0015664
RHO-BWI-C-62
Volume I
1 of 2

Site Locality Identification Study: Hanford Site

Volume I: Methodology, Guidelines, And Screening

Woodward-Clyde Consultants

Prepared for the United States
Department of Energy
Under Contract DE-AC06-77RL01030

Rockwell International

Rockwell Hanford Operations
Energy Systems Group
Richland, WA 99352

Rockwell International

Rockwell Hanford Operations
Energy Systems Group
Richland, WA 99352

RHO-BWI-C-62
Volume I

SITE LOCALITY IDENTIFICATION STUDY: HANFORD SITE

VOLUME I: METHODOLOGY, GUIDELINES, AND SCREENING

by

Staff

Woodward-Clyde Consultants

July 1980

Prepared for Rockwell Hanford Operations
A Prime Contractor to U.S. Department of Energy,
Under Contract Number DE-AC06-77RL01030

NOTICE

WOODWARD-CLYDE CONSULTANTS
Consulting Engineers, Geologists, and Environmental Scientists
Three Embarcadero Center, Suite 700
San Francisco, California 94111

PREFACE

In 1976, the U.S. Department of Energy (DOE) created the National Waste Terminal Storage (NWTS) Program to provide a comprehensive solution to the problem of commercial nuclear waste isolation. One of the elements of the NWTS Program was the analysis of the feasibility of siting a repository on the Hanford Site. The Hanford Site was selected for study because of its present commitment to nuclear waste management activities and the necessary dedication of this site to this commitment in the future.

In 1976 and 1977, preliminary investigations indicated that the Hanford Site indeed possessed many geologic characteristics favorable to the siting of a nuclear waste repository. Thus, in 1978, a study was initiated to identify site localities within the Hanford Site where a repository for nuclear waste could be sited. This study consisted of a series of screening steps that progressively reduced the land area to be subjected to further study based on geotechnical, safety, socioeconomic, and statutory guidelines.

Guidelines were developed for each screening step to provide a numerical basis for attaining basic programmatic objectives and to represent specific levels of achievement. Two types of guidelines were developed; inclusionary and classifying. Under inclusionary guidelines, candidate localities are included if they meet defined minimum levels of achievements allowable based on limitations by regulatory or statutory requirements, technological limitations, or gross economic considerations. Classifying guidelines were defined as those not requiring a specific level of achievement, but which provided a basis for differentiating between prospective sites based on a more subjective evaluation.

These guidelines and specific considerations were developed by the Basalt Waste Isolation Project (BWIP) in parallel with the Office of Nuclear Waste Isolation's (ONWI) site-qualification criteria (ONWI-33 (2), 1979). The similarities of the BWIP considerations with ONWI-33 (2) are shown in Table A. It should be noted that the ONWI criteria refer to repository sites, while the BWIP considerations have been used to evaluate the acceptability of site localities within which one or more repository sites may potentially be located. Many of these BWIP considerations are site specific and not applicable to other non-basalt locations.

As a result of the site identification study, five site localities were identified within the boundary of the Hanford Site (Figure A). The proposed site localities meet the guidelines and specific considerations developed by BWIP and the ONWI site-qualification criteria.

The site identification study was conducted by Woodward-Clyde Consultants under the direction of Rockwell Hanford Operations. Volume I of this report contains the details of this study. In support thereof, a comprehensive listing of annotated references was compiled. Those publications, papers, and maps necessary to understanding the site study have been listed in Volume II. Supporting geologic and hydrologic studies conducted during the site identification study are reported elsewhere.

The next step in the site-identification process is to examine which of these site localities have preferential attributes that make them more acceptable for a waste isolation repository. This step is presently under way.

Dr. Raul A. Deju
Rockwell Hanford Operations

TABLE A

COMPARISON OF ONWI-33(2) SITE QUALIFICATION CRITERIA AND AND BWIP SCREENING CONSIDERATIONS

ONWI-33(2) Site Qualification Criteria, Draft, November 21, 1979	BWIP Site Identification Consideration	
2.1 Site Geometry		
The repository site shall be located in a geologic environment with geometry adequate for repository placement		
a. Minimum depth	Stratigraphic Characteristics	
b. Thickness of host rock	a. Bedrock dip	Evaluate areas on basis of bedrock dip:
c. Lateral extent of host rock units		A = 0 to 5 degrees
		B = 5 to 10 degrees
		C = >10 degrees
	b. Presence of suitable stratigraphic characteristics	Include areas where basalt flows with desirable internal structure, density, porosity, extent, continuity, etc. are >100 feet thick within the proposed repository depth zone
	c. Thickness of underlying basalt	Include areas where thickness of underlying repository host rock-type material at the repository depth is >500 feet
	Erosion/Denudation	
	Location with respect to potential areas of erosion or denudation	a. Include areas >0.5 mile from steep-walled canyons or slopes
		b. Evaluate areas on basis of elevation of underground repository above base level
2.2 Tectonic Environment		
The repository site shall be located such that credible tectonic events can be shown to cause no unacceptable reduction in repository performance		

TABLE A (Continued)

ONWI-33(2) Site Qualification Criteria, Draft, November 21, 1979	BWIP Site Identification Consideration	
a. Ground motion from the maximum credible earthquake will not have an unacceptable adverse impact on repository performance	<u>Ground Motion</u>	
	Location with respect to potential earthquake sources and estimated levels of ground motion	a. Include areas that may be subject to 40% g peak surface acceleration from known and interpreted earthquake sources
		b. Include areas >12 miles from felt epicenters >MM V and >6 miles from instrumental epicenters magnitude 4.0 which occur in concentrations or clusters as interpreted from historical earthquake epicenter plot maps
		c. Evaluate areas and their locations with respect to isolated earthquakes of epicentral intensities MMV and magnitude <4.0 based on estimated location errors and geologic and tectonic setting
		d. Evaluate areas and their locations with respect to shallow (>35-mile depth) microearthquakes based on location error, geologic and tectonic setting, and local and regional stress regime
b. Quaternary faults will have no unacceptable adverse impact	<u>Generation of New Faults</u>	
	Location with respect to future potentially capable tectonic structures	Include areas >5 miles from folds interpreted to be capable of forming new faults
	<u>Fault Rupture</u>	
	Horizontal and vertical distance from known faults interpreted to be capable	a. Include areas >5 miles, horizontally and vertically, from known faults interpreted to be capable

TABLE A (Continued)

ONWI-33(2) Site Qualification Criteria, Draft, November 21, 1979	BWIP Site Identification Consideration	
		b. Include areas >5 miles, horizontally and vertically, from known faults whose capabilities are unknown which have low potential for a capability evaluation
	Horizontal and vertical distance from known faults interpreted to be not capable and zones of fracturing and jointing	a. Include areas >0.5 mile from known faults interpreted to be not capable and from zones of fracturing and jointing
		b. Include areas >0.5 mile from known faults whose capabilities are unknown, but which have a high potential for a capability evaluation
	Location with respect to lineaments and postulated faults	Evaluate areas on basis of proximity to linear features (lineaments) as interpreted from remote sensing and geophysical data and postulated faults
c. Centers of Quaternary igneous activity will not have an unacceptable adverse impact	<u>Volcanic Effects</u>	
	Distance from Quaternary ash fall sources	Evaluate areas on basis of exposure to tephra fall from Quaternary stratovolcanoes:
		a. >150 miles to source
		b. 40 to 150 miles to source
		c. >40 miles to source
	<u>Future New Volcanic Activity</u>	
	Location with respect to probability of new volcanic sources	Evaluate areas on basis of probability and proximity to areas of interpreted new volcanic sources and effects

TABLE A (Continued)

ONWI-33(2) Site Qualification Criteria, Draft, November 21, 1979	BWIP Site Identification Consideration	
d. Long-term continuing uplift or subsidence will have no adverse impact	<u>Tectonic Movement</u>	
e. The tectonic environment can be evaluated to identify the tectonic elements and their impact with a high degree of confidence	Location with respect to potential bedrock folding	Evaluate areas on basis of proximity to bedrock folds (anticlines, synclines, or monoclines)
2.3 <u>Subsurface Hydrology and Geochemistry</u>		
The repository site shall have subsurface hydrologic and geochemical characteristics compatible with waste isolation		
a. The hydrologic and geochemical regime will prevent radionuclides from leaving the repository and being transported to the biosphere in amounts or levels above those specified	<u>Ground Water Contamination</u> Location with respect to natural and man-made discharge areas	Evaluate areas on basis of distance from discharge areas and estimated contaminant travel time
b. The hydrologic regime will allow construction of shafts and maintenance of shaft liners and seals by state-of-the-art means	The screening process does not provide adequate information to prepare a matching consideration for the equivalent ONWI criteria.	
c. Subsurface dissolution must be shown to have no unacceptable adverse impact on performance	Not applicable in basalt	
2.4 <u>Surface Hydrology</u>		
The surface hydrologic system, both during anticipated climatic cycles and during extreme natural phenomena, will not cause unacceptable adverse impact		
a. Nearby surface-water bodies, embayments, streams, floodplains, runoff, or drainage under present or future climatological conditions can be shown to present no unacceptable adverse impact	<u>Flooding</u> Height above selected flood level	a. Include areas outside of primary floodplains and published maximum flood levels b. Evaluate areas on basis of height above primary floodplains and estimated published maximum flood levels

TABLE A (Continued)

ONWI-33(2) Site Qualification Criteria, Draft, November 21, 1979	BWIP Site Identification Consideration	
		c. Evaluate areas on basis of location with respect to areas where catastrophic flooding (i.e., Spokane floods) has occurred in Quaternary time
2.5 Geologic Characteristics		
The repository site shall have geologic characteristics compatible with waste isolation		
a. Stratigraphic evaluation will include characterization of physical, structural, mineralogical, and geochemical features of the rock unit	Stratigraphic Characteristics (See 2.1)	
b. Host rock units will be shown to be compatible with anticipated chemical, thermal, and radiological stresses	Thermomechanical Effects Thickness of host rock flow and general characteristics	Evaluate flow thicknesses and characteristics of potential host rock
c. The repository shall be located without undue hazard to repository personnel	Reactor and Defense Facilities Location with respect to reactor and defense facilities, possible missile generators, and possible vapor sources	a. Include areas away from facilities occupying 18,000 acres or more b. Include areas >0.6 mile from potential explosion, fire, missile hazards c. Include areas >0.6 mile from potential sources of noxious or flammable vapors d. Evaluate areas on basis of proximity to hazardous facilities

TABLE A (Continued)

ONWI-33(2) Site Qualification Criteria, Draft, November 21, 1979	BWIP Site Identification Consideration	
2.6 Surface Characteristics		
The repository site and its surrounding area shall possess surface characteristics which are compatible with waste disposal		
a. Surface features will not adversely affect repository performance	Ground Failure	
	Location with respect to landslides and potential landslides	a. Include areas not on mapped landslides b. Evaluate areas on basis of probability of landsliding: A = Low probability of a landslide B = Slight probability of a landslide C = Higher probability of a landslide
	Characteristics of foundation conditions	Evaluate general foundation conditions: a. Bedrock area (0 to 20 feet consolidated material) b. Shallow alluvial area (20 to 100 feet unconsolidated material) c. Deep alluvial area (>100 feet unconsolidated material)
b. Surface features, combined with meteorological conditions, shall not affect access to the repository	Site Preparation (Surface)	
	Terrain ruggedness	Subjective evaluation for terrain characteristics (i.e., slope approximately 15%, relief and degree of dissection)

TABLE A (Continued)

ONWI-33(2) Site Qualification Criteria, Draft, November 21, 1979	BWIP Site Identification Consideration	
	Usable land area	Evaluate available land area for dominant site preparation costs, slope, local relief, degree of dissection, size of area, location and juxtaposition of relatively level areas, water supply, access, and amount of excavation and fill necessary to fit 2,400 acres of surface facilities
2.7 <u>Human Intrusion</u> The repository site shall be located so that likelihood of consequences of past or future human intrusion will cause no unacceptable adverse impact		
a. Future intrusion due to the site's containing, or appearing to contain, economically exploitable deposits shall not have adverse impact	<u>Subsurface Mineral Exploration and Extraction</u> Location with respect to existing and potential future mineral exploration and extraction	a. Include areas away from existing subsurface mineral extraction b. Evaluate areas on basis of proximity to potential future mineral exploration or extraction
b. The site shall be located so that exploration history can be defined and shown to have no adverse impact on performance	<u>Potential Significant or Incompatible Land Uses</u> Location with respect to potential future significant or incompatible land uses	Evaluate areas with respect to potential future uses. The evaluation will focus on agriculture: a. Potentially irrigable lands b. Arable soils c. Marginal soils d. Submarginal soils

TABLE A (Continued)

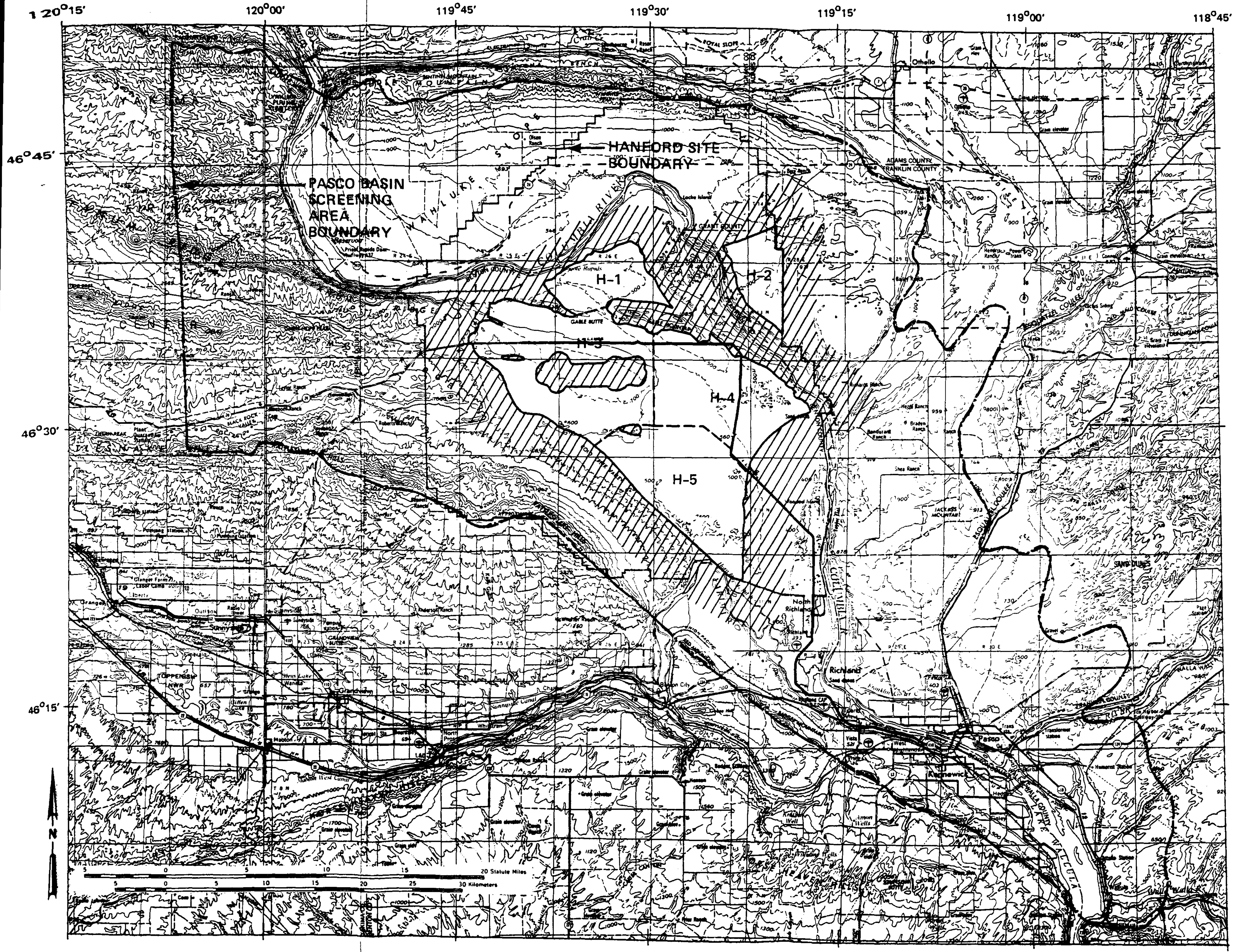
ONWI-33(2) Site Qualification Criteria, Draft, November 21, 1979	BWIP Site Identification Consideration	
c. The site shall be located on land for which the federal government can obtain ownership, can control access, and obtain ownership of all necessary surface and subsurface rights to assure that all surface and subsurface rights to assure that all surface and subsurface activities will not be adversely affected	(Primary instructions for BWIP were to evaluate the wholly owned and controlled, nuclear-dedicated Hanford Site for potential repository siting)	
2.8 <u>Proximity to Population Centers</u>		
The repository site shall have characteristics that tend to minimize the risk to the population from potential radiation exposure		
a. Transportation of nuclear material shall be considered as part of the repository system	(Transportation studies are starting in fiscal year 1980)	
b. The repository shall be located a distance away from urban areas	<u>Operational Radiation Release</u>	
	Distance from population	a. Include areas >3 miles from population >2,500
		b. Include areas >1 mile from any incorporated community
		c. Include areas >1 mile from any urbanized area
2.9 <u>Environment</u>		
The repository site shall be located with due consideration to potential environmental impacts and to prevent land-use conflicts		
a. Due consideration to potential environmental impacts must be made	<u>Protected Ecological Areas</u>	
	Location with respect to protected ecological areas	Include areas outside of designated protected ecological areas A = ≥18,000 acres B = 5,000 to 18,000 acres C = <5,000 acres

TABLE A (Continued)

ONWI-33(2) Site Qualification Criteria, Draft, November 21, 1979	BWIP Site Identification Consideration	
	Culturally Important Areas	
	Location with respect to designated scenic areas	Include areas greater than a calculated distance based on height of surface repository
	Location with respect to all designated areas	Include areas outside of designated culturally important areas A = ≥18,000 acres B = 5,000 to 18,000 acres C = <5,000 acres
	Protected and Endangered Species	
	Location with respect to protected and endangered species	Include areas outside of known locations of protected and endangered species
	Biologically Important Areas	
	Location with respect to biologically important areas	Evaluate areas based on proximity to biologically important areas
b. Siting shall reduce the likelihood or consequence of land-use conflicts	Existing Significant, Specialty, or Incompatible Land Uses	
	Location with respect to significant, specialty, or incompatible land uses	Include areas outside of mapped extent of specialty agriculture, irrigated agriculture, incompatible facilities, or other land uses that are locally limited and regionally significant
	Potential Significant or Incompatible Land Use	
	Location with respect to significant, specialty, or incompatible land uses	Evaluate areas with respect to potential future uses. The evaluation will focus on agriculture.

TABLE A (Continued)

ONWI-33(2) Site Qualification Criteria, Draft, November 21, 1979	BWIP Site Identification Consideration	
	<u>Site Preparation (Subsurface)</u>	
2.10 <u>Social, Political, and Economic</u>	Mining and excavation costs	Evaluate areas on basis of thickness of overburden, depth of shafts, host rock characteristics, configuration, and length of tunnels (spoil, etc.), excavated volume, etc.
Due considerations shall be given to social, political, and economic impacts on communities affected		
a. Social, political, and economic impacts must be managed by mitigation or compensation strategies	(This category of criteria was not addressed directly in the screening process, as it did not provide a means of distinguishing one site from another. Impact of all sites on the Hanford Site or the surrounding communities would be nearly the same)	
b. Conflicts with existing legal requirements must be avoided. The site must be accepted by the established processes of affected governments		
c. Adequate capability for handling and transportation requirements either exists or can be provided without impact on the affected communities	<u>Transportation</u>	
	Distance from transportation corridors	a. Include areas >0.6 mile from U.S. highways, interstate highways, railroads, and navigable waterways
		b. Evaluate areas on basis of proximity to transportation corridors
<u>No Comparable ONWI Criteria</u>	<u>Aircraft Impact</u>	
	Distance from airports	a. Include areas >5 miles from airports shown on state airport plans, accommodating aircraft >12,500 pounds gross weight or any military airport



EXPLANATION:

H-3 — Site locality

NOTES:

See Section IV–4.5 for rationale for the selection of Site Locality Boundaries

Base map from USGS 1:250,000 scale maps of Yakima and Walla Walla quadrangles

FIGURE A

SITE LOCALITIES ON THE HANFORD SITE

TABLE A (Continued)

ONWI-33(2) Site Qualification Criteria, Draft, November 21, 1979	BWIP Site Identification Consideration	
		b. For airports with 12,500 operations per year, but less than 50,000, include areas d miles from airport: $d = \sqrt{0.002 \text{ (operations)}}$
		c. For airports with 50,000 to 100,000 operations per year, 10 miles from airport. For airports with 100,000 operations per year, include areas d miles from airport $d = \sqrt{0.001 \text{ (operations)}}$
	Locations with respect to commercial jet routes and military routes	Evaluate areas with respect to proximity to high-frequency routes
	Location with respect to restricted airspace	Include areas away from the limits of restricted airspace defining military airspace usage
	Considerations not covered by ONWI-33(2)	
No Comparable ONWI Criteria	Induced Seismicity	
	Location with respect to sources of induced seismicity and potential future earthquake sources	a. Include areas >5 miles from existing reservoirs >100 feet deep b. Evaluate areas on basis of proximity to future reservoirs and interpreted sources of induced seismicity B = 0 to 5 miles
	National Defense and Security	
	Proximity to facilities or areas interpreted to be possible defense or security risks	Evaluate areas on basis of proximity to facilities or areas interpreted to be attractive military or terrorist targets

- Minimize adverse environmental and socioeconomic impact related to
  - Construction
  - Operation
  - Closure and surveillance.

The cost objective was derived from NEPA and the associated NRC regulations, which require an exposition of cost-benefit relationships and the manner in which they are considered in evaluating alternative sites. The cost objective was particularized by stage of repository development:

- Minimize system costs related to
  - Construction and impact mitigation
  - Operation and maintenance
  - Closure, decommissioning, and surveillance.

The three major objectives (safety, environmental, and cost) were considered to embrace the totality of concerns pertinent to a siting decision. Two major practical objectives of a siting decision are; maximize licensability of the proposed facility and maximize public acceptance. Both of these objectives were considered to be inherent in the safety, environmental, and cost objectives: that is, a site locality that achieves highly on all objectives should be licensable, and the siting decision should be acceptable to the public.

3.1.3 Considerations and Measures

For each of the general objectives established in the above step, one or more "considerations" or technical matters of concern were identified to describe the subject matter that must be addressed in order to orient the siting study toward achievement of the objectives. The considerations reflect characteristics, conditions, or processes in the study areas safety was then restated to bear on conditions or events that could be associated with the causes or consequences of radiation releases from a repository. These conditions or events were grouped into natural hazards, man-made hazards or events, and repository-induced events. The safety objective was then particularized to state:

- Maximize public health and safety in relation to
  - Natural hazards
  - Man-made hazards and events
  - Repository-induced events.

Implied here is that achievement of this objective is related to the prevention or minimization of the possiblity or consequence of radiation releases to the biosphere. Other non-radioactive byproducts or emission streams, while thought not to be significant to repository siting, were also considered in this objective.

The environmental objective was derived from NEPA (42 USC 4341), which requires the appropriate federal agency (in this case, the NRC) to account for environmental factors in its decision-making process and to align its decisions reasonably with national environmental policy guidelines. In practice, this means that the site identification process pursued by an applicant for a NRC license must demonstrate avoidance and minimization of conflict with environmental values and that the site submitted for NRC review must be defendable in terms of a balance between environmental impacts and other siting considerations. "Environment" as used here refers to both the natural and man-made environments. The time frame covered by a NRC environmental review covers all phases of repository development, use, and decommissioning. Therefore, the environmental objective was particularized as:

establishment of objectives for the siting decision. The overall goal was to identify "suitable" sites for a nuclear waste repository and its associated surface facilities that have a high probability of being licensed. Existing and anticipated regulations, national and state environmental legislation, and principles of sound engineering practice provided basic guidance for the interpretation of the word "suitable" and, hence, for the articulation of more precise siting objectives. Each objective derived from this intitial interpretation was serially refined and restated in increasingly greater detail to reflect specific characteristics of the repository facilities, as well as conditions and concerns with the study area. The hierarchy of objectives thus established provided the framework for choosing and applying guidelines to identify site localities.

In a November 1978 proposed general statement of policy for licensing requirements for a repository (NRC, 1978a), the NRC indicated that the proposed repository application would require a site safety review and would be required to comply with the National Environmental Policy Act (NEPA). From these conditions and from past siting and licensing experience with the NRC, it was deduced that, for a repository site to be accepted as suitable by the NRC, the site must meet the following objectives:

- Maximize public health and safety
- Minimize adverse environmental and socioeconomic impact
- Minimize cost necessary to attain the requisite levels of safety, as well as costs of mitigation.

The overriding concern for safety considers the possibility that, through an accident or routine operation, unacceptably high levels of radioactivity will be released to the biosphere. The objective of maximizing public health and

- The design and operation of most surface facilities will be governed by existing safety and environmental licensing requirements, and the licensing requirements for the underground facility will be similar.

- Nominal design and performance characteristics of the repository have been estimated; these have been discussed previously as given basic information.

- The long-term, safety-related characteristics of the host rock system can be estimated and used in the selection of guidelines; similarly, appropriate judgments can be made regarding long-term social, economic, and political considerations applicable to repository siting.

- The repository will be designed for two time frames; a relatively short emplacement and retrieval phase and a much longer isolation phase.

- The site locality identification study will be based on available data; siting guidelines will be based on currently available technology.

It is further assumed that forthcoming repository licensing requirements will be written by, or adapted in the style of, the NRC. In the interim, existing NRC regulations pertaining to other nuclear fuel cycle facilities (mining, enrichment, fuel fabrication, power reactors, fuel reprocessing and fuel handling, and storage) provide a reasonable basis for estimating the scope of siting considerations and the degree of conservatism appropriate to repository licensing.

3.1.2 Objectives

The first step in the approach to develop guidelines was the

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Page

LIST OF TABLES

LIST OF FIGURES

SUMMARY

Presented in this report are the results of the site locality identification study for the Hanford Site using a screening process. To enable evaluation of the entire Hanford Site, the screening process was applied to a somewhat larger area; i.e., the Pasco Basin. The study consisted of a series of screening steps that progressively focused on smaller areas which are within the Hanford Site and which had a higher potential for containing suitable repository sites for nuclear waste than the areas not included for further study. Five site localities, designated H-1, H-2, H-3, H-4, H-5 (Figure A), varying in size from approximately 10 to 50 square miles, were identified on the Hanford Site. It is anticipated that each site locality may contain one or more candidate sites suitable for a nuclear waste repository.

The site locality identification study began with definition of objectives and the development of guidelines for screening. Three objectives were defined: a) maximize public health and safety; b) minimize adverse environmental and socioeconomic impacts; and c) minimize system costs. The screening guidelines have numerical values that provided the basis for the successive reduction of the area under study and to focus on smaller areas that had a higher likelihood of containing suitable sites.

The guidelines were developed to measure the achievement of the siting objectives. Twenty-eight considerations expressing areas of concern were identified under each objective (e.g., earthquake ground motion under public health and safety, culturally important areas under environmental impacts, site preparation costs under system costs), and the guidelines were established to represent specific levels of achievement under

each consideration. Two varieties of guidelines were developed; inclusionary guidelines and classifying guidelines. The inclusionary guidelines established, or interpreted, minimum levels of achievement based on regulatory or statute requirements, technological limitations, or gross economic considerations. For example, areas included for further study and which lie outside of national parks and monuments were a guideline responsive to a statute or regulation prohibiting developments such as a repository in national parks and recognized the concerns under the consideration of culturally important areas. Also included for further study are areas interpreted to be subject to moderate to low earthquake ground motion (<40% g horizontal acceleration); this guideline was responsive essentially to gross economic considerations, and in part to technological limitations, that recognized the concerns for earthquake ground motion. Classifying guidelines were those for which a finite level of achievement was not required, but which provided bases for differentiating between siting areas. For example, the subjective evaluation of distance to ground-water discharge areas was used to differentiate between siting areas and to guide professional judgments, although no minimum distance was established.

The approach to guideline development (applicable to the entire siting study) was selected to meet anticipated regulatory agency requirements for an objective and systematic site identification method and to provide traceability and documentation in the siting study record. For example, any site locality identified on the basis of these guidelines may be discussed and evaluated in terms of the siting objectives set forth at the outset of the study; the decision to include or remove any area or locality may be traced through the guidelines to systematically applied rules that are directly related to the objectives.

The screening process utilized the guidelines to reduce the area under consideration and identify areas for further study. Three basic screening steps were used to successively reduce the Pasco Basin screening area and identify the five site localities on the Hanford Site. Each step essentially consisted of two substeps: a) selection of the guidelines to be applied in that step; and b) manual application of the guidelines on overlay maps of the area under consideration. A composite overlay, representing the application of all the guidelines used in a given screening step, identified the area to be included for further study in subsequent screening steps. All inclusionary guidelines were given equal weight during the screening process. An inherent aspect of screening processes is that weighting is not practical during application of the guidelines. This methodology presumes that if no suitable sites are identified within the stated guidelines, then either no suitable sites exist, or the guidelines are too strict. However, in the Hanford Site screening process, five site localities were identified.

The first step in screening consisted of the application of 14 inclusionary guidelines (representing 9 considerations) to the siting area to define one large candidate area of approximately 500 square miles. More than 50% of the candidate area occurred within the Hanford Site.

In the second step of screening, the boundaries of the candidate area were transferred to larger scale maps, and seven inclusionary guidelines (representing seven considerations of the siting objectives) were applied to define four subareas within the candidate area. The subareas ranged from approximately 10 square miles to approximately 200 square miles for one which occurred almost entirely within the Hanford Site.

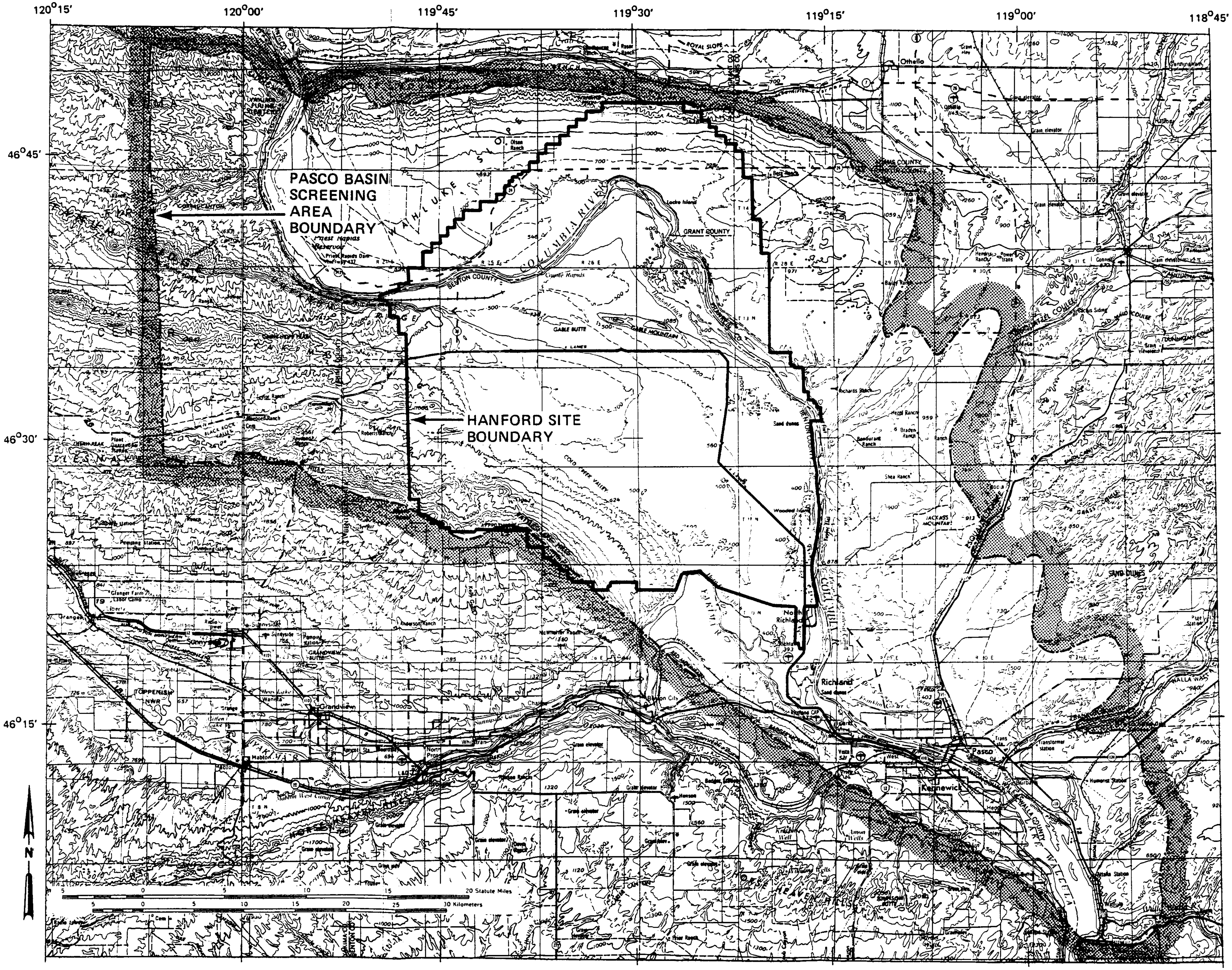
The third step of screening consisted of the application of classifying guidelines to the subareas for the purpose of evaluating them with respect to the identification of site localities. Those subareas or portions of subareas lying outside the Hanford Site were considered to be not obviously superior to the subareas occurring within the boundaries. Further evaluation of the subareas then concentrated on the Hanford Site, and the impacts of the inclusionary and classifying guidelines affecting the subsurface were compared to those affecting only the surface. Based on an evaluation of the combined effect of the application of surface and subsurface guidelines, the five site localities shown on Figure A were identified on the Hanford Site. Future siting efforts in the five site localities on the Hanford Site will include the identification of one or more candidate repository sites in each of the localities.

I. INTRODUCTION

1. GENERAL

Under Prime Contract DE-AC06-77RL01030 to the U.S. Department of Energy (abbreviated DOE in this report), Rockwell Hanford Operations (abbreviated Rockwell) is investigating the concept of radioactive waste storage in basalt. As a part of this investigation, the study described here was to define site localities within which candidate sites for the disposal of radioactive wastes may be identified. The study area was the Hanford Site, which extends over approximately 570 square miles in eastern Washington (see Figure I-1). The site localities identified in this study range in size from 10 square miles to 50 square miles. In future steps of the study, candidate sites of approximately 10 square miles will be identified within the site localities.

For siting purposes, a repository was considered to consist of surface and subsurface facilities capable of receiving daily rail and/or truck shipments of radioactive waste contained in shielded shipping casks, removing the waste from the shipping cask, transferring the waste into a transport shaft or tunnel which would provide access to an underground storage area, and placing the waste within the underground storage area, most likely in specially prepared boreholes. In addition to the waste repository, the candidate sites, which would be located in the site localities, should be capable of accommodating a facility for the packaging of high-, intermediate-, and low-level waste and a facility for storage of radioactive waste prior to packaging, possibly consisting of water basins similar to those in use at light water nuclear reactor plants.



NOTE:
Base map from USGS 1:250,000 scale maps of Yakima and Walla Walla quadrangles.

FIGURE I-1

PASCO BASIN SCREENING AREA AND HANFORD SITE BOUNDARIES

2. METHODOLOGY

The overall goal of the study was to identify site localities that have a high likelihood of containing suitable sites for locating a radioactive waste repository. Because the size of the site localities was considerably smaller than the study area (the Hanford Site), a systematic methodology was required that would permit focusing on progressively smaller areas having higher likelihood of containing suitable sites than the areas removed from further consideration. Moreover, the methodology should be traceable and flexible so that revisions could be made to accommodate possible changes in objectives, licensing framework, technology of waste management, or socioeconomic values.

A methodology based on decision analysis was established to accomplish the overall goal. The methodology has the requisite features outlined above and is described in the following chapters of this volume. In essence, the methodology consisted of the following items:

- Identification of objectives and development of guidelines for application to the study area;
- A multi-step screening process that permits the application of guidelines to smaller and smaller areas until the site localities have been identified;
- Development of a data base of appropriate scope and detail that could be utilized for defining the conditions within the areas defined in each substep of the screening process.

The assumptions, procedure, and results of the development of guidelines and the screening process are described in this volume. Development of a data base is described in Volume II.

It is important to note that the study described in this report concludes with the siting areas (the site localities) which are larger than repository candidate sites. Additional work will be necessary to identify candidate sites within the site localities. Thus, future steps in the site identification process will consist of candidate site identification followed by site evaluation, design, licensing, and construction.

An integral part of the siting study methodology was the quality assurance program. The program consisted of planned, systematically employed actions to assure that the consulting services conformed to the requirements of WCC, Rockwell, and Title 10, Code of Federal Regulations, Chapter 50 (10 CFR 50) Appendix B. The program was executed in accordance with controlled written policies, procedures, and instructions. The principal elements of the quality assurance program included organization, training, review and control, nonconformance and corrective action, protection, and documentation.

3. SCOPE OF THIS VOLUME

This report is organized into five sections and one appendix. The project definition and the scope of the study are described in Section I, Introduction. The approach, framework, and methodology for the siting process utilized in the study are described in Section II. The approach, methodology, and results of guideline development are described in Section III. The implementation and results of screening to obtain site localities on the Hanford Site are described in Section IV, and concluding remarks are given in Section V. Detailed discussions of the guidelines and their rationale are presented in the Appendix to this volume.

II. SITING PROCESS DESCRIPTION

1. GENERAL

The site identification process used for screening of the Pasco Basin to identify potential repository site localities on the Hanford Site is described in this section. The siting methodology for this study was designed to systematically and rapidly focus on areas where there is a high likelihood of finding suitable repository sites. Carried to completion (i.e., identification of candidate sites), the approach to the methodology would consist of the following:

- Definition of objectives and establishment of guidelines which form the basis for site locality identification;

- A screening process to identify candidate sites starting from the relatively large study area and progressively concentrating on smaller and smaller areas;

- A ranking process to preferentially order candidate sites based on a decision analysis approach.

The content of this study terminated with the identification of site localities on the Hanford Site, which is one step prior to the identification of candidate repository sites. The following discussions concentrate on the siting process to identify site localities, but also briefly consider the identification of candidate sites and their ranking.

2. FRAMEWORK

In developing a specific approach to repository siting on the Hanford Site, including the development of screening guidelines, the following general assumptions were applied:

- Licensing will be required for the proposed facility which will be under the authority of the U.S. Nuclear Regulatory Commission (NRC). The Department of Energy (DOE) will be the license applicant. The licensing process may also include reviews by other federal agencies, such as the U.S. Environmental Protection Agency (EPA) and the U.S. Army Corps of Engineers, which require specific permits. Licensing reviews may also be made by state agencies and other local jurisdictions where the repository will be located.

- The design of the surface facilities will be governed, as a minimum, by the current safety and environmental licensing requirements. Similar licensing requirements for the underground facility are not currently available. It is, however, anticipated that they would be as stringent as those for the surface facility and that certain additional constraints might be imposed, based on a substantially longer design life (extending over thousands of years).

- The operational characteristics of the repository have been based on present preconceptual design considerations and can be used to assess site suitability. The various components of the proposed repository will include surface and subsurface areas and may include a packaging facility and a lag storage facility. The depth below grade of the subsurface facilities is considered to be between 2,000 and 4,000 feet.

- The long-term, safety-related characteristics of the repository medium (basalt) can be adequately estimated and used in the selection of siting guidelines. Similarly, appropriate judgments can be made regarding social, economic, and political considerations applicable to repository siting.

- The siting study should consider two time frames. In the first time frame, the repository would be in operation over some length of time during which the stored wastes would be retrievable. In the second time frame, the radioactive waste placed in the repository would be permanently isolated from the biosphere to the maximum degree practicable. Specific numerical limits for the two time frames are yet to be established.

- The selection of guidelines and assessment of the conditions in the study area are based principally on currently available data.

3. SITING PROCESS METHODOLOGY

The siting process methodology, as stated previously, consisted primarily of three steps: a) the development of guidelines used in screening; b) the screening process to identify areas having a high likelihood of containing suitable nuclear waste repositories; and c) a ranking process to order candidate sites identified in the screening process. These steps are briefly described below.

A necessary part of the methodology which has significant impact on each step, was the collection, review, and cataloging of available published and unpublished data on the geology, tectonics, hydrology, land use, ecology, etc. of the study area. These data provided the necessary information to complete the steps of the siting process. The collection and review of these data were based on the following assumptions:

- The data reviewed consisted of readily available data generated to the present date;

- The review and evaluation of data were for probable utilization in a site identification process with the application of present-day technology;

- The coverage and detail of data could vary depending upon the area in question; the data utilized for a regional assessment may not be the same as the data utilized for assessing considerably smaller areas.

The process of the data collection used for this study and a catalog of the data considered for use in this study are given in Volume II, Data Cataloging.

3.1 Development of Screening Guidelines

The objective of this step in the siting process methodology was to establish guidelines for the screening process. The approach used in guideline development consisted of the following steps:

- Define the overall goal and objectives for the proposed repository and their relationship to the siting study;

- Define and establish the considerations that describe the concerns of each objective;

- Define measures for each consideration, and establish the appropriate numerical screening guidelines for each measure;

- Review the guidelines with respect to completeness and sensitivity to changes in basic information used to develop the guidelines;

- Select guidelines for use in the siting study.

Figure II-1 is a flow diagram illustrating the various steps in the development of screening guidelines. The relationships between the overall goal of the siting study, objectives, considerations, measures, and guidelines are illustrated in Figure II-2. These terms are defined in Table II-1.

3.2 Screening Process

The objective of screening was to systematically and rapidly focus on portions of the Hanford Site where the likelihood of finding suitable repository sites was high relative to other parts of the screening area. The process described here and in the example presented at the end of this section was designed to lead ultimately to the identification of specific candidate sites. This report, however, covers only the first few steps of screening leading to the identification of site localities.

On the completion of more detailed study of these site localities, specific candidate sites may be identified and evaluated using the process described below.

Each step of screening consisted of two sub-steps; selection of the guidelines to be applied in that step, and manual application of the guidelines on overlay maps of the study area. Two varieties of screening guidelines were used; inclusionary and classifying. Inclusionary guidelines are those for which a finite level of achievement must be reached

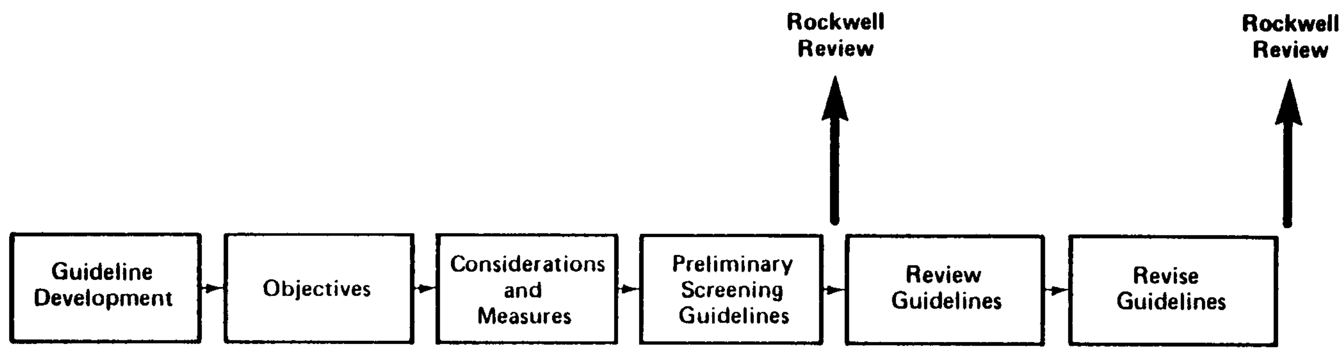


FIGURE II-1

STEPS IN GUIDELINE DEVELOPMENT

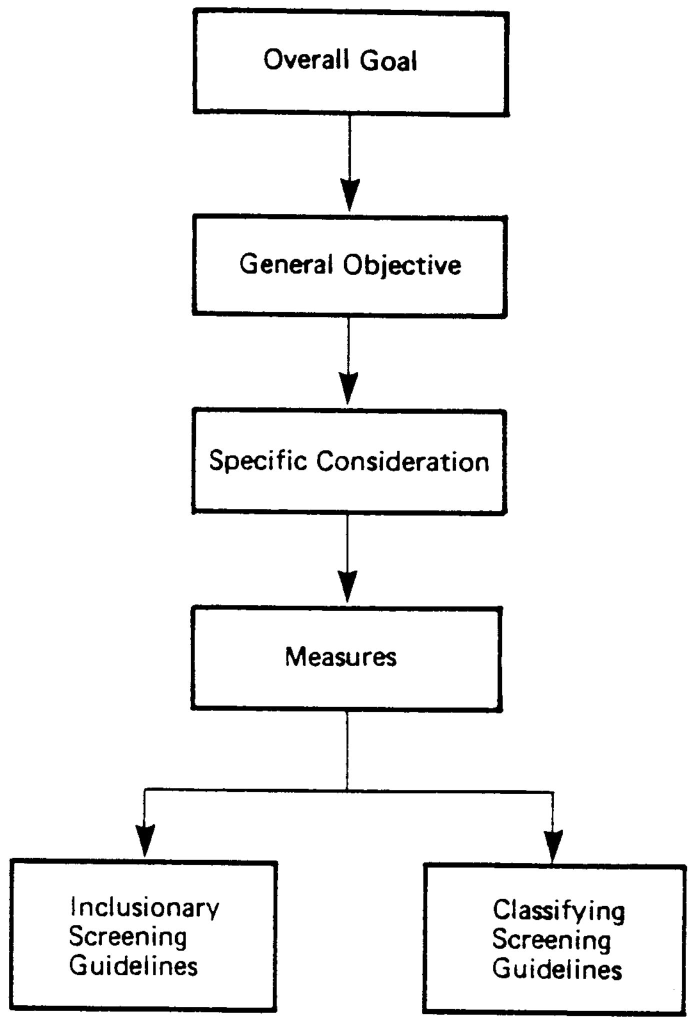


FIGURE II-2

RELATIONSHIPS OF TERMS USED IN SCREENING

TABLE II-I

DEFINITION OF TERMS USED IN GUIDELINE DEVELOPMENT

Overall Goal: The first step in the siting process is to develop a formal statement of the overall goal of the study; that is, identifying acceptable sites for a nuclear waste repository.

Objectives: A step in the siting process is to identify objectives that are to be addressed for meeting the overall goal (for example, maximizing public health and safety).

Consideration and Measure: A step in the siting process in which objective issues are broken down into specific considerations for which a measure can be identified, and those specific considerations for which some level of achievement is required are identified. For example, for surface faulting, which is a safety consideration for repositories, the measure was distance of site from capable faults.

Guidelines: A step in the siting process to establish guidelines which define the required level of achievement. These guidelines were used to include areas for further consideration and were referred to as inclusionary guidelines and classifying guidelines. These guidelines can change with time as they may depend on social, political, technological, and financial conditions. Additional siting work done in the future may use different and/or additional guidelines as conditions change.

Inclusionary Guidelines: Inclusionary guidelines were selected to provide a mechanism for successfully reducing the study area (or remaining portions of the study area) under consideration and were not used to permanently or definitely exclude areas. Each guideline was chosen to represent an acceptable level of achievement of the pertinent objective, in terms of the consideration under study. Areas which met these guidelines were included for further studies because they had a higher probability of containing acceptable sites. Areas which did not meet these guidelines may also contain acceptable sites, but have a lower probability of containing such sites. As the study focused on those areas which continued to have the highest probability of containing acceptable sites, those areas failing to meet the inclusionary guidelines were not retained for continued study at this time.

TABLE II-1 (Continued)

Classifying Guidelines: No minimum or maximum values are established for these guidelines. The interpreted value of the guidelines is used to classify each candidate area or subarea, with respect to the relative magnitude of additional safety safeguards and environmental restrictions that could be required to achieve an acceptable level of performance. The classifications are, in turn, used to identify groups of areas with similar characteristics as an aid to organizing more detailed analyses and field studies.

to meet siting objectives. An example is the proximity to hazardous facilities, a finite value likely to be imposed in licensing. Classifying guidelines are those for which a finite level of achievement is not required, but which can provide a basis for differentiation between areas. An example is potential land use, in which areas can be differentiated on the basis of their relative suitability for cultivation and irrigation in the future. It is preferable to locate potential repository sites in areas where the potential for intensive agricultural activity is low relative to other areas.

Areas identified by various screening guidelines were mapped on overlays. Portions of the study area that failed to meet inclusionary guidelines were shaded. When several overlays (each one showing a different set of mapped guidelines) were superimposed, all shaded portions were outlined and removed from further consideration in the study. The boundaries of areas defined by the mapping of classifying guidelines were transferred onto the composite map and was used in the evaluation and preferential identification of smaller portions of the study area considered in the subsequent step of screening. At each step of screening, the results of an overlay-composite process were transferred to larger scale maps which are suitable for more detailed evaluation and mapping. This process is schematically illustrated in Figure II-3. Section IV, following, is a hypothetical example of the application of screening guidelines.

In this study, a distinction was drawn between screening guidelines that apply only to surface facilities during the operation phase and those that apply to subsurface facilities during the operation and/or isolation phase. This distinction recognized that portions of the subsurface facility (e.g., horizontal galleries) may be located logically and safely deep

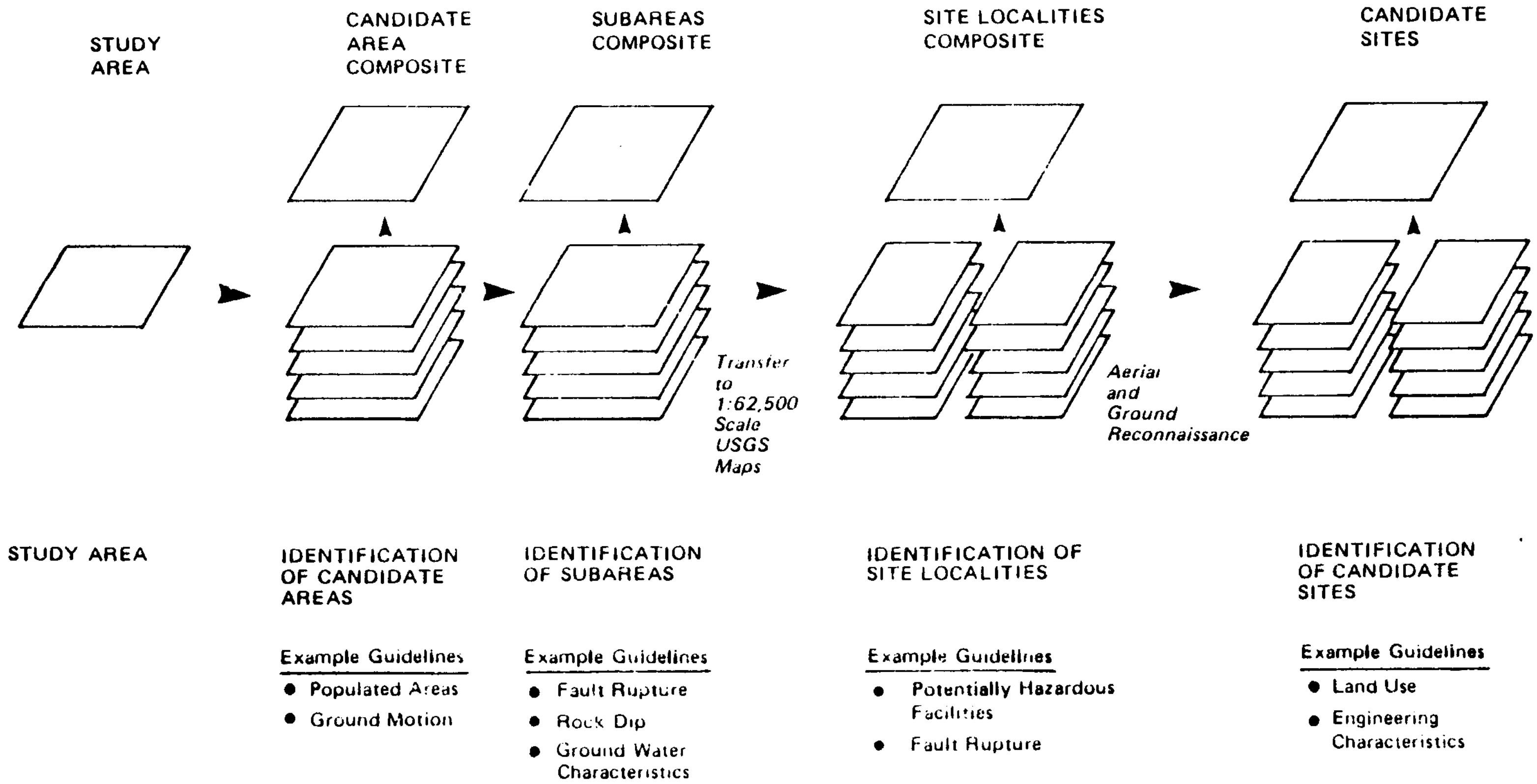


FIGURE II-3

ILLUSTRATIVE EXAMPLE OF SCREENING PROCESS beneath a portion of the surface which is not of itself suitable for siting a nuclear material handling facility. An example of this situation is a repository site located near a potentially hazardous industrial plant. For safety of operation of the waste handling and lag storage components, a minimum lateral setback of the surface facilities from the industrial plant could be required, but portions of the subsurface facility, protected by several thousand feet of basalt, might logically run beneath the industrial plant in question. In order to leave open the option of such a facility configuration, the surface-only guidelines were separately identified and carried forward into all steps of screening. This resulted in the identification of relatively small land areas (localities) having a variety of surface-subsurface siting options.

Areas in the Pasco Basin were screened in three steps to identify site localities on the Hanford Site: a) candidate areas were identified based on regional considerations and guidelines; b) subareas were identified based on more detailed and localized considerations and guidelines; and c) site localities were delineated within the areas remaining. The development of the considerations and guidelines used in screening are discussed in Section III, and implementation of the screening process is discussed in Section IV. Site localities (Figure IV-9) were drawn to define areas of approximately equal size as constrained by the configuration of the most favorable siting area.

3.3 Ranking Process

The screening process, carried to completion, would result in the identification of a small number of candidate repository sites. The purpose of ranking is to differentiate among candidate sites in terms of the siting objectives developed for the study. The current study terminated with the identification of site localities. The identification of candidate sites and their ranking would be the result of future work.

Ranking of the candidate sites may be based on a decision analysis approach. The basis for the approach is that decisions are made on the basis of the data at hand, the decision - maker's judgments about the likelihood of the occurrence of various consequences given those data, and his preferences for these consequences. The decision analysis approach breaks the problem into parts which are easier to analyze than the whole, and then puts the parts back together using a logical and systematic procedure. The procedure for putting the parts together depends on the decision makers. The experience, professional judgment, and knowledge of the individuals responsible to the decision maker for making the siting decision should be utilized. Decision analysis provides procedures for formalizing the judgments and preferences of the decision makers and integrating these elements to evaluate alternative courses of action.

Figure II-4 is a summary of the basic steps of ranking which are described below. A more detailed discussion of the decision analysis approach is presented by Keeney and Nair (1977).

Step 1: Structure the Problem. In this step, the alternatives (candidate sites) are identified, and the siting objectives and considerations, measures, and guidelines are chosen to identify and evaluate the sites.

Step 2: Determine the Magnitude and Likelihood of Impacts. In this step, the consequences (costs, environmental impacts)

STEP 1 Defining and Structuring the Problem

This step requires:

- Describing alternatives;
- Describing the existing environment;
- Identifying potential areas of impact;
- Establishing objectives (e.g., minimizing adverse impacts) and measures of effectiveness in achieving these objectives; and
- Identifying decision makers and interested parties.

The chronology of the solution process is also established, and options for collecting additional information are specified.

STEP 2 Determining the Magnitude and Likelihood of Impacts

- The impacts of each alternative are stated in terms of the specified measures of effectiveness.
- If there are uncertainties, the likelihood of each possible impact is quantified.

STEP 3 Determining the Preference Structure

- The preferences of the decision maker(s) with regard to the achievement of the various objectives are quantified.
- The value tradeoffs between competing objectives are assessed.

STEP 4 Evaluating the Alternatives

- Information obtained in the first three steps is rationally and consistently integrated to determine a course of action.

FIGURE II–4

STEPS IN THE RANKING PROCESS

of choosing each alternative candidate site are estimated, as are the uncertainty or variability of these estimates.

Step 3: Determine the Preference Structure. In this step, an assessment is made of the relative importance of different levels of the same impact or cost, of the relative importance of one impact versus another, and of the role of uncertainty in the decision process. This assessment establishes the framework and rules whereby the consequences of choosing one site over another will be evaluated.

Step 4: Evaluation and Sensitivity Analysis. This step combines the information from the preceding steps in a formal analysis that results in a rank order of sites. This rank order reflects the impacts and uncertainty surrounding any particular site choice, seen in the context of the preference structure assessed in Step 3. Sensitivity analysis of the ranking is then performed by varying the inputs to the evaluation and noting changes in the resultant rank order; the candidate sites or different points of view (preferences) that might be involved in evaluating the outcome of the siting study.

4. EXAMPLE OF THE SCREENING PROCESS

4.1 General

The purpose of this section is to describe the screening process and the application of screening guidelines. Following is a hypothetical description of the screening guidelines for an example related to fault rupture.

4.2 Application of Screening Guidelines

Most of the data used in screening are mapped. In general, this consists of the preparation of a base map, preparation or collection of source data maps, interpretation of these source data according to the guidelines, preparation of interpretive overlays to the base map, and superimposition of interpretive maps to yield a composite overlay. The composite overlay is a graphic display of all areas interpreted to meet guidelines related to a set of considerations studied in a given step of screening. Each step in screening corresponds to a change in map scale or a change in the evaluation technique as the study focuses on smaller and smaller areas having progressively higher likelihoods of containing suitable repository sites. At the end of each screening step, the result is mapped. In steps where inclusionary guidelines are applied, the composite overlay map is the evaluation technique and the result. In steps where classifying guidelines are applied, the guidelines are applied to maps and then evaluated. The steps normally employed in screening are listed below, and Table II-2 contains definitions of the area designations used.

- Identification of candidate areas
- Identification of subareas
- Identification of site localities
- Identification of candidate sites.

To illustrate the manner in which guidelines are applied in screening, the following example has been prepared. This example describes the consideration of fault rupture. It is a

TABLE II-2

AREA DESIGNATIONS USED IN SCREENING

Screening Area: For the purposes of this siting study, it is the Pasco Basin (approximately 1,600 square miles).

Study Area: The area covered by this repository candidate site locality identification study (approximately 570 square miles on the Hanford Site).

Candidate Area: Portions of the study area that have a higher potential of containing suitable sites for a waste repository than the rest of the study area. (Typically, a candidate area covers several hundred square miles and is derived by the application of inclusionary guidelines.)

Subarea: Portions of candidate areas that have a higher potential of containing sites than other portions. The subarea is typically defined on a larger scale map than that used to identify candidate areas and is derived by the application of inclusionary guidelines. Subareas represent refinements of candidate areas and may still cover more than a hundred square miles.

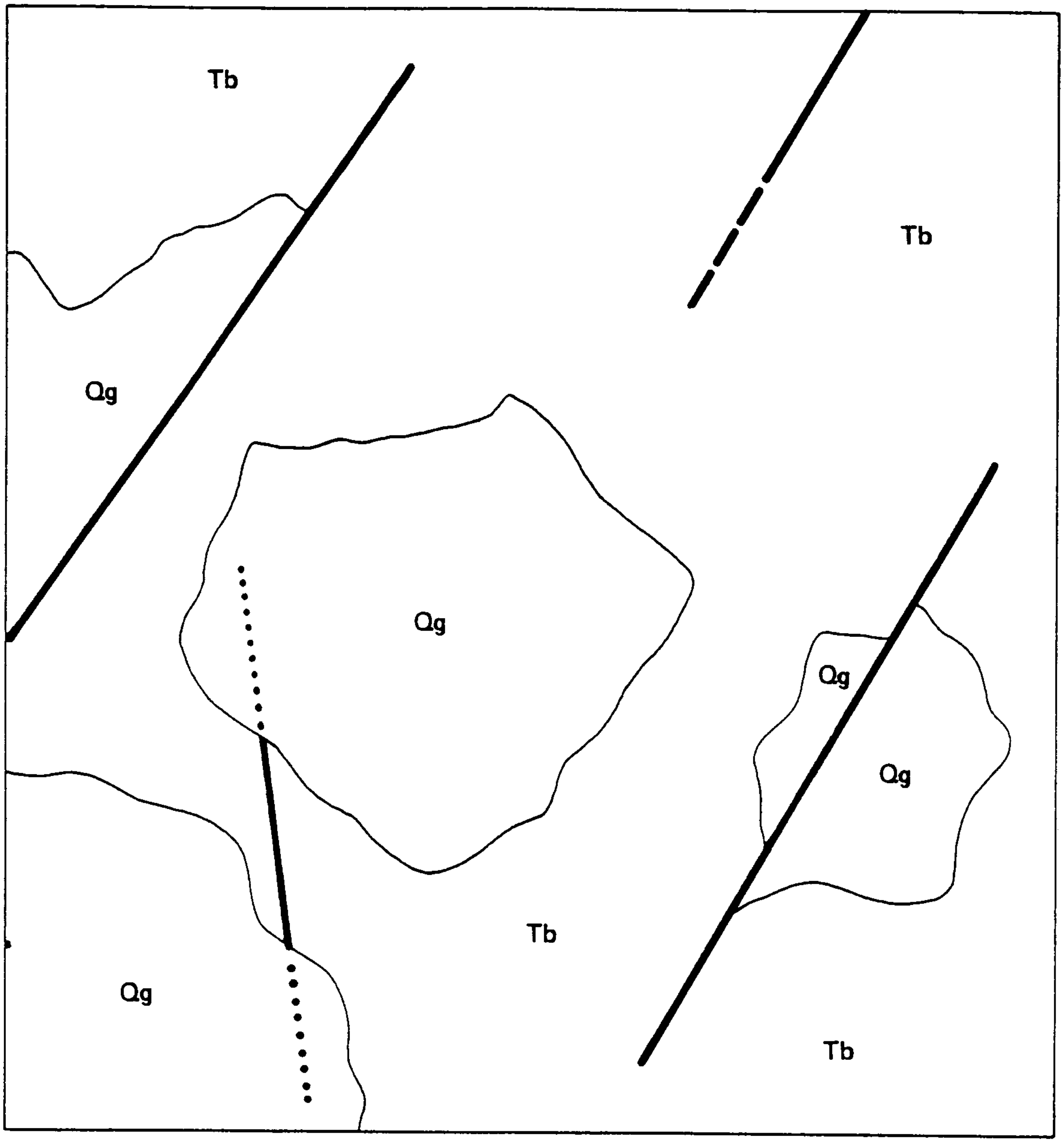
Site Locality: Portions of subareas that have a higher potential of containing suitable sites for a waste repository than the rest of the subarea. (Typically, a site locality covers an area up to 40 square miles.)

Candidate Site: A specific location within a site locality considered to be suitable for locating a repository. Not all site localities may contain candidate sites; this determination is made following field visits to site localities and a detailed characterization of the site localities. (Typically, a candidate site may cover an area up to 10 square miles.) It should be noted that the current siting study described in this report does not proceed to the identification of candidate sites, but terminates with site localities.

useful illustration because it involves the application of both inclusionary and classifying guidelines at several levels during the progress of a siting study. A discussion of the consideration of fault rupture and the development of the guidelines which describe it are presented in the appendix to this volume.

The consideration of fault rupture may be utilized at three significant levels in the siting study, and the guidelines may be applied to obtain candidate areas, site localities, and candidate sites. Prior to the application of the guidelines, however, an examination is made of the regional tectonic regime, geologic structure, and historical geology in order to evaluate the tectonic activity in the study area. Using this information, the first application of the guidelines involves the use of the inclusionary guideline, which includes for further study areas greater than 5 miles from known faults interpreted to be capable. To accomplish this, all known faults (observable on the scale of geologic maps being utilized) are identified on an overlay of the study Table II-2 area. This overlay becomes the data map depicting fault rupture (Figure II-5). The literature sources and the mapped relationships of the faults are used to evaluate the age of movement of the faults. The faults may be categorized as follows:

- Known faults interpreted to be capable (based on mapped relationships and/or literature);
- Known faults of unknown capability which appear to have a low potential for a fault capability evaluation;
- Known faults interpreted to be noncapable (based on mapped relationships and/or literature); and



Qg	Pleistocene - Holocene Deposits
Tb	Tertiary Rocks
(fault symbol)	Fault; dashed where approximate, dotted where concealed

0 5 Miles

FIGURE II-5

SCHEMATIC DRAWING OF DATA MAP FOR FAULT RUPTURE

- Known faults of unknown capability which appear to have a high potential for a fault capability evaluation.

The data map is then overlaid and lines are drawn representing the inclusionary guideline setback of 5 miles from known faults interpreted as being capable. The resulting map is the screening overlay for fault rupture which may be applied in the first step of screening (Figure II-3). When this map is overlaid with the other screening maps used in step one, the resulting areas outside of the composite overlays are designated candidate areas (Figure II-6).

Following the application of inclusionary guidelines (such as for fault rupture) to obtain candidate areas, other inclusionary guidelines and evaluations are utilized to successfully reduce the study area so that subareas remain. The next use of the consideration of fault rupture involves the application of inclusionary and classification guidelines to obtain site localities.

Using detailed geologic and structural geologic information available for the subareas, known faults are again identified and categorized. In addition, the data are examined to identify lineaments and postulated faults or structures. This information is compiled onto overlays of a large-scale base map of the subareas and the inclusionary guidelines are applied. If a known fault is interpreted as being potentially capable, a 5-mile inclusionary setback is applied (see Section III - 3.1.4). If a known fault is interpreted as being noncapable, the setback is one-half mile, as illustrated in Figure II-7. Following the application of the inclusionary guidelines, the remaining area is evaluated with respect to location and orientation of lineaments and postulated faults. That is, the areas farther away from postulated faults and lineaments are judged to be preferentially better than those closer.

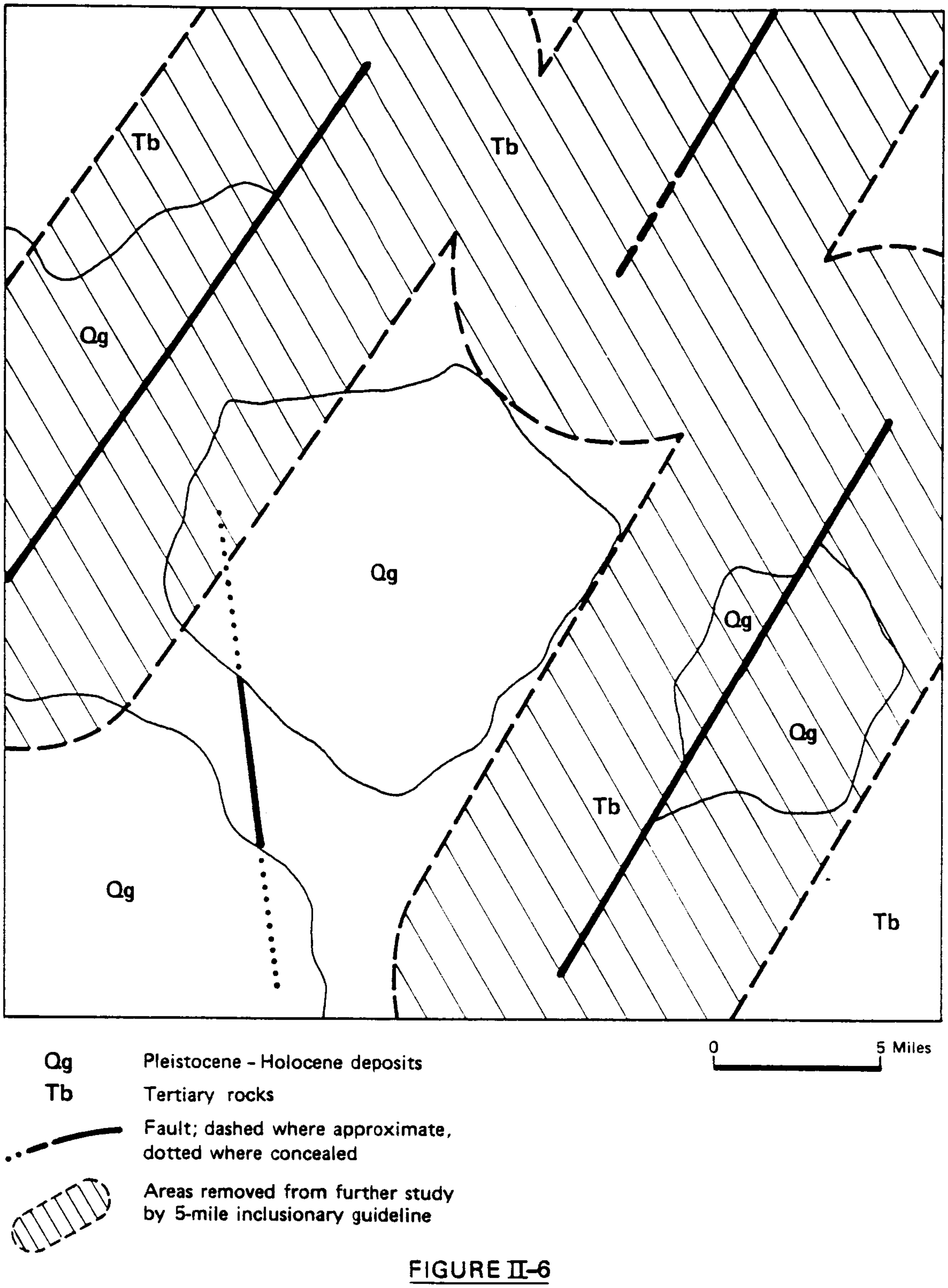
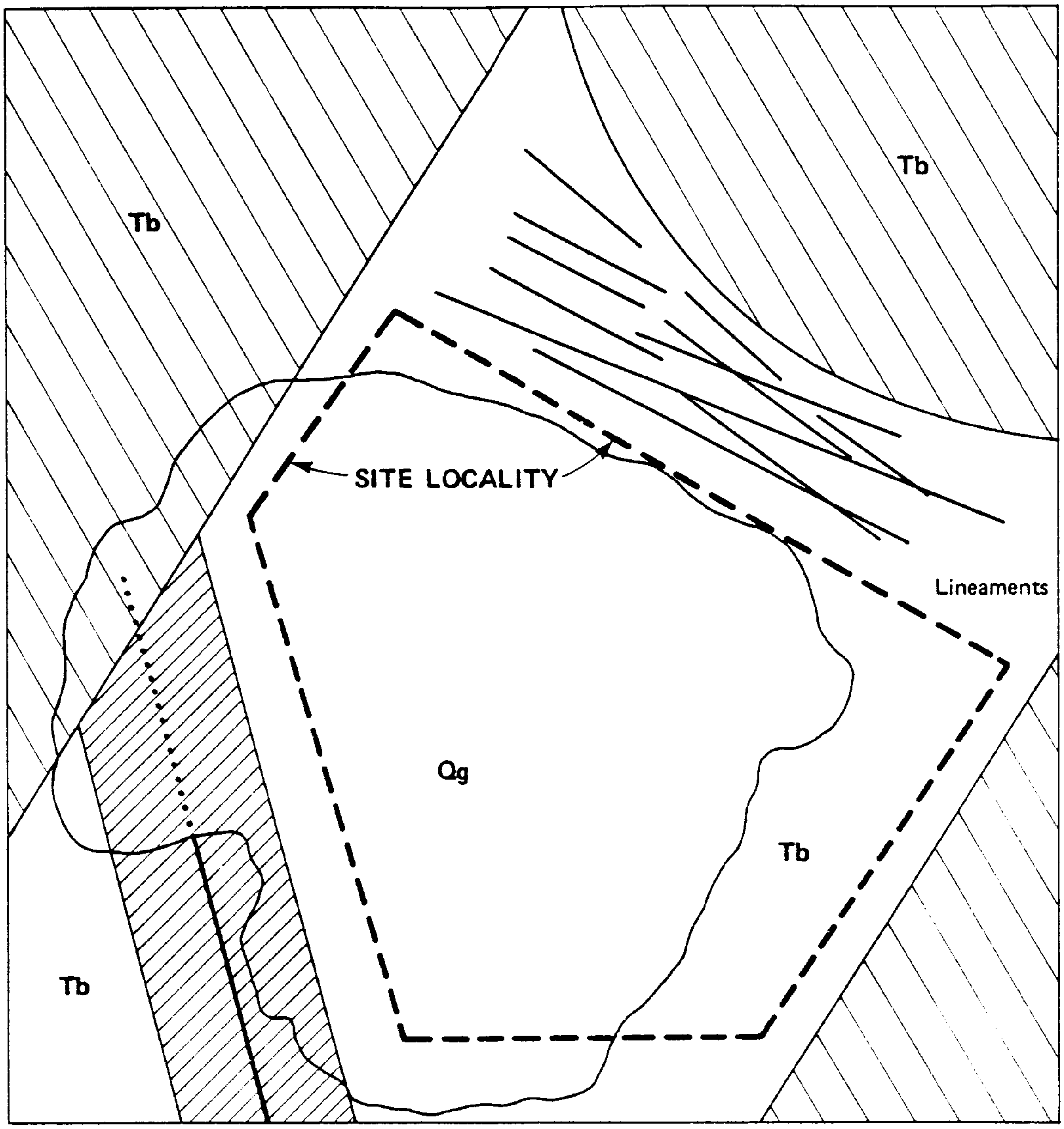


FIGURE II-6

SCHEMATIC DRAWING OF APPLICATION OF FIVE-MILE INCLUSIONARY GUIDELINE FOR FAULT RUPTURE



Qg	Pleistocene - Holocene deposits
Tb	Tertiary rocks
——— • • • •	Fault, dotted where concealed
(symbol)	Area removed from study through previous application of 5-mile inclusionary guideline
(symbol)	Area removed from further study by application of ½-mile inclusionary guideline

0 ½ 1 Mile

<u>FIGURE II-7</u>

SCHEMATIC DRAWING OF APPLICATION OF ONE-HALF-MILE INCLUSIONARY GUIDELINE AND CLASSIFYING GUIDELINE FOR FAULT RUPTURE TO IDENTIFY SITE LOCALITY

After the inclusionary and classifying guidelines for fault rupture are applied, the results are combined with the results of the application of other classifying as well as inclusionary guidelines. The areas remaining, following the application of all inclusionary guidelines, are evaluated, and site localities that have the most favorable characteristics are preferentially identified in the subareas. For example, using only the consideration of fault rupture (Figure II-7), a site locality may be identified because the area is not in close proximity to the lineaments. Thus, the location appears to offer the most favorable characteristics in the subarea regarding the consideration of fault rupture.

The final application of the consideration of fault rupture involves the subjective evaluation of the site localities' location and proximity to the mapped geologic structures. In this step, candidate sites are identified through the comparison of the site localities and their respective relative proximities to mapped faults and fault systems. Candidate sites may be identified in those parts of all site localities that appear to be the least affected by mapped geologic structures. Alternatively, candidate sites may be identified only in those site localities which appear to be relatively free of mapped structures or unaffected by mapped structures. Thus, the identified candidate sites would have a higher likelihood of containing suitable repository sites with respect to the consideration of fault rupture.

III. GUIDELINE DEVELOPMENT FOR SCREENING

1. GENERAL

The overall goal of the site locality identification study was to identify areas suitable for a nuclear waste repository. In the context of the current study, this meant identifying site localities on the Hanford Site through a screening process beginning with the Pasco Basin. Working objectives associated with this overall goal were a) to minimize adverse conditions affecting public health and safety, b) to minimize adverse environmental impacts, and c) to minimize the cost associated with the development and construction of such a repository. Corollaries to these objectives were a) that the identified site localities should be capable of containing candidate sites meeting the desired performance characteristics of a repository, and b) that these site localities are suitable within the regulatory, legislative, and public acceptance framework. These objectives and their corollaries provided the basis for the development of the siting guidelines.

The approach to the development of siting guidelines consisted of the following steps, which are illustrated in Figure III-1.

- Identify and evaluate the baseline conditions which described the proposed nuclear waste repository, its physical characteristics and properties, and its expected performance characteristics. These baseline conditions provided a basis for the development of guidelines.

- Develop the guidelines using the baseline information. These guidelines were developed to meet the objectives concerned with public health and safety, environmental

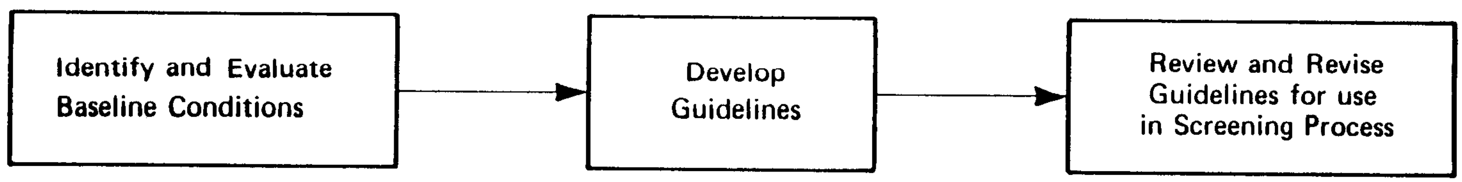


FIGURE III-1

APPROACH TO GUIDELINE DEVELOPMENT

impacts, and system cost. In addition, the guidelines were based on the existing licensing and regulatory framework for nuclear facilities and the anticipated framework for nuclear waste repositories. These guidelines were reviewed and the revised guidelines were were used in screening to identify site localities on the Hanford Site.

2. BASELINE CONDITIONS USED IN GUIDELINE DEVELOPMENT

An essential part of the development of siting guidelines was the identification and selection of basic information or data that established baseline conditions describing a reference nuclear waste repository. This information provided qualitative and quantitative descriptive and facility performance information which provided a basis for establishing numerical guidelines in the siting process. For example, the size or acreage of a desired facility must be estimated, otherwise areas might be identified which are physically too small to contain the proposed facility. Table III-1 is a summary of the baseline conditions used in guideline development.

2.1 Discussion

The baseline conditions summarized in Table III-1 were derived in two ways: a) by using Rockwell preconceptual repository design guidance and performance characteristics of the repository and waste; and b) by evaluations of the WCC project team. The following discussions briefly describe the categories of information contained in Table III-1 and the derivation of the baseline conditions in each category.

TABLE III-1

BASELINE CONDITIONS USED IN GUIDELINE DEVELOPMENT

Category	Item	Value or Condition Used in This Study	Source or Basis
Facility Description	Type of Facility	Receiving and handling facilities may have Cat. I components	Rockwell
	Total Area (surface facilities)	2.2 square miles	WCC
	Nominal Configuration (surface facilities)	1.6 x 1.4 miles	WCC
	Nominal Volume of Rock Spoil	24×10^6 to 32×10^6 cubic yards	Rockwell
	Power Supply	Dedicated	Rockwell
	Water Supply	Onsite wells, with cooling towers	Rockwell
	Depth to Repository	2,000 to 4,000 feet	Rockwell
	Area (subsurface)	Approx. 10 square miles	Rockwell
	Repository Expansion	Expansion of repository is probable in future	Rockwell
	Design Basis Earthquake	Facilities will have SSE/OBE[a] evaluation and reviews	Rockwell

TABLE III-1 (Continued)

Category	Item	Value or Condition Used in This Study	Source or Basis
Waste Description	Type of Waste	SURF, LL-TRU[b] (IL-TRU, HLW, CW as alternatives to SURF)	Rockwell
	Waste Form	Solid	Rockwell
	Total Time Period of Waste Inventory to be Stored	1973 through 2000	Rockwell
	Period of Waste Aging	10 years minimum	Rockwell
	Retrievability of Waste	Up to 25 years after emplacement	Rockwell
Repository Host Rock	Type	Basalt of the Columbia River Group	Rockwell Rockwell
	Flow Thickness	100 feet minimum	Rockwell
	Flow Dip	Less than 5 degrees is optimum condition	Rockwell
	Strata Continuity	Flows >100 feet thickness of formations within basalt of Columbia Plateau are continuous for at least a 10-mile radius from source of stratigraphic data	WCC
Performance Characteristics	Time Frame	Operational phase: 60 years; isolation phase up to 10,000 years	WCC

TABLE III-1 (Continued)

Category	Item	Value or Condition Used in This Study	Source or Basis
	Radiation Releases	Within 10 CFR 100, 10 CFR 20 during operational phase	WCC
	Natural and Man-Made	Sealing and plugging works and future boreholes do not penetrate repository Natural isolation barriers are effective over the isolation period	WCC
	Climate	Future climatic changes are considered to affect all areas of the Columbia Plateau equally	WCC
	Geologic and Tectonic Conditions	The geologic and tectonic processes, patterns, and conditions existing at present in the Columbia Plateau region are likely to be similar over the next 10,000 years	WCC
Legal and Licensing	Licensing Authority State Sanction	The repository will be licensed by and under the authority of the NRC State laws prohibiting nuclear waste storage are not considered for the technical purposes of this study	WCC

TABLE III-1 (Continued)

Category	Item	Value or Condition Used in This Study	Source or Basis
System Economics	Total Cost	Cost components are construction and site preparation cost, facility cost for design against natural and man-made hazards, cost of mitigation of impact, and operating costs	WCC
Environmental and Socio-Economic Conditions	Administrative Control	Considered to be similar to the present framework, through operating phase	WCC
Ownership and Control	Ownership and Control	Ownership and control of repository area and mineral and water rights will be under government authority	WCC

---

[a] SSE - Safe Shutdown Earthquake; OBE - Operating Basis Earthquake

[b] SURF - Spent unreprocessed fuel; LL-TRU - Low-level transuranic waste; IL-TRU - Intermediate-level transuranic waste; HLW - High-level waste; CW - Cladding waste

Source or Basis

Rockwell: Based on Rockwell files

WCC: Values based on WCC files or established by WCC project team

2.1.1 Facility Description

The majority of the information in this category deals with the physical dimensions, geometry, and types of facilities that are expected or planned for the surface and underground components of the nuclear waste repository. The majority of these data are derived from Rockwell files. These baseline conditions provide data significant to developing screening guidelines dealing with radiation releases, system costs, and environmental impacts. For example, the size of the surface facility will affect how guidelines are developed for assessing site preparation costs where topography, access, and usable land area may be important.

2.1.2 Waste Description

The data listed under waste description affect the radionuclide inventory and thus influence the potential emissions from repository facilities. A knowedge of potential emissions is important because this factor impacts the setback distance from population centers, which is an important siting guideline. Operating emissions have been found to be similar to those for a nuclear power plant; thus, the siting guidelines concerning operational radiation releases from a repository are similar. The analysis used to compare operating emissions of repositories and nuclear power plants is given in Volume II, Appendix D.

2.1.3 Repository Host Rock Characteristics

The baseline conditions provide information concerning the stratigraphic characteristics of the proposed repository in basalt. These data provide limits around which the guidelines can be built. For example, to require that the host rock must be within the Columbia Plateau basalt provides a stratigraphic limit around which guidelines can be developed. Likewise, a minimum flow thickness of 100 feet provides another stratigraphic limit.

2.1.4 Performance Characteristics

The information in this category includes reference conditions concerning the time frame of the repository, radiation releases, and the long-term stability of the repository and its environment.

A baseline condition that has a significant impact upon guideline development is the time frame. It is particularly important in the selection of guidelines concerned with long-term geologic stability.

Various proposals for the isolation phase have ranged from a few hundred years to 100,000 years (National Academy of Sciences, 1978). Such a wide range in time can affect guideline development. To arrive at an estimate for the isolation period time frame, the types of wastes expected to be stored in the repository and their decay rates were evaluated. This evaluation suggests that the radioactivity of the wastes decays by approximately five orders of magnitude in the period of 3,000 to 10,000 years. In addition, Cohen (1977) and the NRC (1978b) suggest that the health hazard of the radioactive waste decreases significantly between 100 and 1,000 years. Because of the uncertainty of the effects of low-level radiation and the toxic effects of the waste, 10,000 years was selected for the isolation time frame. The operational time frame of 60 years is an estimate.

2.1.5 Other Categories

The remaining categories are concerned with legal, economic, and socioeconomic conditions of the proposed repository and/or environment.

2.2 Information Considered But Not Used

In addition to developing the baseline conditions for use in guideline development, certain considerations regarding rock mechanics, natural hazards, etc., were found to be not applicable to the formulation of siting guidelines. These considerations either were generally too broad in scope and could not be used to differentiate one area from another or were too detailed such that data with which to differentiate areas do not exist. Table III-2 lists examples of specific considerations which were examined for use in guideline development, but were found to be not applicable or could not be utilized.

3. METHODOLOGY AND RESULTS OF GUIDELINE DEVELOPMENT

The methodology used to develop site locality identification guidelines and the results of guideline development are presented in this section. The word "guideline," as used here, means a set of rules chosen to guide a site identification process through screening and ranking. However, in the context of the site locality identification study for the Hanford Site, the guideline development described below concentrates on screening guidelines.

Some guidelines are said to be "inclusionary," meaning they are used to include areas for further consideration in the study. Other guidelines are said to be "classifying," meaning they are used to classify or characterize smaller areas as an aid to evaluation. More detailed definitions of the guidelines are included in Table II-1. The general approach used to develop the siting guidelines, a review of the implementation of this approach, and a presentation of results (the guidelines) follow.

TABLE III-2

EXAMPLES OF CONSIDERATION EXAMINED FOR
GUIDELINE DEVELOPMENT BUT NOT USED

Consideration	Remarks
Meteorite Impact	Meteorite impact is considered to have the same probability throughout the Pasco Basin and cannot be used to differentiate areas
Severe Weather	Severe weather, to the point of affecting repository facilities, was considered to be undifferentiable throughout the study area
Mechanical, Chemical, and Physical Interactions Between Waste and Rock	Information on these considerations will generally not be available in enough detail to differentiate areas on the basis of these properties and interactions
Future Socioeconomic Development	Adequate information does not exist to predict and assess future socioeconomic development for the isolation phase
Repository-Induced Seismicity	Available information regarding potential repository-induced seismicity will generally not be adequate to differentiate areas
Continental Glaciation	Direct effects of past continental glaciations have not affected the study area. Information does not exist to predict the future effects, if any, within the study area to adequately differentiate between areas

3.1 Approach, Implementation, and Results

The basic logic of the approach began with articulation of objectives of the repository siting decision and proceeded systematically to refine these objectives and identify means of measuring achievement of the objectives. The results of this process were the guidelines. Sites identified by the guidelines can be shown to meet minimum levels of achievement of the siting objectives used. The steps in the approach are shown schematically in Figure III-2.

This approach was selected to meet anticipated regulatory agency requirements for an objective and systematic site identification method and to provide a mechanism for traceability and documentation in the project record. For example, any site locality identified on the basis of these guidelines may be discussed and evaluated in terms of the siting objectives set forth at the outset of the study; and the decision to include or remove any area or locality may be traced through the guidelines to systematically applied rules that are directly related to siting objectives.

3.1.1 Key Assumptions

The key assumptions guiding the site locality identification study are provided in Section II of this volume and are restated below. They are important to the development of screening guidelines in providing additional bases for implementing the approach and methodology.

- The repository will require licensing involving the NRC, other federal agencies, and possible state and local entities.

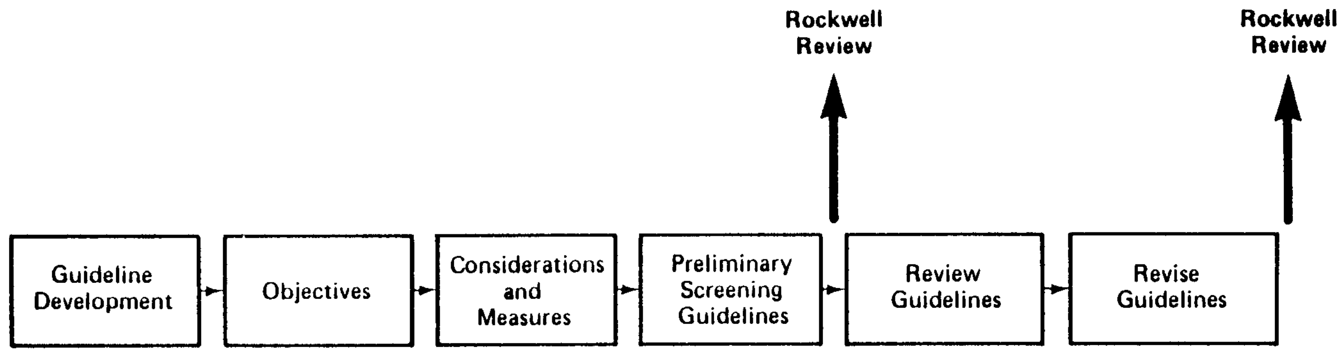


FIGURE III-2

STEPS IN GUIDELINE DEVELOPMENT

- The design and operation of most surface facilities will be governed by existing safety and environmental licensing requirements, and the licensing requirements for the underground facility will be similar.

- Nominal design and performance characteristics of the repository have been estimated; these have been discussed previously as given basic information.

- The long-term, safety-related characteristics of the host rock system can be estimated and used in the selection of guidelines; similarly, appropriate judgments can be made regarding long-term social, economic, and political considerations applicable to repository siting.

- The repository will be designed for two time frames; a relatively short emplacement and retrieval phase and a much longer isolation phase.

- The site locality identification study will be based on available data; siting guidelines will be based on currently available technology.

It is further assumed that forthcoming repository licensing requirements will be written by, or adapted in the style of, the NRC. In the interim, existing NRC regulations pertaining to other nuclear fuel cycle facilities (mining, enrichment, fuel fabrication, power reactors, fuel reprocessing and fuel handling, and storage) provide a reasonable basis for estimating the scope of siting considerations and the degree of conservatism appropriate to repository licensing.

3.1.2 Objectives

The first step in the approach to develop guidelines was the establishment of objectives for the siting decision. The overall goal was to identify "suitable" sites for a nuclear waste repository and its associated surface facilities that have a high probability of being licensed. Existing and anticipated regulations, national and state environmental legislation, and principles of sound engineering practice provided basic guidance for the interpretation of the word "suitable" and, hence, for the articulation of more precise siting objectives. Each objective derived from this intitial interpretation was serially refined and restated in increasingly greater detail to reflect specific characteristics of the repository facilities, as well as conditions and concerns with the study area. The hierarchy of objectives thus established provided the framework for choosing and applying guidelines to identify site localities.

In a November 1978 proposed general statement of policy for licensing requirements for a repository (NRC, 1978a), the NRC indicated that the proposed repository application would require a site safety review and would be required to comply with the National Environmental Policy Act (NEPA). From these conditions and from past siting and licensing experience with the NRC, it was deduced that, for a repository site to be accepted as suitable by the NRC, the site must meet the following objectives:

- Maximize public health and safety
- Minimize adverse environmental and socioeconomic impact
- Minimize cost necessary to attain the requisite levels of safety, as well as costs of mitigation.

The overriding concern for safety considers the possibility that, through an accident or routine operation, unacceptably high levels of radioactivity will be released to the biosphere. The objective of maximizing public health and safety was then restated to bear on conditions or events that could be associated with the causes or consequences of radiation releases from a repository. These conditions or events were grouped into natural hazards, man-made hazards or events, and repository-induced events. The safety objective was then particularized to state:

- Maximize public health and safety in relation to
  - Natural hazards
  - Man-made hazards and events
  - Repository-induced events.

Implied here is that achievement of this objective is related to the prevention or minimization of the possiblity or consequence of radiation releases to the biosphere. Other non-radioactive byproducts or emission streams, while thought not to be significant to repository siting, were also considered in this objective.

The environmental objective was derived from NEPA (42 USC 4341), which requires the appropriate federal agency (in this case, the NRC) to account for environmental factors in its decision-making process and to align its decisions reasonably with national environmental policy guidelines. In practice, this means that the site identification process pursued by an applicant for a NRC license must demonstrate avoidance and minimization of conflict with environmental values and that the site submitted for NRC review must be defendable in terms of a balance between environmental impacts and other siting considerations. "Environment" as used here refers to both the natural and man-made environments. The time frame covered by a NRC environmental review covers all phases of repository development, use, and decommissioning. Therefore, the environmental objective was particularized as:

- Minimize adverse environmental and socioeconomic impact related to
  - Construction
  - Operation
  - Closure and surveillance.

The cost objective was derived from NEPA and the associated NRC regulations, which require an exposition of cost-benefit relationships and the manner in which they are considered in evaluating alternative sites. The cost objective was particularized by stage of repository development:

- Minimize system costs related to
  - Construction and impact mitigation
  - Operation and maintenance
  - Closure, decommissioning, and surveillance.

The three major objectives (safety, environmental, and cost) were considered to embrace the totality of concerns pertinent to a siting decision. Two major practical objectives of a siting decision are; maximize licensability of the proposed facility and maximize public acceptance. Both of these objectives were considered to be inherent in the safety, environmental, and cost objectives: that is, a site locality that achieves highly on all objectives should be licensable, and the siting decision should be acceptable to the public.

3.1.3 Considerations and Measures

For each of the general objectives established in the above step, one or more "considerations" or technical matters of concern were identified to describe the subject matter that must be addressed in order to orient the siting study toward achievement of the objectives. The considerations reflect characteristics, conditions, or processes in the study areas that may affect suitability of a repository site. An example of a consideration related to a safety objective is fault rupture which is a technical matter that must be addressed in the siting study to assure achievement of the safety objective.

For each consideration, a measure was selected or developed to allow differentiation between areas or localities in terms of the consideration. Using fault rupture as an example, a measure may be stated as the distance from capable faults and those interpreted to be capable. This measure provides a means of assessing the degree to which a repository at any location in the study area can achieve the objective of maximizing safety in relation to fault rupture.

The selection of considerations was based on the nominal repository design and performance characteristic estimates, the pertinent regulatory guidance, and assessment of the natural and man-made characteristics of the study area. In addition, the set of considerations was limited to those considerations that might be expected to differ from one location to another. If a consideration was estimated to have an equal probability of occurrence or an equal manifestation of significance at all locations in the study area, it was not included in the set. For example, meteorite impact was estimated to have an equal probability of occurrence at all locations in the study area and was not included as a siting consideration. Likewise, if a condition or event was not known or expected to occur in the study area, it was not included as a siting consideration. For example, seismic sea waves are natural hazards that could affect the safety of operation of a repository, but they do not occur in or affect any portion of the study area. The identification of considerations took into account both the short-term operating time frame and the long-term isolation time frame.

The choice of measures for the considerations was based on prior NRC licensing experience and relevant regulatory positions, on the availability of data, and on the need to portray as many of the measures as possible on maps. In many cases, the measure was used as a proxy for the siting consideration or its associated effects. For example, the ground motion consideration is measured in miles; the motion itself is traditionally measured in terms of acceleration. In this study, the range of acceleration levels was inferred from a magnitude-acceleration attenuation relationship, and the magnitude was estimated from a fault rupture length-magnitude relationship. On a map, this consideration was portrayed as a distance (in miles) from faults of different lengths; the distance representing a range of acceleration levels.

The considerations and measures selected appear in Table III-3 and are further explained in the appendix to this volume.

3.1.4 Establishment of Guidelines

For some considerations, a specific level of achievement was required or implied by statute, regulation, technological limitations, or gross economic considerations. In these cases, a limit was established for the appropriate measure. The value of the measure at which the limit was set was an inclusionary guideline. The limit was used to identify locations that met the minimum requirements for that consideration. In the fault rupture example, it is generally accepted by the scientific community that most effects of fault rupture (surface rupture, lurching, severe deformation, etc.) occur within 5 miles of the capable structure (Bonilla, 1967). In addition, it is generally considered difficult to accommodate in design for fault rupture

TABLE III-3

SUMMARY OF GUIDELINES USED FOR SCREENING

Consideration	Measure	Guideline (3)	Possible Use To Obtain	Applicability and Time Frame (1) (2)
OBJECTIVE: MAXIMUM PUBLIC HEALTH AND SAFETY				
A) Natural Hazards				
1) Fault Rupture	a) Horizontal and vertical distance from known faults interpreted to be capable	a) Include areas >5 miles, horizontally and vertically, from known faults interpreted to be capable	Candidate Area Site Locality	O and I S and U
		b) Include areas >5 miles, horizontally and vertically, from known faults whose capabilities are unknown which have low potential for a capability evaluation	Candidate Area Site Locality	
	b) Horizontal and vertical distance from known faults interpreted to be not capable and zones of fracturing and jointing	a) Include areas >0.5 mile from known faults interpreted to be not capable and from zones of fracturing and jointing	Subarea	O and I S and U
		b) Include areas 0.5 mile from known faults whose capabilities are unknown, but which have a high potential for a capability evaluation	Subarea	
	c) Location with respect to lineaments and postulated faults	Evaluate areas on basis of proximity to linear features (lineaments) as interpreted from remote sensing and geophysical data and postulated faults	Site Locality	C and I S and U
2) Generation of New Faults	Location with respect to future potentially capable tectonic structures	Include areas >5 miles from folds interpreted to be capable of forming new faults	Candidate Area Site Locality	O and I S and U
3) Ground Motion	Location with respect to potential earthquake sources and estimated levels of ground motion	a) Include areas that may be subject to <40% g peak surface acceleration from known and interpreted earthquake sources	Candidate Area	O and I S and U

---

(1) O = Operation Phase (0 to 60 years); I = Isolation Phase (10,000 years)
(2) Applicability of guidelines to the surface (S) repository facilities and/or the subsurface (U) repository facilities
(3) See Appendix for discussion of quantitative aspects of guidelines

TABLE III-3 (Continued)

Consideration	Measure	Guideline (3)	Possible Use To Obtain	Applicability and Time Frame (1) (2)
		b) Include areas >12 miles from felt epicenters >MM V and >6 miles from instrumental epicenters > magnitude 4.0 which occur in concentrations or clusters as interpreted from historical earthquake epicenter plot maps	Candidate Area	O and I S and U
		c) Evaluate areas and their locations with respect to isolated earthquakes of epicentral intensities > MM V and magnitude >4.0, based on estimated location errors and geologic and tectonic setting	Site Locality	O and I S and U
		d) Evaluate areas and their locations with respect to shallow (< 35-mile depth) microearthquakes based on location error, geologic and tectonic setting, and local and regional stress regime	Site Locality	O and I S and U
4) **Tectonic Movement**	Location with respect to potential bedrock folding	Evaluate areas on basis of proximity to bedrock folds (anticlines, synclines, or monoclines)	Site Locality	I U
5) **Ground-Water Contamination**	Location with respect to natural and man-made discharge areas	Evaluate areas on basis of distance from discharge areas and interpreted contaminant travel time	Site Locality	I U
6) **Flooding**	Height above selected floor level	a) Include areas outside of primary floodplains and published maximum flood levels	Subarea Site Locality	O and I S and U
		b) Evaluate areas on basis of height above primary floodplains and estimated published maximum flood levels	Site Locality	I U
		c) Evaluate areas on basis of location with respect to areas where catastrophic flooding (i.e., Spokane Floods) has occurred in Quaternary time	Site Locality	I U

---

(1) O = Operation Phase (0 to 60 years); I = Isolation Phase (10,000 years)
(2) Applicability of guidelines to the surface (S) repository facilities and/or the subsurface (U) repository facilities
(3) See Appendix for discussion of quantitative aspects of guidelines

TABLE III-3 (Continued)

Consideration	Measure	Guideline (3)	Possible Use To Obtain	Applicability and Time Frame (1) (2)
7) Volcanic Effects	Distance from Quaternary ash fall sources	Evaluate areas on basis of exposure to tephra fall from Quaternary strato-volcanoes:		O S and U
		>150 miles to source		
		40 to 150 miles to source		
		<40 miles to source		
8) Future New Volcanic Activity	Location with respect to probability of new volcanic sources	Evaluate areas on basis of probability and proximity to areas of interpreted new volcanic sources and effects		I U
9) Ground Failure	a) Location with respect to landslides and potential landslides	a) Include areas not on mapped landslides	Subarea	O S
		b) Evaluate areas on basis of probability of landsliding:	Subarea	O S
		A = Low probability of a landslide		
		B = Slight probability of a landslide		
		C = Higher probability of a landslide		
	b) Characteristics of foundation conditions	Evaluate general foundation conditions:	Site Locality	O
		Bedrock area (0 to 20 feet consolidated material)		
		Shallow alluvial area (20 to 100 feet unconsolidated material)		
		Deep alluvial area (>100 feet unconsolidated material)		
10) Erosion/ Denudation	Location with respect to potential areas of erosion or denudation	a) Include areas >0.5 mile from steep-walled canyons or slopes	Subarea	I U
		b) Evaluate areas on basis of elevation of underground repository above base level:	Site Locality	I U

---

(1) O = Operation Phase (0 to 60 years); I = Isolation Phase (10,000 years)
(2) Applicability of guidelines to the surface (S) repository facilities and/or the subsurface (U) repository facilities
(3) See Appendix for discussion of quantitative aspects of guidelines

TABLE III-3 (Continued)

Consideration	Measure	Guideline (3)	Possible Use To Obtain	Applicability and Time Frame (1) (2)
		A = Repository elevation below base level (sea level)		
		B = Repository elevation above base level (sea level)		
11) Stratigraphic Characteristics	a) Bedrock dip	Evaluate areas on basis of bedrock dip: 0 to 5 degrees 5 to 10 degrees > 10 degrees	Site Locality	O U
	b) Presence of suitable stratigraphic characteristics	Include areas where basalt flows with desirable internal structure density, porosity, extent, continuity, etc. are >100 feet thick within the proposed repository depth zone	Site Locality	O and I U
	c) Thickness of underlying basalt	Include areas where thickness of underlying repository host rock-type material at the repository depth is >500 feet	Site Locality	O and I U
B) Man-Made Hazards				
1) Aircraft Impact	a) Distance from airports	a) Include areas >5 miles from airports shown on state airport plans, accommodating aircraft >12,500 pounds gross weight or any military airport	Candidate Area	O S
		b) For airports with >12,500 operations per year, but less than 50,000, include areas >d miles from airport: $d = \sqrt{0.002 \text{ (operations)}}$	Candidate Area	O S

---

(1) O = Operation Phase (0 to 60 years); I = Isolation Phase (10,000 years)
(2) Applicability of guidelines to the surface (S) repository facilities and/or the subsurface (U) repository facilities
(3) See Appendix for discussion of quantitative aspects of guidelines

TABLE III-3 (Continued)

Consideration	Measure	Guideline (3)	Possible Use To Obtain	Applicability and Time Frame (1) (2)
		c) For airports with 50,000 to 100,000 operations per year, 10 miles from airport. For airports with >100,000 operations per year include areas >d miles from airport $d = \sqrt{0.001 \text{ (operations)}}$	Candidate Area	O S
	b) Locations with respect to commercial jet routes and military routes	Evaluate areas with respect to proximity to high-frequency routes	Site Locality	O S
	c) Location with respect to restricted airspace	Include areas away from the limits of restricted airspace defining military airspace usage	Candidate Area	O S
2) **Hazardous Facilities (Reactor and Defense Facilities)**	a) Location with respect to hazardous facilities, possible missile generators, and possible vapor sources	a) Include areas away from facilities occupying 18,000 areas or more	Candidate Area	O S
		b) Include areas >0.6 mile from potential explosion, fire, missile hazards	Subarea	O S
		c) Include areas >0.6 mile from potential sources of noxious or flammable vapors	Site Locality	O S
		d) Evaluate areas on basis of proximity to hazardous facilities	Site Locality	O S
3) **Transportation**	b) Distance from transportation corridors	a) Include areas >0.6 mile from U.S. highways, interstate highways, railroads, and navigable highways	Site Locality Candidate Area	O S
		b) Evaluate areas on basis of proximity to transportation corridors	Candidate Area	O S

---

(1) O = Operation Phase (0 to 60 years); I = Isolation Phase (10,000 years)
(2) Applicability of guidelines to the surface (S) repository facilities and/or the subsurface (U) repository facilities
(3) See Appendix for discussion of quantitative aspects of guidelines

TABLE III-3 (Continued)

Consideration	Measure	Guideline (3)	Possible Use To Obtain	Applicability and Time Frame (1) (2)
4) Induced Seismicity	Location with respect to sources of induced seismicity and potential future earthquake sources	a) Include areas >5 miles from existing reservoirs >100 feet deep	Subarea	O and I S and U
		b) Evaluate areas on basis of proximity to future reservoirs and interpreted sources of induced seismicity A = >5 miles B = 0 to 5 miles	Site Locality	I U
5) Subsurface Mineral Exploration and Extraction	Location with respect to existing and potential future mineral exploration and extraction	a) Include areas away from existing subsurface mineral extraction	Site Locality	O and I U
		b) Evaluate areas on basis of proximity to potential future mineral exploration or extraction		I U
6) National Defense and Security	Proximity to facilities or areas interpreted to be possible defense or security risks	Evaluate areas on basis of proximity to facilities or areas interpreted to be attractive military or terrorist targets	Site Locality	O and I S and U
C) Repository-Induced Events				
1) Thermo-Mechanical Effects	Thickness of host rock flow and general rock characteristics	Evaluate flow thicknesses and characteristics of potential host rock	Site Locality	O and I U
2) Operational Radiation Release	Distance from population	a) Include areas >3 miles from population >2,500	Candidate Area	O S
		b) Include areas >1 mile from any incorporated community	Candidate Area	O S
		c) Include areas >1 mile from any urbanized area		O S

---

(1) O = Operation Phase (0 to 60 years); I = Isolation Phase (10,000 years)
(2) Applicability of guidelines to the surface (S) repository facilities and/or the subsurface (U) repository facilities
(3) See Appendix for discussion of quantitative aspects of guidelines

TABLE III-3 (Continued)

Consideration	Measure	Guideline (3)	Possible Use To Obtain	Applicability and Time Frame (1) (2)
OBJECTIVE: MINIMIZE ADVERSE ENVIRONMENTAL IMPACTS				
1) Protected Ecological Areas	Location with respect to protected ecological areas	Include areas outside of designated protected ecological areas of:		O S
		≥18,000 acres	Candidate Area	
		5 to 18,000 acres		
		<5,000 acres		
2) Culturally Important Areas:	a) Location with respect to designated scenic areas	Include areas greater than a calculated distance based on height of surface repository	Candidate Area Subarea	O S
Indian Reservations Parks, Monuments, Wilderness, Primitive Areas, Roadless Area of National Forest, Bureau of Land Management Roadless Recreation Area, Archaeological Sites	b) Location with respect to all designated areas	Include areas outside of designated culturally important areas of:		O S
		≥18,000 acres		
		5 to 18,000 acres		
		<5,000 acres		
3) Protected and Endangered Species	Location with respect to protected and endangered species	Include areas outside of known locations of protected and endangered species		O S
4) Biologically Important Areas	Location with respect to biologically important areas	Evaluate areas based on proximity to biologically important areas		O
5) Existing Significant, Specialty, or Incompatible Land Uses	Location with respect to significant, specialty, or incompatible land uses	Include areas outside of mapped extent of specialty agriculture, irrigated agriculture, incompatible facilities, or other land uses that are locally limited and regionally significant	Site Locality	O S

----

(1) O = Operation Phase (0 to 60 years); I = Isolation Phase (10,000 years)
(2) Applicability of guidelines to the surface (S) repository facilities and/or the subsurface (U) repository facilities
(3) See Appendix for discussion of quantitative aspects of guidelines

TABLE III-3 (Continued)

Consideration	Measure	Guideline (3)	Possible Use To Obtain	Applicability and Time Frame (1) (2)
6) Potential Significant or Incompatible Land Uses	Location with respect to potential future significant or incompatible land uses	Evaluate areas with respect to potential future uses. The evaluation will focus on agriculture: a) Potentially irrigable lands b) Arable soils c) Marginal soils d) Submarginal soils		I S
OBJECTIVE: MINIMIZE SYSTEM COSTS				
1) Site Preparation (Surface)	a) Terrain ruggedness	Subjective evaluation for terrain characteristics (i.e., slope approximately >15%, relief and degree of dissection)	Candidate Area Subarea	O S
	b) Usable land area	Evaluate available land area for dominant site preparation costs, slope, local relief, degree of dissection, size of area, location and juxtaposition of relatively level areas, water supply, access, and amount of excavation and fill necessary to fit 2,400 acres of surface facilities	Site Locality	O S
2) Site Preparation (Subsurface)	Mining and excavation costs	Evaluate areas on basis of thickness of overburden, depth of shafts, host rock characteristics, configuration, and length of tunnels (spoil, etc.), excavated volume, etc.		O S

---

(1) O = Operation Phase (0 to 60 years); I = Isolation Phase (10,000 years)
(2) Applicability of guidelines to the surface (S) repository facilities and/or the subsurface (U) repository facilities
(3) See Appendix for discussion of quantitative aspects of guidelines

that occurs within 5 miles of a capable structure. Hence, a limit was set on the measure of the fault rupture consideration; in this case, locations within 5 miles of capable faults were removed from consideration in the siting study because they failed to meet the minimum level of achievement of the safety objective as expressed in relation to the fault rupture consideration. For considerations where no specific level of achievement was required, the measure itself, or a non-prescriptive classificatory interpretation of it, was the guideline and was used to characterize or classify areas and localities. If the guidelines were used to identify groups of areas or localities with similar characteristics, it was called a "classifying guideline."

All of the guidelines selected for the many considerations developed in the process described above were not assessed meaningfully at the same level of detail or on maps of the same scale. For this reason, it was often necessary to repeat the measurement of some considerations at several steps of the screening process. For example, if an inclusionary guideline was stated as "include areas outside of protected ecological reserves," and if such reserves could vary in size from a few acres to several tens of thousands of acres, it was necessary to restate this guideline in terms appropriate to the several scales of maps characteristically used in a screening process. Thus, in the first step of screening (which uses small-scale maps), the guideline was stated as "include areas outside of protected ecological reserves larger than 18,000 acres" (an area that is readily discernible on maps of 1:500,000 scale). In subsequent steps of screening, the guideline was restated to consider smaller ecological reserves.

The guidelines selected for the site locality identification study are presented in Table III-3. Each guideline is shown in relation to the pertinent objective, consideration, and measure. The background and rationale for selecting the various guidelines and considerations are discussed in Appendix A to this volume.

3.2 Review and Revision of Guidelines

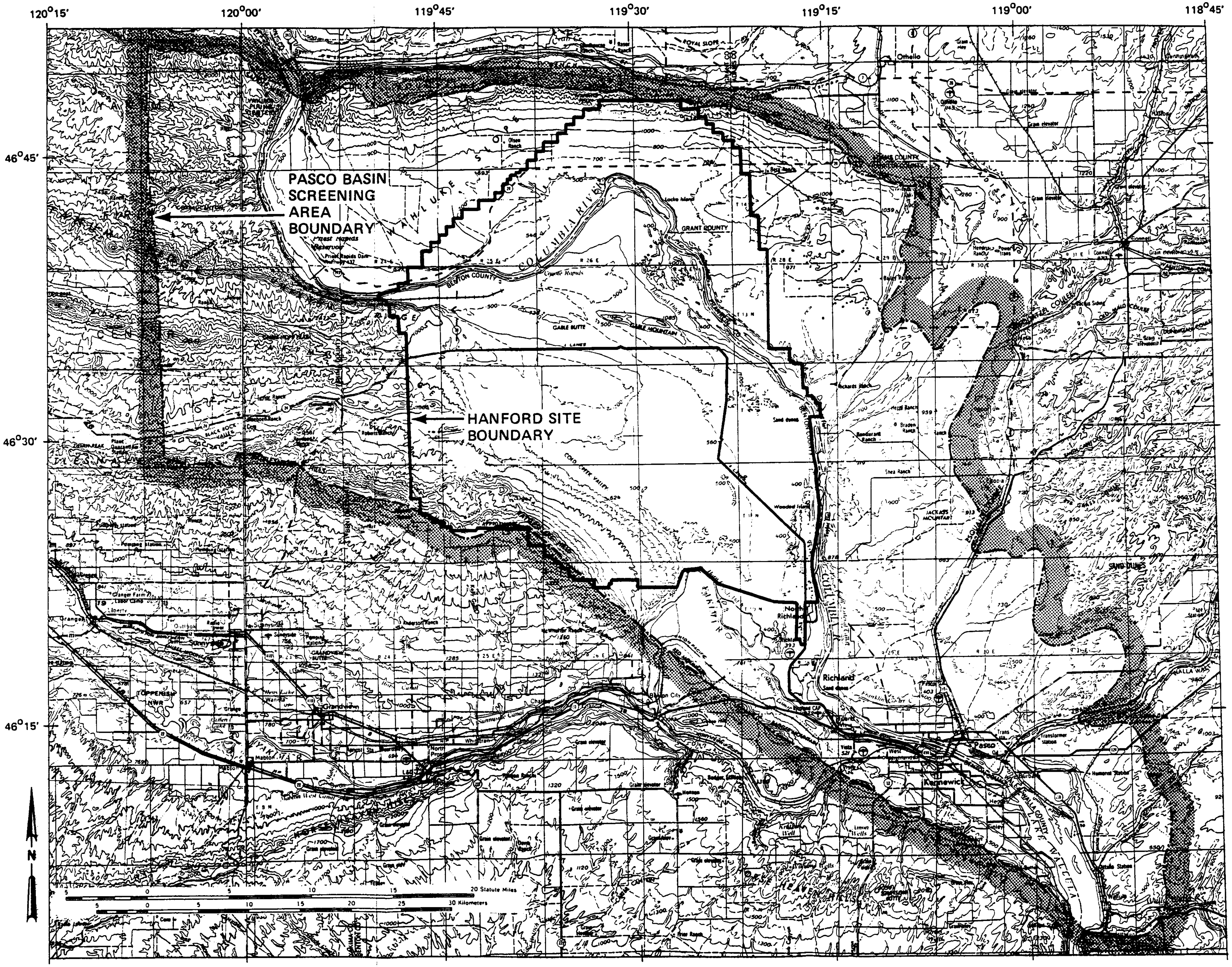
The final step in guideline development was to review the set of established guidelines for completeness, appropriateness, responsiveness to governmental regulations and guidelines, consistency, and practicality in application. Modifications suggested by this review were made, and a revised set of guidelines was issued. It is important to note that this review and revision process can take place at any time in the future. The siting methodology and the guideline development task within it are structured to allow accommodation of new or revised information; the effect of a changed objective, a technological advance, or a new or revised regulation can be isolated within the rigorously defined hierarchy of guidelines and played out in the corresponding steps of screening or ranking. At the outset of the siting study, however, the emphases on guideline review were a) consistency within the set of guidelines, b) compatibility with emerging repository design concepts and repository systems development, c) compliance with regulation, d) completeness and reasonableness in comparison to previous or concurrent repository siting guideline development efforts, and e) the ability to portray guidelines on maps. This review was accomplished through an examination of pertinent literature, comparison with successfully applied sets of guidelines that have been used to site similar large facilities, meetings with the Rockwell engineering and geosciences staff, and test applications of selected guidelines on a portion of the study area.

IV. IMPLEMENTATION AND RESULTS OF SCREENING

1. GENERAL

Screening in the Pasco Basin was conducted to locate potential repository site localities on the Hanford Site. Screening was initiated in the Pasco Basin to provide a broader scope from which to study processes that might affect the Hanford Site, and to determine whether there are any apparent, obviously superior site localities in a natural region outside of the Hanford Site (i.e., the Pasco Basin). The Pasco Basin screening area and Hanford Site boundaries are shown in Figure IV-1. For the purpose of this study, the Pasco Basin can be defined with the following boundaries.

The axis of the Saddle Mountains anticline forms the northern edge of the basin. The southern edge is the axis of the Rattlesnake Hills-Wallula Gap structure. The "Hog Ranch axis" as defined by Mackin (1961) and mapped by Bentley (1977) was used as the western edge of the basin. The axis is an alignment of the structural culmination of several anticlines and nearly coincides with the drainage divide between the Yakima and Columbia Rivers. The eastern edge of the basin is more difficult to define, as there are no drainage divides or structural features. However, the edge of Quaternary sediments, as shown on the Columbia Plateau tectonic map of Newcomb (1970), was used to define the eastern edge of the Pasco Basin, thus defining this boundary on the basis of a sedimentary basin.



NOTE:
Base map from USGS 1:250,000 scale maps of Yakima and Walla Walla quadrangles.

FIGURE IV-1

PASCO BASIN SCREENING AREA AND HANFORD SITE BOUNDARIES

Screening within the Pasco Basin was accomplished through an overlay process, which is illustrated in Figure IV-2. Each overlay represents the results of the application of an individual screening guideline to the study area (see Section III and the appendix to this volume for guideline development and rationale, respectively). When the individual overlays are combined, the compilation results in similar areas being included for further study which have a higher likelihood of containing suitable nuclear waste repository sites based on the application of the guidelines.

For screening of the Pasco Basin to identify site localities on the Hanford Site, the overlay process was conducted in three steps which resulted in three distinct and successively smaller areas to be considered for further study; candidate areas, subareas, and site localities. The relationship of these areas to the study area is illustrated in Figure IV-3 and definitions of the area designations are given in Table IV-1.

In the following discussions, the application of the screening guidelines employed at each step in screening the Pasco Basin are described and the results of each step are presented.

2. IDENTIFICATION OF CANDIDATE AREAS

The first step in screening the Pasco Basin resulted in the definition of candidate areas. Screening involved the use of inclusionary guidelines which represent a total of nine considerations under the working objectives of maximizing public health and safety, minimizing adverse environmental impacts, and minimizing system costs. The considerations and guidelines used are listed in Table IV-2.

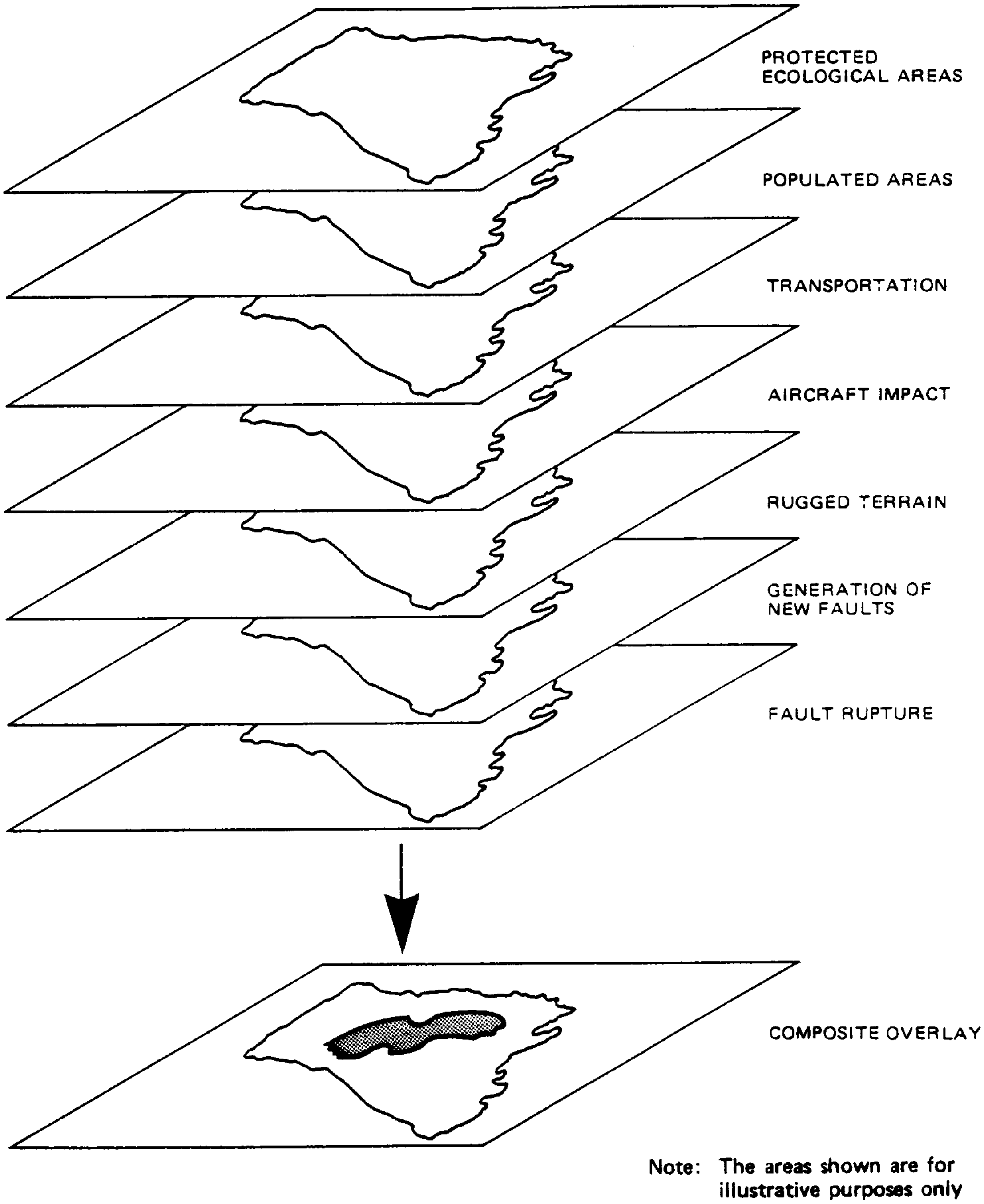


FIGURE IV-2

THE OVERLAY PROCESS

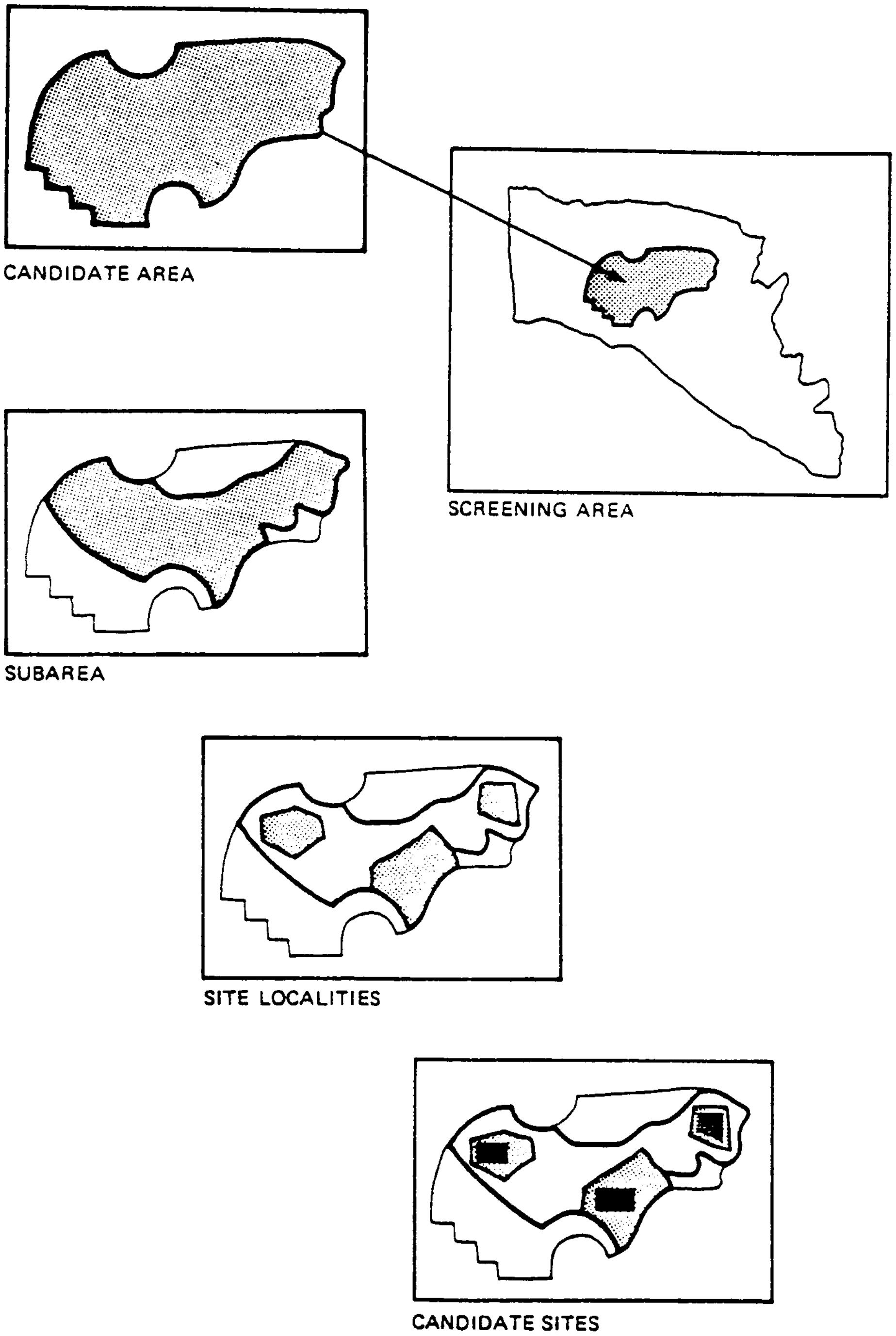


FIGURE IV-3

RELATIONSHIP OF AREA DESIGNATIONS

TABLE IV-1

AREA DESIGNATIONS USED IN SCREENING

Screening Area: For the purposes of this siting study, it is the Pasco Basin (approximately 1,600 square miles).

Study Area: The area covered by this repository candidate site locality identification study (approximately 570 square miles on the Hanford Site).

Candidate Area: Portions of the study area that have a higher potential of containing suitable sites for a waste repository than the rest of the study area. (Typically, a candidate area covers several hundred square miles and is derived by the application of inclusionary guidelines.)

Subarea: Portions of candidate areas that have a higher potential of containing sites than other portions. The subarea is typically defined on a larger scale map than that used to identify candidate areas and is derived by the application of inclusionary guidelines. Subareas represent refinements of candidate areas and may still cover more than a hundred square miles.

Site Locality: Portions of subareas that have a higher potential of containing suitable sites for a waste repository than the rest of the subarea. (Typically, a site locality covers an area up to 50 square miles.)

Candidate Site: A specific location within a site locality considered to be suitable for locating a repository. Not all site localities may contain candidate sites; this determination is made following field visits to site localities and a detailed characterization of the site localities. (Typically, a candidate site may cover an area up to 10 square miles.) It should be noted that the current siting study described in this report does not proceed to the identification of candidate sites, but terminates with site localities.

TABLE IV-2

CONSIDERATIONS AND GUIDELINES USED IN THE CANDIDATE AREA SCREENING OF THE PASCO BASIN

OBJECTIVE: MAXIMIZE PUBLIC HEALTH AND SAFETY

Consideration	Measure	Guidelines[1]
Fault Rupture	Distance from known faults interpreted to be capable	Include areas >5 miles from known faults interpreted to be capable and known faults whose capability is unknown
Generation of New Faults	Location with respect to future potentially capable tectonic structures	Include areas >5 miles from folds interpreted to be capable of forming new faults
Ground Motion	Location with respect to earthquake sources and estimated levels of ground motion	a) Include areas that may be subject to less than 40% g peak surface acceleration from known and interpreted earthquake sources b) Include areas >12 miles from felt epicenters > MM V and >6 miles from instrumental epicenters > magnitude 4.0 which occur in concentrations or clusters as interpreted from historical earthquake epicenter plot maps
Aircraft Impact	a) Distance from airports	a) Include areas >5 miles from airports shown on state airport plans, accommodating aircraft ≥12,500 pounds gross weight, or any military airport b) For airports with >12,500 yearly operations, but with less than 50,000, d miles from airport: $d = \sqrt{0.002 \text{ (operations)}}$

[1]See Appendix for discussion of quantitative aspects of guidelines

TABLE IV-2 (Continued)

Consideration	Measure	Guidelines[1]
	b) Location with respect to restricted airspace	Include areas away from the limits of restricted airspace defining intense military usage
Transportation	Distance from transportation corridors	Include areas >0.6 mile from U.S. highways, interstate highways, and major railroads and navigable waterways
Operational Radiation Release	Distance from population	a) Include areas >3 miles from populations of >2,500
		b) Include areas >1 mile from any incorporated community

OBJECTIVE: MINIMIZE ADVERSE ENVIRONMENTAL IMPACTS

Consideration	Measure	Guideline
Protected Ecological Areas	Location with respect to protected ecological areas	Include areas outside of designated protected ecological areas
Culturally Important Areas	Location with respect to all designated areas greater than 5,000 acres	Include areas outside of designated culturally important areas greater than 5,000 acres

OBJECTIVE: MINIMIZE SYSTEM COSTS

Consideration	Measure	Guideline
Site Preparation Costs (Surface)	Terrain ruggedness	Include areas outside of rugged terrain

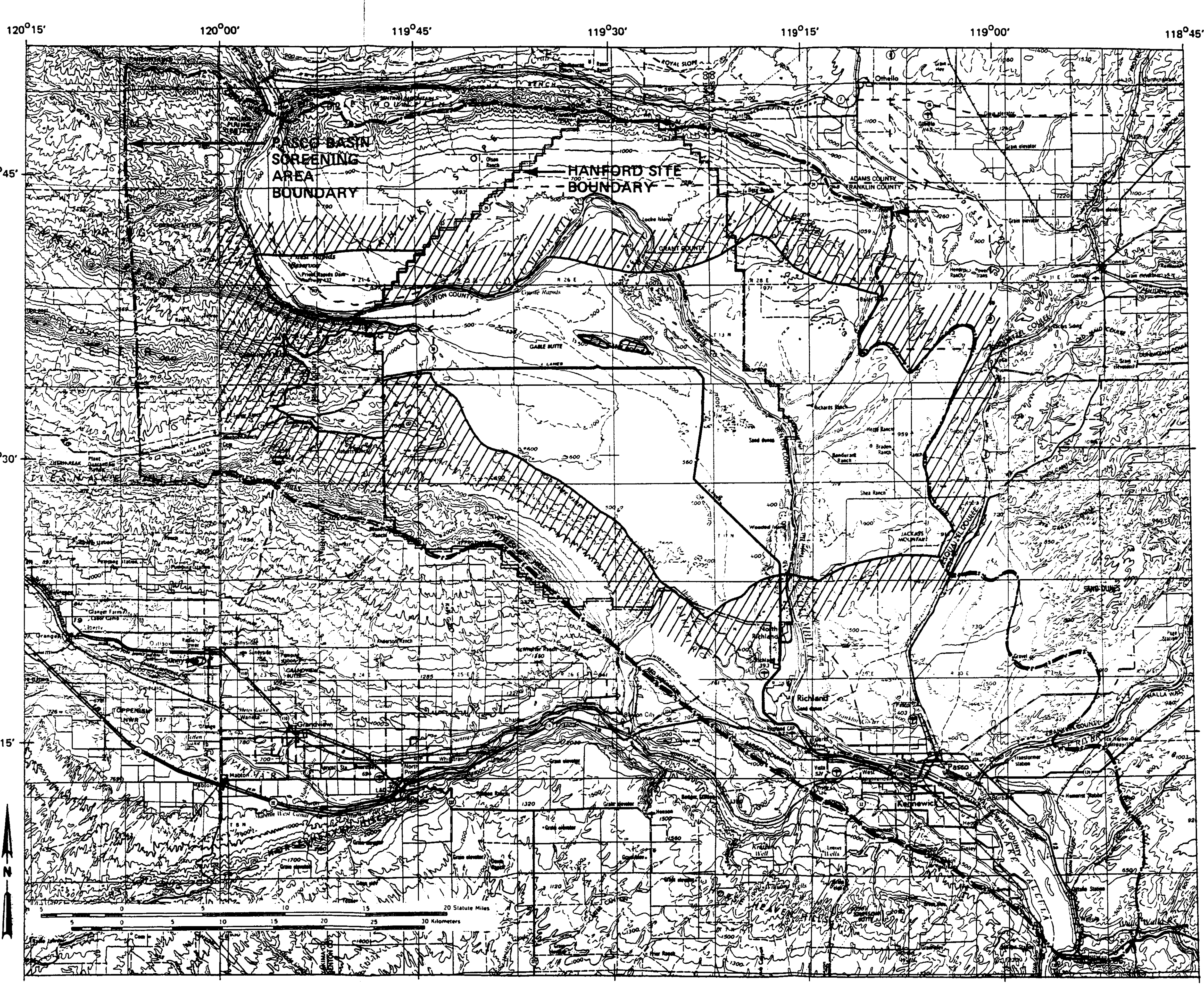
[1] See Appendix for discussion of quantitative aspects of guidelines

A more detailed description of the guidelines and rationale is given in the appendix to this volume.

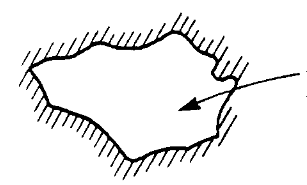
The inclusionary guidelines used in the screening successively reduced the size of the area to identify the remaining area as having a higher likelihood of containing suitable nuclear waste repository sites. The guidelines used for candidate area screening (Table IV-2) were selected because the data were available over the study area and they could be readily and easily depicted on the 1:250,000-scale screening overlays. Surface and subsurface guidelines were developed and applied independently during the screening process to differentiate between performance objectives that may relate only to the operational phase of the surface facilities and the longer term performance objectives of the repository. Hydrological guidelines and the other remaining guidelines were not applied during this step of the screening because they are more readily applicable to the increasing levels of detail used in later screening steps.

The area remaining in the Pasco Basin following application of considerations in the first step in screening is termed the candidate area. Figure IV-4 depicts the candidate area resulting from the first step in screening. The relationship of this screening step to other screening steps is illustrated in Figure IV-3.

The application of the guidelines used under each consideration and the data sources utilized in the application of the guidelines to the screening area are described below.



EXPLANATION:



Candidate area included for further study

NOTE:

Base map from USGS 1:250,000 scale maps of Yakima and Walla Walla quadrangles.

FIGURE IV-4

PASCO BASIN CANDIDATE AREA

2.1 Fault Rupture

Areas considered to have a high potential for fault rupture were considered unsuitable for repository siting. The guideline considered capable faults as defined by the NRC in 10 CFR 100, Appendix A.

As presented in the available data, all known faults within the study area or near the study area were examined. These known faults were evaluated as to their capability as defined by the NRC in 10 CFR 100. Those faults which either have been reported in the literature as being capable or have exhibited mapped relationships suggestive of Quaternary movement were the Wallula Gap fault system and the Saddle Mountains fault. The inclusionary guideline was then applied to these known faults, and only areas greater than 5 miles from mapped traces of these faults were included for further study.

The data sources examined and used for the application of this guideline included Grolier and Bingham (1971 and 1978) and WPPSS (1977a and 1977b).

2.2 Generation of New Faults

Because of the long isolation period for the repository (approximately 10,000 years), the potential for generation of new faults and reactivation of existing faults was studied to locate areas having a higher likelihood of containing suitable repository sites. Faulting in the Columbia Plateau appears to be closely associated with bedrock folding; thus, the folds (anticlines, synclines, and monoclines) were examined as potential generators of new faults.

Available geologic and tectonic literature for the Pasco Basin area was examined to identify bedrock folds interpreted to have a potential for generating new faults. Folds that fit this category generally exhibit relatively higher rates of Quaternary movement and associated faulting or have been designated as potentially active structures by previous studies in the Pasco Basin area. Two folds were identified that appear to fit this category; the Saddle Mountain anticline and the Rattlesnake Hills anticline. The Saddle Mountains anticline exhibits evidence of capable faulting, prominent geomorphic expression, and deformed Early Quaternary sediments. The Rattlesnake Hills anticline has been considered a capable structure in its southern extent by site safety studies done for nuclear power plants in the region. After the Rattlesnake Hills and Saddle Mountains anticlines were identified, the areas within 5 miles of the mapped axes of the folds were not retained for further study.

The data sources examined and utilized for this consideration include WPPSS (1977a and 1977b), Grolier and Bingham (1971 and 1978), Thoms and Others (1977), and Bentley (1977).

2.3 Ground Motion

Areas estimated to have a high potential for moderate to high peak seismic acceleration were considered unsuitable for repository siting. For this consideration, faults at least 12 miles long were examined as possible earthquake sources. The capability of the faults was evaluated using the NRC definition provided in 10 CFR 100, Appendix A. A fault was considered potentially capable if there was no evidence of noncapability.

Also considered here were areas within 12 miles of felt epicenters greater than MM V and within 6 miles of instrumental epicenters greater than magnitude 4.0 which occurred in clusters or concentrations as interpreted from historical earthquake epicenter plot maps. This consideration had no effect on the Pasco Basin screening area.

Setback distances were established for faults interpreted as being capable and faults of unknown capability. Noncapable faults were not considered. The setback distance establishes the boundary of an area estimated to experience moderate to high ground motion ($\geq$40% g horizontal acceleration) as determined from fault-rupture length-magnitude relationships and earthquake attenuation relationships. The following setback distances were used to define areas included on the basis of ground motion:

Mapped Fault Length (miles)	Setback Distance (miles)
12 to 24	5
24 to 60	10
>60	15

Using a geologic structure data base map, enclosures at these setback distances were drawn around the faults under consideration; the resulting enclosed areas were plotted on an overlay map of the study area and were removed from further consideration. Affected structures in the Pasco Basin are the Rattlesnake Hills and the Saddle Mountains.

The data sources utilized for this consideration included Reidel (1978), Newcomb (1970), WPPSS (1977a and 1977b), Portland General Electric Company (1974), Shannon and Wilson (1973a and 1973b), and Woodward-Clyde Consultants (1979).

2.4 Aircraft Impact

It is considered a hazard to the safety of the repository to be sited in an area with a high risk of aircraft impact. At this screening step, large airports, restricted airspace, and airports having a large number of operations were considered. A 5-mile setback was given to airports accommodating aircraft with at least 12,500 pounds gross weight. Areas underlying restricted airspace were removed from consideration. The distance (d) from airports having greater than 12,500 operations per year was determined from this table:

Operations Per Year	Setback Distance (in miles)
$>12,500$ but $<50,000$	$d = \sqrt{0.002\ (op)}$
$\geq 50,000$ but $\leq 100,000$	$d = 10$
100,000	$d = \sqrt{0.001\ (op)}$

Airports accommodating at least 12,500 pounds gross weight aircraft and within 5 miles of the Pasco Basin are Tri-Cities and Richland. The area within 5 miles of these airports was plotted on the "aircraft impact" overlay and removed from further consideration.

The Tri-Cities Airport handles over 100,000 operations per year. The calculated setback distance for this airport is 10.2 miles. A circle with that radius was plotted on the overlay and the area within the circle was removed from further consideration.

The restricted airspace from the U.S. Army's Yakima Firing Center was plotted on the overlay from the National Oceanic and Atmospheric Administration (NOAA) aeronautical chart, and the area was removed from further consideration.

The data sources examined and used for the considerations of aircraft impact include NOAA (1979), Aerospace Corporation (1973), and FAA (1978).

2.5 Transportation

Areas close to major transportation routes were considered to be subject to potential accidents. U.S. highways, interstate highways, and major railroads were considered.

The area within 0.6 mile of major railroads was plotted on the "Transportation" overlay and removed from further consideration. Presently, no interstate highways pass through the Pasco Basin. Interstate-82 is planned to pass through the southern part of the Pasco Basin, and the area within 0.6 mile of its planned route was removed from consideration. U.S. Highway 395 traverses the eastern part of the Pasco Basin, and the area within 0.6 mile of it was also removed from further consideration.

The data sources used for this consideration included Woodward-Clyde Consultants (1979).

2.6 Operational Radiation Release

Populated areas were not considered to be suitable for repository siting. Areas of current and projected moderate or greater population density and urbanized places were removed from consideration using a setback distance based on calculated concentrations of gaseous radioacive emissions expected from operations of the repository and associated facilities. For towns with populations greater than 2,500, the setback distance was 3 miles. For smaller towns, the setback distance was 1 mile.

Towns within the Pasco Basin with populations greater than 2,500 were Pasco, Richland, West Richland, and Kennewick. The area within 3 miles of these towns was plotted on the "Operational Radiation Release" overlay of the base map and removed from further consideration. Eight smaller incorporated towns were located within the Pasco Basin and a 1-mile radius area around them was also removed.

The data sources used for the consideration of operational radiation release included U.S. Bureau of the Census (1977) and USGS 1:250,000 topographic maps.

2.7 Protected Ecological Areas

Designated and proposed ecological areas were considered unsuitable for repository sites. Protected ecological areas were defined as those for which binding land-use restrictions are established or proposed to protect or enhance ecological values. These areas include wildlife reserves, wildlife management areas, and wildlife refuges.

Within the Pasco Basin, there are two protected ecological areas; the Saddle Mountains National Wildlife Refuge and the Arid Lands Ecology Reserve. These were plotted on an overlay of the study area and removed from further consideration. Both of these lie wholly within the Hanford Site.

The data sources examined and used for this consideration included U.S. Fish and Wildlife Service (1976] and Franklin and Others (1972).

2.8 Culturally Important Areas

Culturally important areas--parks greater than 5,000 acres, wilderness areas, designated wild and scenic rivers, Indian reservations--were considered at this screening step, but there are none in or near the Pasco Basin.

2.9 Terrain Ruggedness

Areas of rugged terrain were not considered to be favorable repository sites because of potential inaccesibility and cost of site preparation. This screen was a subjective evaluation of terrain characteristics (i.e., topography, slope, relief, and degree of dissection). Numerous small areas of very rugged terrain and several larger areas of fairly rugged terrain were not considered for this screening stage due to the small scale and large contour interval (200 feet) of the base maps. Areas of greater than 15% were outlined on data base overlays of the study area and were removed from further study.

The data sources used for the consideration of rugged terrain were USGS 1:250,000 topographic maps of the Walla Walla and Yakima 1-degree x 2-degree quadrangles.

2.10 Candidate Area

When the seven overlays representing the application of the guidelines for nine considerations of the first step in screening were compiled, the results were termed the "candidate area." This area is shown in Figure IV-4. The boundaries of this area were then transferred to 1:62,500-scale base maps for use in the next step in screening to identify subareas.

3. IDENTIFICATION OF SUBAREAS

The second step in screening of the Pasco Basin, to identify subareas, involved the use of inclusionary guidelines which represent a total of seven considerations under the working objectives of maximizing public health and safety, minimizing adverse environmental impacts, and minimizing system costs. The considerations and guidelines used to identify subareas from within the candidate area are listed in Table IV-3.

The considerations and guidelines used in this screening step were selected because the data were available over the study area, and they could be readily and easily depicted on the 1:62,500- scale screening overlays. A more detailed description of the guidelines and rationale is given in the appendix to this volume.

When the screening maps representing the several considerations were overlaid, the resulting areas included for further study were termed subareas. The subareas within the Pasco Basin are depicted on Figure IV-5. The relationship of this step in screening to other screening steps is illustrated in Figure IV-3.

In the following discussions, the application of the guidelines used under each consideration are described, and the data sources examined and used for each consideration are listed.

TABLE IV-3

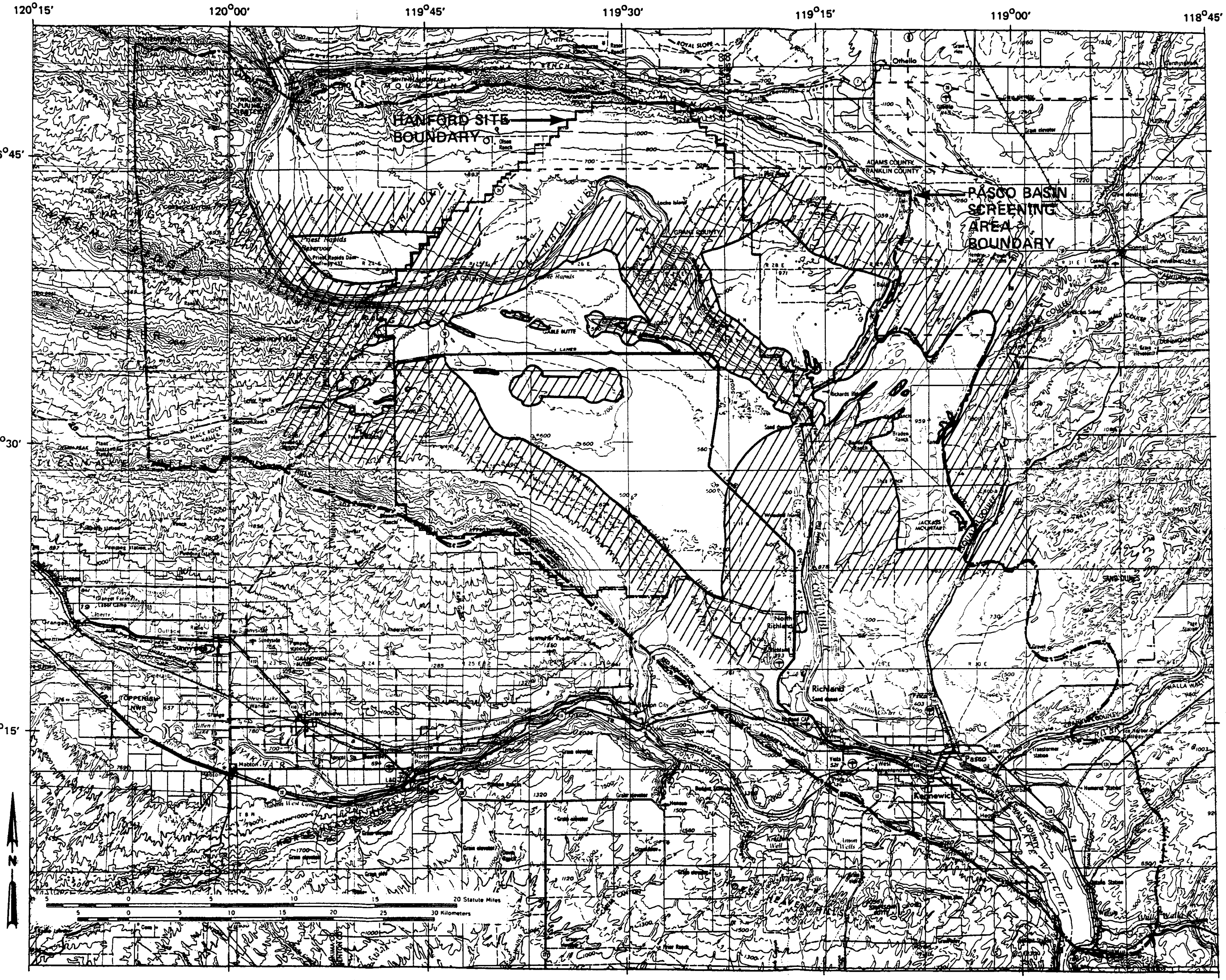
CONSIDERATIONS AND GUIDELINES USED IN SUBAREA SCREENING OF PASCO BASIN

OBJECTIVE: MAXIMIZE PUBLIC HEALTH AND SAFETY

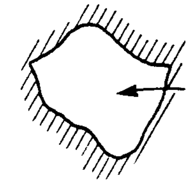
Consideration	Measure	Guidelines
Fault Rupture	Horizontal and vertical distance from known faults interpreted to be not capable, and from zones of fracturing and jointing	Include areas >0.5 mile from known faults interpreted to be not capable, known faults of unknown capability which have a high potential for a capability evaluation, and from zones of fracturing and jointing
Flooding	Height above selected flood level	Include areas outside primary floodplain and estimated PMF levels
Ground Failure	Location with respect to landslides and potential landslides	Include areas not on mapped landslides
Erosion/ Denudation	Location with respect to potential areas of erosion and denudation	Include areas >0.5 mile from steep-walled canyons or slopes
Hazardous Facilities	Distance from possible missile or noxious vapor generators	Include areas 0.6 mile from facilities with potential explosion, fire, or missile hazards
Induced Seismicity	Location with respect to sources of induced seismicity and potential earthquake sources	Include area >5 miles from existing reservoirs >100 feet deep

OBJECTIVE: MINIMIZE SYSTEM COSTS

Consideration	Measure	Guidelines
Site Preparation (surface)	Terrain ruggedness	Subjective evaluation for terrain characteristics (i.e., topography, slope, relief, and degree of dissection)



EXPLANATION:



Subareas included for further study

NOTE:
Base map from USGS 1:250,000 scale maps of Yakima and Walla Walla quadrangles.

FIGURE IV-5

SUBAREAS WITHIN PASCO BASIN

3.1 Fault Rupture

Areas having non-capable faults and zones of tectonically induced fracturing or jointing were not considered to be suitable repository sites because a fault could provide a pathway between the repository and the biosphere. Therefore, a setback distance was set at 0.5 mile from known faults interpreted to be non-capable.

Within the Pasco Basin candidate area, there were three faults shown on maps by Newcomb and Others (1972) and WPPSS (1977a); two are on Gable Mountain and the third is on Umtanum Ridge. A 0.5-mile envelope around these faults was drawn on overlays of the base maps, and the area within each envelope was removed from further consideration.

The sources of data utilized for the consideration of fault rupture included Newcomb and Others (1972) and WPPSS (1977a).

3.2 Flooding

Areas subject to inundation by floods present a potential hazard for surface facilities for a repository. The Columbia River and Yakima River were considered. The Yakima River did not affect the identification of subareas in terms of potential flooding.

The area which would be inundated by the estimated maximum flood on the Columbia River, as shown on the Washington Public Power Supply System's map in the WNP-2 PSAR, was delineated on the "flooding" overlays of the base maps and was removed from further consideration.

The sources of data examined and utilized for the consideration of flooding included Newcomb and Others (1972), ERDA (1976a), and WPPSS (1977a).

3.3 Landslides

Landslides are areas of existing ground instability and are, therefore, unsuitable for siting surface facilities for a repository.

Mapped landslides occur along the White Bluffs and Gable Mountain within the Pasco Basin candidate area. These landslides were traced on an overlay of the base maps and were removed from further consideration.

The sources of data used for this consideration included Newcomb and Others (1972), and Grolier and Bingham (1971).

3.4 Erosion/Denudation

The potential for erosion and denudation may affect the safety of a repository site. High, very steep slopes (greater than 40%) have a potential for erosion.

The main part of the Pasco Basin affected by this guideline is the White Bluffs region along the Columbia River. Smaller areas occur along coulee walls and along the Yakima and Umtanum Ridges. The area within 0.5 mile of the top of the steep slopes was delineated on overlays of the base maps and was removed from further consideration.

The source of the data for this consideration were the USGS 1:62,500-scale topographic maps of the study area.

3.5 Hazardous Facilities

Areas near facilities with a potential for explosions or generating missiles or noxious vapors are unsuitable for surface facility siting. A 0.6-mile setback from these facilities was used as the screening guideline.

There are potential hazards from several facilities on the Hanford Site. These are the WPPSS nuclear power plants, the Fast Flux Test Facility, the N Reactor, and some of the facilities in the 200 East and 200 West Areas. A 0.6-mile envelope was drawn around each of these facilities on overlays of the study area, and the area within each was removed from further consideration.

The sources of data used for the consideration of hazardous facilities included AEC (1970), and WPPSS (1977a and 1977b).

3.6 Induced Seismicity

Areas with a potential for induced seismicity are not considered to be suitable repository sites. Reservoirs with a maximum depth greater than 100 feet were considered to be potential sources of induced seismicity.

The reservoir impounded by McNary Dam is the only one which affects the Pasco Basin area. This reservoir backs up water in Lake Wallula to Wooded Island. The area within 5 miles of this reservoir was outlined on overlays of the study area and removed from further consideration. The proposed Ben Franklin dam, if built, would not create a reservoir greater than 100 feet deep.

The sources of data examined and utilized included U.S. Army Corps of Engineers (1975), U.S. Committee, International

Commission on Large Dams (1958, 1963, 1968), Columbia-North Pacific Technical Staff (1970).

3.7 Terrain Ruggedness

Areas of rugged terrain are not considered to provide favorable surface facility sites because of potential inaccessibility and cost of site preparation.

This screen is a subjective evaluation of terrain characteristics (i.e., topography, slope, relief, and degree of dissection). It was reapplied at the subarea level because of the smaller contour interval (20 or 40 feet) and larger map scale which provided a more detailed and complete data base for guideline application.

Areas with high, steep slopes (greater than 15%) or deep dissection were delineated on overlays of the 1:62,500-scale base maps and were removed from further consideration.

The data sources used to define rugged terrain were USGS 1:62,500-scale topographic maps of the study areas.

3.8 Subareas

When the seven sets of overlays depicting the application of the guidelines under the above considerations were compiled, the resulting areas included for further study were termed "subareas." The subareas are shown in Figure IV-5. These subareas were then carried into the next step in screening to identify site localities.

4. IDENTIFICATION OF SITE LOCALITIES

4.1 General

Site localities on the Hanford Site were identified through an evaluation of the subareas based on the classifying guidelines presented in Table III-5 and discussed in the appendix to this volume. This evaluation was conducted in two steps:

- Evaluation of subareas within the Pasco Basin screening area outside of the Hanford Site and

- Evaluation of the subareas within the Hanford Site.

The first step was designed to determine whether any apparent, obviously superior site localities occur in the subareas within the Pasco Basin outside of the Hanford Site based on an evaluation comparing them to subareas on the Hanford Site and utilizing the classifying guidelines.

The results of this evaluation (discussed below) indicate that no obviously superior site localities appear to occur within the screening area outside the Hanford Site, thus further study was concentrated on the Hanford Site utilizing the evaluation of the second step. The distribution of subareas outside of the Hanford Site is indicated in Figure IV-5.

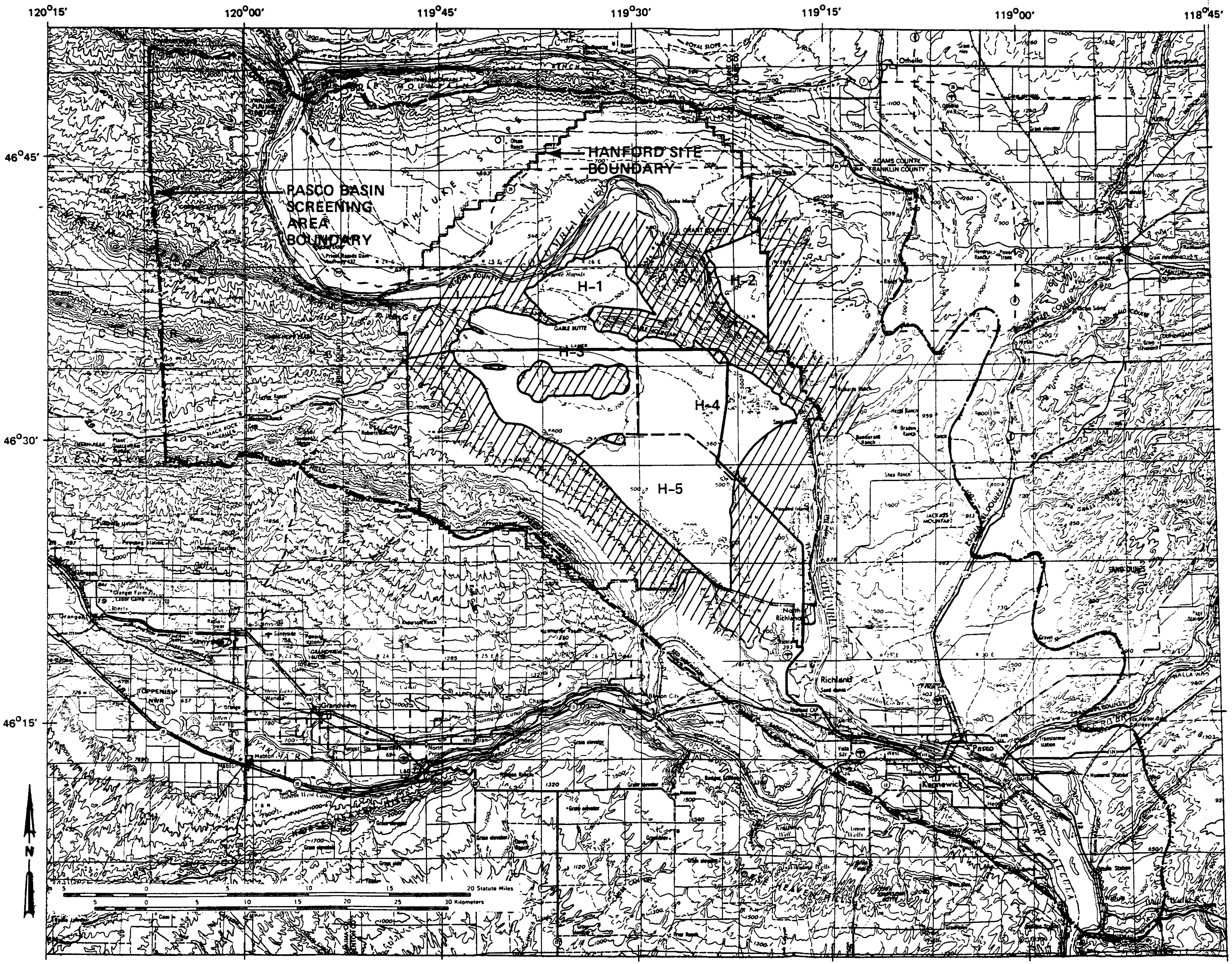
In the second step, the evaluation of subareas on the Hanford Site was an examination of the results from the application of those guidelines (both inclusionary and classifying) as they affect the subsurface compared to those that affect the surface.

Certain screening guidelines used to locate candidate areas and subareas affected only the location of surface facilities. For example, part of a repository could be located beneath a landslide or a hazardous facility as long as the surface facilities were located at a safe distance. Similarly, some subsurface areas might be unsuitable for a repository even though the overlying surface area appeared suitable. For these reasons, it was decided to study the available surface and subsurface areas separately prior to identifying site localities to evaluate the impact of the surface versus the subsurface screens. The combined surface and subsurface available areas were then evaluated, and site localities were identified in the resulting areas because of their higher likelihood of containing suitable repository sites based on the results of the application of the screening guidelines. The results of the identification of site localities are depicted in Figure IV-6. The relationship of this step to other steps in the screening process is illustrated in Figure IV-3.

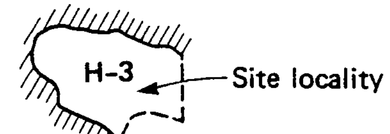
4.2 Evaluation of Subareas Outside of the Hanford Site

Two subareas were located in the Pasco Basin outside of the Hanford Site. Two others were located partly within and partly outside of the Hanford Site. All of the subareas outside of the Hanford Site were evaluated with respect to the classifying guidelines and to determine if apparently superior areas exist outside of the Hanford Site. Figure IV-5 can be used to locate these subareas.

The first subarea, located just east of Priest Rapids Dam, is presently used for irrigated farming. It is adjacent to the Columbia River and the Saddle Mountains National Wildlife Refuge. On the basis of land use and hydrology, this area was considered to be not obviously superior to subareas on the Hanford Site.



EXPLANATION:



NOTES:

See Section IV–4.5 for rationale for the selection of Site Locality Boundaries.

Base map from USGS 1:250,000 scale maps of Yakima and Walla Walla quadrangles.

FIGURE IV-6

SITE LOCALITIES ON THE HANFORD SITE

A second subarea is located south of Umtanum Ridge and west of the Hanford Site. This subarea is continuous onto the Hanford Site. The soil is suitable for irrigated farming, several deep wells have been drilled, and it is in close proximity to the Columbia River. Yakima Ridge traverses the area and appears to contain areas where the bedrock dip is greater than 5 degrees. Umtanum Ridge and Rattlesnake Hills are in close proximity to the subarea. On the basis of land use, hydrology, bedrock dip, and tectonic stability, this subarea was considered to be not superior to subareas on the Hanford Site.

A third subarea is located adjacent to and continuous with the northeastern part of the Hanford Site. This subarea is underlain by loess and is presently used for intensive irrigated agriculture. It is also near the Columbia River. On the basis of land use and hydrology, this subarea was considered to be not obviously superior to subareas on the Hanford Site.

The fourth subarea is located east of the Columbia River and east of the Hanford Site. This land is part of the Columbia Basin Irrigation Project and used for irrigated agriculture. Several irrigation canals and pumping stations are located within this subarea. It is also near the Columbia River. On the basis of land use and hydrologic evaluations, this subarea is not considered superior to subareas on the Hanford Site.

Because no area of the Pasco Basin outside of the Hanford Site was found to be obviously superior to areas within the Hanford Site, further study to identify site localities was concentrated on the subareas of the Hanford Site.

4.3 Subsurface Evaluation of Subareas on the Hanford Site

An overlay was made of the Hanford Site showing only those screens (based on both inclusionary and classifying guidelines) which affected the subsurface area. Screens not used were aircraft impact, transportation, protected ecological areas, terrain ruggedness, flooding, landslides, erosion, denudation, and hazardous facilities. Evaluations of bedrock dip, microearthquake activity, and hydrology were added to the results of the subarea screening. The results show the available area for repository siting (Figure IV-7).

4.3.1 Bedrock Dip

This evaluation is related to construction and operation costs of the repository. The greater the dip, the more difficult and costly the construction of a repository becomes. There are no specific data on bedrock dip within the Hanford Site at repository depth; however, a contour map has been prepared on the surface of the basalt. Elevation changes of more than 500 feet per mile may reflect bedrock dips of 5 degrees or more. They could also reflect erosion prior to burial or thinning of flows. Because all areas having rapid subsurface elevation changes coincided with mapped anticlines or extensions along strike of mapped anticlines, it may be assumed that the elevation changes are at least partly due to folding of bedrock. Therefore, these areas are generally less favorable for repository siting.

4.3.2 Microseismicity

Although the sources of microearthquake activity have not been determined in the Pasco Basin, it was considered desirable to locate the repository away from locations of microearthquake clusters.

NOTE:
Base map from USGS 1:62,500 scale maps of Richland, Hanford, Priest Rapids, Coyote Rapids, Mesa, Corral Canyon and Eltopia quadrangles.

FIGURE IV-7

HANFORD SITE:
AVAILABLE SUBSURFACE AREA

4.3.3 Hydrology

It is desirable to site a repository away from areas of possible discharge, such as the Columbia River, as data on ground-water flow at depth in the Hanford Site area are insufficient to determine where and if the deep ground-water flow discharges into the Columbia River. It was considered that at least the area directly under the Columbia River was unfavorable, so that area was delineated on the "available subsurface area" overlay. It was judged to be prudent to avoid siting directly beneath the river based on the possible need for extensive additional studies to satisfy licensing concerns.

4.3.4. Results of Evaluation of Subsurface Area

When the evaluation of the subareas delineated by the classifying guidelines are combined with the areas delineated by the evaluation of the inclusionary guidelines, the resulting area describes the available subsurface area on the Hanford Site, which is considered to have a higher likelihood of containing suitable repository sites.

4.4 Surface Evaluation of Subareas on the Hanford Site

The available surface area within the Hanford Site is defined by the inclusionary guidelines representing the considerations of hazardous facilities, flooding, rugged terrain, erosion/denudation, landslides, and protected ecological areas. The area so defined is illustrated on Figure IV-8 and reflects the boundaries defined during the identification of subareas, except for the Hanford Site boundary to the west and east. Evaluations based on the classifying guidelines did not allow for adequate differentiation between areas based on the available data.

NOTE:
Base map from USGS 1:62,500 scale maps of Richland, Hanford, Priest Rapids, Coyote Rapids, Mesa, Corral Canyon and Eltopia quadrangles.

#

FIGURE IV-8

HANFORD SITE:
AVAILABLE SURFACE AREA

4.5 Identification of Site Localities

The evaluation of the effect of surface and subsurface screens on one another indicated that the area resulting from the combined effect of the screens was more suitable and had a higher likelihood of containing suitable waste repository sites. Although it is recognized that suitable subsurface area may exist beneath areas affected by surface screens, the combined area provides more logistically sound areas by avoiding the need for protracted surface and subsurface facilities, and thus a less costly option for repositories. In addition, the combined area continued to provide sufficient area and adequate geotechnical conditions for the identification of several site localities. Therefore, the combined area resulting from the application of surface and subsurface screens was examined to identify site localities (Figure IV-9).

Three general areas were defined by the combined screens; east of the Columbia River, north of Gable Mountain, and south of Gable Mountain. Using the general size of a site locality as less than 50 square miles and more than 10 square miles, five site localities (H-1 through H-5) were identified in the three areas, as indicated on Figure IV-9. The boundaries describing site localities H-1 and H-2 are defined by screening boundaries. The three site localities south of Gable Mountain are defined somewhat arbitrarily to maintain equal size. A small subarea west of site locality H-3 was not considered further due to its small size which would preclude a repository based on a subsurface area of 10 square miles.

To characterize the existing conditions within each site locality and to provide a basis for evaluating the site localities with respect to identifying candidate sites in future steps of the siting process, 23 descriptive parameters

FIGURE IV-9

HANFORD SITE: COMPILATION OF AVAILABLE AREA AND SITE LOCALITIES were selected representing geology, hydrology, seismology, land use, ecology, and man-made hazards. The estimated ranges of the existing conditions in each of these categories, for each site locality, are presented in Table IV-4.

TABLE IV-4

ESTIMATED RANGE OF EXISTING CONDITIONS AT SITE LOCALITIES ON THE HANFORD SITE

Parameter	Site Locality H-1	Site Locality H-2	Site Locality H-3	Site Locality H-4	Site Locality H-5
GEOLOGY/HYDROLOGY					
Estimated depth to basalt within site locality	400 to 700 feet	450 to 800 feet	0 (Gable Butte) to ~700 feet	0 (Gable Mtn.) to ~700 feet	~0 (south) to ~700 feet (north)
Estimated depth to Ringold Formation within site locality	~10 to ~60 feet	0 to ~50 feet	~25 to ~100 feet	~50 to ~150 feet	~50 to ~125 feet
Estimated basalt stratigraphic characteristics within site locality	Approximately flat-lying, except at south boundary	Approximately flat-lying; uniform; no apparent structure; beds thin to north	All edges dip slightly toward center; structural low near wells DC-4, -5. Yakima Ridge anticline crosses southern part	Dipping slightly to southern tip of site locality near wells DC-7, -8; northwest area is structurally complex	Southern 2/3 dips slightly to north; northern 1/3 dips slightly south; Yakima Ridge anticline may affect western parts
Estimated depth to Umtanum marker bed	>3,000 feet	>3,000 feet	~3,000 to 3,800 feet	~3,000 to 3,800 feet	~3,000 to 3,800 feet
Formations in repository zone (2,000- to 4,000-foot depth)	Upper part of Grande Ronde	Lower Wanapum-upper Grande Ronde	Lower Wanapum-upper Grande Ronde	Lower Wanapum-upper Grande Ronde	Lower Wanapum-upper Grande Ronde
Distance to nearest anticlines and faults	Measured from Gable Mountain anticline and associated faults. 0.25 to 3.25 miles	Measured from Gable Mountain and Saddle Mountains anticlines. 3.5 to 7.25 miles	Measured from Gable Mountain anticline and faults, and Umtanum and Yakima Ridge anticlines. 0 to 4 miles	Measured from Gable Mountain anticline and faults and Yakima Ridge anticline. 0 to 8 miles	Measured from Yakima Ridge anticline. 0 to 5 miles

TABLE IV-4 (Continued)

Parameter	Site Locality H-1	Site Locality H-2	Site Locality H-3	Site Locality H-4	Site Locality H-5
Distance to rivers	0.5 to 4.5 miles	1 to 4 miles	1.75 to 10.5 o miles	0.25 to 8 miles	0 to 10 miles
Estimated depth to water table	<50 to >150 feet	∿300 feet	<50 to >350 feet	<50 to >150 feet	∿130 to >190 feet
Estimated distance to irrigation wells	8 to 11 miles	1 to 5 miles	3 to 13 miles	2 to 12 miles	6 to 11.5 miles
SEISMOLOGY (Based on historical seismicity)					
Microearthquake: (Magnitude 1.0 from 1969 to 1977)					
a) Spatial distribution (trends)	No trend	No trend	Some trend northwest	No trend	No trend
b) Seismographic instrument coverage within or near site locality (USGS or University of Washington)	3 instruments	No instruments	4 instruments	2 instruments	1 instrument
c) Focal depth distribution	≤8.5 miles	≤18 miles	≤18 miles	No recorded events	≤18 miles
d) Temporal distribution of events in or near site locality	Swarm behavior	Swarm behavior	Random occurrences	No recorded events $M_L \geq 1$	Swarm behavior

TABLE IV-4 (Continued)

Parameter	Site Locality H-1	Site Locality H-2	Site Locality H-3	Site Locality H-4	Site Locality H-5
e) Magnitude distribution	M_L 1 to 3; $M_L \leq 2.5$ for swarms	M_L 1 to 3; $M_L \leq 2.5$ for swarms	M_L 1 to 2	Not applicable	M_L 1 to 3 $M_L \leq 2.5$ for swarms
f) Possible association with irrigation	Yes	Yes	Not applicable	Not applicable	Yes
Estimated horizontal bedrock accelerations from offsite historical earthquakes and distances for MM V and/or magnitude 4.0	2 to 8 miles; ≤ 0.02 g	5 to 11 miles ≤ 0.02 g	7 to 13 miles ≤ 0.02 g	13 to 24 miles ≤ 0.02 g	8 to 24 miles; ≤ 0.02 g
LAND USE/ECOLOGY					
Amount of surface area underlain by irrigable soil	∿35% (center of H-1 from north to south)	∿20% (all in southern part of H-2)	∿20% (all along and east edges of H-3)	∿4%	0%
Estimated amount of site locality with important wildlife habitat	10%	55%	75%	65%	80%
Estimated distance from protected ecological areas	0.75 to 7 miles	5 to 11 miles	0 to 7.5 miles	3.5 to 11 miles	0 to 5.75 miles

TABLE IV-4 (Continued)

Parameter	Site Locality H-1	Site Locality H-2	Site Locality H-3	Site Locality H-4	Site Locality H-5
MAN-MADE HAZARDS					
Distance to hazardous facilities	N-Reactor and 200 West Area; 0.75 to 5 miles	N-Reactor and and 200 East Area; 8 to 11.5 miles	200 West and 200 East Areas; 0.6 to 5 miles	200 East Area, FFTF, and WPPSS sites; 0.25 to 6.5 miles	200 East Area, FFTF, and WPPSS sites; 0.6 to 6.75 miles
Low-altitude military routes; high-altitude jet routes	Almost entire site locality within limits of jet route J143; only approximately 0.75-mile strip in northwest part lies outside; outside limits of low-altitude military routes	Almost entire site locality within limits of jet route J143; only south-eastern tip lies outside; outside limits of low-altitude military routes	Almost entire site locality within limits of jet route J143; only south-eastern and northwestern corners lie outside; outside low-altitude military routes	The northwestern 1/3 of site locality is within limits of jet route J143; outside limits of low-altitude military routes	Entire site locality lies outside limits of jet route J143 and low-altitude military routes
Contaminated soil and water: area-extent-level	Not applicable	Not applicable	Surface soil: some contamination. Unconfined ground-water: some contamination	Surface soil: none. Unconfined ground-water: some contamination	Surface soil: none. Unconfined ground-water: some contamination
Deep wells (>1,000 feet); distance and depth	Distance: 3 to 6.5 miles Depth: None in site locality	Distance: 1.5 miles to nearest deep well; Depth: None in site locality	Distance: 0 to 4 miles Depth: 1,046 to 5,700 feet (4 wells)	Distance: 0 to 5.5 miles Depth: 1,403 to and 4,100 feet (2 wells)	Distance: 0 to to 6 miles Depth: 1,292 and 1,490 feet (2 wells)

V. CONCLUDING REMARKS

This report presented the results of the site locality identification study for locating potential areas for a radioactive waste repository on the Hanford site. The study consisted of a screening and evaluation process carried out with the help of guidelines to focus on progressively smaller areas which had a higher potential for containing suitable sites for locating a radioactive waste repository than the areas not included for further analysis. The screening process was applied in two substeps to identify subareas within the Hanford site. These subareas were later evaluated in a series of substeps to identify five site localities designated as H-1, H-2, H-3, H-4, and H-5 (Figure IV-9). The site localities vary in size from approximately 10 to 50 square miles and were delineated based on an evaluation of conditions within them. It is anticipated that each site locality may contain one or more candidate sites that may be suitable for the construction of a repository.

Additional work will be necessary to identify candidate sites within the site localities. The methodology for additional work will be similar to the methodology described in Section II of this volume.

APPENDIX

GUIDELINES AND RATIONALE

APPENDIX

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

TABLE

APPENDIX
GUIDELINES AND RATIONALE

A.1 INTRODUCTION

This appendix is a discussion of the various considerations and guidelines used in the site locality identification study and the rationale utilized to select each guideline. The objectives of the guidelines and the considerations from which they were derived are maximize public health and safety, minimize environmental impacts, and minimize system costs. The anticipated approach for the use of each guideline and its relevance to the siting of a nuclear waste repository are discussed. Definitions of key terms are included with the guideline discussion. A summary of the siting guidelines is presented in Table III-3, and a list of the objectives and considerations is presented in Table A-1.

The siting methodology and guidelines used in the screening process are based on current licensing and regulatory requirements for nuclear facilities. The quantitative aspects of guidelines were derived from USNRC 10 CFR 100 and other regulatory documents, technical requirements of waste management, and previous experience and professional judgment in licensing.

A.2 PUBLIC HEALTH AND SAFETY

The considerations and guidelines developed to maximize public health and safety deal with hazards, effects, or events and fall into three general categories; natural hazards, man-made hazards or events, and repository-induced events.

TABLE A-1

OBJECTIVES AND CONSIDERATIONS OF SCREENING PROCESS

OBJECTIVE: MAXIMIZE PUBLIC HEALTH AND SAFETY

Consideration

A. Natural Hazards

- Fault Rupture
- Generation of New Faults
- Ground Motion
- Tectonic Movement
- Ground-water Contamination
- Flooding
- Volcanic Effects
- Future New Volcanic Activity
- Ground Failure
- Erosion/Denudation
- Stratigraphic Characteristics

B. Man-Made Hazards

- Aircraft Impact
- Hazardous Facilities
- Transportation
- Induced Seismicity
- Subsurface Mineral Exploration and Extraction
- National Defense and Security

TABLE A-1 (continued)

C. Repository-Induced Events
   Thermo-mechanical Effects
   Operational Radiation Release

OBJECTIVE: MINIMIZE ADVERSE ENVIRONMENTAL IMPACTS

Consideration

Protected Ecological Areas

Culturally Important Areas

Protected and Endangered Species

Biologically Important Areas

Existing Significant, Specialty, or Incompatible Land Uses

Potential Significant or Incompatible Land Uses

OBJECTIVE: MINIMIZE SYSTEM COSTS

Consideration

Site Preparation (Surface)

Site Preparation (Subsurface)

A.2.1 Natural Hazards

A.2.1.1 Fault Rupture

The potential for fault rupture is studied to describe the locations, orientations, lengths, and displacements of faults interpreted as being capable, faults of unknown capability, and non-capable faults in the study area. This evaluation serves to determine areas of higher potential for fault rupture, areas which are relatively less desirable for a nuclear waste repository.

Relevance to Siting. Displacement along an active fault through the subsurface repository and/or through surface facilities related to the repository may affect the safety of a potential site. In addition, because it is probable that licensing will be under the authority of the NRC and will most likely be similar to other nuclear facilities, faults will need to be evaluated.

In addition to capable faulting, potential repositories located on or near non-capable faults or fractured zones of tectonic origin may be relatively less desirable because of the potential for increased pathways to the biosphere and less desirable foundation conditions.

Measure. Three sets of measures are derived to describe the fault rupture consideration. The first set applies to capable faulting where the horizontal as well as vertical distance from known faults interpreted to be capable are important. The second set considers the distance from non-capable faults and/or distance from zones of fracturing/jointing. The third set considers the location with respect to lineaments and postulated faults.

<u>Guidelines</u>. Two sets of inclusionary guidelines and one classifying guideline corresponding to the three sets of measures are used.

Below are listed the inclusionary guidelines applicable to known faults interpreted to be capable and known faults of unknown capability which have a low potential for a capability evaluation:

- Include areas to within 5 miles, horizontally and vertically, of known faults interpreted to be capable and logical projections of these faults.

- Include areas to within 5 miles, vertically and horizontally, of known faults of unknown capability and which have a low potential for capability evaluation and their logical projections.

The inclusionary guidelines applicable to non-capable faults or fractures and faults of unknown capability which have a high potential for a capability evaluation are:

- Include areas to within 0.5 mile of known faults interpreted to be non-capable and to within 0.5 mile of zones of fracturing or jointing.

- Include areas to within 0.5 mile of known faults of unknown capability which have a high potential for capability evaluations.

The classifying guideline for lineaments and postulated faults is:

- Evaluate areas on the basis of their proximity to linear features (lineaments) as interpreted from remote sensing data (i.e., satellite and aerial imagery), geophysical data (i.e., aeromagnetics, gravity data, seismic data), and postulated faults.

Rationale. The potential for fault rupture is considered in the NRC review process for nuclear facilities. In this review, capable faults or faults interpreted to be capable that are greater than 1,000 feet in length and are located within 5 miles of the facility must have detailed studies to determine the possibility for fault rupture. These studies are conducted within an area called the "zone requiring detailed faulting investigations." Nuclear facilities may not be located within such a zone unless detailed studies demonstrate that the need to design for the effects of surface faulting has been properly determined.

Because a nuclear waste repository will likely be subject to similar site suitability criteria for fault rupture, the 5-mile setback from capable and potentially capable faults is considered to reasonably satisfy the present and future NRC regulatory position concerning fault rupture. Extending this guideline to the subsurface is a logical assumption because of the underground facilities of the repository. In addition, if a fault cannot reasonably be proven to be non-capable, or has a low potential for a fault capability evaluation, it may be considered capable. Due to the difficulty of proving capability and resultant licensing delays, faults of unknown capability and having a low potential for a capability evaluation are subjected to the same guideline as capable faults.

Siting to within 0.5 mile of non-capable faults and fractures is based primarily upon the desire to avoid siting on any fault or fracture that may provide pathways to the biosphere.

Approach. The capable fault inclusionary guidelines may be applied to obtain candidate areas at all steps in the screening process because of the importance to siting of this guideline. The areas included in each step by these guidelines are based on the level of detail of the data for each step in the screening process; thus, the guidelines are reapplied at each step as the level and detail of the data increase. The non-capable fault inclusionary guidelines may be applied to obtain site localities, while the classifying guideline may be used to evaluate areas to obtain site localities.

All known faults are identified and subjected to the inclusionary guidelines. Areas delineated on the basis of the inclusionary guidelines are plotted on overlay maps for the particular screening step and removed from further consideration.

All known faults are examined for classification into four groups:

- Known faults interpreted as capable according to the definition of a capable fault in NRC 10 CFR 100, Appendix A (see Definition of Terms)

- Known faults interpreted as non-capable based on local stratigraphy and the tectonic history of the area

- Known faults for which the capability could not be determined from the presently available data, but which appear to have a high probability for a capability evaluation based on the available stratigraphic and structural data

- Known faults for which the capability could not be determined from presently available data, but which appear to have a low probability for a fault capability evaluation based on the available stratigraphic and structural data.

Geologic maps and literature on the geologic structure, tectonics, seismicity, and geologic history of particular areas under study are used to identify known faults interpreted as being capable. If a particular known fault is shown to displace sediments younger than 500,000 years has historical seismicity associated with it, or can be shown to be structurally associated with a capable fault, it is classified as capable.

Known faults interpreted as being non-capable are identified from evidence indicating that undeformed sediments generally 500,000 years old or less overlie the fault.

Known faults are identified as of unknown capability when there is no definite geologic evidence to determine whether displacement on the fault is older or younger than 500,000 years. They are considered to have a high probability for a successful fault capability evaluation if Quaternary stratigraphy (useful for determining age of displacement along a fault) occurs near or on the projection of the fault in question and appears to be useful to a fault capability evaluation. The faults are considered to have a low probability for a successful fault capability evaluation if no Quaternary stratigraphy exists in the vicinity of the faults in question.

Following identification and classification of the known faults and/or fractures, the inclusionary guidelines are applied and the areas meeting the guidelines are included for further study.

The classifying guideline is applied in the following manner:

- Geologic and tectonic literature are reviewed to identify and locate lineaments and postulated faults interpreted to be significant to the tectonic structure of the Pasco Basin.

- Areas within the study area are subjectively evaluated with respect to their proximity to the identified lineaments and postulated faults.

- Areas are preferentially identied for further study.

Definition of Terms. "Capable fault:" A capable fault as defined by the NRC (10 CFR 100) is a tectonic fault which has exhibited one or more of the following characteristics, as cited from 10 CFR 100:

"(1) Movement at or near the ground surface at least once within the past 35,000 years or movement of a recurring nature within the past 500,000 years;"

"(2) Macro-seismicity instrumentally determined with records of sufficient precision to demonstrate a direct relationship with the fault;"

"(3) A structural relationship to a capable fault according to characteristics (1) or (2) of this paragraph such that movement on one could be reasonably expected to be accompanied by movement on the other."

"In some cases, the geologic evidence of past activity at or near the ground surface along a particular fault may be obscured at a particular site. This might occur, for example, "at a site having a deep overburden. For these cases, evidence may exist elsewhere along the fault from which an evaluation of its characteristics in the vicinity of the site can be reasonably based. Such evidence shall be used in determining whether the fault is a capable fault within this definition.

"Notwithstanding the foregoing paragraphs (1), (2), and (3), structural association of a fault with geologic structural features which are geologically old (at least pre-Quaternary), such as many of those found in the eastern region of the United States, shall, in the absence of conflicting evidence, demonstrate that the fault is not a capable fault within this definition."

A.2.1.2 Generation of New Faults

Because of the long time frame proposed for the repository isolation period (10,000 years), the potential generation of new faults and potential reactivation of existing faults are studied to delineate areas considered to have a lower potential for new or renewed fault rupture. Thus, these areas have a higher likelihood of containing suitable nuclear waste repository sites.

Relevance to Siting. The relevance to siting of the generation of new faults and reactivation of existing faults is the same as for fault rupture (see Section A.2.1.1). This consideration becomes more significant during the isolation period because fault rupture during the operation period is most likely to occur on existing capable faults.

Measure. The measure selected to represent the generation of new faults is the location of the fault with respect to future, potentially capable tectonic structures.

Guideline. Locations within the study area and within 5 miles of those portions of anticlines, synclines, and monoclines interpreted as being potentially capable in the future are interpreted as having a potential for the generation of new faults or reactivation of existing faults. This guideline may be applied to obtain subareas and to obtain site localities.

Rationale. Based on a review of geologic, structural geologic, and tectonic data for the Pasco Basin and surrounding region, the major faulting appears to be associated with and concentrated near the axes of bedrock folds. Any future new faulting is also likely to occur along or near fold axes. The 5-mile setback is based on the capable fault setback discussed in Section A.2.1.1.

Approach. The approach used in applying this guideline consists of identifying and locating bedrock folds in the study area and defining those interpreted to be potentially capable in the future. This process may be done at two screening steps; to obtain subareas and also to obtain site localities. Each step uses data of significantly different levels of detail.

To obtain subareas, regional-scale data are used to identify and locate bedrock folds within the study area. The folds are examined and evaluated on the basis of the age of deformation, degree and intensity of deformation, rate of movement, and regional and local tectonic framework. Based on this evaluation, the folds believed to be potentially capable of generating new faults are identified, and areas greater than 5 miles from those portions of the axes of the folds are included for further study. The same process may be used to obtain site localities; however, the data used are more detailed.

Definition of Terms.

"Fold:" a curve or a bend of rock strata, usually a product of tectonic deformation.

"Anticline:" a fold, the core of which contains the stratigraphically older rocks that is convex upward.

"Syncline:" a fold, the core of which contains the stratigraphically younger rocks that is concave upward.

"Monocline:" a unit of strata that dips or flexes from the horizontal in only one direction and is not part of an anticline or syncline; generally a large feature of gentle dip.

"Capable fault:" see Section A.2.1.1.

A.2.1.3 Ground Motion

Ground motion is studied in order to describe the potential for seismic ground shaking in the study area. Although there will be facilities under ground as well as on the surface, results of a preliminary literature review indicate that vibratory ground motion at depth in a rock environment probably would be less than at the surface (Brekke and Glass, 1973). The location of historical seismicity and the estimated level of potential ground motion are used to define a relative level of potential hazard to the surface facilities and belowground repository galleries and tunnels. In this manner, the relative desirability of an area for repository siting is defined.

Relevance to Siting. The response of the site to potential ground motion, over the operational lifetime of the facility, can affect both the safety and design costs of surface and subsurface facilities. Additionally, a requirement of baseline seismic monitoring can cause delays in licensing.

Measure. The estimated level of ground motion (horizontal acceleration) and the location of a site away from close proximity to historical earthquake activity are the measures used in establishing the guidelines for the consideration of ground motion. The estimates of horizontal acceleration are based on identifying potentially capable faults and applying applicable empirical relationships between length of fault rupture, earthquake magnitude, and horizontal base rock acceleration.

Guidelines. Four guidelines are used to define the consideration of ground motion. The first is an inclusionary guideline where portions of the study area considered to have a high likelihood of experiencing moderate to low horizontal accelerations (less than 0.40 g) are included for further study. This guideline may be used to obtain candidate areas. The second guideline is also inclusionary and includes for further study those areas greater than 12 miles from felt epicenters which are larger than MM V and greater than 6 miles from instrumental epicenters larger than magnitude 4 and which occur in concentrations or clusters. This guideline may be used to obtain subareas. The remaining two guidelines are classifying. One is used to evaluate areas with respect to isolated historical earthquakes having epicentral intensities MM V and/or magnitudes greater than 4.0 based on estimated location and the surrounding geologic and tectonic setting. The other is an evaluation of areas with respect to shallow microearthquakes (less than 3.5 miles depth) based on location errors, geologic and tectonic setting, and the local and regional stress regime. Both classifying guidelines may be used to preferentially identify and evaluate areas to obtain site localities.

Rationale. A potential horizontal acceleration of moderate to low severity (0.40 g or less) is considered to be an acceptable characteristic for aboveground and belowground facilities of a waste repository. Major manufacturers of Nuclear Steam Supply System (NSSS) components for nuclear power plants generally design for acceleration of 0.25 g as a minimum, and designs for higher accelerations up to 0.75 g have been completed. Potential accelerations of up to 0.40 g probably would not require significant additional expenditures for either seismic design or would cause delays related to additional seismic investigations; however, designs in excess of 0.40 g are significantly more expensive and may cause licensing delays.

The inclusion of areas away from concentrations or clusters of larger historical earthquakes (MM V or greater and magnitude 5 or greater) is reasonable, in that the probable tectonic origin for the earthquakes and the probable location errors associated with the epicenters are recognized. Such clusters or concentrations of earthquakes present patterns which have more certainty of having a meaningful identification with probable active tectonic structures than single, isolated earthquakes.

For earthquakes that cannot be readily associated with or assumed to be associated with tectonic structures, as with the inclusionary guidelines, such earthquakes are evaluated with classifying guidelines. These classifying guidelines recognize that siting repository facilities in close proximity to isolated larger earthquakes or to the reported locations of microearthquake activity is generally not desirable because of the increased level of study involved in the subsequent review and licensing process. The two classifying guidelines take into account the uncertainty of location and variation in detection threshold as they change with time, population distribution, and instrument coverage.

Approach. The approach used in applying the first inclusionary guideline for ground motion, "include areas with horizontal acceleration (less than 0.40 g)," consists of several steps. In the first step, two interpretive maps are developed; a fault map of the study area and an earthquake epicenter map. The fault map is based on available regional geologic, structural geologic, and tectonic data. The earthquake epicenter map is prepared with the following requirements:

- Include instrumental data for all earthquakes of magnitude greater than zero.
- Include all earthquakes based on maximum felt reports.
- When data sources cite more than one epicentral location, available data on felt effects and/or instrument coverage will be analyzed in order to select the most probable location.

In the second step, the fault and earthquake epicenter maps are evaluated to identify potential earthquake sources. The faults are classified into three categories; faults interpreted to be capable, non-capable faults, and faults of unknown capability. Capable faults are those that meet the criteria for capable faults specified by the NRC in 10 CFR 100, Appendix A. Faults of unknown capability are those on which the age of the last movement cannot be ascertained from the available data. Only faults interpreted to be capable and faults of unknown capability and that are longer than 12 miles are considered as potential earthquake sources in evaluating the ground motion potential. Faults of smaller length are examined for the consideration of fault rupture (see Section A.2.1.1) or are evaluated during the later stages of the screening process.

The third step consists of using empirical relations comparing earthquake sources to horizontal ground acceleration at the surface. Potential earthquake sources identified in step two are assigned a magnitude based on an earthquake magnitude-fault rupture-length empirical correlation (Patwardhan and Others, 1975) using half of the fault length as the rupture length. The probability of occurrence of the assigned magnitude earthquake is considered to be the same everywhere along a capable or potentially capable fault. Next, peak horizontal acceleration on rock is estimated for the given earthquake magnitude. Setback distances based on earthquake magnitude and peak horizontal acceleration are estimated from the faults (Tocher and Patwardhan, 1975) and represent peak horizontal acceleration on rock at the surface of less than 0.40 g. Because of the large number of faults greater than 12 miles in length, the following table, which indicates the setbacks to be used, simplifies the application of this guideline.

Fault Length (miles)	Setback Distance (miles)
12 to 24	5
24 to 60	10
>60	15

Lines are drawn around the potential earthquake sources at the appropriate setback distances. Areas outside these enclosures are considered to have a higher likelihood of experiencing moderate or low acceleration from earthquake ground shaking.

The approach used in applying the second inclusionary guideline consists a) of identifying concentrations or clusters of historical seismicity having epicentral intensities greater than MM V and magnitude 4 (using epicenter map prepared for limiting guideline above), and b) of drawing the radii of 12 miles and 6 miles (for the felt epicenters and instrumental epicenters, respectively) and forming an envelope of all overlapping or contiguous circles. Areas outside these enveloped clusters are considered to have a higher likelihood of experiencing moderate to low accelerations from earthquake ground motion.

The approach used in applying the classifying guidelines consists of the following steps:

- Identification of areas of shallow (less than 3.5 miles depth) microearthquakes and isolated larger (MM V and greater, magnitude 4 and greater) earthquakes. The deeper microearthquakes (greater than 3.5 miles depth) are generally random, spatially and temporally, and are recognized generally only within the microearthquake network areas. These deeper microearthquakes are considered to occur equally randomly throughout the areas.

- Evaluation of the earthquakes identified above based on potential location errors, the geologic and tectonic setting, and the local and possibly regional stress regimes.

- Preferential identification of areas having a higher likelihood of containing suitable nuclear waste repository sites based on the evaluations of the tectonic setting in relation to historical earthquake and possible location errors.

Definition of Terms.

"Capable fault:" see Section A.2.1.1.

"Epicenter:" the point on the earth's surface that is directly above the focus of an earthquake.

"Microearthquake:" for the purposes of this study, an earthquake which is not felt or has a magnitude of less than 3.

"Macroearthquake:" for the purposes of this study, a felt earthquake or an earthquake having a magnitude of 3 or greater.

A.2.1.4 Tectonic Movement

Tectonic movement is used to define areas of potential differential tectonic movement (as opposed to uniform regional movement) which may occur during the isolation period of the repository, particularly in the subsurface facilities. The level or potential for differential tectonic movement defines areas of relative desirability for locating a nuclear waste repository.

Relevance to Siting. Potential differential tectonic movements localized at or near a repository site may affect the safety of the site through local uplift/subsidence, through changes in the local stress regime which may initiate new patterns or modify existing patterns of geologic structure (e.g., fractures, joints), or through potential changes in the local ground-water regime. Avoiding areas of existing and potential future tectonic movement can not only increase the suitability of the repository site but can also decrease the potential for delays in licensing.

Measure. Past differential tectonic movement in the Pasco Basin has been concentrated on or near bedrock folds (anticlines, synclines, and monoclines), and future differential tectonic movement is likely to occur along existing folds. Thus, the measure used for this consideration is location with respect to potential bedrock folding (including anticlines, synclines, and monoclines).

Guideline. A classifying guideline is used to describe the potential for differential tectonic movement. It is used to preferentially identify and evaluate site localities and is stated as follows: Evaluate areas on the basis of proximity to bedrock folds (anticlines, synclines, or monoclines) using data on the extent and degree of folding as interpreted from available geologic and structural geologic information.

Rationale. Based on a review of geologic and structural geologic studies in the basalt of the Pasco Basin (Newcomb and Others, 1972; Grolier and Bingham, 1971 and 1978; Jones and Landon, 1978; and Reidel, 1978), the classifying guideline is believed to reasonably represent the concern for the consideration of differential tectonic movement. The available data suggest that bedrock folding in the Columbia Plateau basalt continued as late as the Ringold Formation (Plio-Pleistocene) and is possibly an on-going process. Recent studies in Japan (Matsuda, 1976) have shown that in active zones of folding, the maximum rate of increasing amplitude or relative uplift at an anticlinal axis of Quaternary folding has been about 1 inch/year. Because of the relative recency of bedrock folding in the Pasco Basin region and the need for a stable geologic environment for the repository, it is felt that the evaluation of areas of past folding will result in the location of sites which have a higher likelihood of being suitable for nuclear waste repositories.

Approach. The approach used for employing the classifying guidelines involves an examination and evaluation of structural geologic maps for the study area. Mapped folds are identified and the guideline is applied to the folds such that areas are evaluated to preferentially identify site localities.

Definition of Terms:

"Tectonics:" branch of geology dealing with the broad structures of the upper part of the earth's crust, their origins, mutual relationships, and evolution.

"Fold:" see Section A.2.1.2.

A.2.1.5 Ground-water Contamination

The ground-water flow system is studied with regard to the potential for radionuclide transport to natural and man-made surface discharge areas. This allows an assessment of the relative desirability of an area for repository siting.

Relevance to Siting. Ground-water flow direction and velocity in formations within and adjacent to the repository host rock affect the degree to which long-term isolation from the biosphere can be achieved.

Measure. The measure selected to represent ground-water contamination is location with respect to natural and man-made discharge areas. Adequate ground-water data are lacking in the Pasco Basin to support a more rigorous application of the ground-water consideration.

Guideline. The guideline used to define the potential for ground-water contamination is a classifying guideline based on proximity to natural and man-made discharge areas. It involves an evaluation of discharge areas and the ground-water characteristics of the region to preferentially select one area over another.

The Pasco Basin has locations that have a high likelihood of containing natural or man-made ground-water discharge points that may be hydraulically interconnected to some degree with deep aquifer systems. In addition, these same locations are characterized by relatively high apparent (composite) horizontal hydraulic gradients. Such localities most likely occur along the Columbia River drainage system and in areas containing a high density of irrigation wells. Thus, areas such as the above are avoided in siting the repository. In addition, because the subsurface migration distance of radionuclides in ground water affects the travel time, it also affects the decay, diffusion, dilution, and absorption potential between the subsurface repository and the biosphere. Thus, generally, the farther away a repository site is selected from these discharge areas, the better. The classification guideline is used to preferentially identify and evaluate site localities.

Rationale. At present, subsurface hydrologic test data are not available in sufficient detail to reliably quantify the vertical and horizontal hydraulic gradients and permeabilities, porosities, dispersion, and absorption of the proposed repository formation or the formations immediately above and below it. Therefore, because it may be difficult to reliably estimate the velocity of radionuclide transport throughout the study region, no numerical inclusionary guidelines have been specified. Rather, by using general hydrogeologic concepts regarding the hydrodynamics of the region, site localities will be evaluated and classified based on their distance from ground-water discharge areas. Recharge areas can affect flowpaths and rates, but they are not considered to be as important as distance to discharge areas until more detailed data are available to determine the interaction of the two.

Approach. The first step in applying this classifying guideline is to examine maps of ground-water level and water well locations within the study area. The second step is to prepare an overlay map of apparent natural and man-made ground-water discharge areas. The areas are then classified using these overlay maps according to the principle that site localities farther away from discharge areas are better.

Definition of Terms.

"Ground water:" all subsurface water in the zone of saturation, including underground streams.

A.2.1.6 Surface Flooding

Surface-water hydrology and river floodplain geomorphology are studied to delineate areas that have a low potential for flooding and thus have a higher likelihood of containing suitable repository sites.

Relevance to Siting. Flooding may affect the safety of surface and subsurface repository facilities. It is reasonable to assume that the NRC position regarding nuclear power plant sites would probably also apply to nuclear repository sites if and when such a position on repository sites is promulgated.

The NRC position states that sites located in river valleys, in floodplains, or along coastlines where there is a potential for flooding will not be evaluated for site suitability until the studies outlined in NRC Regulatory Guide

1.59 have been made. These factors make flooding potential relevant to repository siting.

Measure. The measure used in applying this consideration to the siting study is the height above a selected flood level. This measure which can be depicted on maps of the study areas reasonably represents the concern of potential surface flooding of repository facilities.

Guidelines. Three guidelines are used to describe the effects of flooding. The first is an inclusionary guideline which identifies locations within the study area that have a high potential for flooding and that are interpreted as being within primary floodplains from topographic and geologic maps or within published probable maximum flood levels. These locations occur adjacent to the Columbia, Snake, Yakima Rivers, and other rivers in the study area. These high flood potential areas, plotted on an overlap map, are not retained for further consideration. Areas above the primary floodplain are evaluated using the following two classifying guidelines:

- Evaluate areas on the basis of their height above primary floodplains and on published probable maximum flood levels and

- Evaluate areas on the basis of their location with respect to areas where catastrophic flooding (i.e., Spokane Floods) has occurred during the Quaternary time.

Rationale. Because floods which have occurred throughout Holocene times have been largely responsible for forming the primary floodplain, it is reasonable that areas outside the primary floodplain will have a significantly lower potential for flooding in the future and that the higher these areas are above the floodplain the better. In addition, although the probability of catastrophic flooding similar to the Spokane Floods is low during the isolation period, preferentially evaluating these areas as possible repository sites is considered reasonable.

Approach. Overlay maps delineating the primary floodplains and published probable maximum flood levels of the rivers in the study area are prepared. The primary floodplains are removed from further consideration. Site localities with higher elevations above the primary floodplain and outside areas of catastrophic flooding are classified as being more favorable with regard to flooding potential.

Definition of Terms.

"Flooding potential:" areas susceptible to flooding by precipitation, wind, or seismically induced floods (i.e., those resulting from dam failure, river blockage or diversion, or distantly or locally generated waves) are considered to have a flooding potential.

A.2.1.7 Volcanic Effects

The type and intensity of potential volcanic ashfall are used to define the relative potential hazard to repository facilities. The distribution of potential volcanic ashfall is used to define the relative desirability of an area for repository siting.

Relevance to Siting. Quaternary volcanic activity, particularly from andesite stratovolcanoes, is common within and along the western and southwestern borders of the Columbia Plateau, particularly in and near the Cascade Mountains. Because of the active nature of some of the volcanoes, volcanic ashfall is considered to be a safety-related factor in site locality identification.

Measure. The measure selected to represent the consideration of volcanic effects is the distance to a potential volcanic ashfall source or its effects. Because the sources can be defined from maps and available data, the measure becomes a mappable quantity adequate to depict the consideration.

Guideline and Approach. The guideline used to describe the potential for volcanic effects is a classifying guideline and is used to assess the far-range effects of potential volcanic ashfall (from the eruption of a Cascade stratovolcano) on a repository site.

The potential thickness of ashfall in an area is estimated on the basis of a model developed for the Pebble Springs Nuclear Power Plant (Shannon and Wilson, 1976; NRC, 1977). In this model, the maximum downwind thickness from the largest ashfall event from Mt. St. Helens is used to describe the total thickness expected, while the ashfall rate from Mt. Katmai, Alaska is used to describe the expected rate. The probability of an ashfall occurring with a great enough thickness that could seriously affect the safety of repository facilities (and thus limit areas) is considered to be low because the closest stratovolcano is at least 75 miles from the study area. From the model, however, classifications for potential thickness of ashfall are established on the basis of distance from potential sources of ash:

A) >150 miles to source
B) 40 to 150 miles to source;
C) <40 miles to source.

This guideline for ashfall would be applied to the closest Cascade stratovolcanoes to arrive at the maximum effect from the above classifications of areas. The classification for potential ashfall is used in the preferential identification and evaluation of site localities.

Rationale. An examination of volcanic effects from Quaternary andesite stratovolcanoes suggests that the near-range effects are concentrated within 12 miles of the stratovolcano. Because the Quaternary stratovolcanoes are at least 75 miles from the study area, no inclusionary guideline is used for them.

Mt. St. Helens is used as the model for ashfall because it has already been used by the NRC in the licensing review of the Pebble Springs Nuclear Power Plant. The model ashfall (Ashfall Y) has produced the greatest thicknesses downwind of the Cascade stratovolcanoes. Based on the model, it is believed that, for distances less than 40 miles, ashfall will have maximum effect on repository facilities and may significantly affect facility design; for distances beyond 150 miles, the effects will be minimal.

A.2.1.8 Future New Volcanic Activity

Future volcanic activity is studied to describe the potential for future new eruptions within the study area and thus to define the relative desirability of an area for a nuclear waste repository.

Relevance to Siting. Because of the long time frame (10,000 years) of the isolation period and the need to maintain a stable geologic environment for that period, the potential for future volcanic activity breaching or affecting the repository becomes important. This is particularly true when siting of the repository occurs within a thick volcanic sequence in an area of past volcanic activity (i.e., the Columbia Plateau).

Measure. The measure selected to represent future volcanic activity is the location of an area with respect to areas which may have a potential for future volcanic activity.

Guideline and Approach. A classifying guideline is used to define the probability of future volcanic activity and its effect on areas of the siting study. The basis for this is an evaluation of available geologic, tectonic, and geophysical data for the study area to ascertain past patterns of volcanic activity. These data are used to estimate future patterns of volcanic activity, if possible, within and near the Pasco Basin and those areas which may have a probability of future eruption. This evaluation is thus used to preferentially identify and evaluate site localities.

A.2.1.9 Ground Failure

Ground failure is used to describe areas of existing ground instability, as well as to delineate areas that may have a potential for ground failure. It serves to define areas that are more desirable for the siting of nuclear waste repository facilities (particularly surface or near-surface facilities).

Relevance to Siting. Siting a repository on unstable ground or in an area having a having potential for ground failure may affect the safety of surface facilities needed for access to a nuclear waste repository. In addition, extensive foundation and slope stability investigations may cause delays in licensing and could also add to the cost of design and construction of repository facilities.

Measure. Two measures were developed to describe the major concerns for the consideration of ground failure. One deals with location with respect to existing landslides or potential landslides; that is, essentially with slope stability. The other deals with characteristics of foundation conditions; that is, with foundation stability. Both measures can be adequately applied to maps to successively reduce areas for further study.

Guidelines and Approach. The approach used to define the consideration of ground failure involves the use of both inclusionary and classifying guidelines. In general, those areas of mapped landslides or interpreted to be landslides are identified and removed from further consideration. The remaining areas are evaluated for potential ground failure as manifested in any of the following phenomena; landslides, liquefaction, subsidence, or differential settlement. The areas are then classified as to the probability of such failure.

Specifically, areas that are mapped as landslides or interpreted to be landslides are outlined and plotted on overlay maps and are not considered further. The inclusionary guideline may be used to obtain site localities. The areas remaining are classified by two sets of classifying guidelines:

- Potential for landslides
  - A) low probability of a landslide
  - B) slight probability of a landslide
  - C) higher probability of a landslide

- General foundation characteristics
  - A) bedrock area (0 to 20 feet of unconsolidated material)

B) shallow alluvial area (20 to 100 feet of unconsolidated material)

C) deep alluvial area (more than 100 feet of unconsolidated material).

The bases for the evaluation of the potential for landslides are the lithologic descriptions of formations from available geologic maps (including all mapped landslides), the history of landslides within each formation, and the presence of mass movement topography as determined from geologic hazard maps and topographic maps. From the above data, landslides are delineated and the remaining areas evaluated as to their potential for landslides (categories A through C above).

The bases for evaluation for other types of potential ground failure include the lithologic descriptions and determinations or estimates of the depth of unconsolidated material throughout the area. The thickness of unconsolidated material in each area is determined or estimated from the available literature on geology. Each area is then classified as to its general foundation characteristics (categories A through C above).

These two classifications are used in the preferential selection and evaluation of site localities.

Rationale. Areas of actual mapped landslides or unstable topography (mass movement topography) and areas that are interpreted to be landslides may affect the safety of repository facilities. Experience has shown that delays in licensing can occur when nuclear facilities are located on or near existing or potential landslides. The potential for landslides and mass movement of the topography can be estimated through a geologic evaluation of the data on the site localities.

Similarly, the thickness of unconsolidated material can affect the safety and cost of repository facilities, in that under seismic stress the materials may be subject to liquefaction. Therefore, the thickness of such materials generally determines the ease and cost of excavations to reach a stable foundation. Experience has shown that the difficulty and cost of foundation preparation increase sharply when the thickness of unconsolidated material exceeds 100 feet and that thicknesses of 0 to 20 feet are more suitable since they approximate bedrock conditions. From this evaluation, areas more closely approximating bedrock conditions are delineated.

Definition of Terms.

"Landslide:" general term for a variety of mass movement land forms and processes involving the moderately rapid to rapid (on the order of 1 foot per year or greater) downslope transport of soil and rock material en masse by means of gravitational body stresses.

"Unconsolidated Material:" clay, silt, sand, gravel, or similar detrital material deposited during comparatively recent geologic time (i.e., late Pleistocene to Recent).

A.2.1.10 Erosion/Denudation

Erosion or denudation of the landscape is studied to describe the potential for exposing the repository to the biosphere during the isolation period. The relative potential for erosion or denudation affecting or breaching the repository is used to define the relative desirability of an area for containing a nuclear waste repository.

Relevance to Siting. The potential for erosion or denudation may affect the safety of a repository site. Erosion or denudation during the isolation period could expose the repository to the biosphere either by breaching the host rock containment or by shortening the pathways to the biosphere. Location of potential repository sites in areas with lower erosion/denudation potential would increase the likelihood of finding suitable repository sites.

Measure. The measure selected to represent erosion or denudation is the location of potential repository sites with respect to areas of potential erosion or denudation. This measure can be depicted as a map distance or can be judged subjectively.

Guidelines. Two sets of guidelines are used to describe the potential for erosion/denudation. The first set is an inclusionary guideline used to obtain candidate site localities. It includes, for further study, areas greater than 0.5 mile from steep-walled canyons (slopes approximately 40%). The second set of guidelines includes the classifying guidelines used in the preferential identificaton and evaluation of site localities. These guidelines classify the study areas into the following:

- Those areas where the proposed repository level would be below mean sea level (base level for erosion).
- Those areas where the proposed repository level would be above mean sea level (base level for erosion).

Rationale: The inclusionary value of 0.5 mile from steep-walled canyons for the consideration of erosion/denudation is based on an evaluation of regional denudation rates in the Pasco Basin area. Hunt (1974) and Judson and Ritter (1964) suggest regional rates of denudation (regional lowering) for the Columbia Plateau, that range from 0.6 inch/1,000 years

Measure. Three measures are used to define the consideration of stratigraphic characteristics:

- Bedrock dip
- Presence of suitable stratigraphic characteristics
- Thickness of underlying host rock-type material.

Guidelines. The guidelines developed to describe these measures are both inclusionary and classifying:

- Bedrock dip: This classifying guideline divides potential repository strata into three groups on the basis of dip; 0 to 5 degrees, 5 to 10 degrees, and greater than 10 degrees.

- Presence of suitable stratigraphy: This guideline essentially states that suitable rock for repository containment must exist at the proposed repository depth and that it must have acceptable thickness, structure and internal strength, and mechanical properties. Areas are evaluated for these suitable characteristics to obtain site localities.

- Thickness of underlying host rock-type material: This inclusionary guideline includes areas where the thickness of the host rock-type material underlying the proposed repository is at least 500 feet.

Rationale. The guideline of bedrock dip applies primarily to the development, construction, and operating costs of the repository. The bracketed ranges in dip reflect the estimated relative ease of construction and operation and, thus, cost of potential repositories which must be located in definite stratigraphic and depth intervals. The greater the dip, the more difficult and costly the construction becomes.

The guidelines concerning the presence of suitable stratigraphic characteristics are based on the need for at least one basalt flow that is greater than 100 feet thick and should ideally occur at the proposed repository depth of 2,000 to 4,000 feet. In addition, unless this flow meets the minimum or estimated minimum structural, strength, mechanical, density, porosity, extent, continuity, etc. requirements for the repository, it may not be suitable. This guideline becomes a classifying guideline if more than one suitable flow is present within the repository depth range. That is, more repository options are available at a site having more suitable flows; thus, such a site becomes more desirable.

The inclusionary guideline for the thickness of underlying host rock-type material stems from the need to ensure that the repository is isolated in rock for which information exists and for which it will probably be designed. The 500-foot-thick limit appears to be reasonable and fits the level of detail of the available data on basalt thickness.

Approach. Geologic data concerning basalt thickness, flow thickness, geologic structure, internal flow characteristics, and stratigraphic characteristics are collected for the subareas and/or candidate zones. These data are used to develop overlays for the inclusionary guidelines of stratigraphic characteristics and thickness of underlying basalt, as well as for the evaluation of areas to identify and evaluate preferred site localities using the classifying guidelines of bedrock dip and suitable stratigraphic characteristics.

A.2.2 Man-Made Hazards

A.2.2.1 Aircraft Impact

Areas having potentially high volumes of low-altitude aircraft traffic are considered to be unsuitable for repository siting and are removed from further study.

Relevance to Siting. The NRC review process will very likely consider the potential hazard to the safety of repository surface structures resulting from aircraft collision with such structures. In addition, segregating airports and air traffic patterns from land uses having potentially hazardous emissions is a generally accepted principle of land-use management.

Measure. The potential hazard of aircraft impact is measured in miles from airports and designated aviation routes or restricted airspace. This measure is a proxy for probability of impact, the assumption being that probability of impact decreases with distance from high traffic areas.

Guidelines. Areas within 5 miles of airports shown on state airport plans as accommodating aircraft of 12,500 pounds gross weight and areas within 5 miles of any military airport will not be included for further study. In addition, the present (and, if available, projected) volume of air traffic at airports will be considered and used to define a setback distance. For airports with more than 12,500 operations per year and fewer than 50,000 operations (an operation is a takeoff or landing; a touch-and-go movement is two operations), the setback distance in miles is equal to the square root of 0.002 (total operations). For airports with 50,000 to 100,000 operations, the setback is 10 miles. For airports with more than 100,000 operations per year, the setback in miles is equal to the square root of 0.001 (total operations). The distance in miles from designated commercial jet lanes and designated military training routes is used as a classifying guideline. Areas within the limits of restricted airspace defining intense, airborne military training activities are not included for further study.

Rationale. The NRC regulatory positions on accident analysis, aircraft considerations, and nearby hazardous facilities as they apply to nuclear power stations are considered to be representative of the degree of conservatism that may be applied to a repository siting safety review. This position is stated in Regulatory Guides 1.70 and 4.7. The following language is taken from Regulatory Guide 4.7

> "A special analysis of such factors as frequency and type of aircraft movement, flight patterns, local meteorology, and topography should be performed for (1) sites located within 5 miles of any existing or projected commercial or military airport, (2) sites located between 5 and 10 miles from any existing or projected commercial or military airport with more than approximately 500 d^2 (where d is in miles) aircraft movements per year, and (3) sites located at distances greater than 10 miles from an airport with more than approximately 1,000 d^2 aircraft movements per year. The analysis should demonstrate that the probability of any potential aircraft affecting the plant in such a way as to cause the release of radioactive materials in excess of the guidelines of 10 CFR Part 100 is less than about 10^{-7} per year. If the probability is on the order of 10^{-7} per year or greater, aircraft impact should be considered in the design of the facility."

The inclusionary guidelines given above for airports are direct translations or numerical conversions of these NRC review formulas. The guidelines are applied to minimize the probability that aircraft could impact at a repository site and to avoid the requirement to perform multiple, detailed risk analyses for sites close to airports.

The classifying guidelines to consider the distance to designated commercial jet lanes and designated military training routes recognize the generally low probability of an accident along such routes when compared to fixed-point sources of traffic.

The inclusionary guideline concerning restricted airspace recognizes that these areas are locations of concentrated, low-level, high-speed and/or low-speed, possibly armed military aircraft activity. They have been designated restricted because of the hazardous nature of their existing usage. Areas included for further study are away from these restricted areas, thus minimizing the requirement to perform detailed risk analyses for aircraft impact and inadvertent weapons firing.

Approach. The 5-mile setback from airports is applied to small-scale maps of the study area. Airports are identified on state airport plans, located on study area maps, and circumscribed with a 5-mile radius. The additional setbacks that correspond to the volume of operations are applied in a similar fashion to larger scale maps of candidate areas. Operation volumes are obtained from state airport plans, the FAA, and from direct contacts to airport traffic managers.

The classifying guideline may be applied to subareas. All or portions of a subarea are described in terms of air miles to the ground locations of commercial and military routes. This information is used in the preferential selection and evaluation of site localities.

The inclusionary guideline for restricted airspace is applied to obtain subareas. It involves identifying the restricted airspace from FAA charts and removing such areas from further study through the overlay process.

Definition of Terms. State airport plans are officially prepared descriptions of present and projected aviation facilities. A common categorization of airports is by gross weight of aircraft accommodated. Airports accommodating aircraft weighing less than 12,500 pounds generally have few or no facilities; FAA control is generally not provided for such airstrips.

A.2.2.2 Hazardous Facilities

Areas currently in a land use that is interpreted as presenting a potential hazard to the safety of operation of a repository and its associated facilities and areas close to and potentially affected by such hazardous uses are not considered to be suitable for siting.

Relevance to Siting. The NRC review process for a proposed repository is likely to consider the effects of accidents or potentially hazardous operations at facilities that contain explosive, corrosive, or flammable materials that could generate missiles, fire, shock waves, or vapor clouds.

Measure. The location of potentially hazardous facilities and distance (in miles) to certain facilities are used as proxies for the potential hazard associated with such facilities.

Guidelines. Large, potentially hazardous facilities (greater than or equal to 18,000 acres in size) are identified and removed from further consideration. Such facilities may include bombing and gunnery ranges, major ordinance depots, and large transportation or trans-shipment centers. Facilities which are possible missile or noxious vapor cloud generators (of any size) are further limited by a 0.6-mile setback, if they have not been removed by application of the first guideline. The large area guideline is applied to obtain candidate areas, potential missile generators are considered at the subarea stage of screening, and vapor cloud sources are considered in the identification of site localities. A classifying guideline evaluates the area remaining, after the inclusionary guidelines are applied, based on proximity to hazardous facilities.

Rationale: The NRC safety review procedures on nearby hazardous facilities as they apply to nuclear power plants, reprocessing plants, and other fuel cycle installations are considered to be representative of the concerns and degree of conservatism that will be applied to a repository siting review. The NRC position on hazardous and potential accidents used in developing these guidelines is stated in Regulatory Guides 1.70 and 4.7. An example of the language appearing in these guides is taken from Regulatory Guide 4.7:

> "Potentially hazardous facilities and activities within 5 miles of a proposed site must be identified. If a preliminary evaluation of potential accidents of these facilities indicates that the potential hazards from shock waves and missiles approach or exceed those of the design-basis tornado for the region (the design-basis tornado is described in Regulatory Guide 1.76), or potential hazards, such as flammable vapor clouds, toxic chemicals or incendiary fragments exist, the suitability of the site can only be determined by detailed evaluation of the potential hazard."

Areas which are presently occupied or used for hazardous facilities or operations (like a bombing range) are not considered suitable for siting. More specific review criteria for sites near sources of missiles, shock waves, or vapor clouds generally require detailed risk analysis, if the hazardous facilities in question are closer than a specified distance, ranging in most cases from 1,148 to 3,280 feet. The 0.6-mile setback proposed above bounds the range of these distances and would thereby alleviate the need for detailed study of most potentially hazardous facilities. The 18,000-acre minimum limit on large areas is chosen as a practical matter related to the size of areas discernible on small-scale maps. For most of these large areas, additional setbacks will not be required because the boundaries of many such areas are established to include a safety zone. Facilities capable of generating noxious vapor clouds are considered later in screening than other facilities because vapor-cloud sources (such as a fertilizer plant or a liquid propane gas storage facility) can be very small operations and are not well known or easily discernible, except by field observation or on large-scale maps.

Approach. Large, hazardous facilities are identified and plotted on small-scale maps of the study area and removed from further consideration. Potential sources of missiles and shock waves are identified within candidate areas, and a 0.6-mile setback is circumscribed. This step may be repeated as smaller areas are identified on larger scale maps. Sources of noxious vapor clouds are identified at the site locality level, plotted on maps of zones, and circumscribed with a 0.6-mile setback. Site locality evaluations will employ the use of the classifying guideline to describe the hazardous facilities near the site localities.

Definition of Terms. Missiles are generally considered to be any objects flying through the air with sufficient mass and velocity to present significant hazard to persons or structures.

A.2.2.3 Transportation

Areas close to highways, railroads, and navigable waterways are not considered to be suitable for siting.

Relevance to Siting. Areas close to major transportation routes (other than airways) are considered to be subject to potential accidents that affect the safety of operation of a repository; in addition, some transportation routes (highways) are considered to be significant transient population generators that should be considered in terms of potential public exposure to radioactivity associated with the repository facilities.

Measure. The distance (in miles) from linear transportation routes is used as a proxy for both potential hazard to a repository from accidents along such routes and potential exposure to radiation of persons using such routes.

Guidelines. Areas within 0.6 mile from U.S. highways, interstate highways, railroads, and navigable waterways are not included for further consideration. This inclusionary guideline is applied to subareas and is used to identify site localities. Site localities are evaluated using a classifying guideline on the basis of proximity to the major transportation routes as well as secondary transportation routes such as state and county highways.

Rationale. The 0.6-mile setback from interstate highways, U.S. highways, railroads, and navigable waterways is consistent with the guideline applied to potential generators of missiles and noxious vapor clouds (see Section A.2.2.2 above). These guidelines would not apply to controlled access routes. The classifying guideline recognizes that secondary transportation routes may carry hazardous materials, although the frequency and thus probability of accident is considered to be low.

A.2.2.4 Induced Seismicity

Induced seismicity caused by man's activities is studied to describe the potential for seismic shaking in the study area. The level of potential ground motion is used to define the relative desirability of an area for a nuclear waste repository.

Relevance to Siting. Although the ground motion potential due to earthquakes associated with the release of regional tectonic stresses has been discussed in Section A.2.1.3, induced seismicity caused by man's activities should be considered. This mechanism of generation of seismic events is not as well understood as that of earthquakes generated mainly from release of tectonic stress and represents an additional safety consideration.

Measure. The measure selected to represent this consideration is location with respect to existing and future sources of induced seismicity. The location of the planned repository away from present and future areas of potential induced seismicity is important.

Guidelines. Two guidelines are used to describe the potential effects of induced seismicity. An inclusionary guideline is used to define potential areas of ground motion associated with existing potential sources of induced seismicity. The guideline is stated as the inclusion of those areas greater than 5 miles from the boundary of existing man-made reservoirs that are more than 100 feet deep. This recognizes that the primary source of induced seismicity is most likely from man-made reservoirs. This inclusionary guideline is used to obtain subareas.

The second guideline classifies areas on the basis of proximity to planned future reservoirs and interpreted sources of induced seismicity in the following manner:

A) >5 miles

B) 0 to 5 miles.

This guideline is used to preferentially identify and evaluate site localities and evaluate candidate sites.

Rationale. Locating the repository site away from present reservoirs is an inclusionary guideline to be used at the subarea level because of the potential for moderate to large magnitude earthquake generation from reservoirs at least 100 feet deep. The issue of the maximum magnitude earthquake that can be reservoir-induced remains a topic of research, and no definitive results are available at present. Therefore, for the purposes of this analysis, the setback distance from the boundary of present reservoirs has been selected as 5 miles.

The classifying guideline was selected because it recognizes both the need to consider future sources of induced seismicity and the uncertainty whether planned reservoirs will ever be constructed. Again, the limit at 5 miles is related to the minimum setback established for ground motion in Section A.2.1.3.

Approach. A map is prepared for candidate areas indicating locations of existing and planned reservoirs. An overlay with a setback of 5 miles is drawn for the boundary of each existing reservoir greater than 100 feet deep. These areas are removed from further consideration.

The data developed for planned or future reservoirs are used to evaluate subareas for the purpose of preferentially identifying and evaluating site localities.

A.2.2.5 Subsurface Mineral Exploration and Extraction

Subsurface mineral exploration and extraction are used to describe the potential for possible breach of the repository through existing and future mining activities. A site with a relatively lower potential for exploration and/or exploitation is considered more suitable for a nuclear waste repository.

Relevance to Siting. Existing drill holes and future exploratory programs could cause a breach of containment in the repository, resulting in pathways to the biosphere. Areas which are attractive to future mineral exploration or are already being exploited are generally undesirable for nuclear waste repositories.

Measure. The measure used to describe this consideration is location with respect to existing and potential future areas of mineral exploration and extraction.

Guidelines and Approach. Both an inclusionary guideline and classifying guideline are used to describe the measure. The inclusionary guideline includes, for further study, those areas outside of the limits of existing subsurface mineral extraction and/or exploration. The approach used to apply this guideline consists of identifying the areas of existing (and past) mining activities, identifying areas of extensive subsurface exploration, and preparing an overlay delineating these areas. Areas outside of the limits of these areas are considered for further study.

The classifying guideline deals with the potential for future mineral exploration and extraction. It is based on an evaluation of the probability of future mineral resource activity to preferentially identify and evaluate candidate sites. To accomplish this, geologic data concerned with mineral resources exploration and mineral production are evaluated to identify areas judged to have a relatively higher likelihood for future exploration and/or exploitation. This information is then used in the classification of areas.

Rationale. Because of the need to avoid possible sources of repository breaching, it is reasonable to avoid areas where mining activities are currently concentrated. Given the uncertainties and vagaries of future developments in the mineral industry, it seems reasonable to classify areas on the basis of perceived future exploration and exploitation.

Definition of Terms.

"Mineral resource:" in the context of this study, a mineral resource includes metallic and non-metallic ores, petroleum resources, and ground water.

"Mining:" in the context of this study, those activities including oil and water-well drilling and surface and subsurface excavation and exploration for mineral resources.

A.2.2.6 National Defense and Security

National defense and security are studied to evaluate the potential for the proposed repository either being affected by nearby defense and security risks or by becoming a risk in itself. Repository sites having relatively lower defense and security risks have a higher likelihood of containing suitable sites.

Relevance to Siting. The repository facilities themselves will contain nuclear waste products that may be attractive security risks. In addition, these wastes if released to the environment through an act of war, sabotage, etc. on a nearby facility, could create radiation hazards. For these reasons, the general defense and security environment of the repository are examined.

Measure. The measure selected to represent the consideration of national defense and security is proximity to facilities or areas interpreted as being potential defense or security risks.

Guideline and Approach. The guideline used in applying national defense and security is a classifying guideline. It involves an evaluation of potential siting areas on the basis of their proximity to facilities or areas (power plants, dams, cities, etc.) which are interpreted to be attractive military or terrorist targets. This guideline is used to preferentially identify and evaluate site localities.

Rationale. Because of the uncertainty in what constitutes a defense or security risk, based on available data, a classifying guideline is considered reasonable to represent this consideration. Certain existing facilities (i.e., dams, power plants, etc.) can be considered to be potential military and/or terrorist targets and, thus, locating areas away frc these facilities may reduce the effects on the repository from potential attacks on such facilities. The repository itself may be considered an attractive target; however, this condition is considered equal to all potential sites and cannot be used to differentiate between areas.

A.2.3 Repository-Induced Events

A.2.3.1 Thermo-mechanical Effects

Thermo-mechanical effects are studied to evaluate the effect of repository operation on the stability of the host rock. Repository locations having desirable thermo-mechanical properties are considered to be suitable for nuclear waste repositories.

Relevance to Siting. The thermo-mechanical properties of the repository rock are significant to the performance of the repository in maintaining adequate containment. If one area is marginally adequate in terms of these properties compared to another area, then the relative suitabilities as potential repositories can be assessed.

Measure. Although the thermo-mechanical properties of any rock are measured by using numerous parameters, the flow thickness appears to be a reasonable measure to apply for the purposes of the siting study. In addition to the thermo-mechanical properties, general engineering properties are also examined.

Guideline and Approach. Based on an examination of the geology, stratigraphy, rock properties, and available laboratory data, a subjective evaluation is made to identify site localities. This evaluation is based primarily on flow thickness and the assumption that, given equal and desirable internal flow characteristics, the thicker the flow, the more suitable will be the thermo-mechanical properties.

Rationale. Because of the lack of detailed data concerning thermo-mechanical rock properties over much of the study area, the use of flow thickness as a measure of the thermo-mechanical properties appears to be reasonable. In general, a thicker flow will perform better under thermal loading, and, in general, a thicker flow will have better mechanical properties because of the greater thickness of homogeneous rock.

A.2.3.2 Operational Radiation Release

Populated areas are not considered to be suitable for repository siting. Areas of current and projected moderate or greater population density and urbanized places are removed from consideration along with a setback distance based on potential concentrations of gaseous radioactive emissions that could result from operation of the repository and associated facilities.

Relevance to Siting. The segregation of major industrial facilities from concentrated residential and commercial areas is a widely accepted principle of land-use management. In addition, the population distribution around nuclear facilities is considered as a safety-related site characteristic by the NRC. Densely populated areas are generally considered to be unacceptable for siting.

Measure. The measure used is distance from populated areas, based on calculated concentrations of gaseous radioactive emissions from a repository and its associated facilities.

Guidelines. Areas within 3 miles of populated places having a present or projected population greater than 2,500 and areas within 1 mile of populated places having a smaller population are removed from further consideration. Specific cumulative population distribution and density around candidate sites will be considered in ranking.

Rationale. Regulatory limits on volumes and concentrations of operational radiation releases and associated doses to the public are set by the NRC in 10 CFR 20, 10 CFR 100, and 40 CFR 190. Using concentrations calculated on the basis of gaseous emission estimates from a repository, the minimum setback from emission sources at a repository site is tentatively calculated to be at least 0.6 mile. This is extended to 1 mile for conservatism. Sites within 1 mile of any urbanized area are not considered to be suitable. The 3-mile setback for places greater than 2,500 population is a density consideration. As a rule of thumb, population densities greater than 200 persons per square mile close to sources of significant radioactive emissions will require detailed analysis and justification before the NRC. At 3 miles, this density would imply a total population of about 5,600. If one town of 2,500 is located within 3 miles, it is reasonable to assume that an equivalent population could be living in all other portions of a 3-mile circle surrounding the site. Therefore, sites within 3 miles of a population center of 2,500 persons would be at or in excess of the threshold densities generally considered acceptable by the NRC. The 3-mile setback is commonly used in nuclear power plant siting and is considered reasonable by the NRC as a first approximation population exclusion.

Approach. Using the latest U.S. census population estimates available, cities and towns with current populations of 2,500 or more are identified and circumscribed with a 3-mile setback. These areas are shown on maps of the study area and are used to identify candidate areas. Smaller populations are considered in subsequent screening steps as appropriate to their size, the scale of maps, and available aerial photographs available. At the zone stage of screening, projected populations are considered. Available projections, current population estimates, and historical population are used as the basis for an extrapolated linear or exponential estimate at the 60th year of operation of the repository. As a check, the projected area and extent of urban areas will also be estimated. The 3-mile setback will be applied to towns projected to be 2,500 or larger in the 60th year, measured from the projected limits of the urbanized area. The 1-mile setback for smaller towns will be applied in a similar fashion. For conservatism, a projected decline in population below the 2,500 population limit will be treated as a static future population, and the 3-mile setback will be applied to the current urban limits. Populations projected in this manner will be used as the basis for cumulative population distribution and density considerations used in ranking.

A.3 ENVIRONMENTAL IMPACTS

The considerations and guidelines developed to meet the objective of minimizing adverse environmental impacts are concerned primarily with avoiding designated or legislated cultural and ecological areas and reducing impacts associated with the preemption of use of a large tract of land, such as a repository. These considerations are primarily concerned with the surface facilities of the repository during the operational time period.

A.3.1 Protected Ecological Areas

Land areas that are of particular ecological value and for which binding land restrictions have been established are considered unsuitable for repository siting. Areas which are considered ecologically important and sensitive, but for which there are no legally defined boundaries or statutory prohibitions, are not considered in the screening steps. The larger of the areas are identified in the screening steps and not considered further.

Relevance to Siting. Each of the ecological areas considered is protected by statutory prohibitions against any development or by permit regulations and permit procedures which are likely to result in delays in the licensing process.

Measure. The measure is the location of the protected area as defined by its legal boundaries. No setback from the boundary is considered in the screening steps unless there is a known requirement for such a setback.

Guidelines and Approach. Areas that have been formally designated by a public agency to be of ecological value and for which binding restrictions on land use affecting repository siting have been established are identified; the public agency placing restrictions on these areas, the types of restrictions, and the reason for protection are described. These areas are plotted and shaded on the appropriate overlay map of the study area. The shaded portions of the study area are considered to be unsuitable for repository siting and are not included for further study.

Protected ecological areas are inclusionary guidelines considered in three screening steps, specifically:

Screening Steps	Guideline
Candidate Areas	Outside areas of greater than 18,000 acres
Subareas	Outside areas of 5,000 to 18,000 acres
Site Localities	Outside areas of less than 5,000 acres

Rationale. Major developments, including repository siting, within the boundaries of these areas are either prohibited or restricted by statutory authority. The decision to examine different size areas in subsequent screening steps is based on the map scale used at the particular step.

Definition of Terms. "Protected ecological areas:" those areas which are protected by binding restrictions on the basis of a particular ecological attribute; they could include critical habitat or threatened or endangered species.

A.3.2 Culturally Important Areas

Areas that are interpreted as being important because of certain values that society may have placed on them (scenic, historical, recreational, or cultural) are considered to be unsuitable for repository siting and are not retained for further consideration.

Relevance to Siting. Scenic, historical, recreational, and cultural areas that have been formally designated by public agencies and for which restrictions have been established to preserve or enhance the cultural values are judged to have a high potential for delays in licensing. These areas are considered to be unsuitable for repository siting.

Measure. The location of culturally important areas is the principal measure. For areas that have been set aside for scenic values, a visual setback distance, measured in miles, is used. This setback distance is a proxy for the degree of visual intrusion into scenic areas that could be associated with such an obstruction as a 600-foot stack at a site. The distance is calculated on the basis of rationale presented below.

Guidelines. Different size areas are considered at different steps in screening, dependent on the scale of maps in use at each step. Areas greater than 18,000 acres are considered on maps of the study area; smaller areas (5 to 18,000 acres and less than 5,000 acres) are considered in identifying subareas and candidate sites.

The areas considered include Indian reservations, parks (national, state, and local), monuments, wilderness areas, primitive areas, roadless areas of National Forests, Bureau of Land Management roadless areas, wilderness study areas, wild and scenic rivers, national shorelines, national recreation areas, outstanding natural landmarks, outstanding natural areas (designated), and archaeological sites. The functions, uses, and values associated with these types of areas vary widely; therefore, different guidelines are employed for different types of culturally important areas. A zone of influence is circumscribed around certain areas using the following guidelines:

- Inclusion of areas farther than a calculated distance (based on the height of repository facilities) from designated scenic areas, trails, wilderness areas, national parks, recreational areas, and designated and proposed wild and scenic rivers

- No consideration for locating sites within areas which have been interpreted as being "culturally important" on the basis of values other than scenic or recreational values.

Rationale. The areas identifed in this step are restricted in use and are considered to be unsuitable for further consideration. The decision to examine areas of different size is based on the map scale used in each step. The zones of influence drawn around scenic areas were selected to limit the visibility of major structures, such as a stack, from the location or boundary of scenic areas. For example, at a distance of 6.5 miles, with no intervening vegetation, and on level ground, a 600-foot stack would subtend an angle of 1 degree on the horizon. The 1-degree angle is judged to provide a "far background" visible effect which would not compromise the scenic values of the designated areas. This approach and the 1-degree value are suggested as an appropriate screening technique for nuclear power plant siting by the NRC staff (Norris, 1974).

Approach. The designated culturally important areas are plotted on maps of the appropriate scale, and the visual setbacks are applied to the appropriate areas. All areas affected by application of these guidelines are removed from further consideration.

A.3.3 Protected and Endangered Species

Areas that are known to be important for the breeding, nesting or feeding activities, or general survival of individuals or populations of threatened or endangered species are considered unsuitable for siting a repository. In many cases, the area has not been officially designated as critical habitat, but the regulatory restrictions and public opposition are likely to cause significant delays in licensing.

Relevance to Siting. The potential for any major development, such as a repository, to jeopardize the survival of a threatened or endangered species will be closely scrutinized by the NRC in the site review process. Any indication that the individuals or populations of the species might be jeopardized is likely to result in delay or denial of the application for license.

Measure. The measure is the location of habitats or specific geographic areas known to be important to the survival of the threatened or endangered species. These locations will be defined as precisely as possible on 1:24,000-scale topographic maps. No setback from the boundary is considered unless one has been specifically recommended by a recognized authority or agency of concern.

Guideline. Areas will be identified on a 1:24,000-scale topographic map in the site identification step, and these areas will not be included for further consideration.

Rationale. General range maps depicting historical or possible distribution of the species and/or its important habitats will not be used to identify the areas of concern. These range maps are not precise enough and would result in large areas being dropped from consideration even though the species never has occupied or will occupy much of the area removed. At the site identification step, known areas can be plotted as precisely as the habitat requirements and, thus, boundaries of the species are known.

Definition of Terms. "Protected or endangered species:" those plants and animals officially listed in the Federal Register by the U.S. Fish and Wildlife Service. However, species listed by the states as rare, threatened, or endangered are not included (unless they also are on the federal list) because they are not officially recognized by the NRC.

A.3.4 Biologically Important Areas

Portions of subareas/zones that were interpreted to be biologically important and highly sensitive to the short- or long-term effects of repository construction or operation are not considered suitable for siting. These areas are removed from further consideration.

Relevance to Siting. The potential effect of the construction or operation of a repository on habitats of important species is considered in the NRC site review process. Such habitats include breeding, nesting, spawning, nursery, feeding, resting, wintering, or seasonal concentration areas and migration routes. Other areas may be considered biologically important because of their high biological productivity or commercial value, and attempts to site in these areas could delay licensing.

Measure. The measure is the location of the biologically important area as precisely as it can be defined from features on the appropriate topographic maps or from published information. No setback from the boundary is considered.

Guidelines and Approach. Biologically important areas are identified on 1:62,500- and 1:24,000-scale maps of subareas. Ecological features considered to be biologically important include freshwater marshes and bogs, "potholes" and other small freshwater ponds, and lowland riparian communities. These areas are plotted on transparent overlay maps. These biologically important areas are used to classify subareas and site localities according to a subjective scale of relative importance. The scale will be determined after data on the subareas and site localities are reviewed and biologically important areas are identified.

Rationale. The above areas are considered to be important for the following reasons:

- Freshwater marshes and bogs are high primary productivity, feeding-resting-nesting areas for numerous kinds of birds.

- Lowland riparian communities have relatively high primary productivity essential to the maintenance of water quality and quantity in streams and rivers, hence important to the maintenance of habitats for salmonids and other important aquatic species.

The NRC states:

> "Important habitats are those that are essential to maintaining the reproductive capacity and vitality of populations of important species or the harvestable crop of economically important species..."

In general, the NRC staff will require detailed justification when the destruction or significant alteration of more than a few percent of important habitat types is proposed.

The reproductive capacity of populations of important species and the harvestable crop of economically important populations must be maintained unless justification for proposed or probable changes can be provided.

A.3.5 Existing Significant, Specialty, or Incompatible Land Uses

Existing significant, specialty, or incompatible land uses are not considered to be suitable for repository siting and are removed from further consideration.

Relevance to Siting. The following general land-use considerations are evaluated in the NRC site review process; compatibility with existing land uses in the site vicinity, the potential effect of facility construction or operation on the productivity of specialty or prime cropland, and the potential visual or physical impact of a site on established or prospective public amenity areas.

Measure. The mapped or observed locations of certain land uses are considered.

Guidelines. Based on an examination of large-scale maps and available county or regional land-use plans, the existing land uses in each subarea are evaluated. The evaluation considers the type, extent, and intensity of major land uses and includes an identification of land uses considered to be incompatible with a repository facility. These uses include restricted-use areas, specialty and irrigated agriculture, urbanization, recreational and tourist areas, and major industrial facilities. These uses are plotted on maps of the subareas and removed from further consideration. This guideline is used to identify site localities.

Rationale. The segregation of major industrial facilities from incompatible land uses is an accepted principle of land-use management. The evaluation of present land use will be based on the professional judgment of an experienced land-use planner in consideration of regulatory positions of the NRC. The land uses considered are characteristically the focus of specific NRC review in licensing proceedings. The NRC position on specialty agriculture is that sites that preempt the use of unusually productive land which is locally limited and regionally significant, or regionally limited and nationally significant, may not be suitable. Irrigated farmland, while more extensive than specialty cropland, may be interpreted as limited and regionally significant. Also, much of the new irrigation water in the study area is produced from wells; a continuation or extension of ground-water development at or adjacent to a repository site is considered to be an incompatible use. Certain nearby industrial facilities will be judged to be incompatible with a repository site, considering plume interaction with repository emission streams. A special case of this consideration is a nearby nuclear power plant, for which a minimum setback distance would be observed on the basis of radiological concentration limits.

Approach. Land uses, such as those described above, will be identified from large-scale maps, aerial photographs, and field observation, will be plotted on maps of subareas, and will be removed from further consideration.

A.3.6 Potential Significant or Incompatible Land Uses

Proposed or potential land uses of the types discussed in Section A.3.5 will be used as a basis for evaluating zones. This is a classifying criterion.

Relevance to Siting. See Section A.3.5.

Guideline. The evaluation will focus on agriculture. Non-agricultural uses that are proposed or planned and included in a public document will also be considered. For potential agricultural lands, four categories will be identified:

- Potentially irrigable lands
- Arable soils
- Marginal soils
- Submarginal soils.

Submarginal soils will be considered to be more suitable for repository siting, followed by marginal soils, arable soils, and potentially irrigated lands (least suitable). The thrust of this classification system is to encourage sites to be selected away from areas that might be developed for agriculture in the future.

Rationale. See Section A.3.5. The hierarchy of land and soils types is used as a classifying guideline (rather than inclusionary) because it is inappropriate to predict the precise locations of agricultural uses far into the future. The guideline presents a range of siting choices with emphasis on areas least likely to undergo cultivation in the future and thereby least likely to be penetrated by wells developed for irrigation purposes.

Approach. This guideline is applied on maps of subareas. Potentially irrigable lands will be identified from state university reports and from maps describing the irrigation and ground-water development potential of the Pasco Basin. Soil classifications will be taken from maps and reports of the Soil Conservation Service and state university departments of agronomy and soils. Land classifications will be mapped on overlays of subarea maps; the mapped limits and the proportion of a subarea occupied by a land classification will be used in the identification of site localities.

A.4 SYSTEM COSTS

The considerations and guidelines developed to meet the objective of minimizing system costs deal primarily with site preparation, both for the surface and in the subsurface. These considerations are either mappable or can be evaluated with the use of maps and, thus, lend themselves to the screening process.

A.4.1 Site Preparation (Surface)

A.4.1.1 Terrain Ruggedness

Areas characterized by predominantly rugged terrain are considered to have a relatively lower likelihood of containing suitable repository sites. Areas so identified are not retained for further study.

Relevance to Siting. The ruggedness of terrain at and around a site can materially affect the cost of site development. Areas having very steep slope and/or highly dissected topography are generally difficult to work in and develop. Such areas have a greater potential for extensive earthwork in site preparation, potentially difficult access for heavy equipment, potential difficulty in developing rail and road access to the site, and relatively higher potential for poor meteorological dispersion characteristics. High slope, high relief, and a high degree of dissection are considered to limit flexibity in choosing facility configurations.

Measure. The measure is a subjective assessment of terrain ruggedness as judged from topographic maps of candidate areas.

Guideline. The topography of candidate areas is examined subjectively on topographic and relief maps and remote sensing imagery. Those portions of the study area showing a high degree of terrain ruggedness (high mountains, steep canyons, and highly dissected lands) will be judged to have a low potential of containing acceptable repository sites and will not be retained for further study. To guide the subjective evaluation, terrain ruggedness is generally defined as those slopes greater than 15% grade occurring over relatively large areas (more than several hundred acres) or deeply eroded topography.

Rationale. The identification of predominantly rugged areas will be based on professional judgment. The intent of such judgment is to define those areas which appear to have a relatively low potential of containing acceptable sites because of potential problems with site preparation, access, and meteorological dispersion.

Approach. Candidate areas will be examined on 1:250,000-scale maps; those portions judged to be excessively rugged will be outlined on overlay maps and removed from further consideration. As appropriate, guidelines for making this determination (such as maximum slope or gross elevation change per unit of distance) will be developed and used.

A.4.1.2 Usable Area

Subareas and site localities are subjectively examined to delineate portions that have sufficient land area for a repository facility and that meet the kinds of subjective topographic guidelines described in Section A.4.1.1.

Relevance to Siting. Development of a repository is a major construction project, the economics and environmental impacts of which are sensitive to the amount and nature of earthwork required to prepare the site for excavation activities and facilities placement. To the extent that it is practical to identify areas that require a minimum of complicated preparation while possessing other generally desirable surface and subsurface characteristics, such areas should be preferred in evaluating subareas and site localities.

Measure. The measure is a subjective assessment of topography as judged from maps and direct field observation.

Guidelines and Approach. Usable area is a classifying guideline used to identify site localities. Maps of subareas will be examined subjectively considering the relative effort and dominant cost factors that would be associated with slope, local relief, degree of dissection, size of available level and non-dissected areas, location and juxtapositon of such areas, potential sources of and distances to water supply and power, access, and the relative amount of excavation and fill that would be necessary to fit 2,000 acres of surface facilities on the landscape. From an examination of maps, portions of subareas that appear to be highly favorable from the standpoint of these considerations will be delineated on overlay maps. These areas will be evaluated and entered into the identification of specific site localities and proposed configurations for surface facilities. In every case where delineations are made, a written description of the judgments and observations leading to the classifications are included in the project documentation.

Rationale. See Section A.4.1.1.

A.4.2 Site Preparation (Subsurface)

The subsurface preparation of the repository is studied to evaluate the relative ease and/or cost of site preparation and, thus, its suitability as a site.

Relevance to Siting. Excavation and mining at a proposed repository may significantly affect the overall cost of the repository. It is preferable to identify sites that tend to reduce the mining and excavation costs.

Measure. The measure selected to represent subsurface site preparation is a subjective evaluation of mining and excavation costs.

Guidelines and Approach. Site localities are examined on the basis of thickness of overburden, depth of shafts, configuration and length of tunnels, excavated volume, etc. A subjective evaluation or classification is made of the site localities in terms of these parameters.

Rationale. Because the data are general and the uncertainties in the data are high, a rigorous comparison of areas is not feasible. The subjective evaluation of subsurface site preparation costs, based on professional judgment, appears to be reasonable in light of the available data.

REFERENCES

AEC, 1970, Hanford works boundary map (EG-164-35): U.S. Atomic Energy Commission.

Aerospace Corporation, 1973, Washington State Airport System Plan: Washington State Aeronautics Commission.

Bentley, R. D., 1977, "Stratigraphy of the Yakima basalts and structural evolution of the Yakima Ridges in the western Columbia Plateau (Field Trip No. 12): in Brown, E. H. and Ellis, R. C. (eds.), Geological excursions in the Pacific Northwest: Department of Geology, Western Washington University, p. 339-389.

Bonilla, M. G., 1967, Historic surface faulting in continental United States and adjacent parts of Mexico: A factor in nuclear facility siting and design: TID-24124, USGS National Center for Earthquake Research.

Brekke, T. L. and Glass, C. E., 1973, Some considerations related to underground siting of nuclear power plants in rock: Department of Civil Engineering, University of California.

Cohen, B. L., 1977, "The disposal of radioactive wastes from fission reactors:" Scientific American, 236 (6), p.21-31.

Columbia-North Pacific Technical Staff, 1970, Appendix V: Water resources comprehensive framework study: Pacific Northwest River Basins Commission, 2 (subregions 7-12).

ERDA, 1976, Evaluation and impact of potential flooding criteria on the Hanford project: U.S. Energy Research and Development Administration.

FAA, 1978, Airport statistics handbook for 1977, tower-operated airports: FAA-AVP-78-10, Advanced Technology, Inc., Federal Aviation Administration.

Franklin, J. F. and Others, 1972, Federal research, natural areas in Oregon and Washington--A guidebook for scientist and educators: U.S. Department of Agriculture, Forest Service.

Grolier, M. J. and Bingham, J. W., 1971, Geologic map and sections of parts of Grant, Adams and Franklin Counties, Washington: U.S. Geological Survey, Miscellaneous Geologic Investigations map I-589.

Grolier, M. J. and Bingham, J. W., 1978, Geology of parts of Grant, Adams and Franklin Counties, east-central Washington: Washington State Division of Geology and Earth Resources Bulletin 71.

Hunt, C. B., 1974, Natural regions of the United States and Canada: W. H. Freeman and Company, 725 p.

Jones, M. G. and Landon, R. D., 1978, Geology of the Nine Canyon map area: RHO-BWI-LD-6, Rockwell Hanford Operations, 54 p.

Judson, S. and Ritter, D. F., 1964, "Rates of regional denudation in the United States:" Journal of Geophysical Research, 69 (16), p. 3395-3401.

Keeney, R. L. and Nair, K., 1977, "Evaluating potential nuclear power plant sites in the Pacific Northwest using decision analysis:" Energy Policy, 5 (1).

Mackin, J. H., 1961, A stratigraphic section in the Yakima Basalt and the Ellensburg Formation in south-central Washington: Washington Division of Mines and Geology Report of Investigations Number 19, 45 p.

Matsuda, T., 1976, "Empirical rules on sense and rate of recent crustal movements:" Journal of the Geodetic Society of Japan, 22 (4), p. 252-263.

National Academy of Sciences, 1978, Geologic criteria for repositories for high-level radioactive wastes: National Research Council pamphlet.

Newcomb, R. C., 1970, Tectonic structure of the main part of the basalt of the Columbia River Group, Washington, Oregon, and Idaho: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-587.

Newcomb, R. C., Strand, J. R., and Frank, F. J., 1972, Geology and groundwater characteristics of the Hanford Reservation of the U.S. Atomic Energy Commission, Washington: U.S. Geological Survey Professional Paper No. 717, 77 p.

NOAA, 1979, Seattle Sectional Aeronautical Chart, 1:500,000 scale: U.S. Department of Commerce, National Oceanic and Atmospheric Administration.

Norris, J. A., 1974, "Selected environmental considerations and their measuring parameters:" in Proceedings of the American Nuclear Society.

NRC, 1977, Safety evaluation report, Pebble Springs Nuclear Plant Units 1 and 2, Supplement No. 3, Docket No. 50-514, 50-515: NUREG-0013, U.S. Nuclear Regulatory Commission.

NRC, 1978a, Proposed statement of general policy, licensing procedures for geologic repositories for high-level radioactive wastes: Federal Register 78-53869 through 78-53872, U.S. Nuclear Regulatory Commission.

NRC, 1978b, Workshops for state review of site suitability criteria for high-level radioactive waste repositories: NUREG-0354, 2 U.S. Nuclear Regulatory Commission.

ONWI Staff, 1979, NWTS criteria for the geologic disposal of nuclear wastes, site-qualification criteria: ONWI-33(2), Office of Nuclear Waste Isolation.

Patwardhan, A. S., Tocher, D., and Savage, E. D., 1975, "Relationships between earthquake and length of fault rupture surface based on aftershock zones:" Geological Society of America, Abstracts with Programs, 7 (3), p. 419.

Portland General Electric Company, 1974, Preliminary Safety Analysis Report, Pebble Springs Nuclear plant: 2.

Reidel, S. P., 1978, Geology of the Saddle Mountains between Sentinel Gap and 119 30 Longitude: RHO-BWI-LD-4, Rockwell Hanford Operations.

Shannon & Wilson, Inc., 1973a, Regional geologic and seismic investigations, Boardman Nuclear Project: 0-618D, prepared for Portland General Electric Company, 43 p.

Shannon & Wilson, Inc., 1973b, Geologic studies of Columbia River basalt structures and age of deformation, The Dalles-Umatilla region, Washington and Oregon, Boardman Nuclear Project: 0-618E, prepared for Portland General Electric Company, 52 p.

Shannon & Wilson, Inc., 1976, Volcanic hazard study potential for volcanic ashfall, Pebble Springs Nuclear Plant Site, Gilliam County, Oregon: prepared for Portland General Electric Company.

Tocher, D. and Patwardhan, A. S., 1975, "Attenuation of peak acceleration in earthquakes:" Geological Society of America, Abstracts with Programs, 7 (3), p. 426.

Thoms, R. E., Anderson, J. L., and Bentley, R. D., 1977, "Geologic studies of the Saddle Mountains-Manastash Ridge and Umtanum Ridge structures:" in Subappendix 2RH, Chapter 8.0 in Amendment 23 for WPPSS Nuclear Projects 1 and 4.

U.S. Army, Corps of Engineers, 1975, Report of the Chief of Engineers on the national programs of inspection of dams.

U.S. Bureau of the Census, 1977, Population estimates and projections: Series P-25, #695, U.S. Department of Commerce.

U.S. Committee, International Commission on Large Dams, 1958, 1963, 1968, World Register of Dams.

U.S. Fish and Wildlife Service, 1976, Map of Saddle Mountains National Wildlife Refuge: scale 1:62,500.

U.S. Geological Survey, Topographic maps for Yakima and Walla Walla quadrangles: scale 1:250,000.

U.S. Geological Survey, Topographic maps of Priest Rapids, Coyote Rapids, Hanford, Mesa, Corral Canyon, Richland, and Eltopia quadrangles: scale 1:62,500.

WPPSS, 1977a, PSAR, WPPSS Nuclear Project No. 1: Washington Public Power Supply System, Inc.

WPPSS, 1977b, PSAR, Amendment 23 (2 volumes) for WPPSS Nuclear Project No. 1: Washington Public Power Supply System, Inc.

Woodward-Clyde Consultants, 1979, Siting technical report candidate sites for coal-fired power plants: prepared for Washington Public Power Supply System, Inc.