[11]. If recreational boating is to take place on the reservoir, this option should be considered as an effective means of cleaning boats on a larger scale, that a single pressure washing hose may not achieve.

Disinfectant stations, where a large basin is filled with hot water, carbonated water or a licenced chemical solution for the removal of INNS from equipment such as nets and waders, should be a permanent feature of the site, preferably stationed at several locations. This cleaning station option is most suited to angling equipment as disinfection of the equipment will help to reduce the risk of pathogenic INNS that may harm the fish stock. The tub must be regularly replenished, cleaned and the contents disposed of safely.

If a licensing application for Virkon® use on site as a measure to control INNS has been accepted, consider installing Virkon® **tyre troughs** at every entrance and exit point on site. All vehicles would have to drive through the troughs, removing INNS harboured in the tread of tyres. Pedestrians may also be encouraged to walk through a trough to clean the soles of their shoes upon entrance and exit of the site. However, a thorough safety plan would have to be established to ensure the Virkon® is being used appropriately and does not pose a significant risk to children, animals and the environment[12]. Tyre troughs must be checked regularly and maintained as often as is necessary, this is a task that the site biosecurity manager must include in the biosecurity plan.

Similarly, several **boot-brushing stations** could be installed throughout the site to encourage all users of the site, especially walkers, to regularly clean their boots in order to reduce the risk of INNS transfer. Boot washing stations are structures typically made of three brushes in a U shape soaked in a disinfectant. They are easy and safe to use but must be regularly maintained in order to uphold their effectiveness. A study by the North American Invasive Species Management Association[13] and the River to River Cooperative Weed Management Area propagated the seeds collected in the mud from several boot brush stations and found that 14 of the 39 species were invasive[13]. NAISMA recommend cleaning the stations annually and replacing any worn brushes; contain the station in a gravel box to reduce the chance of natural seed propagation and regularly remove seedlings and plants growing within the box and the immediate surrounding area[13].

Sticky mats are underfoot matting that when walked on capture loose material on the soles of shoes. They are typically used to capture micro-organisms to help create a sterile environment[14]. They are a simple way of superficially cleaning the soles of shoes and are safe to use by children, unlike some of the more intensive cleaning methods discussed. Although not typically used for the prevention of INNS, the mats would in theory be effective at capturing dirt that may contain small INNS animals or plant fragments. Sticky mats can be used to capture pet litter pellets, which provides good evidence that larger materials such as dirt would be

[11] Michigan State University (n.d.). Mobile Boat Wash Parts. Clean Boats Clean Waters. Available at: Mobile Boat Wash Anatomy - Clean Boats Clean Waters (msu.edu) . [Accessed on: 03/12/2020].
[12] Natural England (2007). Boot Disinfection Procedures when using Antec Virkon S. Occupational Health and Safety Team.
[13] NAISMA (2020). Boot Brush Stations: Are They Effective? North American Invasive Species Management Association. Available at: https://naisma.org/2020/03/12/boot-brush-stations-are-they-effective/ . [Accessed on: 18/12/2020].
[14] Dahmardehei, M., Alinejad, F., Ansari, F., Bahramian, M. and Barati, M. (2016). Effect of sticky mat usage in control of nosocomial infection in Motahary Burn Hospital. Iranian Journal of Microbiology, 8, 3:210–213.

successfully captured[15]. The mats must be checked regularly and replaced when necessary, this is a task that the site biosecurity manager would need to include in the biosecurity plan. They are likely to require replacing on a very regular basis though, as dirt from walkers' boots in doorways will collect rapidly on the mats. Given the lack of evidence for their use as an INNS control measure, we would therefore not recommend these to be used until further evidence for their use becomes available.

A9.1.2.2. Waste disposal

If no drainage system is in place, the wastewater produced from the wash down activity will be left to evaporate and/or run-off. The wastewater may re-enter the reservoir, potentially contaminating the waterbody with INNS. The designated washing area should be well away from the water's edge to avoid this. All wastewater must be disposed of appropriately to avoid further contamination. For example, if a drainage pipe system is installed, this must be regularly checked for any INNS that may establish themselves and block the pipe works, such as zebra mussels[16]. Some different options of waste disposal are provided below, but in any case, must be an integral feature of the wash down facilities.

Underneath the integrated cleaning facilities such as the purpose-built wash down room and/ or the boat wash unit, grated flooring should connect to a drainage pipe. The pipe could be directed to a designated terrestrial area away from the water's edge. Aquatic INNS will not survive terrestrial exposure and can therefore be eradicated. It can take approximately two days for the zebra and quagga mussel to die from desiccation[17], while aquatic plants such as Canadian water weed and Nuttall's weed can die in just a few hours, depending on the climatic conditions[18]. However, the Check Clean Dry campaign suggests that aquatic INNS may survive for up to two weeks in a damp environment. Therefore, the discharge point would need to be regularly checked for any surviving INNS and maintained to remove them.

Alternatively, the drained wastewater could simply be connected to the **sewer system**, although there is a risk that INNS such as zebra mussels may establish themselves within the sewage pipe and block the system. Extreme blockage of the sewers by zebra mussels is unlikely to take place if the site is uncontaminated and external water users adhere to strict biosecurity measures. However, in the case that wastewater must be treated before it is discharged into the sewers, you may wish to consider a **septic tank**. Chemical treatment of all waste materials in the tank, ensures INNS have been killed before the wastewater enters the sewers. This will prevent INNS such as zebra mussels from establishing themselves and blocking the sewer network. Septic tanks are unsightly and if chemical treatment is applied this can easily leach out of the base of the tank and into the environment. Septic tanks must also be maintained, as in the case of heavy rainfall they could overflow and run-off into the environment. Due to high environmental, social and operational costs associated with septic tanks in this case, they are not recommended.

A9.1.2.3. Cleaning method

Safety information with regards to the cleaning method available must be clearly displayed (Natural England, 2007). Guidance on best practice for cleaning equipment with the available methods should also be displayed, this may include:

- Wear eye protection[12]
- Brush away from yourself[12]
- Pay extra attention to soles and heels of shoes, seams and hard to reach areas[12]
- Place cleaned items in a clean container to prevent re-contamination

There are several different methods of effective INNS removal from equipment, however, they each have their draw backs that have been considered below.

Hot water is an effective and environmentally safe method of killing aquatic INNS. A temperature of >35°C for 15 minutes, or >45°C for 1 second has been proven effective for 100% mortality in killer shrimp, zebra mussels

[15] Schafer, RF. (2020). Sticky Mats for Catching Pet Litter. United States Patent Application Publication. Publication Number: US 2020/0113150 A1. Available at: https://patentimages.storage.googleapis.com/08/13/72/061f7c2a1926f3/US20200113150A1.pdf . [Accessed on: 07/12/2020].

[16] Aldridge DC., Elliott P., Moggridge GD. (2006). Microencapsulated biobullets for the control of biofouling zebra mussels. *Environmental Science and Technology,* 40:975–979.

[17] Collas, FPL., Koopman, KR., Hendricks, AJ., Van Der Velde, G., Verbrugge, LNH. and Leuven, RSEW. (2014). Effects of desiccation on native and non-native molluscs in rivers. Freshwater Biology, 59, 41–55.

[18] Coughlan, NE., Cuthbert, RN., Kelly, TC. and Jansen, MAK. (2018). Parched plants: survival and viability of invasive aquatic macrophytes following exposure to various desiccation regimes. Aquatic Botany, 150, 9–15.

and quagga mussels[19]. However, the provision of hot water throughout the day for a net dip station would be costly and difficult to maintain, unless a specialised hot water tap is installed. Similarly, aerosol water droplets have a rapid cooling rate, so if hot water is to be applied as a spray the temperature of the water at the nozzle must be even higher. Hot water also poses a serious burns risk, especially if the site welcomes children and pets[19].

Pressure washing is a form of mechanical removal of INNS, particularly effective for attached biofouling organisms such as zebra and quagga mussels[19]. As it only uses water, this is environmentally safe to use, however, the operational cost of running water and electricity use would be high. Pressure washing may damage weak or delicate equipment, so alternative manual washing facilities must also be available.

CO_2 induces narcotisation of aquatic animal species such as killer shrimp[22]. The use of **carbonated water** is therefore a method of prompting INNS to drop from treated equipment and as such is not effective against plant INNS. Carbonated water as a biosecurity option for aquatic animal INNS could be implemented as a carbonated dip net station for equipment before water users enter the water. Alternatively, it could be implemented as a bubble curtain around the launching area of the reservoir, through which boats must pass. However, this is not an effective method for preventing INNS entering the water, as they would drop into the waterbody upon the boat entering the water. Pipelines carrying the CO_2 would need to be installed either in the sediment for the bubble curtain or into the dip net basin and compressed CO_2 gas in cylinders would require gas safety training to be undertaken[19]. As such, this biosecurity measure is not recommended as it will require greater maintenance of the pipelines and gas cylinders than some of the less resource intensive cleaning methods discussed.

The use of **aeration** with a continuous stream of air bubbles to reduce biofouling on structures has been found to be >99 % effective, compared to not aerated surfaces[20]. Aeration is not an effective method at reducing plant INNS. This method could be used on stationary submerged structures such as pontoons and jetties. It is environmentally safe and eliminates the need for pressurised gas cylinders to be on site, as would be the case for CO_2. However, similar to the carbonated water method, aeration pipes must be installed, and their operation would incur ongoing electricity costs[20]. Air diffusers will be installed within the reservoir in order to deliver bubble mixing to prevent thermal stratification in order to maintain good water quality[21]. It is therefore recommended that at the same stage of site development, aeration pipelines are installed around the boat launching area and all permanent and semi-permanent structures within the reservoir to reduce biofouling and reduce the establishment of INNS such as zebra mussels by reducing available habitat.

Iodine and Virkon® are commonly used **disinfectants** that work against many pathogens. Virkon® Aquatic contains ingredients suitable for aquatic application[19]. Although Virkon Aquatic has been used as a control of INNS such as mussels[22], neither Virkon® nor iodine are listed as insecticides under the Biocidal Products Directive (98/8/EC). Therefore, an application for licensing must be submitted and accepted before use as an INNS control measure[19]. As such, APEM does not recommend the use of unlicensed disinfectants as a control agent for INNS.

[19] Sebire, M., Rimmer, G., Hicks, R., Parker, SJ. and Stebbing, P. (2018). A preliminary investigation into biosecurity treatments to manage the invasive killer shrimp (*Dikerogammarus villosus*). Management of Biological Invasions, 9, 2:101–113.
[20] Bullard, SG., Shumway, SE. and Davis, CV. (2010). The use of aeration as a simple and environmentally sound means to prevent biofouling. Biofouling, 26:5, 587–593.
[21] Thames Water Utilities Ltd. (2016). Severn Thames Transfer: Water Quality and Ecology Assessment – Phase 2.
[22] Stockton-Fiti, K. and Moffitt, C. (2017). Safety and efficacy of Virkon® aquatic as a control tool for invasive Molluscs in aquaculture. Aquaculture, 480, pp.71–76.

Table A9.1-1 – Biosecurity cleaning options and scores

Mitigation Method	Feature	Efficacy Score	Feasibility Score	Cumulative Score
Cleaning Facilities				
Purpose built wash-down wet room and separate dry room	Water sports clubhouse and equipment	3	2	5
Boat wash down unit		3	2	5
Pressure washing hose		3	3	6
Disinfectant stations		3	2	5
Boot washing	Walkers	3	3	6
Tyre troughs	Vehicles, car parks, boat parks and road access	3	2	5
Waste Disposal				
Septic tank	Water sports clubhouse and equipment	2	1	3
Main sewers connection		2	3	5
Terrestrial drainage area		3	2	5
Cleaning Method				
Hot water	Equipment	3	1	4
Pressure washing		3	2	5
Carbonated water	Permanent and semi-permanent structures in the reservoir	2	1	3
Aeration		2	2	4

A9.1.3. Site development and maintenance

A9.1.3.1. Development

Hard surfaces such as concrete should be built, rather than soil or grass for weak points with a high use frequency such as car parks, access points for boating and angling, equipment cleaning and storage facilities and boat parks. Hard surfaces are easier to clean and provide a better backdrop for identifying INNS that may drop from equipment, clothing or vehicles. Whereas grass and soil surfaces are more likely to aid establishment of INNS as they may be hidden or find a suitable habitat in the naturalised substrate. The feasibility of this option is low because it is visually unappealing, environmentally damaging and costly.

Deer fencing around the perimeter of the site could help to exclude larger INNS identified in the local area such as Sika deer. The fence must be at least 1.8 m tall to prevent Sika deer from entering[23]. Weak points in the fence line such as roads and pathways into and out of site would benefit from a deer grid. Although such fencing is effective at keeping invasive deer out, it will also keep native terrestrial species out of the site such as otters and badgers.

Bird deterrents installed around the site, may help to deter bird INNS from settling and establishing on site. However, the deterrents are not species specific so will also deter native bird species from coming to the site

[23] Scottish Government (2018). Management options and capital items – Deer Fence. Rural Payments and Services [online]. Available at: https://www.ruralpayments.org/publicsite/futures/topics/all-schemes/agri-environment-climate-scheme/management-options-and-capital-items/deer-fence/ . [Accessed on: 07/12/2020].

and birds may become accustomed to the deterrent rendering them ineffective in the long-term[24]. Both deer fencing and bird deterrents are relatively effective methods of excluding certain INNS and are therefore recommended for this purpose. However, the overall impact on native biodiversity may require careful consideration.

Rhizome resistant or **root barrier fabrics** could be used around all naturalised areas of the site. These materials can help limit rhizomal spread of INNS plant species[25]. Ideally, several isolated areas should have this material in place rather than just along the perimeter of the site, because if an INN plant species is introduced onto site in the future, it may be contained to a limited area where it can be managed accordingly. Root barrier fabric is also not species specific so will negatively impact the spread of native species. However, natural dispersal by means of wind or attachment to animals for example, will not be prevented by this option.

When naturalising the terrestrial areas of the site, only plant **native plant species** and ensure plants are from reputable nurseries that have a biosecurity plan in place. It is illegal to intentionally plant INNS. Please therefore note that this should be standard operational procedure rather than a biosecurity option.

Fish stocking will take place periodically in the angling pond in order for angling to take place. Fish stocking may also take place in the reservoir for ornamental and biodiversity purposes. Ensure that the fish chosen to stock the angling pond and reservoir are only native fish species and request certification of pathogen free stock (several notorious aquatic pathogens are INNS) from the fish stock provider[26;3]. Only obtain fish stock from a provider with a biosecurity plan in place[26;3]. Once the reservoir and angling pond are stocked, it may be worthwhile to find a knowledgeable fish veterinarian to conduct regular fish health checks.

All building **materials, machinery, equipment, and staff** must be **checked for INNS** contamination before coming onto site. Species such as Japanese knotweed may be attached to building materials and could be easily introduced onto site, if not thoroughly inspected. Again, this should be standard procedure rather than an optional precaution.

A9.1.3.2. Maintenance

All **structures that are submerged** in the water (e.g. jetties) must be **checked for INNS** before they are submerged and after they have been removed. This will not only reduce the likelihood of introduction of INNS into the waterbody but will also help identify early signs of INNS establishment that can be investigated and controlled. When submerged structures are removed, they should be cleaned of any biofouling. A scraper should be used first to remove heavy encrustations, before a pressure washer is used to remove residual waste material. Extra care should be taken to thoroughly clean crevices where INNS may be hidden. The structure must be dried thoroughly before it is submerged[27]. This should be a standard operational procedure carried out anytime permanent or semi-permanent structures are maintained and as a part of regular INNS surveys of the site.

Safe disposal of waste that may be contaminated with INNS is important. Drying organic waste is an effective way of killing aquatic INNS species, such as biofouling organisms that have been removed. However, if the waste contains in-organic materials such as paint, it must be disposed of in a licensed landfill or with the Environment Agency[27]. INNS plant waste can be composted or put in a municipal waste facility, unless species such as Japanese knotweed or giant hogweed are present in which case the plant waste must be disposed of as hazardous controlled waste[25].

If chemicals (e.g. herbicides) are to be used to control INNS, their application must be mindful of the ultimate destination of the chemical[25]. Chemicals may leach into the reservoir and cause harm to aquatic organisms and/or water quality, so their use should be away from the water's edge.

Regular **monitoring surveys** of the aquatic, riparian and terrestrial areas of the site should be conducted to detect whether any INNS have been introduced to the site. If in-house experience in INNS field surveys is not available, external contractors should be sought out to undertake surveys and produce a report of findings and recommendations for INNS removal and/or control. All report findings should be collated by the biosecurity manager and appropriate action taken based on the results.

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[24] RSPB (n.d.). Bird scarers and deterrents [online]. Available at: Bird Scarers & Deterrents for Use in Gardens - The RSPB. [Accessed on: 07/12/2020].
[25] Defra (2011). Horticultural Code of Practice. Helping to prevent the spread of invasive non-native species [online]. Available at: http://www.nonnativespecies.org//index.cfm?pageid=299 . [Accessed on: 07/12/2020].
[26] The University of Maine (2000). Fish Diseases in Aquaculture. The Fish Site. [online]. Available at: Fish Diseases in Aquaculture | The Fish Site. [Accessed on: 07/12/2020].
[27] Environment Agency (2011). Biosecurity for submerged structures [online]. Available at: http://www.nonnativespecies.org/downloadDocument.cfm?id=568 . [Accessed 07/12/2020].

Table A9.1-2 – Site development biosecurity measures and scores

Mitigation Method	Asset	Efficacy Score	Feasibility Score	Cumulative Score
Site Development				
Hard surfaces for high risk points	Access points for water users	2	2	4
Deer fencing and grids	Site perimeter access points	3	1	4
Bird deterrents	Entire site	2	1	3
Root barrier fabric	Woodland	2	2	4

A9.1.4. Aquatic recreational activities

Recreational use of waterbodies has been found to be responsible for approximately 40% of aquatic INNS introductions in Europe[28].

A9.1.4.1. Structural

Reducing the **number of access points** into the water ensures greater control over potential routes of INNS introductions[29]. This should be an integral part of the site design and is therefore not considered to be optional. These access points should be hard surfaces only, as that will allow for easier detection of any INNS that may drop from boats, trailers, or angling equipment. It will also reduce the likelihood of any dropped INNS to hide or establish themselves, as may be the case in the soil or grass. There should be clear signposting at each access point to remind users to be wary of INNS through the Check Clean Dry campaign.

Physical nets in the water, spanning from the sediment to the surface of the water around the boat launching area, are an effective way of containing any plant INNS that may have been introduced when trailers and boats are initially submerged in the water[8]. Boats can easily manoeuvre over and out of the netted area, leaving any newly introduced plant INNS behind. The netted area can be marked by buoys and signposting on the launching area can instruct boat users how to navigate the netting. Regular surveying of the netted area to check for the establishment of any INNS populations would need to take place to then activate a process of removal. Plant INNS become entangled in the netting and are easily removed when the netting is removed, cleaned and replaced. Netting around the drawdown tower may also be a viable option as this could trap any INNS that are at risk of introduction into the reservoir from the River Thames via the RWT.

Similarly, a **curtain of CO_2 bubbles** around the launching area could be installed through a pipeline embedded in the sediment[19]. CO_2 is unfavourable to most aquatic species and acts as a narcotic for species such as *Dikerogammarus villosus* (Killer Shrimp). The narcotised species will drop from the boat before it is removed from the water[19]. The CO_2 curtain is an effective method of containing INNS in the launching area. This method would also be suitable surrounding the draw down tower where the RWT from the River Thames enters the reservoir.

A9.1.4.2. Boating equipment

Provision of **site owned water sports and boating equipment**, such as kayaks, canoes, wet suits and trailers, would reduce the need for recreational users of the reservoir to bring privately owned equipment[29]. Privately owned equipment is likely to be used in other waterbodies and therefore poses a risk of INNS dispersal from one waterbody to another if not cleaned sufficiently. Logistical consideration would need to be given to storage and security of the equipment.

[28] Gallardo B. and Aldridge DC. (2013). The ''dirty dozen'': socio-economic factors amplify the invasion potential of 12 high-risk aquatic invasive species in Great Britain and Ireland. Journal of Applied Ecology.
[29] Environment Agency (2011a). Biosecurity for boat users [online]. Available at: https://secure.fera.defra.gov.uk/nonnativespecies/downloadDocument.cfm?id=664 . [Accessed 07/12/2020].

Proper equipment care before and after submergence in water is very important in reducing the risk of INNS transfer and dispersal. Aquatic INNS are likely to become lodged or trapped in the equipment and could survive for an extended time if suitably wet conditions are maintained between uses. This provides ample risk for INNS to be transferred between waterbodies. General advice on equipment use/maintenance to reduce the risk of INNS transfer includes:

- Store the **outboard engine and anchor** out of the water when not in use[29]. Aquatic plants can become entangled in the engine and anchor and they may not only be an invasive species but could also harbour other INNS such as mussels[30].
- Small INNS may be harboured in the **standing water** of bilges, bait buckets, kayaks, or canoes, so this must be **emptied** before leaving site[30;29].
- The **engine** should be **run at ¾ throttle** for 5 minutes at the end of use to clear INNS from exhaust system[29].
- **Water cooled systems** should be **washed** through with tap water to dislodge loosely harboured INNS[29].
- When washing down, extra care must be taken to thoroughly clean **hard to reach areas**, the water intake and propeller[29].
- Use of a **propeller bag** to catch any INNS that may drop during transport. Check, clean and dry the propeller bag after each use[29].
- **Check launching trailer and rear of vehicle** for any INNS that may have become attached while launching and landing the boat.

A9.1.4.3. Angling equipment

The third largest reason for INN fish species introductions in North America is the release of live bait and in the UK, 65% of anglers release their surplus live bait into the water[31;32]. It is therefore strongly recommended that the use of **live bait** is **prohibited** in the angling pond and/or reservoir.

Provision of **site owned angling equipment**, such as nets, waders, and rods, would reduce the need for recreational users of the angling pond to bring privately owned equipment[29]. Privately owned equipment is likely to be used in other waterbodies and therefore poses a risk of INNS dispersal from one waterbody to another if not cleaned sufficiently.

Proper equipment care before and after submergence in water is very important in reducing the risk of INNS transfer and dispersal. Aquatic INNS are likely to become lodged or trapped in the equipment and could survive for an extended time if suitably wet conditions are maintained between uses. This provides ample risk for INNS to be transferred between waterbodies. General advice on the use/maintenance of angling equipment to reduce the risk of INNS includes:

- Have **duplicates of clean kit** for different waterbodies[33].
- Anglers should carry **personal cleaning kits** with them (e.g. stiff brush, waterproof gloves, clean water) so they can clean equipment between uses[33]
- When cleaning waders and boots, extra attention must be given to the **seams and seals** of waders and boots and nets. Hang equipment to dry[34].
- If dip net stations are available, these should be used.
- Implementation of Check Clean Dry campaign guidance.

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[30] WRMP19 (2017). WRMP19 Resource Option Development. Raw Water Transfer Feasibility – Update.
[31] Padilla, DK. And Williams, SL. (2004). Beyond ballast water: aquarium and ornamental trades as sources of invasive species in aquatic ecosystems. The Ecological Society of America, 2 (3): 131–138.
[32] Anderson LG., White PCL., Stebbing PD., Stentiford G., Dunn AM. (2014b). Biosecurity and Vector Behaviour: Evaluating the Potential Threat Posed by Anglers and Canoeists as Pathways for the Spread of Invasive Non-Native Species and Pathogens. PLOS one: 9(4).
[33] The Riverfly Partnership (n.d.). Invasive Non-Native Species, and Biosecurity [online]. Available at: https://www.riverflies.org/non-natives . [Accessed on: 07/12/2020].
[34] Environment Agency (2011b). Biosecurity for anglers [online]. Available at: https://secure.fera.defra.gov.uk/nonnativespecies/downloadDocument.cfm?id=492 . [Accessed 07/12/2020].

A9.1.4.4. Aquatic recreational users

All recreational users of the reservoir and angling pond must log in and out of site and confirm on the sign in sheet that they have cleaned and inspected their equipment for INNS before and after use. When cleaning and inspecting, they must implement the Check Clean Dry campaign guidance.

Ask recreational users to familiarise themselves with the aquatic INNS recorded in the local area[29] and report any sightings on site to a member of staff. Provision of photographic evidence and location details should be encouraged, so that any INNS reports can be investigated.

If an invasive crab or crayfish is accidently caught and the water user is able to humanely kill it, they should do so[35]. If unable to kill it or unsure of its identification, then it should be returned to where it was found[35]. Report the sighting as described above.

A9.1.4.5. Events

Events will encourage visitors from outside of the local area to the site which could greatly increase the risk of transfer of novel INNS that are not currently present in the site vicinity. It is therefore recommended that events are **limited in number and scale**. However, if larger events are intended then biosecurity must be highly prioritised to reduce the risk of additional INNS being introduced to the site. The feasibility of this option is low because a reduction in events will have a negative social and economic impact. As with many options a conflict of interest on site is present here and the final decision must carefully consider the functional purpose of the reservoir.

Pathogens are ubiquitous in surface waters, but fish can become more susceptible to disease when they are stressed[36]. Fishing matches are highly stressful events for fish, which in turn could make them more susceptible to disease. Fish are kept in very high densities in nets during these matches which can facilitate disease transmission and increase the chance for mechanical damage which can provide an entry point for disease. As such, events that impose unnecessary stress of the fish should be prohibited and **fish welfare should be prioritised.**

When hosting a water sports event, such as angling or boating competitions, biosecurity measures could be incorporated into the event's management plan. Where possible, provide **site-owned equipment** that could be borrowed for the event[6]. Ask all participants to **ensure that any personal equipment being brought onto site is clean and dry**. **Provide a cleaning station** for any participants that arrive with damp or dirty kit, and for any participants who wish to clean their equipment after the event[6]. Include a **tick box on the sign in/sign out sheet** that confirms thorough equipment inspection and cleaning has taken place before and after the event[6].

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[35] Gov.uk (2020). Invasive non-native (alien) animal species: rules in England and Wales. Department for Environment, Food and Rural Affairs.
[36] Conte, F. (2004). Stress and the welfare of cultured fish. Applied Animal Behaviour Science, 86(3–4), pp.205–223.

Table A9.1-3 – Recreational activity biosecurity measures and scores

Mitigation Method	Asset	Efficacy Score	Feasibility Score	Cumulative Score
Structural				
Physical net around launching area	Jetty, slipway and pier	2	2	4
CO_2 bubble curtain		2	1	3
Aquatic Recreational Activity				
Site owned equipment	Boats and water sports	3	2	5
Prohibit live bait	Angling pond	3	3	6
Events				
Limit size and frequency of events	Angling pond and reservoir	3	2	5

A9.1.5. Raw water transfer

Transfers of raw water are used to help supply and distribute water to other locations through anthropogenic means[37]. RWTs can provide habitat corridors for INNS between areas that are naturally not connected or facilitate increased spread between areas by providing a more direct pathway[38].

Canals provide a bi-directional route of dispersal for INNS, unless artificial barriers to movement are installed[30]. Due to the open nature of a canal, dispersal of INNS may still be quite high even if screens are installed in the water, because recreational users of the canal could still transfer INNS either side of the screen[30].

A9.1.5.1. Preventative measures

Filtration and screening of the water is a commonly used method of preventing transfer of aquatic INNS with movements of raw water. The plans for the pipeline include a **PWWC** (passive wedge wire cylinder) screen at the river intake structure which will exclude fish from the River Thames entering the pipeline. This will be very useful in reducing the likelihood of fish INNS, such as the common carp, which has been recorded in the downstream reach of the River Thames from Culham to Benson (and is therefore likely to be present in the upstream reach too), invading the reservoir via the raw water transfer.

Sand filters are effective in the prevention of small aquatic INNS dispersal as they can trap juvenile stages such as veliger larvae of mussels, if the sand is fine enough[21]. However, fine sand filters may not support high water velocities and veligers of mussels may not be trapped[39]. The filters would need to be regularly checked, cleaned and replaced which would incur high costs and is therefore not a recommended method for INNS control.

An **overhang** to all pipes in the reservoir should be incorporated into the initial design as an overhang can act as a barrier to INNS that may otherwise enter the pipeline. Similarly, the draw down towers should be built with biosecurity in mind, making the surfaces easy to clean, with minimal crevices and ideally coated in a biocidal paint or silicone coat.

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[37] Grant EHC., Lynch HJ., Muneepeerakul R., Arunachalam M., Rodríguez-Iturbe I. and Fagan WF. (2012). Interbasin Water Transfer, riverine connectivity, and spatial controls on fish biodiversity. PlosOne, 7 (issue 3).
[38] Van der Windt HJ. and Swart JAA. (2008). Ecological corridors, connecting science and politics: the case of the Green River in the Netherlands. Journal of Applied Ecology, 45: 124–132.
[39] Xu, M., Wang, Z., Duan, X., Zhuang, M. and De Souza, FT. (2009). Ecological measures of controlling invasion of golden mussel (*Limnoperna fortune*) in water transfer systems. 33rd IAHR Congress: Water Engineering for a Sustainable Environment.

The pipeline could be lined with anti-fouling **biocidal paint**, which is made with toxicants such as tributylin oxide which is known to be detrimental to the environmental and human health[40]. Care must therefore be taken to assess the leaching potential of such a paint in case of causing harm to human health if contact water sports are to take place in the reservoir. However, toxic anti-fouling paints such as these are proven to be successful at preventing organisms from attaching to surfaces[40].

Similarly, a **silicone-based coating** which is non-toxic, can be applied to help reduce the attachment strength of organisms such as mussels[40]. However, this coating is only effective when the water velocity reaches a speed of >20 knots, when sufficient drag is achieved to remove the biofoul[41]. This biosecurity measures is recommended if it can be implemented in conjunction with periodic fast flow events, as described in the operational measures section below.

Mussel Mast'R Aquatic Invasive Species Filter is a pumped filtration system that removes aquatic INNS before the water is moved into ballast tanks[42]. It is a tested alternative to ballast decontamination processes which can be timely and costly. The cost of the equipment is $229, however, replacement filters must be bought for $79 each which would incur a long-term continual cost[43].

A9.1.5.2. Operational measures

Pipelines are a closed system which can allow a greater level of control of INNS entry and exit. However, pipelines can be subject to biofouling by species such as the zebra mussel, which would result in the need for regular maintenance and removal of attached organisms[21]. **Manual cleaning** by wiping, brushing and scraping biofouled surfaces is an effective, but labour intensive, way of removing attached INNS[44]. As pipelines are closed structures manual cleaning is not a viable method of removing INNS from the interior walls and as such this is not a standalone method for controlling biofouling organisms. Nevertheless, manual cleaning of the river intake and the draw down tower, remains a good option for removing biofoulling encrustations, and regular manual cleaning of these structures should be incorporated as part of general site maintenance.

Changes to flow in the transfer pipeline may be a relatively simple and cost-effective method for reducing the spread of aquatic INNS, if changes to the flow programme are approved by the administrator. Periodically **stopping the flow of water** and allowing the pipe to fully dry out would kill any aquatic INNS that have entered the pipe[28]. This could be planned for seasonal periods where little or no water transfer is required. Water transfers could also be planned to **coincide with non-reproductive seasons** of key INNS, so as to reduce the dispersal of the INNS when propagule pressure is raised[30]. As the purpose of the RWT from the reservoir into the River Thames is primarily to support river flow in the Thames, choosing to halt flow because of an active INNS reproductive season is unlikely to be viable and is therefore not recommended.

Another method to help prevent biofouling of the pipeline would be to **transfer the water at a high velocity**[21]. This method is not suitable for long distance transfers[39], but as this pipeline is planned to be relatively short, at 3340 m long between the river intake structure and the pumping station, this may still be a feasible option. Zebra mussels are well adapted to natural high velocities, dominating over quagga mussel populations in velocities of up to 180 cm/s[45]. Both zebra and quagga mussels synthesize byssal threads in order to attach to substrates in flowing water, although zebra mussels have been found to produce a greater number of these threads, allowing them to colonise habitats with higher velocities[45]. At 180 cm/s just 13% of zebra mussels are dislodged, compared to 68% of quagga mussels[45]. Therefore, a velocity of at least 180 cm/s in the pipeline would be required to periodically flush out some attached zebra and quagga mussels. Periodic fast flow through the pipeline would need to be agreed upon with water resource management and the applicability of this measure in the proposed pipeline for SESRO may not be possible. As such this has not been recommended further but may be of interest for further internal discussions.

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[40] Daffron, KA., Lewis, JA. and Johnston, EL. (2011). Antifouling strategies: History and regulation, ecological impacts and mitigation. Maine Pollution Bulletin 62, pp. 453–465.
[41] Srinivasan, M. and Swain, G. (2007). Managing the use of copper-based antifouling paints. Environ. Manage. 39, 423–441.
[42] Middlebrook D. (2014). Tech innovation makes waters safer from aquatic invasive species [online]. Available at: https://www.trpa.org/tech-innovation-makes-waters-safer-from-aquatic-invasive-species/ [Accessed on: 12/03/2020].
[43] Wake Worx. Online Shop – Mussel Mast'R. Available at: https://wake-worx.com/shop/mussel-mastr/ [Accessed on: 02/12/2020].
[44] Gule, NP., Begum, NM. and Klumperman B. (2015). Advances in Biofouling Mitigation: A Review. Critical Reviews in Environmental Science and Technology.
[45] Peyer, S., McCarthy, A. and Lee, C. (2009). Zebra mussels anchor byssal threads faster and tighter than quagga mussels in flow. Journal of Experimental Biology, 212(13), pp.2027–2036.

An overview of the mitigations measures that could be implemented in the pipeline are presented in Table A9.1-4 below.

Table A9.1-4 – RWT biosecurity measures and scores

Mitigation Method	Efficacy Score	Feasibility Score	Cumulative Score
Preventative measure			
Sand filters	3	2	5
Pipe overhang	2	3	5
Biocidal paint	2	1	3
Silicone-based coating	2	2	4
Mussel Mast'R Aquatic Invasive Species Filter	3	1	4
Operational measure			
Stopping flow to dry out the pipeline	2	2	4

A9.1.5.3. Water treatment

There are several water treatment options specifically designed to reduce and/or prevent bivalve colonisation.

Coagulation treatment promotes clumping of finer particles in the water, including the veligers of mussel INNS[46]. Subsequent **flocculation** removes the clumped veligers from the water. However, this method does not kill the veligers, and the waste produced must therefore be disposed of appropriately and in a way to ensure that the veligers are not re-introduced into the water system. The treatment of the water in this way, either in the pipeline or in the reservoir itself, may not be suitable due to the high level of aquatic activities proposed for the site and because the floccs are unsightly.

Chlorination of the water is a common method of killing bivalves such as zebra mussels. Chlorination is achieved using substances such as hypochlorite, chlorine gas or chlorine dioxide[47]. Although effective, it poses a health risk to humans and non-target species, can take several days to work and is corrosive to submerged equipment and surfaces[47]. Mussels can also detect chlorine in the water and close their valves in response to it, so this method is not 100% effective.

Some novel mussel control methods that claim to be environmentally safe to use are now widely available. **BioBullets** are one such method, whereby potassium chloride, a chemical harmful to mussels but not to most other organisms, is encapsulated by a food substance which is readily eaten by mussels[16]. The ingested chemical eventually leads to death. This method relies upon the bioconcentration effect, so a relatively small concentration of the active ingredient is required[16]. BioBullets also dissolve after a few hours in the water, reducing the risk of long-term environmental pollution effects[16].

Zequanox is another purportedly safe alternative to chemical control of zebra mussels and quagga mussels[47]. It is made of dead *Pseudomonas fluorescens* cells that are ingested by mussels and subsequently kill them. Applications of Zequanox require 6–8 hours[47]. Repeat applications would incur repeat costs.

[46] Mackie GL. and Kilgour BW. (1995). Efficacy and role of alum in removal of zebra mussel veliger larvae from raw water-supplies. Water Research 29, 731–744.
[47] Rackl SM. (2013). Controlling invasive mussels [online]. Available at: https://www.waterpowermagazine.com/features/featurecontrolling-invasive-mussels/ [Accessed on: 12/03/20].

Table A9.1-5 – Water treatment biosecurity measures and scores

Mitigation Method	Efficacy Score	Feasibility Score	Cumulative Score
Coagulation and flocculation	2	1	3
Chlorination	2	1	3
BioBullets	2	2	4
Zequanox	2	2	4