Reply to Reviewers

Manuscript ID esurf-2021-46 entitled “The role of geological mouth islands on the morphodynamics of back-barrier tidal basins”

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Note to the Editor and Reviewers:

The comments and suggestions of the Editor and the reviewers are copied in *italic grey font*. The reply to each comment by the reviewers is written in normal font and appears just after the original comment or question.

We wish to thank the editor and reviewers for their valuable comments and suggestions that have resulted in a more insightful manuscript.

Reviewer No. 1

This paper from a very strong research group describes a study on the effects of the presence of the islands around the gorge of a tidal inlet on the morphodynamics of the tidal inlet systems using idealized numerical modelling. Basically, it is about the role of the geological constrains on the morphodynamics of tidal inlets, an interesting and important subject. The study already provides some useful insights and the paper is well written. Therefore, I support the eventual publication of the paper. Obviously, the subject dealt by the paper is a wide one. I would consider the study described by the paper as a start for studies on the subject. Many suggestions for extending and / or improving the study can be made. I would appreciate if the authors can consider the following suggestions for revising the manuscript. I would understand if not all suggestions can be implemented before finishing the present paper, but then please consider them in the discussion section of the paper.

Reply: We wish to thank the reviewer for providing very constructive and detailed comments. We have addressed the comments carefully and merged our responses into the revised manuscript.

1. In the introduction section two pairs of nearby tidal inlets have been presented for a comparison between tidal inlets with and without islands near the inlet gorge. Can this part be extended by elaborating more on what we learn from the comparison? What are exactly the different characteristics of the geomorphology of inlets with islands from those without islands? How are the results from the comparison linked to the present modelling study?

Reply: We fully agree with the reviewer that it is necessary to link the comparison more closely with this study. The relevant content has been added to the introduction section and discussion.

Two pairs of nearby tidal inlets have some similar characteristics: (1) They are both semi-enclosed bays characterized by a large area inside the bay and a narrow tidal inlet, which can effectively reduce waves; (2) Forced by similar tidal currents and small river discharge (Jiang and Meng, 2008).

However, some characteristics are still site-specific: (1) Sediment composition. Massachusetts Bay is a muddy environment, while Plymouth Bay is Sandy (Ford, 2010). The difference of sediment composition may be one of the reasons for the formation of different morphologies. (2) Local hydrodynamics. Sediment composition may also be the result of the long-term interaction between hydrodynamic and sediment transport (Zhou et al., 2016a). Geomorphology is highly related to the local hydrodynamics (Van Der Wegen and Roelvink, 2008; Coco et al., 2013), which determines the sediment transport and trigger morphological changes. By comparing two pairs of inlets, although they are close, the local hydrodynamic is somewhat different. Normally, a larger velocity is formed at the narrower tidal inlet. The inlet of Massachusetts Bay is wider, but the current near the inlet is still stronger (Knebel et al., 1991). In addition to the varying width of tidal inlets, there is also an obvious geomorphic difference driven by the presence of islands and its effect on morphodynamic processes has not been studied systematically. From this point of view, cases of different numbers of islands are designed to investigate the effect of varying inlet widths narrowed by mouth islands on morphological evolution.

2. Can you present something about the morphology of the Dongshan Bay, the reference tidal inlet system for the idealized modelling? Would it be possible to make a comparison between the model results and the real morphology of this bay? Even for idealized modelling study I think it is important to present some validation of the used model.

Reply: To start with, we think it is useful to recall the objectives of this present study as already introduced in the initial submission. This is a schematised modelling study with the Dongshan Bay as a reference site, aiming to provide some physical insights into the effect of mouth islands on morphodynamic evolution. Our modelling study focuses on the physical mechanisms underlying a phenomenon rather than exactly trying to reproduce a set of observations. Choosing Dongshan Bay as the reference site is useful because there are some basic data (e.g., tidal range, river discharge and major sediment type) that allow us to model.

For the interest of the reviewer, we have made a general comparison between the model results and the real morphology of Dongshan Bay (Figure R1). Model results show that the morphology is overall consistent in terms of pattern formation, and the trend of morphological evolution is also consistent with the real configuration (Liang et al., 2016), even though our model predicts a more intricate network. However, there are a number of model simplifications (e.g., our simplified tidal forcing or uniform grain size for the whole domain) and local factors (e.g., human activities) that directly affect the morphological changes. Therefore, it is difficult to really reproduce the channel-shoal morphology based on this idealized model, which is not the focus of this study and this figure would not add to the paper.

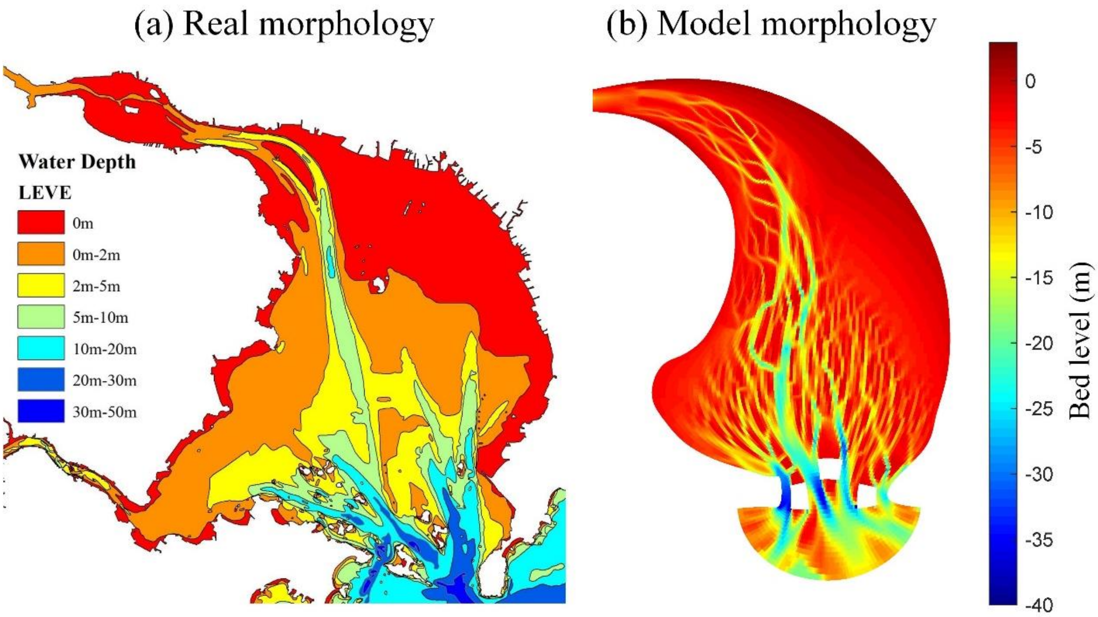

Figure R1 Comparison of real morphology of Dongshan Bay and model results

3. It seems to me that the major effect of the islands in the idealized model is narrowing the gorge of the inlet. Therefore, please discuss on what really matters, the varying width at the inlet gorge or the number of islands?

Reply: The reviewer is correct that the effects of varying widths and different numbers of islands play similar roles in term of converging flow and enhancing flow velocity.

However, the existence of islands can also exert additional influences on local tidal hydrodynamic when they are formed in different locations. Due to the obstruction of the island and the fast velocity on both sides of the island, a velocity gradient is formed between the channels and behind the island, resulting in the formation of eddies. The eddies generated by strong tidal flow past islands, have an important role in natural coastal protection, since they cause waves to refract and dissipate tidal energy (Neill et al., 2012). This provides a sedimentary environment behind the island, forming a back-barrier deposition and obviously affecting the local channel-shoal morphology of tidal basin.

Furthermore, different from a single inlet system, the existence of different numbers of islands can divide one tidal inlet into several tidal channels of varying width and velocities, affecting the local tidal asymmetry. We analyse tidal asymmetry at four locations near the tidal inlet under different cases. Model results show that a different tidal asymmetry occurs in two tidal channels of different width (Figure R2 b). The narrower tidal channel is flood-dominated while the wider one is ebb-dominated. The possible reason may be that the velocity gradient between two tidal channels leads to the tidal currents in the narrower tidal inlet flow into the wider tidal inlet, weakening its flood tide. Overall, we think the role of islands is broader than just narrowing the width of tidal inlet, since the whole hydrodynamic field can be affected.

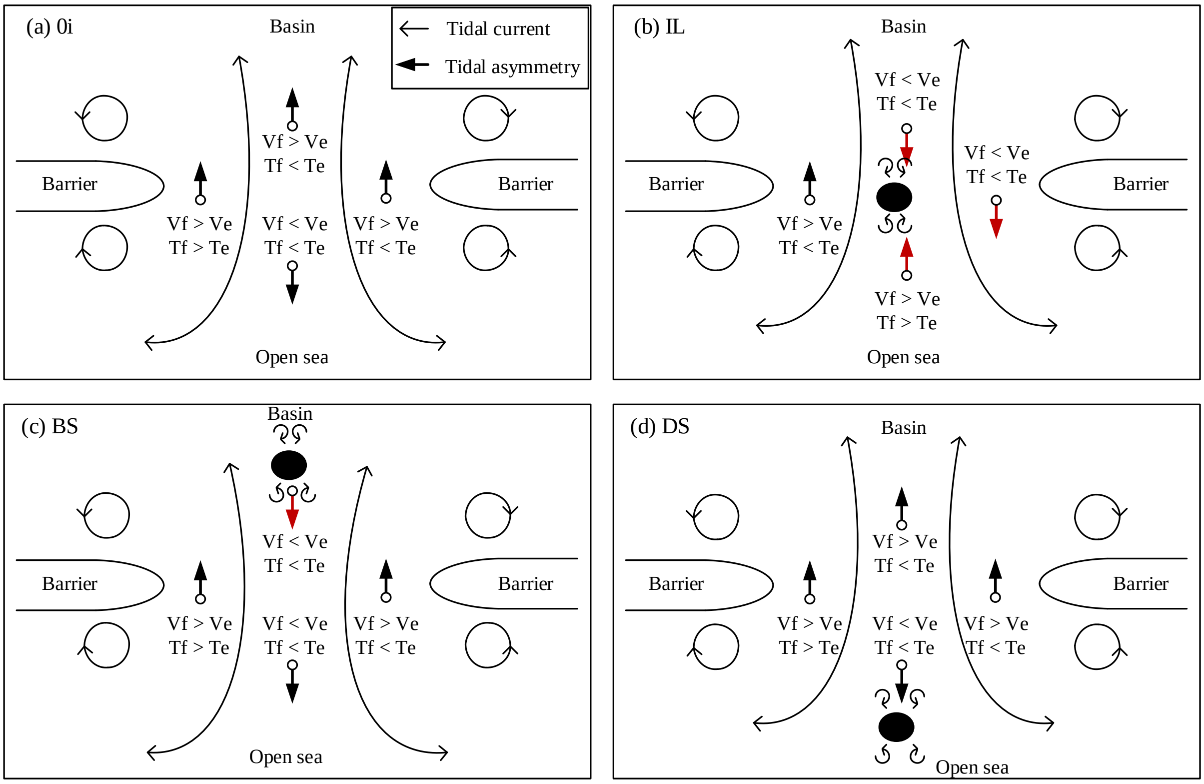

Figure R2 Initial tidal asymmetry of different observation points near tidal inlet of different cases: (a) 0i-case; (b) IL-case; (c) BS-case; and (d) DS-case. In each figure, small arrows represent the direction of tidal currents, while solid arrows represent tidal asymmetry.

4. The model results show that sediment export takes place in all cases. Can you please discuss on the mechanism(s) causing this seaward residual sediment transport? Is this due to the residual flow velocity caused by the river discharge and the flow compensating Stoke's drift?

Reply: Yes, the reviewer is correct that the export of sediment is probably due to the Stokes return flow. In this study, the river discharge is relatively small (50 m^3/s), so its impact on residual current and residual sediment transport is limited. A phase lag between the water levels and velocities induces a landward Stokes drift that causes a landward accumulation of water and momentum, resulting in a water level gradient (negative seaward) (Van Der Wegen et al., 2008; Van Der Wegen and Roelvink, 2008). This water level gradient induces a seaward return flow (Stokes return flow), enhancing the ebb dominant and exporting character of the basin. In this study, it is worth noting that the residual currents are landward in the initial bathymetry, while the net residual sediment is seaward (Fig. 7). A possible explanation can be provided in terms of the Stokes return flow that interacts with the tidal current generating larger residual sediment transport than residual current (Guo et al., 2014).

5. More detailed, at what time are the flow velocity and sediment transport presented in Fig.14? Please consider changing the scales of the vertical axes of pictures a and c. Picture a does not show any differences between the four cases seemingly in in contradiction with the results presented in e.g. Fig.13. The relative differences in sediment transport between the cases should be much larger than those in flow velocity because of the non-linear relationship between sediment transport and velocity. However, picture c does not show this, most likely because of the used scale of the vertical axis.

Reply: Very good suggestion. The time in the Fig. 14 is the result at high tide of the initial year. We have deleted figure a in Fig. 14 since they have little difference. We have also adjusted the vertical axis of Fig. 14 and zoom in locally, as shown in the following figure. It can be seen from the enlarged figure that the relative difference in sediment transport is indeed greater than those in flow velocity.

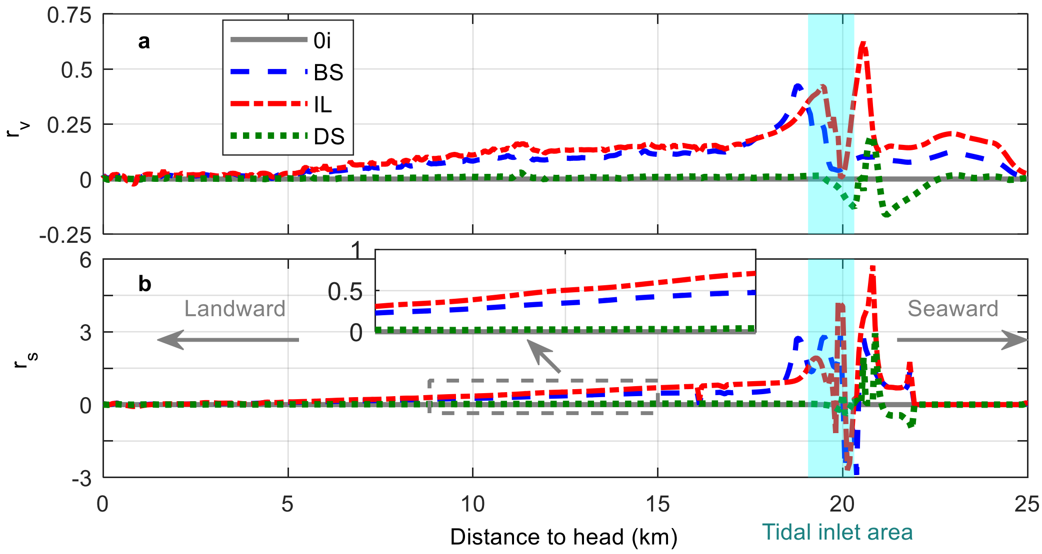

Figure 14 Longitudinal variations of cross-sectionally averaged flow velocity (a) and sediment transport (b) compared to the case of zero island at high tide of the first year.

Line 27 – I would remove "empirical"

Reply: Agreed.

Line 39 – I think that you mean "anthropogenic" instead of "anthropologic"

Reply: Agreed and modified accordingly.

Line 93 – Replace "under" by "with"?

Reply: Agreed and changed.

Line 138-139 – Is it not prescribed that the bed level is not changing?

Reply: Yes, in this way to ensure that the boundary bed level remains unchanged.

Line 143-145 – "which suggests"? I cannot follow the reasoning.

Reply: Following the comment, we think the reason is really a bit of a stretch, so we remove it all.

Line 151 – "the shape of rectangular prism"?

Reply: Sorry, "prism" should be removed. What I want to indicate is a rectangle shape.

Line 188 – Replace "higher" by "stronger"?

Reply: Agreed and changed.

Line 189 – Replace "show" by "shown".

Reply: Agreed and changed.

Line 195 – "continue"?

Reply: Sorry, I don't understand this comment.

Line 380-381 – What do you mean by "horizontal" and "vertical" redistribution? In the model only horizontal sediment transport (from one grid cell to another) is simulated.

Reply: Sorry, this may be a wrong expression. What I want to indicate is that "horizontal" means the sediment moves from one grid to another, and "vertical" means that the tidal channel is gradually deepening, but the shape and size of channel network change little.

Line 393 – Remove "as"?

Reply: Agreed and modified accordingly.

Line 410 – "integrated averaged"? Consider removing "integrated".

Reply: Agreed and changed.

Line 468-469 – I am not quite sure if you can claim "hence providing … systems". No discussion is on this is provided in the manuscript.

Reply: Agreed. We have revised it to the following sentence:

Overall, this study shed lights on the influence of mouth islands (which may be submerged under future sea level rise) on the long-term morphodynamic evolution of tidal basins, hence providing new insights into the evolution of these systems.

Reviewer No. 2

Wei et al. design a number of numerical modeling simulations using Delft 3D to quantify the effect of islands near inlets on the hydrodynamics and morphology of bay environments. The research topic is interesting and of societal importance. Their results are interesting and well explained in general.

Reply: We wish to thank the reviewer for providing very detailed comments and suggestions. We have addressed the comments carefully and clarified many statements.

The first figure the authors include in the paper illustrates the potential effects that islands can potentially play on the hypsometry of bays. Those without islands seem to develop more shoals and a more distinct tidal channel network than those with islands. This is a very interesting observation, but the authors do not seem to be able to capture this dichotomy in their simulations. I would suggest the authors expand the discussion and mention additional factors that could explain these differences.

Maybe additional model runs in a future paper? Are there alternative geometric arrangements for the islands that have not been included that could potentially lead to larger differences in bay morphology? Is there a difference in terms of dredging between bays?

Reply: We fully agree with the reviewer that it is necessary to expand the discussion to explain the differences. We have added some more physics-based discussion in the revised manuscript, as follows:

"4.3 Implications for realistic tidal basins

Even though this study is inspired by observations at a pair of adjacent tidal basins, this study has been highly simplified in order to gain direct knowledge of the role of mouth islands. Numerical experiments demonstrate that the presence of mouth islands can significantly affect the local hydrodynamics and residual sediment transport, and thus influence local channel-shoal morphology. However, in this study, all simulations result in the development of a dendritic channel network that cannot explain the dichotomy shown in the comparison, which implies that mouth islands are only one of the determinative factors contributing to the overall shape of the basin morphology. It is therefore worth nothing other potential effects that possibly lead to the different morphology.

From a morphodynamic standpoint, initial bathymetry and tidal range play a significant role in the development of channel network and intertidal area (Dastgheib et al., 2008; Van Maanen et al., 2013a; Zhou et al., 2014). Initial bathymetry influences the overall sediment availability, while tidal range affects the bed level change by determining the amount of sediment can be redistributed. By comparing two tidal inlets that they are close and sharing similar tidal ranges, but we observe quite different bathymetries (Figure 1). The average water depth in Massachusetts Bay is about 6 m (Signell and Butman, 1992), which is larger than 2 m in Plymouth Bay (Gontz et al., 2013). This shows that different amounts of sediment can be redistributed in the basins, which is one of possible reasons accounting for the differences in morphology. Besides, the sedimentary environment is also different. Massachusetts Bay is a muddy environment, while Plymouth Bay is sandy (Ford, 2010). The sediment properties are found to influence the final profile shape and vertical distribution of sediment (Zhou et al., 2016b), thus affecting the overall morphology. Also, a stronger velocity is developed at the inlet of Massachusetts Bay (Knebel et al., 1991), which may also result in the suspension and export of fine sediment. Finally, human activities have a major impact on basin morphology and since the Boston harbour is in Massachusetts Bay, waterway dredging can be one of the main factors attributed to the deeper watershed and over-deepened channel.

With the focus on the role of mouth islands, some assumptions and simplifications have been inevitably made in our numerical modelling, in order to make it easier to interpret model results and clarify potential insights. However, further research effort should be made to shed light on some of the neglected mechanisms: (1) The mouth islands are considered in the model as non-erodible and of rectangular shape, while natural islands are often slowly eroded with time and have irregular shapes. (2) The effect of wave action is excluded in the model while it may have a great influence on the morphodynamic evolution of tidal basins especially on the ebb-delta area. Nearshore waves can enhance alongshore sediment resuspension and drift, resulting in more sediment being transported to the open sea and forming larger ebb deltas (Hayes, 1980; Fagherazzi and Wiberg, 2009). (3) Sea level change is not considered in this model, while it may play a role in the morphological evolution at the centennial and millennial timescales. Particularly, some of the low islands may be submerged with sea level rise. Besides, existing studies have suggested that the sediment transport pattern may shift from exporting to importing forced by sea level rise (Dronkers et al., 1990; Van Der Wegen, 2013; Van Maanen et al., 2013b). (4) Salt-tolerant vegetation (e.g., salt marshes and mangroves) is found to play an important role on basin morphological evolution, which is not considered in this model. A number of studies have indicated that vegetation can trap and stabilize sediment by decreasing the flow velocity (Townend et al., 2016; Chen et al., 2018). On the other hand, the sedimentary environment can also help vegetation to grow, forming positive feedback between morphology and vegetation.”

Line 17 – …numerically explore…

Reply: Agreed.

Line 62 – …the pathway and sediment distribution are different…

Reply: Agreed and modified accordingly.

Line 76 – …have developed…

Reply: Agreed and changed.

Line 77 – …As showed in Figure 1…

Reply: Agreed and modified.

Line 78 – In contrast?

Reply: Agreed and modified.

Line 95 – …as a reference basin size…

Reply: Agreed and modified.

Line 106 – as follows:

Reply: Agreed and changed.

Line 109 – … is the relative density (remove and) …

Reply: Agreed and changed accordingly.

Line 116 – I suggest the authors better describe the sensitivity tests.

Reply: Agreed. We have provided more details on sensitivity tests in the revised manuscript, as follows:

“Some sensitivity tests with varying MF values are performed in order to select the MF value. Specifically, it is necessary to ensure that the increased bed elevation in each time-step is small enough relative to the water depth, so that the hydrodynamic process in the next time step is not significantly different from the morphological factor of application 1 (Ranasinghe et al., 2011; Van Der Wegen and Roelvink, 2012). In this way, on the basis of ensuring the calculation accuracy, the MF value is selected as 50 to reduce the computational cost.”

Line 121 – For the initial basin bathymetry an idealized …

Reply: Agreed and modified.

Line 142 – Islands can potentially be submerged or even disappear…

Reply: Agreed and modified accordingly.

Line 189 – …is shown…

Reply: Agreed and changed.

Line 205 – …in Figures …

Reply: Agreed and modified.

Line 212 – …slender tidal channels…?

Reply: We have removed the words in the revised manuscript. What we want to describe is that the inlet-island case develops a larger number of tidal channels compared with the other two cases.

Line 218 – …resulting in the convergence of tidal currents entering …

Reply: Agreed and modified accordingly.

Line 233 – … evolution of a basin

Reply: Agreed and changed.

Line 241 – …with the tidal basin…

Reply: Agreed and changed.

Line 245 – Initially the residual currents are 0.4m/s. Not that significant of a decrease?

Reply: Yes, the reviewer is correct that the maximum magnitude of residual currents after 300 years only decreases to 0.3 m/s. However, they only develop in tidal channels, and the residual currents in some shallow shoal tidal flats is smaller comparing to the initial stage. Therefore, we can only point out that the residual currents have decreased, but not significantly.

Line 251 – …of the residual sediment…

Reply: Agreed and modified.

Line 268 – …to a similar pattern …

Reply: Agreed and changed.

Line 301 – I would mention early in this section what cross-sectional area the authors refer to. Equation (4) – I suggest the authors include the limits of the summatory. Is it a function of both x and y?

Reply: Thanks for the good suggestion. We have added some text to the revised manuscript to indicate the cross-sectional area we used. The cross section we used in this study is located in the tidal inlet (see also Fig. 8h), which has a minimum width. Besides, we have also added the limits of the summation in the Equation (4). It is a function along the inlet. The sum of the along-inlet velocity component of the whole cross section is used to calculate the tidal prism.

Line 330 – …there is a decrease…

Reply: Agreed and modified.

Line 374 – …the tidal flat slows…

Reply: Agreed and modified.

Line 394 – …inner basins undergo more erosion…

Reply: Agreed and modified.

Line 401 – a key role?

Reply: We agree that the delta-side island can affect local hydrodynamics, and to some extent, local sediment transport and morphological change. However, by comparing to the cases of islands in other locations, the sediment volume change is relatively small (Fig. 13). Moreover, the cross-sectional averaged velocity and sediment flux are similar to the case without islands (Fig. 14). Therefore, we think that the effect of delta-side island on the morphodynamic process is less than that of islands in other locations.

Line 439 – … will shed light on…

Reply: Agreed and modified.

Line 445 – centennial

Reply: Agreed and changed.

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