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FINAL MARK-UP

SITE NOMINATION ENVIRONMENTAL ASSESSMENT FOR THE BASALT WASTE ISOLATION PROJECT

Date 3 August 1984

Basalt Waste Isolation Project Staff

Prepared for the U.S. Department of Energy under Contract DE-AC06-77RL01030

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GUIDE TO THE BASALT WASTE ISOLATION PROJECT ENVIRONMENTAL ASSESSMENT

The following guide to the Nuclear Waste Policy Act Site Nomination Environmental Assessment for the Basalt Waste Isolation Project provides a roadmap to the organization of this document. Due to the statutory requirements of the Nuclear Waste Policy Act, this document is both technically complex and somewhat organizationally redundant. For the purposes of initial reader ~~organization,~~ orientation, Figure A indicates the relationships among the chapters of this Environmental Assessment. Also, a cross-reference matrix at the end of this guide indicates where specific topics are discussed in the document.

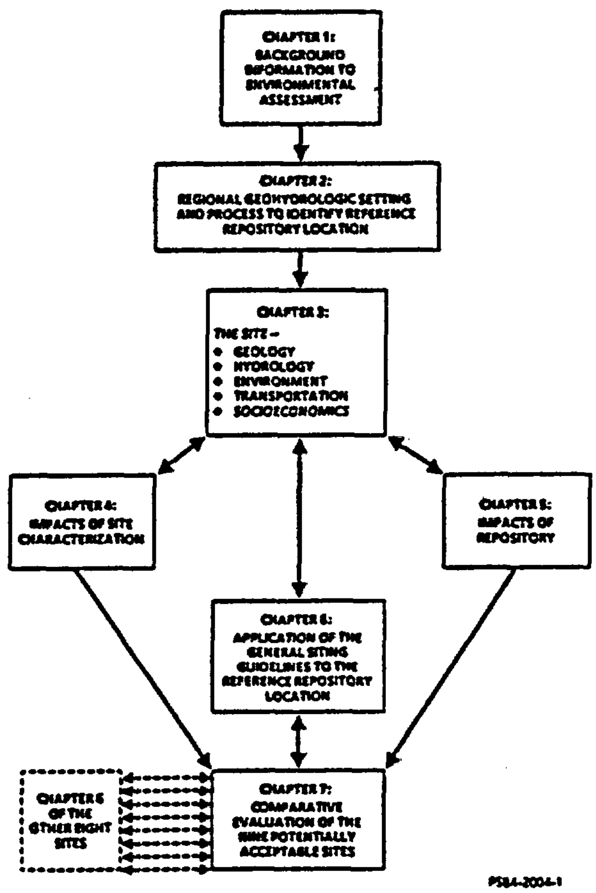

Figure A. The flowchart above depicts the relationship among the chapters of the Environmental Assessment.

The reader is encouraged to use this roadmap as a lead-in to the specific summaries that precede Chapters 2 through 6. These summaries provide a less technical overview of the information to follow. The reader is also encouraged to take advantage of the cross-reference matrices included in the chapter summaries. Each matrix in sections of

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the document that are related to, or provide more information on, topics discussed in that chapter.

The Environmental Assessment provides a basis for the nomination of a potentially acceptable site (in this case, the reference repository location on the Hanford Site in the State of Washington) for the location of the first high-level nuclear waste repository. Chapter 1 begins the Environmental Assessment by introducing the reader to concepts concerning radioactive waste disposal in mined geologic repositories, and discusses the Nuclear Waste Policy Act, its requirements, and the General Siting Guidelines. It also summarizes the overall decision process from screening to the selection of sites, and groups the sites by geohydrologic setting. Chapter 7 concludes the Environmental Assessment by presenting a reasonable comparative evaluation of the nine potentially acceptable sites according to the General Siting Guidelines.

To adequately present a comparative evaluation based on the General Siting Guidelines, which are required by the Nuclear Waste Policy Act of 1982, baseline information must be first presented. In this regard, Chapter 2 begins the technical discussion of the Environmental Assessment by introducing the regional geohydrological setting that encompasses the reference repository location, that is, the Columbia Plateau, and by explaining how this site was identified for further study. It should be noted that the reference repository location was identified before the passage of the Nuclear Waste Policy Act of 1982. The systematic screening process used in this identification process utilized objectives very similar to those of the General Siting Guidelines. Then, to determine whether this site should be retained for further consideration, the reference repository location is evaluated against the disqualifying conditions of the General Siting Guidelines, which are discussed in more detail in Chapter 6.

Chapter 3, a chapter of central importance to the Environmental Assessment provides the necessary technical baseline for the evaluations within Chapters 4, 5, 6, and ultimately, 7. Chapter 3 discusses the important characteristics of the Pasco Basin and the Hanford Site, on which the reference repository location is situated, in terms of geology, hydrology, environmental setting, transportation, and socioeconomics. Note, however, that Chapter 3 makes no judgments concerning the relative merits of the reference repository location; rather, it supplies information that will be used in later chapters.

A primary purpose of the Environmental Assessment is to support the Secretary of Energy in making a determination, based on scientific information as to which of the nine potentially acceptable sites are to be recommended for site characterization, Chapter 4 describes the site characterization process for the reference repository location. It also indicates what environmental and socioeconomic impacts in the area could be expected as a result of this characterization process. Chapter 4 refers to the baseline data accumulated and presented in Chapter 3.

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Similarly, Chapter 5 uses the data in Chapter 3 to discuss the expected effects of construction and operation of a repository on the geology, hydrology, environment, transportation, and socioeconomics of the area should the site ultimately be selected for siting of a nuclear waste repository. Chapter 5 also discusses the conceptual design of the repository. Together, Chapters 4 and 5 emphasize environmental impacts, and are analogous to environmental documents produced pursuant to the National Environmental Policy Act of 1969.

Chapter 6 then makes use of much of the information presented thus far in the document, and evaluates the reference repository location according to the General Siting Guidelines in terms of qualifying conditions, favorable conditions, potentially adverse conditions, and (when present in the General Siting Guidelines) disqualifying conditions. This chapter is generally more technical in presentation than the preceding chapters, and the reader is urged to take advantage of the glossary provided in the back of this document, as well as of the cross-reference matrix provided as part of the summary preceding the chapter.

Finally, Chapter 7 relies on information presented in Chapters 4, 5, and 6 of each of the nine Environmental Assessments to make a reasonable comparative evaluation of the nine potentially acceptable sites.

Because the organization of the Environmental Assessment allows each chapter to draw on or refer to information presented elsewhere in the document, a cross-reference matrix that directs the reader to related sections within this document is presented in Table A.

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CHAPTER 2 SUMMARY

Chapter 2 explains the process by which the reference repository location on the Hanford Site in the State of Washington was identified as a potentially acceptable site for a high-level nuclear waste repository. The site selection described in this chapter begins with an analysis of the regional geohydrologic setting—in this case, the Columbia Plateau (Section 2.1). Chapter 3 will provide a more detailed discussion of the geohydrology of the Pasco Basin within the Columbia Plateau, and of the Hanford Site, which contains the reference repository location. Because much of the above information is related, Table 2-A presents a cross-reference matrix to help the reader locate sections in Chapter 3 and in the rest of this document that relate to topics found in Chapter 2.

Section 2.1 discusses the geohydrology of the Columbia Plateau. Geologically, the Columbia Plateau is a flood-basalt province of south-central Washington State which was formed primarily through the eruption of lava between 6 and 17 million years ago. Structurally, the Columbia Plateau is divided into three different areas: The Yakima Fold Belt subprovince, the Palouse subprovince, and the Blue Mountains subprovince. The Yakima Fold Belt subprovince covers the central and western parts of the Columbia Plateau, including the Cold Creek syncline, in which the reference repository is located.

Over 50 different basalt flows (relatively horizontal layers of past lava flows) within the Columbia Plateau have been identified, totaling perhaps as much as 5,000 meters (16,000 feet) in thickness. The flows vary in thickness from a few centimeters to more than 90 meters (300 feet). Sedimentary deposits overlie and are interbedded with the upper part of the basalt sequence. The Grande Ronde Basalt, the most areally extensive and most voluminous of the Columbia River Basalt Group in the Pasco Basin, includes the four flows identified as candidate repository horizons: Rocky Coulee flow, Cohassett flow, McCoy Canyon flow, and Umtanum flow. According to current data, each candidate horizon is continuous within the Pasco Basin and is more than 40 meters (130 feet) thick.

The seismicity of the Columbia Plateau (instrumentally monitored since 1969) is considered moderate.

Studies of the region's tectonics indicate that over millions of years the Columbia Plateau has been subjected to north-south compressive forces as a result of tectonic plate interactions. These forces have manifested themselves in a series of low profile ridges or uplifts (anticlines) and broad valleys (synclines)—for example, the Cold Creek syncline.

The major feature of the Columbia Plateau's surface-water hydrology is the Columbia River, which enters the plateau from the north. The portion of the Columbia Plateau within the State of Washington can be divided into basins according to the major surface drainage system present (e.g., the Pasco Basin, in which the Hanford Site lies).

Table 2-A. Sections related to Chapter 2 discussions.

	Chapter 2	Chapter 3	Chapter 4	Chapter 5	Chapter 6
GEOLOGY Stratigraphy Structure Seismicity	2.1.1 2.1.1.1 2.1.1.2 2.1.1.3	3.2 3.2.2 3.2.3 3.2.4	4.2.1.1 4.1.1.1 4.1.1.1	5.2.1.1	
TECTONICS	2.1.2	3.2.3	4.1.1.2		6.3.1.7/6.3.3.4
SURFACE-WATER HYDROLOGY	2.1.3 (or maybe 2.1.3.1)	3.3.1	4.2.1.2.1	5.2.1.2.1	6.3.3.3/6.3.3.1
GROUND-WATER HYDROLOGY Columbia Plateau and Pasco Basin Regional Ground-Water Management	2.1.4 2.1.4.2 2.1.4.3	3.3.2	4.2.1.2.2	5.2.1.2.2	6.3.3.3
GEOHYDROLOGY	2.3.1				6.3.1.1
EROSION	2.3.2				6.3.1.5
DISSOLUTION	2.3.3				6.3.1.6
POSTCLOSURE TECTONICS	2.3.4				6.3.1.7
NATURAL RESOURCES	2.3.5				6.3.1.8
POPULATION DENSITY AND DISTRIBUTION	2.3.6				6.2.1.2
OFFSITE INSTALLATIONS AND OPERATIONS	2.3.7				6.2.1.5
ENVIRONMENTAL QUALITY	2.3.8				6.2.1.6
SOCIOECONOMICS	2.3.9				
ROCK CHARACTERISTICS	2.3.10				6.3.1.3
HYDROLOGY	2.3.11				6.3.3.3
PRECLOSURE TECTONICS	2.3.12				6.3.3.4

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Ground water beneath this region lies in both the confined aquifers (located in flow tops and in interbed sediments between the basalt flows), and in unconfined aquifers (mainly in those sediments above the basalt flows).

Investigators used the information concerning the geohydrology of the Columbia Plateau to identify potentially acceptable sites (and thus, the reference repository location) within this region. Repository screening and selection guidelines were developed by the Basalt Waste Isolation Project in 1980 and 1981. These guidelines included the identification of:

- Geological factors such as existing fault zones.
- Structures capable of generating new faults.
- General ground-water characteristics within the Hanford Site.
- Erosion and flooding potentials.
- Protected ecological reserves and species.
- Potential for aircraft impact.
- Proximity to hazardous facilities.
- Past mineral exploration and extraction.
- Incompatible land use.

Preliminary consideration was given to socioeconomic factors, culturally important areas, conflicting land use and transportation impacts, and site preparation costs.

Section 2.2 summarizes how the above criteria were used in the screening process to identify the reference repository location. Through initial screening, the Cold Creek syncline was selected for further evaluation. A number of boreholes were drilled, and on the basis of the new data, a reference repository location was selected. A principal borehole location was then selected within the reference repository location. Based on information obtained from the principal borehole, a site was chosen for the exploratory shaft. Final selection criteria of the Basalt Waste Isolation Project eliminated those basalt flows at a shallow depth, and those bounded by sedimentary interbeds, as they either were not considered sufficient for long-term radiological safety, or did not provide the thickness required for repository construction. The above criteria, along with criteria aimed at avoiding hydrologically significant features such as regions of high hydraulic conductivity and proximity to aquifers, allowed investigators to narrow the search to the above-mentioned four basalt flows, each of which is considered a suitable repository horizon. The Cohassett flow, however, is the preferred flow.

Finally, Section 2.3 initially evaluates the reference repository location against the disqualifying conditions of the General Siting Guidelines (DOE, 1984) to determine whether this site should be retained for further consideration. Although final conclusions will require site characterization, based on the data collected over the past seven years the reference repository location is not disqualified by any of the twelve disqualifying conditions.

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Chapter 2

DECISION PROCESS BY WHICH THE SITE PROPOSED FOR NOMINATION WAS IDENTIFIED

2.1 GEOHYDROLOGIC SETTING

2.1.1 Regional Geology

The reference repository location lies within the central portion of the Cold Creek syncline (Fig. 2-1). This syncline is part of the Pasco Basin, one of several structural and topographic basins located within the Columbia Plateau. The Columbia Plateau is defined by the distribution of Miocene flood basalts of the Columbia River Basalt Group and lies primarily within the Columbia Basin and northern part of the Central Mountains subprovinces of the Columbia Intermontane Physiographic Province (Fig. 2-2).

The lavas of the Columbia Plateau comprise a tholeiitic flood-basalt province covering an area of approximately 200,000 square kilometers (78,000 square miles) and having an estimated volume of 375,000 cubic kilometers (90,000 cubic miles) (Reidel et al., 1981, p. 1). The plateau is both a structural and topographic depression with its low point in the vicinity of the reference repository location. Here, the accumulation of flows of the Columbia River Basalt Group and interbedded sediments attain their maximum thickness, perhaps as much as 5,000 meters (16,000 feet) (Mitchell and Bergstrom, 1983).

The basalt flows of the Columbia Plateau formed between 6 and 17 million years before the present (Watkins and Baksi, 1974; McKee et al., 1977; McKee et al., 1981) when large volumes of lava were erupted from north-northwest-trending linear vent systems now preserved as dikes (Waters, 1961; Taubeneck, 1970; Swanson et al., 1975, 1977; Fruchter and Baldwin, 1975; Price, 1977). Because of their low viscosity and large volume, the lavas spread considerable distances from their source fissures. In doing so, lavas inundated older rocks and structures within the plateau interior, onlapped highlands, and diverted drainages around the plateau margin. Individual basalt flows are voluminous, generally 10 to 29 cubic kilometers (2 to 6 cubic miles), with a maximum known volume of 696 cubic kilometers (145 cubic miles). Flows range in thickness from a few centimeters (inches) to more than 91 meters (300 feet), with an average thickness of 22 to 36 meters (90 to 120 feet).

The internal structures that develop during emplacement and subsequent cooling of the molten lava are termed intraflow structures. Three primary types were found: the vesicular or brecciated flow top, the entablature, and the colonnade (Fig. 2-3). The flow top typically consists of the upper few meters (feet) of a flow, although vesicular and brecciated basalt can form up to half the thickness. The flow interior

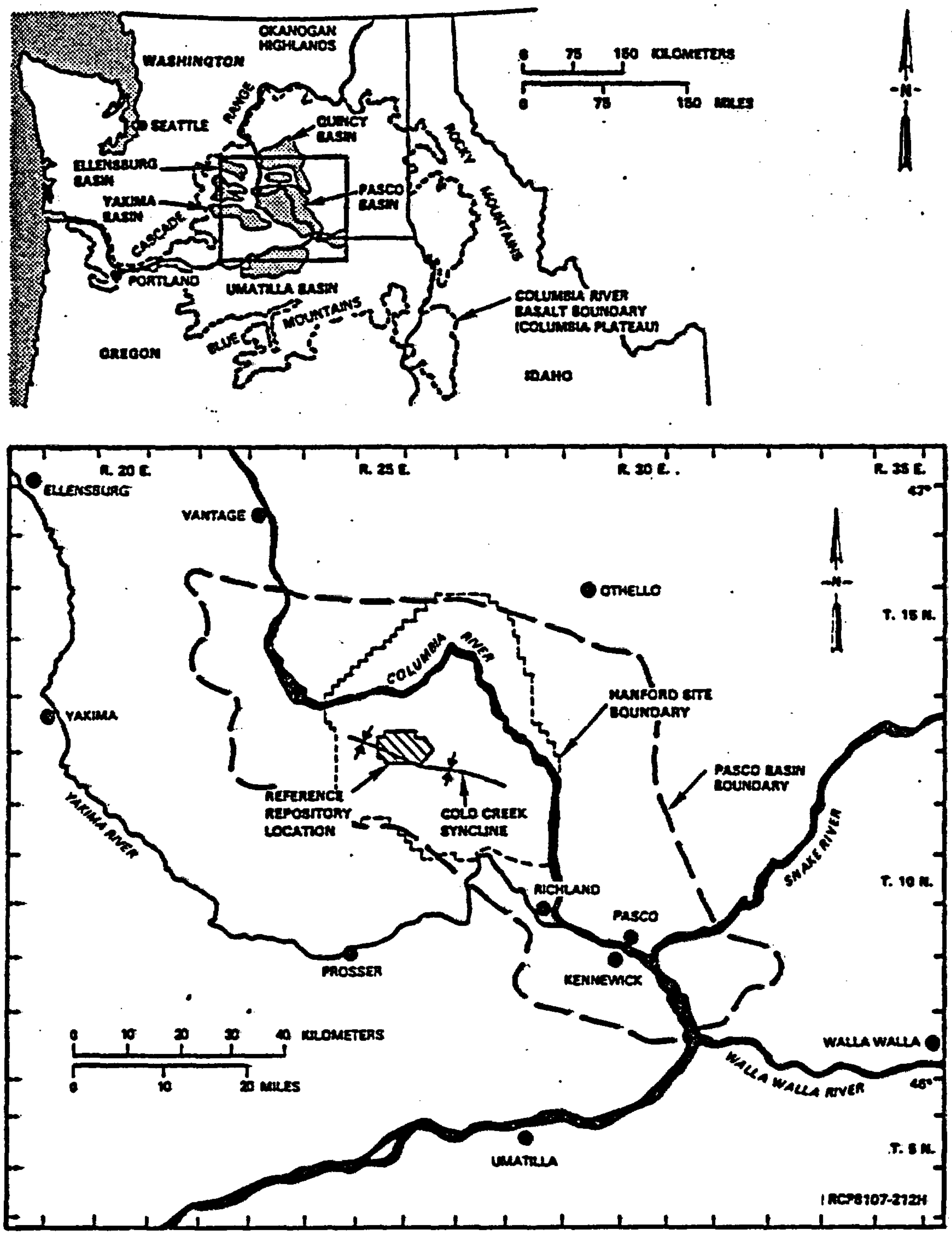

Figure 2-1. Location of the Hanford Site, southeastern Washington State.

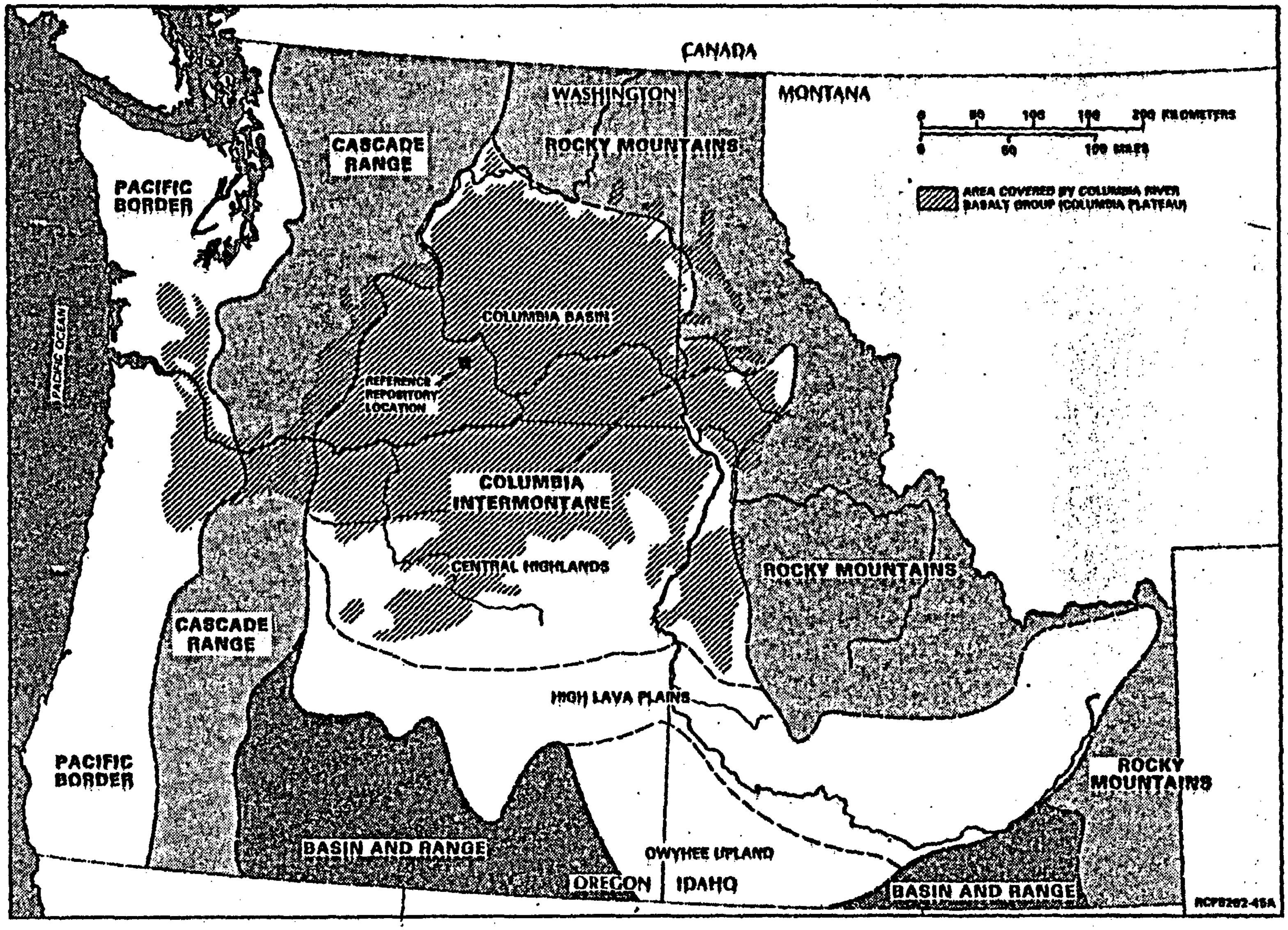

Figure 2-2. Divisions of the Columbia Intermontane Physiographic Province (after Freeman et al., 1945).

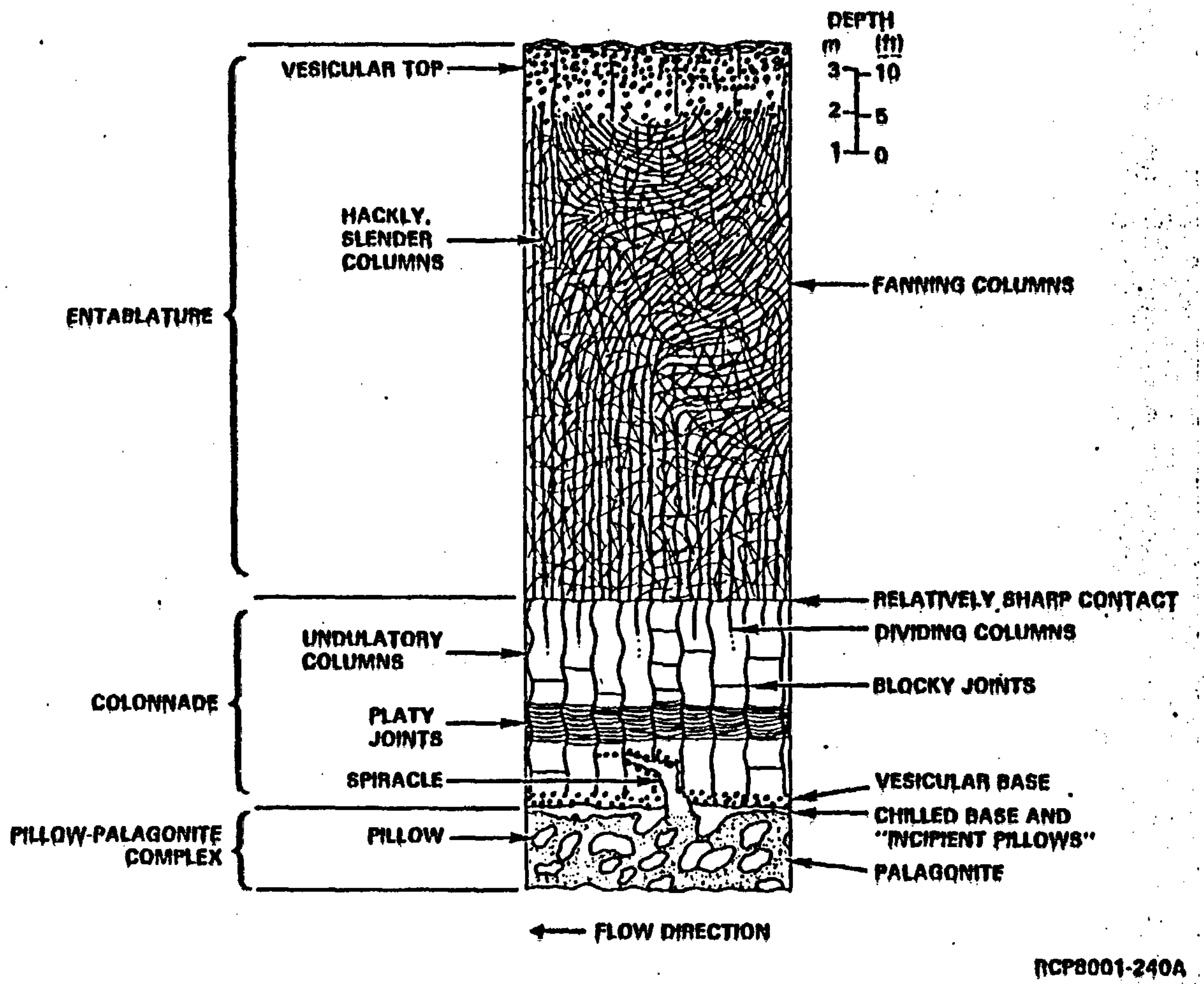

Figure 2-3, Cross section of a typical flow in the Columbia River Basalt Group, showing, in idealized form, jointing patterns and other structures (from Swanson and Wright, 1976).

consists of entablature and colonnade. The entablature is composed of jointed rock with relatively small columns (approximately 0.2- to 1.0-meter (0.7- to 3.0-foot) diameter). The orientation of columns ranges from vertical to horizontal. The colonnade consists of relatively well-formed columns (approximately 0.5- to 2-meter (1.6- to 6.5-foot) diameter) with fewer fractures than the entablature. Columns are normally upright but radiate locally and exhibit a variety of internal features. In some flows, the entablature overlies a single colonnade; in other flows, colonnade and entablature zones may be repeated in the flow interior. The basal portion of a basalt flow is usually a thin (approximately 0.5-meter (1.6-foot)) zone of fractured, glassy basalt. Spiracles (zones of fissured glassy rock) may extend a few meters (feet) into the lower portion of a flow.

Fracture logging of basalt flows indicates that fracture abundances in core samples range from about 1 to 40 fractures per meter (less than 1 to 12 fractures per foot) (Long and WCC, 1984, p. I-69). Most of these fractures have narrow widths (less than 0.5 millimeter (0.002 inch)) now filled with multiple generations of secondary minerals. The exact mineral distribution in fractures will differ among basalt flows in response to varying depths of burial, fracture widths, and basalt flow composition. Dominant secondary minerals are clay, zeolite, silica, and pyrite (Long and Davidson, 1981, pp. 5-38 to 5-40). The volume of unfilled fractures, particularly in the dense interior of basalt flows, is typically small, less than 0.4 volume percent.

2.1.1.1 Stratigraphy

Regional geologic maps at a scale of 1 to 250,000 define the stratigraphy and structure of the Columbia River Basalt Group (Swanson et al., 1979a, 1981). This map compilation shows a plateau-wide basalt stratigraphy. Figure 2-4 gives the stratigraphic nomenclature for the Columbia River Basalt Group of the Columbia Plateau. Basalt flows throughout the region can be correlated through a combination of chemical, paleomagnetic, and field techniques.

The Columbia River Basalt Group has been divided into 5 formations, 19 members, and 4 informal paleomagnetic subdivisions (Swanson et al., 1979b, pp. 6 and 7; Camp, 1981, pp. 669 through 678). The oldest formation (about 17 million years old), the Imnaha Basalt, crops out only within the extreme southeastern portion of the plateau where it is conformably overlain by flows of the Grande Ronde Basalt (that is 14.6 to 15.8 million years old). The Picture Gorge Basalt crops out only in the southwestern Columbia Plateau and is considered partly equivalent in age to the Grande Ronde Basalt.

The Grande Ronde Basalt is the most areally extensive and voluminous unit of the Columbia River Basalt Group underlying most of the Columbia Plateau (Fig. 2-5). The basalt comprising this formation was extruded between 14 and 17 million years ago from vents, now exposed as dikes, in the southeastern portion of the plateau. The known thickness of the

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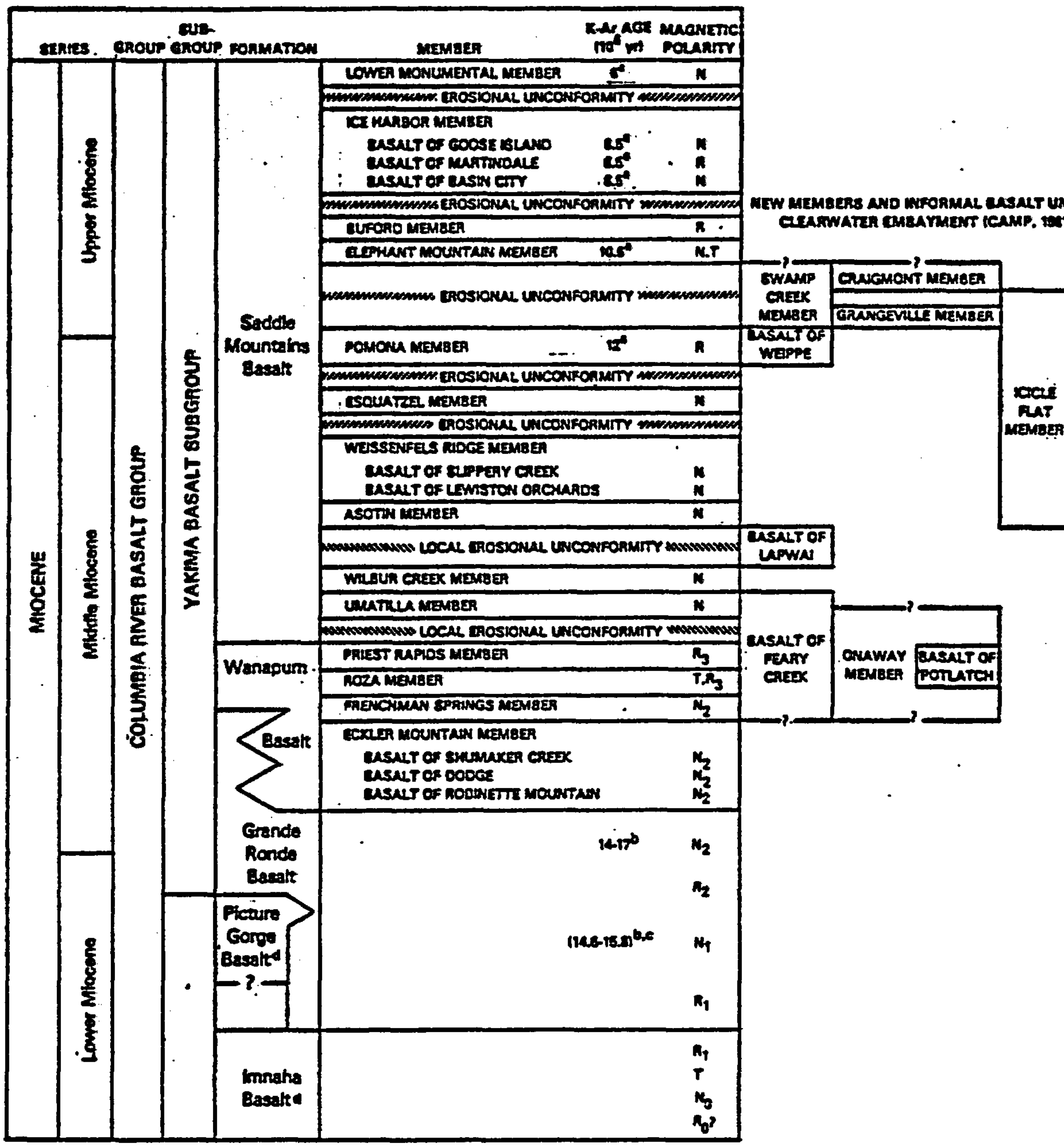

[a]DATA FROM McKEE et al. (1977)
[b]DATA MOSTLY FROM WATKINS AND BAKSI (1974)
[c]INFORMATION IN PARENTHESES REFERS TO PICTURE GORGE BASALT
[d]THE IMNAHA AND PICTURE GORGE BASALTS ARE NOWHERE KNOWN TO BE IN CONTACT. INTERPRETATION OF PRELIMINARY MAGNETOSTRATIGRAPHIC DATA SUGGESTS THAT THE IMNAHA IS OLDER.

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Figure 2-4. Regional Columbia River Basalt Group stratigraphic nomenclature (after Swanson et al., 1979b).

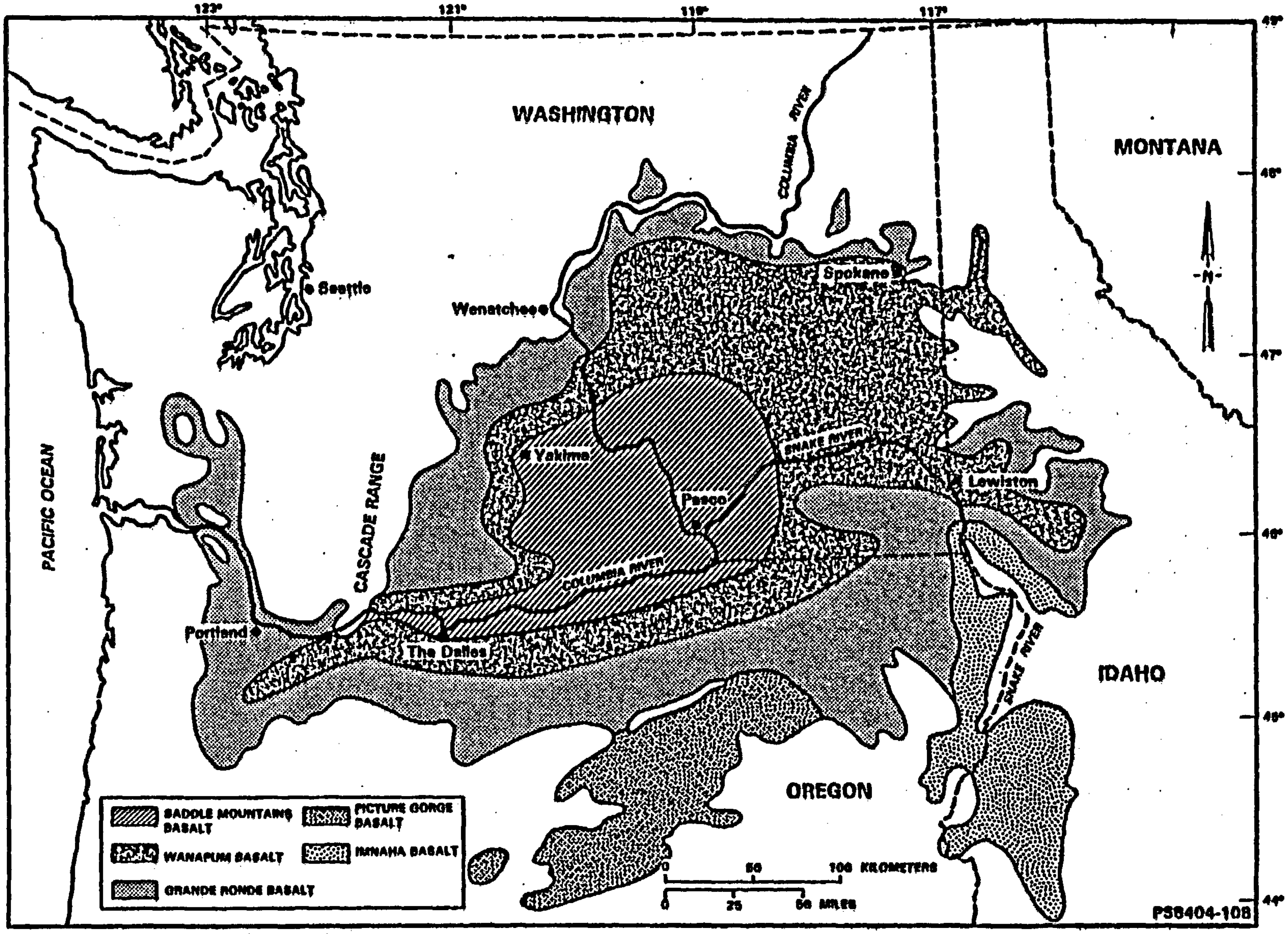

Figure 2-5. Distribution of Columbia River Basalt Group (after Wright et al., 1973).

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Grande Ronde Basalt ranges from tens of meters along the margins of the Columbia Plateau to more than 1,000 meters (3,000 feet) within the Pasco Basin. The only consistently mappable, regional subdivisions of the Grande Ronde Basalt are four magnetostratigraphic units defined on the basis of dominant magnetic polarity: reversed-one (R_1), normal-one (N_1), reversed-two (R_2), and normal-two (N_2) (listed in order of decreasing age) (Swanson et al., 1979b, p. G20).

A subdivision of Grande Ronde Basalt (beyond the regional magnetic units) has not been recorded on reconnaissance geologic maps; previous work revealed distinctive Grande Ronde Basalt flows, herein termed "through-running" flows (Long and Landon, 1981). Identifiable through a combination of chemical, paleomagnetic, and field techniques, they generally have a known areal extent of over 250 square kilometers (100 square miles) and a thickness of over 30 meters (100 feet). Although such flows are particularly evident in the deep canyon exposures of Grande Ronde Basalt in the southeastern portion of the plateau, they are also recognized in the Pasco Basin and include the four flows currently being considered for potential host rocks for a nuclear repository in the reference repository location. See Section 3-2 for a more detailed discussion of the geology of the reference repository location.

Grande Ronde Basalt is overlain the Wanapum Basalt, the second-most voluminous of the formations. Wanapum Basalt flows erupted between 13.5 and 14 million years before present and define much of the Columbia Plateau surface (see Fig. 2-5). These flows can be subdivided into four recognized members. Source dikes for three of the four members have been identified in the eastern Columbia Plateau.

Finally, the Saddle Mountains Basalt is the youngest formation of the Columbia River Basalt Group and can be divided into at least 10, and perhaps as many as 16, members (see Fig. 2-4). Members of the Saddle Mountains Basalt display the greatest petrographic, chemical, and paleomagnetic variability of any formation of the Columbia River Basalt Group. Because of their distinctive character, these members form distinctive, mappable horizons throughout the region.

The Saddle Mountains Basalt was extruded between 6 and 13.5 million years ago. The extrusion period was marked by waning volcanism, by the development of thick, sediments between flows, and by folding and canyon cutting. Most of the flows were erupted from fissures located in the southeastern and south-central portion of the plateau. The distribution of several of the Saddle Mountains Basalt members in relation to their source vents indicates that they advanced down ancestral drainages (primarily the Snake River) to reach the central and western portions of the Columbia Plateau. The distribution of Saddle Mountains Basalt flows and intercalated sedimentary units can be used to indicate the locations and timing of the development of structures within the plateau (see Subsection 3.2.3.8).

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The stratigraphy and structure of late Cenozoic sediments within Columbia Plateau have also been defined through the compilation of a regional geologic map at a scale of 1 to 250,000 (Fig. 2-6). The most widespread late Cenozoic sedimentary deposits in the State of Washington include the suprabasalt Ellensburg Formation and Ringold Formation, the Pleistocene catastrophic flood deposits, and Pleistocene to Recent loess deposits.

The Ellensburg Formation includes weakly lithified clastic and volcaniclastic sediments, which occur within the western and central portions of the Columbia Plateau. Units of the formation underlie, interfinger, and overlie flows of the Columbia River Basalt Group (Bentley, 1977; Waitt, 1979). The Ellensburg Formation ~~deposits are~~ is thickens ~~thicker and~~ becomes coarser grained in the far western portion of the Columbia Plateau and reflect a nearby Cascade Range source area.

The Mio-Pliocene Ringold Formation overlies the Columbia River Basalt Group in the central plateau. Sediments of this formation have been subdivided into several fluvial units (see Subsection 3.2.~~1.8~~ 2.5).

The central and eastern portions of the Columbia Plateau are dominated by erosional features and sedimentary deposits of the Channeled Scablands. During Pleistocene glaciation, the present scabland area was subjected to a number of catastrophic floods that resulted from the break-up of ice dams impounding glacial lakes in Idaho, Montana, and northeastern Washington (Bretz, 1923; Waitt, 1980). The number and sequence of floods are not known, but most surficial flood deposits are thought to be associated with the last major flood dated at approximately 13,000 years before present (Mullineaux et al., 1977, p. 1105).

The eastern portion of the plateau is covered by eolian loess that includes four distinct units: three Pleistocene units and a younger late Wisconsinan to Recent loess have been correlated with glacial events in the region (Myers, Price et al., 1979).

2.1.1.2 Structure

The above stratigraphic framework (established by geologic mapping) has been used to interpret the structural character of the Columbia Plateau. In general, the plateau can be divided into three areas of different structural character, informally termed the Yakima Fold Belt subprovince, the Palouse subprovince, and the Blue Mountains subprovince (Fig. 2-7).

The Yakima Fold Belt subprovince covers the central and western parts of the Columbia Plateau and includes the Pasco Basin in which the reference repository location is situated. This subprovince is characterized by narrow, linear anticlines and broad synclines. These structures extend eastward from the western margin to the approximate center of the plateau, where they generally die out. Most known faults are associated with the anticlinal fold axes and probably developed concurrently with folding (Price, 1982).

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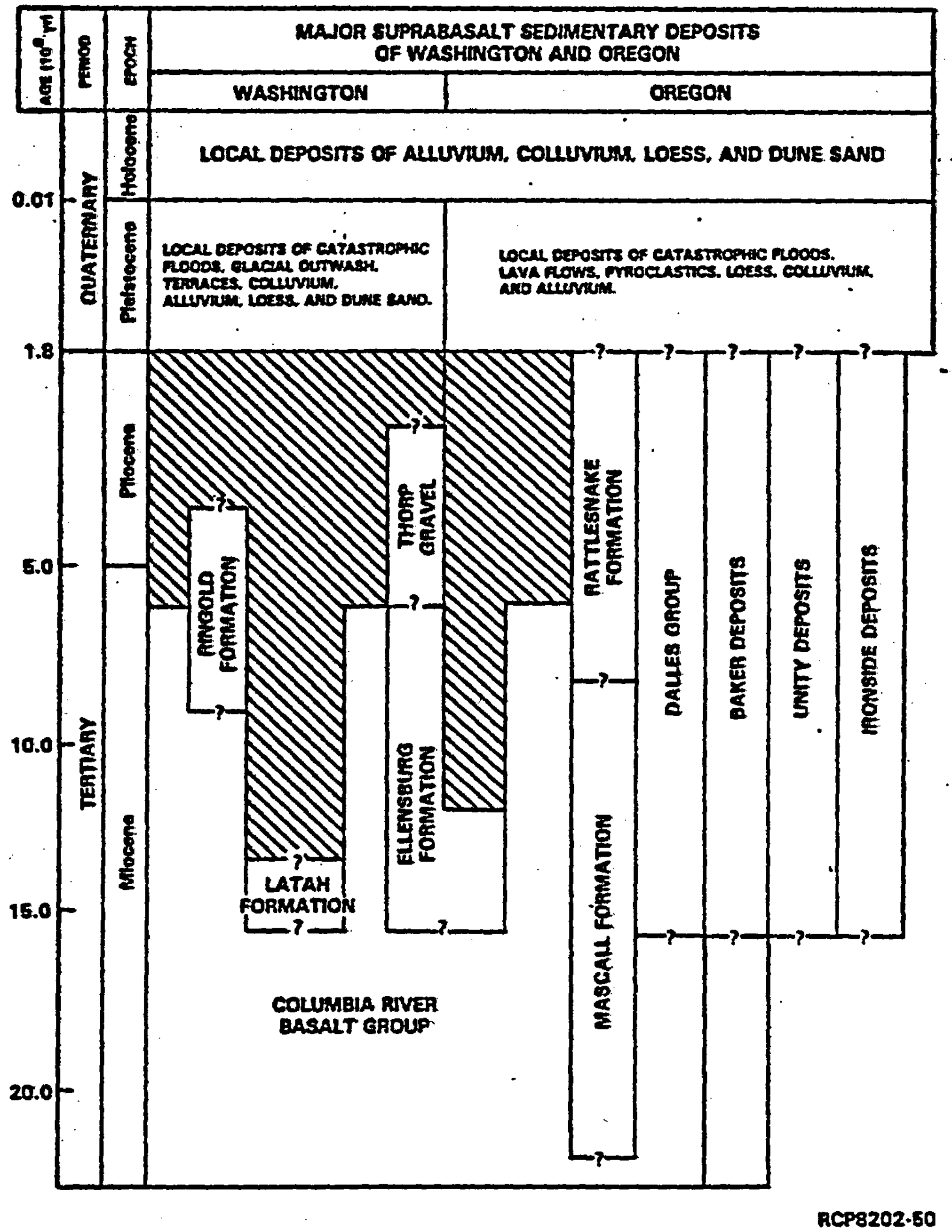

Figure 2-6. General stratigraphic relationship of suprabasalt sediments.

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The Palouse subprovince is located in the northeastern portion of the Columbia Plateau. The subprovince is underlain by basalt flows with a regional dip of less than 5 degrees to the southwest. The distribution of basalt flows indicates that this dip is a reflection of regional subsidence that began in Grande Ronde Basalt time (Hooper and Camp, 1981; Reidel, 1983). In general, the Palouse subprovince is structurally simple, with the most prominent structures consisting of broad folds with tens of meters of amplitude.

The Blue Mountains subprovince is located in the southern portion of the Columbia Plateau. This subprovince is essentially a broad, northeast-trending anticlinal arch that was uplifted during Miocene-Pliocene time.

2.1.1.3 Seismicity

Although records of earthquakes in the Pacific Northwest go back to approximately 1850, early records are very qualitative and yield only general information about seismicity in the Columbia Plateau. Before a network of seismographs was installed in 1969, earthquakes were documented mainly from reports of felt earthquakes (Myers, Price et al., 1979, pp. IV-1 through IV-11; Weston, 1977, pp. 2RJ-1 through 2RJ-21; WPPSS, 1981, pp. 2.5J-6 through 2.5J-10). Figure 2-8 shows the distribution and intensity of historical earthquakes and indicates that the Columbia Plateau is in an area of moderate seismicity (Berg and Baker, 1963, pp. 95 through 108; Rasmussen, 1967, pp. 463 through 476). Figure 2-9 indicates the earthquakes above magnitude 3.0 (detected by instruments) since 1969 within the Columbia Plateau. The seismic activity is concentrated around the northern and western part of the Columbia Plateau. Although seismic activity above magnitude 3.0 has occurred in the central Columbia Plateau region (associated with earthquake swarms), activity above magnitude 3.5 is most commonly found around the northern and western Columbia Plateau, and a few events occur along the border between Washington and Oregon.

Earthquake swarms are the predominant seismic events of the Columbia Plateau (Rohay and Davis, 1983, pp. 6-1 to 6-11). Earthquake swarms (as detected and located by the regional seismic network) may contain ~~several~~ as few as four to greater than 100 locatable earthquakes of magnitude 1.0 to 3.5, but most are smaller than magnitude 2.0. These earthquake swarms typically last a few days to several months and occur in a volume of rock with typical dimensions of 2 by 5 kilometers (1 by 3 miles) areally and 3 to 5 kilometers (2 to 3 miles) vertically. During a swarm, no distinctively large event is followed by a generally decreasing level of seismicity, as is typical of a mainshock-aftershock sequence. Swarm earthquakes tend to gradually increase and decay in frequency, but not in magnitude.

Earthquake swarm activity is concentrated in the central portion of the Columbia Plateau, principally north and east of the Hanford Site (Fig. 2-10). In this region earthquakes larger than magnitude 3.0 also occur, including possibly the largest magnitude swarm-related earthquake. This was instrumentally recorded, December 20, 1973, as a magnitude 4.4 earthquake and located in the Royal area (see Fig. 2-10).

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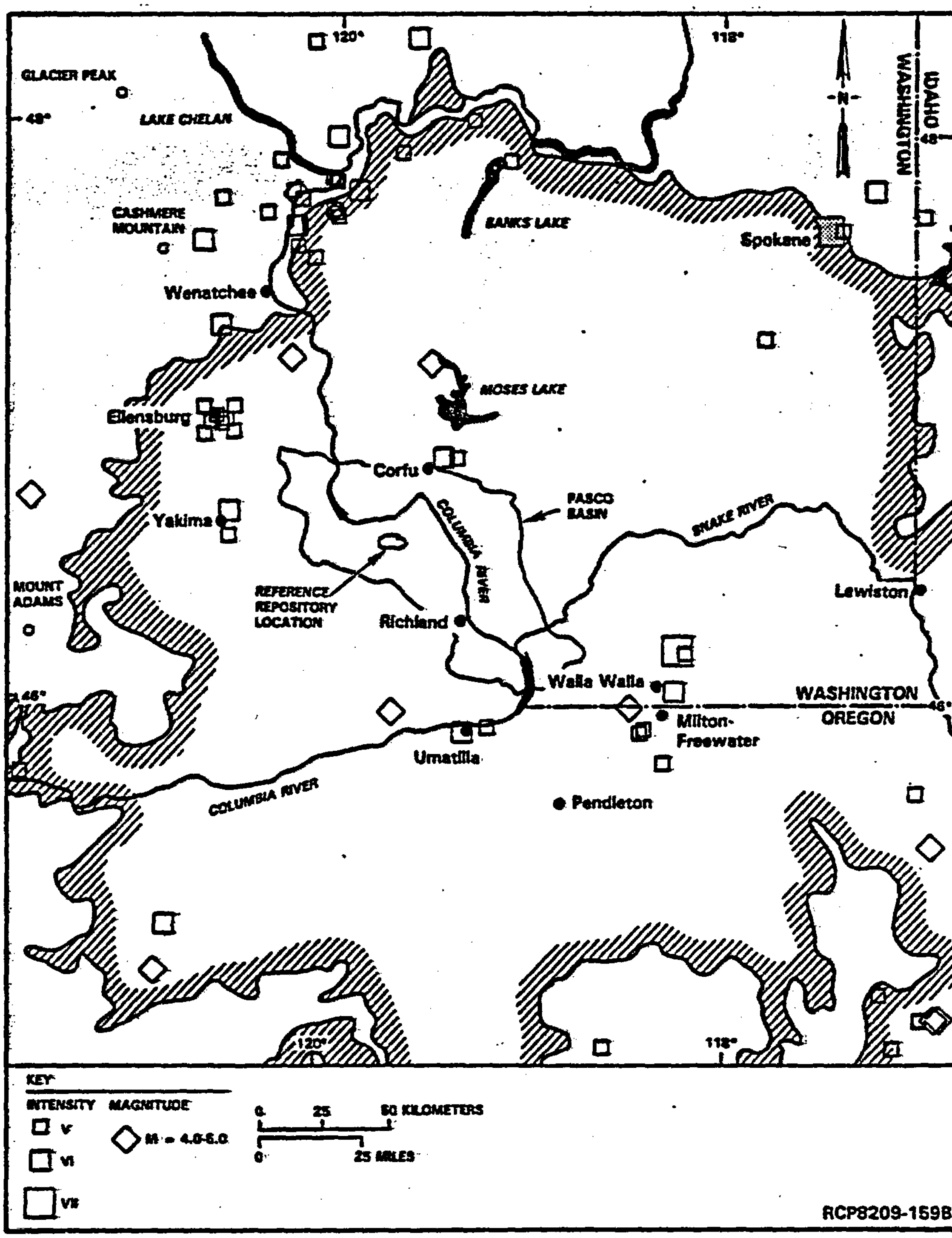

Figure 2-6. Historical seismicity of the Columbia Plateau. All earthquakes between 1850 and 1969 with modified Mercalli intensity equal to or greater than V are shown.

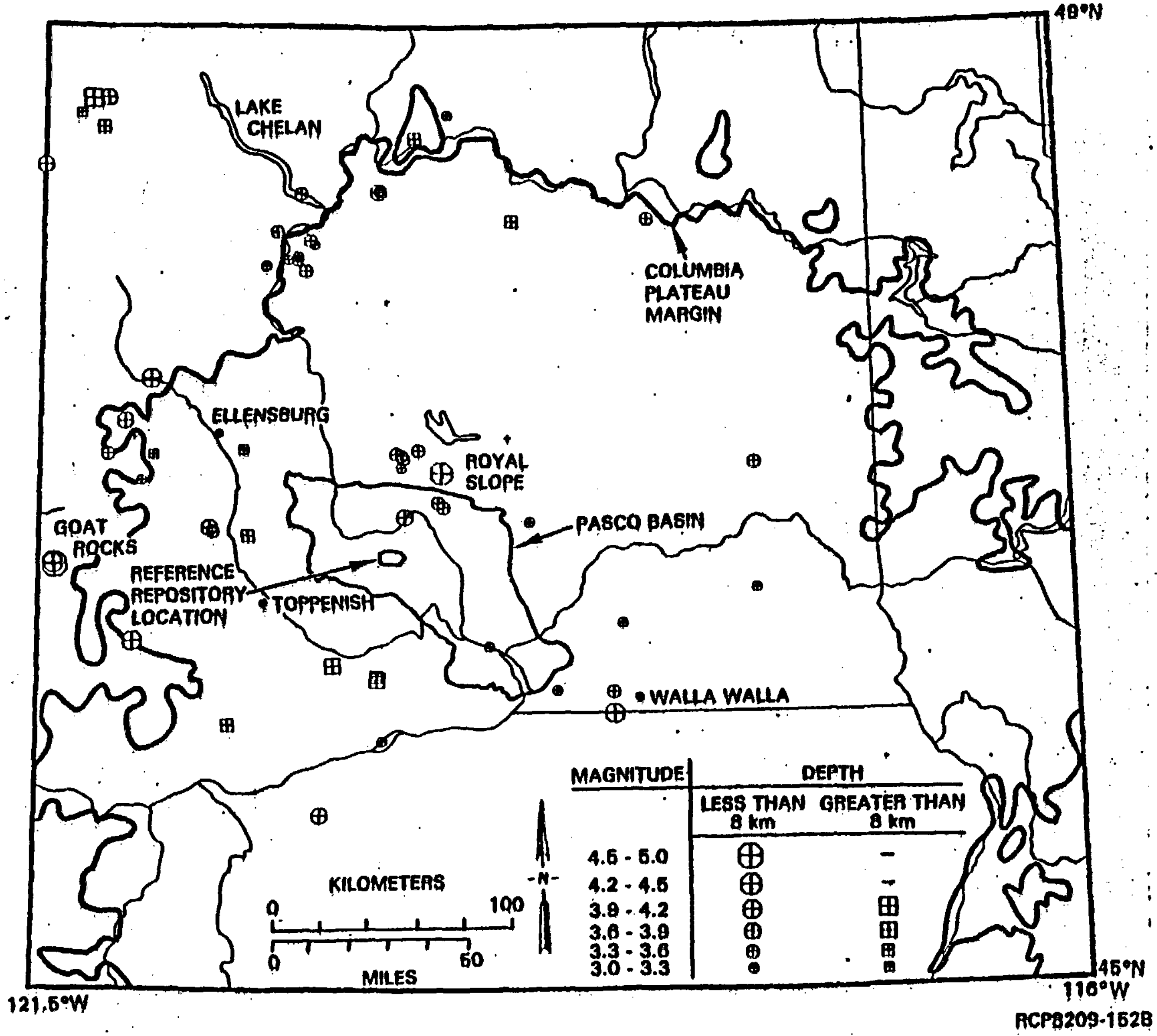

Figure 2-9. Instrumental seismicity (post 1969) above magnitude 3.0, Columbia Plateau Tectonic Province.

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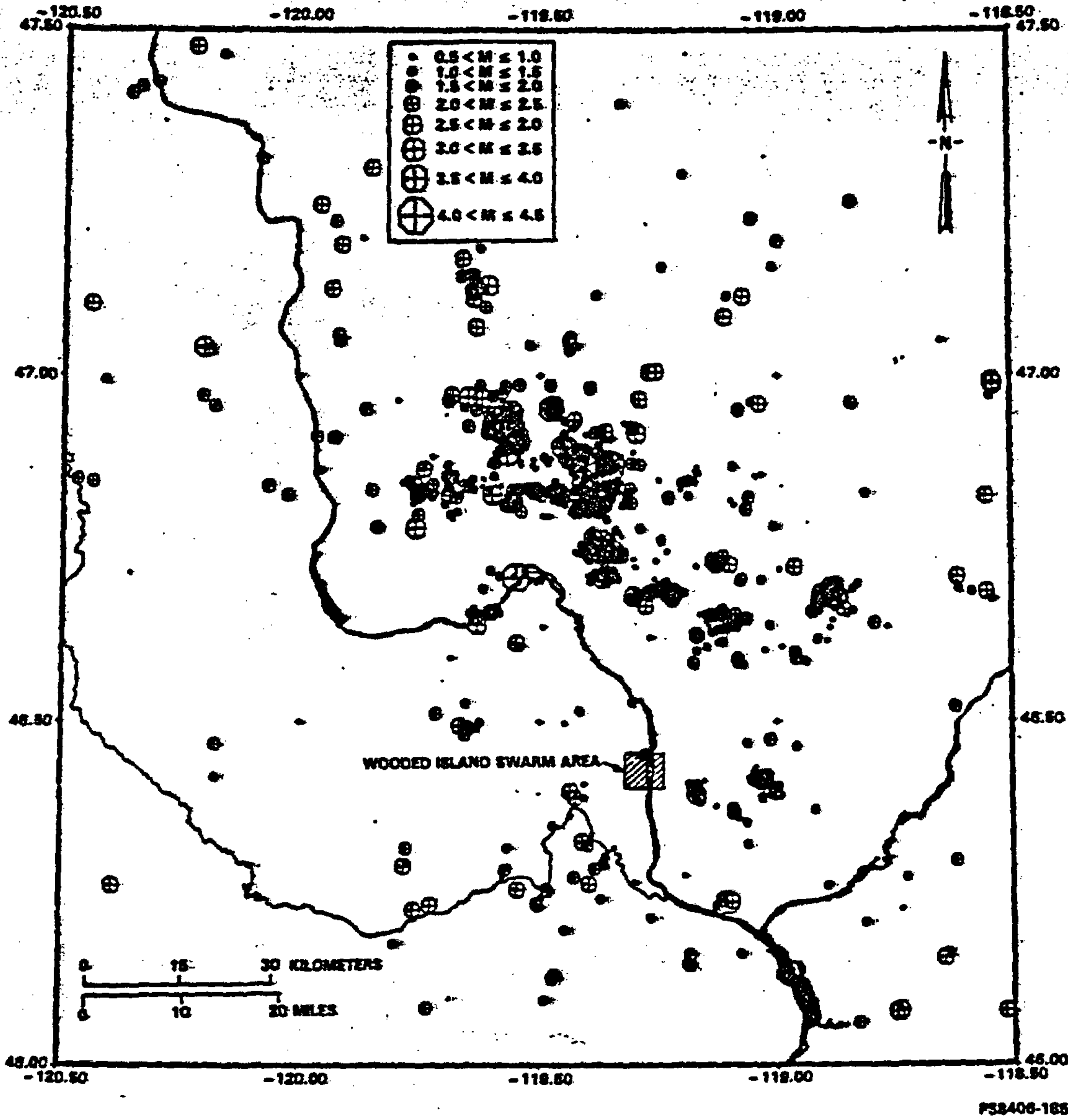

Figure 2-10. Shallow earthquakes in the central Columbia Plateau, Pasco Basin, and surrounding area: 1969 to 1983

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Earthquakes occur to a depth of 28 kilometers (18 miles) in the Columbia Plateau region, but at a much lower frequency than the shallower swarm earthquakes (UWGP, 1979, pp. 1 through 35). This 28-kilometer (18-mile) depth is the approximate thickness of the crust as determined from seismic refraction studies (Caggiano, 1983, pp. 2 through 7). Generally, no large concentration of deep seismicity is apparent in the areas of intense shallow swarm activity below approximately 8 kilometers (5 miles). Deep seismicity generally takes place in a seemingly random pattern, associated neither with known geologic structures or areas of shallow seismicity (see Fig. 2-9).

Focal mechanisms of earthquakes in eastern Washington indicate a response to a nearly horizontal principal compression, oriented north-south (Rohay and Davis, 1983, pp. 6-10 to 6-15). In the central Columbia Plateau region (Fig. 2-11), the minimum compression (or extension) is generally near vertical, reflected in thrust or reverse faulting on east-west striking planes. These principal stress directions are in good agreement with mapped east-west orientations of fold axes and associated thrust or reverse faults. Recent in situ stress measurements using the hydrofracturing method also indicate that the maximum horizontal stress at a 1-kilometer (0.6-mile) depth is oriented approximately north-south (Kim and Haimson, 1982, p. 4.6-4.10).

2.1.2 Tectonics

Geologic data suggest that the Columbia Plateau, including the Pasco Basin, was deforming at a low-average rate of strain in the middle to late Miocene; geodetic data indicate that this rate has continued into the late Cenozoic. The basis for these statements is listed below:

- Average uplift rates (vertical strain rates) for the Pasco Basin were approximately 40 to 80 meters per million years (131 to 262 feet per million years) on anticlinal folds from 14.5 to 10.5 million years ago (Reidel and Fecht, 1982). Once initiated, deformation appears to have continued along the same structures formed in the Miocene.

- Quaternary sediments overlying faults associated with Yakima Fold Belt anticlines generally do not appear offset. Sediments of the suprabasalt Ellensburg Formation and Ringold Formation were involved in the folding process, but younger sediments are generally undeformed. However, areas of possible Quarternary faulting were observed along Toppenish Ridge, located 80 kilometers (50 miles) to the southwest of the reference repository location (Campbell and Bentley, 1981); near Wallula Gap located 70 kilometers (45 miles) to the southeast; and at Gable Mountain located 8 kilometers (5 miles) to the northeast. An average displacement of less than 0.01 millimeter (0.0004 inch) per year (horizontal stain rate) was calculated for the Gable Mountain faulting (PSPL, 1982).

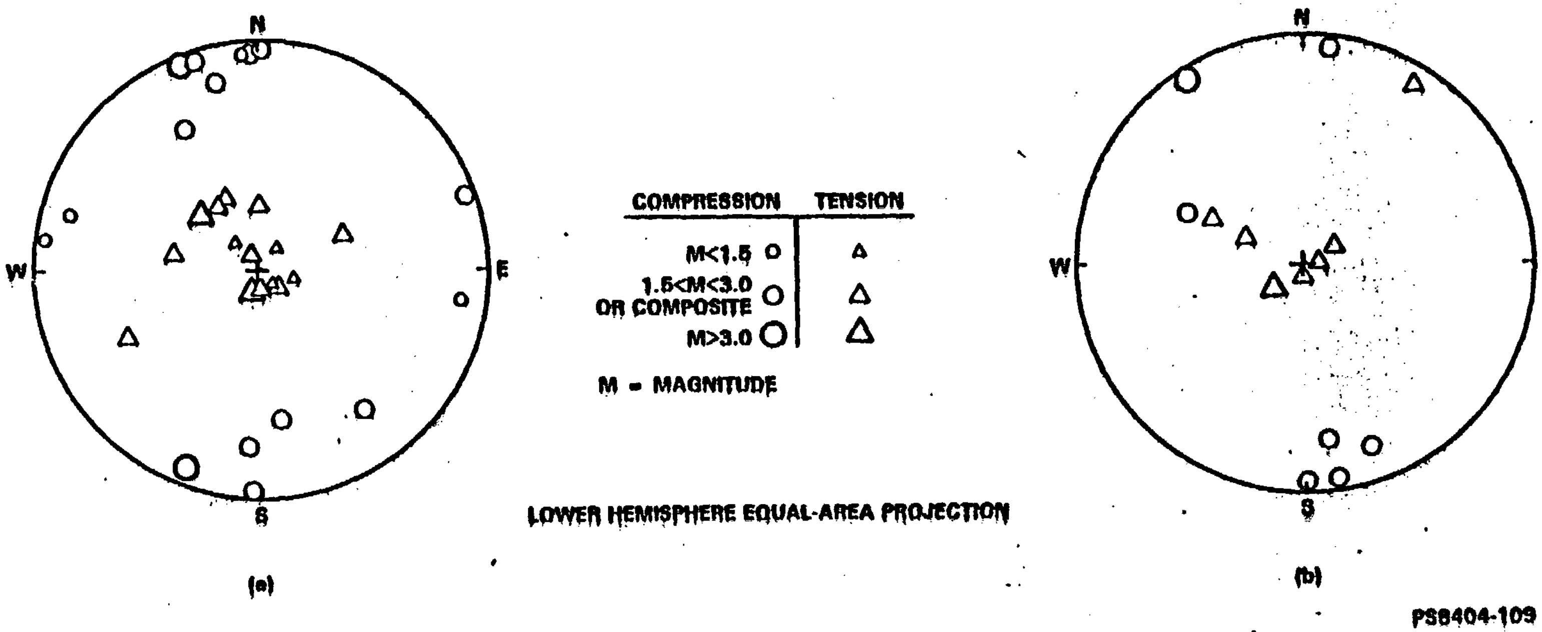

Figure 2-11. Stereo plots of compression and tension axes derived from focal mechanism solutions: (a) central Columbia Plaueau shallow events; (b) central Columbia Plateau deep events.

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- Historically, few earthquakes have been felt in the Pasco Basin, and most of these occurred beyond the margins of the basin (Rasmussen, 1967; WPPSS, 1981).

- Six trilateration surveys across the Pasco Basin indicate that nonuniform compression at a rate of less than 0.1 millimeter per kilometer per year (0.0006 inch per mile per year) (near the limit of detection) is occurring along northeast and northwest axes (Savage et al., 1981).

- Instrumental earthquake data for eastern Washington indicate minor stress release as micro-earthquakes (UWGP, 1979). The frequence, areal distribution, and mechanisms suggest that stress is not relieved as earthquakes along geologically mapped or unmapped faults. The east-west to northwest trend of folds and faults and the north-south trend of dikes in the basalt suggest north-south compression; such compression agrees with the stress field determined from focal mechanism solutions (Rohay and Davis, 1983).

2.1.3 Regional surface hydrology

This section outlines the regional surface hydrologic setting of the Columbia Plateau focusing on the State of Washington. The surface hydrology and flooding potential within the Pasco Basin, Hanford Site, and reference repository location are addressed in Subsection 3.3.1.

The Columbia River, along its 1,954-kilometer (1,214-mile) course, drains portions of seven states and Canada (Fig. 2-12), an area of approximately 670,000 square kilometers (259,000 square miles). The river enters the Columbia Plateau from the north where it joins with the Spokane River and begins a westerly and then southerly course. Along this southerly course, the river cuts through several anticlinal ridge structures, including the Saddle Mountains (at Sentinel Gap), before turning eastward at Umtanum Ridge near the location where it enters the Hanford Site (Fig. 2-13). On clearing the easternmost surface expression of the Umtanum Ridge-Gable Mountain anticline, the Columbia River resumes its southerly course, joining with the Yakima River from the west and the Snake River, its principal tributary, from the east below the Hanford Site, in the vicinity of the Tri-Cities (Richland, Kennewick, and Pasco, Washington). Beyond this point, it is joined by the Walla Walla River before cutting across the Horse Heaven Hills anticline at Wallula Gap. The Columbia River then begins a 480-kilometer (300-mile) westerly course to its mouth at the Pacific Ocean. The average annual discharge of the Columbia River out of the Pasco Basin is on the order of 1.7 x 10^{11} cubic meters (140,000,000-acre feet) (Gephart et al., 1979).

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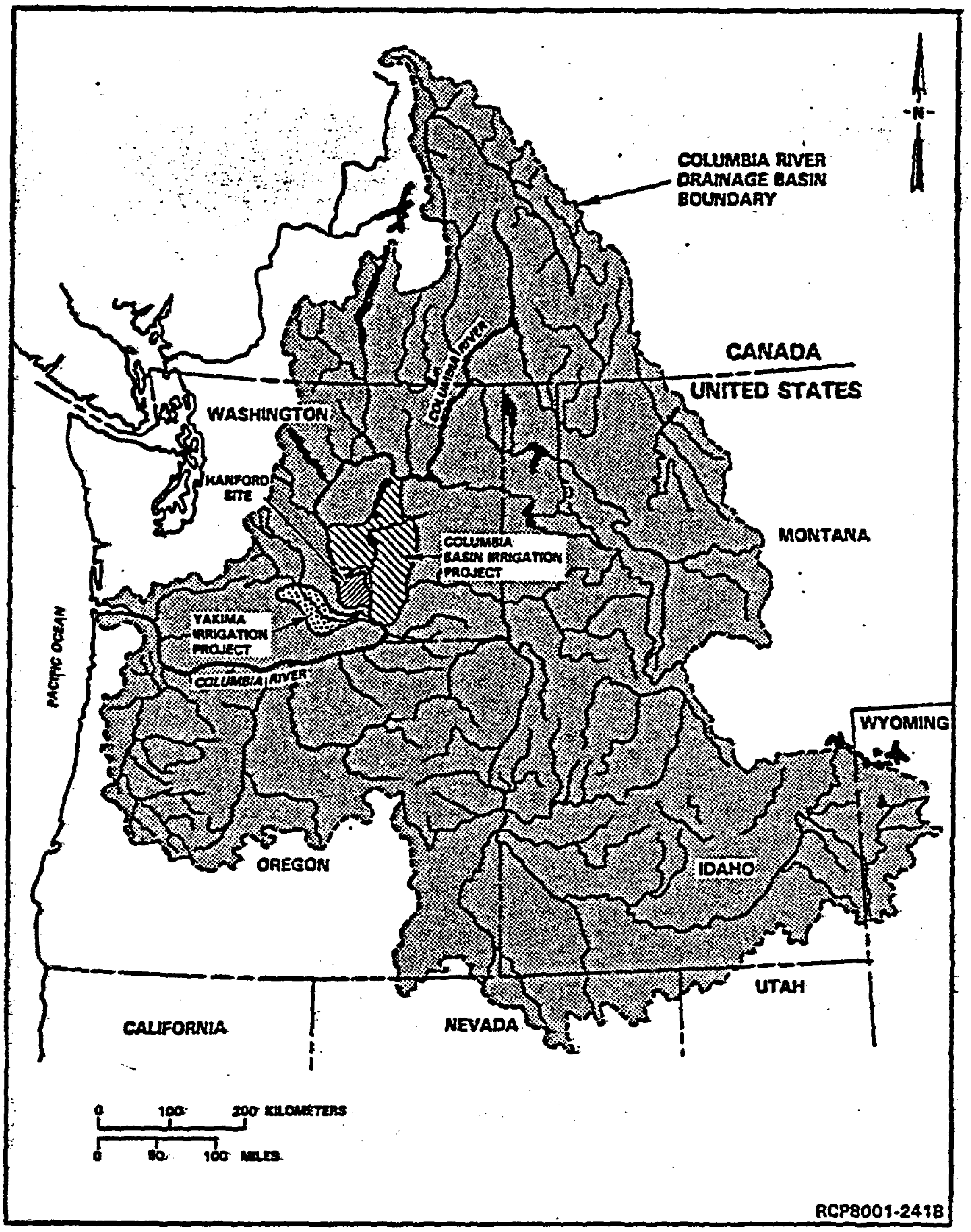

Figure 2-12. Columbia River drainage basin.

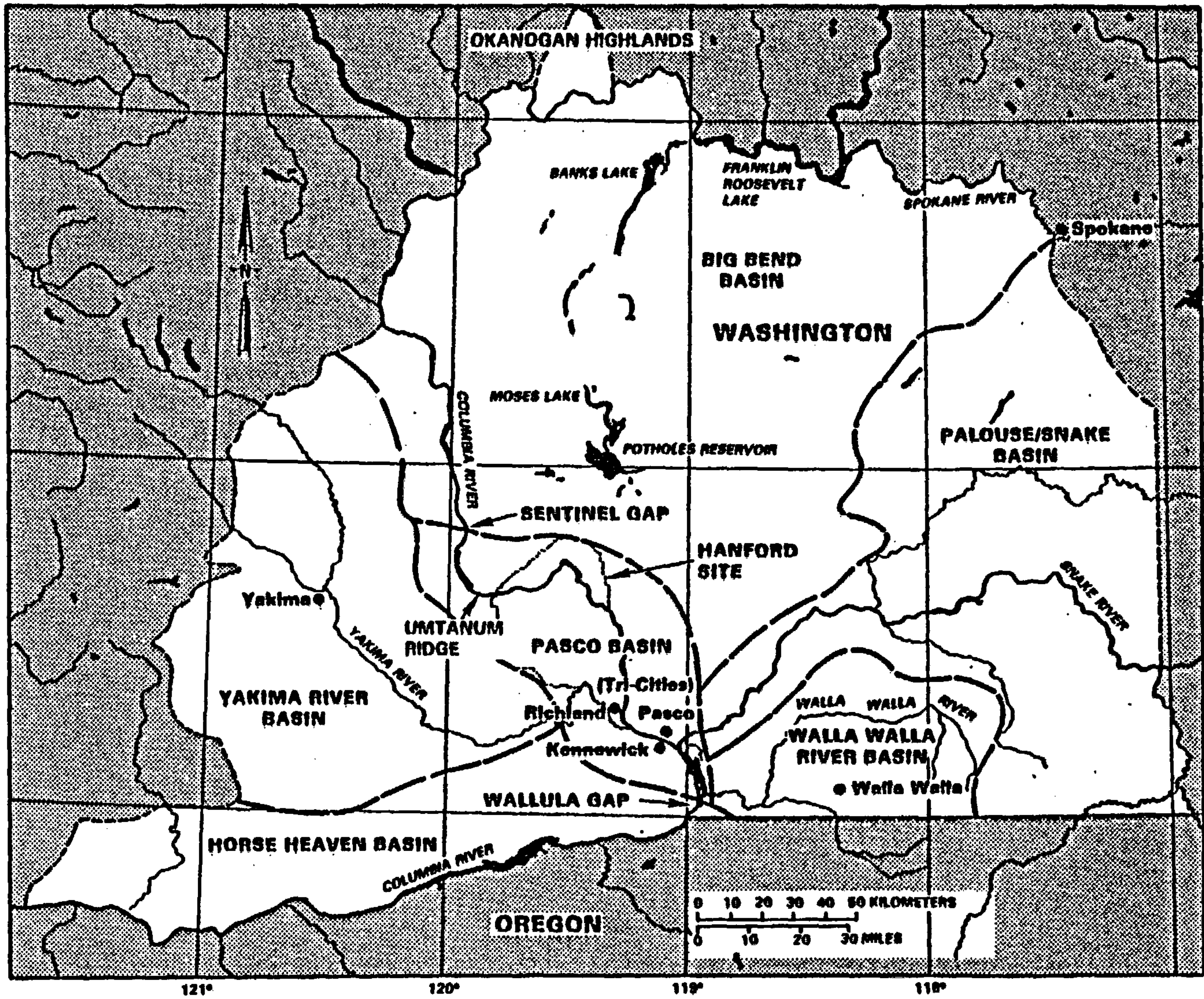

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Figure 2-13. Hydrologic basins designated for the Columbia Plateau (after Leonhart, 1979).

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The portion of the Columbia Plateau within the State of Washington can be divided into basins according to the major surface drainage systems present. Figure 2-13 shows such a division (Leonhart, 1979). The Pasco Basin, in which the Hanford Site lies, is one of these basins.

An extensive network of multipurpose water-resource projects is located along the course of the Columbia River (Fig. 2-14). Most notably, the Grand Coulee Dam backs up to a capacity of 1.2 x 10^{10} cubic meters (9,400,000 acre-feet) of water. Combined with the 1.9 x 10^{10} cubic meters (15,500,000 acre-feet) of storage upstream in Canadian reservoirs, 25 a total of 3.1 x 10^{10} cubic meters (~~20,~~000,0000 acre-feet) of usable storage are available in the basin above Grande Coulee Dam to regulate the flow of the Columbia River for power and flood control. Additionally, the system has been designed to deliver a full supply of water to 443,130 hectares (1,095,000 acres) of irrigable land within the Columbia Basin Irrigation Project, located north and east of the Hanford Site (see Fig. 2-12). The Yakima Irrigation Project, located along the Yakima River, maintains a storage capacity of approximately 1.2 x 10^9 cubic meters ~~(1,000,000~~ 950,000 acre-feet) and is designated to deliver irrigation water to 186,800 hectares (461,500 acres). Although no comparably significant irrigation development is set up along the Snake River, several dams and reservoir projects have been constructed for other multipurpose uses. The current hydraulic regime along the Columbia and Snake Rivers as they pass through the Columbia Plateau region is discussed in U.S. Army Corps of Engineers (COE, 1976) and U.S. Department of Energy (DOE, 1982).

2.1.4 Regional ground-water hydrology

This section presents a broad discussion of regional ground-water hydrology within the Columbia River basalts of Washington State. Topics addressed include ground-water occurrence in basalt formations, piezometric surfaces, hydrochemistry, ground-water use and regional ground-water management. The ground-water hydrology of the Hanford Site and vicinity is addressed in Section 3.3.2.

As part of the research into understanding regional ground-water movement in basalt, an interagency hydrology working group was formed in 1983. This group consists of representatives from the U.S. Geological Survery, Pacific Northwest Laboratory, and Basalt Waste Isolation Project who share data and conduct computer model studies to ~~more closely define~~ examine hydrologic properties and ground-water flow dynamics within portions of the Columbia Plateau, particularly those areas surrounding the Pasco Basin. In addition, a regional ground-water monitoring program has been established for measuring hydraulic head changes with time and for collecting ground-water samples. This monitoring program ~~is part of~~ utilizes data collected in part from the U.S. Geologic Survey's national ground-water survey entitled "Regional Aquifer System Assessment (RASA)." Portions of the regional ground-water hydrology discussion are taken from the U.S. Department of Energy (DOE, 1982).

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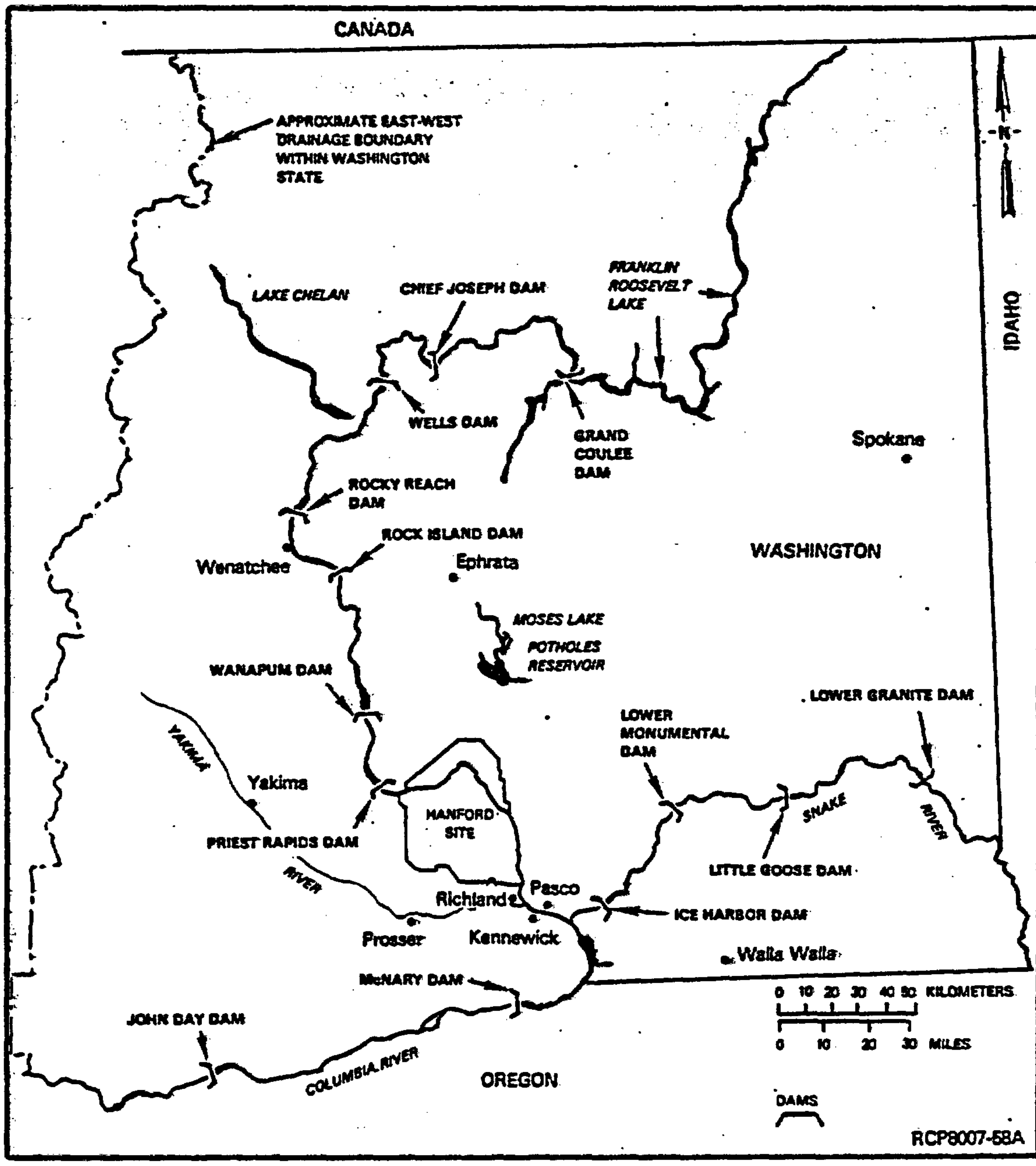

Figure 2-14. Locations of principal dams within the Columbia Plateau study area (after Leonhart, 1980).

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The areal distribution of the principal basalt formations within the Columbia Plateau--the Saddle Mountains, Wanapum, and Grande Ronde Basalts (see Fig. 2-5)--is important to understanding regional ground-water movement both across the Columbia Plateau and within the Pasco Basin (Gephart et al., 1979; DOE, 1982). In this regard, the following observations are offered:

- Ground water in shallow basalts in each structural basin of the Columbia Plateau is probably recharged and discharged locally. This corresponds with Toth's (1963) local ground-water system. Thus, depending on location within the Columbia Plateau, the Saddle Mountains Basalt would form the local system in one basin while the Wanapum Basalt or Grande Ronde Basalt could form the local flow system in another basin. Deeper intermediate or regional flow systems underlying larger sections of the Columbia Plateau would form interbasin ground-water systems. The topographic effects of the major anticlines trending eastward across portions of the Columbia Plateau (see Section 2.1.1) could contribute to the development of local flow systems and perhaps complicate (impede, redirect, or vertically mix) interbasin regional movement of ground water.

- Most of the Saddle Mountains Basalt in the Columbia Plateau lies within, and adjacent to the Pasco Basin. As discussed in Subsection 3.3.2, data suggest that ground-water in this formation is locally recharged and discharged.

- For most regional geohydrologic purposes, the Wanapum Basalt and Grande Ronde Basalt flows can be considered present and continuous; whereas, as noted above, the Saddle Mountains Basalt is discontinuous. The regional lateral continuity of these deeper basalts, particularly in the eastern half of the Columbia Plateau, would favor development of areally extensive, regional ground-water flow patterns. This flow most likely converges toward the lowest topographic area of the Columbia Plateau (i.e., the Pasco Basin).

- The Grande Ronde Basalt comprises 85 percent of the total rock volume of the Columbia River Basalt Group (Reidel et al., 1981). Outcrops of Grande Ronde Basalt are principally restricted to the northwest and southeast portions of the Columbia Plateau, plus isolated localities where surface erosion has exposed the formation (see Fig. 2-5). Throughout most of the Columbia Plateau the Grande Ronde Basalt was covered by the younger Wanapum Basalt and Saddle Mountains Basalt flows. Regionally, ground-water recharge of the Grande Ronde Basalt is believed to occur along margins of the Columbia Plateau where the formation is at or close to ground surface (DOE, 1982). Here, the Grande Ronde Basalt outcrops in areas of high elevation and, thus, in regions of greater-than-average precipitation for the plateau. In addition, large portions of the Columbia and Snake Rivers flow atop Grande Ronde Basalt bedrock along which ground-water recharge and (or) discharge can take place. Ground water can also move in and out of the Grande Ronde Basalt as a result of leakage from adjoining basalt formations.

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- Basalt flows older than the Grande Ronde Basalt (i.e., Imnaha Basalt and Picture Gorge Basalt) are probably of minor importance to the regional hydrologic dynamics due to their limited volumes and areal extent (see Fig. 2-5).

See Subsection 3.3.2 for a general discussion of ground-water occurrence within, and basic hydrologic properties of, a basalt sequence.

Regionally, discrete and composite potentiometric surfaces (hydraulic head trends) within the Columbia River Basalt formations were mapped by Tanaka et al. (1979). The general accuracy and limitations of data used were discussed in Tanaka et al. (1979) and further detailed in Gephart et al. (1979). Figures 2-15 and 2-16 reproduce some of these data as three-dimensional perspective views. A comparison between these figures and regional bedrock maps for corresponding rock units reveals similarities in surface trends and attitudes. This suggests that regional ground-water movement generally follows the regional bedrock dip as noted by Newcomb (1982). Figures 2-15 and 2-16 also suggest that the Pasco Basin, in relation to the surrounding plateau, is an area of regional ground-water flow convergence. This is expected since the basin occupies the lowest topographic area in the Columbia Plateau.

In addition to these potentiometric maps, the piezometric network established by the State of Washington Department of Ecology also examines vertical hydraulic head relationships in the Columbia Plateau region. The locations of wells comprising this network are shown in Figure 2-17. Principally, these regional ground-water monitoring wells were located in areas of heavy irrigation such as the Columbia Basin and Yakima Irrigation Projects. A schematic representation of the vertical head distribution at these sites is also provided (see Fig. 2-17). Note that these schematics are intended to represent only general relationships and vertical-head distributions for a fixed period of time. A summary of construction statistics with respect to these monitoring wells is given in a report by the U.S. Department of Energy (DOE, 1982), which also discusses the head relationships and time-variant characteristics observed. From these vertical-head data, the following generalizations are noted:

- The data show a general trend of decreasing hydraulic heads with increasing depth from ground surface in many wells, which means that ground-water recharge is taking place at those respective locations.

- At certain locations, head similarities are observed over tens to hundreds of meters (feet) of the vertical section. This could be attributed to any one (or combination of) the following natural or artificial factors:

  - high vertical communication

  - relative vertical positioning of the open intervals of the piezometers

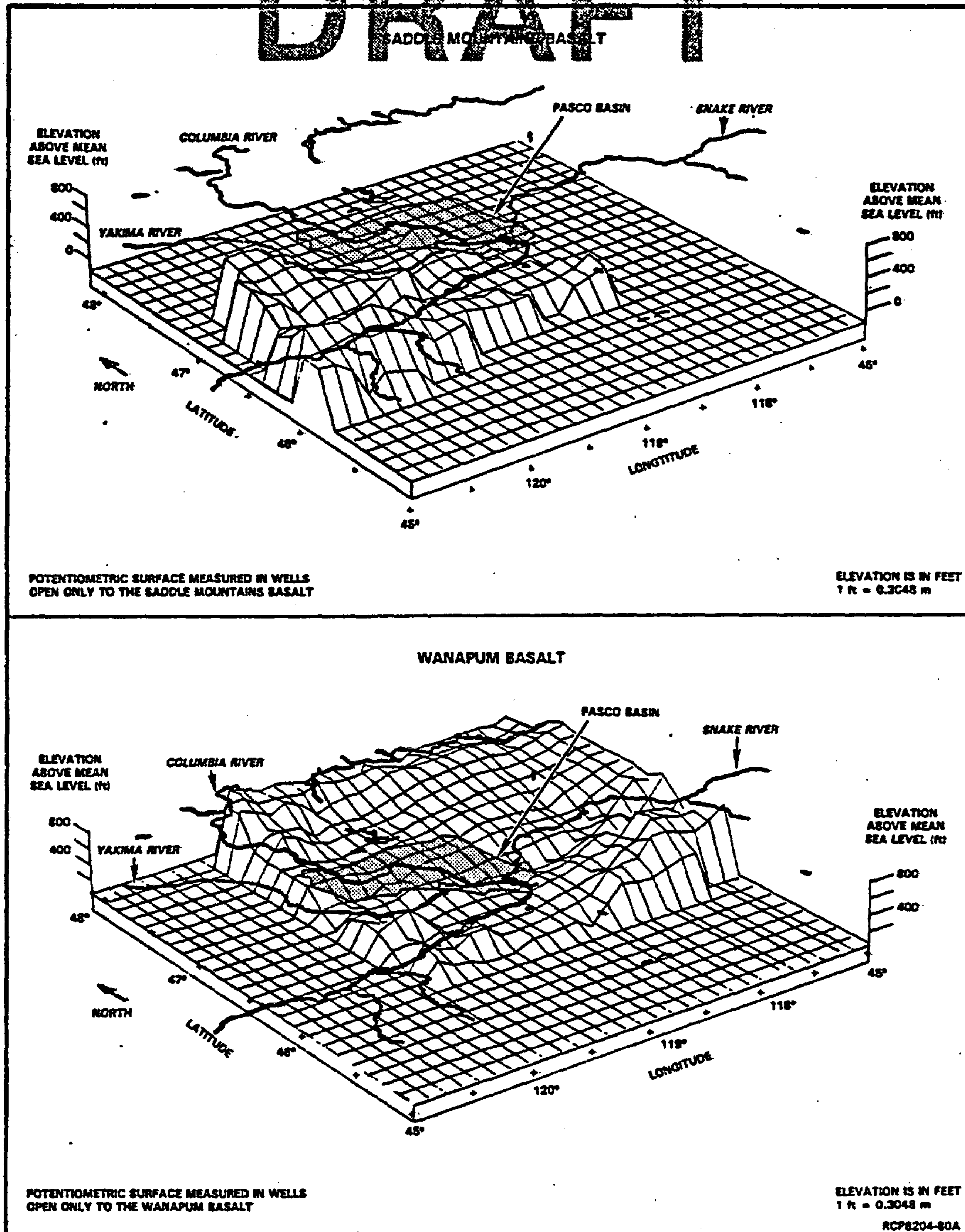

Figure 2-15. Three-dimensional perspective views showing the regional potentiometric surface (hydraulic head) configuration of the Saddle Mountains ~~Basalt~~ and Wanapum Basalts ~~flows~~.

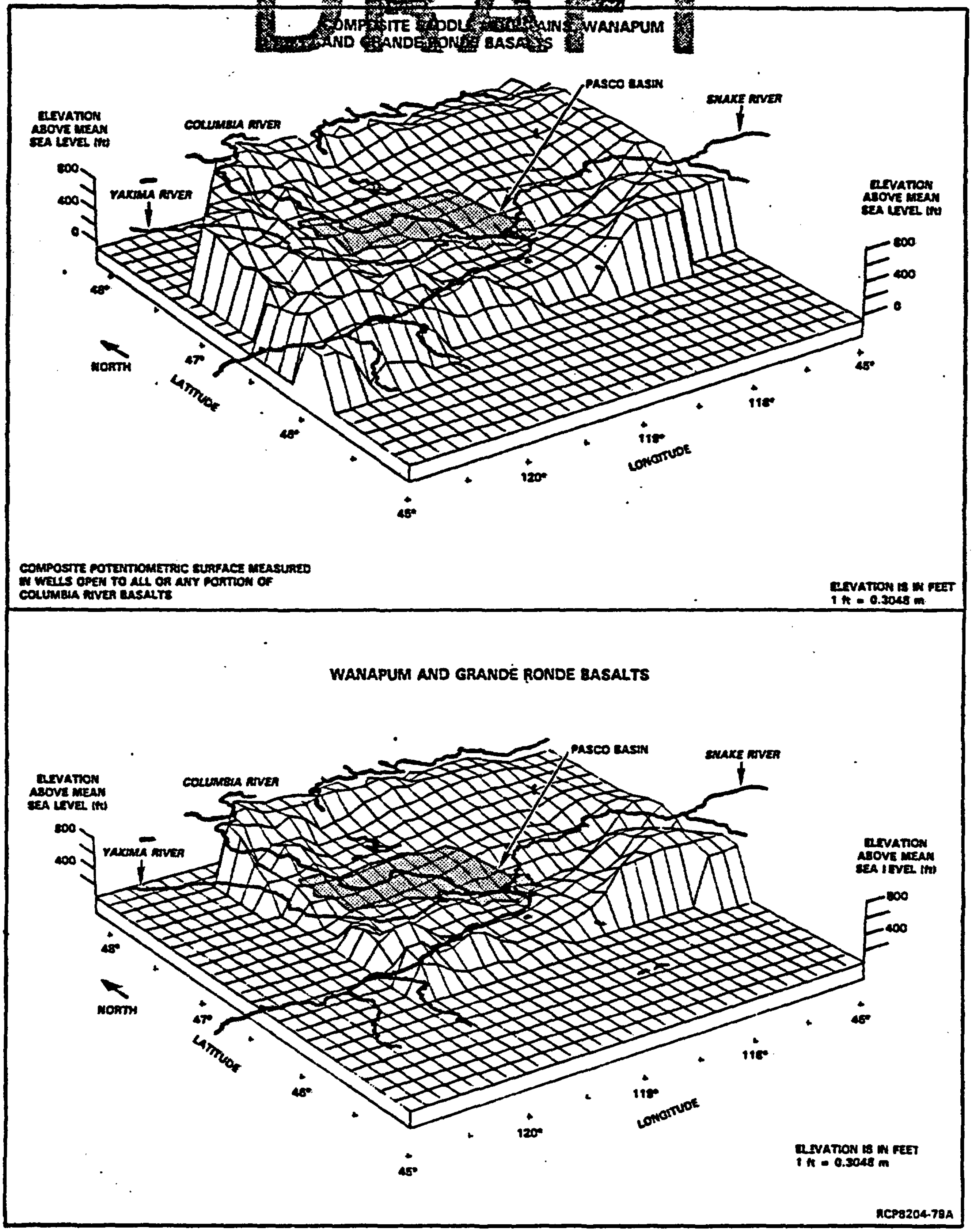

Figure 2-16. Three-dimensional perspective views showing the regional potentiometric surfaces for various strata within the Columbia River Basalt Group.

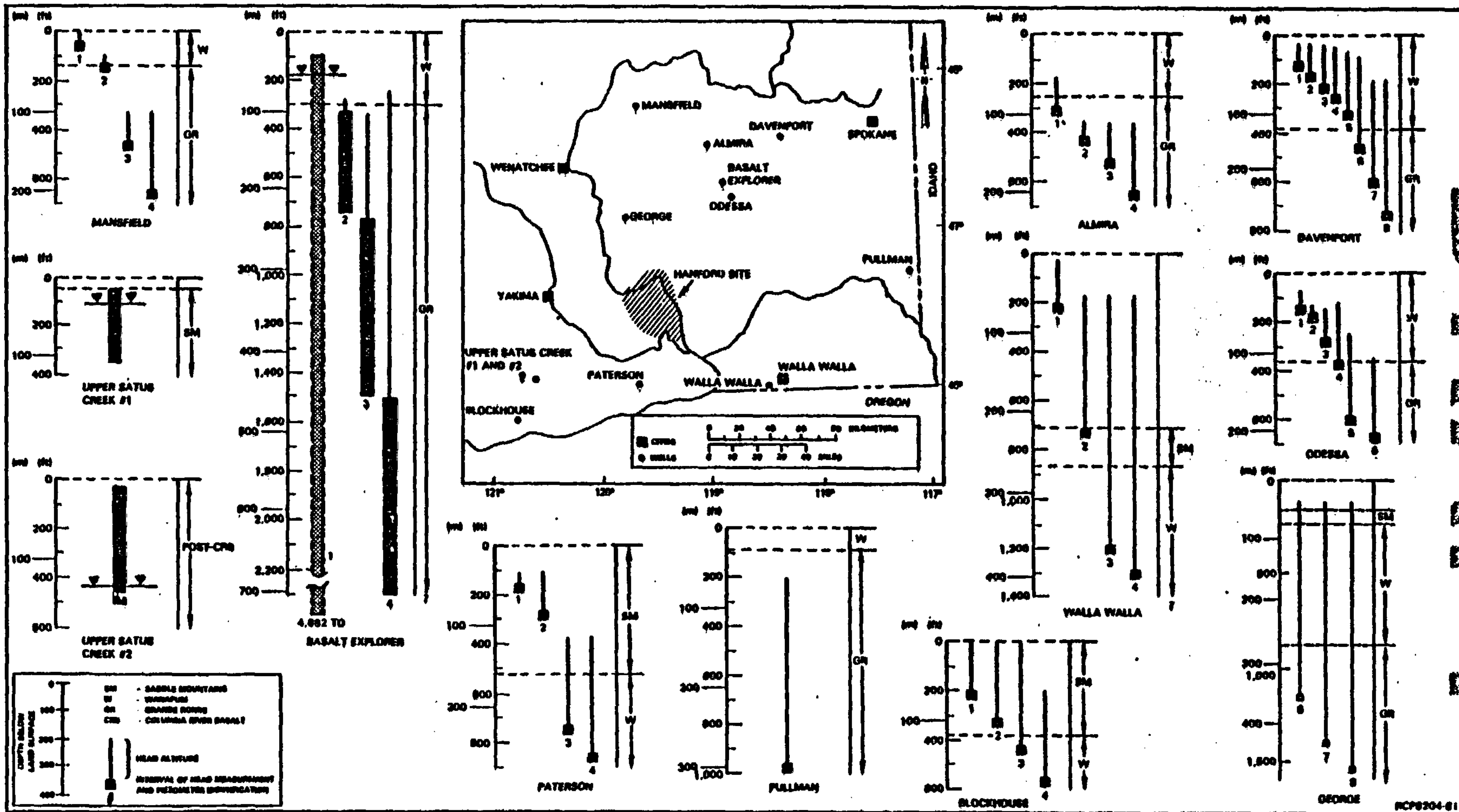

Figure 2-17. Locations and vertical-head distributions of the State of Washington ~~State~~ Department of Ecology test observation wells.

- failure of piezometer seals

- nearby ground-water use patterns

- well location--in area of lateral ground-water movement.

- At certain locations, a significant head drop across a threshold depth may be interpreted. While this may be a real phenomenon, several factors (including those factors just noted) prevent its confirmation, based on the available data. These include:

  - irregular intervals represented by piezometer placement over the vertical section

  - ground-water use

  - local hydrogeologic factors.

- The distribution of wells across the region tends to provide data that allow researchers to evaluate vertical-head distributions of the Wanapum Basalt and Grande Ronde Basalt flows at locations where these units are nearest the surface and closer to their probable recharge source. The wells south of the Hanford Site are designated to monitor conditions only within the Saddle Mountains Basalt and Wanapum Basalt flows. Therefore, vertical-head distributions of the Grande Ronde Basalt at locations south of the Hanford Site are presently unknown (DOE, 1982).

Because the piezometers shown in Figure 2-17 have been monitored by the U.S. Geological Survey on a periodic basis since installation, the time-variant behavior of the potentiometric surfaces within the Columbia Plateau can also be evaluated. A brief description of the dynamic behavior observed at each of the State of Washington Department of Ecology test/observation wells is found in U.S. Department of Energy (DOE, 1982).

2.1.4.1 Regional ground-water chemistry

Ground-water chemical analyses available for the Columbia Plateau are usually composite and represent water samples obtained from a number of hydrogeologic units penetrated at the sampled well site. Hydrochemical data for individual basalt formations and specific basalt flows within the Columbia Plateau are primarily limited to data obtained at the Hanford Site.

Hydrochemical data for ground water within the Columbia River Basalt Group are reported on a regional basis by Walters and Grolier (1959), Van Denburgh and Santos (1965), and Newcomb (1972). Chemical data for separate areas within the Columbia Plateau are available from several sources including Eakin (1946), Sceva et al. (1949), Foxworthy (1962), Foxworthy and Washburn (1963), and Newcomb (1965). Results from several of these studies are summarized in Gephart et al. (1979) and U.S. Department of Energy (DOE, 1982).

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Regional hydrochemical data discussed in U.S. Department of Energy (DOE, 1982) are based on analyses obtained from the ground-water-quality data files of the U.S. Geological Survey for the Washington State portion of the Columbia Plateau, exclusive of the Pasco Basin. Specific information for the Pasco Basin is addressed in U.S. Department of Energy (DOE, 1982). Figure 2-18 shows locations of regional sampling sites for which there appear to be reliable hydrochemical data from the basalt as addressed in U.S. Department of Energy (DOE, 1982). For most locations, available hydrochemical data consist of major inorganic constituents and selected trace elements.

Table 2-1 presents the range and mean composition of chemical constituents within the ground water of the Columbia River Basalt Group. These data are principally from wells penetrating the Saddle Mountains Basalt or upper Wanapum Basalt flows. These data indicate that, regionally, ground waters generally possess a low total-dissolved-solids content (e.g., less than approximately 350 milligrams per liter). Principal chemical constituents are present in the following dominance relationship (by weight): bicarbonate, which is greater than silica, which is greater than sodium, which is greater than calcium equals sulfate, which is greater than magnesium. Chemical classifications for these ground waters range from calcium-magnesium bicarbonate to sodium bicarbonate sulfate types. Regional dissimilarities in ground-water composition are ascribed to differences in aquifer samples, ground-water mixing due to multiple aquifer completions, sources of recharge, and rock/ground-water reactions.

Concentrations for trace elements reported in basalt ground waters across the Columbia Plateau are low and are commonly below detection levels of the analytical equipment used. The principal trace elements present are aluminum, boron, iron, manganese, strontium, and zinc (DOE, 1982). The higher concentration values for iron and manganese suggest that some analyses may exhibit the effects of poor sampling procedures and (or) the corrosion of well casings.

Isotopic data for the Columbia River Basalt Group are primarily available from sampling locations concentrated within the Pasco Basin as reported in U.S. Department of Energy (DOE, 1982). Isotopic data for most of the remaining portion of the Columbia Plateau are limited to carbon-14 analyses as, for example, reported by Crosby and Chatters (1965), Silar (1969), and Robinson (1971). These data are not distributed uniformly, but are confined primarily to two small areas within the southeastern portion of the plateau. Absolute ground-water ages cannot be reliably calculated from these regional data because of ground water mixing across different basalt horizons in the sampled boreholes and the lack of carbon-13 (dead carbon) corrections in the carbon-14 analyses. Due to the lack of carbon corrections, age dates (from modern to greater than 32,000 years before present) cited by the above authors are considered relative and can only be compared qualitatively.

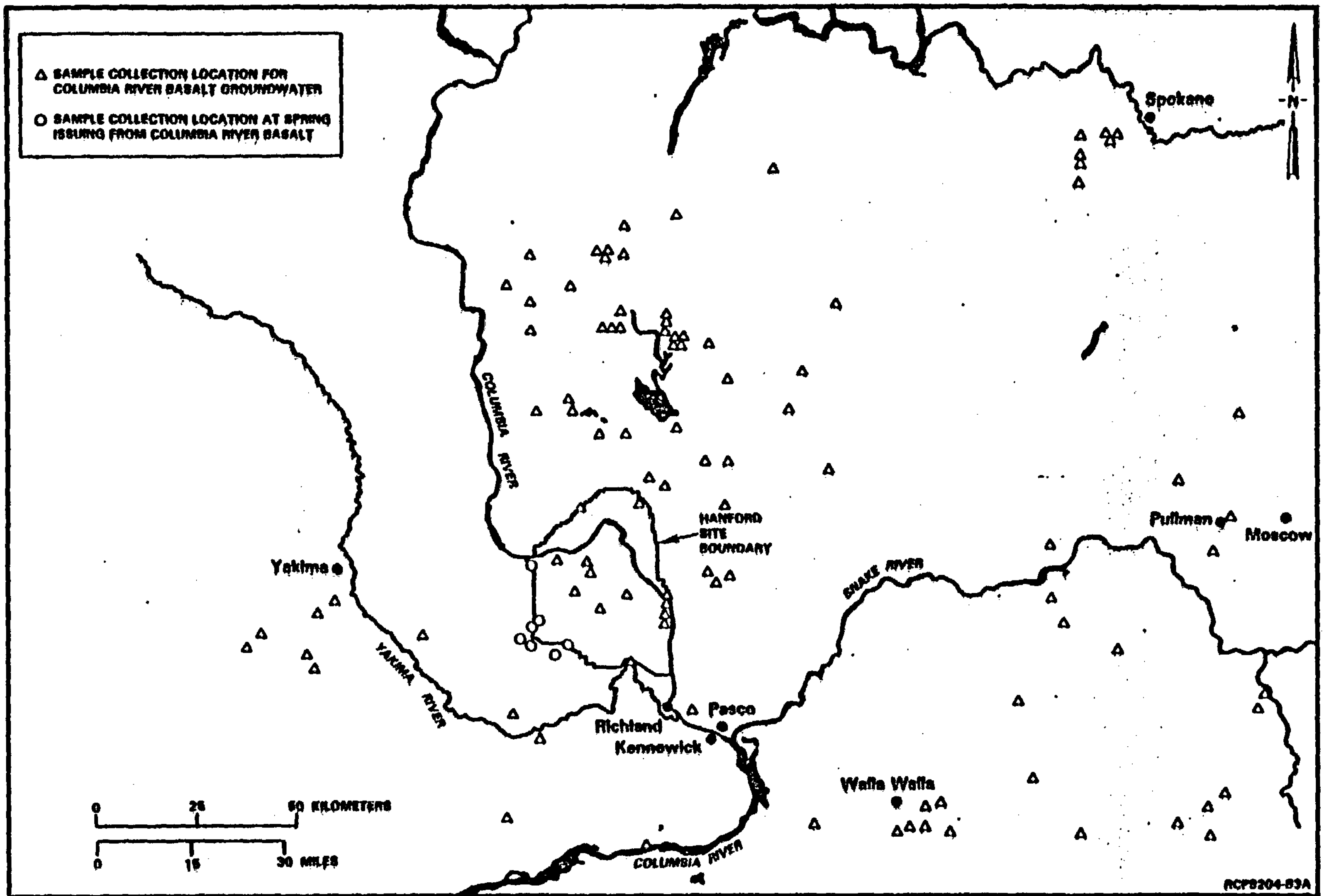

Figure 2-18. Sampling sites for ground water collected from Columbia River Basalt zones (after DOE, 1982).

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Table 2-1. Range in concentration and mean composition of major chemical constituents within ground water of the Columbia River Basalt Group.

Constituent	Range (mg/L)[a]	Mean (mg/L)[a]
Anions:		
Alkalinity, as HCO_3^-	72 to 297	160
Cl^-	0.5 to 56	12
SO_4^{-2}	0.2 to 95	21
NO_3^-	0.01 to 18	2.3
F^-	0.1 to 3.9	0.76
Cations:		
Na^+	7.8 to 80	34
K^+	0.1 to 38	6.5
Ca^{+2}	2.1 to 64	21
Mg^{+2}	0.2 to 24	10
SiO_2	30 to 83	55
Total dissolved solids	154 to 510	325

[a]Based on 83 hydrochemical analyses.

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Overall, regional hydrochemistry is only preliminarily understood. This results from the scarcity of three-dimensionally distributed hydrochemical data, most of which have been collected from shallow wells drilled less than a few hundred meters deep. Many of these wells sample only the dilute, local ground-water chemical types. There are few deep (i.e., 500 to 1,500 meters (about 1,600 to 5,000 feet) deep) ground water sampling wells outside of the Hanford Site in the Pasco Basin. Many of the shallow regional wells sampled are used for water supply, which is the topic of the next section.

2.1.4.2 Ground-water use in the Columbia Plateau and Pasco Basin

Detailed information on ground-water use within the Pasco Basin and the surrounding region can be found in several sources. Of principal interest are reports by Bell and Leonhart (1980), Brown (1979), Dion and Lum (1977), Foxworthy (1979), Geosciences Group, George Leaming Associates (GG/GLA, 1981), Pacific Northwest River Basins Commission (1980), Stephan et al. (1979), Wukelic et al. (1981), and U.S. Department of Energy (DOE, 1982). Additionally, numerous records are maintained in open file by state and federal agencies. In particular, the U.S. Geological Survey maintains a computerized file known as the Groundwater Site Inventory Data Base, which is a systematic digital collection of available data for permitted water wells. The Basalt Waste Isolation Project has acquired digital tapes of these records corresponding to 15 counties in southeastern Washington and 4 counties in northeastern Oregon. This assemblage represents data for nearly 15,000 wells.

The Groundwater Site Inventory Data Base can be used to tally the number of wells within the region according to use designation. Although such statistics do not provide an evaluation of the quantities of water withdrawn, they can be useful in describing the dominant types of ground-water use within an area and in generalizing well construction characteristics. Table 2-2 provides such a data reduction for the Columbia Plateau and the Pasco Basin. Another reduction of the data in terms of generic groupings is given in Table 2-3. In reviewing these tables, note that approximately 50 percent of the total number of wells within both the Columbia Plateau and the Pasco Basin are used for households (domestic); again, however, these numbers do not speak to the water volumes withdrawn, and it can be generalized that most of the wells are of relatively shallow depth (less than 150 meters, 490 feet). Agricultural use represents one-third of the total number of wells. Industrial users represent a comparatively small segment of the total number. The overall well-use distribution for the Pasco Basin is comparable to that of the Columbia Plateau.

The distribution of well uses in the Pasco Basin according to selected depth intervals is shown in Figure 2-19. This histogram shows that approximately 65 percent of the wells reported in the Groundwater Site Inventory Data Base derive water from less than 60 meters (195 feet) below ground surface. For most locations, this depth interval may be

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Table 2-2. Distribution of wells according to major use categories within the Columbia Plateau and Pasco Basin.

Wells	Human contact or consumption[a]	Industrial[b]	Agriculture or irrigation[c]	Total[d]
		COLUMBIA PLATEAU		
Total number	7,409	312	3,158	10,879
Percentage in a given category	68.1	2.9	20.0	100
		PASCO BASIN		
Total number	574	33	190	797
Percentage in a given category	72.0	4.1	23.8	100

[a]Includes wells designated as being used for bottling, domestic, medicinal, commercial, public supply, recreation, and institutional.

[b]Includes wells designated as being used for air conditioning, dewatering, fire fighting, and other industrial activities.

[c]Includes wells designated as being used for irrigation and stock watering.

[d]Includes only wells within the Groundwater Site Inventory Data Base having use designations. Wells designated as "other use" or "unused" were excluded.

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Table 2-3. Distribution of wells within the Columbia Plateau and Pasco Basin according to use.

Use	Columbia Plateau wells		Pasco Basin wells	
	Total	%	Total	%
Air conditioning	2	0.0	0	0
Bottling	1	0.0	0	0
Commercial	19	0.2	2	0.2
Dewatering	19	0.2	0	0
Fire	24	0.2	0	0
Domestic	6,664	53.3	493	49.4
Irrigation	2,804	22.4	167	16.7
Medicinal	3	0.0	0	0
Industrial	267	2.1	33	3.3
Public supply	645	5.2	76	7.6
Recreation	5	0.0	1	0.1
Stock	354	2.8	23	2.3
Institutional	42	0.3	2	0.2
Unused	1,582	12.7	189	18.9
Other	64	0.5	12	1.2
Total	12,495		998	
Data base total[a]	14,566		1,820	
Percentage		85.8[b]		54.8[b]

[a]U.S. Geological Survey Groundwater Site Inventory Data Base.

[b]Percentage of the data base total for which water-use information is available.

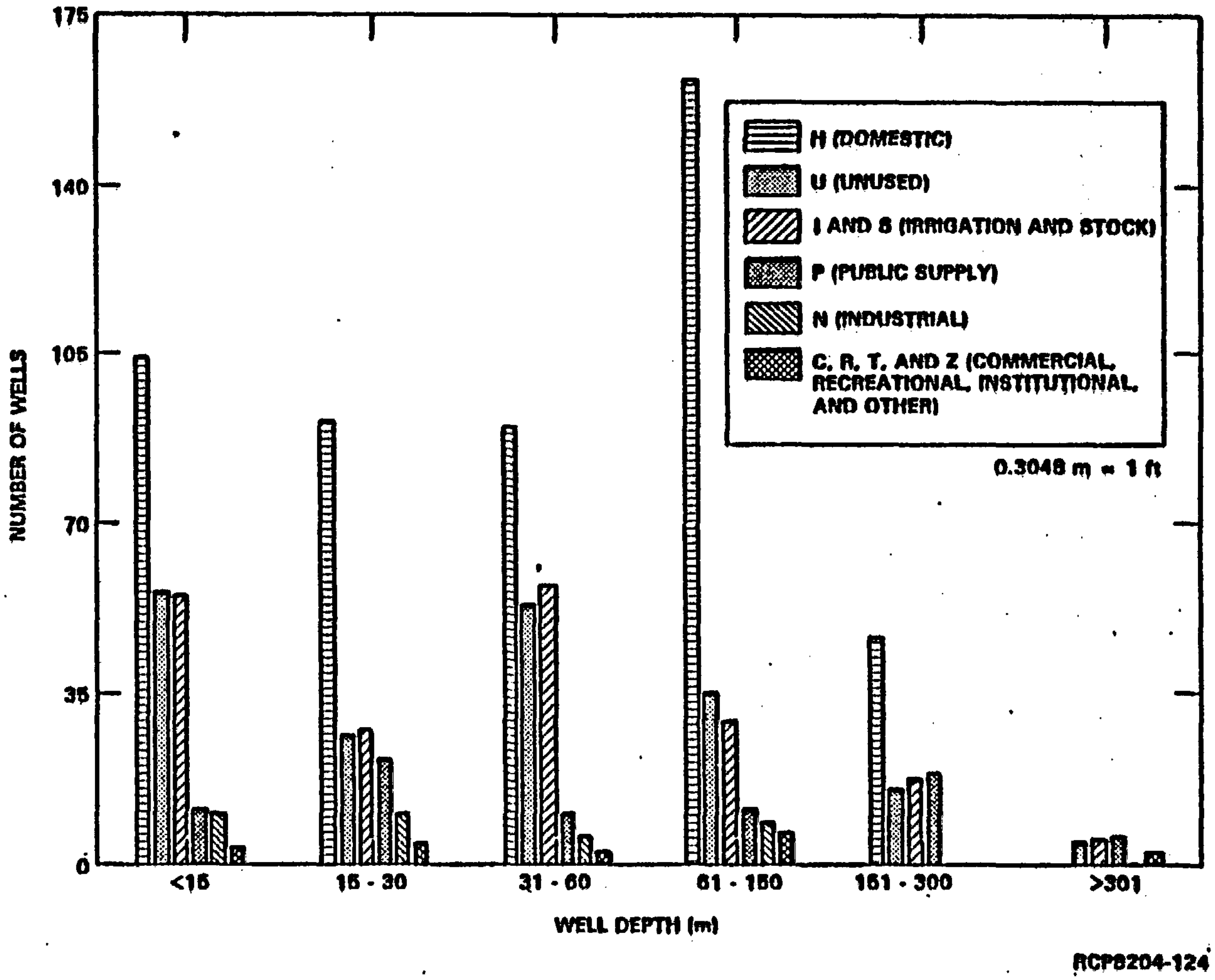

Figure 2-19. Frequency of well-use types listed in depth intervals for the Pasco Basin.

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considered to approximate the range of depth for the unconsolidated aquifers. The histogram also shows that approximately 50 percent of the wells in the Pasco Basin are used for domestic water supply.

A compilation of total ground-water quantities used in the Pasco Basin by agricultural (irrigation), municipal, industrial, and domestic ground-water users is given in Table 2-4. Figures given for agricultural and domestic ground-water users are based on 1980 data, and statistics cited for industrial and municipal ground-water users are based on 1975 data (DOE, 1982).

The long-term impacts of ground-water withdrawal throughout the Columbia Plateau region have been predicted and observed (Foxworthy, 1979; Luzier and Burt, 1974; Luzier et al., 1968; Luzier and Skrivan, 1973). Predictions indicate that there will be water-level declines of several meters per year in aquifers of the Wanapum Basalt and Grande Ronde Basalt flows. These declines are predicted for areas outside the Pasco Basin where the Wanapum Basalt and Grande Ronde Basalt flows are closer to the surface than they are within the Pasco Basin and are actively pumped for ground-water supplies.

Within the Pasco Basin, a similar phenomenon is seen in the upper Cold Creek Valley lying on the western boundary of the Hanford Site, where irrigated agricultural activities have been expanding. The average water-level elevation within the Priest Rapids Member (Wanapum Basalt formation) in the Cold Creek Valley declined approximately 10 meters (30 feet) from 1979 to 1982 (DOE, 1982). Also, data show that over the last 50 years water levels in the Cold Creek Valley have declined approximately 60 meters (195 feet) due to ground-water development (Newcomb, 1961).

In other areas, various activities have contributed to an increase in water-level evaluations of "shallow" aquifers. Most notable is the Columbia Basin Irrigation Project, which lies north and northeast of the Pasco Basin and extends into the eastern and northern portions of the basin (see Fig. 2-12). Before irrigation began in the Columbia Basin Irrigation Project, there was little ground water in the shallow sands and gravels above the basalt, and ground-water levels in the basalt were a few tens of meters below ground surface. After irrigation commenced in 1952, the upper confined aquifers of the Columbia River Basalt Group experienced a water-level rise. Water levels in typical wells drilled into the basalt aquifers underlying the Columbia Basin Irrigation Project have increased as much as 6 to 12 meters (20 to 40 feet) per year (DOE, 1982). This water-level rise is due to leakage of excess irrigation water from overlying unconfined aquifers across rock formations and probably along well casings and in open boreholes. Some researchers have estimated that approximately 20 to 40 percent of the water applied for irrigation (depending on location within the project) undergoes deep percolation into the water table (Gephart et al., 1979).

To properly manage ground-water use within the Columbia Plateau, the Washington State Department of Ecology has established regional ground-water management areas. This is the topic of the following section.

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Table 2-4. Ground water use in the Pasco Basin.

Ground water users	Quantity (m^3)	Year
Agriculture (irrigation)	2.5×10^8	1980
Municipal (exclusive of industry)	1.1×10^7	1975
Industrial (self and municipally supplied)	1.9×10^{10}	1975
Domestic	7×10^5	1980

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2.1.4.3 Regional ground-water management

Regulation of public ground water within the State of Washington is an authority delegated to the State of Washington Department of Ecology. Specifically, Chapter 90.44 of the Revised Code of Washington extends the applicability of the state surface-water statutes to the appropriation and beneficial use of ground water within the state. The State of Washington Department of Ecology has thus far designated two "ground-water management subareas" within the Columbia Plateau under the authority of the Washington Administrative Code (WAC, 1973, Chapters 173-124; 173-128; 173-130; and 173-134) and is controlling ground-water development within certain portions of the Columbia Basin Project area (WAC, 1973, Chapter 508-14).

In general, the approach to regional ground-water management by the State of Washington Department of Ecology involves the following two activities:

1. reconnaissance and evaluation of ground-water conditions
2. regulation of use.

The reconnaissance and evaluation activities consist of annual mass (water-level) measurements that are plotted to determine the rates of water-level decline for various zones. This is used as a basis for management and regulation. As a rule of thumb, the State of Washington Department of Ecology considers a situation serious when water-level declines in wells approach 9.2 meters (30 feet) within a 3-year period. This formula was established for the Odessa subarea and reflects the type of agricultural practice there.

The Pasco Basin "straddles" the regional responsibility of the State of Washington Department of Ecology. The Eastern Regional Office in Spokane, Washington, is responsible for ground-water management activities east of the Columbia River; whereas, the Central Regional Office in Yakima, Washington, handles the area west of the Columbia River to approximately the crest of the Cascade Range (see Fig. 2-13). ~~The regulatory responsibility of the Washington State Department of Ecology does not include the Hanford Site because it is a facility of the Federal Government.~~

The above geohydrological setting of the Columbia Plateau and Pasco Basin provides the background for the sections that follow. Section 2.2 will identify the potentially acceptable sites, and the specific choice within the setting, and in doing so the section describes the screening process by which the choice was arrived at.

Groundwater withdrawl on the Hanford Site by the Federal Government has been very limited and has not been subject to the State groundwater management programs.

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2.2 SITE SCREENING PROCESS AND IDENTIFICATION OF CANDIDATE REPOSITORY HORIZONS ON THE HANFORD SITE

Since 1976, the Basalt Waste Isolation Project has been responsible within the Civilian Radioactive Waste Management Program for investigating the Hanford Site to determine if a suitable location can be identified for geologic isolation of commercial nuclear waste. Two primary factors led to the selection of the Hanford Site for exploration and screening to determine its suitability. First, the Hanford Site is situated in the center of a region covered by one of the largest (200,000 square kilometers (78,000 square miles)) crystalline rock types in the United States, the Columbia River Basalt Group. Second, the Hanford Site is a federally owned land tract that has been committed to nuclear activities for over 41 years (GAO, 1979; Congressional Record--House 1979). Because of these two factors, the Civilian Radioactive Waste Management Program included the basalts beneath the Hanford Site as one of the rock types considered for potential siting of a nuclear waste repository. Intensive studies have been conducted since 1976 to determine the geologic and hydrologic characteristics of the Hanford Site and surrounding area (see Fig. 2-1), assess the feasibility of disposing of these high-level nuclear wastes in basalt, and provide the technology needed to design and construct such a repository in basalt, should feasibility be proven (ARHCO, 1976; Myers, Price et al., 1979; Gephart et al., 1979; Smith et al., 1980; Myers and Price, 1981).

In 1978, a site-screening study was initiated to systematically narrow the Pasco Basin screening area (approximately 4,850 square kilometers (1,900 square miles); see Fig. 2-1) to a preferred candidate site, or reference repository location, of approximately 47 square kilometers (18 square miles). This study was completed in May 1981 (WCC, 1981). Borehole cores, borehole testing results, geophysical data, and modeling results were then analyzed within the reference repository location to identify a site for a principal borehole and exploratory shaft. These borehole and shaft locations were selected in May 1982. In mid-1982, screening of the basalt strata underlying the reference repository location was initiated to identify one of the basalt flows as a preferred candidate repository horizon. Such identification was necessary so that performance assessment, design studies, and planning for in situ testing could proceed on the basis of a single, specific horizon. This study was completed in September 1983 (Ash, 1983).

The following sections review the basis for the selection of the reference repository location, the site for the principal borehole and exploratory shaft, and the selection of the preferred candidate repository horizon. Note that the reference repository location was selected before siting criteria were developed by the National Waste Terminal Storage Program (the predecessor to the Civilian Radioactive Waste Management Program)) or the development of General Siting Guidelines required by the Nuclear Waste Policy Act of 1982.

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2.2.1 Identification of a reference repository location

Seven key assumptions guiding the site identification study were important in establishing the objectives and development of screening guidelines. These are Hanford Site screening guidelines, not the General Siting Guidelines later developed by the U.S. Department of Energy. This process was completed before the Nuclear Waste Policy Act was passed. These key assumptions are restated as follows:

- The repository will require licensing involving the Nuclear Regulatory Commission, other federal agencies, and possibly state and local entities.
- The design and operation of most surface facilities will be governed by existing safety and environmental licensing requirements.
- Nominal design and performance characteristics for the repository have been established.
- The long-term safety-related characteristics of the host rock system can be estimated and can be used in the selection guidelines.
- The repository will be designed for two time frames: a relative short emplacement and retrieval phase, and a much longer isolation phase.
- The site identification study will be based on available data; General Siting Guidelines will be based on currently available technology.
- The repository licensing requirements will be written in the style of those for other nuclear fuel cycle facilities.

On the basis of these assumptions, several objectives were established to reflect specific desired characteristics of the repository facilities, as well as conditions and concerns with the study area. The hierarchy of objectives provided the framework for choosing and applying guidelines to identify site localities. A proposed general statement of policy for licensing requirements for a repository, which was issued by the U.S. Nuclear Regulatory Commission (NRC, 1978), indicated that to be accepted as suitable a site must:

- ~~Maximize~~ Minimize effects on public health and safety.
- Minimize adverse environmental and socioeconomic impacts.
- Minimize cost necessary to attain the requisite levels of safety, and minimize costs of mitigation.

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The above objectives were then expanded and restated to bear on conditions or events that could be associated with an underground repository; thus, the objectives were to:

- ~~Maximize~~ Minimize effects on public health and safety in relation to natural hazards, manmade hazards and events, and repository-induced events.
- Minimize adverse environmental and socioeconomic impacts related to construction, operation, and closure and surveillance.
- Minimize system costs related to construction and impact mitigation, operation and maintenance, closure, decommissioning, and surveillance.

For each of the objectives established, "considerations" or technical matters of concern were identified to describe the subject matter that must be addressed to orient the siting study to reflect characteristics, conditions, or processes in the study area. For example, one consideration related to a safety objective would be a fault rupture, which must be addressed in the siting study.

For some considerations (technical matters of concern) a special level of achievement was required or implied by statute, regulation, technological limitations, or gross economic considerations. Again using fault rupture as an example, a measure may be stated as the distance from capable faults and those interpreted to be capable, thus indicating the degree to which a repository at any location can maximize safety in relation to fault rupture.

The choice of measures for the considerations was based on (1) prior U.S. Nuclear Regulatory Commission licensing experience and relevant regulatory positions, (2) the availability of data, and (3) 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 kilometers (miles) from a fault. The motion itself is traditionally measured in terms of acceleration. In this study, the range of acceleration levels was inferred from a relationship between magnitude-acceleration attenuation 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 represented a range of acceleration levels.

The value of the measure at which the limit was set was an "inclusionary" guideline. This limit was used to identify locations that met the minimum requirements for that consideration. In the fault rupture example, two considerations were evaluated based on general viewpoints of the scientific community. First, it is generally accepted that most effects of a fault rupture occur within 8 kilometers (5 miles) of the capable structure. Second, it is generally considered difficult to design an underground facility that will accommodate a fault rupture. Hence, a

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limit was set on the measure of the fault rupture consideration: locations within 8 kilometers (5 miles) of capable faults were removed from consideration in the siting study.

For considerations where no specific level of achievement was required, the measure itself was used to identify groups of localities with similar characteristics. These guidelines were called classifying guidelines. The considerations, measures, and guidelines used for the site identification study are found in a report by Woodward-Clyde Consultants (WCC, 1980, Vol. I, Appendix A), along with a detailed discussion of the background and rationale for selecting the various measures and guidelines.

2.2.1.1 Identification of site localities

As part of the Basalt Waste Isolation Project activities to systematically assess the feasibility of constructing and operating a repository at the Hanford Site, a site screening was done. The site screening work to identify a suitable location for a repository at the Hanford Site was done by Woodward-Clyde Consultants (WCC, 1980). The Pasco Basin was selected for screening to provide a broader scope from which to study processes that might affect the Hanford Site, and to determine whether any obviously superior sites are located in a natural region outside, but contiguous to, the Hanford Site.

The first step in screening the study area was to define the candidate area. The considerations used at this step were active faults, ground motion, aircraft impact, transportation, operational radiation release, protected ecological areas, culturally important areas, and site preparation costs. Figure 2-20 shows the candidate area defined by the composite overlay.

The second step in the screening of the Pasco Basin was to delineate subareas. Seven inclusionary considerations with more restrictive measures were used in this screening step: fault rupture, flooding, ground failure, erosion denudation, hazardous facilities, induced seismicity, and site preparation costs. When the overlays depicting these seven guidelines were compiled, the subareas shown in Figure 2-21 were identified. These subareas were then evaluated in the next step in the screening process to identify site locations. The evaluation of subareas was conducted in two steps: (1) evaluation of subareas outside of the Hanford Site boundary, and (2) evaluation of the subareas within the Hanford Site boundary.

The first step was designed to determine whether any obviously superior sites are located in the subareas outside the Hanford Site. The results of this evaluation indicated that three of the four subareas that were outside the Hanford Site (L, M, and N in Fig. 2-21) were used for irrigated farming and were near the Columbia River. The fourth subarea (designated by the letter P in Fig. 2-21), in addition to being used for

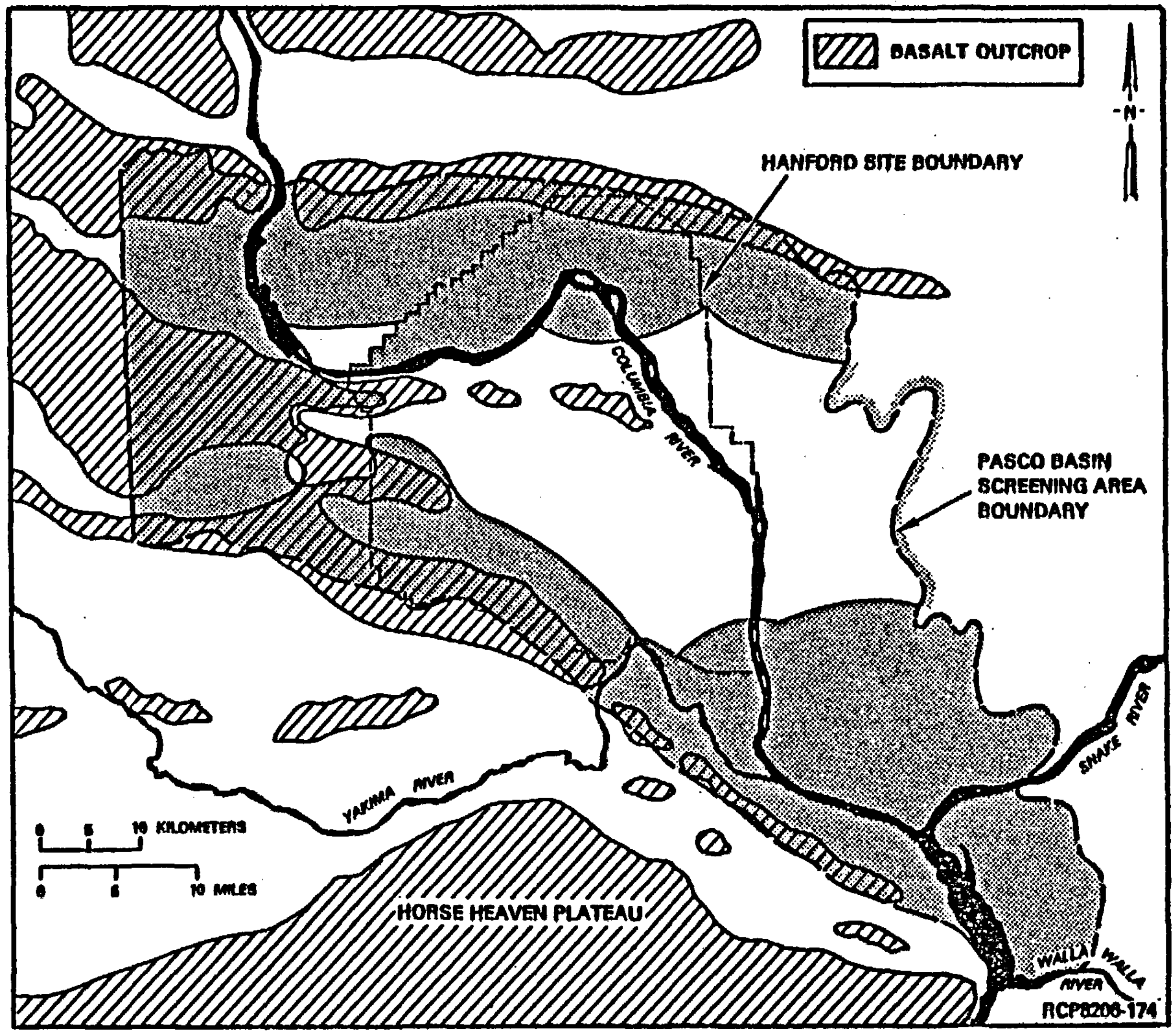

Figure 2-20. Candidate area (outlined with shaded area).

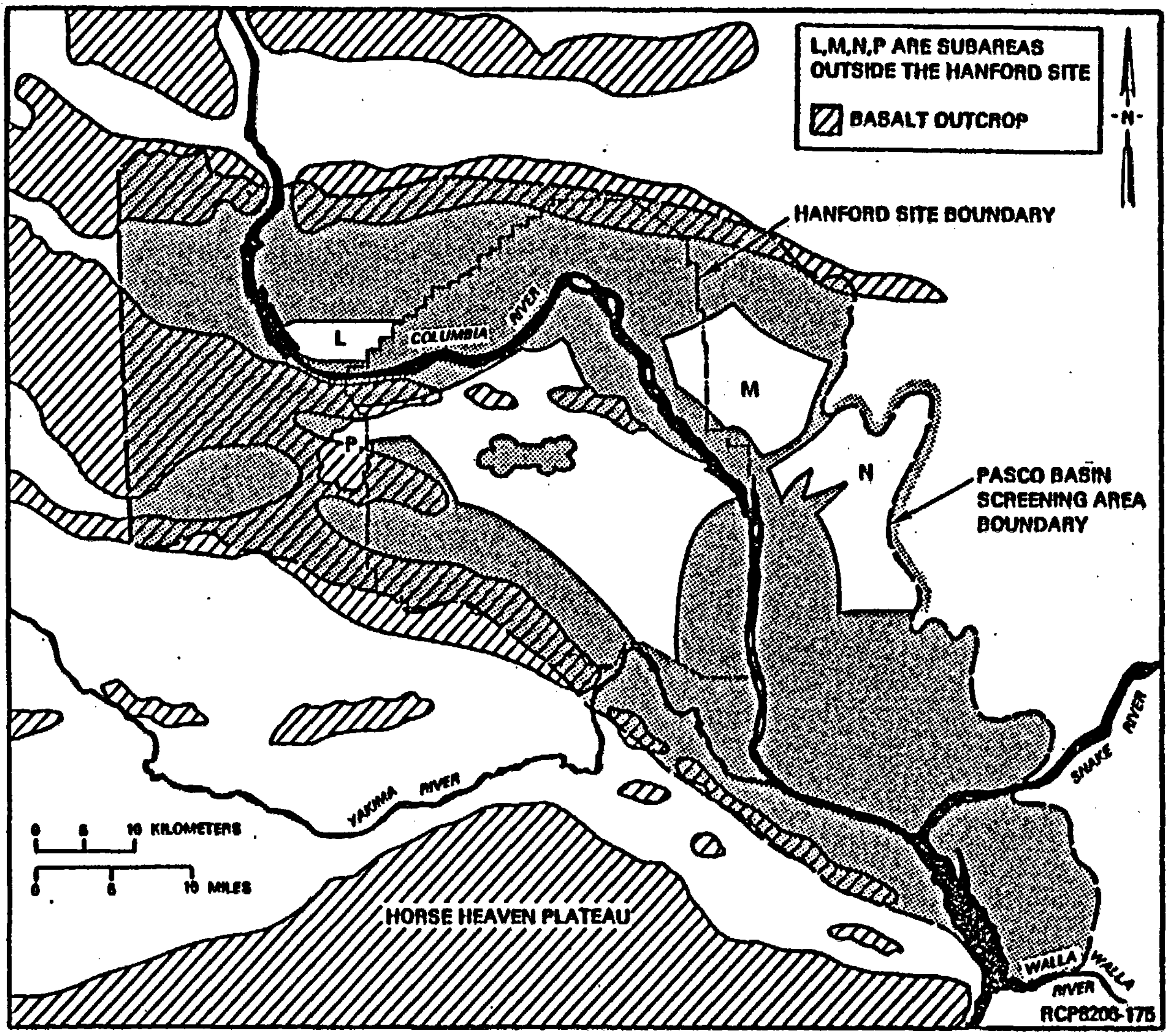

Figure 2-21. Subareas (unshaded).

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irrigated farming, was an area where the bedrock dip was greater than 5 degrees; one of the baseline conditions for the repository host rock was a flow dip of less than 5 degrees. On the basis of land use, hydrology, and bedrock dip, these sites were not obviously superior to those found within the Hanford Site and, therefore, were given no further consideration.

The next step in the evaluation of subareas within the Hanford Site (before the identification of site locations) was to study the available surface and subsurface areas separately and to evaluate surface and subsurface considerations. In all circumstances the subsurface considerations took precedence over the surface considerations; that is, the subsurface screening showed obvious superiority, the surface screen was downgraded. The area resulting by combining the surface and subsurface screens was judged to be more suitable and to have a higher likelihood of containing suitable waste repository sites.

The general size of a potential site is less than 130 square kilometers (50 square miles) and greater than 26 square kilometers (10 square miles); five potential sites were identified. Figure 2-22 shows the location of these five sites designated H-1 through H-5. The boundaries of the three site localities south of Gable Mountain were defined somewhat arbitrarily to maintain equal size.

2.2.1.2 Identification and ranking of candidate sites

The initial step in identifying the reference repository location was to identify candidate sites within the five site localities. The size of a candidate site was determined from repository baseline conditions established at the beginning of the screening process. An area of approximately 26 square kilometers (10 square miles) was selected to include surface and subsurface facilities and an exclusion area buffer zone.

The candidate sites were identified through a selective and successive examination and evaluation of the range of conditions for 23 parameters that reflect the objectives of the siting study (WCC, 1981).

Consideration was also given to established U.S. Nuclear Regulatory Commission reactor siting criteria (NRC, 1975), the Office of Nuclear Waste Isolation draft site qualification criteria (ONWI, 1979), U.S. Nuclear Regulatory Commission draft repository criteria (NRC, 1980), and National Academy of Sciences guidelines (NAS-NRC, 1978). The relationship of the Office of Nuclear Waste Isolation generic repository criteria and the site-specific consideration used for candidate site identification is given in two Rockwell Hanford Operations documents (Rockwell, 1980; 1981).

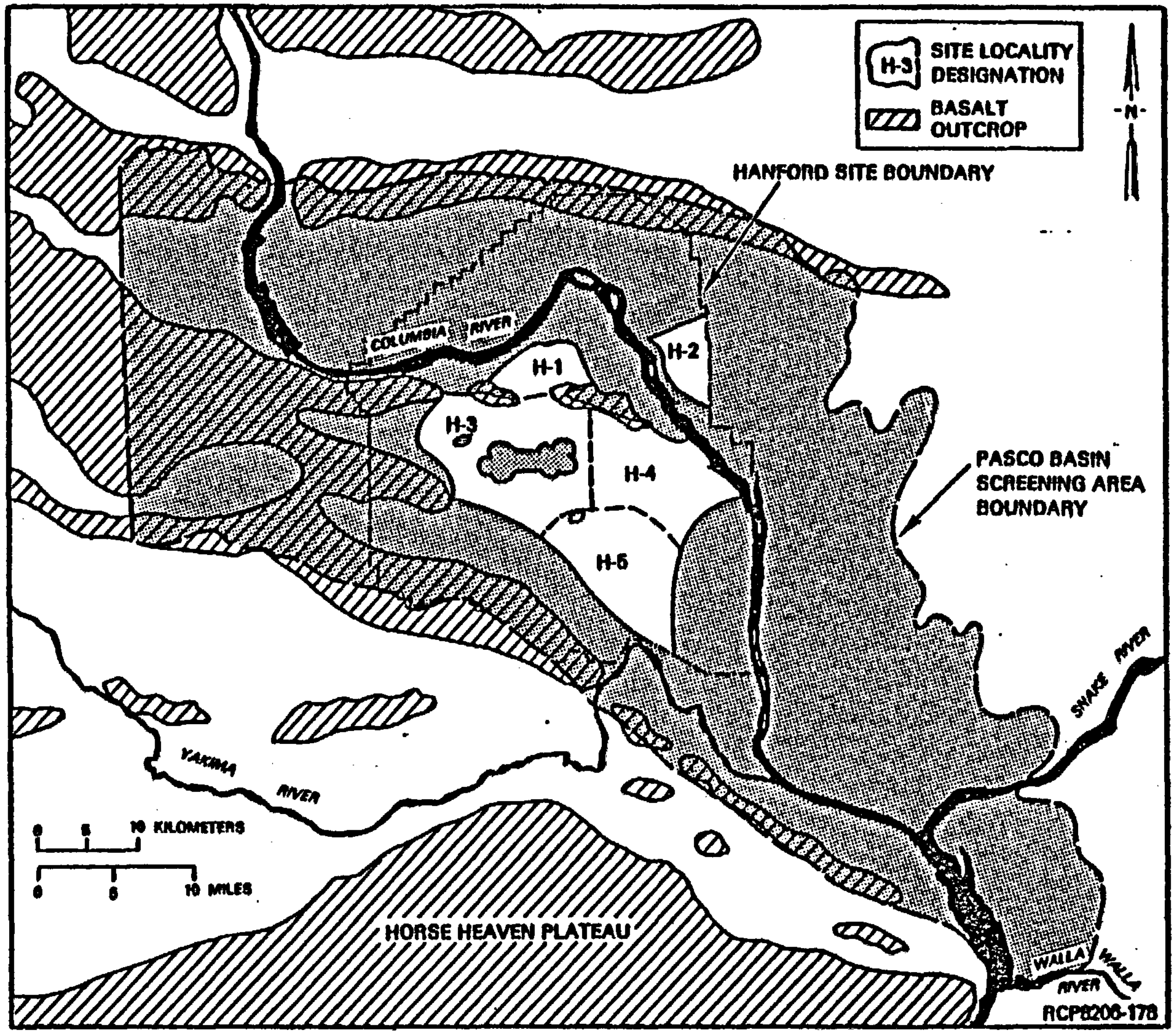

Figure 2-22. Site localities.

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To identify candidate sites, screening overlays representing the range of conditions and the area affected by each parameter under consideration were superimposed. The results of this overlay process were used to identify the portion within each locality with the most desirable characteristics with regard to the parameters. Nine candidate sites were thus identified within the site localities, lettered R through Z in Figure 2-23. Seven of the nine candidate sites (R through X) lie in a group within the Cold Creek syncline, a major structural feature of the Pasco Basin. Two other candidate sites (Y and Z) lie outside this structure.

A review of site conditions showed that candidate sites Y and Z, near the Columbia River, were not technically superior to those in the Cold Creek syncline, were closer to the Columbia River, and were more distant from transportation, safety, and support facilities. For these reasons, candidate sites Y and Z were removed from further study.

The remaining seven contiguous candidate sites in the Cold Creek syncline displayed geologic and physical similarities throughout the siting process. These sites were renamed A through G (Fig. 2-24) and were further evaluated to identify a reference repository location. However, because the seven contiguous sites appeared to be so closely matched, further evaluation of the Cold Creek syncline was based on a more detailed study in the siting area. Results of the geologic field work were subsequently summarized in Myers and Price.(1981).

Because of the linear trends resulting from the geophysical studies in the Cold Creek syncline (Myers and Price, 1981), the boundaries of the seven candidate sites were reevaluated. For ease of comparison with previous work, the original candidate site boundaries (A through G) were maintained and three additional candidate site boundaries were superimposed on portions of the original seven sites (but outside of the influence of the more prominent geophysical lineaments). These additional sites were designated H, J, and K (Fig. 2-25).

Preliminary evaluation of the ten candiate sites (A through K) indicated that the sites were too closely matched to be differentiated by routine ranking. Thus, a decision analysis process was applied. An enlarged data base was compiled and referred to as the criteria matrix. The criteria matrix included a description of physical, socioeconomic, and biological conditions at the candidate sites using information available as of May 1980.

Criteria were selected from a detailed evaluation of the criteria matrix. The ten ranking criteria were as follows:

- Bedrock fractures and faults.
- Lineaments.
- Potential earthquake sources.

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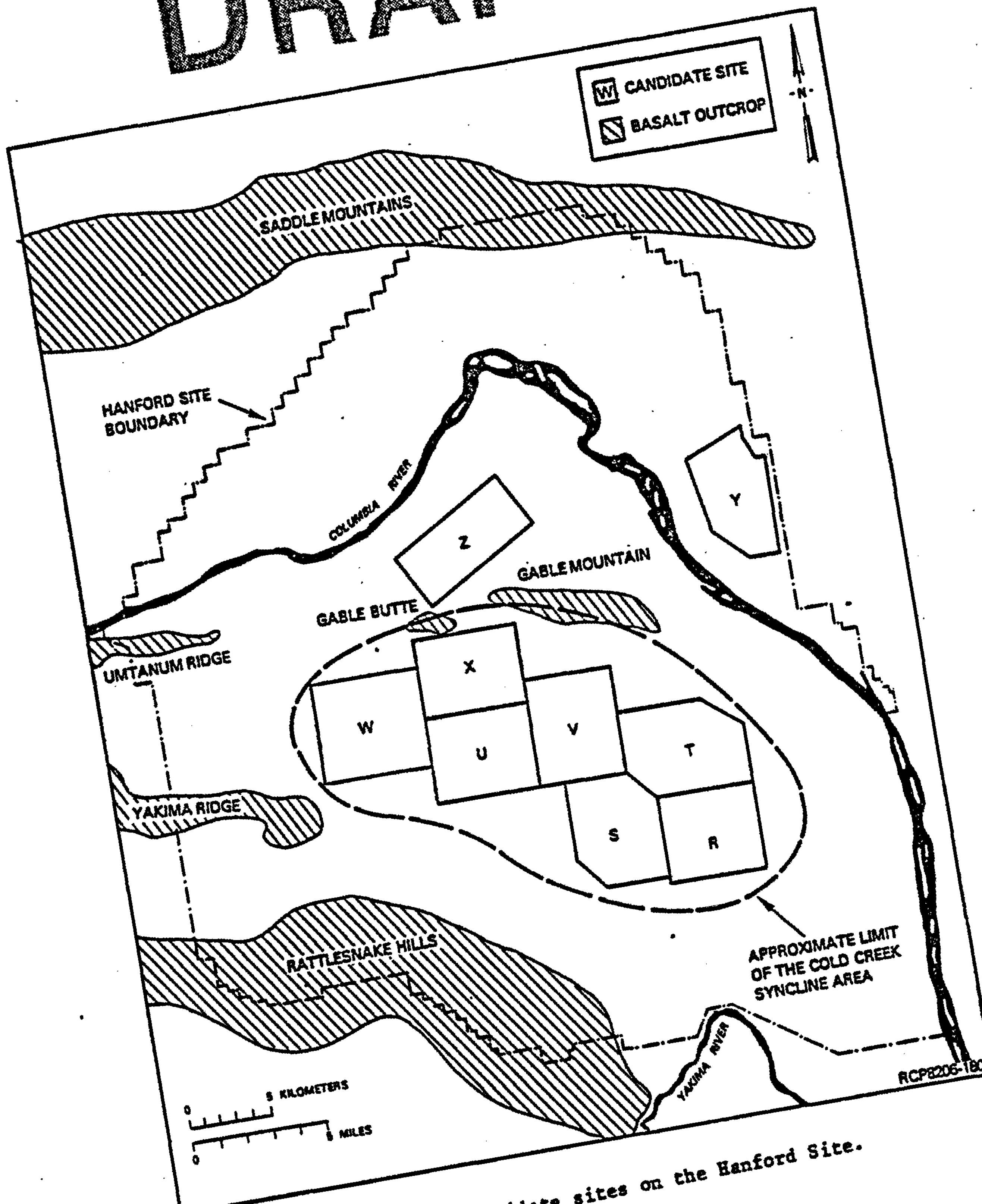

Figure 2-23. Candidate sites on the Hanford Site.

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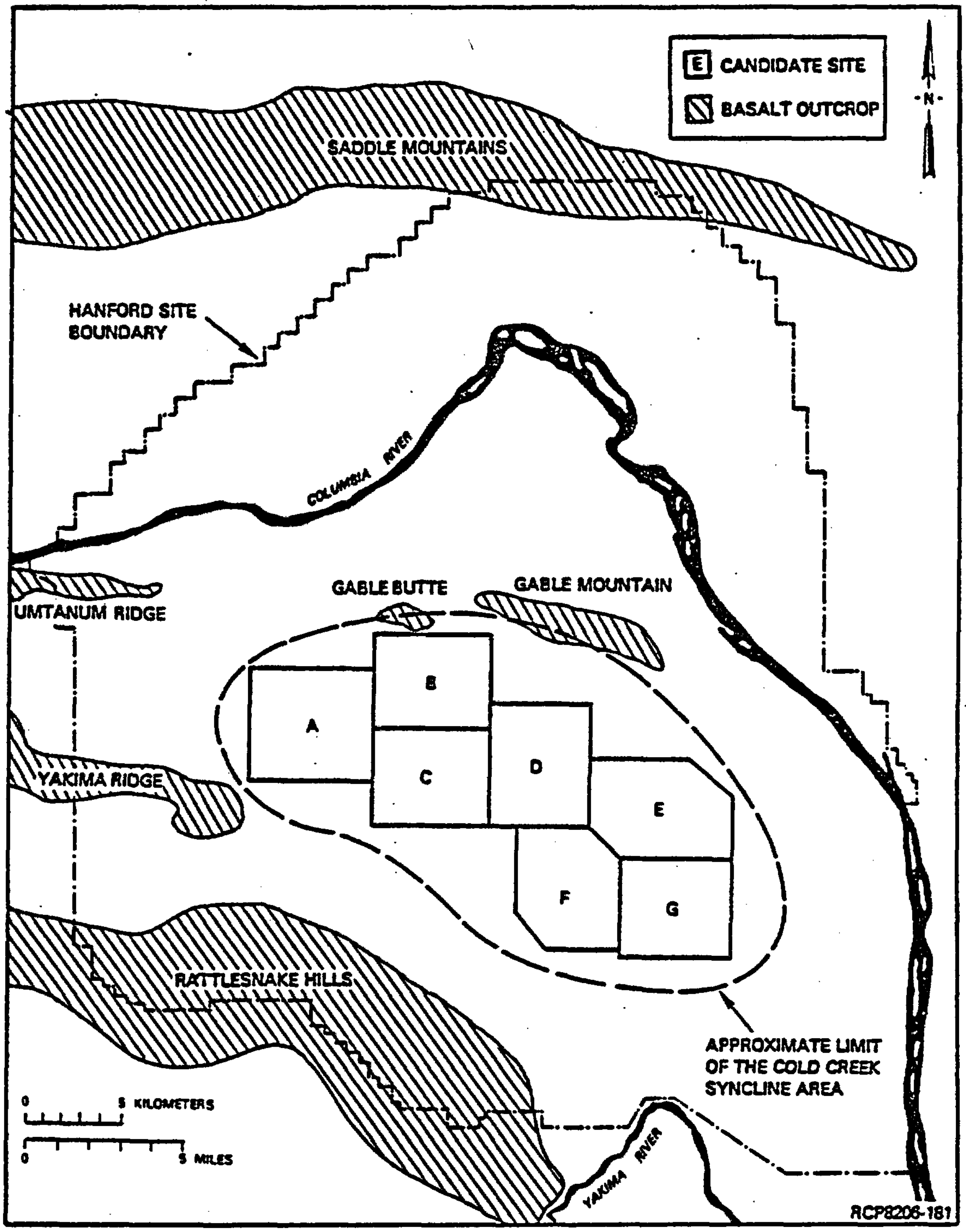

Figure 2-24. Initial candidate sites in the Cold Creek syncline area.

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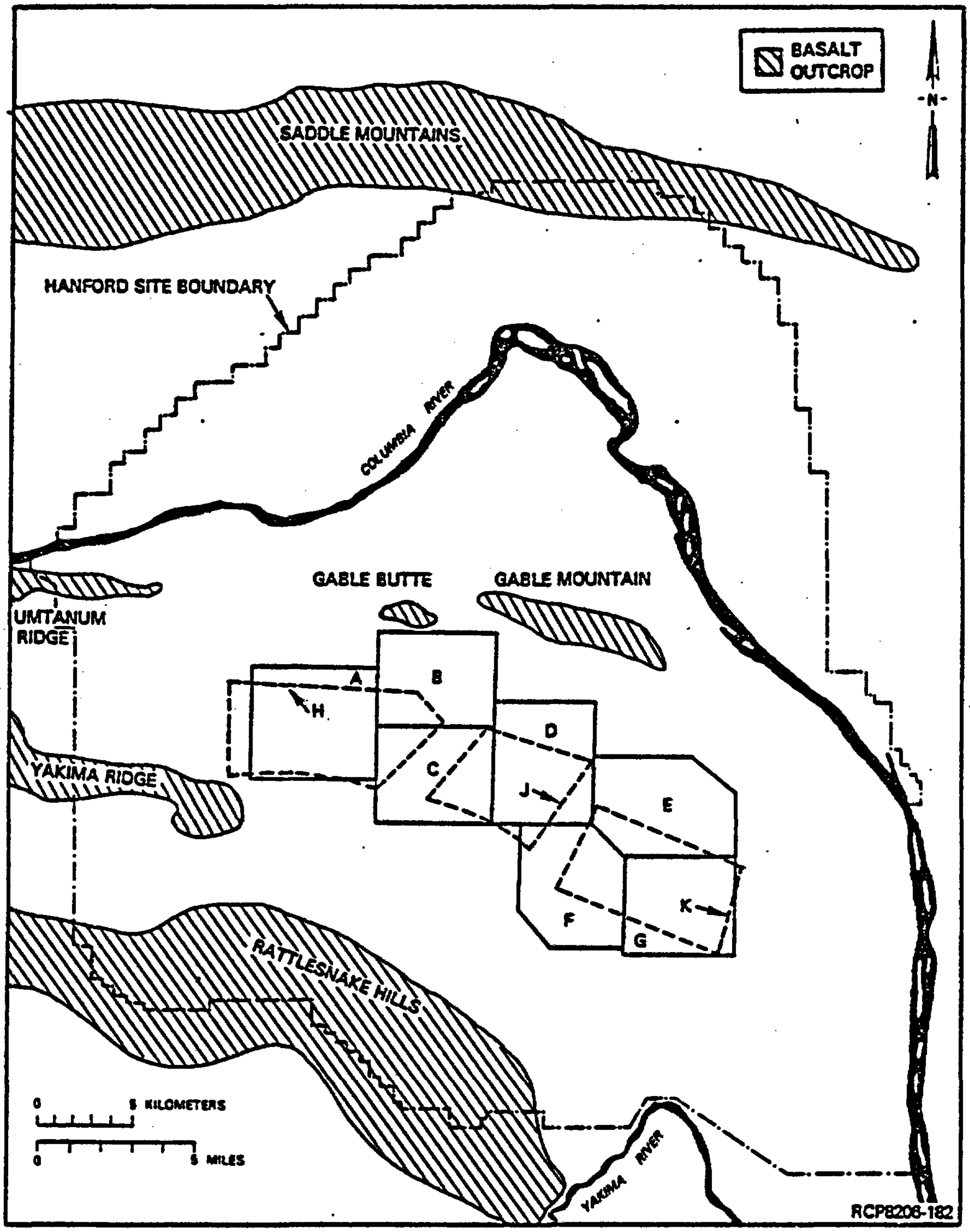

Figure 2-25. Ten candidate sites. The three superimposed candidate sites (H, J, and K) avoid prominent geophysical lineaments.

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- Ground-water travel times.
- Contaminated soil/contaminated ground water/surface facilities.
- Thickness of the reference barrier interior (assumed to be Umtanum flow).
- Tiering within the host flow.
- Vegetative natural communities.
- Unique microhabitats.
- Special species.

For the purpose of the site screening process, the Umtanum flow was selected as the reference horizon because it exhibited promising repository characteristics such as a relatively thick dense interior with low porosity (based on recovered core and geophysical logs) and apparent lateral continuity (Myers and Price, 1981).

Dominance analysis was used for the site ranking and was carried out by a siting committee formed of technical representatives from Woodward-Clyde Consultants and Rockwell Hanford Operations. First, measures for those ranking criteria were developed that could be used to differentiate the candidate sites. The ranking criteria and their measures were derived from a detailed evaluation of criteria and data comprising the criteria matrix. Once the ranking criteria were defined, they were applied to each candidate site. The siting committee judged each site according to available published and unpublished data as outlined by the criteria matrix and their own professional judgment. The favorable or unfavorable consequence of each site in terms of the measures for each ranking criteria was then established.

The next step in the dominance analysis was to determine preference for a series of consequences. This became necessary because of the number of criteria and alternative variations; thus, a simple dominance analysis was too difficult to perform and ordinal dominance analysis was used. Ordinal dominance analysis allowed the siting committee to assess trade offs to determine the relative importance of the measures used in differentiating among candidate sites. These trade offs were examined in two ways. First, if given a hypothetical site with all the criteria at the most desirable levels, and given that one criterion had to be changed to its least desirable level, which one would be changed. The criterion selected for this question had the least weight. The question was then repeated progressively until all criteria were ranked.

The second way of assessing trade offs required the determination of how much one was willing to give up from one criterion to enhance a second criterion. This rank ordering should agree with the first method. The information for ranking was then synthesized, which merely involved discussion and evaluation of all sites by the siting committee with respect to the ranking criteria, site characteristics, and analysis method.

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The results of the ordinal dominance analysis are shown in Table 2-5. The additive numerical functions were determined based on the site-ranking value terms. The results of the ranking show that site H is dominant over all other sites. Site A, which is almost totally included within Site H, has about the same dominance numerial value (0.834 and 0.860, respectively). These two sites were combined to form the reference repository location, Site ~~X~~ AH (Fig. 2-26).

Because of the heavy weighting of the lineament and thickness criteria, the substitution of a thick Grande Ronde Basalt Formation other than the Umtamum flow, as the reference horizon would not be expected to alter the results of this screening. Such a substitution has been made as the result of a study conducted specifically to identify the preferred candidate repository horizon (see Subsection 2.2.1).

2.2.2 Identification of principal borehole site and exploratory shaft site

With the identification of the A-H site as the reference repository location, the Basalt Waste Isolation Project in conjunction with the Basalt Waste Isolation Project Architect-Engineer, Raymond Kaiser determined the Engineers Inc./Parsons Brinckerhoff Quade & Douglas, Inc. ~~met to locate a proposed~~ site for a principal borehole for an exploratory shaft. Six shallow boreholes (designated by an RRL- (for reference repository location) prefix in Fig. 2-27) were drilled to evaluate the overall dip of the basalt units. The results indicated an overall dip of less than 1° across the reference repository location. The axis of the Cold Creek syncline was also determined more precisely. Figure 2-27 is a contour map of the top of basalt beneath the reference repository location and shows the location of boreholes drilled for characterization.

To help select a specific location for construction of a principal borehole for an exploratory shaft, exclusion-area criteria were developed. These criteria are land use, surface contamination, ground-water contamination, and exploratory shaft and repository orientation. A composite overlay of the reference repository location is shown in Figure 2-28, which is the result of screening of land use considerations, surface contamination, ground-water contamination, and exploratory shaft setback requirements. This composite shows that the area remaining for consideration is in sections 2, 3, 10, and 11 in the western half of the reference repository location. Within this area, adequate space exists for location of the exploratory shaft and repository area. The location of the principal borehole was selected near the intersection of these sections at the site of the existing borehole, RRL-2. This borehole had been cored to a depth of approximately 520 meters (1,700 feet) and was suitable for deepening to 1,177 meters (3,860 feet).

Table 2-5. Ordinal dominance analysis results.

Candidate site	l'	l'+h	l'+t	l'+h+t	l'+h+t +p	l'+h+t +p+g'	l'+h+t +p+g'+b	Site ranking value	Site dominated by
A	1.84	2.51	2.84	3.51	4.26	4.39	4.66	0.834	H
B	0.50	1.50	1.17	2.17	2.79	3.05	3.15	0.496	A,H,J
C	1.00	1.58	1.67	2.25	2.72	2.97	3.47	0.550	A,H
D	0.66	1.41	0.99	1.74	2.62	3.12	3.28	0.495	A,H,J
E	0.66	1.33	0.66	1.33	2.33	2.83	2.95	0.442	A,C,D,H,J
F	0	0	0.33	0.33	0.33	0.46	0.92	0.088	All
G	0.84	0.84	0.84	0.84	1.25	1.25	1.25	0.255	A,C,H,J,K
H	2.00	2.67	3.00	3.67	4.36	4.49	4.68	0.860	--
J	1.16	1.83	1.49	2.17	2.79	3.28	3.70	0.584	A,H
K	1.16	1.33	1.16	1.33	1.71	1.84	1.84	0.366	A,H,J

l' = lineaments.
h = thickness of host flow.
t = tiering in host flow.
p = potential earthquake.
g' = ground-water travel time.
b = bedrock fracture.

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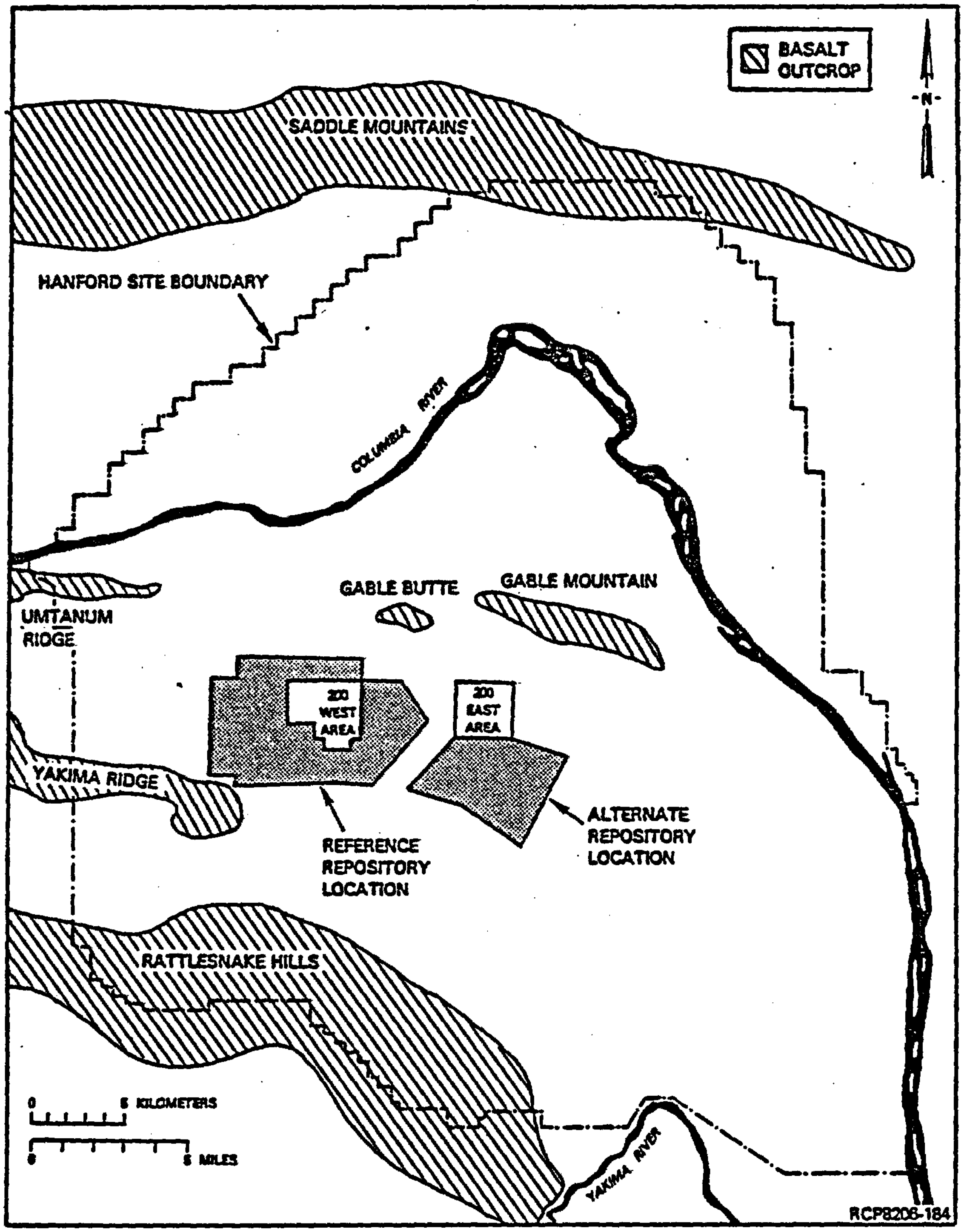

Figure 2-26. Location of the reference repository location and alternate repository location.

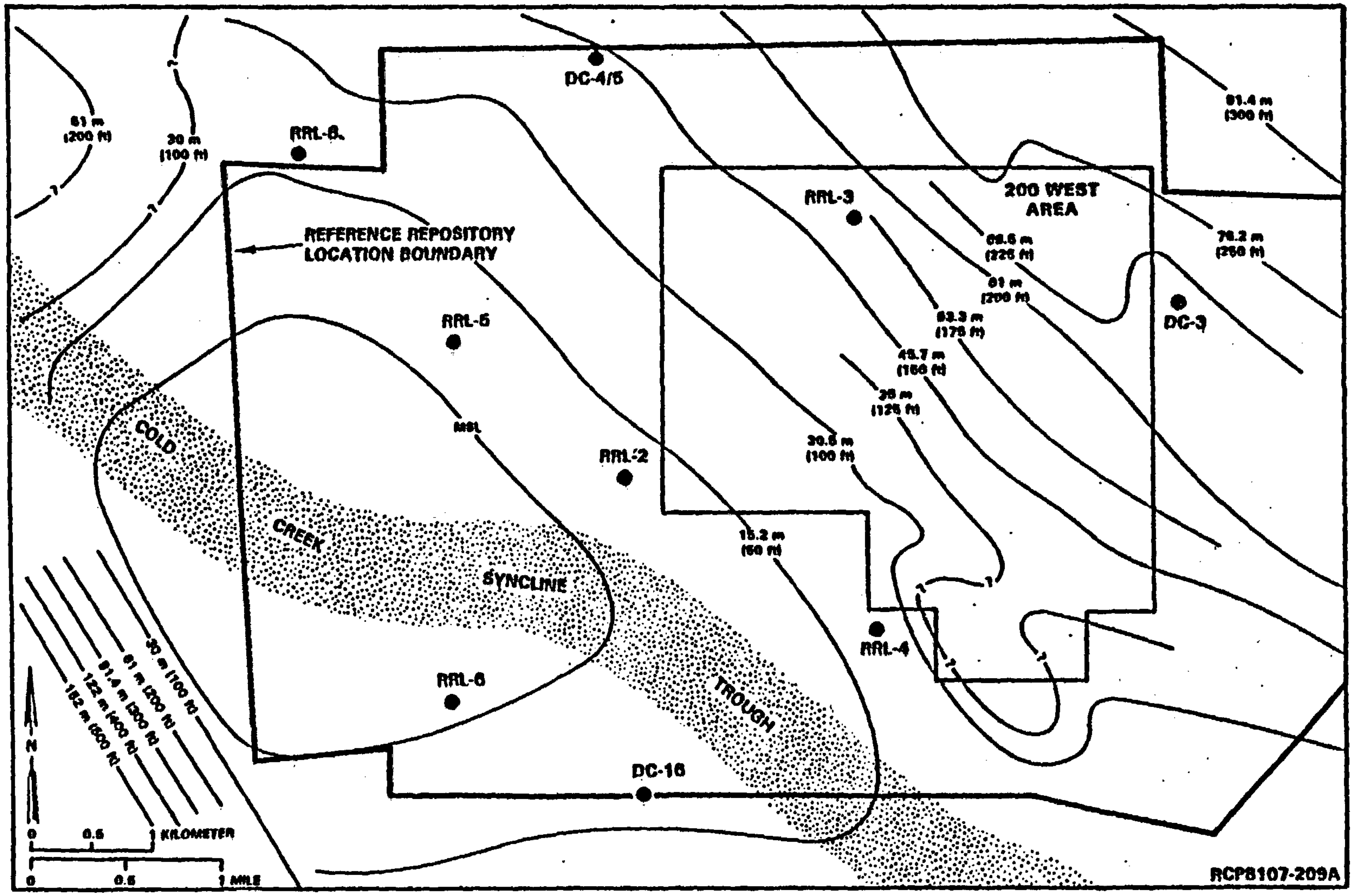

Figure 2-27. Top-of-basalt contours in the reference repository location.

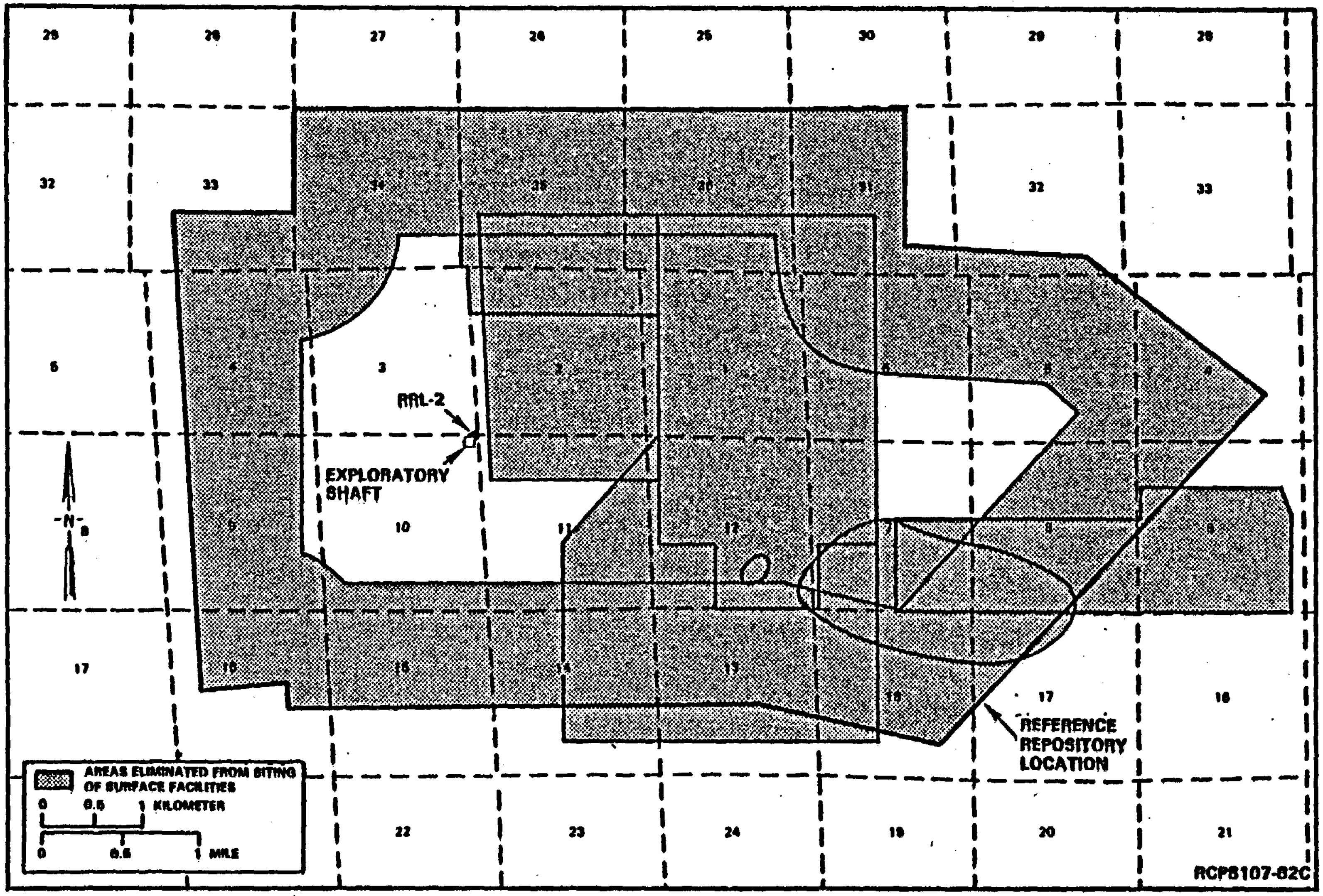

Figure 2-28. A composite overlay showing suitable areas for siting within the reference repository location (unshaded areas within the A-H Site).

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2.2.3 Identification of preferred candidate repository horizon

During the initial phase of the Basalt Waste Isolation Project, geotechnical and engineering studies focused on the Umtanum flow as the reference horizon. This focus was based on a progressive accumulation and analysis of technical data starting as early as 1968. As the Basalt Waste Isolation Project moved toward engineering design for an exploratory shaft, it became increasingly apparent that the actual identification of the horizon or flow in which shaft breakout would occur should be subject to more rigorous analysis, similar to the decision analysis technique used to identify the reference repository location. A decision analysis methodology (Keeney and Raiffa, 1976) provided a quantitative approach for using available data and expert judgment to identify the preferred horizon. Four steps guided the implementation of this methodology: (1) structure the analysis; (2) describe the consequences for each alternative candidate repository horizon; (3) assess the preferences; and (4) rank the alternative candidate repository horizons.

The purpose of the analysis was to identify a preferred candidate repository horizon within the reference repository location for a nuclear waste repository. It was recognized throughout the study that new data resulting from ongoing site characterization activities could alter the outcome of the study. This is particularly true in the area of geohydrology, where there is considerable debate regarding the ground-water flow characteristics of the site. Thus, the preferred candidate repository horizon that has been identified maybe subject to revision as a result of new data.

In identifying the alternatives to be ranked, all stratigraphic horizons beneath the reference repository location shallower than approximately 1,200 meters (3,940 feet) deep were possible alternatives. A screening process was used to focus study on those horizons with higher potential for meeting the objectives of a nuclear waste repository in basalt. The screening process was designed to systematically select a manageable number of flows for detailed consideration in ranking. To do this screening criteria were applied to each potential alternative; then professional judgment determined whether flows should be retained as candidates. As a result, three screening criteria were selected, the first of which was to exclude sedimentary interbeds and sediments overlying the basalt from further consideration. The second criteria was to exclude flows with a minimum thickness of dense interior (the relatively impermeable, dense middle part of a flow) of less than 24 meters (79 feet). The third criteria was to exclude flows above the deepest tapped aquifer within 10 kilometers (6 miles) of the proposed repository.

When these three criteria were applied, the following five flows were identified as candidate repository horizons.

1. Frenchman Spring flow 6.
2. Rocky Coulee flow.
3. Cohassett flow.
4. McCoy Canyon flow.
5. Umtanum flow.

The Frenchman Spring flow 6 was excluded as a candidate, based on professional judgment, because it occurs in a formation with relatively high hydraulic conductivity of flow tops, it ~~has a relatively high stratigraphic position,~~ is shallower than the other candidate horizons and there is lesser confidence in its stratigraphic correlation and continuity relative to the other candidates. The stratigraphic positions of the remaining four candidate repository horizons are shaded in Figure 2-29.

The technical data compiled for identification of the preferred candidate repository horizons represent all data and interpretations on the candidate horizons available in mid-1983 (Ash, 1983). These data were collected under field and laboratory conditions and encompass current knowledge of Basalt Waste Isolation Project geology, geohydrology, waste package environment, rock mechanics, waste package and repository design, and performance assessment.

Based on available data, the major geologic differences among the four candidate repository horizons are (1) the depth of the flows below ground surface, (2) thickness of dense interior of the flows, and (3) the character and predictability of internal structures.

Available geohydrologic information indicates that the principal hydrologic differences among the candidate repository horizons are (1) zones of relatively high hydraulic conductivity in the Umtanum flow top, and (2) the shorter vertical distance from the shallowest horizon (Rocky Coulee flow) to overlying zones of relatively high hydraulic conductivity in the Wanapum Basalt flow. Other hydraulic properties, such as hydraulic head, porosity, dispersivity, and hydrochemistry, are similar for the four flows (unless the existing data are insufficient, in which case no comparison is made).

Among the four candidate repository horizons, the principal differences that could affect the waste package are temperature and pressure, although the temperature differences among horizons are not expected to significantly affect the waste package design. However, the respective hydrostatic pressures of the candidate repository horizons will affect the thickness of the canister wall required for mechanical integrity.

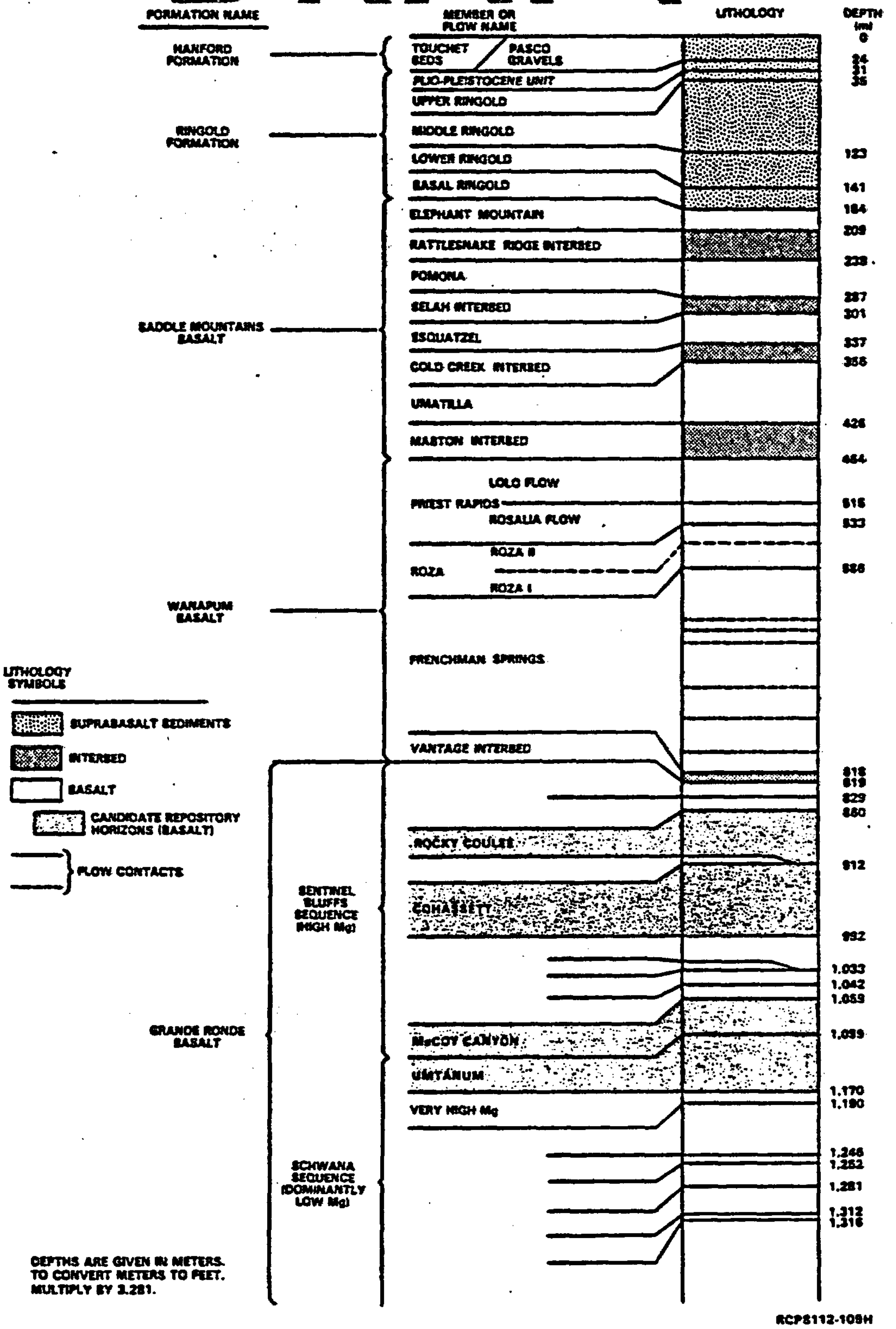

Figure 2-29. General stratigraphy of the reference repository location showing position of the candidate repository horizons. Depths are from borehole RRL-2.

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The characteristics of the rock mechanics considered were in situ stress, uniaxial compressive strength, thermal conductivity, and rock mass classification. The maximum in situ stress from hydrofracture measurements in the reference repository location is in the horizontal plane, oriented from due north to approximately N. 8° W. The ratio of horizontal to vertical stress measurements in borehole RRL-2 is approximately 2.2 to 2.7. Relatively large uncertainties are associated with stress measurements obtained by the hydrofracturing technique and in situ stress was not determined for all candidate horizons in borehole RRL-2. Available data on uniaxial compressive strength, thermal conductivity, and rock mass classification for all four candidate horizons were so similar that they did not form a basis for distinguishing between flows.

From the standpoint of construction cost and schedule, there was a distinct benefit to constructing the repository at the shallower candidate repository horizons as opposed to the deeper ones. Construction of the repository in the Umtanum flow would be the most costly (approximately $4 billion). The estimated rough order-of-magnitude cost savings between the Umtanum and Rocky Coulee flows is approximately $290 million; between the Umatanum and Cohassett flows is approximately $210 million; and between the McCoy Canyon and Umtanum flows is approximately $80 million. ~~Technological~~ risks are less for the higher flows, and they provide a more hospitable operating environment due to their lower temperatures. X

A preliminary performance assessment was conducted to compare the four candidate repository horizons. For comparison purposes, the cumulative activity of iodine-129 crossing a vertical boundary at 1.6 kilometers (1 mile) from the edge of a repository over 10,000 years was calculated for each candidate horizon. The results, expressed in curies per 1,000 metric tons (1,100 tons) of heavy metal, are listed below.

Flow	Ci/1,000 metric tons of heavy metal
Rocky Coulee	0.001
Cohassett	0.0001
McCoy Canyon	0.10
Umtanum	1.0

These estimates of radionuclide transport are preliminary, and are suitable for comparison purposes only. They will be modified in the future to reflect new hydrologic data and revised conceptual models of radionuclide transport and ground-water flow. The results of a preliminary analysis of ground-water median travel times along the fastest pathline to a vertical boundary (10 kilometers (6 miles) from the edge of the proposed repository) are given below in stratigraphic order.

- Rocky Coulee flow (38,000 years).
- Cohassett flow (64,000 years).
- McCoy Canyon flow (34,000 years).
- Umtanum flow (36,000 years).

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The calculated median travel times are useful only for comparative purposes because they reflect a limited hydrologic data base and a simplified conceptual model.

Another distinction among the four candidate horizons is the distance between a given radionuclide concentration level in the dispersal plume and selected overlying aquifers. For comparison purposes, the positions of the maximum permissible concentration of iodine-129 in the dispersal plume at 10,000 years with respect to the base of the Priest Rapids Member are given as follows:

Flow	Position (meters (feet))
Rocky Coulee	285 (935)
Cohassett	335 (1,099)
McCoy Canyon	460 (1,509)
Umtanum	510 (1,673)

These values represent a relative safety factor against radionuclide contamination of the Priest Rapids Member. The base of the Priest Rapids Member is used solely for purposes of comparison; another stratigraphic datum, such as the Vantage interbed or even the upper contact of the Rocky Coulee flow, might well have been chosen. The significant aspect of these data is that they provide a consistent relative comparison of the depth to which radionuclides could be confined in each of the candidate repository horizons. As with the other estimates of repository performance, these data are preliminary and will ~~be reexamined for confirmation in the future in the light of new hydrologic data as they are collected and conceptual models as they are developed.~~ continue to be evaluated with new hydrologic data and the development of conceptual models. ~~developed~~

2.2.3.1 Application of decision analysis to the candidate repository horizons

Once the candidate repository horizons were identified and available data for them compiled, a multidisciplinary study team could develop a set of measures for ranking the four candidate horizons. The principal ranking objectives were to (1) maximize repository performance, (2) maximize ease of construction, and (3) minimize costs. These objectives provided a guideline for developing the following eight ranking measures.

- Performance-related measures.
  - Cumulative releases of iodine-129 across a vertical boundary at 1.6 kilometers (1 mile) over 10,000 years.
  - Ground water travel times from the repository to the accessible environment along the fastest pathline.

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   - Vertical distance between the 1.0 maximum-permissible-concentration plume for iodine-129 and the base of the Priest Rapids Member after 10,000 years.

- Construction-related measures.

   - Mean thickness of dense interior (constructibility).

   - Minimum thickness of dense interior (variability-predictability).

   - Mean percent of the dense interior exhibiting vesiculation.

- Cost-related measures.

   - Savings in construction costs relative to the Umtanum flow.

   - Savings in construction schedule relative to the Umtanum flow.

The next step in the decision analysis was to assign the appropriate numerical level for each ranking measure for each candidate repository horizon. The numerical estimates were used as the basis for ranking the alternatives. Numerical levels were assigned in two evaluations. The first was deterministic, using single numbers as the levels of the ranking measures. The second was probabilistic and used probability distributions to describe the levels of the ranking measures. The probabilistic evaluation quantitatively described the uncertainties in the levels assigned to the ranking measures. The uncertainties for each measure level were derived either from the technical data available (Ash, 1983), or by structured interview techniques with Rockwell Hanford Operations scientists and engineers.

The numerical estimates indicated that none of the candidate repository horizons was obviously superior on all ranking measures. The next step in the decision analysis was to assess the preferences and develop trade offs between the ranking measures that established the relative importance of each measure.

Trade offs were developed by the multidisciplinary study team in structured group and individual meetings with decision analysts from Woodward-Clyde Consultants. Team members were asked specific questions regarding their preferences for one measure level versus another over the range of levels covered by all four candidate repository horizons. These preferences were then combined to calculate scaling constants for each measure that would consistently relate one measure to another and reflect both the relative importance and the range of values for each measure.

The last step in the decision analysis was to compute the expected utility of the four candidate repository horizons from the information developed. Two sets of expected utilities were computed: one used the deterministic ranking measure levels, and one used the probability distribution developed for the ranking measure levels.

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~~Finally,~~ the Cohassett flow ranks the highest of the four candidate repository horizons under both the deterministic and the probabilistic cases (Fig. 2-30). In the deterministic case, the Rocky Coulee, McCoy Canyon, and Umtanum flows all rank closely. In the probabilistic case, there was a distinct difference in the ranking of the flows. The multidisciplinary study team believes that the probabilistic ranking best represents the comparison of horizons. In addition, the Cohassett flow ranks highest under a variety of assumptions about the relative importance of the ranking measures. For any of the other candidates to rank highest, almost all the importance would have to be placed on either the plume depth or cost measures, the two measures on which the Cohassett flow does not rank highest. Moreover, the highest rank for the Cohassett flow is not sensitive to wide variations in levels of the measures. If the percentage of Cohassett flow interior exhibiting vesicles was much higher (20 percent instead of 0 percent), the flow would still rank highest; or if the radionuclide plume depth of the flow was closer to the Priest Rapids Member (200 meters (656 feet) instead of 335 meters (1,099 feet)), it would still rank highest.

2.2.3.2 Application of expert judgment to the candidate repository horizons

Members of the Department of Energy-Richland Operations Office Basalt Waste Isolation Project Overview Committee and their consultants (Bartlett, 1983) in conjunction with the Basalt Waste Isolation Project staff ~~informally~~ assessed the candidate repository horizons based on the technical data available (Ash, 1983). The assessment presupposed identification of the four candidate repository horizons and was mainly deductive.

The principal conclusion from this review is that the Cohassett flow, with few exceptions, has characteristics that appear to be more favorable for a repository than those of the other candidate repository horizons. The main exception is that the Cohassett flow, because of its stratigraphic position, does not confine radionuclides to as great a depth as the McCoy Canyon or Umtanum flows. However, the Cohassett flow still provides vertical confinement that, based on preliminary modeling results, prevents significant contamination of the overlying, relatively high-permeability zones in the Wanapum Basalt and Saddle Mountains Basalt. Vertical confinement thus appears adequate. Consequently, the other two performance comparisons (radionuclide release and ground-water travel time) for which the Cohassett flow shows better performance than the other candidate horizons, tends to offset its lesser performance on vertical confinement. ~~This result could change if modeling assumptions or characteristics are changed in the light of new data or different conceptual models of ground-water flow. However, currently, there are no compelling reasons to recommend one of the deeper horizons~~.

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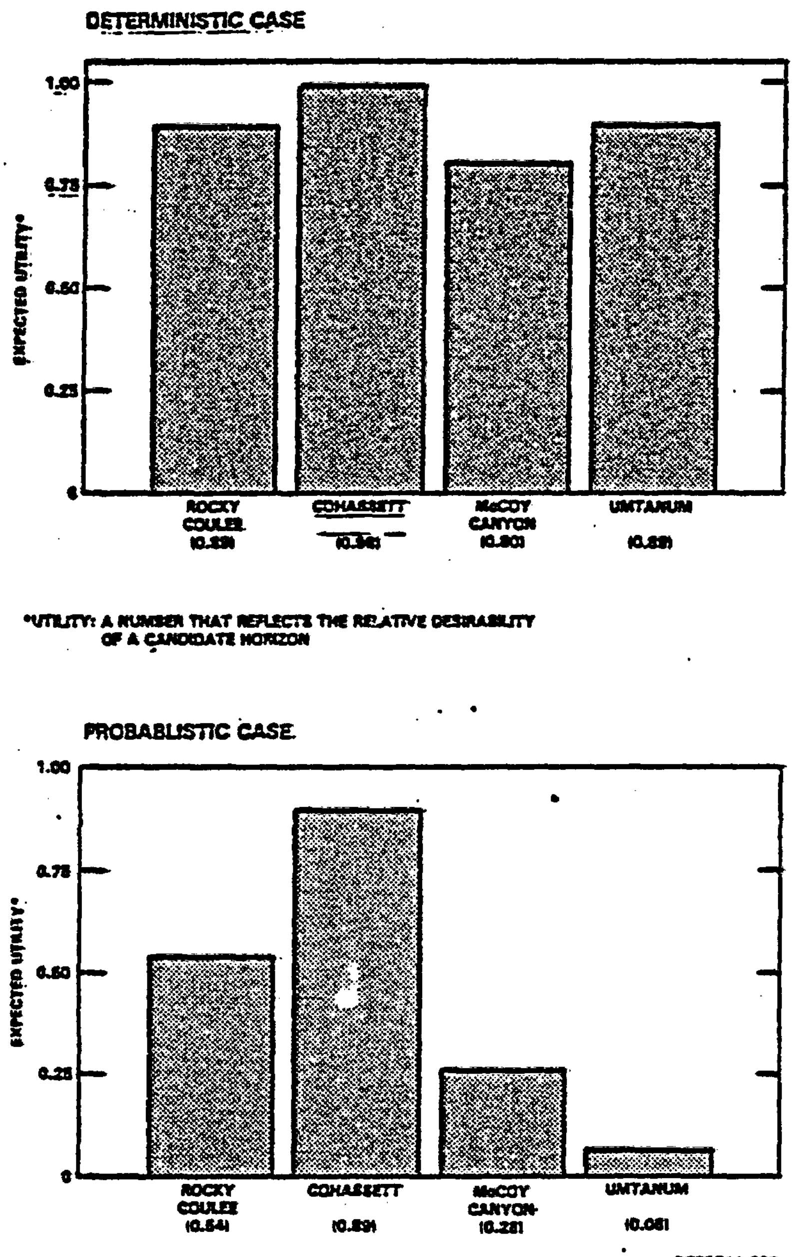

Figure 2-30. Comparison of results of ranking of the candidate repository horizons for both the deterministic and the probabilistic cases.

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In summary, based on the currently recognized differences among the candidate repository horizons, application of expert judgment identifies the Cohassett flow as the preferred candidate repository horizon. This result corroborates the result obtained using the decision analysis approach.

Again, it is recognized that the selection of the preferred candidate horizon is subject to review and revision as new data are acquired and analyzed. On the basis of currently available information, all four candidate horizons identified through this study are considered to be suitable candidate repository horizons.

~~As noted,~~ the screening guidelines used for selecting the site were not those now available as the General Siting Guidelines (DOE, 1984), although some elements were identical and some were very similar. Section 2.3 addresses an evaluation of the preferred location against the disqualifying conditions of the General Siting Guidelines (DOE, 1984) that was performed to determine whether there was any immediate reason to drop the site location from further consideration.

2.3 SUMMARY OF THE EVALUATION OF THE POTENTIALLY ACCEPTABLE SITE WITHIN THE GEOHYDROLOGIC SETTING

This section presents a short summary of the evaluation of disqualifying conditions contained in the General Siting Guidelines (DOE, 1984) as have been applied to the reference repository location. The preceding section (Section 2.2) of this chapter summarizes the screening process by which the reference repository location was identified for consideration as a potentially acceptable site for a nuclear waste repository. The process for the selection of the first site for a repository was established by the Nuclear Waste Policy Act of 1982. In accordance with the Act, the Secretary of Energy notified the State of Washington on February 2, 1983, that the reference repository location on the Hanford Site had been selected as a potentially acceptable site for a repository. The next step in the site selection process is the submission of this site nomination environment assessment. This Environmental Assessment will be used to reduce the number of potentially acceptable sites under consideration for nomination as candidate sites to a minimum of three. It is prudent to ensure, at this step in the siting process, that no obvious disqualifying conditions exist at any of the nine potentially acceptable sites. Table 2-6 summarizes the evaluation of the reference repository location with respect to the disqualifying conditions set forth in the General Siting Guidelines (DOE, 1984). Based on our current knowledge, obvious disqualifying conditions have not been identified that would result in rejecting the reference repository location from further consideration for a nuclear waste repository. The detailed analysis of each disqualifying condition is presented in Chapter 6 in conjunction with the evaluation of qualifying, favorable, and potentially adverse conditions of the appropriate siting guideline.

Table 2-6. Summary of evaluations of the reference repository location against the disqualifying conditions. (Sheet 1 of 2)

Disqualifying condition[a]	Conclusion[b]	Reference[c]	Synopsis[d]
1. 10 CFR 960.4-2-1: GEOHYDROLOGY – Less than 1,000 years ground-water travel time (unless releases of radionuclides are less than those allowed by system guidelines)	NOT DISQUALIFIED	6.3.1.1.11	The evidence does not support a finding that the reference repository location is disqualified. Most likely flow time to the accessible environment is expected to exceed 1,000 years
2. 10 CFR 960.4-2-5: EROSION – Any portion of underground facility less than 200 meters (656 feet) deep	NOT DISQUALIFIED	6.3.1.5.8	The evidence supports a finding that the reference repository location is not disqualified on the basis of evidence and is not likely to be disqualified. The uppermost candidate horizon for a repository is more than 850 meters (2,789 feet) deep
3. 10 CFR 960.4-2-6: DISSOLUTION – Dissolution during first 10,000 years causing hydraulic pathway with releases greater than allowed by system guideline	NOT DISQUALIFIED	6.3.1.6.5	The evidence supports a finding that the reference repository location is not disqualified [redacted] and is not likely to be disqualified. Basalt not generally considered soluble; disqualifier is more appropriate for evaporites
4. 10 CFR 960.4-2-7: TECTONICS (POSTCLOSURE) – Nature and rates of fault movement or other ground motion expected such that loss of waste isolation is likely to occur	NOT DISQUALIFIED	6.3.1.7.10	The evidence does not support a finding that the reference repository location is disqualified. Fault movement or other ground motion are not expected to result in a loss of waste isolation
5. 10 CFR 960.4-2-8.1: NATURAL RESOURCES – Previous mineral exploration creating significant pathways between repository and accessible environment – Future activities outside the controlled area expected to cause loss of waste isolation	NOT DISQUALIFIED	6.3.1.8.9 6.3.1.8.10	The evidence does not support a finding that the reference repository location is disqualified. No identified at-depth exploration occurs in the reference repository location and exploration for natural resources away from the reference repository location are not expected to cause loss of waste isolation
6. 10 CFR 960.5-2-1: POPULATION DENSITY AND DISTRIBUTION – Any surface facility in a highly populated area – Any surface facility adjacent to a 1.6- by 1.6-kilometer (1- by 1-mile) area with 1,000 people – Inability to develop an emergency preparedness plan	NOT DISQUALIFIED	6.2.1.2.5	The evidence supports a finding that the reference repository location is not disqualified on the basis of evidence and is not likely to be disqualified. Reference repository location is located in the central Hanford Site within a controlled access area and distant from densely populated areas
7. 10 CFR 960.5-2-4: OFFSITE INSTALLATIONS AND OPERATIONS – Atomic energy defense activities that would irreconcilable conflict with repository activities	NOT DISQUALIFIED	6.2.1.5.6	The evidence does not support a finding that the reference repository location is disqualified. Irreconcilable conflicts due to current atomic energy defense activities not anticipated

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Table 2-6. Summary of evaluations of the reference repository location against the disqualifying conditions. (Sheet 2 of 2)

Disqualifying condition[a]	Conclusion[b]	Reference[c]	Synopsis[d]
8. 10 CFR 960.5-2-5: ENVIRONMENTAL QUALITY – unacceptable impacts – repository or support facility in National Park, National Wildlife Refuge, or National Wild and Scenic River System – Irreconcilable conflict with previously designated land use	NOT DISQUALIFIED	6.2.1.6.11	The evidence supports a finding that the reference repository location is not disqualified [redacted] and is not likely to be disqualified. No unacceptable adverse impacts have been identified and the repository would not conflict with any other land use
9. 10 CFR 960.5-2-6: SOCIOECONOMIC IMPACTS – Repository activities significantly degrading water quality or significantly reducing water quantity available	NOT DISQUALIFIED	6.2.1.7.11	The evidence does not support a finding that the reference repository location is disqualified. No significant reduction in water quality or quantity is anticipated
10. 10 CFR 960.5-2-9: ROCK CHARACTERISTICS – Significant risk to health and safety of operating personnel	NOT DISQUALIFIED	6.3.3.2.10	The evidence does not support a finding that the reference repository location is disqualified. No rock characteristics that could cause or lead to significant health or safety risks have been identified
11. 10 CFR 960.5-2-10: HYDROLOGY – Control of expected ground-water conditions beyond reasonably available technology	NOT DISQUALIFIED	6.3.3.3.7	The evidence does not support a finding that the reference repository location is disqualified. Engineering technology is reasonably available for controlling ground-water conditions encountered during exploratory shaft construction or during repository construction, and operation
12. 10 CFR 960.5-2-11: TECTONICS (PRECLOSURE) – Nature and rates of fault movement or ground motion such that complex engineering measures will be required for exploratory shaft construction or repository construction, operation, or closure	NOT DISQUALIFIED	6.3.3.4.7	The evidence does not support a finding that the reference repository location is disqualified. Probability of ground motion in preclosure period is low so reasonably available technology can be utilized in construction of shafts and subsurface facilities; repository operations and closure not expected to require complex engineering measures

[a]General Siting Guidelines (draft 10 CFR 960; DOE, 1984).
[b]Not disqualified--no obvious disqualifying conditions have been identified.
[c]Subsection containing detailed analysis of disqualifying condition.
[d]Synopsis from detailed analysis of disqualifying condition in Chapter 6.

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2.3.1 Geohydrology (Section 960.4-2-1(d))

2.3.1.1 Disqualifying condition

"A site shall be disqualified if the pre-waste-emplacement ground-water travel time from the disturbed zone to the accessible environment is expected to be less than 1,000 years, along any pathway of likely and significant radionuclide travel."

2.3.1.2 Summary of the Geohydrology disqualifier analysis

A final conclusion on this disqualifying condition for a pre-waste-emplacement ground-water travel time is not possible at this time. Additional data need to be collected to define the geohydrologic properties of the ground-water environment in and surrounding the reference repository location. However, a preliminary finding on disqualifying conditions is required by the General Siting Guidelines (DOE, 1984) so that potentially acceptable sites might be identified and compared for nomination and recommendation. Therefore, based upon available data and current understanding of the groundwater system, the pre-waste-emplacement ground-water travel time to the accessible environment is expected to be greater than 1,000 years. The evidence does not support a finding that the reference repository location is disqualified.

Refer to Subsection 6.3.1.1.11 for a detailed discussion of this disqualifying condition.

2.3.2 Erosion (Section 960.4-2-5(d))

2.3.2.1 Disqualifying condition

"The site shall be disqualified if site conditions do not allow all portions of the underground facility to be situated at least 200 meters below the directly overlying ground surface."

2.3.2.2 Summary of the Erosion disqualifier analysis

The depth of the uppermost candidate horizon is greater than 850 meters (2,789 feet) below the ground surface at the reference repository location. Potential erosion scenarios suggest this depth is more than sufficient to maintain over 400 meters (1,312 feet) between the ground surface and a repository. Therefore, the evidence supports a finding that the reference repository location is not disqualified on the basis of this evidence and is not likely to be disqualified.

Refer to Subsection 6.3.1.5.8 for a detailed discussion of this disqualifying condition.

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2.3.3 Dissolution (Section 960.4-2-6(d))

2.3.3.1 Disqualifying condition

"The site shall be disqualified if it is likely that, during the first 10,000 years after closure, active dissolution, as predicted on the basis of the geologic record, would result in a loss of waste isolation."

2.3.3.2 Summary of the Dissolution disqualifier analysis

Active dissolution fronts do not occur in basalt. Therefore, the evidence supports a finding that the reference repository location is not disqualified on the basis of this evidence and is not likely to be disqualified.

Refer to Subsection 6.3.1.6.5 for a detailed discussion of this disqualifying condition.

2.3.4 Tectonics (Section 960.4-2-7(d))

2.3.4.1 Disqualifying condition

"A site shall be disqualified if, based on the geologic record during the Quaternary Period, the nature and rates of fault movement or other ground motion are expected to be such that a loss of waste isolation is likely to occur."

2.3.4.2 Summary of the Tectonics disqualifier analysis

The nature and rates of fault movement or other ground motion at the reference repository location are not expected to result in a loss of waste isolation. Therefore, the evidence does not support a finding that the reference repository location is disqualified.

Refer to Subsection 6.3.1.7.10 for a detailed discussion of this disqualifying condition.

2.3.5 Natural Resources (Section 960.4-2-8-1(d))

2.3.5.1 Disqualifying conditions

"A site shall be disqualified if:

(1) Previous exploration, mining, or extraction activities for resources of commercial importance at the site have created significant pathways between the projected underground facility and the accessible environment; or

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(2) Ongoing or likely future activities to recover presently valuable natural mineral resources outside the controlled area would be expected to lead to an inadvertent loss of waste isolation."

2.3.5.2 Summary of the Natural Resources disqualifying analysis

The available data show a lack of major previous exploration, mining, or extraction of resources in the reference repository location. This data base is not expected to change. Therefore, the evidence supports a finding that the reference repository location is not disqualified on the basis of this evidence and is not likely to be disqualified.

Refer to Subsection 6.3.1.8.9 for a detailed discussion of disqualifying condition (1).

In addition, possible future activities to recover presently valuable natural mineral resources (high-unit value or oil and gas) outside the controlled area are not expected to lead to an inadvertent loss of waste isolation, therefore, the evidence does not support a finding that the reference repository location is disqualified.

Refer to Subsection 6.3.1.8.10 for a detailed discussion of disqualifying condition (2).

2.3.6 Population Density and Distribution (Section 960.5-2-1(d))

2.3.6.1 Disqualifying conditions

"A site shall be disqualified if:

(1) Any surface facility of a repository would be located in a highly populated area; or

(2) Any surface facility of a repository would be located adjacent to an area 1 mile by 1 mile having a population of not less than 1,000 individuals as enumerated by the most recent U.S. census; or

(3) The DOE could not develop an emergency preparedness program which meets the requirements specified in DOE Order 5500.3 (Reactor and Non-Reactor Facility Emergency Planning, Preparedness, and Response Program for Department of Energy Operations) and related guides or, when issued by the NRC, in 10 CFR 60, subpart I, 'Emergency Planning Criteria.' "

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2.3.6.2 Summary of the Population Density and Distribution disqualifier analysis

The reference repository location is not disqualified for any of the above three disqualifying conditions. The site is not located in or adjacent to a highly populated area and an extensive Emergency Preparedness Program is already in place for the Hanford Site. Therefore, the evidence supports a finding that the reference repository location is not disqualified on this basis and is not likely to be disqualified.

Refer to Subsection 6.2.1.2.5 for a detailed disucssion of these disqualifying conditions.

2.3.7 <u>Offsite Installation and Operations</u> (Section 960.5-2-4(d))

2.3.7.1 Disqualifying condition

"A Site shall be disqualified if atomic energy defense activities in proximity to the site are expected to conflict irreconcilably with repository siting, construction, operation, closure, or decommissioning."

2.3.7.2 Summary of the Offsite Installation and Operations disqualifier analysis

The reference repository location is not disqualified on the basis of the potentially disqualifying condition. The proximity of the reference repository location to ~~existing hazardous and nuclear~~ defense facilities is not expected to pose irreconcilable conflicts. From a siting standpoint, many of Hanford's attributes, particularly those associated with its comparative remoteness, also support its potential suitability as a repository site. Sufficient area exists within the reference repository location to allow a buffer zone between the proposed repository surface facilities and the 200 West Area, the nearest of the ~~potentially hazardous and~~ defense-related activity areas. Therefore, the evidence does not support a finding that the reference repository location is disqualified.

Refer to Subsection 6.2.1.5.6 for a detailed discussion of this disqualifying condition.

2.3.8 <u>Environmental Quality</u> (Section 960.5-2-5(d))

2.3.8.1 Disqualifying condition

"Any of the following conditions shall <u>disqualify</u> a site:

(1) During repository siting, construction, operation, closure, or decommissioning the quality of the environment in the affected area could not be adequately protected or projected

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environmental impacts in the affected area could not be mitigated to an acceptable degree, taking into account programmatic, technical, social, economic, and environmental factors.

(2) Any part of the restricted area or repository support facilities would be located within the boundaries of a component of the National Park System, the National Wildlife Refuge System, the National Wilderness Preservation System, or the National Wild and Scenic Rivers System.

(3) The presence of the restricted area or the repository support facilities would conflict irreconcilably with the previously designated resource-preservation use of a component of the National Park System, the National Wildlife Refuge System, the National Wilderness Preservation System, or the National Wild and Scenic Rivers System, or National Forest Lands, or any comparably significant State protected resource that was dedicated to resource preservation at the time of the enactment of the Act."

2.3.8.2 Summary of the Environmental Quality disqualifier analysis

The siting of a repository at the reference repository location is not projected to have unacceptable adverse impacts on the quality of the environment. ~~Two things~~ The two primary factors that serve to minimize potential environmental impacts are: (1) the remoteness of the reference repository location from human habitation, and (2) the absence of any federally recognized threatened and endangered species at the reference repository location. Significant Federal or State protected resources do not exist at or near the reference repository location; hence, no conflicts exist. Therefore, the evidence supports a finding that the reference repository location is not disqualified on the basis of this evidence and is not likely to be disqualified.

Refer to Subsection 6.2.1.6.11 for a detailed discussion of these disqualifying conditions.

2.3.9 <u>Socioeconomic Impacts</u> (Section 960-5-2-6(d))

2.3.9.1 Disqualifying condition

"A site shall be disqualified if repository construction, operation, or closure would significantly degrade the quality, or significantly reduce the quantity, of water from major sources of offsite supplies presently suitable for human consumption or crop irrigation and such impacts cannot be compensated for, or mitigated by, reasonable measures."

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2.3.9.2 Summary of the Socioeconomic Impacts disqualifier analysis

Based on expected repository construction methods, operation designs and waste isolation performance following closure, a repository built in the reference repository location is not anticipated to significantly degrade water quality or reduce water quantities from major sources of offsite supplies. Therefore, the evidence does not support a finding that the reference repository location is disqualified.

Refer to Subsection 6.2.1.7.11 for a detailed discussion of this disqualifying condition.

2.3.10 <u>Rock Characteristics</u> (Section 960.5-2-9(d))

2.3.10.1 Disqualifying condition

"The site shall be <u>disqualified</u> if the rock characteristics are such that the activities associated with repository construction, operation, or closure are predicted to cause significant risk to the health and safety of personnel, taking into account mitigating measures that use reasonably available technology."

2.3.10.2 Summary of the Rock Characteristics disqualifying analysis

Qualification or disqualification of a repository in basalt based on rock characteristics is not possible at this time. Available geomechanics data obtained to date from laboratory, field, and in situ testing, and case history studies of similar underground construction projects suggest that the effects of potentially hazardous conditions on the construction, operation, and closure of a repository at the reference repository location is not expected to cause significant risk to the health and safety of personnel. This takes into account mitigating measures that use reasonably available technology. Therefore, the evidence does not support a finding that the reference repository location is disqualified.

Refer to Subsection 6.3.3.2.10 for a detailed discussion of this disqualifying condition.

2.3.11 <u>Hydrology</u> (Section 960.5-2-10)

2.3.11.1 Disqualifying condition

"A site shall be disqualified if, based on expected ground-water conditions, it is likely that engineering measures that are beyond reasonably available technology will be required for exploratory-shaft construction or for repository construction, operation, or closure."

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2.3.11.2 Summary of the Hydrology disqualifier analysis

Current construction data, case history studies of underground construction projects, and understanding of the basalt geohydrologic environment suggest that the ground-water conditions likely encountered in basalt during exploratory shaft construction and repository construction, operation, or closure will require ~~only available~~, or reasonably available technology. Therefore, the evidence does not support a finding that the reference repository location is disqualified.

Refer to Subsection 6.3.3.3.7 for a detailed discussion of this disqualifying condition.

2.3.12 Tectonics (Section 960.5-2-11(d))

2.3.12.1 Disqualifying condition

"A site shall be disqualified if, based on the expected nature and rates of fault movement or other ground motion, it is likely that engineering measures that are beyond reasonably available technology will be required for exploratory-shaft construction or for repository construction, operation or closure."

2.3.12.2 Summary of the Tectonics disqualifier analysis

Existing engineering measures could be used, if needed, in exploratory shaft or repository. ~~since~~ the probability of ground motion that could adversely affect a repository in the reference repository location during the preclosure period is considered to be low. Therefore, the evidence does not support a finding that the reference repository location is disqualified.

The Basis For this statement stems from the fact

Refer to Subsection 6.3.3.4.7 for a detailed discussion of this disqualifying condition.

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CHAPTER 3 SUMMARY

Whereas Chapter 2 described the general geologic setting of the Columbia Plateau region, Chapter 3 narrows the focus of this document to the Pasco Basin and the Hanford Site, on which the reference repository location is situated. The indepth information presented in this chapter provides background understanding on the geology and hydrology (Sections 3.2 and 3.3), the environmental setting (Section 3.4), and the transportation and socioeconomic situation of this area (Sections 3.5 and 3.6) that supplies the basis for decisions and findings reported in Chapters 4, 5, and 6.

The reference repository location (Section 3.1) is situated near the center of the 1,500-square-kilometer (570-square-mile) Hanford Site in south-central Washington, the broad valley known as the Cold Creek syncline. The area lies within the Pasco Basin, the structural and topographic low of the Columbia Plateau, and north of the junction of the Snake and Yakima Rivers with the Columbia River. The Pasco Basin is bordered on the north by the Saddle Mountains, on the south by the Rattlesnake Hills, and on the west by the eastern ends of the Umtanum and Yakima Ridges. Gable Mountain and Gable Butte, two prominent anticlinal ridges of basalt within the Hanford Site, are aligned with the eastern segment of the Umtanum Ridge.

Studies of the physiography and geomorphology of the Pasco Basin (Section 3.2.1) show that it is divided into three major landform systems (i.e., areas of recurring landforms, processes, and effects): ridge terrain, lower slope terrain, and basin and valley terrain. The latter terrain system describes the reference repository location.

As mentioned in the discussion on stratigraphy in Chapter 2, the major stratigraphic units in the reference repository location (Section 3.2.2) are the Grande Ronde Basalt, Wanapum Basalt, and Saddle Mountains Basalt of the Columbia River Basalt Group; the major fluvial units are the Ellensburg Formation, Ringold Formation, and Hanford Formation. Over 50 basalt flows within the Pasco Basin have been identified, totaling more than 3,000 meters (10,000 feet) in thickness. Sedimentary deposits overlie the basalt sequence, and are commonly interbedded with the uppermost basalt flows that the basin has been forming. Four of these basalt flows have been identified as candidate repository horizons. These horizons lie within the Grande Ronde Basalt, the thickest basalt sequence of the Columbia River Basalt Group; they are:

- Rocky Coulee flow--53 meters (175 feet).
- Cohassett flow--76 meters (250 feet).
- McCoy Canyon flow--67 meters (220 feet).
- Umtanum flow--67 meters (220 feet).

The candidate horizons are continuous throughout the Pasco Basin.

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Structurally, the Cold Creek syncline, in which the reference repository location is situated, occupies the low area between the Umtanum Ridge-Gable Mountain structure and the Yakima Ridge structure (Section 3.2.3). The structure of the top of the basalt and of the deeper horizons within the area is interpreted as nearly flat, with very gentle dips toward the trough of the Cold Creek syncline. Based on geophysical surveys and surface and subsurface mapping, the central and eastern parts of the Cold Creek Valley depression appear to be relatively free of potentially adverse bedrock structures.

The seismicity of the Pasco Basin (instrumentally monitored since 1969) is low to moderate (Section 3.2.4). No shallow-depth earthquake swarms--less than 4 kilometers (2 miles)--have been recorded within the boundaries of the reference repository location. Microearthquake activity in the area around the reference repository location has been recorded, but has been largely confined to a crust of 28-kilometer (17-mile) thickness, and has been characterized by swarms of low-magnitude earthquakes that occur predominantly in the basalts.

Section 3.3 of this chapter discusses the surface and subsurface hydrologic systems within and in the vicinity of the Hanford Site. Studies of surface drainage patterns, and evaluations of the potential for seasonal or catastrophic flooding, indicate that expected surface-water conditions do not pose a problem to the reference repository location.

The definition of ground-water recharge and discharge patterns, and of ground-water movement, ~~however, is more complex and less certain.~~ is in a preliminary state of understanding. Additional hydrologic testing and analyses are required to fully characterize the site's ground-water flow system. Ground water ~~beneath the area of concern lies~~ occurs in confined aquifers within basalt flow tops and interbedded sediments, and in a shallow sedimentary unconfined aquifer. Movement in the basalts most likely ~~occurs~~ takes place along flow pathways found in three groups of geologic features:

- Discontinuities within basalt layers.
- Contacts between basalt layers.
- Bedrock structural discontinuities crossing basalt layers (e.g., fault or fracture zones).

The bedrock structural discontinuities that cross basalt layers could have larger vertical hydraulic conductivities than the confining aquitards. Potentially, such structural discontinuities could vertically connect shallow and deep ground-water flow systems; however, the discontinuities investigated thus far appear to restrict flow. A number of alternative ground-water flow concepts have been suggested and are being evaluated through hydrologic characterization and testing.

Section 3.4 details the environmental setting of the Hanford Site in terms of land use, terrestrial and aquatic ecosystems, meteorological conditions and air quality, noise, aesthetics, and archaeological, cultural, and historical resources. The Hanford Site has been used for Federal nuclear activities for the past 41 years, and currently includes

Four conceptual models were developed to describe groundwater movement in a basalt medium. Differences between models center on the extent of vertical leakage across basalt flow interiors and the influence of structural discontinuities in vertically interconnecting flow systems.

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an Arid Lands Ecology Reserve, and area ~~leased~~ to the U.S. Fish and Wildlife Service and to the Washington State Department of Game. These areas were established primarily to act as buffer zones for nuclear activities carried on at the Hanford Site.

The Hanford Site is characterized as a shrub-steppe grassland, dominated by the sagebrush/cheatgrass community, which provides food, cover, and shelter to many species of wildlife. Aquatic habitats on the Hanford Site are limited to the Columbia River system. No federally recognized threatened or endangered animal species are found within the reference repository location; however, one threatened bird species, the bald eagle, and one endangered bird species, the peregrine falcon, have been infrequently sighted within the ~~area~~ boundaries. Three additional bird species that are found within the reference repository location are being considered as potential candidates for protection on the federal threatened and endangered species list: the ferruginous hawk, the Swainson's hawk, and the long-billed curlew. No federally recognized threatened or endangered plant species are found within the reference repository location.

The section on meteorological conditions and air quality (3.4.3) discusses wind, temperature, precipitation, climatological diffusion conditions, and air quality on the Hanford Site.

Section 3.5 details the excellent transportation network that facilitates travel and the marketing of goods and commodities within the Tri-Cities region (Richland, Kennewick, and Pasco, Washington--located ~~35 kilometers (22 miles), 45 kilometers (28 miles), and 45 kilometers (28 miles), respectively,~~ from the ~~Hanford Site~~). The Tri-Cities are served by the Burlington Northern and the Union Pacific railroads, and by four important highway routes that are separate from, but provide access to, major interstate highways.

The discussion of socioeconomic conditions in this chapter (Section 3.6) is based on data from about 1965 up to the present, and covers population density and distribution, economic conditions, community services, social conditions, and fiscal conditions and government structure. The study region for this analysis is defined as the area surrounding the Hanford Site, specifically, the Tri-Cities, West Richland, and Benton City, and the contiguous unincorporated areas. The study region was characterized during the decade of the 1970's as one of the most rapidly growing metropolitan areas in the nation. Currently, however, the region is experiencing a major economic downswing. The analysis in this chapter addresses the socioeconomic effects of that decline and the prognosis for future recovery.

As indicated at the beginning of this summary, the detailed data in Chapter 3 provides the background for understanding the discussions of Chapters 4, 5, and 6. Table 3-A provides a cross-reference matrix to help the reader locate the sections in this document that are related to topics discussed in Chapter 3.

Table 3-A. Sections related to Chapter 3 discussions.

	Chapter 2	Chapter 3	Chapter 4	Chapter 5	Chapter 6
GEOLOGY	2.1.1	3.2	4.2.1.1	5.2.1.1	
Physiography and Geomorphology		3.2.1			
Stratigraphy	2.1.1.1	3.2.2	4.1.1.1		
Structure and Tectonics	2.1.1.2/2.1.2	3.2.3	4.1.1.1/4.1.1.2		6.3.1.7/6.3.3.4
Seismicity	2.1.1.3	3.2.4			
SURFACE-WATER HYDROLOGY	2.1.3	3.3.1	4.2.1.2.1	5.2.1.2.1	6.3.3.3/6.3.3.1
Pasco Basin		3.3.1.1			
Hanford Site		3.3.1.2			
Surface Flooding Potential		3.3.1.3			6.3.3.1
Surface-Water Use in Pasco Basin		3.3.1.4			
Surface-Water Demand		3.3.1.5			
Surface-Water Intakes in Pasco Basin		3.3.1.6			
GROUND-WATER HYDROLOGY	2.1.4	3.3.2	4.2.1.2.2	5.2.1.2.2	6.3.3.3
Potential Pathways		3.3.2.1			
Alternative Flow Concepts		3.3.2.2			
ENVIRONMENTAL SETTING		3.4	4.2.1.3	5.2.1.3	6.2.1.6/6.2.2.2
Land Use (Site Ownership and Control)		3.4.1	4.2.2.6	5.2.3.6	6.2.1.1/6.2.1.3
Terrestrial and Aquatic Ecosystems		3.4.2	4.2.1.3.1	5.2.1.3.1	
Meteorlogical and Air Quality		3.4.3	4.2.1.3.2	5.2.1.3.2	
Noise		3.4.4	4.2.1.3.3	5.2.1.3.3	
Aesthetic Resources		3.4.5	4.2.1.3.4	5.2.1.3.4	
Archaeological, Cultural, and Historical Resources		3.4.6	4.2.1.3.5	5.2.1.3.5	
TRANSPORTATION		3.5		5.2.2	6.2.1.8/6.2.2.2
Railroad Service		3.5.1		5.2.2.4	
Highway Service		3.5.2		5.2.2.3	
Repository Access Routes		3.5.3		5.2.3.6	
SOCIOECONOMIC CONDITIONS	2.3.9	3.6	4.2.2	5.2.3	6.2.1.7/6.2.2.2
Population Density and Distribution		3.6.1	4.2.2.1	5.2.3.1	6.2.1.2
Economic Conditions		3.6.2	4.2.2.2	5.2.3.2	
Community Services		3.6.3	4.2.2.3	5.2.3.3	
Social Conditions		3.6.4	4.2.2.4	5.2.3.4	
Fiscal Conditions and Gov't Structures		3.6.5	4.2.2.5	5.2.3.5	

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Chapter 3

THE SITE

3.1 LOCATION AND TOPOGRAPHY

The reference repository location is ~~located~~ near the center of the 1,500-square kilometer (570-square mile) Hanford Site in south-central Washington (Fig. 3-1). The area lies within the Pasco Basin, the structural and topographic low part of the Columbia Plateau, and north of the junction of the Snake and Yakima Rivers with the Columbia River. The terrain of the central and eastern Hanford Site, including the reference repository location is relatively flat (Fig. 3-2) with subtle topographic features primarily formed by ~~catastrophic flooding~~ that inundated the Pasco Basin prior to approximately 13,000 years ago. These topographic features have been locally masked by east-west trending sand dunes that attest to the semiarid climate of the region. The terrain of the northern and western Hanford Site has moderate to steep topographic ridges composed of basalt and locally veneered with sediments. The vegetation mosaic of the Hanford Site consists of a variety of shrub-steppe communities identified by the most conspicuous or most abundant plant species, which in the reference repository location is the sagebrush/cheatgrass community.

3.2 GEOLOGIC CONDITIONS

3.2.1 Physiography and geomorphology

The Columbia Basin subprovince of the Columbia Intermontane province, discussed in Section 2.1.1, is divided into six sections on the basis of general morphology: (1) Central Plains, (2) Yakima Folds, (3) Waterville Plateau, (4) Channeled Scablands, (5) Palouse Hills, and (6) North-Central Oregon Plateau (Fig. 3-3).

The reference repository location is ~~located~~ in the west central part of the Pasco Basin near the western boundary of the Central Plains section of the Columbia Basin subprovince (see Fig. 3-3). The Pasco Basin is divided into three major landform systems or areas of recurring landforms, processes, and effects (Myers, Price, et al., 1979, pp. III-166 through III-171). These are the ridge, lower slope, and basin and valley terrains (Fig. 3-4). The ridge terrain consists of prominent anticlinal basalt ridges and is located in the Yakima Folds section of the Columbia Basin subprovince. The lower slope terrain consists primarily of middle and lower slopes of anticlinal basaltic ridges of the Yakima Folds section, but also includes portions of the bordering Central Plains section. The basin and valley terrain, including the reference repository location, consists of the low-relief, sediment-filled portion of the Pasco

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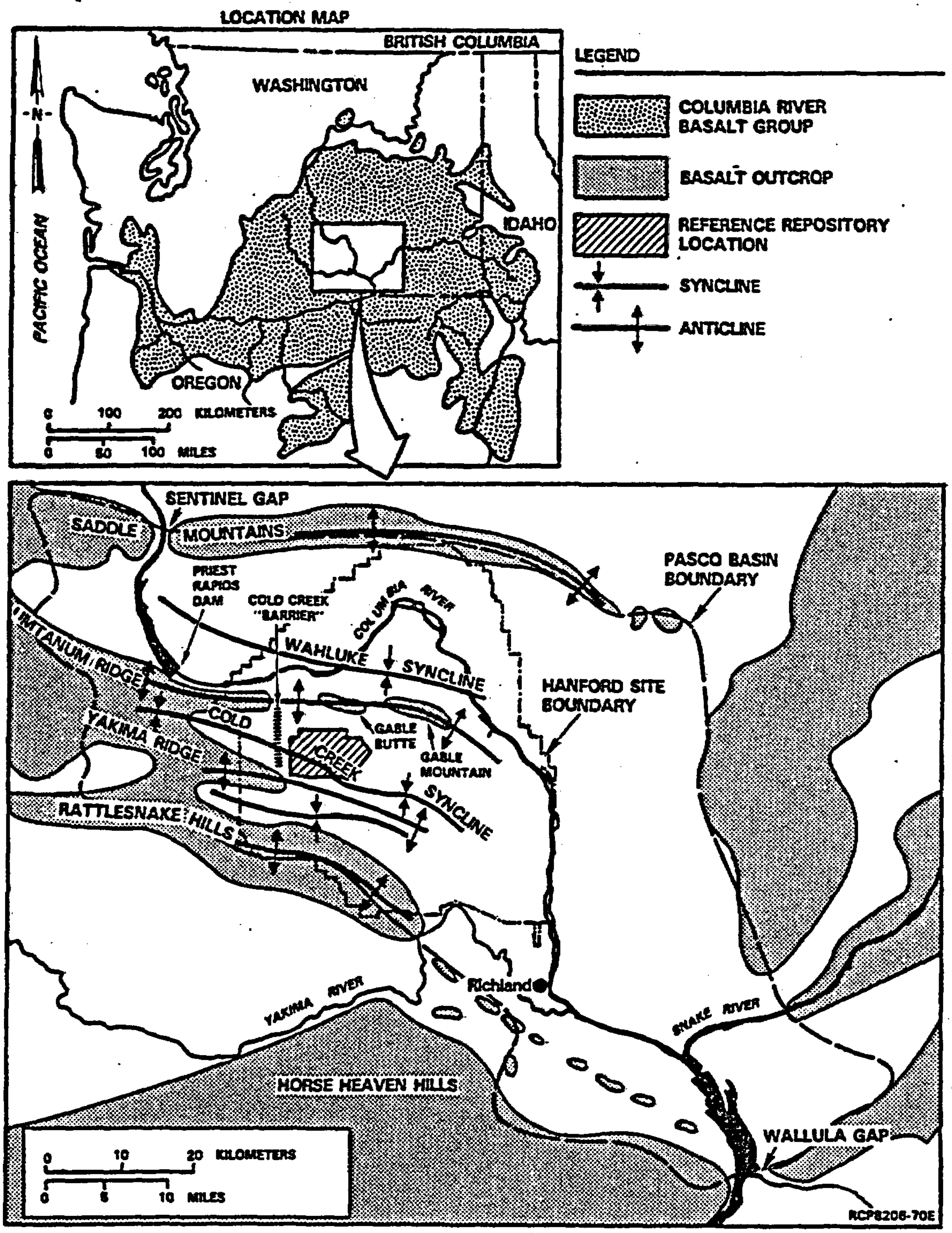

Figure 3-1. Extent of the Columbia River Basalt Group, Pasco Basin, and reference repository location.

Figure 3-2. A view of the reference repository location, looking south from the Umtanum Bar. Rattlesnake Hills are in the background.

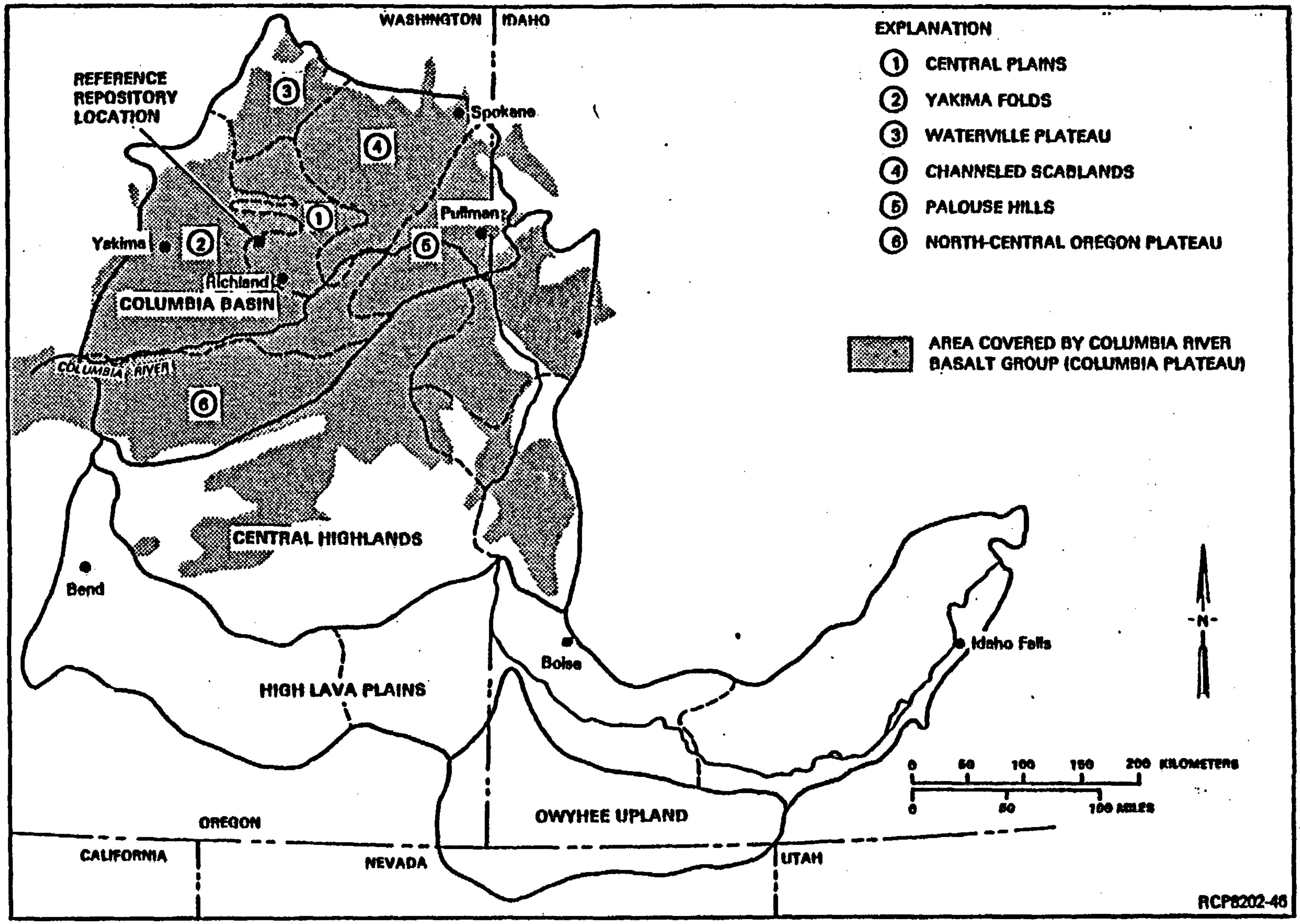

Figure 3-3. Divisions of the Columbia Intermontane Province (after Freeman et al., 1945).

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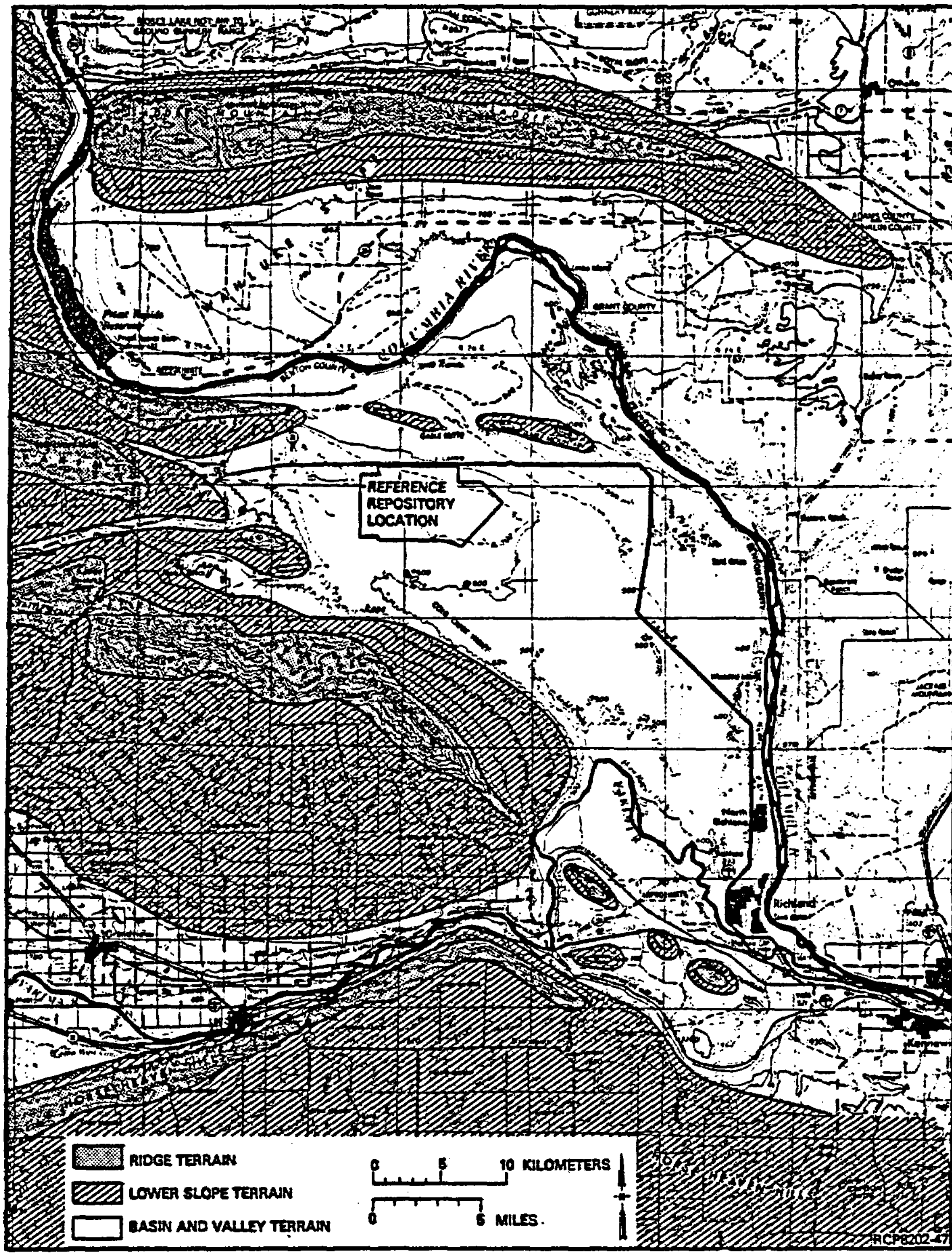

Figure 3-4. Map of major landform systems of the Pasco Basin.

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Basin in the Central Plains section and the synclinal valleys of the Yakima Folds section. A more detailed description of these three landform systems is given in Myers, Price et al. (1979, pp. III-166 through III-171).

The reference repository location is in the western part of the basin and valley terrain and is divided into four geomorphic units: (1) Umtanum Ridge bar, (2) 200 Areas bar, (3) central Hanford sand plain, and (4) Cold Creek alluvial plain (Fig. 3-5). These units are defined topographically and by sediment texture. Judging by the undissected nature of these units, with the exception of the Cold Creek alluvial plain, minimal erosion has occurred since formation by catastrophic floodwaters in the late Pleistocene (about 13,000 years ago).

Two gravel bars of catastrophic flood origin are present within the reference repository location (see Fig. 3-5). Based on a description of flood bars by Baker (1973, pp. 35 through 42) the Umtanum Ridge bar is classified as an eddy bar while the 200 Areas bar represents an expansion bar. The southeast-extending Umtanum Ridge bar covers an area of approximately 6 square kilometers (2.5 square miles), and is the highest topographic feature in the reference repository location. It represents a late Pleistocene eddy bar that developed behind the east end of Umtanum Ridge. The bar is relatively flat and streamlined in shape. Locally steep gradients (up to 15 percent) on south-facing slopes of the bar occur within the reference repository location. The relief on the bar within the reference repository location is approximately 30 meters (100 feet) and the bar elevations range from approximately 215 meters (705 feet) at the base of the south slope to approximately 245 meters (800 feet) at the crest of the bar.

The 200 Areas bar is a lower elevation, down valley continuation of the Umtanum Ridge bar, trending southeast. This bar is the most extensive geomorphic unit in the reference repository location, covering approximately 20 square kilometers (8 square miles). The 200 Areas bar formed as the result of decelerating flow of catastrophic floodwaters in the expanded reach south of the Umtanum Ridge-Gable Mountain structure (see Fig. 3-1). The general form of the bar is very broad and relatively flat, and not streamlined like the Umtanum Ridge bar. The maximum elevation of the bar is approximately 230 meters (750 feet) and the lowest elevation in the reference repository location is approximately 200 meters (650 feet) along the north slope of the bar. The 200 Areas bar is composed of coarse sand and gravel in the north and east parts of the reference repository location that laterally grades to silty medium-to-coarse sand at the southwestern limit of the bar. Modification of the bar by Holocene geomorphic processes is minor and mainly from wind action.

The central Hanford sand plain is located south of the flood bars in the southern part of the reference repository location. This plain, formed during late Pleistocene flooding by the deposition fine-grained sediments on the lee of the Umtanum Ridge bar. The sand plain, which covers approximately 15 square kilometers (6 square miles) of the reference repository location, is relatively flat, sloping gently toward the center of Cold Creek Valley.

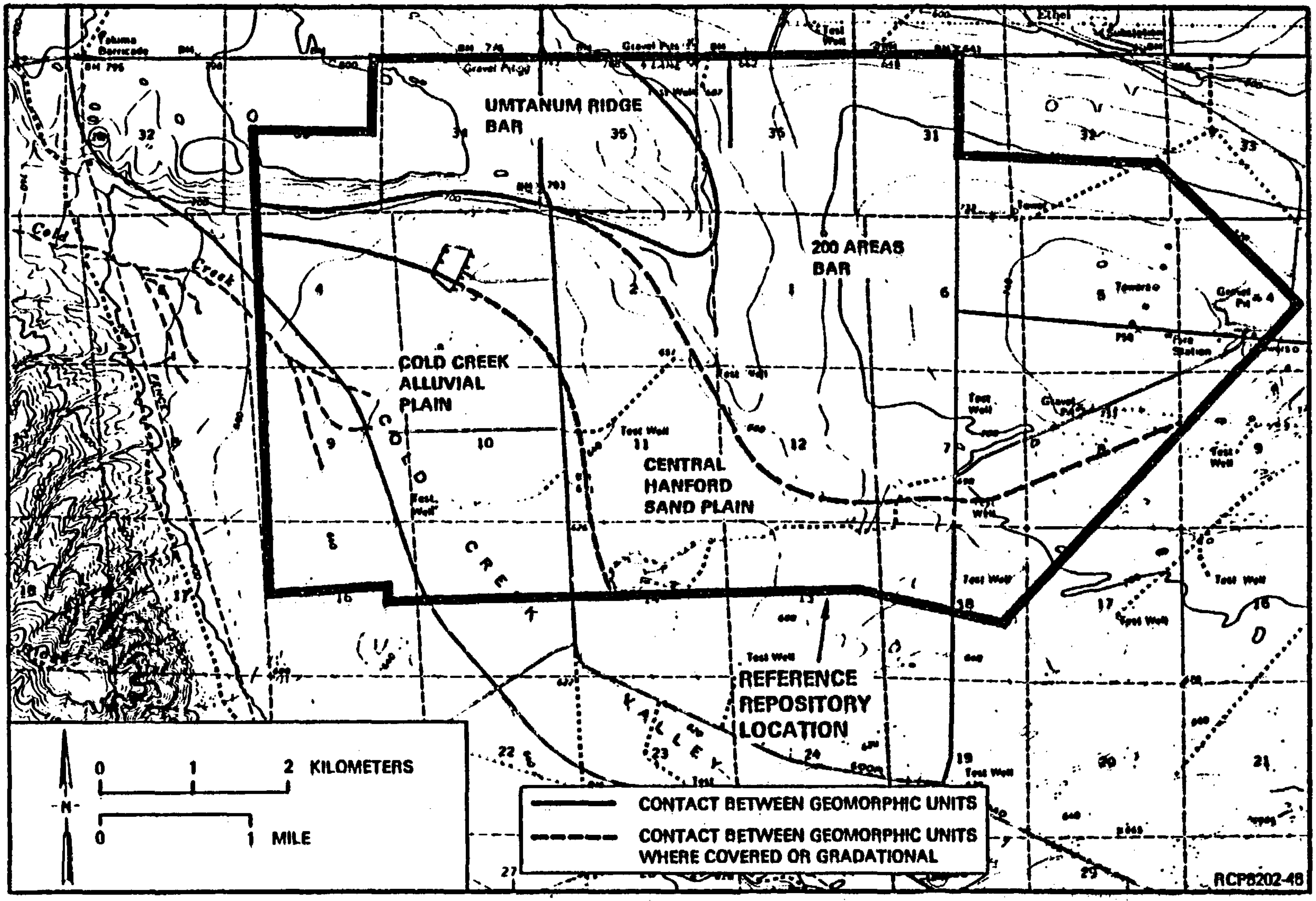

Figure 3-5. Geomorphic map of the reference repository location.

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Holocene alluvium deposited along Cold Creek is superimposed on the western portion of the central Hanford sand plain. Sloping slightly to the southeast down Cold Creek Valley, the Cold Creek alluvial plain ranges in elevation from approximately 205 meters (675 feet) to the northwest to 190 meters (625 feet) to the southeast.

The plain is composed of granules of fine sand and silt. The active portions of the alluvial plain can be distinguished by dendritic and distributary drainage patterns. Parts of the inactive alluvial plain surface have been slightly modified by winds that have formed a thin sand cover.

3.2.2 Stratigraphy

The Pasco Basin, located near the center of the Columbia Plateau (see Fig. 2-1), is underlain by a thick sequence of Miocene tholeiitic basalt flows that are, in places, interbedded with and overlain by clastic sediments of Miocene or younger age (Fig. 3-6). These basalt flows collectively form the Columbia River Basalt Group (see Section 2.1.1) that beneath the Pasco Basin and vicinity consists of three formations: Grande Ronde Basalt, Wanapum Basalt, and Saddle Mountains Basalt (Swanson et al., 1979b). Sedimentary rocks of Miocene age interbedded with the basalts in the Pasco Basin are designated the Ellensburg Formation (Brown, 1959; Newcomb et al., 1972).

Overlying the basalts and interbedded sediments in topographic and structural lows of the central plateau are semiconsolidated sediments of the Mio-Pliocene Ringold Formation (Merriam and Buwalda, 1917). The thickest sequence of Ringold Formation sediments occurs in the Pasco Basin where approximately 365 meters (1,200 feet) of coarse-to-fine-grained clastic sediments were deposited by ancestral rivers. In the central Pasco Basin the Ringold Formation is informally subdivided into four fluvial facies: basal, lower, middle, and upper Ringold Formation units (Tallman et al., 1981; Bjornstad, 1984).

The Quaternary Period in the central Columbia Plateau is dominated by Pleistocene catastrophic floods that scoured the Channeled Scablands and deposited glaciofluvial sediments in topographic lows. In the Pasco Basin, the glaciofluvial sediments are informally designated the Hanford formation.

Loess, dune sand, alluvium, as well as landslide debris, colluvium and talus veneer the flanks of the basaltic ridges bounding the Pasco Basin. These deposits range from Pleistocene to present in age (Myers, Price et al., 1979).

The major stratigraphic units present in the reference repository location are the Grande Ronde Basalt, Wanapum Basalt, and Saddle Mountains Basalt of the Columbia River Basalt Group; and the Ellensburg Formation, Ringold Formation, and Hanford formation, which are major fluvial units (see Fig. 3-6). A thin veneer of surficial sediments is present over much

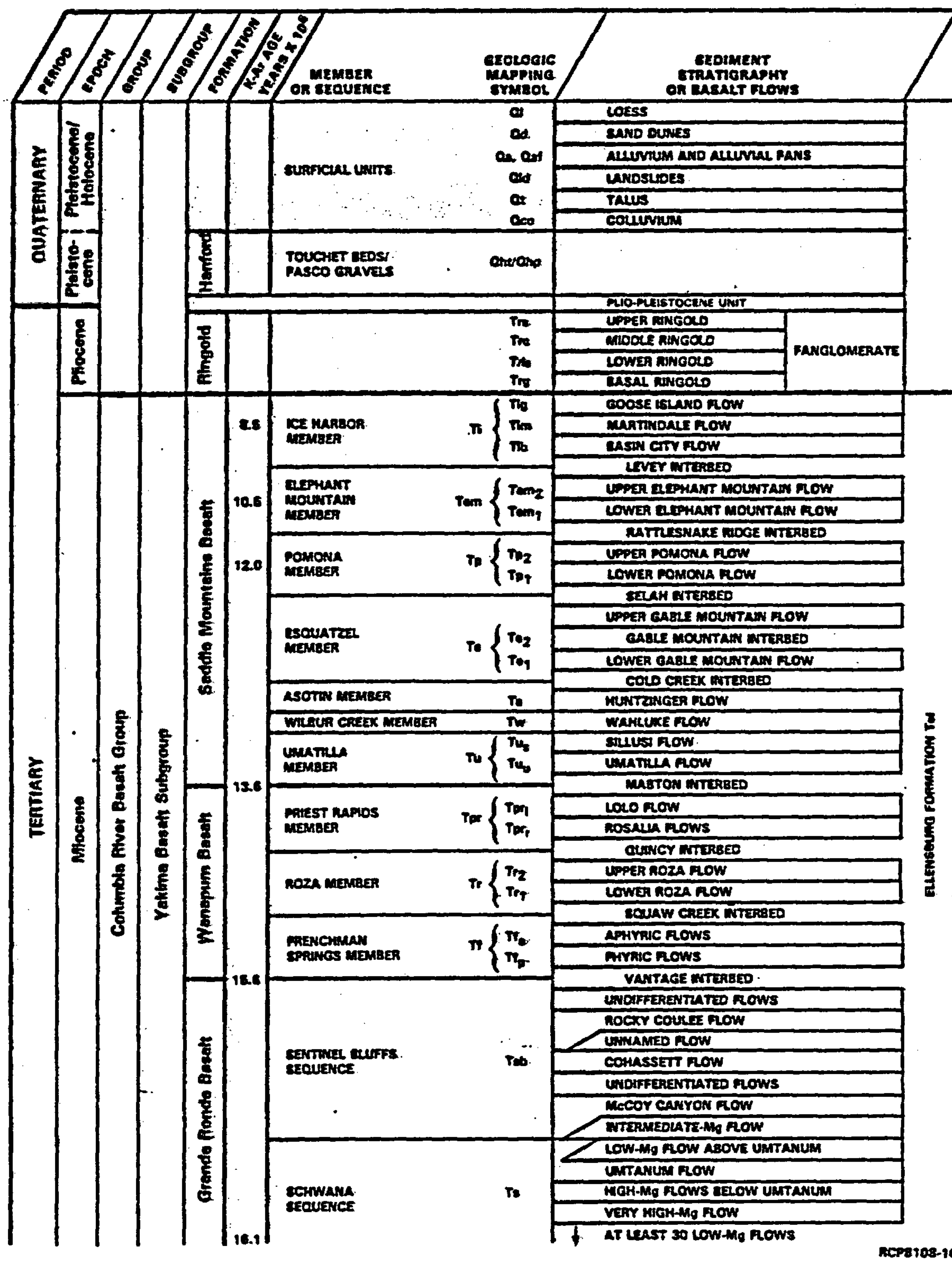

Figure 3-6. Stratigraphic units present in the reference repository location.

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of the area. Stratigraphic descriptions of the geologic units in the reference repository location given below are based on borehole data (Fig. 3-7).

3.2.2.1 Grande Ronde Basalt

As was previously summarized in Chapter 2, the Grande Ronde Basalt (erupted 17 to 15.6 million years ago) is a thick sequence of at least 56 basalt flows in the Pasco Basin that are typically fine grained and aphyric or sparsely microphyric with few consistent textural differences among flows. Grande Ronde Basalt flows are correlated regionally on the basis of magnetostratigraphic polarity units (from oldest to youngest: R_1, N_1, R_2, N_2) defined by reversals in the paleomagnetic polarity of the flows (Figure 2-4; Swanson et al., 1979b). Flows recognized within the Pasco Basin are of the N_2 and R_2 magnetostratigraphic units. In addition, two major informal sequences of flows distinguished on the basis of chemical composition (primarily differences in magnesium) have been recognized in the Pasco Basin and reference repository location: The Schwana sequence and the Sentinel Bluffs sequence (Myers, Price et al., 1979). The boundary between the Schwana and the Sentinel Bluffs sequences is termed the magnesium horizon (ARHCO, 1976). Grande Ronde Basalt within the reference repository location is overlain by up to 20 flows of Wanapum Basalt and Saddle Mountains Basalt and interbedded sediments of the Ellensburg Formation (see Fig. 3-6 and 3-8).

The Schwana sequence lies within the R_2 and N_2 magnetostratigraphic units and consists of dominantly low magnesium flows (less than about 4.0 weight percent magnesium oxide). Several flows of high magnesium chemistry (greater than 40, less than 5.5 weight percent magnesium oxide) are found in the Schwana sequence and a single flow of very high magnesium oxide content (greater than 5.5 weight percent magnesium oxide) is found near the top of the sequence (Long and Landon, 1981). The Umtanum flow, a flow near the top of the sequence, has been identified as one of the four candidate horizons for a nuclear waste repository at the Hanford Site.

Basalts of the Schwana sequence extend much deeper than most boreholes in the Pasco Basin have penetrated. Borehole RSH-1 in the Rattlesnake Hills encountered basalt to a depth of about 3,200 meters (10,650 feet). This is about 1,500 meters (5,000 feet) deeper than other deep boreholes in the Pasco Basin. The hole did not reach the base of the basalts, so a total thickness for the Schwana sequence in the Pasco Basin is known only from estimates based on geophysical data. Its thickness beneath the reference repository location is estimated to be about 1,800 meters (5,900 feet) (Caggiano and Duncan, 1983). Moreover, it is likely that the deeper parts of the Schwana section contain R_1 and N_1 paleomagnetic units.

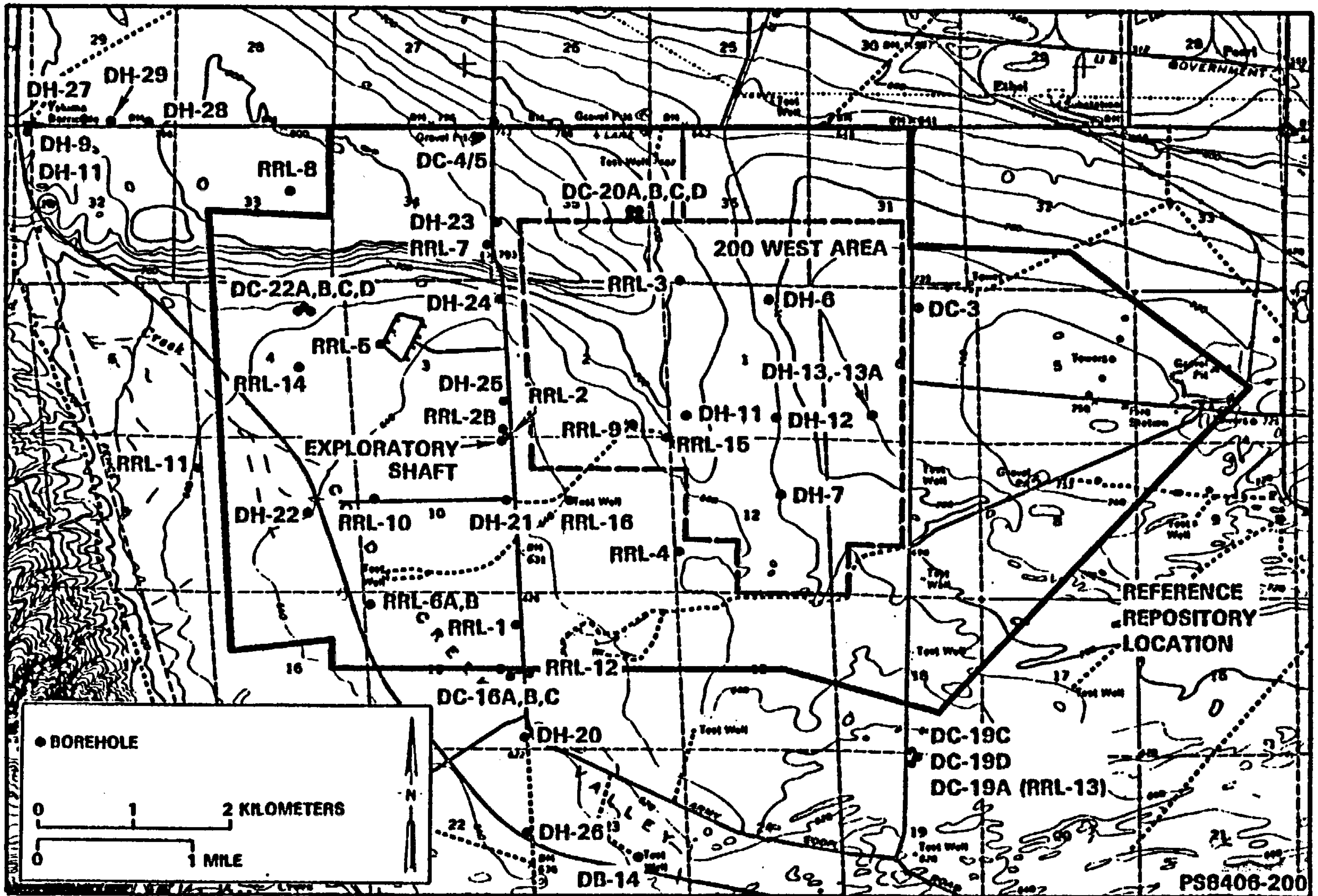

Figure 3-7. Borehole location map of the reference repository location.

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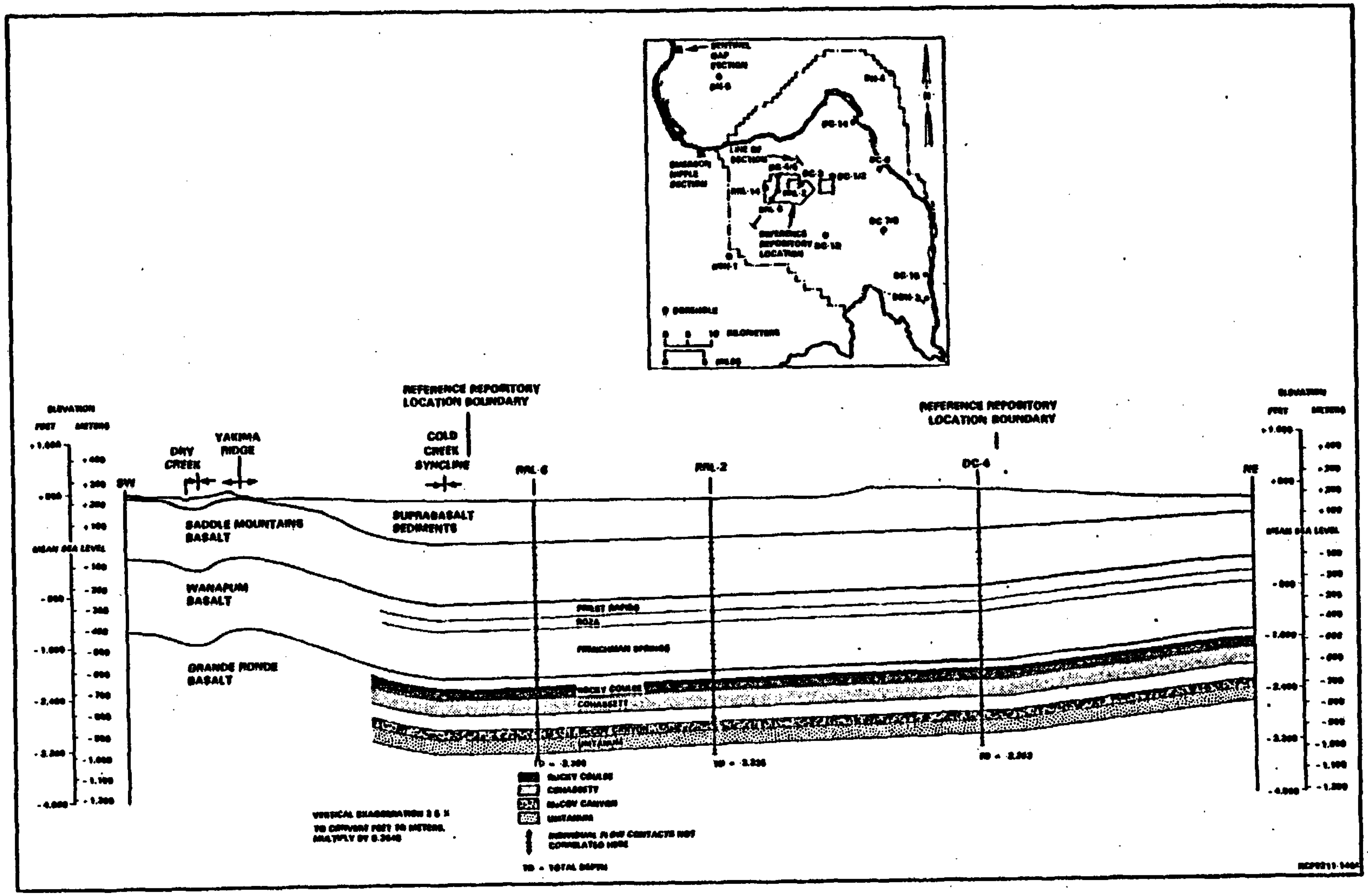

Figure 3-8. Geologic cross section through the reference repository location.

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The Sentinel Bluffs sequence consists of 8 flows in the reference repository location, all of high-magnesium chemical type (greater than approximately 4.0 weight percent magnesium oxide). Basalt flows in this sequence lie within the N_2 magnetostratigraphic unit (Long and Landon, 1981). Individual flows within the sequence vary in thickness from 8.5 meters (28 feet) to 80 meters (260 feet). The Rocky Coulee, Cohassett, and McCoy Canyon flows at the Schwana sequence have been identified as candidate horizons for a nuclear waste repository in the reference repository location.

Flows of the Sentinel Bluffs sequence and flows from the upper portion of the Schwana sequence have been correlated from one location to another across the Pasco Basin (Long and WCC, 1984 and Fig. 3-8). The geographic distribution of the thickness of the total Sentinel Bluffs sequence in the Pasco Basin is shown in Figure 3-9. The sequence is thinner to the east and northeast, which is probably the result of the regional southwest-dipping paleoslope (Swanson and Wright, 1976) that flattens out in the area now occupied by the Pasco Basin. This flattening resulted in ponding of flows in part of the area now occupied by the Pasco Basin and thinning onto the paleoslope to the east and northeast. In the vicinity of the reference repository location, the Sentinel Bluffs sequence maintains a relatively consistent thickness.

3.2.2.1.1 Umtanum flow

The Umtanum flow is of the low-magnesium Grande Ronde chemical type (Table 3-1) and the uppermost flow in the Schwana sequence throughout most of the Pasco Basin (see Fig. 3-6). It is correlated on the basis of its relatively high titanium oxide content, its low paleomagnetic inclination, and on its stratigraphic position relative to the magnesium horizon (Long and WCC, 1984). In the Pasco Basin, the Umtanum flow thins to the northeast (Fig. 3-10) and is not present in surface sections located about 50 kilometers (30 miles) north of the Pasco Basin (Long and Landon, 1981). It also thins to the west of the Emerson Nipple section, based on data from Price (1982). The Umtanum is thickest in the area of Emerson Nipple and Sentinel Gap surface sections and in the southeast near boreholes DC-15 and DDH-3. Current data suggest a broad zone of relatively constant thickness occurs in the central Pasco Basin. Within the reference repository location the thickness is variable (ranging from about 61 to 71 meters (198 to 230 feet)) and possibly related to the development of the thick flow-top breccia found in the Umtanum flow in portions of the reference repository location. The top of the Umtanum flow lies from about 1,059 to 1,135 meters (3,475 to 3,725 feet) below ground surface in the reference repository location.

Interpretation of core from the Umtanum flow indicates that it internally consists of a single entablature and colonnade where it has been drilled in the reference repository location. The dense interior (colonnade and entablature) as depicted in Figure 3-10 varies in thickness, but is greater than 24 meters (80 feet) in boreholes within the reference repository location. Cores of the Umtanum flow for the reference repository location also indicate that its flow top is variable

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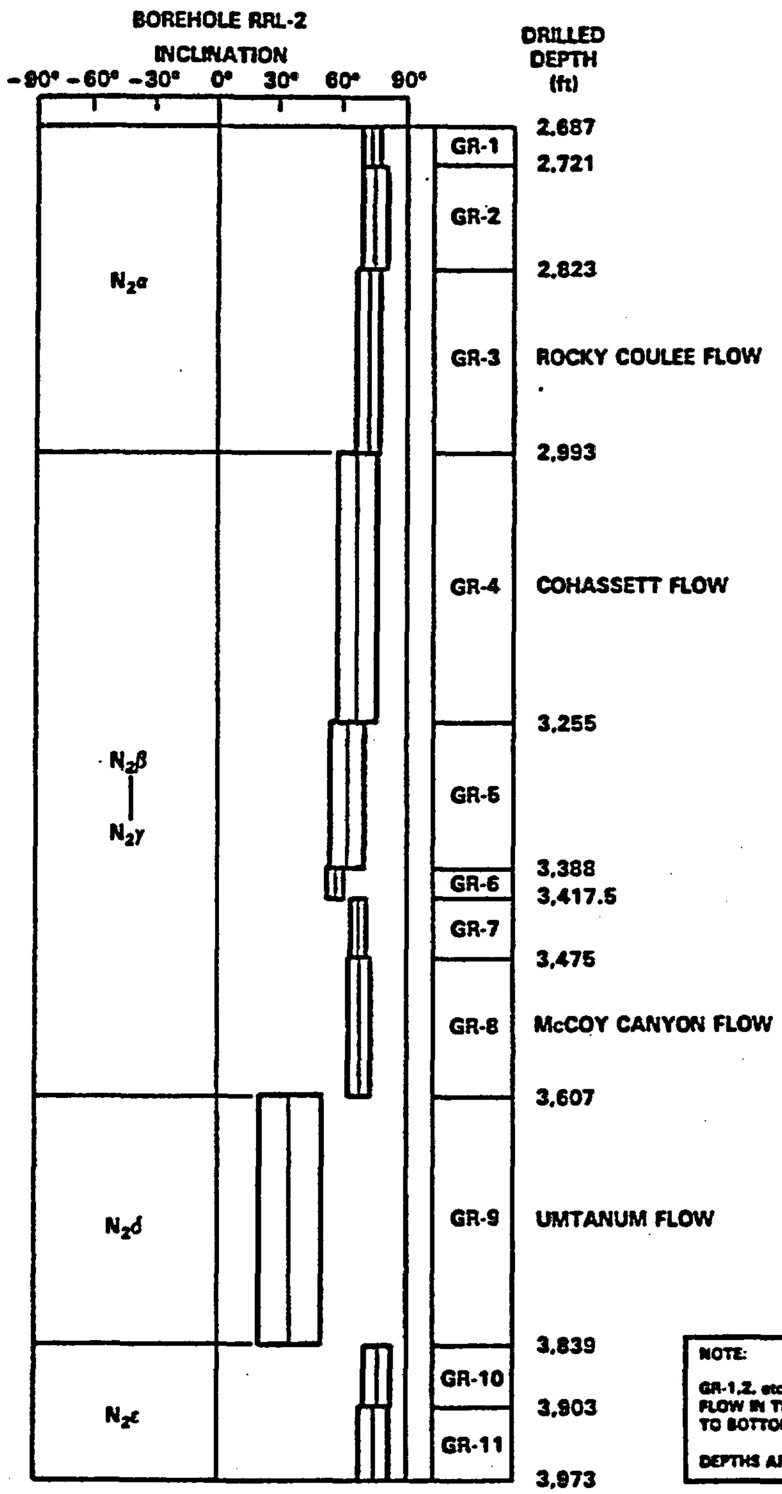

NOTE:

GR-1,2, etc. IS THE DESIGNATION GIVEN A PARTICULAR FLOW IN THE BOREHOLE, NUMBERED IN ORDER FROM TOP TO BOTTOM FOR THE GRANDE RONDE BASALT GROUP.

DEPTHS ARE IN FEET. 1 ft = 0.3048 m

0.31 m

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FIGURE 3-8(a). Paleomagnetic Data from Grande Ronde Basalt in borehole RRL-2

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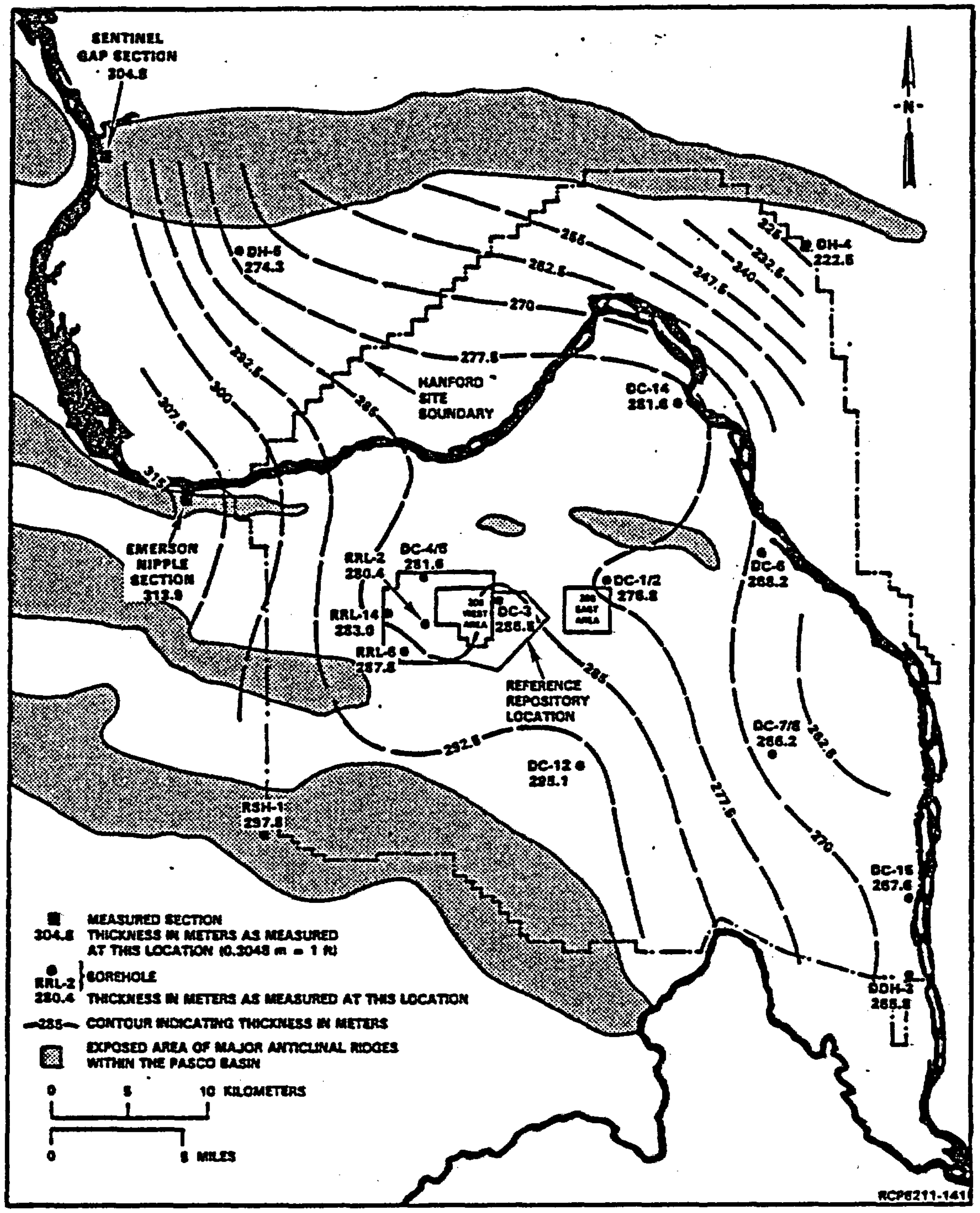

Figure 3-9. Sentinel Bluffs sequence isopach.

Table 3-1. Means of major and minor oxides (wt%) of the candidate horizon.

Oxide	Rocky Coulee flow, 34 samples		Cohassett flow, 42 samples		McCoy Canyon flow, 38 samples		Umtanum flow, 53 samples	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
SiO_2	54.10	0.63	53.38	0.43	53.58	0.51	54.65	0.79
Al_2O_3	15.13	0.36	15.07	0.39	14.96	0.33	14.68	0.31
FeO	11.42	0.29	11.70	0.32	12.30	0.28	12.91	0.28
MgO	4.81	0.20	5.04	0.20	4.62	0.25	3.53	0.19
CaO	8.54	0.29	8.82	0.29	8.44	0.22	7.19	0.28
K_2O	1.14	0.09	1.01	0.12	1.01	0.12	1.52	0.24
Na_2O	2.43	0.35	2.49	0.32	2.45	0.39	2.55	0.40
TiO_2	1.73	0.06	1.78	0.07	1.95	0.08	2.18	0.07
MnO	0.21	0.01	0.21	0.01	0.21	0.01	0.22	0.01
P_2O_5	0.30	0.02	0.28	0.03	0.29	0.02	0.35	0.01

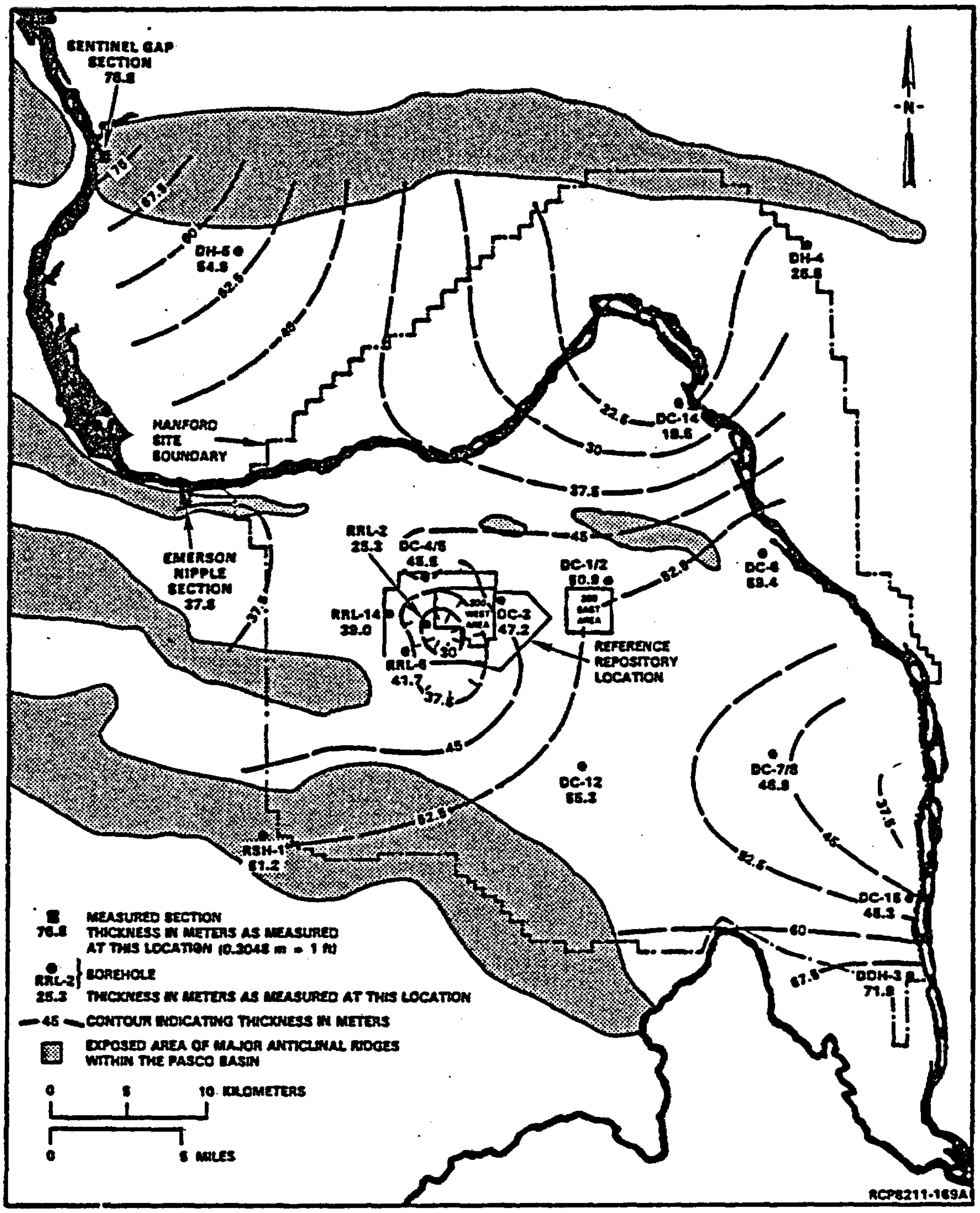

Figure 3-10. Isopach of the dense interior of the Umtanum flow.

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in thickness, ranging from 17 to 45 meters (56 to 148 feet). In borehole RRL-2, the Umtanum flow is apparently similar to the outcrop at the Emerson Nipple section (Fig. 3-11). At this section there is a great amount of variability in the flow-top breccia of the Umtanum flow. Fanning of the entablature occurs wherever dimples of flow top extend into the entablature. Conceivably, borehole RRL-2 penetrated an area of thickened flow top associated with fanning entablature columns. On the other hand, the relatively thick breccia encountered in borehole RRL-2 may represent the average thickness in the area, in which case local areas of greater thickness probably occur. Data, however, from boreholes DC-4, RRL-6, and RRL-14 indicate lesser flow-top thickness. A general area of greatly thickened flow-top breccia in the central part of the reference repository location is interpreted to be less than about 2 kilometers (1 mile) in radius since such a thickness of flow-top breccia was not observed in boreholes DC-4, RRL-6, or RRL-14. The outcrop at Emerson Nipple suggests areas of thickening extend at least 100 meters (300 feet) laterally.

3.2.2.1.2 McCoy Canyon flow

The McCoy Canyon flow is of the high-magnesium Grande Ronde chemical type (see Table 3-1) and is the lowermost flow of the Sentinel Bluffs sequence (see Fig. 3-6). It is correlated within the Pasco Basin and to the north on the basis of its position relative to the magnesium horizon and on its major element chemistry as a possible chemical subtype (Long et al., 1980). The total thickness of the flow varies from 73 meters (240 feet) at Sentinel Gap to 25 meters (82 feet) at borehole DDH-3 (Fig. 3-12). An area in which the flow is relatively thick occurs to the northwest and west of the Pasco Basin and is similar to an area of thickening in the underlying Umtanum flow; apparently, a similar structural low existed in this area when both the McCoy Canyon and Umtanum flows were emplaced. To the southeast, where the McCoy Canyon flow thins, it may have covered constructional topography formed by the Umtaum flow. The flow also thins progressively to the northeast on the southwest-dipping paleoslope of Swanson and Wright (1976).

In the reference repository location, the McCoy Canyon flow lies directly on top of the Umtanum flow. The McCoy Canyon flow thins about 11 meters (36 feet) across the reference repository location ranging from 34 to 45 meters (112 to 148 feet). The top of the flow lies from about 1,025 to 1,090 meters (3,365 to 3,575 feet) below the ground surface.

The internal character of the McCoy Canyon flow is interpreted to be multitiered intraflow structures of colonnade and entablature in the reference repository location, based on borehole data. Cores of the McCoy Canyon flow for the reference repository location reveal that its dense interior is about 30 meters (100 feet) in thickness (Fig. 3-13). However, its interior is sporadically interrupted by vesiculation which, if extensive, could reduce the available dense interior for repository construction. The flow-top thickness of the McCoy Canyon flow is apparently somewhat more variable than that of the Cohassett flow. Tiering in the flow is not readily correlated from borehole to borehole.

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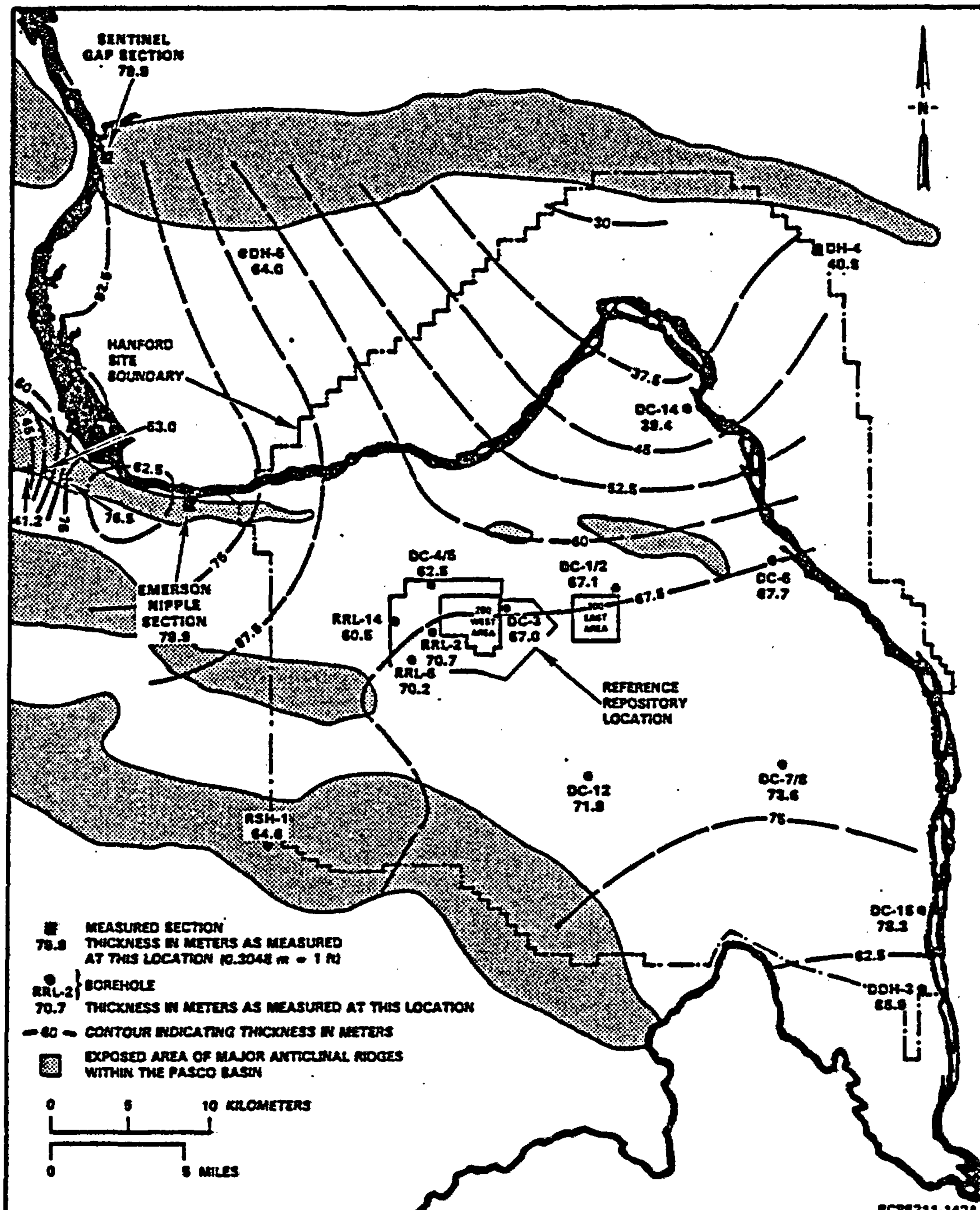

Figure 3-11. Umtanum flow isopach.

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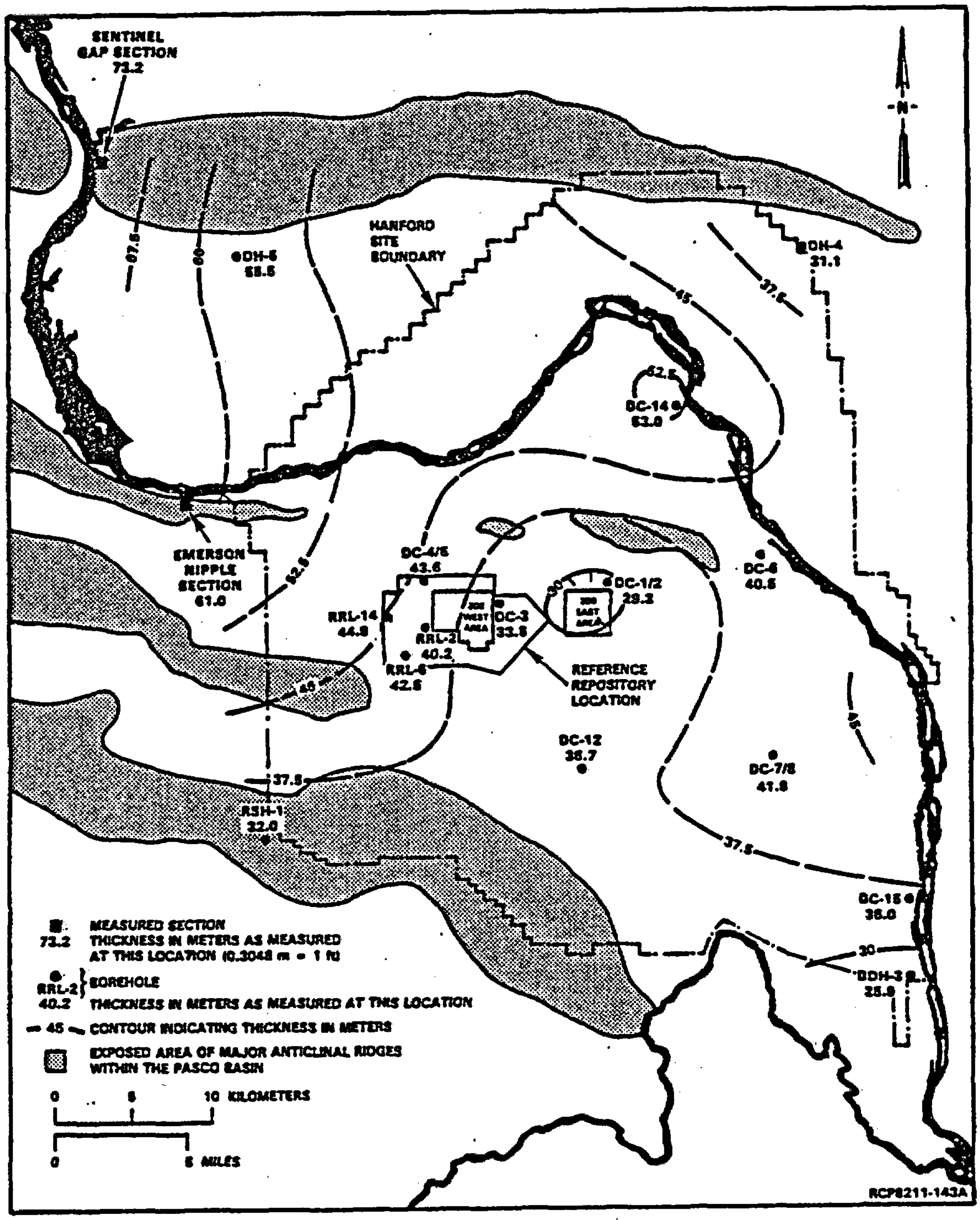

Figure 3-12. McCoy Canyon flow isopach.

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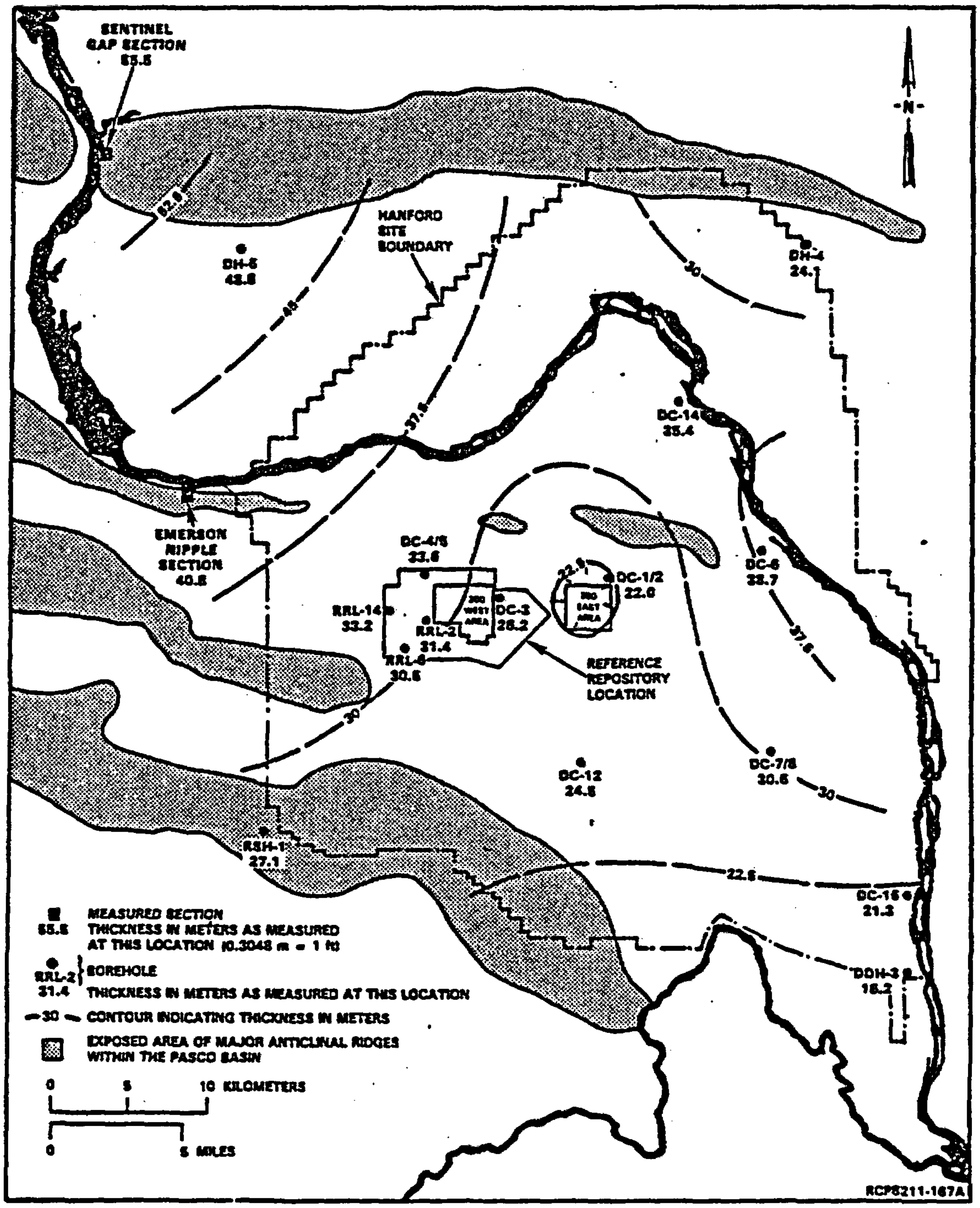

Figure 3-13. Isopach of the dense interior of the McCoy Canyon flow.

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3.2.2.1.3 Cohassett flow

The Cohassett flow is of the high-magnesium Grande Ronde chemical type (see Table 3-1) stratigraphically positioned near the center of the Sentinel Bluffs sequence (see Fig. 3-6) and can be correlated throughout the entire basin. Correlations of the Cohassett flow are based primarily on stratigraphic position and thickness (Long and WCC, 1984). The Cohassett flow, as illustrated in Figure 3-14, is thickest in the central Pasco Basin, maintains a fairly consistent thickness in the reference repository location, and thins in the southeastern portion of the map area. The thinning of the flow in the southeast is thought to be related to the mechanics of flow emplacement and not related to thinning over a topographic high, either structural or constructional.

The Cohassett flow is the thickest of the flow candidate horizons in the reference repository location with a range from 73 to 82 meters (240 to 270 feet) (see Fig. 3-14). The top of the Cohassett flow lies 869 to 943 meters (2,850 to 3,095 feet) below the ground surface.

Cohassett flow core samples show that it is consistently a multitiered flow within the Pasco Basin. The colonnade/entablature tiers are not readily correlated from borehole to borehole in the reference repository location. A vesicular zone in the Cohassett flow is consistently located at about 30 ± 5 meters (100 ± 15 feet) into the flow. It ranges from about 3.0 to 8.5 meters (10 to 28 feet) in thickness and is interpreted to be continuous within the flow throughout the reference repository location. The vesicular zone separates the Cohassett flow into upper and lower dense interiors. The dense interior above the vesicular zone ranges from 16 to 23 meters (53 to 75 feet) thickness within the reference repository location (Fig. 3-15). The dense interior below the vesicular zone is relatively thick, ranging from about 36 to 46 meters (120 to 150 feet) (Fig. 3-16).

3.2.2.1.4 Rocky Coulee flow

The Rocky Coulee flow is of the high-magnesium Grande Ronde chemical type (see Table 3-1) and lies within the upper third of the Sentinel Bluffs sequence (see Fig. 3-6). The flow is interpreted to occur throughout the Pasco Basin (Long and WCC, 1984) and is correlated with the Rocky Coulee flow of Mackin (1961). Within the Pasco Basin, the Rocky Coulee flow is correlated on the basis of stratigraphic position, thickness, and chromium content. The flow, as shown in Figure 3-17, is thickest in the southeast and thinnest in the northeast portions of the basin. In the reference repository location, the flow maintains a relatively consistent thickness but thins in the eastern part of the reference repository location. At borehole DC-3, in the eastern portion of the reference repository location, the flow is about 10 meters (30 feet) thinner than in the remainder of the reference repository location. Thinning of the Rocky Coulee flow in the eastern reference repository location is attributed to emplacement of the flow over a single thin flow of limited extent that overlies the Cohassett flow in this area.

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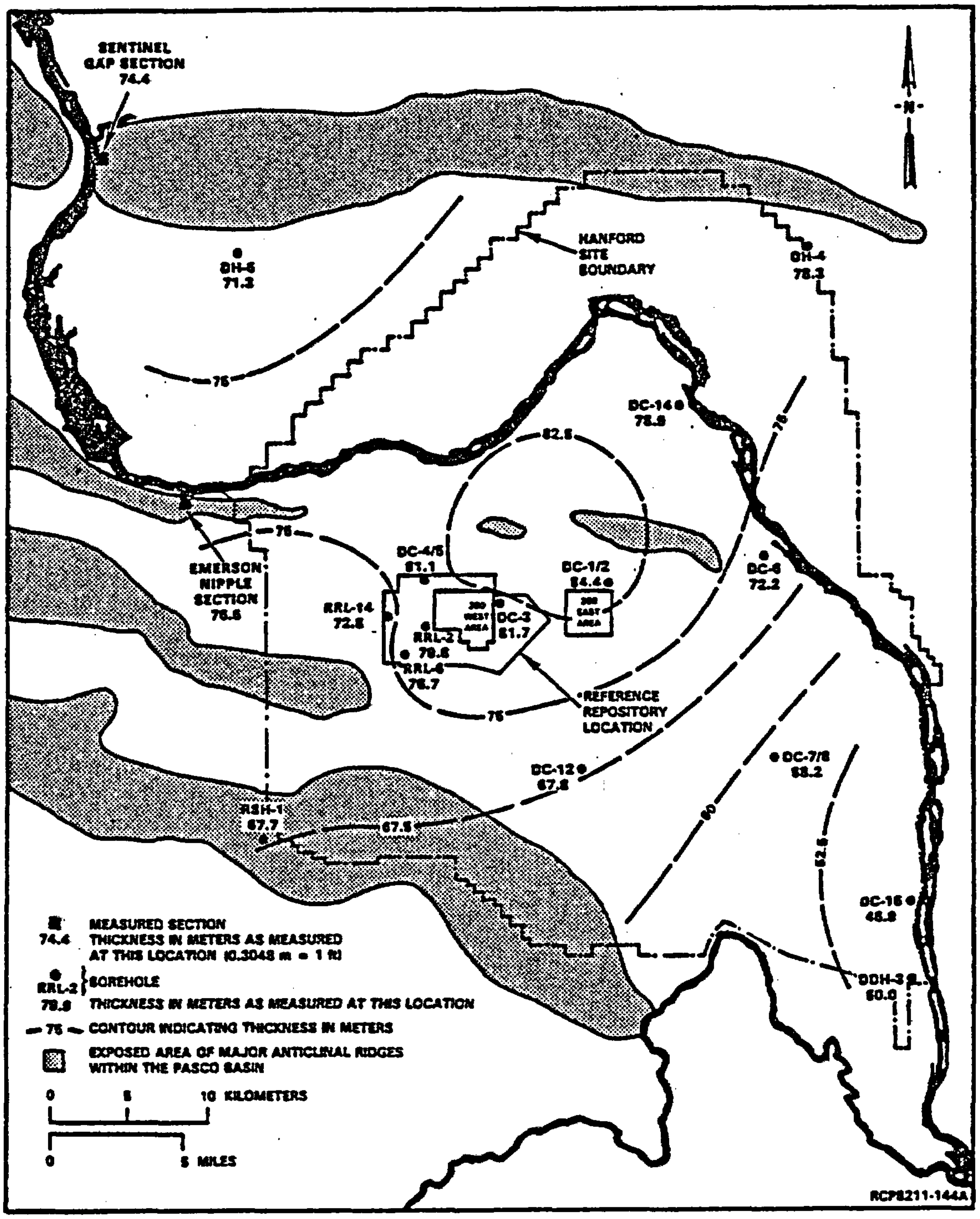

Figure 3-14. Cohassett flow isopach.

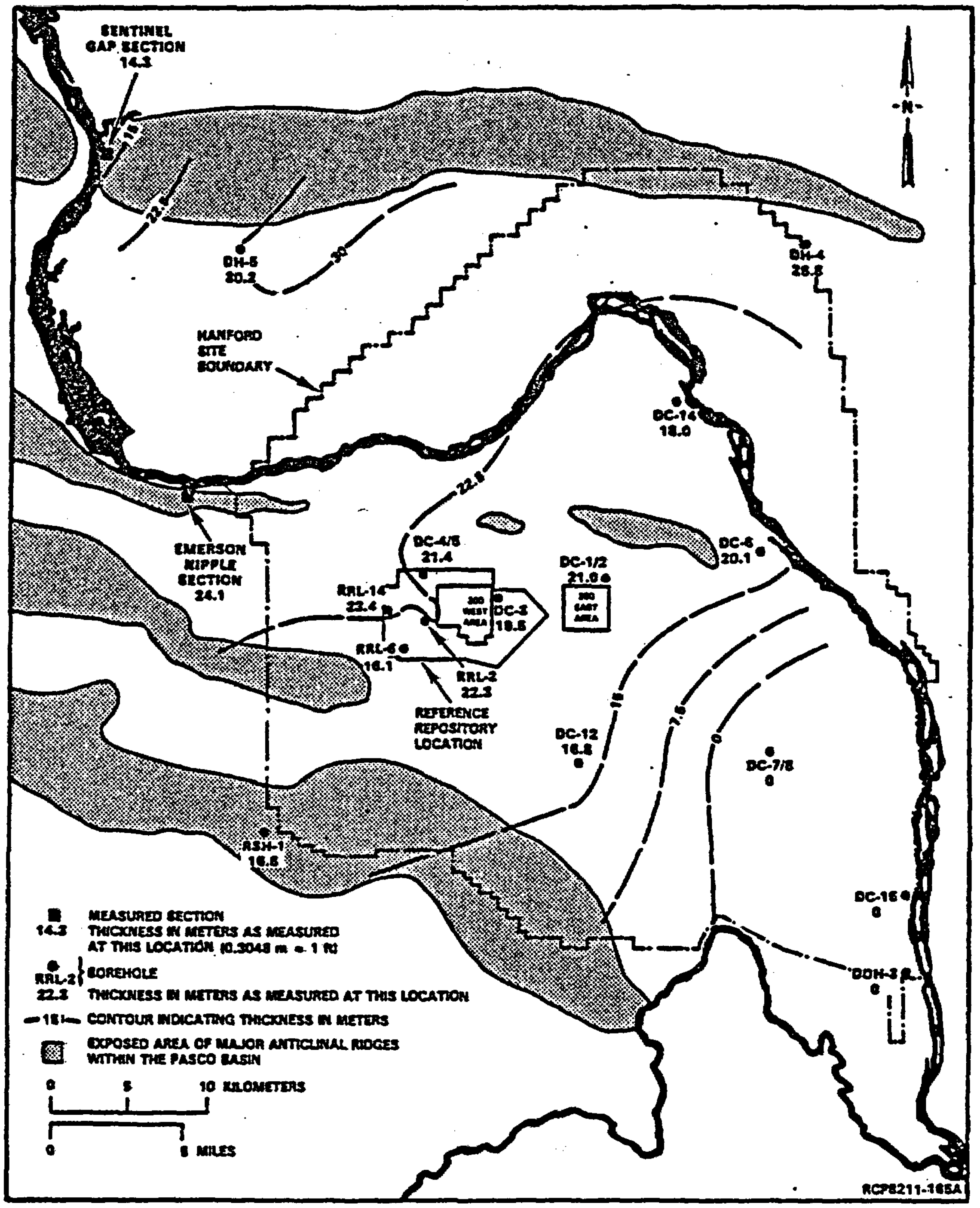

Figure 3-15. Isopach of the dense interior of the Cohassett flow above the vesicular zone.

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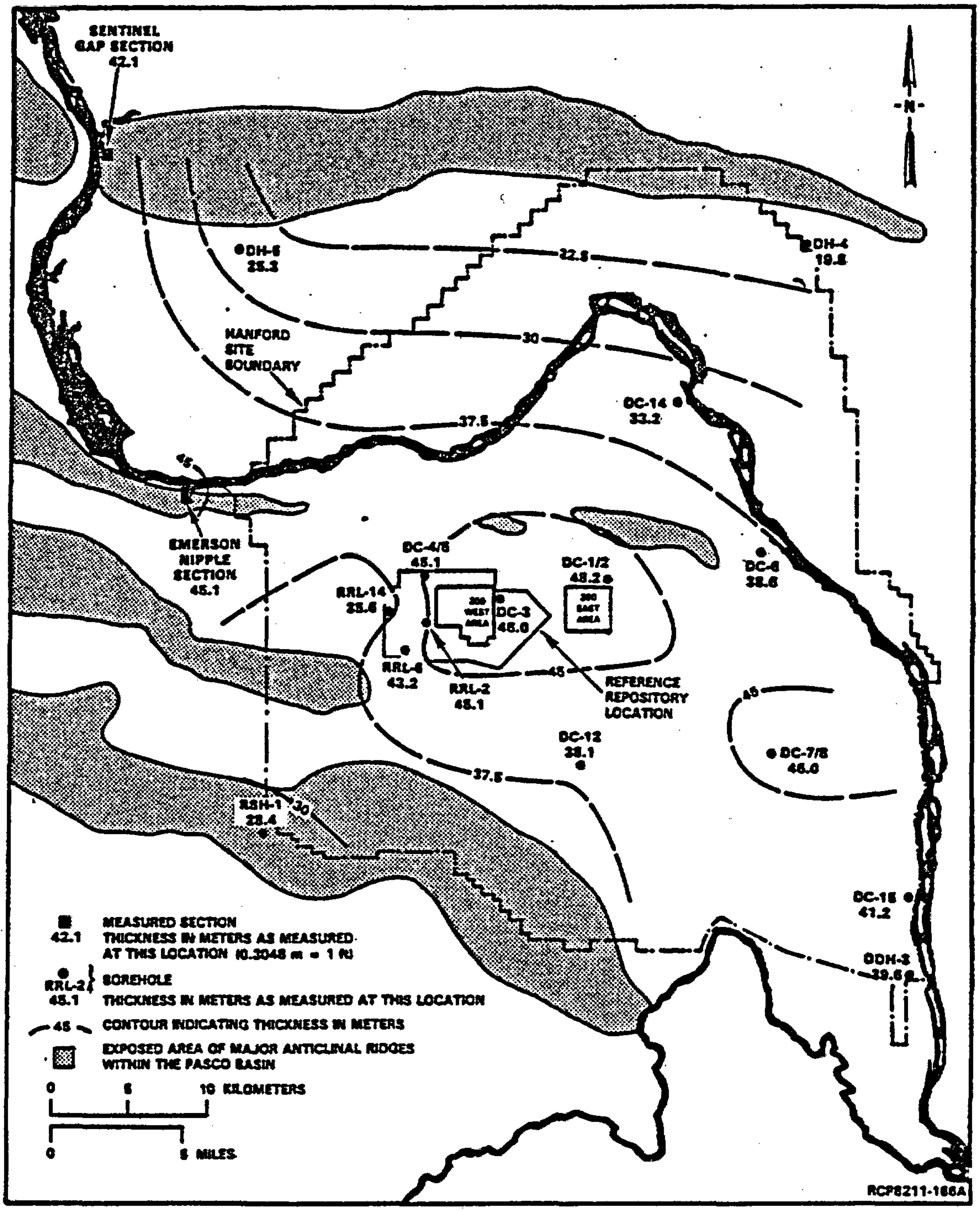

Figure 3-16. Isopach of the dense interior of the Cohassett flow below the vesicular zone.

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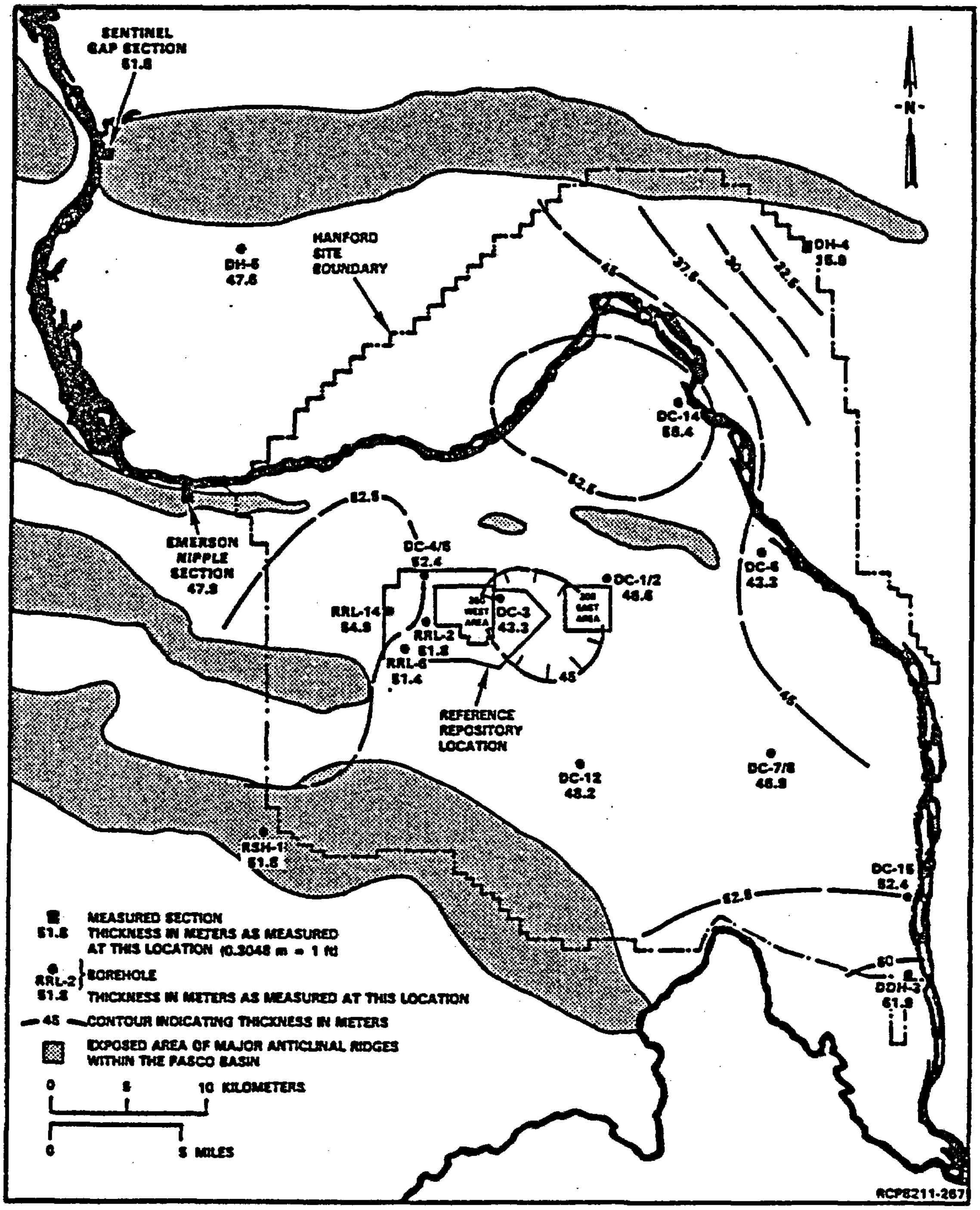

Figure 3-17. Rocky Coulee flow isopach.

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Samples of the core from the Rocky Coulee flow indicate that the flow has multitiered intraflow structures of colonnade and entablature. The tiers of colonnade and entablature do not appear to correlate between boreholes, suggesting that there is lateral variation of the colonnade and entablature over distances of a few kilometers or less. The Rocky Coulee flow top ranges in thickness within the reference repository location from about 5 to 25 meters (17 to 81 feet). The dense interior of the flow ranges in thickness from about 27 to 47 meters (89 to 153 feet) (Fig. 3-18). It appears to thin significantly from southeast to northwest across the reference repository location, reflecting primarily vesiculation beneath the flow top in the upper part of the flow.

3.2.2.2 Wanapum Basalt

The Wanapum Basalt consists of three members in the Pasco Basin: (1) Frenchman Springs, (2) Roza, and (3) Priest Rapids. The Vantage interbed separates this formation from the underlying Grande Ronde Basalt; the Mabton interbed separates the Wanapum Basalt from the overlying Saddle Mountains Basalt (see Fig. 3-6).

The Wanapum Basalt is typically fine-to-medium grained with some flows containing olivine and plagioclase phenocrysts. The petrographic characteristics combined with distinct chemical differences, termed the "TiO_2 discontinuity" (Siems et al., 1974), permit easy distinction of the Wanapum Basalt from the Grande Ronde Basalt.

The Wanapum Basalt is between 14 and 13.5 million years old (Watkins and Baksi, 1974) and was erupted from linear vents on the east side of the plateau (Swanson et al., 1979a). It is thickest in the central area of the Cold Creek syncline around the reference repository location, but thins from west to east and over the Rattlesnake Hills and Umtanum Ridge-Gable Mountain structures in the reference repository location (see Fig. 3-1). The Wanapum Basalt totally consists of 10 to 13 flows, and is approximately 335 meters (1,100 feet) thick.

3.2.2.2.1 Frenchman Springs Member

The Frenchman Springs Member is the oldest member of the Wanapum Basalt in the Pasco Basin and consists of seven to nine flows in the Cold Creek syncline. It is approximately 215 meters (775 feet) thick in the reference repository location. The flows are all medium-to-fine grained and contain plagioclase phenocrysts. Within the Pasco Basin, the flows can be grouped into "phyric" and "aphyric" units based on relative phenocryst abundance.

The average chemical composition of the Frenchman Springs Member is given in Table 3-2. The composition falls within the Frenchman Springs chemical type of Wright et al. (1973), but there is no obvious difference in chemical composition between the phyric and aphyric flows from the Pasco Basin area.

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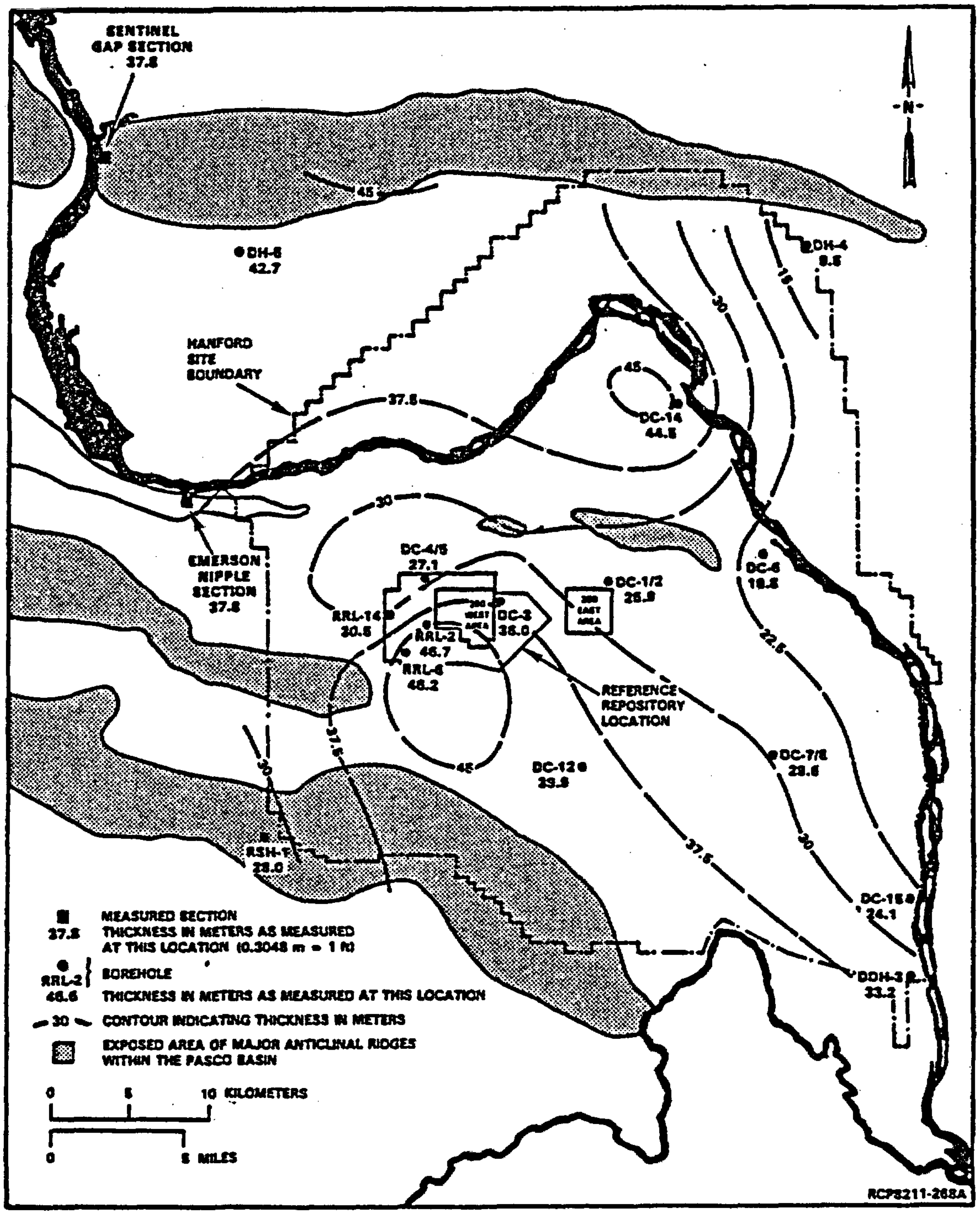

Figure 3-18. Isopach of the dense interior of the Rocky Coulee flow.

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Table 3-2. Average chemical composition of flows from the Wanapum and Saddle Mountains Basalts, Pasco Basin. (Sheet 1 of 3)

Oxide	Frenchman Springs Member plagioclase phyric flows		Frenchman Springs Member aphyric flows	
	43 samples		28 samples	
	Mean	Standard deviation	Mean	Standard deviation
SiO_2	51.24	0.37	51.27	0.39
Al_2O_3	13.93	0.29	14.04	0.32
TiO_2	2.98	0.08	2.92	0.08
FeO*	12.83	0.44	12.69	0.37
MnO	0.24	0.01	0.23	0.01
CaO	8.34	0.17	8.34	0.15
MgO	4.22	0.25	4.21	0.23
K_2O	1.15	0.14	1.29	0.12
Na_2O	2.54	0.14	2.49	0.17
P_2O_5	0.53	0.05	0.52	0.04

Oxide	Rosa Member		Priest Rapids Member Rosalia flow	
	13 samples		15 samples	
	Mean	Standard deviation	Mean	Standard deviation
SiO_2	50.60	0.35	49.85	0.35
Al_2O_3	14.35	0.37	13.70	0.21
TiO_2	3.01	0.11	3.48	0.05
FeO*	12.44	0.54	13.47	0.31
MnO	0.23	0.01	0.24	0.01
CaO	8.65	0.20	8.55	0.19
MgO	4.59	0.31	4.49	0.22
K_2O	1.17	0.13	1.05	0.20
Na_2O	2.43	0.20	2.50	0.22
P_2O_5	0.54	0.03	0.66	0.02

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Table 3-2. Average chemical composition of flows from the Wanapum and Saddle Mountains Basalts, Pasco Basin. (Sheet 2 of 3)

Oxide	Priest Rapids Member Lolo flow		Umatilla Member Sillusi flow	
	19 samples		26 samples	
	Mean	Standard deviation	Mean	Standard deviation
SiO_2	49.87	0.53	54.31	0.73
Al_2O_3	14.28	0.30	14.70	0.60
TiO_2	3.15	0.09	2.83	0.30
FeO*	12.20	0.45	10.48	0.92
MnO	0.24	0.01	0.22	0.02
CaO	9.00	0.63	6.60	0.64
MgO	5.18	0.31	2.61	0.26
K_2O	0.98	0.11	2.62	0.36
Na_2O	2.45	0.17	2.82	0.25
P_2O_5	0.66	0.02	0.81	0.05

Oxide	Umatilla Member Umatilla flow		Esquatzel Member	
	19 samples		26 samples	
	Mean	Standard deviation	Mean	Standard deviation
SiO_2	53.65	0.59	52.78	0.47
Al_2O_3	14.51	0.27	14.24	0.27
TiO_2	2.99	0.11	3.02	0.10
FeO*	10.87	0.72	11.68	0.50
MnO	0.22	0.05	0.21	0.02
CaO	6.68	0.37	7.65	0.22
MgO	3.00	0.31	3.75	0.22
K_2O	2.52	0.14	1.78	0.13
Na_2O	2.84	0.24	2.50	0.14
P_2O_5	0.72	0.02	0.37	0.02

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Table 3-2. Average chemical composition of flows from the Wanapum and Saddle Mountains Basalts, Pasco Basin.
(Sheet 3 of 3)

Oxide	Pomona Member		Elephant Mountain Member Lower flow	
	67 samples		23 samples	
	Mean	Standard deviation	Mean	Standard deviation
SiO_2	51.81	0.38	50.76	0.33
Al_2O_3	15.41	0.28	13.76	0.30
TiO_2	1.63	0.06	3.49	0.06
FeO*	8.68	0.39	13.08	0.51
MnO	0.19	0.01	0.23	0.01
CaO	10.62	0.30	8.38	0.19
MgO	6.73	0.27	4.22	0.14
K_2O	0.53	0.10	1.30	0.10
Na_2O	2.16	0.12	2.29	0.21
P_2O_5	0.24	0.02	0.49	0.01

NOTE: Taken from Reidel and Fecht (1981).

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The flows of the Frenchman Spring Member north of the Pasco Basin were sampled for remanent magnetic polarity by Van Alstine and Gillett (1981) as part of the Basalt Waste Isolation Project stratigraphic studies. Their findings are comparable with those of Rietman (1966), Kienle et al. (1978), and Sheriff and Bentley (1980). Van Alstine and Gillett (1981) found that the magnetic polarity of the two lowest flows, the Ginkgo and Sand Hollow flows (Table 3-3), are nearly identical with mean declinations of 146.1 degrees and 144.7 degrees and mean inclination of 42.1 degrees and 39.8 degrees, respectively. The youngest flow, the Sentinel Gap flow (see Table 3-3), has a mean declination of 5.0 degrees and a mean inclination of 62.8 degrees.

The total thickness of the Frenchman Springs Member thins from south to north and from east to west across the Pasco Basin (Reidel et al., 1980). The greatest number of flows is present in the southeastern part of the Pasco Basin and the least number in the northwestern part. In the central part of the Cold Creek syncline area, there are between seven and nine flows or flow lobes. An abrupt thinning occurs onto the Rattlesnake Mountain structure to the south of the Cold Creek syncline (see Fig. 3-1). The greatest thickness occurs on the east side of the Cold Creek syncline. Due to the similarities between flows, the correlation of individual flows across the area is currently not possible.

3.2.2.2.2 Roza Member

One to two flows or flow lobes of similar physical and chemical composition comprise the Roza Member in the Pasco Basin and reference repository location. The member is approximately 53 meters (175 feet) thick in the reference repository location. It is distinguished in hand specimen, typically by the presence of single plagioclase phenocrysts up to 1.5 centimeters (0.6 inches) in size set in a fine-grained groundmass.

The average chemical composition of the Roza Member from the Pasco Basin is given in Table 3-2. It generally falls within the Frenchman Springs chemical type of Wright et al. (1973) and cannot be distinguished from the flows of Frenchman Springs Member on chemical composition alone.

The magnetic polarity of the Roza Member was determined by Rietman (1966) to be transitional, but Choiniere and Swanson (1979) found that in the southeastern part of the Columbia Plateau, the oldest Roza flow has reversed polarity. Van Alstine and Gillett (1981) found that the two Roza flows in core from a borehole south of the Saddle Mountains have low-mean inclinations (+3.3 and 7.5 degrees), lower than that reported by Choiniere and Swanson (1979) (see Table 3-3). Packer and Petty (1979) sampled the Roza flow in core drilled from the central Hanford Site, and found results similar to those of Van Alstine and Gillett (1981).

The Roza Member reaches its greatest thickness in the central part of the Cold Creek syncline and just north of Gable Mountain. It thins across Rattlesnake Mountain and the Umtanum Ridge-Gable Mountain structure, but thickens along the northern flank of the Umtanum Ridge-Gable Mountain structure in the Wahluke syncline (see Fig. 3-1).

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Table 3-3. Paleomagnetic polarity of Wanapum Basalt and Saddle Mountains Basalt flows.

Member	Flow or location	Mean declination	Mean inclination	Alpha 95	Source of information
Ice Harbor	Goose Island	51.3 33.5	+19.2 +31.9	11.7 13.3	a
	Martindale	185.1 168.2	-55.1 -65.0	3.0 3.3	a
	Basin City	317.0 319.3	+34.7 +49.5	4.2 6.3	a
Elephant Mountain	Site 1 Site 2	6.9 14.2	+59.6 +62.5	4.2 8.3	a
	Site 3 Site 4	111.5 127.9	-25.6 -39.5	9.3 9.8	a
		133.2	-39.2	8.6	b
Pomona	Site 1 Site 2	187.8 186.3	-51.9 -53.4	1.7 2.2	a
	Site 3 Site 4	203.4 195.4	-54.6 -50.6	2.0 2.9	a
		193.5	-52.7	9.5	b
Esquatzel	Site 1 Site 2	340.8 308.0	+63.0 +81.0	3.6 11.4	a
		348.4	+64.8	8.6	b
Asotin	Huntzinger	23.7	+80.6	4.5	b
Wilbur Creek	Wahluke	345.7	+72.1	3.4	b
Umatilla	Sillusi Umatilla	321.7 324.3	+32.2 +31.7	2.6 3.4	b b
Priest Rapids	Lolo	190.5	-64.9	2.8	b
Roza	Site 1 Site 2	214.2 184.7	-14.7 -38.7	7.3 7.0	a
French Springs	Sentinel Gap Sand Hollow Ginkgo	5.0 144.7 146.1	+62.8 +39.8 +42.1	2.2 3.6 2.6	b b b

[a]Choiniere and Swanson (1979).
[b]Van Alstine and Gillett (1981).

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3.2.2.2.3 Priest Rapids Member

The Priest Rapids Member is the youngest member of the Wanapum Basalt (Swanson et al., 1979b) and consists of two distinct flows in the Cold Creek syncline as elsewhere in the Pasco Basin. In core from the Priest Rapids Dam site (see Fig. 3-1), four flows are present, but the three lowest are now considered to be flow lobes of the same flow (Reidel et al., 1980). The member is approximately 46 meters (150 feet) thick in the reference repository location. The older flow is typically coarser grained with rare olivine and plagioclase phenocrysts. The younger flow has small olivine phenocrysts (less than 5 millimeters (0.2 inches) and rare glomerocrysts or phenocrysts of plagioclase. This texture varies from glassy to fine grained with distinct zones having a diabasic texture.

Both flows have distinct chemical compositions (see Table 3-2). The older flow is chemically similar to the Rosalia chemical type of Swanson et al. (1979b), while the younger flow is chemically similar to the Lolo chemical type of Wright et al. (1973). The Lolo flow has lower titanic oxide and higher iron oxide than the Rosalia flow.

Van Alstine and Gillett (1981) sampled a surface exposure of the Lolo flow in the Saddle Mountains for magnetic polarity. The flow was found to have a mean declination of 190.5 degrees and a mean inclination of -64.9 degrees (see Table 3-3). These data are comparable to the inclination of the Lolo flow in core drilled from the central Hanford Site sampled by Packer and Petty (1979). Packer and Petty (1979) also found the Rosalia flow from this core to have reversed magnetic polarity.

The Priest Rapids Member reaches its greatest thickness in an area between the northern flank of Rattlesnake Mountain and the Cold Creek syncline, it thins abruptly across the crest of Rattlesnake Mountain, along the Umtanum Ridge-Gable Mountain structure and along a small, northwest-trending zone on the east side of the Cold Creek syncline.

Both the Rosalia and Lolo flows of the Priest Rapids Member are present throughout most of the Cold Creek syncline area. The lower flow, the Rosalia, is thickest in the trough of the Wahluke syncline (see Fig. 3-1) and Cold Creek syncline, and thins across the Umtanum Ridge-Gable Mountain structure and Rattlesnake Mountain (Reidel et al., 1980). It is thicker on the south side of the Cold Creek syncline and thins northward, abruptly pinching near the southeast boundary of the Hanford Site.

The Lolo flow is also thicker on the southern margin of the Cold Creek syncline and thins across the Umtanum Ridge-Gable Mountain structure and Rattlesnake Mountain. The maximum thickness occurs in a northwest-southeast zone that parallels the present axis of the Cold Creek syncline. Evidence for ponding and slow cooling along the north side of Rattlesnake Mountain is apparent from areas where the basalt has a diabasic texture. The Lolo flow also pinches out on the east side of the Pasco Basin beyond the limits of the Hanford Site (Reidel et al., 1980).

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3.2.2.3 Saddle Mountains Basalt

The Saddle Mountains Basalt consists of seven members in the Pasco Basin: (1) Umatilla, (2) Wilbur Creek, (3) Asotin, (4) Esquatzel, (5) Pomona, (6) Elephant Mountain, and (7) Ice Harbor (see Fig. 3-6). The Umatilla, Esquatzel, Pomona, and Elephant Mountain are the only members of the Saddle Mountains Basalt present in the reference repository location. The Saddle Mountains Basalt in the Pasco Basin ranges in age from 13.5 to 8.5 million years before present (Watkins and Baksi, 1974; McKee et al., 1977; ARHCO, 1976).

The Saddle Mountains Basalt flows were erupted over a much greater interval of time than the flows of any other formation of the Columbia River Basalt Group (Swanson et al., 1979b) and contain widely diverse petrographic characteristics, chemical types, and magnetic inclinations. Vents for the Saddle Mountains Basalt have been recognized in eastern Washington, northeastern Oregon, and western Idaho (Taubeneck, 1970; Price, 1977; Ross, 1978; Camp, in Swanson et al., 1979a).

Thickness variations in the Saddle Mountains Basalt are greater and more complex than in the Wanapum Basalt because of (1) thinning over structures, (2) a greater time between eruptions, and (3) the limited extent of many flows. Variations in data could also be attributable, in part, to the greater amount of information available for the Saddle Mountains Basalt than for other formations (Reidel et al., 1980).

Only the members of the Saddle Mountains Basalt present in the reference repository location are discussed below. Information on those members not present in the reference repository location can be found in Swanson et al. (1979b) and Reidel and Fecht (1981).

3.2.2.3.1 <u>Umatilla Member</u>

The Umatilla Member is approximately 70 meters (225 feet) thick in the reference repository location and consists of two flows in the Pasco Basin. Based on chemical correlations with the type localities described by Laval (1956), the younger flow is the Sillusi flow and the older flow is the Umatilla flow (see Fig. 3-6). Both flows are fine-grained to glassy with rare microphenocrysts of plagioclase and olivine and even rarer silicic xenoliths of basement rock.

Both the Umatilla and Sillusi flows have similar overall chemical compositions and fall into the Umatilla chemical type of Wright et al. (1973). Distinct differences in chemical composition, however, allow the flows to be distinguished. The Umatilla flow has higher titanic oxide, magnesium oxide, and lower phosphorus pentoxide than the Sillusi flow (see Table 3-2).

Reitman (1966) found that the Umatilla Member has normal magnetic polarity. Van Alstine and Gillett (1981) found that the Umatilla and

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Sillusi flows have nearly identical mean declinations of 324.3 degrees and 321.7 degrees and mean inclinations of +31.7 degrees and +32.2 degrees, respectively (see Table 3-3). They suggest that this indicates that the flows were erupted nearly contemporaneously.

The flows of the Umatilla Member entered the Pasco Basin from the south and filled the Cold Creek syncline. The overall geometry of the Umatilla Member is that of a wedge that thins to the north. The member pinches out just north of the Umtanum Ridge-Gable Mountain trend and just east of the Cold Creek syncline (Reidel et al., 1980). It is much thinner on the crest of Rattlesnake Mountain and Yakima Ridge (see Fig. 3-1). Thinning is also apparent across the subsurface extensions of Gable Mountain and Gable Butte.

Both the Umatilla and Sillusi flows are present throughout most of the Cold Creek syncline. The Umatilla flow is the thicker flow in the western and southern parts of the syncline, but the Sillusi flow is the only flow present in the eastern part and is the thicker flow in the northern part of the syncline. The western part of the Cold Creek syncline was covered first by the Umatilla flow and then the Sillusi flow was later directed along the northern and eastern margins of the Umatilla flow with some onlap. This distribution was probably a result of the Sillusi flow filling the low area formed between the gently westward-dipping, regional paleoslope and the northward-tapering margin of the Umatilla flow.

3.2.2.3.2 Esquatzel Member

The Esquatzel Member in the Pasco Basin consists of one to two flows or flow lobes that total approximately 70 meters (225 feet) thick in the reference repository location. In the eastern Cold Creek syncline, there are two Esquatzel flows or flow lobes that occur locally with a vitric tuff between them.

The Esquatzel Member is plagioclase-phyric to glomerophyric and contains microphenocrysts of clinopyroxene. The abundance of phenocrysts varies throughout the Cold Creek syncline area; some localities are completely void of phenocrysts.

The average chemical composition of the Esquatzel Member is given in Table 3-2 and falls within the Esquatzel chemical type of Swanson et al. (1979b). Van Alstine and Gillett (1981) indicated that flows of the Esquatzel Member have normal polarity with a mean declination of 348.4 degrees and a mean inclination of +64.8 degrees (see Table 3-3). These results are similar to those determined by Choiniere and Swanson (1979).

Flows of the Esquatzel Member entered the Pasco Basin from the east near Mesa in a channel that was cut into the Priest Rapids Member (Swanson et al., 1979a; Reidel et al., 1980). It is confined to the southern and eastern parts of the Pasco Basin and pinches out along and north of the

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Umtanum Ridge-Gable Mountain structure. It is thicker in the western Cold Creeks syncline area north of the Yakima Ridge subsurface extension. It also thins across the subsurface extension of the Yakima Ridge and Rattlesnake Mountain structures and pinches out just south of the present crest of Rattlesnake Mountain. The Esquatzel Member exited the Pasco Basin in channels to the west (Goff, 1981; Goff and Myers, 1978; Reidel et al., 1980).

Several factors probably controlled the distribution of the Esquatzel Member in the Cold Creek syncline. First, the margin of the Huntzinger flow of the Asotin Member (see Fig. 3-6) formed a barrier that prevented the Esquatzel flow from spreading across the northern Pasco Basin. The channel that the Esquatzel flow occupies near Mesa is probably part of the same channel that is now filled by sediments along the southern margin of the Huntzinger flow in the Cold Creek syncline. The Umtanum Ridge-Gable Mountain structure was a structural high that influenced the spread of the Esquatzel flows to the west, as indicated by the absence of the Esquatzel Member west of Gable Butte. Rattlesnake Mountain was also important in controlling flows of the Esquatzel Member, as evidenced by its pinchout near the present crest.

3.2.2.3.3 Pomona Member

The Pomona Member has been dated at 12 million years before present (McKee et al., 1977). The member consists of one to two flows or flow lobes in the Pasco Basin, but only one flow approximately 80 meters (260 feet) thick is present in the reference repository location.

The texture of the Pomona Member is relatively uniform across the Pasco Basin. It typically is fine grained to glassy with wedge-shaped plagioclase phenocrysts and rare olivine.

The Pomona Member has a distinct chemical composition (Pomona chemical type of Wright et al., 1973) with little overall variance (see Table 3-2). The member has reversed magnetic polarity (Reitman, 1966; Choiniere and Swanson, 1979). This polarity was corroborated by Van Alstine and Gillett (1981) who also found that the Pomona Member has the tightest inclination and declination grouping of any flow analyzed from the Columbia River Basalt Group. The Pomona Member has a mean declination of 193.5 degrees and a mean inclination of -52.7 degrees (see Table 3-3).

The Pomona Member is present throughout most of the Pasco Basin and reaches its greatest thickness in the southeast portion of the Cold Creek syncline and just north of Gable Mountain in the Wahluke syncline. The Pomona Member thins over the Umtanum Ridge-Gable Mountain structure, Rattlesnake Mountain, and the subsurface extension of Yakima Ridge.

The volume of Pomona lava that was flowing into the Pasco Basin was considerably greater than that of the Umatilla Member and Esquatzel Members. This volume overcame any effects of flow edges and topography, and the Pomona flow buried the topography of the Cold Creek syncline and much of the Pasco Basin.

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3.2.2.3.4 Elephant Mountain Member

The Elephant Mountain Member has been dated at 10.5 million years before present (McKee et al., 1977) and consists of two separate flows: (1) Elephant Mountain flow (Waters, 1955, 1961) and (2) Ward Gap flow (Schmincke, 1967b). Only the Elephant Mountain flow is present in the reference repository location and is approximately 25 meters (80 feet) thick.

The texture of both of the flows is medium-to-fine grained with abundant microphenocrysts of plagioclase. Where lava ponded, the flows exhibit a coarse-grained texture. Both flows (see Table 3-2) fit the Elephant Mountain chemical type of Wright et al. (1973).

Choiniere and Swanson (1979) and Rietman (1966) reported that the Elephant Mountain Member has transitional to normal magnetic polarity. Van Alstine and Gillett (1981) sampled surface exposures and found that both flows yielded a mean declination of 133.2 degrees and a mean inclination of -39.2 degrees (see Table 3-3).

The Elephant Mountain Member is stratigraphically younger than the Rattlesnake Ridge interbed of the Ellensburg Formation, but in many areas an invasive relationship between basalt and sediment has been observed. Both Elephant Mountain Member flows pinch out in the northwest part of the Cold Creek syncline. The member is thicker in the eastern part of the Cold Creek syncline area and thins toward Rattlesnake Mountain. The Elephant Mountain flow has a greater lateral extent than the Ward Gap flow, but both flows pinch out near the northwest corner of the reference repository location. The Elephant Mountain Member defines the top of basalt over most of ~~in~~ the ~~western~~ Cold Creek syncline ~~area.~~ on the Hanford Site.

3.2.2.4 Ellensburg Formation

The Ellensburg Formation is a Miocene fluvial sequence that is relatively thick along the western margin of the plateau and thins eastward onto the central Columbia Plateau. Within the Pasco Basin and reference repository location, Ellensburg Formation sediments are primarily interbedded with the Wanapum Basalt and Saddle Mountains Basalt flows. The nomenclature for the Ellensburg Formation in the Pasco Basin is presented in Figure 3-6. The lateral extent and thickness of the sediments generally increase upward in the section.

The Ellensburg Formation of the central plateau is composed of two major and distinct lithologies of different provenance (Schmincke, 1964, 1967a; Swanson et al., 1979b). One includes volcaniclastic sediments deposited as ashfall and by tributary rivers flowing onto the central plateau. The other includes clastic, plutonic, and metamorphic rock derived from Rocky Mountain terrain that was carried onto the plateau by westward-flowing, ancestral rivers. These two major lithologies occur either as distinct or mixed deposits within the Ellensburg Formation of

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the Pasco Basin. The stratigraphic and geochemical characteristics at the Ellensburg formation in the Pasco Basin have not as yet been studied in detail. Determination of these characteristics are included in plans for site characterization (see Section 4.1.1).

3.2.2.5 Ringold Formation

The Ringold Formation overlies the Columbia River Basalt Group within most of the Pasco Basin (see Fig. 3-6), except where (1) basalt outcrops, (2) the glaciofluvial Hanford formation onlaps ridges above the margin of the Ringold Formation, or (3) the Ringold Formation has been eroded and Hanford formation sediments have been deposited directly on basalt. Based on fossils and paleomagnetic data in the Pasco Basin, the Ringold Formation is interpreted to range from 8.5 million years (post-Ice Harbor Member) to 3.7 million years in age (Tallman et al., 1981, pp. 2 through 25). Ringold Formation sediments were deposited in a fluvial environment with some lacustrine and fanglomerate facies.

The Ringold Formation in the Pasco Basin is classified into three section types (Tallman et al., 1981, pp. 2-3 through 2-7; Fig. 3-19). The Ringold Formation in the reference repository location is represented primarily in section Type I, composed of basal, lower, middle, and upper textural units (Fig. 3-20). The following discussion is based on borehole studies of the Ringold Formation and other suprabasalt sediments in the reference repository location by Bjornstad (1984). The suprabasalt stratigraphy was developed using the boreholes within and adjacent to the reference repository location (see Fig. 3-7).

Within the reference repository location the Ringold sequence ranges from about 105 to 215 meters (about 350 to 700 feet) in thickness.

In the reference repository location, the basal Ringold unit overlies the Elephant Mountain Member of the Saddle Mountains Basalt (see Fig. 3-20). The basal Ringold unit represents a complete fining-upward, fluvial cycle consisting of three correlative subunits. These are from oldest to youngest: (1) a coarse facies, (2) a fine facies, and (3) a paleosol. The coarse facies is composed of an angular medium-to-coarse sand and well-rounded, polished, cobble gravel. Secondary fining-upward cycles are common within the basal Ringold unit coarse facies but occur locally and are not usually correlative from one borehole to another.

Overlying the basal Ringold unit coarse facies is a conformable sequence of cross-laminated and micaceous, light-colored mud (e.g., mixture of silt and clay) and sand that marks the transition to a lower-energy fluvial environment. This facies grades upward into and is capped by a well-developed laterally extensive paleosol. The paleosol is composed of two relic soil horizons: a laminar to massive, white caliche representative of a "C" horizon overlain by a massive, olive-colored, illuvial "B" soil horizon.

Laminated silt and clay of the lower Ringold unit overlie the basal Ringold unit in the reference repository location (see Fig. 3-20). In the reference repository location, the lower Ringold is disconformable with

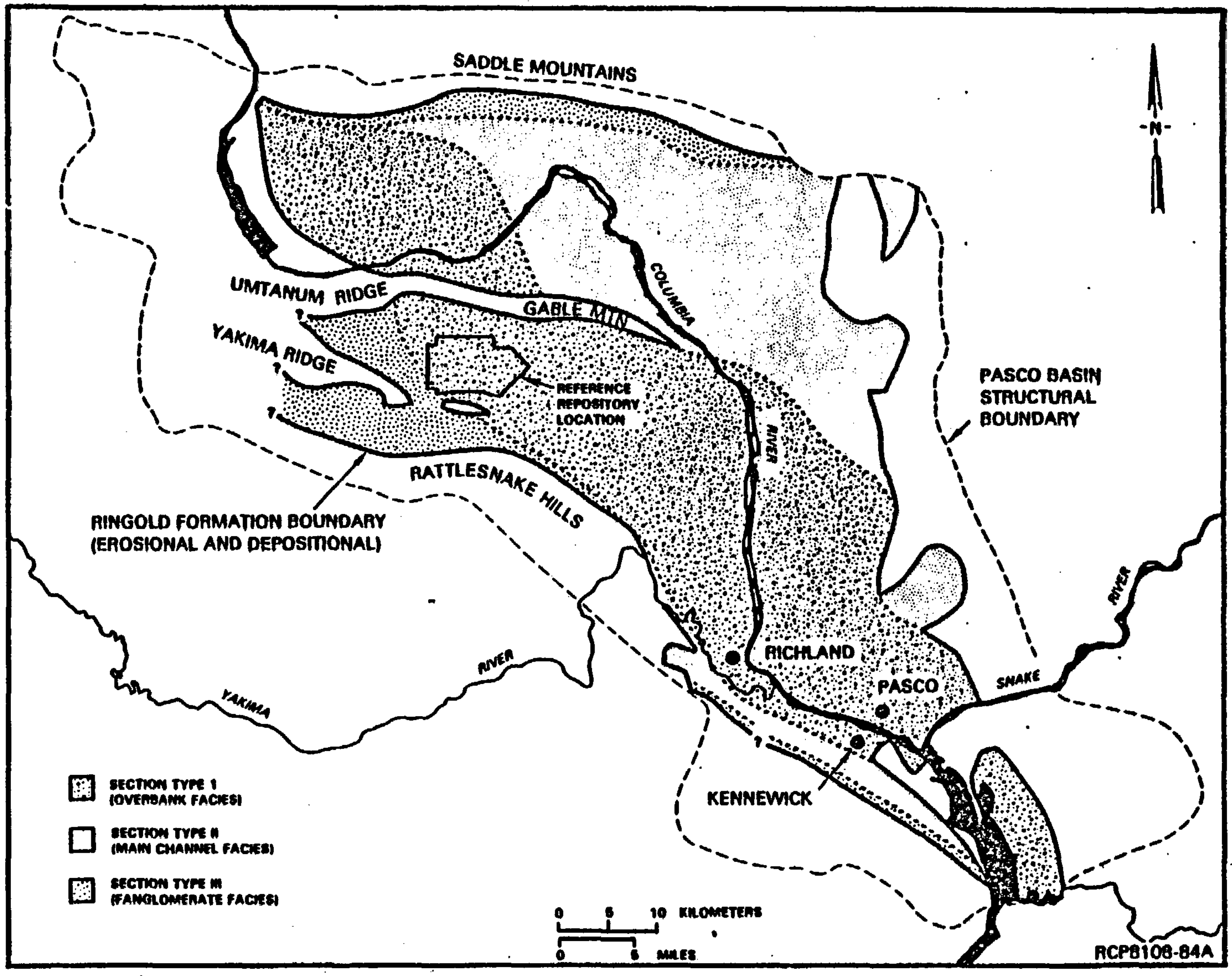

Figure 3-19. Distribution of Ringold Formation selection types.

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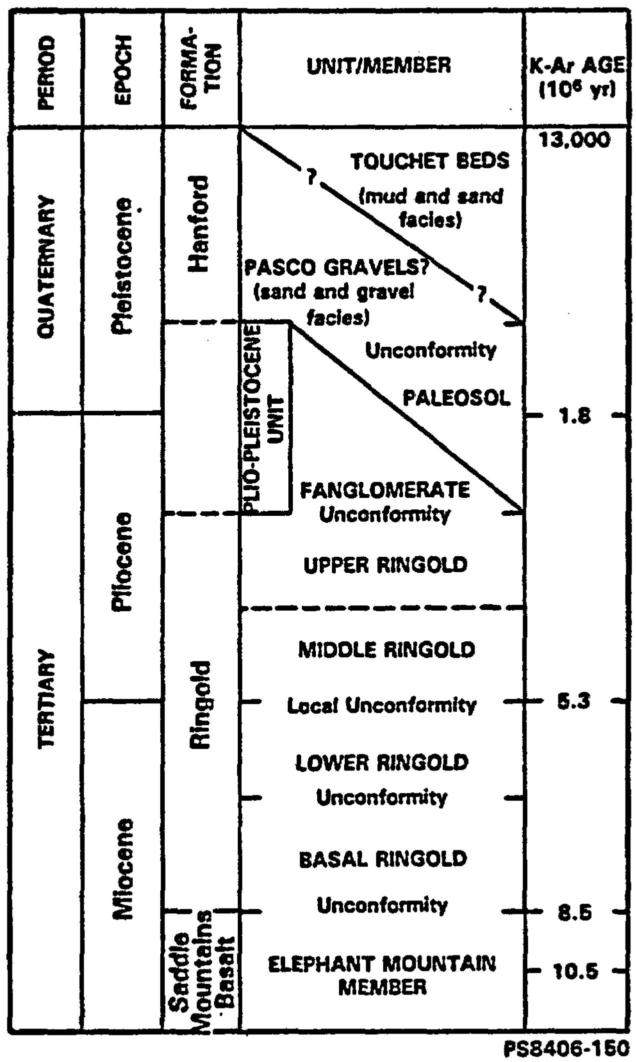

FIGURE 3-20. Suprabasalt stratigraphy in the reference repository location.

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the basal Ringold Formation paleosol and is distinguishable by: (1) the presence of primary sedimentary structures, (2) a distinct gray versus olive color, and (3) a significantly higher natural gamma response in geophysical logs.

The middle Ringold unit, the thickest of the suprabasalt units, is unconformable with the lower Ringold unit with up to several meters (feet), locally, of erosional relief (see Fig. 3-20). The middle Ringold unit is texturally and mineralogically similar to sandy gravel of the basal Ringold facies (Tallman et al., 1981, pp. 2-27 through 2-19) except for a higher proportion of quartzite to volcanic porphyry lithologies for the middle Ringold unit. Locally, the middle Ringold unit sequence is intercalated with thin zones of current-laminated sand and mud.

The upper Ringold unit conformably overlies the middle Ringold unit in the reference repository location (see Fig. 3-20). It consists of alternately bedded and laminated sand and mud representative of a low-energy fluvial environment. The maximum elevation of upper Ringold unit over the reference repository location was probably much higher at one time as indicated by the present elevation of the upper Ringold unit preserved in the White Bluffs to the east (277 meters (900 feet)). The large variations in thickness of the upper Ringold unit in the reference repository location are primarily due to erosion by more recent local streams. Figure 3-21 shows an incised paleostream channel in the Ringold Formation along the axis of the Cold Creek syncline.

3.2.2.6 Plio-Pleistocene Unit

Overlying the Ringold Formation in the reference repository location is the Plio-Pleistocene unit that consists of two subunits: a fanglomerate and a paleosol (see Fig. 3-20). The fanglomerate facies is generally composed of angular, poorly sorted, gravel derived from the mass wastage off the ridges surrounding the Cold Creek syncline (Bjornstad, 1984). The basaltic gravel is often intercalated with zones of loess and caliche which represent intermittent periods of alluvial fan stabilization. The fanglomerate facies is thickest beneath the present Cold Creek Valley where coarse sidestream facies partially filled a paleochannel. Within the reference repository location, the fanglomerate facies becomes thinner and finer to the northeast where it grades into a paleosol, which developed after incision of the Ringold surface. The Plio-Pleistocene unit appears to correlate with fanglomerate sequences present near the base of the basaltic ridges that bound the Pasco Basin on the north, west and south.

3.2.2.7 Hanford formation

Catastrophic flood deposits of the Hanford formation were deposited when ice dams in western Montana and northern Idaho were breached, allowing large volumes of water to spill across eastern and central Washington (Bretz, 1923, pp. 51 through 55). Evidence exists for multiple floods; however, the exact timing and frequency of these floods is

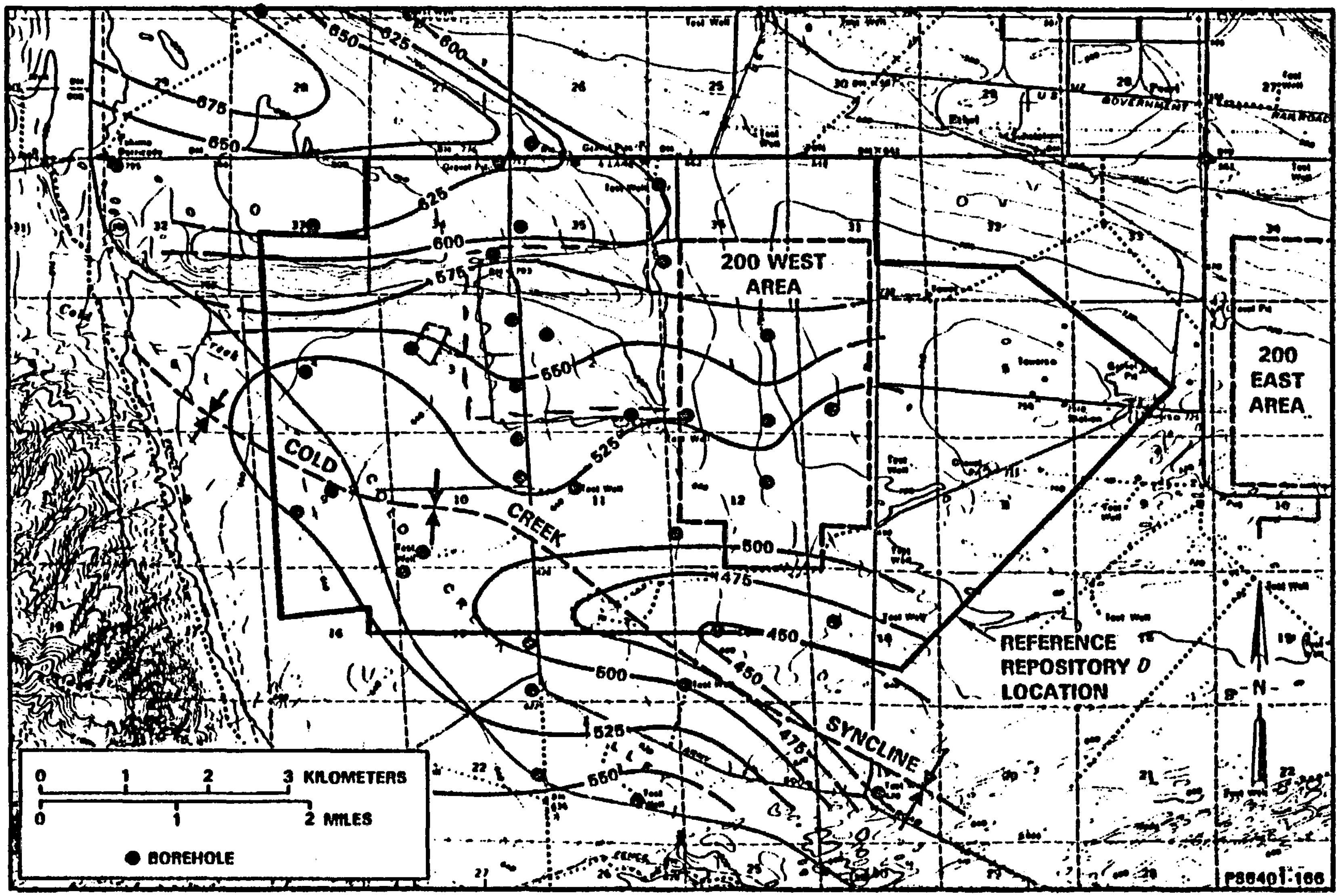

Figure 3-21. Top of the Ringold Formation. Contour pattern indicates maximum post-Ringold incision occurred near the trend of the present Cold Creek Valley.

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undetermined (Baker, 1983, pp. 123 and 124). Most of the sediments are late Pleistocene, with the last major flood sequence dated at approximately 13,000 years before present (Mullineaux et al., 1977, p. 1105). These deposits (referred to as the Hanford formation in the Pasco Basin) are composed of two facies: a flood facies (Pasco Gravel) and slack water facies (Touchet Beds) (see Fig. 3-6 and 3-20).

Pasco Gravels are composed of coarse sand and gravel. They are restricted mainly to the late Pleistocene flood bars that developed along high-energy flood channelways. Two such flood bars are present within the reference repository location: the Umtanum Ridge bar to the north and the 200 Areas bar, which is a continuation of the Umtanum Ridge bar to the southeast (see Section 3.2.1). The Pasco Gravels have been subdivided into the Missoula and pre-Missoula gravels by Puget Sound Power & Light Company (PSPL, 1982, p. 2R-22 and 2R-23) in the central Hanford Site. There is no confirmed evidence for pre-Missoula gravels in the reference repository location.

Touchet Beds are a rhythmically bedded and fine-grained, slackwater flood facies deposited away from the flood bars and generally coeval with the Pasco Gravels. They are most common in the southern and western parts of the reference repository location and to the east where they underlie Pasco Gravels associated with the 200 Areas flood bar.

check conversion 3,936 (ft) feet

structural relief on the Basaltic ridges is up to about 1200 meters (3600 ft), the wavelengths are typically 5 to 10 kilometers (3-6 miles).

3.2.3 Structure and Tectonics

The Pasco Basin and reference repository location are located along the eastern boundary of the Yakima Fold Belt structural subprovince (see Fig. 2-6). Structures in the Pasco Basin area are characterized by long, narrow anticlines and broad synclines extending generally eastward from the western Columbia Plateau to the Pasco Basin where they generally die out (Fig. 3-22). Most known faults within the region are associated with anticlinal fold axes, thrust or reverse (although normal faults are also present), and probably developed concurrently with folding. Anticlinal folds bound the Pasco Basin on the north (Saddle Mountains) and south (Rattlesnake Hills) and plunge eastward to the Pasco Basin from the west (Umtanum Ridge and Yakima) (see Fig. 3-21). These anticlinal folds typically are concentric, gentle to tight, and upright to inclined. The gentle, upright folds are generally symmetric, whereas the tighter inclined folds are asymmetric, with the steeper limb sometimes vertical to overturned (Price, 1982, p. 12). Asymmetric folds are generally vergent to the north.

that encompasses about 4,850 square kilometers (1900 square miles) of the central Columbia Plateau

The Pasco Basin is elongate northwest-southeast and is somewhat arcuate in form (see Fig. 3-1). Main structural trends in the basin are easterly in the northwestern part and southerly in the southeastern part (see Fig. 3-22). The Saddle Mountains structure is convex to the north and forms the northern boundary of the basin. The southern boundary is formed by the Rattlesnake Hills structure which is convex to the south. The geometry of the central basin reflects these two structures. In the

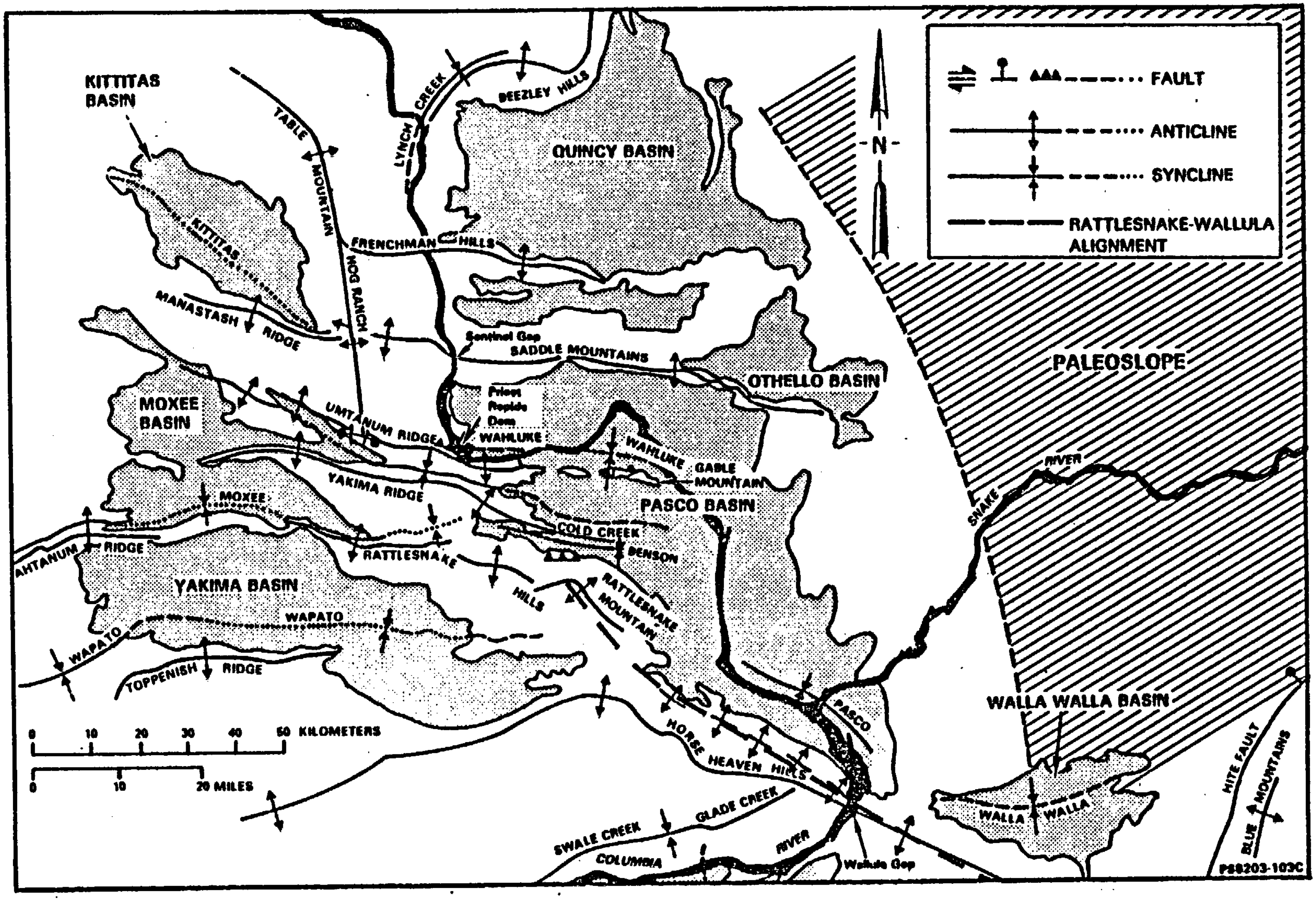

Figure 3-22. Generalized geologic structure map of central Columbia Plateau.

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northwestern part of the basin, the Wahluke syncline, Umtanum Ridge-Gable Mountain structure, Cold Creek syncline, Yakima Ridge structure, and Benson Ranch syncline trend subparallel to the Saddle Mountains structure. The north Pasco Basin structure and portions of the Pasco syncline reflect the Rattlesnake Hills structures. Structural relief decreases eastward from the western basin margin and many folds terminate within the central Pasco Basin. The southeastern part is structurally less deformed by first-order folds than the southwestern part of the basin.

3.2.3.1 Wahluke Syncline

The Wahluke syncline lies between the Saddle Mountains structure and the Umtanum Ridge-Gable Mountain structure. The trough line of the Wahluke syncline is much nearer the Umtanum Ridge-Gable Mountain structure than the Saddle Mountains structures; consequently, its cross section is asymmetric with a steep southern limb. The top of basalt is approximately 61 meters (200 feet) below mean sea level in the lowest part of the Wahluke syncline.

3.2.3.2 Umtanum Ridge-Gable Mountain structure

The Umtanum Ridge-Gable Mountain structure extends from the east end of Gable Mountain on the Hanford Site westward and west-northwestward to southwest of Ellensburg, Washington, a distance of 110 kilometers (70 miles) (see Fig. 3-22). This discussion is confined to that portion of the structure within the Pasco Basin, which is divided into two segments in the basin: (1) Umtanum Ridge segment, and (2) Gable Butte and Gable Mountain segment.

Eastern Umtanum Ridge segment is an asymmetrical, box-shaped, overturned, plunging anticline whose crestal surface bifurcates into several subsidiary en echelon folds along the major fold trend (Goff and Myers, 1978; Goff, 1981). The fold is flanked by the Wahluke syncline and Cold Creek syncline to the north and south, respectively. In the Priest Rapids Dam area (see Fig. 3-21), the fold is interpreted by Bentley (1980) to consist of three imbricate thrust slices in which the basalt is folded, overturned, and thrust over relatively undeformed Mabton-equivalent sediments of the Ellensburg Formation. Structural relief and complexity appear to decrease toward the central Pasco Basin. Here, the structure is interpreted by Goff (1981) as a simple, asymmetrical, eastward-plunging anticline with a steeply dipping north limb. Although the fault is covered east of the Priest Rapids Dam area, fault displacement is expected to decrease as structural relief decreases. Current judgment is that the Umtanum fault probably dies out approximately 11 kilometers (7 miles) east of Priest Rapids Dam (Myers, 1981).

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Gable Mountain and Gable Butte are topographically isolated, anticlinal ridges of basalt and interbedded sediments that are the only extensive bedrock outcrops in the central Pasco Basin (see Fig. 3-9). Portions of this segment of the Umtanum Ridge-Gable Mountain structure have been mapped by Newcomb et al. (1972), Bingham et al. (1970), Washington Public Power Supply System (WPPSS, 1974), Brooks (1974), Fecht (1978), and Puget Sound Power & Light Company (PSPL, 1982). The surface expression of Gable Mountain and Gable Butte is a series of westerly trending, doubly plunging, en echelon anticlines and synclines. These structures are interpreted as second-order folds within the closure of an asymmetrical first-order fold, consistent with the interpretation of Fecht (1978). These folds are flanked by the Wahluke syncline and Cold Creek syncline to the north and south, respectively. Although the geometry of the first-order fold is somewhat obscured by the second-order folds, it has been estimated from surface exposures, geophysical surveys, and borehole data. The southern flank of the first-order fold has a gentle southerly dip (approximately 2 degrees); the northern flank has a steeper northerly dip (approximately 11 degrees). The structural relief on this segment of the Umtanum Ridge–Gable Mountain structure is up to about 400 meters (1300 feet).

Second-order folds on Gable Mountain and Gable Butte trend west to northwest, with the exception of a northeasterly trending syncline on Gable Butte. Generally, second-order fold axes are parallel and form a westerly trending, en echelon pattern across Gable Mountain and Gable Butte. The axial trends of individual second-order folds are generally curvilinear. The termini of the hinge lines in both anticlinal and synclinal folds are either doubly plunging or are subdued by surrounding folds having higher amplitudes and greater wavelengths. The second-order folds tend to be asymmeterical in profile, with the two larger, second-order folds on Gable Mountain having opposite directions of asymmetery. Angles subtended by the two flanks and the fold closure of the second-order folds range from open to gentle, and angular to rounded, depending on the amplitude and wavelength of a given fold.

Faulting on Gable Mountain has recently been investigated by Golder Associates (PSPL, 1982, Section 20) and U.S. Nuclear Regulatory Commission (NRC, 1982b, Appendixes G and H). These studies examined three previously mapped faults, termed the south and central faults, which are located in the central Gable Mountain area and the west fault on the west end of Gable Mountain (Bingham et al., 1970, pp. 48 through 62; Fecht, 1978, pp. 43 through 47). During these investigations a fourth, buried fault was discovered in the central Gable Mountain area. All faults on Gable Mountain, except for the west fault, are reverse faults that dip toward the north or south with displacements of approximately 12, 50, and 98 meters (40, 165, and 300 feet) for the south, central, and buried reverse faults, respectively. The west fault is interpreted as a north-trending normal fault. The faults on Gable Mountain are tear faults, interpreted to be in response to folding. The length of the faults are controlled by ... with small displacement, perhaps as much as 10 meters (30 feet).

New trenches in the central Gable Mountain area exposed offsets of up to approximately 6 centimeters (0.2 feet) along narrow fractures in glaciofluvial sediments that are continuous with a reverse fault in the basalt. These offset sediments are correlated with other glaciofluvial

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sediments that contain the 13,000-years-before-present Mount St. Helens "set S" ash. Borehole data shows that the fault has much greater displacement in the basalt at depth (the top of the Esquatzel flow is offset approximately 50 meters (160 feet)). The displacement in the glaciofluvial sediments is interpreted (PSPL, 1982, p. 20-5) to be either the latest movement on an older fault of greater displacement at depth or caused by rapid loading and unloading during catastrophic flooding. The U.S. Nuclear Regulatory Commission and U.S. Geological Survey consider the faults in the central Gable Mountain area capable, but of relatively low seismic potential (NRC, 1982b, Supplement 1, p. 2-3). Long-term average displacement rates on the fault were calculated to be very low (approximately 6×10^{-4} centimeters (2×10^{-4} inches) per year) (NRC, 1982b, Supplement 1, p. 2-9).

3.2.3.3 Cold Creek Syncline

The Cold Creek syncline in which the reference repository location is situated occupies the structural low between the Umtanum Ridge-Gable Mountain structure and the Yakima Ridge structure. The Cold Creek syncline is an asymmetric, open, broad, and relatively flat-bottomed fold. The steeper limb is the south limb. Two depressions lie along the trough line of the Cold Creek syncline: Cold Creek Valley depression and Wye Barricade depression located on the western part and eastern part of the Pasco Basin, respectively (see Fig. 3-22). The top of basalt in the center of the Cold Creek Valley depression is nearly flat, except, perhaps, for small, monoclinal flexures. The Wye Barricade depression is a large, irregular-shaped area. The depression appears to be divided into northern and southern subdepressions separated by a buried, asymmetric, low amplitude anticline. The Cold Creek syncline plunges and dies out to the east in the vicinity of the Wye Barricade depression. A key aspect of site-identification work has been the delineation of ~~relatively~~ intact volumes of Saddle Mountains, Wanapum, and upper Grande Ronde Basalt flows in the Cold Creek syncline area. These ~~relatively~~ intact volumes of bedrock are bounded by known or inferred geologic structures, excluding intraflow structures. Based on the results of geophysical surveys and surface and subsurface mapping, the western Cold Creek syncline area is ~~tentatively~~ interpreted to consist of large ~~, relatively~~ intact volumes of bedrock whose boundaries are defined by major or intermediate structures. Overall, the central and eastern parts of the Cold Creek Valley depression, which includes the reference repository location, appear to be free of potentially adverse bedrock structures. ~~relative to other parts of the Cold Creek syncline area and Hanford Site.~~ The structure of the top of basalt and the structure at deeper horizons within this area are interpreted as being nearly flat lying with very gentle dips toward the trough of the Cold Creek syncline, and with a slight westward component of dip toward the deepest point of the Cold Creek Valley depression.

3.2.3.4 Yakima Ridge Structure

The Yakima Ridge structure is a group of topographic ridges representing the surficial expressions of plunging anticlines, monoclines, and related faults. This structure extends west-northwest from the western margin of the Pasco Basin to near Yakima, Washington, a distance of approximately 60 kilometers (37 miles). This discussion is confined to the easternmost one-third of the structure within the Pasco Basin.

The Yakima Ridge structure within the Pasco Basin has been studied by Goff and Gardner for Rockwell Hanford Operations, Bond et al. (1978), Kienle in Washington Public Power Supply System (WPPSS, 1977) and Cochran (1982). The dominant fold within the Yakima Ridge structure is the Cairn Hope Peak anticline. The shorter and steeper north limb of this anticline dips 30 to 40 degrees north and its wider southern limb dips 10 to 15 degrees south. The Cairn Hope Peak anticline trends N70-N75°W and plunges gently southeastward. The southern limb of the Cairn Hope Peak anticline contains two monoclines. The northernmost of the two monoclines, the Cairn Hope Peak monocline trends N60°W and is interpreted by Bond et al. (1978) to merge into the Silver Dollar Fault of Goff and Myers (1978). The southern unnamed monocline trends N70°E.

The Silver Dollar fault offsets Frenchman Spring Member against Umatilla and Pomona Members across a fault breccia zone 50 to 70 meters (165 to 230 feet) wide (Goff and Myers, 1978). The mapped length of the fault is approximately 5 kilometers (3 miles). Because exposures of the fault zone are poor, the inclination of the fault surface is not readily determinable. The Silver Dollar fault was interpreted by Goff and Myers (1978) and Goff for Rockwell Hanford Operations as a high-angle, reverse fault, but by Bond et al. (1978) as possibly a normal fault.

Several small, en echelon anticlines and synclines have been mapped that form the eastern part of the Yakima Ridge. These are open, doubly plunging, slightly asymmetrical, second-order folds; collectively they form the first-order Yakima Ridge structure in that area. The easternmost surface exposure of the Yakima Ridge structure, as mapped by Bond et al. (1978), is represented by two anticlines and a syncline, which plunges eastward into the Pasco Basin. Two faults are known to occur in this portion of the ridge. The first is located on the south flank of the south limb of Yakima Ridge. The fault is westerly trending with an inferred reverse displacement. The second fault is nearly vertical and was mapped by Bond et al. (1978) as truncating the west end of the southernmost second-order anticline. A third fault was proposed by Kienle (in WPPSS, 1977) and by Bond et al. (1978) to account for a linear escarpment and apparent structural displacement on the extreme eastern and southern ends of Yakima Ridge. The existence and nature of such a fault have not been confirmed because of the limited exposure in that area.

The Yakima Ridge plunges east-southeast into the central Pasco Basin. The buried structural high is interpreted as an eastward extension of the Yakima Ridge structure. Current interpretations are that the buried structure is a westerly plunging anticline, based on extensive geophysical

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study by Cochran (1982). The relationship between Yakima Ridge and the Yakima Ridge extension has not been clearly defined, but a saddle or syncline with some possible faulting appears to be separating the two structures.

3.2.3.5 Benson Ranch Syncline

The Benson Ranch syncline (Myers, Price et al., 1979, Plate III-4a) is a subtle syncline situated between the Yakima Ridge and the Rattlesnake Hills structures (see Fig. 3-22). From borehole data, the Benson Ranch syncline appears midway between the two bounding structures. The syncline gently plunges from Dry Creek Valley toward the central basin on the east. The Benson Ranch syncline is probably down-dropped to the east along the same northwest-trending fault that is postulated to offset the Yakima Ridge structure. The Benson Ranch aeromagnetic anomalies and linears indicate that the Benson Ranch syncline and Yakima Ridge anticline continue southwest into the central Pasco Basin, ~~but probably~~ and die out toward the Wye Barricade depression.

3.2.3.6 Pasco Syncline

The Pasco syncline is a broad, low-amplitude depression in the southeastern part of the Pasco Basin. It lies between the Jackass Mountain structure and the Rattlesnake Hills structure and has sinuous trend and loses definition to the north in the Wye Barricade depression. North of the easterly trending segment of the Pasco syncline is a series of small domes aligned parallel to the syncline (Myers, Price et al., 1979; see Plate III-4a). These domes are low relief, areally small features, with short arcuate trends.

3.2.3.7 Rattlesnake-Wallula alignment

The Cle Elum-Wallula lineament is a ~~The most intense zone of deformation within the Pasco Basin region is interpreted to be the~~ 40-kilometer (25-mile) wide zone that can be traced from Cle Elum, Washington, southeast to the Blue Mountains, a distance of approximately 200 kilometers (125 miles). This zone is referred to as the Cle Elum-Wallula deformed belt (Kienle et al., 1977, p. 2RH.7-1). The Cle Elum-Wallula parallels the western and southern boundaries of the Pasco Basin from Wallula Gap northwest to the Saddle Mountains. The segment of the ~~trend~~ lineament between Snively Basin at the north end of Rattlesnake Mountain and the Hite fault along the front of the Blue Mountains is designated the Rattlesnake-Wallula alignment (see Fig. 3-22). It has been interpreted as a continuous 120-kilometer-(75-mile) long right-lateral strike slip or right lateral oblique slip fault which was modeled during the development of siesmic design for the WNP-2 nuclear power plant of the Washington Public Power Supply System on the Hanford Site (WPPSS, 1981, pp. 2.5-131 through 2.5-143; NRC, 1982b, pp. 2-12, 29, 30). The stratigraphy exposed

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in trenches along the Wallula fault system indicates that there has been activity along this fault in the Quaternary. The geomorphic continuity along the Rattlesnake-Wallula alignment has led to the interpretation that this feature is a ~~120-kilometer- (75-mile-) long~~ capable fault (NRC, 1982b, pp. H-4 and H-20), largely in the absence of distinct geologic evidence to the contrary. While there is considerable uncertainty in this interpretation, the continuity of the structure as a possible expression of deep structure has been assumed.

3.2.3.8 Structural Analysis

Structural analysis of Yakima folds in the Pasco Basin area shows that little deformation, other than tectonic jointing, has taken place in the anticlinal crests and that little or no deformation occurred in the syncline trough (Price, 1981). The gently dipping limbs of the anticlines contain widely disseminated, discrete shear zones or faults. The width of these zones is narrow, generally on the order of a few centimeters (inches), although faults up to a meter (3 feet) in width have been observed (Moak, 1981). The steeply inclined flows that are typically present along the north limb of Yakima folds contain the more extensive faulting or brecciation. Thrust and reverse faults with fault zones often 100 meters (300 feet) in width are commonly observed (Myers, Price, et al., 1979). Second-order folds of approximately 5 kilometers (3 miles) of wavelength are present on many anticlinal ridges and are subparallel to en echelon with the major folds. Minor layer-internal faults and cross faults are commonly observed on the fold limbs.

Available structural and tectonic data permit a preliminary interpretation of the pattern and chronology of deformation in the Pasco Basin and reference repository location. Deformation of basalt was in progress during late Grande Ronde time (approximately 14.5 million years before present) as evidenced by the thickness and distribution of flows (Reidel et al., 1983). Uplift on Miocene topography that is presumably of structural origin proceeded at low average rates of between 40 to 80 meters per million years (0.04 and 0.08 millimeters per year) (130 to 260 feet per million years (2×10^{-3} to 4×10^{-3} inches per year)) during the period 14.5 to 10.5 million years ago and this can be interpeted as the vertical component of strain. If these low average rates of uplift are projected to the present, they account for the currently observed structural relief and the elevation of flows on Rattlesnake Hills and the Saddle Mountains. Subsidence in the Cold Creek syncline in the central Pasco Basin relative to the projected Palouse slope of southeastern Washington proceeded at similar rates (Reidel et al., 1983). The decreasing dip of progressively younger strata of the Miocene-Pliocene Ringold Formation on the flanks of anticlines similarly suggests that deformation at relatively low rates of vertical strain was continuous during Neogene and Quaternary time and resulted in greater deformation of older units. Contemporary deformation appears to be continuing at these long-term low average rates as evidenced by the level and distribution of earthquakes and the measured shortening of lines of a

trilateration survey over the period of 1972 to 1981 (Rohay and Davis, 1983). Horizontal strain indicated by six geodetic surveys is of the order of 0.02 to 0.04 millimeters per kilometers per year (2×10^3 to 4×10^{-3} inches per mile per year) compression.

Geologic and seismologic data indicate that the axes of crustal shortening are oriented generally north-south and are nearly horizontal. The nearly east-west strike of anticlinal and synclinal axes and accompanying subparallel thrust and reverse faults suggest nearly north-south, nearly horizontal compression as do the steeply dipping northwest (and some northeast) trending faults. Focal mechanism solutions (for individual events and composites of several presumably related events) suggest that the axis of maximum compression is nearly horizontal and oriented slightly west of north. The axis of minimum compression from fault plane solutions is nearly vertical. Focal planes trend generally east-west, dip steeply, and result from essentially reverse faulting, with little, if any, strike-slip component (see Section 2.1.1.3). This pattern holds for shallow as well as deeper events (greater than 6 kilometers (4 miles)). Measurement of in situ stress by hydraulic fracturing near the reference repository location in the Umtanum flow resulted in a mean (of six measurements) principal compression of North 23 degrees East, and a near vertical axis of least compression (Kim and Haimson, 1982). Geodetic data suggests that the principle compression is directed east-west (Rohay and Davis, 1983) although the strain measurements barely exceed the mesurement error.

Deformation (i.e., vertical strain) in the central Columbia Plateau appears to have established zones of weakness (first-order structures) by at least middle Miocene. Subsequent deformation appears to have occurred along these established first-order structures with subsequent development of lower-order structures in relation to first-order structures, but with no obvious development of very geologically youthful structures. Deformation appears to have been in progress at least 14.5 million years ago and appears to have continued, at least in some structures, to the late Pleistocene or Holocene (Caggiano, 1983).

3.2.4 Seismicity of the reference repository location

No earthquakes were instrumentally located near the reference repository location prior to the installation of a network of seismographs in the central Columbia Plateau in 1969. Since installation of the initial regional network, all earthquakes above 1.8 magnitude have been consistently located with a 1- to 2-kilometer (0.6- to 1.2-mile) epicentral accuracy; depths are accurate to plus or minus 2 kilometers (1.2 miles), with somewhat greater error for shallow events.

The seismicity of the reference repository location is relatively low in comparison to the moderate seismicity of the central Columbia Plateau region (see Fig. 2-9). No shallow depth (less than 4 kilometers (2 miles))

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~~earthquake swarms~~ have ~~actually~~ occurred within the boundaries of the reference repository location although three earthquake sequences (described below) have occurred nearby (Fig. 3-23).

There have been three areas of swarm-type activity within 10 kilometers (6 miles) of the reference repository location. Between November 10 and November 26, 1969, four events occurred between a 3- and 10-kilometer (2- and 6-mile) depth at the southern boundary of the reference repository location. The maximum event had a coda magnitude of 2.2.

The second area is approximately 10 to 15 kilometers (6 to 9 miles north of the reference repository location site. This area appears to have a northeast-southwest trend of activity. Sixty-seven events have been located in this area between 1969 and present. The two most significant earthquakes in this area were a 3.8 coda magnitude, occurring on October 25, 1971, and a 3.4 coda magnitude, occurring on October 20, 1983. Most of the activity appears to be at less than 2 kilometers (1.2 miles) depth.

The third swarm area is located approximately 5 to 8 kilometers (3 to 5 miles) south of the Hanford Site. There have been two activity periods: July 8 through November 4, 1979, and again on August 24 and 25, 1981. Between 1979 and 1981, 15 events occurred, all less than 5 kilometers (3 miles) deep. The largest event was a 2.4 coda magnitude.

A few deeper earthquakes (greater than 4 kilometers (2 miles) in depth) have been recorded within the boundaries of the reference repository location (Fig. 3-24). The earthquakes occur near the base or beneath the Columbia River Basalt Group and are all small, less than coda magnitude 2.5.

Earthquake locations and occurrence rates indicate that the reference repository location is located in an area of relatively low seismicity (see Fig. 2-9 and 3-13). Microearthquake activity in the area around the reference repository location is largely shallow, confined to a crust of 28-kilometer (17-mile) thickness, and is characterized by swarms of low-magnitude earthquakes that occur predominantly in the basalts.

3.3 HYDROLOGIC CONDITIONS

The following two sections address the basic surface and subsurface hydrologic systems within and in the vicinity of the Hanford Site. Specific emphasis is given to the reference repository location. Section 3.3.1 addresses the topic of surface drainage and potential flooding. Subsection 3.3.2 deals with ground-water hydrology.

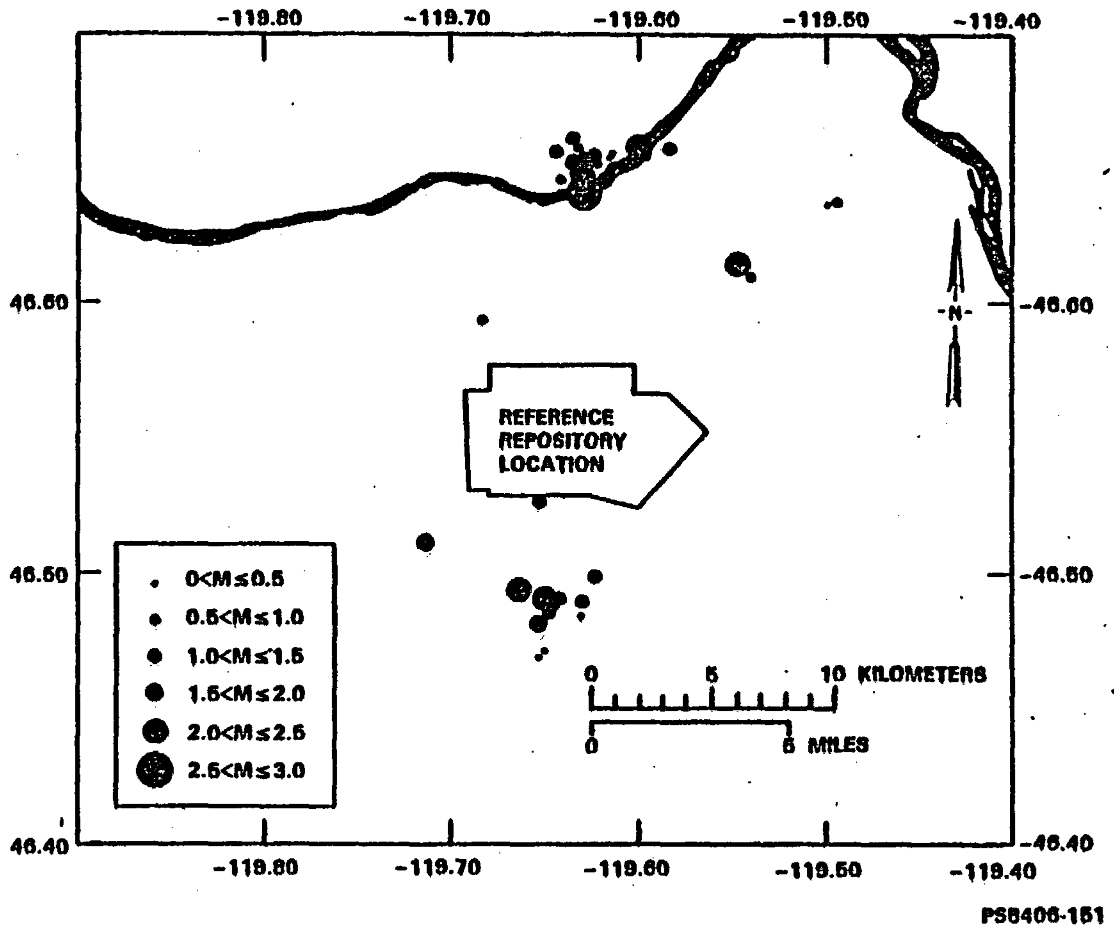

Figure 3-23. Earthquakes located by the University of Washington within 10 kilometers (6.2 miles) of the reference repository location, 1969 through March 1983. All detected earthquakes larger than M coda equal 0, with focal depths less than 4 kilometers (2.5 miles), are shown.

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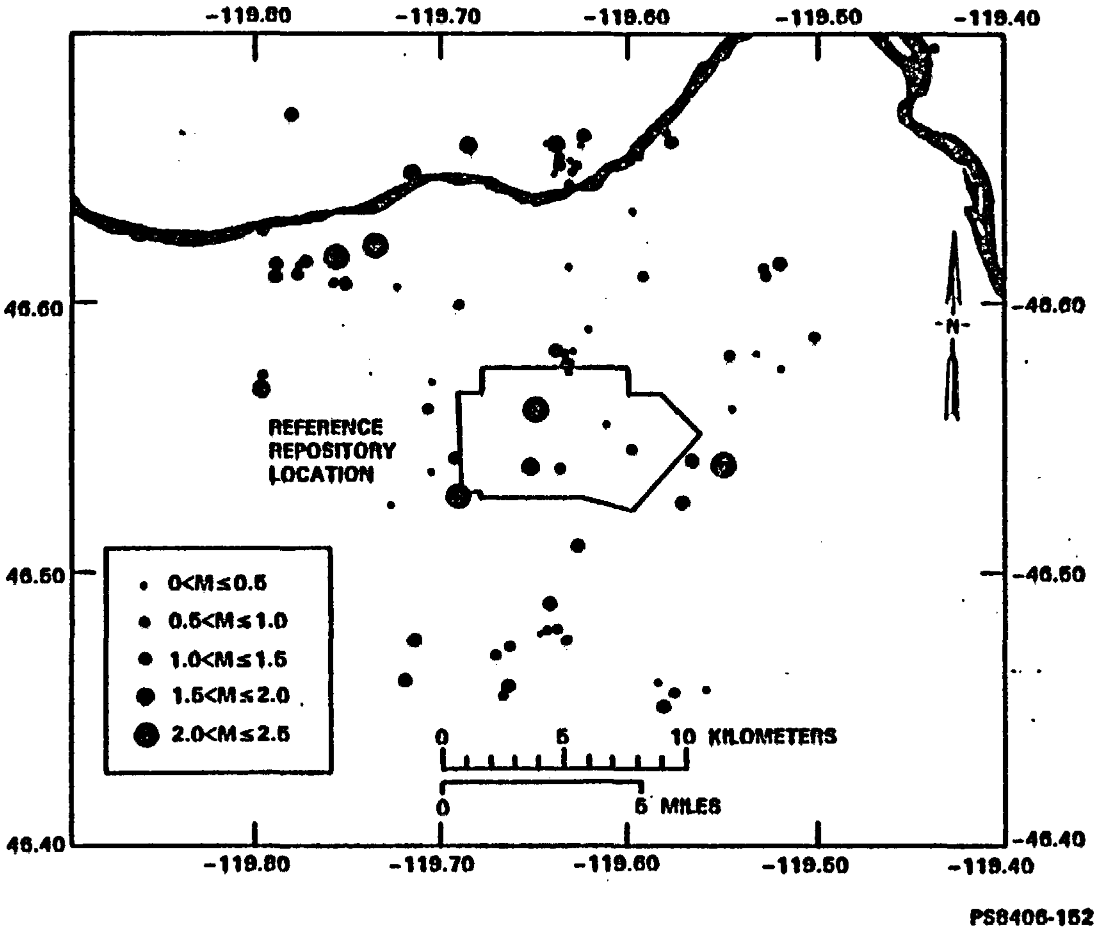

Figure 3-24. Earthquakes located by the University of Washington within 10 kilometers (6.2 miles) of the reference repository location, 1969 through March 1983. All earthquakes greater than 4 kilometers (2.5 miles) deep are shown.

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3.3.1 Surface water

This section examines the surface hydrology of the Pasco Basin and the Hanford Site. Surface flooding potentials are also addressed. The regional surface hydrologic setting is described in Section 2.1.

3.3.1.1 Pasco Basin

The Pasco Basin occupies approximately 4,850 kilometers (1,900 square miles) and is located within the centermost portion of the Columbia Plateau (see Fig. 2-13). Because of its topographically low position within the plateau, surface drainage enters the Pasco Basin from several other basins.

The Columbia River is joined in the Pasco Basin by major tributaries including the Yakima, Snake, and Walla Walla Rivers. No perennial streams are supported by hydrologic systems operating solely within the Pasco Basin.

Mean annual precipitation within the Pasco Basin ranges from less than 18 centimeters (7 inches) within the Hanford Site to just over 38 centimeters (15 inches) atop Rattlesnake Mountain (see Section 3.4.3). Total precipitation over the entire basin is estimated at 9.9×10^8 cubic meters (800,000 acre-feet) annually, averaging less than 20 centimeters (8 inches). Mean annual runoff is very low, generally less than 1.3 centimeters (0.5 inch) for most of the basin. Total annual runoff is less than 3.1×10^7 cubic meters (25,000 acre-feet) per year, and the basin-wide runoff coefficient, for all practical purposes, is zero.

Average annual evaporation can exceed 152 centimeters (60 inches). Average annual lake evaporation ranges from approximately 100 to over 105 centimeters (39 to over 42 inches). Actual evapotranspiration for a 15-centimeter (6-inch) water-holding-capacity soil (uncultivated) is approximately 19 to 22 centimeters (7.5 to 8.5 inches). Based on this estimate, total actual evapotranspiration for the basin would be approximately 9.9×10^8 cubic meters (800,000 acre-feet) annually.

Streamflow within the Pasco Basin is recorded as inflow at the U.S. Geological Survey gage below Priest Rapids Dam and outflow at the gage below McNary Dam (see Fig. 2-13). Average annual flow at these stations is 1.1×10^{11} and 1.7×10^{11} cubic meters (89,000,000 and 140,000,000 acre-feet), respectively. A total gaged flow of approximately 5.5×10^{10} cubic meters (44,830,000 acre-feet) per year enters from tributaries, and an additional 2.8×10^8 cubic meters (225,000 acre-feet) enter as irrigation returns. ~~This surface water budget implies that substantial ground-water quantities are discharged to the Columbia River in the Pasco Basin (Gephart et al., 1979). However~~, the error band associated with the surface water volumes measured prevents a strong quantitative evaluation of ~~this~~ inflow from being made.

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3.3.1.2 Hanford Site

The Hanford Site occupies approximately one-third of the land area within the Pasco Basin. Primary surface water features associated with the Hanford Site include the Columbia and Yakima Rivers. Several surface ponds and ditches are present, and are generally associated with fuel and waste processing activities (Fig. 3-25).

Flow from approximately two-thirds of the Hanford Site is considered to drain directly into the Columbia River, although runoff is extremely low. The reference repository location straddles a divide between the Columbia and Yakima River watersheds. The section of the Columbia River along the Hanford Site reach, which extends from the headwaters of Lake Wallula to the Priest Rapids Dam, has been inventoried and is described in detail in the U.S. Army Corps of Engineers (COE, 1977). Flow along this reach is controlled by the Priest Rapids Dam. Several drains and intakes are also present along this reach. Most notably, these include irrigation outfalls from the Columbia Basin Project and Hanford Site intakes for the onsite water import system.

Cold Creek and its tributary, Dry Creek, are ephemeral streams within the Yakima River drainage system along the southern boundary of the Hanford Site (see Fig. 3-25). Approximately one-third of the Hanford Site is drained by the Yakima River system. The southwestern two-thirds of the reference repository location is considered to be situated within the Cold Creek watershed.

The Yakima River bordering the southern portion of the Hanford Site has a low annual flow, compared to the Columbia River. Average annual discharge of the Yakima River, measured at Kiona, Washington, is on the order of 3.3×10^9 cubic meters (2,700,000 acre-feet).

West Lake, a shallow (less-than-1-meter (-3-foot)) pond, is the only natural pond within the Hanford Site. Its presence is probably attributable to a combination of factors, such as its location within a topographic depression (which places it closer to the water table) and vertical ground-water leakage from shallow confined aquifers (due to the location of the pond along the Gable Mountain anticlinal axis) (Gephart et al., 1976). The pond generally averages 4 hectares (10 acres) in size. Additionally, a number of manmade ditches and ponds (see Fig. 3-25) are used for the disposal of low-level radioactive wastes, certain industrial wastes, other laboratory and sanitary wastes, and for the discharge of water used for plant cooling (ERDA, 1975; Gephart et al., 1976).

The Hanford Site also incorporates the hydrometeorological extremes found within the Pasco Basin with respect to precipitation and evapotranspiration. The lowest precipitation and highest evapotranspiration values within the basin tend to occur within the lower elevations toward the center of the Hanford Site; whereas, the opposite extremes are found atop Rattlesnake Mountain (see Fig. 3-16).

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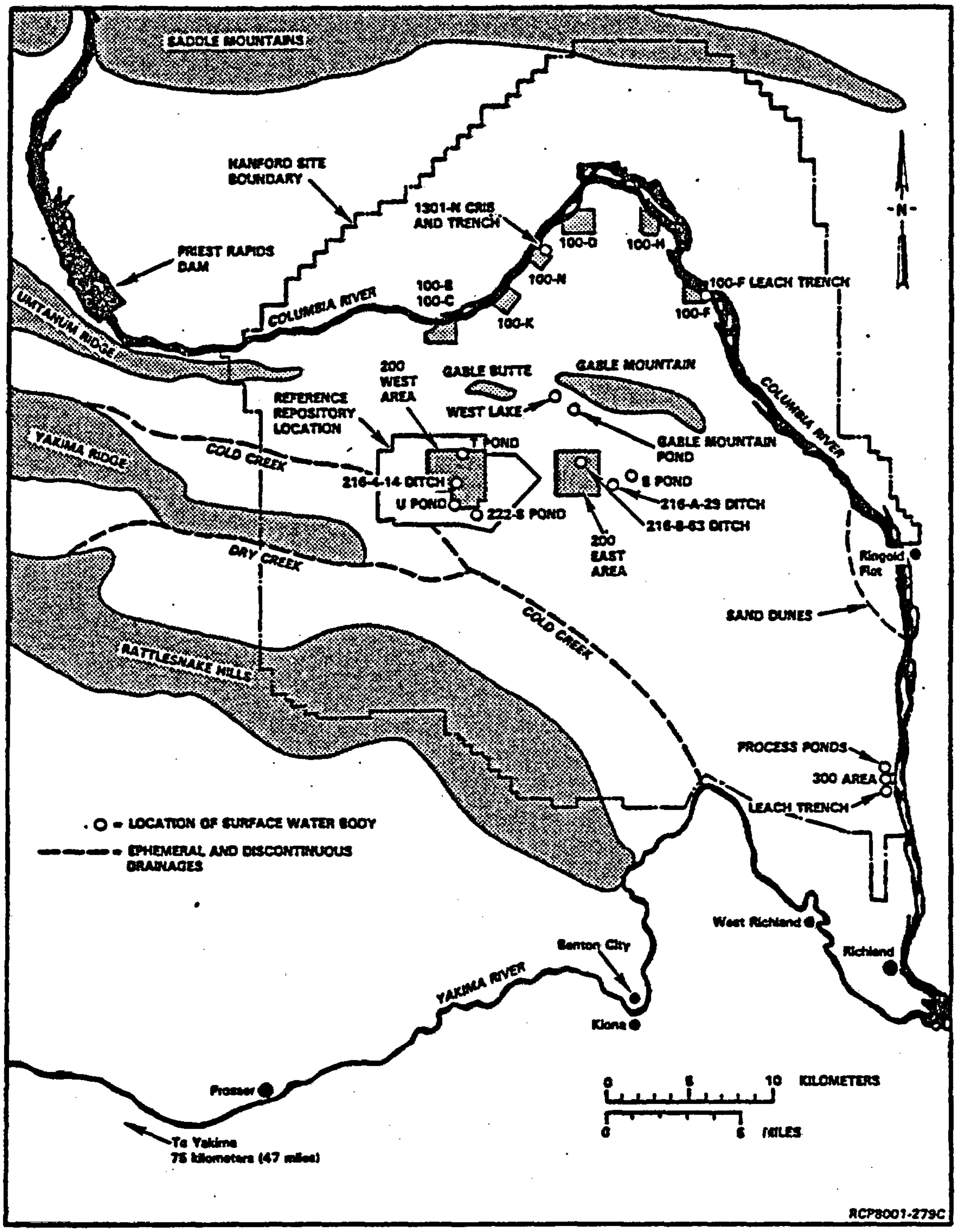

Figure 3-25. Surface water bodies including ephemeral creeks on the Hanford Site.

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3.3.1.3 Surface flooding potential

Several documents contribute to our understanding and evaluation of flooding potentials within the reference repository location and the Pasco Basin. The primary report is by the U.S. Corps of Engineers (COE, 1951) on artificial flooding along the Columbia River, based on failure scenarios of the Grand Coulee Dam. Other key reports include those by U.S. Energy Research and Development Administration (ERDA, 1976), U.S. Federal Emergency Management Agency (FEMA, 1980), and Washington Public Power Supply System (WPPSS, 1981). Cummans et al. (1975) summarized a methodology for determining flooding characteristics of small watersheds, such as the Cold Creek drainage area in eastern Washington. Reports dealing specifically with the probable impacts of flooding on Basalt Waste Isolation Project activities and the reference repository location include Leonhart (1980) and Skaggs and Walters (1981). Discussions of the nature of catastrophic flooding associated with Pleistocene glaciation are provided in U.S. Department of Energy (DOE, 1982e) and are summarized in Subsections ~~2.2.1.1.~~ 2.1.1.1 and 3.2.2.7.

3.3.1.3.1 Flood history of the Columbia River

Major floods on the Columbia River are characteristically the result of rapid melting of the winter snowpack over a wide area augmented by above-normal precipitation. The maximum historical flood on record occurred June 7, 1894. The peak discharge at the Hanford Site was 20,950 cubic meters per second (740,000 cubic feet per second). The largest recent flood took place in 1948 with an observed peak discharge of 19,540 cubic meters per second (690,000 cubic feet per second) at the Hanford Site. The probability of flooding at the magnitude of the 1894 and 1948 floods has been greatly lowered due to upstream regulation at Priest Rapids Dam (see Fig. 3-25). River flows currently range between 1,020 and 4,530 cubic meters per second (36,000 and 160,000 cubic feet per second), whereas unregulated flows (prior to Priest Rapids Dam construction) ranged between 1,980 and 10,760 cubic meters per second (70,000 and 380,000 cubic feet per second) (WPPSS, 1981).

The 1894 flood inundated areas below 122 meters (400 feet) above mean sea level. The flood plain associated with the flood is shown in Figure 3-26. A flood of this magnitude would inundate sections of Richland but would not reach the reference repository location, which has land surface elevations of 190 to 245 meters (625 to 800 feet) above mean sea level.

3.3.1.3.2 Flood history of the Yakima River

Since 1862, there have been ~~less~~ fewer than 20 major floods on the Yakima River. The most severe occurred in November 1906, December 1933, and May 1948. Discharge magnitudes were 1,870, 1,900, and 1,050 cubic meters per second (66,000, 67,000, and 37,000 cubic feet per second), respectively (WPPSS, 1981). The recurrence intervals for the 1933 and 1948 floods are estimated at 170 and 33 years, respectively.

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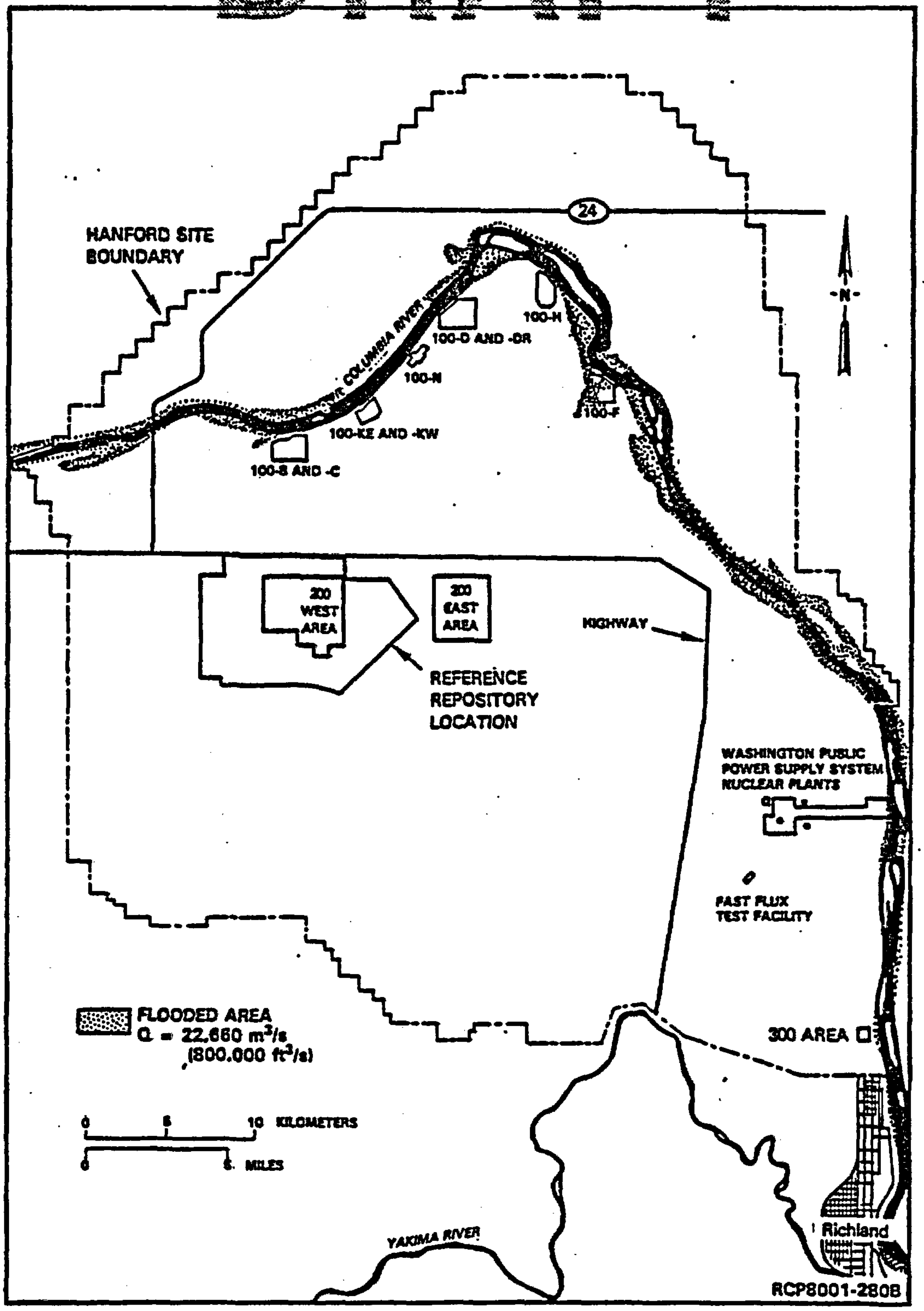

Figure 3-26. Flooded area during the 1894 flood (after ERDA, 1976).

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The development of irrigation reservoirs within the Yakima River Basin has considerably reduced the flood potential of the river. For example, the December 1933 flood was reduced from 2,350 to 1,530 cubic meters per second (83,000 to 54,000 cubic feet per second) at Yakima, Washington, by management of upstream reservoir storage facilities. A December 1959 flood which, if uncontrolled, could have reached a magnitude of 1,560 cubic meters per second (55,000 cubic feet per second) at Yakima, was held at 780 cubic meters per second (27,400 cubic feet per second) by the reservoir system.

Lands susceptible to a 100-year flood on the Yakima River are shown in Figure 3-27. Flooded areas near Horn Rapids could extend into the southern section of the Hanford Site; however, these waters would not reach the reference repository location. The Yakima River upstream from Horn Rapids is physically separated from the Hanford Site by Rattlesnake Mountain. This topographic barrier prevents potential flooding on the Yakima River from reaching the reference repository location.

3.3.1.3.3 <u>Flood potential</u>

Associated with the evaluation of flood potential is the concept of the probable maximum flood, which is determined from the upper limit of precipitation falling on a drainage area and other hydrologic factors (such as antecedent moisture conditions, snowmelt, and tributary conditions) that result in maximum runoff. The probable maximum flood for the Columbia River below Priest Rapids Dam has been calculated to be 39,650 cubic meters per second (1,400,000 cubic feet per second) (COE, 1951, 1969). The flood plain associated with the probable maximum flood is shown in Figure 3-28. This flood would inundate the 100 Areas located adjacent to the Columbia River, but the central portion of the Hanford Site, including the reference repository location, would remain unaffected.

Potential dam failures on the Columbia River have also been extensively evaluated. Upstream dam failures may arise from a number of causes; however, the magnitude of the resulting flood depends on the degree of breach. The U.S. Army Corps of Engineers (COE, 1951) evaluated a number of scenarios on the effects of failures at Grand Coulee Dam, assuming flow conditions on the order of 11,330 cubic meters per second (400,000 cubic feet per second). The resulting discharge at the outfall of the dam was determined to be 595,000 cubic meters per second (21,000,000 cubic feet per second). Near 100-N Area on the Hanford Site, this flow would diminish to 227,000 cubic meters per second (8,000,000 cubic feet per second). The resulting land inundation from the 50 percent breach scenario is depicted in Figure 3-29. In addition to areas inundated by the probable maximum flood, the remainder of the 100 Areas, nearly all of Richland, Washington, and the 300 Area would be flooded. To add additional perspective, major flooding would occur in Portland, Oregon. The reference repository location would remain above the resultant flood waters. No determinations were made with respect to breaches greater than 50 percent at Grand Coulee Dam or to failures of dams upstream of Grand Coulee Dam and associated resonant failures of dams downstream (COE, 1951).

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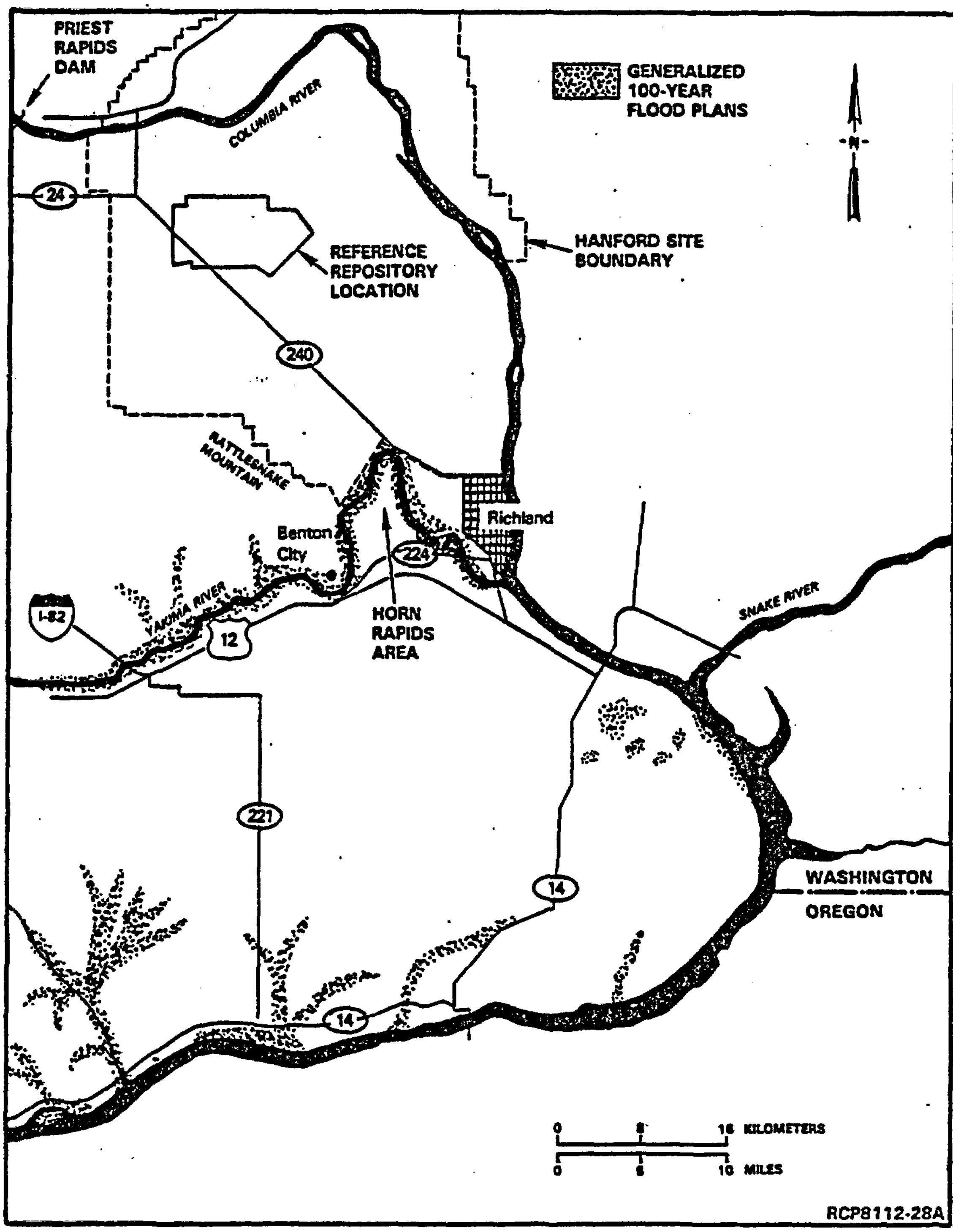

Figure 3-27. Flooded area from a 100-year flood of the Yakima River in the vicinity of the Hanford Site (FEMA, 1980).

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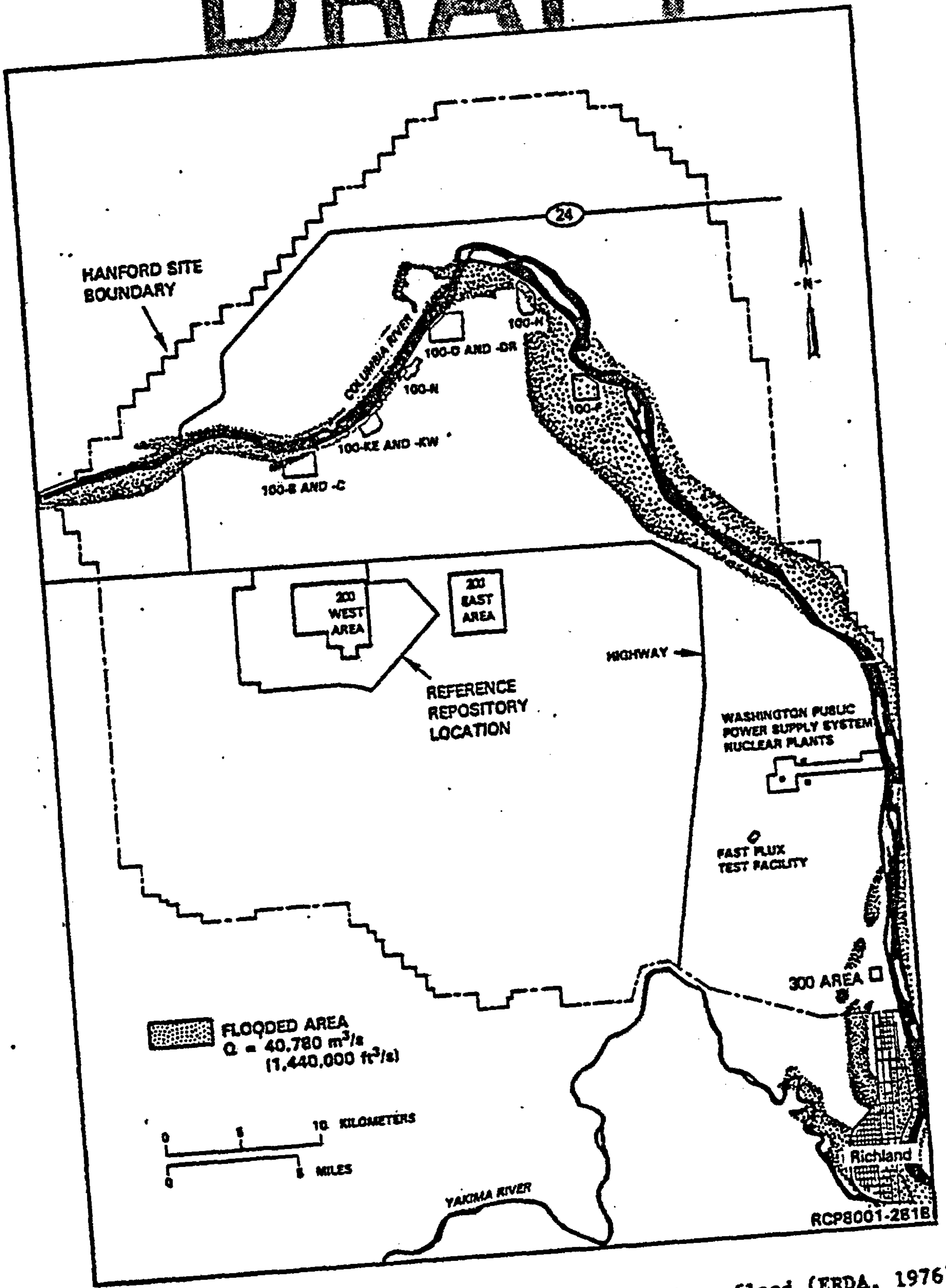

Figure 3-28. Flooded area for the probable maximum flood (ERDA, 1976).

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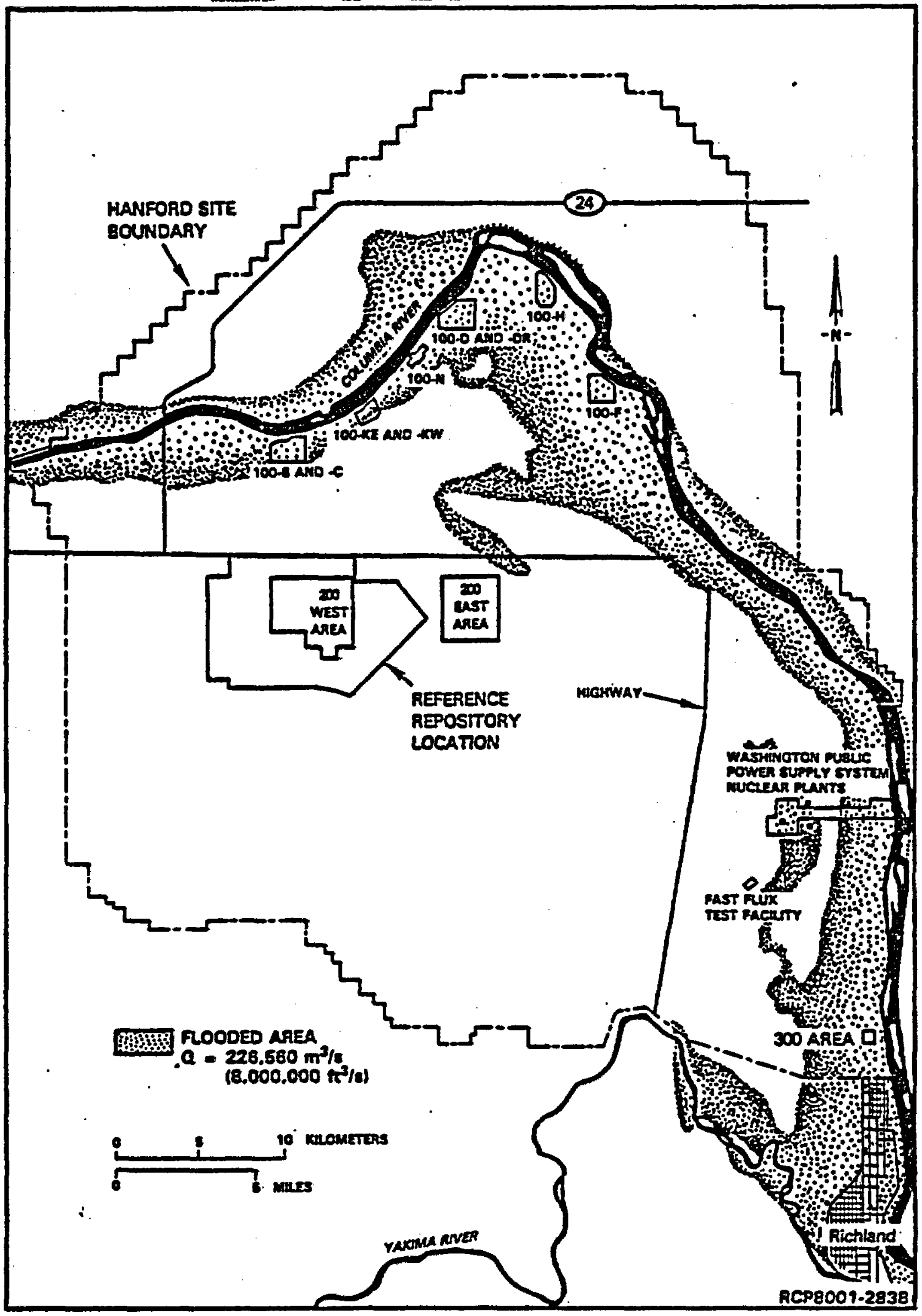

Figure 3-29. Flooded area resulting from a 50 percent breach of Grand Coulee Dam (after ERDA, 1976).

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A third catastrophic event that could result in flooding portions of the Hanford Site is river blockage and flooding due to landslides along the Columbia River. One potential slide area extends along a 75-meter (250-foot) high bluff bordering the east side of the Columbia River upstream from Richland, Washington. This area is commonly referred to as White Bluffs. Calculations indicate that an 8 x 10^5 cubic meters (1 x 10^6 cubic yards) landslide concurrent with a flood flow of 17,000 cubic meters per second (600,000 cubic feet per second) (200-year flood) would result in a flood wave crest elevation of 122 meters (400 feet) above mean sea level (Harty, 1979). The reference repository location would be unaffected from such an event. Areas inundated from such a landslide event are similar to those shown in Figure 3-28. Catastrophic flooding of the Hanford Site and vicinity during the recent geologic past is discussed in Subsection 3.2.2.7.

3.3.1.3.4 Cold Creek watershed

The Cold Creek watershed is located along the western boundary of the Pasco Basin. As shown in Figure 3-28, this watershed is bordered on the west by the Rattlesnake Hills and Yakima Ridge, on the north by Umtanum Ridge, and on the east by the central portion of the Hanford Site. This rectangular-shaped, 870-square kilometer (336-square mile) basin is ephemeral and a part of the Yakima River drainage system. Elevations in the Cold Creek watershed range from approximately 128 meters (420 feet) above mean sea level at its outlet to over 1,100 meters (3,500 feet) above mean sea level at its headwaters along Yakima Ridge.

The reference repository location lies primarily within the Cold Creek watershed. Cold Creek, trending northwest-southeast within the southwestern portion of the wash, is the only defined channel within the southeastern portion of the watershed (see Fig. 3-25).

The drainage system within the Cold Creek watershed may be described as ephemeral and discontinuous. This means that the stream flows only in direct response to precipitation events (i.e., it receives no contribution from discharging ground water or sustained snowmelt runoff). Further, for most runoff events, the water within the channel infiltrates within a given distance of flow. Skaggs and Walters (1981) suggest that the Cold Creek watershed behaves essentially as two distinct drainage systems for most runoff events. The source of the upper drainage system is the area bounded by Umtanum Ridge and Yakima Ridge, whereas the lower drainage system occurs near the confluence of Cold Creek and Dry Creek (see Fig. 3-25).

3.3.1.3.5 Flash flood potential within the reference repository location

Skaggs and Walters (1981) examined the potential for flash flooding in the reference repository location from the ephemeral stream called Cold Creek. Results indicate a potential for limited flooding along the southwestern portion of the reference repository location (Fig. 3-30). Analyses suggest that approximately 9 square kilometers (3.5 square miles) of the reference repository location could be inundated by a probable

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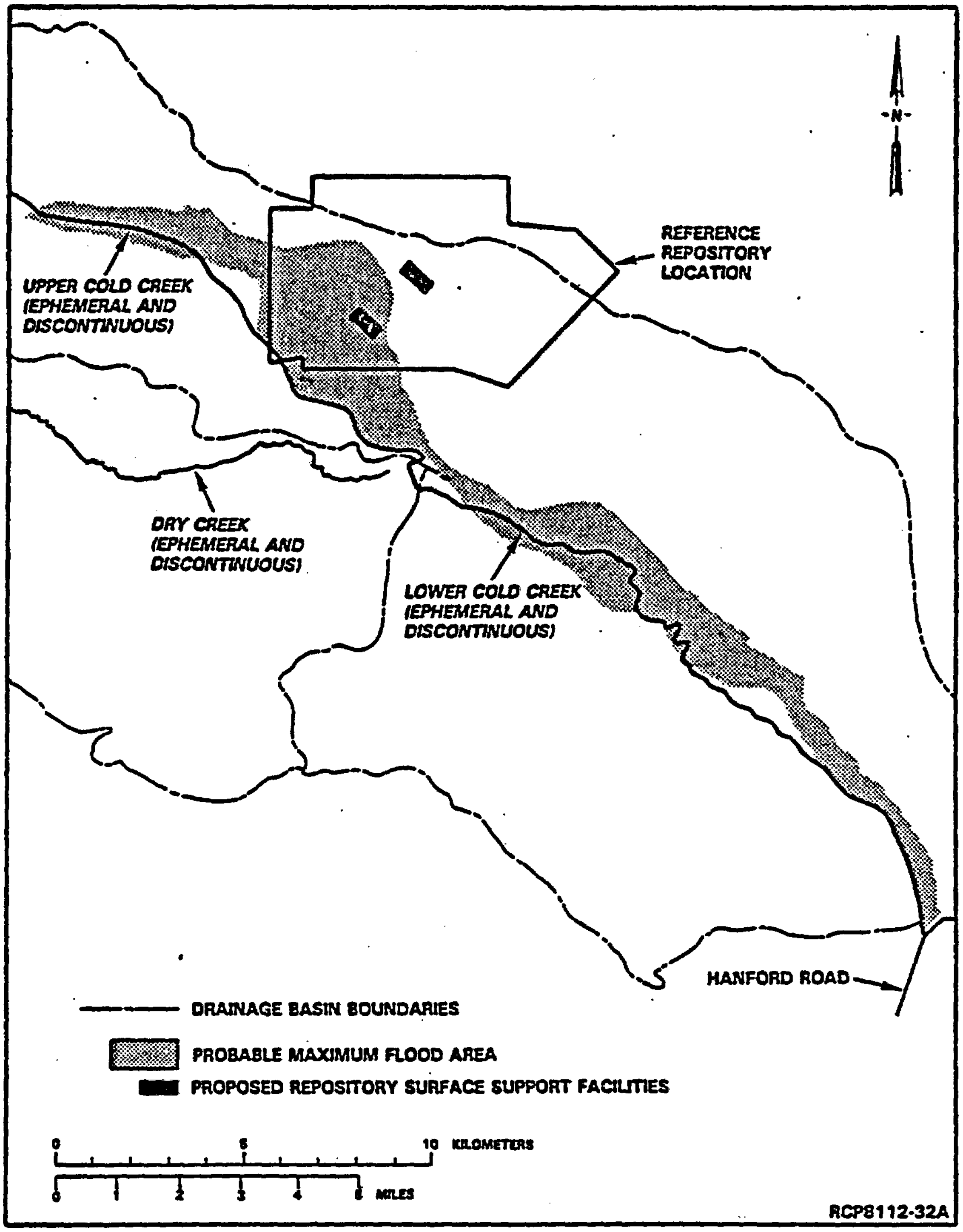

Figure 3-30. Extent of probable maximum flood in Cold Creek area.

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maximum flood. Portions of this flood might extend into the area considered for repository surface support facilities. Using conservative factors on precipitation events/magnitudes, infiltration, surface roughness and topography, a maximum flood depth of 2.3 meters (7.7 feet) was calculated along the southwestern border of the reference repository location. This area is the topographically lowest point within the reference repository location. Theoretically, the recurrence interval of a probable maximum flood cannot be defined. In the same analyses, a 100-year peak stage flood was estimated to have a smaller flood extent with a depth of approximately 1 meter (3 feet) above the valley floor. These waters would not reach the area considered for repository support facilities and such floods would be of short duration.

3.3.1.3.6 Proposed damsite

An additional damsite (Ben Franklin Dam) has been proposed for construction on the Columbia River along the Hanford Site reach approximately 16 kilometers (10 miles) upstream from Richland (see Fig. 2-14 for identification of existing damsites along Columbia and Snake Rivers). No schedules or dates are published. The Ben Franklin Dam would be a low-head, run-of-the-river dam, having a 15-bay spillway and a navigation lock, all on a straight axis across the river. An assessment of the possible effects of such a facility on Hanford Site activities was made by Harty (1979). However, the study did not attempt to evaluate the possible effects of the facility on a deep repository. The inundation of the Columbia River along the Hanford Site reach, resulting from maintenance of the reservoir at the 122-meter (400-foot) level, is shown in Figure 3-31. Surface inundation would be restricted to the immediate vicinity of the Columbia River. Harty's (1979) predicted water table elevation and rise within the sediments overlying the Columbia River Basalt Group resulting from this impoundment is shown in Figure 3-32. Beneath the reference repository location, the expected water table rise averages approximately 3 meters (10 feet). This is approximately 10 percent of the existing water table rise resulting from present and past Hanford Site waste water disposal (see Section 2.1.4).

3.3.1.4 Surface water use within the Pasco Basin

Water use within Benton and Franklin Counties of the State of Washington may be considered to approximate the total user composition and demand within the Pasco Basin. The one notable exception may be irrigation water use within the Wahluke Slope area, north of the Columbia River and just northwest of the Hanford Site along the southern slope of the Saddle Mountains. According to estimates from LANDSAT (Wukelic et al., 1981) and U-2 data, as well as survey statistics, approximately 12,000 hectares (30,000 acres) within this area are receiving irrigation. Water use may be approximated by assuming annual irrigation application on the order of 12,800 cubic meters per hectare (4.2 acre-feet per acre). Thus, the resulting annual estimate of water use would be approximately 1.5×10^8 cubic meters (40,000 million gallons). Annual water use

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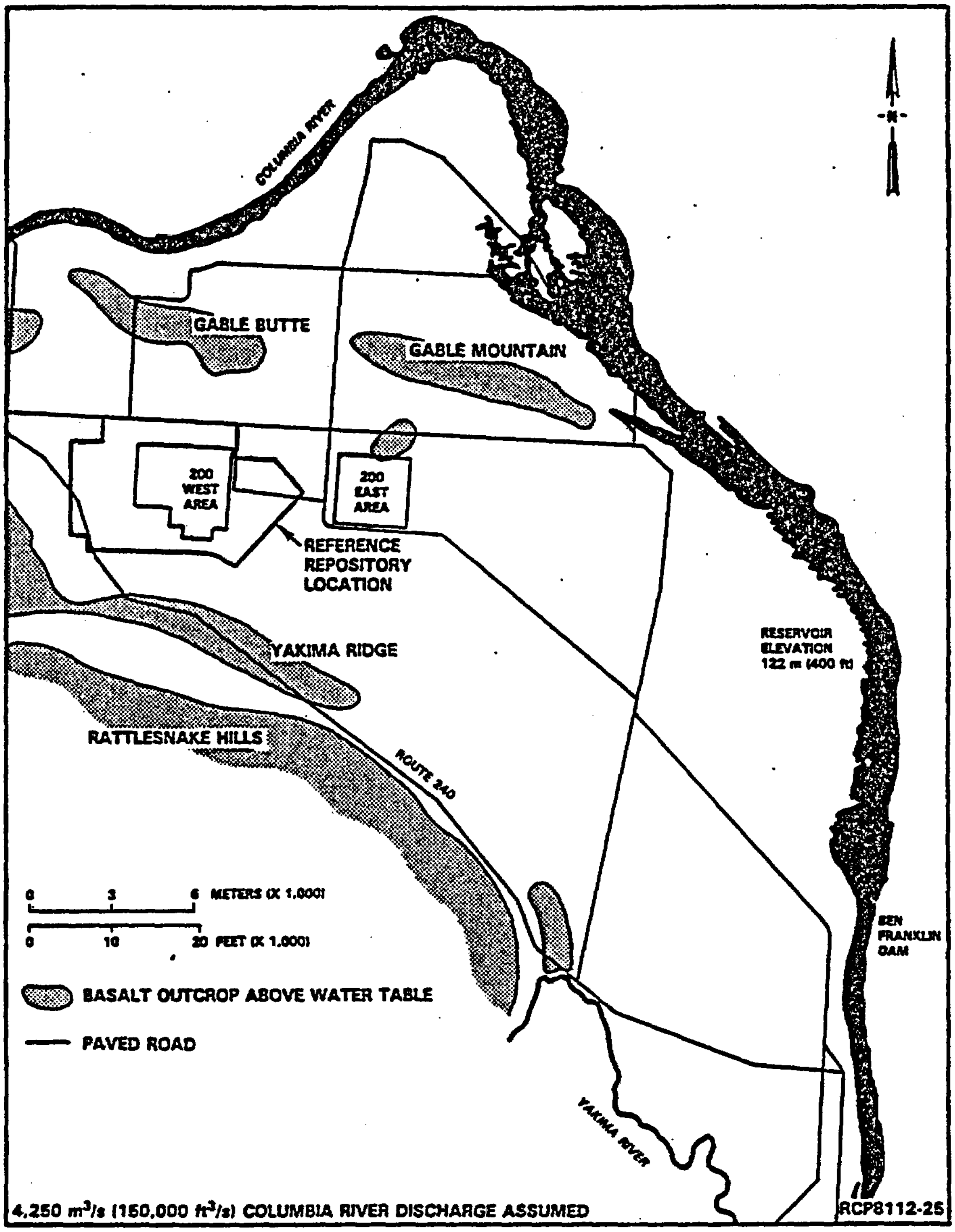

Figure 3-31. Inundation along the Hanford Reach of the Columbia River resulting from operation of Ben Franklin Dam (after PNL, 1967).

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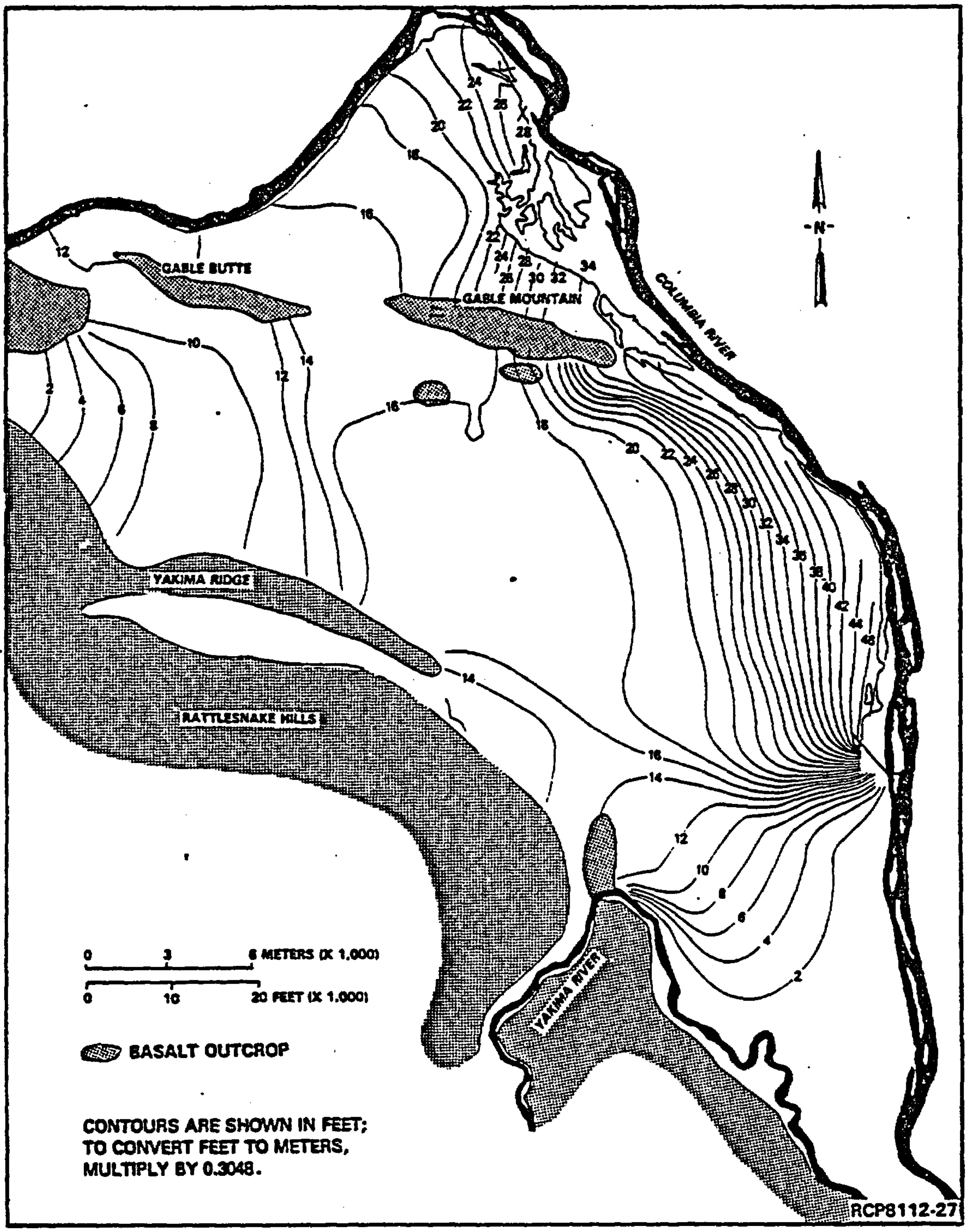

Figure 3-32. Predicted water table rise in sediments overlying the basalts for Ben Franklin Dam (after Harty, 1979).

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within Benton and Franklin Counties totals nearly one-fourth of the total demand within the State of Washington, according to 1975 water use statistics (Dion and Lum, 1977). This equals a volume of over 2.3 x 10^9 cubic meters (600,000 million gallons or approximately 1.9 million acre-feet). The more significant portions of water demand occur within the industrial and agricultural sectors, which represent 22 and 76 percent, respectively, of the basin water demand. Municipal water use within Benton and Franklin Counties represents less than 2 percent of the total water use within the Pasco Basin.

Primarily, water is supplied from surface water sources. Ground-water withdrawals (see Section 2.1.4) comprise less than 10 percent of the total Benton and Franklin County demand. Table 3-4 presents the distribution of water demands as a percentage of the state total for Benton and Franklin Counties.

3.3.1.5 Surface water demand

A preliminary report was prepared on surface water resource development and potential within the Pasco Basin (Bell and Leonhart, 1980). Later, an economic evaluation of the present and projected Pasco Basin water resource situation (Leaming, 1981) issued projections to the year 2080. The projections were based largely on the reported 1975 water use statistics by Dion and Lum (1977). The combined results of the above studies were addressed in U.S. Department of Energy (DOE, 1982b). X

The total surface water demand of the individual projections for municipally supplied, industrial, and agricultural needs are shown graphically in Figure 3-33. The figure shows that by the year 2080 total annual demand for consumptive water uses at 1980 real costs (i.e., present worth of future value) might increase between 36 and 265 percent over 1980 demand. The "most likely" scenario shows that the increase will be on the order of approximately 83 percent. Leaming (1981) concluded that surface water availability exceeds by orders of magnitude this increased demand, assuming no extra-basin constraints are imposed.

3.3.1.6 Surface water intakes within the Pasco Basin

Known diversions of Columbia River water for various municipal, industrial, and agricultural purposes within the Pasco Basin are shown on Figure 3-34. Table 3-5 provides a listing of the locations and types of these withdrawals.

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Table 3-4. The 1975 water use totals and composition for Benton and Franklin Counties as a percentage of the State of Washington totals.

Type of use	Ground water	Surface water	Total from both sources
Municipal	3	9	6
Industrial	9	35	31
Irrigation	10	25	25
Total	4	26	24

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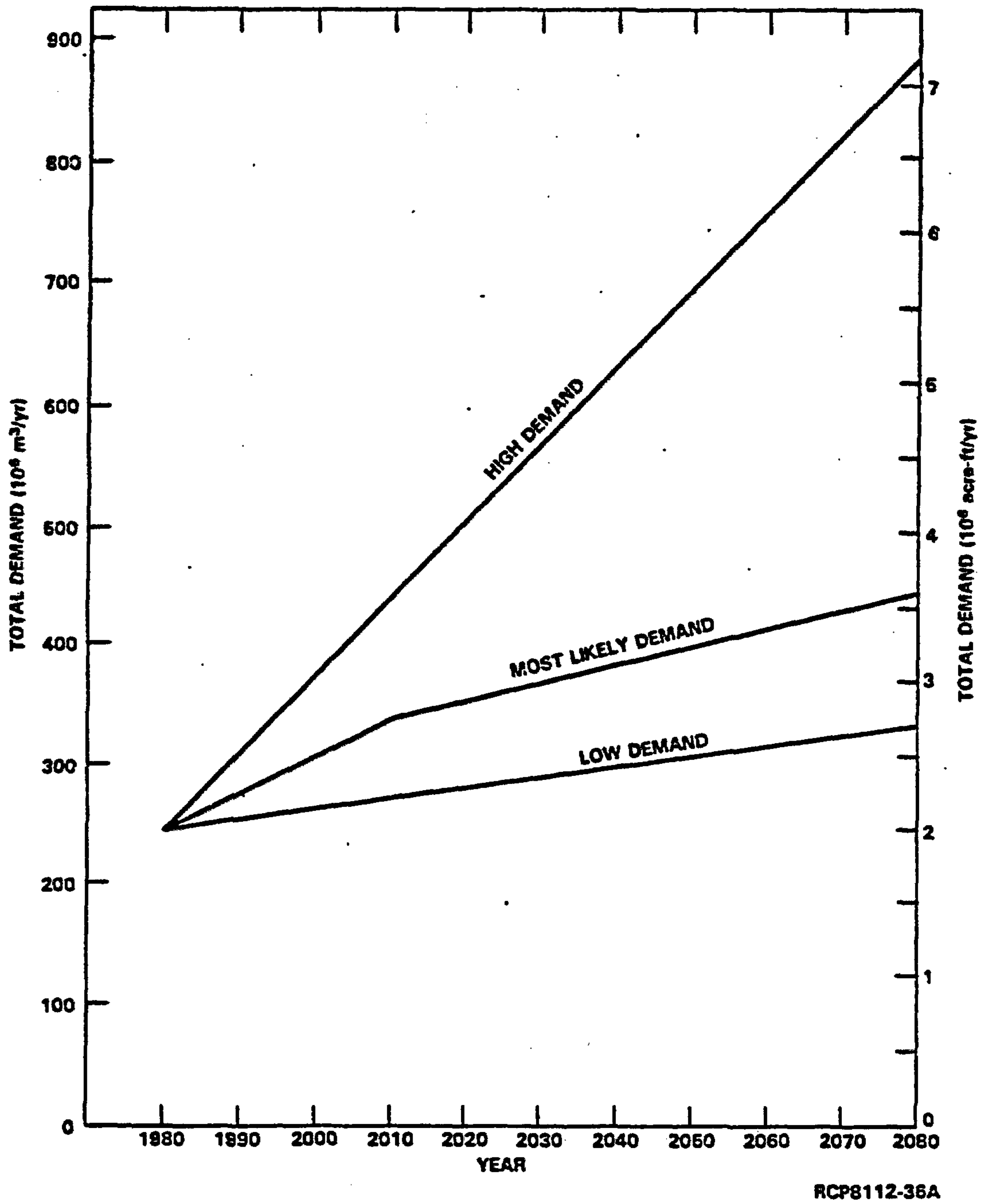

Figure 3-33. Projected demand for water in the Pasco Basin.

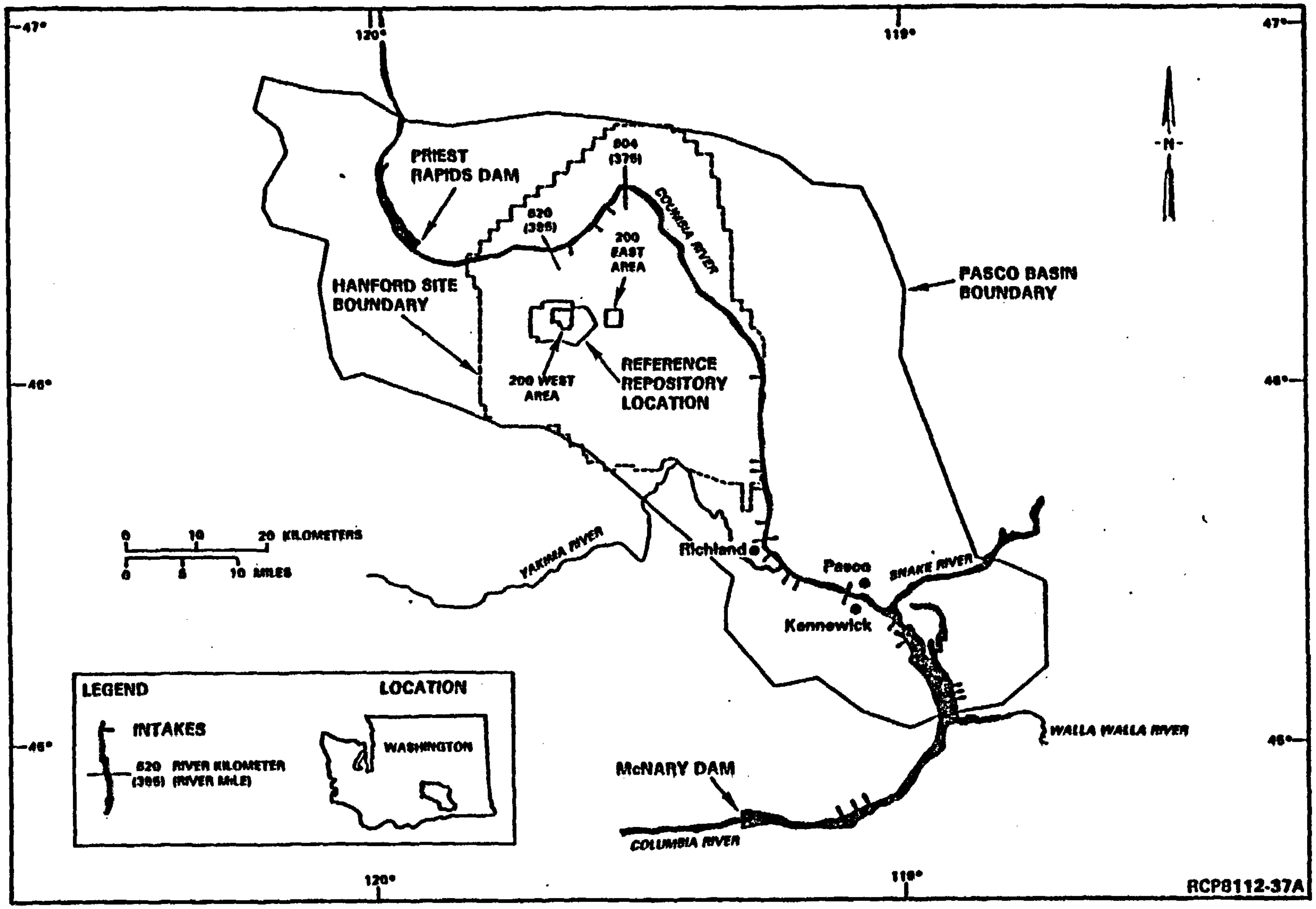

Figure 3-34. Surface water intakes in the Pasco Basin.

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Table 3-5. Summary of downstream surface water uses for the Columbia River. (Sheet 1 of 2)

User[a]	Location of intake		Bank	Annual quantity withdrawn		Type of use[b]	Population served (if municipal)
	River km	River mi		m^3E+06	acre-ft		
Hanford Site (200 Areas)	620	385	Right	c	c	N	--
Hanford Site (100 K Area)	615	382	Right	2.54	2,056	N	--
Hanford Site (100 N Area)	610	379	Right	568	460,405	N	--
Hanford Site (200 Areas)	607	377	Right	c	c	N	--
WPPSS	565	351	Right	80.4	65,160	N	--
Peter Kiewit Sons' Co.	565	351	Right	0.89	724	N	--
L. L. Bailey	558	347	Left	1.84	1,448	I	--
H. D. Loyd	558	347	Left	0.88	717	I	--
Central Premix Cement	558	347	Left	1.79	1,448	N	--
Hanford Site (300 Area)	554	344	Right	2.33	1,888	N	--
Battelle Memorial Inst.	552	343	Right	3.93	3,186	I	--
Univ. of Washington	550	342	Right	1.56	1,267	I	--
City of Richland	550	342	Right	0.60	485	M	d
City of Richland	546	339	Right	27.7	22,444	M	d
City of Richland	546	339	Right	20.8	16,833	M	d
City of Richland	546	339	Right	27.7	22,444	M	d
City of Richland	546	339	Right	83.1	67,332	M	d
E. C. Watts	544	338	Right	0.28	224	I	--
H. S. Petty	544	338	Right	0.43	348	I	--
N. H. & M. E. Ketchersid	544	388	Left	1.48	1,202	I	--
G. C. Walkley	544	388	Left	2.07	1,680	I	--
R. T. Justesen	541	336	Right	2.27	1,839	I	--
Central Premix Concrete	541	336	Right	0.98	796	N	--
City of Richland	538	334	Right	1.79	1,448	I	--
Benton County	534	332	Right	0.89	724	I	--
City of Kennewick	528	328	Right	49.7	40,327	M	d
City of Pasco	528	328	Left	31.3	25,340	M	d
F. J. Henokel	521	324	Right	0.001	11	I	--
Allied Chemical	521	324	Right	3.17	2,570	N	--

Table 3-5. Summary of downstream surface water uses for the Columbia River. (Sheet 2 of 2)

User[a]	Location of intake		Bank	Annual quantity withdrawn		Type of use[b]	Population served (if municipal)
	River km	River mi		m^3E+06	acre-ft		
Chevron Chemical	520	323	Right	3.37	2,729	N	--
Chevron Chemical	520	323	Right	35.7	28,960	N	--
Philips Pac. Chemical	520	323	Right	73.2	59,368	N	--
Philips Pac. Chemical	520	323	Right	17.9	14,480	N	--
Boise Cascade Corp.	512	318	Left	21.9	17,738	N	--
L. D. Hoyte	510	317	Left	161	130,175	I	--
D. Howe	509	316	Left	5.72	4,634	I	--
Crawford & Sons	489	304	Right	29.3	23,747	I	--
Barborosa Farms	489	304	Right	17.9	14,480	I	--
Crawford & Sons	489	304	Right	6.79	5,502	I	--
Rainier Nat. Bank	489	304	Right	8.40	6,806	I	--
Anderson & Coffin	486	302	Right	216	175,208	I	--
Horse Heaven Farms	484	301	Right	73.2	59,368	I	--
Horse Heaven Farms	484	301	Right	491	398,200	I	--
Horse Heaven Farms	484	301	Right	259	209,960	I	--
Anderson & Coffin	484	301	Right	216	175,208	I	--
Total				2,554.8			

[a]Taken from Washington Public Power Supply System (WPPSS, 1981a) and U.S. Energy Research and Development Administration (ERDA, 1975).

[b]I = irrigation
M = municipal use
N = industrial use.

[c]Annual water use for the Hanford Site 200 Areas operations withdrawn at river kilometer 620 (river mile 385) and river kilometer 607 (river mile 377) reported as a total figure of 22.4 million cubic meters (18,166 acre-feet).

[d]Municipal populations served by Richland, Kennewick, and Pasco water supply systems are approximately 34,250, 33,200, and 17,300, respectively.

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3.3.2 Ground water

This section describes the general hydraulic characteristics and ground-water flow pathways~~, and conceptual models~~ believed to exist beneath the reference repository location and vicinity as evidenced from available data.

Ground water beneath the Hanford Site occurs in both a shallow, unconfined aquifer consisting of fluvial and lacustrine sediments lying atop the basalts, and within deeper confined aquifers consisting of basalt flow tops and sedimentary interbeds.

The unconfined aquifer thickness varies between 0 and 75 meters (0 to 250 feet). It is thickest along the eastern edge of the reference repository location, where 40 years of local water disposal to surface ponds have raised the water table approximately 25 meters (80 feet) (ERDA, 1975). The hydraulic conductivity of the unconfined aquifer is generally 10^{-2} to 10^{-3} meter per second (10^{-3} to 10^{-2} feet per day) for coarse sand and gravels and as low as 10^{-7} meter per second (10^{-2} foot per day) for finer grained, indurated sediments (Gephart et al., 1979). Storativity values are typically 10^{-1} to 10^{-2}. The ground-water composition is that of a dilute (less than or approximately 350 milligrams per liter (350 parts per million) total dissolved solids) calcium-bicarbonate chemical type. Other principal chemical constituents include sulfate, silica, magnesium, and nitrate (the latter contributed through the disposal of chemical reprocessing waters). Ground-water recharge is from both precipitation and runoff in nearby hills and artificial recharge from water disposal to ponds. Discharge is to the Columbia River along a hydraulic head gradient of approximately 10^{-3} meter per meter (10^{-3} foot per foot). A summary of the major unconfined aquifer test programs and findings for the Hanford Site are contained in U.S. Energy Research and Development Administration (ERDA, 1975) and Gephart et al. (1979). A routine onsite ground-water monitoring program reports on the unconfined aquifer contamination resulting from waste water disposal on the Hanford Site (Eddy, 1983).

Existing hydrologic data do not lend to a single interpretation of the ground-water flow system (Subsection 3.3.2.~~5~~ 2). However, a number of basic concepts addressing the overall ground-water flow dynamics in and around the Hanford Site have been proposed by investigators based on available data; these are discussed below. Planned data collection activities directed to answer questions on the geohydrologic setting beneath the Hanford Site are discussed in Section 4.1.

Within basalt formations, principal ground-water occurrence is within flow tops and interbeds, which possess the largest hydraulic conductivity values found in basalt. The basalt flow interiors separating individual flow tops appear to act as semiconfining aquitards through which some degree of vertical leakage occurs along cooling fractures (see Subsection 3.3.2.~~3~~ 2 for discussion of alternative conceptual models). This

concept of ground-water occurrence principally within flow contacts/interbeds separated by flow interiors of low hydraulic conductivity has been reported by many field investigations, such as the following:

- LaSala et al. (1973, pp. 17 and 22) state: ". . . basaltic rocks consistently show that basalt flows yield little water but that thin zones of rubbly or fractured rock along the contacts of basalt flows yield large quantities of water" and "The most permeable water bearing zones in the basaltic rocks occur along the contacts of some of the flows. . . .Such zones generally are only a few feet thick and make up a small percentage of the total basaltic-rock section."

- Newcomb (1965) notes that permeable zones comprise about one-tenth of the vertical section of the total basalt sequence.

- In the Luzier and Burt (1974, pp. 2 and 8) study of the basalt hydrology in east-central Washington, they address the inherent "low vertical permeability of individual basalt flows." This concept of flow interiors having low hydraulic conductivities and aquifer occurrence in flow tops/interbeds appears in Washington State water resource publications regarding basalt.

- The U.S. Department of Energy (DOE, 1982c) documents preliminary data and conceptual discussions regarding the apparent large differences in hydraulic conductivities between flow tops/interbeds and basalt flow interiors. It is also noted that only a small percentage (approximately 5 percent) of the total basalt thickness appears to constitute permeable ground-water flow paths.

Local ground-water recharge to shallow basalts beneath the Hanford Site results from precipitation and runoff on basalt outcrops surrounding the Pasco Basin (LaSala and Doty, 1971; Gephart et al., 1979). This concept is based on a variety of data sources, including basalt outcrop maps, precipitation distribution, plus decreasing hydraulic heads, increasing total dissolved solids, and cationic exchange processes taking place in ground waters sampled progressively distant from major basalt outcrops. Regional recharge of deep basalts is thought to result from interbasin ground-water movement originating northeast and northwest of the Pasco Basin in areas where the Wanapum Basalt and Grande Ronde Basalt flows extensively outcrop (Tanaka et al., 1979; Gephart et al., 1979). For example, Tanaka et al. (1979, p. 28) state "all surface- and ground-water flow from the other subbasins directly or indirectly, with the exception of the Horse Heaven Hills subbasin, enters or flows through the Pasco subbasin" (see Fig. 2-13). Though a quantitative framework describing regional ground-water movement is currently unavailable, studies are directed toward finding answers and resolving differences in ground-water flow model conceptualizations (see Section 4.1).

Ground water probably discharges from the shallow basalt to the overlying unconfined aquifer and the Columbia River. The discharge area(s) for deep ground waters remains uncertain. Investigators have

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speculated that discharge is south of the Hanford Site (LaSala and Doty, 1971; LaSala et al., 1973; DOE, 1982e). Along these flow paths, water is under artesian pressures. Areas of natural flowing artesian wells exist within the Cold Creek Valley west of the reference repository location and along the Columbia River where lowland elevations exist.

Though specifics are currently unavailable, it has been proposed that the shallow basalt ground waters beneath the Hanford Site are locally recharged and discharged while deeper flow systems are part of a more regional interbasin ground-water system. This would be consistent with the concepts of shallow, intermediate, and regional ground-water flow systems as proposed by Toth (1963) in his generic studies of ground-water flow patterns. The hydraulic affect of major geologic structures on ground-water flow, such as anticlines crossing portions of the Columbia Plateau, is currently unanswered but is being addressed (see Section 4.1).

Based on limited available data, hydraulic head changes in the deep basalts of the Cold Creek synclinal area appear to be slow and of small magnitude while head variations are larger in shallower basalts (Leventhal, 1983). For example, the five piezometers in borehole DC-1 monitor four intervals within the Grande Ronde Basalt flows between the depths of 888 and 1,478 meters (2,913 and 4,850 feet) and one composite zone within the Wanapum Basalt flow between the depth of 372 and 642 meters (1,219 and 2,105 feet). This borehole is located 4 kilometers (2.5 miles) northeast of the reference repository location. Except for piezometer 4, which has behaved erratically since installation in 1973 (LaSala, 1973; Gephart et al., 1979), maximum head variations over the last decade have been slow and minor (approximately 1 meter (3 feet)). According to historical records, the basic equilibration period (i.e., beginning of a hydraulic head distribution maintained in following years) in the four good piezometers appears to be on the order of days to a few weeks.

An active borehole monitoring program is also maintained in approximately 10 shallow "DB" boreholes completed in the lower Saddle Mountains Basalt and upper Wanapum Basalt flows. These holes are located adjacent to the Columbia River, within the Cold Creek syncline and in the Cold Creek Valley. A summary of hydraulic head measurements is contained in Leventhal (1983). In general, data indicate head changes of approximately plus or minus 1 meter (3 feet) near the Columbia River since monitoring began in the late 1970's, with the possibility of a slow head increase (approximately 1 meter (3 feet) last year) in the upper Wanapum Basalt flow. Near the Yakima River, heads in the lower Saddle Mountains Basalt flow have declined approximately 1 meter (3 feet) since monitoring began in 1978. Centrally in the Cold Creek syncline, heads in the lower Saddle Mountains Basalt flows have varied about plus or minus 0.5 meter (1.6 feet) in the last 6 years. Heads have declined some 10 meters (30 feet) in the upper Wanapum Basalt flow west of the Cold Creek barrier in an area close to heavy ground-water withdrawals (see Fig. 3-1).

When the above data are combined with existing preliminary hydraulic head information collected on a progressive drill and test basis, a preliminary understanding emerges of the broad head patterns that might

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exist across the Hanford Site. The western Hanford Site, that region closest to the Rattlesnake Hills and the Yakima Ridge and Umtanum Ridge, appears to be a recharge area for the shallow basalts (see Fig. 3-25). Here, hydraulic heads decrease with depth. Eastward across the Hanford Site, heads become more uniform with depth in the central Cold Creek syncline, suggesting lateral ground-water movement. Close to the Columbia River, heads either increase with depth or have a variable pattern suggesting potential discharge. In deep basalt flows (principally Wanapum Basalt and Grande Ronde Basalt), available hydraulic head data indicate either generally uniform heads or a slight upward gradient. The dominant head decreases, and increases with depth characteristic of the shallow basalts do not appear to exist. Overall, ground water appears to flow southeast. These generalized head patterns have been reported or suggested by several investigators; for example, LaSala and Doty (1971, p. 60) state: "water in the basaltic rock possibly moves from where it enters the rocks on the ridges and plateaus fringing the Pasco Basin to the Columbia River or the low ground south of the Reservation near Wallula Gap" (see Fig. 3-1). In like manner, LaSala et al. (1973, p. 4) state: "The ground water beneath the main part of the Hanford Reservation, south and west of the Columbia River, moves southeastward from the recharge areas in the uplands, including Cold Creek and Dry Creek Valleys, and ultimately discharges to the Columbia River south of the reservation." The above broad concepts appear supported by data collected and reported in Gephart et al. (1979), U.S. Department of Energy (DOE, 1982e), and U.S. Department of Energy/U.S. Nuclear Regulatory Commission (DOE/NRC, 1984). A lateral hydraulic gradient of approximately 10^{-4} meter per meter (10^{-4} foot per foot) is reported based on available data (Long and WCC, 1984; DOE, 1982e).

Because of the possibility that a hydraulic low might exist along the Umtanum Ridge-Gable Mountain structure, the U.S. Department of Energy (DOE, 1982e, p. 5.1-203) states "Because of a hydraulic low near the Umtanum Ridge-Gable Mountain anticline, shallow ground waters from the northern portion of the reference repository location may flow north rather than east to southeast; whether the hydraulic low extends to the Wanapum and Grande Ronde Basalts is an unanswered question."

The above statements on hydraulic head patterns are not given as conclusions but rather conceptualizations based on information available by researchers at the time of their studies. Some controversy exists concerning the representativeness of heads acquired over a period of time on a progressive drill and test basis and the possible hydraulic affects of post waste water disposal on the Hanford Site. Therefore, because of the apparently low hydraulic gradient in the deep basalts beneath the Hanford Site (DOE, 1982e) and the fact that time variant heads are an essential ingredient of site characterization, additional monitoring wells were installed in and around the reference repository location (see Section 4.1.1). Preliminary data from these piezometers appear to be supporting the earlier concepts of generally horizontal and low hydraulic gradients existing in the deep basalts in and near the reference repository location (Yeatman and Bryce, 1984a, 1984b).

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Areal and stratigraphic changes in ground-water chemistry characterize basalt ground waters beneath the Hanford Site (Graham et al., 1982). The stratigraphic position of these changes is believed to delineate flow system boundaries, and to identify chemical evolution taking place along ground-water flow paths. Some locations of potential mixing of deep and shallow ground waters have also been identified using these data. Overall, shallow basalts are of a sodium-bicarbonate chemical type; deep basalts are of a sodium-chloride chemical type. Table 3-6 summarizes the range of concentration and mean compositions of major inorganic constituents in basalt ground waters sampled beneath the entire Hanford Site. On a borehole-by-borehole basis, chemical and isotopic shifts can be pronounced (DOE, 1982). The stratigraphic boundaries separating chemical types vary depending on location. Studies are underway to understand the basalt/ground-water interactions controlling these chemical types and to interpret the geochemistry role in developing a ground-water conceptual model.

The concept of minimal vertical ground-water leakage between flow systems was suggested by LaSala and Doty (1971, p. 59). Based on their test results at borehole DC-1, they state: "The chemical and isotopic characteristics of the groundwater show a strong horizontal zonation of the deeper water in the well. . . .This zonation indicates that little, if any, vertical movement of water has occurred at the site of the well." Whether or not this conceptualization is correct must be determined through further study. However, it is recognized that over broad regions, ground-water movement (even across basalt flow interiors of apparently low hydraulic conductivity) can be an important consideration in understanding regional flow dynamics and geochemical evolution. Future geochemical modeling is directed toward evaluating hydrochemical zonations.

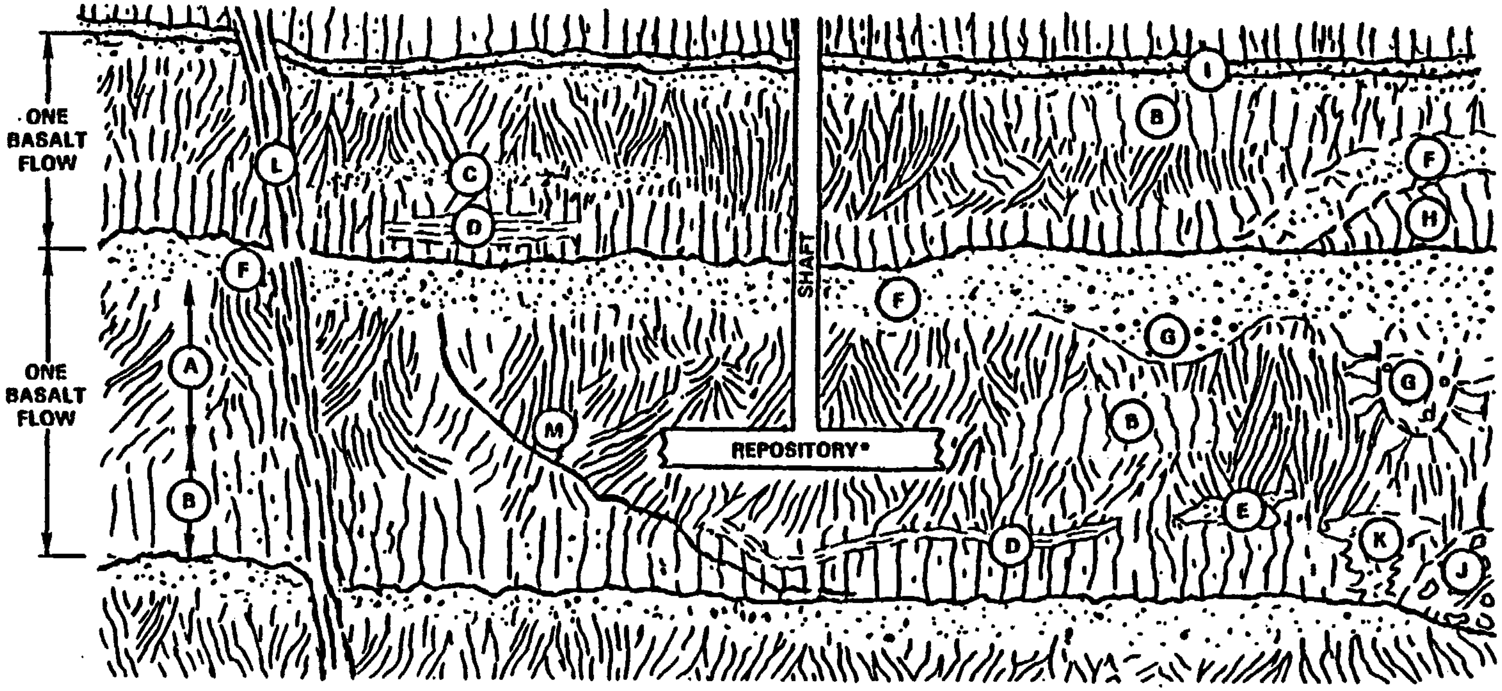
The Basalt Waste Isolation Project has undertaken and is undertaking an extensive outside review of the hydrochemical program (e.g., Bentley, 1982; LBL, 1983; Jenne et al., 1983). The purpose of these reviews is to continually improve data interpretation as well as analytical and sampling procedures through consultation with recognized experts.

3.3.2.1 Potential ground-water pathways

Ground-water movement in basalt most likely occurs along pathways found in three groups of features: (1) discontinuities within flow interiors, (2) flow contacts and sedimentary interbeds, and (3) bedrock structures (Gephart et al., 1983). These features are illustrated in Figure 3-35, as is the hypothetical location of a repository within the dense central part of a generic flow interior. As noted in Figure 3-36, no horizontal or vertical scale is implied. Figure 3-35 simply illustrates the range of possible interbasalt and intrabasalt flow features that might exist and influence ground-water movement. The figure does not imply that all or any specific combination of features is expected to occur in a given area. Each of the above three categories is discussed below in regard to possible ground-water and solute pathways near a repository.

Table 3-6. Range of concentration and mean compositions of major inorganic constituents of basalt ground waters.

Constituent	Basalt					
	Saddle Mountains		Wanapum		Grande Ronde	
	Range	Mean	Range	Mean	Range	Mean
Anions (mg/L)						
Total alkalinity as HCO_3^-	104-303	194	110-211	174	64-251	157
Cl^-	3.4-63	12	4.1-452	98	71-507	221
SO_4^{-2}	0.5-107	43	0.5-38	7.3	1.7-199	92
NO_3^-	0.5-7.6	0.5	0.5	0.5	0.5	0.5
F^-	0.3-7.6	1.2	0.45-27	8.6	11-44	27
Cations (mg/L)						
Na^+	16-122	60	27-346	120	161-373	269
K^+	6.2-14	10	7.1-35	16	0.4-25	9.7
Ca^+	0.5-55	13	0.5-18	6.1	1.0-10	2.7
Mg^+	0.08-16	4.1	0.1-10.3	2.5	0.01-0.17	0.04
SiO_2 (mg/L)	21-91	61	56-120	75	82-162	103
Total dissolved solids (mg/L)	227-518	369	298-1,009	486	527-1,129	830
pH (field)	7.0-9.4	8.2	7.5-9.5	8.9	9.13-10.6	9.6



*HYPOTHETICAL LOCATION

NO HORIZONTAL OR VERTICAL SCALE INTENDED

FLOW INTERIOR DISCONTINUITIES

- A ENTABLATURE JOINTS
- B COLONNADE JOINTS
- C VESICULAR ZONE
- D PLATY ZONE
- E LOCAL FRACTURED ZONE

FLOW CONTACT

- F FLOW TOP
- G LOCAL THICKENING OF FLOW-TOP BRECCIA
- H FLOW TERMINATION
- I SEDIMENTARY INTERBED
- J PILLOW BRECCIA
- K SPIRACLE OR SPIRACLE-LIKE FEATURE

BEDROCK STRUCTURAL DISCONTINUITIES

- L FAULT OR FRACTURE ZONE, HINGE OF FOLD, OR SHEAR ZONE
- M LOCALIZED TECTONIC FRACTURE

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Figure 3-35. Hypothetical composite cross section of possible geologic features in a layered basalt sequence (Gephart et al., 1983).

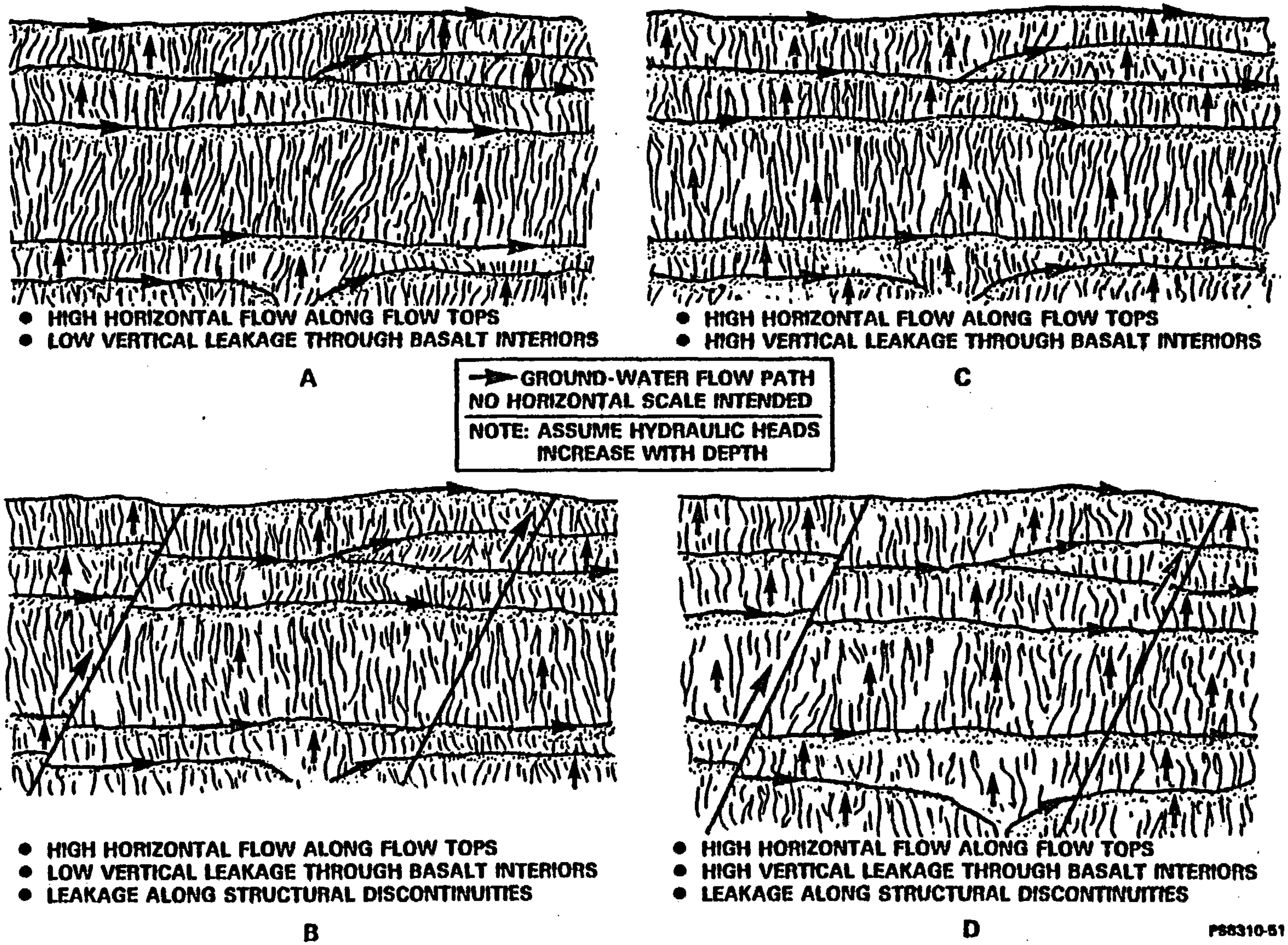

Figure 3-36. Alternative concepts for ground-water movement based on anistrophy contracts and hypothetical structures (Gephart et al., 1983).

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3.3.2.1.1 Flow interiors

Ground water moving from a repository would travel through fractures in the flow interior before reaching flow contacts or bedrock structures. The most ubiquitous discontinuities within the flow interior are cooling fractures found in the entablature and colonnade portions of a flow (see Fig. 3-35, features A and B).

Ten hydrologic tests (using pulse and constant head injection test methods as described in Strait et al., 1982) have been conducted across the dense entablature and colonnade portions of the individual flow interiors. These tests were done at depths from approximately 350 to 1,190 meters (1,150 to 3,900 feet) beneath the Hanford Site. The horizontal hydraulic conductivities measured were less than or equal to 10^{-11} meter per second (10^{-6} foot per day). Low hydraulic conductivities for flow interiors have also been reported by other investigators (e.g., LaSala and Doty, 1971; Newcomb, 1982). Such values in a fractured medium are attributed to a high degree of secondary mineral infilling and dead-end space in cooling fractures, in addition to lithostatic loading (DOE, 1982). Field tests quantifying vertical hydraulic conductivities and evaluating test methodologies within flow interiors are in progress. An initial ratio test conducted in boreholes DC-4 and -5 (see Fig. 3-7) by Spane et al. (1983) suggests a vertical hydraulic conductivity of less than 10^{-11} meter per second (10^{-5} foot per day) for a test zone in the Rocky Coulee flow interior. Since this is the first test of its kind in basalt, an uncertainty cannot yet be assigned to the measured value. Results from this test indicate that the use of the ratio method for determining vertical hydraulic conductivity of flow interiors may be of limited application. Other test methods are under investigation (see Section 4.1.1).

In lieu of direct available measurements, estimates of the anisotopic ratio for vertical-to-horizontal permeability within flow interiors have been derived by considering a hexagonal cooling-joint geometry and applying a flow balance (DOE, 1982). The ratio obtained was approximately 2 to 1. In addition, statistical modeling of fracture sets indicates a maximum anisotopic ratio of approximately 3.5 to 1 (Sagar and Runchal, 1982). Thus, once several field measurements become available, it is the vertical hydraulic conductivity of undeformed flow interiors probably will be determined to be of the approximate order of magnitude as horizontal conductivity values currently reported.

Uncertainty in hydrologic test results, such as those outlined in this and the following section, is related to the extent that analytical assumptions are satisfied as well as to the relative hydraulic conductivity of the rock tested. For example, an uncertainty of approximately 2X or 3X might apply to a rock of higher hydraulic conductivity (greater than approximately 10^{-6} meter per second (10^{-1} foot per day)) when data interpretations from several accepted analytical solutions are compared. On the other hand, when a single solution (e.g., Theis, 1935; Cooper and Jacob, 1946; Papadopulos and Cooper, 1967) is used, results of multiple tests in the same rock zone can be nearly identical. Equipment compliance and test system unknowns

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increase uncertainties in test results for rocks of low hydraulic conductivity. Such test uncertainties are common to all rock types. Overall, the Basalt Waste Isolation Project assigns an uncertainty of approximately 2X to 3X to measurements of flow-top and interbed hydraulic conductivity. For flow interiors, the values reported are considered high because equipment compliance results in an overestimation of the true hydraulic conductivity (i.e., if a flow interior test results in a 10^{-10} meter per second (10^{-5} foot per day) horizontal conductivity, the actual in situ value is probably lower).

Few examples are formally available for comparing test interpretations conducted by different organizations. One available comparison is given in Table 3-7. These calculations by Jackson (1982) and Wilson (1983) are essentially identical.

Besides entablature and colonnade joints, other discontinuities potentially present within flow interiors include vesicular zones, platy zones, and zones of localized fracturing. These features are illustrated as features C, D, and E in Figure 3-35.

Within the Cold Creek syncline, a vesicular zone in the entablature of the Cohassett flow was hydrologically tested at three borehole sites. Hydraulic conductivity values ranged between 10^{-8} and 10^{-13} meter per second (10^{-3} and 10^{-8} foot per day) (Long and WCC, 1984). Whether such low hydraulic conductivity is a typical characteristic of such vesicular zones is not known.

A localized fracture zone approximately 1-meter (3-feet) thick was identified in the entablature near the base of the Umtanum flow in one borehole located in the reference repository location. A hydraulic conductivity of 10^{-4} meter per second (10^{1} feet per day) was calculated from pump and slug tests (Strait and Spane, 1983). This is the highest hydraulic conductivity measured in a flow interior on the Hanford Site. Hydrologic tests across the Umtanum flow entablature/colonnade contact in other onsite boreholes indicate values of approximately 10^{-13} meter per second (10^{-8} foot per day). Though the extent of this fracture zone is unknown, it is presently considered as a localized feature (as symbolically shown as feature E in Figure 3-35) because at other borehole sites tested, this same stratigraphic zone possesses a much lower hydraulic conductivity typical of other basalt flow interiors studied.

3.3.2.1.2 <u>Flow contacts and sedimentary interbeds</u>. After ground water travels through joints or other pathways within a basalt interior, it may enter a flow contact. Commonly, these contacts represent the closest zones of higher hydraulic conductivity near the repository. Flow contacts may contain features F through K in Figure 3-35.

A flow top (feature F and G in Fig. 3-35) may form a more or less continuous layer atop the flow interior. The flow top of an areal extensive basalt flow may cover several thousand square kilometers (several thousand square miles) while its thickness, internal characteristics, and hydrologic properties spatially vary. Flow

Table 3-7. Comparison of hydrologic properties from borehole DC-7 and -8 tests in the McCoy Canyon flow top of the Grande Ronde Basalt.

Reference	Transmissivity (ft/d)		Hydraulic conductivity (ft/d)		Storativity best estimate
	Range	Best estimate	Range	Best estimate	
Jackson (1982)	0.39-0.84	0.78	0.011-0.023	0.021	4×10^{-5}
Wilson (1983)	0.17-1.25	not given	0.011-0.034	0.020	3×10^{-5}

NOTE: To convert feet to meters, multiply by 0.3048.

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termination (pinch outs), such as feature H in Figure 3-35, represent places where ground water could move from one flow top to another without traversing a basalt interior.

Associated with some flow tops are sedimentary interbeds (feature I in Fig. 3-35). Most interbeds within the Pasco Basin vicinity are located in the Saddle Mountains Basalt, approximately 400 meters (1,300 ft) above the shallowest basalt flow currently considered for a repository (see Fig. 3-6).

To date, nearly 200 single-hole hydrologic tests have been conducted in flow tops and interbeds in some 35 separate boreholes across the Hanford Site. These data indicate that within both the Saddle Mountains Basalt and Wanapum Basalt flows, the hydraulic conductivities of most individual flow tops and interbeds range between approximately 10^{-4} and 10^{-7} meter per second (10^{1} and 10^{-2} foot per day) with a geometric mean of approximately 10^{-5} meter per second (10^{0} foot per day). Most hydraulic conductivity values within Grande Ronde Basalt flow tops range between approximately 10^{-5} and 10^{-9} meter per second (10^{0} and 10^{-4} foot per day) with a geometric mean of approximately 10^{-7} meter per second (10^{-2} foot per day) (Long and WCC, 1984). In heterogeneous media such as basalt, the use of geometric mean values is generally considered to provide the best integration of hydraulic conductivity over a large area (Neuman, 1982; Snow, 1965).

Existing hydrologic data, based on single-hole tests, suggest that flow-top hydraulic conductivities are heterogeneous across the reference repository location. For example, the hydraulic conductivity of the Rocky Coulee flow top changes only slightly from 10^{-6} to 10^{-7} meter per second (10^{-1} to 10^{-2} foot per day) while that of the Cohassett flow top ranges between 10^{-6} to 10^{-11} meter per second (10^{-1} to 10^{-6} foot per day). Furthermore, geophysical log traces indicate that ground-water movement is sometimes channeled along narrow intervals (less than or approximately 1 meter (3 feet)) as opposed to being averaged across the entire effective thickness of the flow top. Such narrow intervals may have a higher local hydraulic conductivity than the "equivalent" permeability of the effective thickness of the flow top. The number and in situ characteristics of these intervals can spatially change.

Two tracer tests have been conducted in the flow top of the McCoy Canyon flow (Bakr et al., 1980; Gelhar, 1982; Leonhart et al., 1982). Dispersivity values reported were 0.45 to 0.85 meter (1.5 to 2.8 feet) with an effective thickness of 2×10^{-3} to 3×10^{-3} meter (7×10^{-3} to 1×10^{-2} foot).

Hydraulic heads measured across flow tops and interbeds by piezometers and also on a progressive drill and test basis suggest that the areal hydraulic gradient in the Cold Creek syncline is approximately 10^{-4} meter per meter (10^{-4} foot per foot). Vertical head measurements across the deep basalts indicate either a slight upward gradient or essentially no gradient (i.e., vertical head profile). These preliminary data suggest that in nonstructurally deformed areas, ground-water movement

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appears to be predominantly lateral with the general flow direction semiconforming to the regional bedrock dip (Newcomb, 1982).

Because pillow breccia zones (feature J in Fig. 3-35) have not been penetrated by boreholes in the Hanford Site, none have been hydrologically tested. Their existence, however, as well as spiracles or spiracle-like features (feature K in Fig. 3-35), should be anticipated based on field observations in the Columbia Plateau. These features represent rock zones of possibly high hydraulic conductivity that may locally influence ground-water movement.

3.3.2.1.3 Bedrock structures. Bedrock structural discontinuities represent zones of potentially significant fracture anisotropy (shown symbolically as features L and M in Fig. 3-35) that may hydraulically connect flow systems above and below a repository, or they may represent low hydraulic conductivity barriers to ground-water movement. All bedrock in the western Pasco Basin is along some portion of a Yakima fold, either on a limb or in a hinge area. The local tectonic setting is described in Section 3.2.3.

Synclinal troughs, where exposed in the Columbia Plateau outside of the Pasco Basin, appear to exhibit less strain than other portions of a Yakima fold structure (Price, 1981). The difficulty of directly extrapolating this regional characteristic to the Cold Creek syncline, however, is that the Cold Creek syncline is filled with sediment, which precludes direct comparison. Because the trough of the Cold Creek syncline is a broad, open structure, it is interpreted to contain fewer bedrock structures relative to anticlinal areas. Nearly flat-lying strata away from anticlinal hinge areas may be crossed by strike slip faults. These faults, designated by feature L in Figure 3-35, may represent bedrock structural discontinuities having a linear extent of perhaps tens of kilometers (tens of miles). Inferred or known bedrock structures in the Cold Creek syncline have been reported (Myers, 1981) and are under investigation.

Observations of cliff exposures, manmade cuts, and tunnels through Columbia River basalt flows indicate that, even where flat lying, the interiors of thick flows are locally crossed by subtle, subhorizontal tectonic fractures that intersect cooling joints (DOE, 1982a). These fractures, shown symbolically as feature M in Figure 3-35, may be continuous on scales of tens to hundreds of meters (tens to hundreds of feet). Many are thought to be of tectonic origin related to fold growth (Price, 1980); others are of uncertain origin and might be phenomena related to deposition or cooling of basalt flows.

The gently dipping limbs of anticlines and synclines within the reference repository location contain small zones of tectonic breccia. These zones are typically approximately 1 meter (3 feet) thick in basalt core and are of unknown lateral extent (Moak, 1981). A 5-meter- (16-foot-) thick tectonic breccia in the Frenchman Springs Member of the Wanapum Basalt flow in one borehole in the reference repository location was hydrologically tested using the pulse technique. A hydraulic

conductivity of approximately 10^{-11} meter per second (10^{-6} foot per day) was measured. Future hydrologic testing will determine whether this value is characteristic of other tectonic breccias.

The Cold Creek hydrologic "barrier" (see Fig. 3-1) is an example of what is interpreted as a bedrock structural discontinuity that represents an impediment to ground-water flow. From west to east across this possible structure, hydraulic heads abruptly drop as much as 150 meters (500 feet). In addition, hydrochemical data suggest that mineralized deep waters may be mixing vertically with more dilute, shallower ground waters along or near this feature. The lateral extent and rate of possible ground-water mixing are yet undefined.

3.3.2.2 Alternative ground-water flow concepts

When the existing geohydrologic data base is too preliminary to conclusively support a single ground-water flow model, alternative working hypotheses must be developed. Such is the case in Figure 3-36 where four concepts are shown depicting ground-water movement in a layered basalt sequence such as beneath the reference repository location (Gephart et al., 1983). These alternative models help to focus hydrologic test and characterization efforts so as to eventually develop a single or narrow range of models suitable for detailed numerical simulation (Section ~~6.2.4~~ 6.4.2). In a broad sense, Figure 3-36 incorporates the range of concepts proposed ~~to identify~~ ground-water flow patterns. These concepts are as follows:

- <u>Concept A</u>: This concept illustrates ground water moving principally within heterogeneous, permeable flow tops separating flow interiors of relatively low vertical and horizontal hydraulic conductivity. Upward ground-water movement into shallower systems can occur as a result of (1) the positioning of flows where the front of one basalt flow of limited extent terminates atop a more continuous flow, creating a direct fluid conduit between two flow tops, or (2) ground-water leakage across low hydraulic conductivity flow interiors over large areas. In Concept A, local features of relatively high hydraulic conductivity (such as thickening of flow-top breccia atop a spiracle) are not commonly juxtaposed. Basically, Concept A depicts an anisotropic, heterogeneous flow system undisturbed by major folds and faults.

- <u>Concept B</u>: This concept is similar to Concept A except basalt flows are crossed by bedrock structural discontinuities having potentially larger vertical hydraulic conductivities than the confining aquitards. On a local scale such discontinuities might represent individual tectonic fractures or shear zones. Regionally, these features could depict major fault zones. If rock movement has occurred, such structures could depict zones where the lateral continuity of flow contacts is disrupted causing a flow contact(s) to terminate against a flow interior(s) of lower

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hydraulic conductivity. In Concept B, structural discontinuities are heterogeneities having the potential for vertically connecting shallow and deep flow systems. Dependent on the extent of fracture mineral infilling and (or) fine gouge materials present, these discontinuities could act as conduits of high hydraulic conductivity or ground-water barriers. Overall, Concept B depicts rock volumes of relatively low vertical leakage bounded by structural discontinuities.

- Concept C: This concept represents a flow system characterized by lateral ground-water movement in flow tops bounded by basalt interiors of relatively high leakage. The anisotropy of flow top and interior hydraulic conductivity is considerably less than in Concept A. In Concept C, ground-water movement between deep and shallow systems occurs as a result of stratigraphic positioning or intersection of flow contacts, vertical leakage through unfilled or partially filled cooling fractures, and other primary features of relatively high hydraulic conductivity that are juxtaposed.

- Concept D: This concept superimposes bedrock structural discontinuities on Concept C. As described under Concept B, such discontinuities might act as vertical conduits and (or) barriers of low hydraulic conductivity. Concept D depicts rock zones of relatively high vertical leakage bounded by structural discontinuities.

As noted, the existing geohydrologic data base is too preliminary to conclusively support a single ground-water flow concept. However, the overall concept currently interpreted as most supported by available data for deep basalts is Concept B of Figure 3-36. Bedrock structural discontinuities in this concept are considered to be less frequent and more widely spaced in the gently dipping limbs of Yakima folds (e.g., within the reference repository location) than in the hinge areas and steeply dipping limbs of these folds. The broad aspects of this conceptual model as it may apply to the Hanford Site and vicinity were discussed in Subsection 3.3.2.

A number of geohydrologic characterization activities are currently underway to reduce the present uncertainty regarding conceptual models and ground-water flow paths. These are discussed in Section 4.1 and include such items as (1) further analysis of potential geologic features depicted in Figure 3-36 as well as large-scale, multiwell pump tests, (2) vertical permeability measurements, (3) installation of piezometers, and (4) plans for exploratory shafts involving breakout and testing within a candidate repository horizon. Studies are also underway of tectonic processes, which may generate new ground-water flow paths or alter the hydrologic properties of existing bedrock structures.

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3.4 ENVIRONMENTAL SETTING

The Hanford Site is bounded on the north by the Saddle Mountains, on the east by the Columbia River, and on the south and west by the Yakima River and Rattlesnake Hills, respectively (see Fig. 3-1). The dominant topographical features of the Hanford Site include the Columbia River (and associated aquatic habitats that act as an attraction and migration corridor for those species associated with water and wetlands), sand dunes located near the Columbia River and the basaltic ridges, including the Rattlesnake Hills, rising to an elevation of more than 1,100 meters (3,600 feet).

The Hanford Site is one of the few large areas of land in the region that is currently not developed for agricultural use. The site is also unique in that use of the area is institutionally controlled and a large portion of the site is restricted to projects directly associated with the nuclear industry. The major nuclear facilities and activities occupy only about 6 percent of the total available land area.

3.4.1 Land use

The two principal land uses within the Pasco Basin are agricultural and Federal Government installations. Agricultural land is mostly north and east of the Columbia River and south of the Yakima River. Most of the agricultural land is used for growing irrigated corps. Government installations include the U.S. Department of Energy's Hanford Site in the north-central portion of the Pasco Basin and the U.S. Army Firing Center along the northwestern edge of the Pasco Basin. Land use in the Columbia Plateau is presented in detail in Wukelic et al. (1981).

The 1,500-square-kilometer (570-square-mile) Hanford Site (Fig. 3-37) was established in 1943 as a national security area for plutonium production and was subsequently designated as a National Environmental Research Park by the U.S. Energy Research and Development Administration (predecessor of the U.S. Department of Energy) in 1977. In 1968, the U.S. Atomic Energy Commission designated 311 square kilometers (120 square miles), south and west of Route 240, as an Arid Lands Ecology Reserve (see Fig. 3-37). During the 1970's, an area of approximately 130 square kilometers (50 square miles) of the Hanford Site north of the Columbia River was made available under a revocable permit to the U.S. Fish and Wildlife Service for the Saddle Mountains National Wildlife Refuge and an area of approximately 220 square kilometers (85 square miles) north of the river (Wahluke Wildlife Recreation Area) was made available under a revocable permit to the State of Washington Department of Game to be used for outdoor recreation. These areas were established to act primarily as buffer zones for nuclear activities carried on at the Hanford Site.

Two parcels of land within the Hanford Site are leased to the State of Washington and the Washington Public Power Supply System. The state subleases a portion of its leased land to U.S. Ecology, Inc. for disposal

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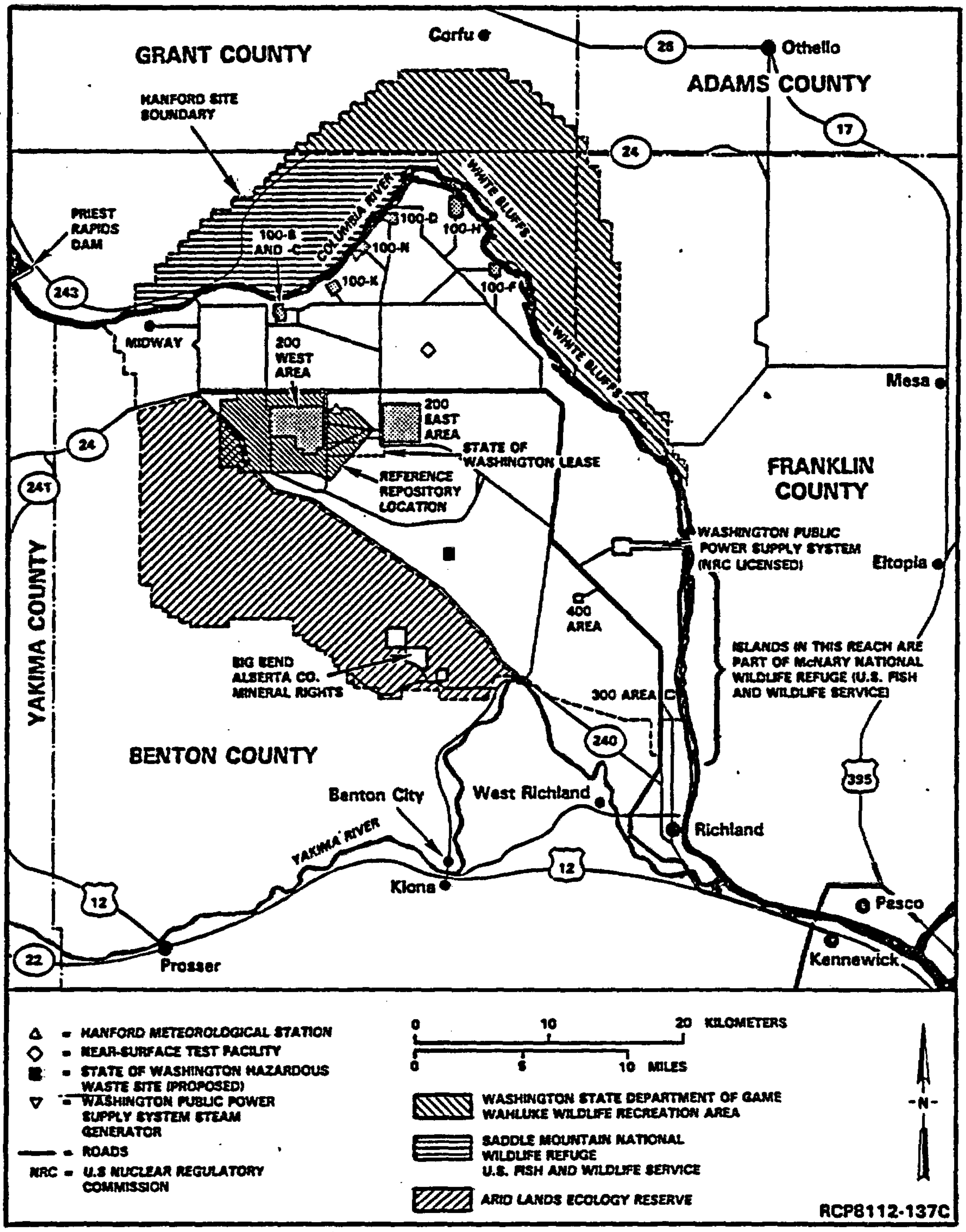

Figure 3-37. Map of the Hanford Site (including land use).

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of low-level radioactive wastes. The Washington Public Power Supply System leased land is the site for three nuclear power reactors; construction is complete, and an operating license issued, on one, construction is deferred on another, and terminated on the third. The state also retains fee title to a section of land for use as a proposed hazardous waste disposal site. In addition, the Big Bend Alberta Company owns the mineral rights for several parcels of land within the Arid Lands Ecology Reserve. The lands designated for the reference repository location consists of acquired land plus sections that have been withdrawn from all forms of appropriation under the public land laws, including the mining and mineral leasing laws. Future plans for the Hanford Site call for the continuation of its present use as an area dedicated primarily to nuclear energy activities (ERDA, 1975).

Lands adjacent to the Hanford Site are privately owned, with the exception of those areas controlled by the State of Washington and county and city governments. The State exercises control over State and Federal highways and special use areas such as parks and wildlife reserves. County and city governments have jurisdiction over publicly owned facilities and establish land use controls within their respective borders.

The closest Indian reservation is ~~owned by~~ that of the Yakima Indian Nation and is located approximately 26 kilometers (16 miles) west of the Hanford Site, 50 kilometers (30 miles) from the reference repository location. The U.S. Army Yakima Firing Center is located approximately 10 kilometers (6 miles) west of the Hanford Site.

3.4.2 Terrestrial and aquatic ecosystems

The Hanford Site has been characterized as a shrub-steppe grassland (Daubenmire, 1970) made up of a variety of plant communities. The sagebrush/cheatgrass community currently dominates the majority of the reference repository location providing food, cover, and shelter to many species of wildlife. THE REFERENCE REPOSITORY LOCATION OCCUPIES THREE PERCENT OF THE HANFORD SITE AREA.

Terrestrial habitats on the Hanford Site are (1) the Rattlesnake Hills, which provide the only mountainous environment on the Hanford Site; (2) sand dunes near the Columbia River, which rise 3 to 5 meters (10 to 16 feet) above ground level and create sandy habitats ranging from less than 1.0 to several hundred hectares (2.5 to several hundred acres) in size; (3) basaltic ridges such as Gable Butte and Gable Mountain; (4) streamside habitats along the Columbia River as well as the ponds and ditches of the Hanford Site area; and (5) exotic trees introduced by man at historic farmsteads, townsites, and artillery emplacements.

Aquatic habitats on the Hanford Site are limited to the Columbia River system (Rickard et al., 1982), several natural springs (e.g., Snively, Bobcat, and Rattlesnake) on the sideslope of Rattlesnake Mountain, one natural pond, West Lake, and several manmade ditches and three manmade ponds. These manmade systems attract many animal species that would not otherwise be found in these normally arid locations.

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Rickard et al. (1981) characterized the 33-hectare (71-acre) Gable Mountain pond (see Fig. 3-25), which was created in 1957 by releasing water from a chemical processing facility. Since that time, the pond has received a more or less constant flow of effluent water. The dominant riparian plants are Bulrush (*Scirpus acutus*) and cattail (*Typha latifolia*). Reed canary-grass (*Phalaris arundinacea*), goldenrod (*Solidago*), barnyard grass (*Echinochloa crusgalli*), Conyza (*Conyza canadensis*), and Russian knapweed (*Centaurea repens*) are some of the common herbaceous species around the pond. The important aquatic plants include: *Myriophyllum heterophyllum*, *Potamogeton richardsonii*, *P. filiformis*, and *Chara*. Russian olive (*Elaeagnus angustifolia*) and Peach-leafed willow (*Salix amygdaloides*) are the dominant tree species which have become established around the shoreline.

B Pond and U Pond (see Fig. 3-25) are similar in many respects to Gable Mountain Pond. However, B Pond is less successionally advanced; whereas, U Pond is more advanced. Many aquatic and riparian associated organisms (birds, mammals, fish, insects) occur at all of the waste ponds. The ponds contain radioactive materials that have entered as a result of accidental releases of contaminated process water.

low but detectable levels of

3.4.2.1 Vegetation

The Hanford Site ecosystem is termed a shrub-steppe ecosystem to distinguish it from the true steppe lands of Asia. The shrub-steppe ecosystem contains several distinct ecological communities, each having common distinguishing features. The vegetation is adapted to tolerate semiarid conditions. The community structure is short, consisting of grasses, forbes, and shrubs with few trees, except along waterways. The Hanford Site is comprised of nine plant communities (Cline et al., 1977): sagebrush/bluebunch wheatgrass, sagebrush-bitterbrush/cheatgrass-Sandberg's bluegrass, sagebrush/cheatgrass-Sandberg's bluegrass, cheatgrass, riparian (streamside) habitats, greasewood, spiny hopsage, winterfat, and thyme buckwheat (Fig. 3-38). Some of these plant communities are extremely limited in distribution. The sagebrush/cheatgrass community currently dominates the proposed reference repository location, with other small tracts of vegetation types interspersed throughout (Fig. 3-39). Some of these other vegetation types are found at World War II army bunker sites dominated by locust trees and Siberian wheatgrass, an undisturbed area consisting of spiny hopsage, and several disturbed areas dominated by tumbleweeds and cheatgrass. These plant communities not only stabilize the soil but provide food, cover, and shelter for many terrestrial animals. The sagebrush/cheatgrass community is particularly susceptible to brush fires during the hot summer months.

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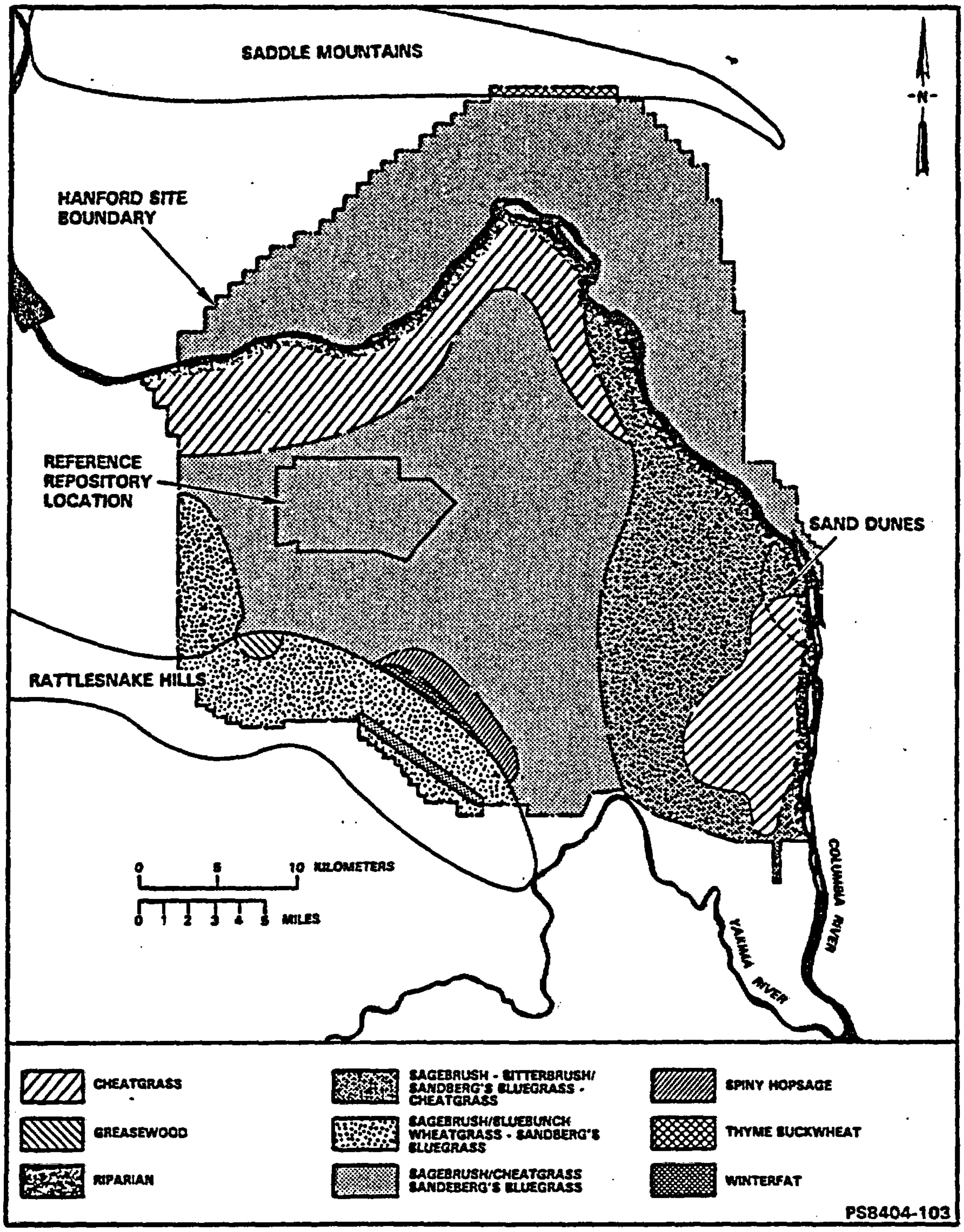

Figure 3-38. Major vegetation types on the Hanford Site.

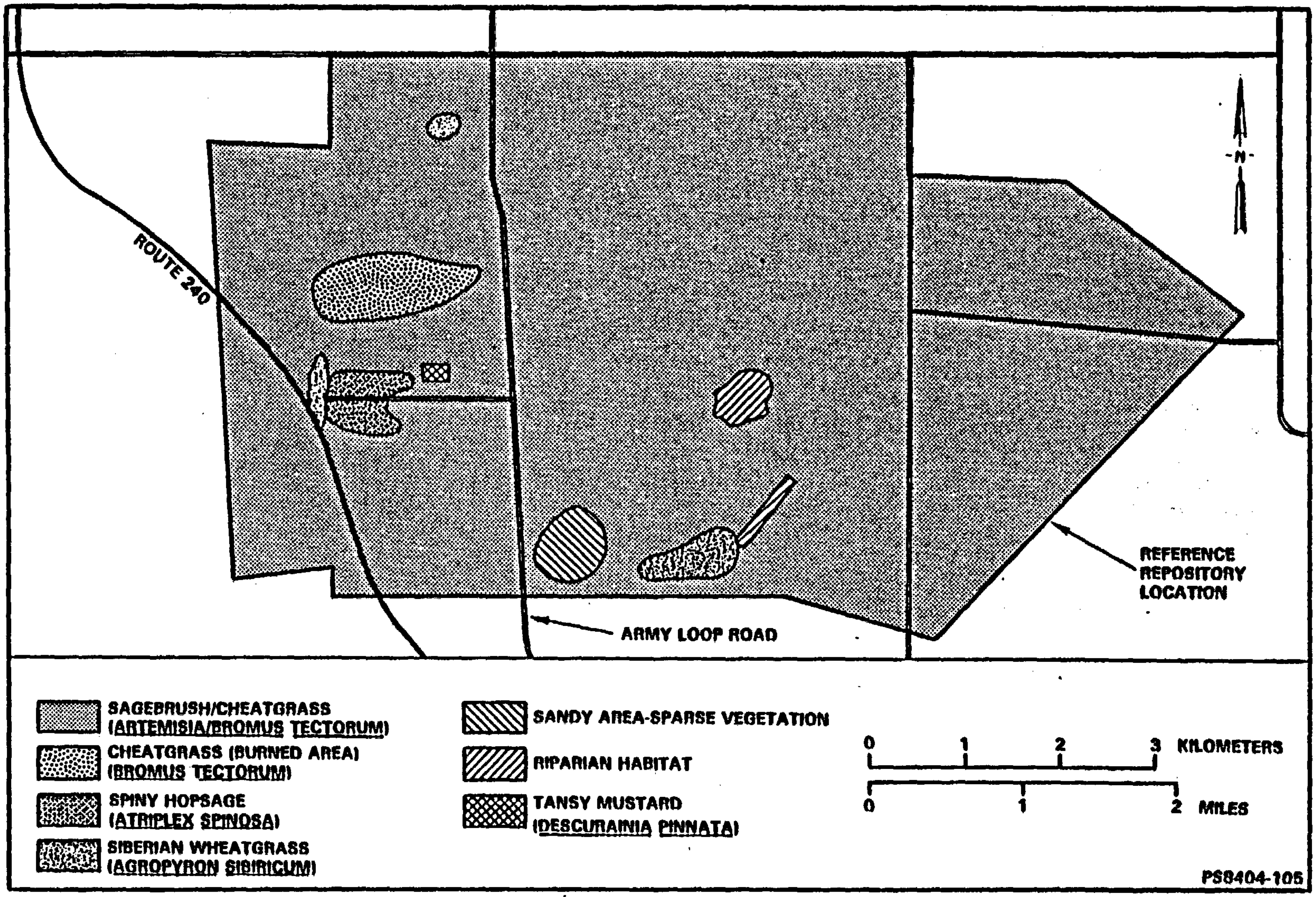

Figure 3-39. Locations of major plant communities within the reference repository location.

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3.4.2.2 Mammals

A total of 27 mammal species (excluding bats) are known to occupy the Hanford Site (Table 3-8) (Rogers and Rickard, 1977). Big-game species include elk and mule deer. Only the mule deer are found with any regularity on the reference repository location. Other mammals that inhabit the Hanford Site include procupine, coyote, striped skunk, badger, racoon, black-tailed hare, and Nuttal's Cottontail rabbit. The coyote and badger are the most common mammalian predators, preying on rodents and other vertebrate organisms. Coyotes are also known to feed on insects, fish, and plant matter. The Great Basin Pocket mouse, deer mouse, Townsend's ground squirrel, and pocket gopher are the common small mammal species that inhabit the reference repository location. Pocket mice, pocket gophers, and Townsend's ground squirrel are excellent burrowers and serve as prey for carnivores.

3.4.2.3 Birds

A list of the most common bird species on the Hanford Site is given in Table 3-9. A more complete list of birds of the Hanford Site is given in U.S. Department of Energy (DOE, 1982b).

The most common upland game birds found within the Hanford Site are the chukar partridge, ringneck pheasant, and California quail. The mourning dove, a migratory game bird, is a common summer resident of the Hanford Site. A variety of raptor species is known to inhabit the Hanford Site. Swainson's hawks, red-tailed hawks, and the American kestrel often nest in trees at the retired army bunker sites and along the Columbia River. Great horned owls, prairie falcons, red-tailed hawks, and the ferruginous hawk nest along the cliffs at Gable Mountain and Gable Butte.

Some of the Hanford Site aquatic areas attract numerous species of waterfowl and shorebirds. These areas are an important stopover point for migrating species and a year-round home to several resident bird species such as magpies, pheasants, song sparrows, and long-billed marsh wrens. Long-billed curlews nest throughout the Hanford Site from March through July and can be expected to nest at the reference repository location (Allen, 1980). Common song and perching birds known to nest within the study site include sage sparrows, Western kingbirds, brewer's blackbirds, Say's phoebes, black-billed magpies, common crows, ravens, loggerhead shrikes, horned larks, and western meadowlarks. Many of these species migrate south during the winter, returning to the Hanford Site to nest in the spring.

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Table 3-8. Common mammal species observed on the Hanford Site.

Common name	Scientific name[a]
Vagrant shrew	Sorex vagrans
Mink	Mustela vison
Longtail weasel	Mustela frenata
Badger	Taxidea taxus
Striped skunk	Mephitis mephitis
Racoon	Procyon lotor
Coyote	Canis latrans
Bobcat	Lynx rufus
Townsend's ground squirrel	Spermophilus townsendii
Beaver	Castor canadensis
Northern pocket gopher	Thomomys talpoides
Great Basin pocket mouse	Perognathus parvus
Western harvest mouse	Reithrodontomys megalotis
Deer mouse	Peromyscus maniculatus
Northern grasshopper mouse	Onychomys leucogaster
Bushy-tailed woodrat	Neotoma cinerea
Motane vole	Microtus montanus
Sagebrush vole	Lagurus curtatus
Muskrat	Ondatra zibethicus
Norway rat	Rattus norvegicus
House mouse	Mus musculus
Porcupine	Erethizon dorsatum
Black-tailed hare	Lepus californicus
White-tailed hare	Lepus townsendii
Nuttall's cottontail rabbit	Sylvilagus nuttallii
Mule deer	Odocoileus hemionus
Elk	Cervus canadensis

[a]Honacki et al. (1982).

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Table 3-9. Common bird species observed on the Hanford Site.

Common name	Scientific name
Chukar partridge	_Alectoris chukar_
Ringneck pheasant	_Phasianus colchicus_
California quail	_Callipepla californica_
Morning dove	_Zenaida macroura_
Swainson's hawk	_Buteo swainsoni_
Red-tailed hawk	_Buteo jamaicensis_
American kestrel	_Falco sparverius_
Great horned owl	_Bubo virginianus_
Prairie falcon	_Falco mexicanus_
Ferruginous hawk	_Buteo regalis_
Long-billed marsh wren	_Cistothorus palustris_
Long-billed curlew	_Numenius americanus_
Sage sparrow	_Amphispiza belli_
Western kingbird	_Tyrannus verticalis_
Brewer's blackbird	_Euphagus cyanocephalus_
Soy's phoebe	_Sayornis saya_
Black-billed magpies	_Pica pica_
Common crow	_Corvus brachyrhynchos_
Common raven	_Corus corax_
Loggerhead shrikes	_Lanius ludovicianus_
Horned larks	_Eremophila alpestris_
Western meadowlarks	_Sturnella neglecta_

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3.4.2.4 Reptiles and amphibians

Reptile and amphibian species are relatively scarce at the Hanford Site. Since amphibians require moisture and standing water in which to propagate, they play only a minor role in the ecosystem of the site; reptiles on the other hand, are more abundant than amphibians because of their physiological adaptions to the semiarid desert environment. Snakes that are most common to the Hanford Site include the gopher snake (Pituophis melanoleucus), Northern Pacific rattlesnake (Crotalus irridus), and Western yellow-bellied racer (Coluber constrictor). The most common lizard is the side-blotched lizard (Uta stansburiana). Lizards depend primarily upon insects as food items, and snakes prey upon a variety of small mammals. Both lizards and snakes are common prey items of mammalian and avian carnivores.

3.4.2.5 Threatened and endangered species

At this time, no federally recognized threatened or endangered animal species (or their critical habitat) are located within the reference repository location. However, although not common within the reference repository location area, one threatened bird species, the bald eagle (Haliaeetus leucocephalus), and one endangered bird species, the peregrine falcon (Falco peregrinus) (FWS, 1983), have been sighted infrequently within the area boundaries during recent field investigations. Both the bald eagle and the peregrine falcon are also classified by the State of Washington as sensitive and endangered, respectively, and are protected by State law (State of Washington, 1983c). Three additional bird species that are found within the reference repository location area are now being considered as potential candidates for protection on the Federal threatened and endangered species list. These are the ferruginous hawk (Buteo regalis), the Swainson's hawk (Buteo swainsoni), and the long-billed curlew (Numenius americanus), all of which nest within or near the reference repository location. Although not yet given official protection under Federal law, the ferruginous hawk is classified as threatened by Washington State. These species are ~~being included~~ in biological investigations.

At this time there are no federally recognized threatened or endangered plant species within the reference repository location. However, the U.S. Fish and Wildlife Severice (FWS, 1980) is currently reviewing the status of several vascular plant species for consideration as proposed threatened species that do occur on the Hanford Site. Included in this category are the Columbia milk-vetch (Astragalus columbianus), and the Persistentsepal yellowcress (Rorippa calycina Variety columbiae). Although the presence of these or other potentially sensitive species within the reference repository location has not been established during recent investigations, investigations are continuing.

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3.4.2.6 Columbia River habitat

The reference repository location is approximately 7 kilometers (4 miles) south of the closest point of the Columbia River (see Fig. 3-37).

The principal biologic elements of the Columbia River habitat may be roughly divided into fisheries and nonfisheries resources.

3.4.2.6.1 Nonfisheries resources

The Hanford reach of the Columbia River is uncharacteristic of other river and stream environs due to the "paucity of tree corridors, willows and cottonwoods, that characteristically border most rivers and streams" (Rickard et al., 1982). Instead of these "tree corridors," one finds plant species capable of rooting in the cobble and gravel substrate, like shrub willows, rushes, grasses, and forbes (Rickard et al., 1982).

The Hanford reach of the Columbia River is also home to numerous bird species, all or part of the year, including the bald eagle (Haliaeetus Leucocephalus), various species of geese and ducks, upland game birds and fish-eating birds (Rickard et al., 1982). The bald eagles winter in the Hanford reach attracted by the supply of salmon carcasses washed ashore during the fall and winter spawning season (Rickard et al., 1982). The Hanford reach is part of the Pacific flyway and, therefore, hosts water fowl during their migration from northern breeding grounds (WPPSS, 1983).

3.4.2.6.2 Fisheries resources

The fisheries resource of the Columbia River is diverse; 44 species of fish have been identified in the Hanford reach (PSPL, 1981). The Chinook (Oncorhynchus tshawytscha), Coho (Oncorhynchus kisutch), and Sockeye salmon (Oncorhynchus nerka), Steelhead trout (Salmo gairdneri), and American shad (Alosa sapidissima) comprise the important anadromous fish species of commercial and recreational value (PSPL, 1981; WPPSS, 1983).

The Hanford reach of the Columbia River serves as the last major spawning ground in this river for Chinook salmon and Steelhead trout; other anadromous fish use the reach as a migration route to spawning areas farther upstream (PSPL, 1981). Other recreationally important fish species include the Mountain whitefish (Prosopium williamsoni), White sturgeon (Acipenser transmontanus), Smallmouth bass (Micropterus salmoides), Yellow perch (Perca falvescens), and Bluegill (Lepomis macrochirus) (PSPL, 1981; WPPSS, 1983). No threatened or endangered fish species have been identified (WPPSS, 1983).

Both the Skagit/Hanford Nuclear Project Application for Site Characterization and the Washington Public Power Supply System Environmental Report, for units one and four, provide more complete description of the fisheries resource in the Hanford reach of the Columbia River (PSPL, 1981; WPPSS, 1983).

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3.4.2.6.3 Water quality

The Washington State Department of Ecology classifies the Columbia River as excellent (Class A) between Grand Coulee Dam and the rivers mouth near Astoria, Oregon (WPPSS, 1983; PNL, 1984). The Class A designation, requires that industrial uses of this water be compatible with other uses including drinking water, wildlife, and recreation (PNL, 1984). The Hanford reach of the Columbia River is the last free flowing portion of the river and is being considered for designation under the Wild and Scenic Rivers Act (USDA, 1970).

The Pacific Northwest Laboratory conducts routine monitoring of Columbia River water quality for both radiological and nonradiological water quality parameters (PNL, 1984). A yearly publication of results has been printed since 1973 (PNL, 1984). Numerous other water quality studies have been conducted on the Columbia River relative to the impact of the Hanford Site over the past 37 years (WPPSS, 1982). ALSO, THE DEPARTMENT OF ENERGY CURRENTLY HOLDS EIGHT NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM PERMITS FOR DISCHARGES INTO THE COLUMBIA RIVER

Radiological monitoring showed low levels of radionuclides in samples of Columbia River water (PNL, 1984). Hydrogen-3 (tritium), strontium-90, iodine-129, and natural uranium were found in slightly higher concentrations downstream of the Hanford Site, but were well below concentration guidelines established by the U.S. Department of Energy and the U.S. Environmental Protection Agency drinking water standards (PNL, 1984).

Temperature is one of the water quality parameters which most affects fish in the Columbia River (WPPSS, 1983). The salmonids are the most sensitive to thermal changes (WPPSS, 1983). The months of July through September are most critical as temperatures peak and reach the upper limits of salmonid tolerance (WPPSS, 1983). Pacific Northwest Laboratory found no significant temperature differences between points above and below the Hanford reach of the Columbia River. Therefore, insolation appears to be the major cause for temperature fluctuations within the Hanford reach (PNL, 1984).

3.4.2.7 Radiological conditions

Radiological surveillance of the Hanford Site and surrounding environs is part of an ongoing program designed to evaluate existing and potential pathways of exposure to contamination from Hanford Site operations. Measurement of the natural background radiation at the Hanford Site began in 1944 with the startup of the first plutonium production reactors. Details of the early surveillance activities have been published in the open literature as topical, periodic reports (Rogers and Richard, 1977, App. D, pp. D.1 through D.8). More recently, the historical record has been maintained through a series of annual reports which evaluate the air, water, soil, flora, and fauna of the Hanford environs in terms of existing and potentially significant radioactive release pathways. Special emphasis is given to pathways of likely environmental reconcentration and those potentially resulting in direct

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exposure to the work force or the public. These annual reports are of three basic types: environmental surveillance, environmental status, and ground-water surveillance.

3.4.2.7.1 Environmental Surveillance reports

The Environmental Surveillance reports summarize offsite sampling data and any pertinent onsite data that affect offsite radiation doses. Also included are discussions of the relationship between observed results and background levels, and an assessment of the impact of site operations on the environment in terms of radiation dose. Typical of these environmental surveillance reports is Sula et al. (1983b).

3.4.2.7.2 Environmental Status reports

The Environmental Status reports address surface and atmospheric measurements made onsite, including both radioactive and nonradioactive environmental discharges. Typical of these status reports ~~is~~ are Sula et al. (1983a), WHEELER et al. (1984), AND GREAGOR ET AL. (1984).

3.4.2.7.3 Ground-Water Surveillance reports

Ground-Water Surveillance reports document the movement of process cooling and waste water discharged from Hanford Site facilities that have reached the unconfined ground water and which contain low levels of radioactive and chemical substances. Eddy et al. (1983) AND WILBUR (1983) typif~~ies~~y the ground-water surveillance reports.

3.4.2.7.4 Radiation source

The sources of radiation in the Hanford Site and vicinity are (after Jamison, 1982):

- Naturally occurring long-lived radionuclides, primarily potassium-40, uranium, thorium, and their decay products.
- Cosmic radiation and naturally occurring radionuclides formed by the interaction of that radiation with stable atmosphere nuclides.
- Fallout from worldwide atmospheric testing of nuclear weapons.
- Radionuclides released to the environment from activities at the Hanford Site.

3.4.2.7.5 Radiation exposures

The concentrations of natural and man-made radionuclides on and around the Hanford Site have resulted in a calculated annual background dose (for calendar 1982) received by the average exposed person living in the Hanford vicinity of 100 millirems per year (Jamison, 1982, pp. 9 through 11). Of this dose, 75 millirem are attributed to external sources (69 millirem of gamma, 6 millirem of neutron) and 25 millirem to internal

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sources (e.g., potassium-40) (Jamison, 1982, pp. 9 through 11). The dose to this average individual attributable to the operations on the Hanford Site has been estimated to be 0.01 millirem per year (ERDA, 1975, pp. III.1 through III.14), the major component of which originates from the remaining plutonium production facility, N Reactor, located at 100-N Area (see Fig. 3-37).

The 50-year whole-body cumulative dose to the maximum individual (i.e., that offsite resident who receives the maximum dose) from Hanford Site effluents has been calculated to be 0.7 millirem. This dose equates to 4 manrem to the population living within 8 kilometers (5 miles) of the Hanford Site (Sula et al., 1983b). In comparison, natural background radiation exposes the individual and the 80-kilometer (50-mile) population to 50-year cumulative dose equivalents of 100 millirem and 34,000 manrem, respectively (Sula et al., 1983b, p. vi).

Four ponds located on the Hanford Site (see Fig. 3-25), outside operating area exclusion fences, have been routinely sampled for radioactivity. Two of the ponds, Gable Mountain Pond and B Pond, north of the 200 East Area, were built in the mid-1950's for disposal of chemical process cooling water and wastes occasionally containing low levels of radioactive contamination (Sula et al., 1983a, p. 21). The Fast Flux Test Facility pond was built in 1978 as a sewage disposal and treatment lagoon and does not receive any radioactive waste. The fourth pond, West Lake, is a natural lake and does not directly receive any discharges from site facilities.

Of these ponds, West Lake exhibits the highest concentrations of gross alpha and gross beta emitters, though a special study in 1975 indicated naturally occurring uranium as the principal source of the radioactivity (Sula et al., 1983b, p. 22). Natural recharge to the lake appears to come from shallow confined aquifers with less exchange occurring between the pond and the shallow unconfined aquifer (Gephart et al., 1976), thus; the naturally occurring radionuclides have been concentrated by evaporation through time (Sula et al., 1983a, p. 22).

The Columbia River constitutes the primary exposure pathway for liquid effluent radioactivity. During the early years of Hanford Site operations (1944 to 1971), thousands of curies per day of short-lived radionuclies were discharged to the river from production reactors located along the shoreline. With the noted exception of the N Reactor, all the other production reactors were closed down ~~in~~ by 1972. The shutdown of these production reactors resulted in a major reduction in radionuclides released to the Columbia River. Since that time, the N Reactor has been outfitted with liquid effluent control systems, further reducing the discharge of radioactive materials to the river. During 1982, for example, statistically higher levels of iodine-129 were noted downstream (than upstream) of the Hanford Site, but the observed levels were very low (maximum was $1.7 \times 10^{-4} + 1.4 \times 10^{-5}$ picocuries per liter). The dose impact from iodine-129 was calculated to be 0.002 millirem to the thyroid of an assumed maximum exposed individual (Sula et al., 1983b, p. 52).

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Both iodine-129 and tritium are found in the unconfined ground-water aquifers as a result of waste discharges in the 200 Areas. The estimated average net increase of iodine-129 in the river resulting from the unconfined ground water was 6 x 10^{-5} picocuries per liter in 1982. During the same interval, the estimated tritium contribution to the river from the ground water was too small to be accurately measured in the presence of relatively high background concentrations found in the river (670±20 picocuries per liter) (Sula et al., 1983b, p. 15). The tritium plume continues to show increasing concentrations near the Columbia River (Eddy et al., 1983, p. 25), though as previously stated, the overall contribution to the river was so small that it could not be accurately measured.

Drinking water obtained from the contaminated unconfined aquifer was consumed by employees at the Fast Flux Test Facility during 1982. The annual whole-body dose attributable to the tritium in the drinking water (average 18 picocuries per milliliter) was calculated to be 0.3 millirem, based on an ingestion rate of 250 liters (66 gallons) per year. Because of the short half life (10 days) in the body, the entire dose commitment is received in the year of exposure. The calculated dose was less than 10 percent of the State of Washington drinking water standard (Eddy et al., 1983, p. 23) for calendar year 1982.

Samples of agricultural foodstuffs, grown in the vicinity of the Hanford Site, have been examined annually for radiological contamination. Recent levels have been consistently low and are probably attributable to global weapons testing. No associations with radioactivity from the Hanford Site have been made since the shutdown of eight production reactors (Sula et al., 1983b, p. v).

Low concentrations of radionuclides attributable to Hanford Site operations have been measured in ducks and game birds collected near operating facilities. Concentrations were low enough that dose resulting from ingestion of these wildlife forms containing the highest observed concentrations would be well below the applicable U.S. Department of Energy radiation protection standard. Fish from the Hanford Site reach of the Columbia River have been found to exhibit cobalt-60 and strontium-90 more frequently than those collected upstream. However, levels are generally too low and too variable to permit any quantifiable differences. Cesium-137 levels measured in Hanford Site deer over a recent two-year interval have been consistently low, potentially resulting in a maximum dose to a consumer of less than 1 percent of the applicable radiation protection standard. (Price, et al., 1984, p. 33)

Soil and vegetation assays taken from the Hanford Site environs have disclosed no discernable differences in the levels of radionuclide concentrations across the geographical area. ~~with the possible exception of uranium. Surface soils across the Columbia River from the 300 Area have slightly higher levels of uranium than other areas surveyed. It has not yet been determined whether the differences are due to naturally occurring uranium in the soil or to operations in the 300 Area (Sula et al., 1983a, p. vi).~~

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3.4.3 Meteorological conditions and air quality

Meteorological data are collected at a number of locations on the Hanford Site. Complete climatological data are available for the Hanford Meteorological Station, located between the 200 Areas in the northeast section of the reference repository location. Data have been collected at the Hanford Meteorological Station since 1945, and temperature and precipitation data from a nearby location are available for the period 1912 through 1943. A summary of these data, for the period through 1980, has been published by Stone et al. (1983). The summary also contains wind data for several locations on and near the Hanford Site. For the purpose of this study, data from the Hanford Meteorological Station are assumed to be representative of the general climatic conditions that exist at the reference repository location. Hanford climatological conditions discussed in this section are based on the data summaries given in Stone et al. (1983).

3.4.3.1 Wind

Wind data are collected routinely at the Hanford Site by the Hanford Meteorological Station and a series of wind telemetry stations are distributed on and around the Hanford Site. An example of these observations is given in Figure 3-40, which presents wind direction frequencies at the Hanford Meteorological Station and 12 of the telemetry sites. Some differences in dominant wind directions as a function of location can be noted in Figure 3-40. These differences can be attributed largely to terrain influences. Disperson models used at the Hanford Site (e.g., Ramsdell and Athey, 1981) account for these effects by using data from each of the wind-measuring sites. However, the Hanford Meteorological Station is located within the reference repository location and wind data from the Hanford Meteorological Station are assumed satisfactory for describing the climatological wind characteristics for this study.

Frequencies of wind direction by month at the Hanford Meteorological Station are given in Figure 3-41 for the 25-year period of 1955 through 1980. Prevailing wind directions are from the northwest in all months. Secondary maximums are indicated for southwesterly winds. The wind direction summaries indicate that winds from the northwest quadrant (i.e., west-northwest, northwest, north-northwest) occur most often during the winter (i.e., December, January, February) and summer (i.e., June, July, August). During the spring and fall, the frequency of southwesterly winds increases with a corresponding decrease in northwest flow. Winds blowing from other directions (e.g., northeast) display minimal variation from month to month.

Monthly and annual joint frequency distributions of wind direction versus wind speed are given in Stone et al. (1983, Table 41, pp. X-13 through X-19). According to these summaries, monthly average wind speeds are lowest during the winter months, averaging 10 to 11 kilometers per hour (6 to 7 miles per hour). The highest wind speeds occur during the

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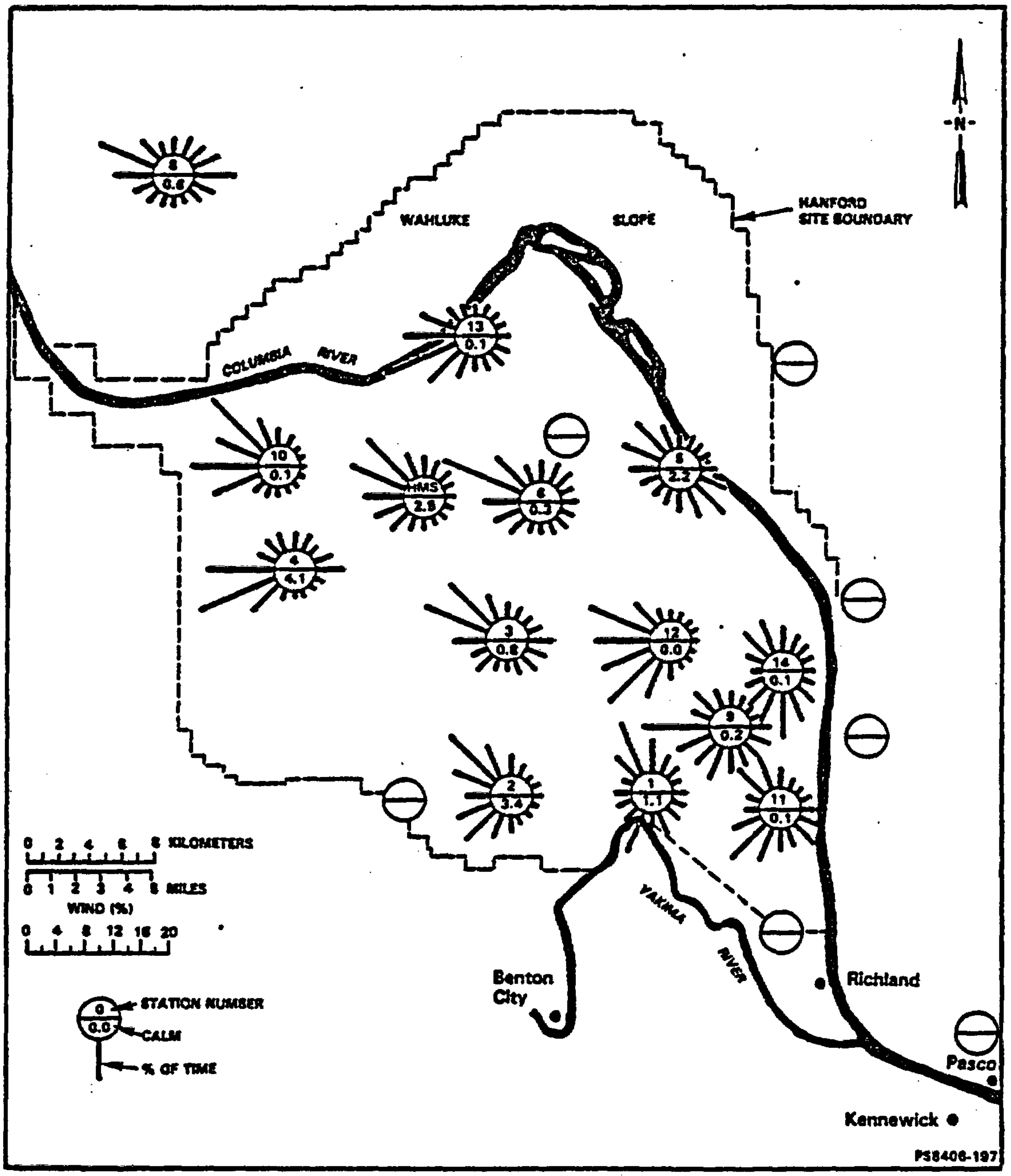

Figure 3-40. Wind roses for the Hanford Telemetry Network.

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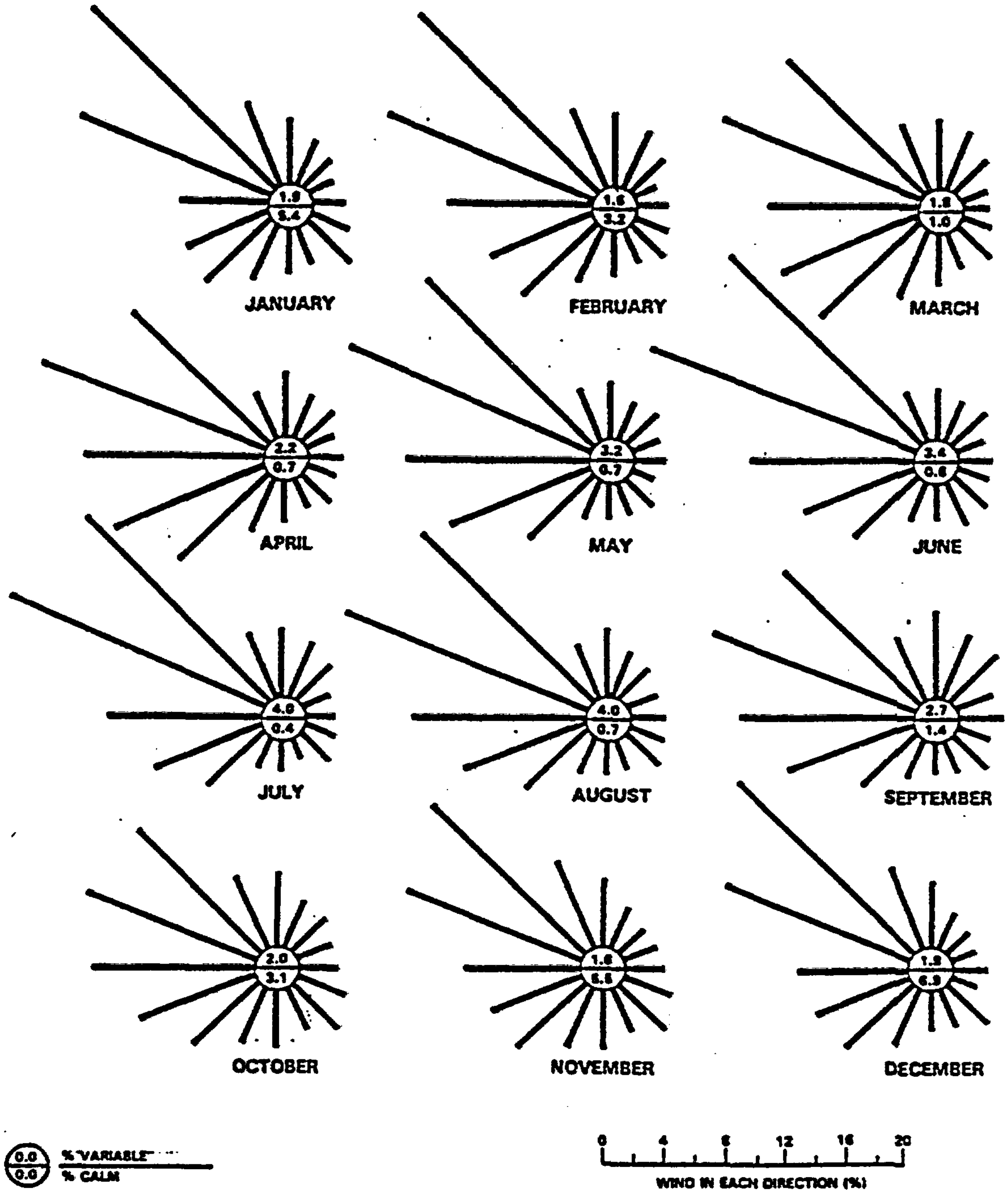

Figure 3-41. Monthly wind roses for Hanford Meteorological Station based on 15.2-meter (50-foot) wind data, 1955 through 1980. (The numbers in the centers are the percentages of calm (top numbers) and variable (bottom numbers) winds. The points of the rose represent the directions from which the winds blow.) (Taken from Stone et al., 1983.))

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summer, averaging 14 to 16 kilometers per hour (9 to 10 miles per hour) on a monthly basis. Maximum wind speeds at the Hanford Meteorological Station occur during the summer and are usually associated with southwesterly winds. For example, most observations of winds exceeding 48 kilometers per hour (30 miles per hour) are from the southwest during the summer. These conditions are responsible for most of the dust storms experienced in the region. Likewise, wind speeds exceeding 90 kilometers per hour (57 miles per hour), which occur in every month at the Hanford Meteorological Station (though more prevalently during the summer), are associated with southwesterly flow.

Other conditions associated with high winds are thunderstorms and summertime afternoon drainage winds. An average of ten thunderstorms occur each year. Although they have been recorded in every month, they are most frequent during the summer months. The winds during thunderstorms show no directional preference. The summertime strong drainage winds are generally northwesterly.

Based on the Hanford Meteorological Station climatological summary (Stone et al. 1983) and National Severe Storms Forecast Center data dase, 22 tornado events have been reported in the vicinity of the Hanford Site (161-kilometer (100-mile) radius) between 1916 and August 1982. At least two tornadoes have occurred since August 1982, and several funnel clouds have been reported. One of the two confirmed tornadoes since August 1982 occurred between Touchet and Lowden, Washington. The other was reported between Connell and Eltopia, Washington. The tornado recurrence interval within a 160-kilometer (100-mile) radius of the Hanford Site is reported in Stone et al. (1983) as one per 146,000 years. The average dimensions for tornadoes within this area for which dimensions are reported are: path length--14.2 kilometer (8.8 miles), path width--39 meters (130 feet). Tornadoes are commonly rated on a scale, originated by Fujita (1971), on the basis of damage that they cause and the area that they affect. The scale ranges from F0 through F5. Tornadoes rated F0 and F1 are described as weak tornadoes; F2 and F3 tornadoes are described as strong, and F4 and F5 tornadoes are described as violent. The tornadoes in the northwest portion of the United States are generally small with ratings of F2 and below. Grazulis (1984) does not list any violent tornadoes for the region.

The maximum wind speed 78 estimated for ~~a~~ THE DESIGN BASIS tornado at the reference repository location is ~~102.4~~ meters per second (~~229~~ 175 miles per hour). The rotational component of the speed is estimated to be ~~80.9~~ 67 meters per second (~~181~~ 150 miles per hour), and the translation component is estimated at ~~21.5~~ 26 meters per second (~~48~~ miles per hour). ~~The total pressure drop is estimated to be 9.69 kilopascals (1.41 pounds per square inch), with a maximum rate of decrease of 3.64 kilopascals per second (0.53 pounds per square inch per second).~~ THE DIFFERENTIAL PRESSURE LOADING RESULTS FROM A 5.2 KILOPASCAL (0.75 POUNDS PER SQUARE INCH) AMBIENT PRESSURE DECREASE IN THREE SECONDS, HELD FOR ONE SECOND, AND RETURN TO AMBIENT AT THE SAME RATE.

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3.4.3.2 Temperature and Humidity

Diurnal and monthly averages and extremes of temperature, dewpoint, and humidity are contained in Stone et al., (1983). Temperature records are summarized for the period 1912 through 1980. Average monthly temperatures range from a low of -1.5°C (29.3°F) in January to a high of 24.7°C (76.4°F) in July. The maximum monthly average temperature at the Hanford Meteorological Station during the winter was 6.9°C (44.5°F), and the lowest was -5.9°C (21.4°F)--both occurring during February. The maximum monthly average temperature during the summer was 27.7°C (81.8°F)--in July, and the lowest was 17.2°C (63.0°F)--in June. The annual average relative humidity at the Hanford Meteorological Station is 54 percent, with maximums during the winter months (averaging approximately 75 percent) and the minimum average relative humidity during the summer (on a monthly basis, approximately 35 percent).

3.4.3.3 Precipitation

Average annual precipitation at the Hanford Meteorological Station is 16 centimeters (6.3 inches). Most of the precipitation takes place during the winter. On the average, the months of November through February account for nearly half of the annual precipitation. Days of the year with greater than 1.3 centimeters (0.5 inch) occur less than 1 percent of the year. Rainfall intensities of 1.3 centimeters (0.5 inch) per hour persisting for one hour (i.e., 1-hour duration) are expected once every 10 years. Rainfall intensities of 2.5 centimeters (1.0 inch) per hour for one hour are expected only once every 500 years. Monthly average snowfall ranges from 0.8 centimeter (0.3 inch) in March to 13.5 centimeters (5.3 inches) in January. The record snowfall occurred in February 1916 with 62 centimeters (24.5 inches) recorded on the ground.

3.4.3.4 Climatological diffusion conditions

Atmospheric transport and diffusion conditions are a function of wind speed, wind direction, atmospheric stability and mixing depth, among other parameters. Generally speaking, poor dispersion conditions will exist when an effluent is released into a stable layer with a low capping inversion and light winds. Good dispersion conditions will prevail when wind speeds are moderate to strong in a neutrally or unstably stratified atmosphere with virtually unlimited vertical mixing. Both sets of conditions are found in the Hanford Meteorological Station data summaries.

The probabilities of extended periods with temperature inversions at the Hanford Site are discussed by Stone et al. (1972). Given an initial observation of inversion conditions between 1 and 61 meters (3 and 200 feet), the probability of inversion persistence for more than 12 hours varies from a low of approximately 0.1 from May through August to a high

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of approximately 0.64 in September and October. The probability that an inversion will persist more than 24 hours reaches a maximum of slightly more than 0.02 in January and February.

The depth of the atmospheric mixing layer is monitored on a continuous basis at the Hanford Meteorological Station using an acoustic sounder. Table 3-10 presents the summaries that have been prepared relating season and time-of-day to the frequency of heights of the mixed layer.

Poor dispersion conditions are most likely to occur during the winter at the Hanford Site. Moderately stable and very stable conditions exist 66 percent of the time during the winter, most often accompanied by light northwest or west-northwest flow and mixing depths less than 500 meters (1,641 feet). Good dispersion conditions prevail during the summer, with unstable or neutral stratification 57 percent of the summer, accompanied by moderate to strong southwesterly or northwesterly winds and deeper mixing depths. Note that the definitions of stability used in the Hanford Meteorological Station data summaries prepared by Stone et al. (1983) are based on numerous atmospheric diffusion tests conducted at the Hanford Site, and do not correspond directly to the stability class definitions in Regulatory Guide 1.23 (NRC, 1974). More recently, McCormack et al. (1984) computed x/Q values for surface and elevated releases from the 200 Areas (among other locations at the Hanford Site). In their study, joint frequency distributions of wind speed, wind direction and stability were based on both the Pasquill-Gifford-Turner approach (Turner, 1969) and the Nuclear Regulatory Commission criteria. The climatological descriptions of wind speed, direction, and stability used by McCormack and his coworkers agree closely with those reported in Stone et al. (1983).

3.4.3.5 Air Quality

Air quality in the vicinity of the Hanford Site is generally quite good. The National Ambient Air Quality Standards, which apply to the proposed repository, are given in Table 3-11. The Benton-Franklin-Walla Walla Counties Air Pollution Control Authority routinely monitors total suspended particulate concentrations at the Hanford Meteorological Station. No other criteria pollutants are routinely monitored by this agency in the region. The discussion of air quality in the Skagit/Hanford draft environmental impact statement (NRC, 1982a, Subsection 4.2.10.2) reflects the current conditions in the Columbia Basin, but does not cover the release of nitrogen oxides.

Releases of nitrogen oxides ~~are~~ associated with the chemical processing of reactor fuel at the PUREX facility at the Hanford Site was resumed in November 1983 for the first time since 1972. Ramsdell (1981) reports on the observed nitrogen oxide levels in the vicinity of the processing facility during the last period of operation (1968 to 1969). Annual average concentrations estimated from these measurements were near or below 12 parts per billion (detection threshold of the instrumentation), which in turn are below the 50 parts per billion annual

THESE RELEASES ARE CONTROLLED UNDER A PREVENTION OF SIGNIFICANT DETERIORATION PERMITS

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Table 3-10. Hanford mixing layer thickness climatology. (Sheet 1 of 2)

Height (m)[a]	Time-of-day[b]					
	004-04	04-08	08-12	12-16	16-20	20-24
			WINTER[c]			
0 to 100	0.1737	0.1737	0.1018	0.1093	0.1737	0.1976
100 to 250	0.4833	0.4775	0.3653	0.2410	0.4641	0.4805
250 to 500	0.2470	0.2485	0.3877	0.392	0.2814	0.2620
500 to 1,000	0.0240	0.0195	0.0464	0.1317	0.0359	0.0150
greater than 1,000	0.0719	0.0808	0.0988	0.1198	0.0449	0.0449
			SPRING[d]			
0 to 100	0.1711	0.0978	0.0109	0.0124	0.1056	0.1662
100 to 250	0.3904	0.3929	0.0994	0.0544	0.1677	0.3168
250 to 500	0.2846	0.3432	0.2655	0.1537	0.2189	0.2407
500 to 1,000	0.0327	0.0699	0.3090	0.3075	0.1599	0.0497
greater than 1,000	0.1213	0.0963	0.3152	0.4721	0.3478	0.2267
			SUMMER[e]			
0 to 100	0.0927	0.0565	0.0134	0.0054	0.0430	0.0766
100 to 250	0.3925	0.3186	0.0255	0.0067	0.1075	0.3226
250 to 500	0.3710	0.4772	0.1949	0.0901	0.1586	0.2245
500 to 1,000	0.0981	0.1048	0.5202	0.4489	0.2675	0.1237
greater than 1,000	0.0457	0.0430	0.2460	0.4489	0.4234	0.2527

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Table 3-10. Hanford mixing layer thickness climatology. (Sheet 2 of 2)

Height (m)[a]	Time-of-day[b]					
	004-04	04-08	08-12	12-16	16-20	20-24
FALL[f]						
0 to 100	0.1544	0.1148	0.0506	0.0342	0.1637	0.1557
100 to 250	0.4126	0.4071	0.1475	0.0738	0.3142	0.3934
250 to 500	0.3292	0.3921	0.4208	0.2965	0.2719	0.3142
500 to 1,000	0.0506	0.0451	0.2691	0.4358	0.1435	0.0656
greater than 1,000	0.0533	0.0410	0.1120	0.1598	0.1066	0.0710
ANNUAL SUMMARY						
1 to 100	0.1464	0.1094	0.0438	0.0394	0.1205	0.1471
100 to 250	0.4191	0.3971	0.1560	0.0915	0.2611	0.3777
250 to 500	0.3104	0.3691	0.3167	0.2328	0.2317	0.2608
500 to 1,000	00527	0.0606	0.2920	0.3368	0.1546	0.0653
greater than 1,000	0.0714	0.0639	0.1915	0.2995	0.2321	0.1492

MEAN VALUES

	Winter	Spring	Summer	Fall	Annual
0 to 100	0.1549	0.0940	0.0479	0.1123	0.1011
100 to 250	0.4187	0.2369	0.1956	0.2914	0.2837
250 to 500	0.3041	0.2511	0.2527	0.3374	0.2869
500 to 1,000	0.0454	0.1548	0.2605	0.1683	0.1603
greater than 1,000	0.0769	0.2633	0.2433	0.0906	0.1679

NOTE: Based on temperature records and acoustic sounder data March 25, 1982 through Jauary 31, 1984.

[a]Meters x 3.281 = feet.
[b]Pacific standard time.
[c]December, January, and February.
[d]March, April, and May.
[e]June, July, and August.
[f]September, October, and November.

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Table 3-11. ~~Natural~~ National ambient air quality standard.

Pollutant	Averaging period				
	1 h	3 h	8 h	24 h	Annual
Carbon monoxide	40,000a	--	10,000a	--	--
Hydrocarbons	160	--	--	--	--
Sulfur dioxide	--	1,300a,b	--	365a,b	80b
Nitrogen oxides	--	--	--	--	100
Total suspended particulates	--	--	--	150a,b	60a

NOTE: All units in micrograms per cubic meters.
[a]Not to be exceeded more than once per year.
[b]Secondary standard.

average nitrogen oxide air quality standard. Recent nitrogen oxide measurements made before the facility restart indicate a background concentration of less than 0.007 parts per million (Sula et al., 1983a). During rennovation of the facilities before fuel processing was resumed, nitrogen oxide emission control equipment was upgraded. As a result, even with fuel processing, the ambient nitrogen oxide concentrations are expected to remain within permissible Federal and State of Washington limits (DOE, 1982a, 1983b).

Wind eroded dust is a problem in the area, but is likely to occur under conditions that are otherwise favorable to pollutant transport and diffusion. In other words, the strong winds, deep mixing layers, and neutral or unstable stability conditions that favor wind erosion and blowing dust episodes also represent conditions which favor pollutant dispersion. Finally, on a short-term basis, the dust storms that occur in the region can produce high total suspended particulate concentrations. However, on both an annual and a short-term basis, the region is in compliance with the National Ambient Air Quality Standards for particulates. All other pollutant levels also satisfy the Federal and State of Wahington standards (Jenne, 1981).

3.4.4 Noise

Background noise at the reference repository location was not measured for this study. However, background noise measurements were conducted by Puget Sound Power & Light Company for the Skagit/Hanford Nuclear Project (PSPL, 1981, Table 2.7-1, and Fig. 2.7-1). Ambient noise levels on the Hanford Site do not exceed Federal and State of Washington noise standards. The noise measurement site nearest the proposed reference repository location recorded ambient noise levels of 32 decibles using the A-scale.

3.4.5 Aesthetic resources

The National Registry of Natural Landmarks lists the following four historic sites, which are within approximately 80 kilometers (50 miles) of the Hanford Site (NPS, 1983).

- Ginkgo Petrified Forest, located in Kittitas County, 47 kilometers (29 miles) east of Ellensburg, 54 kilometers (36 miles) north-northwest of the reference repository location.

- Grand Coulee, located in Grant County between the towns of Grand Coulee and Soap Lake, 88 kilometers (55 miles) north of the reference repository location.

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- Wallula Gap, located in Benton and Walla Walla Counties, approximately 26 kilometers (16 miles) south of Pasco, 80 kilometers (50 miles) south-southeast of the reference repository location.

- Umtanum Ridge Water Gap, located in Kittitas County, approximately 23 kilometers (14 miles) north of Yakima, 69 kilometers (43 miles) west-northwest of the reference repository location.

One of the most notable natural features of this area is the Columbia River, the Hanford Site reach of which is the last free-flowing stretch of this river in the United States. The White Bluffs, rising 100 to 165 meters (340 to 540 feet) above the eastern shoreline of the river, provide another natural landmark. The southwestern edge of the Hanford Site is marked by the Rattlesnake Mountain, the highest peak in the vicinity of the Hanford Site. Other natural features in the area include Sentinel Gap and the Saddle Mountains to the north of the Hanford Site, the Yakima River to the south, and the Snake River to the southeast.

3.4.6 Archaeological, cultural, and historical resources

Although the area surrounding the Columbia River was one of the most densely inhabited regions of the aboriginal North America, with the exception of sites located on the Hanford Site reach of the Columbia River, evidence of this aboriginal culture has been virtually erased. Controlled access to the Hanford Site has protected these remaining sites from destruction by relic collectors. At present, nine archeological properties on the Hanford Site are listed in the National Register of Historic Places (State of Washington, 1981b).

Some of the Rattlesnake Springs sites, which are within 2.5 kilometers (1.6 miles) of the reference repository location boundary, are the closest known archaeological sites. A number of other archeological sites, which are not of national significance, have been identified on the Hanford Site (Rice, 1968a, 1968b). Areas along the Columbia River shoreline are particularly rich in Indian artifacts. In 1981 and again in 1982, archaeological field surveys were conducted to intensively investigate the reference repository location. These studies concluded that none of the repository undertakings will have an affect on significant cultural resources (Rice, 1984a; 1984b).

3.5 TRANSPORTATION

An excellent transportation network facilitates travel and the marketing of goods and commodities within the Tri-Cities (Richland, Pasco, and Kennewick, Washington) region, which is about 40 kilometers (25 miles) southeast of the proposed repository site. Commercial air transportation is available at the Tri-Cities Airport, which offers direct service to

major regional cities with connections to cities nationwide via several airlines. Transportation of bulk commodities along the Columbia River and Snake River is available through barge lines, and a network of rail transportation is provided by Burlington Northern, Union Pacific, and Amtrak. Interstate highways and State routes connect the region to major metropolitan areas throughout the Northwest. Several highway projects are under construction or are planned; these include: (1) a new Columbia River bridge connecting Interstate 82 to Interstate 84 in Oregon, (2) new Columbia River and Yakima River bridges (Interstate 182) in Richland providing a third link between Benton and Franklin Counties, and (3) completion of Interstate 82 and Interstate 182, which will connect the Tri-Cities to Seattle to the west and the Tri-Cities to Interstate 84 to the south. The major improvements planned for U.S. Highway 395 to the north and east include widening to four lanes and increasing the Snake River bridge to four lanes.

3.5.1 Railroad service

The Tri-Cities is served by the Burlington Northern and Union Pacific Railroads, making the area one of the few between the Cascade and Rocky Mountains to be linked to both systems. In addition, a short line operated by the U.S. Department of Energy runs in the Richland-Hanford Site Area.

Agricultural products, fuel, and fertilizer, plus construction materials and equipment, are the principal commodities shipped by rail in this area. Manufactured fertilizer products, grain, and frozen food make up the greatest share of outgoing commodities. Large quantities of other food products also leave the Tri-Cities by rail. The inbound freight includes fertilizer, raw materials, chemicals, fuel, farm equipment, and construction supplies and equipment.

Figure 3-42 shows the major rail lines of the Burlington Northern and Union Pacific Railroads in the Pacific Northwest states.

3.5.1.1 Burlington Northern Railroad

The Burlington Northern is the longest railroad in the United States. Its tracks stretch from Canada to the Florida Panhandle, from the Gulf of Mexico to the Great Lakes and into the Pacific Northwest. The Tri-Cities is at the hub of the Burlington Northern lines in the Pacific Northwest, which extends 373 kilometers (232 miles) southwest to Portland, 404 kilometers (251 miles) northwest to Seattle, and 233 kilometers (145 miles) northeast to Spokane. A computerized classification yard is located in Pasco. Trains move into the yard and are broken up and blocked to move east, west, north, or south.

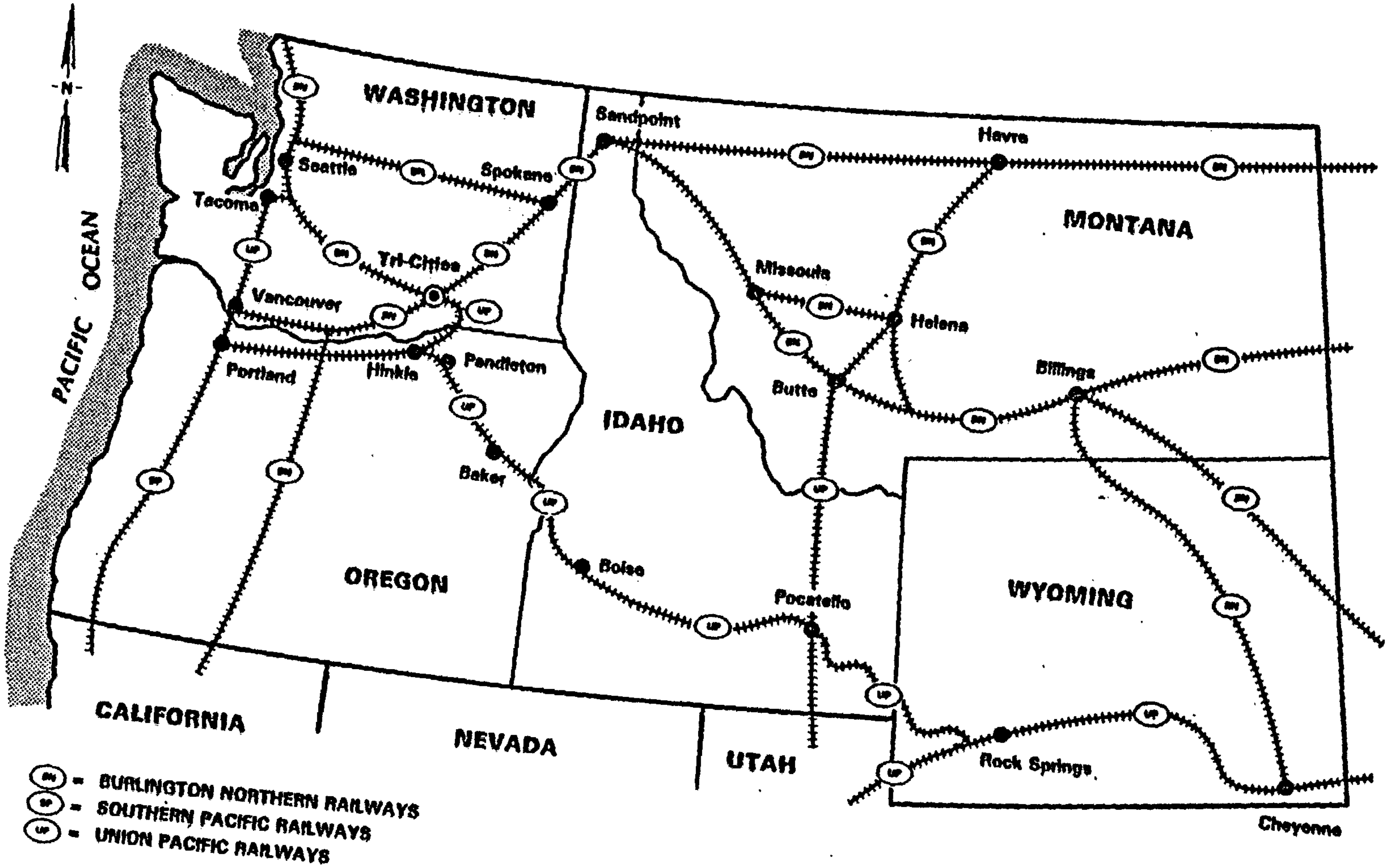

Figure 3-42. Major Pacific Northwest rail lines providing access to the Tri-Cities, Washington: Burlington Northern (N) and Union Pacific (UP).

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3.5.1.2 Union Pacific Railroad

The recent merger of the Union Pacific, Missouri Pacific, and Western Pacific makes the Union Pacific the second longest railroad in the United States. The Union Pacific now connects the Pacific Northwest, San Francisco, and Los Angeles on the west coast to both the Great Lakes region and the Gulf of Mexico to the east. All service to the Pacific Northwest over the Union Pacific system goes through the modern, computerized regional classification yard at Hinkle, Oregon, some 80 kilometers (50 miles) south of the Tri-Cities. The Tri-Cities is served by the Yakima branch, which connects directly to the regional classification yard at Hinkle.

3.5.1.3 U.S. Department of Energy

The U.S. Department of Energy controls the rail access into the Hanford Site; their trackage ties in with the Union Pacific tracks southeast of the Richland "Y" area near the U.S. Highway 12 and Route 240 interchange. Both the Burlington Northern and Union Pacific have trackage ~~unlimited access~~ rights over the U.S. Department of Energy trackage between the Richland "Y" area and the U.S. Department of Energy 1100 Area in north Richland. The U.S. Department of Energy tracks serving the Hanford Site are installed parallel to the Route 240 Bypass to the west of Richland's central business district.

3.5.2 <u>Highway service</u>

The east-west interstate highways providing ready access to the Tri-Cities area are Interstate 90 and 84, which run north and south of the Tri-Cities, respectively (Fig. 3-43). These two highways provide the major links to Seattle, Washington, and Portland, Oregon. The primary north-south highway is Interstate 5, which connects Seattle and Portland, and runs the entire length of the West Coast. In California, this highway connects to several east-west interstate highways.

The Tri-Cities region is served by four important highway routes separate from, but providing access to, the major interstate highways. The local and regional highway network in the Tri-Cities region is shown in Figure 3-44. U.S. Highway 12 comes from the Puget Sound area and continues through to the Midwest via Walla Walla and Lewiston; U.S. Highway 395 begins north of Spokane at the Canadian border and extends south to southern California; Route 14 provides intrastate traffic between the Tri-Cities and Vancouver, Washington; and Route 240 provides access to Interstate 90 at Vantage. Interstate 90 extends from Seattle through the Midwest to Chicago, Cleveland, Buffalo, and Boston. Interstate 84 provides access from Portland to Salt Lake City, Omaha, Chicago, Cleveland, and New York. Regional segments of new interstate highways (Interstate 82 and Interstate 182) are currently under construction. These new segments will further improve access to the Hanford Site. These new Interstate highways will connect Interstate 84 in Oregon to a point just south of Richland, Washington. Thereby replacing existing two-lane highways and bypassing the existing four-lane highway between Kennewick and Richland, Washington.

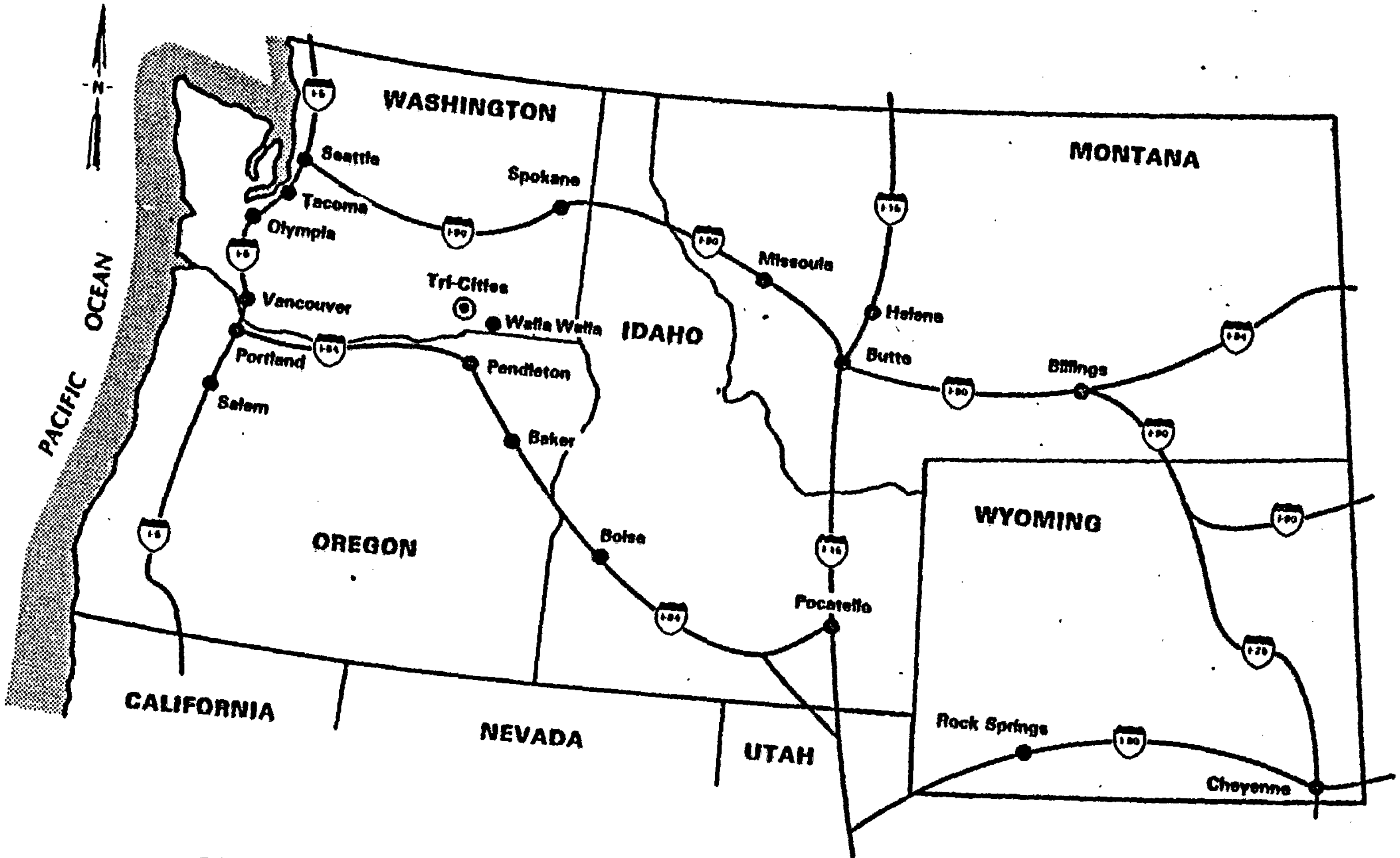

Figure 3-43. Major Pacific Northwest interstate highways providing access to the Tri-Cities, Washington.

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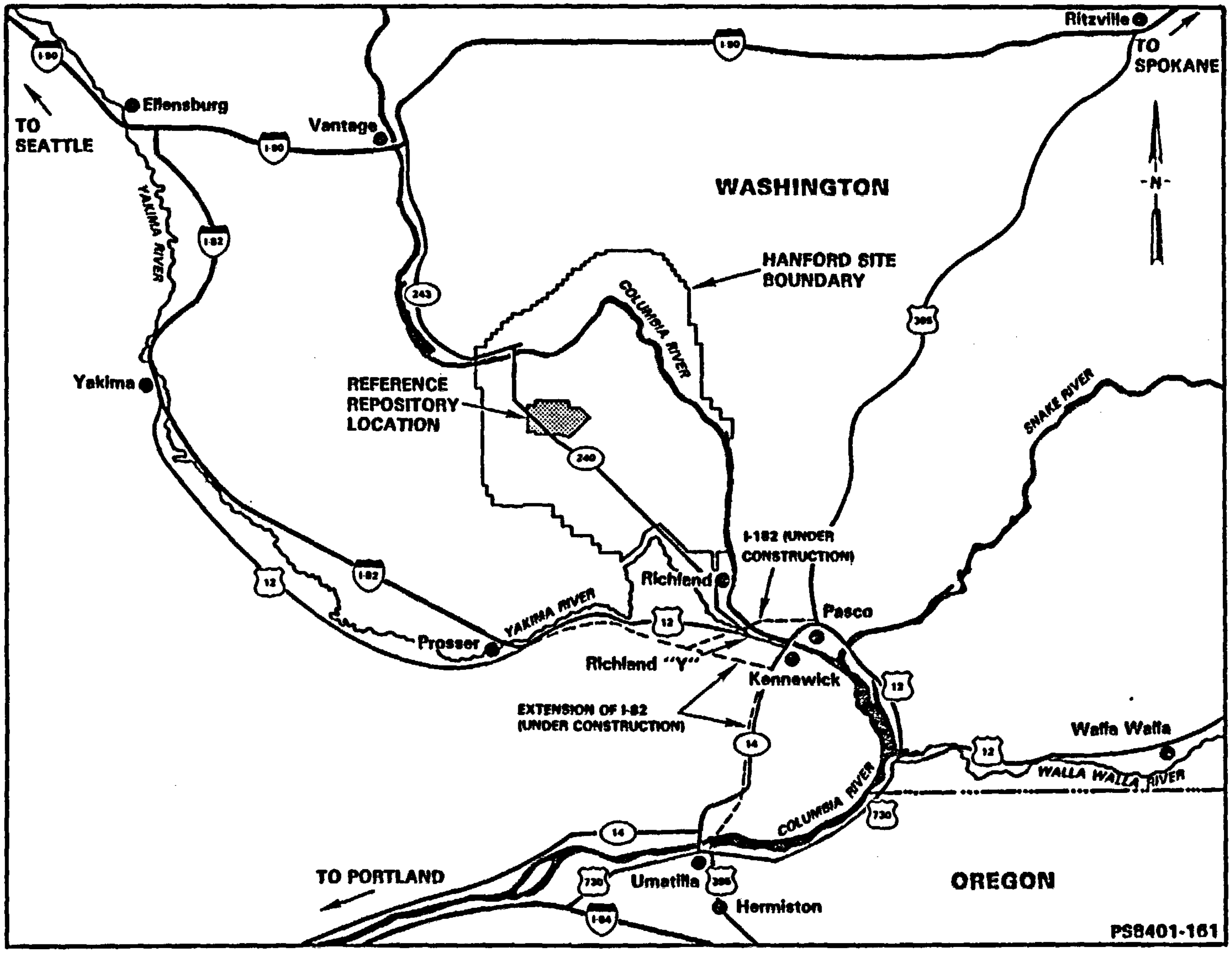

Figure 3-44. Local and regional highway network linking Tri-cities, Washington, with major interstate highways.

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Major highways within the Tri-Cities area are predominantly four-lane facilities carrying between 30,000 and 50,000 vehicles per day. With the new facilities planned and under construction, highway capacities will be adequate to meet highway transportation needs into the turn of the century.

3.5.3 Repository access routes

Two alternate truck access routes to the reference repository location are under consideration. One alternate truck route

The State of Washington is ~~empowered to designate~~ acceptable state highway routes to the repository. ~~A logical truck route to the reference repository location would be through the Tri-Cities (along existing bypass routes) and into the Hanford Site at the southern end.~~ STET The highway network within the Hanford Site is shown in Figure 3-45. Trucks will go north past the 300 Area, then northwest past the Fast-Flux Test Facility and the Washington Public Power Supply System nuclear power reactor WNP-2. At the highway intersection shown in Figure 3-45, trucks will be stopped briefly at the Wye Barricade for security inspection. The trucks will then proceed northwest and pass alongside the perimeter fences of the 200 Areas. A new road, approximately 5 kilometers (3 miles) long, will be constructed to allow access to the reference repository location from the vicinity of the 200 West Area. Another ~~An~~ alternate truck access route would utilize Route 240, which runs ~~alongside the southwest boundary of~~ through the Hanford Site; a new access road less than 5 kilometers (3 miles) long would extend from Route 240 to the reference repository location.

The Hanford Site railroad system extends from the west side of Richland throughout the Hanford Site, as shown in Figure 3-45. Railroad tracks serve both of the 200 Areas. A new railroad spur of less than 5 kilometers (3 miles) is needed to run to the reference repository location from the vicinity of the 200 West Area.

3.6 SOCIOECONOMIC CONDITIONS

The discussion of socioeconomic conditions in this section is based on data from about 1965 up to the present. Based on the most currently available information, conditions are forecast through the year 2010 (Section 5.2.3). Socioeconomic conditions over the full period of time from 1965 until 2010 are presented as the appropriate baseline against which project-related effects can be judged. The study region is defined in this analysis as the area surrounding the local project site (Hanford Site) that is expected to experience the major share of demographic, economic, infrastructure, and social impacts from a potential repository in basalt. Recent studies of the repository in basalt have defined the primary study area boundary in terms of the Tri-Cities, West Richland, Benton City, and the contiguous unincorporated areas (DOE, 1982b, 1983a; Cluett et al., 1984). These areas have been most affected by employment and demographic changes in the recent past at the Hanford Site. However, because some important data (such as population size, employment size, and

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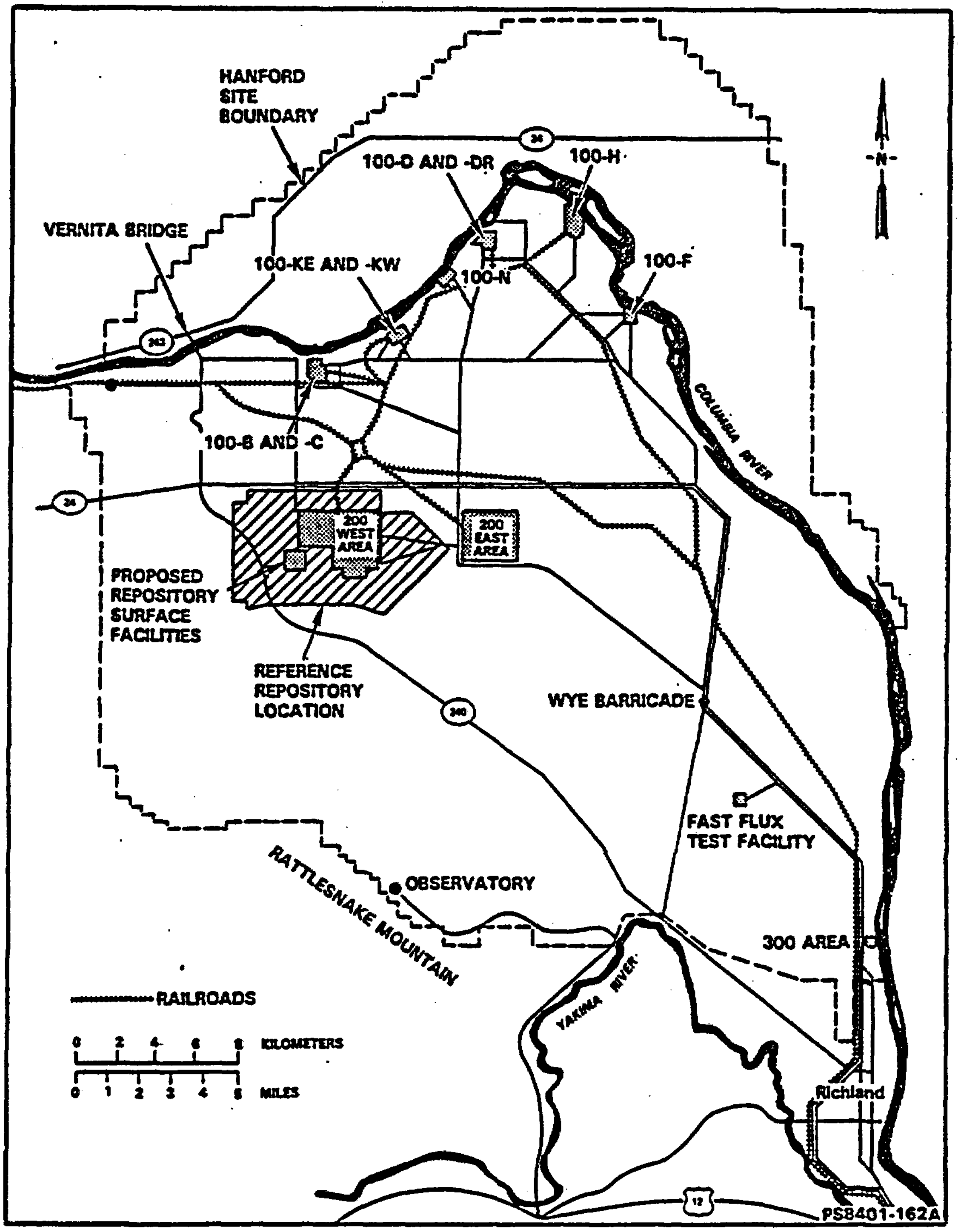

Figure 3-45. Transportation network within the Hanford Site.

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housing characteristics) are limited for unincorporated parts of the study region, analysis will focus on the Benton and Franklin Counties and will be augmented with data (where available) from the cities located near the local site. Possible significant socioeconomic impacts likely to be caused by the construction and operation of a repository in basalt will be evaluated in Section 5.2.3 in terms of the baseline conditions described here.

The study region associated with the Hanford Site has been characterized during the decade of the 1970's as one of the most rapidly growing metropolitan areas in the nation. It could be misleading to assess the potential socioeconomic impacts of the proposed repository development in terms of "boomtown" effects that typify rural sites. In addition, the study region is currently experiencing a major reversal of a well-established pattern of rapid economic and demographic growth. This analysis will address the socioeconomic effects of that decline and the prognosis for future recovery.

3.6.1 Population density and distribution

Approximately 60 percent of the population of this study region is concentrated in the Tri-Cities, namely, Richland, Kennewick, and Pasco (see Fig. 3-37 for a map of the study region). The ratio between the population of the Tri-Cities and the bicounty study region has remained relatively constant since the mid-1960's, in spite of the exceptionally rapid growth in population between 1973 and 1981. Data on population size for Benton and Franklin Counties are provided in Table 3-12. The population density for Benton County is 25 persons per square kilometer (64 persons per square mile); for Franklin County it is 11 persons per square kilometer (28 persons per square mile). Only 73 persons actually reside on the Hanford Site (total area of 1,500 square kilometers (570-square miles)) at Midway (see Fig. 3-37), for a population density substantially less than one person per square kilometer. Data for each of five cities, including the Tri-Cities, located near the Hanford Site are provided in Table 3-13. None of these cities is in close proximity to the proposed repository site in terms of Nuclear Waste Policy Act requirements. The nearest large settlements are 32 kilometers (20 miles) or more from the site. Trends in population size in the study region are illustrated in Figures 3-46 and 3-47.

The rapid growth of construction activity on the Washington Public Power Supply System nuclear power plants beginning in 1973 directly caused most of the population growth observed between 1973 and 1981. This population growth was concentrated primarily in Benton County. During the Washington Public Power Supply System construction period, Benton County grew at an average annual rate of 6.2 percent compared to the 3.7 percent growth rate in Franklin County. In contrast, during the pre-Washington Public Power Supply System period, Benton County grew less rapidly than Franklin County--0.9 percent compared to a 1.4 percent growth rate. Nevertheless, the population of Benton County increased by many more

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Table 3-12. Population of Benton and Franklin Counties: 1965 to 1982.

Year	Benton County	Average annual rate of change(%)	Franklin County	Average annual rate of change(%)	Total Benton-Franklin County	Average annual rate of change(%)
			PRE-SUPPLY SYSTEM[a] PERIOD			
1965	63,301		24,158		87,459	
1966	64,019		24,504		88,523	
1967	64,433		24,865		89,298	
1968	65,276		25,061		90,337	
1969	65,418	0.9	24,891	1.4	90,309	1.1
1970[b]	67,540		25,816		93,356	
1971	67,069		26,430		93,499	
1972	67,214		26,508		93,722	
1973	68,264		27,025		95,289	
			SUPPLY SYSTEM[a] CONSTRUCTION PERIOD			
1973	68,264		27,025		95,289	
1974	71,850		27,469		99,319	
1975	77,054		27,868		104,922	
1976	84,341		29,699		114,040	
1977	90,365	6.2	29,804	3.7	120,169	5.5
1978	98,238		32,567		130,805	
1979	104,941		34,262		139,203	
1980[b]	109,444		35,025		144,469	
1981	112,010		36,250		148,260	
			SUPPLY SYSTEM[a] RAMPDOWN PERIOD			
1981	112,010	-3.0	36,025	-2.4	148,260	-3.0
1982	108,724		35,186		143,910	

NOTE: U.S. Bureau of the Census (BOC, 1960, 1970, 1980).

[a]Washington Public Power Supply System.

[b]Reliable data were available only for the census years 1960, 1970, and 1980. To develop more reasonable intercensal estimates, the annual rates of change in the resident civilian labor force were compared with the population from the U.S. Bureau of the Census between 1960 and 1970. Estimates through 1973 were computed this way. Similarly, changes in the labor force between 1973 and 1980 were used to provide population estimates for the 1973 to 1982 period.

Table 3-13. Population of cities near the Hanford Site: 1965 to 1982.

Year	Richland	Average annual rate of change (%)	Kennewick	Average annual rate of change (%)	Pasco	Average annual rate of change (%)	West Richland	Average annual rate of change (%)	Benton City	Average annual rate of change (%)
PRE-SUPPLY SYSTEM[a] PERIOD										
1965	25,900		15,200		15,800		1,350		1,185	
1966	26,500		15,400		16,350		1,350		1,185	
1967	26,500		15,400		16,400		1,350		1,185	
1968	28,500		16,000		16,600		1,127		1,185	
1969	28,900	0.3	16,500	0.8	17,000	-1.5	1,130	-1.2	1,185	-0.9
1970	26,290		15,212		13,920		1,143		1,070	
1971	26,300		15,400		13,920		1,143		1,093	
1972	26,350		15,580		14,000		1,159		1,090	
1973	26,600		16,200		14,050		1,225		1,100	
SUPPLY SYSTEM[a] CONSTRUCTION PERIOD										
1973	26,600		16,200		14,050		1,225		1,100	
1974	28,000		16,800		14,100		1,247		1,125	
1975	28,600		18,253		14,450		1,477		1,315	
1976	30,009		21,301		14,618		1,561		1,422	
1977	31,050	3.0	23,638	9.5	15,375	3.6	2,024	14.1	1,583	8.4
1978	32,350		26,564		16,000		2,311		1,917	
1979	33,550		29,810		16,370		2,641		1,900	
1980	33,578		34,397		18,425		2,938		2,087	
1981	33,700		34,700		18,700		3,783		2,150	
SUPPLY SYSTEM[a] RAMPDOWN PERIOD										
1981	33,700	-0.4	34,700	1.9	18,700	1.9	3,783	3.9	2,150	-14.0
1982	33,550		35,350		19,050		3,934		1,870	

NOTE: Actual distances to the Hanford Site are: Richland, 35 km (22 mi); Kennewick, 45 km (28 mi); Pasco, 45 km (28 mi); West Richland, 32 km (20 mi); Benton City, 32 km (20 mi). Figures for 1960 to 1968 are from Schmid and Schmid (1969); 1970 to 1983 are from State of Washington (1979, 1980, 1981b, 1982b, 1983a).

[a]Washington Public Power Supply System.

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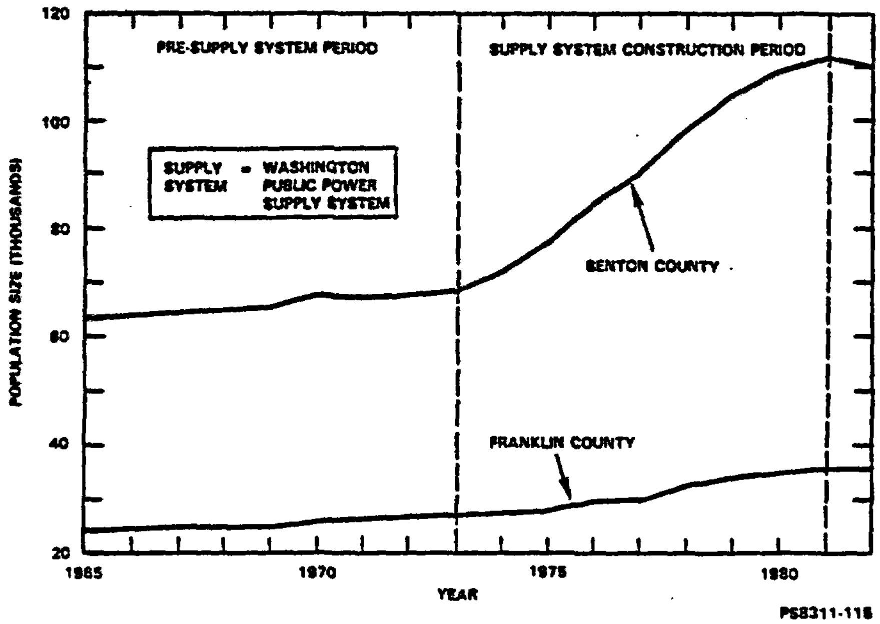

Figure 3-46. Population trends for Benton and Franklin Counties: 1965 to 1982.

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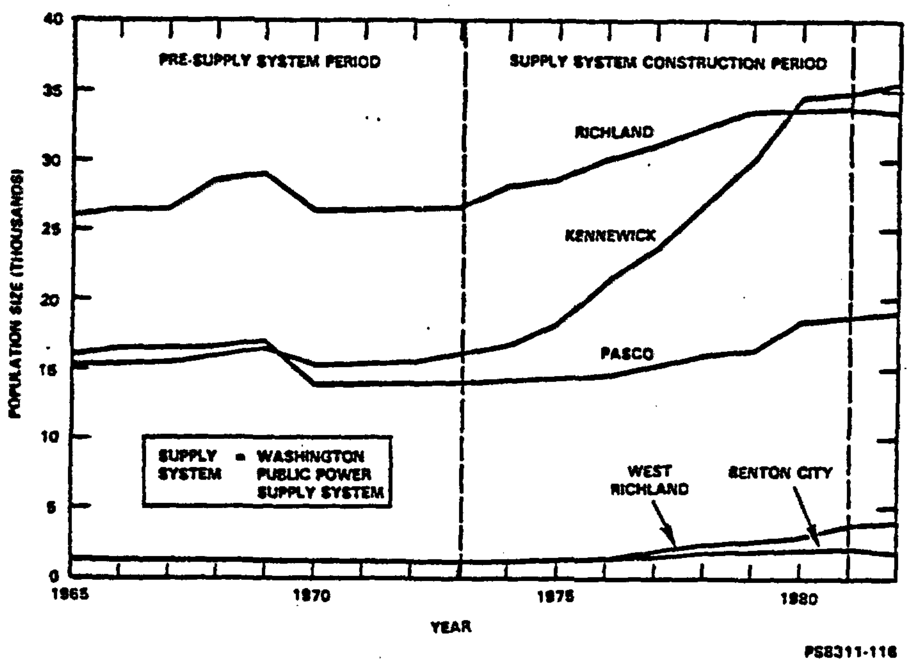

Figure 3-47. Population trends for cities near the Hanford Site: 1965 to 1982.

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people in both periods compared with Franklin County. Net in-migration in the 1970 to 1980 period accounted for 80 percent of the growth in Benton County and almost 36 percent of the growth in Franklin County (State of Washington, 1981a). The balance of total growth is due to natural increase, the excess of births over deaths.

Table 3-13 illustrates that the largest increase in population size of the cities near the Hanford Site was experienced in Kennewick (in Benton County) during the Washington Public Power Supply System construction period. From 1973 to 1981, the population of Kennewick grew at a rate approaching 10 percent per year, nearly a twelvefold increase compared to the pre-Washington Public Power Supply System period growth rate. But the growth in Benton County spread beyond the Tri-Cities, especially to West Richland and Benton City. Before Washington Public Power Supply System construction activities began in 1973, the population of Benton City remained constant at around 1,100 persons but almost doubled in size between 1973 and 1981. The most rapid growth, however, took place in West Richland, where population grew at an average annual rate of 14.1 percent during this period. In Franklin County the rapid population growth during the Washington Public Power Supply System construction period was concentrated in Pasco and the surrounding unincorporated areas.

Pinpointing the exact components of growth in each of the above municipalities is difficult, however, because each has also grown due to annexation of adjacent unincorporated areas. According to a recent analysis, "from 1970 to 1980, the cities of Richland, Pasco, Kennewick, and West Richland had expanded their municipal boundaries by 51 percent" (State of Washington, 1982a, p. 5). Table 3-14 illustrates the increase in area since 1960 for each of the Tri-Cities, West Richland, and Benton City. This table also shows how population density in these five cities has changed in response to both population growth and to periodic annexations of adjacent land area. The data suggest that the effect of population growth in the urbanized areas around the Hanford Site has been to maintain a fairly constant urban density over time by concentrating new settlement on the outskirts of existing communities. As these peripheral suburban areas approach the density of the central city, they tend to be annexed into that city. The effect of future population growth, such as might be caused by the reference repository, probably would be similar. Of course, some new population growth will take place in other outlying areas or in areas of relatively sparce settlement. Available land for residential settlement in the Tri-Cities region is not particularly constrained at this time; therefore, the population densities of the major cities near the Hanford Site are not likely to exceed those observed in recent years within the time frame of this analysis (see Table 3-14).

Tables 3-12 and 3-13 illustrate the dramatic reversal in regional economic and demographic activity that began in mid-1981 when Washington Public Power Supply System plant WNP-1 was mothballed and WNP-4 construction work was terminated. Preliminary economic and demographic data suggest that the effects of the Washington Public Power Supply System downtrend can be expected to continue at least for several more years.

Table 3-14. Population density for cities (per square mile) near the Hanford Site: 1960 to 1983.

Year	Richland		Kennewick		Pasco		West Richland		Benton City	
	Area (mi^2)	Population density	Area (mi^2)	Population density	Area (mi^2)	Population density	Area (mi^2)	Population density	Area (mi^2)	Population density
1960	12.8	1,840	4.5	3,165	7.7	1,886	1.4	962	1.3	931
1968	25.3	1,128	6.2	2,581	11.2	1,485	1.4	805	1.3	912
1970	23.9	1,100	6.4	2,377	11.2	1,243	1.4	811	1.3	823
1972	27.8	949	9.5	1,647	11.4	1,229	1.4	822	1.3	838
1973	27.8	958	9.5	1,702	11.4	1,234	1.4	869	1.3	846
1974	28.1	996	9.8	1,714	11.4	1,237	1.4	884	1.3	865
1975	28.9	990	10.8	1,696	11.4	1,268	1.4	1,048	1.3	1,012
1976	28.9	1,039	11.5	1,855	11.4	1,282	1.4	1,107	1.3	1,094
1977	28.9	1,075	12.0	1,967	11.7	1,317	1.7	1,177	1.3	1,218
1978	28.9	1,119	12.1	2,190	12.8	1,255	1.8	1,270	1.3	1,475
1979	29.3	1,146	14.2	2,102	13.8	1,188	2.2	1,217	1.3	1,462
1980	32.0	1,050	15.5	2,218	15.7	1,175	3.1	938	13.8	151
1981	32.0	1,053	15.7	2,217	15.7	1,193	19.1	198	14.2	152
1982	32.0	1,048	15.8	2,112	15.7	1,215	19.3	203	14.5	135
1983	32.1	997	16.3	2,194	23.2	825	20.7	187	14.5	129

NOTE: Figures for 1965 to 1969 are from Schmid and Schmid (1969; Table 1); 1970 to 1982 are from State of Washington (1979, 1980, 1981b, 1982b, 1983a).

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3.6.2 Economic conditions

Economic conditions in this study region can be characterized in terms of three distinct time periods over the last two decades. Before Washington Public Power Supply System construction activities between 1965 and 1973, employment grew at the steady, moderate rate of 2.4 percent per year (Table 3-15). Then, as construction activities increased rapidly on the three Washington Public Power Supply System nuclear power plants at the Hanford Site, employment growth averaged 8.3 percent per year between 1973 and 1981.

The primary sectors of employment growth in the study region include not only the Washington Public Power Supply System and its contractors but also the U.S. Department of Energy and its contractors and the agriculture sector. Out of a total employment level of 75,600 persons in 1981, almost 29,000 persons, or 38.2 percent, were employed in one of these sectors. Table 3-16 shows employment by selected industry groups in Benton and Franklin Counties from 1967 to 1982. Employment for the Washington Public Power Supply System and the U.S. Department of Energy are included in several of the other sectors, particularly construction and government. Therefore, total employment shown in Table 3-15 equals the sum of employment in agriculture, construction, manufacturing, sales service, and government as shown in Table 3-16.

During the pre-Washington Public Power Supply System period, the major employment growth occurred in the agricultural and construction sectors. Between 1967 and 1973, the agricultural sector grew at an average annual rate of nearly 11 percent, due to large irrigation projects undertaken in the region, and the construction sector grew at over 5 percent. In comparison, other industries exhibited little growth, except for service-based industries that grew at an average annual rate of almost 2 percent. Overall, primary sector employment grew by approximately 4,300 jobs and the secondary sector employment grew by only approximately 775 jobs. This means that every 10 primary sector jobs created approximately 2 secondary sector jobs.

During the Washington Public Power Supply System construction period from 1973 to 1981, economic and demographic growth in the study region was caused primarily by growth in employment offered by the Washington Public Power Supply System and its contractors. Washington Public Power Supply System-related employment increased at an average rate of approximately 39 percent per year. This growth was supplemented by an annual growth rate of 4.2 percent in the agricultural sector and 5.6 percent in the U.S. Department of Energy sector. The U.S. Department of Energy employment increased mostly during the first half of the period; since 1977, employment has remained at approximately 12,000 employees. Increasing employment opportunities in these three primary sectors during this phase, at a combined average annual rate of 11.1 percent, resulted in average annual employment growth rates of 6.6 percent in manufacturing, 8.6 percent in retail and wholesale, 6.6 percent in service-based

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Table 3-15. Labor force, employment, and unemployment in Benton and Franklin Counties: 1965 to 1982.

Year	Resident civilian labor force	Average annual growth rate	Employment	Average annual growth rate	Unemployment	Annual unemployment rate
PRE-SUPPLY SYSTEM[a] PERIOD						
1965	34,080	2.8	32,170	2.4	1,910	5.6
1966	35,160		33,060		1,810	5.1
1967	35,960		33,910		2,000	5.6
1968	37,050		34,410		2,480	6.7
1969	37,020		34,530		2,460	6.6
1970	40,330		36,570		3,760	9.3
1971	40,490		36,500		3,990	9.9
1972	40,740		36,960		3,780	9.3
1973	42,520		38,960		3,560	8.4
SUPPLY SYSTEM[a] CONSTRUCTION PERIOD						
1973	42,520	8.4	38,960	8.3	3,560	8.4
1974	45,270		42,300		2,970	6.6
1975	49,190		45,550		3,640	7.4
1976	55,800		51,800		4,000	7.2
1977	60,400		55,500		4,900	8.1
1978	68,670		64,340		4,330	6.3
1979	75,450		70,480		4,970	6.6
1980	79,810		72,000		7,810	9.8
1981	83,000		75,600		7,400	8.9
SUPPLY SYSTEM[a] RAMPDOWN PERIOD						
1981	83,000	-1.9	75,600	-8.0	7,400	8.9
1982	81,400		69,800		11,600	14.3

NOTE: Figures for 1970 to 1982 are from State of Washington (1983); 1963 to 1969 are from Benton Franklin Governmental Conference (1983).

[a]Washington Public Power Supply System.

Table 3-16. Employment by selected groups in Benton and Franklin Counties: 1967 to 1982.

Period	Year	Primary employment[a]						Nonagricultural employment[b,c]									
		Supply system[d,e]	Average annual rate of change (%)	DOE[f]	Average annual rate of change (%)	Agricultural[b,g]	Average annual rate of change (%)	Construction	Average annual rate of change (%)	Manufacturing	Average annual rate of change (%)	Retail and wholesale	Average annual rate of change (%)	Service-based industry[h]	Average annual rate of change (%)	Government	Average annual rate of change (%)
Pre-Supply System[b]	1967	-	-	9,000		1,909		2,432		5,946		5,572		11,413		6,557	
	1968	-	-	8,850		2,170		1,900		5,930		5,697		12,272		6,441	
	1969	-	-	8,500		2,472		2,094		5,850		5,811		12,068		6,234	
	1970	-	-	7,900	-2.9	3,065	10.7	1,908	5.1	6,022	0.2	6,211	2.6	12,726	1.5	6,638	0.8
	1971	-	-	6,500		3,233		1,859		5,767		6,368		12,683		6,671	
	1972	-	-	7,000		3,249		2,567		5,763		6,438		12,402		6,549	
	1973	530	-	7,570		3,773		3,300		6,014		6,506		12,466		6,900	
Supply System[b] Construction	1973	530		7,570		3,773		3,300		6,014		6,506		12,466		6,900	
	1974	1,115		8,700		4,376		4,175		6,339		6,808		13,324		7,278	
	1975	1,946		9,800		4,608		5,458		6,859		7,025		13,565		8,035	
	1976	2,954		10,680		5,850		5,663		7,614		8,509		15,408		8,676	
	1977	3,412	38.7	12,300	5.6	4,315	4.2	7,720	10.8	8,259	6.6	9,354	8.6	17,132	6.6	8,728	6.0
	1978	7,097		11,750		4,456		9,936		9,428		11,193		19,716		9,618	
	1979	8,926		12,000		5,113		11,910		9,804		12,148		20,673		10,031	
	1980	7,935		12,100		5,228		10,847		9,843		12,216		22,151		11,715	
	1981	11,728		11,880		5,291		14,908		10,226		12,942		21,090		11,150	
Supply System[b] Rampdown	1981	11,728	-28.3	11,880	-3.3	5,291	1.0	10,226	-30.5	10,226	2.8	12,942	-1.7	21,090	-2.9	11,150	-2.5
	1982	8,841		11,500		5,344		10,135		10,521		12,729		20,490		10,874	

NOTE: Total employment from the U.S. Bureau of Economic Analysis (non-agricultural employment plus agriculture) is slightly less than the total employment provided by the Washington State Employment Security Department (see Table 3-15). Therefore, the ratio between the two was determined for each year and multiplied times the individual U.S. Bureau of Economic Analysis employment categories.

[a]See the text for definition of primary employment as used in this report.

[b]Figures from 1967 to 1974 were estimated from the U.S. Bureau of Economic Analysis (1983); figures from 1975 to 1980 are from the U.S. Bureau of Economic Analysis (1987) baseline forecasts

[c]Figures from 1981 to 1982 are from McGinnis and Schau (1983).

[d]Washington Public Power Supply System.

[e]Data from McGinnis and Schau (1983).

[f]Data from State of Washington (1982a)

[g]Figures from 1981 are estimated from Cluett et al. (1984, Table 5-3); figures from 1982 are estimated from Cluett et al. (1984, Table 6-1).

[h]Includes service, transportation, finance, and real estate

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industries, and 6.0 percent in the government sector. During this period of time primary sector jobs increased by 17,026 compared to 19,614 jobs in the secondary sector (i.e., 1.2 secondary sector jobs for every primary sector job, or a primary sector-based total employment multiplier of 2.2).

This substantial growth in the secondary sector of the regional economy due to Washington Public Power Supply System construction activities at the Hanford Site suggests that the region was perceived as providing long-term economic stability and future growth potential. Such an atmosphere encouraged families to settle in the region permanently and fostered optimism regarding the future course of the regional economy.

Table 3-16 illustrates the significant decline in regional employment due to lost construction jobs, primarily on the Washington Public Power Supply System projects, that began in mid-1981. Further employment losses in the region are expected to continue through 1984 and to be accompanied by losses in population. Based on the observed loss of population between 1981 and 1982 (and its relationship to declining employment during that period), along with projected declines in primary sector jobs (particularly within the Washington Public Power Supply System), total employment could decline an additional 18 percent and population could decline an additional 6 percent. Figure 3-48 illustrates the changes in labor force and employment in the region between 1965 and 1982. The shaded area between these two curves represents trends in unemployment. That gap has widened dramatically since 1981 and probably will continue to do so for several more years. The real uncertainty concerns how individuals and families will react to recent events. If the perception of long-term economic opportunity is being eroded by recent events and near-term employment prospects, then significant numbers of people could decide to leave the region.

3.6.3 Community services

The community services that have been affected by past developments in the study region include public water supply, waste water disposal, solid waste disposal, fire and police protection services, health services, education, local transportation, and housing. Although private housing is not strictly a community service, it is closely linked to demands for those services and for that reason is discussed in this section.

The increase in the growth rates of housing units, which is evident between 1973 and 1981, indicates that the housing stock was increased as the population increased. For example, the average annual rate of increase in housing stock in Benton and Franklin Counties was 1.6 percent between 1965 and 1973 and between 1973 and 1981 it was 7.8 percent; the population increase was 1.1 percent and 3.7 percent for the respective periods (Table 3-17). During the high growth period of the 1970's, the largest numbers of people moved into the three largest cities of the area: Kennewick, Richland, and Pasco. The rate of increase in the

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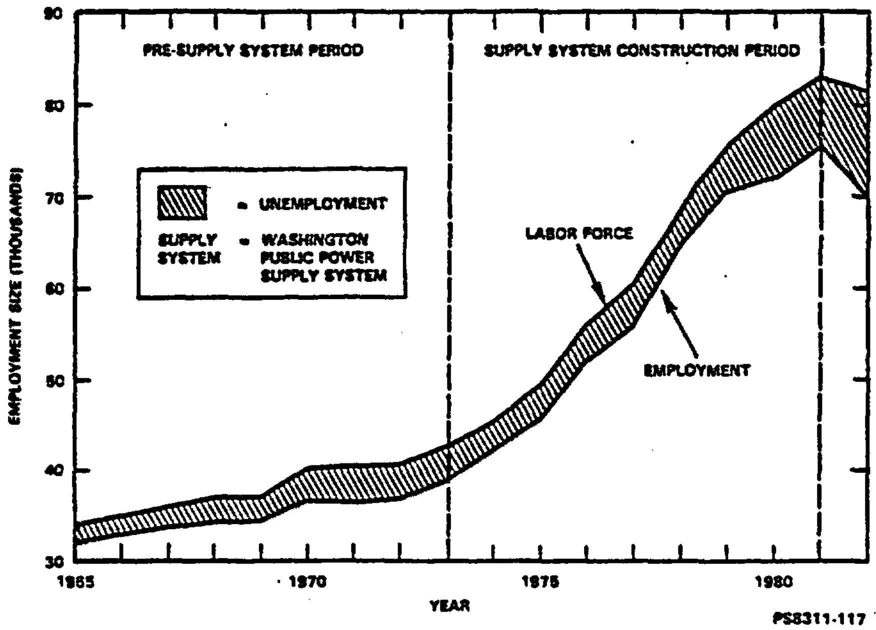

Figure 3-48. Labor force and total employment in Benton and Franklin Counties: 1965 to 1982.

Table 3-17. Comparison between average annual percentage rates of change in population and housing units: 1965 to 1981.

Year	Counties			Tri-Cities			
	Benton	Franklin	Combined	Richland	Kennewick	Pasco	Combined
			POPULATION[a]				
1965-1973	0.9	1.4	1.1	0.3	0.8	-1.5	--
1973-1981	6.2	3.7	3.7	3.0	9.5	3.6	--
			HOUSING UNITS[b]				
1965-1973	1.4	2.0	1.6	--	--	--	--
1973-1981	8.7	5.4	7.8	6.2[c]	10.6[c]	7.2[c]	8.3[c]

[a]Based on data in Tables 3-8 and 3-9.

[b]For county figures: rates of change are calculated on housing unit statistics from the U.S. Bureau of Census (BOC, 1960, 1970, 1980). For Tri-Cities figures: rates of change are calculated from data on housing unit statistics from the Tri-Cities Real Estate Research Committee (1982) (not available prior to 1975).

[c]1975 to 1981.

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housing supply in each of these three communities more than kept pace with the rate of population growth each community experienced (see Table 3-13). One indicator of this is the vacancy rate in these communities during the period of high growth (Table 3-18). Figures available from 1975 to 1982 indicate a very tight housing market in the initial years of the high-growth period. For example, the vacancy rate in Benton and Franklin Counties, and in the Tri-Cities specifically, was below 1 percent in 1975 and 1976. However, the overall vacancy rate climbed over 1 percent beginning in 1977, indicating that the supply of new housing units was more than keeping pace with the population influx. By 1981 the vacancy rate in the Tri-Cities was 4.3 percent.

As the population of the area declines as a result of the Washington Public Power Supply System rampdown, the vacancy rate for all housing units can be expected to go higher, particularly for multifamily housing that is composed primarily of rental units. The 1982 vacancy rate for single-family dwellings remained fairly low, at 2.5 percent for the Tri-Cities, but multifamily units for the same year reached a high 12.1 percent vacancy rate, both due to the overbuilding of these units and to the departure of temporary construction workers. According to the 1980 U.S. Census of Housing, homeowner units in the State of Washington experienced a vacancy rate of 2.1 percent and rental units had a rate of 7.3 percent. Thus, during 1980 at least, the study area experienced housing vacancy rates somewhat higher than the state average, particularly in rental units. More than 30 percent of the housing in Benton and Franklin Counties has been added since 1973 (Table 3-19) making much of it relatively high priced due to the costs of that period.

New housing growth, such as was experienced between 1973 and 1981, requires an associated increase in energy, communications, water and sewer, and solid waste services. The most recent and complete analysis of other community services, their capacities and programs for expansion was developed by Puget Sound Power and Light Company (NRC, 1982c). The results of that study, coupled with the current decline in population and economic activity, indicate that all the important services have sufficient reserve capacity at this time, and probably for at least the next decade, to handle the future needs associated with the reference repository project.

At the time of the Washington Public Power Supply System rampdown in 1981, the major incorporated communities of Benton and Franklin Counties were using less than the capacities of their water systems (NRC, 1982c), and, in addition, they were planning improvements in anticipation of future growth. With the recent decline in population, impacts on water system capacities are unlikely for some time. Before the Washington Public Power Supply System rampdown, most of the incorporated jurisdictions had identified some need to improve their waste water treatment facilities; although, most of these plans were for small expansions (NRC, 1982c). The two major landfills are expected to meet existing and future solid waste disposal needs through 1990 (NRC, 1982c). Fire and police protection services have typically increased proportionately with population growth in the Tri-Cities and can be expected to continue to do so (NRC, 1982c). Health care facilities in the region have expanded to accommodate the growing population. As a result,

the City of Richland expects to begin operation of a major new sewage treatment facility in the mid-1980's.

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Table 3-18. Tri-Cities housing vacancies: 1975 to 1982.

Year	Total units (no.)	Total units (%)	Single-family units (no.)	Single-family units (%)	Multifamily[a] units (no.)	Multifamily[a] units (%)	Mobile homes/ trailers (no.)	Mobile homes/ trailers (%)
SUPPLY SYSTEM[b] CONSTRUCTION PERIOD								
1975	183	0.6	114	0.5	54	1.6	15	0.7
1976	282	0.8	171	0.6	96	1.8	15	0.6
1977	651	1.7	232	0.9	384	4.1	35	0.9
1978	573	1.3	256	0.9	286	2.7	31	0.6
1979	923	2.0	330	1.2	548	4.4	45	0.9
1980	1,316	2.8	367	1.2	855	7.0	94	1.6
1981	2,138	4.3	459	1.5	1,551	11.3	128	2.1
SUPPLY SYSTEM[b] RAMPDOWN PERIOD								
1981	2,138	4.3	459	1.5	1,551	11.3	128	2.1
1982	2,553	5.1	757	2.5	1,604	12.1	192	3.2

NOTE: Tri-Cities Real Estate Research Committee (1982).
[a]Includes condominiums.
[b]Washington Public Power Supply System.

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Table 3-19. Number of housing units in Benton and Franklin Counties: 1973 to 1982.

Year	County	
	Benton	Franklin
1973	21,976	8,946
1974	23,551	9,159
1975	25,906	9,353
1976	29,351	10,263
1977	32,332	10,317
1978	36,415	11,763
1979	40,065	12,693
1980[a]	42,610	13,122
1981	44,094	13,825

NOTE: U.S. Bureau of the Census (BOC, 1970, 1980).

[a]Census Year: Intercensal estimates based on employment and population change.

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a wide range of health care and social services is offered (NRC, 1982c). As a result of school capacity pressures in the latter half of the 1970's, a considerable amount of new construction and additions to facilities has taken place. Some of these projects were planned prior to the 1981 downturn in the economy and were actually carried out in 1982 and 1983. The schools in the area currently have an excess capacity, estimated to be around 8,800 student positions in 1982 (Cluett et al., 1984).

Local traffic congestion has been one of the major community problems since the beginning of the high growth period in the early 1970's. The major municipalities are arranged geographically in a linear pattern with respect to the Hanford Site, which tends to create transportation bottlenecks during periods of heavy use. Thus, transportation planning in the region has received special attention, and a number of recent and prospective developments suggest that the effect of these bottlenecks will be reduced in the future. There have been recent improvements in the roads in the area, particularly in some of the formerly congested intersections. The Interstate 182 bridge over the Columbia River is nearing completion and should relieve congestion substantially on the routes to Richland and the Hanford Site from Kennewick and Pasco, as well as alter residential growth patterns. Also, an increased emphasis is being placed on the development and use of mass public transportation in the region. Traffic volume in the Tri-Cities grew steadily from the mid-1970's and generally followed the pattern of employment and population growth associated with development on the Hanford Site. Traffic volumes in 1981 were at an all-time peak (NRC, 1982c) and often exceeded the capacity of the major arterials connecting the Hanford Site with the major residential areas. Since 1981 the average daily traffic volume on the major arterials in the area has significantly decreased due to the rampdown of the Washington Public Power Supply System activities at the Hanford Site. With the transportation improvements and planning now in effect, congestion levels should continue to diminish, especially while overall population remains below the 1981 level.

3.6.4 Social conditions

The social conditions of a community refer in general to the level of satisfaction community residents have with the quality of life they experience. Social conditions also refer to the network of social relationships people experience in their community and their attitude toward and participation in community social life. Social conditions in the study region have been shaped significantly by economic developments since the 1940's, particularly the growth of the Hanford Site activities and Columbia Basin Project. Since the study region now contains a large metropolitan complex, it is unlikely to experience the stereotypical "boomtown" socioeconomic impacts of rapid development. Yet, the current social conditions of the region are a direct product of rapid economic and population growth experienced in the 1970's. For the next several years, social conditions will be shaped by the effects of the Washington Public Power Supply System rampdown and the community perception of the prospects for the future.

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The prosperity of the 1960's and 1970's had a positive effect on social conditions. First, it created a sense of optimism regarding future economic opportunity in the region. Both a highly skilled and educated work force and a construction trades work force that typically is highly mobile settled in the region on a relatively permanent basis, confident in the economic future of the region. Second, the rapid growth of the last 10 years demonstrated the ability of the region to manage potentially adverse consequences without serious problems. In addition, the resident population has become accustomed to rapid growth, and there is no evidence of a disproportionate rise in such indicators of social disruption as crime rates, alcoholism and mental health problems, marital disruptions, or psychological problems. Other measures of social conditions would include employee turnover rates, and general public acceptance of the nuclear-related activities characteristic of Hanford Site developments. ~~While there have been some recent local as well as state-wide expressions of dissatisfaction with activities being performed on the Hanford Site programs and the lack of adequate public involvement in the decision and policy process~~, social conditions with regard to potential public acceptance of the proposed reference repository can generally be described as favorable in this region (Nealey and Rankin, 1978). A SURVEY CONDUCTED WITHIN THE STATE OF WASHINGTON SHOWED CITIZENS TO HAVE CONCERNS ABOUT THE RISK ASSOCIATED WITH NUCLEAR WASTE DISPOSAL BUT ALSO A RECOGNITION BY THOSE SURVEYED THAT DISPOSAL OF WASTE IS A SOLUBLE PROBLEM (COMMUNICATION DESIGN, 1983)

The condition that provides cause for the most concern in the study region is the apparent vulnerability of the region to rapid economic decline. Although the current period of economic decline is probably temporary, its duration, severity and, ultimately, its effect on regional social conditions, is uncertain.

3.6.5 Fiscal conditions and government structure

Fiscal conditions in this study region can be understood in terms of the various governing bodies and taxing authorities that collect revenues and expend them for community services. The major revenue collecting bodies include the two counties, the three cities of Richland, Kennewick, and Pasco, and various utilities and other smaller municipalities within the two counties. Because of the large metropolitan base of the Tri-Cities and its associated administrative complexity and experience, the fiscal structure and capability of the region has been well adapted to the socioeconomic conditions that are characterized by rapid change. Thus, in the past growth periods, the fiscal effects of maintaining revenues in balance with expenditures while insuring an equitable distribution of fiscal benefits throughout the region have been adequately handled. It is currently less clear how the fiscal institutions of the region will be able to manage a period of rapid decline in economic activity and population.

Although a large portion of the Hanford Site, including the specific proposed location of the repository, is within the boundaries of Benton County, and a smaller portion is within Franklin County, the Hanford Site falls under the jurisdiction of the Federal Government. ~~As a Federal reservation, the land and activities therein are tax exempt~~ The Federal government activities on the reservation are tax exempt, and there is

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no compensation for property taxes lost due to the tax exempt status of the Hanford Site. However, the U.S. Department of Energy contractors on the Hanford Site pay sales and use taxes and business and occupational taxes in accordance with the requirements of the State of Washington law.

The Tri-Cities clearly have received the major portion of the population growth and economic prosperity associated with past development activities at the Hanford Site. They also have experienced the bulk of the fiscal effects from these major projects. In the Tri-Cities, total operating revenues increased more rapidly between 1975 and 1981 than did the population in all three cities (Table 3-20). Richland and Kennewick displayed higher rates of growth in revenues compared to Pasco. In Richland, revenue grew much faster during this period than population. The relatively healthier fiscal situation in Richland and Kennewick than in Pasco is presumably due to the proximity and accessibility of the former two cities to the Washington Public Power Supply System construction site, and, therefore, to the greater amount of indirect or secondary economic growth associated with the Washington Public Power Supply System construction activity. This bicounty region appears to be quite adaptable from a fiscal standpoint. Revenues and expenditures have kept pace with population growth during this period of rapid expansion in the region as indicated in the data in Table 3-20. That is, per capita revenues and expenditures have not suffered during this growth phase, implying a maintenance of adequate service levels.

Between 1975 and 1981, total operating revenues in real terms (1981 dollars) for Benton County grew much more rapidly than the revenues for Franklin County; this reflects the distribution of the new population during the period. Table 3-20 indicated that Benton County received both the bulk of the new population and had the higher rates of growth in revenues and expenditures. Benton County received approximately 80 percent of the total bicounty population increase and approximately 85 percent of the total revenue increase experienced between 1975 and 1981. The fluctuations in total operational per capita revenues and expenditures from 1975 to 1981 (see Table 3-20) in part reflect political and administrative variations and one time revenues from year to year.

Overall declines in both revenues and expenditures are to be expected, in keeping with the current decline in economic activity and population, which began in mid-1981. However, expenditures were higher in Richland and in the region as a whole in 1981 than in 1980. This may be due to a lag effect between the beginning of the decline and programs designed and implemented at an earlier date to accommodate an increasing population. Since Benton County and the cities of Richland and Kennewick had the greater growth associated with Hanford Site activities, they are likely to experience the greater decline during the current downswing in the economy.

Table 3-20. Comparison between average rates of increase in population, revenues, and expenditures: 1975 to 1981.

	Counties		Tri-Cities		
	Benton	Franklin	Richland	Kennewick	Pasco
Population change[a]	43,746[b]	9,225[b]	7,100[c]	18,500[c]	4,650[c]
Average annual rate of population increase[a]	6.2%	3.7%	3.0%	9.5%	3.6%
Average annual rate of revenue change[d]	9.2%	2.4%	7.4%	10.2%	4.3%
Average annual rate of expenditure change[d]	10.9%	3.6%	11.6%	16.2%	3.8%

[a]1973 to 1981.
[b]Based on data from Table 3-17.
[c]Based on data from Table 3-18.
[d]Based on data from Cluett et al. (1984; Tables 5-18, 5-19, 5-20, and 5-21). These supporting data are expressed in constant 1981 dollars.

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3.6.6 Affected indians

Section 2(2) of the Nuclear Waste Policy Act of 1982 defines an "Affected Indian Tribe" as any Indian tribe:

A. Within whose reservation boundaries a monitored retrievable storage facility, test and evaluation facility, or repository for high-level radioactive waste or spent fuel is proposed to be located;

B. Whose federally defined possessory or usage rights to other lands outside of the reservation's boundaries arising out of congressionally ratified treaties may be substantially and adversely affected by the locating of such a facility.

Provided, that the Secretary of the Interior finds, upon petition of the appropriate governmental officials of the tribe, that such effects are both substantial and adverse to the tribe.

In a letter dated March 30, 1983, the U.S. Department of Interior certified that under Section 2(2)B of the Nuclear Waste Policy Act of 1982, the Yakima Indian Nation is an "Affected Indian Tribe" (DOI, 1983a). This finding was based on the potential impact of the proposed repository at Hanford on the negotiated off-reservation fishing rights of the Yakima Indian Nation.

The Confederated Tribes of the Umatilla Indian Reservation have also been granted the status of an "Affected Indian Tribe" by the U.S. Department of Interior. In a letter to the U.S. Department of Energy on July 13, 1983, the U.S. Department of Interior cited the potential impacts to the tribes off-reservation fishing and hunting rights as the basis for their being granted such status (DOI, 1983b).

The Yakima Indian Reservation is located about 50 kilometers (30 miles) from the proposed repository site at its nearest point, and the Indian population settlements are concentrated even further from the site. The Umatilla Indian Reservation is located about 120 kilometers (75 miles) from the proposed repository site. Both reservations are well beyond the boundaries selected as the primary socioeconomic impact area. To date, the Indians have had no significant social or economic participation in activities at the Hanford Site or in the Tri-City area.

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CHAPTER 4 SUMMARY

To better determine the suitability of a site for a geologic repository, a complete understanding of the geologic and hydrologic conditions of the site is needed. Such an understanding is possible through site characterization, defined by the Nuclear Waste Policy Act of 1982 (Section 2) as:

"(A) siting research activities with respect to a test and evaluation facility at a candidate site; and

(B) activities, whether in the laboratory or in the field, undertaken to establish the geologic condition and the ranges of the parameters of a candidate site relevant to the location of a repository, including borings, surface excavations, excavations of exploratory shafts, limited subsurface lateral excavations and borings, and in situ testing needed to evaluate the suitability of a candidate site for the location of a repository, but not including preliminary borings and geophysical testing needed to assess whether site characterization should be undertaken."

Chapter 4 describes the activities associated with site characterization at the reference repository location, and how these activities are expected to affect the environment described in Chapter 3.

Section 4.1 outlines the activities associated with field studies, the sinking of exploratory shafts, and other studies that constitute site characterization.

The overall emphasis of the field studies is to reduce uncertainty concerning the geologic system and the ground-water flow system, so that compliance, or noncompliance, with the appropriate regulatory criteria can be examined. Specific work plans being developed for these field studies include:

- Lithologic characterization - to characterize the stratigraphy, intraflow structures, fractures, and mineralogy/petrology of the basalt flows within and in the vicinity of the reference repository location.
- Tectonic characterization - to define the past, present, and projected (over an anticipated 10,000-year time frame) structural and tectonic setting of the reference repository location.
- ~~Drilling and~~ Hydrologic parameter testing - to identify the surface boreholes and hydrologic tests that characterize ground-water flow paths within and surrounding the reference repository location that are important to an understanding of radionuclide migration to the accessible environment.

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- Ground-water monitoring - to identify the basic strategy for acquiring hydraulic head data across the reference repository location and the Hanford Site.

- Hydrochemistry studies - to characterize the ground-water chemistry beneath the Hanford Site and the transport characteristics of key radionuclides along likely ground-water flow paths from the repository.

The discussion in this chapter of the Exploratory Shaft Program describes activities related to shaft construction, testing, and final disposition. Briefly, a Phase I shaft will be sunk to provide access to the preferred candidate repository horizon. (A Phase II shaft will be drilled ~~135~~ 305 meters (~~450~~ 1000 feet) south of the Phase I shaft, to comply with U.S. Department of Energy safety requirements.) Then, a shaft station will be constructed in the candidate repository horizon to allow in situ characterization. In situ studies will include geologic, hydrologic, and geomechanic characterization tests. Final disposition of shaft facilities has not been determined, although some possibilities are presented here.

Laboratory studies will be performed as integral parts of the above field activities. Socioeconomic, environmental, meteorological, and archaeological studies will project the expected impacts of repository-related activities.

Section 4.2 covers the possible effects of the activities associated with the above site characterization on the physical environment, as well as on the socioeconomics of the area. Drilling of the shafts is expected to have no significant effect on the geology of the site.

Drilling of the shafts will not result in discharges to surface waters. Also, ~~because of~~ the extensive basalt outcroppings on the Columbia Plateau, no adverse impacts are expected ~~from~~ leachate from the spoil pile. On the other hand, the drilling of the shafts could have two major impacts on ground-water hydrology. First, shaft construction could interfere with measurements and monitoring of the natural variations in ground-water levels. Second, construction could interfere with the natural interconnections of aquifers. Thus, before the shafts are constructed, baseline monitoring will determine the natural, unperturbed fluctuations in water levels in various basalt flow tops. If these natural fluctuations vary considerably after the shaft is constructed, man-induced changes can be differentiated from those naturally anticipated.

Impacts on the environmental setting as a result of site characterization are discussed in terms of the ecosystem; air quality; noise; aesthetics; archaeological, cultural, and historical resources; and radiological effects. Included in this discussion is a table that summarizes the expected impacts on native biota due to site characterization activites.

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The socioeconomic effects of site characterization are discussed in terms of population density and distribution; economic conditions; community services; social conditions; fiscal conditions and government structure; and land use, access, and surface and mineral rights.

Section 4.2.3 discusses occupational safety and health concerns related to site characterization, noting that the principal risks are similar to those associated with most underground mining preparations.

Finally, Section 4.2.4 notes that alternative site characterization activities that might reduce effects were not identified because: (1) the effects of sinking exploratory shafts using the blind-boring technique are expected to be minimal, and (2) no alternative to sinking this shaft would be suitable for providing the necessary data at depth.

As mentioned earlier, much of the information presented in this chapter refers to background data presented in Chapter 3. Chapter 5 next discusses the expected effects of actually locating and operating a repository at the Hanford Site, and is structured similarly to Chapter 4. Table 4-A provides a cross-reference matrix to direct the reader to sections in the rest of the document related to topics presented in this chapter.

Table 4-A. Sections related to Chapter 4 discussions.

	Chapter 2	Chapter 3	Chapter 4	Chapter 5	Chapter 6
FIELD STUDIES					
Lithologic Characterization	2.1.1.1/2.1.1.2	3.2.2/3.2.3	4.1.1.1		
Tectonic Characterization	2.1.2	3.2.3	4.1.1.2		6.3.1.7/6.3.3.4
Hydrologic Parameter Testing			4.1.1.3		
Ground-Water Monitoring			4.1.1.4		
Hydrochemical Characterization			4.1.1.5		
Exploratory Shaft			4.1.1.6		
OTHER ACTIVITIES					
Laboratory Tests			4.1.2.1		
Socioeconomic Activities		3.6	4.1.2.2/4.2.2	5.2.3	6.2.1.7/6.2.2.2
Environmental Studies		3.4	4.1.2.3/4.2.1.3	5.2.1.3	6.2.1.6/6.2.2.2
Meteorlogical Studies		3.4.3	4.1.2.4		6.2.1.4
Archaeological Studies		3.4.6	4.1.2.5/4.2.1.3.5	5.2.1.3.5	
Geochemistry			4.1.2.6		6.3.1.2
EXPECTED EFFECTS ON PHYSICAL ENVIRONMENT					
Geology	2.1.1	3.2	4.2.1.1	5.2.1.1	
Hydrology	2.1.3/2.1.4	3.3.1/3.3.2	4.2.1.2	5.2.1.2.1/5.2.1.2.2	6.3.3.3
Environmental Setting		3.4	4.1.3.3/4.2.1.3	5.2.1.3	
SOCIOECONOMICS		3.6	4.1.3.2/4.2.2	5.2.3	6.2.1.7/6.2.2.2
Population Density and Dist.		3.6.1	4.2.2.1	5.2.3.1	6.2.1.2
Economic Conditions		3.6.2	4.2.2.2	5.2.3.2	
Community Services		3.6.3	4.2.2.3	5.2.3.3	
Social Conditions		3.6.4	4.2.2.4	5.2.3.4	
Fiscal Conditions and Government Structure		3.6.5	4.2.2.5	5.2.3.5	
Land Use, Access, and Surface and Mineral Rights		3.4.1	4.2.2.6	5.2.3.6	6.2.1.1/6.2.1.3
OCCUPATIONAL SAFETY AND HEALTH			4.2.3	5.2.4	
ALTERNATIVE SITE CHARACTERIZATION ACTIVITIES			4.2.4		

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Chapter 4

SITE CHARACTERIZATION ACTIVITIES AND EXPECTED EFFECTS

4.1 SITE CHARACTERIZATION ACTIVITIES

This section discusses characterization activities that are planned for the reference repository location, following the Nuclear Waste Policy Act definition of "site characterization" which is:

"(A) siting research activities with respect to a test and evaluation facility at a candidate site; and

(B) activities, whether in the laboratory or in the field, undertaken to establish the geologic condition and the ranges of the parameters of a candidate site relevant to the location of a repository, including borings, surface excavations, excavations of exploratory shafts, limited subsurface lateral excavations and borings, and in situ testing needed to evaluate the suitability of a candidate site for the location of a repository, but not including preliminary borings and geophysical testing needed to assess whether site characterization should be undertaken."

4.1.1 Field studies

The overall emphasis of the field studies is to reduce uncertainty in understanding the ground-water flow system and geologic environment so that compliance or lack of compliance with appropriate regulatory criteria can be properly examined. This goal will require the development of a geohydrologic data base and conceptual/numerical models describing the geologic setting, ground-water movement, and potential for radionuclide transport. Steps in the development of a basic geohydrologic model are outlined in Figure 4-1. Much of the existing site characterization data, as noted in this Environmental Assessment, has been summarized in other reports (e.g., Myers et al., 1979; Gephart et al., 1979; Myers and Price, 1981; DOE, 1982c; Long and WCC, 1984), or is based on results of work under way by the Basalt Waste Isolation Project staff or subcontractor personnel. Review of portions of this data base and characterization effort has been completed by several organizations including the U.S. Nuclear Regulatory Commission (NRC, 1983), U.S. Geological Survey (USGS, 1983), State of Washington (1983), and Pacific Northwest Laboratory (1983). The critiques provided by these organizations are being utilized in the development of detailed plans and programs for site characterization activities.

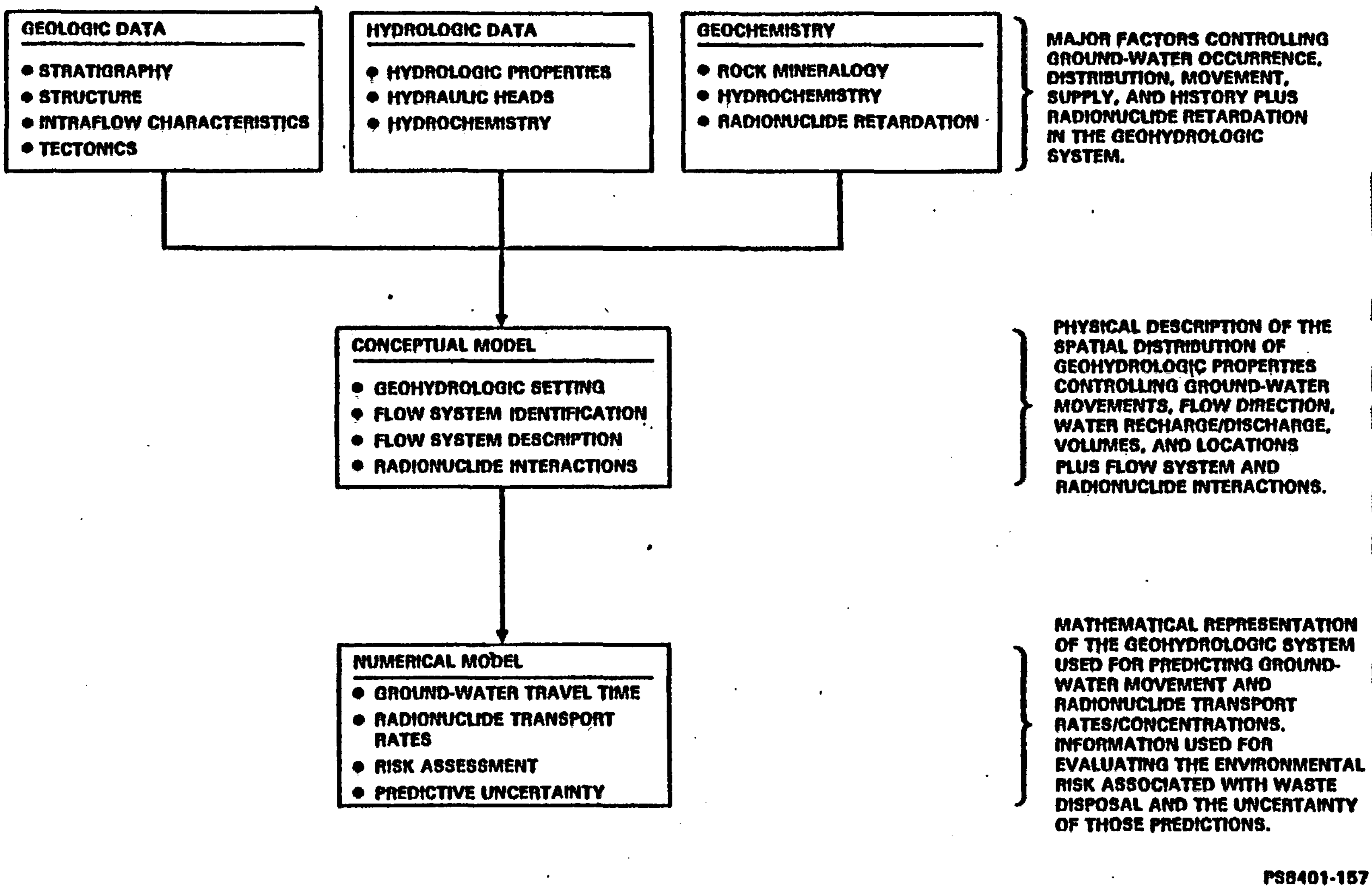

Figure 4-1. Development of a basic geohydrologic model.

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Additional specific work plans are being developed and are described in this section. These include:

- Lithologic characterization.
- Tectonic characterization.
- Hydrologic parameter testing.
- Ground-water monitoring.
- Hydrochemical characterization.
- Exploratory shaft.

4.1.1.1 Lithologic characterization

The objective of these studies is to characterize the stratigraphy, intraflow structures, fractures, and mineralogy/petrology of the basalt flows within and in the vicinity of the reference repository location. Studies needed to define the lithologic characteristics of interbeds will also be included. Data needs for lithologic characterization will primarily be met by investigations of outcrops, core, and borehole logs and through laboratory studies of outcrop and core samples. Studies planned include the following:

- Stratigraphic setting.
- Intraflow structures.
- Fracture characterization.
- Mineralogy/petrology.

4.1.1.1.1 Stratigraphic setting

Stratigraphic studies will entail the acquisition and interpretation of outcrop and borehole data within the Pasco Basin to refine the stratigraphic framework and to determine the variations in thickness, geometry, and attitude (strike and dip) of basalt flows and interbeds. Analytical data will be used to determine and (or) confirm rock stratigraphic units, chemical stratigraphic units, magnetostratigraphic units, and borehole-geophysical-log stratigraphic units. Study of field exposures of candidate repository horizons will be oriented toward determining typical, short-range (tens of meters) and long-range (hundreds of meters) variations in flow thickness.

4.1.1.1.2 Intraflow structures

Studies of intraflow structures involve the acquisition and interpretation of data relating to variations in flow top, entablature, colonnade, and other primary features, particularly for the candidate repository horizons. Outcrop studies will entail examination of photographs of actual cliff exposures wherein intraflow structure variations can be directly measured. Intraflow structures in boreholes

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will be determined by detailed core logging, petrographic analysis, and borehole geophysics. Studies will include an evaluation of the kriging method to statistically characterize the thickness variations of intraflow structures within candidate repository horizons.

4.1.1.1.3 Fracture characterization

Work will include an analysis of the orientation, distribution, aperture infilling, and origin of fractures, discontinuities, and heterogeneities within candidate repository horizons and surrounding strata. Fracture orientation and spacing data will be compared with petrographic data (quantitative model analysis and qualitative texture analysis) from surface exposures of the candidate repository horizons. These data will be used to determine the extent to which petrography can be used to predict fracture spacing at depth from core samples by utilizing known fracture characteristics in surface exposures and by fracture spacing from the core itself. Aperture infilling data will be obtained from detailed measurement of fracture width and estimation of relative proportions of infilling minerals in core samples.

4.1.1.1.4 Mineralogy/petrology

Work will include the characterization of the mineralogy and petrology of candidate repository horizons and interbeds. Composition of fracture aperture infillings (secondary minerals) will also be addressed. Data needs will be provided by X-ray diffraction, electron microprobe, and optical and electron microscopy. Subsurface and surface data will be used to predict the mineralogy and petrologic properties of the candidate repository horizons within the reference repository location and serve as basic input to hydrochemical modeling efforts.

4.1.1.2 Tectonic characterization

The objective of this work is to define the past, present, and projected (over an anticipated 10,000-year time frame) structural and tectonic setting of the reference repository location. Data needs will primarily be fulfilled by geologic, geophysical, and instrumental monitoring studies. Topics in these studies include the following:

- Structural and tectonic setting.
- Contemporary setting.
- Tectonic modeling.

4.1.1.2.1 Structural and tectonic setting

Geologic and geophysical studies to characterize the structural and tectonic setting of the reference repository location will be performed. Determinations of the locations, geometry, age, and evolution of secondary structures (e.g., faults, folds, fractures) will be carried out through a

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combination of geologic mapping, paleomagnetic studies, kinematic modeling, borehole studies, trenching studies, and geophysical surveys within the Pasco Basin and vicinity. Study of selected areas within the region will also be conducted to enhance and support interpretations of more site-specific findings.

4.1.1.2.2 Contemporary setting

Seismic surveillance and geodetic data will be utilized to assess the nature and magnitude of contemporary deformation of the Cold Creek syncline and reference repository location. Such work will include a continuation of regional seismic monitoring by a network of surface seismometers already established in eastern Washington. The regional network will be supplemented by portable and permanent surface and subsurface seismometers deployed to gather detailed data on microseismic activity within the Pasco Basin, Cold Creek syncline, and the reference repository location. Pertinent data will also be provided by periodic resurveying of existing and newly established trilateration arrays and leveling stations within the Pasco Basin area.

4.1.1.2.3 Tectonic modeling

This item includes work to integrate all geological, geophysical, historical, geodetic, and seismic monitoring data collected during site characterization. Work involves a review and assessment of current tectonic models with specific application to the Pasco Basin and the reference repository location. Pertinent models will be evaluated in terms of their impact on preclosure and postclosure repository performance. Interpretations produced as a result of this work will serve as the basis for input to seismic design of a repository.

4.1.1.3 Hydrologic parameter testing

The objective of this work is to complete hydrologic parameter characterization suitable for evaluation of the ground-water flow paths within and surrounding the reference repository location critical in understanding radionuclide migration to the accessible environment. Test facilities specifically designed for hydrologic testing will be used for characterization within and in the vicinity of the reference repository location. Elsewhere on the Hanford Site some existing wells and planned boreholes will be tested. A limited number of wells located off the Hanford Site may also be drilled and (or) tested. These would be located in areas considered critical in understanding the regional geohydrologic setting as needed for addressing regulatory criteria. Testing programs being developed include:

- Large-scale hydrologic stress tests.
- Small-scale hydrologic stress tests.
- Tracer tests.
- Mud effects.

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4.1.1.3.1 Large-scale hydrologic stress tests

Multiple-hole tests will be designed to stress select flow tops and interbeds across large distances (several thousand meters). These tests will provide large-scale measurement of transmissivity and storativity. By monitoring hydraulic heads both above and below given basalt flows, estimates of vertical transmissivity across basalt flow interiors may be possible.

4.1.1.3.2 Small-scale hydrologic tests

These single-hole hydrologic tests only stress rock volumes in the immediate vicinity of the borehole. These tests are reconnaissance in nature and will provide small-scale measurement of transmissivity and hydraulic head measurements recorded on a progressive drill and test basis.

4.1.1.3.3 Tracer tests

These single- and multiple-surface hole tests use conservative and nonconservative (sorptive) tracers. The use of low-level radioactive and nonradioactive tracers is planned. These tests will provide estimates of effective porosity and dispersivity for select basalt flow tops and interbeds. The possibility of moving tracers from one flow top to another (across a flow interior) will be examined as a means of calculating the effective porosity and dispersivity of a flow interior using surface boreholes. Tracer tests will be conducted as part of both the large- and small-scale hydraulic testing.

4.1.1.3.4 Mud effects

These tests evaluate the possible effect drilling muds have had on hydrologic test results in both low and high transmissive rock zones. Test results will assist in quantifying the uncertainty in past hydrologic tests, which were mostly conducted on holes drilled with muds.

4.1.1.4 Ground-water monitoring

The ground-water monitoring studies will identify the basic strategy for acquiring hydraulic head data across the reference repository location, Hanford Site, and portions of the larger Columbia Plateau. These studies will determine borehole locations, stratigraphic intervals, and criteria upon which monitoring frequency may be established. Topics include the following:

- New piezometers.
- Existing piezometers.
- Drill and test hydraulic heads.
- Bridge plug installations.

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4.1.1.4.1 New piezometers

Locations are identified where new piezometers are planned. This includes single and cluster piezometric sites. Data collected will center upon understanding spatial and stratigraphic head distributions and their changes as a function of time. These data will also help evaluate the reliability of historical head data collected on a progressive drill and test basis.

4.1.1.4.2 Existing piezometers

The existing ground-water monitoring network will be maintained and expanded as new piezometers are available. A selection of existing boreholes open across several basalt flows have instrumentation installed for hydraulic head monitoring within one or more flow tops. Existing regional wells outside of the Hanford Site suitable for monitoring have also been identified and integrated into the existing U.S. Geological Survey regional ground-water monitoring network. If existing wells do not exist (or are unavailable) in areas outside the Hanford Site where head data are considered critical, then new piezometers may be drilled.

4.1.1.4.3 Drill and test hydraulic heads

As single exploratory holes are drilled, hydraulic heads will be measured on a progressive drill and test basis. Though these head measurements are considered less reliable than those collected over a period of time in permanent piezometers, such information serves as a useful preliminary indication of local head distributions.

4.1.1.4.4 Bridge plug installations

In open, deep boreholes on the Hanford Site, not undergoing active hydrologic testing or monitoring, bridge plugs will be installed in the open section of each hole to minimize fluid communication within the holes. This will reduce the chances of disturbing the natural hydraulic head patterns on the Hanford Site or in the reference repository location.

4.1.1.5 Hydrochemical characterization

The hydrochemistry studies will characterize the ground-water chemistry beneath the Hanford Site and the transport characteristics of key radionuclides along likely ground-water flow paths from the repository. Work will include the following:

- Ground-water sampling.
- Sampling techniques.
- Radionuclide transport.
- Geochemical modeling.

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4.1.1.5.1 Ground-water sampling

Sampling of ground waters from existing and new boreholes for determining the spatial and stratigraphic changes in mass chemistry, stable isotopes, radioisotopes, dissolved gases, and trace elements will be done. This information is needed to quantify the in situ ground-water environment for understanding its evolution and effect on waste transport.

4.1.1.5.2 Sampling techniques

Work is in progress to evaluate and improve, as necessary, ground-water sampling techniques to assure high sample quality. This includes estimation of the effects of drilling mud on sample quality and development of downhole sampling devices.

4.1.1.5.3 Radionuclide transport

Transport characteristics of key radionuclides will be studied, including those features that retard radionuclide migration (e.g., sorption, precipitation, filtration) and those that prevent retardation reactions from occurring (e.g., complexation, colloid migration). These transport characteristics involve identification of key radionuclides, understanding waste/rock/ground-water interactions, and definition of the geohydrologic properties of likely flow paths for radionuclides. Measured field sorption characteristics of a select list of radionuclides will be extrapolated to other key radionuclides using laboratory sorption studies.

4.1.1.5.4 Geochemical modeling

Numerical modeling of the ground-water chemistry to understand its origin, evolution, and the potential for future changes that may impact radionuclide transport will be conducted.

4.1.1.6 Exploratory shaft

NEED TO STATE WHICH SURFACE FACILITIES ARE COMPLETED.

The Exploratory Shaft Program is an extension of field studies that will involve the drilling of two large-diameter (2.8-meter (9.2-foot)) holes and excavation of underground tunnels. This facility provides access to the preferred candidate horizon for in situ geohydrologic and geomechanical characterization. Shaft and tunnel construction themselves will address questions on the constructibility, rock stability, and ground-water inflow conditions of a deep mine within basalt. Information gained will be combined with data collected from surface boreholes to develop a more thorough understanding of the actual subsurface environment of the preferred candidate horizon and surrounding basalt flows. To be in compliance with DOE Order 5480.1A Safety Requirements, two shafts are required to ensure personnel safety.

The Exploratory Shaft Program is divided into two phases. Phase I consists of construction of a first shaft, porthole hydrologic testing

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through the shaft casing, shaft station breakout, shaft station geomechanics testing, and geologic characterization. Phase II includes the construction of a second shaft, excavation of drifts, constructibility monitoring, performance of in situ tests, and further geologic characterization. The principal construction and characterization activities of the Exploratory Shaft Program are discussed below.

4.1.1.6.1 Construction

The Phase I shaft will be blind bored (drilled), lined with a watertight steel casing, and the annular space between the casing and rock wall grout filled. The shaft will have a 183-centimeter (72-inch) inside diameter, and will be emplaced deep enough to permit shaft station breakout at the selected candidate horizon. Figure 4-2 illustrates the completion dimensions and depth of the shaft for the lowest candidate repository horizon (see Section 2.2.3). This depth is used for analyses of environmental impacts to provide a bounding scenario (i.e., shafts to lesser depths would have no greater impacts). Current plans are to drill the exploratory shafts to a depth of ___ meters (___ feet) consistent with the depth of the Grande Ronde flow

During drilling, the shaft will be filled with a fluid consisting of water, bentonite clay, and a biodegradable polymer. This fluid provides hydrostatic support to the shaft wall, lubricates and cools the drill bit and reamers, and carries rock chips to the surface by fluid circulation. The shaft will penetrate several aquifers (see Subsection 6.3.3.3.3). The hydrostatic pressure of the drilling fluid will keep major ground-water quantities from entering the hole. When drilling is completed, a steel liner will be placed in the hole one section at a time. Following liner emplacement, a cement grout will be pumped into the annular space between the liner and the hole wall. Grouting continues until the entire liner is sealed in place.

Water inflow is one risk associated with breakout from the shaft. To examine the effectiveness of the cement grout seal surrounding the liner, boreholes will be drilled through specially designed portholes in the shaft casing and tests conducted.

The initial breakout point is called the shaft station (Fig. 4-3). This station is a 2.7- by 4- by 15.2-meter (9- by 13- by 50-foot) long drift constructed in the preferred candidate horizon. The shaft station will serve two purposes. First, it will help verify that the at-depth basalt is suitable for large-scale (drift) construction. Second, the station will provide working space to install Phase II construction equipment. The completion of geomechanics testing in the shaft station marks the end of the Phase I program.

At the completion of Phase I, the shaft drill rig will be moved 137 to 244 meters (450 to 800 feet) south where the Phase II shaft will be drilled. The inside diameter of the second shaft will be the same as the first shaft (1.8 meters (6 feet)), and will be drilled to a depth that will allow a breakout at the same elevation as the Phase I shaft station. The outside diameter of the hole will be 2.8 meters (9.2 feet). It will be constructed using the blind boring method, and will follow a construction sequence similar to that of the Phase I shaft.

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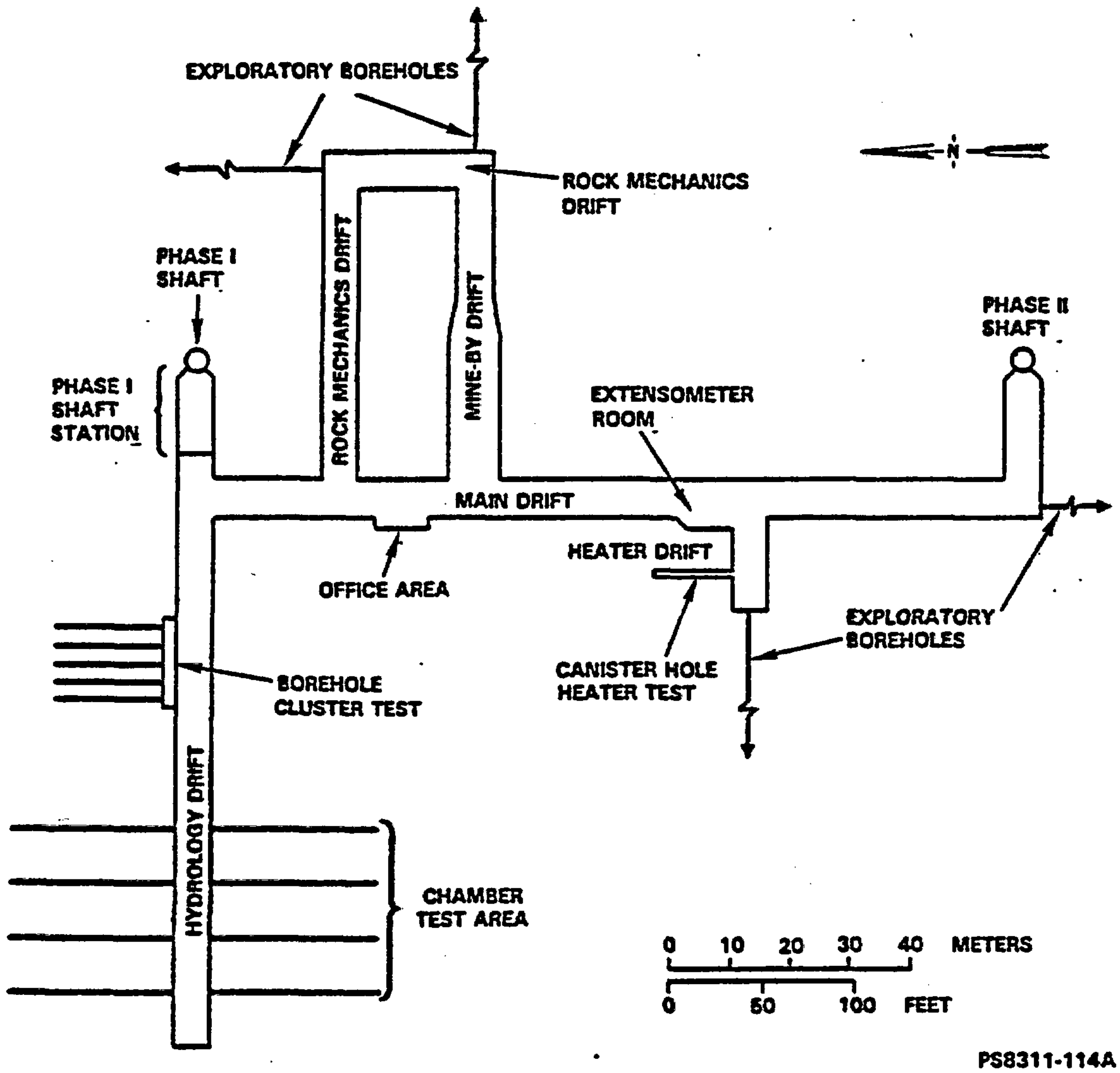

Figure 4-3. Exploratory ~~shaft-Phase II~~ Shaft Program Underground Facility conceptual arrangement.

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4.1.1.6.2 Geologic characterization

The emphasis in this effort is on mapping and evaluating the fracture characteristics of the preferred candidate horizon. This is accomplished by completing detailed fracture logging of core from boreholes drilled from within the shaft and drifts. Particularly significant are the four exploratory boreholes drilled horizontally approximately 305 meters (1,000 feet) into the flow interior from the Phase II drifts (see Fig. 4-3). Fracture mapping of the tunnel walls will also take place concurrent with construction. The above fracture data will provide researchers with a knowledge of in situ fracture distributions, widths, mineral infillings and origins. This is critical to understanding the specific near-field geologic environment of a repository built within a basalt flow interior.

4.1.1.6.3 Hydrologic characterization

Hydrologic tests undertaken within the exploratory shaft facility are focused on characterizing the flow interior of the preferred candidate horizon. Properties measured include hydraulic conductivity, storativity, effective porosity, dispersivity, and diffusion. Test methodology, duration, and success are highly dependent on the actual in situ conditions encountered at depth. At present, four test approaches are planned. These include:

1. Chamber test - This is a large-scale test of the hydraulic conductivity of a flow interior using a 50-meter (164-foot) long drift monitored by boreholes cored from within and adjacent to the tunnel.

2. Cluster test - A borehole cluster room is planned for development off of the access tunnel to the chamber test room. Cross-hole hydrologic and tracer tests are planned for measuring hydraulic conductivity, effective porosity, dispersivity, and diffusion within the interior of the preferred candidate horizon.

3. Exploratory borehole tests - These boreholes will be cored and fracture logged. Afterwards, hydrologic tests are planned for measuring hydraulic conductivity distributions in four directions from the underground tunnels (see Fig. 4-3). This information provides researchers a better understanding of the areally distributed hydraulic conductivity within a basalt interior as determined from coreholes drilled at right angles to the predominantly vertical fracture patterns of a flow interior.

4. Other borehole tests - Many boreholes cored within the cluster area, chamber room, and from the shafts themselves will be hydrologically tested. Plans include coring and testing in holes penetrating flow interiors and flow tops. Ground-water samples will be collected from selected boreholes penetrating zones of high hydraulic conductivity. Monitoring of hydraulic heads will also take place.

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Directly observing the quantity and the distribution of ground-water *inflow* ~~leakage~~ into the drifts will also help in selecting the ground-water conceptual model most descriptive of basalts in the reference repository location (see Subsection 3.3.2.2.1).

4.1.1.6.4 Geomechanics characterization

Geomechanical tests and monitoring will be performed within the exploratory shaft facilities during Phase I and II. The outcome of these tests are critical to *evaluating* ~~understanding~~ the feasibility of constructing underground facilities that are *stable* ~~safe~~ and that have rock conditions suitable for waste emplacement, isolation, and retrievability. ~~Several rock properties and~~ *Geoengineering properties and* rock mass behavior characteristics will be evaluated including:

- Rate and magnitude of rock deformation around openings.
- *Performance* ~~Stability~~ of rock support systems.
- In situ stresses and their orientation.
- *Nature and extent of the disturbed rock zone.* ~~Measurement of stress-induced phenomena such as crack propagation.~~
- Rock mass *mechanical and thermal properties.* ~~deformational behavior under elevated temperatures (heater test area in Fig. 4-3).~~
- Stability of horizontally drilled waste emplacment holes *during* ~~following~~ *excavation* ~~construction~~ and heating.

Of particular importance in *the* geomechanics characterization *program are* ~~is~~ the mine-by ~~drift~~ and heater tests (see Fig. 4-3). ~~Instruments extending from the rock mechanics drift will measure rock mass deformation as the mine-by drift is constructed. In like manner, specially designed steel rods will be installed in the extensometer room to measure rock deformation resulting from electric heaters warming up the rock in the heater drift and canister hole areas.~~ *These are tests in which the stability and performance of prototypic repository room and canister scale openings are monitored under at-depth ambient and, for the canister opening, elevated temperature conditions. Geoengineering properties of the rock mass are also obtained in these tests.*

4.1.2 Other activities

4.1.2.1 Laboratory tests

Inasmuch as some laboratory tests are performed as an integral part of field activities, it would be inappropriate to discuss them as separate activities. In many instances, samples are collected in the field but analyzed in the laboratory. Extensive laboratory studies to determine materials properties are being conducted in conventional laboratory and hot-cell facilities.

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4.1.2.2 Socioeconomic activities

Socioeconomic studies will primarily focus on the following:

- Population density and distribution.
- Economic conditions.
- Community services.
- Social conditions.
- Fiscal conditions and government structure.

The purpose of these studies is to accurately project any socioeconomic impacts that would be felt in the surrounding communities due to repository-related activities. Development of preliminary mitigation plans for anticipated socioeconomic effects would occur during site characterization.

4.1.2.3 Environmental studies

During site characterization, detailed environmental studies would be conducted at the reference repository location to characterize native plant communities and to determine the distribution and densities of animal species. Early emphasis would be on identification of threatened or endangered species, especially those known to frequent the Hanford Site and surrounding area. Detailed species lists and (or) voucher specimens will be prepared to support environmental report requirements.

4.1.2.4 Meteorological studies

The Hanford Meteorological Station is located within the reference repository location. A data base of approximately 30 years has been collected at the meteorological station. A minimum of two years of meteorological data is necessary to meet the requirements of the U.S. Nuclear Regulatory Commission (NRC, 1972). Meteorological measurements at the Hanford Meteorological Station meet or exceed the guidelines contained in the U.S. Nuclear Regulatory Commission Regulatory Guide 1.23 (NRC, 1974).

4.1.2.5 Archaeological surveys

The Hanford Site has been subjected to general archaeological reconnaissance surveys that showed Indian activities at the Hanford Site and surrounding areas were primarily concentrated along the Columbia River (ERDA, 1975, Vol. I, pp. II.3-8 through -9). A detailed archaeological survey of the reference repository location, concentrating on areas where surface facilities would be expected to be located, will be conducted.

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Archaeological sites will be identified to facilitate cataloging or relocation if a repository is constructed at the reference repository location.

On the basis of the above activities planned during the field studies and the sinking of the exploratory shafts, the next section outlines potential effects on the Hanford Site and its ~~environment, that is, its~~ physical environment and ~~its~~ socioeconomic environment. move to next page

4.1.2.6 Geochemistry studies

Geochemistry studies are defined here as referring to geochemical processes occurring in the waste package, near-field environment. Work will include the following:

- Redox conditions in the waste package and adjacent host rock.
- Radionuclide reactions and transport in the waste package and adjacent host rock.

The majority of the data will be collected from laboratory experiments that simulate expected repository conditions (e.g., temperature, pressure, and ground water). Control of geochemical parameters is very difficult to achieve in the field and relatively little geochemical data will be derived from field or in situ experiments.

4.1.2.6.1 ~~Redox~~ Reduction (oxidation) conditions and other ground-water characteristics in the waste package and adjacent rock

The redox (reduction/oxidation) condition in the waste package system will have a major impact on the oxidation state of multivalent radionuclides (e.g., actinides, technetium-99). This in turn affects the solubilities and release rates of these radionuclides and their release rates into the adjacent host rock and eventually the accessible environment. Tests are being conducted to determine the rate of return to the reducing environment following emplacement as a result of hydrothermal reaction between crushed basalt in the packing material and ground water (e.g., measurement of oxygen consumption rates, development of high-temperature Eh-pH probes to be used in hydrothermal experiments, and measurement of redox sensitive elemental pairs such as astatine (III/V) in hydrothermally altered solutions). Other changes in ground-water characteristics, such as major cation and anion concentrations and pH, are being measured as a function of time in hydrothermal experiments.

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4.1.2.6.2 Radionuclide reactivity and transport in the waste package and adjacent host rock

Following container breaching and waste form dissolution, radionuclide transport rates through the packing material into the host rock will provide the source term for far-field transport analyses. Laboratory tests are being completed to determine radionuclide solubility/sorption reactions and maximum steady-state concentrations in hydrothermal solutions altered by reaction with waste package materials (e.g., waste form, container, and packing) and host rock. Diffusion coefficients are also being measured that input to analytical models describing radionuclide transport through the packing material.

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4.2 EXPECTED EFFECTS OF SITE CHARACTERIZATION

A wide variety of geologic and hydrologic techniques have been employed to survey and characterize areas of the Hanford Site. Most processes, such as aerial and satellite photography and magnetometer surveys, have no discernible environmental effect~~, and, accordingly, do not require environmental documentation~~. Borehole drilling has sufficient potential impact to require a brief environmental evaluation of each proposed drill site. Since the beginning of the screening process in 1978, the Basalt Waste Isolation Project has drilled, reentered and deepened, or conducted tests in approximately 66 boreholes on the Hanford Site. Past borehole drilling has ~~adversely~~ impacted several "state" sensitive wildlife species, particularly the Swainson's Hawk and long-billed Curlew that nested near borehole sites. A careful evaluation of past disturbances is planned to determine tolerance levels of various wildlife species to drilling-related disturbances.

Additional boreholes are planned to be drilled during the next few years of site characterization activities. The main purpose for the new boreholes will be to provide hydrologic data necessary to more fully define the hydrologic system beneath and beyond the Hanford Site. For each new borehole, an environmental evaluation will be prepared to ensure that impacts are minimized.

Construction of the shafts and related facilities, for detailed site characterization presents the greatest potential for adverse environmental impacts of all the site characterization activities. The impacts of the Phase I shaft construction, operation, and decommissioning were addressed in an earlier National Environmental Policy Act Environmental Assessment (DOE, 1982b). Construction of the Phase II shaft is expected to have impacts similar in kind and quantity. Much of the following information is summarized from the earlier Environmental Assessment.

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4.2.1 Expected effects on the physical environment

The expected effects of site characterization activities on the physical environment are divided into the following three categories:

- Effects on the site geology.
- Effects on the site hydrology.
- Effects on the environmental setting.

4.2.1.1 Geology

Drilling of the shafts and underground test facilities is expected to have no significant effect on the geology of the site. No anticipated instabilities which could cause problems during site characterization (e.g., uplift or subsidence) exist at the site.

4.2.1.2 Hydrology

Site characterization impacts on hydrology are presented in two parts: impacts on surficial hydrology and impacts on ground-water hydrology.

4.2.1.2.1 Surficial

Subsection 4.1.1.3 outlines the hydrologic parameter testing planned as part of the site characterization program. This study includes conducting hydrologic stress tests which require discharge of large ground water quantities. During site characterization, approximately 12 such tests are planned during which 1.6×10^3 m^3 to 1.6×10^5 m^3 (1 to 130 acre-feet) of ground water would be discharged over a 30 day pretest period. Average discharge volumes are estimated to be 3.2×10^4 m^3 (26 acre-feet). The area of water release is not yet determined. Expected impacts include temporary water ponding, increase in local soil moisture content, and the greening of nearby flora. No manmade radioactivity is associated with the deep ground waters to be discharged.

Drilling of the shafts will not result in any discharges to surface waters. The drilling fluids will be contained in lined pits to prevent seepage. Sanitary wastes will be disposed of by means of a septic tank/drain field complex.

To determine if leachate from the spoil pile is a problem, detailed chemical analysis will be made of the rock that will constitute the pile. On the basis of this analysis, the necessary appropriate effluent monitoring plans and physical barriers (e.g., dikes, berms, and liquid collection sumps) will be established to prevent water from leaching chemicals from the spoil pile into the site surface. However, there are

extensive basalt outcroppings on the Columbia Plateau (see Fig. 3-1) that do not present a leach problem to the surrounding area; therefore, there are no adverse impacts projected due to leachate from the spoil pile.

4.2.1.2.2 <u>Ground water</u>

Shaft drilling can potentially have two impacts on the ground-water flow system in the reference repository location. First, shaft construction may interfere with the measurement of natural variations in baseline ground-water levels. The extent of such interference depends on how well isolation is maintained between aquifers during shaft drilling by the use of muds and loss circulation materials. Second, shaft construction may provide a vertical conduit for some quantity of ground water mixing that would have otherwise not existed. That is, in the localized area around the shafts, previously isolated aquifers may become connected (e.g., as a result of a poor shaft seal). In order to determine if either of these interferences is present, site characterization activities will proceed as a logical, sequential process. Prior to shaft construction, baseline monitoring will be conducted to determine the natural, unperturbed, fluctuation in water levels in various basalt flow tops. If there are changes to these natural fluctuations after construction of the shafts, man-induced changes can be differentiated from natural variability. In addition, selected large-scale hydrologic tests can be completed before and after shaft sinking to determine whether or not shaft emplacement has had a measureable effect on aquifer interconnection.

4.2.1.3 Environmental setting

Site characterization impacts on the environmental setting are presented in the following six parts.

- Ecosystem impacts.
- Air quality impacts.
- Noise impacts.
- Aesthetic impacts.
- Archaeological, cultural, and historic resource impacts.
- Radiological impacts.

4.2.1.3.1 <u>Ecosystems</u>

Table 4-1 summarizes the expected effects of site characterization activities on ecosystems. The major impact of site characterization activities on the ecosystems, are on the terrestrial ecosystem. Impacts on the aquatic ecosystem are minimized because most of the activities are not carried out in the vicinity of aquatic habitats.

4.2.1.3.1.1 <u>Terrestrial</u>. Borehole locations were selected to acquire necessary data while minimizing environmental impact. It was recognized that, in the shrub-steppe ecology of the Hanford Site, land

Table 4-1. Summary of expected impacts on native biota from Basalt Waste Isolation Project site characterization activities. (Sheet 1 of 2)

Activities	Organisms that may be impacted				
	Endangered and threatened species	Swainson's hawk, other birds of prey	Long-billed curlew	Other wildlife	Native plant communities
Off-road travel for: engineering surveys environmental surveys	No impact so long as surveys are conducted away from bald eagle habitat alongside the river	May cause some nest desertion and loss of young if conducted during critical spring nesting season. Minimized by following recommendations of Fyfe and Olendorff (1976)	May cause some nest desertion and loss of young if conducted during critical spring nesting season. Minimized by following recommendations of Fyfe and Olendorff (1976)	No significant impact	No impact
Archaeological surveys	May cause minor disturbance to wintering bald eagles. Potential impact can be eliminated by conducting surveys between August and October	May cause some nest desertion and loss of young if conducted during critical spring nesting season. Minimized by following recommendations of Fyfe and Olendorff (1976)	May cause some nest desertion and loss of young if conducted during critical spring nesting season. Minimized by following recommendations of Fyfe and Olendorff (1976)	No significant impact	No impact
Field studies - borehole drilling and testing	May displace wintering bald eagles if activity occurs near Columbia River. Potential impact can be eliminated by limiting drilling/testing to months of April through October for any sites adjacent to wintering eagle habitat	May cause some nest desertion and loss of young if conducted during critical spring nesting season. Minimized by following recommendations of Fyfe and Olendorff (1976)	May decrease nesting success within 1-km (0.6 mi) radius of drilling/testing sites if activity occurs during critical spring nesting season	Will cause minor temporary displacement of animals that are sensitive to noise and/or human activity	Will cause loss of some native plants at borehole site. Impact will be minor because of limited area
Exploratory shaft construction	No impact because of remoteness of site from bald eagle habitat	May cause nest desertion to one or two of approximately 15 to 18 pairs of Swainson's hawks nesting on the Hanford Site	Status of curlew nesting near the reference repository location is unknown. If nesting occurs nearby (within 1 km (0.6 mi)), nesting success may be decreased	Noise and habitat loss will cause displacement of some native wildlife in the vicinity of the site	Several hectares of native plant community will be physically destroyed by construction activity. Vegetation on limited adjacent areas may be damaged by windblown soil or other materials. Total area that will be impacted is small compared to the hundreds of hectares of similar plant community type nearby

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Table 4-1. Summary of expected impacts on native biota from Basalt Waste Isolation Project site characterization activities. (Sheet 2 of 2)

Activities	Organisms that may be impacted				
	Endangered and threatened species	Swainson's hawk, other birds of prey	Long-billed curlew	Other wildlife	Native plant communities
Exploratory shaft operation	No impact	Noise and increases in local traffic will not result in impacts beyond those resulting from exploratory shaft construction	Status of curlew nesting near the reference repository location is unknown. If nesting occurs nearby (within 1 km (0.6 mi)), nesting success may be decreased	No impacts in addition to those identified as a result of exploratory shaft construction	No impact
Increased Potential for accidental range fires due to Exploratory Shaft Program activities	No impact	~~Probability of range fire increased.~~ Fire could result in temporary loss of prey resources to the birds	~~Probability of range fire increased.~~ Fire could destroy nests or result in temporary loss of nesting habitat	~~Probability of range fire increased.~~ Fire could cause temporary reduction in animal populations through loss of habitat	~~Probability of range fire increased.~~ Composition of native plant community would be ~~tem~~[illegible] altered ~~for a period of years~~ if fire occurs
Increased travel on established roads in support of all above activities	No impact	No impact	No impact	Most mammals and reptiles and some birds will have increased probability of collision with vehicles. Some animals will be killed. Overall impact expected to be minor	No impact

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surface disturbance would constitute the greatest potential for adverse environmental impact, due to the potential of increased wind-erosion and loss of wildlife habitat. Each potential drill site was examined to ensure that: (1) it was located as close as possible to existing roads; (2) it was not within a wetland, 100-year flood-plain, or prime or unique farmland or rangeland; (3) it was not within a known archaeological, cultural, or historical site; and (4) site activities would not adversely impact any threatened or endangered plant or animal species, nor any wild, scenic, or recreation river.

Land surface disturbance at the typical drill site was limited to selective clearing and grading of a 0.4-hectare (1.0-acre) site, construction of approximately 300 meters (1,000 feet) of single-lane dirt road, digging, and lining of a 6- by 9- by 1.2-meter (20- by 30- by 4-foot) mud pit, and laying of a 45- by 90-meter (150- by 300-foot) compacted gravel drilling-support pad. At the conclusion of the testing, current plans call for the refilling of all mud pits, and the returning of the drill sites, as closely as practicable, to their natural state.

The major construction impact were associated with the exploratory shaft program was the selective clearing and grading of 18 hectares (46 acres) of shrub-steppe terrain. More than half the plants within this area were destroyed and all the animals ~~will be~~ displaced during construction activities. Ongoing biological monitoring continues to show no federally threatened or endangered species resident on the Exploratory Shaft Program site. The Swainson's hawk, and long-billed Curlew, however, both nest ~~on or~~ near the site. These species are both candidates for Federal Endangered or Threatened Species status (FWS, 1982). Site personnel will be instructed to avoid visiting for the purpose of observing, or otherwise entering adjacent areas inhabited by endangered or threatened species or candidate species. Since reproductive failure is a likely result of indiscriminate human disturbance to nesting sites, emphasis will be placed on limiting personnel to the site proper during critical times of the year for nesting birds.

The most significant potential for environmental effects directly related to the construction of the shafts are those resulting from digging mud pits and from accumulating drill cuttings and mined rock, called "muck," in spoil piles. The mud pit complex covers approximately 0.4 hectare (1.0 acre) with a series of shallow pits. The bottom of the pits are ~~covered~~ ~~lined~~ with clay to prevent seepage.

The approximate volume of material to be removed during Phase I of the Exploratory Shaft Program is 7,100 cubic meters (251,000 cubic feet). The volume of this material is expected to increase to approximately 14,000 cubic meters (500,000 cubic feet) on removal, due to fragmentation and loose packing in a spoil pile. The same volume of material will be removed from the Phase II shaft. In addition, up to 9,300 cubic meters (328,000 cubic feet) of fragmented basalts mined from the drifts will be added to the spoil pile. The possible mechanisms by which spoil piles can cause environmental damage are dust emissions (see Subsection 4.2.1.3.2), chemical leaching (see Subsection 4.2.1.2.1), and mechanical slip or

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collapse. A conservative mining practice will be followed in establishing the slope of the spoil pile sides, taking into consideration the changes in angle of repose that may be caused by saturation by heavy rainfall. This will preclude impacts due to landslip or collapse of the spoil pile.

With the exception of sanitary waste, which ~~will be~~ was disposed of through the onsite septic tank/drain field, all construction wastes and refuse will be collected and trucked from the site for disposal in the existing Hanford Site landfill facility. Structural materials of the installed septic tank/drain field are virtually inert, and the ~~contemplated~~ system is ~~will be very~~ small compared to similar active systems for the 200 West Area (DOE, 1982a) and deactivated systems associated with abandoned military cantonments nearby. No significant environmental effects ~~are~~ were ~~anticipated~~ noted. The presence of workmen during construction of the system ~~will~~ disturbed wildlife, however, and the digging of the drain field and tank hole ~~will~~ also disturbed plant communities.

The laying of the site waterline from the 200 West Area required the clearing of a 6.2-meter- (20-foot-) wide strip of ground 4.8 kilometers (3 miles) long. Construction of the overhead powerline caused partial disturbance to a 4.6-meter by 10.4-kilometer (15-foot by 6.5-mile) area. Natural vegetation will be allowed to reestablish itself along both rights-of-way. Cheatgrass, however, will probably invade the disturbed land, and ~~native~~ other species are not expected to recolonize the site in the near future (Cline et al., 1977).

The potential effect on the terrestrial ecosystem associated with the operational phase of the Exploratory Shaft Program will be minor compared to the potential impacts of construction. The most significant source of dust, noise, and effluent production will be the commuter vehicles used by site personnel at the beginning and end of each shift. This traffic may impact wildlife in several ways. Collisions of wildlife with vehicles is expected to occur at the same rate as any other roadway. ~~particularly with~~ Black-tailed hares, mule deer, coyote, badger, and burrowing owls are the primary animals at risk due to vehicular traffic. Travel will be restricted to major routes so that sensitive species, particularly the Swainson's hawk, will not be disturbed by passing cars or passersby stopping to observe wildlife.

In the event that the shafts are to be decommissioned, the effects of the decommissioning process would be very similar in type and magnitude to the effects of site preparation. The major exception being that wildlife disruption would be relatively minor, since the site will have been inhabited by personnel continuously until decommissioning, and most major wildlife disturbances will have already occurred.

4.2.1.3.1.2 Aquatic. The majority of site characterization activities are not conducted in the vicinity of aquatic habitat; therefore, the potential for impact is low. However, any activities carried out along the Columbia River have the potential of disturbing the Bald Eagles winter habitat. EVERY EFFORT IS MADE TO MINIMIZE THE POTENTIAL FOR SUCH IMPACTS.

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4.2.1.3.2 Air quality

Emissions of nonradiological pollutants can be expected during the field test phase and the construction, operating, and decommissioning phases of the Exploratory Shaft Program. The majority of these emissions can be attributed to the combustion of fuel oil by construction equipment (e.g., graders, bulldozers, trucks, etc.), and the generation of fugitive dust by machinery and wind erosion. Fuel combustion will produce some emissions of sulfur dioxide, nitrogen oxides, hydrocarbons, and carbon monoxide. The amount of pollutants emitted will depend on the number of vehicles operating, the quantity of fuel consumed, and any pollution abatement equipment installed on the vehicles. Dust emissions will contribute to ambient total suspended particulate concentrations, and will depend upon the surface area exposed to mechanical and (or) wind erosion, the amount of mechanical activity, ambient wind speeds, characteristics of the soil (e.g., density, particle size distributions), and any dust suppression techniques that may be used (e.g., water spraying).

Emission rates for the various operations related to the field tests and the exploratory shafts have not been explicity determined. However, some guidance can be obtained indirectly by examining the engineering aspects of these operations. For example, land surface disturbance at typical drill site was limited to selective clearing and grading of a 0.4-hectare (1.0-acre) site, construction of approximately 300 meters (1,000 feet) of single-lane dirt road, digging and lining of a 6- by 9- by 1.2-meter (20- by 30- by 4-foot) mud pit, and laying of a 45- by 90-meter (150- by 300-foot) compacted gravel drilling-support pad.

This activity, and subsequent drilling resulted in the production of some airborne dust and regulated air pollutants (particulates, sulfur oxides, carbon monoxide, hydrocarbons, photochemical oxidants, and nitrogen oxides). Dust emissions were controlled with wet-suppression techniques in compliance with General Regulation 80-7 of the Benton-Franklin-Walla Walla Counties Air Pollution Control Authority (APCA, 1980). Regulated pollutant emissions averaged less than 570 kilograms (1,250 pounds) per month per site.

Construction during the Exploratory Shaft Program ~~will~~ involves disturbance at a larger area than the typical field test site. The Exploratory Shaft Program requires selective clearing of an 18-hectare (46-acre) area, construction of mud pits, and the accumulation of material removed from the shaft in spoil piles. The mud pit complex covers approximately 0.4 hectare (1.0 acre) with a series of shallow pits, subdivided by baffles and dikes and surrounded by low berms approximately 2 meters (6.6 feet) high. The majority of mud pit impact resulted from soil disturbance and unavoidable fugitive dust emissions during construction. Appropriate suppression techniques were employed to minimize dust emissions.

Following construction of the surface support facilities and the completion of the shafts and underground facility, a few years of testing will ensue, followed by construction of a series of drifts. Once underground development is completed, the shafts and their associated

support facilities will enter a period of extensive testing. The potential environmental impacts associated with this operational phase will be minor compared to the potential impacts of construction. The most significant source of dust and effluent production will be the commuter vehicles used by site personnel at the beginning and end of each shift.

Decommissioning of the shafts is expected to generate emissions comparable to those produced during the site preparation phase.

As discussed in Subsection 3.4.3.5, present air quality at the Hanford Site is quite good, with the exception of high concentrations of airborne dust during dust storms. Fugitive dust emissions at times may be sizeable depending on operations and ambient conditions. However, the Benton-Franklin-Walla Walla Counties Air Pollution Control Authority total suspended particulate monitor at the Hanford Site monitoring station has not recorded particulate concentrations that exceed applicable air quality standards, even though major construction operations have occurred routinely on the Hanford Site. Of course, exposure of the monitor to airborne particulate depends on a number of factors, such as prevailing wind speed and direction, when fugitive dust emissions occur. A final evaluation of dust impacts will require engineering data on construction activities associated with the various operations. However, the distance from the site to the Hanford Site boundary, meteorological conditions associated with fugitive dust dispersion, deposition of material due to gravitational settling, and use of dust suppression techniques should mitigate any significant impacts. Emissions from construction equipment due to fuel combustion are expected to be minor, and ambient pollutant levels at the Hanford Site boundary should not be significantly affected.

4.2.1.3.3 Noise

The remoteness of the site from human habitation and from occupied Hanford Site facilities mitigates the effects of any high drilling-noise levels to humans. However, wildlife species nesting and residing nearby may be impacted by noise. Noise can adversely affect the productivity, density, or behavior of wildlife (Fletcher and Busnel, 1978). Drilling activities will generate noise levels that could reach 110 decibels immediately adjacent to the noise sources. Muffler systems will be used on heavy equipment during construction to minimize adverse environmental impacts. Impact on members of the general public will meet the requirements of the Noise Control Act of 1972.

4.2.1.3.4 Aesthetics

CHARACTERIZATION ACTIVITIES ON

While visible from Route 240, the aesthetic impact of the site will be minimal. Approximately 2.3 kilometers (1.4 miles) of existing gravel road will be upgraded by paving. A new gate and guard station will be added at the outside fence. The most prominent feature, the drill rig, will not be near or on a line of sight to any scenic view or outlook. The site buildings will be small and will be similar to numerous structures in the area.

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4.2.1.3.5 Archaeological, cultural, and historical resources

In 1981 and again in 1982, archaeological field surveys were conducted to intensively investigate the reference repository location. No potential archaeological resources where identified or are known to exist. These studies concluded that none of the repository undertakings will have an affect on significant cultural resources (Rice, 1984a, 1984b).

4.2.1.3.6 Radiological impacts

Drilling of the shafts may result in some mixing of the shallow unconfined ground water with the drilling mud. As the drilling mud is circulated up to the mud pit, some ground water may be brought to the surface. The tritium concentration in the unconfined aquifer at the exploratory shafts sites is less than 2 picocuries per milliliter (Wilbur et al., 1983) (the drinking water standard for tritium is 20 picocuries per milliliter), and any tritium brought to the surface by the drilling mud would be diluted even further. No major radiological impacts are anticipated due to the exploratory shafts activities.

A potential source of short-term radiological impact will be the use of radioactive tracers (see subsection 4.1.1.3.3) to determine effective porosity and dispersivity for selected basalt flows and interbeds. Tracers used for these determinations typically have radiological half-lives of several hours to several days. Therefore, no significant radiological impacts are expected from the use of tracers.

4.2.2 Socioeconomics

To some extent, the level and duration of site characterization activities and, therefore, the level of staffing required and resources consumed, will govern the socioeconomic impacts produced. In the event that subsurface data indicate that the site is unsuitable for use as a repository, and in the event no other productive uses are identified for the facilities, the shafts will be decommissioned. It is also possible that the shafts ~~eventually will~~ could be incorporated into ~~a waste disposal~~ the repository facility and eventually decommissioned as part of that facility.

4.2.2.1 Population density and distribution

A current onsite staffing forecast for the construction, operation, and completion of testing of the Exploratory Shaft Program is shown in Table 4-2.

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Table 4-2. Staffing forecast for testing of the Exploratory Shaft Program.

Year	Activity	Work force*
1	Construction and Engineering	110
2	Construction and Engineering	130
3	Operation	200
4	Operation	200
5	Operation	140
6	Completion of Testing	80

*Includes both surface and subsurface personnel.

To determine the impact of the Exploratory Shaft Program work force on the area population, the following assumptions are made:

- All 200 workers inmigrate and bring 2 dependents.
- The addition of 200 Exploratory Shaft Program workers creates 240 new jobs in the secondary sector of the economy.
- 240 people inmigrate, to fill the new secondary sector jobs, and bring 2 dependents each.

The site characterization effort could increase the Tri-Cities area population by as many as 1,300 persons, or approximately 1.5 percent. Since many of these jobs will likely be taken by unemployed workers currently in the labor force, actual impacts are expected to be less than this amount. For comparison, recent layoffs in local industry have eliminated thousands of jobs, and employment losses in the region are expected to continue through 1984 (see Section 3.6.1).

The impacts on the Tri-City area due to a 1.5 percent population increase would be negligible.

4.2.2.2 Economic conditions

Resource requirements for the Exploratory Shaft Program are presented in Table 4-3. These quantity estimates are "orders of magnitude" and are not intended to be precise.

During construction of the shafts, local suppliers and services will be purchased when they are readily available and competitively priced. Given the extent to which the local economy has developed in relation to

Table 4-3. Resources committed to the Exploratory Shaft Program.

Resources	Period					
	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
Energy:						
Gasoline, L (gal)	106,000 (28,000)	132,000 (35,000)	189,000 (50,000)	114,000 (30,000)	114,000 (30,000)	114,000 (30,000)
Diesel oil, L (gal)	33,000 (10,000)	15,000 (4,000)	15,000 (4,000)	15,000 (4,000)	15,000 (4,000)	15,000 (4,000)
Electricity, megawatt-hour	23,900	22,250	25,000	25,000	25,000	25,000
60% Dynamite, kg (lb)		14,000 (31,000)				
Material:						
Stabilized base, m^3 (ft^3)	31,000 (1,080,000)					
Concrete, m^3 (ft^3)	500 (19,000)					
Grout, m^3 (ft^3)	4,000 (143,000)					
Shotcrete, m^3 (ft^3)	300 (9,500)					
Structural steel, t (tons)	1,800 (62,000)					
Fence (chain link), m^2 (ft^2)	11,000 (118,000)					
Fence posts, each	6,000					

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large construction projects, it seems likely that a number of local firms will be able to provide materials and services. Given an estimated project program cost of greater than 100 million dollars, the economic impacts of the project could be very beneficial.

4.2.2.3 Community services

As discussed in Subsection 3.6.3, community services in the Tri-Cities area expanded with the rapidly growing population of the 1970's. With the sudden rampdown of the Washington Public Power Supply System in the early 1980's, community services were left under utilized. With the relatively small workforce required for site characterization activities, there will be no significant effects on community services.

4.2.2.4 Social conditions

The size of the expected Exploratory Shaft Program work force is so small, relative to the current population baseline, that increases in social disruption due to the Exploratory Shaft Program are ~~very~~ unlikely.

4.2.2.5 Fiscal conditions and government structure

The U.S. Department of Energy contractors on the Hanford Site pay sales and use taxes and business and occupational taxes in accordance with the requirements of the State of Washington laws. Given the small work force requirement (200 people) ~~of a projected~~ for an estimated greater than 100 million dollar project, the fiscal impacts on the local government will probably be small. ~~The likely potential for effects on government structure is insignificant.~~ ALSO, SECTION 116 OF THE NUCLEAR WASTE POLICY ACT PROVIDES THAT THE SECRETARY OF ENERGY SHALL GRANT TO EACH STATE AND UNIT OF GENERAL LOCAL GOVERNMENT, IN WHICH A SITE FOR CHARACTERIZATION IS APPROVED, AN AMOUNT EQUAL TO THE AMOUNT THE STATE OR GENERAL LOCAL GOVERNMENT WOULD RECEIVE IF THEY WERE AUTHORIZED TO TAX SITE CHARACTERIZATION ACTIVITIES, DEVELOPMENT OR OPERATION OF A REPOSITORY.

4.2.2.6 Land use, access, and surface and mineral rights

The site for the Exploratory Shaft Program is located on the Hanford Site, which is controlled by the U.S. Department of Energy. It is approximately 1.9 kilometers (1.2 miles) west of the nearest chemical processing facility. The U.S. Department of Energy has dedicated the Exploratory Shaft Program site to site characterization activities; therefore, there are no land use conflicts due to these activities. Access to the Exploratory Shaft Program site will be by a road from Route 240, which is 2.7 kilometers (1.7 miles) to the west. An automated gating system will control access to the site. Site access will not interfere with other uses or security requirements of the Hanford Site; hence, no access impacts are projected.

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As discussed in Subsection 6.2.1.1, lands designated for the reference repository location (i.e., the Exploratory Shaft Program site) have been withdrawn from all forms of appropriation under the public land laws, including the mining and mineral leasing laws. Therefore, site characterization activities will not impact surface or mineral rights.

4.2.3 Occupational safety and health

The system design description for the Exploratory Shaft Program describes the principal risks, design basis casualty events, and protective systems for the Exploratory Shaft Program (RKE/PB, 1983). The principal risks are similiar to those associated with most underground mining preparations. Design basis casualty events are those projected problems, delays, and accidents that could happen in a shaft and mine operation. Protective systems are the remedies and actions, including physical as well as administrative controls and measures, that are taken to avoid or minimize the effects of casualty events. The principal safety issues identified are: (1) localized rock fall, (2) flooding, (3) explosion, (4) fire, (5) downhole fall, (6) inoperative hoist, (7) inadequate air, (8) power failure, (9) electrical hazards, and (10) excessive noise. To minimize personnel risks due to these hazards, the requirements of DOE Order 5480.1A will be followed.

4.2.4 Alternative site characterization activities that would avoid adverse impacts

The design and performance analysis of a nuclear waste facility in geologic materials encompasses essentially the same elements as for any large underground construction project. Characteristics of the geologic setting, including geologic and hydrologic conditions (e.g., lithology, structure, water inflow, etc.) and in situ stress, are combined with knowledge of the physical and mechanical properties of the rock mass (e.g., deformability, strength, etc.) and knowledge of the function and mechanical properties of rock support systems (e.g., rock bolts, shotcrete, etc.) to configure a stable opening. This process is facilitated by the use of numerical modeling techniques and feedback from performance observations in trial and (or) production excavations. However, the presence of nuclear waste materials complicates this design and performance analysis process by introducing elevated temperatures into the geologic setting and by requiring that radionuclide migration be minimized. Additional input to the analysis in the form of rock mass thermal and thermomechanical properties is required, as well as additional observations of the stability of hydrologic performance of the heated rock mass.

These data will be obtained from several sources including the Exploratory Shaft Program. Some of the data from the Exploratory Shaft Program will be used as confirmatory or supplementary to other primary data sources. Data needs such as rock mass performance characteristics,

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hydrologic properties of a flow interior, and distribution or existence of tectonic features cannot be reliably obtained by any methods other than in situ testing. Therefore, no alternative site characterization activities would be suitable for fulfilling these data needs.

Alternatives to the proposed shaft design include alternate methods of shaft construction; varying the number of shafts; and varying the size, number, and location of underground test chambers. Some variations of the design of surface-support facilities are also possible as a function of the shaft design. The environmental effects of such variations would be minimal, relating mostly to small differences in sizing of the surface-support area and its facilities.

A somewhat more significant difference in effect would result from a change in shaft-construction methodology. The only other current method of sinking a shaft is that of drilling shot holes, blasting, and mechanically removing the fragmented overburden. (This is the principal conventional mining technique of the mineral industry.) Employing this method for the penetration of aquifers requires the use of auxiliary techniques to prevent flooding in the shaft. Depending upon the volumetric flow rates of the aquifers encountered, these techniques involve some combination of (1) shaft pumping, (2) drilling through blowout preventers near the bottom of the shaft, and injecting high-pressure grout in an annulus ahead of the advancing shaft, or (3) drilling a large number of small-diameter wells around the prospective shaft location and injecting highly chilled brine to freeze the ground water around the shaft location until the shaft can be dug and cased.

Due to the potentially high volumetric flow rates of some of the aquifers the shafts must penetrate, probably all three of these techniques would be required in conjunction with a conventional drill-and-blast shaft. Compared to the proposed support facilities for a bored shaft, the necessary brine-chilling plant would be large, costly, and energy intensive. Also, the large number of wells required to inject the brine could interfere with testing following construction.

Considering that rock characterization is the primary purpose of the Exploratory Shaft Program, conventional drill-and-blast methods, used in conjunction with aquifer freezing, would alter the subterranean environment for some distance from the shaft axis. Fracturing from the blasting process would extend into the surrounding rock, and the drilling process, to be successful, would markedly alter shaft area thermodynamics. All of these effects would reduce the credibility of data gathered from the test areas due to the perturbations caused by shaft construction. In summary, use of the drill and blast method would increase the environmental cost/benefit ratio, causing increased expenditures of resources and increased surface environmental impact to acquire a given amount of data.

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Therefore, it has been determined that the preferred alternative for sinking the exploratory shafts at the reference repository location is the blind-boring method. Environmental impacts are expected to be less than or ~~equal to~~ in the same range of impacts that would result from conventional shaft sinking techniques.

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CHAPTER 5 SUMMARY

Chapter 5 describes as required by the Nuclear Waste Policy Act the conceptual design of the repository and the potential regional effects of locating and operating a repository at the reference location. This evaluation, however, does not indicate that the reference repository location has been, or will be, selected as a final repository site. The reader should note that the design process is ongoing and will change; however, any effects of those changes on the environment are expected to be small.

The repository design description in Section 5.1 includes surface and subsurface facilities, and the process by which high-level nuclear waste and spent fuel are to be emplaced within the repository. The ~~current~~ Basalt Waste Isolation Project conceptual design includes the following phases:

- Initial development phase - construction of the surface buildings and facilities; construction of the subsurface facilities, including the shafts, shaft pillar area, a portion of the main accesses, and airways.
- Operations period - completion of repository development and emplacement of waste.
- Caretaker-retrievability - general maintenance and monitoring before backfilling (the waste is retrievable during this phase).
- Backfill phase - backfilling of all drifts (access openings) within the panel area.

The decommissioning phase (i.e., backfilling the main entries and shaft pillar; plugging and sealing the repository; and demolishing, removing, and burying the facilities) and the terminal phase are not considered in the ~~current~~ Conceptual System Design ~~Description~~. These phases will be added as the design is updated.

Section 5.2 then discusses the effects that the construction and operation of a repository could have on the physical environment (i.e., on the site geology, hydrology, and environmental setting), on transportation, and on socioeconomic conditions.

~~Briefly,~~ The drilling of shafts, and subsurface excavation at the bottom of the shafts, are not expected to significantly affect the geology of the site. Effects on surficial hydrology are expected to be minimal. Some interactions between the repository and ground water will take place, although the magnitude of the effect is uncertain at this time. ~~This section suggests some possibilities.~~

In a construction operation of this size, some environmental impacts are inevitable. Although the Hanford Site can be generally characterized as a remote area and as ~~a nonfragile physical~~ an environment of low diversity, some wildlife species may be adversely affected, particularly the Swainson's hawk. ~~No known nesting sites~~, however, ~~are found~~ on the reference repository location. ~~and~~ no threatened or endangered species have been observed. Overall, the expected environmental effects of locating a repository on the Hanford Site are not considered to be significant.

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Also covered under environmental setting are: air quality; noise; aesthetics; archaeological, cultural, and historical resources; and radiological effects. Concerning the latter, no radiological effects are expected from construction activities, and the dose to the public from an operating repository is expected to be ~~comparable~~ analogous to the low dose ~~that~~ received by the public results from fuel handling and storage operations at a typical nuclear power station. Tables 5-3 and 5-4 are presented to summarize the effects expected from construction and operation of a repository at the reference repository location.

Radiological and nonradiological effects from transportation associated with the construction and operation of a nuclear waste repository (by either rail or highway) are expected to be ~~negligible~~ minimal. Socioeconomic impacts will probably be small, ~~but positive.~~ with positive attributes outweighing any negative attributes.

Chapter 5 closes with a discussion of occupational health and safety. ~~The usual nonradiological safety and health risks can be expected from such a large construction project.~~ Radiation exposure to employees during operation should be well below all allowable limits.

The reader is referred to Table 5-A for a cross-reference matrix that indicates other sections in this document that are related to topics discussed in this chapter.

Nonradiological safety and health risks are expected to be similar to those normally resulting from a large construction project.

Table 5-A. Sections related to Chapter 5 discussions.

	Chapter 2	Chapter 3	Chapter 4	Chapter 5	Chapter 6
DESIGN REQUIREMENTS USED TO GENERATE CONCEPTUAL SYSTEM DESIGN DESCRIPTION				5.1.1	
DESCRIPTION OF EXISTING CONCEPTUAL DESIGN				5.1.2	
ONGOING ENGINEERING STUDIES				5.1.3	
WASTE PACKAGE OPTIMIZATION STUDY				5.1.4	
EXPECTED EFFECTS ON THE PHYSICAL ENVIRONMENT				5.2.1	
Geology	2.1.1	3.2	4.2.1.1	5.2.1.1	
Hydrology	2.1.3/2.1.4	3.3.1/3.3.2	4.2.1.2	5.2.1.2	6.3.3.3
Environmental Setting		3.4	4.1.2.3/4.2.1.3	5.2.1.3	
EXPECTED EFFECTS OF TRANSPORTATION		3.5		5.2.2	6.2.1.8/6.2.2.2
Radioactive Waste Shipment Bases				5.2.2.1	
Types of Nonradioactive Shipments				5.2.2.2	
Highway Transport		3.5.2		5.2.2.3	
Railroad Transport		3.5.1		5.2.2.4	
Potential Radiological Effects				5.2.2.5	
Safety				5.2.2.6	
EXPECTED EFFECTS ON SOCIOECONOMIC CONDITIONS		3.6	4.1.2.2/4.2.2	5.2.3	6.2.1.7/6.2.2.2
Population Density and Distribution		3.6.1	4.2.2.1	5.2.3.1	6.2.1.2
Economic Conditions		3.6.2	4.2.2.2	5.2.3.2	
Community Services		3.6.3	4.2.2.3	5.2.3.3	
Social Conditions		3.6.4	4.2.2.4	5.2.3.4	
Fiscal Conditions and Government Structures		3.6.5	4.2.2.5	5.2.3.5	
Land Use, Access, Surface, and Mineral Rights		3.4.1	4.2.2.6	5.2.3.6	
OCCUPATIONAL SAFETY AND HEALTH			4.2.3	5.2.4	

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Chapter 5

THE REPOSITORY AND THE REGIONAL AND LOCAL EFFECTS OF LOCATING A REPOSITORY AT THE SITE

5.1 THE REPOSITORY

The function of the repository is to isolate nuclear waste from the biosphere so that it poses no significant threat to public health and safety. The repository will be designed for a specific capacity, but the design will not preclude limited future repository expansion. The basic requirement for a repository is given in the Nuclear Waste Policy Act of 1982, which limits a storage capacity for spent fuel or its equivalent as high-level waste to 70,000 metric tons (approximately 77,000 tons) of heavy metal prior to the start-up of a second repository.

The draft mission plan (DOE, 1984b) confirms that a key Department of Energy objective is to have its first repository in operation in 1998. In order to ensure meeting this objective, a reference waste acceptance schedule has been adopted which requires a gradual build-up of receipt rates in the early years of repository operation. Consistent with these receipt rates, the U.S. Department of Energy has adopted a reference schedule which incorporates the concept of a two-phase approach to construction and operation of the repository. The most recent U.S. Department of Energy document providing formally approved design requirements is Generic Requirements for a Mined Geologic Disposal System (DOE, 1984a). This document provides the following salient requirements:

- The amount of waste emplaced in the repository shall not exceed 70,000 metric tons (approximately 77,000 tons) of heavy metal or spent fuel, or its equivalent in high-level waste until such time as a second repository is in operation.
- Although the most likely waste form is spent fuel, the design shall not preclude reprocesed wastes (commercial high-level waste). X
- Consideration is being given to including surge storage capacity equivalent to 3 months waste receipts (i.e., 100 metric tons (110 tons) equivalent for Phase I operation and up to 750 metric tons (830 tons) equivalent for Phase II operation). Such capacity would assist in minimizing the impact of scheduled or unscheduled interruptions in repository operations on the offsite transportation and waste shippers. The storage facility would be capable of storing the waste as received from offsite as well as the prepared waste packages onsite.
- In the extreme case, the repository may be required to handle some spent fuel cooled as little as 5 years with burn-ups approximating 50,000 mega-watt days per metric ton of heavy metal. (For purposes of

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(RKE/PB, 1983)

impact analyses, the 1982 Conceptual System Design Description basis was used. This design basis is for 10-year-old spent fuel with a nominal burn-up of 33,000 mega-watt days per metric ton of heavy metal.)

- The underground waste handling system will be designed to permit waste retrieval throughout the waste emplacement period and up to 50 years after the emplacement operations are initiated.

- The receipt rate during the first 5 years will increase from an initial rate of 400 metric tons (440 tons) per year to 1,800 metric tons (approximately 2,000 tons) of heavy metal per year.

- The receipt rate for the remainder of the emplacement period is 3,000 metric tons (approximately 3,300 tons) of heavy metal per year.

- It is assumed that the repository construction period for emplacing the first years waste will take approximately 7 years, although waste could be received in 4 1/2 years under the proposed two-stage construction process. It is further assumed that repository operations would last for 28 years based on a receipt rate of 3,000 metric tons (3,300 tons) of uranium per year. The U.S. Nuclear Regulatory Commission requires the U.S. Department of Energy to design the repository to allow waste retrieval at any time up to 50 years after beginning repository operation. Assuming that waste could be retrieved in approximately the same period it took to construct and operate the repository, the overall preclosure repository period would be approximately 92 years (Fig. 5-1). Table 5-1 shows potential changes to repository design and projected impacts due to a two-phase repository approach.

These requirements ~~have not yet been~~ will be incorporated in the final repository design, if the requirements are adopted.

It is anticipated some of the above generic requirements will be changed as further engineering studies and programmatic goals are finalized. The updated conceptual design, scheduled to start in 1985 and be complete in 1986, will consider the latest requirements. if the reference repository location is recommended for site characterization

5.1.1 Design requirements used for the 1982 Conceptual System Design Description

The 1982 Conceptual System Design Description (1982 Conceptual Design) (RKE/PB, 1983) discussed in this subsection is a ~~process model only~~. preliminary design which will be modified as part of the normal design process. The work on the 1982 Conceptual Design was performed in 1981 and 1982, and it was issued in 1983. The expected quantities and some of the waste forms have changed since the design requirements for the existing 1982 Conceptual Design were given. Furthermore, additional geotechnical data have been obtained. Nonetheless, the discussion of the 1982 Conceptual Design does, however, provide a basis on which to evaluate the general methodology for waste storage.

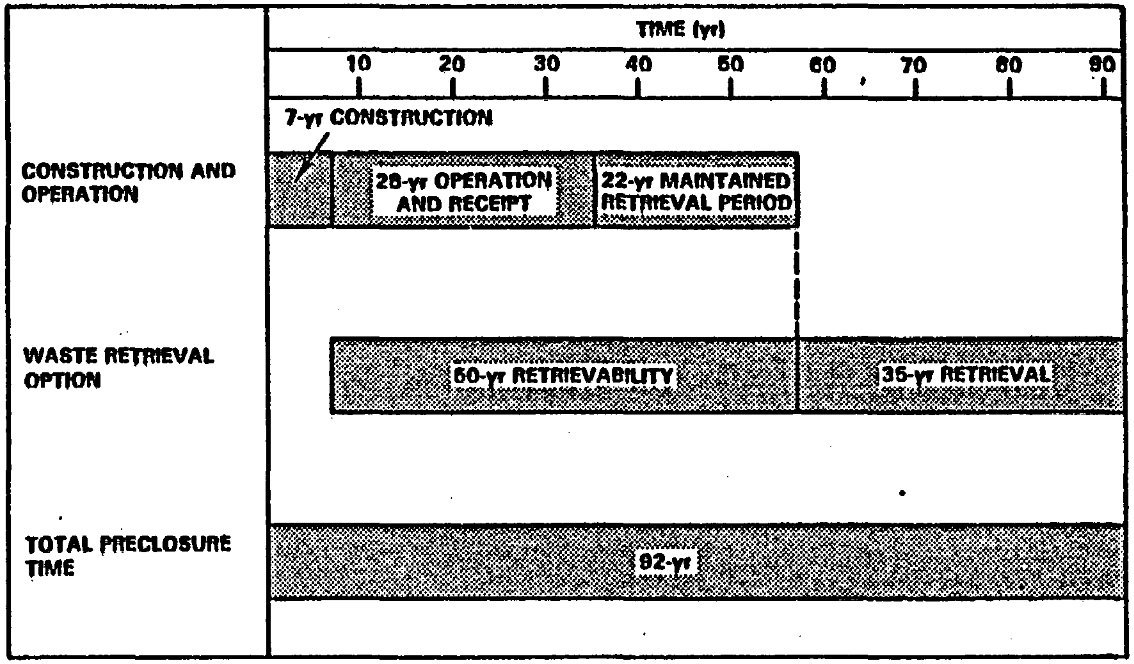

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Figure 5-1. Operating period for a two-stage repository.

Table 5-1. Change in projected impacts due to a two-phase repository.

Impact sources	Current repository concept	Two-phase repository concept	Change in projected impacts[c]
Number of shafts	Nine	Nine[a]	No change
Size of shafts	Seven 3.7-meter (12-foot) inside diameter Two 3.1-meter (10-foot) inside diameter	One 1.9-meter (6-foot) inside diameter Four 2.7-meter (8 3/4-foot) inside diameter Four 3.7-meter (12-foot) inside diameter	Minor increase in rock volume excavated from shafts — NO NET CHANGE IN ENVIRONMENTAL IMPACTS
Total waste inventory	70,000 metric tons (77,000 tons) of ~~uranium~~ HEAVY METAL	70,000 metric tons (77,000 tons) of ~~uranium~~ HEAVY METAL	No change
Preclosure period	85 years	92 years	~~Higher socioeconomic impacts during early years~~ PEAK WORK FORCE IS EARLIER AND SLIGHTLY LARGER- NO SIGNIFICANT INCREASE IN IMPACTS
Construction of waste handling facilities	One	One[b]	No change~~; if existing facility is expanded, impacts could be less~~
Surface area required	198 hectares (490 acres)	235 hectares (580 acres)	Increased POTENTIAL FOR disruption to wildlife and habitat; increased potential for dust

[a]For full-scale operation, the exploratory shafts may be deactivated.

[b]One waste handling facility is available on the Hanford Site, 25 kilometers (16 miles) from the proposed repository surface facilities location. Construction of a new waste handling facility may not be required if the existing facility is expanded.

[c] THE PROJECTED SOCIOECONOMIC AND ENVIRONMENTAL IMPACTS OF REPOSITORY CONSTRUCTION AND OPERATION AT THE HANFORD SITE ARE SMALL (SECTION 5.2). THE DIFFERENCES IDENTIFIED IN THIS TABLE ARE THE RESULT OF SMALL DIFFERENCES BETWEEN DESIGN CONCEPT ALTERNATIVES.

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Nuclear waste forms considered for the 1982 Conceptual Design (RKE/PB, 1983) are as follows:

- Containers enclosing spent fuel assemblies from commercial boiling water reactors and pressurized water reactors.
- Containers enclosing canisters of vitrified commercial high-level waste.
- Drums of solidified transuranic wastes.

Within the limits of the specifications stated in Section 5.1 above, the 1982 Conceptual Design currently available for the repository serves the following purposes:

- To allow a comparison of site characteristics, and design concepts to evaluate how the engineered structures can best fit into the natural site system.
- To orient the design process so that program generic requirements (DOE, 1984), regulatory requirements (NRC, 1981), functional, and operating needs can be evaluated against a tangible early design concept.
- To serve as a basis for developing initial order of magnitude cost and schedule estimates.
- To serve as a basis for doing initial preclosure safety analyses, which will support the updated Conceptual and Title I Designs. Such analyses will identify safety and operating risks, which can be accommodated in more detailed design efforts.

5.1.1.1 Repository phasing

The 1982 Conceptual Design (RKE/PB, 1983) covers only the initial developmental, operational, caretaker- retrievability, and backfill phases of the repository. The decommissioning and terminal phases are not considered in the 1982 Conceptual Design. These phases are described below.

- The initial development phase includes construction of the surface buildings and facilities, as well as the subsurface facilities (including the shafts, shaft pillar area, a portion of the main accesses, and airways) required for the excavation of emplacement panels for a 5-year period of waste receipts with emplacement holes for receipts for a 1-year period.
- The operations period includes the completion of repository development and the operational emplacement of waste, and is subdivided into four overlapping periods of activity.

- Mining development includes the completion of remaining waste panels, main accesses, and airways.

- General mining operations include general mining administration, maintenance, upkeep, and ground control.

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- Emplacement hole drilling depends on the waste emplacement method to be used, but it will include providing the necessary openings for the emplacement of waste containers.

- Waste emplacement period is defined as all activities associated with waste emplacement, including the emplacement of packing around the waste containers.

- The caretaker-retrievability phase includes general maintenance, and monitoring before backfilling; the waste is retrievable during this phase.

- The backfill phase includes backfilling of all drifts (access openings) within the panel area. Packing around the waste in the emplacement opening would be installed during this period if it was not done during the waste emplacement period.

- The decommissioning phase ~~was not considered in the 1982 Conceptual Design~~ but will be added as the design is updated. It includes backfilling the main entries and shaft pillar. The repository is then sealed, and surface facilities ~~demolished~~ removed ~~and (or) buried~~.

- The terminal phase follows decommissioning and was not considered in the 1982 Conceptual Design, but will also be added as the design is updated. It is anticipated that placement of permanent markers would take place during this phase.

5.1.1.2 Projected work force and major material commitments

The approximate manpower requirements given in the 1982 Conceptual Design (RKE/PB, 1983), based on an expected capacity of 47,400 metric tons (approximately 52,200 tons) of heavy metal, are as follows:

People (approximate)

	Minimum	Maximum	Average
Initial development phase	200	1,100	650
Operations period	500	900	700
Caretaker-retrievability phase	--	--	110
Backfill phase	--	--	200

The projected, major material requirements are as follows:

- Structural steel--25,082 metric tons (27,600 tons).

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- Rebar--11,115 metric tons (12,248 tons).
- Rail track--14,512 meters (47,600 feet).
- Concrete (includes shotcrete)--120,165 cubic meters (157,160 cubic yards).

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5.1.2 Description of 1982 Conceptual Design

The 1982 Conceptual Design (RKE/PB, 1983) predates the adoption of the 70,000 metric ton (77,000 ton) design capacity; it is based on an ultimate capacity to dispose of spent fuel and commercial high-level waste equivalent to a total of 47,400 metric tons (52,200 tons) heavy metal. Design of the subsurface disposal facilities is based on a 50/50 split between spent fuel and commercial high-level waste on the basis of weight. Spent fuel quantities are based on the ratio of 59 percent pressurized water reactor and 41 percent boiling water reactor by weight. The spent fuel is assumed to have been removed from the reactor core a minimum of 10 years prior to shipment to the repository or conversion to commercial high-level waste. Disposal capacity is also provided for 32,000 drums of low-level transuranic waste received from offsite, in addition to any inplant-generated wastes. The design receipt rate is 1,072 containers of spent fuel per year or the metric ton heavy metal equivalent of commercial high-level waste, or any combination thereof. The design provides the option of waste retrieval for up to 50 years after the initial waste emplacement.

The 1982 Conceptual Design (RKE/PB, 1983) was started in 1981, completed in 1982, and issued in early 1983. As discussed above, it is expected that the 1982 Conceptual Design will be updated to reflect new disposal quantities and design data in 1985/1986. However, the 1982 Conceptual Design does include descriptions of generic design concepts to meet general design requirement for any repository. Therefore, the following discussion is this subsection on surface facilities, waste handling, ventilation, monitoring systems, radioactive waste control and disposal, nonradioactive waste control and disposal, and subsurface facilities is provided as a generic rather than a specific concepts model. It is not anticipated these generic concepts will change significantly during the updating of the conceptual design. The current design concept is given in Subsection 5.1.3.2, and deals primarily with the underground (subsurface) layout of the repository.

An artist's rendering of the underground layout based on the 1982 Conceptual Design is shown in Figure 5-2. The primary components of the repository are the surface facilities, the shafts, and the repository horizon consisting of the shaft pillar, waste storage panels, and ventilation drifts.

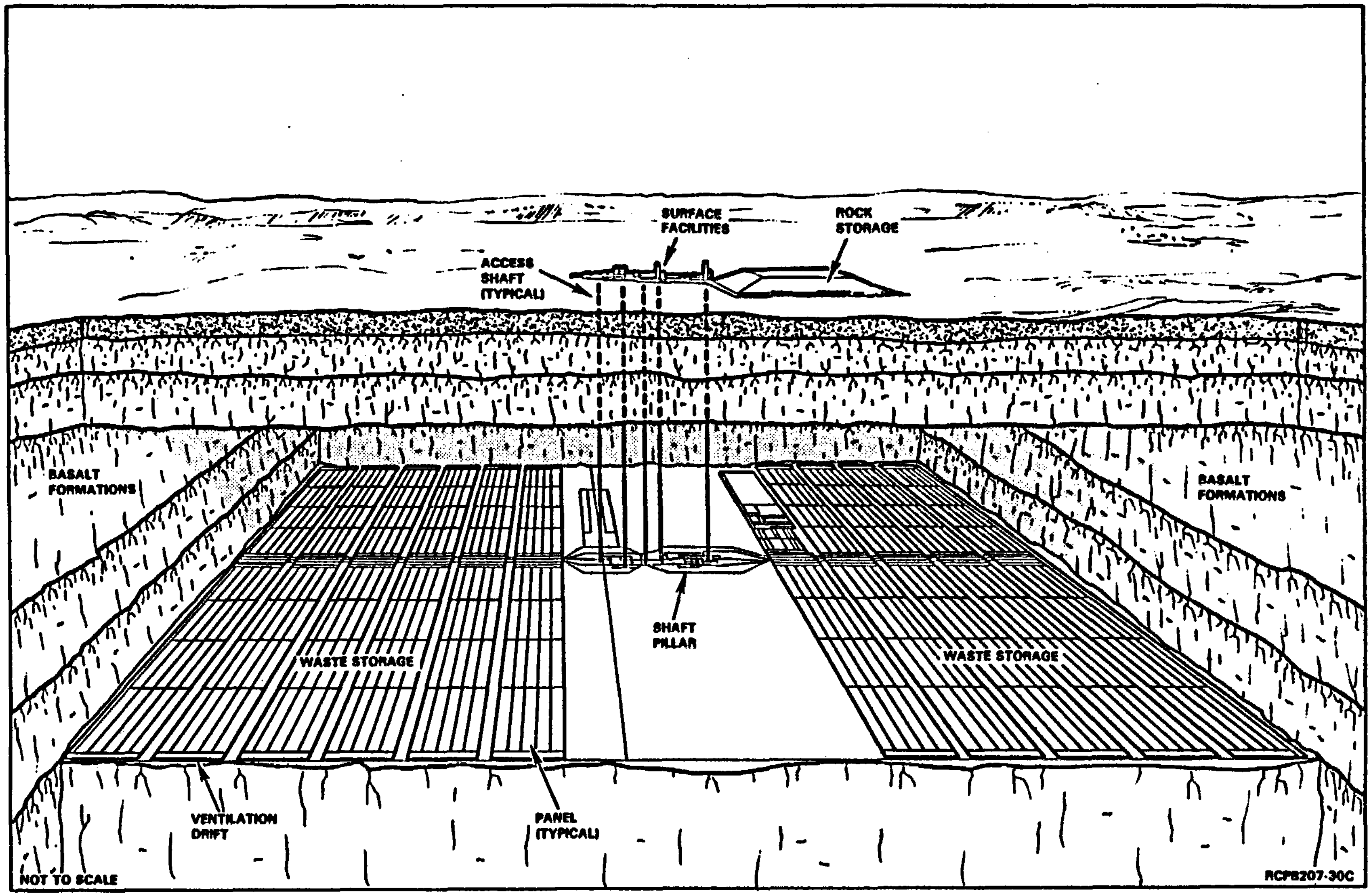

Figure 5-2. Conceptual design of the proposed reference repository.

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According to the 1982 Conceptual Design, the sequential emplacement process (see Fig. 5-29) for spent fuel, or commercial high-level waste is as follows:

1. Arrives at repository by truck or rail.

2. Moves to the primary hot cell for inspection, preparation, and containerization (Fig. 5-3).

3. Containers are loaded into the waste transport shaft cage.

4. Containers are transported down the shaft to the shaft pillar area (Fig. 5-4).

5. Containers are transported from the shaft pillar area via the main entries (see Fig. 5-4) to the emplacement room by the waste transporter. Once the waste transporter is in the emplacement room, the container is loaded in a 0.8-meter- (30-inch-) diameter by 61-meter- (200-foot-) long emplacement hole (Fig. 5-5).

6. Containers are left in the emplacement hole until retrieval (the reverse process of emplacement) or until the retrieval period is over.

Following the retrieval period, the emplacement holes are packed and the underground openings are backfilled with an engineered fill material of low permeability (presently composed of bentonite clay and crushed basalt). Figure 5-6 shows emplacement hole backfilling and plugging equipment. This process is generic for any repository, and the following discussion in this subsection provides the generic design basis for this sequential emplacement process.

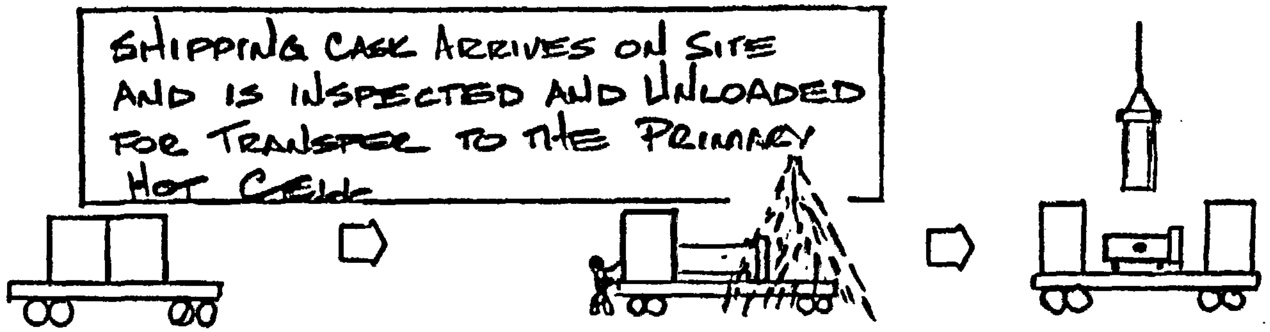
5.1.2.1 Surface facilities - 1982 Conceptual Design

Most of the 1982 Conceptual Design (RKE/PB, 1983) surface facilities will be located in the central process area (Fig. 5-7). This area includes all shaft access to the underground and waste handling/monitoring facilities.

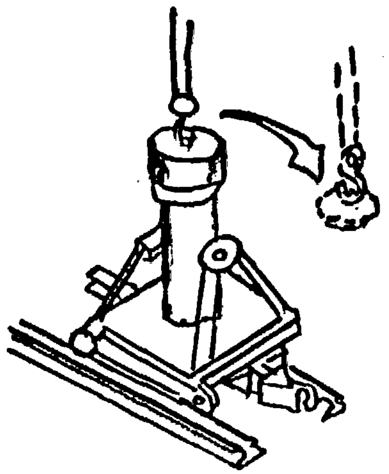
The 1982 Conceptual Design repository will consist of an 81-hectare (200-acre) control process area located over and contained within the surface projection of the 550 hectare (1,334 acre) subsurface facility. Surrounding the projection of the subsurface facility to the surface is a 2-kilometer (1.2-mile) control zone. The total area enclosed by the outside boundary of the control zone is approximately 4,126 hectares (10,195 acres). The entire control process area will be surrounded by a double security fence.

For the purposes of this assessment, only those facilities that affect the handling or monitoring of nuclear waste or other potential pollutants (e.g., diesel oil) are discussed. The location, size, capacity, and other requirements of the facilities may change somewhat in future design activities. Generically however, the repository will need water, power, waste handling, and other facilities.

SHIPPING CASK ARRIVES ON SITE AND IS INSPECTED AND UNLOADED FOR TRANSFER TO THE PRIMARY HOT CELL



CASK MOVES INTO THE PRIMARY HOT CELL IN THE WASTE HANDLING BUILDING



WASTE IS REMOVED FROM THE CASK AND CONTAINERIZED

CONTAINER PLACED IN TRANSPORT CASK AND LOADED INTO WASTE TRANSFER SHAFT

WASTE IS TRANSPORTED DOWN THE SHAFT AND PREPARED FOR TRANSFER TO THE EMPLACEMENT HOLE VIA TRANSPORTER IN THE SHAFT PILLAR AREA

WASTE IS PLACED IN EMPLACEMENT HOLE

FIGURE 5-2a
GENERALIZED EMPLACEMENT PROCESS

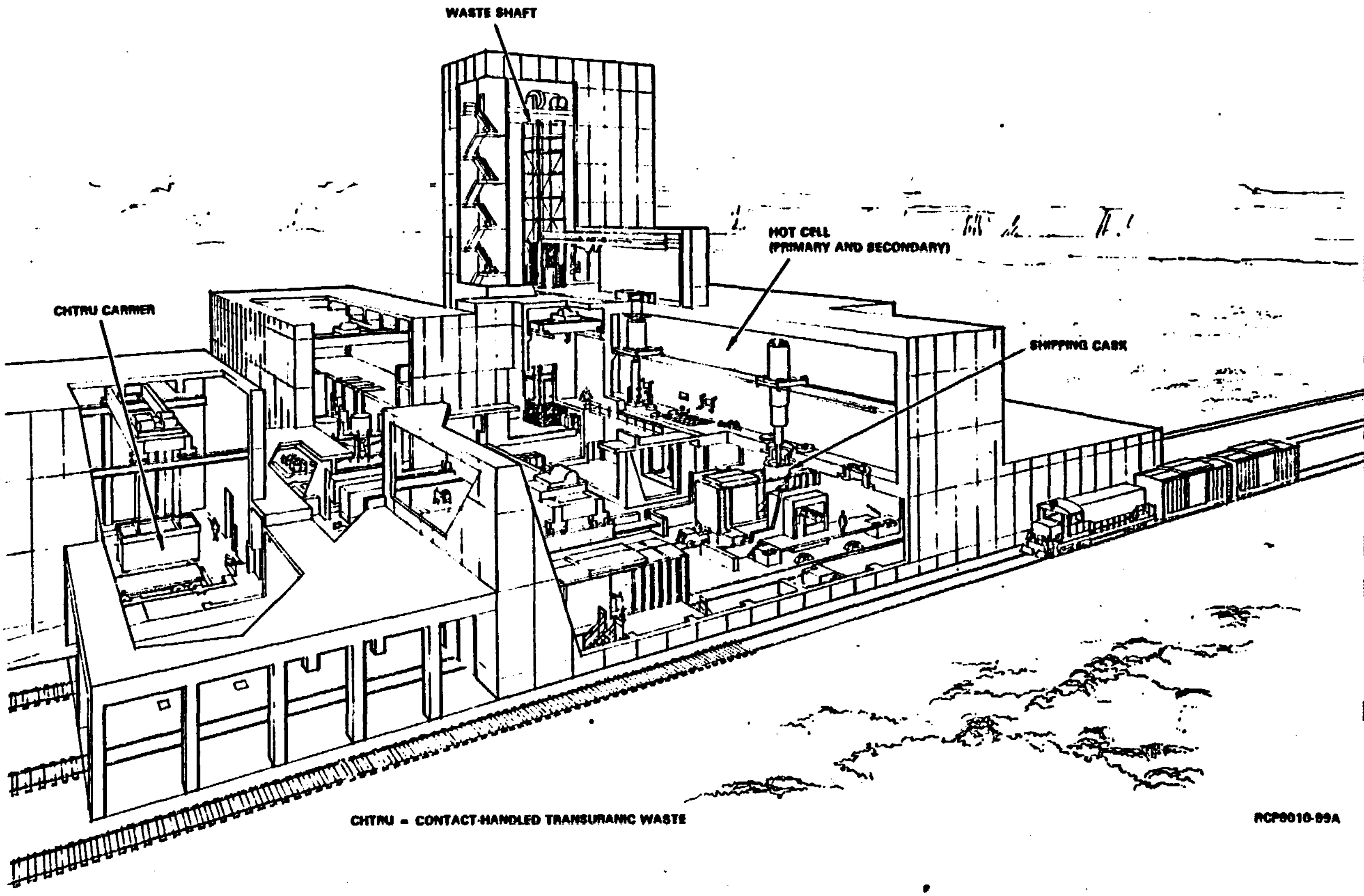


Figure 5-3. Waste handling building (taken from RKE/PB, 1983).

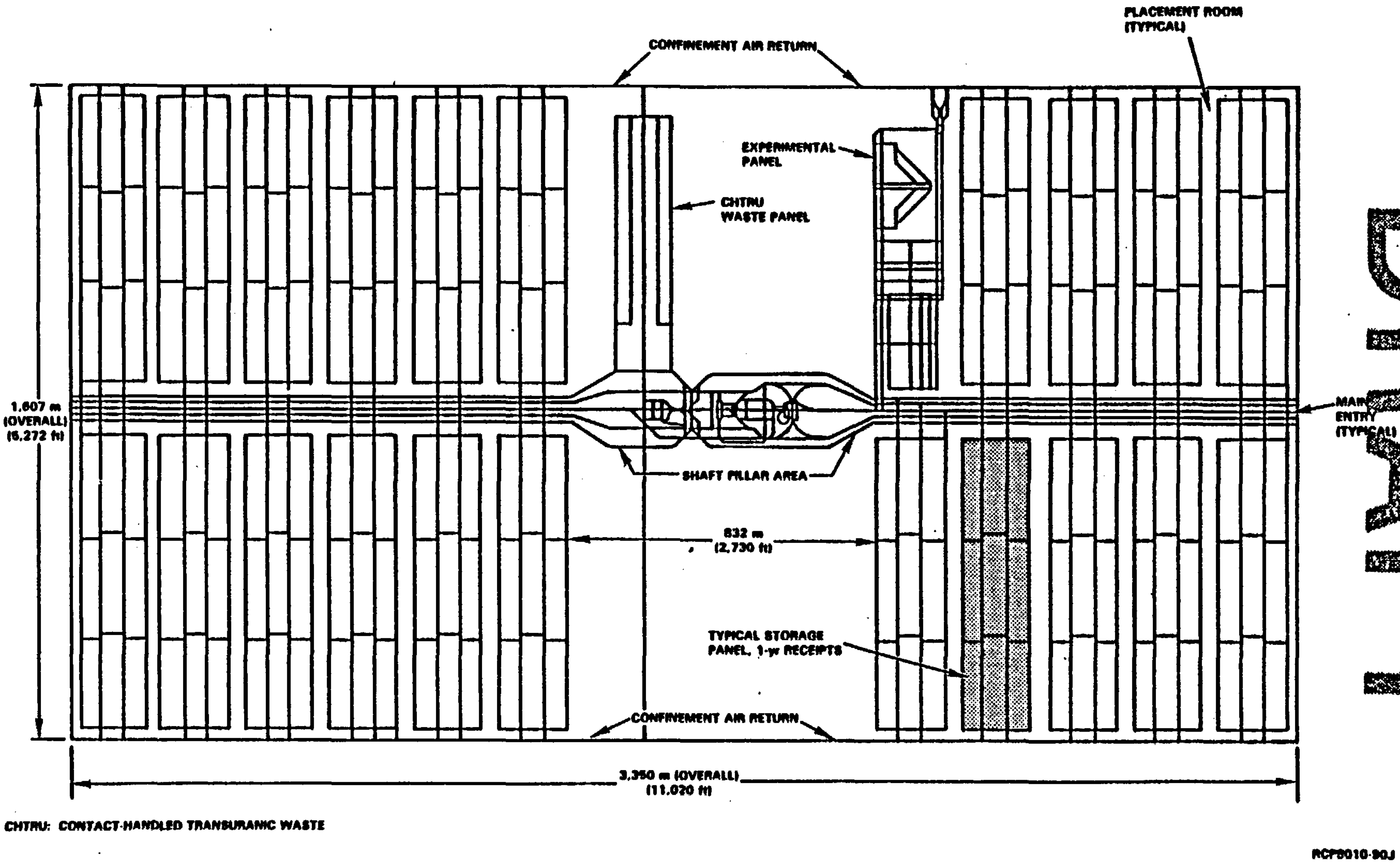


Figure 5-4. Underground facilities layout (taken from RKE/PB, 1983).

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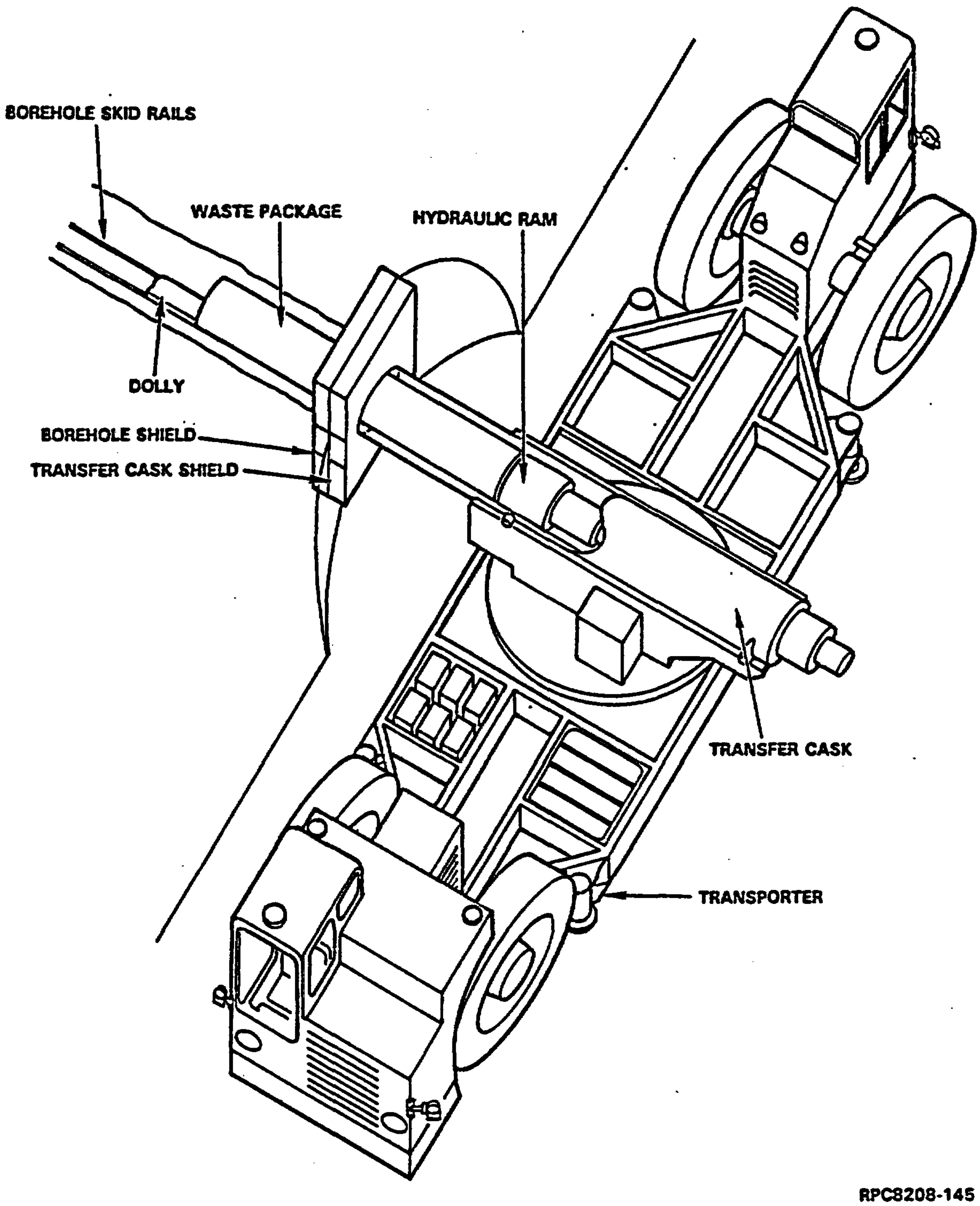

Figure 5-5. Transporter in emplacement operation (taken from RKE/PB, 1983).

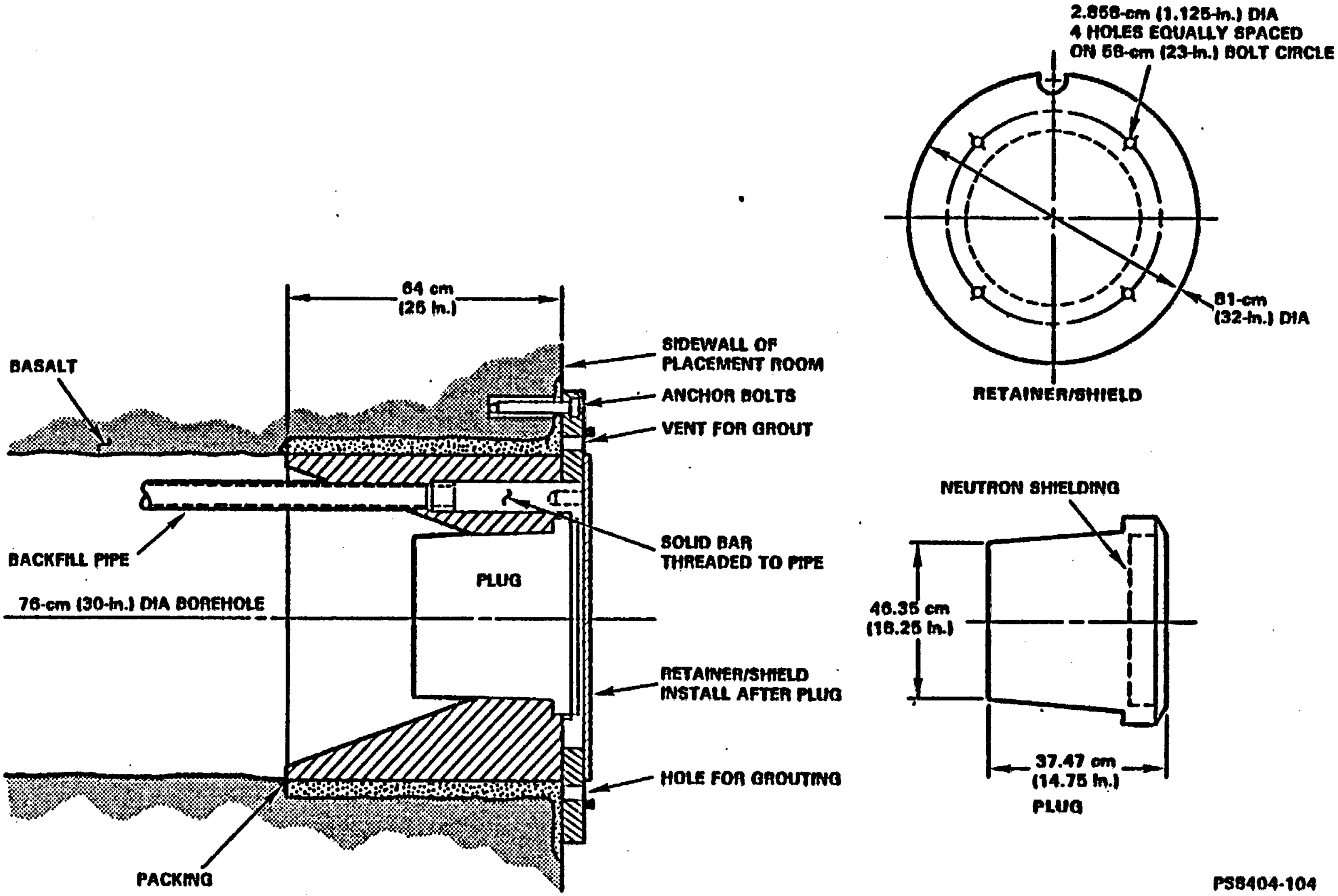

Figure 5-6. Placement hole backfilling and plugging equipment (taken from RKE/PB, 1983).

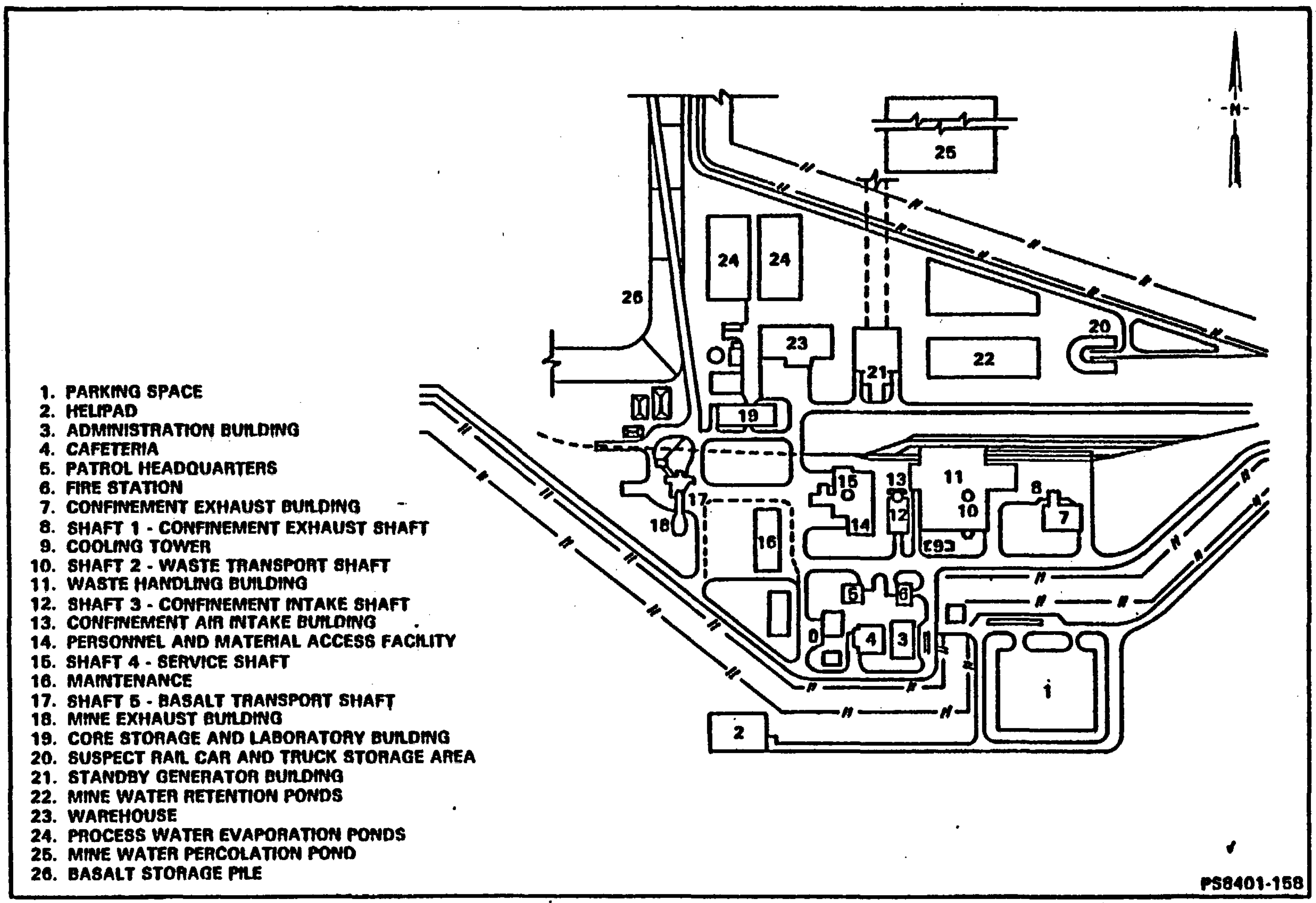

Figure 5-7. Surface facilities plan—central process area.

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The design was based on the underground repository facilities being placed in the Umtanum flow in the reference repository location. Current geotechnical data suggests that the Cohassett flow may provide a more favorable location (see Section 2.2). The flow location has minimal impact on the surface facilities.

Raw water will be supplied from the Columbia River to the reference repository water treatment plant through a pipeline approximately 12 kilometers (7.4 miles) long. Two new pumps will be installed at the existing river pump station.

Buried storage tanks for petroleum products are provided. Service station-type transfer pumps are provided at each tank.

Two new 138 kilovolt transmission lines, routed over separate parallel rights-of-way will connect the repository to the Hanford Site power system. A new telephone line will connect the surface facilities at the repository to the Hanford Site telephone network.

5.1.2.1.1 Waste handling - 1982 Conceptual Design

In the 1982 Conceptual Design (RKE/PB, 1983), the rail or truck shipping cask for spent fuel or commercial high-level waste will be held in a near-horizontal position during shipment. In the receiving area beneath the hot cell of the waste handling building, the cask will be tilted to the vertical position for unloading and mated with a shielding collar lowered from the hot cell. The rail car will be leveled and immobilized on jacks. After removal of the shielding plugs for the hot cell and the cask, each container will be raised into the primary hot cell, checked at the automated smear station, and placed temporarily in the surge storage pit (which has a capacity of 20 containers). From there, it will be transferred to one of two process tanks, which will be equipped for (1) welding the cover on a carbon-steel container for commercial high-level waste; (2) rewelding a faulty weld for either commercial high-level waste overpack or spent fuel container; (3) over-packing to bring a received canister into compliance; (4) inspecting spent fuel or commercial high-level waste container weldments; (5) decontaminating, if necessary; and (6) transferring waste containers to the secondary hot cell. for surface contaminate

The hot cells are equipped for rewelding a faulty weld, and for inspection of weldments by both the leak test (helium mass spectrometer method) and a structural integrity test (ultrasonic). The decontamination of containers is accomplished in the hot cell process tanks by the use of high pressure decontamination liquid.

The hot cell design will make contact maintenance feasible by providing shielding for surge storage positions and the process tanks. The hot cell will be divided into a primary and a secondary cell. Waste containers will be transferred from the possibly contaminated primary hot cell, through a decontamination station, to the secondary (and cleaner) hot cell. The secondary hot cell will be maintained clean to assure that the transfer cask remains clean and that clean containers are emplaced.

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The completed, clean container will be lowered from the secondary hot cell into a shielded transfer cask, which will reduce radiation levels to 1 millirem per hour at 1 meter (3 feet) from the cask surface. This

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transfer cask will shield the waste container during its journey from the hot cell to the waste transport shaft cage, down the shaft, and out to final emplacement.

5.1.2.1.2 Ventilation - 1982 Conceptual Design

Ventilation for the 1982 Conceptual Design (RKE/PB, 1983) repository will consist of separate systems for waste handling and development areas. The ventilation system for both the surface and underground facilities is discussed under this section as the bulk of the system control will be located at the surface. The ventilation system may be affected by a change in the repository horizon as the rock temperature increases with depth.

The confinement ventilation system will use multiple fans and air filtering systems to provide redundancy. A radiation monitoring system will extend throughout the subsurface confinement airways and in the exhaust shaft to permit detection of unacceptable levels of airborne radioactive or toxic materials in sufficient time to switch the airflow to high efficiency particulate air filters in the confinement exhaust building.

High efficiency particulate air filtration will only be activated when the instrumentation system detects radioactivity in the ventilation circuit. Normal operation airflows will bypass the filters. All exhaust shafts that handle potentially contaminated air will be equipped with high efficiency particulate air filters. The layout of the ventilation circuit within the air system will be such that ventilation air flows from zones of lesser contamination potential to zones of higher contamination potential.

The system will be sized for emplacement and occasional retrieval during the operating phase, for retrieval or maintenance during the caretaker phase, and for backfill.

The intake (fresh) ventilation air will be cooled in the repository. A cooling tower on the surface may be necessary to dissipate heat to the atmosphere. The size of the cooling plant and its associated cooling tower has not yet been determined.

5.1.2.1.3 Monitoring systems - 1982 Conceptual Design

The 1982 Conceptual Design (RKE/PB, 1983) radiation monitoring system will be furnished for the surface buildings, the central process area and perimeter, and the waste disposal facilities. A general description of the radiation monitoring system functions, design requirements, and conceptual design is given below, followed by special descriptions of the system components in various facilities.

The functions of the radiation monitoring system will be to ensure the safety of the public and repository personnel under both normal and abnormal conditions, and to aid operating personnel in controlling the piping and transportation systems that handle radioactive materials. To

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do so, this system will be designed to monitor overall credible ranges and to record at a central location all normal and abnormal conditions of radioactivity that are important to public and repository safety and to systems control. Radiation monitoring instrumentation will be the type normally used in nuclear facilities. Electronic portions will be solid-state, plug-in board devices. All instrumentation will be required to conform to applicable quality assurance requirements.

The overall instrumentation system will include subsidiary systems for radiation monitoring, process systems, mined openings, environmental recording, power distribution, and fire alarms. Radiation instrumentation will be furnished in the categories of radiation sensing, personnel examination, and process control.

Area monitors for gamma radiation will be located around onsite buildings in numbers and at locations depending on building size, activity taking place, and potential for contamination in the area. The monitors designed for outdoor use will be equipped with conventional circuitry, alarm lights, audible warning devices, and meters to indicate the amount of gamma radiation present in the area.

Radon gas monitors will be located in protected areas above and below ground to continuously measure and record levels of radon gas.

Fluid samplers for radioactivity will be located on effluent lines and on storm drains downstream from the repository location to continuously monitor for any radioactive contamination in storm runoff water. The stream flow rate will also be monitored. These effluent lines will be monitored and alarmed at the central control console. The central console will be designed to also accept input from offsite radiation instrumentation, which will not be a part of the reference repository design.

Perimeter monitors will be placed around the boundary of the central process area, with the heaviest concentration of these on the south-eastern, or downwind, repository border. Three types of monitors are provided: (1) area gamma; (2) beta-gamma, fixed-filter particulate; and (3) ion-chamber dosimeter. The first two will report to the central console; local alarms will be provided in areas of normal personnel occupancy to allow personnel movement from possible areas of contamination. The ion-chamber dosimeters will be read periodically by health physics personnel for record purposes.

Area, air particulate, and radon monitors will be placed in the repository horizon. The radon gas monitors will be backed up by periodic grab samples for laboratory analysis and by working-level determinations. Subsurface drainage water will be monitored at the surface by off-line sampling.

A continuous air monitor will be installed at the exhaust air inlet above the shaft station at the bottom of the confinement exhaust shaft. If this monitor detects radiation in the air stream, it will automatically activate the diversion of exhaust air through the high efficiency

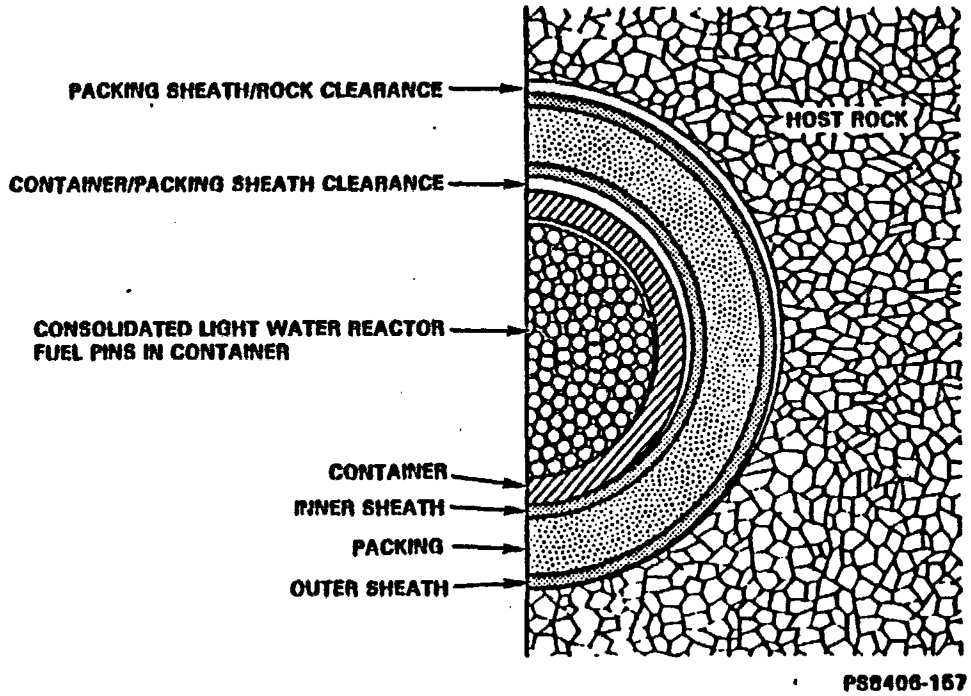

Figure 5-8(a). Typical cross-section of waste package consolidated light water reactor fuel pins.

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particulate air filters at the surface. A similar, continuous air monitor will sample the exhaust air at the confinement air exhaust stack, which will continuously monitor the air exhausted to the environment.

Area monitors and continuous air monitors will be located to provide complete coverage for areas subject to contamination. Gas monitors are provided at the service and operating galleries and the maintenance shop. Sampling connections will be provided on all radioactive gas piping at suitable locations. Criticality monitors will be placed at the hot cell and the transfer cask canyon. Portal monitors will be located at all air locks. Hand and foot monitors will be provided at the change rooms. Portable survey instruments will be located at the health physics office and at change rooms. Area monitors, portable monitors, and portable survey instruments will be located in all other buildings on an as-required basis, depending on the likelihood of contamination.

In-line and off-line radiation monitors associated with the process piping system will be set to alarm if the radioactivity in a system exceeds a preset level. Off-line monitors will be used (1) where temperatures, pressures, or flow rates exceed the operating limits of in-line devices; (2) where the obstruction caused by the in-line monitor would result in significantly reduced flow; and (3) where pipe sizes are so large that shielding the pipe section containing the monitor is impractical.

The operation of specially designed truck and rail monitors at the gates into the site will be similar in principle to that of personnel portal monitors. They will be used for detecting incoming trucks and rail cars emitting gamma radiation above acceptable limits. Such vehicles would be routed to the suspect rail car and truck holding area for determination of proper disposition. Upon leaving the surface facilities of the proposed repository, the portal monitors will also be utilized to detect any loose contamination to ensure that radioactive materials do not leave the area.

5.1.2.1.4 Radi~~ation~~oactive waste control and disposal - 1982 Conceptual Design

A system to collect, process, and immobilize the solid radioactive waste generated by repository operations is provided by the 1982 Conceptual Design (RKE/PB, 1983). This system will provide for the following:

- Collection of solid radioactive waste.
- Radioactive waste shredding and size reduction.
- Incineration that results in a cooled radioactive ash product suitable for immobilization.
- Immobilization in 208-liter (55-gallon) drums.
- Prevention of uncontrolled escape of radioactive gases.
- Removal, bagging, and disposal of noncombustible materials.
- Remote operation behind shield walls for protection of system operators.

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The system will consist of incinerator and immobilization subsystems. Both subsystems of the solid radioactive waste system will be located in the radioactive waste treatment area of the waste handling building.

The function of the liquid radioactive waste system will be to collect, treat, and dispose of liquid radioactive wastes generated by repository operations. The liquid radioactive waste sources will ~~be~~ include shower water, reverse osmosis concentrate, ion-exchange resin sluicing water, cask flushing and venting water, radiation monitoring system drains, floor drains and sumps at the waste handling building, hot cell process tank drain, floor drains from the health physics laboratory in the industrial safety center, liquid radioactive waste vault sump, and floor drains from the confinement exhaust ventilation building. The liquid radioactive waste treatment system will be sized for a flow rate of 38 liters (10 gallons) per minute.

The gaseous radioactive waste system will collect and ~~purify~~ process gaseous radioactive wastes from gas-emitting sources at the surface facilities. This ~~The purification~~ process will remove radioactive liquid droplets and particles. The ~~purified~~ gas will then be discharged to the primary confinement ventilation system of the waste handling building, which in turn will exhaust waste air and gases through high efficiency particulate air filters to the exhaust stack. Two ~~purification~~ process trains (one on 100 percent standby) will be provided.

¶ → The on-site generated wastes discussed in this subsection will be disposed of in the repository.

5.1.2.1.5 Nonradioactive waste control and disposal - 1982 Conceptual Design

Systems are provided for disposal of nonradioactive repository-generated waste, which will include solid waste, process liquids, subsurface repository drainage water, and sanitary sewage by the 1982 Conceptual Design (RKE/PB, 1983).

Inert solid waste will be collected and sorted, if economically justifiable, to recover reusable materials. The residue will be compacted, bagged, or baled, depending on waste type; hauled to the disposal area; and buried. Estimated quantities are, for general facilities, 1.4 to 2.8 kilograms (3 to 6 pounds) per person per day, and for the warehouse, 0.8 cubic meter (1 cubic yard) per day, compacted volume.

Solid wastes will be generated in offices, restrooms, laboratory rooms, training facilities, ~~cafeteria~~ lunch room, warehouse, equipment and machinery repair facilities, maintenance areas, the repository horizon, and other locations. Used, nonradioactive air filter units from the various ventilation systems will be considered solid wastes.

The maintenance building, administration building, and ~~cafeteria~~ lunch room will contribute the highest per capita amount of solid waste, estimated for this project at 2.7 kilograms (6 pounds) per person per day. All other

Hazardous wastes under the Resource Conservation and Recovery Act will be disposed of in accordance with U.S. Environmental Protection Agency and State of Washington requirements. Such wastes could include solvents, empty chemical containers, and unused decontamination solutions.

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buildings except the warehouse are assumed to generate solid waste at half that rate. The warehouse waste production is assumed on a volume basis, not a per capita basis.

Compactors will be located in the waste handling building, personnel and material access facility, maintenance building, administration

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building, ~~cafeteria,~~ lunchroom industrial safety center, security building, and warehouse. Wastes and used air filter units will be brought from the remaining buildings to the nearest compactor. One operator at each location will compact wastes into packages, either in plastic bags or wire-tied bales, depending on the type of waste. Filter units and warehousing wastes are estimated to be compactible to one-third volume.

The nonradioactive process liquids disposal system will dispose of laboratory wastes, cooling tower blowdown, and washdown wastes from the maintenance shop and warehouse. The sum of these waste streams is estimated to average 15 liters (4 gallons) per minute over a 24-hour day. This low amount of average waste flow will be made possible by side stream treatment of the cooling tower circulating water, a method that reduces cooling tower blowdown to nearly zero.

Two adjacent evaporation ponds will be provided south of the warehouse building for disposal of these liquid process wastes. One pond will undergo sludge removal while the other is in operation. Removed sludge will be hauled to an existing Hanford Site sludge disposal area. The warehouse washdown waste material will drain by gravity pipeline to the ponds, while the maintenance building washdown and cooling tower blowdown wastes will be collected in sumps, then pumped to the ponds; flow recorders will be placed in both lines. The laboratory wastes from the industrial safety building and the core storage and laboratory building will be treated first in a neutralization pit filled with crushed limestone, then pumped to the ponds.

The subsurface water will be collected in initial settling sumps for removal of large solids before it is routed to the dewatering pumps. The subsurface water pumping and disposal system will collect normal and abnormal subsurface drainage water, pump it to the surface, and dispose of it in surface disposal facilities. Normal water accumulation will consist of drilling water; in-leakage of ground water to shafts, entries, and rooms; and condensation in shafts. Abnormal water accumulation would be expected should excavation intersect a geologic anomaly (e.g., fracture) connected to aquifers.

In the surface disposal facilities the subsurface water will be tested for radioactivity and disposed of by ground percolation if the water is not contaminated. Retention and deionization will be provided for radioactive water before release to percolation ponds. The surface disposal system for subsurface water will be completely separate from the surface liquid radioactive waste treatment system.

The subsurface water will be discharged to one of two lined retention ponds on the surface at the south side of the central process area. Flow measuring devices will be provided on the discharge lines, and provisions will be made for vadose zone and ground-water monitoring. The discharge lines to the pond will be continuously sampled for radioactivity. If none is found, the retention pond will be drained by gravity to ultimate disposal through a percolation pond. If radioactivity is present, the retention pond will not be drained and a portable deionizer will be used to remove radioactivity from the pond water. The deionized water then will be

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discharged to the percolation pond and the resin beads will be disposed of in the radioactive waste incinerator. ~~in the waste handling building.~~

The sanitary sewage system will collect sanitary sewage from the repository buildings, transfer the sewage to the treatment plant, treat the sewage, and dispose of the treatment plant effluent. The system will conform to the requirements of all applicable U.S. Department of Energy, Rockwell Hanford Operations, local, and State of Washington regulations. The system will also provide for the sanitary sewage of the total repository staffing at the rate of 170 liters (45 gallons) per person per day, plus a 25 percent factor for future expansion. Sewer piping will be designed for self-cleaning velocities at two-thirds full capacity. Treatment will provide at least 95 percent reduction in the biological oxygen demand. Liquid effluent will be disposed of at the repository location by chlorination and surface percolation. Sludge will be hauled offsite to an existing Hanford Site sludge disposal area.

The system configuration will include gravity sewers to a lift station, a force main to an extended aeration package treatment plant, sludge drying beds, and a pipe to surface drainage for liquid effluent disposal. Septic tanks and tile drain fields will be provided at remote buildings.

5.1.2.2 Subsurface facilities - 1982 Conceptual Design

The principal components of the 1982 Conceptual Design (RKE/PB, 1983) subsurface facilities are the shaft pillar area, the shafts, and the underground drifts.

The shaft pillar area will provide a minimum number of openings for access, ventilation, and travel and to accommodate services and equipment for supervisory administration, mining and survey control, first aid, safety and fire prevention, warehouse, subsurface repository maintenance, subsurface dewatering, distribution of electric power and other utilities, waste transfer, ventilation distribution, subsurface refrigeration station, equipment decontamination, underground explosives storage magazine, battery charging, crushing, basalt surge bin and skip-loading facilities, rail haulage system, and sump pumping stations. The shaft pillar area is best described in terms of its functional areas and its major accessways--the five access shafts.

5.1.2.2.1 Basalt transfer shaft - 1982 Conceptual Design

The 1982 Conceptual Design (RKE/PB, 1983) basalt handling system will include surge storage at the basalt transfer shaft for broken basalt coming from mining operations. The basalt transfer shaft will serve as a ventilation exhaust shaft for the development ventilation system.

5.1.2.2.2 Service shaft - 1982 Conceptual Design

The 1982 Conceptual Design (RKE/PB, 1983) service shaft will provide access to the subsurface facilities for personnel, material, and mine intake air. Facilities around the shaft

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include subsurface repository control, subsurface maintenance, stores, a cooling station, and switchgear. Mining development fans maintain a positive pressure with respect to the confinement ventilation system.

5.1.2.2.3 Confinement air intake shaft - 1982 Conceptual Design

The 1982 Conceptual Design (RKE/PB, 1983) confinement air intake system will bring fresh air from the surface. The shaft pillar area will be the starting point for the direction of airflow into the rooms and panels where waste will be disposed. Fans and air locks will allow movement of the transporter to and from the confinement air intake and the waste transport shafts. The shaft pillar area will provide a smooth transition of air inflow to the main airways.

5.1.2.2.4 Waste transport shaft - 1982 Conceptual Design

The 1982 Conceptual Design (RKE/PB, 1983) waste transport shaft station will provide entry for the spent fuel/commercial high-level waste transfer casks and contact-handled transuranic-waste pallets to the subsurface facilities. The station will be isolated by air lock doors and regulators to control airflow into the shaft pillar. A barrier to unauthorized personnel entry during waste handling will be provided. The waste transport station area will contain a shop for transporter maintenance, an area for decontamination, and a battery-charging station.

5.1.2.2.5 Confinement exhaust shaft - 1982 Conceptual Design

The 1982 Conceptual Design (RKE/PB, 1983) confinement exhaust shaft station will be at the west end of the shaft pillar. It will be 91 meters (300 feet) from the waste transport shaft station and will be isolated by airflow regulators and air lock doors. Most confinement air returned to the atmosphere will pass through the confinement exhaust shaft. A small amount of air will be drawn up the waste transport shaft and exhausted through the waste handling building to prevent accidental release of radioactive material back to the shaft station.

5.1.2.2.6 Main drift (access) functions - 1982 Conceptual Design

The 1982 Conceptual Design (RKE/PB, 1983) main accesses to emplacement panels will be the airways and travel routes between the shafts and the waste panel areas. The main accesses will serve as:

- Accessways connecting the waste shaft station to the waste emplacement locations.
- Haulageways and accessways for bulk materials, mining equipment, supplies, and personnel.
- Accessways for utilities, dewatering lines, and maintenance facilities.
- Airways for mining and confinement air systems.

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Accessways will be arched, roof-bolted, and shotcreted, as necessary, for stability and safety. There will be a drainage ditch on one side. The accessways will be driven slightly upgrade to allow drainage toward the shafts.

Pressure differentials to assure the proper control of air leakage from the work area ventilation system to the confinement ventilation will be monitored by instrumentation. Repairs will be made immediately in case of damage to, or improper leakage in, the stoppings or engineered barriers separating the mine development air and confinement air systems.

5.1.2.2.7 Waste emplacement panels - 1982 Conceptual Design

The 1982 Conceptual Design (RKE/PB, 1983) waste panels will be divided into emplacement rooms designed to contain spent fuel and processed high-level waste containers. The following paragraphs discuss the functions, design requirements, and the design of the emplacement panels.

A waste panel will be a discrete area encompassing emplacement rooms or corridors from which waste containers will be placed into long horizontal boreholes. Depending on their status, the waste panels (during the operational and emplacement phase of the repository) will be serviced by two independent ventilation splits from the confinement ventilation system.

During the initial development phase of the repository, before waste emplacement begins, mining activities may be supported by the temporary development ventilation system and the confinement ventilation systems, making possible greater activity to accelerate development. However, after the initial development phase is completed and prior to waste emplacement, the two ventilation systems will be completely isolated from each other by construction of appropriate doors and bulkheads.

Once the waste emplacement period of the repository commences, waste panels under development (before they are used for waste package emplacement) will be serviced solely by the mining development ventilation system through the mine intake and mine exhaust airways. Confinement areas will be serviced solely by the confinement ventilation system through the confinement intake and return airways. Exhaust air from confinement areas will not be permitted to flow through areas ordinarily occupied by personnel.

5.1.2.2.8 Engineered barriers - 1982 Conceptual Design

The 1982 Conceptual Design (RKE/PB, 1983) system of multiple barriers, both natural and manmade, will be provided. The basalt formation in which the repository is constructed will provide natural barriers. The two engineered barriers are:

1. Waste Package System

- Waste form.
- Canister (processed waste only).
- Container.
- Packaging.

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2. Repository Seal System

- Emplacement hole seal.
- Drift seals.
- Shaft seals.
- Borehole seals.
- Backfill.

Forms of high-level waste to be placed in the repository for the existing 1982 Conceptual Design (RKE/PB, 1983) include spent fuel in carbon steel containers and reprocessed commercial high-level waste in stainless steel canisters, which are enclosed in carbon steel containers.

5.1.3 Ongoing engineering studies

Engineering studies have been completed or are ongoing since the 1982 Conceptual Design (RKE/PB, 1983) was completed. The principal objectives of the engineering studies have been to identify development needs and performance measurements or provide a basis for developing a site characterization plan.

Table A-1 provides the salient requirements and results of these engineering studies. The Waste Package Configuration Alternatives Study (Westinghouse, 1984) addressed an evaluation of a technical component of the repository that has little impact on the overall facility design concept. The Shaft Optimization, Tunnel Optimization, and Waste Emplacement Optimization Studies (RKE/PB, 1983) did not impact the 1982 Conceptual Design (RKE/PB, 1983) concept significantly either. The Underground Repository Layout Study (RKE/PB, 1984, Draft) is ongoing, but the waste emplacement concept has changed substantially from the 1982 Conceptual Design. The two-stage repository most closely proximates the 1982 Conceptual Design concept modified for approximately the same storage requirements as required by the Generic Requirements document (DOE, 1984). However, the emplacement concept used in the 1982 Conceptual Design and the two-stage repository do not provide the degree of certainty for emplacement and retrieval success. The two-stage repository and the extended repository on Table A-1 are shown for illustration of design requirement sensitivity only.

5.1.3.1 Optimization and alternative studies

The following five engineering studies have been completed since preparation of the 1982 Conceptual Design (RKE/P3, 1983) to determine development needs and performance requirements, and to provide information to supplement the 1982 Conceptual Design.

- Assessment of the Impact on the Nuclear Waste Repository in Basalt Conceptual Design of Increasing Receipts to a Total Waste Equivalent of 72,000 Metric Tons of Heavy Metal (RKE/PB, 1984).

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- Shaft Optimization Study (RKE/PB, 1984).
- Tunnel Optimization Study (RKE/PB, 1984).
- Waste Emplacement Optimization Study (RKE/PB, 1984).
- Waste Package Configuration Alternatives Study (Westinghouse, 1984).

The total storage capacity of 72,000 metric tons (approximately 79,300 tons) of heavy metal used for the first study listed above is 2,000 metric tons (approximately 2,200 tons) higher than current requirements. Using the existing 1982 Conceptual Design (RKE/PB, 1983) as a basis for evaluation and comparing it to the two-stage repository concept, which is the most similar to the 1982 Conceptual Design, there is no significant increase in capital construction costs (for the first 5 years) for a nuclear waste repository in basalt resulting from an increase in capacity 47,400 metric tons (approximately 52,200 tons) to 72,000 metric tons (approximately 79,300 tons) of heavy metal. The operating costs, however, are increased significantly by virtue of the extended operational period (6 years additional). Although the repository storage capacity would increase 52 percent, the increase in volume mined for the emplacement panels would be only 21 percent. The additional

Table A-1. Salient Requirements and Results Comparisons for Design Concept Development Activities

Item	1982 CSDD	Capacity Increase Study[a] TSR	Capacity Increase Study[a] ER	Shaft Optimization Study	Tunnel Optimization Study	Waste Emplacement Optimization Study	Underground Layout Study
Requirements							
Years of emplacement	20	5 + 21	30	20	20	20	5 + 20
Total MTHM to be emplaced	47,400	72,000	72,000	47,400	47,400	47,400	70,000
MTHM receipt rate (T/yr)	2,370	1,800 (5 yr) 3,000 (21 yr)	2,400	2,370	2,370	2,370	1,800 (5 yr) 3,000 (80 yr)
Results							
Subsurface areal extent (ha)	554.0	761.6	726.0	-	-	-	821
Surface mined basalt pile area (ha)	16.9	23.3	24.3	-	-	-	-
Total surface operations staffing	493.0	504.0	493.0	-	-	-	-
Total peak subsurface operational staffing	374.0	446.0	374.0	-	-	-	-
Emplacement concept[b]	multiple	multiple	multiple	-	-	single	single

[a]The capacity increase study refers to a completed engineering study "Assessment of the Impact on the NWRB Conceptual Design of Increasing Receipts to a Total Waste Equivalent of 72,000 Metric Tons of Heavy Metal" (RKE/PB, 1984). The TSR abbreviation is for "Two-Stage Repository" due to the 1800/300 MTHM receipt rates. The ER abbreviation is for "Extended Repository" indicating the increase in years of emplacement.

[b]Multiple indicates the storage of multiple containers in one storage hole. Single indicates one canister stored in a single hole.

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ventilation capacity requires an increase of 57 percent for fan horsepower and a 44 percent increase in precooling air. No significant impacts are estimated in total staffing requirements as shown on Table A-1.

The Shaft Optimization Study (RKE/PB, 1983) assesses the required shaft diameters based on operational requirements, the technology required to drill large-diameter shafts, and the shaft lining requirements. Findings of the shaft optimization study indicate the largest shaft size required for the repository is 3.66 meters (12 feet) in diameter. A solid steel, as opposed to a concrete/steel composite liner, is recommended for all shafts through the largest shafts diameter recommended.

The Tunnel Optimization Study (RKE/PB, 1984) assesses methods and requirements for repository layout, excavation methods, rock support, and drift (underground opening) size and shape. The results of this study indicate the following:

- Layout--This activity required considerable integration with findings in the Waste Emplacement Optimization Study. Basically, the findings indicate that a central shaft pillar area with an overall rectangular shape provides the best layout. However, a detailed investigation of the layout and shaft pillar area was beyond the scope of the study. Design concepts such as evaluation of the shaft pillar and evaluation and optimization of the ventilation network were not considered.

- Excavation methods--The drill and blast method is recommended for waste panel development and the use of tunnel-boring machines is recommended for rapid development of main entries.

- Rock support--Cement-grouted dowels with microsilica shotcrete are the preferred alternative. Openings using tunnel-boring machine-excavation for a circular opening will require welded wire fabric or steel straps in addition to the shotcrete and dowels for operational purposes because shotcrete should not be applied in the vicinity of the machine as the dust and aggregate rebound will damage moving parts on the machine.

- Drift size/shape--The preferred shape in the panel (heated) areas is near-elliptical, approximately 6.71-meters (22-feet) wide by 3.25-meters (10.67-feet) high. The height and width will be primarily dictated by the size of the container transporter and the loading of containers in emplacement holes perpendicular to the emplacement room. The main entries with much lower heats from the stored waste may use the circular shapes because the thermal stress superimposed on the in situ stress is lower. A drift excavated by a tunnel-boring machine with a 4.57-meter (15-foot) diameter is recommended for the main entries.

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The Waste Emplacement Optimization Study (RKE/PB, 1984) considers the emplacement, retrieval, and effect of the thermal loading of the containers on the repository as a whole. The principal finding of this study indicates that storage of containers in horizontal holes perpendicular to the placement room offers the most advantages. Short placement holes (9.14 meters (30 feet) or less) appear to offer an advantage over long boreholes (61 meters (200 feet) or more) as there is a much higher expectation that emplacement and retrieval of waste containers can be accomplished successfully.

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The short placement holes (Fig. 5-8) used in the waste emplacement optimization study are 76 centimeters (30 inches) in diameter. The diameter of the holes may be increased should it be necessary to provide more packing (backfill) thickness. This study includes the near-field performance for mitigation of radionuclide migration.

The Waste Package Configuration Alternatives Study (Westinghouse, 1984) has been completed in draft form, and in conjunction with the Waste Emplacement Optimization Study, formed the basis for selection of a reference waste package concept to be used in waste package advance conceptual design. The Waste Package Configuration Alternatives Study considered 23 alternative designs for spent fuel using emplacment geometry, container materials, packing form, and spent fuel configuration (i.e., consolidated fuel rods versus intact fuel assemblies) as design variables. Combining the preferred features from both studies resulted in the following emplacement concepts: (1) long (305-meter (1,000-foot)) indrift placement; (2) short (6-meter (20-foot)) indrift placement; and (3) short (6-meter (20-foot)) borehole placement. All concepts employed a container wall thickness suitable for radiation attenuation to mitigate ground-water radiolysis, as well as to meet corrosion and structural requirements. The short borehole concept was selected as the reference concept for waste package advanced conceptual design.

The shaft, tunnel, and waste emplacement optimization studies described above used a maximum storage capacity of 47,400 metric tons (52,140 tons) of heavy metal as in the current 1982 Conceptual Design (RKE/PB, 1983). However, new geotechnical data was incorporated to reflect the results of site exploration investigations conducted since the 1982 Conceptual Design was issued.

5.1.3.2 Current design concepts

A detailed underground repository layout study (RKE/PB, 1984) is currently underway based on the January, 1984, draft of the Generic Requirements for a Mined Geologic Disposal System (DOE, 1984). The study is currently scheduled for completion in late 1984 and information given in this subsection is preliminary relative to the study. It is recognized that this study does not incorporate changes in the most recent version of the generic requirements document, but it does reflect an acceptable concept for the underground portion of the repository. Integration of the latest requirements will be accomplished in the updated conceptual design as discussed in Section 5.1. The impact on surface facilities, waste handling, monitoring, and water handling were not evaluated in detail. Subsection 5.1.2 provides a description of generic design concepts not discussed in this subsection based on the 1982 Conceptual Design (RKE/PB, 1983).

5.1.3.2.1 Design functions

The underground repository layout (RKE/PB, 1984) is being designed as a single-phase repository to accommodate 70,000 metric tons (77,000 tons)

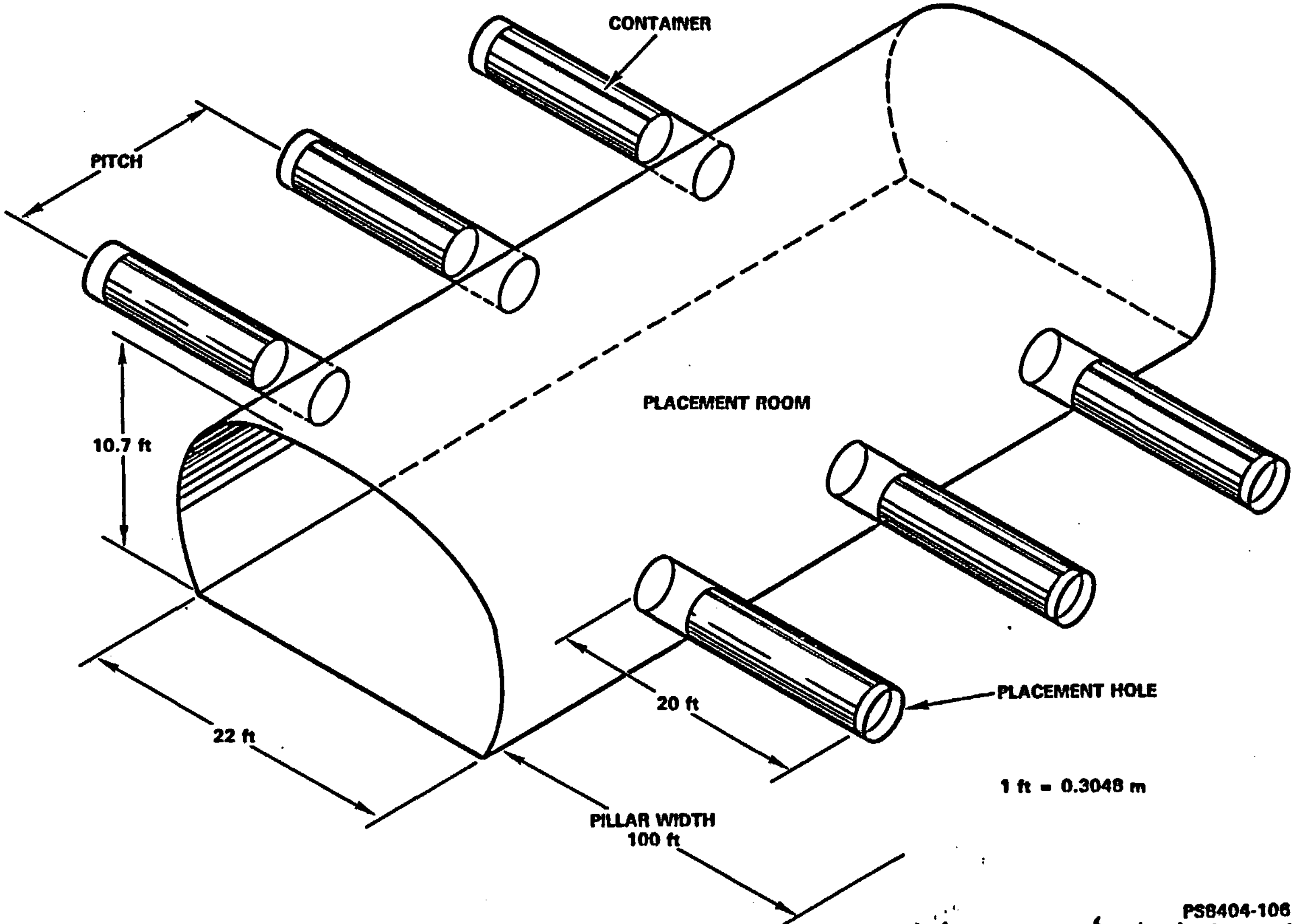

Figure 5-8. Conceptualization of placement room with short, horizontal placement holes.

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of heavy metal waste with a minimum age of 10 years. Receipt rates are up to 1,800 metric tons (_____ tons) of heavy metal per year during the first 5 years of operation and up to 3,000 metric tons (_____ tons) of heavy metal per year thereafter until the 70,000 metric tons (____ tons) of heavy metal capacity is reached.

X The repository capacity and receipt rates used to generate the 1982 Conceptual Design (RKE/PB, 1983) are discussed in Section 5.1.2.

5.1.3.2.2 Design ~~requirements~~ Features

Table A presents the salient waste emplacment features for the ~~layout~~ current design concept ~~study~~ as compared to the 1982 Conceptual Design (RKE/PB, 1983). The container data and packing requirements resulted in part from the Waste Package Configuration Alternatives Study (Westinghouse, 1984). The emplacment hole diameter is derived from container and packing requirements. The emplacement hole length and number of containers per emplacement hole were evaluated in the Waste Emplacement Optimization Study. As shown in Table A, the number of meters of emplacement room per container is much lower for multiple container storage as used in the 1982 Conceptual Design. The ratios shown consider symmetrical storage (i.e., two storage holes directly across from each other) for both the 1982 Conceptual Design and ~~Detailed~~ Repository Layout Study. The primary reason for selecting single container storage in an emplacement hole for the Waste Emplacement Optimization Study and the ~~Detailed~~ Repository Layout Study is certainty of emplacement and retrieval of the container.

Table B summarizes the more important geotechnical data used for the 1982 Conceptual Design and the ~~Detailed~~ Repository Layout Study. The basalt flow selected for the ~~Detailed~~ Repository Layout Study is the Cohassett flow. Geotechnical data for the Umtanum flow was limited at the time the 1982 Conceptual Design was prepared; however, later testing shows it is ~~of roughly the~~ approximately the same strength as the Cohassett flow. Furthermore, the direction of maximum horizontal stress in the 1982 Conceptual Design has changed approximately 90 degrees. This is due to the lack of data during the 1982 Conceptual Design in which time maximum stress orientation was assumed to be east-west. Subsequent testing has changed this assumption. A comparison of the allowable rock stresses and the intact compressive strength illustrates a trend toward more conservatism in geotechnical design requirements. Although the intact compressive strength is higher for the Cohassett flow than the 1982 Conceptual Design value, the allowable stresses remain very similar. This will be discussed further in the following subsection.

Table C compares the ventilation requirements for the 1982 Conceptual Design and the ~~Detailed~~ Repository Layout Study. ~~Subsection 5.1.3.2.1, compares the allowable air temperatures for personnel access into underground openings, which is an important design requirement and function~~. Other than the decrease in virgin rock temperature, the requirements have not changed significantly. However, the increase in total storage capacity, and the increase in emplacement room total length due to single container storage, not shown on the table, contribute significantly to the total ventilation flow requirement.

TABLE A

WASTE EMPLACEMENT COMPARISON

DESCRIPTION	1982 CONCEPTUAL DESIGN	CURRENT DESIGN CONCEPT
Container heat generation (PWR)	1650 watts	2020 watts
Container diameter	41.7 cm (16.4 in)	50.3 cm (19.8 in)
Container length	4.11 m (13.5 ft)	4.11 m (13.5 ft)
*Packing method	Pnuematic	Pre-Packaged sections
Packing thickness	15.2 cm (6 in)	15.2 cm (6 in)
Placement hole diameter	76.2 cm (30 in)	89.0 cm (35 in)
Placement hole pitch (c-c spacing)	18.3 m (60 ft)	6.7 m (22 ft)
Placement hole length	61 m (200 ft)	6.1 m (20 ft)
Containers of spent fuel (PWR) per placement hole	13	1 ea
Meter of placement room/containers	0.7	3.3

*Packing is a mixture of bentonite and crushed basalt

TABLE B

GEOTECHNICAL COMPARISON

DESCRIPTION	1982 CONCEPTUAL DESIGN	CURRENT DESIGN CONCEPT
Reference Basalt Flow	Umtanum	Cohassett
Depth to bottom of dense interior	1170 m (3,838 ft)	983 m (3,225 ft)
Estimated thickness of dense interior	65.5 m (215 ft)	68.1 m (223 ft)
Intact Compressive Strength	207 MPa (30,000 psi)	~~333~~ 290 MPa (~~48,375~~ 42,050 psi)
Allowable rock stress in Placement Hole	186 MPa (27,000 psi)	201 MPa (29,099 psi)
Allowable rock stress in Placement Room	166 MPa (24,000 psi)	157 MPa (22,813 psi)
In Situ Stress Ratio (max. horiz/vertical)	2:1	2.5:1
Maximum In Situ Stress Magnitude	60 MPa (8,740 psi)	58 MPa (8,410 psi)
Maximum In Situ Stress Direction	E-W	N3°W

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TABLE C

VENTILATION REQUIREMENTS COMPARISON

DESCRIPTION	1982 CONCEPTUAL DESIGN	CURRENT DESIGN CONCEPT
Maximum Number of Shafts	5	9
Maximum Shaft Inside-Diameter	No limit defined	3.7 m (12 ft)
Main Airway (drift) maximum velocity	457 m/min (1,500 ft/min)	457 m/min (1,500 ft/min)
Service Shaft maximum velocity	610 m/min (2,000 ft/min)	610 m/min (2,000 ft/min)
Ventilation Shafts maximum velocity	1,067 m/min (3,500 ft/min)	1,220 m/min (4,000 ft/min)
Virgin Rock Temperature	57°C (134°F)	52°C (125°F)

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5.1.3.2.3 Design approach and assumptions

The development of the Detailed Repository Layout Study used the following methodology:

- Provided ventilation network analysis and climatic simulation.

- Assumed the drill and blast excavation technique as recommended in the Tunnel Optimization Study.

- Assumed the rail haulage system for rock recommended in the 1982 Conceptual Design (RKE/PB, 1983). However, the practicality of rail haulage and the efficiency of the rock handling system from the heading face through the shaft hoisting system was evaluated due to the increase in required waste storage.

- Assumed all water entering the underground drainage/transport system is considered suspect for contamination. Natural drainage is assumed to be away from the shaft pillar towards the outer extremities of the repository. This assumption was made to protect the shaft pillar as it is considered critical for operations and emergency responses.

- The waste handling requirements and design is based on the existing 1982 Conceptual Design. Minor modifications have been made to the width of the emplacement rooms under the assumption that current waste package concept will require greater room for emplacment.

- The geotechnical design methodology is used to estimate emplacement hole pitch, container-to-container spacing, pillar width, and the emplacement room shape. Repository requirements (waste type, waste age, amount of waste, etc.), and geological conditions (in situ stress, rock mass strength, and rock mass mechanical and thermal properties, etc.) must be considered for the repository design.

The in situ stress field is estimated from small-diameter boreholes using the hydrofracturing technique. Measurements taken in the Cohassett flow indicate a mean value of approximately 2.5 for the ratio of horizontal to vertical stress. At-depth measurements would be conducted at the Exploratory Shaft Facility to obtain accurate at-depth information (see subsection 4.1.1.6.4).

The rock mass strength was developed through a sequence of steps starting with the development of an intact rock failure envelope (intact strength curve) based on Hoek and Brown (1983) failure criteria. To account for the jointed and interlocking nature of the basalt rock mass, the intact failure envelope was reduced proportional to the test results of Rosengren and Jaeger (1968). A further reduction in the failure envelope (rock mass strength curve) was made to account for the influence of opening size (volumetric effects) on the rock mass strength. Hardy and Hocking's (1980) failure criteria, which accounts for size effects, was

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used to determine the rock mass strength reduction factors for the emplacement holes and drifts (i.e., emplacement rooms). The reduced rock mass strength for each size of opening was then used as the allowable stress for design purposes.

A linear elastic analysis was used to calculate the rock stresses around the openings. This is a very conservative analysis that does not account for the redistribution of stress away from the opening surface due to nonelastic deformation of the rock mass immediately adjacent to the opening.

An appropriate rock mass volume for each opening size was selected to compare excavation- and thermal-induced stresses with rock mass strength. The rock mass volume was determined in the back (roof) and invert (floor) as the stresses are highest at these locations due to the high horizontal-to-vertical stress ratio. The rock mass volume in the back and invert was estimated to have a depth of 1/6 the excavation width and a length of 1/3 of the excavation width. Rock stresses were averaged over the depth of this representative rock volume, and compared with the rock mass strength of the same representative rock volume. The emplacement hole pitch and emplacement room spacing were determined such that the average rock stress is less than the allowable stress (i.e., spacing distance is inversely proportional to the average stress).

No credit was taken for the grouted dowel and shotcrete rock reinforcement that is anticipated for general use at the repository. The rock reinforcement system will improve the stability and deformation characteristics of the underground excavations.

In summary, due to the lack of in situ rock mass property data and the use of linear elastic models, a conservative design methodology has been used to provide a repository design. Until the design parameters and methodology can be verified with site specific data obtained at depth, the proposed repository layout can only be considered to present design concepts. Further design considerations are presented in Subsection 6.3.3.2.4.

5.1.3.2.4 Underground Repository Layout Study results

on which the current design concept is based,

The results of the physical dimensions for the Underground Repository Layout study are shown in Table D. The repository length-to-width ratio has changed slightly from the 1982 Conceptual Design (RKE/PB, 1983), but the areal extent has increased by approximately 48 percent. This increase is due primarily to the following:

- The storage capacity has increased by 50 percent.
- The emplacement concept with single container storage and less pitch between holes has yielded a 471 percent increase in the length of emplacement room per container stored. However, this is partially offset by a pillar width reduction from 65 meters (212 feet) to 30 meters (100 feet).

TABLE D

PHYSICAL COMPARISON

DESCRIPTION	1982 CONCEPTUAL DESIGN	CURRENT DESIGN CONCEPT
Overall Underground Dimensions	1,607 m (5,272 ft) x 3,359 m (11,020 ft)	1,930 m (6,330 ft) x 4149 m (13,608 ft)
Areal Extent	554 Hectares (1,334 acres)	821 hectares (1,977 acres)
Total length-Placement rooms	27,622 m (90,600 ft)	156,097 m (512,000 ft)
Size-Placement Rooms	3.06 m (10 ft) x 6.1 m (20 ft)	3.06 (10 ft) x 7.01 m (23 ft)

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The maximum quantity of ventilation air required (Table E) has increased by approximately 253 percent. This increase is primarily attributable to the storage capacity increasing by 56 percent.

Some methane has been found dissolved in the ground water at the reference repository location (see Subsection 6.3.3.2.10.4). The Underground Repository Layout Study examined the potential for methane buildup to explosive concentrations. The analysis determined that the ventilation system as designed for the layout study had sufficient airflow in every opening to dilute expected methane inflows to below the 0.25 percent concentration acceptable in limited "non-gassy" mines (30 CFR Part 57).

The number of shafts has increased from five shafts in the 1982 Conceptual Design to nine shafts. This is an 80 percent increase in the number of shafts, but the cross-sectional area has increased only 40 percent. The ____-meter- (12-foot-) maximum shaft diameter used was taken from the Shaft Optimization Study (RKE/PB, 1983).

The repository layout is similar to the 1982 Conceptual Design (RKE/PB, 1983) layout. It has been sized to accommodate 70,000 metric tons (_____ tons) of heavy metal waste. Some of the ventilation shafts are located on the outer periphery of the repository in the shaft pillar to enhance constructability and safety. The Underground Repository Layout Study has been completed in sufficient detail to provide design concept requirements for site characterization planning.

5.1.4 Waste package description

5.1.4.1 Waste form

A typical cross-section of a spent fuel waste package is shown in Figure 5-8a.

Potential waste forms for the nuclear waste repository in basalt are consolidated ~~compacted~~ fuel rods and commercial high-level waste from reprocessing of spent fuel. The dimensions, heat outputs, and other characteristics are given in Table 5-2.

Consolidated spent fuel ~~compacted~~ rods are placed in waste containers approximately 51 centimeters (20 inches) in outer diameter by 410 centimeters (151 inches) long. This container size was established in relation to the maximum heat generation rate of the fuel rods: approximately 2,200 watts for rods from four pressurized water reactor assemblies, 10 years out-of-reactor. (Nine boiling water reactor assemblies have approximately the same heat load as four fuel assemblies from a pressurized water reactor. Younger fuel will be accommodated through internal design of the container (i.e., the container dimensions are not changed). The number of a specific type of fuel rods placed in a container may vary. For identification purposes, the number of rods should be equivalent to a whole number of assemblies.

Commercial high-level waste consists of vitrified waste (i.e., borosilicate glass) enclosed in a standard size stainless steel canister, which is 32.5 centimeters (12.8 inches) outside diameter by 305 centimeters (120 inches) long. The heat generation rate of the

TABLE E

VENTILATION COMPARISON

DESCRIPTION	1982 CONCEPTUAL DESIGN	CURRENT DESIGN CONCEPT
Maximum air volume and Phase	Backfilling [11,980 m^3/min (423,000 ft^3/min)]	Operations [30,302 m^3/min (1,070,00 ft^3/min)]
Room cooldown time for backfilling	90 days	53 days
Number & diameter of Shafts		
Waste Handling	1 ea at 3.7 m (12 ft)	1 ea at 3.7 m (12 ft)
Service/Mine Intake	1 ea at 4.9 m (16 ft)	1 ea at 3.7 m (12 ft)
Basalt Hoisting/Mine Exhaust	1 ea at 4.3 m (14 ft)	1 ea at 3.7 m (12 ft)
Mine Intake	NA	1 ea at 3.1 m (10 ft)
Mine Exhaust	NA	1 ea at 3.1 m (10 ft)
Confinement Intake	1 ea at 3.7 m (12 ft)	2 ea at 3.7 m (12 ft)
Confinement Exhaust	1 ea at 3.4 m (11 ft)	2 ea at 3.7 m (12 ft)

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Table 5-2. Waste package characteristics.

Parameter	Spent fuel	Defense high-level waste	Commercial high-level waste
Container outside diameter (centimeters)	50.3	≈80.9	45.6
Required borehole diameter (centimeters)	89.0	≈120.0	84.0
Waste container overall length (centimeters)	411.0	≈333.0	325.0
Loaded weight of container (metric ton)	7.6	7.8	2.7

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commercial high-level waste is approximately 2,200 watts. The reference commercial high-level waste case is based on processing wastes resulting from spent fuel that would have been 10 years out-of-reactor had it not been processed (an example of an emplaced waste package is provided in Subsection 6.4.2.3.3).

5.1.4.2 Container

The reference material for containers for spent fuel, ~~defense high-level waste,~~ and commercial high-level waste is low-carbon steel. Alternate materials are being investigated and include, for example, Fe9Cr1Mo (low alloy steel) and Cupronickel 90-10. The containment time required by 10 CFR 60 (NRC, 1983) is a minimum of 300 to 1,000 years. The container thickness is based on the structural requirements necessary to withstand hydrostatic pressure, additional thickness for a corrosion allowance based on 1,000 year corrosion depth, and any additional thickness that may be required to reduce ground-water radiolysis to acceptable levels. (Currently, no such additional thickness is estimated to be required.)

The internal diameter of the reference spent fuel container is sized to accept the rods from four pressure water reactor assemblies. The rods will be installed in a tight fit for the largest expected number and size of fuel rods. The internal length of the reference spent fuel container is sized to accept the longest expected fuel rods with a small clearance between the container head and fuel rod ends.

~~Each defense high-level waste canister will be placed in a defense high-level waste container with a 2.5-centimeter- (1-inch-) diametral clearance. A 3-centimeter- (1.2-inch-) end clearance is provided between the end of the canister and the container head.~~

Each commercial high-level waste canister will be placed in a commercial high-level waste container with a 2.5-centimeter- (1-inch-) ~~diametral~~ clearance. A clearance of 2.5 centimeters (1 inch) is provided between the end of the canister and the inside of the container head.

5.1.4.3 Waste container configuration and packing

The reference waste container and packing materials are emplaced in a short horizontal borehole. Packing material is packaged or preformed in an annular shape and is emplaced first in the short horizontal borehole, followed by the waste container. The packing material is 75 percent crushed basalt and 25 percent bentonite clay. The packing material will have a minimum thickness of 15.2 centimeters (6 inches). A typical plan view is shown in Figure 5-9 to illustrate the terminology used in describing waste-emplacement configurations. Figure 5-10 illustrates how the waste package components will be placed in the borehole.

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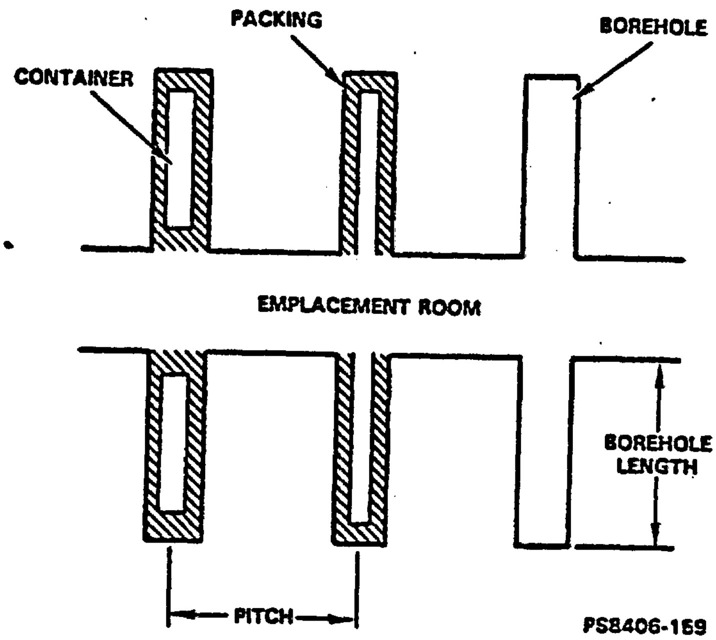

Figure 5-9. Typical plan view for waste emplacement.

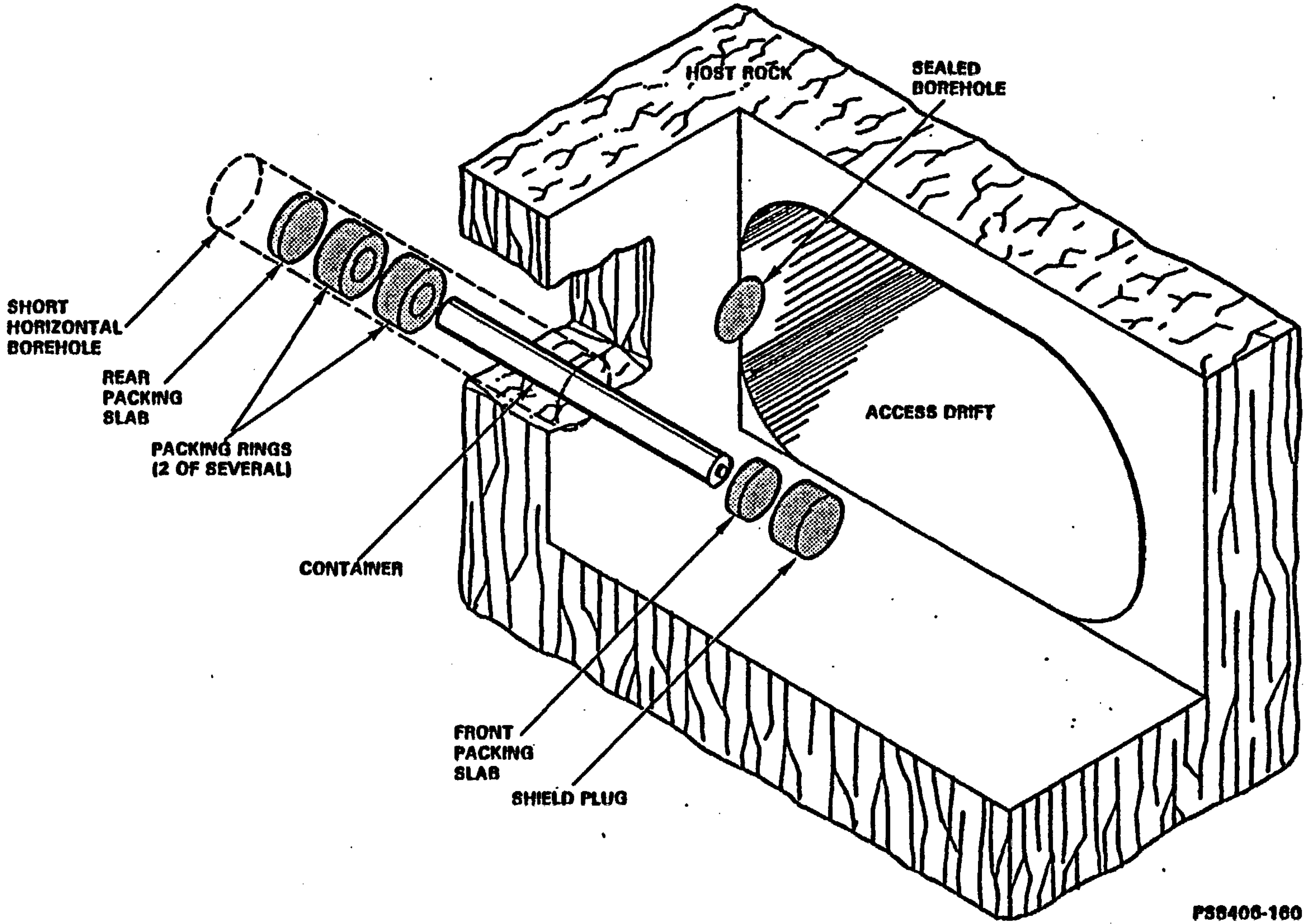

Figure 5-10. Cutaway showing Basalt Waste Isolation Project waste package emplacement sequence.

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The short horizontal waste emplacement hole will be a bored hole. No emplacement sleeve or packing retainer is necessary because the packing has a sheath. Alternative versions of this design may use pneumatic transport to emplace the packing around emplaced containers, and a thicker packing (i.e., more than 15.2 centimeters (6 inches)) if future engineering studies show that these alternatives offer advantages over the reference design.

The layout and excavation of the repository is based on the reference container size and heat loading. Younger or higher burnup spent fuel will be accommodated by adjusting the amount of a given fuel (number of rods) in the container. The borehole size required for the standardized spent fuel container is 89 centimeters (35 inches) in diameter, which allows for clearances between the container, prepackaged packing, and borehole wall, as well as for the thickness of the packing sheath.

~~For defense high-level waste emplacement, a borehole of 120 centimeters (47 inches) is required to provide clearances between the container, prepackaged packing, and borehole wall, including the thickness of the packing sheath material.~~

The commercial high-level waste emplacement, a borehole of 84 centimeters (33 inches) is required to provide clearances between the container, prepackaged packing, and borehole wall, including the thickness of the packing sheath material.

5.2 EXPECTED REGIONAL AND LOCAL EFFECTS

This section describes the regional and local impacts that could be expected if a repository is constructed and operated at the reference repository location. Impacts on the physical environment, impacts due to transportation, and socioeconomic effects are evaluated. Table 5-3 summarizes the expected effects. These effects are based on the Conceptual System Design Description (see Section 5.1.1). This design is currently undergoing revision (see subsection 5.1.3.2) and some impacts could change. However, it is not expected that design modifications and (or) refinements would significantly increase environmental impacts. A final impact analysis will be presented in the final environmental impact statement if the reference repository location at Hanford is recommended for site characterization.

5.2.1 Expected effects on the physical environment

In a construction and operation project of this size, it is inevitable that there will be some environmental impacts. Major site construction impacts are associated with surface support facilities for the repository. Repository-related development away from the reference repository location consists of transportation facilities, utilities, and the visitors center. The Hanford Site, however, can generally be

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Table 5-3. Summary of expected effects from construction and operation of a repository at the Hanford Site.

Category	Expected effect
Geology	No identifiable effect
Hydrology: Surficial Ground water	 Essentially no effect; no connection to surface water No identifiable effect from normal operations
Ecosystems: Terrestial Aquatic	MAJOR ~~No identifiable~~ effect WILL BE ~~except~~ loss of ground cover in central process area Two federally protected bird species have been sighted in area; however, no nests have been observed No effect expected
Air quality	Temporary particulate problem (onsite only) during site clearing; no measurable effect offsite
Noise	Temporarily high decibel level (onsite only) during principal construction period; no measurable effect offsite
Aesthetics	No measurable effects expected in site area
Archaeological, cultural, historical	No potential resources identified or known to exist in site area
Radiological impacts	No significant radiation dose offsite expected; at most a small fraction of background dose ~~Uncertain long-term effect if migration in ground water ? occurs ?~~
Transportation	Negligible effects (both radiological and nonradiological) by either rail or truck; at most a small fraction of background dose
Socioeconomic	No definitive adverse effects on local or regional infrastructure Beneficial effect on employment opportunities
Occupational safety	Usual nonradiological safety and health effects from construction and operation Employee radiation exposure well below all allowable limits

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characterized as a remote area and a nonfragile physical environment, thus, the expected effects of locating a repository on the Hanford Site are manageable.

The expected effects on the physical environment of locating a repository on the Hanford Site are divided into the following three catagories:

- Effects on the site geology.
- Effects on the site hydrology.
- Effects on the environmental setting.

5.2.1.1 Geology

Drilling of shafts and subsurface excavation at the bottom of the shafts is expected to have no significant effect on the geology of the site. Localized phenomena, such as rock bursts may be possible (see Subsection 6.3.1.3).

5.2.1.2 Hydrology

Repository impacts on hydrology are presented in two parts: impacts on surficial hydrology and impacts on ground-water hydrology.

5.2.1.2.1 Surficial

There are no surface streams in the vicinity of the reference repository, which is located on a high upland plateau; thus, effects on surficial hydrology are expected to be minimal. None the less, indeterminate quantities of water may be encountered in shaft drilling and subsurface excavation which will have to be disposed of, possibly by the ponds customarily used on site for disposal of uncontaminated water. Quantities of water will be needed for tailings pile dust control and collected underground water may be utilized for this purpose.

5.2.1.2.2 Ground water

Some interactions between the repository and ground water are ~~possible or~~ probable, but the magnitude of the effect is uncertain at this time. ~~Ideal site conditions would be such that the ground-water travel time along any path of likely radionuclide travel to the accessible environment would exceed 10,000 years. It is expected that the selected horizon in the basalt underneath the Hanford Site fulfills this condition; however, this is based on preliminary data and has a considerable range of uncertainty (see subsection 6.3.1.1.3).~~ Various ground-water strata will be intersected during shaft drilling (see Subsection 6.3.3.3.3); however, significant alteration of the predrilling condition is not expected since the shaft will be cased and grouted to preclude this.

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5.2.1.3 Environmental setting

Repository impacts on the environmental setting are presented in the following six subsections:

- Ecosystem.
- Air quality.
- Noise.
- Aesthetic.
- Archaeological, cultural, and historical.
- Radiological impacts.

5.2.1.3.1 <u>Ecosystems</u>

Repository construction will have some effects on the local ecosystem, although insufficient information is available to quantify these effects. By utilizing existing Hanford Site facilities as much as possible, environmental impacts away from the reference repository location will be minimized. Also, before decisions are made regarding construction, environmental evaluations will be conducted and used as input. Construction practices that minimize impacts will be used including dust suppression, soil stabilization, and allowing natural vegetation to reestablish along rights-of-way. However, reestablishment of native vegetation through natural succession is unlikely since once disturbed, land on the Hanford Site becomes dominated by almost pure stands of cheatgrass (<u>Bromus tectorium</u>) (Rickard et al., 1976). Techniques are available, however, for reclaiming surface-disturbed lands with native seed sources. Experimental plots along rights-of-way will provide data on the feasibility of revegetation with native species. Typically, impacts associated with a repository will be no greater than those associated with other major construction projects on the Hanford Site (PSPL, 1981; WPPSS, 1981; DOE, 1982). The nearness of the repository to tree plantings along Army Loop Road (used by raptorial birds for nesting) and to habitats used by many native wildlife species considered sensitive by the State of Washington (1983), is cause for some concern. Access to the surface facilities of the repository during construction, operation, and closure would be directly from State Route 240, thus avoiding Army Loop Road. Every attempt will be made to maintain the existing preconstruction integrity of native habitats and wildlife communities. The workforce will not be permitted access to any of the sensitive plant and wildlife areas. Planned monitoring programs will include plant and animal studies to examine the impacts of construction and operation of the repository the native biota. A summary of the projected impacts on the native biota is given in Table 5-4.

Ecological impacts of incoming utilities will be significantly influenced by the locations of the routes, which have not yet been selected. The severity of the impacts will depend on the location, duration of construction, and timing of construction activities. Specifically, incoming utilities consist of water, electric power, and telephone. Raw water will be supplied from the Columbia River by an existing river pump station, which will be modified by the addition of new

Table 5-4. Summary of expected impacts of locating a repository at the site on native biota.

	RARE AND ENDANGERED SPECIES	SWAINSON'S HAWK AND OTHER BIRDS OF PREY	LONG-BILLED CURLEW	OTHER NATIVE WILDLIFE	NATIVE PLANT COMMUNITIES
ACCESS ROAD	No effect	May cause disturbance to nesting birds, particularly if traffic stops to view wildlife	May cause disturbance to nesting birds, particularly if traffic stops to view wildlife	May cause disturbance to nesting birds, particularly if traffic stops to view wildlife	Will destroy and thus remove some native land from productivity
HELICOPTER	No effect if helicopter flights follow predetermined routes, which are removed from wildlife	No effect if helicopter flights follow predetermined routes, which are removed from wildlife	No effect if helicopter flights follow predetermined routes, which are removed from wildlife	No effect if helicopter flights follow predetermined routes, which are removed from wildlife	No effect
BURIED PIPELINE	Will disturb Bald Eagles wintering along the Columbia River. Impact can be minimized by careful planning of pipeline route and timing of construction	Will impact nesting birds if construction occurs near nest sites	Will impact nesting birds if construction occurs near nest sites	Will directly affect some wildlife species that utilize the plant communities destroyed by digging the pipeline	Will destroy and thus remove some native plant communities from productivity
PUMPS	No effect; existing pump facilities will be used	No effect	Noise from pumps may disrupt some nesting activity and brood rearing	May disturb Canada Goose brood-rearing areas through noise, installation, and maintenance of pumps	No effect
138-KILOVOLT TRANSMISSION AND TELEPHONE LINES	No effect	May provide nest sites for raptorial birds. Lines could cause electrocutions of birds of prey perching on wires or poles	Construction of power and phone lines would impact curlews if construction occurred from March 1 through August 1. Eliminate impacts by constructing lines at other times	Mechanical disturbance of habitats by machinery would impact wildlife	Cause mechanical disturbance to the soil and thus eliminate or alter a few hectares of native habitat
VISITORS CENTER CONSTRUCTION	No effect	Construction noise and presence of equipment, people, and finally the visitors center itself would disturb birds of prey nesting nearby	Construction noise and presence of equipment, people, and the visitors center would disturb nesting curlews	The land required for the visitors center would be removed from productivity. The wildlife associated with the land would be displaced or destroyed	Removes several hectares of native landscape from productivity
RIGHT-OF-WAYS MANAGEMENT	No effect	No measurable effect	No measurable effect	Right-of-way vegetation would be dominated by cheatgrass. Wildlife that utilize cheatgrass would benefit, species requiring native habitats would not	Would change the species composition of plants along right-of-ways

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pumps and other appurtenant equipment. A new buried pipeline will connect these pumps to the surface facilities at the reference repository location. Two new 138-kilovolt transmission lines, routed over separate parallel rights of way, will connect the repository to the Hanford Site power system, and a new overhead telephone line will connect the surface facilities at the repository site to the Hanford Site telephone network.

The major construction impacts at the repository site will be the selective clearing and grading of over 80 hectares (200 acres) of shrub-steppe terrain (i.e., all of the central process area plus an area outside the central process area for a parking lot, helicopter landing pad, and a mine water percolation pond). Any topsoil stripped at this time will be stockpiled for future replacement and planting. Throughout the design, construction, and operation of the repository, every effort will be made to achieve an environmental balance to lessen the adverse effects on wildlife. Removal of vegetation will be minimized.

The Current Conceptual Design Description has provisions for a helicopter landing pad (see Fig. 5-7). Helicopter noise and presence in the air are very disturbing to wildlife and can be expected to impact deer, coyote, badger, hares, and birds of prey, in particular. Helicopter routes will be studied and flight paths causing the least disturbance will be identified.

Following clearing and grading, the culverts, drainage structures, and large-diameter storm sewers will be installed. Excavations and embankments will be formed; storm drainage ditches and structures will be constructed. Dust and erosion control measures will continue during the entire construction phase until final paving, erosion control, and planting are provided.

At this time, there are no federally recognized threatened or endangered animal species, or their critical habitat, known to occur within the reference repository location. However, although not common within the reference repository location area, one threatened bird species, the bald eagle (Haliaeetus leucocephalus) and one endangered bird species, the peregrine falcon (Falco peregrinus) (FWS, 1980) have been sighted infrequently within the ~~area~~ boundaries during recent field investigations. Three additional bird species that nest within or near the reference repository location area are now being considered as potential candidates for protection on the Federal threatened and endangered species list. These are the ferruginous hawk (Buteo regalis), the Swainson's hawk (Buteo swainsoni), and the long-billed curlew (Numenius americanus). Although not yet given official protection, these species are being included in biological investigations. ~~The Washington Department of Game also lists over 40 animal species common to the repository area on their "sensitive" list (State of Washington, 1983).~~ Every effort has been and will continue to be made to minimize impacts on critical habitat due to site activities.

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At this time there are no federally recognized threatened or endangered plant species known to occur within the reference repository location. However, the U.S. Fish and Wildlife Service is currently reviewing the status of several vascular plant species for consideration as proposed threatened species that do occur on the Hanford Site. Included in this category are the Columbia milk-vetch (Astragalus columbianus), the Hood River milk-vetch (Astragalus hoodianus), and the Persistentsepal yellowcress (Rorippa calycina Variety columbiae). The presence of these or other potentially sensitive species within the reference repository location has not been established during recent investigations; however, these investigations continue.

Also included among concerns for the ecosystem are "affected Indian tribe" fishing rights. The Yakima Indian Nation and the Confederated Tribes of the Umatilla Indian Reservation have been designated by the U.S. Department of Interior as "affected Indian tribes" based on off-reservation fishing rights (see Section 3.6). However, the U.S. Department of Interior also states that no scientific data are available to prove that a repository will have adverse impacts on fisheries (DOI, 1983a, 1983b). It is expected that compliance with regulatory requirements of the U.S. Environmental Protection Agency will minimize any potentially adverse effects.

Finally, neither construction nor operation of the proposed repository is expected to have any measurable effects on local or regional water quality.

5.2.1.3.2 Air quality

The primary sources of nonradiological pollutants at the reference repository location are fuel combustion by construction equipment and the generation of fugitive dust by mechnical activity and/or wind erosion. Graders, bulldozers, trucks, and the like will emit sulfur dioxide, nitrogen oxides, hydrocarbons, carbon monoxide, etc. The amount of these pollutants emitted will depend on the number and type of vehicle uses, the quantity of fuel consumed, and any pollution abatement equipment installed on the vehicles. Dust emissions will contribute to ambient total suspended particulate concentrations. The amount of fugitive dust generated will depend on the surface area exposed, the amount of mechanical activity, ambient wind conditions (speed, direction), characteristics of the soil (e.g., density, particle size distribution), and any dust suppression techniques which may be used (e.g., water or chemical sprays, vegetation, use of gravel, etc.).

Emission rates for gaseous pollutants and particulates due to the various transportation, construction, and operations activities have not been explicitly determined. Other major construction activities at the Hanford Site, however, did not provide any significant air qualiy impacts (PSPL, 1981; WPPSS, 1981). The primary air quality nuisance at the Hanford Site is dust. Watering or other approved dust control methods will be used to control fugitive dust. Roadways at the repository location will be watered or covered by protective material such as gravel or pavement to decrease the impact of windblown soil. Emissions resulting from the activities of heavy equipment will be controlled to comply with

AS DETAILS OF THE REPOSITORY DESIGN AND OPERATIONS BECOME AVAILABLE, EVALUATION OF POTENTIAL EMISSIONS WILL BE MADE TO DETERMINE PERMIT REQUIREMENTS.

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applicable standards. Construction vehicles will be maintained in good mechanical condition so emissions will conform to standards. Impacts associated with a repository should be no greater than those associated with other major construction projects that have taken place on the Hanford Site (PSPL, 1981; WPPSS, 1981; DOE, 1982).

Air quality impacts ~~due to the expected~~ cooling tower for ventilation air used at the repository are expected to be small in comparison to the existing cooling tower for the nearby commercial nuclear power plant (Washington Public Power Supply System WNP-2).

5.2.1.3.3 Noise

There will be temporarily high noise levels at the repository site during the site-clearing phase from earthmovers, bulldozers, scrapers, etc., and from the drilling opertions associated with the sinking of the shafts. Use of protective gear by employees is indicated.

Effective muffler systems will be used on heavy equipment during construction to minimize adverse environmental impacts. The remoteness of the repository from human habitation and from occupied Hanford Site facilities mitigates the effects of any construction noise levels. Impacts on members of the general public will meet the requirements of the Noise Control Act of 1972; no measureable elevation of background noise levels at the site boundaries are anticipated. Effects of noise on wildlife residing nearby are currently unknown, but some level of impact is expected (Fletcher and Busnel, 1978).

5.2.1.3.4 Aesthetics

The general level of onsite aesthetics will not be adversely affected by construction of the repository. Although expected to be somewhat visible from Route 240, the appearance of the surface facilities will be generally comparable to other visible facilities on the Hanford Site.

5.2.1.3.5 Archaeological, cultural, and historical resources

No potential resources in this category have been identified in the reference repository location or are known to exist. Confirming evidence, supplied by archaeological surveys of the reference repository location, concluded that none of the repository undertakings will have an effect upon significant cultural resources (Rice, 1984a, 1984b).

5.2.1.3.6 Radiological impacts

Remote handling of spent fuel is to be practiced in receiving, inspecting, and placing containers for transport in heavily-shielded casks to the waste storage area (see Subsection 5.1.1.1). The casks are shielded to the extent that surface radiation levels on the order of 1 millirem per hour are anticipated. With remotely conducted canister placement, no significant radiation exposure is expected.

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Radioactive emission and radiation doses from repository facilities were estimated based on the conceptual design for the reference repository (see Subsection 6.2.1.5 and Section 6.4.1). The radiation doses from normal operations of the above ground facilities most likely would result from receiving, disassembling, and repacking of container of spent fuel. The gaseous emissions associated with these activities would be similar to those associated with spent fuel handling at commercial nuclear reactors.

Routine radiological releases from geologic repositories during normal operation will consist principally of radon emanating from exposed rock faces and radon's decay products. These releases will also occur from backfilling operations but are negligible compared to radon releases during repository construction (DOE, 1980). A summary of 70-year whole-body doses to the regional population from the releases of naturally occurring radionuclides during repository construction is given in U.S. Department of Energy (1980). Based on calculated doses to the regional population, no health effects are expected from construction of a geologic repository for spent fuel or for reprocessing wastes (DOE, 1980). Preclosure performance assessment is discussed in detail in Section 6.4.1.

Population exposure in the distant future (greater than 10,000 years) is also expected to be negligible even if some groundwater transport does occur. Postclosure performance assessment is discussed in Section 6.4.2.

5.2.2 Expected effects of transportation

This section addresses the expected regional and local effects of transportation associated with locating a repository at the Hanford Site. Included in this section are the radiological effects on the regional populace under both normal and accident conditions, and safety effects (i.e., nonradiological safety). The radiological and nonradiological safety effects of transportation are estimated based on nationally applicable risk factors developed by the Transportation Technology Center at Sandia National Laboratories (see Transportation Appendix), and on local population density data along probable routes.

The expected effects of transportation covered in this section are limited to regional and local effects. The outer boundary for regional effects is defined as the highway intersection with the nearest major interstate highway or the railroad connection with major rail lines. The effects associated with access routes constructed specifically for the repository are covered in Chapter 6 (see Subsection 6.2.1.8) of this document. The nationwide cost and risk impacts of radioactive-waste transportation to a repository are described in Chapter 7, which presents a comparison of candidate repository sites. Generic information related to transportation safety and environmental impacts is presented in an appendix to this document.

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5.2.2.1 Radioactive waste shipment bases

The radioactive waste shipment bases used in this section are derived from the most recent guidance to repository projects and are consistent with both national waste projections and the provisions of the Nuclear Waste Policy Act of 1982. Currently, the first repository is planned to receive 70,000 metric tons (77,000 tons) of uranium in the form of spent fuel, or the equivalent quantity of commercial high-level waste, during its operating life until a second repository becomes available. Current forecasts of the viability of a commercial nuclear fuel reprocessing industry indicate that the first repository is likely to receive all spent fuel and no commercial high-level waste; therefore, spent fuel is emphasized in this section as the probable waste form. Table 5-5 summarizes the spent fuel shipment projections.

The spent fuel shipment projections shown in Table 5-5 are based upon low-capacity shipping casks for both truck and rail shipments. The cask capacities indicated in the footnotes to Table 5-5 correspond to existing shipping casks that have already been used for spent fuel shipment. These existing casks were designed for shipping short-cooled spent fuel (i.e., only a few months after reactor discharge) to a reprocessing facility. For the longer-aged spent fuel (i.e., about 5 to 25 years after reactor discharge) to be shipped to a repository, shipping casks having about twice the capacity of existing casks are within current technology without compromising nuclear safety performance or exceeding shipping weight limits. It is intended that these higher-capacity shipping casks will be designed, constructed, and used for shipments to the repository. Thus the shipment frequencies presented in this document are conservatively high by about a factor of two.

5.2.2.2 Types of nonradioactive shipments

Shipment of nonradioactive materials to and from the repository ~~has no radiological safety implications but still~~ is a concern from the standpoint of transportation system adequacy and traffic safety. During the repository construction period, construction supplies and equipment (e.g., concrete or its constituents, rebar, steel plate, piping, wire, drilling and excavating tools, and purchased plant equipment items) will be transported to the proposed repository site via truck, rail, and perhaps barge. Similarly, during the repository operating period, other types of supplies and equipment (e.g., backfill materials and replacement equipment and parts) will also be transported to the proposed repository site. Shipments away from the proposed repository site will consist primarily of empty spent fuel casks and empty material transport vehicles. Nonradioactive-waste shipments away from the repository will be minimal; current plans are to store all excavated rock onsite, most of which will be used later for backfilling excavated openings.

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Table 5-5. Spent fuel shipments to the first repository.

Shipment parameter	Pressurized water reactor (PWR)	Boiling water reactor (BWR)	Total of both reactor types
Spent fuel assemblies:			
Total number	96,000	140,000	236,000
Average number per year	3,430	5,000	8,430
Quantity of uranium:			
Total metric tons[a]	44,000	26,000	70,000
Average metric tons per year	1,570	930	2,500
Truck shipments (if all shipped by truck):[b]			
Total shipments	96,000	70,000	166,000
Average shipments per year	3,430	2,500	5,930
Rail shipments (if all shipped by rail):[c]			
Total shipments	13,710	7,780	21,490
Average shipments per year	490	280	770

[a]To convert metric tons to tons multiply by 1.1.
[b]Assumed truck cask capacity is 1 PWR or 2 BWR fuel assemblies.
[c]Assumed rail cask capacity is 7 PWR or 18 BWR fuel assemblies.

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The quantities and shipping frequency of nonradioactive material to the repository are not estimated in this report since (1) the repository design is in an early stage and is subject to change; (2) firm construction schedules have not yet been established; and (3) the quantity and safety of these shipments are judged to be of less concern than for the radioactive material shipments, even though short-term shipment frequencies (i.e., during construction) could be high enough to impact routine traffic patterns.

5.2.2.3 Highway transport

The existing highway routes to the proposed repository were described in Section 3.1.5. Highway shipments to the Hanford Site travel via one of two major east-west interstate highways: Interstate 90 to the north and Interstate 84 to the south. Exit points from these interstate highways depend on the direction of travel, which is assumed to be from east to west since most radioactive-waste shipments will originate east of the Hanford Site. The State of Washington is authorized to designate specific routes to be used within its borders from the interstate highways to the repository access roads.

Trucks heading west on Interstate 90 will exit onto U.S. Highway 395 near Ritzville, Washington, and follow U.S. Highway 395 south to Pasco, Washington. Near Pasco, these shipments will exit U.S. Highway 395, going onto U.S. Highway 12, and travel west across the Columbia River, through Kennewick, Washington, to Richland, Washington. At the southern end of Richland, these trucks will enter Route 240, bypass the city of Richland, and enter the Hanford Site at its southern end.

Trucks heading west on Interstate 84 will exit onto U.S. Highway 395 near Stanfield, Oregon, and follow U.S. Highway 395 north to its intersection with U.S. Highway 730. These shipments will follow U.S. Highway 730 for a short distance to the west and cross the Columbia River via a bridge on the eastern edge of Umatilla, Oregon. On the Washington side of the Columbia River, these trucks will connect and follow State Route 14 north to Kennewick, Washington, where they will connect with U.S. Highway 12. From this point, the route is the same as that traveled by trucks coming from the north. An extension of Interstate 82 and a new Interstate 182 are currently under construction; these new interstate highways will provide a replacement route for State Route 14 and a means of bypassing U.S. Highway 12 between Kennewick and Richland, Washington.

Both of the regional highway routes identified above pass through sparsely populated areas. To allow evaluation of the environmental impacts of radioactive-waste transportation by truck, population density data along these transportation corridors have been utilized. These data consist of population density ranges and highway segment lengths, which correspond to the given range for a distance of 1 kilometer (0.6 miles) on either side of the highway. Although the regional highway system is generally considered to extend only to the interstate highway, data presented here include portions of the interstate (Interstate 90 to Coeur d'Alene, Idaho, and Interstate 84 to Boise, Idaho). These data are summarized in Table 5-6.

Table 5-6. Population densities along highway routes to the Hanford Site.

Population density range[a] (persons per km^2[b])	Northern route (via I-90 from Coeur d'Alene, Idaho)		Southern route (via I-84 from Boise, Idaho)	
	Sum of segment lengths (km)	Percent of total	Sum of segment lengths (km)	Percent of total
Less than 1	174.1	56.2	258.3	55.1
1-10	11.7	3.8	--	--
10-30	10.0	3.2	26.7	5.7
30-60	10.0	3.2	62.1	13.2
60-100	10.0	3.2	20.2	4.3
100-300	36.0	11.6	52.8	11.3
300-600	43.0	13.9	48.6	10.4
600-1000	15.2	4.9	--	--
Totals	310.0	100.0	468.7	100.0

[a]Within one kilometer (km) of highway.
[b]To convert kilometers to miles, multiply by 0.6.

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A review of Table 5-5 indicates that, if all spent fuel shipments were made by truck, about 16 trucks per day would be received at the proposed repository. As indicated earlier (Subsection 5.2.2.1), shipment frequencies presented in this document are about twice those which are actually intended, due to the conservatively low shipping capacity assumptions that have been used. The radiological and nonradiological impacts of truck shipments are presented later in this section on the assumed basis that all shipments are by truck. However, a more probable transportation modal split between truck and rail would be approximately 70 percent by rail and 30 percent by truck, since the inherent payload advantages of rail shipment will ideally be constrained only by the lack of rail access to some nuclear power reactor sites. Using this 70/30 split, the proposed repository would receive only about 5 truck shipments per day. Traffic impacts of these truck shipments are reduced by the availability of two primary highway routes. There is currently no basis for forecasting the relative split between these two routes. The frequency of truck shipments would not be sufficient to warrant improvements to the existing highway network. Even if all spent fuel shipments were by truck and only one route was used, 16 trucks per day would be a moderate increment to the existing traffic. Thus, any future improvement of the local and regional highway network would be based on overall comprehensive traffic growth projections, to which the repository-related traffic would be only one contribution.

5.2.2.4 Railroad transport

As described in Section 3.1.5, two major railroad lines (i.e., Burlington Northern and Union Pacific) serve the Hanford Site. For shipments from the east, these two railroad lines generally follow the same routes as the highway system. The Union Pacific route follows Interstate 84 from Boise, Idaho, to Hinkle, Oregon, then follows the Columbia River to the Hanford Site. The Burlington Northern route crosses Idaho north of Interstate 90, then passes southwest through Spokane, Washington, to Pasco, Washington, then heads west to the Hanford Site. Hinkle, Oregon, and Pasco, Washington, are the locations of regional classification yards for the Union Pacific and Burlington Northern railroads, respectively.

Population density data specific to these railroad routes are not presented here. However, a national study of radioactive-waste transportation (Wilmot et al., 1983) has indicated that the distribution of population densities along railroad routes to the Hanford Site is nearly equal to the corresponding distribution for highway routes. Population densities along railroad routes are generally slightly below those along highway routes.

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If all spent fuel shipments were made by rail, approximately two railroad cars per day would be received at the repository. This number would be reduced to two every 3 days for the forecasted 70/30 split between rail and truck shipments. As indicated earlier (Subsection 5.2.2.1), shipment frequencies presented in this document are about twice those which are actually intended, due to the conservatively low shipping cask capacity assumptions that have been used. The radiological and nonradiological impacts of rail shipments are presented later in this section on the assumed basis that all shipments are by rail. These rail shipment frequencies would be a small increment to current rail traffic, and no improvements to the existing rail system are currently deemed necessary as a result of repository operation.

, pending further study,

5.2.2.5 Potential radiological effects

The radiological effects presented in this subsection, and the nonradiological effects presented in the next subsection, cover the transportation mode scenarios of 100 percent truck and 100 percent rail. For all practical purposes, these are bounding scenarios; that is, actual effects will be somewhere between the all-truck and all-rail values, depending on the actual split between truck and rail. Actual effects could exceed the upper-bound values only if transportation routes are lengthened, such as by including an intermediate transloading facility for enroute switching of transportation modes between truck and rail.

The tabulated radiological and nonradiological effects presented in the remainder of Section 5.2.2 are specific to transportation of spent fuel. Commercial high-level waste would be transported instead of spent fuel if nuclear fuel reprocessing is performed. Converting to commercial high-level waste from spent fuel would reduce the number of shipments to a repository by approximately 80 percent for all-truck shipment and by approximately 90 percent for all-rail shipment, based on the spent fuel shipment bases used for Table 5-4. Total radiological effects in the region of the repository would decrease accordingly; although the unit risk factors for accidents are an order of magnitude greater for commercial high-level waste than for spent fuel, accidents are a small fraction of the total radiological effects. Nonradiological effects would also decrease by approximately the same percentages as the reductions in shipment frequency in the repository region.

The potential radiological effects associated with normal conditions were calculated for the regional highway distances and population densities shown in Table 5-6. These data were combined with nationally applicable "unit risk factors" developed in a recent national study of radioactive-waste transportation risks (see Transportation Appendix). Unit risk factors have been developed for both truck and rail shipments, under normal conditions, and have been further subcategorized into occupational and non-occupational risks. These unit risk factors take into account the low levels of radiation exposure received by both the transportation crews (occupational) and the population surrounding the

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route (non-occupational). For this report, the regional rail population densities and distances were assumed equal to those for truck; thus, tabulated values for rail ~~have no real-world basis, but merely~~ serve to illustrate unit risk factor differences between truck and rail. The results of these calculations, expressed as latent cancers over the repository receiving period, are presented in Table 5-7. Note in the table that all spent fuel shipments are covered by any one of the four quadrants in the table, and that the ~~actual~~ impacts ~~will be some~~ weighted average of the impacts shown in the four quadrants, depending on the splits between transportation modes and between routes.

The potential radiological effects of postulated accidents have also been ~~calculated~~ by using unit risk factors for accidents (see Transportation Appendix). In the case of accidents, the unit risk factors take into account probable accident severity, quantity of radioactive material released, and generalized dispersion characteristics. Other than the change in unit risk factor values, all aspects of the accident calculations parallel those for normal conditions. The unit risk factors for accidents lump all radiation exposures under the heading 'non-occupational', although crew members are included as possible members of the exposed population. The results of these accident calculations are shown in Table 5-8; as with Table 5-7, each of the four quadrants in Table 5-8 cover all spent fuel shipments to the proposed repository.

5.2.2.6 Safety

The nonradiological effects of transportation by truck and rail have been calculated by using the same unit-risk-factor approach that was used for the calculations of radiological effects. Unit risk factors are presented in the Transportation Appendix of this document for accidents and are based on accident frequencies and consequences from historical data on similar truck and rail accidents. The results of these calculations are shown in Table 5-9. As with other tables in this section, each of the four quadrants in Table 5-9 covers all spent fuel shipments to the proposed repository. Unit risk factors have been developed for normal conditions and take into account the effects of pollutants emitted by engines; however, these factors apply only to urban areas, since the effects ~~are insignificant for~~ low population densities. Therefore, nonradiological effects for normal conditions are not presented in this report.

5.2.3 Expected effects on socioeconomic conditions

This section compares the manpower requirements for the reference repository with the expected baseline conditions in the study region at the time of the projected start of construction on the repository. As shown in Figure 5-11, the expected effects in several categories of socioeconomic conditions are considered as a joint product of the

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Table 5-7. Radiological effects of normal conditions.

Mode/exposure type	Latent cancers throughout operating period	
	All northern route	All southern route
All truck:		
Occupational	0.04	0.05
Non-occupational	0.19	0.27
Total	0.23	0.32
All rail:		
Occupational	0.0002	0.0003
Non-occupational	1.14	1.72
Total	1.14	1.72

NOTE: Based on unit risk factors presented in the Transportation Appendix.

Table 5-8. Radiological effects of accidents.

Mode	Latent cancers throughout operating period	
	All northern route	All southern route
All truck	0.0019	0.0022
All rail	0.0018	0.0021

NOTE: Based on unit risk factors presented in the Transportation Appendix.

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Table 5-9. Nonradiological effects of accidents.

Mode/population	Total fatalities and injuries throughout operating period			
	All northern route		All southern route	
	Fatalities	Injuries	Fatalities	Injuries
All truck:				
Occupational	0.6	1.2	0.9	1.9
Non-occupational	2.0	34.0	3.3	54.0
Total	2.6	35.0	4.2	56.0
All rail:				
Occupational	0.01	1.3	0.01	1.9
Non-occupational	0.11	0.2	0.17	0.3
Total	0.12	1.5	0.18	2.2

NOTE: Based on unit risk factors presented in the Transportation Appendix.

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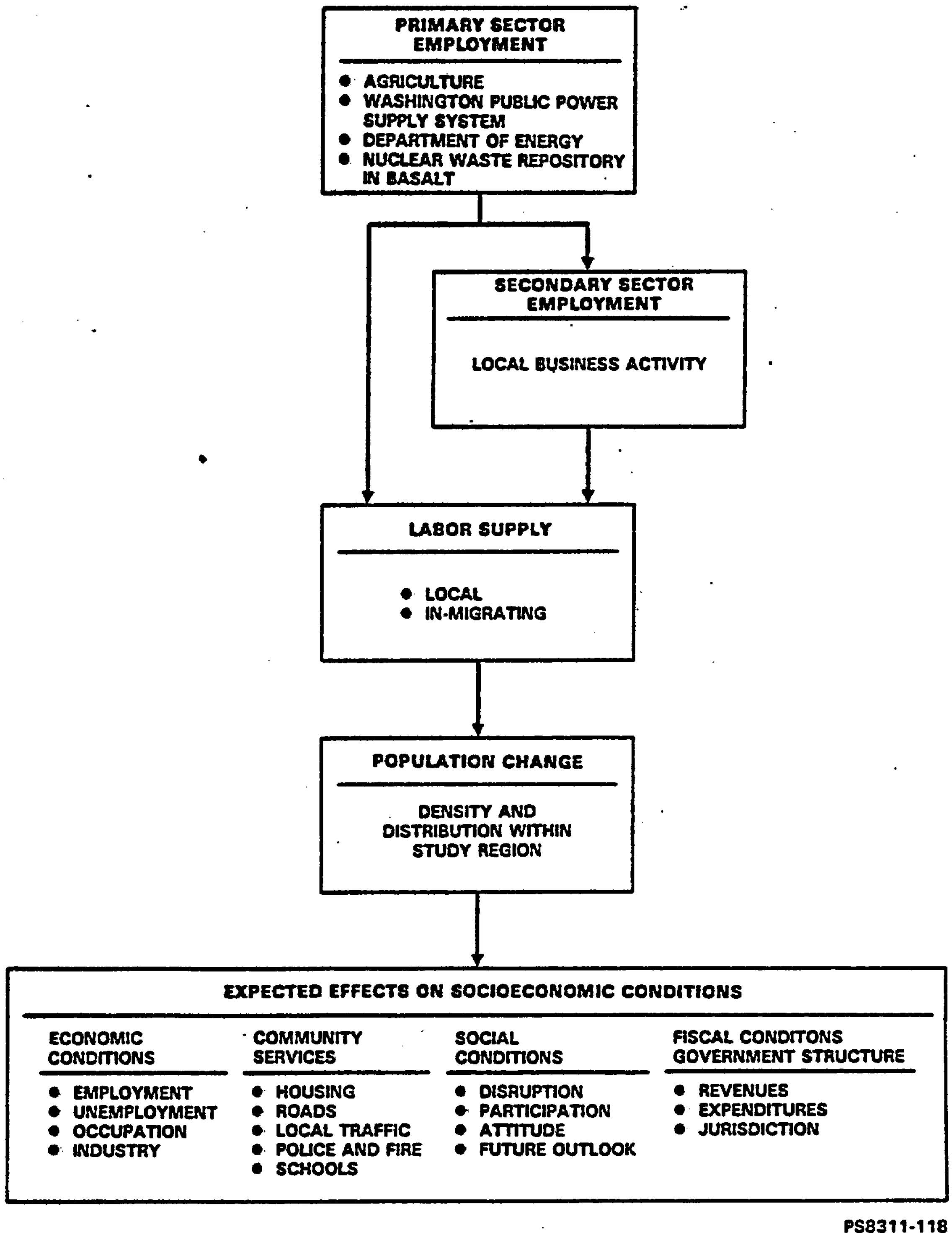

Figure 5-11. Socioeconomic impact assessment framework.

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employment requirements of the repository and labor supply in the region. The difficult aspect of the analysis is to forecast a reasonable future baseline, particularly with respect to economic and demographic conditions in the region. Two uncertain aspects of this forecast are (1) the extent and duration of the employment decline triggered by the rampdown of the Washington Public Power Supply System nuclear power plant construction, and (2) the sources and prospects for future economic recovery and growth in the region over the next three decades.

The analysis in this section is based on an optimistic forecast that assumes that total employment and population will bottom out in 1984 and resume a pattern of growth that will regain the 1981 peak level of employment and population again by 1996, after which employment is forecast to grow at 1.9 percent per year and population at 1.2 percent per year (see Cluett et al., 1984, for assumptions and procedures used in developing employment and population forecasts). These rates are more consistent with the pre-Washington Public Power Supply System growth phase than with the high rates of growth during Washington Public Power Supply System construction. Historical and projected growth in total employment and population for Benton and Franklin Counties are illustrated in Figure 5-12. The bulge in employment and population between 1986 and 1991 is due to an assumed restart of WNP-1, which is currently mothballed. While lower growth scenarios can be assumed, and they may even be more plausible, this high scenario brings the region closer to the capacity of its infrastructure. This is a conservative way to assess possible reference repository impacts, since work force and population growth due to the reference repository would be more likely to alter regional socioeconomic conditions under high baseline growth assumptions. If, under these conditions, impacts appear unlikely, then they could be said to be even less likely under any other plausible scenario.

The relevant aspects of the reference repository conceptual design to socioeconomic conditions include the following:

- Scheduling of project construction and operation. Work is currently assumed to begin in approximately 1994 and last for approximately 80 years, through the backfill phase. This assessment focuses on the 8-year construction phase and the first few years of operations, during which time most of the work force-related effects can be expected. Forecasts beyond 2010 are far too uncertain to be worthwhile.

- Work force requirements. The construction work force is expected to peak in the fifth year at around 1,100 workers but average approximately 450 workers per year throughout this 8-year phase. For the next 16 years, the operations work force is more constant at an average level of approximately 815 workers per year. The work force level tends to decline thereafter, especially during the last 50 years of the project. Very little information is currently available on the skill composition of the work force; however, it is likely that between 20 and 30 percent of the total

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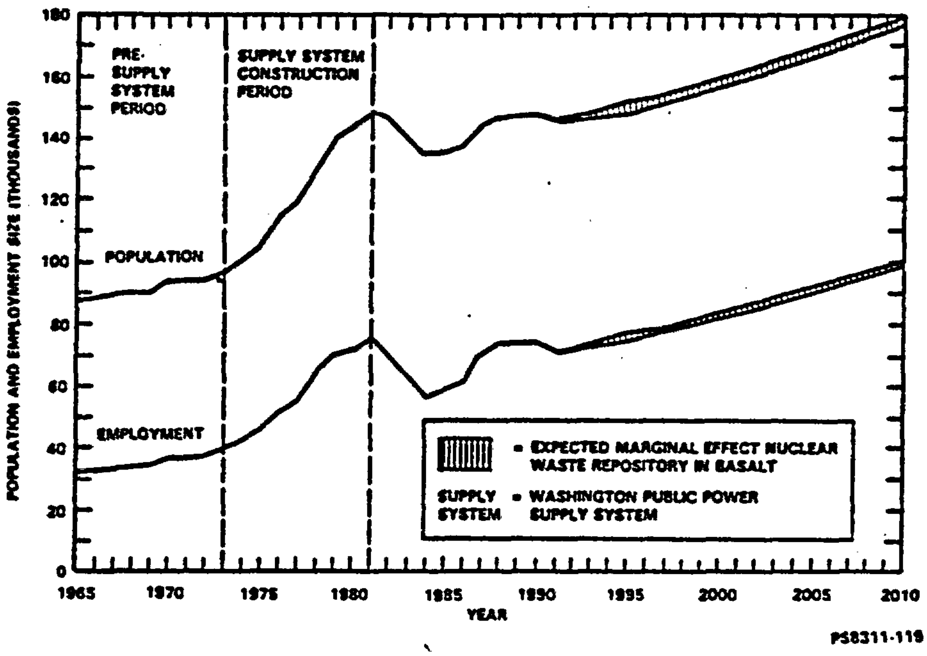

Figure 5-12. Employment and population proiections in Benton and Franklin Counties.

work force requirement will be miners. This is important for a socioeconomic assessment because miners are in short supply in the regional labor force and, therefore, a high proportion of them can be expected to in-migrate.

- Resource requirements. The development of a repository at the Hanford Site would clearly have impacts that go beyond work force-related effects. For example, constructing and operating a large, mined repository will involve the acquisition of materials and supplies, which can have an impact on the local economy. These resource requirements are not precisely specified at this time. They are indirectly accounted for in the discussion below as part of the secondary economic effects of the repository development activity.

5.2.3.1 Population density and distribution

The expected demographic effects of the repository are evaluated in terms of the total growth in regional population that is likely to be directly caused by the project. The maximum increase in population size over the base population that would be caused by the repository is estimated to be 3,900. This will have been achieved by about 1995. Thereafter, the population effects of the project would decline with declining work force size requirements to approximately 2,900 persons more than the base population in 1999 through the year 2010. These population estimates account for persons in-migrating to work directly on the repository, secondary employment growth caused by the project, and family dependents associated with both groups. They represent an upper bound estimate. If it is assumed that only 75 percent of all mining personnel in-migrate and 25 percent of all other personnel in-migrate, then a more likely estimate of the peak population increase would be about 1,700 persons in 1995, declining to about 1,100 persons between 1999 and 2010. This analysis will assume the maximum estimate as a conservative approach to assessing potential impacts.

The peak population effect of the repository represents approximately 2.6 percent of the forecast baseline population expected to be resident in the study region at that time under the optimistic growth scenario discussed earlier. The average population growth caused by the repository during this period is likely to be less than 2 percent of the baseline population (see Fig. 5-12). Since this population will be dispersed residentially throughout the Richland-Kennewick-Pasco metropolitan area, and to a lesser degree to other communities within commuting distance, the effects on population density are expected to be negligible.
Section 3.6.1 discussed how population growth in the region historically has been concentrated around the largest existing communities. The process of annexation of residential land adjacent to urban core areas has helped maintain a fairly constant urban density in recent years. Future settlement of the new population that would be attracted to the region by the proposed repository can be expected to follow a similar pattern, with

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most of the settlement occurring in or near the Tri-Cities. The relatively small numbers of in-migrants that are expected due to the repository should not have a measurable effect on population density in this area. Since most of the new settlement is expected to be small and to take place in existing urban residential areas, no adverse impacts on agricultural lands are likely. The overall effect on demographic conditions is clearly small relative to the expected baseline and also compared with the population dynamics experienced in the study region in recent years.

5.2.3.2 Economic conditions

This subsection focuses on population and employment because those aspects of the socioeconomic character of the region are considered to be the primary determinants of socioeconomic impacts. Income and living standards, major markets, business growth and capital availability can largely be traced to changes in employment. The economic base model used here essentially captures these other attributes of the region's economic conditions through the use of the secondary employment multiplier. In the Tri-Cities area, income and living standards are quite high on both a state and national comparative basis, due to a young, high technology and highly educated work force. The area has many of the attibutes of a regional trade center with a highly developed, complex economy. Major aspects of the economy are characterized in terms of the larger employers (see Section 3.6). The proposed repository development is not expected to alter these characteristics of the region. U.S. Department of Energy and agricultural employment, for example, are dependent on factors other than the proposed repository development. Growth in the agricultural sector is expected to continue in the future as new land comes under irrigation and expectations of U.S. Department of Energy related employment growth are based on increased use of U.S. Department of Energy facilities and on defense, research. nuclear material production and energy

The maximum increase in employment and population due to the repository would be observed in the mid-1990's. At that time, the total employment in the region could increase by over 2,400 jobs because of the repository, and the population in the region could increase by almost 3,900 persons. Thereafter, the repository-induced employment would decline to approximately 1,200 as the construction activity winds down. Secondary employment should remain relatively stable during the transition from the construction to the operational phase. In the operational phase, from the year 2000 onwards, the repository can be expected to generate over 1,800 direct and indirect jobs and an increase in population of nearly 2,800 persons, although in reality this number will be smaller due to some portion of the jobs that will be taken by persons already living in the study region. The expected marginal growth effects of the construction and operation of the repository on employment and population are illustrated in Figure 5-12. Table 5-10 shows the projected baseline population (without the repository) in the study region between 1980 and 2010 in 5-year increments, the total potential impact of the repository in

Table 5-10. Projected baseline population and repository impact: 1980 to 2010.

Year	Baseline popuation projection[a]	Maximum population impact due to repository[b]	Percent (maximum) repository of baseline	Likely population impact due to repository[c]	Percent (likely) repository of baseline
1980	144,469				
1985	134,992				
1990	147,484	742	0.5	375	0.3
1995	148,281	3,890	2.6	1,735	1.2
2000	157,154	2,969	1.9	1,190	0.8
2005	167,173	2,826	1.7	1,111	0.7
2010	178,496	2,826	1.6	1,111	0.6

[a]For Benton and Franklin Counties, based on Cluett et al. (1984).
[b]Assumes all jobs are taken by in-migrants.
[c]Assumes 75 percent of mining jobs and 25 percent of non-mining jobs are taken by in-migrants.

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[a]For Benton and Franklin Counties, based on Cluett et al. (1984).
[b]Assumes all jobs are taken by in-migrants.
[c]Assumes 75 percent of mining jobs and 25 percent of non-mining jobs are taken by in-migrants.

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causing new population growth in the region (assuming all new jobs are filled by in-migrants), and an estimate of the more likely size of population in-migration due to the repository.

Under the optimistic future growth scenario assumed for this analysis, the region is not likely to have excess resources or capacity after the mid-1990's. On the other hand, it is not likely to be overextended either. In fact, for the first time since the early 1980's, the region would be entering a phase of economic activity exceeding the levels it had reached in the past. Even though the region will have "caught up" with its former levels of population and employment, the rate of growth will be considerably less than that which was caused by growth in Washington Public Power Supply System construction activity. Also, during the early 1990's the projected restart of WNP-1 would be nearing completion as the repository is starting construction, and many workers finishing WNP-1 construction could be expected to be available to start work on the repository. To account for the possibility that many jobs on the repository could be filled by workers already living in the study area, two alternative population growth scenarios were presented in Table 5-10; however, the more conservative approach is taken in the analysis of potential impacts that all jobs will be filled by in-migrants.

Quite independent of whether the repository-induced employment and population are positively received, the magnitude of the impacts in relation to the overall size of the employment and population in the local area needs to be noted. The repository-induced employment and population growth rates do not exceed 1.4 and 0.8 percent per year, respectively. These are average annual growth rates computed from the proposed start of the reference repository construction in 1990 to the peak of construction impacts in 1995.

During the Washington Public Power Supply System construction period from 1973 to 1978, Benton and Franklin Counties experienced an employment growth of 36,640 jobs, or 10.0 percent per year and a population growth of 52,971 persons, or 6.3 percent per year, implying an employment-based population multiplier of 1.4. Considering the relatively successful accommodation to those growth rates, it is not likely that the repository construction, under its current conceptualization and under the baseline conditions forecast for the area, will lead to negative socioeconomic impacts of any major significance in the region.

5.2.3.3 Community services

In-migrants moving into the region in the 1990's to work on the proposed repository will find available services that were developed during the high-growth decade of the 1970's. Housing vacancies are expected to be higher than they were just prior to the Washington Public Power Supply System rampdown in the early 1980's as economic activity and population growth attempts to catch up to the previous peak years during

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the expected recovery period of the 1990's. Road networks and other community support infrastructures, including health, schools, police and fire, water and sewer, and other community services are not expected to be at or very near capacity before the year 2000 due to the significant employment and population losses in the early 1980's.

The potential effects of the proposed repository on community services can be estimated by comparing a forecast of likely demand for the service due to the direct and indirect effects of the repository with estimates of the available supply of that service. Using housing as an example and assuming the baseline conditions discussed in Section 3.6, potential repository effects on region housing conditions can be estimated. At the beginning of the repository construction in the 1990's, population in the study region is expected to be somewhat below the level that was achieved by 1981 just prior to the Washington Public Power Supply System rampdown phase. In 1981, there was an estimated 2,000 vacant dwelling units in the Tri-Cities alone (see Table 3-18), not including mobile homes and trailers. Even if conservative assumptions are made of no further growth in housing stock in the Tri-Cities, and of the removal of 50 percent of the excess housing due to dilapidation, this leaves an estimated 1,000 vacant units, plus the vacant housing in the remaining area of the counties and vacant mobile homes. Assuming there are three persons per household (Malhotra and Manninen, 1980), the estimated project-related population increase of 3,900 persons would require approximately 1,300 housing units. The excess requirement of 300 units could most likely be assumed to be available through mobile homes, trailers, and in other parts of the study area outside the Tri-Cities. Futhermore, it is probable that the housing capacity will be more than adequate for the project-related population increase due to several additional factors. In fact, housing continued to increase in the area even after the population decline began in 1981, which would imply an even greater number of vacant dwellings than was used for this estimate. Also, new building undoubtedly will take place during the period of growth assumed between 1985 and 1990. Thirdly, if the WNP-1 project is undertaken, the calculation of a population increase of 3,900 is probably an overestimate because part of both the necessary primary and secondary work force will already be in place in the study area and available to be absorbed into the repository work force on completion of WNP-1. Table 5-10 provides a more likely forecast of the population growth attributable to the direct and indirect effects of the proposed repository, assuming a portion of the available jobs are taken by persons already living in the study region.

In addition to housing, traffic congestion is another major aspect of the Tri-Cities region that has been particularly sensitive to population increase and, in particular, to the traffic volume associated with activities on the Hanford Site. Traffic volume has decreased in conjunction with the decrease in activities at the Hanford Site since 1981. Also, due to an increased emphasis on transportation planning, the traffic congestion situation was improving in other ways apart from the decrease in construction activity and population. These improvements, such as better intersection design and completion of the Interstate 182

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bridge across the Columbia River, will serve to alleviate certain aspects of congestion that would otherwise have been anticipated as construction activity at the Hanford Site and population in the study area increased. The geographic setting of the metropolitan area, with the linear arrangement of the communities and the location along the Columbia River, will continue to contribute to some degree of traffic congestion. However, this congestion would be related most directly to access to the Hanford Site and limited to times of peak commuting traffic to the Hanford Site. The staggering of shift hours and the increased use of mass transportation to the Hanford Site have been used in the past to ~~try to~~ minimize commuter congestion and undoubtedly will be utilized in the future. Furthermore, the total amount of increased traffic to the Hanford Site in conjunction with the repository will be lower than that associated with the traffic related to the Washington Public Power Supply System peak construction period.

Although the period of extraordinarily high growth experienced between 1973 and 1981 in the study area had put pressure on the utilities and services of the region, there do not appear to have been any substantial gaps in the services to the population. Section 3.6.3 discussed the current conditions in the major community services (see also Cluett et al., 1984; PSPL, 1981). None of these services is expected to be significantly impacted by the projected growth in employment and population due to the repository. In fact, most of the community services will have excess capacity at the time of repository construction in 1990. In addition, the planning and development of increased capacity in community services often establishes a momentum that leads to facility expansion beyond the need dictated by current conditions. Given the largely unanticipated Washington Public Power Supply System cutbacks in 1981, it is likely that the capacity of region community services was expanded beyond the immediate needs of the residents at that time.However, with declining population and economic activity, revenues will drop and budgets will need to be readjusted. As the region proceeds through the projected decline and recovery phase, all the community services will be affected, including the staffing levels and space utilization requirements of such services as health, social services, education, and public safety. However, given adequate lead time and notification regarding future development activities in the region, the affected departments and agencies are expected to be able to adequately adjust to changing economic and population conditions.

5.2.3.4 Social conditions

During the last decade, a highly skilled labor force, from construction workers to professionals, has settled permanently around the Hanford Site with confidence that continued growth and employment opportunity was virtually assured. The unexpected rampdown of the two major Washington Public Power Supply System construction projects in mid-1981 came as a shock to this area. While it is clear that a significant decline in employment and population has taken place in the

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interim, it also appears that many residents have not yet decided whether to stay or leave. This decision depends on a number of factors, including perceptions of opportunities elsewhere and the likelihood that this area will experience a turnaround. While this study has not identified any single major development that can replace the void created by the Washington Public Power Supply System rampdown, slow but steady expansion of the U.S. Department of Energy activities and agricultural development seems likely.

Viewed against this background, the proposed repository development is a relatively small but positive contributor to area recovery from the decline of the early 1980's. Whatever socioeconomic effects on social conditions the repository might cause, they would ~~almost surely be~~ likely be on balance positive. If the repository occurs as an isolated Hanford Site activity, its longer term beneficial effects are doubtful. However, the size of the expected in-migrating work force is small enough, relative to the projected baseline population, that increases in social.disruption due to the repository (e.g., crime, family problems, mental health problems, etc.) are unlikely.

The social structure of the area may change by bringing together proponents and opponents of a nuclear waste repository. ~~A more difficult question to answer is whether the proposed repository will stimulate enough public interest to influence the level of public participation in the policy-making processes of the region or the desire of the public to become more involved in decisions regarding the Hanford Site activities.~~ One area of potential social concern is the likelihood of debate over the transportation of nuclear waste materials into the study region and related attention to local versus state concurrence rights. The Yakima Indian Nation and the Confederated Tribes of the Umatilla Indian Reservation are special interest groups that have expressed concern with regard to Hanford Site activities in the past. See insert next page ~~Although they have been designated "affected Indian tribes" by the U.S. Department of Interior under the Nuclear Waste Policy Act, that designation refers specifically to the off-reservation fishing rights of the Indians.~~

People living in the study area now are looking to the latter half of the 1980's and the decade of the 1990's for indications of the economic viability of the area--for reasons to stay rather than leave. This study projects a slow but sustained recovery for the area, and the proposed repository would serve as a stabilizing factor that would strengthen the expected rebound of the area. The analysis presented in this study indicates that large energy developments like the repository do not have to bring adverse socioeconomic impacts in their wake. Considered in context and given careful planning, the proposed reference repository could be socioeconomically beneficial for this area.

5.2.3.5 Fiscal conditions and government structures

As was the pattern during the high growth period of the 1970's, it seems probable that the greater benefits of the growth associated with the repository will again accrue to Richland and Kennewick, and to a lesser

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They have been designated "affected Indian tribes" by the U.S. Department of Interior under the Nuclear Waste Policy Act of 1982 because of their off-reservation treaty fishing rights. A consultation and cooperation agreement is currently being negotiated with the Yakimas and will be negotiated with the Umatillas if they so desire.(11)

degree to Pasco. However, the increased accessibility of Pasco, due to the Interstate 182 bridge, may make Pasco more desirable than it was previously and increase the share it receives of new activity in the future. This would place a greater burden on Pasco to be administratively prepared to take advantage of the opportunity for greater revenues and to plan for meeting greater demands for facilities, infrastructures, and services.

The kinds of fiscal issues that can be important for assessing the potential for socioeconomic impacts focus largely on the balance between revenues and expenditures and the likelihood of some lag time between the receipt of revenues and the need to make expenditures for the maintenance of an adequate standard of living. The revenues that are likely to be generated in the study area due to the construction and operation of the proposed repository will derive both directly and indirectly from wages and salaries paid to workers on the project and from expenditures for material resources. The indirect economic or fiscal benefits that can be expected have been largely accounted for in the secondary employment growth in the region (see Section 3.6.5 and Cluett et al., 1984). Furthermore, U.S. Department of Energy contractors on the Hanford Site pay sales and use taxes and business and occupation taxes in accordance with the requirements of Washington State law. Special assistance also may be made available to compensate for the tax exempt status of the Federal land on which the site would be located. Compensation may also be available for any project-induced school impacts. Aside from the usual role of the state with respect to the distribution of resources to local-level jurisdictions, the state is the negotiating point for the U.S. Department of Energy with respect to negotiations over financial assistance related to the construction and operation of the proposed nuclear repository. This negotiating body is the Nuclear Waste Policy and Review Board of the Washington Department of Ecology.

It is not as yet possible to say what will be the result of the current economic downturn associated with the Washington Public Power Supply System rampdown, because data are not yet available to specify the fiscal condition of the region during this period of economic decline. In general, in view of the record of fiscal adaptability in the Tri-Cities during the period of high growth in the 1970's, the less steep growth curve projected to be associated with the construction and operation of the repository probably will not create serious problems in management or financing for the area.

5.2.3.6 Land use, access, surface, and mineral rights

The reference repository location is within the Hanford Site which is owned by the Federal government and controlled by the U.S. Department of Energy. Through the site screening process (see Section 2.2) the U.S. Department of Energy avoided areas on the Hanford Site in which the proposed repository would present a land use conflict.

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Access to the proposed repository surface facilities will require the addition of less than 5 kilometers (3 miles) of new road (see Section 3.5.3). Site access will not interfere with other uses or security requirements on the Hanford Site; hence, no access impacts are projected.

As discussed in Section 3.4.1, lands designated for the reference repository location have been withdrawn from all forms of appropriation under the public land laws, including the mining and mineral leasing laws. Therefore, the proposed repository will not affect surface or mineral rights. Surface facilities for a repository would only occupy a relatively small portion of the reference repository location and would be approximately 3 miles (5 kilometers) from state-leased lands on the reference repository location.

5.2.4 Occupational safety and health

Mining safety associated with repository construction, operation, and closure is discussed in detail in Subsection 6.3.3.2 and summarized below. The potentially hazardous conditions that may impact personnel safety include (1) excavated opening instabilities, (2) the potential for rock bursts, (3) water inflow under high pressure, (4) the presence of methane, and (5) high rock temperature. Available geomechanics data obtained from laboratory, field, and in situ testing, and case history studies of similar underground construction projects, suggest that the effect of these potentially hazardous conditions on the construction, operation, and closure of a repository at the reference repository location can be mitigated using existing technology and will not cause significant risks to personnel health and safety.

Personnel safety associated with normal repository operations and abnormal/accident conditions is discussed in detail in Section 6.4.1. Under normal operating conditions, waste handling poses some potential for radiation exposure to personnel. Subsection 5.1.1.1 discusses some of the design features that eliminate or reduce these risks. Potential radiological hazards resulting from normal and abnormal repository operations are summarized in Subsection 6.4.1.4.

Abnormal operating or accident conditions leading to potential radiation exposure to personnel include: (1) an undetected contaminated cask, container, or vehicle in the waste handling area; (2) exposure from unshielded hot cell ports; (3) exposure to unshielded waste containers; and (4) exposure to breached casks or drums.

Abnormal operating or accident conditions that could lead to a radiological release from a loss of containment incident include (1) waste shaft hoist failure, (2) fuel assembly drop, (3) natural phenomena, and (4) explosion and fire.

This chapter has discussed the effects of locating a repository on the site. Coupled with the discussion of the effects of site characterization that is in Chapter 4, it completes the environmental analysis of the site. Chapter 6 now considers the suitability of the site for development as a repository in the light of this environmental

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analysis, and considers also the site conditions which effect the feasibility of operation of the repository. It does this by evaluating the reference repository location against the General Siting Guidelines.

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