Process for Developing Alternate Scenarios at NRC Sites Involved in D & D and License Termination

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Abstract

A process for the development of alternate scenarios at sites involved in Decontamination and Decommissioning and license termination using site-specific information is presented as an extension of the NUREG-1549 screening framework and, as such, assumes the same starting point as the framework—the resident farmer. Important steps in this process are the initial dose assessment, iterative dose assessments, and sensitivity analyses. Since the initial dose assessment is done using the NRC-approved default pathways and parameters for the resident farmer, the introduction of site-specific information is unlikely to increase the assessed dose. A process schematic and discussion dialog is presented to guide the user through a logical process for introducing new information into the dose assessment. This iterative process will help the user to keep information gathering and assessment to a minimum. At any point in the process when an iterative dose assessment shows that the Total Effective Dose Equivalent (TEDE) to an average member of the critical group does not exceed 25 mrem/yr, the process is completed and there is no need to collect or introduce additional data.

This process takes the user through NUREG-1549 framework into the introduction of both physical and cultural data and poses seven critical questions.

1. What is the current land use?
2. What is the future land use?
3. Is groundwater available?
4. Is groundwater suitable for aquatic life?
5. Is groundwater suitable for agriculture?
6. Is groundwater potable?
7. Are soil and topography suitable for agriculture?

Detailed discussion is presented for each of these questions, including standards that would have to be met and documentation that would have to be presented to the NRC if the answers to these questions lead to an alternate scenario and the removal of one or more pathways. While this process presents a logical path for a user to follow in eliminating pathways and thereby defining alternate scenarios, users are encouraged to bypass process steps when results from sensitivity analyses indicate certain pathways are not critical to the computed TEDE or the overall decision process (NUREG-1549) suggests a more optimal path to license termination.

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Contents

List of Figures

List of Tables

Acronyms

ALARA	as low as reasonably achievable
BOD	biochemical oxygen demand
BRAC	Base Realignment and Closure
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
D&D	Decontamination & Decommissioning
DoD	Department of Defense
DOE	U.S. Department of Energy
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
GIS	Geographic Information Systems
HLW	High Level Waste
ICRP	International Commission on Radiological Protection
IHI	Inadvertent Human Intruder
LLW	Low Level Waste
MCL	Maximum Contaminant Level
MOP	Member of Public
mrem	millirem
NAS	National Academy of Science
NEA	Nuclear Energy Agency
NRC	Nuclear Regulatory Commission
NRCS	Natural Resources Conservation Service
NUREG	Nuclear Regulatory
NWPA	Nuclear Waste Policy Act
OSWER	Office of Solid Waste and Emergency Response
RCRA	Resource Conservation and Recovery Act
SCS	Soil Conservation Service
SDMP	Site Decommissioning and Management Plan
SNL	Sandia National Laboratories
TDS	total dissolved solids
TEDE	total effective dose equivalent
TRU	Transuranic
USDA	U. S. Department of Agriculture
USGS	U.S. Geological Survey
WIPP	Waste Isolation Pilot Plant

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1.0 Introduction

1.1 Purpose

This report provides the Nuclear Regulatory Commission (NRC) with a process for developing acceptable land-use scenarios based on site-specific physical and cultural information and is expected to be used in the review of dose assessments at sites undergoing decommissioning. This approach is systematic and objective and provides practical guidance on implementation and consistency in reviewing license termination plans.

The process for developing alternate scenarios complements the screening framework (Figure 1) as proposed in NUREG-1549 [NRC, 1998] and is meant to be used in conjunction with the methodology set forth in that document.

Two basic screening scenarios are identified in NUREG-1549; the residential farmer and the building occupancy scenario. The residential farmer scenario is meant to be applied to sites with land and water contamination and the building occupancy scenario is to be applied to sites with contaminated structures. A generic critical group, with acceptable default parameter values to represent the average member of each group, is associated with each scenario. The default pathways, models and parameter values for the critical group combine to form exposure scenarios.

1.2 Background

There is significant variability within Site Decommissioning Management Plan (SDMP) sites with respect to geography and site contamination. The original purpose of the site, historical development, and the resulting processes that generated the site contamination vary widely across the current array of SDMP sites. Contamination has occurred in buildings, process equipment and other site structures, soils (surface and subsurface), ponds, lagoons, surface waters, and groundwater. Sites are located in urban and suburban, residential, commercial and industrial, rural, and agricultural areas, and many are located on or directly adjacent to rivers, lakes, oceans, estuaries, wetlands, floodplains, or wildlife areas. The waste form is highly variable: as slag, general soil or sediment contamination, sludge, debris, dust or sand piles, packaged (drums, crates, etc.), and dispersed in liquid media. Generation of radon gas over that caused by natural sources may also be a potential problem at these sites.

In general, scenarios represent possible realizations of the future state of the system [Cranwell et al., 1990]. Scenarios are needed to establish potential future conditions which might lead to human exposure.

1.3 Appendices

Appendix A provides tables of sources of information for the assessment of current and future land use.

Appendix B provides tables of specific exposure pathways for the resident farmer scenario, the building occupancy scenario, and a master list of potential exposure pathways for site-specific scenarios.

Appendix C provides information with regard to scenario development for performance assessment approaches, objectives, and standards used by other U.S. and international agencies.

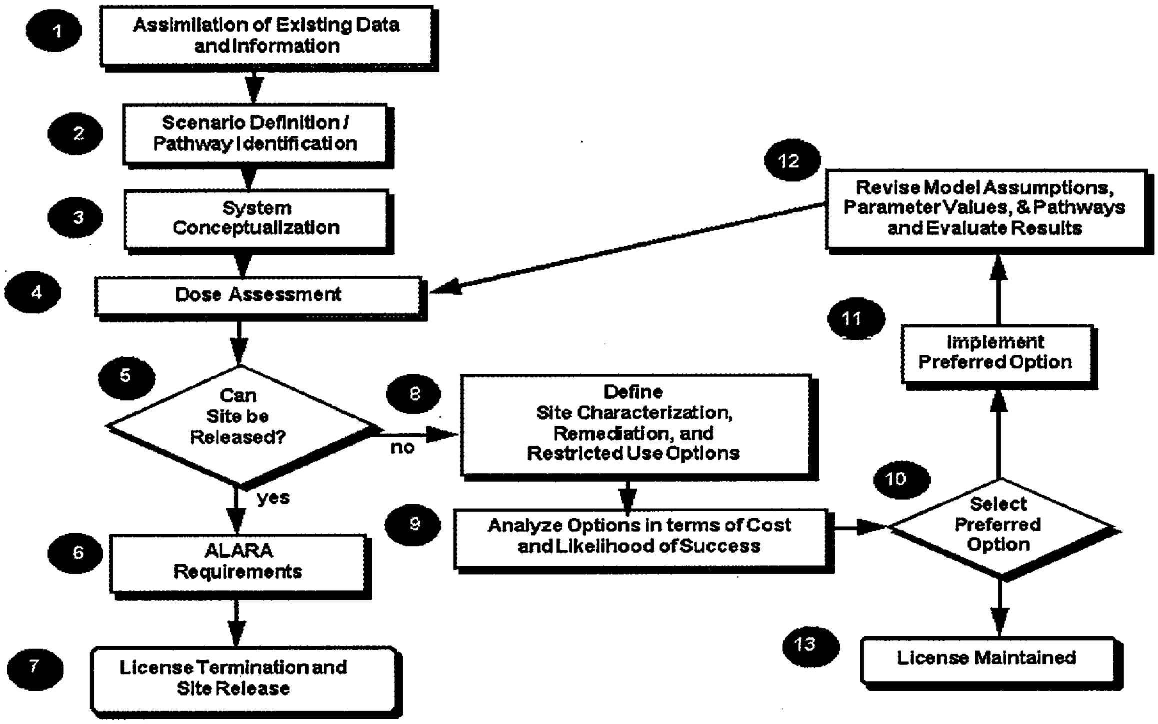

Figure 1. Decommissioning Framework (from NUREG-1549)

2.0 Regulations and Nuclear Regulatory Commission Guidance

The NRC evaluates requests from commercial facility owner/operators for the termination of NRC operating licenses for their facilities. An overall framework for decision making, based on the criteria in 10 CFR 20 Part E, is defined in NUREG 1549. This framework utilizes iterative sequences of information gathering, dose assessment, and decision making. Each assessment is designed to provide a defensible basis for license termination. Implementing this framework requires a process for assessing dose that can be used with various amounts of information. To provide the greatest flexibility for tailoring data collection to site conditions, the dose assessment for the initial iteration should require a minimum amount of site data. The regulations and guidance pertaining to license termination are summarized in the next two sections.

2.1 10 CFR Part 20, Subpart E

The final license termination rule is contained in Subpart E of 10CFR Part 20 [NRC, 1993]. Subpart E sets a 1000-year timeframe for analysis and provides the regulatory basis for determining when a site is suitable for license termination.

Sections 20.1402 and 20.1403 of Subpart E include requirements for unrestricted and restricted use of facilities after license termination. In addition to specific dose limits, additional requirements include demonstrating that residual radioactivity is as low as reasonably achievable (ALARA), financial assurance, and public participation for restricted use.

Section 20.1402 states that a site is considered acceptable for unrestricted use if the residual radioactivity distinguishable from background radiation results in a Total Effective Dose Equivalent (TEDE) to an average member of the critical group that does not exceed 25 mrem/yr, and the residual radioactivity has been reduced to ALARA levels.

Section 20.1403 states that a site is considered acceptable for release with restriction on land use if the residual radioactivity distinguishable from background radiation results in a TEDE to an average member of the critical group that does not exceed 25 mrem/yr with the restrictions in place and the TEDE does not exceed 100 mrem/yr or 500 mrem/yr to the average member of the critical group if the land-use restrictions fail at some point. This section of the regulation also addresses the need for ALARA, financial assurance, and public participation for restricted use.

The dose limitations refer to an "average member of the critical group." The critical group is defined in section 20.1003 as "the group of individuals reasonably expected to receive the greatest exposure to residual radioactivity for any applicable set of circumstances."

In the supplemental information for the final rule, the concept of the average member of the critical group is explained further: "... if the site were released for unrestricted use, the critical group would be the group of individuals reasonably expected to be the most highly exposed considering all reasonable potential future uses of the site. ... The average member of the critical group is an individual who is assumed to represent the most likely exposure scenario based on prudently conservative exposure assumptions and parameter values within model calculations."

The use of a critical group approach is consistent with the International Commission on Radiological Protection (ICRP) and the National Academy of Science (NAS) recommendations for this type of assessment [Cochran, 1996].

2.2 NUREG/CR-5512

NUREG/CR-5512, Vol. 1 [Kennedy and Strenge, 1992] present descriptions, definitions, assumptions, parameter values, and mathematical formulations for the building occupancy and residential generic scenarios.

NUREG/CR-5512 Vol. 2 [Wernig et al., 1999] is a user's manual for the DandD software package. DandD is a Microsoft Windows program that implements the dose models for the four generic scenarios defined in Vol. 1.

NUREG/CR-5512 Vol. 3 [Beyeler et al., 1999] describes an analysis of the input parameters to the generic models of the building occupancy and residential scenarios. The analysis includes a review of published information related to the input parameters, definition of a probability distribution based on this information, and identification of default parameter values for the DandD models.

NUREG/CR-5512 Vol. 4 [Haaker et al., 1999] provides a comparison of the assumptions, models, and default parameters used in three dose assessment codes: DandD 1.0, RESRAD 5.61, and RESRAD-Build 1.50.

2.3 NUREG-1549

NUREG-1549 presents an overall framework for dose assessment and decision making at sites where the licensee has decided to begin the decommissioning and license termination process and was meant to be guidance for the implementation of 10 CFR Part 20, Subpart E. The framework can be used throughout the decommissioning and license termination process for sites ranging from simple sites to the most complex or contaminated sites.

This framework assists the licensee, the NRC, and other stakeholders in making decommissioning decisions and provides an approach for treating some uncertainty associated with contaminated sites.

3.0 Process Schematic

The process for developing alternate scenarios is presented in this report as an eleven-panel schematic flow diagram (Figures 3 through 13). This diagram is supported by text in Sections 4, 5, and 6. Figure 2 presents the legend for the basic resident farmer drawing used in the schematic flow diagram.

The schematic begins with the definition of the source and takes the user through a step-by-step procedure of using site-specific information to alter the resident farmer scenario by removing pathways. The supporting text should be referred to for specific details about steps, standards, and data needed to defend the removal of a pathway.

Although this step-by-step process provides an efficient way to introduce site-specific data to rule out pathways, shortcuts can be and should be taken at specific points in the process when data developed by the decision analysis (NUREG 1549)warrants it. For example, if the decision analysis shows the aquatic pathway to be primary in the computation of the TEDE, the user should skip other pathways and focus on evidence that could rule out that pathway.

In another example, if the contamination at a site is fully contained within a building (and would reasonably be expected to remain there throughout the period when it could cause a TEDE greater than the threshold), the default resident farmer scenario would not be applicable and the building occupant scenario should be used.

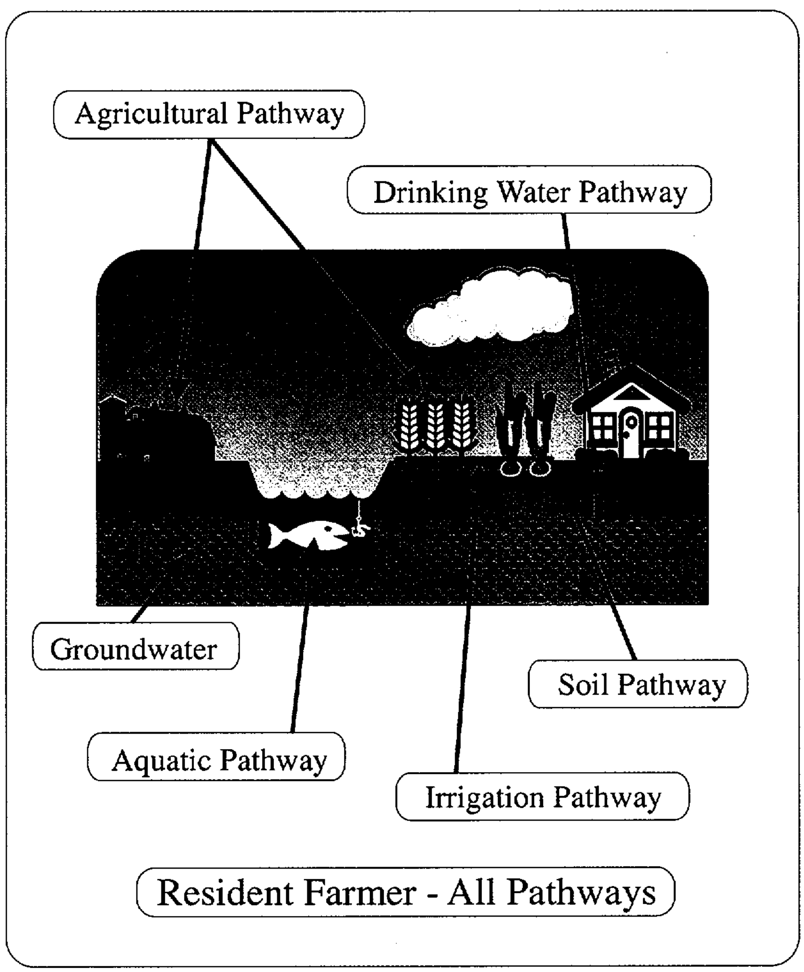

Figure 2. Resident Farmer - All Pathways.

3.1 Panel 1 - Beginning the Process

The first panel (Figure 3) begins with a more detailed version of the NUREG-1549 screening framework (Figure 1) and shows the context of this process in relation to that framework. This panel takes the user from defining the source through initial and iterative dose assessments, to sensitivity and decision analyses, and finally to the use of site-specific information to develop alternate scenarios.

While this schematic shows other actions that can be taken subsequent to the sensitivity analysis, the schematic (and this report) concentrate solely on those actions associated with the process for developing alternate scenarios through the introduction of specific information. Other actions include the use of site-specific information to modify pathway parameters, changing or altering the pathway models, release of license for restricted use, and cleaning up the site.

Section 4 of this report (Initial Computation) provides descriptions of processes shown in Figure 3 with regard to the source definition and the initial and iterative dose assessments. Section 5 (Sensitivity Analysis) describes a sensitivity analysis process and presents an example of both text and graphics reports developed using the NRC software DandD 1.0. This example shows how a sensitivity analysis can help the user understand which specific pathway and radionuclides dominate the computed dose.

If the initial computation results in a TEDE to an average member of the critical group that exceeds 25 mrem/yr, and the sensitivity analysis indicates the best path is to develop alternate scenarios, the user would proceed to Panel 2 (Figure 4) to consider land use. The projected use of the land is critical to beginning of this process. If the future use of the land is shown to be urban or industrial, rather than the default resident farmer, the starting scenarios contain significantly fewer pathways than the resident farmer scenario and the TEDE will always be significantly lower than the initial TEDE.

3.2 Panel 2 - Land Use Data

The second panel (Figure 4) illustrates the decisions necessary to determine if there is sufficient evidence to bypass the resident farmer scenario and go directly to an urban or industrial worker scenario. These decisions are based on the persistence of the TEDE over the 25 mrem/yr threshold and on the current and projected land use at the site. Future land use must be projected for the time period that the TEDE is expected to be greater than the 25 mrem/yr threshold.

One hundred years is considered a reasonable cut-off point for future land use projections (see Section 6.1 for a more detailed discussion of this threshold). If a TEDE greater than the 25 mrem/yr threshold persists for 100 years or longer, the resident farmer scenario should be used (as a starting point), regardless of the current land use.

Section 6.1 presents procedures for determining current land use and for estimating future land use. Appendix A presents tables of land use information types and websites where land use information might be obtained.

Panel 2 will direct the user either to Panel 3, to begin the process of devolving the resident farmer scenario by removing pathways, or to Panel 11 where the urban resident and the industrial worker scenarios are considered.

3.3 Panel 3 - Start with Resident Farmer

The third panel (Figure 5) is a continuation of Panel 2 and begins the process of introducing physical information about the site. The starting point here is the resident farmer scenario with all pathways (the default scenario). Since water is critical to the key pathways in this scenario, the first question to ask is "Is groundwater available?"

If groundwater is not available, the groundwater pathway (and all pathways that depend on groundwater) would be removed from the resident farmer scenario, resulting in a resident farmer scenario where all water needs are assumed to be met through an outside, uncontaminated water source. Section 6.2.1 addresses the availability of groundwater and the documentation that would need to be submitted to NRC if the licencee wants to remove the groundwater pathway on the basis of groundwater unavailablility.

If groundwater is unavailable, an iterative dose assessment should be done to see if the TEDE to an average member of the critical group still exceeds 25 mrem/yr. If it still exceeds this threshold value, the next logical question to ask is "Are soil and topography at this site suitable for agriculture?" The details of this issue are addressed in Section 6.2.2.

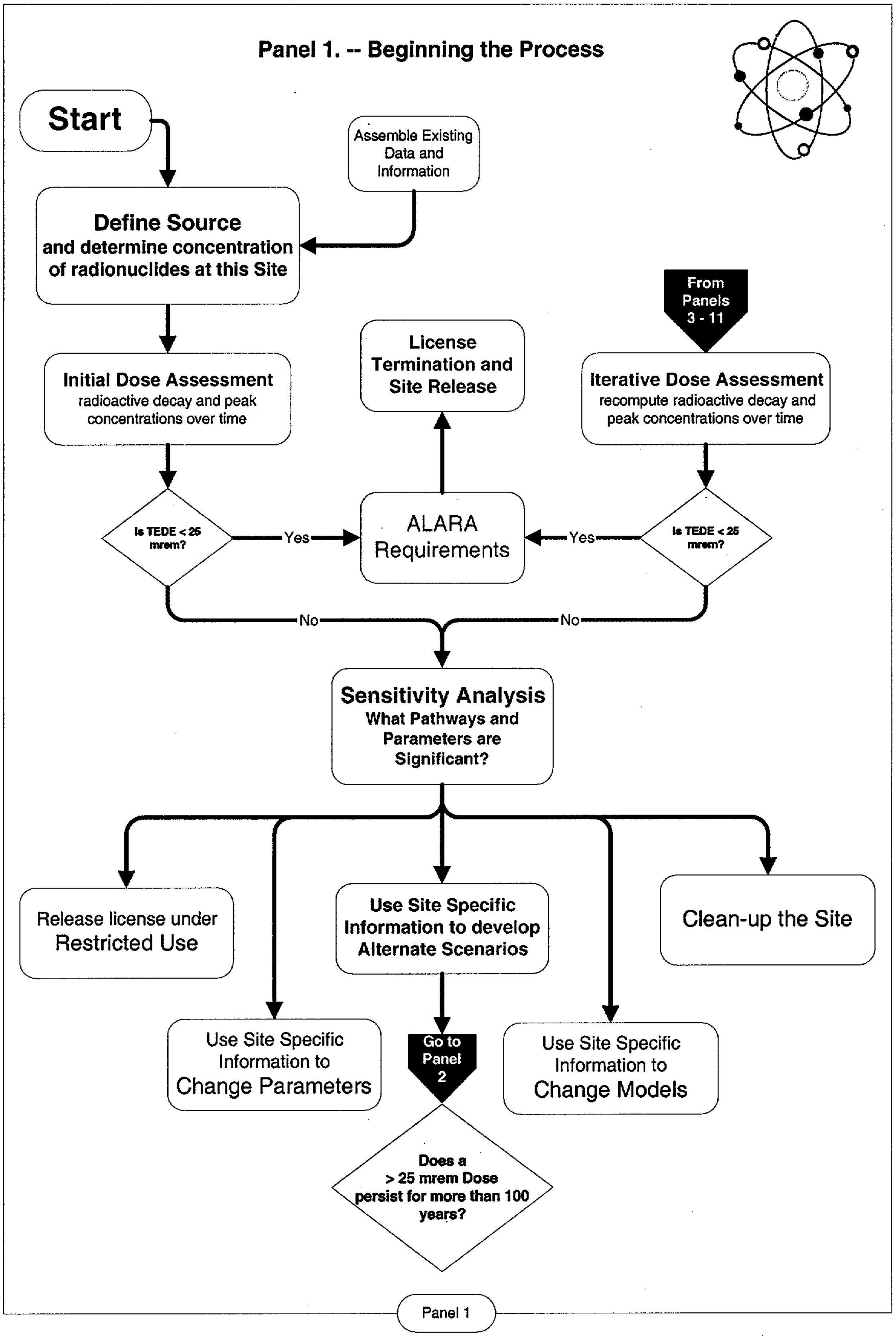

Figure 3. Panel 1 - Beginning the Process.

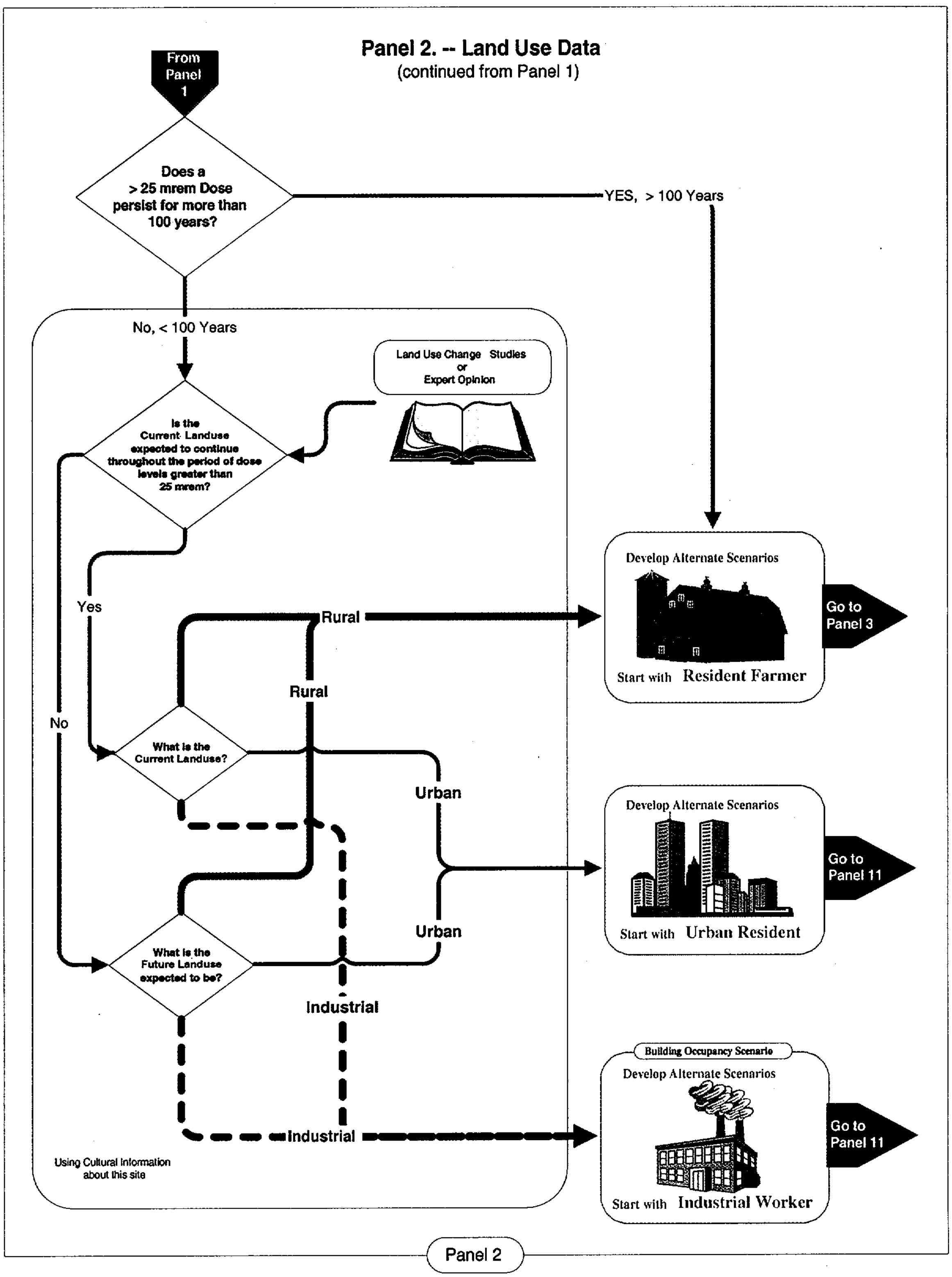

Figure 4. Panel 2 - Land Use Data.

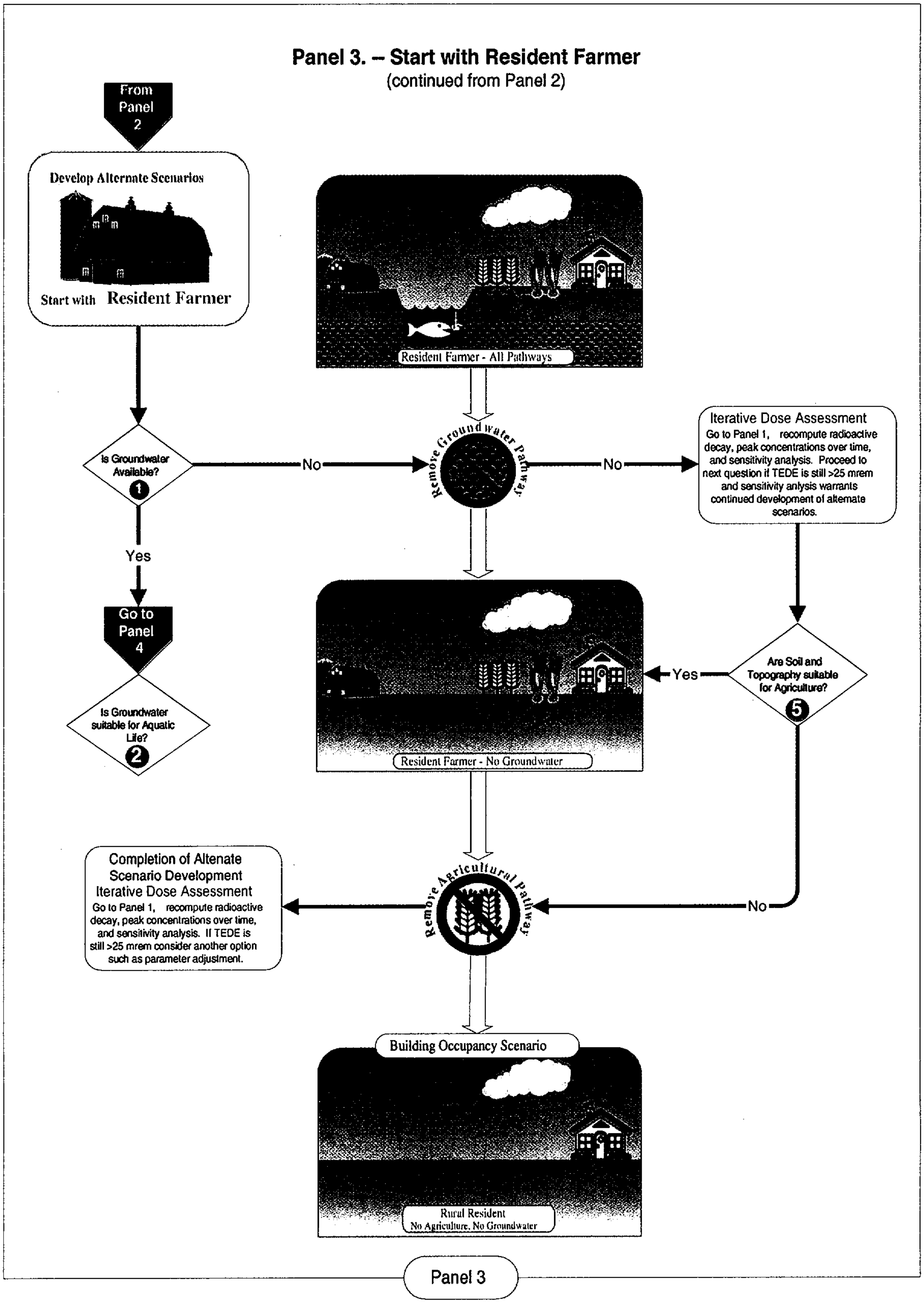

Figure 5. Panel 3 - Start with Resident Farmer.

If the answer to this question is "No," that either soil or topography at this site are determined to be unsuitable for agriculture, the agricultural pathway would be removed resulting in a scenario that has a rural resident with no agriculture, pond, or drinking water, since the groundwater pathway had already been removed. The resident farmer scenario has now devolved into a what is essentially a building occupancy scenario combined with modified external exposure and inhalation pathways. Section 6.2.2 describes the documentation that should be submitted to NRC if the licencee wants to remove the agricultural pathway on the basis of either topography or soil being unsuitable to agriculture.

After the agricultural pathway is removed, another dose assessment would be done for a scenario that includes only the building occupancy scenario and external exposure and inhalation pathways. These pathways should be modified to reflect that the resident is no longer working on the "farm." If the TEDE to an average member of the critical group still exceeds 25 mrem/yr, the user should begin a more critical analysis of the pathway parameters for the pathways in this scenario, but there is no need, at this point, to continue with alternate scenario development.

If the first question on this panel, "Is groundwater available?" is answered "Yes," the user would go to Panel 4 where the suitability of groundwater for aquatic life is considered.

3.4 Panel 4 - Aquatic Life

The fourth panel (Figure 6) is a continuation of Panel 3. This panel starts with a resident farmer and all pathways. Groundwater is available, but is it suitable for aquatic life?

Section 6.2.1.2 considers the suitability of groundwater as an environment for the resident farmers' fishery and presents the standards for this water to be considered acceptable for this use. If the water is unsuitable for aquatic life, the aquatic pathway would be removed, resulting in a resident farmer scenario with no pond. An iterative dose assessment would be performed, and if the TEDE to an average member of the critical group still exceeds 25 mrem/yr, the user would go to Panel 5 to consider the suitability of groundwater for agricultural use.

If the answer to the first question is "Yes," the groundwater is suitable for a pond, cultural data for the area should be introduced to answer the question, "Do residents of this area use ponds as fisheries?" See Section 6.1.2 for more details on information sources and documentation needed. If the answer is "No," the user would proceed as in the previous paragraph for the removal of the aquatic pathway and subsequent analyses, including iterative dose assessment. If the answer is "Yes," the user would go to Panel 6 to consider the suitability of groundwater for agriculture.

3.5 Panel 5 - Agriculture - No Pond

The fifth panel (Figure 7) is a continuation of Panel 4. This panel starts with a resident farmer without a pond. Groundwater is available, but it is not suitable for a pond. The question asked here: "Is the groundwater suitable for agricultural use?"

Section 6.2.1.3 considers the suitability of groundwater for agriculture and presents the standards for this water to be considered acceptable for this use. If the water is unsuitable for irrigation (growing crops), it should not be considered suitable as drinking water for the farmer or for his animals. In this case, the following pathways would be removed: the irrigation pathway, the drinking water pathway, and any pathways associated with farm animals drinking water.

The resultant scenario would be a resident farmer scenario with no groundwater use. All water needs would be met by uncontaminated water from an outside source, but the farmer would still be growing crops in contaminated soil and his animals would still be ingesting contaminated food and soil.

If an iterative dose assessment shows the TEDE to an average member of the critical group still exceeds 25 mrem/yr, the next logical question to ask is "Are soil and topography at this site suitable for agriculture?" Additional details concerning this issue can be found in Section 6.2.2. If the answer to this question is "No," and either soil or topography at this site are determined to be unsuitable for agriculture, the agricultural pathway would be removed, leaving a rural resident with no agriculture, pond, or drinking water, since these pathways have already been removed.

The resident farmer scenario has now devolved into a what is essentially a building occupancy scenario combined with modified external exposure and inhalation pathways. Section 6.2.2 presents the documentation that would need to be submitted to NRC if the licencee wants to remove the agricultural pathway on the basis of either topography or soil being unsuitable to agriculture.

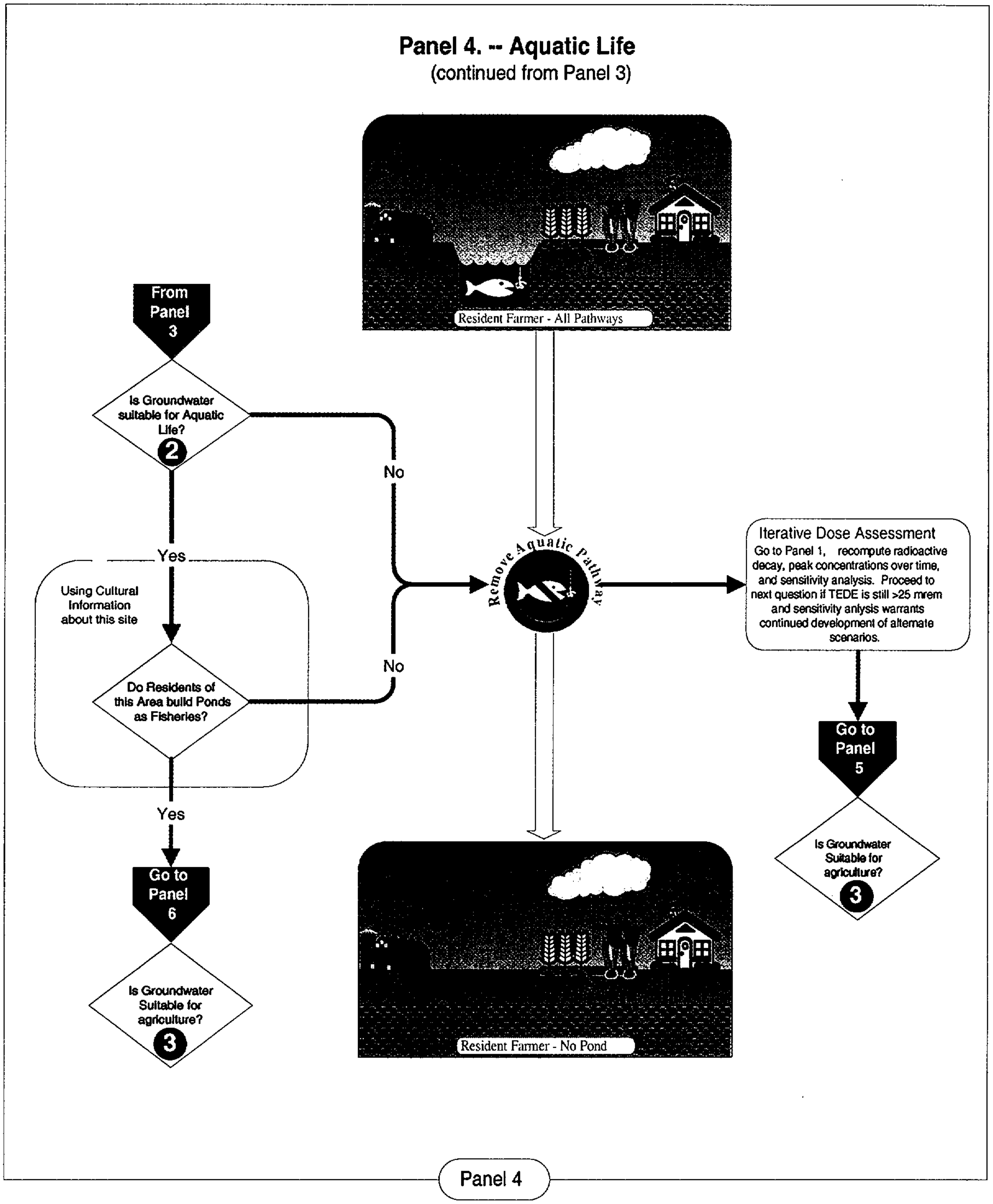

Figure 6. Panel 4 - Aquatic Life.

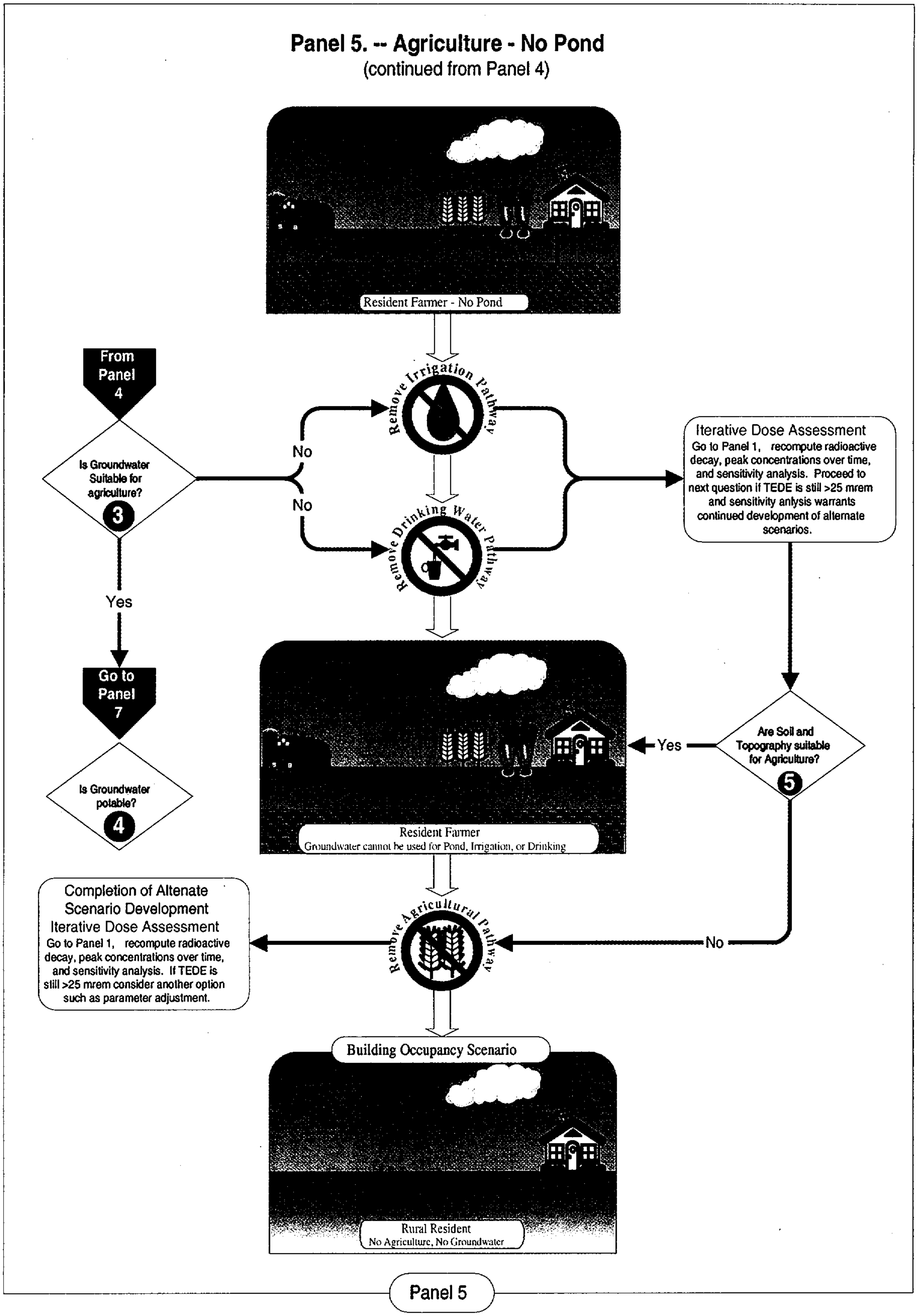

Figure 7. Panel 5 - Agriculture - No Pond.

After the agricultural pathway is removed, another dose assessment would be done. If the TEDE to an average member of the critical group still exceeds 25 mrem/yr, the user should begin to analyze the critical parameters for the this scenario, but there is no need, at this point, to continue with alternate scenario development.

If the answer to the question regarding the suitability of the soil and topography at this site for agriculture is "Yes," the scenario returns to that of a resident farmer with no groundwater use getting all his water needs met by uncontaminated water from an outside source. For this situation, the scenario has been defined and there is no need to introduce additional site data. An iterative dose assessment should be done after critical parameters have been modified.

If the answer to the first question in this panel, "Is groundwater suitable for agriculture?" is "Yes," the user would go to Panel 7 to consider the potability of the groundwater.

3.6 Panel 6 - Agriculture - All Pathways

The sixth panel (Figure 8) is also a continuation of Panel 4, but it starts with a resident farmer and all pathways. Groundwater is available and it is suitable for a pond. The question asked here is the same as in Panel 5: "Is the groundwater suitable for agricultural use?"

The procedure here is identical to Panel 5, except that in each resultant scenario, the farmer still has a pond. In the final situation, where both questions have been answered with a "No," the scenario is of a rural resident with a pond—the building occupancy scenario combined with the aquatic scenario and modified versions of the external exposure and inhalation pathways.

If the answer to the first question in this panel, "Is groundwater suitable for agriculture?" is "Yes," the user would go Panel 8 to consider the potability of the groundwater.

3.7 Panel 7 - Potability - No Pond

The seventh panel (Figure 9) is a continuation of Panel 5, a resident farmer without a pond. Groundwater is available and is suitable for agriculture, but it is not suitable for a pond. The question asked here: "Is the groundwater potable?" Can the farmer drink the water?

Section 6.2.1.4 considers the potability of groundwater, drinking water standards, and documentation needed for the NRC. If the groundwater does not meet drinking water standards, the drinking water pathway would be removed, and an iterative dose assessment would be done. If TEDE to an average member of the critical group still exceeds 25 mrem/yr, the user would consider the suitability of the soil and topography for agricultural use.

The suitability of the topography and soil for agriculture would be considered in the same manner as it was in Panel 5. If either the soil or topography is determined to be unsuitable, the agricultural pathway and the irrigation pathway would be removed and the scenario would devolve to the building occupancy scenario of a rural resident with no pond, no agriculture, and no drinking water.

After the agricultural pathway is removed, another dose assessment would be done, and if TEDE to an average member of the critical group still exceeds 25 mrem/yr, the user should begin analysis of the critical parameters for the building occupancy scenario. If the TEDE is still above the threshold value, the user would need to consider modifications to the critical parameters, but there would be no need, at this point, to continue with alternate scenario development.

If the answer to the first question in this panel, "Is groundwater potable?" is "Yes," the user would go to Panel 9 to consider the suitability of the soil and topography.

3.8 Panel 8 - Potability - All Pathways

The eighth panel (Figure 10) is the continuation of Panel 6 and is almost the same as Panel 7, except that it starts with a resident farmer and all pathways. Groundwater is available and is suitable for both pond and agriculture. As with Panel 7, the question asked here is, can the farmer drink the water?

The procedure here is identical to Panel 7, except that in each resultant scenario the farmer still has a pond. In the final situation, where both questions have been answered with a "No," the scenario would be that of a rural resident with a pond—the building occupancy scenario combined with the aquatic scenario and modified versions of the external exposure and inhalation pathways.

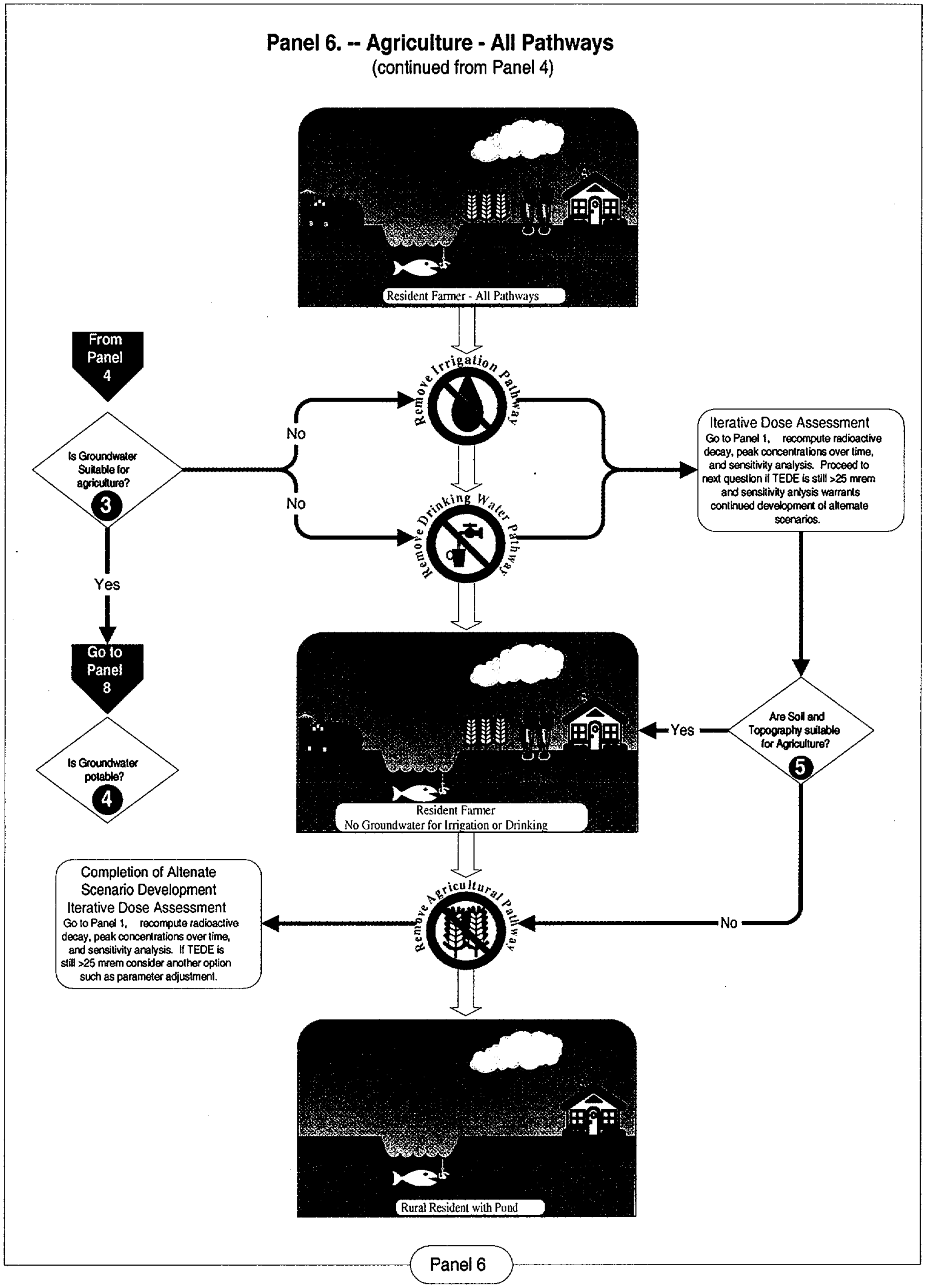

Figure 8. Panel 6 - Agriculture - All Pathways.

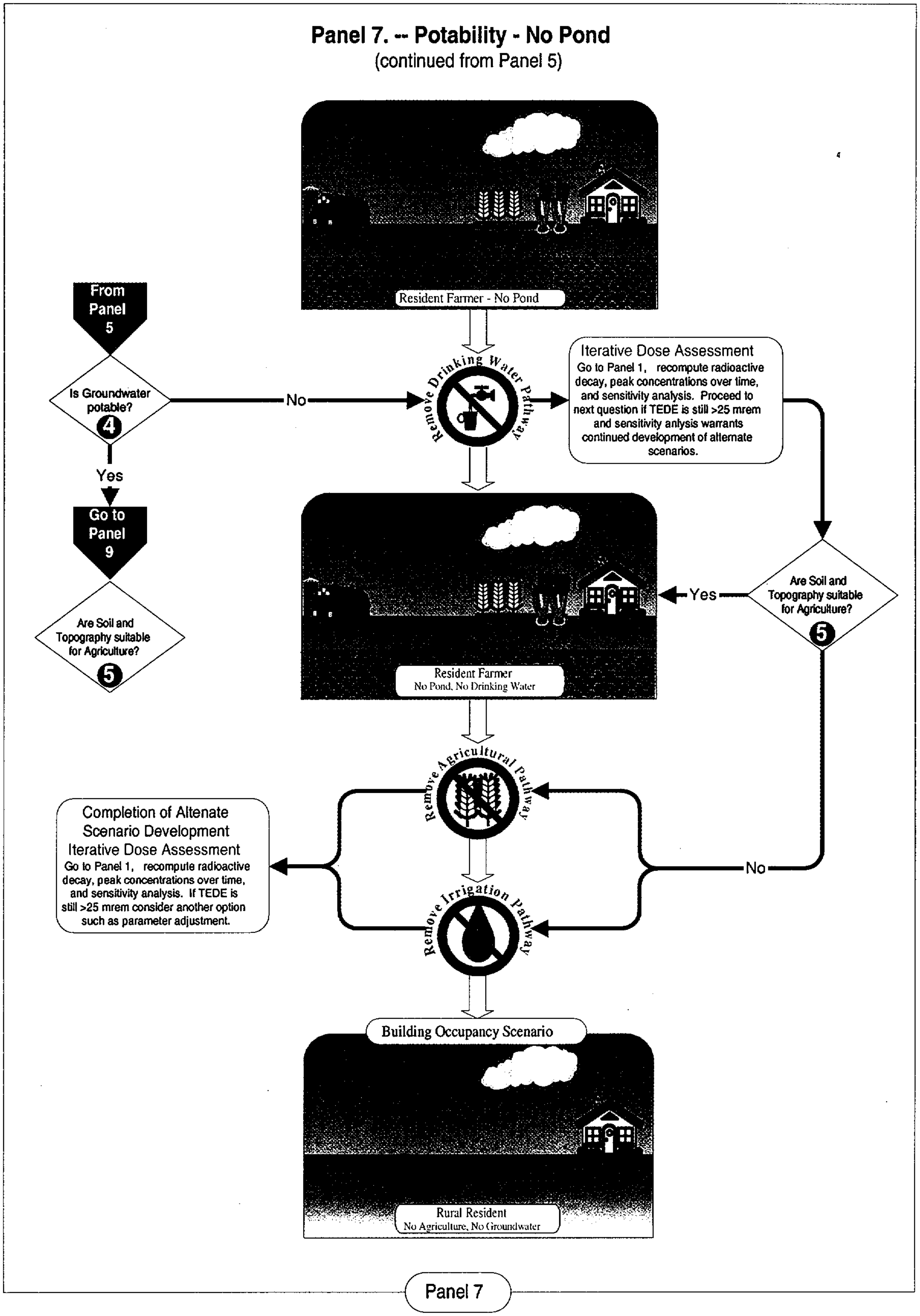

Figure 9. Panel 7 - Potability - No Pond.

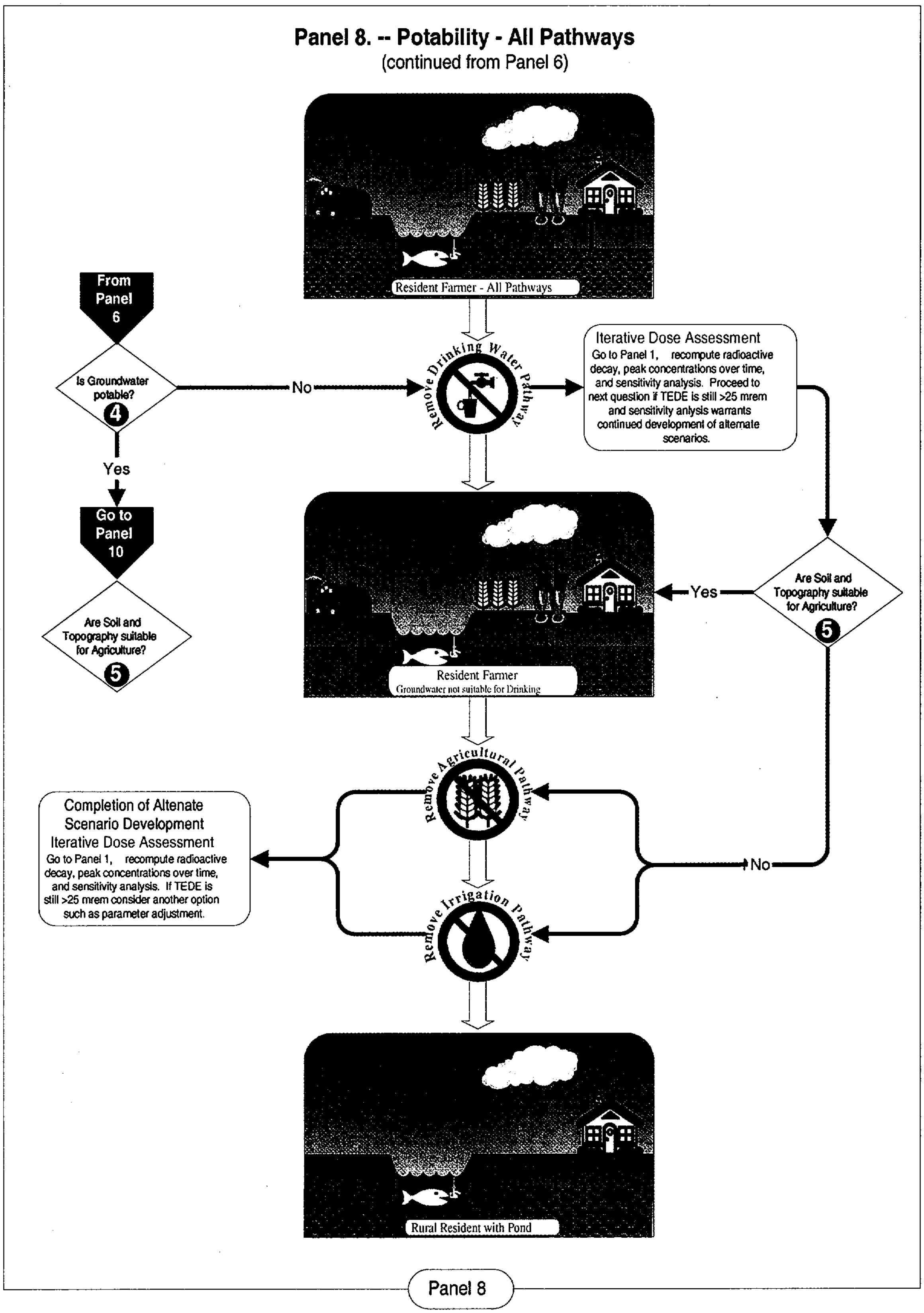

Figure 10. Panel 8 - Potability - All Pathways.

As with Panel 7, if the answer to the first question in this panel, "Is groundwater potable?" is "Yes," the user would go Panel 10 to consider the suitability of topography and soil for agriculture.

3.9 Panel 9 - Topography and Soil - No Pond

The ninth panel (Figure 11) is the continuation of Panel 7; it starts with a resident farmer with no pond. Groundwater is available, and although not suitable for a pond, it is suitable for both agriculture and drinking. The question here is the suitability of topography and soil for agriculture.

The question of the suitability of topography and soil for agriculture is considered in the same manner as it was for Panel 5. If either the soil or topography is determined to be unsuitable, the scenario would devolve to a rural resident with drinking water but no pond. This would essentially be the building occupancy scenario combined with the drinking water scenario, and modified versions of the external exposure and inhalation pathways.

After the agricultural pathway is removed, another dose assessment would be done, and if the TEDE to an average member of the critical group still exceeds 25 mrem/yr, the user should begin analysis of the critical parameters for this scenario, but there would no need, at this point, to continue with alternate scenario development.

If the answer to the first question in this panel regarding the suitability of topography and soil for agriculture is "Yes," the user would assume that the correct scenario is the resident farmer with all pathways except a pond, and would begin examining critical parameters for that scenario using information from a sensitivity analysis.

3.10 Panel 10 - Topography and Soil - All Pathways

The tenth panel (Figure 12) is the continuation of Panel 8; it starts with a resident farmer and all pathways. Groundwater is available and is suitable for a pond, for agriculture, and for drinking. The question now is the suitability of topography and soil for agriculture. This suitability of topography and soil for agriculture is considered here in the same manner as it was in Panel 5. If either the soil or topography is determined to be unsuitable, the scenario would devolve to a rural resident with drinking water and a pond. This would essentially be the building occupancy scenario combined with the drinking water scenario, the aquatic scenario, and modified versions of the external exposure and inhalation pathways.

After the agricultural pathway is removed, another dose assessment would be done and if TEDE to an average member of the critical group still exceeds 25 mrem/yr, the user should begin analysis of the critical parameters for this scenario, but there would be no need, at this point, to continue with alternate scenario development.

If the answer to the first question in this panel regarding the suitability of topography and soil for agriculture is "Yes," the user would assume that the correct scenario is the resident farmer with all pathways and would begin examining critical parameters based on a sensitivity analysis.

3.11 Panel 11 - Urban Resident and Industrial Worker

The eleventh panel (Figure 13) is the continuation of Panel 2; it starts with the urban resident scenario or the industrial worker scenario.

3.11.1 Urban Resident

The urban resident scenario is essentially a building occupancy scenario that includes a garden scenario (modified from the resident farmer scenario) and modified versions of the external exposure and inhalation pathways. Cultural information regarding future land use is introduced here to answer the question, "Is this urban resident likely to have a garden?" The information presented in Section 6.1 and specifically 6.1.2.2 can be used to help answer this question and determine the documentation that would need to be submitted to the NRC on this issue.

If the urban resident is likely to have a garden, the user should begin analysis of the critical parameters for this scenario, but there would be no need, at this point, to continue with alternate scenario development.

If it is considered unlikely for the urban resident to have a garden, the garden pathway would be removed, and an iterative dose assessment would be done. If TEDE to an average member of the critical group still exceeds 25 mrem/yr, the user should begin analysis of the critical parameters for the urban resident scenario, but there would be no need, at this point, to continue with alternate scenario development.

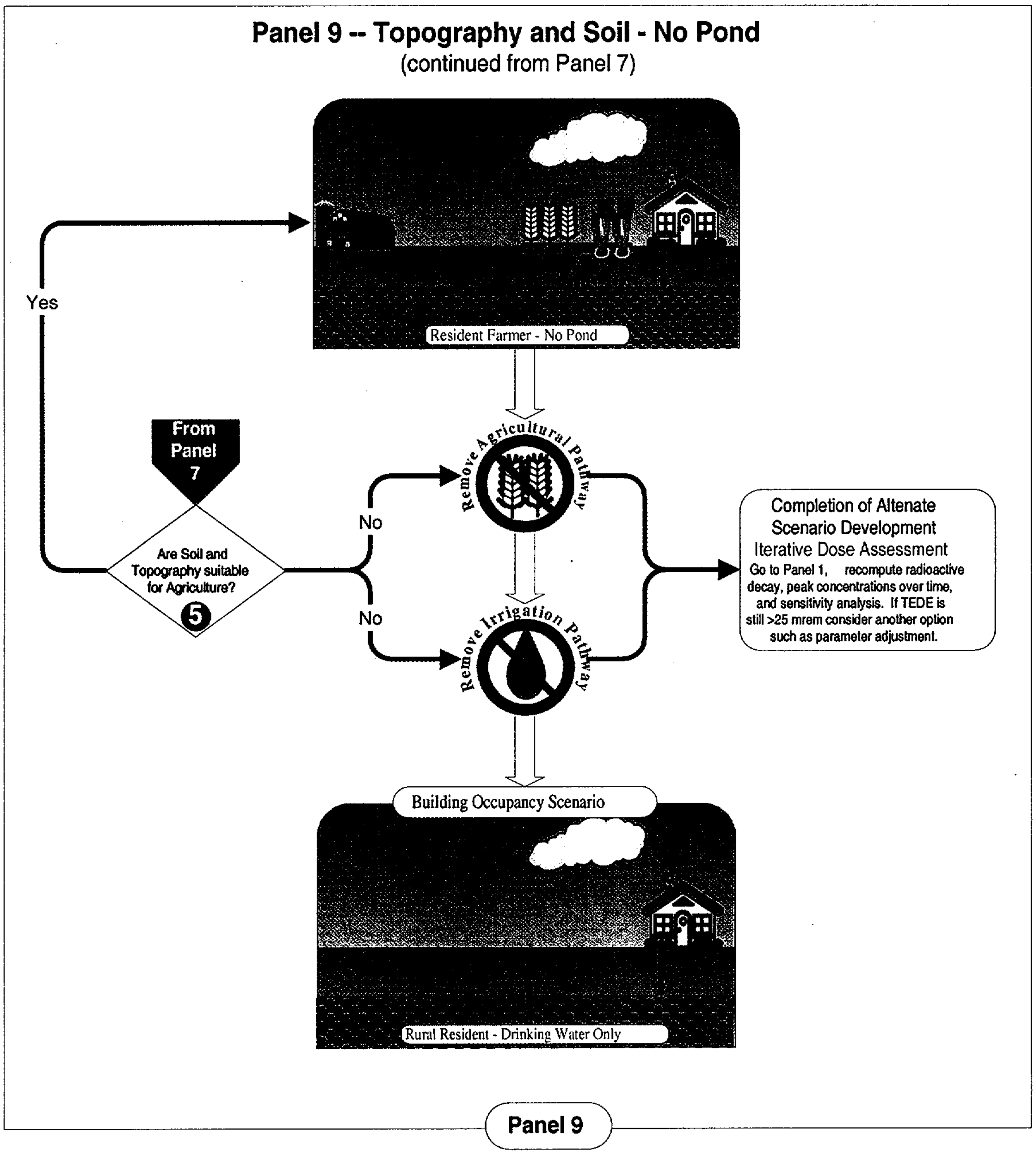

Figure 11. Panel 9 - Topography and Soil - No Pond.

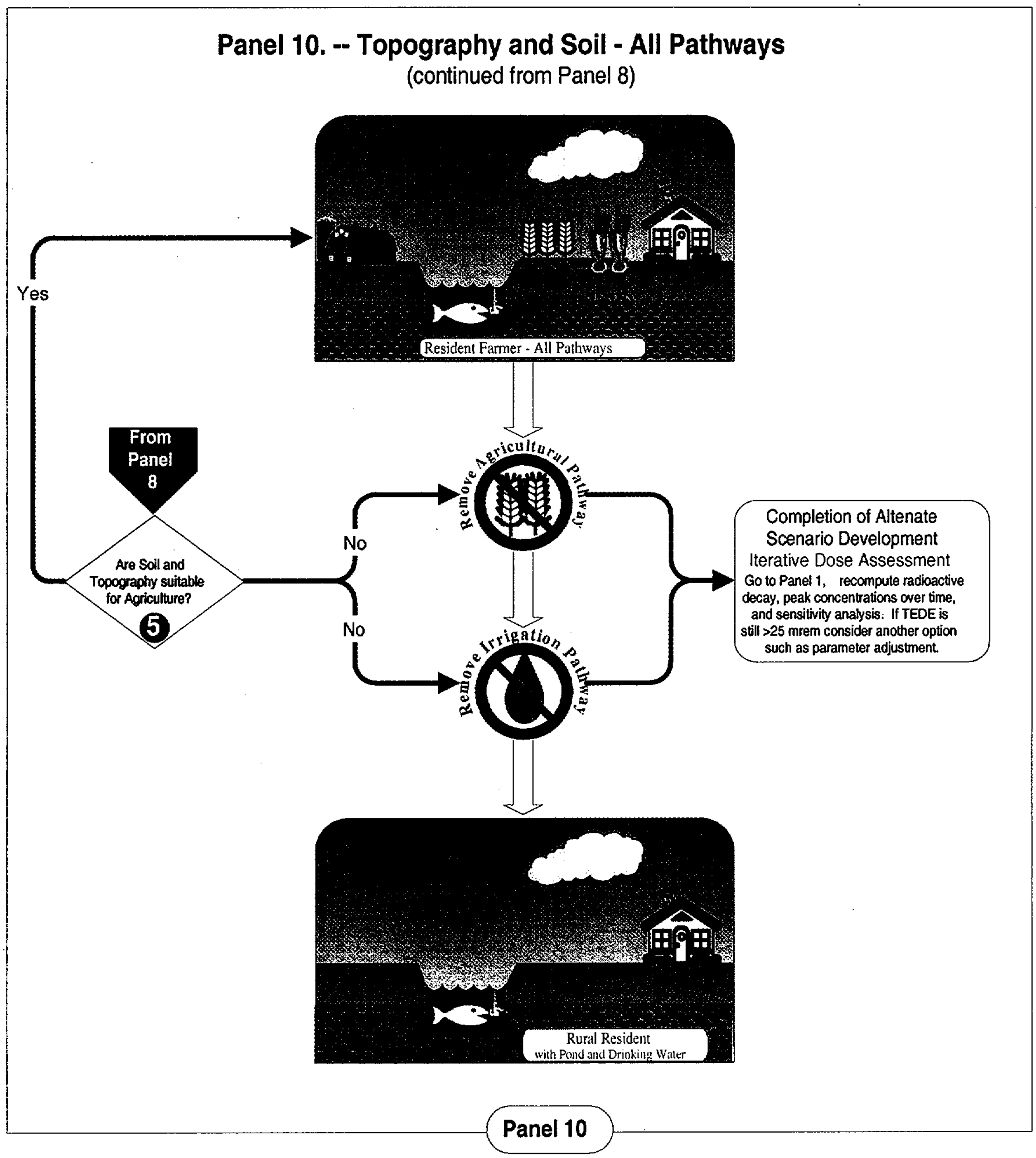

Figure 12. Panel 10 - Topography and Soil - All Pathways.

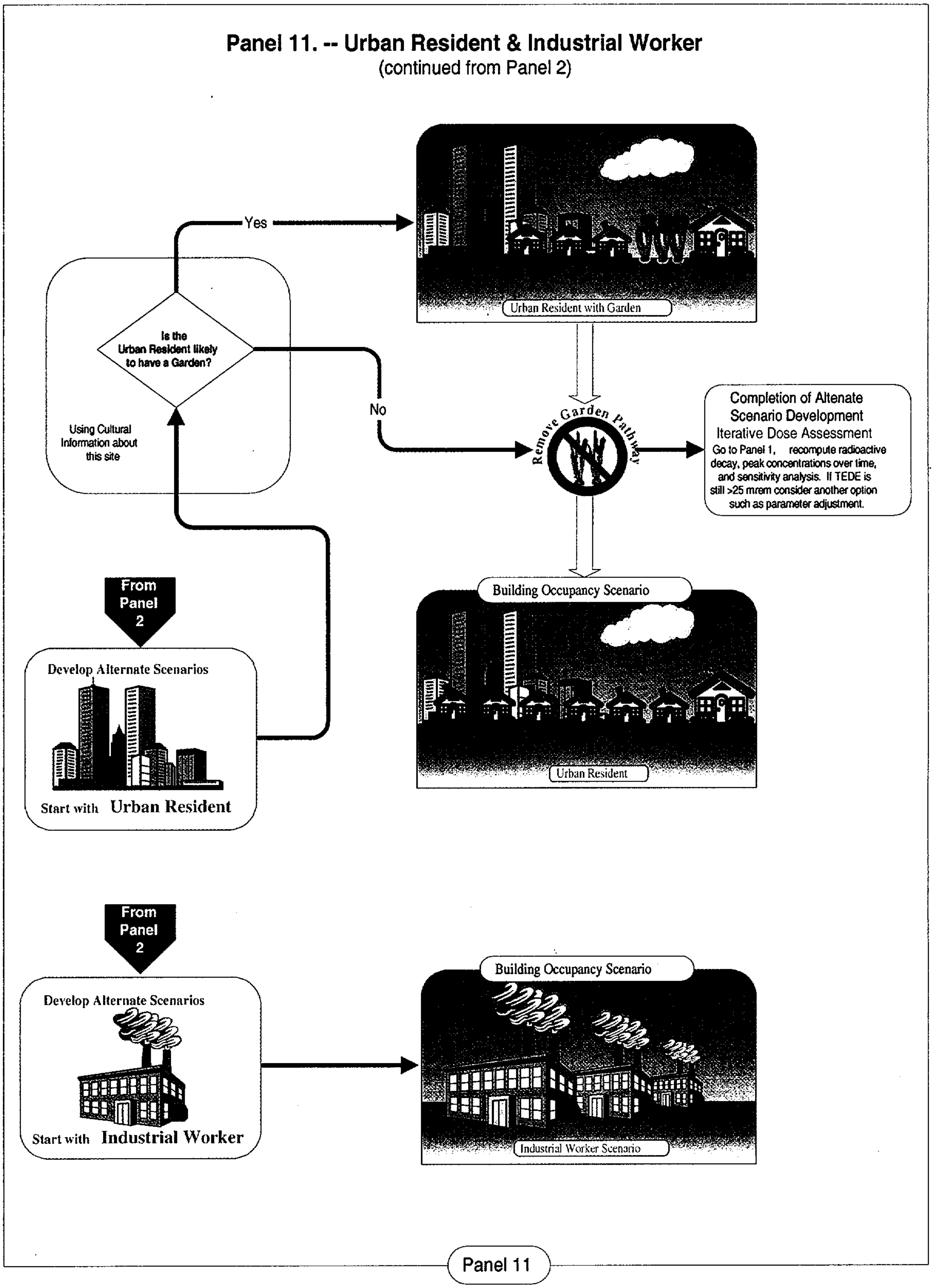

Figure 13. Panel 11 - Urban Resident and Industrial Worker.

3.11.2 Industrial Worker

The industrial worker scenario includes the building occupancy scenario and modified versions of the external exposure and inhalation pathways. While there is no additional site-specific information to further devolve this scenario, site-specific information can be used to modify the pathway parameters for this scenario.

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4.0 Initial Computation

The process for developing alternate scenarios begins with the decommissioning and license termination framework as described in NUREG-1549. The process described in this report integrates with the 1549 framework (shown in Figure 1) and expands upon the introduction of site-specific information, the revision of pathways, and iterative dose assessment. Figure 3 shows a more detailed framework diagram that includes the sensitivity analysis step and highlights the process that uses site-specific information to develop alternate scenarios.

4.1 Define Source

4.1.1 Assemble Existing Data

Existing data for the site must be gathered, assembled, and evaluated. The first step is to determine the types and amounts of radioactive material possessed by the licensee at this site; this information is needed to perform the initial dose assessment.

Information about any surveys and leak tests that have been performed, as well as any records important to decommissioning as described in 10 CFR Parts 30.35, 40.36, 50.75, 70.25, and 72.30, need to be assembled as appropriate. This information may be needed to quantify the amount of contamination present at the site.

Information regarding groundwater depth and quality, soil type, and local cultural practices may be needed to develop alternate scenarios, to evaluate models, or to modify model parameters, but an initial dose assessment can be performed before expending resources to gather this data. If the initial dose assessment, using site-specific source concentrations, default pathways, and default pathway parameters, shows TEDE to an average member of the critical group to not exceed 25 mrem/yr, there is no reason to gather and evaluate this site-specific information.

4.1.2 Calculate Source Concentration

The calculation of source concentration should be done according to NRC-approved methodologies.

4.2 Initial Dose Assessment

Since the process for alternate scenario development set forth in this document is essentially a devolution of the resident farmer scenario, the initial dose assessment must be done using the default resident farmer scenario with its associated default pathways and parameters. Within this process of devolution, pathways will be removed as appropriate site-specific information is introduced.

The exception to this would be if the contamination at a site is fully contained within a building. If the case can be made that the contaminant would remain in the building throughout the period when it could cause a TEDE to an average member of the critical group to exceed the 25 mrem/yr threshold, the default resident farmer scenario would not be applicable and the building occupant scenario should be used.

Whenever pathways are removed, the user is expected to perform an iterative dose assessment that reflects the new scenario. These recurring computations are best done using software which has 1) the built-in NRC-approved default parameters and pathways, 2) procedures for removing entire pathways, and 3) procedures for modifying pathway parameters.

If the initial dose assessment results in TEDE to an average member of the critical group that does not exceed 25 mrem/yr, there is no need to collect more data or to develop alternate scenarios for this site. After ALARA concerns have been met, the site would be considered a candidate for unrestricted use.

If this dose assessment results in TEDE to an average member of the critical group that is greater than 25 mrem/yr, one of the options is to use site-specific information to modify the resident farmer scenario by eliminating pathways that are inappropriate for the site in question. There are other options at this point, but this report concentrates on the development of alternate scenarios.

If the process presented in this report is followed, the amount of data that needs to be gathered and the level of analyses that need to be done will be kept as low as possible. The first step in this process is to perform a sensitivity analysis by examining the results of the initial dose assessment to determine the pathways and radionuclides that significantly influence the TEDE. Section 5 provides greater detail on this procedure and gives a specific example of a sensitivity analysis.

4.3 Iterative Dose Assessment

Iterative dose assessments should be done whenever a pathway is eliminated or parameters are modified. Since the process began with the resident farmer scenario and default pathways and parameters, the introduction of site-specific data should reduce the TEDE.

If at any point in the process, the iterative dose assessment shows the TEDE to an average member of the critical group does not exceed 25 mrem/yr, there is no need to introduce more data nor to continue developing alternate scenarios. After ALARA concerns have been met, the site should be acceptable for release.

If the TEDE to an average member of the critical group exceeds 25 mrem/yr, the user should do another sensitivity analysis and consider whether it is best to continue with the development of alternate scenarios or to consider one of the other options such as parameter adjustment, changing models, cleaning up the site, or releasing the site under restricted use.

5.0 Sensitivity Analysis

If the dose assessment shows that a 25 mrem TEDE to the average member of the critical group persists for more than 100 years, the results of initial or iterative dose assessments need to be examined to determine which pathways and parameters are significant. This sensitivity analysis will help the user concentrate subsequent analyses on those pathways or parameters that are major contributors to the TEDE. It is for these pathways or parameters that the inclusion of site-specific data will most likely reduce the TEDE. As the user moves through this process, shortcuts should be taken, jumping to those pathways that are significant and ignoring those that are not.

A simple sensitivity analysis can be done following the initial dose assessment and following each iterative dose assessment as pathways are eliminated or parameters are modified. The results of the dose assessment will show the percentage of the TEDE attributable to each major pathway and to each of the radionuclides.

5.1 Examples

The example shown here was done using DandD 1.0, but the sensitivity analysis can be done using any NRC-accepted methodology. The DandD 1.0 NRC text report provides information on the pathway and radionuclide components of the TEDE for the peak dose only. The graphics report provides additional information on the history of dose and radionuclide history over time. This example illustrates how both types of information are needed before introducing site-specific information to modify the scenario.

5.1.1 Example NRC Text Report

The NRC text report shows the peak dose (TEDE) in mrem/yr and the year it will occur. It also provides, for that peak dose, the percentages of that value attributable to each of the major exposure pathways and to each contributing radionuclide. Assessment of this information will help the reviewer concentrate subsequent analyses on those pathways or parameters that are the major contributors to the TEDE.

In the example shown below, the following radionuclides and concentrations have been assessed using default pathway and parameters.

Radionuclide	Concentration (pCi/gram)
14C	19.3
60Co	0.41
90Sr	9.77

The portion of the NRC text report presented below shows that a peak dose of 575 mrem/yr occurs one year after license termination; that 99.9% of this dose is due to the agricultural pathway; and that 95% of the dose can be attribute to strontium 90.

```
The peak dose of 5.75E+002 TEDE (mrem)
occurred 1.00 year(s) after license
termination.

Pathway Component of
Maximum Annual Dose
============================

Pathway          TEDE (mrem)       Percentage
=============================================
External            3.99E-001            0.07
Inhalation          7.85E-004            0.00
Agricult.           5.75E+002           99.93
Soil                2.15E-002            0.00
Drinking            4.00E-013            0.00
Irrigated           5.63E-012            0.00
Aquatic             3.87E-011            0.00
---------------------------------------------
Total               5.75E+002          100.00

Radionuclide Component of
Maximum Annual Dose
============================

Radionuclide     TEDE (mrem)       Percentage
=============================================
14C                 1.79E+000            0.31
58Co                2.95E-001            0.05
90Sr                5.48E+002           95.31
90Y                 2.49E+001            4.32
---------------------------------------------
Total               5.75E+002          100.00
```

While this information indicates the need to concentrate on the agricultural pathway and the contribution of strontium 90, the graphics report gives additional valuable information contained in the dose history.

5.1.2 Example Graphics Report

The graphics report for this example (Figures 14 and 15) provides additional valuable information to consider before proceeding with the analyses using site-specific information. The dose history of the pathways (Figure 14) shows a high dose from the agricultural pathway that peaks at year one and then rapidly decays to less than 25 mrem/yr within 12 years, but it also shows that doses from the aquatic and irrigation pathways combine to create a TEDE greater than 25 mrem from year 30 through year 45. The dose history of the radionuclides (Figure 15) shows that strontium 90 is responsible for the agricultural peak and that carbon 14 is responsible for this secondary peak.

The graphics report provides the following information that is not available in the NRC text report; 1) that the strontium 90 dose lasts only 12 years and 2) that a secondary peak from carbon 14 will persist above the threshold value for 15 years, after the strontium 90 peak has dropped below 1 mrem/yr. As the user introduces specific information for this site, carbon 14, the aquatic and irrigation pathways, strontium 90, and the agricultural pathway must be considered.

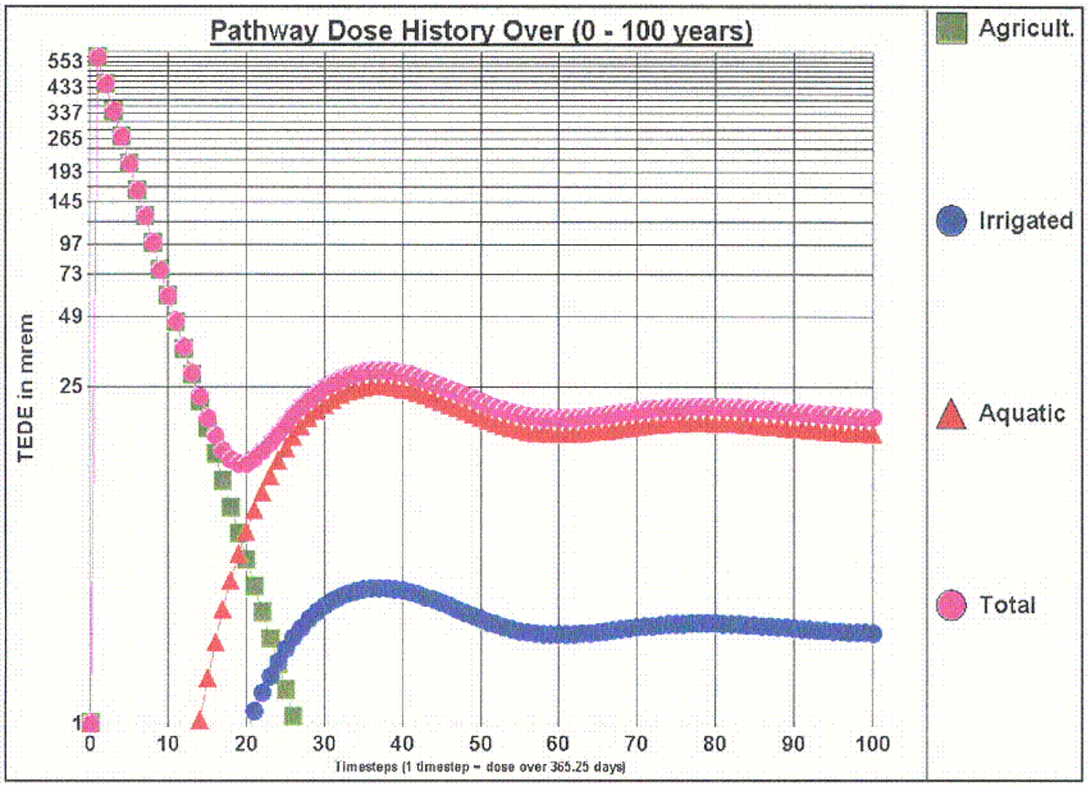

Figure 14. Pathway Dose History.

C1

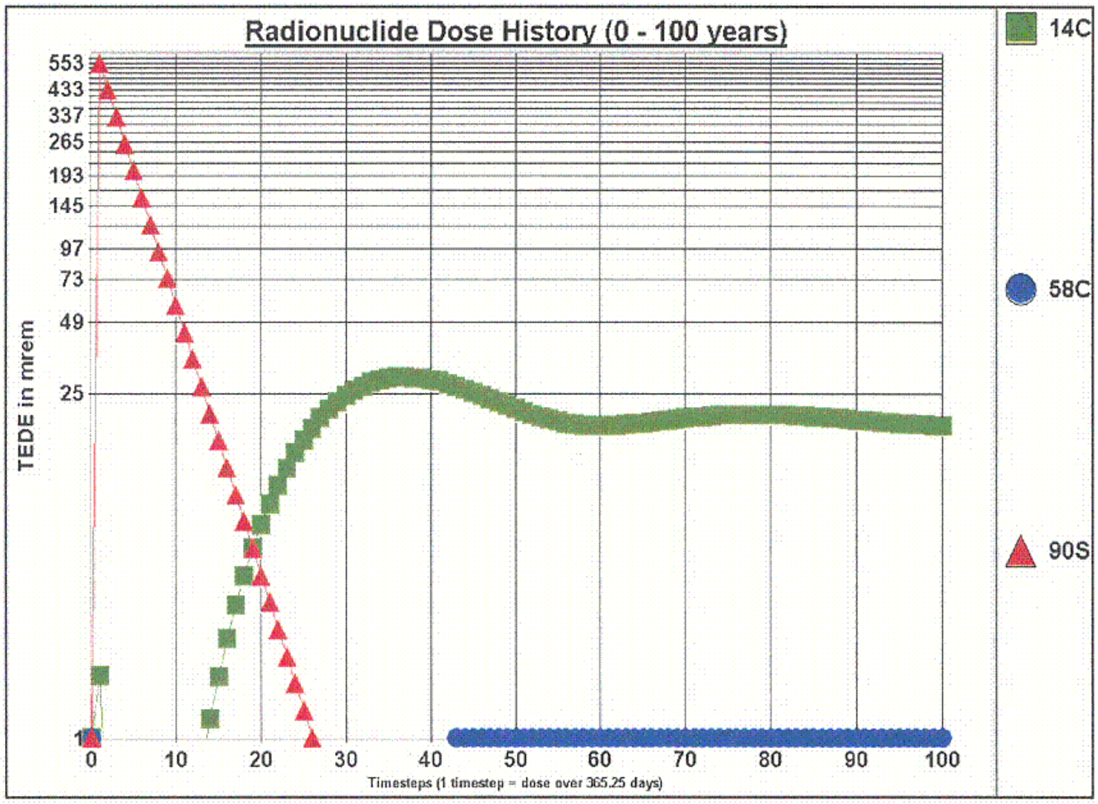

Figure 15. Radionuclide Dose History.

C2

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6.0 Introducing Site-Specific Information

Site-specific information can be divided into two broad categories: cultural information and physical information. Physical information includes the location, climate, topography, geology, soil types, water availability, etc. of the site. Cultural information is essentially how the human population uses the land. Physical properties of land are unchanging, while cultural properties are constantly changing. In reality, physical properties change (sometimes as a result of cultural activities), but the change is slow compared to the cultural use of the land.

The dose assessment process defined in NUREG-1549 starts with a resident farmer scenario based on NRC-approved default pathways and parameters. The scenario, pathways, and the parameters have been defined such that the introduction of site-specific cultural or physical information is likely to reduce the TEDE.

6.1 Cultural Information

For developing alternate scenarios, the most important element of cultural information about any site is the future land use. The future is assessed on the basis of the past and the present. Experience has shown that while this is an inexact science, the near future can be estimated with some degree of confidence. Over what timeframe can we confidently estimate the future? It depends on the location, the culture, and what is being estimated. For the problem at hand, estimating doses to individuals from radionuclides in the environment, it is substantially less than 1,000 years. We propose that no reliance be placed on predictions of human behavior beyond 100 years.

Therefore, there is no point in assessing either current or future land use if long-lived radionuclides are present at this site that can cause a TEDE greater than 25 mrem/yr to persist over 100 years. Since the future use of this site cannot be predicted confidently beyond 100 years, the resident farmer scenario with default pathways and parameters should be used throughout the dose assessment process.

Future land use should be estimated only in those situations where the assessed TEDE greater than 25 mrem/yr does not persist for longer than 100 years and the sensitivity and data worth analysis (NUREG-1549) has shown that other options of dose reduction are more expensive and time-consuming.

6.1.1 Current Land Use

The determination of current land use is the initial step in the process of estimating future land use. Land use must be determined not only for the site, but also for the land within an 80-km (50-mile) radius surrounding the site. This assessment of land use does not need to be complicated or detailed; it should be fairly simple, dividing the land into only three categories: urban, rural, or industrial.

Current land use can be determined through one or more of the following information sources:

- site description,
- topographic maps,
- planning agencies,
- zoning maps,
- aerial photographs, or
- site visits.

The majority of the U.S. has codified land use/zoning, and many administrative areas have developed land use master plans. For this reason, the primary source of information on current land use will be the planning agencies of the state, county, and/or municipality in which the Decontamination & Decommissioning (D&D) site resides. In most cases, the easiest way to find these planning agencies is in the government section of the local phone book.

There is also a large amount of data available on the Internet at websites maintained by government agencies. Appendix A lists current websites for every state in the U.S. These websites contain indices to a large variety of data about each state. Land use planning information is also often available at these sites.[1]

Assumptions and predictions regarding future land uses are important considerations in the development of scenario definitions and descriptions for analysis. If the site currently exists in a highly populated urban area, a residential farmer scenario is very unlikely within the next 100 years. Exposure scenarios for certain sites may exclude exposures via agricultural pathways if agricultural land uses are clearly incompatible with existing and anticipated future

[1]Websites are volatile; addresses and the amount and type of information at any website may change at any time.

conditions at the sites. Exposures via ingestion of contaminated groundwater may be discounted if the affected groundwater is of such poor quality as to preclude human consumption.

6.1.1.1 The Use of Ponds as Fisheries

In addition to physical limitations on the likelihood of a farmer using a pond as a fishery, local cultural information should be used to determine if local residents currently engage in this practice. The local USDA county extension agent might answer this question. Contact information for county extension agents can be found at http://www.reeusda.gov/.

6.1.2 Future Land Use

An estimate of future land use should be done only for those sites where the radionuclides are short-lived and a TEDE greater than 25 mrem/yr is not expected to last for longer than 100 years. Specific local conditions should be taken into account when deciding how far into the future land use can be estimated. In areas where rapid change has occurred in the past, this cutoff might be considerably less than 100 years, whereas in other areas, such as the heart of a large city, it may be reasonable to argue that urban conditions will prevail for more than 100 years.

The first step in estimating future land use is to determine the current land use at the site. The past use of the land should also be ascertained because it is the combination of past and present uses that will indicate what changes have occurred and the rate of those changes. This information should be used in a documented process that a reviewer would be able to follow. This documentation should include the types and sources of material that were used and how the final projected use was determined. Appendix A lists possible types of source documents that may contain useful information.

Land use and changes in land use within the 80-km (50-mile) radius of the site must be considered as part of this process. For example, a site that is currently located in a rural area within 16–32 km (10–20 miles) of a growing metropolitan area will likely be in the suburbs of the metropolitan area within a decade or two, depending on population growth.

The 80-km (50-mile) radius is only a suggestion for determining the size of the area to consider. There may be valid reasons for increasing or decreasing the area of consideration, depending on local conditions and the length of time that a TEDE greater than the 25 mrem threshold is expected to occur. Other factors that may influence this decision are critical pathways and the estimated distribution of contamination.

6.1.2.1 Sources of Information for Determining Future Land Use

In helping the NRC establish a policy on the treatment of future land use, approaches taken by other federal agencies for treating future land use were reviewed. Within these agencies, the closest analogy to the NRC D&D problem is EPA's Office of Solid Waste and Emergency Response (OSWER) superfund program. The primary EPA document on this subject is EPA OSWER Directive No. 9355.7-04: Land Use in the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Remedy Selection Process, dated May 25, 1995. The Department of Defense (DoD) also references this directive for use in the Base Realignment and Closure (BRAC) program. Appendix A is based on the OSWER directive and contains information types which were used in determining possible data/information sources.

The are many sources at the federal, state, and local levels for the information types listed in Table A-2 of Appendix A. The list of sources provided here is not definitive, but the sources listed will, in most cases, be able to point the user to additional sources of information.

Much of the information used to describe current land uses and to determine possible future land uses is geographic in nature. Therefore, the sources provided (Table A-2, Appendix A) are for government geographic information system (GIS) providers at both the national and state levels. State GIS organizations will be able to direct the user to local sources for much of this information and, in many cases, may have links to that information directly from their data sites.

Table A-3 in Appendix A lists federal government sources for data useful for determining possible future land use, and Table A-4 in Appendix A lists each state and the corresponding location for digital data.

6.1.2.2 Urban Gardens

The subsistence farm associated with the resident farmer is unlikely to exist in an urban situation and can generally be excluded from urban scenario dose assessment. However, gardens are very likely to exist in urban and suburban settings. The "Victory Gardens" of World War II demonstrate the possibility of widespread urban gardens. Therefore, gardens should be included in the urban scenario dose assessment. Exceptions to having gardens in the urban scenario include the core of large cities like New York, where gardens are highly unlikely.

> **Documentation to be Submitted to NRC**
>
> **Current Land Use** should be documented by maps, descriptions, or information from one of the other sources listed in Appendix A.
>
> **Estimates of Future Land Use** should be supported by the documented process described in Section 6.1.2.

6.2 Physical Information about Site

Physical information about the site includes climate, topography, vegetation, and, most importantly, water. Since water is itself a pathway and a key element in many other pathways, its availability, quality, and proximity are very important.

6.2.1 Groundwater and Surface Water

Groundwater is present at some depth at most every site and therefore it has been included in the default (residential farmer) scenario. The only surface water in the default scenario is a pond. Fish are assumed to be grown in the pond and consumed by the resident. For this discussion, the pond is assumed to be a surface expression of the groundwater system. That is, the pond is either an isolated surface depression that extends below the water table or a man-made pond filled by groundwater.

There are several key questions about groundwater that must be answered using site-specific information. The most important question regards the availability of water. Subsequent questions regard its quality and suitability for use.

6.2.1.1 Is Sufficient Groundwater Available?

The first question that must be answered is "Is groundwater available as a resource for the scenario resident?" More specific questions are:

1. Is there sufficient groundwater that can reasonably be pumped by the resident to irrigate a small farm and provide domestic drinking water?
2. Are there ponds at the site connected to the groundwater system or is there a potential for such ponds to form?
3. Is it likely that the groundwater would be pumped into a fish pond?

With regard to the first question, the resident would need to drill a well into an aquifer that has water sufficient for home use and agriculture. Under the assumption that the well drilling and pumping technology available to the resident is similar to what exists today, it would not be unreasonable for the farmer to drill a well to and pump from a depth of 400 feet or more. Specific local conditions should be considered when deciding how deep the resident farmer would be able to go for water. Recognize, however, that as the depth to water increases, it is less likely that the groundwater would become contaminated from the residual radiation at the site. In other words, changes to the depth to water in the dose assessment should be done prior to or in conjunction with any changes to the scenario itself.

Another critical groundwater issue is how much water is available. NUREG/CR-5512, Vol. 3 [Beyeler et al., 1999] defines the minimum water needs for a resident farmer to be 118,000 l/yr. (31,172 gal/yr) for domestic uses and 1.29 $l/m^2/day$ (0.0317 $gal/ft^2/day$) for average annual irrigation needs. Assuming the default irrigated area of 2400 m^2 (25,833 ft^2), the average annual irrigation needs would be 1.13×10^6 l (2.99×10^5 gal). This leads to two questions: 1) does the aquifer contain sufficient water to supply the residential farmer over the lifetime of the farmer (i.e., 70 years)? and 2) does the aquifer yield enough water on a daily basis to supply the required demand?

The amount of water required over the lifetime of the farmer is 8,742,000 l (2,309,392 gal). This amount then needs to be compared with the amount of storage in the aquifer. The total aquifer storage can be estimated by multiplying the aquifer's area times its thickness times its specific yield (note: confined aquifers are not considered here because they are unlikely to become contaminated from the residual radioactivity). Local trends in groundwater decline should also be taken into account. In areas where groundwater is being withdrawn at an unsustainable rate, water levels will be dropping. If it can be reasonably assumed that this trend will continue into the future, this should be taken into account when assessing the availability of groundwater for the resident farmer. The calculated TEDE can then be adjusted by the ratio of the available water to the total water required.

The desired aquifer properties need to be assessed to determine how much water can be supplied on daily basis. The daily domestic needs of the resident farmer would be 323 l/day (85.3 gal/day). Annual irrigation needs are based on a 180-day growing season, the peak daily demand for irrigation water would be 6280 l/day (1660 gal/day), and the total daily demand during the growing season would be 6600 l/day (1740 gal/day). If the groundwater available is not sufficient to meet the daily demands of the farmer, pathway parameters should be modified to fit the available water with first priority going to drinking water, second to the remaining domestic needs, and last priority going to agriculture.

For example, if the aquifer can supply only 6,000 l/day (1583 gal/day), the farmer's domestic needs of 323 l/day would be met first, leaving 5,677 l/day (1497 gal/day) for irrigation. The area that the farmer can irrigate would be reduced to reflect the smaller amount of water available. In this case, irrigated area would be reduced to 2170 m^2 (90% of the default area).

$$newA_r = A_r\left(\frac{V_{avail}}{V_{irr}}\right)$$

$$newA_r = 2{,}400\left(\frac{5{,}677}{6{,}280}\right)$$

$$newA_r = 2{,}170$$

where:

A_r = default irrigated area (m^2)
$newA_r$ = new (adjusted) irrigated area (m^2)
V_{irr} = Volume of water needed for irrigation (l/day)
V_{avail} = Volume of water available (l/day)

The second question was: "Are there ponds at the site connected to the groundwater system or is there a potential for such ponds to form?" Addressing this question requires knowledge of existing conditions (i.e. identification and understanding of the origin of existing ponds) and an assessment of the topography and projected changes to groundwater levels. Note that if groundwater is unavailable at a site, then there is no possibility of having a groundwater-sustained pond.

Documentation to be Submitted to NRC

Groundwater Unavailable: USGS or independent consultant report showing that either groundwater does not exist, that it is too deep to be used by a subsistence farmer, or that it is not available in sufficient quantities to meet the farmers' needs.

The last question was: "Is it likely that the groundwater would be pumped into a fish pond?" It may or may not be reasonable to expect that the farmer would continually pump water into a pond to maintain it as a fishery. We recommend that the assessment of the potential for creating a pond by pumping groundwater be based on current local practices (i.e., do people currently pump groundwater to create fish ponds).

Documentation to be Submitted to NRC

Groundwater Unavailable for Fish Pond: USGS or independent consultant report showing that either groundwater does not exist, or that it is too deep to connect to a surface water pond and/or that no one in the area pumps groundwater to create fish ponds.

6.2.1.2 Is Groundwater Suitable for Aquatic Life?

The quality of surface water is critical to the support of aquatic life and is affected by 1) the chemical and physical conditions that exist in the pond, 2) runoff from exposed soil, and 3) condensation/entrapment of contaminants from the air (e.g., pollutants, acid rain, etc). Recommended standards for surface waters have been proposed [Viessman and Hammer, 1985] and are listed in Table 1.

Table 1. EPA Standards for Surface Waters to Support Freshwater Aquatic Life

Component	Recommended Limits
Dissolved oxygen	5 mg/l (minimum)
Suspended solids	0.90 × (transmission from seasonally established norm)
Fecal coliform bacteria	14 per 100 ml (shellfish)
pH	6.5-9.0
Oil and grease	0.01 × LC_{50}*
Elemental phosphorus	0.0001 mg/l
Phosphate	1.0 mg/l
Chlorine	0.01 mg/l
Ammonia	0.2 mg/l

* LC_{50} represents the concentration that kills 50% of the test specimens.

The concentration of dissolved oxygen in surface water is affected by the biochemical oxygen demand (BOD) of the ecosystem, and while critical to aquatic life, a deficiency in dissolved oxygen that exists in groundwater should not be assumed for surface water connected to groundwater, i.e. the pond. Thus, these criteria should only be applied to surface water that actually exists on the site, rather than to groundwater.

Sedimentation of suspended solids can cause a buildup of organic matter in sediments. These materials undergo metabolic degradation by aerobic soil microorganisms with the concomitant depletion of dissolved oxygen. However, neither low dissolved oxygen or high suspended sediments would be sufficient in themselves to disqualify water for a fishery, since both of these situations can be treated by the homeowner.

Other contaminants, such as dissolved ammonia, can contribute to oxygen depletion by nitrification. Ammonia is toxic to fish and other aquatic animals. Acute toxicity occurs to warm-water species at ammonia levels of 0.4 mg/l.

The presence of coliform bacteria is sometimes indicative of other, more virulent pathogens in surface water and must be considered when fish or other aquatic animals are produced for human consumption.

If the quality of the groundwater (and hence the pond) lies outside of the acceptable standards for aquatic life and cannot be easily treated by the homeowner, the aquatic pathway should be removed from the resident farmer scenario.

Documentation to be Submitted to NRC

Groundwater Unsuitable for Aquatic Life: USGS or independent consultant report showing that groundwater quality is poorer than the standards listed for this use.

6.2.1.3 Is Groundwater Suitable for Agriculture?

The quality of groundwater for agricultural uses needs to be considered separately for irrigation and for livestock drinking. For example, groundwater contaminated by fertilizers and herbicides can be very beneficial to crops through irrigation, but can have an adverse effect on the health and productivity of livestock and poultry.

6.2.1.3.1 Suitability of Groundwater for Livestock

The suitability of groundwater for livestock is considered first. Based on extensive studies by the USDA, recommended limits for chemicals in drinking water for livestock and poultry have been published [http://www.montana. edu/wwwpb/ag/baudr146.html, http://www.cahe.nmsu. edu/pubs/_m/m-112.html]. Table 2 identifies common contaminants in groundwater and the recommended maximum concentrations for consumption by livestock and poultry.

Table 2. Recommended Limits for Components in Drinking Water for Livestock and Poultry

Component	Maximum Concentration (mg/l)
Aluminum	5
Arsenic	0.02
Boron	5
Cadmium	0.05
Chromium	1
Cobalt	0.5
Copper	2
Fluoride	2
Iron	5
Lead	0.05-0.10
Mercury	0.01
Nitrate + Nitrite	100
Nitrite	10
Selenium	0.05-0.10
Vanadium	0.1
Zinc	25
(Mg,Na) sulfates	5,000
Alkalinity	2,000

In addition to acute and chronic toxicity from the elements in Table 2, high concentrations of dissolved solids in drinking water can lead to various degrees of mineral toxicity in animals. Most minerals and dissolved solids found in water provide nutritional benefits when present within limited concentration ranges (e.g., selenium). At high concentrations, however, common minerals can lead to acute or chronic effects that impact the quality of animal products and overall productivity.

The salinity, or total dissolved solids, should be a consideration when evaluating groundwater for animal consumption. Although 10,000 mg/l is acceptable under some conditions, the health, and ultimately the productivity, of animals is affected to various degrees by the salinity. Table 3 provides a breakdown of conditions that have been observed and documented in livestock and poultry for various concentrations of dissolved solids in drinking water.

If the quality of the groundwater is less than acceptable as a drinking source for farm animals, that pathway should be removed from the resident farmer scenario.

Table 3. Effects of Drinking Water Salinity on Livestock

Salinity Limits for Livestock Drinking Water	Conditions
Less than 1,000 mg/l	Excellent for all classes of livestock and poultry
1,000-3,000 mg/l	Temporary mild diarrhea in livestock and poultry
3,000-5,000 mg/l	Satisfactory for livestock. Increased morbidity contributes to poor growth in poultry.
5,000-7,000 mg/l	Marginal quality for livestock. Not suitable for poultry and pregnant and lactating animals.
7,000-10,000 mg/l	Considerable risk for pregnant and lactating animals
Above 10,000 mg/l	Unacceptable

6.2.1.3.2 Suitability of Groundwater for Irrigation

The second question in evaluating the suitability of water for agriculture is in regard to its suitability for irrigation. The suitability of water for irrigation is based primarily on salinity as indicated by total dissolved solids (TDS), but other ions and elements can also be toxic to plants. The permissible limits of TDS are shown in Table 4. Table 5 shows recommended long-term limits for other constituents.

If the quality of the groundwater, in terms of TDS, lies within Class 4 or 5 of Table 4, or if any dissolved constituents listed in Table 5 is higher than the recommended limits, the irrigation pathway could be removed from the resident farmer scenario.

Table 4. Permissible Limits of Dissolved Solids for Classes of Irrigation Water
(from http://agnews.tamu.edu/drought/drghtpak98/drght58.htm)

Classes of Water	Total Dissolved Solids (ppm)
Class 1. Excellent	175
Class 2. Good	175 - 525
Class 3. Permissible	525 - 1,400
Class 4. Doubtful	1,400 - 2,100
Class 5. Unsuitable	> 2,100

Table 5. Recommended Limits for Constituents in Irrigation Water
(from http://agnews.tamu.edu/drought/drghtpak98/drght59.html)

Constituent	Long Term Use (mg/l)
Aluminum (Al)	5.0
Arsenic (As)	0.10
Beryllium (Be)	0.10
Boron (B)	0.75
Cadmium (Cd)	0.01
Chromium (Cr)	0.1
Cobalt (Co)	0.05
Copper (Cu)	0.2
Floride (F-)	1.0
Iron (Fe)	5.0
Lead (Pb)	5.0
Lithium (Li)	2.5
Manganese (Mg)	0.2
Molybdenum (Mo)	0.01
Nickel (Ni)	0.2
Selenium (Se)	0.02
Vanadium (V)	0.1
Zinc (Zn)	2.0

Documentation to be Submitted to NRC

Groundwater Unsuitable for Agriculture: USGS or independent consultant report showing that groundwater quality is poorer than the standards listed for either livestock drinking or for irrigation.

6.2.1.4 Is Groundwater Suitable for Drinking Water?

This question can be addressed by comparing the quality of the groundwater with EPA drinking water standards. 40 CFR Part 141, National Primary Drinking Water Regulations, defines standards for public water systems in the U.S. Primary drinking water standards specify approval limits for microorganisms, including bacteria and viruses, specific inorganic and organic chemicals, and turbidity. Secondary standards identified in 40 CFR Part 143, National Secondary Drinking Water Regulations, set recommended limits on benign contaminants and define physical characteristics that address aesthetics of drinking water (e.g., color and odor).

Tables 6 to 8 specify the Maximum Contaminant Levels (MCLs) of contaminants in drinking water delivered to any user of a public water system. The contaminants are distinguished as A) inorganic chemicals, B) organic chemicals and, C) microorganisms. Although turbidity is a measured physical parameter, it is included with microorganisms because turbid water is generally associated with microorganisms or provides a medium for microbial growth.

Table 6. National Primary Drinking Water Standards for Inorganic Chemicals

Contaminant	Maximum Contaminant Level
Antimony	0.006 mg/l
Arsenic	0.05 mg/l
Asbestos (<10um)	7×10^6 fibers/l
Barium	2 mg/l
Beryllium	0.004 mg/l
Cadmium	0.005 mg/l
Chromium	0.1 mg/l
Copper	1.3 mg/l
Cyanide	0.2 mg/l
Fluoride	4.0 mg/l
Lead	0.015 mg/l
Mercury	0.002 mg/l
Nitrate	10 mg/l
Nitrite	1 mg/l
Selenium	0.05 mg/l
Thallium	0.002 mg/l

Table 7. National Primary Drinking Water Standards for Microorganisms

Contaminant	Maximum Allowable Concentration
Giardia lamblia	99.9% killed/inactivated
Heterotrophic plate count	<500 bacterial colonies per mill
Legionella	No limit (if *Giardia* and viruses are controlled)
Total Coliforms (including fecal coliform and *E. Coli*)	5%
Turbidity	5 NTU
Viruses (enteric)	99.99% killed/inactivated

Table 9 specifies recommended secondary standards for drinking water. Although the secondary standards are not regulated, they serve as a guide for water quality and may, in some instances, be regulated at the state or local level.

Table 8. National Primary Drinking Water Standards for Organic Chemicals

Contaminant	MCL (mg/l)	Contaminant	MCL (mg/l)	Contaminant	MCL (mg/l)
Acrylamide	0.05% (dosed at 1 mg/l)	Dichloromethane	0.005	Methoxychlor	0.04
Alachlor	0.002	1,2-Dichloropropane	0.005	Osamyl	0.2
Atrazine	0.003	Di(2-ethylhexyl)adipate	0.4	Polychlorinated biphenyls (PCBs)	0.005
Benzene	0.005	Di(2-ethylhexyl)phthalate	0.006	Pentachlorophenol	0.001
Benzo(a)pyrene	0.0002	Dinoseb	0.007	Picloram	0.5
Carbofuran	0.04	Dioxin (2,3,7,8-TCDD)	3×10^{-8}	Simazine	0.004
Carbon tetrachloride	0.005	Diquat	0.02	Styrene	0.1
Chlordane	0.002	Endothall	0.1	Tetrachloroethylene	0.005
Chlorobenzene	0.1	Endrin	0.002	Toluene	1
2,4-Dichlorophenoxyacetic acid (2,4-D)	0.07	Epichlorohydrin	0.01% (dosed at 20 mg/l)	Trihalomethanes	0.10
Dalapon	0.2	Ethylbenzene	0.7	Toxaphene	0.003
1,2-Dibromo-3-chloropropane (DBCP)	0.0002	Ethylene dibromide	0.00005	Silvex	0.05
o-Dichlorobenzene	0.6	Glyphosate	0.7	1,2,4-Trichlorobenzene	0.07
p-Dichlorobenzene	0.075	Heptachlor	0.0004	1,1,1-Trichloroethane	0.2
1,2-Dichloroethane	0.005	Heptachlor epoxide	0.0002	1,1,2-Trichloroethane	0.005
1,1-Dichloroethylene	0.007	Hexachlorobenzene	0.001	Trichloroethylene	0.005
cis-1,2-Dichloroethylene	0.07	Hexachlorochclopentadiene	0.05	Vinyl chloride	0.002
trans-1,2-Dichloroethylene	0.1	Lindane	0.0002	Xylenes (total)	10

Documentation to be Submitted to NRC

Groundwater Not Potable: USGS or independent consultant report that shows that groundwater quality is poorer than either the primary or secondary standards for drinking water.

Table 9. National Secondary Drinking Water Standards

Contaminant	Secondary Standard
Aluminum	0.05-0.2 mg/l
Chloride	250 mg/l
Color	15 (color units)
Copper	1.0 mg/l
Corrosivity	noncorrosive
Fluoride	2.0 mg/l
Foaming Agents	0.5 mg/l
Iron	0.3 mg/l
Manganese	0.05 mg/l
Odor	2 threshold odor number
pH	6.5-8.5
Silver	0.10 mg/l
Sulfate250 mg/l	
Total Dissolved Solids	500 mg/l
Zinc	5 mg/l

6.2.2 Topography and Soil

6.2.2.1 Is Soil Suitable for Agriculture?

Soil performs several functions related to plant growth. It forms a media in which roots penetrate, thereby providing a source of stability and nourishment. Nourishment can be provided by the nutrients available in the soil, by fertilizers, or by soil amendments.

Agriculture could be excluded from a scenario if the site is an outcropping of bedrock without appreciable soil or debris that could serve to anchor plants. With suitable fertilizers or soil amendments, plants can readily be grown in "soil free" materials, such as mineral sand, gravel, perlite, pumice, crushed bricks, or glass wool. Consequently, the absence of soil in the traditional sense at a site does not eliminate plant ingestion as a pathway. However, soilless gardening requires more management than traditional gardening methods, so it is more likely to be used for growing vegetables and herbs than for the production of commodity items such as grains or livestock fodder [Nicholls, 1997]. In addition, plants grown in this manner would not be exposed to contaminated soil and their only potential to become contaminated is from irrigation with contaminated groundwater.

Areas consisting of made land, where there is abundant debris and cobbles with little or no soil, would also not lend themselves to mechanized agriculture. In the absence of mechanized agriculture, commodity food items and fodder are not likely crops. However, it would be difficult to exclude vegetable gardens from scenarios at such sites. In addition, it would be difficult to justify exclusion of livestock forage from scenarios at such sites.

Agriculture pathways could be excluded if the soil is too toxic or inhospitable to plants. For example, no agriculture is apt to occur on the bed of a dry salt lake. In addition, crops are not apt to be grown in made land that contains such a high percentage of concrete materials that extraordinary efforts would be required to maintain the soil pH in a range that is tolerated by plants.

If the soil at this site can be documented to show that it would not support the resident farmers' agricultural efforts, this pathway should be eliminated or modified.

Documentation to be Submitted to NRC

Soil Unsuitable for Agriculture: NRCS (Soil Conversation Service [SCS]) or independent consultant report that shows quality of soil is poorer than the standards listed for this use.

6.2.2.2 Is Topography Suitable for Agriculture?

In the past few hundred years, the Dutch built dikes and converted shoals into productive farmlands. Today, explosives and earth-moving equipment can easily change features of the landscape, making it suitable for agricultural or residential use.

Consequently, locality or accessibility may form a basis for eliminating certain agricultural pathways from scenarios in the next century, but not for a period of 1000 years.

Ignoring the fact that topography may change with time as a result of civil engineering projects, there are probable limits to the types of terrain where mechanized agriculture can be used. Tractors will likely always be unstable on slopes, so there will always be a practical limit on the slopes that can be put under mechanized agriculture. In the absence of mechanized agriculture, persons are more likely to practice gardening than to grow commodity food items. They are also more likely to allow livestock to forage than to grow fodder crops.

There isn't a predictable maximum safe slope that tractors may traverse without the danger of rollover. However, operating a tractor on a 30 degree (2 to 1) slope is hazardous to the point that the average member of the critical group is not likely to attempt it.

If the topography at the site is too steep or too erratic to support the type of farming expected within the resident farmer scenario, the agricultural pathway should be removed or modified in accordance with this finding. There may also be aspects of the topography that would limit farming or other specific activities at the site.

Documentation to be Submitted to NRC

Topography Unsuitable for Agriculture: USGS or similar topographic map, hand-drawn map, or description that provides enough detail to illustrate the topography that limits farming at this site.

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7.0 Summary

The process presented in this document is an extension of the NUREG-1549 screening framework. It uses a logical step-by-step procedure for introducing site-specific information to develop alternate scenarios by eliminating pathways from the default resident farmer scenario. As the process schematic leads the user through the steps required to remove pathways, iterative dose assessments assure that no more information than is necessary will be assembled and analyzed for this purpose. Once the TEDE to an average member of the critical group drops below 25 mrem/yr, the process is completed and the user may proceed to license termination. Following the initial dose assessment and each of the iterative dose assessments, sensitivity analyses help the user introduce evidence that can rule out those pathways that are responsible for the high dose.

Physical and cultural information are introduced to answer a series of questions about the site. The future use of the land may be key to what assumptions the user can make about the starting scenario. Information on current land use, past land use, and a history of land use changes can be used to determine the probable future use of the land. If the TEDE to an average member of the critical group persists at a dose above 25 mrem/yr for a period longer than 100 years, future land use cannot be predicted and the user would start with the resident farmer scenario. If the future land use can reasonably be predicted to be either urban or industrial, the resident farmer scenario can be bypassed, allowing the user to concentrate on these two simpler scenarios.

The residential farmer scenario is meant to be applied to sites with land and water contamination and the building occupancy scenario is to be applied to sites with contaminated structures. In a resident farmer scenario, the most important aspect of the physical nature of the site is the nature and availability of water. The answers to each of four critical questions about water at the site can determine if major pathways can be removed from the scenario. If groundwater is not available, all of the pathways that rely on groundwater as a key component can be removed: irrigation, aquatic, and drinking. If groundwater is not suitable for aquatic life, the aquatic pathway can be removed. If groundwater is not suitable for agriculture, irrigation and drinking water pathways can be removed. If the water is not potable, the drinking water pathway can be removed. Detailed discussion is presented to help the user answer these questions, to understand the standards that have to be met for this pathway to be ruled out, and the documentation that must be presented to the NRC.

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