REVIEW OF THE AMCHITKA INDEPENDENT ASSESSMENT SCIENCE PLAN

By

A Subcommittee of the CRESP Peer Review Committee

Submitted to CRESP, February 2004

Introduction

This is a review of the Amchitka Independent Assessment Science Plan, as set forth in the 167-page document of the same title dated May 28, 2003. The review, performed by selected members of the CRESP Peer Review Committee (Table 1), was undertaken at the request of the leadership of the multi-university Consortium for Risk Evaluation with Stakeholder Participation (CRESP). Specifically, the reviewers were asked to: 1) evaluate the Plan, with particular reference to those factors and issues that are likely to need the most careful attention in preparing for the Plan's implementation; 2) comment on the appropriateness, adequacy, and quality of the methods and approaches that are adopted in the Plan; and 3) suggest how the work that is called for in the Plan could be made most effective and credible. It is to address these issues that this report has been formulated.

Comments on the Science Plan's Scientific Approach

The Science Plan is designed to investigate the present and future risks to human health associated with the underground testing of nuclear weapons on Amchitka Island in the period 1965-1971. Hence, the stated specific objectives of the Plan are:

1) "to determine whether or not current or future radionuclide releases from the shot cavities to the marine environment pose significant risks to human health and the ecosystem;
2) "to reduce uncertainty about the extent of the hazard and nature of the risks to human health and the ecosystem associated with any potential current or future radionuclide release to the marine environment and the factors that may affect such risks; and
3) "to devise and communicate an appropriate monitoring plan that would detect potential significant future risks to human health and the marine ecosystem as early as practical."

In pursuit of these objectives, the following are identified as important targets of inquiry and questions of concern:

1) current levels of radionuclides in the marine environment and food web, especially in those species that could cause the greatest radiation dose to human and ecological receptors;
2) the properties of radionuclides in the marine environment from the tests that can be distinguished from other potential sources;
3) the properties of the hydrogeolologic system that constitute the fracture-dominated pathway between nuclear test shot cavities and the ocean; and
4) processes for transfer, accumulation, and attenuation of radionuclide concentration in the hydrogeologic and marine systems;
5) the specific radionuclides that should be looked for;
6) the foods that are consumed by Aleuts;
7) the levels of test-related contamination that are found now or might be found in the future;

8) whether these levels would pose a threat to human health or ecological receptors; and
9) how we will know if such threats arise in the future.

To address these questions, the Plan seeks to characterize and sample, to the extent possible, the various steps in the pathways taken by radionuclides in traveling from one or more of the shot cavities to reach human and ecological receptors. For this purpose, the Plan focuses on the following:

1) characterization of the physical environment, together with contaminant transport models, to permit efficient, targeted sampling for radionuclide contamination;
2) analysis of human food, relevant components of the food web, and the general biological environment for immediate confirmation of human safety or warning of risk;
3) sampling strategy, analyses, and results for incorporation into or modification of existing contaminant transport and risk models to reduce the uncertainty in determining the rate and magnitude of risks associated with potential future radionuclide release;
4) data collection to reduce uncertainties in the DOE's screening risk assessment and groundwater models; and
5) identification of indicator species suitable for long-term modeling.

The sampling strategies are to be planned in consultation with stakeholders, and the sampling itself is to be performed in collaboration with Aleut fishermen, hunters, and student interns, based in part also on laboratory analyses and consultations with commercial fishermen and various agency personnel. The results of the sampling are to be shared with stakeholders, who are to play a role in interpreting their significance, as well as being published in the open literature.

To implement the plan in question, the project is to be managed by CRESP, and the work is to be organized into the following research tasks and subtasks, each under the leadership of the respective Task Coordinator(s) listed:

1.Sampling the Marine Environment
- 1.1. Biological Sampling [Stephen Jewett (U. of Alaska, Fairbanks) and Joanna Burger (Rutgers)]
- 1.2. Physical Marine Environment [Sathy Naidu (U. of Alaska, Fairbanks)]
- 1.3. Radionuclide Analysis of Marine Samples [Rod Hand (INEEL and CRESP)]
- 1.4. Consumption of Marine Food by Humans [Kari Hamrick (U. of Alaska, Anchorage) and Joanna Burger (Rutgers)]

2. Ocean Conditions
- 2.1. Ocean Floor Characterization [Jennifer Reynolds (U. of Alaska, Fairbanks) and John Lindsay (National Oceanographic and Atmospheric Administration)]

- 2.2. Salinity Structure and Discharge [Mark Johnson and Whitledge (U. of Alaska, Fairbanks)]
- 2.3 Ocean Circulation [Mark Johnson and Zygmunt Kowalik (U. of Alaska, Fairbanks)]

3. Amchitka Geology and Hydrology
   - 3.1. Amchitka Data Recovery and Synthesis [Frank Manhein (U.S. Geological Survey)]
   - 3.2.Amchitka Structure and Determination of Subsurfce Freshwater/saltwater Interface [Herbert A. Pierce (U.S. Geological Survey)]
   - 3.3 Groundwater Recharge [David Barnes and Daqing Yang (U.of Alaska, Fairbanks)]
   - 3.4.Radionuclide Content of the Test Area: The Source Term [David W. Layton and David. K. Smith (Lawrence Livermore National Laboratory)]
   - 3.5.Water/rock Interaction in the Rock Envelope [David Barnes (U. of Alaska, Fairbanks)]
   - 3.6.Radionuclide Sorption on Sediments [Sathy Naidu (U.of Alaska, Fairbanks)]
   - 3.7. Deformation of the Amchitka Massif [Jeff Freymueller (U. of Alaska, Fairbanks)]
4. Stakeholder Dimensions
   - 4.1 Stakeholder Participation [Larry Duffy (U.of Alaska, Fairbanks)]
   - 4.2.Long-Term Monitoring [CRESP]

The plan's timeline calls for its major tasks to be accomplished within a 3-year funding period, throughout which the appropriate Data Quality Objectives process (as designated by EPA) is to be followed systematically. Furthermore, to maximize the effectiveness of the plan within the limited timeframe in question, each of its various tasks, subtasks, and task components has been assigned a priority ranking on the basis of its expected importance to attainment of the plan's overall objectives

The Plan's <u>Scientific Approach,</u> as described above, is extremely ambitious but is also logical and appropriate. In addition, the Plan's proposal to conduct the study in stages and to use the lessons gained to guide in the planning and execution of later stages is well conceived. The Plan is also to be commended for giving proper weight to stakeholder interests and for encouraging active stakeholder involvement in the program.

As noted, however, in Section H. <u>Chemical Tracers and Radiological Signature</u>, the "selection of chemical components to be traced is a key to the success of the investigation" but is complicated by the fact that the source terms for the nuclear tests conducted at Amchitka are classified. The classified nature of the source terms poses serious technical problems in addressing exposures and other aspects of source term quantification, as well as problems in trying to utilize the data in a Plan that is to be non-classified and transparent in all other aspects. It is essential, therefore, that these problems be addressed at the outset, and that appropriate efforts be made to distinguish between those radionuclides in the marine environment which may be attributable to the Amchitka nuclear tests and those which come from other sources. Also, it is critically important to the success of the study that these problems be communicated effectively to all concerned and documented appropriately in all relevant publications. Openness must be the driving theme.

Comments on the Quality Assurance and Data Quality Objectives

It is commendable that the Plan is designed to follow the iterative, 7-step Data Quality Objectives (DQO) process recommended by the EPA. The fact that the process provides a systematic procedure for defining the criteria to be satisfied by the data collection design and that it is to be linked to other important QA determinants significantly enhances the Plan.

Comments on the Health and Safety Plan

Given the hazardous nature of the fieldwork and the potentially hazardous nature of some of the laboratory work that are called for in the Science Plan, the Plan's systematic provision for the proper training, supervision, equipment, and other measures that are needed to protect the health and safety of involved personnel are well conceived.

Comments on the Prioritization of Tasks and Subtasks

The Plan's timeline calls for its major tasks to be accomplished within a 3-year funding period, and to maximize its effectiveness within this limited timeframe, each of the Plan's various tasks, subtasks, and task components has been assigned a priority ranking on the basis of its expected importance to attainment of the project's overall objectives. It is noteworthy, moreover, that the prioritization scheme provides options for continuous rethinking of data needs and targets of opportunity for the productive investment of the limited resources on a priority basis. This lack of rigidity in the Plan is a positive feature.

Those tasks and subtasks which were assigned the highest priority ranking at a meeting with stakeholders at the Desert Research Institute in Las Vegas on February 19, 2003, include:

- Subtask 1.1.2 Main biological sampling, 2004-2005
- Subtask 1.3 Radionuclide analysis of marine samples
- Subtask 1.3.1 Radionuclide analysis of biota
- Subtask 1.4 Consumption of marine food by humans
- Subtask 2.2 Salinity structure and discharge
- Subtask 3.1 Data recovery and synthesis
- Subtask 3.2 Subsurface freshwater/saltwater interface
- Subtask 3.3 Groundwater recharge
- Subtask 3.4 Radionuclide content of the test area
- Subtask 4.2 Monitoring component of long-term stewardship

While the subtasks listed clearly deserve high, if not the highest level of, priority, the failure to include Subtask 4.1 Stakeholder Participation in the list is a puzzling omission. If it was not merely an oversight, the omission has potentially serious implications since it is contradictory to one of the Plan's central thrusts.

Also, since the acquisition of almost any reliable new information would be useful if obtained in sufficient amounts, the criterion for evaluating the "Probability that the project will be successful in generating useful data" (item A. 2.a. in Section IX of the Plan) should be changed from "At all" to "A significant amount".

Comments on Task 1. Sampling the Marine Environment, including :
Subtask 1.1 Biological Sampling
Subtask 1.2 Physical Marine Environment
Subtask 1.3 Radionuclide Analysis of Marine Samples
Subtask 1.4 Consumption of Marine Food by Humans

The key questions to be addressed by these tasks are stated to be the following:

1. "Are the food resources potentially harvested by subsistence, recreational, or commercial fisheries 'safe' to eat currently?"
2. "Is the biota of the Amchitka environment currently contaminated by anthropogenic pollutants from test shots; if not, what are the baseline levels of contaminants?"
3. "Are the levels of contaminants high enough to pose harm to any species or interfere with the dynamics of the ecosystem?"
4. "What are the current risks and risk scenarios?"
5. "What species are appropriate for long-term monitoring?"
6. "What is the biodiversity at the target and reference sites?"
7. "What are the ecospecific bioconcentration factors (BCF) and bioaccumulation factors (BAF) that should be incorporated in future ecological risk assessments?"

Biological sampling to determine the nature and extent of human health risks associated with the consumption of seafood is a real challenge in a marine environment as complex as the one around Amchitka Island with its complex topography, periodic earth movements, tidal and channel flows and circulatory currents, strong seasonal gradients, and secular changes in ecological equilibria associated with over-fishing and global climate change. Deciding when, where and how to collect samples presents the greatest challenge. Also important, but more straightforward, planning for the study requires decisions on the size of samples needed for detecting levels of concern or interest, the most efficient technologies for collecting and preserving samples, and for conducting laboratory analyses that are sufficiently sensitive and specific.

In view of the challenge, the budget limitations, and the field conditions, the plan to conduct the study in stages, and to use the lessons gained along the way to guide the planning and execution of the later stages is well conceived. This approach also should allow the investigators to take advantage of the stakeholders knowledge, guidance, and participation in sample collection, and to keep them well informed of progress and reasons for any changes in the plan.

The Plan does a good job of explaining the strategy for the collection of species that can serve both as important foods and as markers for other species that are not to be collected. Also, the collection of comparable samples at sites believed most likely to be contaminated as well as at reference sites where contamination from the Amchitka test sites is not likely is well conceived. It would be desirable, however, to expand on the material related to the various populations that may be exposed to radiation from the three Amchitka nuclear tests, since certain sections of the Plan currently cover population groups that are not projected to be considered in the determination of exposures to selected categories of people. Furthermore, since the designation and use of "control" sites and areas is important in the interpretation of exposure data, as pointed out in the Plan, it would be helpful to devote a special section of the Plan to "control sites and areas," especially for those situations where the exposure to radiation approaches background levels.

The attention to gaining data on biodiversity is also a plus. For some users of the Plan, however, it would be helpful to include a section on the sampling and analysis of threatened and/or endangered species, since these add a special and unique dimension to the environmental program and one that may not be fully appreciated by all.

The plans for water and sediment sampling, and for radionuclide analyses seem to be adequate, in general, but the procedures that will be used to deal with potential "plate-out" of radionuclides or their precipitation and possible colloidal behavior after sample collection are not specified.

The plans for the determination of consumption patterns for marine food are relatively sketchy, and largely devoted to gathering questionnaire data on the foods consumed by the native populations. It is not clear if the data will be adequate when combined with the data on contamination levels of the sampled marine life since there didn't seem to be any information of which parts of the marine life were eaten or whether food preparation techniques affected dietary intake. In this connection, the meaning of the statement on "assessing foods of Aleuts to the 7th generation," which appears in the last sentence of the third paragraph of the Work Plan in Subtask 1.2, is not clear. Further explanation of this statement and perhaps an explanatory literature reference would be helpful.

Comments on Task 2. Ocean Conditions: including:
Subtask 2.1. Ocean Floor Characterization
Subtask 2.2. Salinity Structure and Discharge
Subtask 2.3. Ocean Circulation

The questions to be addressed in this task and its subtasks include the following:

1. "What is the position and form of faults and fault zones as they extend from the test sites onto the sea floor?"
2. "Where is freshwater groundwater originating from the Amchitka test shots flowing into the ocean?"
3. "What is the extent of dilution and mixing occurring for the freshwater discharged through the sea floor?"
4. "If submarine discharge of radionuclides originating from the Amchitka test shots occurs, to what extent will they be dispersed and where will they impact?"
5. "Will ocean- and near-shore currents transport discharged radionuclides to areas of high biological productivity where bioaccumulation may occur?"

The description of each subtask presents background knowledge, critical information gaps, and opportunities created by modern measurement technologies and modeling approaches. Collectively, the tasks promise to produce: much better problem definition; a description of the status of weapon testing debris migration into ocean water, sediment, and biosphere; and baseline determinations for future measurement programs that may be needed.

The reviewers are not experts on the adequacy of the technologies to be used for the planned work, but are impressed by the presentation of the capabilities of the measurement technologies for mapping the seabed in Figures 15 and 16, and by the logical sequence of steps to be taken to generate the necessary data base. The plans for mapping ocean currents and mixing between the Bering Sea and North Pacific also seem to be well designed.

Overall, the planning for Task 2 is judged to be well conceived, and the prospects for its successful completion are rated as excellent.

Comments on Task 3. Amchitka Geology and Hydrology, including:
Subtask 3.1. Amchitka Data Recovery and Synthesis
Subtask 3.2. Amchitka Structure and Determination of Subsurface Freshwater/Saltwater Interface
Subtask 3.3. Groundwater Recharge
Subtask 3.4. Radionuclide Content of the Test Area: the Source Term
Subtask 3.5. Water/Rock Interaction in the Rock Envelope
Subtask 3.6. Radionuclide Sorption on Sediments
Subtask 3.7. Deformation of the Amchitka Massif

The questions that these tasks are designed to address include the following:

1. "What archival information on Amchitka geology and bathymetry is available that can be made available to Amchitka researchers and synthesized to address current data needs?"

2. "To what extent is currently available bathymetry suitable to meet needs for planned field sampling and surveying activities?"

3. "What other geospatial data relevant to current assessment and long-term stewardship can be recovered from earlier data sources (reports, maps, charts, etc.)?"

4. "How can historic data be linked to current and future data?"

5. "What is the location of the subsurface freshwater/saltwater interface on-shore and off-shore in the vicinity of the test shots?"

6. "What are the locations of fractures and faults adjacent to and extending seaward from the test shot locations?"

7. "What are the horizontal ratios of anisotropy, secondary porosity values,and strike directions as a function of depth for each of the test shot locations?

8. "What is the typical annual recharge rate on Amchitka island?"

9. "Given the measured value of recharge, what is the configuration and depth of the interface between the saltwater and freshwater?"

10. "What radioactive material was deposited by the tests?"

11. "Which radionuclides should be analyzed for in biota, sediment, and water samples?"

12. "Can impacts from Amchitka test shots on the marine environment be distinguished from other sources of radionuclide contamination?"

13. "What are the effective diffusion coefficients for the dominant rock types?"

14. "What are the partitioning coefficients for key radionuclides on the dominant rock types?"

15. "How significant of a factor is diffusion on the movement of radionuclides through the subsurface?"

16. "What is the capacity of the clays deposited around Amchitka island to scavange, by adsorption, particle-reactive radionuclides discharged into the marine environment from the Amchitka shots?"

17. "What is the motion of crustal blocks within the Amchitka region, whichfaults are active, and what is the current orientation of the stress field?"

18. "What is the status of the faults in close proximity to the test sites?"

It is difficult to assess the significance of the various studies proposed without a reference framework. The various sections of the plan are all intended to assess the radionuclide releases produced by the three explosions, of which Cannikin was the dominant event, although Milrow (~1000kt) was also substantial. Yet there is no diagram indicating a vertical section of the physical layout of the cavities; their relationship to the ocean floor and flanks of the island; the faulting and its presumed interaction with the cavity (Figure 3c provides very limited insight); the assumed (or calculated) pattern of groundwater flow, etc. Figure 13 (p. 67) suggests strongly that a major component of the planned studies is aimed at reduction of uncertainties in the groundwater flow model prepared by the Desert Research Institute for the US Dept of Energy. However, the only insight into the details of the model is the statement on p.60 that it is a "stochastically based groundwater flow and contaminant transport model for Amchitka Island." Figure 7 is the only indication that the nuclear explosion(s) occurred under the island. Does the DRI model predict that the groundwater flow and transport pathways go directly from the cavity to the ocean, as could be inferred from this diagram?

Furthermore, the Cannikin nuclear explosion was by far the largest underground test conducted anywhere by the United States. At 5000kt it was huge! Using the scaling rules for crater size, etc. from other tests around the world, it would appear that the underground crater was conceivably over 500m (~ 1650 ft) in radius (Rc), with a rubble-filled chimney extending for something of the order of 5Rc (8000ft at least) or more above the underground shotpoint. Since the shot was apparently at a depth of 6000ft, this implies that the cavity may have reached the surface, giving rise to Lake Cannikin, as discussed in the attached addendum to this report.

Although it has been noted in studies of underground nuclear testing by France on the atolls of Mururoa and Fangataufa in the South Pacific, where the explosions were deep enough so that a substantial thickness of unfractured rock remained between the chimney and the surface of the atoll (or the lagoon), that the rate of upward flow of groundwater through the cavity toward the surface was controlled significantly by the permeability of the (largely undamaged) rock below the cavity and the ability of water to flow into the chimney to replace the water in the rising plume, this may not be the case in the open chimney of the Cannikin crater, due to the absence of an intact cover.

Also, the temperature of the water in the Cannikin cavity/chimney should still be significantly above that of the background rock and groundwater, which would suggest that the flow is still by convection up toward the island. It may be that once arriving at the fresh water/saltwater interface the release of radionuclides to the biosphere will have occurred and that run-off into the ocean will produce possible contamination. Is this the likely pathway, or is it believed that faults connecting the cavity with the ocean floor will be responsible for substantial release? Is the ocean floor below the elevation of the shot point for Cannikin and Milrow? What is the driving force for such a pathway? Wouldn't ocean saltwater tend to flow along the fault toward the cavity if groundwater were flowing toward the cavity?

Although it is possible -- albeit likely -- that the DRI model addresses these issues and that they are explained in the Desert Research Institute report (DOE 2002b), a brief outline of the main features and prediction of the DRI model in this Science Plan would aid greatly in assessing the merit of much of the proposed work.

It is also noted on p.6 of the Science Plan that

> "The Department of Energy (DOE) and its stakeholders have agreed that an Independent Scientific Assessment of the Amchitka environment is necessary at this time, and this was cited in a Formal Letter of Intent."

This review would suggest that an independent scientific assessment of the DRI numerical model itself (e.g. by comparison of predictions against those of other numerical models of the Amchitka environment) should be an important component of the the overall assessment,and should precede the mounting of large experimental campaigns intended to "reduce model uncertainty".

Specific Comments on each of the various Subtasks:

The Task 3.1 effort to obtain all relevant available field data and to establish a data base is commendable. Presumably the resulting data will be used to test the DRI model.

Task 3.2: This would appear to be worthwhile, but the accent on locating transmissive faults suggests that flow from the cavities directly to the ocean is suspected to be a primary source of leakage of radionuclides to the biosphere Is this actually predicted by the DOE model?

Task 3.3: This is also worthwhile but will require a model to use the results and make predictions.

Task 3.4: This is an important task, given the numerous possible sources of radionuclide contamination of the Amchitka region.

Tasks 3.5 and 3.6. Determination of sorption and diffusion of various radionuclides in subsurface rock and in ocean floor marine clay sediments: The resulting data will be useful in demonstrating the extent to which radionuclides in the cavity water can move to and through the biosphere. Dilution by the mass of ocean water is very likely to reduce any radionuclides to harmless concentrations without the benefit of sorption and diffusion, but the projected studies could provide added assurance to stakeholders.

Task 3.7 Study of the Deformation of the Amchitka Massif and determination of the orientation of the stress field: Establishment of a regional seismic network to monitor fault activity should help assess the potential for displacement of faults that pass through the explosion cavities. The likelihood that such movements will result in release of groundwater and of radionuclides is not clear to these reviewers, since they have not seen the DRI model and what it predicts concerning the direction of flow of water along such faults. Nor is it clear how such faults communicate with the ocean floor. It is noted that "During the Cannikin test, water was expelled from some faults that slipped in response to explosion" Although fault slip can and does occur during an explosion it is difficult to establish that water ejected at this time is in communication with the explosion cavity.

Given the complex rock structural environment of Amchitka it is to be expected that the local stress field is heterogeneous i.e. the orientation and magnitude of stresses will vary considerably from place to place within the region. Although these reviewers fully support the establishment of a seismic network for the region as a means of monitoring fault activity in the vicinity of the cavities, and reassuring stakeholders concerning release of radionuclides in this way, the work needs to be coupled with an analysis of the groundwater flows and radionuclide transport along fractures resulting from such slippage, and their significance.

In summary, it appears that some potentially valuable research and observational work is being proposed. All of the work is designed to provide reliable assessments of radionuclide releases to the biosphere. Eventually, all observations will need to be integrated into a coherent "story", and evaluated against model predictions. We would have been more comfortable in judging the individual tasks if they could have been related to an overall hypothesis (or model) of how radionuclides are expected to move from the cavities to the biosphere. It may be that all that would be necessary to accomplish this is to add to the Science Plan a discussion of the DRI model for Amchitka, and to ask each "task leader" to indicate which parts of the model were to be addressed by the proposed research in the task in question.

Comments on Task 4. Stakeholder Dimensions, including:
Subtask 4.1. Stakeholder Participation
Subtask 4.2. Long-Term Monitoring

The questions that these tasks are designed to address are stated to include the following:

1. “How shall Aleut communities and other stakeholders be involved in the Science Plan?”

2. “What are the stakeholders’ main concerns?”

3. “What kinds of information are needed to keep stakeholders informed of the process?”

4. “What are the needs for establishing a credible monitoring program?”

5. "What long-term monitoring would be appropriate for the Amchitka site to determine when and if additional contamination is occurring, to determine whether it poses a risk to humans or consumers?"

6. "How should Amchitka's long-term monitoring be integrated and maintained in the stewardship plan?"

In recognition of the fact that "stakeholder participation involves a range of communities" and that the "continued involvement of all parties is essential to the Plan's design, implementation, and interpretation," the Plan appropriately states that "extensive efforts will be made to make all data, analyses and interpretations available to those who are interested. To this end, the Plan is designed to promote participation by the Aleut community through: 1) periodic workshops to develop plans for research, review progress, and discuss results and 2) internships for Aleut students who show an interest in and aptitude for science. The Plan also notes, however, that the "precise methodology used to involve the full range of Aleut Native communities and other stakeholders will vary, and will be fully developed in conjunction with each individual group," including efforts to address the concerns of "natural resource trustees," the "public," and others, in keeping with the recommendations of the National Research Council's 2000 report on the "Long-Term Institutional Management of U.S. Department of Energy Legacy Waste Sites."

The Plan does an excellent job in involving stakeholders in almost every aspect of the work that is planned. The efforts to date appear to be well structured, well developed, and well communicated to all who are involved in the various parts of the Plan. Such efforts are essential if stakeholders are to be integrated adequately into the planning and successful implementation of the Plan.

While these aspects of the Plan are praiseworthy insofar as they go, it is not clear that they embrace adequately all who may be concerned. Many people who are not directly affected may nevertheless be deeply concerned, so that it might be helpful if the Plan were to replace the term "stakeholders" with "interested and affected parties," the terminology adopted by the National Research Council in its 1996 report entitled "Understanding Risk."

Furthermore, it is not clear why Subtask 4.2 Long-Term Monitoring should differ from the other subtasks in having no specific Task Coordinator designated to be responsible for its further development and implementation. Given the obviously high importance of this subtask, the lack of a specific Task Coordinator for it seems likely to constitute a potentially troublesome deficiency unless corrected or justified in due course.

Management and Oversight

The four major tasks and respective subtasks listed above are projected in the Plan to constitute only the "core" of the work that is needed to address the problems at hand, and that a “necklace” of additional, well-linked efforts will ultimately be required to round out a “Complete Science Plan.” The resources for managing the “core” are projected to become available over a 3-year period through a grant of $3.1 million to CRESP from the Department of Energy. The “core” tasks are therefore to be managed by CRESP, in consultation with the Amchitka Oversight Committee, the Interagency Amchitka Policy Group, and other concerned parties, along with efforts to integrate such tasks effectively with related tasks that lie outside the “core.” Systematic efforts are therefore to be made to keep all interest parties informed and to gain their input as the project evolves.

The plans for the Management and Oversight of the work in question, including the relevant timelines that are projected, appear to be logical and well conceived. As noted in footnote 8, however, the amount budgeted for the “core” is likely to be inadequate, as was recognized by the government agencies that sent letters after the meeting in Las Vegas. Nevertheless, the fact that he letter from the Aleution/Pribiloff Islands Association states that “Not withstanding the $3.1 million committed to the project by the NNSA/NSO the full plan must be implemented,” points to a potentially serious problem which should be addressed without delay.

Editorial Comments

Page 3, Figures and Tables, etc.: most of the Figures and Tables differ in numbers between the Index and the text. In the following remarks, the numbers in the text are used as a base of reference.

Page 7, last paragraph, line 2, etc.: “long-term” is not properly hyphenated. This is a problem (inconsistent) with these words and many others through-out the report.

Page 8, 1st paragraph, Pages 9-10, etc.: the source terms for the three detonations are classified. The impacts of this must be clearly and frequently discussed. One important impact is the degree of care used in discussing open process, transparency, availability to the public, etc.

Page 14, 2nd paragraph, line 4.: the “)” after the date should be closed.

Page 15, last paragraph, etc.: the emphasis should be on the populations, groups, etc. studied rather than on those not to be included.

Page 16, Figure 2, and the Index for Fig. 2.: in the Index, the word “south” should be “source”.

Page 16, Figure 2, Title and discussion under the Fig.: the format, in general, should be the Fig., a brief title, and the discussion in the text and/or pertinent footnotes.

Page 18, Table 1, footnotes: the “a” and “b” should be switched so that they are in chronological order.

Page 19, Table 2, footnote: the “*” should be added to the “ENSO” in the Table.

Page 24, 1st paragraph, line 8: “are” should be replaced with “is”.

Page 25 or 26, Chronology: “Milrow” should be added to the Chronology.

Page 28, 3rd paragraph, etc.: brief discussion of exposures to be left out?

Page 28, last paragraph: brief discussion of “open development” and “transparency of process”? Perhaps these need to be expanded as they are critical to an understanding of the impact of the “classification of source terms”.

Page 30, Figure 4: this Figure is not legible in this copy.
Page 32, Figure 6: this Figure is not legible in this copy.
Page 32, Figure 6, title and discussion: a brief title should be used with the lengthy discussion moved to the text.
Page 34, last paragraph, lines 6 & 7: the definition of "other high-level species" is needed.
Page 34, last paragraph, line 10: (and their nuclear weapons)" should be added after "submarines."
Page 35, Figure 7, and footnotes: M/T" is used in the Figure whereas "MT" is used in the Footnote.
Page 39, last line on the page: "nuclear tests have also been conducted below the water table should be added."
Page 39, Figure 8: it would be preferable to use a brief title and to include the other data in the discussion and footnotes.
Page 40, 1st paragraph, line 5: The current wording that the "chimney always extends to the "surface" is incorrect.
Page 44, Figure 11: should Long Shot data be on this figure?
Page 50, Figure 12: This Figure should have a brief title "Marine Food Web for Amchitka" with the discussion moved to the text.
Page 59, Table 6, Item 4, 1st line: "two-year" should be hyphenated.
Page 60, Table 7, Column 3: "Test" should be Tests".
Page 62, last 2 lines on the page: The wording is accurate and needed in various places. The classification of source term is a major limitation.
Page 67, Figure 13, bottom part: The reference "(DOE, 2002b)" needs the ")" added.
Pages 70 – 72, Table 8: These should include the notation of "Table 8, Continued".
Page 79, 2nd paragraph, line 1: "were" should be changed to "was."
Pages 81 and 82, Table 10: Use the Figure, a brief title, and move the discussion to the text.
Pages 81 and 82, Table 10, footnotes: These should be placed in chronological order in the body of the Table.
Page 82, Table 10: Show as "Table 10, Continued".
Page 85, Subtask 1.1.4: Will walrus be sampled perhaps using samples of ivory?
Page 85, 4th paragraph, lines 5 and 6: The analyses of results will be published in the peer-reviewed literature. How does this impact the classification of the basic source terms?
Page 86, item 3 and lines 6 and 7: What happened to the Number 4 Uncertainty? It is not shown in this listing.
Page 87, 3rd paragraph, line 12: There should be more discussion regarding the selection of control sites. What are the criteria, etc.?
Page 88, 2nd paragraph: What procedures are planned that will deal with potential "plate-out" of radionuclides or their precipitation and possible colloidal behavior during and after sample collection?
Page 89, 2nd paragraph: The rationale for the establishment of "a reference site" is needed.
Page 92, Table 11: Above the Table, it should indicate "Table 11, Continued".

Page 92, footnote for Table 11: wording involving DOE (the funding agency) technical belief: Is this appropriate?
Page 92, footnote for Table 11: Is “NNSA-NV pers comm.” a reference? If so, it should appear in the References on Page 157.
Page 98, line 3: “101” should be deleted.
Pages 98, 99, and 100: Each Figure should have its own title, and any needed discussion should be in the text.
Pages 99 and 100: Figures not legible.
Page 101, Figure 16: Figure is not legible. Also, the discussion should be in the text.
Page 102, Milestones: To be consistent, the estimated dates should be given for Milestones 4 and 5.
Page 108, 3rd paragraph, line 2: “the” should be inserted before “north.”
Page 109, Figure 17: Figure is not legible.
Page 109, line 18: this sentence is incomplete: (add "was based")after (DOE 2002b)?
Page 110, 3rd paragraph, line 4: “were” should be changed to “was.”
Page 113, 1st paragraph, line 2: “are” should be changed to “is.”
Page 114, Figures 18a and 18b: it would be preferable to use a short title such as “Equipment used for GPS station” and put the discussion in the text.
Page 116, 3rd paragraph, line 13: “hope” should be changed to “plan.”
Page 118. 2004, first line: "final selection."
Page 119, Task 3.4: If possible, this important subject, i.e. the “source term” should be expanded.
Page 121, 6th line from bottom: and basalt with Cs only weakly sorbed to both Materials.
Page 121, last paragraph, line 3: an “s” should be added to “material.”
Page 124, 1st paragraph: why not select “3H”?
Page 125, large paragraph, line 6: what is the “western Lower 48”
Pages 129-131, Figures 19, 20 and 21: these tables should be moved up to follow page 127 (first mention in the text).
Page 129, Figure 19: this Figure is not legible.
Page 131, Figure 21: this Figure is not legible.
Page 132, 5th paragraph, line 2: this might be an appropriate place to define and expand on “the public”.
Page 135, Footnote 2: the first Footnote was on page 4.
Page 139, Figure 22: the bottom part of this Figure is not legible.
Page 140, Footnote 9: the appropriateness of these comments and their place in the Science Plan can be questioned.
Page 142, Table 12: “Table 12, Continued” should appear at the top of the table.
Pages 164-166, Appendix 1: this “Letter of Intent for Amchitka Island” is very difficult to read in this copy.

Table 1. Members of the CRESP PEER Review Committee who comprised the Subcommittee that prepared this report

John F. Ahearne, Ph.D., Director, Sigma Xi Ethics Program, and Adjunct Professor, Duke University

Melvin W. Carter, Ph.D., International Radiation Protection Consultant, and Neely Professor Emeritus, Georgia Institute of Technology

Charles Fairhurst, Ph.D., Professor of Mining Engineering and Rock Mechanics, University of Minnesota

Morton Lippmann, Ph.D., Professor of Environmental Medicine, New York University

Arthur C. Upton, M.D., Clinical Professor of Environmental and Community Medicine, UMDNJ - Robert Wood Johnson Medical School*

*Chairman

ADDENDUM

The Cannikin Underground Nuclear Explosion; Cavity and Chimney Development.

The nuclear explosion, code-named Cannikin, detonated November 6, 1971 on Amchitka Island, Alsaka, (Figure 1) was the largest underground explosion in the history of the U.S. nuclear weapons testing program. Stated to be of 'somewhat less than 5 megatons (Mt) yield' [Claassen 1978], the explosion was detonated at a depth of 5875ft (1790m) below ground surface, and resulted in the development of an underground cavity and subsequent collapse of the overlying rock to the surface. (The actual location of the explosion is referred to as Ground Zero.) A surface depression was also generated, resulting in the formation of a body of water at the surface, subsequently named Lake Cannikin (Figure 2).

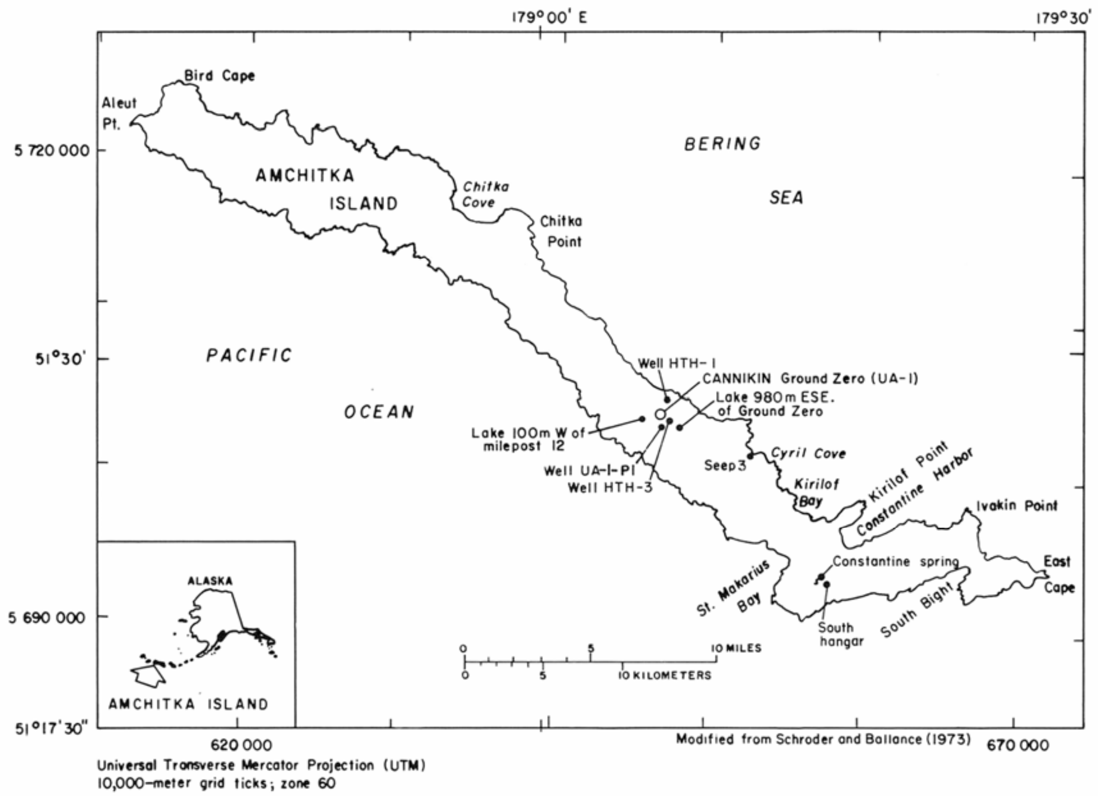

Figure 1. Location of the Cannikin Underground Nuclear Test, Amchitka Island, Alaska.

Claassen (1978) has presented a series of diagrams depicting the cavity and associated chimney resulting from the explosion, and conditions in the chimney over a period of 543days, from the time of the explosion on November 6 1971, to May 3 1973.

Figure 3 shows four of the diagrams (13 total) to illustrate the type of information contained in them. All of the diagrams depict a vertical slice through the explosion along the section AA' shown in Figure 2.

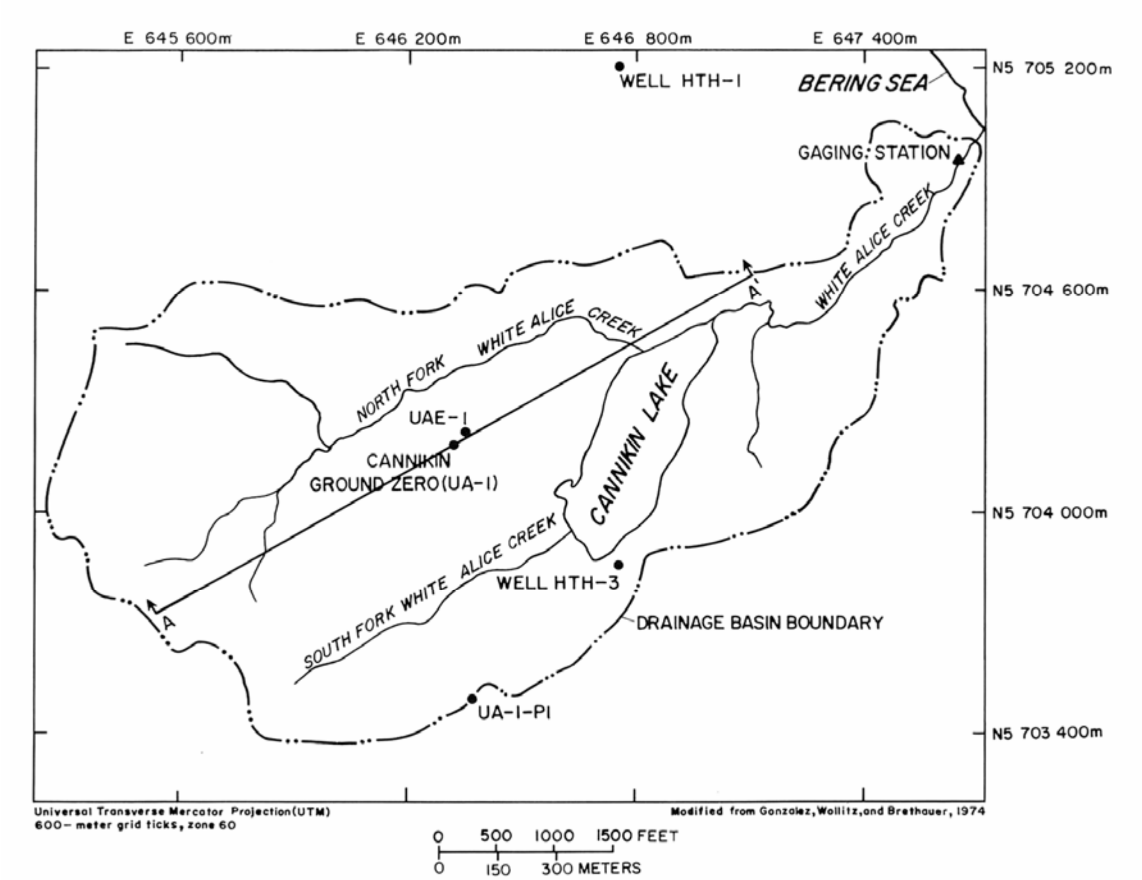

Figure 2. Location of 'Ground Zero' for the Cannikin Test, and Lake Cannikin.

The values shown on the right of Figure 3J represent the height in feet from an arbitrary datum located at the base of the cavity. Both the diameter of the cavity (approximately 1200 ft as scaled from the drawing) and width of the chimney are assumed and idealized values. The shaded circle concentric with the cavity (and twice the cavity diameter) represents a region (referred to by Claassen as the 'Shock Zone') within which the rock is considered to be intensely fractured. A borehole, UA-1-P1, started outside the chimney radius at the surface (see Figure 2), was deviated to intersect the chimney and the base of the cavity, to obtain cores of the solidified melt (containing radionuclides generated by the explosion) at the base of the cavity. The height of water in the chimney was deduced by monitoring of the water level in this borehole.

The diagrams indicate that the water table prior to the explosion was very close to the surface; Lake Cannikin started to develop in August 1972, and water in the chimney reached the original water table level in May 1973.

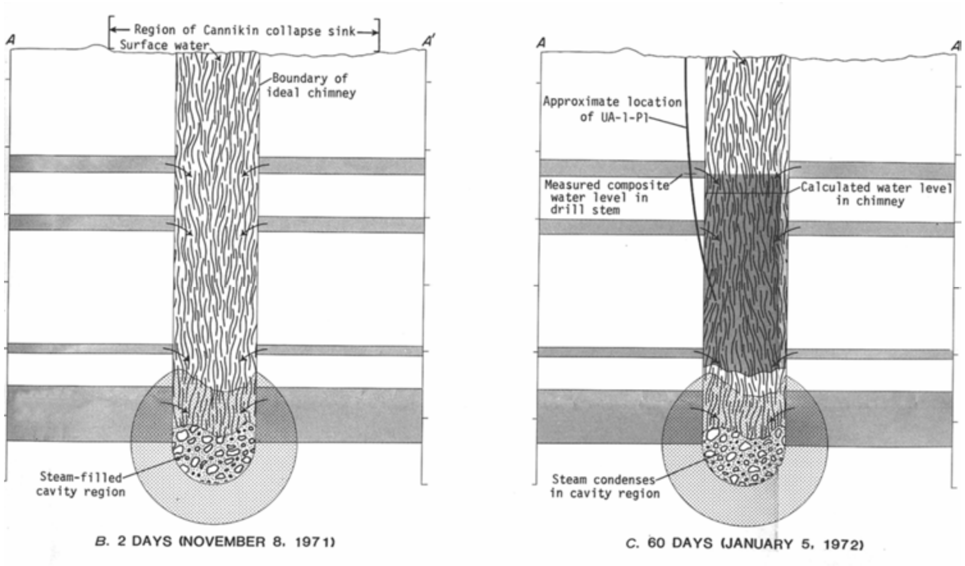

Figure 3. Conditions in the Cavity and Chimney Produced by the Cannikin Explosion. B. 2 Days after the Explosion; C. 60 Days after the Explosion.

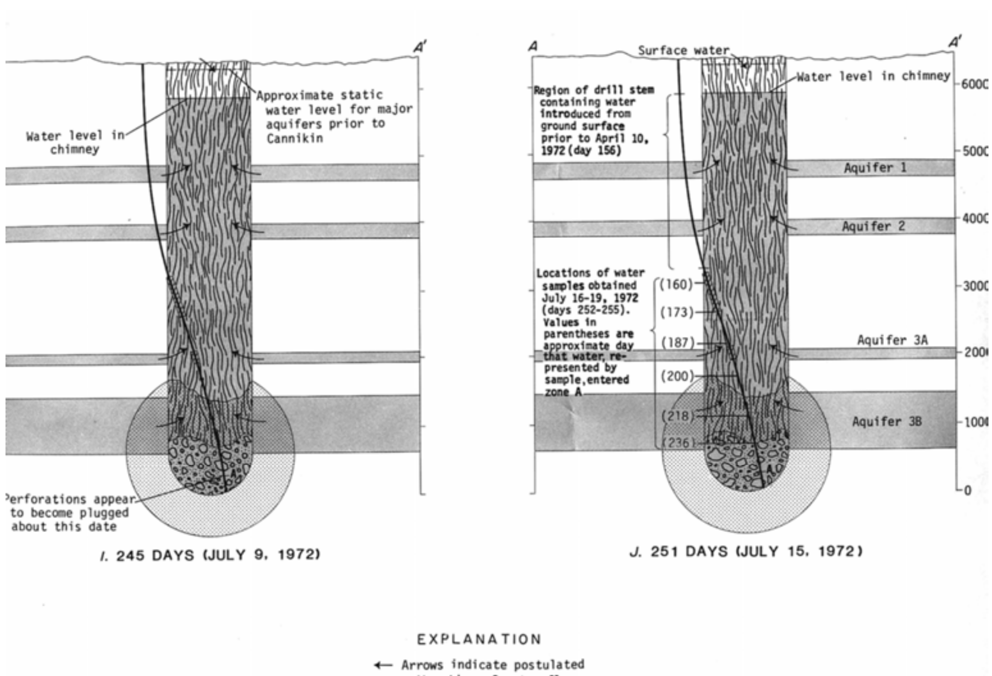

Figure 3. Conditions in the Cavity and Chimney Produced by the Cannikin Explosion. I. 245 Days after the Explosion; J. 251 Days after the Explosion

It is interesting that Lake Cannikin did not form directly over the ground zero, but is centered approximately 1500 ft to the East. The subsidence trough created by the explosion (identified as 'Region of Cannikin collapse sink' in Figure 3B) is approximately 4000ft in diameter and is concentric with ground zero. This suggests that some local surface (or near-surface) features may have influenced the location of Lake Cannikin

Formation and Size of the Cannikin Cavity and Chimney.

Underground nuclear tests have been carried out in a variety of rock types in various parts of the world (volcanic tuff, basalt, granite, limestone….). It is found that the range of damage around the shot-point increases in direct proportion to the cube root of the explosion yield (Y) in kilotons. Thus, the radius R_c of the explosion cavity is given by the expression

$$R_c = K\, Y^{1/3} \qquad (1)$$

where K is a constant of the order of 10 ~12 meters for a 1 kT yield explosion.

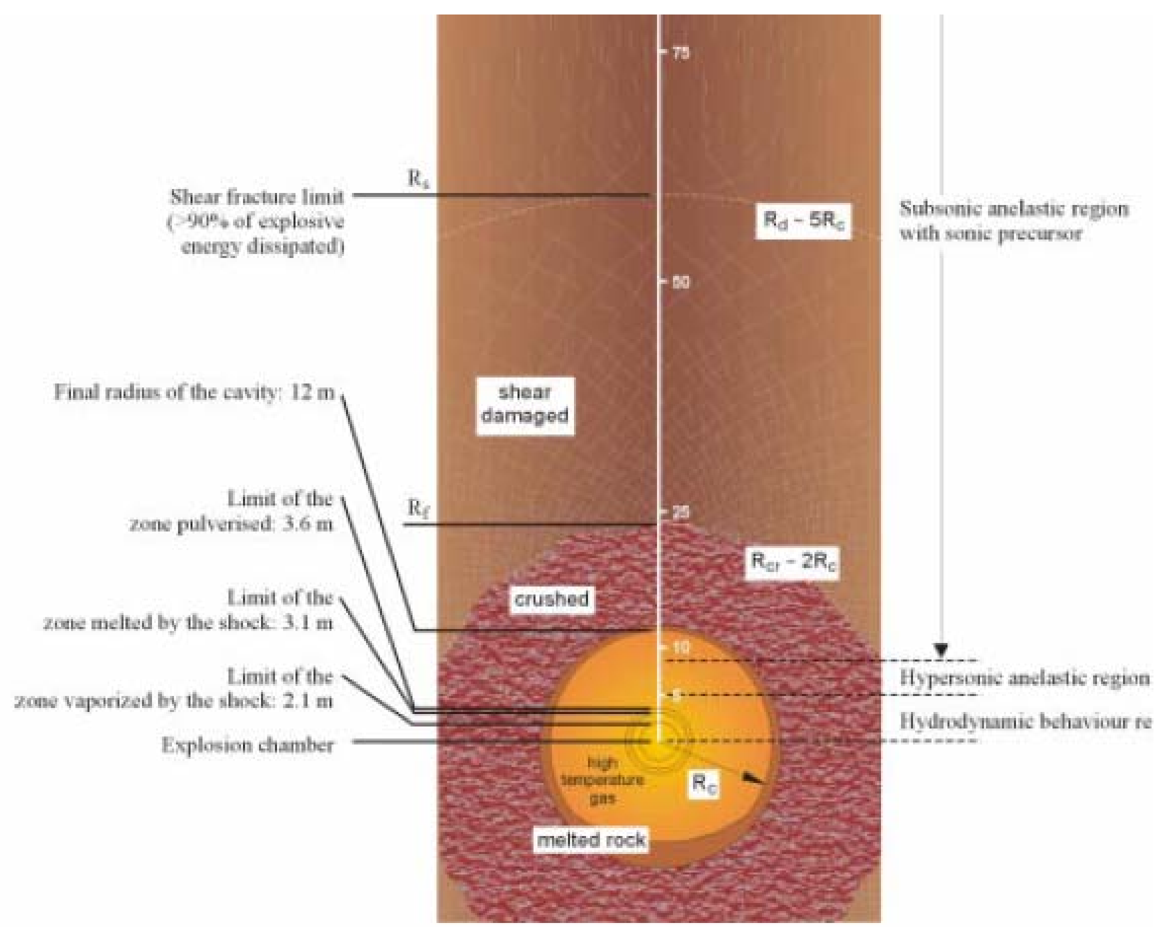

Figure 4 Regions of Damage around a One - Kiloton (1 Kt) Underground Nuclear Explosion.

Figure 4 shows the corresponding values for the extent of various damage regimes in terms of radial distance from the shot point for a 1Kt explosion. The almost instantaneous generation of extremely high temperature and pressure in the explosion chamber at the instant of detonation generates a shock wave traveling radially away from the shot-point. Rock in immediate contact with the explosion chamber is vaporized; slightly further away the rock is melted as the wave passes; this gives way to intense pulverization, crushing, fracturing, and fragmentation /cracking at progressively greater distances. Eventually the wave degenerates to an elastic (seismic) wave that propagates to very large distances. These zones and their typical extent are illustrated in Figure 4. In all cases, these distances can be scaled using the cube root scaling law, as indicated by Equation 1 above.[1]

The height of the chimney, H_c, above the cavity is usually found to range from

$$H_c = (5\sim8)\ R_c\ .$$

Thus, for a 5Mt yield explosion, as in the case of the Cannikin event, the cavity radius could be expected to be

$$R_c = (10\sim12).\ Y^{1/3} = (10\sim12)\ (5000)^{1/3} = (10\sim12)\ x17.0$$
$$= (170\sim204)\ m = (550\sim660)\ ft.$$
$$\text{and}\ \ H_c = (5\sim8)\ R_c = (5\sim8)\ 600 = (3000\sim 4800)\ ft$$

The mean value of this range of cavity radii i.e. ~600 ft., or 1200 ft diameter, coincides almost exactly with the value used by Claassen in Figures 2 above. Although he describes some calculations for R_c (using cube-root scaling, but with a depth-dependent value for K in Equation 1) that arrive at a value of R_c = 133 m (430 ft), he concludes that this value should be increased by 34% to "best fit the observed phenomena." [2] A 34% increase over 133m corresponds approximately to 180 m (580 ft), which is very close to the previously calculated values.

The height of the chimney above the Cannikin cavity appears to be considerably higher than that which is usually found in underground nuclear explosions.[3]

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[1] The volume of rock displaced to allow formation of the cavity is almost all 'taken up' by elastic deformation of the rock mass that extends from the start of the elastic regime 5 R_c to infinity, i.e. only a very small proportion of this volume is accommodated by increase in density of the rock due to melting

[2] He finds, in effect, that the larger cavity radius, and corresponding chimney volume are more consistent with calculations of heat generated by the explosion and the temperature rise in the water-filled chimney.

[3] The chimney height is limited by 'bulking' of the rock above the cavity, as it breaks and collapses to fill the cavity volume. The chimney can only progress to a height H_c that is consistent with the bulk density of

Summary. Computations suggest that the size of the cavity and chimney created by the Cannikin explosion are of the order of 580~600 ft radius.

References

Claassen, H.C. (1978). *Hydrologic Processes and Radionuclide Distribution in a Cavity and Chimney Produced by the Cannikin Nuclear Explosion, Amchitka Island, Alaska.* Hydrology of Nuclear Test Sites. Geological Survey Professional Paper 712-D, U.S. Government Printing Office, Washington. D.C.

Note: Claassen indicates that details concerning the size, depth etc. of the Amchitka explosion were obtained from the following report: Merritt, M.L. (1973). *Physical and biological effects of Cannikin*, U.S. Atomic Energy Commission rep't NVO-123 106p.

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the broken rock. The limiting heights of (5~8) R_c correspond to bulk densities of the order of (25 -16)% lower than the density of the intact rock. [This assumes a cylindrical chimney of constant radius R_c] While a higher bulk density cannot be ruled out (especially in laminated ,volcanic rock such as at Amchitka), it could be informative to examine the evidence on which the high chimney is based. Is it well established that the chimney did in fact reach the surface? The surface depression observed is very probably a consequence of reflection of the elastic wave at the surface and does not necessarily indicate that the chimney has propagated to the surface.