SMITH BAY WHARF

DRAFT ENVIRONMENTAL IMPACT STATEMENT

APPENDIX H

PREPARED FOR KANGAROO ISLAND PLANTATION TIMBERS BY ENVIRONMENTAL PROJECTS

JANUARY 2019

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APPENDIX **H**

APPENDIX H – AQUACULTURE STUDIES

Appendix H1 – Assessment of Risks to the Yumbah Aquaculture Facility and Proposed Mitigation Measures – Professor Anthony Cheshire

Assessment of risks to the Yumbah aquaculture facility from the construction and operation of the proposed KI Seaport and proposed mitigation measures

Prepared for

Kangaroo Island Plantation Timber Pty Ltd

By

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Science to Manage Uncertainty

Adelaide, South Australia.

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Disclaimer:

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Glossary and Abbreviations

Term	Definition
actual FCR see also 'effective FCR'	The FCR (see below) as measured in a laboratory where controlled conditions account for wastage, un-eaten food and where other losses cannot occur. This measure tells us more about the nutritional value of the food that is eaten rather than about the commercial reality of the production outcomes.
aquaculture	Farming of aquatic organisms for the purposes of trade or business or research but does not include an activity declared by regulation not to be aquaculture.
aquaculture - equipment	Includes: 1. a farming structure; or 2. equipment used to anchor or indicate the presence of farming structures; or 3. a barge used to feed aquatic organisms; or 4. equipment used to mark-off or indicate the boundaries of a licence area; or 5. other equipment used for the purposes of aquaculture.
aquaculture - farming system	A term that refers to the way in which farming is conducted and includes but is not limited to: 1. Flow-through systems where water is extracted from the environment (e.g. the ocean, a river, creek, stream or bore) and then flows through the operation before being discharged back to the environment; 2. Re-circulation system where water is circulated through the farming system and then treated (e.g. filtered, sterilized) before being sent back through the farming system. 3. Intensive farming where animal density is kept high requiring a high level of attention to husbandry, feeding, disease control. 4. Extensive farming where animal densities are lower and farming may be conducted with no (or only a small amount of) external inputs such as food. This list cannot be exhaustive as novel farming systems are continually being developed and modified.
aquatic organism	Any species that lives some or all of its life in water, and includes the reproductive products and body parts of the organism.
DAC	Development Assessment Commission
DEWNR or DEW	SA Department of Environment, Water and Natural Resources SA Department of Environment and Water
discharge to State Waters	Release of waste or used water into State Waters. In the context of this review this includes the release of waters from an aquaculture farm into any water body that is defined as State Waters.
ecologically sustainable development	An activity that is managed to ensure that communities provide for their economic, social and physical well-being while: 1. natural and physical resources are maintained to meet the reasonably foreseeable needs of future generations; and 2. biological diversity and ecological processes and systems are protected; and 3. adverse effects on the environment are avoided, remedied or mitigated.
effective FCR	The FCR as measured in a farming situation where total feed input is measured against total animal production. This measure includes food that is wasted, not eaten, or, in sea-farms, eaten by other animals. It is the best measure to use in assessing farm management.
EMP	Environmental Monitoring Program as defined in the Aquaculture Regulations (2016).

Term	Definition
environment	Means land, air, water, organisms and ecosystems, and includes: 1. human-made or modified structures or areas; 2. the amenity values of an area.
environmental harm	Any harm or potential harm to the environment (of whatever degree or duration) and includes: 1. an environmental nuisance; 2. anything declared by regulation (after consultation under section 5A of the *Environment Protection Act 1993*) or by an environment protection policy to be environmental harm.
environmental management system	A systematic approach to dealing with the environmental aspects of an organisation's operation; a 'tool' that enables an organisation of any size or type to control the impact of its activities, products, or services on the natural environment.
environmental nuisance	Under the *Environment Protection Act 1993* an environmental nuisance means: (a) any adverse effect on an amenity value of an area that— (i) is caused by pollution; and (ii) unreasonably interferes with or is likely to interfere unreasonably with the enjoyment of the area by persons occupying a place within, or lawfully resorting to, the area; or (b) any unsightly or offensive condition caused by pollution;
EPA	South Australian Environment Protection Authority
ESD	See Ecologically Sustainable Development
exotic species	A species which does not naturally occur in the location where aquaculture is being conducted (e.g. pacific oyster or other imported species) but may also include species which, while native to South Australia, are not naturally found in the area where they are being farmed.
farming of aquatic organisms	An organised rearing process involving propagation or regular stocking or feeding of the organisms or protection of the organisms from predators or other similar intervention in the organisms' natural life cycles.
farming structures	Structures used for the farming of aquatic organisms and land based infrastructure including hatcheries or raceways but also includes sea cages and racks, longlines and submerged lines used for aquaculture, together with their associated baskets, barrels, lanterns and other culture units.
FCR	Food Conversion Ratio – reported as the ratio of the amount of food fed to fish divided by the amount of the total fresh-weight of product. Typical values might be around 1.0 to 3.0. This implies that between 1.0 to 3.0 tonnes of feed is required for every tonne of product (whole live weight). Note that this is not reported as dry matter input over dry matter production; pelleted feeds, in particular, are typically low in moisture content and the product is weighed fresh (i.e. with a high moisture content) so it is technically possible to get values of less than 1.0 (i.e. produce more than 1 tonne of product for every tonne of food) but only under very tight management arrangements and when using an optimal feed formulation.
FRDC	Fisheries Research and Development Corporation
FTE	Full Time Equivalent – assumes full time is 37.5 hours per week e.g. 0.5 FTE is working half-time.

Term	Definition
general environmental duty	Means that a person must not undertake an activity that pollutes, or might pollute, the environment unless the person takes all reasonable and practicable measures to prevent or minimise any resulting environmental harm as per Part 4 of the *Environment Protection Act 1993*.
KIPT	Kangaroo Island Plantation Timber Pty Ltd
notifiable disease	Under the *Livestock Act 1997,* there are a number of diseases of aquatic organisms that, when suspected by owners, licence holders, vets or laboratories must be reported to an Inspector of Livestock within a defined timeframe.
PIRSA	Primary Industries and Regions South Australia, Fisheries and Aquaculture Division
PER	Public Environmental Report
risk	A probability or threat of damage, injury, liability, loss, or any other negative occurrence that is caused by external or internal vulnerabilities, and that may be avoided through preemptive action.
risk - environmental risk	Actual or potential threat of adverse effects on living organisms and environments by effluents, emissions, wastes, diseases, exotic escapes, resource depletion, etc., arising out of an organization's activities. In the context of this study relating to the conduct of a development.
risk – inherent risk	The probability of loss arising out of circumstances or existing in an environment, in the absence of any action to control or modify the circumstances. In the context of this study the environmental risk present without taking account of any risk management strategies or other practices.
risk - residual risk	Exposure to loss remaining after other known risks have been countered, factored in, or eliminated. In the context of this study the environmental risk present after taking account of the risk management strategies and practices adopted to manage the development and acknowledging the nature (ecological and environmental values) of the receiving environment.
TEPS	Threatened endangered and protected species: generally considered to be species of conservation significance that warrant attention during any environmental risk assessment.

1. Executive Overview

1.1. Background

The export of harvested timber directly to markets overseas requires the development of a deep-water wharf on Kangaroo Island. The KI Seaport would be capable of handling the Panamax Bulk Carriers of up to 60,000 deadweight tonnes (DWT) and having a draft of 11.75 metres. Once established, KIPT expects that the wharf will be used for 30-75 days per annum for timber exports, which will be sufficient for the sustainable yield of the entire Kangaroo Island forestry estate, including trees owned by other parties. Based on current plantation species and yields, this equates to between 10 and 20 shipments a year in perpetuity.

The construction and operation of the KI Seaport will present a number of potential risks to the land-based abalone aquaculture facility that operates on the land adjacent to the site of the Seaport development. These risks need to be identified, evaluated and, where appropriate, management and mitigation strategies need to be developed and implemented.

1.2. Scope of work required

The work presented in this report aims to consider the extent to which the proposed development is likely to impact on the operations of the Yumbah Kangaroo Island Pty Ltd land-based abalone farm at Smith Bay. The key issues considered include:

1. Impact of increased suspended sediment loads and other water quality impacts, generated from both the construction and operation of the Seaport, on the seawater supply to the abalone farm.
2. Effects from atmospheric deposition of dust and sediment from construction and operational activities of the KI Seaport.
3. Effects of extraneous light from the construction and operation of the KI Seaport facility on the abalone farm
4. Effects of noise and vibration from the construction and operation of the KI Seaport facility on the abalone farm
5. Impacts of changes in coastal processes, associated with the establishment of a causeway perpendicular to shore, on the seawater supply to the abalone farm.

1.3. Approach

Results from a suite of technical studies (sediment composition, hydrodynamic modelling, and ambient water quality monitoring) were analysed in context with a detailed review of the scientific literature concerning the biology (ecology, physiology and life history) of abalone. The focus of the analysis was to understand the tolerance and vulnerabilities of abalone, in an aquaculture environment, to the potential impacts from the construction and operation of the proposed facility.

1.4. Conclusions

The capital dredging program has the potential to affect water quality, principally suspended sediment loads, at the Yumbah seawater intakes under some dredging scenarios. While abalone are more resilient to suspended sediments than a number of other aquaculture species, having evolved to inhabit environments that routinely see them exposed to high levels of suspended sediments, the construction and operational activities will need to be managed to ensure that water quality at the Yumbah seawater intakes is protected. Suspended sediment loads should be managed to ensure that they do not exceed 25 mg/L (99th percentile) with median levels (50th percentile) not exceeding 10 mg/L. To achieve this outcome the capital dredging program would require a dredge management plan that would incorporate both pro-active management of dredging activity around tidal cycles (e.g. avoidance of dredging during dodge tides) along with real time monitoring of *in-situ* turbidity, with appropriate turbidity thresholds (25 mg/L) to trigger management interventions.

There are not likely to be any substantive issues from noise and vibration, light spill or air-borne dust on the operations of the abalone farm.

The study also concluded that land-based abalone farms in South Australia are particularly vulnerable to climate change impacts that have resulted in increased sea water temperatures. It should be noted that the predicted changes in coastal processes associated with the causeway may result in a very slight increase in water temperature at the Yumbah seawater intakes (maximum effect less than 0.1^{O}C). Such an increase may provide benefits during winter but may increase the risk of summer mortality events. While this potential increase in temperature is unlikely to be detectable, particularly against the existing background of climate change induced changes to seawater temperature, mitigation strategies (e.g. culverts through the causeway) should be considered as part of the design criteria.

The analysis also highlighted potential benefits from the creation of the causeway. Discharges from Smith Creek currently impact on water quality in Smith Bay but the construction of a solid causeway (possibly with a gated culvert) would likely provide ancillary benefits to the aquaculture farm by directing the Smith Creek discharges further offshore. This would reduce the extent to which the discharges mix with the intake water flowing onto the abalone farm and thereby compromise animal health.

2. Background to the KI Seaport development

2.1. Overview of the port development proposal

Kangaroo Island Plantation Timbers Ltd (KIPT) controls approximately 25,500 ha of land on Kangaroo Island. Around 23,000 ha (90%) is planted with hardwood species (Blue gum, *Eucalyptus globulus* and Shining gum, *Eucalyptus nitens*) and 2,500 ha (10%) with softwood (Monterey pine, *Pinus radiata*). Being older, the softwood estate represents about 19% of the Company's standing timber. KIPT also owns land at Smith Bay considered suitable for a deep-water timber export facility.

KIPT's standing timber assets on the Island currently exceed 3.6 million tonnes and are expected to grow to at least 5.4 million tonnes by the time harvest operations commence. The KIPT resource is sufficient to establish a sustainable plantation forestry industry on the Island based on the export of timber products (i.e. sawlogs, peeler logs and woodchips) to markets in Asia.

The export of harvested timber directly to markets overseas requires the development of a deep-water wharf on Kangaroo Island. The KI Seaport would be capable of handling the Panamax Bulk Carriers of up to 60,000 deadweight tonnes (DWT) and having a draft of 11.75 metres. Once established, KIPT expects that the wharf will be used for 30-75 days per annum for timber exports, which will be sufficient for the sustainable yield of the entire Kangaroo Island forestry estate, including trees owned by other parties. Based on current plantation species and yields, this equates to between 10 and 20 shipments a year in perpetuity.

2.1.1. Pontoon wharf, causeway construction and dredging operations

The KI Seaport (conceptual layout shown in Figure H-1) would consist of a pontoon wharf, held in place by restraint dolphins – piled steel structures that extend above the water level and are not connected to shore. The pontoon wharf would be 168 metres long and 41 metres wide, with additional mooring structures provided for vessel head and stern lines. The berth face of the wharf would be positioned approximately parallel to shore along the 11.5-metre water depth contour. The approaches will be dredged to a depth of up to 13.5 metres to safely accommodate fully-laden Panamax vessels in a range of sea conditions.

The wharf would be accessed from land by an approach consisting of a solid rock armoured causeway and suspended jetty deck structure which connects the approach to the pontoon via a linkspan bridge at its seaward end.

2.1.2. Land-based infrastructure and activities

The on-shore timber storage area would be divided into two terraces to provide around 4.1 ha of flat space on the otherwise gently sloping site. This arrangement would be used to stockpile up to 56,250 tonnes of logs within the southern storage area (equal to around 150 per cent of maximum anticipated vessel capacity) and up to 80,000 tonnes of woodchips in the northern storage area. The southern storage area may also be used to store bulk agricultural cargo such as grain, and general container cargo destined for export in periods when logs were not being shipped in large quantities. The maturity profile of the timber estate means that there will be several years when there are few, if any, log exports and other years in which only a limited quantity of logs will be handled, so that it is expected that the log storage area will be available, when needed, for other cargoes.

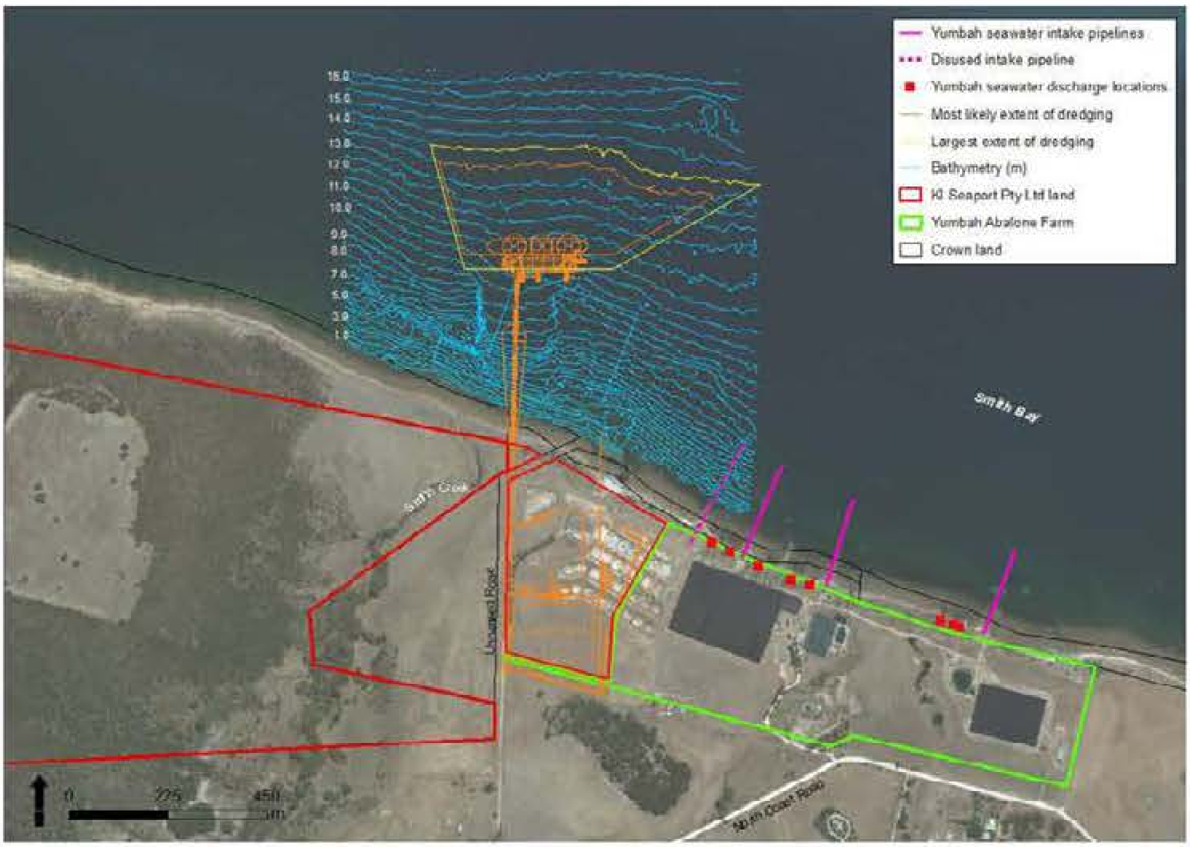


Figure H-1: Proposed layout for the wharf development and log storage areas. Note also the covered areas towards the lower right of the image which are the shade-mesh covered raceways and holding tanks belonging to the Yumbah abalone farm.

2.2. EIS requirements for the development of the facility

On 16 February 2017, the Minister for Planning ('the Minister') declared the deep-water port facility at Smith Bay on Kangaroo Island to be assessed as a Major Development pursuant to Section 46 of the Development Act 1993 (the Act) (published in the Government Gazette on 23 February 2017). Section 46 of the Act ensures that matters affecting the environment, the community or the economy to a significant extent, are fully examined and taken into account in the assessment of this proposal.

The Development Assessment Commission (DAC) has set the level of assessment for the development to be an Environmental Impact Statement (Assessment) and has developed Guidelines (DAC 2017) for the preparation of the assessment document.

Due to the nature of proposal, the sensitivity of the receiving coastal and marine environment and potential impacts on the adjacent aquaculture industry, the EIS guidelines (DAC 2017) have specifically identified a critical need for a study on the potential impacts of construction and operation of the development on aquaculture in the region. In the case of Smith Bay this comprises a single commercial operation, the land-based abalone farm owned and operated by Yumbah Kangaroo Island Pty Ltd (Figure H-1).

The EIS guidelines have specifically identified a number of issues that need to be addressed (Table H-1). This report looks at the construction and operational aspects of the KI Seaport and outlines how these may impact on the Yumbah aquaculture operation as well as providing recommendations on appropriate management or mitigation strategies.

This report does not attempt to provide an analysis of the economic or social aspects of this matter.

Table H-1: Issues relating to aquaculture that have been identified in the EIS guidelines(DAC 2017) and addressed in this report.

No	Guideline
N/A	A description of the current commercial activities occurring in the area and marine environment (including land-based aquaculture and fisheries activities)
2.7	Outline impacts that dredging may have on sediment loads and the neighbouring commercial land-based aquaculture operation. Detail measures for managing these impacts, including management of dredge spoil.
2.9	Describe the contaminants and toxicants that may accumulate on the property and the risks during stormwater events (where not managed) to the adjacent aquatic environments and commercial industries (e.g. fisheries and aquaculture) that rely on those environments.
2.13	Describe the impact of dust emissions on the nearby aquaculture industry and identify mitigating measures that will be used to manage these impacts.
2.14	Describe the potential impacts of increased shipping traffic and activities in Smith Bay from offshore anchoring, transhipment or pilotage (especially on marine fauna, water quality, recreational activities and amenity), including effects on commercial aquaculture activities in the region.
2.19	Identify any possible changes to the seabed, bathymetry, sedimentary profiles (including particle sizes), and sand movement water flow and tidal movement patterns as a result of the development during both the construction and operational phases (include information on potential pooling of water upstream from the proposed causeway). Identify the impacts this may have on sensitive marine flora and fauna (including seagrasses, macro algae and other reef habitat), and commercial aquaculture activities in the region, and outline mitigation strategies.
2.20	Identify the risks from the exposure of fine sediments or clays that would impact adversely on water quality (turbidity and light penetration) and contribute to the production of sediment plumes in the region during both construction and operation phases. Outline the impacts this may have on commercial aquaculture activities in the region.
2.21	Describe, and provide baseline information on, the level of oceanic connectivity between the proposed development site and the intake areas used by commercial aquaculture ventures in the region (include observed information from hydrodynamic and coastal process modelling undertaken for a minimum of 6 months) and identify the impacts that the construction and use (including ship movements) of the proposed in-sea components of the proposal will have on this connectivity.
2.22	In addition to the above, outline all other potential impacts on the nearby commercial aquaculture ventures, their likelihood and severity, and identify mitigation measures that will be used and their effectiveness (include efficiency reports on silt curtains and sand filters if proposed).
4.13	Describe the impacts (economic, social & environmental) of use of the upgraded public boat ramp. Outline potential users, the impacts expected from increased public access to and use of Smith Bay (including on the water quality in relation to the existing aquaculture operation in the vicinity). Describe measures that will be undertaken to mitigate these impacts.
5.2	Outline the impacts of dust and/or particle generation on the existing commercial operations and any other identified nearby sensitive receivers in the vicinity of the proposed development, in particular the existing abalone farm.

3. Overview of Abalone Aquaculture at Smith Bay

3.1. Introduction

Abalone (*Haliotis* spp.) aquaculture in Australia began in the late 1980's and has since grown to an industry with a gross value of production of $28.7 million (FY2016) comprising a production volume of 757 tonnes (representing an 11% reduction in national production from the previous year; ABARES 2017). Around 50% of this production comes from South Australia ($14.7 million, 350 tonnes representing a 5% increase in volume from the previous year; ABARES 2017).

The most common production platform used in Australia consists of a land-based grow-out system using flat concrete raceways (slab tanks; Figure H-2) which provide an artificial habitat for animals to live on. It generally takes total of 3 (and sometimes up to 4) years to grow animals to market size (shell length of around 100 mm) and animals need to be carefully husbanded throughout this period; this includes the provision of food (generally manufactured pellets) and fresh sea water (pumped in from the sea).

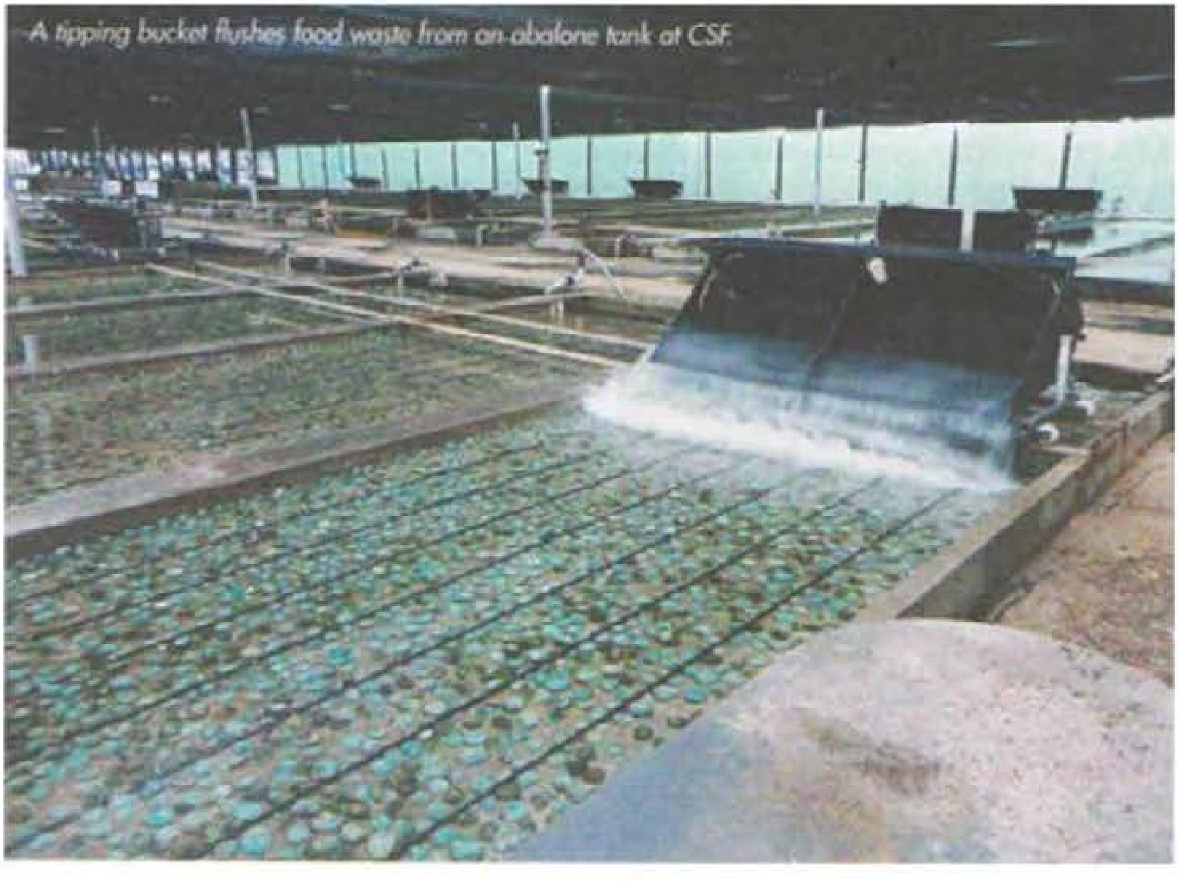


Figure H-2: Image from Austasia Aquaculture (winter 2013) showing raceway with abalone distributed along it and a "tipper" sending a pulse of water down the raceway. The tipper is used on some farms help clean the raceway by mobilising waste material.

A typical abalone farm will have four major systems:

1. A broodstock holding system where mature adult abalone are held for breeding purposes.
2. A hatchery where larval abalone are produced.
3. A nursery where juvenile (post-larval) abalone are raised (typically to 15-20 mm in shell length).
4. A grow-out area (see e.g. Figure H-2) where abalone are grown out to market size (typically 80-120 mm in shell length).

3.2. The importance of water

Any on-land abalone production system is fundamentally dependent upon the provision of an adequate supply of seawater with appropriate quality characteristics particularly in terms of temperature, salinity and nutrient status (Heasman and Savva 2007; Yumbah 2018). This water is pumped throughout the farm, to provide oxygen to abalone, but also to carry away waste materials. Oxygen is critical to support life through respiration; abalone cannot breathe air directly and can only obtain oxygen by gas exchange (uptake of oxygen and release of carbon dioxide) through the gills. Waste materials including unconsumed feed, exudates and faeces are discharged into the water and then washed back into the sea.

Across any farm (except for the hatchery system which generally operates on a recirculation or static system) water is provided by continuous pumping from the sea. The influent water comes in at a rate which will vary depending on farm size (typically between 400 to 2,000 L/s) and this water needs to flow 24 hours per day, 365 days of the year. Pumping at a rate of 2,000 L/s is the equivalent of around 70 Olympic sized swimming pools of water flowing through the farm every day.

Pumping water is necessarily a major cost for farms hence most farms are situated on land that is only a few metres above sea level and in areas with access to a good supply of cool (14-20 ^{O}C) well oxygenated seawater. Most farms pump seawater using mains connected electric pumps, but all farms will also have either diesel pumps or diesel generators to back-up the main system. Pumping water is therefore a major cost for any land-based abalone farm and, while we don't have data for this particular farm, Yumbah (2018) suggest that typical energy usage for a well-designed farm is likely to be around 10 MWh/tonne/annum (or around 1GWh per year for a 100 tonne production facility). Costs are entirely dependent on the nature of the supply (e.g. grid connected vs self-generated) but key determinants of pumping costs are:

1) Supply type including whether diesel or electric pumps are used,
2) Volume of seawater being pumped,
3) Operating head (height above sea level) of the highest point on the farm,
4) Level of fouling in pipes (fouling increases friction and reduces flow rates requiring more pumping pressure to maintain volumes).

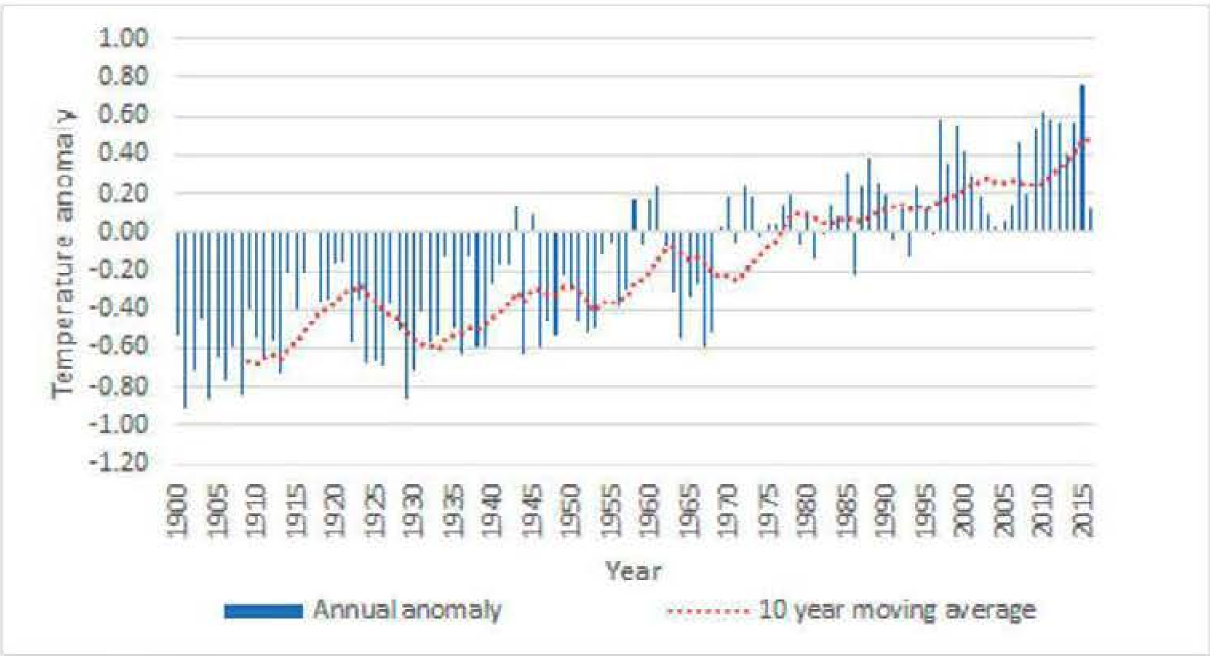
Temperature of the influent water is also important in that it is a key determinant of the volume of water that needs to be pumped; when ambient temperature is above 20^{O}C pumping rates may increase by up to 25% to ensure effective supply of oxygenated water at the lowest temperature possible. Typically, water will increase in temperature as it moves around the farm. Increases may be in the order of 2^{O}C from inlet to delivery to the slab tanks, this can be modulated to some extent by increasing the pumping rate, burying pipes to reduce exposure to direct sunlight or insulation of pipes against ambient air temperatures.

If water stops flowing through a farm, abalone may begin to die within a matter of 20-30 minutes and catastrophic mortalities may occur if flow is not restored within an hour. Consequently, many farms have multiply redundant systems so that the failure of one pump or breakage or blockage of a pipe cannot cause such catastrophic failures in the supply of water to the whole farm.

The piping systems, which conduct water around farms, must be kept free of internal obstructions (such as the growth of filter feeding shellfish, sponges or other sessile invertebrates inside the pipes) thereby minimizing frictional drag which will both increase pumping costs and compromise water quality by reducing oxygen or elevating levels of wastes such as ammonia in the influent water.

Most farms cannot use any on-land storage of water, the volumes required are simply too high to allow effective storage and any storage system is likely to exacerbate problems of water heating particularly during summer[1]. As noted above a single Olympic sized swimming pool would provide storage for about 15-20 minutes operation.

A major risk to the abalone aquaculture industry in South Australia is from the ongoing increases in water temperature as a result of climate change (Doubleday *et al.* 2013). Seawater temperature is rising consistent with overall patterns of global warming and in southern Australia is currently about 0.8 ^{o}C above the 1960-1990 average or about 1.2^{o}C since the early part of the 20^{th} Century (Figure H-3).



One aspect of this rise in temperature is that the capacity for water to hold oxygen (which abalone need to support life) decreases as the water temperature increases (Figure H-4). On hot days, the water cannot hold as much oxygen and therefore may not be sufficient to meet the respiratory requirements of animals which may then die.

To illustrate the implications of this change, a farm with a standing stock of 135 tonne (similar to the Yumbah KI operation) and a pumping volume of 2000 L/s would typically see a reduction in

[1] Notwithstanding, Yumbah (2018) do make provision for a reserve water system in their design documentation for a new facility in Victoria however the practical implementation of such a design is yet to be tested on a commercial abalone farm in Australia.

oxygen content of the influent water from 7.52 mg/L (at 19°C) down to 6.75 mg/L (at 25°C). If one then assumes an oxygen consumption rate of 90 mg/kg/h (typical for abalone; Burke *et al.* 2001) this would result in a reduction in the oxygen concentration as the water moves through the farm by around 2 mg/L. Under the warmer conditions this represents a 30% reduction in available oxygen and would likely cause oxygen stress to those abalone at the downstream end of the raceways. One response to this issue is for farms to increase the rate at which seawater is pumped in order to try and get more water flowing down each raceway (providing more oxygen and reducing the propensity for water to warm during transit through the farm) but the capacity to do this is limited by both the available pumping capacity (which is generally configured to meet the normal daily demand and not these more extreme conditions) compounded by the impact of additional pumping on the cost of farming operations (although a mass mortality due to heat stress is likely to be more costly than the cost of pumping per se).

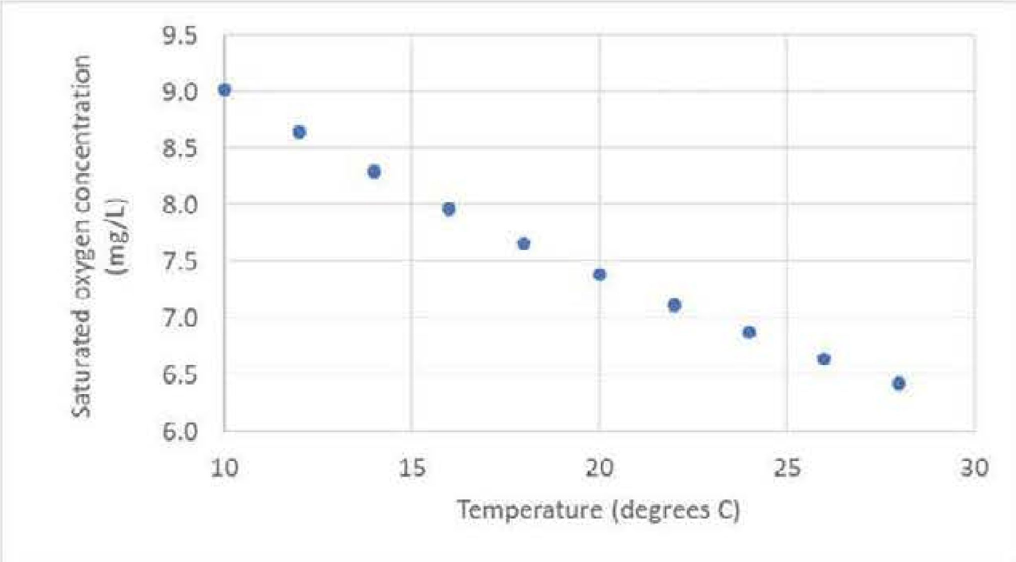


Figure H-4: Change in the saturated oxygen concentration of water as temperature increases. This demonstrates that as water temperature increases the amount of oxygen it can hold without becoming super-saturated will decrease. This will reduce the amount of oxygen available to animals to support their respiratory requirements.

One of the fundamental problems with abalone aquaculture is that abalone, particularly when they reach their 3rd year of life, tend to experience substantially higher rates of mortality associated with incidents of high summer temperatures. Over the last 25 years, abalone farms in South Australia have been known to lose as much as 20-25% of their entire stock in a single day when extreme summer temperatures cause elevations in water temperature on the raceways. Vandepeer (2006; referencing Gilroy and Edwards 1999 and Madigan *et al.* 2000) reported that green lip abalone had a 50% critical thermal maximum of 27.5°C but that farms across South Australia report substantial mortality events at much lower temperatures (22-23°C; Vandepeer 2006). Notably, in 2012/2013, the Kangaroo Island farm experienced losses of 50% of all animals in a growth trial under conditions of elevated temperatures (Stone *et al.* 2014).

Recent work has started to reveal a genetic basis for temperature mortality and resilience suggesting that this issue may be addressed through breeding programs (Shiel *et al.* 2017). Notwithstanding, most farms in South Australia are currently vulnerable to summer mortalities (van der Peer 2006, Doubleday *et al.* 2013) and this presents a fundamental risk to the industry particularly as climate change has already resulted in substantial increases in sea-surface temperatures in southern Australia (Bureau of Meteorology; Figure H-3)

While summer mortality is not fully understood there are likely to be many other factors that contribute including, as noted above, reductions in the oxygen holding capacity of water but there is also evidence of substantially increased disease susceptibility at higher temperatures. In addition to direct impacts from increases in temperature there is potential for ocean acidification (an additional impact from global climate change) to impact on ammonia oxidation rates in marine systems (Kitidis *et al.* 2011; Beman *et al.* 2011). Given the results from the work by Vandepeer (2006) which indicates a potential interaction between temperature and ammonium levels on increasing summer mortality rates this suggests that there are even greater risks to the future of the industry in South Australia that will not be resolved simply by addressing temperature sensitivity in isolation.

In summary, the importance of good water quality to the health of the abalone aquaculture sector cannot be understated and the very real risks of global climate change to this industry need to be addressed if the industry is to survive into the future. On current trends the future viability of the industry is clearly threatened by rises in summer water temperature and ocean acidification (Doubleday *et al.* 2013) and unless a substantial improvement in temperature tolerance of cultivated abalone can be achieved the viability of the South Australian industry will be at risk over coming years.

3.3. Feed requirements

The second major cost on a farm is food. Despite commentaries around the importance of diatoms in the early life-history phases (e.g. McShane 2017), the principle source of food for animals across the bulk of their life on a farm is from manufactured feeds in the form of dried (15% moisture content) pellets. These feeds are highly nutritious and a typical Food Conversion Ratio (FCR) is around 1.2 – 1.5 :1 (or 1.2 to 1.5 tonne of feed to produce 1 tonne of abalone). With current feed costs of around $2,500 per tonne this would imply a feed cost for a farm with 135 tonnes of production per year in the order of $400,000 - $500,000 per annum[2]. It is not unusual however for growth to stall due to various stresses on farms (temperature impacts, disease challenges, system failures, etc.) and the effective FCR may therefore be higher[3].

Additional information on the feed requirements for juvenile (nursery stage abalone) is discussed below (Section 3.4.3 Nursery).

3.4. Key farming systems

3.4.1. Broodstock holding system

The production system starts with the breeding adults (broodstock), which are animals that have either been collected from the wild or selected from existing farm stock. These animals must be capable of producing viable eggs (females) or sperm (males).

Most abalone farms hold prime breeding stock (broodstock) in a series of specially constructed tanks or troughs that isolate them from the rest of the farm to minimize the risk of disease transfer from farmed animals. The tanks are supplied with a constant supply of fresh seawater that flows through the tank thereby ensuring a ready supply of oxygen for the animals.

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[2] Noting that Yumbah operate their own feed production through Eyre Peninsula Aquafeeds and a newly opened plant at Lonsdale this is still a useful number to use for the purposes of transfer pricing arrangements.

[3] Yumbah (2018) report effective FCR's of around 1.45:1.

Broodstock are fed on manufactured feed pellets (the same as for the animals on the grow-out raceways).

Broodstock are selected on the basis of desirable traits including growth rate, temperature tolerance and disease resistance. Many farms operate breeding programs to manage broodstock selection. Broodstock represent the "stud" potential of the farm in that they are used to produce the larvae which can then be grown on as commercial stock.

3.4.2. Hatchery system

Abalone are broadcast spawners and comprise separate male and female animals. Females may release up to 2 million eggs in a single spawning event.

Male and female animals are placed in large aquaria or tubs with filtered, UV sterilized, oxygen rich seawater. They are stimulated to release their gametes using a variety of techniques including manipulation of light and temperature. Gametes are checked for their fitness and then sperm and eggs (male and female gametes) are mixed to achieve fertilization. Once fertilised the abalone larvae may remain suspended in the water column for 24 to 72 hours.

Abalone larvae are lecithotrophic which means that they do not feed during the larval stage but rather they rely upon the yolk-sack for nutrition.

Mortality during the larval phase can be high (30-90%) but because many millions of larvae can be produced this is not generally problematic and farms can normally produce many times more larvae than they will actually need to provide for restocking.

3.4.3. Nursery

The nursery comprises a series of tanks with a continuous supply of flow-through seawater, in which the nursery plates are held. Abalone larvae are introduced to the nursery tanks and allowed to settle onto the plates. Settlement and attachment to substrate will occur quickly (within a couple of hours) but metamorphosis of the larvae into something that is recognizable as a juvenile abalone (i.e. a tiny marine snail) will typically take a number of days to complete.

In an aquaculture environment, the larvae are encouraged to settle onto appropriately conditioned surfaces, typically comprising PVC plastic sheets ("nursery sheets" or "plates") that have been inoculated with a film of diatoms (microalgae). These nursery plates are mounted vertically in tanks of filtered seawater (ideally filtered to 10 µm; Heasman and Savva 2007) see right hand panel (Figure H-5).

The production of these plates generally occurs in tanks fed with filtered seawater to which fertilisers may be added to promote diatom growth (Heasman and Savva 2007). In some case cultured algae may also be employed (see Ingerson *et al.* 2007; Figure H-5). However, each abalone hatchery has its own approach to the development and maintenance of diatom communities on plates for the settlement and metamorphosis of larval abalone (Heasman and Savva 2007).

Once settled onto plates in the nursery tanks abalone are on-grown by feeding on a variety of algal species (this includes *Ulvella* species) which, like diatoms, are cultured and grown on the PVC sheets. In many cases a nursery will contain many tanks with plates that are just used to grow fresh algae (i.e. they don't contain abalone) and these plates are transferred to the nursery tanks containing abalone as additional food is required.

Nursery tanks typically hold thousands of nursery plates (Figure H-5) and there is a significant labour involved in ensuring that plates have a good stock of algae to feed the growing juveniles. There is often a need to transfer heavily populated plates on which the algal supply is over-grazed from one tank to another to even out the distribution of animals across nursery tanks and to ensure good growth during this phase.

Figure H-5: Left panel - stock diatom cultures being prepared on an abalone farm in China. Right panel - nursery sheets covered in diatoms; note the rack that holds the sheets in a vertical orientation. The brownish colouration is a diatom film that provides food for the juvenile abalone. The tanks in the background will each hold hundreds of the sheet racks and tens of thousands of sheets.

3.4.4. Grow-out on raceways

After a period of 6-8 months, juvenile abalone are graded out of the nursery and placed on the raceways. At this stage animals are typically between 12 and 18 mm in shell length. The raceways, sometimes referred to as slab-tanks, comprise flat concrete channels (typically 2.5 to 3.0 m wide and 20 to 50 m long) where the abalone live for the rest of their time on the farm. Water depth along the raceway is maintained at a few centimetres (3-5) by maintaining a continuous flow of water down the raceway. The direction of flow is often reversed every 2-3 days as abalone typically move up-current and thus will congregate at one end of the raceway if the water direction remains constant.

Transfer to raceway grow-out can be facilitated by a continuation of the microalgal feed using diatoms scraped from conditioned nursery plates (Heasman and Savva 2007). This approach permits a degree of transitional food for the abalone as they are weaned onto the formulated feeds that are used for the remainder of the grow-out period (Heasman and Savva 2007, Ingerson *et al.* 2007).

Growout will typically take a further 30-36 months depending on the quality of the farming system. The time taken to reach marketable size is fundamentally dependent upon growth rates which can be linked to:

1. Genetic quality of the animals which is a function of the quality of broodstock and the effectiveness of the grading processes applied to weed-out slow growing animals; typically, farms will spawn animals of a range of grades (A, B and C) which are differentiated based on growth rate during the nursery rearing phase.
2. Quality and quantity of food provided to support growth; most farms rely upon manufactured (pelleted) feeds to provide the essential nutrition to support growth, animals are fed according to a schedule which varies as animals grow and depending on the source (composition) of the manufactured feed.

3. Overall quality of animal husbandry which is determined by the quality of care given to animals over the course of their lifetime; this is essentially dependent upon the knowledge and training of staff.
4. Animal health (e.g. parasite infestations or other diseases); diseases can impact on both mortality rates and on growth rates.
5. Episodic environmental impacts, particularly including excessively hot weather which will impact on both mortality rates and on growth rates.

The bulk of the water used on the farms is used on the raceways. A continuous flow of water down the raceway keeps animals supplied with oxygen. Pulse flows from tippers (Figure H-2) help to keep the raceway clean by washing away faeces, un-eaten food and sediments that have been deposited.

Farms may typically pump in the order of 400 to 2,000 L/s around 85% of which is likely to be used on raceways with the remainder flowing to nursery tanks and for other purposes (e.g. channel flushing and cleaning). The volume pumped depends on a number of operational issues. In Victoria, where temperatures are typically cooler, a farm with a 100-tonne annual production (likely stocking levels of around 140 tonne including animals of all ages) pumps 1,000 L/s (Yumbah 2018) but Yumbah have stated that their Kangaroo Island farm requires 2,000 L/s. Superficially this is close to double the water requirement but not unreasonable given the challenges in SA of maintaining lower temperatures particularly during summer.

Temperature will increase if flow volumes are low (due to the absorption of heat from the air) and this impacts on abalone health and on the oxygen-holding capacity of water (warmer water holds less oxygen to support respiration by the animals, but animal respiration can be higher in warmer conditions – therefore the need to pump a dis-proportionately higher volume of water)(see Section 3.2).

Once abalone reach market size they are harvested and sent for processing which generally involves shucking (removing the meat from the shell). In most cases, they are then washed and frozen for export to international markets (typically in Asia and particularly to China).

3.5. Performance indices for abalone farms

A number of Key Performance Indicators (KPIs) can be used to assess the performance of an abalone farm; these are defined below.

Growth rate – generally measured in mm/month. Animals on a well-managed farm with good quality stock (i.e. spawned from high performing brood-stock) will generally achieve growth rates of better than 2.8 mm per month (averaged across the entire period). Such stock (classed as A-grade), will reach 100 mm in shell length at 36 months. B-grade stock (minimum 2.2 mm/month) are commonly found on many farms and are expected to reach a minimum size of 80 mm in 36 months. Animals growing at less than 2.2 mm/month (C-grade) are often culled or sold out at the smaller size; some farms will keep them on and thereby need to extend the production period.

Mortality rate – generally measured as percentage of animals of a given cohort (spawning group) over a year. Many farms operate commercially with mortality rates of 30% per annum (compounding across the lifecycle so effectively 51% over a 3-year growth cycle). While some farms experience higher mortality rates, this makes it very hard to achieve commercial outcomes. Mortality rates are generally not constant over the lifetime of a cohort and many farms suffer higher rates in the 3rd year. The issue of mortality rates is also linked to growth rate, slow growing animals have more chance of dying before they reach market size (nominally a shell-length of 80-120 mm); hence, growth rate has a compounding effect on mortality.

Feed Conversion Ratio (FCR) – is measured by the total weight of food fed to a cohort of animals over a given period of time divided by the increase in weight of the animals over that time period. Most land-farms should achieve an FCR in the order of 1:3 – 1.5:1. Effectively for every tonne (or more) of food that is fed to the animals you achieve a tonne in growth. The important issue here is that growth is measured in fresh weight (noting animals are about 70% water) and the food is a low moisture pellet (around 15% moisture content).

Meat yield – is measured as the fresh weight of meat as a percentage of the whole live weight. Values greater than 30% (up to 34%) are generally considered excellent, values above 27% are good, better than 23% is fair and less than 23% would be considered poor. Meat yield will reflect a number of aspects of the life history of the abalone; older abalone (2+ years) may become gravid (sexually mature) and this means that energy is put into production of gonads (sex-tissues) and therefore meat yield, as a proportion of total live weight, will be lower at some times of the year. Farmed abalone may also have shallow shells and therefore lower meat content when compared to wild animals of similar size (measured as shell-length).

Meat size grade – the market for abalone can be divided into 10-gram size grades with the smallest grade 10-20 g (meat weight) abalone being generally lower value (on a per kg meat weight basis[4]) than the higher grades 20-30 g, 30-40 g or better. This provides a basis for working backwards to the minimum sizes that are commercial; an animal producing 10 g of meat with a 25% yield will be 40 g in live weight. A 40 g animal will generally be in the order of 70 mm shell-length and this would be close to the absolute minimum for commercial harvest. Ideally farms are targeting the 20-30 grade as the minimum grade. Assuming a 25% yield, animals would have a live weight of 80 g which requires them to be around 85 mm in shell-length. Generally, the target size is >95 mm providing animals at the top of 20-30 grade (at 25% yield) and well into the 30-40 grade if harvested at the optimal time (i.e. when meat yields exceed 30% of live weight).

3.6. Overview of the Smith Bay Aquaculture Operation (Yumbah)

Yumbah Kangaroo Island Pty Ltd (Yumbah) operates an abalone farm in an onshore facility at Smith Bay (Figure H-1). The facility operates across two Aquaculture licences (Table H-3)[5]. The Kangaroo Island farm is one of four farms operated by Yumbah Australia wide.

Yumbah have not provided any substantive advice or material about their operations to the EIS team. Notwithstanding there are a number of public sources of information (Table H-2) available including the Yumbah website (www.yumbah.com) as well as a number of public statements including in newspaper articles (Weekly Times, 15 August 2017), in a presentation to the Natural Resource Committee of the SA Parliament (Yumbah 2017) and through a thought piece authored by a consultant to Yumbah (Paul McShane; McShane 2017) all of which provide material that outlines the nature of the Yumbah Kangaroo Island farming system. In addition Yumbah have published a document (Yumbah 2018) that provides generic information about their Victorian farming operations.

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[4] Yumbah quote prices in the range of $50 to $60 per kg whole weight which would equate to around $160 per kg meat weight (see https://yumbah.com/snails-pace-is-fast-money-in-yumbahs-coastal-agribusiness-game published 24-Apr-2018).

[5] Noting that Yumbah has subsequently purchased a parcel of land and obtained access to licence FT000634 which is immediately adjacent to the proposed KIPT facility.

Yumbah have indicated (Weekly Times, 15 August 2017) that they have four farms including two in South Australia, one in Tasmania and one in Victoria. Across these four farms they claim to produce a total of 700 tonnes of abalone worth $29 million annually. The four farms include hatcheries and grow out tanks at Port Lincoln (about 10 million animals per year) and Kangaroo Island (about 3 million animals per year) as well as farms at Bicheno in Tasmania (2 million animals per year) and Narrawong in Victoria (no hatchery but grows out 5 million animals per year). Collectively the four sites grow out 15 million abalone annually which ultimately produce 7 million animals per year into the market (with the balance being lost through culling and mortality with some being sent to markets where small abalone are valued).

Grow out at Kangaroo Island comprises mainly greenlip abalone (*Haliotis laevigata*) but they may produce some tiger abalone that are hybrids of greenlip and blacklip (*Haliotis rubra*). Time to market is quoted as 3 to 4 years to reach a market size of 100 g to 120 g but it is apparent that some of the production is in smaller animals (e.g. in the >85 mm size range with a weight of 80 g to 100 g; see https://yumbah.com/our-harvest/our-products accessed 22-Sep-2018).

While Yumbah have not provided a breakdown of the per farm production it is possible to estimate this from the various figures that have been provided. Total production tonnage from the Kangaroo Island farm is likely to be around 1/5th of Yumbah's total production (3 million out of 15 million animals into the farm per year) implying a harvest of around 140 tonnes.

This figure of 140 tonnes is not consistent with the figure that they provided to the Natural Resource Committee of the SA Parliament (NRC; Yumbah 2017) which stated that production levels were around 170[6] tonne (out of the total company wide production of 700 tonnes). This production they argued contributed some $90 million to the SA economy and directly employed 77 people (Yumbah 2017). The data presented in Yumbah's presentation to the NRC are somewhat ambiguous in that they claim, in the same document, that total farm standing stock (including all 1 and 2-year-old animals in the production system not just those harvested) is 170 tonnes.

Similarly, Yumbah's website indicates employment of 25 people at Kangaroo Island and 24 at Port Lincoln (total SA employment of 49; website accessed on 9-Apr-2018) a figure that is at odds with the statement to the NRC (Yumbah 2017) of "77 people, mainly in regional South Australia". It would appear that the figure of 77 is more consistent with the total employment across the group including all of the Victorian (20 full time staff), Tasmanian (12 full time staff) and South Australian farms (49 full time staff) providing a national total of 81 full time staff.

Table H-2: Estimates of the scope and scale of Yumbah operations in SA and for the Kangaroo Island farm.

Claim	Weekly times article	Yumbah 2017	Other
Yumbah total production across four farms	700 tonnes per annum	700 tonnes per annum (states this as the company wide production)	ABARES (2017; Table 8) indicates abalone aquaculture production Australia wide was 757 tonnes in FY2016.
Total value of production across four farms	$29 million for all four farms	$90 million to SA economy (presumably using a multiplier value for economic impact).	ABARES (2017; Table 8) indicates that the farm gate value for abalone aquaculture production Australia wide was $28.7 million in FY2016.

[6] Noting that the Hansard record of the presentation to the NRC indicates that the site capacity is some 160 tonnes.

Claim	Weekly times article	Yumbah 2017	Other
Yumbah KI total production	1/5th of 700 tonnes = 140 tonnes	170 tonnes (this figure is likely to be closer to the total farm stock level given that is how it is quoted later in Yumbah 2017)	ABARES (2017; Table 20) indicates that the farm gate value for South Australian abalone aquaculture production was $14.7 million with a total production tonnage of 350 tonnes in FY2016.

The figures available in the public domain about the Yumbah operation can also be compared to the fishery and aquaculture statistics reported by ABARES (Australian Government Department of Agriculture and Water Resources; Table H-2). The 2015/16 production statistics for abalone (ABARES 2017) indicate an Australia wide production volume of 757 tonnes with a GVP of $28.7 million. South Australian abalone aquaculture contributed some 350 tonnes of production with a GVP of $14.7 million.

It is relevant to note that apart from a number of experimental farming systems in Louth Bay the Yumbah operations at both Boston Point and Kangaroo Island represent the only abalone farming operations in South Australia. There are only two other land-based farms that are licenced to farm abalone; the now defunct Streaky Bay facility (the licence was held by GP No 4 Pty Ltd which has been placed into Administration) and the Clean Seas operation at Arno Bay which does not currently produce farmed abalone. Yumbah Kangaroo Island Pty Ltd have recently acquired another licence (Active as of 1-Jul-2018) which is immediately adjacent to the KI Seaport land holding on Kangaroo Island. This licence is not currently producing any product.

On the basis of these statistics (and not accounting for any additional capacity that might have been introduced in the 2016/17 financial year) Yumbah's stated enterprise wide production in 2017 (Weekly Times, 15 August 2017) would have comprised some 92% of Australia's total 2015/2016 aquaculture abalone production delivering around 102% of the GVP for 2016 (note that figures for 2016/17 have not yet been published by ABARES).

The accuracy of these numbers cannot be verified other than to note that there are a number of other Australian producers that have substantial operations in their own right including, for example, Great Southern Waters in Victoria (acknowledged as Australia's largest individual abalone farm) which claim to have produced around 220 tonnes per annum in 2015 (comprising 29% of national production using the ABARES figures; ABARES 2017) .

While the full scope of the Kangaroo Island operation is not explicitly reported through these various documents it is possible to apply some broad industry metrics to the operations that can estimate the relative scope and scale of the Yumbah Kangaroo Island operations. These metrics rely upon assumptions about the amount of space required to grow abalone in an on-land farming system and the typical labour cost of such an enterprise and should be read as indicative but not definitive: by their very nature they cannot be validated and should not be interpreted as such.

Table H-3 estimates the productive area on both the Port Lincoln farms and the Kangaroo Island farm. These data represent the total covered area (areas covered in shade cloth) which can be obtained from Google Map images of the sites; the covered area is greater than the actual area of raceway available for growing out the animals, but the numbers still provide a basis to compare and contrast the operations.

Assuming that areas are generally allocated as indicated in Table H-3, the Nursery areas at the Port Lincoln and Kangaroo Island farms likely comprise around 10% and 6.2% respectively of the total covered area (noting that in both cases this is totalled across the two respective licenced areas at each of the locations). It should also be noted that some of the Port Lincoln nursery may be used for the production of oyster spat (see https://yumbah.com/boost-for-spat-nursery accessed 22-Sep-2018).

Based on these metrics the estimated raceway area of the Kangaroo Island farm would be in the order of 37,000 m^2 which would indicate a utilisation efficiency of around 62% of the covered area. This is likely to be a reasonable estimate in that the area under the shade nets includes walkways and other space allocated to provide access to the raceways and supporting infrastructure[7].

In the context of the information provided in Table H-3 this indicates that the Kangaroo Island operation has a total covered raceway area of around 60,036 m^2 compared to 72,068 m^2 at Port Lincoln (i.e. the Kangaroo Island farm has around 45% of the total productive area for the SA based operations).

Assuming that the production efficiency of the two operations is more or less the same then this would provide for a production of up to 150 tonnes per annum at Kangaroo Island on the basis that this is 45% of the ABARES reported production levels (i.e. a total of 350 tonne from SA in 2015/16 of which probably not more than 20 tonne came from the Streaky Bay operation with the remainder being from the KI and Port Lincoln farms).

Table H-3: Estimates of farming areas operated by Yumbah in South Australia. Estimates were based on Google Maps (accessed 01-Jun-2018) analysis of covered areas and AgInsight data on PIRSA Landbased Category D Licences for abalone.

Area name	ID	Area	Assumed purpose	Licence Number
Yumbah Port Lincoln	1	9,841	Raceway	FT00423
Yumbah Port Lincoln	2	8,631	Raceway	FT00423
Yumbah Port Lincoln	3	7,153	Raceway	FT00423
Yumbah Port Lincoln	4	6,140	Nursery	FT00423
Yumbah Port Lincoln	5	4,156	Raceway	FT00423
Yumbah Port Lincoln	6	560	Covered	FT00423
Yumbah Port Lincoln	7	28,752	Raceway	FT00620
Yumbah Port Lincoln	8	6,617	Nursery	FT00620
Yumbah Kangaroo Island	9	38,325	Raceway	FT00558
Yumbah Kangaroo Island	10	4,533	Nursery	FT00558
Yumbah Kangaroo Island	11	17,178	Raceway	FT00702

Similar estimates can be made using FTE figures, but these are somewhat less reliable in that they depend on assumptions about work place efficiency. Nevertheless, assuming that the farms are managed similarly we would also conclude a more or less 50:50 split in production based on 24 and 25 FTE's at KI and Port Lincoln respectively.

In previous years the SAS abalone farm (now part of the Yumbah Port Lincoln operation) aimed to produce around 80-90 tonne per annum. This farm has a raceway covered area of around 28,752 m^2 which provides for an effective production rate of 2.95 kg/m^2 (note that this is production

[7] A utilisation efficiency of 62% is consistent with the figures provided in Yumbah (2018) which indicates a covered area to raceway area ratio of 1.62 as the objective in their proposal for a new farm near Portland in Victoria.

measured against total covered area not raceway area). On that basis the total production for the two Yumbah farms in SA (assuming the space allocation as shown in Table H-3) could be around 337 tonne which compares favourably with ABARES published value for SA aquacultured abalone production of 350 tonne (less 20 tonne for production on other non-Yumbah farms).

These estimates are not meant to be taken as absolute values, rather they provide a basis for triangulating assumptions concerning the scope and scale of the operations and thereby provide a basis for estimating operational parameters of the farming system.

3.6.1. Farm operations

The abalone farm sources seawater from Smith Bay via 15 intake pipelines (in three locations; Figure H-1) extending up to 220 metres into Smith Bay to a depth of approximately 6 metres. The intakes consist of 'risers' that extend approximately 2 metres above the seafloor (Figure H-6). Other than coarse filters covering the intakes to exclude fish, the intake seawater is not filtered.

Seawater that has been used on the farm is subsequently discharged onto the beach via several pipelines at the edge of the Yumbah property; this water flows across the beach into Smith Bay (Figure H-1). In effect, Yumbah relies upon dilution into seawater to ensure that the discharge of its wastewater into the intertidal zone does not result in these contaminated waters re-entering the farm system via the intake pipes that are placed offshore.

The only section of an abalone farm that does not use the flow-through seawater system is the hatchery, which generally operates on a recirculation or static system. Seawater used in abalone hatcheries is sourced from the intake pipes but is then filtered, (generally to at least 10 μm to remove fine suspended matter), and generally it is then ultra-violet (UV) sterilized.

Standard practice is to run the water used in the nursery tanks through a bank of rapid sand filters (RSFs) which would remove most of the larger particulates (i.e. those in the >20 μm size range) from the influent water.

Figure H-6: Yumbah seawater intakes (risers) in Smith Bay (photo taken David Wiltshire).

The principle source of food for animals across the bulk of their life on a farm comprises manufactured feeds in the form of dried pellets. Yumbah produces its own pelleted feed at a factory in Lonsdale, South Australia. Nursery stock are generally fed on diatoms and a variety of other algal species that are intensively cultured on PVC plastic sheets. Growth of algae (diatoms or cultured filamentous species such as *Ulvella* sp.) is enhanced by using added nutrients (fertilisers). The plastic plates upon which the algae grow are then placed in the nursery tanks to provide food for the juvenile animals (as per 3.4.3).

3.6.2. Existing Smith Bay environment

Physical features of the Smith Bay marine environment that are relevant to the operation of the abalone farm are: ambient suspended sediment loads (or turbidity), temperature, seafloor sediment characteristics, nutrients, chemical contaminants and dissolved oxygen; these are detailed in Chapter 9 and the associated EIS Appendices.

Dust deposition is also likely to be relevant to the Yumbah operation (Chapter 9). Dust modelling has shown that Smith Bay is likely to experience atmospheric dust deposition at background rates of around 2 g/m^2/month (equivalent to the typical average rates for coastal and agricultural/pastoral sites in South Australia; Chapter 9).

Although the general quality of the seawater in Smith Bay is considered to be high, there is evidence to suggest that it may be compromised during storm events by inputs of suspended sediment from the highly degraded Smith Creek (and potentially other smaller creeks that discharge into adjacent waters). Smith Creek (see Figure H-1) has unstable, eroding banks and is at times enriched with nutrients due to agricultural runoff and uncontrolled access to the watercourse by sheep (EPA 2013, confirmed through EP technical investigations). Relatively large amounts of sediment are likely to enter Smith Bay during severe rain events and produce turbid conditions. Subsequent settlement and resuspension processes during times of high wave energy could produce ongoing periods of relatively high turbidity that are unlikely to have occurred before the Smith Creek catchment was cleared and developed for farming.

The existing levels of suspended sediment (i.e. turbidity) in Smith Bay were found to be variable during the period of monitoring, ranging from < 1 NTU during calm conditions to 5–8 NTU during storm events (see Chapter 9).

As detailed above, another water quality parameter of potential concern for the operation of the abalone farm is seawater temperature. Data collected for the EIS throughout 2017, using moored data buoys that were equipped with a suite of water quality and hydrodynamic sensors (detailed in Chapter 10), show the mean seawater temperature during the monitoring period at Smith Bay within 300 m of shore during summer was around 21–22 ^{O}C, but there were spikes up to 25 ^{O}C recorded during heatwaves (see Chapter 9). While the critical thermal maximum for greenlip abalone is reported to be 27.5 ^{O}C, many farms across South Australia have reported substantial mortality events at much lower temperatures (22-23 ^{O}C; Vandepeer 2006). On this basis, the existing thermal profile observed in Smith Bay over the summer months and the lack of a comprehensive understanding of either the actual cause or treatment options for the summer mortality syndrome (Doubleday *et al.* 2013) must be considered a high-risk factor for the existing abalone operation.

4. Assessment of potential risks during construction and operation of the wharf

4.1. Introduction

The construction and operation of the wharf facility presents a number of potential risks to the operations of the Yumbah abalone farm and these need to be outlined so as to provide a basis for the development of appropriate control and mitigation strategies.

The key risk issues detailed in this report comprise:

1. Mobilisation of sediments from the capital dredging program, tailwater discharges from dewatering of sediments on land, causeway construction, maintenance dredging and shipping operations all of which have the potential to impact on farming operations through impacts on ambient water quality in Smith Bay by causing:
    a. increases in total suspended solids (TSS) loads,
    b. suspension of anoxic sediments that impact on ambient oxygen levels,
    c. release of sediment bound toxicants and pollutants, and
    d. release of sediment bound nutrients.
2. Air-borne dust deposition on farming structures (including raceways) impacting on water quality within the farm.
3. Light-spill onto the abalone farm emanating from infrastructure in the hard-standing area and along the wharf/causeway as well as from transport vehicles.
4. Noise and vibration from construction and operations including from truck movements and the operation of machinery.
5. Changes in coastal processes (primarily associated with the construction of the causeway) that would impact on nearshore circulation with the potential to:
    a. affect water temperature due to reduced mixing in the vicinity of the causeway, and
    b. change sedimentation and resuspension processes due to changes in benthic sheer stress in the vicinity of the causeway and in the dredged areas.
6. Increases in the frequency of harmful algal blooms (specifically red-tides).
7. Potential for beneficial outcomes to water quality in the vicinity of the Yumbah seawater intakes due to the diversion of Smith Creek discharges further offshore.

Each of these matters is dealt with in more detail in the following.

4.2. Risk: Suspension and mobilisation of marine sediments

Any operation that causes an increase in suspended sediment loads (including dredging, tailwater disposal, causeway in-fill and ship movements) has the potential to impact on water quality for the land-based abalone farm in a number of ways including:

1. Suspended sediments that enter the farm via the seawater intakes may compromise abalone production through increases in mortality and reductions in growth and performance of animals on-farm.
2. Increases in turbidity (and hence light attenuation) of water taken onto the farm may impact on the photosynthetic rates of algae used to feed abalone in the nursery phase of the aquaculture operations.
3. The potential for the mobilisation of anoxic sediments and / or sediments with high biochemical oxygen demand may result in a reduction of oxygen in the water taken onto the farm and thereby impact on oxygen supply to abalone causing increases in mortality and reductions in growth and performance of animals on-farm.
4. The mobilisation of sediment-bound toxicants particularly including chlorinated hydrocarbons and heavy metals may similarly impact on the health of animals on-farm.
5. The mobilisation of sediment-bound nutrients have the potential to cause blooms of harmful or toxic algae that may result in compromised water quality (high algal loads and reduced oxygen levels) and thereby impact on growth and performance of animals on-farm.

In the context of this study the work by COOE (2017) has shown that there are no risks from contaminated or nutrient rich sediments and there is only a very small deposit of anoxic sediments (which is outside the area where dredging is proposed) and thus it would not be expected to have a material effect on oxygen concentration of the water body in Smith Bay. Accordingly, the only likely impact is from the direct suspension of sediments resulting in an elevated TSS in the water column.

4.2.1. Activities leading to sediment suspension and mobilisation

4.2.1.1. Construction dredging of the access channel and birthing pocket

A detailed bathymetric assessment of Smith Bay has determined that the total volume of material that needs to be dredged in order to provide for an appropriate depth in both the access channel and berthing-pocket is expected to be around 100,000 m^3 but may be as much as 200,000 m^3, which represents a small to medium sized dredging operation[8].

Notwithstanding the small-medium scale of this dredging program, the major drivers of how much sediment is mobilised will be:

1. The engineering approach to dredging (i.e. the use of cutter-suction dredge – CSD - with pump-ashore rather than a bucket dredge system, or a trailer suction hopper dredge) noting that a CSD will substantially reduce the amount of sediment mobilised during dredging relative to other methods;

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[8] For example, the Adelaide Coastal Beach Sand Replenishment Dredging Program (ACBSRDP) typically dredged volumes of between 150,000 m^3 and 180,000 m^3 at rates of 2,600 m^3/d (Cheshire and Miller 2000). These operations caused minimal impacts to benthic habitats which were not persistent in time. However, on one occasion the ACBSRDP conducted a dredging program where around 500,000 m^3 was dredged at a rate of 26,000 m^3/day which resulted in a substantial and persistent environmental impact (Cheshire and Miller 2000).

Similarly, the Outer Harbour dredging program will dredge 1.5 million m^3 of material and dispose of this off-shore in Gulf St Vincent.

2. The rate at which dredging occurs (expected to be around 2,000 m^3/day), which comprises a low extraction rate and will likely result in a reduced rate of sediment suspension; and
3. The particle size distribution of the sediments which will determine the propensity for finer fractions to become and remain suspended in the water column thereby allowing dispersal of the plume over larger areas.

Using the estimates provided for the total dredge volume (i.e. 100,000-200,000 m^3) it is possible to estimate the likely rates at which sediment will be dredged and the likely rate at which such an operation will suspend sediments in the water column. When combined with detailed information on the composition of sediments, and particularly the particle size distribution of sediments (COOE 2017) we can then predict the mobility of sediments and the consequences of the dredging operations on key water quality parameters including total suspended sediments (TSS). This quantitative estimate of sediment suspension can then be used in conjunction with the hydrodynamic model (BMT 2018a) to predict the likely amount of sediment that is subsequently transported to the seawater intakes for the Yumbah aquaculture operation.

The hydrodynamic study (BMT 2018a) specifically provided a detailed outline of the dredging operation as a basis for evaluating the risk associated with the proposal. Detail has been provided about the sediment classes (particle size distribution), dredging rate (volume dredged per day), the type of dredge (CSD) that will be employed and the way in which the dredging operation will be managed including downtime (efficiency %; Table H-4).

Table H-4: Outline of dredging operation taken from Table 5-2 CSD productivity assumptions (BMT 2018a).

Material Class	Design Scenario A material volume (m^3)	Design Scenario B material volume (m^3)	Production rate (m^3/h)	Efficiency (% time working)
Class 1	75,000	150,000	250	60%
Class 2	25,000	50,000	200	60%
TOTAL	100,000	200,000	–	–

In addition, the BMT (2018a) study has synthesised data from COOE (2017) which provides a detailed analysis of sediment types and particularly the particle size distribution of sediments as a basis for determining the likely transport pathways and volumes for different types of sediments (Class 1 and Class 2 sediments as defined in BMT 2018a). This work has indicated that dredging operation is likely to encounter sediments comprising a mixture of 75% Silty-Sand and 25% Sandy-Silt (Table H-5) based on Wentworth sediment particle size classes (Table H-6).

Table H-5: Material classes (derived by BMT from COOE (2017). The data presented were taken directly from Table 5-1 in BMT (2018).

Material Class	Description	Fraction of total	*In-situ* Dry Density (kg/m^3)	Particle Size Distribution				
				Clay	Silt	Fine Sand	Coarse Sand	Gravel / Cobbles
Class 1	Silty Sand	75%	1,600	13%	12%	25%	30%	20%
Class 2	Sandy Silt	25%	1,300	22%	35%	25%	14%	4%
TOTAL		**100%**	**1,525**	**15%**	**18%**	**25%**	**26%**	**16%**

Table H-6: Wentworth sediment particle size classification system as defined in ISO 14688-1:2002.

Sediment Type	Name	Code	Min diameter (µm)
Boulder/Cobble	Large boulder	LBo	630,000
	Boulder	Bo	200,000
	Cobble	Co	63,000
Gravel	Coarse gravel	CGr	20,000
	Medium gravel	MGr	6,300
	Fine gravel	FGr	2,000
Sand	Coarse sand	CSa	630
	Medium sand	MSa	200
	Fine sand	FSa	63
Silt	Coarse silt	CSi	20
	Medium silt	MSi	6
	Fine silt	FSi	2
Clay	Clay	Cl	

It should be noted that the impact of dredging on water quality is primarily determined by how the dredging operation is managed, including the rate at which dredging occurs and the type and operation of the dredging equipment. Previous work has demonstrated that a high level of environmental protection can be achieved when dredging rates do not exceed an average of 2,600 m^3/d (averaged over a 2-3 month dredging operation[9]; Cheshire and Miller 2000).

In their analysis, BMT (2018) have considered a wide range of issues related to conduct of the dredging program and these have been synthesised, through the model, into a report on the likely impacts on water quality at the Yumbah water intakes.

4.2.1.2. Discharge of tailwater from sediments pumped ashore

Tailwater comprises water than drains out of sediments that have been pumped ashore. Most of the sediments remain as placed but a very small fraction, comprising very fine sediments, will be returned to the sea immediately adjacent to the sediment storage area. The analysis by BMT (2018) incorporated sediment inputs from tailwater into the overall analysis of sediment mobilisation because this process happens contemporaneously with the dredging. These two sources were then combined into the analysis and the results and sediment loads at the Yumbah seawater intakes takes account of suspended sediments derived from both the dredging and the tailwater discharge.

4.2.1.3. Leakage of sediments from causeway during construction

The potential for sediments to leak from the causeway during construction was also modelled by BMT (2018). They considered the impact of a worst-case scenario in which the core is exposed to erosion from storm events during construction. The analysis assumed that causeway construction would occur after the capital dredging program and on that basis sediment leakage during causeway construction was assessed separately to the suspension of sediments from dredging or the return of tailwater.

[9] Noting that rates will vary from one day to another based on operational conditions and this figure therefore includes days where dredge production is somewhat higher as well as days where dredging operations are somewhat lower.

4.2.1.4. Maintenance dredging of the access channel and berthing pocket

The requirement for dredging of the access channel and berthing pocket will depend upon the rate at which new material is deposited in these areas. The hydrodynamic modelling undertaken by BMT (2018) included an assessment of the extent to which the development is likely to change benthic sheer stresses across the model domain. Changes in benthic sheer stress provides the basis for determining whether there are likely to be changes in sedimentation (and resuspension) rates. The analysis indicates that sedimentation rates are not likely to be substantial and thus maintenance dredging programs, if required, are likely to be small and infrequent.

Maintenance dredging programs, if required, are likely to be conducted using infrastructure and management arrangements that are directly comparable to those used for the capital dredging program (but with substantially reduced dredge volumes). Furthermore, given that the location of maintenance dredging will be essentially the same as for the capital dredging program the results from the existing analyses provide a basis for assessing the risks from the maintenance dredging operations.

4.2.1.5. Sediment suspension during ship operations due to pressure wave propagation and propeller wash

It is possible that sediments may be suspended during ship movements (due to displacement waves and propeller wash).

BMT (2018) modelled the propeller wash caused by inbound and outbound ships at the proposed wharf facility. In so doing they modelled the effect of a Panamax Class ship (DWT = 63,000 tonne). This allowed an analysis of the likely extent of sediment resuspension under normal ship operations. The conclusion from their work was that the amounts of sediments suspended from shipping operations are likely to be so small that they would not be detectable against the natural background levels at the Yumbah seawater intakes.

4.2.2. Are abalone sensitive by suspended sediments?

4.2.2.1. Background

This section provides a review of the potential risks to abalone from sediments suspended in the water column. Literature on the impact of sediments on abalone comprises a number of studies undertaken on field populations as well as series of studies on abalone in research and aquaculture settings.

This analysis includes a review of the scientific literature as well as new information obtained from ecotoxicology studies undertaken on juvenile greenlip abalone. The literature provides a broad context against which the ecotoxicology results have been discussed.

To understand the potential for suspended sediments to impact on abalone in the Yumbah aquaculture farm the following section provides:

1. A summary of what is known about the biology and ecophysiology of abalone. This includes information about how abalone have evolved to live within an environment where they are naturally exposed and have adaptations to enable them to cope with some level of suspended sediments.
2. A summary of relevant studies, for other species of abalone, and an associated meta-analysis of these studies which provides a quantitative estimate of a guideline No Observable Effect Concentration (NOEC) for *Haliotis discus* (Pacific Abalone).
3. A consideration of the existing evidence on the water quality characteristics of the Yumbah Narrawong farm in Victoria which provides a direct test of the susceptibility of greenlip abalone to suspended sediments in a commercial aquaculture setting.