Reviewer Comments

Technical Guidance for the Design of Offshore Aquaculture Installations in the Gulf of Mexico

Peer Reviewers

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Reviewer #1 Comments

1. [Introduction, page 5]: Suggest substituting prevent with "reduce the potential for".

2. [General Site Characteristics Title, page 6]: Add a statement that documentation of the following site investigations and studies should be included in the permit application.

3. [Permit site, page 6]: Add "including the sweep of the mooring line"

4. [Bottom sediment types, page 6]:

    a. Change "power" to "capacity."

    b. Add "Bottom sediment datasets."

    c. Add "The method and depth of sampling should be sufficient to provide the necessary geotechnical data for design of the anticipated anchoring system."

    d. Suggest adding a paragraph or separate section discussing geologic hazards. "Geologic hazards such as slope instability, turbidity flows, or hard bottoms which could impact the ability to anchor the facility to the seabed should be considered in selecting the project site or in designing the facility. A hazard assessment should be made and any recommended mitigation measures discussed."

5. [Subassembly technical drawings, page 9]: Add "mooring lines"

6. [System Analysis and Loading, page 10]: Reference the API RP 2SK for mooring and anchor design.

7. [Anchors and ground tackle, page 18]: Include "Design and Analysis of Stationkeeping Systems for Floating Structures (API RP 2SK [24])."

8. [Anchors and ground tackle, page 18]: Include "Anchor systems should be proof-loaded prior to installation of the aquaculture facility."

Reviewer #2 Comments

1. [Bottom sediment types, page 6]: I recommend sediment samples collected be tested for Total Organic Carbon and dissolved oxygen levels in water column be monitored around the site or at locations where waste material from the proposed may adversely affect sediment quality.

2. [Influence of biofouling, page 12]: One of the causes attributed to the net pen failure incident in Washington State is excessive biofouling on the stock net. The applicant should establish the minimum level of biofouling based on capability of the net cleaning equipment employed and operating/maintenance procedures established.

3. [Auxiliary Equipment, page 18]: The auxiliary equipment employed at salmon net pens also include generators, fuel tanks, blower/air supply for fish in the pens.

Reviewer #3 Comments

1. [Permit Site, page 5]: By this you mean move operations to another location within the site to accommodate fallowing requirements. Please reword and clarify.

2. [Bottom Sediment Types, page 6]: Consideration should be given to not just providing samples, but perhaps conducting cone penetrometer tests.

3. [Wind speed, direction and fetch, page 7]:

    a. Serious consideration should be given to wind gusts. Our research shows that gusts can contribute significantly to aquaculture mooring line tensions.

4. [Wave Conditions, page 7]:

    a. Offshore class guidelines usually specify a minimum return period that should be considered.

    b. "The energy in an irregular sea state can be represented by a spectrum."

5. [Typical Conditions, page 7]: By this do you mean operational conditions?

6. [Extreme Conditions, page 7]: Extreme wave condition development should include analysis using Weibull for extreme heights. However, a typical applicant may not have access to all this. Default values should be provided, or a source of information should be provided.

7. [Offshore current velocity condition, page 8]: Weibull. Again this is not something an applicant would do normally.

8. [Hydrostatic analysis, page 10]: Unless it is bottom-fixed. How about during tow-out condition?

9. [Hydrostatic analysis, page 10]: This requirement should be stipulated e.g. ABS A+B > C +D type rule.

10. [Hydrostatic analysis, page 10]: Unless the system uses tensioned moorings.

11. [Static tension configuration, page 10]:
    a. This section does not consider mooring ropes (HMPE).

    b. Due to their low elasticity and hysteresis, the rope might still go slack even if it is pretensioned initially.

    c. Also, with ropes two stiffness values are normally specified.

12. [Static tension configuration, page 10]: How about the offset condition of the mooring system? Does that need to be provided?

13. [Time domain analysis, page 11]: You should comment on CFD analysis. Software for such analysis is becoming more prevalent.

14. [Time domain analysis, page 11]: There are quite a few recent references for this formula. DNV RP C205 is one of them.

15. [Time domain analysis, page 11]: Clarifications needed on Eq. 1. In particular the following: Why does the tangential force not have an absolute velocity term? If Ct and Cn are assumed dimensionless, then the tangential force term is missing density, area/length and time. A bracket is perhaps missing.

16. [Time domain analysis, page 11]: Reliable sources for these coefficients should be mentioned

17. [Time domain analysis, page 11]: This is not straightforward to do. Good reference for doing like Chakrabarti's Offshore structure modeling can be provided.

18. [Time domain analysis, page 11]: This is very vague. Is this RAO for a vessel? Most operators would buy a vessel. Furthermore, RAOs are well suited for frequency domain analysis rather than time domain. It might be better to clarify this in the context of next section.

19. [Frequency domain dynamic and quasi-static analysis]: Question is what is acceptable for permitting and approval.

20. [Accidental Loads, page 12]: Any criterion for this? Such as one line broken case?

21. [Design Factors to address uncertainty, page 12,13]:

    a. This section presents a very ambiguous approach. It is inconclusive. Why not specify the approaches and sources, and then ask the GAP applicants to justify their choice of safety factors?
    b. Of factors of safety
    c. This phrase is confusing. Suggest clarifying.
    d. This can be misleading. Even 1.1 is greater than 1, but will not be acceptable.

22. [Design life and risk assessment, page 13]: The encounter probability is only one part of the risk assessment. One has to look at the probability of exceedance of a threshold value for each component and then adopt a uniform risk value for key components.

23. [Loads specific to fish containment structures, page 14]:

    a. Is it appropriate to recommend suitable guidance for each type as the requirements can be quite different.

    b. Such statements are very vague. Better to provide references or stipulate some boundaries.

24. [Fish containment materials, page 15]:
    a. Is this a requirement?

    b. Some of these criteria may be addressed if the net cage is bought from a reputable manufacturer.

25. [Other containment mesh materials, page 15]: "Meshes…."

26. [Rope, page 16]: "Same as before."

27. Many of these properties change when the rope goes from wet to dry conditions. The specification should cover both these conditions.

28. [Steel chain, page 16]: I suggest that instead of describing various grades, better specify the minimum grade that will be acceptable.

29. [Mooring connectors, page 18]: Can this be done? Finding design loads and factors? How can this be correlated with the size, other than manufacturer's recommendation?

30. [Equipment and maintenance of records, page 20]: Inspection and maintenance schedule requirements are treated separate from the overall design. Often times, safety factors or design conditions can be reduced or compromised if frequency of inspection and

maintenance can be correspondingly increased. In the case of aquaculture farms, this should not be a problem, since inspection can be done when the livestock is being monitored.

31. [Annex, page 27]: I would also recommend adding an annex similar to Appendix C in API RP 2SK. It gives a simplified approach of calculating forces, and that can be converted into a useful spreadsheet tool for cross checking complex calculations.

Reviewer #4 Comments

1. SUMMARY: The document is a very good starting point for developing the guidance for offshore aquaculture installations with unmanned components in federal waters in the Gulf of Mexico, the stated goal. One of the difficulties in writing this document is that the systems for offshore aquaculture are yet to be developed, and one can only extrapolate from near-shore aquaculture in protected waters, aided by the experience of the offshore industry, to the experiences and rules of which frequent references are made. Hence this has to be viewed as a starting point to a continuing effort, until it morphs into a comprehensive technical guidance along the lines of API and ABS documents, and the aquaculture documents for protected waters.

2. SECTION 2. General Site Characteristics: This is a comprehensive and well described section, except for some points elaborated below.
    a. 2.61: The JONSWAP sea spectrum (p. 7) is for fetch-limited conditions of the North Sea. There are limitations for its use depending on proximity to land and direction of storm. Wider band spectra are possible.

    b. Concerning the use of the 50 year storm (p. 8), the comments on equation (5) below apply to dispell the illusion of an inherent safety factor in the use of 50 yr (or 100 yr) storm, even when the life of the structure is significantly shorter.

    c. It is quoted that the metacentric height should be positive (p. 10). A threshold value should be set for certain floating structures.

3. There is an error in equation (1) (p. 11): The axial drag term has the same form as the normal drag and it is a quadratic function of the axial velocity and proportional to reference area etc.

4. For equation (2) (p. 11) further conditions must be set. The frequencies have to be randomized around their nominal values to avoid a periodic time signal, whose statistics for longer times are not the same as for the spectrum.

5. Equation (5) and the accompanying table are useful because they demonstrate the lack of inherent safety factor in simply using the 50 yr -- or any other extreme storm. The table should be extended to show the effect of using, in addition to an extreme storm, a safety factor, whose effect on safety is very significant.

6. Other types of fish cages should be mentioned, including flexible and submersible structures. In general, the guidance should allow for novel designs that will probably be needed for operations offshore and for safety in hurricanes.

7. Other types of netting should be mentioned, including impermeable membranes that are being considered in other countries. These require a different set of calculations as their shape changes with the external loads, particularly current and waves, and may include dynamic membrane response and sloshing.

8. The section on mooring components is too detailed compared with the other sections, particularly since the API rules cover these components adequately.

9. Since the guidance is for unmanned components, continuous inspection and servicing is significant. The need for sensors that convey information continuously, and/or frequent inspection with manned or unmanned vehicles should be discussed.

Reviewer #5 Comments

1. [Introduction]: It should be made clear that these will be minimum requirements….not just suggestions. See comment at the end of this section.

2. [Introduction]: Designers need a bit more definitive direction provided, otherwise it will be too wide open and the document will not have enough "bite" to affect the outcomes associated with permit applications. I have been involved in development of Shoreline Master Program regulation development (and as a designer using them) in WA state that regulate waterfront developments. Those are a balance between providing a high-level guidance to being overly prescriptive. The lesson learned from those regulations is something that is a balance between the two is effective; flexibility to designer but minimum requirements need to be established and prescribed; if not a developer will skirt the intent of the requirement to save money and the govt regulatory agency will have no means to deny the application. I see this document as being that middle ground but needing that element of some "bite" to ensure a fall back position for review of applications when an applicant proposes something that is not justified from an engineering, construction or risk perspective. A number of my comments refer to this. It would be worthwhile to review the entire document from this perspective. What those minimum requirements are can be derived from existing documentation, standards and referenced already being used for the development of the technical guidance. Could include….-Evaluation of both typical and extreme conditions, -Fouling (minimum), -Load Combinations; evaluate combination of wind, current and waves in accordance with industry standard practice. -Fatigue .

3. Introduction: It might be a good idea to expand on this a little more…see later comments. What is the expectation of the applicant to use the information outlined in this document. What if an applicant disregards everything in this guidance document and wants to propose something that isn't in accordance with this guidance or industry accepted practice? I think there should be a little more "teeth" to a requirement to follow this as a minimum requirement. Maybe something like this……"The requirements outlined in

this guidance document are minimum requirements that should be addressed in application documentation. Deviation from the minimum is acceptable if documented with justification and reference to equivalent standards are provided in the design documentation."

4. I reviewed the API, Scottish Stds and Norway Stds and they all have minimum requirements for these design considerations. There should be use of a minimum requirement on these critical design factors.

   [General Site Characteristics]: Terminology. Would it makes sense to change from "should" to "shall"? Maybe not a big deal but I typically use "shall" as it indicates a requirement that is <u>mandatory</u>. Want to make sure the guidelines have some bite to them and not leave open interpretation of applicant that they may not need to.

5. [Seafloor survey]: What format is the survey need to be provided in? Being specific on what is required for submission is important to give the reviewers the information needed. It's one thing to state a requirement or standards but another to state what needs to be submitted and format thereof. The bathymetric survey shall be plotted xxxxxx with reference to MLLW datum, horizontal datum, north arrow, and lat/long of survey area. This is a theme to consider throughout the document.

6. [Bottom Sediment Types]: How many samples would be required per permitted site or per some measurement (SQ Ft). Need to be a bit more specific on minimum requirements.

7. [Bottom Sediment Types]: A reference standard you may want to consider including for sediment type and corresponding anchor design is the SP-2209-OCN Handbook for Marine Geotechnical Engineering.

8. [Bottom Sediment Types]: Add the sentence, "Sieve analysis on a sample in accordance with ASTM xxx and provide the percent passing #200 sieve."

9. [Tide and surge water levels]: Add "GAP applicants should characterize water level conditions for the proposed site as it corresponds to the design of the proposed structure.

10. [Wind speed direction and fetch]: I added an introductory sentence to be consistent with section 2.6. Also, I read this as the applicant can select either method. Is that the intent or would there be situations or types of proposed facilities where the site-specific analysis would want to be required.

11. [Wave conditions – Overview]: Include the following: "The designer shall consider both typical and extreme conditions in their structure analysis as outlined in the following paragraphs."

12. [Extreme wave conditions]: A range is allowed. Should this be a specific value? Could state that it should be a minimum of 50-year (or whichever). Then the designer or owner

has the option to design to more extreme conditions. This would be a minimum performance standard but not a specific requirement. Same for the typical wave conditions and current velocities.

13. [Offshore current velocity conditions]: I shifted this down so there was an intro paragraph, then separate paragraphs for measurements vs. existing data sets. Keeping it organized like that makes it easier to read and understand the requirements.

14. [Offshore current velocity conditions]: Shall be represented…..if it is desired to have applicant submit it should state is shall be …

15. [Offshore current velocity – current rose format]: I would make it a requirement as it is important for the designer to review information in that format as well as being helpful to the reviewer.

16. [System Layout and Technical Drawing]: There needs to be a requirement that connects information provided in Section 3 relates to the information generated in section 4. They are not mutually exclusive. Maybe something like this…. "Mooring system analysis and loading information shall be provided to demonstrate the proposed system shown in the layout drawings is suitable for the proposed site in accordance with these guidelines."

17. [System Layout and Technical Drawing]: "Shall?

18. [System Layout and Technical Drawing]: Would make sense to have a general statement about the basis of the design. Design Life, standards used, design storm, etc….

19. [Frequency domain dynamic analysis and quasi-static analysis]: It is not being required. If not required, then there should be some relation to a subsequent safety factor requirement….higher safety factor or load factor for quasi-state analysis procedures. A general statement such as that would give the intent without having to state an actual value. The designer then would have to justify the selection based on industry standards being proposed.

20. [Frequency domain dynamic analysis and quasi-static analysis]: Some sort of guidance here would be good if flexibility is being provided to the designer so they can weigh the pros/cons of either method. Maybe a little more language added to the end of this paragraph.

21. [Influence of biofouling]: Minimum required biofouling percentage for computations? Seems like there should be some specificity on the minimum to be accounted for in the design.

22. [Accidental loads]: How many? There are different schools of thought on this and how many should be assumed to be broken for the analysis. Minimum of one line or line with largest load to ensure continuity of system for the design condition.

23. [Deployment loads]: There should also be a requirement for there to be written instructions with graphics describing how and under what conditions the system can be towed. If this isn't provided, there is a risk of damage to the system and the towing company will likely just make a guess. A disconnect between predicted design loads and actual service load is high without the written instruction requirements.

24. [Design factors to address uncertainty]:
    a. As a designer, I utilize both Ultimate Strength Limit State Design (ULS such as LRFD) and Serviceability or Allowable limit state (such as ASD). It appears you are trying to provide the option to the designer to use either methods. I personally believe the ULS is a better method for these types of marine structures that account for risk and variability and complexity of the dynamic environmental loading and associated design for the same reasons the seismic codes have migrated more to the ULS for structure design. But I see the value in keeping it open too.

    b. If keeping it open, this section needs some clarification on what the requirements are of the designer. I would suggest a statement at the start of paragraph 4.6 that introduces this topic that two different methods are available depending on the standards selected by the engineer and shall be documented in the Basis of Design (see later comment in section 4…new section 4.7). It should be required that the selected design method should be used uniformly throughout the structure design and not mix and match methods with respect to component design.

    c. API appears to rely upon ASD type serviceability limit state and Norway Standards and Scottish Standards rely upon ULS. Either could work but I think this section needs a little more background and definition on what is required and what standards will apply.

    a. [Design factors to address uncertainty]: Use "Strength Limit State" for "Partial Coefficient Approach." [Design factors to address uncertainty]: Use "Serviceability Limit State" for "Allowable Stress Design."

    b. [Design factors to address uncertainty]: This section appears to be more commentary than requirements or standards. Should probably be modified to provide better direction as a requirement.

    c. [Design factors to address uncertainty]: As described above, the LRFD is something used in various codes and standards. IBC, US Army Corps of Engineers, BSI, etc… all have limit state design recommendations/requirements for different types of structures and facilities. The same type of method can be applied to the net pen structures. There is a reference to NS-EN 1990 (Eurocode – Basis of Structural Design) document which should provide clarity on this. This is similar to the IBC and LRFD codes. A few other examples are…..US Army Corps of Engineers has … ETL 1110-2-584, 30 June 2014, DESIGN OF HYDRAULIC STEEL STRUCTURES. Considerations for env loads, fatigue,

service vs. ultimate stress, extreme floods, etc… BS 6349-1:1984 Maritime structures. General criteria. Is another publication that has discussion on this topic.

d. [Design factors to address uncertainty]: This seems to be more commentary than guidance or minimum standards. If it is decided to not specify exact values then I would suggest something like the following: "Load and Material factor values should be assigned by the engineer of record in accordance with industry accepted practice for marine structures as outlined in the referenced standards. The load and material factors should be clearly stated in the Basis of Design." I would eliminate the commentary as it leaves it a bit too vague for a designer to know what is required. The above statement or something similar would help provide clear direction but without specifically calling out a number.

e. [Design factors to address uncertainty]: This is the basic "Allowable Stress Design" equation but there is not mention of what Safety Factor minimum and for what type of condition or load case. This can vary depending on the scenario and purpose for the safety factor (risk, type of load, human life safety, etc.). Service load design (SF of788 1.3 to 5 or more) vs ultimate load design (minimal SF).

f. [Design factors to address uncertainty]: The design life of the entire facility or structure needs to be stated, then the design of the components will occur relative to that. This statement doesn't directly connect to the table below….components vs. overall structure.

g. [Design factors to address uncertainty]: This seems to leave it open ended. The US Army Corps of Engineers and the BSI/EUROCODE have designated maximum probably of occurrence for a specified design life. Should that be required here or at least point to those standards from one of those which relates to marine facilities and structures so there is some benchmark? Seems like a minimum standard should be required to ensure some influence over the risk of the facility to damage that will be installed in the GoM. API states 100 year condition unless design life is less than 20 years, then a justification for deviation and risk assessment be submitted.

25. [Basis of Design]: I am suggesting to add a section such as this. As a designer, this is an important tool to convey the details and decisions made to get to a proposed design. For a reviewer, it will make the review process more streamlined and provide justification for comments relative to these standards. I think the BOD will also help with your intent to not be as prescriptive in this document and allow it to be more like a technical guidance If the allowable-stress design approach is applied, the GAP applicant should justify safety factor values in the Basis-of-Design document. If the allowable-stress design approach is applied, the GAP applicant should justify safety factor values in the Basis-of-Design document rather than detailed standards. You will provide flexibility but the applicant will need to justify their decisions in this document. If they can't make a good case for their assumptions (as part of this BOD), it would help provide the basis for a comment or

denial of the permit. It would be worthwhile to provide additional description in here regarding the purpose and what you would expect to see if you were the reviewer of the applicants technical information. [Basis of Design]: Should there be some sort of risk analysis required as part of the application that integrates with the BOD and the design standards/calcs.

26. [Specification of Individual Components]:
    a. Preventing "exceedance of"

    b. [Specification of Individual Components]: Edits: "exceedance of ultimate stress conditions, permanent deformation strain, and reserve strength to account for"

    c. [Specification of Individual Components]: This may a bit too vague. Might need to be reworded…… Design factors developed in accordance with this guidance document and referenced industry standard practice shall be described in the basis of design.

27. [Specification of Individual Components]: Does this apply on the gulf coast?

28. [Specification of Individual Components]: Consider using SP-2209-OCN Handbook for Marine Geotechnical Engineering as well.

29. [Deployment and operations protocols]: Inspection requirements or guidance? Would be worthwhile that there is a requirement to incorporate a periodic inspection as part of the ongoing operation and maintenance plan.

29. Also, should be requirement for the following: -Change in location of the proposed aquaculture system would require new analysis prior to approval. -change in mooring scheme or mooring system components from what is proposed would require additional new analysis. These are very critical as the system is site specific and heavily dependent on the mooring system design…if those change then the prior analysis may no longer be applicable.

30. [Requirements for Documentation]: Would be good to have a section stating what the minimum requirements for documentation would be. Mooring plan sketch (as-built), mooring system description, etc… should be requirements for the documentation. See NS 9415, section 11.10.

31. [Related Technical Guidance]: Consider referencing the Handbook for Marine Geotechnical Engineering, SP 2209-OCN.