19/RC/64

The Hearing Panel

23 October 2019

Reporting Officer's Final Recommendation

Hearing of Application – APP 20181316 - Zane Smith & Jim Maass Barrett

Compiled by Andrew Maclennan, Senior Resource Management Consultant

Application:

Zane Smith and Jim Maass Barrett have applied to:

- discharge shell, sediment and organic material on the seabed;
- discharge water associated with the harvesting of shellfish;
- establish permanent structures in the Coastal Marine Area;
- allow exclusive and preferential occupation for a marine farm within Big Glory Bay, Stewart Island.

Introduction

This addendum responds to Minute #2 of the Hearing Commissioner, dated 23 September 2019. The following addendum addresses the following matters:

- An updated effects assessment
- Provides an updated effects conclusion
- Provides an updated planning analysis
- Provides a final recommendation
- Discuss a recommend duration
- Provides a set of proposed conditions

Updated effects assessment

The submitter (Sanford Limited) has provided a response to the further information and s42A addendum. They have raised concerns about the conclusions reached in relation to navigation effects, cumulative effects, and the updated planning analysis included within the s42A addendum.

Navigation effects

Legal Framework

In order to assess the level of effects associated with the proposed application I consider it important to restate that legal framework in which the application is being processed within. As set out within Mr Doesburg's legal opinion:

- Navigation safety effects are relevant effects that can be included in the Commissioner's assessment of effects.
- The submitter does not have an implied occupation right to navigate freely between the sites, to the extent the application is precluded from being granted.
- The submitter's existing coastal permits include the requirement to fallow their salmon farming sites, however the fallowing plan does not specify what path is to be taken when moving the salmon farming operations between the multiple sites.

The submitter has confirmed as part of the submitters reply that they agree with the legal framework set out above.

Existing resource consents

When considering the submitter's existing resource consents, it is noted that while the conditions of the submitters consent require them to fallow their sites, how they undertake the fallowing to date has been an operational matter. The submitter's existing coastal permits have not sought exclusive occupation over a navigation pathway, nor have they included the method or navigation path used to move their cages. So, while the method and navigation route used by the submitters in the past to fallow their salmon farm site does not form part of their existing coastal permit, their existing coastal permits do require that the fallowing does take place. As the current consent application will affect the submitter's ability to safely achieve the requirements of their consent, this is where the potential adverse navigation effects lie.

Submitter's response to further information

As part of the submitter's reply Sanford has noted that:

> *'Mr Swart provided direct evidence at the hearing that the salmon farms must be moved as a single unit and cannot be 'broken down' and moved separately.'* [1]

I assume that this includes consideration of Sanford's ability to move its own mussel lines (referred to in more detail below). The information provided in the reply provides clarification that there are no alternative methods of moving the salmon farm. In the absence of any evidence to the contrary from the applicant, I accept the submitter's evidence on this point.

In relation to whether there are any alternative navigation routes that could be used to move the salmon farm, as part of the submitter's reply they have noted that:

> *'Mr Swart and Mr Eriksson have given evidence that Sanford cannot control or require movement of existing mussel farms in order to allow space to transport farms or the transporter pen.'*[2]

As part of the Reply Addendum, it was not suggested that the submitter could control or require movement of existing mussel farms held by a third party (i.e. not the submitter) in order to create a navigation route that would allow the movement of the farms. However, in paragraph 30 Mr Chia's evidence he states that:

> *'Within the Bay there are 35 consented mussel farm areas, 24 of these consents are exercised by Sanford'*

Further in paragraph 51 of Mr Erikson's evidence he states that:

> *'Sometimes mussel lines (on Sanford farms) need to be removed before the salmon farm can be moved safely.'*

Also, within paragraph 25. of Mr Swart's evidence he notes that:

> *'..the Mussel Manager may be asked to remove lines from a mussel farm to improve vessel access for completing a salmon farm relocation.'*

Given that both Mr Eriksson and Mr Swart have provided evidence that the submitter does remove mussel lines to allow the navigation of the salmon farm as part of their existing process when moving the salmon cages, the Reply Addendum was suggesting that moving mussel lines within the submitter's existing mussels farms could allow for an alternative navigation route. This appears to be overlooked in the submitter's reply.

<u>Effects assessment</u>

When considering the application's potential effect on navigation safety I note that the Regional Coastal Plan for Southland (Coastal Plan) includes a definition of 'navigation' which reads:

'the act or process of managing or directing the course of a ship using maps and instruments'

This definition of navigation within the context of the Coastal Plan has assisted in framing my effects assessment as, based on this definition, I consider it is the navigational safety of these vessels that are required to move the submitters salmon cages the Coastal Plan seeks to manage.

Based on the evidence provided by the submitter that there are no alternative methods of achieving the fallowing rotation, and therefore complying with their existing conditions of consent, I consider that the application will have an adverse effect on the navigation safety of the vessels that are used when the submitters are moving their salmon cages, which is a requirement of their existing coastal permits.

I consider it is helpful to consider the navigation effects of each application site individually before coming to a final recommendation. In reaching my conclusions below, I have relied on the evidence

[2] Paragraph 28 of the submitter response to further information and s42A addendum

provided by the submitter and Mr Cleaver, and note that no contrary expert evidence has been provided on these issues by the applicant:

<u>Site 1</u>

The Mr Cleaver (the Harbourmaster) has provided the following assessment of site 1:

> *'Marine farm site no.1 – the proposed position will create a navigation safety hazard for vessels relocating marine farms north of this site. Changing the shape of the farm will allow vessels to safely transit.'*

Mr Eriksson has provided a table[3] within his evidence which highlights the salmon farm locations that will be affected by the applicant's proposal. When considering the location of proposed site 1 Mr Eriksson states that the location of site 1 would affect the submitters ability to access the following sites: MF 320, MF 366, MF 474 all of which are located along the northern edge of Big Glory Bay.

Based on the assessments above I consider that proposed site 1 will have a more than minor effect on navigation safety of vessels within Big Glory Bay. However, if the applicant can demonstrate to the Commissioner that a safe navigational passage can be provided to the north of proposed site 1 by reducing the size of the site, as suggested by Mr Cleaver, I consider that the level of effect could potentially be reduced.

<u>Site 2</u>

The Mr Cleaver's assessment of site 2 is as follows:

> *'Marine farm site no.2 – I have no navigation safety concerns with this proposed site.'*

When considering the location of proposed site 2 Mr Eriksson states that the location of site 2 would affect the submitters ability to access the following sites: MFL 249, MF 321, MF 338, MF 339, and MFL 340. Given the location of proposed sites 2 and 3 Mr Eriksson has grouped his assessment of these sites together. While I can understand why Mr Erikson has grouped his assessment of these two sites, I consider his assessment is less robust than considering the sites on an individual basis because it does not take into account the potential navigational pathway if only one of the two sites were to be approved.

Within the submitter's response to further information and s42A addendum they have provided comment on harbourmasters assessment stating:

> *'Sanford considers that the Harbourmaster's conclusions support its significant concerns. It maintains the full suite of its concerns regarding navigation including in respect of a "smaller" site 1 (there has been no amendment of the application), and site 2. It relies on the evidence of Mr Eriksson.'*[4]

I have relied on the assessment of Mr Cleaver when coming to the conclusion proposed site 2 will have a minor effect on navigation safety of vessels within Big Glory Bay.

<u>Site 3</u>

The Mr Cleaver's assessment of site 3 is as follows:

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[3] Table 2 on pages 16 – 18 of Mr Eriksson evidence

[4] Paragraphs 19 of the submitters response to further information and s42A addendum

Marine farm site no.3 – Of the three proposed sites, this site creates the most risk to navigation safety for consented users relocating marine farms. The proposed position for this site is not supported.'

As noted above, when considering the location of proposed site 3 Mr Eriksson states that the location of site 2 would affect the submitters ability to access the following sites: MFL 249, MF 321, MF 338, MF 339, and MFL 340.

I have relied on the assessment of the both Mr Cleaver and Mr Eriksson when coming to the conclusion proposed site 3 will have a more than minor effect on navigation safety of vessels within Big Glory Bay.

Based on the assessments above, in its current form, I consider that proposed application will have a more than minor effect on navigation safety of vessels within Big Glory Bay. However, if the applicant was to amend the scope of the application to the extent that the they could demonstrate to the Commissioner that navigation safety of vessels within Big Glory Bay was reduced, this could change my assessment of the application.

Within the submitter's response to further information and the s42A addendum they have provided comment on harbourmasters assessment stating:

'Sanford considers that, given the errors in notification, in order for all marine farm owners in Big Glory Bay to have a proper understanding of the location of any "smaller" site 1 will require a new application and re-notification and could not be granted by the Commissioner on the material currently provided.'[5]

I disagree with the submitter's view that a new application and re-notification is required to progress an application with reduced effects. I consider that if the applicant wishes to reduce the scope of the application and therefore reduce the potential adverse effects of the application, the Commissioner can assess the amended application on its merits.

<u>Ecological Carrying Capacity</u>

As part of the submitter's response to further information and the s42A addendum they have included a Statement of evidence from Dr Hartstein the Director and Senior Oceanographer at Aquadynamic Solutions. Dr Hartstein evidence states:

'I have carefully read the carrying capacity sections provided by Dr. Stenton-Dozey. I do not agree with her assessment and consider that she has made several fundamental errors.'

He states that:

'I estimate that the CT/RT ratio for Big Glory Bay is approximately 0.7-0.8. Although I accept that calculating an exact figure will always result in some uncertainty, I am convinced that the ratio for Big Glory Bay is significantly less than 1, thus confirming that the proposed mussel farms are beyond the carrying capacity of the bay.'

Dr Stenton-Dozey has reviewed the statement of evidence from Dr Hartstein and has provided an updated version of her advice. This updated advice is attached in Appendix 1 to this report. Dr Stenton-Dozey report states that:

[5] Paragraphs 20 of the submitters response to further information and s42A addendum

'The simple tools used in this report to ascertain the cumulative impact of adding three proposed mussel farms have indicated effects on the ecological carrying capacity of BGB are likely to be minor.

The Pelagic Effect Assessment Criterion based on the ratio of clearance time over water retention time (CT/RT) was calculated for different ha of mussel farming that considers ha occupied before 2011, post-2011 when salmon farming increased and ha that would be occupied with the proposed 16 ha added. For all these ha occupancies without the additional 16 ha, CT/RT ratios ranged between 1.14–1.47 and with 16 ha added, between 1.03–1.30. All these ratios are >1 which means the criterion for not exceeding the ecological carry capacity of BGB has been met with the addition of 16 ha.

An alternative method using size-dependent mussel filtration rates suggested that 11.6% of the mid-tide bay volume is processed daily by present mussel farms increasing to 13.1% with the proposed addition of 16 ha of mussel farms. This is filtration volume is greater than the estimated daily tidal exchange rate (7–10%) suggesting mussel production depends to some extent on in-bay phytoplankton primary production.

It is feasible that in-bay primary production takes place since the bay-wide water mass has a long residency time of 14-28 days which is sufficient to allow for phytoplankton turnover rates of 2–5 days.

Long-term trends in chlorophyll-a concentrations show no significant change supporting the view that mussels depend on both in-bay and entrained phytoplankton production.'

I have considered the evidence of both Dr Hartstein and Dr Stenton-Dozey. I consider that Dr Stenton-Dozey's updated advice addresses the issues raised by Dr Hartstein and therefore I prefer Dr Stenton-Dozey's evidence. Accordingly, I consider that the application's cumulative effects on carrying capacity will be minor.

Effects Conclusion

Within my Reporting Officers Addendum I have suggested that the actual and potential effects of the application include effects on:

- Occupation and navigation
- Landscape and visual amenity and natural character
- Ecological carrying capacity
- Wildlife
- Water Quality (Hydrodynamics)
- Benthic environment and indigenous biodiversity
- Cultural values
- Biosecurity
- Benthic survey and monitoring.

Based on the information provided within the application, at the hearing, and within the submitters reply, I maintin the view that that the effects of the application on: landscape, wildlife, benthic environment, cultural values, biosecurity and benthic survey and monitoring will be less than minor, provided suitable conditions of consent are imposed.

Based information provided within the within the submitters reply, I have re-considered my position as to the application's potential adverse effects on the ecological carrying capacity of Big Glory Bay, and also the navigation safety within Big Glory Bay. Given the information provided within Dr Stenton-Dozey updated report, I consider that the applications cumulative effects on carrying capacity will be minor. Based on the assessments of Mr Cleaver and Mr Eriksson, in its current form, I consider that proposed application will have a more than minor effect on navigation safety of vessels within Big Glory Bay.

Updated Planning Analysis

The New Zealand Coastal Policy Statement

Within Dr Mitchell's statement of supplementary evidence[6] he has stated that:

> *'…I also remain of the opinion, as set out in paragraph 44 of my primary evidence, that a precautionary approach to these applications is required by virtue of Policy 3 of the NZCPS, my conclusion in that regard remains unchanged from my primary evidence.'*

I maintain the view that based on the updated review provided by NIWA, I consider that the potential effects of the application on hydrodynamics and phytoplankton depletion are known and are considered to be minor. Accordingly, I maintain the view that, in relation to these effects, a precautionary approach is not required by Policy 3 of the NZCPS.

In relation to the effects on navigation set out above, I acknowledge that there is a difference of opinion between Mr Eriksson and Mr Cleaver regarding navigational effects of the application, specifically in relation the navigational effect created by sites 1 and 2. I consider this does represent an uncertainty as to the level of navigational effect created by the proposal, however I do not agree that in the context of policy 3 on the NZCPS this represents a 'potentially significant adverse effect'. As noted in the effect's assessment above, I consider that this potential effect to be more than minor. Accordingly, I maintain the view that a precautionary approach is not required by Policy 3 of the NZCPS.

The Regional Policy Statement

Within Dr Mitchell's statement of evidence[7] he has provided an assessment of two objectives[8] and two policies[9] within the RPS which are directly relevant to this application.

Dr Mitchell states:

> *'…I do not consider the proposal avoids, remedies or mitigates its adverse effects on navigation, and the applicant has provided no factual basis to confirm that the cumulative effects on hydrodynamic processes and carrying capacity will be avoided, remedied or mitigated. Therefore, I cannot conclude that the proposal aligns with Objective COAST.2 – Activities in the coastal environment, Objective COAST.5 – Aquaculture (c), or Policy COAST.5 – Management of effects on coastal water quality and ecosystems. I also cannot conclude that*

[6] Paragraphs 20 of Dr Mitchell's statement of supplementary evidence

[7] Paragraphs 49 – 53 of Dr Mitchell's statement of evidence

[8] Objective COAST.2 and Objective COAST.5

[9] Policy COAST.4 and Policy COAST.5

the proposal is "appropriate aquaculture" in terms of Policy COAST.4 – Infrastructure, port, aquaculture, mineral extraction and energy projects.'[10]

Based on the submitters response to further information and s42A addendum I have reconsidered my view as to whether the application is consistent with objectives and policies within the RPS discussed above. I maintain the view that the application is consistent with the direction of the RPS in relation to managing the adverse effects associated with carrying capacity of the receiving environment.

In relation to managing the adverse effects associated with navigation safety, as noted in the effects assessment above, I consider that sites 1 and 3 of the application will have a more than minor effect of the navigation safety of the receiving environment. As such, I agree with Dr Mitchell assessment that the application is inconsistent with Objective COAST.2 and Objective COAST.5 as the application in its current form will not avoid, remedy, or mitigate the adverse effects on navigation safety.

I note that my assessment of the balance of the relevant objectives and policies of the RPS set out in my Section 42a report remains unchanged.

<u>The Coastal Plan for Southland</u>

Within Dr Mitchell's statement of evidence[11] he has provided an assessment of a number of objectives and policies within the Coastal Plan which he considered to be relevant to this application. He states that:

> *'Because the proposal does not avoid, remedy or mitigate adverse effects on navigation, and the applicant has provided no information to confirm that it will avoid, remedy or mitigate the cumulative effects on hydrodynamic processes and carrying capacity, in my opinion, the proposal is clearly contrary to these provisions.'*

Within his supplementary statement of evidence[12], he has stated that analysis of the objectives and policies of the Coastal Plan are unchanged from that set out in paragraphs 54 to 58 of his primary evidence.

Based on the submitter's response to further information and the s42A addendum I have reconsidered my view of whether the application is consistent with objectives and polices within the Coastal Plan discussed above. I maintain the view that the application is consistent with the direction Coastal Plan in relation to managing the adverse effects associated with carrying capacity of the receiving environment.

In relation to managing the adverse effects associated with navigation safety, as noted in the effect's assessment above, I consider that sites 1 and 3 of the application will have a more than minor effect on the navigation safety of the receiving environment. As such, I agree with Dr Mitchell assessment that the application is inconsistent with the following provisions of the Coastal Plan:

Objective 5.3.6 - Safe environment

Objective 11.2.1 - Location of structures

Objective 11.8.1 - Safe and efficient navigation

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[10] Paragraph 53 of Dr Mitchell's statement of evidence

[11] Dated 9 September 2019

[12] Dated 19 October 2019

Objective 15.1.1 - Avoid, remedy or mitigate any adverse effects

Policy 11.2.1 - New structures and extensions to existing structures

Policy 11.8.2 - Avoid adverse effects on navigation safety

I note that my assessment of the balance of the relevant objectives and policies of the Coastal Plan set out in my Section 42a report remains unchanged.

Section 104D of the RMA

Within paragraphs 57 and 58 of his evidence, Dr Mitchell has concluded that the proposal does not satisfy the requirements of section 104D.

Section 104D of the RMA states:

1. *Despite any decision made for the purpose of notification in relation to adverse effects, a consent authority may grant a resource consent for a non-complying activity only if it is satisfied that either—*
   a. *the adverse effects of the activity on the environment (other than any effect to which section 104(3)(a)(ii) applies) will be minor; or*
   b. *the application is for an activity that will not be contrary to the objectives and policies of—*
      i. *the relevant plan, if there is a plan but no proposed plan in respect of the activity; or*
      ii. *the relevant proposed plan, if there is a proposed plan but no relevant plan in respect of the activity; or*
      iii. *both the relevant plan and the relevant proposed plan, if there is both a plan and a proposed plan in respect of the activity.*
2. *To avoid doubt, section 104(2) applies to the determination of an application for a non-complying activity.*

When considering the 'gateway' test within Section 104D, as noted within my effect's assessment above, I have concluded that if the application was to proceed in its current form I consider that the navigation effects associated with proposed sites 1 and 3 would be more than minor, and therefore the application would fail limb (a) of the gateway test.

As noted in my assessment of the objectives and policies above, I consider that the application will be inconsistent with some of the objectives and policies of the both the RPS and the Coastal Plan that require safe navigation. However, I have also acknowledged that my assessment of the balance of the relevant objectives and policies of the RPS and Coastal Plan set out in my Section 42a report remains unchanged. Given that the direction within Policy 11.8.2 includes very directive language that any adverse effects from structures and activities on navigation safety shall be avoided, I have considered on balance, that the application is inconsistent with the direction within the Coastal Plan and therefore will fail limb (b) of the gateway test.

Section 104 of the RMA

Given my conclusion under section 104D, it is not necessary to provide an assessment under section 104 of the RMA. However, for completeness, in the context of the application's more than minor effects on navigation safety and the RPS and Coastal Plan's objectives and policies that seek to avoid, remedy and mitigate such effects, I consider that the application does not warrant approval under section 104 in its current form.

Final recommendation

Recommendation

I recommend, pursuant to sections 104, 104D, 105, 107 and 108 and subject to Part 2 of the RMA to REFUSE the application.

This recommendation is based on the potential navigation effects associated with proposed sites 1 and 3. My opinion on potential navigation is based on the evidence provided. This includes the evidence from the submitter and the Harbourmaster. I note the applicant did not provide any evidence concerning effects on navigation safety. However, I consider that if the applicant was to amend the scope of the application to the extent that the they could demonstrate to the Commissioner that navigation safety of vessels within Big Glory Bay were reduced to a minor level, this would change my assessment of the application.

Duration

In the event this application is granted, I have discussed a proposed duration below.

The applicants are seeking a consent duration of approximately 20 years (they seek that the consent expire on 1 January 2040). They are aware that all other consents in Big Glory Bay have a common expiry date of 1 January 2025. The applicant considers that a 2025 expiry date, would be too short and would not provide security for a new development, particularly given that it will take some time to get the sites set up and seeded with mussels. The applicants consider that sufficient time is required to establish farming on all sites, gather information associated with their farming activity, and to get a reasonable return on the investment required for the proposed development.

The RMA and relevant plans provide the following guidance on duration:

- Section 123A of the RMA limits the duration of coastal permits for aquaculture activities to at least 20 years unless a shorter period is requested by the applicant or is required to ensure adverse effects on the environment are adequately managed, and no more than 35 years;
- the CPS, RPS and RCP do not provide any specific guidance on duration for aquaculture consents;
- the Te Tangi a Tauira IMP provides guidance that durations over 25 years are essentially making decisions for the next generation, and consents should not be granted where it is not known what the effects may be over the long-term.

Environment Southland have obtained legal advice from Wynn Williams setting out the situations in which section 123A(2) of the Resource Management Act 1991 (RMA), which sets out the criteria for imposing a shorter duration of consent for aquaculture activities, is triggered. This advice is attached in Appendix 1.

This advice has concluded that:

> *'Section 123A was introduced into the RMA as part of the 2011 aquaculture reforms, with the purpose of the 20-year minimum consent duration to provide investment certainty to encourage investment in aquaculture. We consider the purpose of the section reinforces the high threshold to be met section 123A(2)(b) is engaged.*

In our opinion, section 123A(2) is engaged where there is a demonstrable adverse effect that can only be addressed through a shorter term. We also consider it is applicable in situations where the effects of the application are uncertain, and granting a consent for a shorter period would enable the effects of the application to be monitored, with the information gained informing a decision on whether to renew the consent for a further duration.

In short, a high threshold must be met to grant a resource consent for a term less than 20 years – the Commissioner must be satisfied on the evidence that:

a. *the application is likely to have an adverse effect on the environment; and*

b. *it is necessary to impose a shorter duration to ensure that adverse effects on the environment are adequately managed'*

As set out in the effect's assessment above, the adverse effects of the proposed application that still being discussed relate to the applications effect on the navigation safety and the carrying capacity of Big Glory Bay.

When considering whether the application's potential effect on navigation safely is such that granting a consent for a shorter period would enable the navigation safety effects of the application to be adequately managed, I consider that this consideration may only be appropriate when considering the effects of proposed site 1. As noted in the effect's assessment above, there was some disagreement between Mr Cleaver and Mr Eriksson as to the potential effects proposed Site 1 would have on the navigation safety of Big Glory Bay. However, I consider that the adverse effects on the environment could more appropriately be managed by introducing a review condition, allowing the Council the ability to review the location of proposed site 1 for the purposes of ensure that any potential adverse effects on navigation safely are being avoided. As such, I do not consider that granting a consent for a shorter period is necessary to ensure that adverse effects on the environment are adequately managed.

When considering whether the applications potential effect on the carrying capacity of the receiving environment is such that granting a consent for a shorter period would enable the effects of the application to be adequately managed, I consider that the further advice from NIWA has concluded that the application effect on the carrying capacity of Big Glory Bay will be minor. As such, I consider a shorter term is not required to mange this effect.

Recommended Conditions of Consent

If the Commissioner is of a mind to grant this application, I have recommended conditions for consideration. These are attached in Appendix 3.

Signed:

Name: Andrew Maclennan
Reporting Officer

Date: 23 October 2019

Appendix 1- Updated technical advice from NIWA on hydrodynamics and phytoplankton depletion

Memo

From	**Jeanie Stenton-Dozey**
To	Andrew Maclennan, Reporting Officer, Environment Southland
CC	Philip Jellyman, Assistant Regional Manager, NIWA Christchurch
Date	23 October 2019
Subject	Comments on Dr Hartstein's review dated 16 October on the carrying capacity section of a report complied by Stenton-Dozey and Plew 2019.

Dear Andrew,

I have carefully considered Dr Hartstein's comments on Section 3, Carrying Capacity, of the above report. I will respond in order of the points raised in each paragraph (indicated in italics), followed by my revised calculations and then end with my conclusions.

16. In this evidence I will provide a brief description of the Pelagic Effect Assessment Criterion Aquaculture Stewardship Council, (ASC). I will then go on to highlight that Dr. Stenton-Dozey has incorrectly interpreted the criterion and what the proposed farms will mean regarding the filtration rate of the bay. I also provide, as Appendix 1, my calculation of the mussel farm carrying capacity in Big Glory Bay.

Dr Hartstein is correct about my misinterpretation of the criterion and I am pleased for all parties that it has been identified. In preparing my original report I was under immense pressure to meet the deadline set by the Commissioner[1], and this did lead to my misinterpretation of how to calculate the value N (number of mussels) in the formula: Clearance time (CT)[2] (number of days) = Vt / (N x C)

Where:

- *Vt* is the total volume of the water body at high tide (L).
- *N* is number of bivalves.
- *C* is average clearance rate (litres/individual species/day) at harvest size.

I incorrectly used the annual harvest tonnage for 2018 to calculate the number of harvest-sized mussels. Now that I have had time to carefully study the criterion, it is clear that bivalve numbers should be based on the peak standing stock during the year (not the harvested stock in any one year) and the clearance rate of harvest-sized mussels must be used for this standing stock (i.e., all occupied farms must be considered stocked with harvest-sized mussels). When I used annual harvested tonnage, mussel numbers (N) were grossly underestimated so even when using the correct average clearance rate (C) for harvest-sized mussels (168 litres/day), CT was overestimated. I have recalculated the CT and water retention time (R) and will discuss this later in my response.

17. The Pelagic Effects Criterion from the Aquaculture Stewardship Council (ASC) uses calculations that compare how long it takes bivalves to clear a body of water vs the time it takes tides to flush that body of water. More specifically, this criterion assesses the rate that <u>mussels consume phytoplankton</u> based on the number of mussels per line, line depth, line spacing, and area being farmed.

[1] Minute #2 of the hearing commissioner

[2] Clearance time is the number of days required for the dominant bivalve stock(s) (wild and cultured) to clear the volume of the bay

The above comment does not require a change to the report, however, on a point of clarity: Phytoplankton consumption rate (food weight/h)[3] is not equivalent to clearance rates (litres/h). The species cultured in New Zealand, *Perna canaliculus,* retains food particles (phytoplankton and suspended particulates) at different efficiencies depending on quality and concentration. Hawkins et al. (1999)[4] calculated the average retention efficiency of phytoplankton as 70% (±30%) and for suspended organic particles as 23% (±10%). The use of clearance rates by ASC (rather then consumption rates) adds a level of conservancy to the assessment of ecological carrying capacity.

18. In the carrying capacity section of the NIWA Executive summary Dr. Stenton-Dozey states the following [my emphasis]:

> *'The Pelagic Effect Assessment Criterion based on the ratio of clearance time over retention time **did not exceed 1** and thus the criterion was met. Based on this indicator the cumulative effect of adding the three new farms does not adversely impact the ecological carrying capacity of BGB.'*

The reviewer is correct. This was a typographical error and the first sentence should (and now does) read in the Executive Summary of Version 2 of the report: "The Pelagic Effect Assessment Criterion based on the ratio of clearance time over water retention time (CT/RT) was calculated for different ha of mussel farming that considers ha occupied before 2011, post-2011 when salmon farming increased and ha that would be occupied with the proposed 16 ha added. For all these ha occupancies without the additional 16 ha, CT/RT ratios ranged between 1.14–1.47 and with 16 ha added, between 1.03–1.30. All these ratios are >1 which means the criterion for not exceeding the ecological carry capacity of BGB has been met with the addition of 16 ha".

20. Based on this conclusion, Dr. Stenton-Dozey demonstrates that the proposed farms will indeed breach the carrying capacity of Big Glory Bay. This contradicts her main findings where she states that the proposed development will not breach the carrying capacity of the embayment or only have a minor impact.

This is merely the reviewer continuing to re-emphasise the typographical error from above. It is clear from reading the report that this was simply a typographical error and that my conclusion in the next sentence is correct. It's also quite clear from the main report that my conclusion was based on CT/RT > 1.

21. I do not agree with Dr.Stenton Dozey's conclusions that the effects are minor, especially when section 3.2 of her report high-light that the Flushing rate is markedly slower than the filtration rate of the mussels.

22. Dr Stenton-Dozey's section 3.2 goes into some detail to describe the mussel filtration rate within Big Glory Bay. A summary of this is:

> *'Since the daily bay water exchange rate with the water outside the bay (7–10%) is less than the daily mussel filtration rate (11–13%), it's likely that mussel production has always depended to some extent on in-bay phytoplankton primary production'.*

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[3] Food weight as μg (or mg) of chlorophyll-*a.* Food weight can also be expressed in other units such as mg of suspended organic particulates.

[4] Hawkins, A.J.S., James, M.R., Hickman, R.W., Hatton, S., Weatherhead, M. (1999) Modelling of suspension-feeding and growth in the green-lipped mussel *Perna canaliculus* exposed to natural and experimental variations of seston availability in the Marlborough Sounds, New Zealand. *Marine Ecology Progress Series*, 191: 217-232. https://www.int-res.com/abstracts/meps/v191/p217-232/.

23. In my opinion, this statement confirms that the mussel farm carrying capacity of the bay will be exceeded as Dr. Stenton-Dozey's analysis clearly shows that the bay-wide mussel filtration rate is faster than the water exchange rate. A filtration rate greater than the exchange rate implies that there is not enough seston to ensure mussels within the embayment grow sustainably and that the carrying capacity is breached. In short, her own calculations indicate that the proposed application within Big Glory Bay is breaching the carrying capacity of the bay, and

24. In the main body of the text Dr. Stenton-Dozey also states:

> *"Historically, mussels in BGB have been reliant on 'old' resident in-bay water, processing between 3–4% by volume daily. It's likely therefore that in-bay phytoplankton production is important source of food for the mussels."*

25. Again, this confirms to me that the ASC criterion has been breached. To ensure sustainability, and that the carrying capacity of the embayment hasn't been exceeded, the supply of water must be faster than the rate of depletion. Dr. Stenton-Dozey's analysis is clearly showing that this isn't the case.

The five comments above are all addressed in my response below:

In my opinion Dr Hartstein's statements in his numbered paragraphs 21–25 ignore in-bay phytoplankton primary production where turnover rates can be between 2–5 days depending on temperature, duration of daylight hours (which varies with season and alters the quantity of photosynthetically available irradiance) and dissolved nitrogen (nitrate and ammonium) availability. These turnover rates are faster than the turnover of the bay water volume (14–28 days) which strongly supports the likelihood of in-bay primary production supplementing phytoplankton that enters from outside coastal waters. This assertion is also supported by the rationale behind a second tier Pelagic Effect Assessment Criterion (ASC 2019). If CT<RT, cultured bivalves may be able to control the ecosystem and an additional assessment is required linking clearance time to primary production time (PPT) in the bay. The rationale for the Tier 2 calculation is that phytoplankton production in a bay can support sustainable aquaculture (i.e., primary production within Big Glory Bay), up to a point, even when the bay is poorly flushed. Primary production time should be shorter than clearance time. Otherwise, the phytoplankton which mussels feed on will quickly be depleted – I have outlined this further in my revised report.

There is no evidence of in-bay phytoplankton biomass (measured as chlorophyll-*a* (μg/L)) depletion in Big Glory Bay. Long-term trend analysis of chlorophyll-*a* concentrations from 1997–2017 shows no significant increase or decline[5]. Increases could be related to an increase in salmon farming resulting in higher levels of dissolved nitrogen with a simultaneous increase in phytoplankton production while a decrease could be related to over-grazing by mussels. Neither of these aquaculture impacts on phytoplankton carrying capacity are evident from the chlorophyll-*a* trends over the last 20 years. Therefore, my assertion that '*Since the daily bay water exchange rate with the water outside the bay (7–10%) is less than the daily mussel filtration rate (11–13%), it's likely that mussel production has always depended to some extent on in-bay phytoplankton primary production*' is supported by the evidence at hand and by the ASC (2019) Tier 2 rationale.

My reply to the comment "*this confirms to me that the ASC criterion has been breached'* is addressed after Hartstein's paragraphs 26–31.

[5] Assessment of ecological effects of expanding salmon farming in Big Glory Bay, Stewart Island – Part 2 Assessment of effects (James, Hartstein, Giles) 26 April 2018, Figure 21, page 13

26. Finally, section 3.3 of Dr Stenton-Dozey's review provides her calculations of the CT/RT ratio based on the ASC criterion. I have gone through these calculations and I consider them to be incorrect. In short, her assessment is that the CT/RT ratio is greater than 3 indicating that the flushing rate of the bay is 3 times faster than the clearance rate (Dr Stenton-Dozey presents calculations where Big Glory Bay has a CT of 16.25 days vs a flushing, RT of only 4.62 days).

27. This contradicts both the executive summary and the findings of her section 3.2 where the mussel farm clearance rate was shown to be faster than the rate of supply i.e.

> *Since the daily bay water exchange rate with the water outside the bay (7–10%) is less than the daily mussel filtration rate (11–13%).*

28. Furthermore, there is no direct evidence to indicate how the flushing rate can now be more than 3 times faster than mussel farm clearance as described in section 3.3, when in fact it is three times less.

29. To address the uncertainty provided in Dr. Stenton-Dozey's report I have made my own assessment of the CT/RT ratio of Big Glory Bay using the ASC Pelagic Effect Assessment Criterion. In doing so, I have used information that I had obtained about the site from my previous hydrodynamic modelling and numerous site visits to provide information on the stocking density, bathymetry data, tidal range and surface area of the embayment etc.

30. A spread sheet showing my calculations for Big Glory Bay is attached as Appendix 1.

31. I estimate that the CT/RT ratio for Big Glory Bay is approximately 0.7-0.8. Although I accept that calculating an exact figure will always result in some uncertainty, I am convinced that the ratio for Big Glory Bay is significantly less than 1, thus confirming that the proposed mussel farms are beyond the carrying capacity of the bay.

As mentioned at the beginning of this memo, Dr Hartstein is correct about my misinterpretation of the criterion and therefore the CT/RT ratios generated were incorrect. I have recalculated CT/RT for several scenarios distinguished by differences in the ha of mussel farming. The details of these calculations are in Version 2 of the Stenton-Dozey and Plew (2019) report which is appended to this memo as a separate file. I have also attached an Appendix A within this memo of Table 3-4 from Version 2 of Stenton-Dozey and Plew (2019) as this table presents the different mussel farming scenarios previously mentioned.

The range of CT/RT ratios I calculated differ from that given by Dr Hartstein in Appendix 1 of his review. The differences relate to how low- and high-tide bay volumes were calculated.

The volume at mid-tide given by James et al. (2018)[6] is 0.189 km^3 (189,000,000,000 litres). This is calculated as bay surface area 12,001,400 m x average depth at mid-tide (m). In this calculation mid-tide depth would be 15.75 m. James et al. (2018a) give an average bay depth of 15.9 m which is close to that in the former calculation, but both are greater than the 15 m given as the estimated average depth in Hartstein's Appendix 1. When a depth of 15.9 m is used, the average water volume of the bay is 190,822,260,000 litres (Appendix A), close to the mid-tide volume. However, both mid-tide and average volumes are greater than that used by Hartstein as the average water volume at high tide (Vt = 180,021,000,000 litres) in his Appendix 1 and this error has an impact on calculating water retention time (R) and hence the CT/RT ratio.

To determine bay volumes, I first calculated the average tidal range to be 1.65 m based on neap and spring tide ranges given in James et al. (2018a): (1.34 m neap tide + 1.95 m spring tide)/2 = 1.65 m) which is similar to that given in Hartstein's Appendix 1 (1.7 m). I rounded the tidal range to 1.7 m to align with Dr

[6] Assessment of ecological effects of expanding salmon farming in Big Glory Bay, Stewart Island – Part 1 Assessment of effects (James, Hartstein, Giles) 26 April 2018 page 13.

Hartsteins’ value. It follows that when a 15.9 m average depth at mid-tide is used that the depth at low tide is 15.9 m – 0.85 m = 15.05 m and at high tide is 15.9 m + 0.85 m = 16.75 m. Using these depths, the respective bay volumes are 180,621,070,000 litres at low tide and 201,023,450,000 litres at high tide. Corresponding volumes given by Hartstein are 165,352,622,489 litres and 180,021,000,000 litres, respectively. Application of the RT formula with a tidal cycle P = 0.517 days (M2 tidal period = 12 h, 25 min) gives a water retention time of 4.83 days compared to Hartstein’s 6.37 days. I back-calculated the estimate of RT = 6.37 says and it seems a P = ~0.542 days was used instead of 0.517 days and I am unclear why this higher value was used.

Other differences between Hartstein’s Appendix 1 and my Appendix A relate to the length of backbones and droppers, the number of mussels per metre of dropper and mussel filtration rates (litres/day). However, these differences do not result in a meaningful discrepancy in the calculation of the volume of water filtered by mussels per day per ha (Hartstein: 261,000,000 litres/day/ha; My calculation: 262,080,000 litres/day/ha).

34. My own calculations of the ASC criterion confirm that the carrying capacity of the embayment has been exceeded.

Hartstein’s comment indicates that from his calculation of the ASC criterion that it should have a CT/RT of <1 so contends that the carrying capacity of the embayment has been exceeded. I disagree with his calculation and outline a number of scenarios (see Appendix A as previously discussed) as to why I do not consider that the carrying capacity is exceeded. For Scenario 1, CT/RT = 1.14; this scenario considers all present allocated aquaculture space to be occupied my mussels (i.e., no salmon farms) — which is not a realistic situation but provides a range for the CT/RT calculations. For Scenario 2, CT/RT = 1.22; this scenario represents peak mussel occupancy prior to 2011. From 2011, salmon farms were relocated to previous mussel farm sites and my best estimate of the present mussel occupancy is 135 ha (Scenario 3, CT/RT = 1.36). I have also included using a mussel occupancy of 125 ha suggested by the Applicant (Scenario 4, CT/RT = 1.47). When the areas of the proposed farms are added to these scenarios, the CT/RT ratios range from 1.04 (Scenario 1 + 16 ha) to 1.30 (Scenario 4 + 16 ha).

These ratios, across all scenarios of different total areas of mussel farming, are all close in value and suggest (based on the Indicator 2.2.1 criterion) that in the past (pre-2011), present and with the proposed farms added, the clearance time for mussels in BGB is marginally higher than the tidal retention time (i.e., the rate that water is replenished through tidal exchange is faster than the rate that water is filtered by the mussels). This is not in conflict with the assessment in Section 3.2 (percentage of in-bay water volume filtered by mussels being 3–4% greater than daily percentage of bay exchanged by tides). The methods used to calculate clearance and water retention rates differ. The CT/RT ratio incorporate tidal exchange in calculations whereas size-dependent mussel percentage water filtered only considers the proportion of mid-tide bay volume filtered. If the ‘daily percentage of water volume filtered’ method is applied to the parameter values in Appendix A (i.e., (N x C) / mid-tide bay volume (189,000,000,000 litres)), the percentages range between 17%–21% depending on the number of hectares of mussel farming. These percentages are higher because harvest-sized mussels were used to calculate C rather than using mussels of different sizes from spat to adults.

The simple tools used to ascertain the cumulative impact of adding three new mussel farms have indicated effects on the ecological carrying capacity of BGB are likely to be minor. The Pelagic Effect Assessment Criterion based on the ratio of clearance time over water retention time (CT/RT) was > 1 over a range of ha mussel farming scenarios (i.e., with differing total areas) both with and without the additional 16 ha of proposed farms. Based on this ASC's Bivalve Standard, my analysis indicates that the addition of 16 ha of mussel farms will not exceed the ecological carrying capacity of BGB.

35. This conclusion is reinforced by the very slow mussel growth rates experienced in Big Glory Bay, as previously addressed in the evidence of Mr Culley and Mr Schofield.

In my opinion it is likely that multiple factors contribute to the slow growth of mussels in BGB. It has been asserted that slow growth is attributed to mussel spat being sourced from the warmer waters of Northland, slow water currents and there being too many mussels in Big Glory Bay[7]. However, another very important factor is the cold-water temperatures in the bay compared to other areas that grow mussels in New Zealand. From my experience of undertaking environment assessments in the bay from 2012–2015 (see reference list in James et al. 2018), water temperatures throughout the water column ranged from ~9°C in winter to a maximum of ~15°C in summer. Cold water temperatures in combination with reduced sunlight contribute to the lower concentrations of chlorophyll-*a* recorded over winter. Key (2002)[8] in a study from July 1999 and July 2000 found a strong seasonal trend in water temperature, chlorophyll-*a* and mussel growth in BGB. Mussel growth was fastest over the summer months, related to increase in water temperature, but primarily food availability as phytoplankton production also increased.

Yours Sincerely,

J. M. E. Stenton-Dozey

Jeanie Stenton-Dozey

Date: 23/10/2019

Approved for release: Phillip Jellyman

Phillip Jellyman

Assistant Regional Manager, Christchurch

Date: 23/10/2019

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[7] Submission of Evidence from Ted Cully 12 September 2019

[8] Key, J. M. (2002, August 24). Growth and condition of the Greenshell mussel, *Perna canaliculus*, in Big Glory Bay, Stewart Island: relationships with environmental parameters (Thesis, Master of Science). Retrieved from http://hdl.handle.net/10523/8350

Appendix A. Parameter values used to determine CT/RT ratios for mussel farms in Big Glory Bay. After Table 3-4 in Stenton-Dozey and Plew (2019, Version 2).

Parameter	Hartstein 16-Oct-19	Hartstein Vol corrected	Scenario 1 161.5 ha	Scenario 2 Pre-2011	Scenario 3 Post-2011 (1)	Scenario 4 Post-2011 (2)	Scenario 1+16ha 161.5 + 16 ha	Scenario 2+16ha Pre-2011	Scenario 3+16ha Post-2011 (1)	Scenario 4+16ha Post-2011 (2)
Total surface area (ha)	1200.14	1200.14	1200.14	1200.14	1200.14	1200.14	1200.14	1200.14	1200.14	1200.14
Total surface area (m^2)	12,001,400	12,001,400	12,001,400	12,001,400	12,001,400	12,001,400	12,001,400	12,001,400	12,001,400	12,001,400
Average depth (m)	15	15	15.9	15.9	15.9	15.9	15.9	15.9	15.9	15.9
Water volume on average depth (litres)	180,021,000,000	180,021,000,000	190,822,260,000	190,822,260,000	190,822,260,000	190,822,260,000	190,822,260,000	190,822,260,000	190,822,260,000	190,822,260,000
Total farm allocation (ha)			161.5	161.5	161.5	161.5	161.5	161.5	161.5	161.5
Total mussel farm coverage (ha)	162.783076	162.783076	161.5	150	135.0	125.0	177.5	166	151.0	141.0
Average reduction for warp line area	12.50%	12.50%	13.50%	13.50%	13.50%	13.50%	13.50%	13.50%	13.50%	13.50%
Cultured occupational area (ha)	145	145	140	130	117	108	154	144	131	122
Mussel farm surface structures as % of bay	12.08%	12.08%	11.64%	10.81%	9.73%	9.01%	12.79%	11.96%	10.88%	10.16%
Length of backbone (m) per hectare	1300	1300	900	900	900	900	900	900	900	900
Depth of dropper lines (m)	15	15	12	12	12	13	12	12	12	13
Total metres of dropper line per hectare of farm	14,500	14,500	10,400	10,400	10,400	10,400	10,400	10,400	10,400	10,400
Number mussels per metre of dropper line	120	120	150	150	150	150	150	150	150	150
Total mussels per hectare of farm	1,740,000.00	1,740,000.00	1,560,000	1,560,000	1,560,000	1,560,000	1,560,000	1,560,000	1,560,000	1,560,000
Filtration rate (litres per day)	150	150	168	168	168	168	168	168	168	168
Water Filtered per day per hectare (litres)	261,000,000	261,000,000	262,080,000	262,080,000	262,080,000	262,080,000	262,080,000	262,080,000	262,080,000	262,080,000
Water Filtered per day by all farms (litre) -N x C	37,845,000,000	37,845,000,000	36,725,270,400	34,118,229,600	30,694,809,600	28,337,400,000	40,352,457,600	37,745,416,800	34,231,579,200	31,964,587,200
Average tidal change (m)	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
Depth at low tide (m)			15.05	15.05	15.05	15.05	15.05	15.05	15.05	15.05
Depth at high tide (m)			16.75	16.75	16.75	16.75	16.75	16.75	16.75	16.75
Average water volume low tide (litres): Vl	165,352,622,489	180,621,070,000	180,621,070,000	180,621,070,000	180,621,070,000	180,621,070,000	180,621,070,000	180,621,070,000	180,621,070,000	180,621,070,000
Average water volume high tide (litres): Vt	180,021,000,000	201,023,450,000	201,023,450,000	201,023,450,000	201,023,450,000	201,023,450,000	201,023,450,000	201,023,450,000	201,023,450,000	201,023,450,000
Tidal cycle (M2 tidal period = 12 hrs, 25 min)/24) days: P		0.517	0.517	0.517	0.517	0.517	0.517	0.517	0.517	0.517
Clearance Time (CT): CT (days) = Vt / (N x C)	4.76	5.31	5.49	5.91	6.55	7.09	5.00	5.34	5.87	6.29
Retention Time (RT): RT (days)= -1 x P / ln (Vl / Vt)	6.37	4.83	4.83	4.83	4.83	4.83	4.83	4.83	4.83	4.83
CT / RT ratio	**0.75**	**1.10**	**1.14**	**1.22**	**1.36**	**1.47**	**1.03**	**1.11**	**1.22**	**1.30**

Comments on cumulative effects of proposed mussel farms in Big Glory Bay

Hydrodynamics and phytoplankton carrying capacity

Prepared for Environment Southland

October 2019

Version 2

Prepared by:
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Executive summary

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- Hydrodynamic effects based on the information provided within the application and further information provided with respect to the size and location of the proposed farm sites.
- The response submitted by the Applicant on phytoplankton carrying capacity and past mussel harvest volumes having been higher in the past.

Hydrodynamics:

- The existing mussel and salmon aquaculture farms in BGB cover a significant portion and their structures likely affects currents (tidal and wind driven) and circulation patterns within the bay.
- There is some evidence of this effect in that the two previous conducted modelling studies (neither of which included the drag from marine farms) showed poor agreement with observations collected within the bay from a current meter deployed between two mussel farms.
- The three proposed mussel farms increase the total consented farm area by 16 ha from ~160 ha, this is the combined consented area for both salmon and mussels (although not all consented area is currently occupied). The proposed farms increase the area consented for aquaculture from ~13% to ~15% of the bay area. The three proposed farms will cause further changes in currents and circulation patterns within the bay.
- However, considering the locations of the proposed farms and the increase in farmed area relative to existing farms, expect that these changes will be minor compared to the impact that the present aquaculture activities likely already have on the bay.

Carrying capacity:

- The simple tools used in this report to ascertain the cumulative impact of adding three proposed mussel farms have indicated effects on the ecological carrying capacity of BGB are likely to be minor.
- The Pelagic Effect Assessment Criterion based on the ratio of clearance time over water retention time (CT/RT) was calculated for different ha of mussel farming that considers ha occupied before 2011, post-2011 when salmon farming increased and ha that would be occupied with the proposed 16 ha added. For all these ha occupancies without the additional 16 ha, CT/RT ratios ranged between 1.14–1.47 and with 16 ha added, between 1.03–1.30. All these ratios are >1 which means the criterion for not exceeding the ecological carry capacity of BGB has been met with the addition of 16 ha.
- An alternative method using size-dependent mussel filtration rates suggested that 11.6% of the mid-tide bay volume is processed daily by present mussel farms increasing to 13.1% with the proposed addition of 16 ha of mussel farms. This is filtration volume is greater than the

estimated daily tidal exchange rate (7–10%) suggesting mussel production depends to some extent on in-bay phytoplankton primary production.

- It is feasible that in-bay primary production takes place since the bay-wide water mass has a long residency time of 14-28 days which is sufficient to allow for phytoplankton turnover rates of 2–5 days.
- Long-term trends in chlorophyll-*a* concentrations show no significant change supporting the view that mussels depend on both in-bay and entrained phytoplankton production.

1 Background

The hearing for the application APP20181316 by Zane Smith and James Maass-Barrett ('the Applicant') for resource consents associated with the establishment and operation of three proposed mussel farm sites totally 16 ha in BGB (Stewart Island) (Figure 1-1), was held on 16 September 2019. The hearing was adjourned following the presentation of submitter evidence to allow for the Reporting Officer to consider all of the evidence presented and to provide an addendum to the s42A Report[1] addressing the potential effects on hydrodynamics and phytoplankton carrying capacity.

The Commissioner asked the Applicant to provide further information relating to the phytoplankton carrying capacity of BGB with evidence to support the Applicant's assertion that mussel volumes produced had peaked at higher levels in the past, without any measured adverse effects on phytoplankton carrying capacity. The Commissioner also raised the need for the Applicant to consider the 'Pelagic Effect Assessment Criterion' from the Aquaculture Stewardship Council (ASC 2019) or a similar scientific method to demonstrate the proposed additional mussel farming is within the carrying capacity of BGB. In accordance the Applicant submitted a Response to a Request for Further Information (RFI)[2] on 2 October 2019. In addition, the Commissioner asked the Reporting Officer for Environment Southland to address the hydrodynamic effects of the application in his reply including an assessment as to whether the effects are less than minor, minor or more than minor. In this regard the Reporting Officer requires the provision of some general comments on hydrodynamic effects based on the information provided within the application and further information provided with respect to the size and location of the proposed farm sites.

Environment Southland requested that NIWA provide comments on:

1. Hydrodynamic effects based on the information provided within the application and further information provided with respect to the size and location of the proposed farm sites.

2. The response to the RFI submitted by the Applicant on phytoplankton carrying capacity and past mussel harvest volumes having been higher in the past.

In both instances NIWA studied the relevant information from the application provided by the Reporting Officer and on the Environment Southland website[3].

Our discussion is presented in two sections: Hydrodynamics by Dr David Plew and Carrying Capacity by Dr Jeanie Stenton-Dozey.

This report (Version 2) supersedes Version 1 which was reviewed by Dr Hartstein (Review dated 19 October 2019). Dr Hartstein correctly noted that in applying the Tier 1 'Pelagic Effect Assessment Criterion' in the Carrying Capacity (Section 3.3), Dr Stenton-Dozey misinterpreted the determination of mussel numbers. These calculations have been revised in this report (Version 2).

[1] 42A Officer's Report Hearing of Application – APP 20181316- Zane Smith & Jim Maass Barrett. Compiled by Andrew Maclennan, Resource Management Consultant

[2] John Engel "Response to additional request for information dated 2 October 2019 for an application for coastal permit for marine farming".

[3] https://www.es.govt.nz/environment/consents/notified-consents/2019/zane-smith-and-jim-maass-barrett

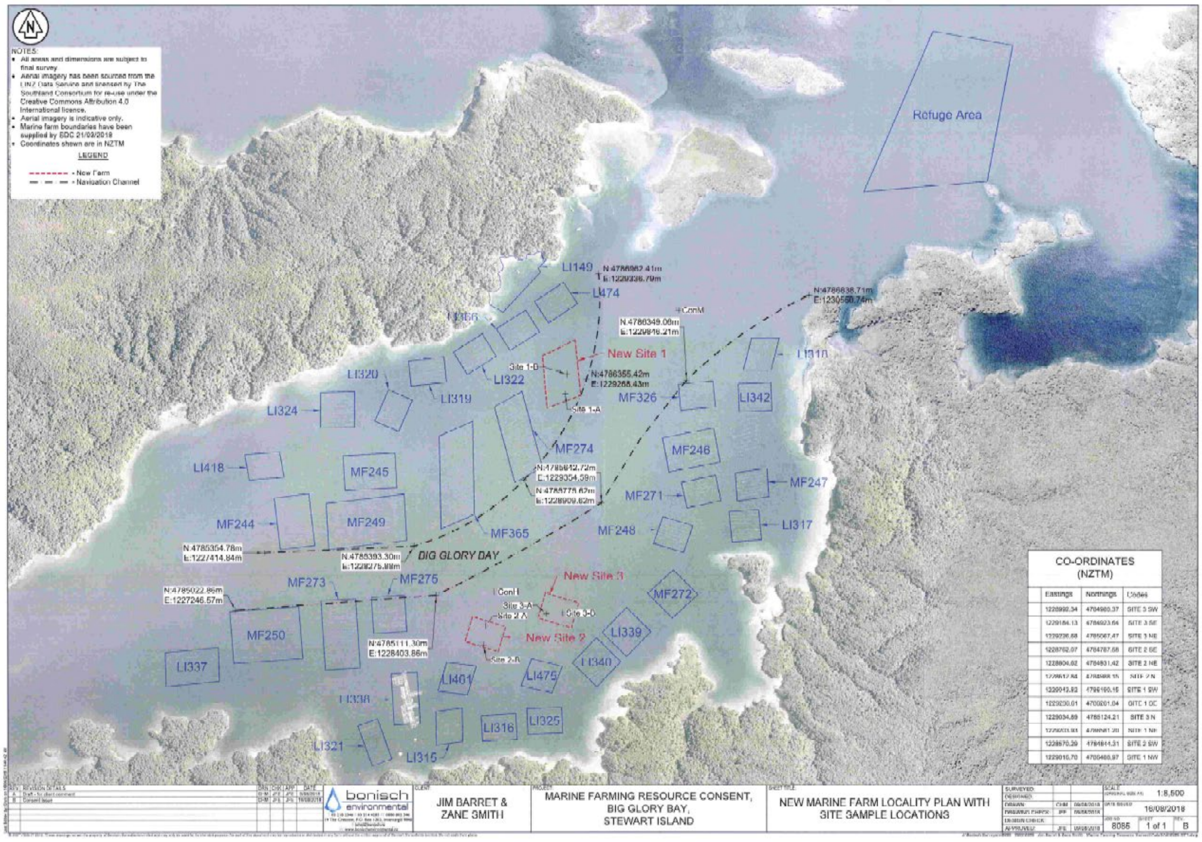

Figure 1-1: New marine farm locality plan in Big Glory Bay. The three proposed sites are marked in red.

2 Hydrodynamics

2.1 General aspects of currents

Currents within coastal embayments such as BGB are largely driven by tides, which flow in and out of the bay every ~12 hours. Tidal currents can transport material a considerable distance, but because they generally reverse direction every 6 hours, often material may end up close to its starting point some 12 hours later. However, tidal currents do not completely reverse, and eddies that form behind headlands, constriction and expansion of flow through narrow passages and steering by coastlines and bathymetry result in net flow patterns, or residual currents, that can be discerned by averaging currents over several tidal cycles.

On top of this, wind also drives currents in the bay, and indirectly affects currents in the bay by modifying coastal currents. Atmospheric pressure changes affect sea level, causing flows into and out of the bay similar to (but generally smaller than) tides. The other factor that can cause currents are differences in water density. In an embayment, fresh-water inputs from streams or runoff form a less dense (lighter) surface layer that flows seaward. As it does, it mixes with and entrains sea water, so that a volume of water significantly greater than the freshwater input to the bay flows out of the bay near the surface. To balance this, there is a deeper inflow of denser sea water. This vertical circulation pattern (outward at the surface, inward at the bottom) is commonly referred to as an estuarine circulation. A flow resembling estuarine circulation can also be caused by heating of surface waters in the bay (by solar radiation). Wind can also drive surface currents one direction, while deeper water moves in different directions.

2.2 Hydrodynamics of Big Glory Bay

The hydrodynamics (the movement of water) in BGB have been investigated through observations and hydrodynamic modelling. Reports and evidence submitted by other parties refer to the use of drogues and current meters by Pridmore and Rutherford in July 1988. While I have been unable to access the original publications in time to prepare this report, a summary of the findings of Pridmore and Rutherford (1990) regarding the internal circulation patterns in BGB was provided in an appendix to the RFI by Engel[4]. A summary diagram is reproduced in Figure 2-1. The net circulation pattern according to Pridmore and Rutherford (1990) is of a general flow towards the mouth of the bay along the northern and southern coastlines. Pridmore and Rutherford (1990) also describe an estuarine-type circulation pattern of net outflow at the surface and inflow near the bed.

I am aware of two hydrodynamic modelling studies of BGB. In 2012, DHI produced a model for Sanford Ltd to consider the impact of increased salmon farming. This model was reviewed by NIWA (Broekhuizen, Hadfield and Stenton-Dozey 2012) who considered that the hydrodynamic model was generally 'sound and fit-for-purpose'. This model was validated against current meter data collected by the Cawthron Institute at two locations – in the entrance to BGB, and in the inner bay between two mussel farms approximately 300 m apart (6 Sep–6 Oct 2010). DHI used the MIKE3 FM HD hydrodynamic model with variable horizontal resolution and 13 vertical layers, forced by tides and wind with steady (non-varying) freshwater inputs included.

[4] s92 Response Tidal flushing – Pridmore 1991 APP-20181316.pdf dated 17 August 2018

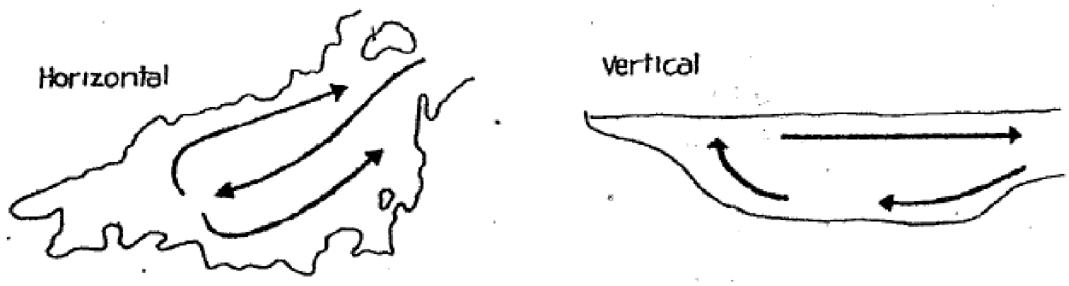

Figure 2-1: Diagram of the internal circulation patterns in Big Glory Bay according to R. Pridmore 1991. Taken from s92 Response Tidal Flushing – Pridmore 1991 APP029181316.pdf.

A second modelling study by Aquatic Environmental Sciences and Aquadynamic Solutions (ADS 2017) used the DELFT3D hydrodynamic model with 40 m horizontal resolution and 10 vertical layers, driven by wind, offshore currents and tides. This model was calibrated and validated using the same current meter described above.

The two models give similar results. The models show large scale eddies and recirculation in the bay. The models show that average currents in the bay are low (< 5 cm/s in the inner bay), and stronger (5–15 cm/s) towards the mouth. They show a general flow towards the mouth of the bay along the northern and southern coastlines (underlying the oscillating tidal flows), and an estuarine-type circulation pattern of net outflow at the surface and inflow near the bed, consistent with the description by Pridmore and Rutherford (1990).

Both models compared well with the current meter that was deployed in the entrance to the bay. However, neither model reproduced the speed or direction of currents at the location of the inner current meter with much accuracy. Both studies attribute this to the presence of the numerous mussel farm and fish farm structures in the bay. Neither model included the effect of mussel or salmon farms, so it is likely that much of the discrepancy between models and data is due to the farms.

2.3 Effects of marine farms on currents

Several peer-reviewed scientific publications show that longline farms (of the type or like those used for culture of Greenshell mussels in New Zealand) impede flow, and cause changes in currents. The greatest change generally occurs within the farmed area itself. Observational studies have detected a wide range of reductions in current speed from 13% (Boyd and Heasman 1998) up to 90% (Lin et al. 2016). This wide range is due to a number of factors including the design of the farm, density of the farming (the spacing between the mussel crop ropes along a longline, and the spacing between longlines), depth of the crop lines relative to the water depth, size of the crop, orientation of the longlines, size of the farm, and the proximity of the farm to other obstructions such as the shore or other farms (which restricts the ability for flow to be diverted around the farm rather than through). For mussel farms in New Zealand, a more typical reduction in flow speed is 20-60% (Plew et al. 2005; Plew 2011b).

The effects of mussel farms on currents extend beyond the boundaries of the farms. Downstream of the farm there is a wake zone with reduced velocities (the size of this is determined by farm size and tidal excursion), and there can be increased velocities around the sides of the farm as flow is diverted around the farm. As an illustration, Figure 2-2 (from Plew 2005) shows transects of water velocities measured through a large mussel farm in Golden Bay, with the arrows indicating the direction and speed of the current. Velocities within and downstream (south-east) of the farmed area are lower than elsewhere, and the direction of the arrows show how flow is diverted around the farm.

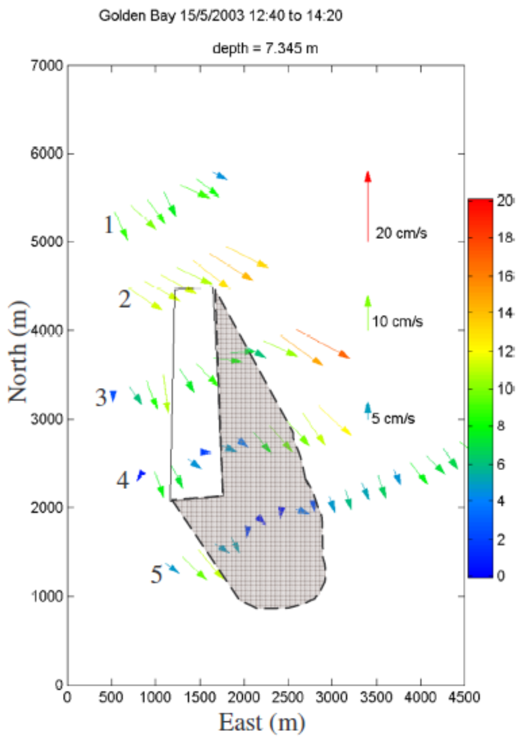

Figure 2-2: Measured water currents through a large mussel farm in Golden Bay. The arrows indicate the speed and direction of currents, which were measured from a current meter mounted on a boat. At this stage of the tide, the predominant current was from north-west to south-east. From Plew (2005).

Multiple marine farms within an embayment have cumulative effects on currents, which can alter circulation patterns with the bay (Grant and Bacher 2001; Plew 2011b; Shi et al. 2011; O'Donncha et al. 2013; Lin et al. 2016; Wang et al. 2018). Fish cages also affect currents in a similar manner (Merceron et al. 2002; Helsley and Kim 2005; Johansson et al. 2007; Winthereig-Rasmussen et al. 2016), and depending on their structure and because of the solidity of the structures compared to mussel farms, may have higher drag. There can be changes in flow direction, some local increases in velocity, but in general the presence of farms causes reductions in the average water velocity within bays. An illustration of this is given in Figure 2-3, which shows results from a modelling study of two bays in the Pelorus Sound (Plew 2011b). The figure on the left shows the residual (time-averaged) currents with no farms, and on the right the change in residual currents caused by mussel farms.

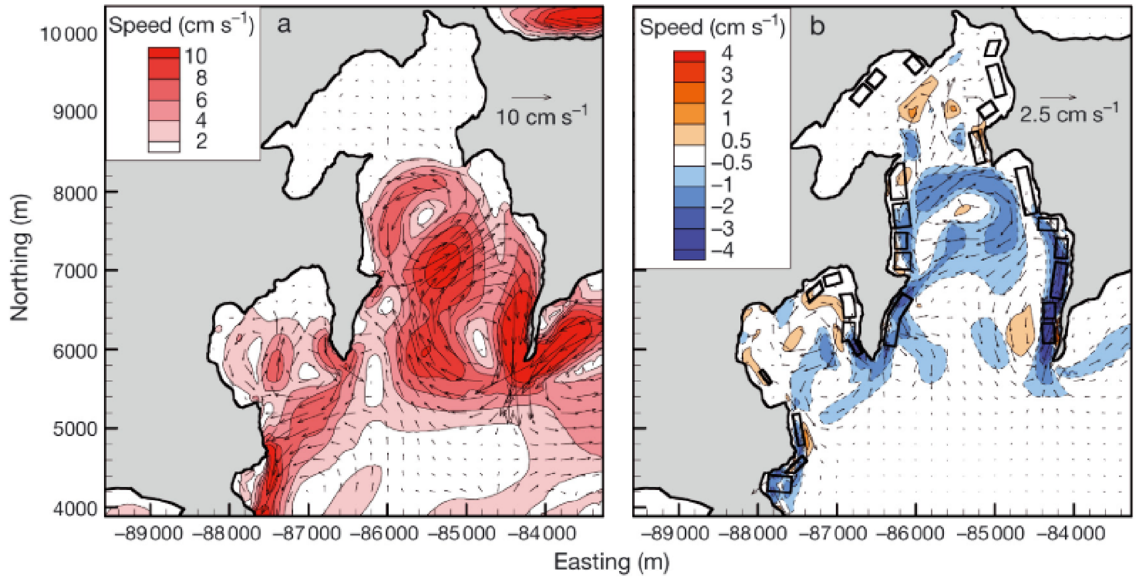

Fig. 5. (a) Residual current speeds with no farms, and (b) difference in residual speeds. Decreases in water speed are indicated with dashed contour lines. Boxes: farm positions

Figure 2-3: (a) residual currents in Port Ligar and Waihinau Bay (Pelorus Sound) in the absence of marine farms, (b) difference in residual currents caused by marine farms (outlined in black). From Plew (2011b).

The location of the farms is also important. Farms located in areas with high current speeds have a large effect on flow within the bay, as do those in areas where flows are constricted, such as through narrow entrances. This is illustrated both in the previous figure as well as in Figure 2-4 below, taken from the same study (Plew 2011b). The figure shows the percentage change in mean water speed caused by different farm layouts. Figure 2-4a shows the changes in current speeds caused by the present farm layout, while Figure 2-4 b-d show changes in current speeds caused by the same amount of farming (occupying the same total surface area) located in different parts of the bay. Under those scenarios, placing the farm in the middle portion of the bay (Figure 2-4c) caused the greatest reduction in current speeds (-19% averaged over the bay) as it blocked a significant fraction of the width of the bay.

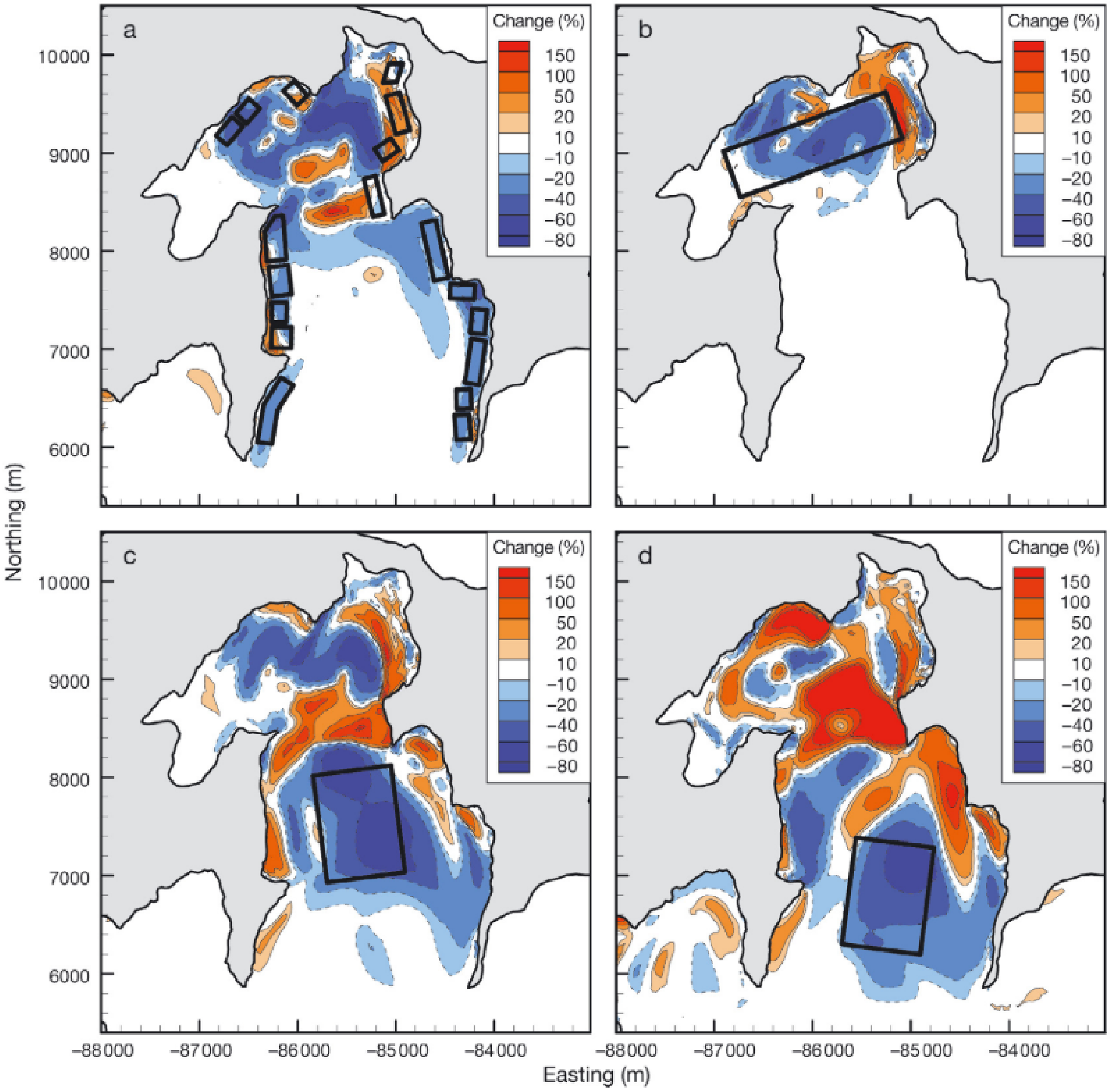

Fig. 7. Comparison of % change in mean water speed for existing farms in Port Ligar (a), and a single large farm covering the same total area located in the (b) inner bay, (c) mid bay, and (d) outer bay. Positive values (solid contours) indicate an increase in mean water speeds compared to simulations with no farms, negative values (dashed contours) indicate a reduction in speed

Figure 2-4: Effect of different layouts of marine farms with the same total farmed area on mean current speeds in Port Ligar. From Plew (2011b).

2.4 Implications of existing farms for the hydrodynamics of Big Glory Bay

Because neither of the two models of BGB included the effects of the farms, neither give a true representation of the present currents and circulation patterns in the bay. BGB already contains several mussel farms, as well as three salmon farms. Of the approximately 1200 ha of the bay, at least 160[5] ha (13.3% of the bay) are already allocated for marine farming. Not all these areas are currently in use. A response from J. Engel (12 Dec 2018)[6] states that in the past, mussel farming would have filled a maximum of 148 ha of BGB and is currently at 125 ha (10.1% of the bay). I estimate that the salmon farms cover an additional area of approximately 3.5 ha based on structure visible in satellite images from 22 Nov 2018. Based on my own work elsewhere and studies by others,

[5] Evidence from Ted Cully states that Sanford Ltd exercise 24 of the 35 consented mussel farm areas, comprising a total area of 161.5 ha. Evidence from Peter Schofield says the bay already has ~162 ha allocated to marine farming. It is not clear to me it 161.5 ha is the total area allocated, or only the area of the 24 areas exercised by Sanford Ltd.

[6] file: Response to further information 11-12-18 APP-20181316.pdf

I expect that the presence of the existing farms will have resulted in reductions of mean current speeds throughout the bay.

Various estimates of flushing time have been given, depending on the method used to calculate the flushing time. The tracer flushing simulations (Hartstein) likely give the most accurate indication of the time taken to replace the water in the bay. In the absence of farms, 85-90% of the water in BGB was replaced in 28 days. With farms present, I expect that this exchange would be slower. In particular, water at the head of the bay would take longer to be replaced due to a reduction in circulation caused by farm drag.

I cannot say with any certainty what the magnitude is of the effects existing farms have on current speeds or flushing times. To do so would require adding the drag of the existing farms into a hydrodynamic model. Commonly this has been done with 2-dimensional, depth-averaged models which do not account for differences in water currents vertically through the water column (Grant and Bacher 2001; Plew 2011a, 2011b; O'Donncha et al. 2013), although increasingly, 3 dimensional models have been used (Shi et al. 2011; O'Donncha et al. 2015; Wang et al. 2018). In general terms, I speculate that throughout the bay, current speeds are generally reduced, although there may be local accelerations around farm perimeters and between farms, such as through the central channel denoted by the dashed lines in Figure 1-1. Overall circulation patterns have likely been altered, and I expect that the strength of outward flowing currents along the north and south coasts reported by Pridmore and Rutherford (1990) and Hartstein (2019) would have been reduced. The overall flushing time has likely increased.

2.5 Effect of the proposed farms on currents

The three proposed mussel farms occupy a total of 16 ha, and their proposed locations are shown in Figure 1-1. These three farms will induce further modification to currents and circulation in addition to that caused by existing farms. Considering the likely, but unquantified, impacts of the existing farms, the additional impact on currents and circulation from the proposed farms would be minor. On the incoming tide, the outmost site (site 1) may divert water towards the open 'navigation' channel. If site MF274 is occupied, then effects on the outgoing tide are likely small. The inner two sites (2 and 3) are in an area of the bay that both models indicate has low current speeds (albeit in the absence of other farms), so I expect would have relatively little effect on overall circulation and flushing times.

To provide any more certainty of the effect of the proposed farms would first require assessing the effects of the existing farms, which to my knowledge has not been done.

I note the comment in the Recommending Report[7] (Section *Water column* Response page 9):

The amount of water coming in and out of the bay does not change but the marine farm structures will deflect water around them and create eddies in the tidal current.

While this statement is correct in that the tidal prism (the difference in volume between high and low tide) will be essentially unaffected by the present or proposed farms, the volume of water flowing in and out of the bay at any instant, and the speed of currents within the bay, may be affected. Water can be flowing in and out of the bay at the same time – for example in on one side while out on the other, or inwards near the bed and outwards near the surface. This has implications for the flushing time of the bay. Furthermore, the drag from the farm removes kinetic energy, likely reducing (slowing) the tendency of water to circulate in gyres or large eddies. However, considering

[7] s92(1) Further information response 17 August 2018 (First) APP-20181316 17_08_2018.pdf

that the proposed farms increase the occupied area from 10 to 12%, I expect that the additional effect on currents within the bay will be minor.

With regard to the impact on sites used by Sanford for salmon farming, the sites that could potentially be affected by the proposed mussel farms are LI321, LI328, LI339 and LI340. LI339 and LI340 are inshore of site 3, which may divert currents towards these two sites, possibly causing small (likely undetectable) increases in current speeds. Conversely, sites LI321 and LI328 are located further into the bay, and could possibly experience a small (again, likely undetectable) reduction in current speeds, particularly on the incoming tide.

2.6 Waves

Mussel farms can attenuate wave energy (Plew et al. 2005), although being flexible and highly porous structures, the effects are not generally considered significant. The attenuation is greatest for short wavelength, short period waves; while longer ocean swell passes through the farm nearly unaffected because the structure moves with the wave. BGB is sheltered from ocean swell, and most wave activity will be from locally generated wind waves. The longest fetch (straight line distance across the water surface) is for winds from the South-West (~ 5 km) or North-East (6 km). A sustained 40 knt wind from either direction would produce waves with significant heights of up to 1.1 m and with wave periods (time between wave crests) of 3–3.5 s. Under such conditions, mussel farms of the size proposed could potentially attenuate reduced wave heights by up to 10%, based on the model proposed by Plew et al. (2005). Again, considering the number of existing farms, I expect that the additional wave attenuation would likely only be detectable in the vicinity of, or a short distance down-wave of, the proposed farms.

2.7 Hydrodynamics – conclusions

BGB is presently used for mussel and salmon aquaculture. A significant portion (~15%) of the bay is currently allocated for aquaculture. The presence of the structures used for mussel and salmon aquaculture likely affects currents (tidal and wind driven) and circulation patterns within the bay. There is some evidence of this in that the two previous conducted modelling studies (neither of which included the drag from marine farms) showed poor agreement with observations collected within the bay from a current meter deployed between two mussel farms. The three proposed mussel farms increase the total consented farm area by 16 ha from ~160 ha currently for both salmon and mussels (although not all consented area is currently occupied). This increases the area consented for aquaculture from ~13.3% to ~15.5% of the bay area. The three proposed farms will cause further changes in currents and circulation patterns within the bay. However, considering the locations of the proposed farms and the increase in farmed area relative to existing farms, I expect that these changes will be minor compared to the impact that the present aquaculture activities likely already have on the bay.

3 Carrying capacity

There is potential for bivalve farming operations to exceed the ecological carrying capacity of a body of water in which they are located. Ecological carrying capacity, for mussel farming, has been defined as the stocking or farm density above which unacceptable ecological impacts begin to manifest (Inglis et al. 2000 referenced in ASC 2019). This happens when the removal of phytoplankton by all bivalve farms in a water body, including the Applicant's sites, outstrips the capacity of the ecosystem to replenish the supply, resulting in adverse conditions for wild and cultured populations (ASC 2019). In this context the inference is that if phytoplankton concentrations are reduced by farmed bivalves to a level that impacts the survival of all filter feeders, ecological carrying capacity has been exceeded. Inter alia, sustainable bivalve culture and phytoplankton primary production will also be compromised leading to impacts on phytoplankton carrying capacity.

From the Applicant's original application for a resource consent in May 2018 to the latest responses by the Applicant to the RFI in October 2019, there has been a broad generic argument presented by the Applicant, Submitters and reviewers on whether the addition of three proposed mussel farms will lead to the exceedance of the ecological carrying capacity of BGB. To address this issue, it is recognised by all parties that the addition of the proposed farms must be assessed in terms of cumulative effects of multiple farms in the bay rather than in isolation. However, to date all arguments have been in general terms with no attempt to (even partially) quantify the interaction between aquaculture and phytoplankton in the bay.

I will first consider the Applicant's arguments in their submission dated 2 October 2019 on why the phytoplankton carrying capacity will not be adversely impacted by the addition of three new mussel farms as requested by the Reporting Officer. I will then address these arguments by assessing the contribution of these proposed farms to the overall mussel Filtration Rate (FR in L/h/ha) in the bay, then discuss 'Pelagic Effect Assessment Criterion' from the Aquaculture Stewardship Council (ASC 2019) followed by a discussion on salmon and mussel farm interactions. In this context FR is equivalent to Clearance Rate (C) as used by the ASC.

3.1 The Applicant's view on phytoplankton carrying capacity

The Applicant has presented their argument that the phytoplankton carrying capacity will not be adversely impacted on the grounds of:

1. Over 20 years of environmental monitoring has not shown any decline in chlorophyll-*a* concentrations (as a proxy for phytoplankton) with annual mussel harvest since 2008 ranging between 2191 and 4615 green-weight tonnes (Figure 3-1)[8].
2. The addition of 16 ha (ha) of mussel farms offsets the removal of ha of mussel farms since 2011 for conversion to salmon farms for growing salmon, holding smolt and/or broodstock and fallowing. The Applicant indicates that after removing ha used for salmon farming, 125 ha is presently occupied by mussel farms in BGB[9].

[8] John Engel "Response to additional request for information dated 2 October 2019 for an application for coastal permit for marine farming". pt. 12 , page 4

[9] Response to further information 11-12-18 APP-20181316.pdf

3. The intensification of salmon farming in BGB would generate more N (dissolved inorganic nitrogen (ammonia and nitrates)) which in turn would be available for phytoplankton production, thus providing more phytoplankton to the bay ecology and more food for cultured mussels[10].

4. Since flushing time of BGB showed approximately 60% exchange by day 14 and 85-90% flushing after 28 days[11] coupled with the fact that phytoplankton regeneration can be in the order of 2–5 days, and the fact that long-term monitoring has not detected a decrease in chlorophyll-*a*, this suggests that phytoplankton in the bay arise from in-bay production as well all as being entrained into the bay from coastal oceanic waters[12].

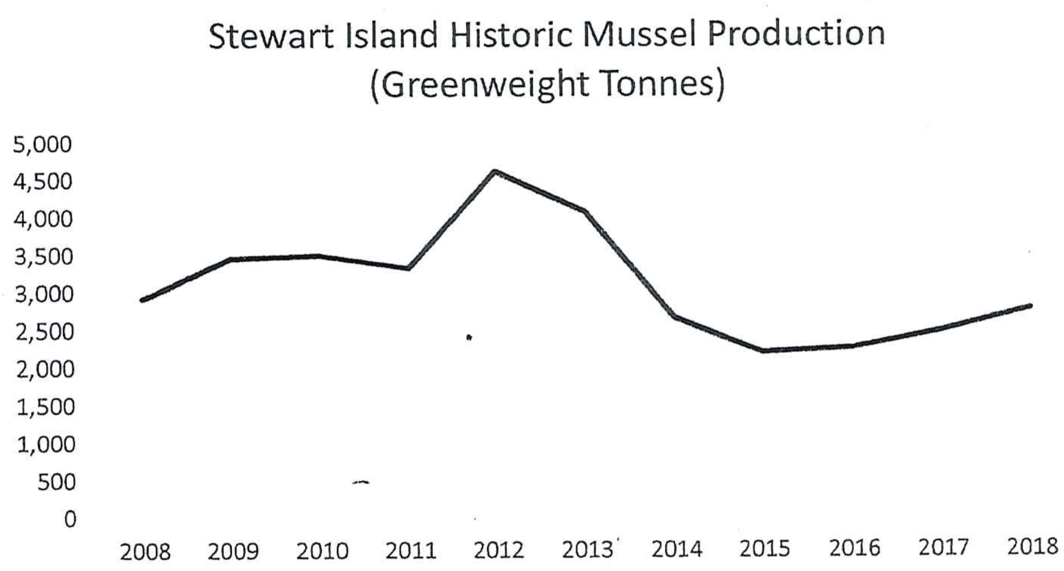

Figure 3-1: Annual mussel production in Big Glory Bay. From: Attachment 2 in John Engel "Response to additional request for information dated 2 October 2019 for an application for coastal permit for marine farming".

3.2 Mussel filtration

It is possible to estimate filtration rate (FR in L/h/ha) for cultured mussel in BGB based on a similar exercise undertaken by NIWA for the Marine Farming Association in the Marlborough Sounds (Stenton-Dozey and Broekhuizen 2019, Table 3-1). In this exercise, different sizes of mussels are considered from spat to harvest size and an assumption is made on what proportion of the dropper line will be occupied by any one size at any one time (note: these estimates are based on extensive discussion with mussel farmers in the Marlborough Sounds and on the layout of the proposed Site 1 farm provided by the Applicant[13]). I have assumed that all mussel farms in BGB will have similar densities per ha as calculated for the proposed 6-ha farm in Table 3-1.

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[10] John Engel "Response to additional request for information dated 2 October 2019 for an application for coastal permit for marine farming". pt. 13, page 4.
[11] Assessment of ecological effects of expanding salmon farming in Big Glory Bay, Stewart Island – Part 2 Assessment of effects (James, Hartstein, Giles) 26 April 2018 page 7.
[12] John Engel "Response to additional request for information dated 2 October 2019 for an application for coastal permit for marine farming". pts.6 to 10 to 9 page 3.
[13] s92(1) Further information response 17 August 2018 (First) APP-20181316.pdf, page 2.

The overall size-dependent mussel filtration per ha of mussel farm is 7286240 L/h/ha = 7286.24 m^3/h/ha = 174869.8 m^3/day/ha. This FR is then multiplied up by the number of ha for the proposed farms, the existing mussel farms and the proposed plus existing farms in Table 3-2. I have used 125 ha for present coverage of mussel farms based on the Applicant's estimate[14] which I think is derived from 162 ha (total aquaculture allocation) – 36.5 ha currently in salmon farm rotation[15].

Table 3-1: For each hectare farmed, the volume of water filtered by mussels. Based on data used in Stenton-Dozey and Broekhuizen (2019). Calculations are based on 15 longlines (180 m each) per 6 ha farm (i.e., Site 1 in Figure 1-1) (2.6 longlines/ha)[16] with a dropper length of 4000 m/longline except for spat lines where we used a dropper length of 6000 m. Mussel filtration rates (FR) per size class (NIWA unpubl. data). Approximately 10% of a dropper was assumed to be devoid of mussels.

Mussel size class (mm)	Shell length (mm)	mussels/m	dropper length (m) / longline used per mussel size class (m)	average dropper portion occupied at any one time	dropper length occupied at any one time (m)	number of mussels on dropper length occupied at any one time	FR (L/h) /mussel	FR (L/h) on dropper length occupied at any one time	FR (L/h) per ha (x2.6 longlines/ha)
No mussels	0	0	6000	0.1	600	0	0	0	0
spat nursery	<35	2000	6000	0.09	540	1080000	0.5	540,000	1,404,000
intermediate seed	35 - 50	800	4000	0.15	600	480000	0.9	432,000	1,123,200
young final seed	50 - 70	160	4000	0.22	880	140800	2	281,600	732,160
half adult	70 - 90	160	4000	0.22	880	140800	4	563,200	1,464,320
harvest adult	90 - 110	160	4000	0.22	880	140800	7	985,600	2,562,560
TOTAL									7,286,240

Table 3-2: Mussel filtration rate (L/day/ha of farm) and the percentage of BGB volume filtered by mussels. For the area of proposed farms (16 ha), the present mussel farms (125 ha) and existing plus propsed farms (141 ha). The mid-tide bay volume was used.

	Proposed farms 16 ha	Existing farms 125 ha	Existing + proposed farms 141 ha
FR (m^3/day)	2,797,916	21,858,720	24,656,636
BGB Volume m^3 at mid-tide[17]	189,000,000	189,000,000	189,000,000
Percentage of mid-tide volume filtered by mussels	1.480	11.565	13.046

Based on this approach, it is estimated that the mussels on the proposed farms will increase the amount of BGB mid-tide water volume processed by cultured mussel daily by 1.48%, raising the 11.56% for the present mussel farm occupancy to 13.05%. This is a small percentage increase and thus minor with respect to the volume of water processed by existing mussels in BGB. However, it should be noted these FRs should be viewed against the daily exchange rate of the bay volume to

[14] Engel August 2018
[15] Statement of evidence of Jacobus (Jaco) Johannes Swart, September 2018, pt 53, page 12
[16] Application Zane Smith and Jim Maass-Barrett May 2018.pdf
[17] Assessment of ecological effects of expanding salmon farming in Big Glory Bay, Stewart Island – Part 1 Assessment of effects (James, Hartstein, Giles) 26 April 2018a page 13.

consider the proportion of 'new' offshore oceanic water being processed by mussels compared to 'old' resident in-bay water (i.e., that portion not exchanged with water outside the bay).

Using the hydrodynamic model presented in ADS (2017) and in the evidence of Neil Hartstein[18], the flushing time of the bay was calculated by filling the bay with a tracer then tracking how much of the tracer remained in the bay over time. The simulations showed 85–90% of the water within BGB is flushed out in 28 days. In such studies, tracer concentrations tend to fall exponentially over time and not in a linear fashion (David Plew, pers. comm.) following a trend similar to that in Figure 3-2 (the actual concentration tends to fluctuate about the trend line due to tidal inflow and outflow, but overall follows this form of decay and the oscillations decrease in magnitude over time).

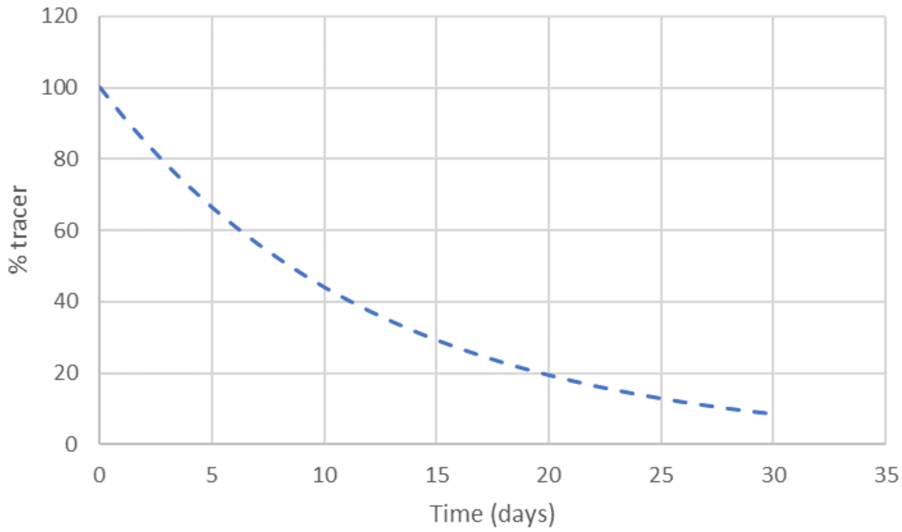

Figure 3-2: Modelled hydrodynamic tracer concentrations tend to fall exponentially over time. Provided by D. Plew.

The curve above can be described by the following equation:

$$M(t) = M_0 \exp(-Kt)$$

where $M(t)$ is the mass of tracer at time t, M_0 the mass of tracer at time 0, and K is the exchange rate. The value of K can be calculated from:

$$K = -\frac{1}{t} ln\left(\frac{M(t)}{M_0}\right)$$

If 10-15% of the tracer remains in the bay after 28 days, then K is in the range 0.068 – 0.082 day^{-1}. This implies that between 7–8% of the bay volume is exchanged each day, which is close to the 10% suggested by Pridmore and Rutherford (1990)[19]. This means that the daily exchange rate (7–10%) is less than the daily mussel FR (11–13%). This implies that historically, mussels in BGB have been reliant on 'old' resident in-bay water, processing between 3–4% by volume daily. It is likely therefore that in-bay phytoplankton production is an important source of food for mussels.

[18] Applicant Summary of evidence Neil Hartstein 11 March 2019
[19] Assessment of ecological effects of expanding salmon farming in Big Glory Bay, Stewart Island – Part 1 Assessment of effects (James, Hartstein, Giles) 26 April 2018a.

3.3 Pelagic Effect Assessment Criterion

The ASC Bivalve Standard addresses ecological carrying capacity using relatively simple calculations that compare how long it takes a population of bivalves to clear a body of water (clearance time or CT) with how long it takes for tides to flush that body of water (retention time or RT). This is different to the assessment of percentage water processed in Section 3.2 which considers the amount of water filtered by mussels relative to (not inclusive of) the bay volume at mid-tide (Table 3-2). According to the Pelagic Effect Assessment Criterion, when carrying capacity is exceeded, farmed areas should have, or be part of, a bay-scale management plan for addressing potential cumulative pelagic effects from multiple farms.

The Applicant considered that the Pelagic Effect Assessment Criterion had limitations[20]:

- as there was no way to make allowances for the large daily input of nitrogen from salmon feed and the assumed consequential increase in phytoplankton growth, and
- since the criteria apply to ecological carrying capacity it has limited use for BGB where the ecological carrying capacity has been historically compromised since marine farming began in the 1980s.

I don't fully understand the Applicant's issues on the limitations of applying the 'Pelagic Effect Assessment Criterion'. Some aspects can be applied, and I do so in the following section. If the area of all farms within a water body, inclusive of the new applications, is less than 10% of the total area of the water body, then requirements 2.2.1 and 2.2.2 (below) need not apply. With the proposed farms, mussel culture will cover an area greater than the criterion of 10% (although this depends on how many areas are occupied by salmon farming activities compared to mussel farming – it is difficult to gauge this distinction from the available documentation).

3.3.1 Indicator 2.2.1

(ASC 2019, page 15 and 32) - The ratio of clearance time (CT)[21] over retention time (RT)[22]: requirement > 1. Both CT and RT can be estimated from available information. First CT, as used in indicator 2.2.1 (Tier 1):

$$CT \text{ (days)} = Vt / (N \times C)$$

Where:

- Vt is the total volume of the water body at high tide (litres).
- N is number of bivalves.
- C is average clearance rate (litres/individual species/day) at harvest size

Bivalve numbers are based on the peak standing stock during the year and the clearance rate of harvest-sized mussels (i.e., all occupied farms must be considered to be stocked with harvest-sized mussels).

Next, RT as used in indicator 2.2.1:

[20] John Engel "Response to additional request for information dated 2 October 2019 for an application for coastal permit for marine farming". pts. 17 to 20, page 5.

[21] Clearance time is the number of days required for the dominant bivalve stock(s) (wild and cultured) to clear the volume of the bay. The dominant species census should be based on the peak standing stock during the year (i.e., harvest stock). The calculation is based on published clearance rate data for the bivalve group (mussels, scallops, clams and oysters).

[22] Retention time is the number of days for tides to flush a volume of water equal to the volume of the bay or water body.

$$RT = -1 \times P / \ln (Vl / Vt)$$

Where:

- P is the tidal periodicity, the length of the tidal cycle in days (M2 tidal period = 12 h and 25 mins = 0.517 days)
- Vl is the total volume of the water body at low tide (litres)
- Vt is the total volume of the water body at high tide (litres)

The parameters used to estimate the standing stock and clearance rate (C) of harvest-sized mussels were derived from Table 3-1 and available documents on the ES web site[23] (Table 3-4). There are four scenarios used to calculated C, distinguished by differences in the ha of mussel farming ranging from Scenario 1 using the highest number of ha to Scenario 4, the least number. The allocated ha for mussel farming is reduced to the area occupied by suspended mussels by subtracting the area holding warp lines and anchors (based on the layout of the proposed 6-ha farm (Site 1)). The length of backbone per ha (900 m) comes from the 180 m double backbone layout of Site 1 = [(180 x 2 x 15)/6]. The length of dropper line per ha of farm is based on 4000 m per double backbone = 10,400 m per ha (Table 3-1). Average tidal change was calculated as the average across neap and spring tide heights (1.35 m neap + 1.95 m spring)/2 = 1.65 m.

Table 3-3: Source of information used to determine the stocking density and Clearance Rate (C) of harvest size mussels in Big Glory Bay.

Parameters and scenarios	Information source
Parameter list	Adapted from Appendix 1 in Hartstein's review (16 October 2019) of version 1 of this report.
Total bay surface area (ha)	James, Hartstein and Giles 2018a[24]
Estimated average depth (m)	James, Hartstein and Giles 2018a[25]
Average reduction for warp line area (based on Site 1 – 6 ha)	Smith and Maas-Barrett 2018[26]
Length of backbone per ha (m)	Smith and Mass-Barrett 2018
Depth of dropper lines (m)	Smith and Mass-Barrett 2018
Metres of dropper line per ha of farm	Table 3-1
Mussel numbers per metre of dropper line at harvest	Engel 2018[27]
Clearance rate (litres per day per harvest-sized mussel)	Table 3-1
Average tidal change (m)	James, Hartstein and Giles 2018a
Scenario 1: Total farm allocation for whole bay: (161.5 ha) (i.e., all mussel and no salmon)	Mitchell 2019[28]
Scenario 2: Pre-2011 Mussel farming area: 161.5 ha – 7.5 salmon (sites 320 and 388) and 4 ha unused (site 149) = 150 ha	James, Hartstein and Giles 2018b[29]

[23] (https://www.es.govt.nz/environment/consents/notified-consents/2019/zane-smith-and-jim-maass-barrett)

[24] Assessment of ecological effects of expanding salmon farming in Big Glory Bay, Stewart Island – Part 1 Assessment of effects (James, Hartstein, Giles) 26 April 2018a

[25] Assessment of ecological effects of expanding salmon farming in Big Glory Bay, Stewart Island – Part 1 Assessment of effects (James, Hartstein, Giles) 26 April 2018a page 11.

[26] Application Zane Smith and Jim Maass-Barrett May 2018

[27] John Engel "Response to additional request for information dated August 2018 for an application for coastal permit for marine farming". pt 1, page 2.

[28] Statement of evidence by Dr Philip Hunter Mitchell 9 September 2019

[29] Assessment of ecological effects of expanding salmon farming in Big Glory Bay, Stewart Island – Part 2 Assessment of effects (James, Hartstein, Giles) 26 April 2018b page 3.

Parameters and scenarios	Information source
Scenario 3: Post-2011(1) Mussel farming area: 135 ha = my best estimate of mussel farms minus relocation of salmon farms for smolt/broodstock, grow-out and fallowing	James, Hartstein and Giles 2018b
Scenario 4: Post-2011 (2) Mussel farming area: 125 ha (I think this is based on 162 ha – 36.5 ha currently in salmon farm rotation)[30]	Engel August 2018[31]

The parameter calculations for the four scenarios and these scenarios plus 16 ha are shown in Table 3-4. The CT/RT ratios were all greater than 1 which is the requirement of the Pelagic Effect Assessment Criterion to conclude that the ecological carrying capacity has not been exceeded. These ratios were all greater than that given in Appendix 1 of Hartstein's review of version 1 of this report (CT/RT= 0.75) because I calculated different low (Vl) and high tide (Vt) water volumes based on different low and high tide depths (Table 3-3, Table 3-4). Application of these volumes to the parameters in Hartstein's Appendix 1 give a CT/RT ratio of 1.10 (see column 2 in Table 3-4).

The differences between low and high tide volumes given by Hartstein (Appendix 1 in review 16 October 2019) and this report arise from the use of different average water depths for high and low tide.

The volume at mid-tide given by James et al. (2018a)[32] is 0.189 km^3 (189,000,000,000 litres). This is calculated as bay surface area 12,001,400 m x average depth at mid-tide (m). In this calculation depth would be 15.75 m. James et al. (2018a) give an average bay depth of 15.9 m which is close to that in the former calculation, but both are greater than the 15 m given as the estimated average depth in Hartstein's Appendix 1. When a depth of 15.9 m is used, the average water volume of the bay is 190,822,260,000 litres, close to the mid-tide volume. However, both mid-tide and average volumes are greater than the value used by Hartstein as the average water volume at high tide (Vt = 180,021,000,000 litres) and this error has an impact on calculating water retention time (R) and hence the CT/RT ratio. Hartstein used a depth of 15 m to calculate this volume.

To determine bay volumes, I first calculated the average tidal range to be 1.65 m based on neap and spring tide ranges given in James et al. (2018a): (1.34 m neap tide + 1.95 m spring tide)/2 = 1.65 m) which is the same as given in Hartstein's Appendix 1 (1.7 m). I rounded my estimate of tidal range to 1.7 m to be consistent with Hartstein's value. It follows that depth at low tide is 15.9 m – 0.85 m = 15.05 m and at high tide it is 15.9 m + 0.85 m = 16.75 m. Using these depths, the respective bay volumes are 180,621,070,000 litres at low tide and 201,023,450,000 litres at high tide. Application of the RT formula with a tidal cycle P = 0.517 days (M2 tidal period = 12 hrs, 25 min) gives a water retention time of 4.83 days compared to Hartstein's 6.37 days. I back-calculated the estimate of RT = 6.37 says and it seems a P = ~0.542 days was used instead of 0.517 days and I am unclear why this higher value was used.

Other differences between Hartstein's Appendix 1 and Table 3-4 (based on information sources given in Table 3-3) relate to the length of backbones and droppers, the number of mussels per metre of dropper and mussel filtration rates (litres/day). However, these differences do not result in

[30] Statement of evidence of Jacobus (Jaco) Johannes Swart, September 2018, pt 53, page 12.
[31] John Engel "Response to additional request for information dated December 2018 for an application for coastal permit for marine farming". page 11
[32] Assessment of ecological effects of expanding salmon farming in Big Glory Bay, Stewart Island – Part 1 Assessment of effects (James, Hartstein, Giles) 26 April 2018a page 13.

meaningful discrepancies in the volume of water filtered by mussels per day per ha (Hartstein: 261,000,000 litres/day/ha and my calculation 262,080,000 litres/day/ha).

For Scenario 1, CT/RT = 1.14; this scenario considers all present allocated aquaculture space to be occupied by mussels (i.e., no salmon farms) which is not a realistic situation but provides a range for the CT/RT calculations. For Scenario 2, CT/RT = 1.22; this scenario represents peak mussel occupancy prior to 2011. From 2011 salmon farms were relocated to previous mussel farm sites and my best estimate of the present mussel occupancy is 135 ha (Scenario 3, CT/RT = 1.36). I have also included using a mussel occupancy of 125 ha suggested by the Applicant (Scenario 4, CT/RT = 1.47). When the areas of the proposed farms are added to these scenarios, the CT/RT ratios range from 1.04 (Scenario 1 + 16 ha) to 1.30 (Scenario 4 + 16 ha).

These ratios, across all scenarios of different total areas of mussel farming, are all close in value and suggest (based on the Indicator 2.2.1 criterion) that in the past (pre-2011), present and with the proposed farms added, the clearance time for mussels in BGB is marginally higher than the tidal retention time (i.e., the rate that water is replenished through tidal exchange is faster than the rate that water is filtered by the mussels). This is not in conflict with the assessment in Section 3.2 (in-bay water volume turnover by mussels being 3–4% greater than daily tidal turnover). The methods used to calculate clearance and water retention rates differ. CT/RT ratio incorporate tidal exchange in calculations whereas size-dependent mussel percentage water turnover only considers the proportion of mid-tide bay volume. If this latter method is applied to the parameter values in Table 3-4 (i.e., (N x C) / mid-tide bay volume (189,000,000,000 litres)), the daily percentage turnover ranges between 17%–21% depending on the number of hectares of mussel farming. These percentages are higher than in Table 3-2 because harvest-sized mussels were used to calculate C rather than using mussels of different sizes from spat to adults.

Table 3-4: Parameters and parameter values used to determine the stocking density and Clearance Rate (C) of harvest-size mussels in Big Glory Bay.

Parameter	Hartstein 16-Oct-19	Hartstein Vol corrected	Scenario 1 161.5 ha	Scenario 2 Pre-2011	Scenario 3 Post-2011 (1)	Scenario 4 Post-2011 (2)	Scenario 1+16ha 161.5 + 16 ha	Scenario 2+16ha Pre-2011	Scenario 3+16ha Post-2011 (1)	Scenario 4+16ha Post-2011 (2)
Total surface area (ha)	1200.14	1200.14	1200.14	1200.14	1200.14	1200.14	1200.14	1200.14	1200.14	1200.14
Total surface area (m^2)	12,001,400	12,001,400	12,001,400	12,001,400	12,001,400	12,001,400	12,001,400	12,001,400	12,001,400	12,001,400
Average depth (m)	15	15	15.9	15.9	15.9	15.9	15.9	15.9	15.9	15.9
Water volume on average depth (litres)	180,021,000,000	180,021,000,000	190,822,260,000	190,822,260,000	190,822,260,000	190,822,260,000	190,822,260,000	190,822,260,000	190,822,260,000	190,822,260,000
Total farm allocation (ha)			161.5	161.5	161.5	161.5	161.5	161.5	161.5	161.5
Total mussel farm coverage (ha)	162.783076	162.783076	161.5	150	135.0	125.0	177.5	166	151.0	141.0
Average reduction for warp line area	12.50%	12.50%	13.50%	13.50%	13.50%	13.50%	13.50%	13.50%	13.50%	13.50%
Cultured occupational area (ha)	145	145	140	130	117	108	154	144	131	122
Mussel farm surface structures as % of bay	12.08%	12.08%	11.64%	10.81%	9.73%	9.01%	12.79%	11.96%	10.88%	10.16%
Length of backbone (m) per ha	1300	1300	900	900	900	900	900	900	900	900
Depth of dropper lines (m)	15	15	12	12	12	13	12	12	12	13
Total metres of dropper line per ha of farm	14,500	14,500	10,400	10,400	10,400	10,400	10,400	10,400	10,400	10,400
Number mussels per metre of dropper line	120	120	150	150	150	150	150	150	150	150
Total mussels per ha of farm	1,740,000.00	1,740,000.00	1,560,000	1,560,000	1,560,000	1,560,000	1,560,000	1,560,000	1,560,000	1,560,000
Filtration rate (litres per day)	150	150	168	168	168	168	168	168	168	168
Water Filtered per day per ha (litres)	261,000,000	261,000,000	262,080,000	262,080,000	262,080,000	262,080,000	262,080,000	262,080,000	262,080,000	262,080,000
Water Filtered per day by all farms (litre) -N x C	37,845,000,000	37,845,000,000	36,725,270,400	34,118,229,600	30,694,809,600	28,337,400,000	40,352,457,600	37,745,416,800	34,231,579,200	31,964,587,200
Average tidal change (m)	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
Depth at low tide (m)	NA	NA	15.05	15.05	15.05	15.05	15.05	15.05	15.05	15.05
Depth at high tide (m)	NA	NA	16.75	16.75	16.75	16.75	16.75	16.75	16.75	16.75
Mid-tide volume (litres)	189,000,000,000	189,000,000,000	189,000,000,000	189,000,000,000	189,000,000,000	189,000,000,000	189,000,000,000	189,000,000,000	189,000,000,000	189,000,000,000
Average water volume low tide (litres): Vl	165,352,622,489	180,621,070,000	180,621,070,000	180,621,070,000	180,621,070,000	180,621,070,000	180,621,070,000	180,621,070,000	180,621,070,000	180,621,070,000
Average water volume high tide (litres): Vt	180,021,000,000	201,023,450,000	201,023,450,000	201,023,450,000	201,023,450,000	201,023,450,000	201,023,450,000	201,023,450,000	201,023,450,000	201,023,450,000
Tidal cycle (M2 tidal period = 12 hrs, 25 min)/24) days: P	0.542	0.517	0.517	0.517	0.517	0.517	0.517	0.517	0.517	0.517
Clearance Time (CT): CT (days) = Vt / (N x C)	4.76	5.31	5.49	5.91	6.55	7.09	5.00	5.34	5.87	6.29
Retention Time (RT): RT (days)= -1 x P / ln (Vl / Vt)	6.37	4.83	4.83	4.83	4.83	4.83	4.83	4.83	4.83	4.83
CT / RT ratio	**0.75**	**1.10**	**1.14**	**1.22**	**1.36**	**1.47**	**1.03**	**1.11**	**1.22**	**1.30**
Percentage of mid-tide volume filtered by harvest-sized mussels (refer to method in Section 3.2)	*20%*	*20%*	*19%*	*18%*	*16%*	*15%*	*21%*	*20%*	*18%*	*17%*

3.3.2 Indicator 2.2.2

(ASC 2019, page 15) Where clearance time is less than retention time, the ratio of clearance time over primary production time (PPT)[33]: requirement > 3 (Tier 2).

According to the Pelagic Effect Assessment Criterion, if CT<RT, cultured bivalves may be able to control the ecosystem and an additional assessment is required linking clearance time to primary production time (PPT) in the bay. The rationale for the Tier 2 calculation is that phytoplankton production in a bay can support sustainable aquaculture (i.e., primary production within BGB), up to a point, even when the bay is poorly flushed. Primary production time should be shorter than clearance time. Otherwise, the phytoplankton which mussels feed on will quickly be depleted. In theory, the requirement could be CT/PPT>1 but in practice CT/PPT should be >3 (ASC 2019).

The only phytoplankton primary time measurements (PPT) made in BGB were in February 1998 (Pridmore and Rutherford 1990)[34]. I do not have access to Pridmore and Rutherford to consider this information. It may be possible to arrive at a coarse estimate of PPT but it is beyond the scope of this report. Since CT/RT is greater than 1 under all scenarios outlined in Table 3-4, application of this indicator is not required according to the Pelagic Effect Assessment Criterion.

3.4 Salmon and mussel farm interactions

Hartstein's evidence (March 2019, page 11)[35] states that water quality modelling shows that TAN (Total Ammonia Nitrogen) levels would increase in BGB by up to 30 µg/litre during the maximum feeding scenario for increased salmon production in BGB. This equated to the model predicting Total N levels to increase by approximately 10% when compared to Total N observations made during the ongoing Sanford's monthly water quality monitoring programme. Based on model results this increase can lead to an increase in chlorophyll-*a* of between 2 and 4 µg/litre for the maximum salmon feeding scenario. The mid-level scenario results show a chlorophyll-*a* increase of between 2–3.5 µg/litre. The question is whether mussel production near salmon farms is enhanced by these increases in chlorophyll-*a* or stated otherwise, can mussels mitigate the effect of increased chlorophyll-*a* as suggested by the Applicant?

By example, a study in the Gulf of Castellammare, Sicily considered whether the growth and reproduction of mussels (i.e., enhancement not mitigation) was stimulated in an integrated multi-trophic aquaculture farm scenario with fish (Sarà et al. 2012). The authors modelled the effect of phytoplankton primary production enrichment at fish cages on shellfish growth and life history traits using 4 years of data. There was a mean increase in chlorophyll-*a* of approximately 45% close (within about 100 m) to fish cages compared to sites away (about 1.5 km) from the cages. Model simulations showed that mussels close to cages could reach greater maximum length by the end of the 4th year compared to those far from cages and in open-sea. Applying these findings to the BGB situation would suggest that the BGB mussels close to salmon farms could benefit from increased chlorophyll-*a* concentrations. However, this study did not assess potential environmental mitigation of excessive phytoplankton production by mussels in the bay system. Although mussels may grow faster around

[33] PPT is the number of days required for the replacement of the standing stock of phytoplankton in the bay (i.e., time-scale of phytoplankton population growth). PPT is the ratio of yearly averages of phytoplankton biomass (B) to phytoplankton primary production (PPP) within the system. B can be estimated from chlorophyll-*a* measurements, published data or satellite predictions assuming a carbon to chlorophyll ratio of 50. PPP can be obtained from published results or model predictions.
[34] Assessment of ecological effects of expanding salmon farming in Big Glory Bay, Stewart Island – Part 1 Assessment of effects (James, Hartstein, Giles) 26 April 2018a.
[35] Applicant Summary of evidence Neil Hartstein 11 March 2019.

salmon farms, its uncertain to what extent mussels may mitigate impacts from salmon farming on water quality in BGB.

3.5 Carrying capacity – conclusions

The simple tools used in this report to ascertain the cumulative impact of adding three proposed mussel farms have indicated effects on the ecological carrying capacity of BGB are likely to be minor. The requirement of the Pelagic Effect Assessment Criterion that the ratio of clearance time (CT) over water retention time (RT) exceeding 1 was met. Based on this indicator the cumulative effect of adding the three proposed farms does suggest that the ecological carrying capacity of BGB will not be exceeded.

When using size-dependent filtration rates as applied to mussel farming in the Marlborough Sounds (Stenton-Dozey and Broekhuizen 2019), the present 125 ha of mussels in BGB process 11.6% of the mid-tide bay volume which increases to 13.1% with the addition of 16 ha of proposed farms. This is greater than the estimated daily tidal exchange rate between the bay and coastal water (7–10%) which suggests mussel production depends to some extent on in-bay phytoplankton primary production. It is feasible that in-bay primary production takes place since the bay-wide water mass has a long residency time of 14–28 days sufficient to allow for phytoplankton turnover rates of 2–5 days. This assertion is also supported by the rationale of the ASC (2019) which states that phytoplankton production in a bay can contribute to sustainable aquaculture.

Phytoplankton biomass (measured as chlorophyll-*a* (μg/L)) in BGB has followed a sustained seasonal pattern since monitoring commenced without any indication of depletion in the presence of mussel farming. Long-term trend analysis of chlorophyll-*a* concentrations from 1997–2017 shows no significant increase or decline in the bay (Figure 3-3). Increases could be related to an increase in salmon farming resulting in higher levels of dissolved nitrogen with a simultaneous increase in phytoplankton production while a decrease could be related to over-grazing by mussels. Neither of these aquaculture impacts on phytoplankton carrying capacity are evident from the chlorophyll-*a* trends over the last 20 years.

Both methods (the Tier 1 Pelagic Effect Assessment Criterion and the application of size-dependent mussel filtration rates) are conservative for assessing the exceedance of ecological carrying capacity of BGB. Firstly, as discussed above, in-bay phytoplankton primary production is not considered and secondly, mussels do not retain all particles during water filtration. The species cultured in New Zealand, *Perna canaliculus,* retains food particles (phytoplankton and suspended particulates) at different efficiencies depending on quality and concentration. Hawkins et al. (1999) calculated the average retention efficiency of phytoplankton as 70% (±30%) and for suspended organic particles as 23% (±10%).

It is predicted from models[36] that the future increase in salmon farming over the next five to six years could increase phytoplankton production in the bay and its possible that mussel production in BGB could benefit to some extent and/or mussels can mitigate the impact of salmon farms as suggested by the Applicant. However, at this stage the certainty of these interactions cannot be determined.

[36] Applicant Summary of evidence Neil Hartstein 11 March 2019.

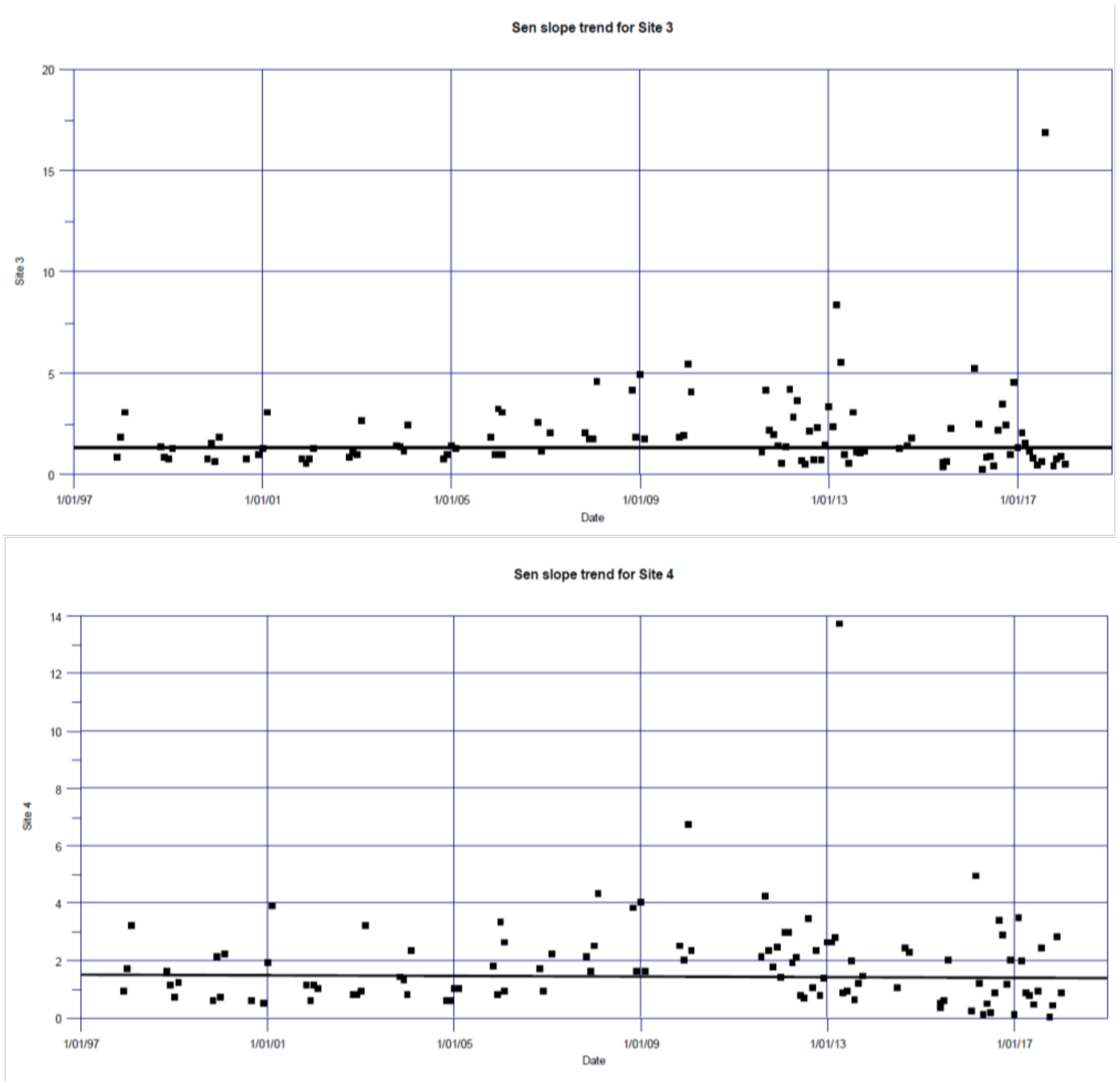

Figure 3-3: Chlorophyll-*a* concentrations (µg/L) for the period 1997–2017. Site 3 is at the mouth of the bay and site 4 is mid-bay. Trend analysed using the Mann-Kendal test. Figure taken from Figure 21, page 13 in James et al. 2018b[37].

There are advanced modelling tools in use in New Zealand that could be applied to bring greater certainty to estimate impacts on ecological carrying capacity by mussel farming. For instance, in assessing impacts of a large mussel farm in Wilson Bay, Firth of Thames three distinct plankton models were applied (Stenton-Dozey, Broekhuizen and Morrisey 2008). One was used to consider the fate of ichthyoplankton. A second was used to quantify impacts upon phytoplankton and zooplankton. A third was used as an alternative means of assessing effects upon phytoplankton. Each model was applied under a variety of hydrodynamic conditions during both winter and summer. Collectively, the results represent an extensive analysis of sensitivity to parameterisation and structural assumptions embodied within the models.

[37] Assessment of ecological effects of expanding salmon farming in Big Glory Bay, Stewart Island – Part 2 Assessment of effects (James, Hartstein, Giles) 26 April 2018b

In the Pelorus Sound, multiple regression models were used to predict aquaculture production (Zeldis, Hadfield and Brooker 2013). Overall, these results show that time series of physical drivers (climatic predictors, including Southern Oscillation Index (SOI), along-shelf winds, sea surface temperature (SST) and Pelorus River flow) were useful for explaining production variation of farmed bivalves.

However, these advanced tools are beyond the scope of the present application for three proposed mussel farms in BGB. Their application is applicable to bay-wide and regional scale farming zones with multiple farms where spatially-explicit long-term monitoring data, in which all farmers participate, underpin models that can more accurately assess the ecological carrying capacity of systems.

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Appendix 2- Legal advice from Wynn Williams relating to duration of consent

MEMORANDUM

Date: 21 October 2019

To: Andrew Maclennan, Reporting Consultant

From: Mike Doesburg

SMITH AND MAASS-BARRETT AQUACULTURE APPLICATION – LEGAL ADVICE CONCERNING DURATION OF AQUACULTURE CONSENT

Background

1. Another legal issue has arisen in the preparation of your final addendum report. The applicant has sought a 20-year term for their resource consent application. However, at the hearing submitters have argued that awarding a term shorter than 20 years is more appropriate. You have asked us to consider the situations in which section 123A(2) of the Resource Management Act 1991 (**RMA**), which sets out the criteria for imposing a shorter duration of consent for aquaculture activities, is triggered.

Advice

2. The duration of consent for aquaculture activities is provided for under section 123A of the RMA. Section 123A(2) states:

> (2) The period specified under subsection (1) must be not less than 20 years from the date of commencement of the consent under section 116A unless-
>
> (a) the applicant has requested a shorted period; or
>
> (b) <u>a shorter period is required to ensure that adverse effects on the environment are adequately managed</u>; or
>
> (c) a national environmental standard expressly allows a shorter period.
>
> (Underline added).

3. In this case, the Applicant has requested a duration of 20 years. In addition, there is no national environmental standard which expressly allows a shorted period. Therefore, to grant a resource consent for period shorter than 20 years, the Commissioner must be satisfied that a shorter period is required to ensure that adverse effects on the environment are adequately managed.

4. We have been unable to identify any authority that provides guidance on the ambit of section 123A(2)(b).[1] In interpreting the section, it is appropriate to apply section 5(1) of the Interpretation Act 1999 and ascertain its meaning from the text and in light of its purpose.

5. The first point to note when interpreting section 123A(2)(b) is the high threshold to be met before the section can be engaged. The term "require" has been described as a

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[1] For completeness, the only Environment Court case we are aware of which discusses the duration of an aquaculture consent in any detail is *Knight Somerville Partnership v Marlborough District Council* [2014] NZEnvC 128. However, in that case, the Court accepted 10-year term initially imposed by the Council was likely to have been a typographical error, with the Court accepting the appropriate consent duration in that case was 20 years (at [101]-[102]).

prescriptive verb by the Environment Court[2] and is defined by the Cambridge Online Dictionary as:

> To need something or make something necessary.

Therefore, the section is only engaged if the decision-maker considers a shorter period is *necessary* to adequately manage an application's adverse effects on the environment.

6. Section 123A was introduced into the RMA as part of the 2011 aquaculture reforms,[3] with the purpose of the 20-year minimum consent duration to provide investment certainty to encourage investment in aquaculture.[4] We consider the purpose of the section reinforces the high threshold to be met section 123A(2)(b) is engaged.

7. In our opinion, section 123A(2) is engaged where there is a demonstrable adverse effect that can only be addressed through a shorter term. We also consider it is applicable in situations where the effects of the application are uncertain, and granting a consent for a shorter period would enable the effects of the application to be monitored, with the information gained informing a decision on whether to renew the consent for a further duration.

8. In short, a high threshold must be met to grant a resource consent for a term less than 20 years – the Commissioner must be satisfied on the evidence that:

   a. the application is likely to have an adverse effect on the environment; and

   b. it is necessary to impose a shorter duration to ensure that adverse effects on the environment are adequately managed.

Wynn Williams

2 *Port Otago Limited v Otago Regional Council* [2018] NZEnvC 183 at [114].

3 Resource Management Amendment Act (No 2) 2011.

4 Derek Nolan QC "The Coastal Environment" in Derek Nolan QC *Environmental and Resource Management Law* (6th ed, Lexis Nexis, Wellington, 2018) at 424; (16 August 2011) 675 NZPD 20934; (16 November 2010) 668 NZPD 15309.

Appendix 3- Recommended conditions of consent

Term and Purpose

1. This consent expires on the 1 January 2040, unless it has been lapsed, cancelled or surrendered at an earlier date pursuant to Sections 125, 126 or 138 respectively of the Resource Management Act 1991.

   Note:
   (a) *In accordance with Sections 125 and 126 of the Resource Management Act 1991, this coastal permit may be lapsed or cancelled if it has not been exercised within 5 years from the date of granting or if exercised in the past but has not been exercised during the preceding 5 years. Continuing to exercise this coastal permit means the site is actively used to farm the authorised species, not just having structures on the site.*
   (b) *Pursuant to Sections 123 and 124 of the Resource Management Act 1991, a new consent may be required at the expiration of this consent. The application will be considered in accordance with the plans in effect at that time, and the adverse effects of the proposed activity. The holder of this coastal permit has a preferential right to apply for a new consent pursuant to Sections 165ZH and 124 of the Resource Management Act 1991.*

2. (a) This consent authorises the placement of structures in, on and over the seabed, and the occupation of the coastal marine area with the structures for the purpose of marine farming the following species:

   - Green-lipped mussels (*Perna canaliculus*);
   - Blue mussels (*Mytilus galloprovicialus*);
   - Ribbed mussels *(Aulacomya ater)*
   - Scallops *(Ostrea chilensis)*

   as described in the application (APP-20181316) for resource consent dated May 2018 and updated with: further information dated 23 August 2018 and 12 December 2018, and an email from the applicant dated 11 July 2019.

   (b) Except for green-lipped mussels, spat and stock shall only be obtained from the Stewart Island / Rakiura coastal waters.

   (c) All green-lipped mussel spat and stock shall be obtained from Ninety Mile Beach, unless authorised by a separate resource consent.

   (d) This consent also authorises the deposition, on the seabed, of material, arising from marine farming the various organisms.

3. The occupation of the coastal marine area for marine farming activities, pursuant to this consent, shall only occur within the application co-ordinates as detailed below and shown on the attached in Appendix 1.

Site	Corner	Eastings	Northings	Area (ha)
Site 1	NE	1229203.93	4786587.20	6
Site 1	SE	1229236.61	4786261.04	
Site 1	SW	1229043.82	4786190.15	
Site 1	NW	1229076.70	4786488.97	
Site 2	NE	1228804.62	4784931.42	5

Site 2	SE	1228762.07	4784787.58	
Site 2	SW	1228570.29	4784844.31	
Site 2	NW	1228612.84	4784988.15	
Site 3	NE	1229226.68	4785067.47	5
Site 3	SE	1229784.13	4784923.64	
Site 3	SW	1228992.34	4784980.37	
Site 3	NW	1229034.89	4785124.21	

4. Except to the extent that it is necessary to achieve the purpose of this consent and for public safety, members of the public shall not be excluded from the marine farm site at all times.

Note: This consent does not authorise exclusive occupation within the authorised area even though the marine farming structures and operations will result in some physical exclusion over part of that area. The extent that the physical exclusion over part of the authorised area is necessary for the normal operation of the marine farm is provided for by this consent (refer to Section 122(5) of the Resource Management Act 1991).

Restrictions on Operations

5. (a) The consent holder shall at all times during the continuance of this consent maintain the marine farm structures, including but not restricted to the associated structures of anchors, lines, droppers, buoys, and if relevant cages and fixed barges, in good repair, appearance and condition. The marine farm structures shall also be secured so as to not create a navigation hazard. No significant alteration or deviation from the authorised structures that may adversely alter the impact on the environment is permitted without the prior written approval of the Council's Director of Environmental Management.

Note: any such alteration may require an application for a new resource consent or an amendment to this consent.

(b) Any authorised officer of the Council may, at all times, enter upon the marine farm structures and view its state of repair, including all associated structures. Upon receipt of a notice in writing, of any defect or want of repair in the structures, requiring the consent holder to repair the structures, the consent holder shall, with all reasonable speed, cause the defect to be removed or the repairs to be made.

6. (a) The consent holder shall ensure all the marine farming structures are laid out and the boundaries of the marine farm marked and lit in accordance with the navigation and safety requirements of the Council's Harbourmaster or their delegate.

Note: Navigation and safety guidelines for aquaculture areas can be found in the "Guideline for Aquaculture Management Areas and Marine Farms" booklet dated December 2005 produced by Maritime New Zealand, or its replacement booklet.

(b) Except for the purpose of navigational safety pursuant to condition 9(a), the exterior colour of any structures used on the marine farm site shall be consistent with the surrounding physical landscape.

7. The consent holder shall manage the marine farming operation in such a way that deposition of shell, and other material, on the seabed is minimised. Any shell and other material

collected from the site shall not be disposed of in the coastal marine area in an unauthorised manner.

8. (a) Any equipment or materials, excluding vessels, used in the coastal marine area, for marine farming purposes, which have been previously used or stored in another geographic coastal marine area, shall be thoroughly cleaned and sterilised before transport to the marine farm site and used. It shall be the consent holder's responsibility to ensure that any marine farming structure, including associated structures, is maintained free of unwanted organisms and pests as identified by either or both Biosecurity New Zealand or the Council's Regional Pest Management Strategy. Any removed unwanted organism or pest shall be disposed of at an authorised land disposal site, to the satisfaction of the Council's Director of Environmental Management.

Note:

(a) Another geographic coastal marine area from Big Glory Bay is outside of the Stewart Island / Rakiura coastal waters.

(b) Under Section 44 of the Biosecurity Act 1993 every person has a duty to inform Biosecurity New Zealand, as soon as practicable, of the presence of an organism not normally seen or otherwise detected in New Zealand.

(c) Under Section 46 of the Biosecurity Act 1993 every person is required, without unreasonable delay, to notify the chief technical officer at Biosecurity New Zealand of the presence or possible presence of notifiable organisms. Unwanted organisms also fit under this category.

(b) The consent holder shall advise the Council's Biosecurity Manager, no later than 5 working days after detecting any incidence of unwanted organisms and/or pests not normally seen or detected within Big Glory Bay.

9. The consent holder shall ensure that:

(a) the marine farm site identification number _____ is displayed above the water level at each four corners of the surface infrastructure block, and if relevant on the salmon marine farm structure, at all times to the satisfaction of the Council's Compliance Manager;

(b) no equipment or materials from the marine farming activity is stored in an unauthorised manner;

(c) all rubbish is removed from the marine farm site and disposed of at an authorised refuse site;

(d) any material lost from the marine farm site is retrieved where relevant, as soon as practicable;

(e) all reasonable steps are taken to retrieve any lost material from the marine farm site that could constitute a navigation hazard, and the Council's Harbourmaster is notified immediately of the situation;

(f) other than the deposition authorised under Condition 2, no oil, diesel, petrol, grey water, detergents, cleaning materials, bilge water, sewage or any other toxic or polluting substances, shall be discharged into the coastal marine area at the site, either directly or indirectly, as a result of exercising this consent;

(g) in the event of any spill of oil or fuel at the marine farm site, the first person to the scene shall:

(i) take immediate steps to contain the spill and to recover it; and

(ii) notify as soon as practicable the Southland Regional Council's pollution hotline on 03 211 5245 that a spill has occurred. Notification shall include the type and quantity of oil or fuel spilled and the steps taken to remedy or mitigate any adverse effects; and

(h) in the event of a spill of any contaminant, no dispersants or degrading agents shall be discharged to water without the approval of the Southland Regional Council.

10. In the event a marine mammal is entangled or stranded within the marine farm structures, the consent holder shall as soon as practicable contact the Department of Conservation Southland Conservancy.

11. Neither the issuing of this consent nor anything contained in it shall affect the liability of the consent holder for any injury caused by the marine farm structures to any vessel or person through any default or neglect of the consent holder.

12. Upon expiry of the period for which the consent is granted, or on any cancellation of the consent, the consent holder shall, if required by the Council to do so, remove the marine farm structures, including all associated structures, entirely from the site and to restore the site as near to its original condition within three months of the date of expiry, or cancellation. If the consent holder fails to do so, the Council may cause the marine farm structures, including all the associated structures, to be removed and the site restored, and may recover the costs incurred by the removal and restoration from the consent holder.

Monitoring

13. (a) The consent holder shall carry out the Big Glory Bay Monitoring Programme specified in Appendix 2.

    (b) The consent holder shall carry the following monitoring programme for the activity authorised by Condition 2(d) of this consent:

        (i) Monitor at least 10 percent of each re-seeded crop transferred to Big Glory Bay by lifting the trays on which seeded stock are attached out of the water and visually inspect for contamination by any unwanted pests and/or species not found within Stewart Island coastal waters at 1, 3, 6 and 12 months after the droppers are hung. Visual Inspections shall also be undertaken at the time the re-seeded crop is harvested. The work is to be carried out by a suitably qualified person to detect unwanted organisms and pests.

        (ii) Ensure that if any unwanted organism, pest (excluding Undaria), and/or species not found within Stewart Island coastal waters is found on the re-seeded crop, the trays and re-seeded stock are removed immediately from the coastal waters and dispose of at an authorised land disposal site. In addition, the surrounding area shall be inspected and, if necessary, cleaned of the unwanted organism pest (excluding Undaria), and/or species not found within Stewart Island coastal waters, and a monitoring program approved by the Council's Director of Environmental Management established to ensure the unwanted organism pest (excluding Undaria), and/or species not found within Stewart Island coastal waters no longer exists at the location. If the unwanted organism pest (excluding Undaria), and/or species not found within Stewart Island coastal waters infestation are such that the biosecurity of Stewart Island is considered to be at risk, then the consent holder shall remove all of the trays and other equipment used for the re-seeded crop from the coastal marine area.

(iii) The consent holder shall maintain a log of all re-seeded spat and stock, including the timing, amount and location of re-seeded spat and stock, treatments and monitoring carried out in accordance with Conditions 13(b)(i) and 13(b)(ii) of this consent. A copy of the entries in this log shall be made available to the Council on request.

14. Monitoring in accordance with the Big Glory Bay Monitoring Programme specified in Appendix 2 shall conform with the following standards:

(a) sample collection, preservation and analysis of the seabed samples shall be carried out by a suitably qualified person or as agreed to, in writing, by the Council's Director of Environmental Management;

(b) sample collection, preservation and analysis of the water quality samples shall be carried out in accordance with the most recent edition of APHA "Standard Methods for the Examination of Water and Wastewater" or as agreed to, in writing, by the Council's Director of Environmental Management;

(c) the monitoring and analyses are to be carried out by a laboratory with IANZ accreditation or equivalent, or as agreed to, in writing, by the Council's Director of Environmental Management;

(d) the result of seabed analysis shall be supplied to the Southland Regional Council no later than five working days of the consent holder receiving them. The methods of analysis are to be specified with the results;

(e) the results of water quality analysis shall be supplied to the Southland Regional Council no later than 20 working days from the end of the month in which the samples are taken. The methods of analysis are to be specified with the results; and

(f) the Southland Regional Council may audit monitor sample collection up to once each year at a cost covered by the consent holder.

15. The consent holder shall undertake an investigation, if the result from any one sample in the Big Glory Bay Monitoring Programme identifies an adverse effect on the environment, to determine the probable cause of the adverse effect. A report shall be provided summarising the results and analysis on completion of the investigation sampling, but no later than two months from the initial sample that identified an adverse effect being provided to the Council.

16. The consent holder shall provide an annual report summarising the results and analysis of the Big Glory Bay Monitoring Programme on completion of the sampling but no later than 31 July each year.

17. In the event that a bay wide review of the Big Glory Bay Monitoring Programme is undertaken, the consent holder shall, within 6 months of the review, reassess the Big Glory Bay Monitoring Programme and propose amendments to ensure consistency with the outcomes of the bay wide review for certification by Southland Regional Council's Team Leader - Compliance Monitoring. Any additional monitoring measures arising from the review will be included in the consent holder's monitoring and reporting.

18. The Southland Regional Council may, in accordance with Sections 128 and 129 of the Act, serve notice, of its intention to review conditions 13 - 16 of the consent for the purposes of undertaking a bay wide review of the Big Glory Bay Monitoring Programme.

Other Permits

19. The granting of this consent does not absolve the consent holder from the responsibility to obtain any approval, permit, licence, concession or consent from any other body.

Council Charges

20. In consideration of the right to occupy Crown land in the coastal marine area for the activity specified above, the consent holder shall, each year, pay to the Southland Regional Council the appropriate coastal occupation charge specified in the Regional Coastal Plan. Each financial year, commencing 1 July, the charge shall be adjusted for inflation in accordance with the Consumer Price Index. The sum payable in the first year of this consent (or the proportion thereof for which the consent is current) is $717.70 plus GST, and shall be payable in advance on invoice. The revenue from this charge shall be used only for the purpose of promoting the sustainable management of the coastal marine area.

21. In addition to the above sum, the consent holder shall pay an administration and monitoring charge to the Southland Regional Council collected in accordance with Section 36 of the Resource Management Act, payable upon invoice.

Biosecurity Management Plan

22. Prior to the insulation of structures and operational activities commencing under this coastal permit, the consent holder shall lodge a Biosecurity Management Plan with the Team Leader – Compliance at Environment Southland for certification. The Biosecurity Management Plan shall be written by a suitably qualified and experienced marine biosecurity professional. The objective of the Biosecurity Management Plan is to address measures to avoid the introduction, exacerbation and spread of any marine unwanted organisms through the marine farming activity and minimise any impacts through propagation on the marine farm if any such species are introduced.

23. The Biosecurity Management Plan shall include, but not be limited to the following:

    (a) Details of the marine pests, unwanted and notifiable organisms and marine fouling organisms, identified by the Ministry for Primary Industries, Council and the marine farming industry, as requiring identification and recording;

    (b) Processes to be applied by staff operating the marine farm and vessels servicing the marine farm to inspect, identify, record and report to the Council on species identified in (a), as well as any marine pest species new to the area. This must include at least the date of observation, organisms observed and location and extent of infestation;

    (c) Timing of reporting to the Council under (b);

    (d) Measures that will be undertaken to avoid the introduction, exacerbation and spread of species identified in (a);

(e) Actions that will be undertaken if any new organisms are observed;

(f) Measures to be taken to educate and train farm staff operating the marine farm on biosecurity requirements and responsibilities; and

(g) Processes and timing for reviewing and updating the Biosecurity Management Plan.

Note: The Biosecurity Management Plan should be developed utilising guidance material including the Aquaculture Biosecurity Handbooks: Assisting New Zealand's commercial and non-commercial aquaculture to minimise on-farm biosecurity risk (Ministry for Primary Industries, 2016) and any subsequent guidance material prepared by the Ministry for Primary Industries or Aquaculture New Zealand.

24. The Biosecurity Management Plan shall be reviewed annually by the consent holder, having regard to any change in circumstances. Any amendments to the Biosecurity Management Plan must be certified by the Team Leader - Compliance Monitoring.

25. The consent holder shall ensure that all farm staff are trained in accordance with the requirements of the Biosecurity Management Plan (Condition 20) to be aware of the presence of any strange or unfamiliar marine and terrestrial species on the farm related vessels, vehicles, structures, machinery and equipment prior to them undertaking duties in marine farm related activities.

26 Before any vessel, structure (including pontoons), machinery or equipment to be used in marine farming activities, including barges to be used in construction and/or maintenance of any marine farming structure, is brought to the marine farm from outside the Southland Region, Council biosecurity staff shall be notified of the planned -activities. This notification shall be provided prior to entry to the Southland Region and may require an inspection for terrestrial and marine unwanted or risk species by a suitably qualified and experienced person.

27. In the event of a bay wide review of biosecurity measures are undertaken, the consent holder shall, within 6 months of the review, reconsider the Biosecurity Management Plan and propose amendments to ensure consistency with the outcomes of the bay wide review for certification by Southland Regional Council's Team Leader - Compliance Monitoring

28. The Southland Regional Council may, in accordance with Sections 128 and 129 of the Act, serve notice, of its intention to review conditions xx of the consent for the purposes of undertaking a bay wide review of biosecurity matters.

Review of Conditions

29. The Southland Regional Council may, in accordance with Sections 128 and 129 of the Act, serve notice, during the months of August to October each year, of its intention to review the conditions of the consent for the purposes of:

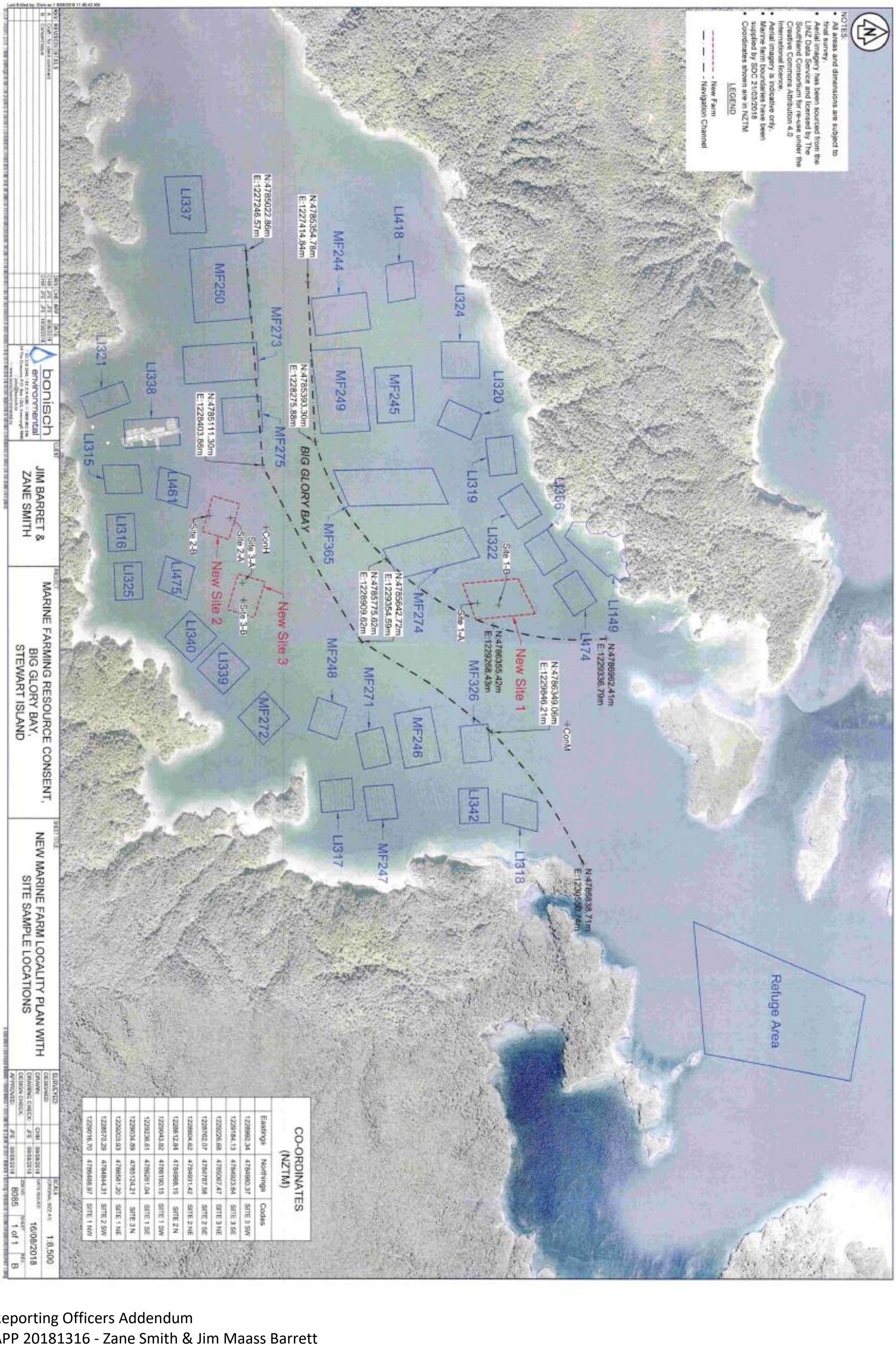
(i) dealing with any adverse effect or cumulative effects on the environment which may arise from the exercise of this consent; or
(ii) considering any changes to information on the effects of marine farming, particularly information gained from monitoring; or

(iii) complying with the requirements of a regional plan; or

(iv) providing for a bond if further investigation and/or information, including relevant case law on the application of bonds to consents, shows that one is necessary to avoid, remedy or mitigate potential adverse effects on the environment.

Note: The consent holder may request the Council to collaboratively review under Section 127 of the Act any specific consent conditions at any time for the same purposes in Condition 20 (a)-(d).

APPENDIX ONE
Location of marine farm sites


NOTES
All areas and dimensions are subject to final survey.
LEGEND
New Farm
Navigation Channel
BIG GLORY BAY
New Site 1
New Site 2
New Site 3
Refuge Area
CO-ORDINATES (NZTM)
bonisch environmental
JIM BARRET & ZANE SMITH
MARINE FARMING RESOURCE CONSENT, BIG GLORY BAY, STEWART ISLAND
NEW MARINE FARM LOCALITY PLAN WITH SITE SAMPLE LOCATIONS
1:8,500
16/08/2018
8085
1 of 1
B

APPENDIX TWO
Big Glory Bay Monitoring Programme

1. The consent holder shall monitor the effects of the marine farming activities on the seabed, as follows:

   (a) (i) except for LI339, LI340, MF249, MF250, MF271, MF272 and MF365, monitoring of the seabed at representative locations under the marine farm site shall be undertaken at least once prior to 1 January 2025.

   Note: It is the Council's intention that the Programme shall monitor at least two marine farm sites per year within the bay from the following marine farm sites LI149, LI315, LI316, LI317, LI318, LI319, LI320, LI321, LI322, LI323, LI324, LI325, LI337, LI338, LI342, LI366, LI418, LI461, LI474, LI475, MF244, MF245, MF246, MF247, MF248, MF273, MF274, MF275 and MF326 so each site is monitored at least once prior to 1 January 2025.

   (ii) in addition to Clause 1(a)(i), monitoring of the seabed at two control sites identified in the Programme and approved, in writing, by the Council's Director of Environmental Management. The monitoring shall occur every year for the first three years, then once every three years thereafter.

   (b) the samples will be analysed for the following to assess the sediment quality:

   - sediment colour, including providing a colour photograph of the sediment sample;
   - depth of the oxygenated layer below the sediment surface;
   - occurrence of hydrogen sulphide;
   - sediment texture and grain size;
   - total organic carbon content; and
   - infaunal and epifauna community composition.

2. The consent holder shall monitor the effects of the marine farming activities on the water quality, as follows:

   (a) (i) monitoring of the water column shall be undertaken monthly for the first two years, commencing from 1 July 2011, by taking samples at four sites within Big Glory Bay and two control sites inside the bay, at a depth of 5 metres, as identified in the Programme and approved, in writing, by the Council's Director of Environmental Management.

   (ii) after the first two years outlined in clause 2(a)(i), monitoring of the water column shall be undertaken three times during the period of 1 November to 30 June each year and once during the period of 1 July to 31 October each year at four sites within Big Glory Bay and two control sites inside the bay, at a depth of 5 metres, as identified in the Programme and approved, in writing, by the Council's Director of Environmental Management.

   (b) the water quality samples will be analysed for the following:

- water temperature;
- chlorophyll *a;*
- vertical seechi depth; and
- dissolved oxygen.