APPENDIX A – Summary Responses to Charge Questions

The following is a summary of comments and recommendations from panel members for revision of the preliminary risk assessment and the associated predictive models.

The charge questions for this consultation are focused on the five primary documents described in Attachment XX. The overall charge to the panel was to comment on the adequacy and readiness of the aforementioned draft documents for further scientific review. In general,

- Do the documents provide adequate descriptions of study design, methods, conclusions, limitations and uncertainties?
- Are there major omissions?
- Are the draft reports sufficient for peer review?

Document 1: Investigation of PCBs Release-Rates from Selected Shipboard Solid Material under Laboratory-Simulated Shallow Ocean (Artificial Reef) Environments, June 2005 (Draft Final)…

- Please provide comments as to whether biodegradation or encrustation processes should have been considered in the study.

- Please provide comments as to the adequacy of the study to support the fate and transport models (PRAM and TDM).

- Please comment on whether the nonliquid-PCB materials selected for evaluation were sufficiently representative of PCB materials on the ex-Oriskany and other vessels to provide a basis for evaluating ship sinkings.

1. From the central-estimate inventory appearing in the CACI report, over 97% of the total estimated content of the Ex-ORISKANY is in the electrical cable insulation (705.5 lbs/722.6 lbs) = 97.6%). The one sample of cable studied in the leaching experiments contained only about 1200 ppm PCBs (0.12%). This means that the representativeness of the single sample used for electrical cable leaching rates is very questionable.

The use of just one sample of the cable when there is likely to be material variability with spatial location in the ship is an issue that needs to be addressed. Consideration should be given to using all the data from the two temperature experiments and pressure experiments as one approach to address this variability more fully.

Also, extrapolation of the results from one sample to the whole vessel makes the scale up quite uncertain.

2. Instead of using zero values, the non-detect measurements will need to be handled more rigorously. The use of zero emission rate for some the congeners and time steps in the TDM based on results from the laboratory leach study may not be an

appropriate representation of the scaled up release scenario for the ex-Oriskany. It is difficult to imagine a scenario where several hundred thousand kilograms of material would have intermittent releases. The Navy needs to either do a better job demonstrating the validity of this assumption or demonstrate that it has little effect on the results. If the intermittent source terms do impact the results then there may be a need to construct plausible release scenarios that take into account the variability of shipboard materials. Although additional experimentation (more samples) would be helpful, there may be an opportunity to use data from the temperature and pressure experiments to explore the variability in the source term more fully.

3. The use of standardized diffusional leaching tests (monolithis and granular) should be examined to mechanistically understand PCB leaching phenomena. The assumption that release rate is linear with respect to concentration of PCB in a given material should be justified. One could imagine a case where the release rate from the material remains constant as the concentration of PCB decreases due to mass transfer limited release, dissolution of the material containing the PCB or (more likely) dissolution of a "pure PCB phase" in the material. If a pure phase (solid or liquid PCB) existed in the material used in the release rate study then linear extrapolation to lower concentrations may under predict release rate while extrapolating to higher concentrations can over predict release rate.

4. The experimental design for the leach tests focused only on aqueous phase release of PCBs. The data obtained do not account for physical erosion and the role of released particles. Further, the cage apparatus used to contain the samples and limit the investigation to aqueous phase release may have introduced artifacts such as PCB adsorption on the cage material. The potential role of particle release and transport and experimental artifacts in the leaching procedure needs to be addressed.

Experimental design (cage apparatus may introduce artifacts), does not account for erosion and roles of particle in suspension), does focus only on the aqueous phase. This may need to be addressed. Also, not accounting for the PCB that sorbs to the glass leaching vessels can bias the results leading to an under estimate of leach rate. The influence of sorption would differ over the course of the experiment because of differences in sample duration where early in the study the samples "saw" only a single bottle while later when the samples were collected on 6-8 week intervals the leachate "saw" 6-8 times the amount of glass. Depending on the magnitude of sorption to glass, this might explain the apparent decrease of release rate later in the study. This potential loss pathway should be quantified and the release rates corrected to account for sorption to glass.

5. REAL WORLD biofilms are involved. Monitoring in the field is going to help inform the parameters in the model including the leaching rate. As far as laboratory leaching tests these data can only go so far. Biofouling and direct transfer of the PCBs to microbial communities are likely occurring.

Document 2: TIME-DYNAMIC MODEL (TDM) Documentation, May, 2005 (Draft Final)

- Please provide recommendations as to the TDM's applicability in ship reefing (i.e., is its short term fate and transport algorithm accurate and applicable).

- Please offer recommendation on the appropriateness of TDM's fate and transport outputs for input in PRAM's exposure algorithm and the resulting comparability of the short- versus long-term exposure results.

- Please comment on the sufficiency of the documentation describing the TDM approach, limitations, and uncertainties?

- Please comment on the soundness of the assumed pycnocline to bound the volume into which PCBs are initially distributed.

- Please make recommendations regarding the accuracy, and/or reasonableness, of TDM's approach, assumptions, inputs, equations, and calculations in regards to the overall prediction of direct PCB exposure to humans and marine organisms.

- Please provide specific opinion regarding TDM's transferability to other naval reefing applications including scenarios that include multiple ships reefed in close proximity.

1. **Model documentation.** The documentation for the TDM is not sufficient to judge the science and the appropriateness. The hydrodynamic model employed in the TDM is unclear and appears to have problems in its formulation. A diagram showing the boundaries and spatial discretization of the flow domain needs to be provided, and the model details (differential equations, boundary conditions, initial conditions, solution technique) need to be provided.

    a. The structure of the model is difficult to understand.
    b. The description of the model needs to be improved in the document such as water mass transport and other parameters.
    c. The chemical equilibrium partitioning constants used are not clearly described.
    d. The 24 hour time frame for chemical reactions should be reviewed in regard to more recent publications and justification for the approach used for reaction rates in the model needs to be presented. (The consideration of instantaneous or rapid (within 24 hours) phase partitioning of PCBs in the model was surprising considering the objective to predict PCB concentrations as a function of time.)
    e. The outer boundary of the flow domain, with specified boundary conditions, is not defined.

f. The hydrodynamic model apparently used is not consistent with advection in a time-varying bottom current flow direction.
g. The cell by cell equations should be included.
h. The mass balance in the model needs to be addressed.

2. **Sensitivity analyses and model parameters**. The modeling done with the TDM has provided some useful analyses in regard to addressing variability and uncertainty. The extent to which certain model assumptions are driving the analyses is unclear, however. There needs to be more sensitivity analyses, addressing many of the assumptions used in the model e.g. internal path length, internal current, eddy diffusivity, foc = 0.01, sediment mixed to 10 cm, (what happens in the sediment – this is not discussed anywhere!), DOC at 0.6 mg/l, TSS at 10 mg/l, no PCBs in the water above the ship. To the extent possible, probabilistic descriptions of model parameters should be used rather than deterministic estimates.

3. **Irreversible sorption formulation.** The idea of irreversible sorption is supported however, using a single factor based on the 1982 paper by DiToro and Horzempa on sorption-desorption of hexachlorobiphenyl for all the homologs is not appropriate. Thus 54.7% of equilibrium value may be incorrect. Furthermore, there has been much more mechanistic work done on sorption/desorption characteristics of hydrophobic organic compounds since 1982 that could inform this model [see the references in Appendix B under the comments from D. Dzombak].

4. **Ship integrity and internal flow rate assumptions**. The assumption about the vessel hull is not necessarily a conservative one. Given that the leach rates are set in Appendix C, there is no question that the same quantity of PCB will released no matter what the hull porosity assumptions are. However, a slower flow rate through the ship would result in a higher residence time and therefore higher concentrations coming out of the ship, but in less volume of water. So, it's not clear if the total mass released per day, say, would be more or less than is currently predicted with the model. The internal-ship flow velocity assumed (1/100 of external flow velocity) appears to have been selected rather arbitrarily. This really needs to be monitored and assessed for ships already in place.

5. **Pycnocline**. While there is information to indicate the existence of a pycnocline near the depth used in the model at various times of the year, the variation of the depth and existence of the pycnocline are not addressed.

Document 3: Prospective Risk Assessment Model (PRAM) Documentation Version 1.4, May 2005 (Draft Final)

- Please provide specific recommendations regarding the sufficiency of PRAM's documentation.

- Are the data used to calibrate the PRAM appropriate

- Please comment on the soundness of PRAM's approach, assumptions, equations, and calculations in predicting direct PCB exposure, uptake, and food web transfers (including bioaccumulation algorithm).

- The choice of ZOI is paramount to accuracy of PRAM's modeled predictions. Please provide recommendations regarding its definition, basis, dimensions, and overall scientific soundness.

- Please provide specific opinion regarding PRAM's transferability to other naval reefing applications including scenarios that include multiple ships reefed in close proximity.

- Lastly, provide comments on the sufficiency of the ex-Vermillion fish tissue study in calibrating and validating the PRAM.

1. The PRAM is well documented for the bioaccumulation and human health modules, but there are gaps in the discussion, presentation of algorithms, and presentation of physical transfer processes that are critically missing from the fate and transport module. This should include a good explanation of why a fugacity-based model was selected for use in a very dynamic water environment, a better description of the transfer functions between the four water components, better documentation of the parameters selected for the model, and an expanded discussion of the uncertainty associated with the PRAM output.

2. There is very little basis provided to evaluate calibration in the absence of a detailed comparison with the data from the other ships. The PRAM appears to have been neither calibrated nor validated. There is a need for a general overview of the complexity levels used in the model with better explanations and evolution of the models. Finally, then the report could proceed into the detailed description of the Fugacity levels.

3. There are some inconsistencies which state whether the PRAM is applied to human health and/or the environment. This should be clearer. General editing and missing references need to be addressed. The PRAM application here focuses solely on PCBs due to specific and understandable regulatory mandates of PCB Bulk Product Waste (40 CFR 761.62c). A reviewer could be concerned that there are other aryl hydrocarbon receptor (AhR)-related dioxin-like chemicals (e.g., dioxins or dibenzofurans) present and that they are not included in the toxic equivalents (TEQs). It would seem that a straightforward statement about other potentially present AhR contaminants would remove any concern of a reader. To assess the effect of PCBs without some statement about other chemicals that work by a similar mode of action will not be adequate for many assessors. As an extreme example to make the point that some discussion of other AhR-mediated toxicants should be included, would this same focus only on PCBs be adequate if a ship used during the Vietnam era to transport Agent Orange was to be sunk? The Biological processes should be better described. Microorganisms are left out of the food web.

The construct of the physical PCB transport component (module 1) in PRAM using fugacity-based algorithms may be used in a very limited sense to evaluate a "worst case" transfer and potential uptake of PCBs. For the purpose of evaluating placement of this particular vessel in this specific instance, PRAM as constructed can be used in this decision only. However, fugacity transfer will be the exception in the dynamic environment in which the ex-ORISKANY will be placed. As such, PRAM cannot be used to accurately predict PCB concentrations in fish tissues over time, and its use should not be extended to any other decision without considerable additional work on the transport functions.

As noted for TDM, one idea is to explore a multi-dimensional finite element fate and transport model for congeners or homologues that better articulates the ship's interior, the near ship environment and the flow field. Hydrodynamic features such as tidal currents, thermal current, and wind/storm-based elliptical wave currents in the absence of, and in the presence of the ex-ORISKANY, should be considered. For instance (albeit simplistically and worthy of some examination), absent effects from a submerged ship, for long duration wind stress factors on the Gulf's surface water's greater than 20 m/s with long fetches (greater 200 km), resultant waves will likely have heights greater than 10m. Under these conditions, elliptical water particle orbits would be expected throughout the water column and will produce significant back and forth movement throughout the reef depth during each wave period.

The existence of a pycnocline to bound the lower/upper water compartments in PRAM, and in the TDM, appears to have been invoked in order to provide for a conservative analysis; i.e., a smaller water volume for the initial distribution of released PCBs. This should be stated explicitly. Pycnoclines are likely more dynamic and variable in reality than described and used in PRAM.

In general, the bioaccumulation algorithms (module 2) are appropriate for their intended use and are consistent with present scientific understanding and practice. Some reviewers believe that a more explicit incorporation of microbial uptake pathways is important to reflect and important pathway and improve the model's overall accuracy. Other reviewers noted the importance of PCB transfer to fouling biofilms or fouling invertebrates that is based on diffusion into the fouling organisms. Another potentially important trophic transfer pathway that appears to have been ignored that does involve transfer via PCB dissolution into the aqueous phase.

The general construct of the human health module is appropriate for its intended use and is consistent with present scientific understanding and practice.

Given the uncertainty associated with the limited PCB leach rate data, PRAM should be updated to perform probabilistic risks to assess the bounds of those uncertainties. To support the ex-Oriskany risk assessment, additional modeling runs are recommended that incorporate probabilistic (Monte Carlo or Hypercube) analysis with at least following variables:

- Mass of PCBs on the ex-Oriskany (bias sampling)
- PCB release rates
- Flow Rates (currents)
- ZOI

The output from these analyses could be used to re-express the human health risks (for fish consumption only) as a probability of exceeding the cancer risk factors (probability of exceeding a 10-6 lifetime cancer risk), and the ecological risks as a probability of exceeding an HQ of 1, 5 and 10.

4. The ZOI in PRAM is a useful construct used within the limits of the fugacity-based algorithms. However, the ZOI is an arbitrary construct based upon the degree of conservatism required by the evaluating Agency(s), and not on a direct measurement of leach rates, transfer functions, or physical conditions that can/will exist between the interior and exterior of the sunken vessel. As such, it is not appropriate to discuss the ZOI in terms of "accuracy" or "overall scientific soundness". It can be appropriate to discuss the ZOI in terms of the relative degree of conservatism included in PRAM, and as such a ZOI of 2 or 3 seems appropriate.

   The Biological processes should be better described. Some reviewers felt that microorganisms were left out of the food web and that was a critical flaw in the model. Other reviewers believe that microorganisms are not likely important in the pathways for the fish species that PRAM intended to model

5. Both the predictions and the data sets need to be addressed in a more formal approach. The problems need to be taken apart into manageable pieces. This again goes into the uncertainty and sensitivity analysis of some of the key drivers of the model.

   a. Release rates
   b. Interior vessel concentrations
   c. ZOI (although 3 seems reasonable)
   d. Vessel dimensions
   e. Current flows
   f. The use of homologs/ congeners, as measured in the laboratory versus those found in the field. It is not possible as yet to mathematically relate the homologs in the water/sediments to what is in the fish. For example: PCB congener 77 will partition in sediment and water in accordance with fugacity theory, but not in fish tissues. By contrast, PCB 126 is often not measured in sediments or water, but is often measured in fish tissue. Thus the exposure estimates used for the total PCBs carry a great deal of uncertainty in regard to toxicity. There is not total agreement on how to address this scientifically, some suggested that the congeners should be addressed but distributions

should be used. More monitoring and assessment would be of value in addressing these questions.

g. Bioaccumulation is predicted well but biomagnification in the trophic levels is underestimated by PRAM, mechanistic or methodological explanations should be sought to describe these differences.

PRAM, as constructed, is not suitable for any other naval reefing application. To overcome this limitation it is recommended that the Navy

- Replace the fugacity-based module 1 with a multi-dimensional fate and transport model that better articulates the ship's interior, the near ship environment and the flow field, and can incorporate simulation of major storm/wave events

- Conduct additional analyses, with replication, on the PCB materials and release rates

- Calibration and validation of the F&T and bioaccumulation / biomagnification modules using a well-designed monitoring program

- Incorporation of a probabilistic assessment in order to evaluate uncertainty in the model projections

6. The TDM (and the PRAM) need to be validated before their usefulness for other applications can be confirmed. Thus there is a need for a validation protocol to be specified for the PRAM, one that takes into account that such “higher order” models require a redefined approach to validation. Since data sets that stress all aspects of the model do not, and are unlikely to exist, or are prohibitively expensive, the usual approach of comparing output with data is not practical. The Panel recommends following the protocol developed by Beck at the University of Georgia.

   The current representation of the ex-VERMILLION fish tissue calibration effort is insufficient to support PRAM. By the Navy's own presentation, there is no confidence in the estimates of PCB mass in the ex-VERMILLION. The inability of PRAM to adequately forecast fish tissue concentrations limits its utility. How the calibration effort was conducted is not clear in the documentation.

Document 4: Ex-ORISKANY Artificial Reef Project Human Health Risk Assessment, June 2005 (Draft Final)

- Please provide specific recommendations on the completeness of the exposure scenarios with regard to selecting the maximally exposed receptor and the length of the chronic exposure duration (i.e., should the initial 2-year pulse PCB release period be considered in chronic exposures).

- Please provide specific recommendations regarding the exposure parameter

selection for the diver scenario and whether its qualitative assessment is sufficient.

- Please provide recommendations regarding the accuracy of the PRAM's PCB congener forecasts in water and fish.

- Please make recommendation regarding sufficiency of the ship's interior flow rate assumptions. Also comment on the potential usefulness of considering catastrophic weather effects on both interior and exterior flow rates.

- Please comment on the selected risk assessment parameters used in the study including toxicity values and risk calculations. Are quantitative risk considerations missing (e.g., dioxin-like PCB risks)?

1. It would help to see one more paragraph in the executive summary that identifies the most important factors in the overall assessments (based on both sensitivity and uncertainty) and why the reader should believe that the values used for these factors in the model are correct (or conservative). This information is provided in some detail in the various documents and appendixes but as part of the Executive Summary the authors should bring these findings forward. For example, I (randy) would like to know up front that the bulkhead insulation and/or cable are most important source(s) of PCB and the grouper contributes most to human exposure because it is assumed to be exposed to 20% vessel interior water.

2. This has used a fairly consistent QRA approach and seems reasonable.

3. Both local exposure assessment and the variability of the fish consumption patterns should be explored and included particularly as a distribution parameter. This will give the local community more confident that their situation is being addressed.

4. Breast-fed infant exposure pathways should be undertaken in the risk assessments.

5. The accuracy of the PRAM's inputs to the human health risk via the individual congeners and the total PCB exposure has some issues that should be described as part of at minimum a qualitative description of the caveats and uncertainties.

    a. Release estimates
    b. Particle settling
    c. The time the fish spend inside the vessel and the interior concentrations. This is a source of uncertainty.
    d. Exploration of other sites which compare the Total PCBs and the congener assessment. Address interior and exterior waters (sampling and methods are problematic), looking at patterns and the fish populations will be informative in framing the bounds needed to address the more toxic PCBs.
    e. The Global contribution of sources, address "this source" compared to other sources of PCBs in the environment.

6. The ZOI dimensions seem reasonable, and a 2 to 5 multiplier (of the ex-Oriskany's volume) is adequate. Factors of 2-2.5 for near-field foragers and 4-5 for less reef-related fish are reasonable. However, it is possible that a "near-field forager" may reside primarily on the down-current side of the vessel essentially residing in the "plume" while the ZOI approach distributes the foraging distance around the vessel. The ZOI also distributes the plume into a volume encircling the vessel. It is unclear whether this distribution based on range is appropriate.

7. The sufficiency of the ex-Vermillion fish tissue study in calibrating and validating the PRAM needs further study and explanation. .According to Johnston et al.'s "Assessing the ecological risk of creating artificial reefs from ex-warships", there was a difference in liver size and lipid content for ex-Vermillion reef fish and those from natural reefs, resulting in higher PCB concentrations. (Lipid content is important in predictions, e.g., Equation 93 on page 2-77.) Some of the variability was attributed to differences in feeding and behavior. This issue needs to be addressed more before tissue data from this reef can be generally applied.

Document 5: Ex-ORISKANY Artificial Reef Project Ecological Risk Assessment, June 2005 (Draft Final)

- Please comment on whether the selected ecological communities and trophic relationships are inclusive and representative of reefing sites. Please also comment on whether the assessment endpoints and conceptual model are acceptable.

- Please comment on whether sufficient toxicological benchmarks are used to be confident that risks to Threatened and Endangered species and other species of critical concern are adequately considered.

- Please comment on the soundness and inclusiveness of the selected assumptions, the inherent uncertainties, and the overall limitations of the ecological risk assessment. Are additional data analyses or risk characterizations warranted to support the conclusions about ecological risks?

- Please specifically identify fundamental analytical flaws and/or key data gaps that might negate or restrict the use of this Ecological Assessment in supporting risk-based reefing (ex-Oriskany as well as other vessel reefing).

- Please comment on the need for acute ecological health concerns given the results of the TDM and reef species colonization timing and uncertainty.

1. A general emphasis is on "ecological receptors that could reside, feed, and/or forage at the artificial reef." The models focused on predicting bioaccumulation in the "food chain of the pelagic, benthic, and reef communities." Assessment endpoints were "effects to survival, growth, and reproduction to the communities and organisms modeled by PRAM as well as ecological consumers that could also feed and forage at the reef."

   Primary producers (Trophic Level 1 or TL1) … algae
   Primary consumers (TL2) … copepods, bivalve, urchin, polychaete, nematode
   Secondary consumers (TL3) …herring, triggerfish, lobster, crab
   Tertiary consumers (TL4) … jack, grouper, flounder

2. Grouping these trophically-defined species by habitat allowed focus also on benthic, pelagic, reef communities and seems appropriate. Additional endpoints were cormorants, herring gulls, sea turtles, dolphins, sharks and barracuda. Have enough attention was being paid to keystone species? It is quite plausible that ecological engineers are important in reefs, e.g., specific hard coral or other encrusting species. Certainly, relevant information can be obtained from sources such as: http://cars.er.usgs.gov/coastaleco/Tech-Rept-Pinnacles-2002/executive_summary/executive_summary.html

3. This is a Screening level risk assessment. And need to be careful of how far you can go in the interpretation. The evaluation of the hazard quotient (eg. HQ 10) and the individual benchmarks for this application of the interpretation of risk may be problematic. This is based on one person's professional judgment and is not scientifically supported. No effect level versus some effects. More conventionally for PCBs to use below 1 is assumed to be no risk and above there is a risk. The use of NOEL, LOEL.

4. The scientific justification for choosing the end-points and those that were deemed to be most sensitive should be addressed.

5. Given the many uncertainties and unknowns for the biological systems, this RA could not likely be applied to other places with confidence. A protocol needs to be developed which is tied to a monitoring program that focuses on transferability, data gaps, both from laboratory and field studies. Post-decision monitoring program that helps to inform the next version of the risk assessment.

6. As a related issue, the same species can vary in its trophic position. Here is an example of lake trout from eight Canadian Shield lakes (Figure from Newman & Unger (2003), Fundamentals of Ecotoxicology, CRC/Lewis Publishers,; Modification of Fig. 2 & 3 of Cabana & Rasmussen. 1994. Nature 372: 255-257.) Thus the model needs to be reinforced by empirical monitoring data.

7. Enormous variation in the PCB concentrations, this drives the need for a probabilistic assessment and examining the uncertainties and the transferability.