General

EnCana has taken under consideration the comments that have been submitted and appreciates the thoroughness of the review performed by Environment Canada as well as the information regarding the recent and ongoing developments in regional wave hindcasts and design criteria determination.

Regarding operational statistics on wind conditions, the editorial errors noted in the comments will be addressed in an update or addendum to the Deep Panuke Design Handbook. If affected by imprecision or errors identified in the comments, revised operational wind statistics will be determined during Project development with the appropriate level of precision to fit specific operational needs as they arise.

The following presents an overview of the development of the methodology used for the derivation of the wave design criteria in the perspective of the points raised in the comments.

The first version of the Deep Panuke Design Handbook was prepared in 2002 to update metocean design parameters used in 1990 for the Panuke/Cohasset project. Following a review of available datasets, extremal analysis techniques and evaluation of the magnitude of the effects of refraction in the local wave climate for the Deep Panuke site, a methodology for wave analysis and extreme wave estimates was developed by AMEC E&E (then COA Inc.). The two following points emerged from this review:

1. The effects of refraction on the local wave climate due to the complex bathymetry in the area of the Deep Panuke field were of very significant magnitude and highly direction dependant.
2. Different data sets, fitting methods and thresholds lead to a wide range of 100-year wave estimates, underlying the large uncertainties intrinsic in extrapolations over long return periods.

A significant effort was put into accounting accurately for the effects of wave refraction by the local bathymetry, as such an effort provides guaranteed improvement upon the accuracy and confidence in extreme estimates, regardless of the error bars inherent in the extrapolation techniques used downstream. For the 2006 revision of the Deep Panuke Design Handbook, wave refraction was modeled with increased resolution from that of 2002. Using a 100m resolution grid based on a recent bathymetric survey of the Deep Panuke project area by EnCana, more than 2000 wave model runs were done for all combinations of incident Hs, Tp and directions (with a resolution of 11.25°) necessary to transfer all AES40 and Waverider data to the MOPU site, so that all the refraction patterns have been accounted for in the transfers. Because the Design Handbook has to remain concise to ensure easy and unambiguous access to design parameters for engineering, only a few figures were included to illustrate refraction effects. Unfortunately, MSC50 became available only after completion of the Deep Panuke Design Handbook. However, the AES40 adequately represents the deep water wave climate off the Deep Panuke site and our analysis based on wave refraction modeled on a 100m resolution grid includes shallow water physics in an appropriate way. It should be noted that the maps of 100 year return of significant Wave height in the MSC50 Wave Atlas available on line for various distributions and storm populations (tropical, extra-tropical, or all combined) all indicate values between 12m and 14m in the area of Deep Panuke. The Design handbook value of 13.7m fits right in the upper part of the MSC50 range.

The AES40 data transferred at the MOPU site includes the effects of refraction by the local bathymetry as accurately and precisely as the Waverider buoy data transferred at the MOPU site do. When it comes to extrapolation to a 100 year horizon, the duration of the latter (less than 7 years) could be argued to be only marginally appropriate. Therefore, it is our opinion that there was no compelling reason to attribute more weight to extreme estimates from the Waverider buoy data transferred at the MOPU site. The range of estimates for the 100 year return Hsig at the MOPU from the two data sets, various fitting methods and threshold values are clearly presented in Table D-1 (Appendix D) and the maximum value of 15.2m (from the Waverider buoy) is clearly identified in Table D-2. This range is consistent with the confidence intervals of each individual estimate that can be derived with the maximum likelihood method. The mean/median was considered a rational way to determine the design Hsig from the range of estimates, in agreement with engineering practices that factor in safety coefficients of 30% when computing environmental loads on structures, acknowledging the relatively large error bars inherent in extrapolation over long return periods from usually short or scarce data sets and recognizing that some assumptions in the theory may not be absolutely verified in practice. An independent analysis and review performed in 2002 by another consulting group (Martec Limited) confirmed the validity of both methodology and results for the 2002 Design Handbook. This approach was approved by Lloyd's Register, the Certifying Authority required by the CNSOPB for the Deep Panuke Project, and therefore was retained for the 2006 revision of the Deep Panuke Design Handbook.

Some comments by Environment Canada require clarification on very specific aspects or interpretation of some material presented in the Deep Panuke Design Handbook and could not be addressed in general response noted above; these are addressed individually as follows.

Clarification on Specific Points

1. Clarifications on Section 1.2 Summary Tables of Design Criteria and Section 5 Water Levels

1.1 Maximum wave crest height and water levels

Comments:

- *Table 1-1 (p. 3) does not include maximum wave crest height, in either the Waves or the Water Levels categories.*
- *In Section 5.4 Maximum Wave Crest Height (p. 101) a previous value of 16.3 m from the PERDDISK for the 100 yr return period is noted, but is also stated that a somewhat higher (but unstated) value would be expected based on the refraction analysis. It is further indicated that non-linear wave theory may be used as an alternative, but a result is not provided. In Section 5.6 Summary – Extreme Water Levels, Table 5-1 states "see section 5.4" for 100 year return crest height. Is the height 16.3 m to be used or is a higher value appropriate? This seems to be a critical value for the design of the MOPU.*

Clarification:

The Design Handbook provides environmental parameters required for engineering. Maximum wave crest height is derived from the 100 year return maximum wave height (100 year Hmax) as part of engineering using appropriate non-linear wave theory. The value 16.3 m and the brief comment are in the Handbook simply for background, but it is understood that the design Maximum Crest Height both for deck height and for loads will be derived during engineering.

1.2 Wave parameters Pipeline Route in near shore Country Harbour

Comment:

Table 1-2 (Wave Parameters – Pipeline Route) is based on AES40 and Table 1-4 (Wave Parameters – Near shore Country Harbour) is based on AES40 transformed using a shallow water wave model. The amount of decrease in wave heights from the nearest section of the pipeline route (2-8.5 km) to the more detailed section near shore (1.5 – 2 km) is surprising. The 100 year return period Hs is 9.3 m in the one, down to 2.1 m in the next, with the depth shown as changing from 30 m to 20 m.

Clarification:

The design wave for a given section of the pipeline is based on the location along that section where waves can be expected to be the highest. In the case of the 2-8.5 km section, this would be at the offshore end of the section (8.5 km), in the open waters off the mouth of the harbour, and would, of course, overestimate the wave conditions at the inshore end of the section (2 km). The two top plots of Figure 3-5 showing incident swell with Hs of 7 m from the two most exposed directions (south and southwest), indicate that in the area of the 8.5 km site, Hs is between 6m and 7m, while at the 2 km (most offshore dot) Hs has dropped to about 2m. Although the representative depth for the 1.5-2 km section is 20 m, Figure 3-5 clearly show that as waves propagate in the complex nearshore region of the mouth of the harbour, refraction results in a drastic loss of energy at the site representative of the 1.5-2 km (indicated by the most offshore dot in the inner harbour in Figure 3-5).

2. Clarifications on Section 3 Waves and Appendix C – Wave Refraction Analysis of Deep Panuke Platform Site

Comment:

In the Summary of Associated Appendices (p. 23), it is stated that the AES40 is an unbiased record of wave parameters. However, it is recognized in Appendix B itself that, in general, the AES40 is slightly high for the field site, which is likely due to it including only deep water physics. It is also recognized in Appendix B that AES40 sometimes underestimates extreme events spanning a short period of time, such as tropical cyclones. This is one of the areas where the MSC50 improves on the performance of the AES40 (Swail et al 2006).

Clarification:

The statement on page 23 is meant in the sense of storm peaks, which are relevant to extremal analysis using the peak over threshold method, rather than for the entire time series. Appendix B also presents examples for which the AES40 product gives higher than observed waves at storm peaks.

Comment:

In Section 3.2.1 Waves at MOPU Site (p. 25), Figure 3-1 shows Hs vs Tp (peak wave period) of the largest storms modelled at Deep Panuke based on a wave refraction analysis of wave buoy data at Cohasset. It shows the peak Hs as near 12 m, with Tp about 16.6s. This was about the same as the peak Hs over the full record from the wave buoy, of near 12 m, in the severe storm of January 2000. Refraction analysis results presented in Appendix C would suggest a higher value would be expected at the Deep Panuke site.

Clarification:

Refraction patterns are highly dependent on the direction of the incident wave relative to bathymetric features (Appendix C shows clearly that a 10 m Hsig from the west at the western boundary of the modeled domain would be increased by about 1.5 m at the MOPU, whereas the same Hsig from the southwest drops to about 9 m at the MOPU). The effects of refraction at two different sites vary depending on their respective position relative to these bathymetric features (the southwesterly incident direction show striking variations of Hsig over short distances, between the field center and the area to its south). Hence, the sample figures in Appendix C indicate that in general, refraction can result in direction-dependent large variations between the incident Hsig at a boundary of the modeled domain and Hsig at a given site within the model domain or between two sites within the domain.

This general visual impression from the sample figure in Appendix C can be misleading when it comes to looking at differences between the Waverider site and the MOPU site. These two sites are relatively close to each other (Waverider site slightly to the north-east of the MOPU site. See Figure C-1) and under closer scrutiny, the sample figures show that differences between these two sites are quite small compared to the range exhibited in these sample figures over the whole domain.

A given sea state and incident direction can result in Hsig at the MOPU site being either similar, or higher, or lower than that at the Waverider site, and differences (either way) do not exceed 1 m. Therefore relatively small differences can be expected between the raw buoy data and the buoy data transferred at the MOPU site which is the case for the January 2000 storm.