Comments of the

YAKIMA INDIAN NATION

on the

DRAFT

ENVIRONMENTAL ASSESSMENT

for the

HANFORD SITE, WASHINGTON

under the

NUCLEAR WASTE POLICY ACT

Volume 1--Comments

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VOLUME 1 -- COMMENTS

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COMMENTS OF THE YAKIMA INDIAN NATION ON THE DRAFT ENVIRONMENTAL ASSESSMENT FOR THE HANFORD SITE, WASHINGTON UNDER THE NUCLEAR WASTE POLICY ACT

EXECUTIVE SUMMARY

The Draft Environmental Assessment (DEA) for a high-level radioactive waste repository on the Hanford Site (referred to as the Basalt Waste Isolation Project, or Hanford) in the State of Washington is biased, based on technical errors and scientifically unsupportable analyses, and does not justify a conclusion that Hanford is a suitable site for consideration as the nation's first repository.

The most glaring technical problems arise from the unjustifiably optimistic selection by DOE's contractor, Rockwell Hanford Operations (RHO), of certain critical parameters which affect the overall assessment of the Hanford site. Depending on the circumstances, RHO either over or underestimates these parameters to support a favorable analysis. The following paragraphs summarize the worst examples.

- The DEA concedes that Hanford ranks poorly in the critical areas of geohydrology, tectonics and costs. However, this is said to be balanced by a favorable geochemical environment. This conclusion is biased and inconsistent with a considerable body of evidence. The following list summarizes some of the most important issues. The specifics of these studies are discussed in the individual comments.
    - Several problem areas exist in the geochemistry presented.
        - Hanford has extremely high fluoride values in the deep groundwater. This has been shown to greatly increase plutonium solubilities, yet this possibility is dismissed by RHO.
        - Organic compounds, at concentrations found in the Grande Ronde groundwater, will reduce adsorption of americium and neptunium in the far-field.

- -- Several problems exist in the waste package subsystem performance analysis.

  - -- Corrosion is the only failure mechanism used in the analysis, in spite of the fact that NRC has questioned whether horizontal boreholes can be held open under the stresses encountered. Mechanical failure of waste packages is ignored.

  - -- All sorption data are derived from short term laboratory tests which were not conducted under the expected conditions to be encountered at depth. Therefore, the results are highly suspect.

-- RHO tends to overestimate or underestimate the following critical parameters:

- -- Pre-emplacement ground water travel times are underestimated.

  - -- Pre-emplacement ground water travel times are based on a conceptual flow model which has not been accepted by the scientific community. The RHO conceptual model has no vertical component of flow. Additionally, the NRC has stated "Further, a range of defensible models which bracket all reasonable interpretations" should have been used (USNRC, 1984). A reasonable alternative interpretation is discussed in the technical appendix (i.e., vertical flow) - this alternative is not currently being considered in travel time estimates used in the EA.

  - -- Ground water travel times use an effective porosity much higher than measured in two tests done in the Grande Ronde flow tops. An arbitrary decision was made to depend on "expert judgement" rather than real data. Use of real data would have resulted in a substantially shorter travel time.

  - -- Errors have been committed in ground water travel time analyses and large differences exist in the results provided by the various models used to support the findings. These variations are indicative of the very large uncertainties which surround these preliminary estimates of ground water travel time.

- -- Tectonic stability is overestimated.

  - -- The DEA claims that the stability of the Hanford site is assured for the next 100,000 years, because no real correlations could be found with the basement structure and surface features such as the Yakima fold belt. However, apparent correlations exist between basement structure, the Columbia and Yakima Rivers, geophysical linears and earthquake swarms which either are not discussed by RHO or not recognized.

  - -- Tectonic models exist which suggest a plate boundary could be in the vicinity of the Pasco Basin with the possibility of episodic movement.

  - -- DOE indicates that an active fault at the site would not present any problems that cannot be solved by engineering. On the contrary, an active fault in the repository would be extremely adverse and in combination with other adverse conditions should be disqualifying.

-- The DEA understates the flood and erosion potential. The Hanford site is located at the site of the most catastrophic floods in the history of the earth - the Missoula floods. However the possibility of renewed flooding is dismissed based on a scenario of a 50% breach of the Grand Coulee Dam.

-- Model boundary conditions used to generate the flow path are arbitrary and have little or no field data to support their use. The YIN modeling could not duplicate the flow path used in the DEA, when field-verified internal pressures were assigned. This indicates that the Rockwell boundary conditions or permeability ratios, or both, are wrong. Since the flow path is determined primarily by boundary conditions, it follows that the flow path used in the DEA is wrong.

-- Flow paths are not reflective of RHO's own geochemistry research. Presentations at BWIP hydrology workshops have shown that mixing and vertical movement of water is possible in several areas of the Pasco Basin, including the Cold Creek Barrier area. The YIN geochemistry analysis indicates that vertical movement of water is occurring in the Pasco Basin. However, DOE has assumed no vertical movement in the flow path and travel time estimates.

-- The DOE method for ranking sites is not quantitative or based on geologic criteria important to isolation potential. A numerical weighting scheme was overlayed on the subjective opinions of individuals who have strong biases and the results do not reflect an intelligent assessment of the desirability of the sites for waste isolation. It has been shown in an independent analysis, using U.S. NRC's model and U.S. EPA's published data and scenarios, that Paradox is far safer than Hanford in terms of health effects, and therefore should be ranked higher than Hanford. It is our opinion the DOE rankings, which place undue emphasis on a variety of rock types, is a thinly veiled ploy to keep as many federally-owned sites in the running as possible.

The selection of Hanford for site characterization would defy technical and economic sense. The site is so geologically complex that enormous amounts of money would have to be spent in what would nonetheless probably be a failing attempt to characterize it with reasonable assurance. Less complex and obviously superior sites exist where characterization would be cost-effective.

The following summarizes the most critical non-technical errors and deficiencies in the DEA:

-- Contrary to DOE's claims, the repository activities would and already have damaged Yakima Indian sacred sites and cultural resources. Construction of a repository at Hanford would violate the federal American Indian Freedom of Religion Act.

-- The DEA does not reflect the overriding importance of this region to the continued existence of the Yakima Indian Nation. The Yakima religious and cultural heritage is dependent upon this land and its resources. The risk of contaminating the water, land, plants, fish, and animals is unacceptable.

-- DOE's conclusions that site ownership and control pose no problem appear to be incorrect because use of Hanford for a waste repository conflicts with rights reserved by treaty to the Yakima Indian Nation and with the conditions of DOE acquisition of the land for solely military purposes.

-- DOE fails to forthrightly disclose or consider that the location of a repository at Hanford conflicts with vital, highly sensitive, and inherently dangerous national security defense facilities on the site. Hanford is probably the most intensely used nuclear defense-related facility on earth and a prime military target. Moreover, accidents at the defense facilities could disrupt or close the repository and vice versa. This should disqualify the site according to DOE's own criteria.

-- Hanford is the only site among those under consideration which has a high population density in the immediate area. These several thousand workers are improperly dismissed by DOE because they are not "members of the general public."

-- DOE's failure to compare the sites using its own "system guidelines" hides the fact that projected waste isolation at Hanford is much worse than for any other site. The method used for comparing sites is invalid and yields misleading results unrelated to the actual merit of the sites on geologic grounds.

-- The DEA does not consider the implications of disposal of all of the nation's defense high-level waste in a repository, but rather improperly assumes that the defense waste already at Hanford will not have to be so disposed.

-- The DEA's transportation analysis does not adequately compare the sites on the basis of overall cost and risk. Hanford is the site which is the greatest distance from most of the waste.

The selection of Hanford is in clear violation of Congress's requirement that the location of the repository shall be decided according to geologic considerations. The site would never have been selected for consideration on geologic grounds. Hanford is being considered only for reasons of expediency: namely, that the site is federally-owned and used for nuclear activities. The DOE guidelines which have permitted consideration of Hanford to proceed this far are inconsistent with the Nuclear Waste Policy Act.

GENERAL COMMENTS

Introduction

The Yakima Indian Nation comments presently being submitted are preliminary. Due to the extremely limited time period for review of the lengthy EA and thousands of pages of references, the late receipt of many of those references by the YIN and its contractors, and the late approval of YIN consultation and cooperation funding for FY-85, these comments are submitted this date under protest. The YIN reserves the right to supplement these comments as need be over the next several weeks.

YIN Comment #: G-1

Statement of Issue: DEA conclusions based on projections of compliance with Environmental Protection Agency Standards for Protection of the Environment from Radioactive Waste Disposal, proposed 40 CFR § 191, are invalid due to the lack of finally promulgated standards.

Discussion: One of the most important findings in the DEA is the finding of compliance with the post-closure system guideline, 10 CFR § 960.4-1, which, in turn, refers to with the EPA standards. The DEA predicts the likelihood of such compliance for the Hanford Site based on a Working Draft #4 of the EPA standards. However, since the likelihood of changes in the final standards vis-a-vis Working Draft #4 appears high, these conclusions are meaningless. DOE cannot reach any conclusions about the likelihood of compliance with the EPA standards until those standards are promulgated in final form.

Recommendation: DOE must not issue final EAs which are not based on analysis against finally-promulgated EPA standards. If there are significant changes in the final standards compared to those draft standards on which the EAs are based, the EAs should be re-issued in draft form for comment.

YIN Comment #: G-2

Statement of Issue: The same DOE contractor that has a billion dollar stake in the selection of the Hanford site for a repository should not be used to analyze the feasibility of a Hanford repository. This presents a conflict of interest.

Discussion: Rockwell Hanford Operations, which has been the prime contractor in the site analysis and selection process, will, as things now stand, also be the contractor during the site characterization stage. If Hanford is selected as one of the three sites to undergo site characterization, contracts in the neighborhood of 800 million dollars will be accorded Hanford contractors during this stage. If Hanford is selected as the repository then billion dollar contracts for construction and operation will be awarded. Findings that have been developed by contractors having such a financial interest do not provide the necessary public assurance in the scientific objectivity of these studies that the Nuclear Waste Policy Act requires. Elementary common sense dictates that a contractor with a huge financial stake in selection of Hanford is unsuitable to perform the analysis used for site suitability and comparison.

Recommendation: DOE should either employ a different contractor to do its analysis of the technical feasibility of BWIP, or continue to employ RHO for that task on the understanding that it will not be considered for a prime contractor position for characterization, construction, or operation if the site is ultimately selected.

EXECUTIVE SUMMARY

YIN Comment #: ES-1

EA Section: 2.2.1 Preliminary findings and determinations

Page 5, paragraph 1

Statement of Issue: The hydrogeologic disqualifying condition is likely to be present at BWIP. Travel times used to determine that Hanford is not disqualified fail to comply with NRC's requests made in USNRC, 1984.

Discussion: The BWIP travel time calculations which conclude that the hydrologic disqualifying condition is not present ignore the NRC's position as shown below. Presentations by BWIP staff at BWIP hydrology workshops have indicated that the potential for vertical flow exists, based on physical and chemical interpretations, in parts of the Pasco Basin, including near the RRL. The DEA travel time estimates fail to consider this potential. The probability of vertical flow has been brought to the attention of DOE numerous times by the NRC and others, including the YIN, in the past, and evidence for vertical mixing has been presented to BWIP. Still, in spite of all this evidence, BWIP stubbornly refuses to acknowledge this situation in their flow models.

Importance to EA findings - BWIP has blatantly ignored NRC guidance and available technical data in determining whether or not the hydrologic disqualifying condition is met. Therefore the determination that Hanford is not disqualified should be withheld until BWIP complies with the requirement listed above.

Relevance to Regulations - The USNRC, 1984, states "For the purposes of resolving Performance Issues 10 through 12, a conceptual hydrogeologic model is expected to include, at a minimum, such components as hydrostratigraphic units, recharge and discharge areas, major structures and discontinuities, distribution of ground water, hydraulic parameters, locations of hydrologic stresses, and degree of transience...*A range of defensible conceptual models of the ground water system should be developed that brackets all reasonable interpretations of data.*"

Recommendation: The determination that Hanford is not disqualified is premature and cannot be justified unless and until BWIP complies with the NRC requirements.

References:

USNRC, September, 1984. "Draft Issue-Oriented Site Technical Position (ISTP) for Basalt Waste Isolation Project (BWIP)," Division of Waste Management, Section 1.0, p. 6.

CHAPTER 1

YIN Comment #: 1-1

EA Section: 1.2.1 Site Screening

Page 1-6

Statement of Issue: A recommendation of the Comptroller General does not constitute legal authority to select candidate sites for repositories on the basis of non-geologic considerations.

Discussion: After explaining that the salt sites were selected as a result of an actual screening process, the DEA states:

> Screening of sites in basalt and tuff was initiated when the DOE began to search for suitable repository sites on some Federal lands where radioactive materials were already present. This approach was recommended by the Comptroller General of the United States (1979). Although land use was the beginning basis for this screening of Federal lands, the subsequent progression to smaller land units was based primarily on evaluations of geologic and hydrologic suitability. The studies began at roughly the area stage.

As a threshold matter, this passage incorrectly suggests that DOE began its investigations of Federal lands after that approach was recommended by the Comptroller General, when in fact those investigations began several years earlier. More importantly, DOE's use of prior land use as the primary criterion for the selection of the Hanford site is inconsistent with the requirement of section 112(a) of the NWPA that detailed geologic considerations should constitute the primary criteria for the selection of sites for repositories. Having predetermined that the sites should be not only federally-owned--but also already used for radioactive material limited the universe of possible sites at the outset to a very few. This limitation had, of course, nothing at all to do with geologic considerations.

DOE argues that since the NWPA required it to identify states with potentially acceptable sites within 90 days of passage of the Act [§ 116(a)], Congress intended to endorse the Department's pre-NWPA site selection activities, including the selection of the Hanford site based on non-geologic considerations. Even if this questionable interpretation were correct, it is clear from the significance attached to the siting guidelines in the NWPA that Congress intended them to be applied at least retroactively to the site selection process for the first repository.

DOE concedes this to a point, and purports in the DEA to evaluate the suitability of the site against the individual guidelines. However, the DEA does not evaluate the process that was used to select the Hanford site against the guidelines. Since the site screening procedures specified in the guidelines [10 CFR § 960.3-2-1] were concededly not used to select the Federal sites, there is no point to an evaluation with respect to that process. However, since the primacy of geologic considerations is the statutorily required keystone of the siting guidelines, at the very least the DEA should include an evaluation as to whether site screening based primarily on geologic considerations would have militated against:

(1) fractured, saturated basalt as a host rock, or

(2) the Columbia Plateau as a geohydrologic setting, or

(3) the Pasco Basin as a preferred area within that setting.

There is substantial evidence from respected technical bodies as diverse as the National Academy of Science, the U.S. Geological Survey, the U.S. Environmental Protection Agency, and BWIP's own Hydrology and Geology Overview Committees [*See* YIN Comment # 2-4 and references, *infra*], that a reasonable geologically based screening process would have rejected fractured basalt and the Columbia Plateau as far more troublesome and uncertain a medium and geohydrologic setting, respectively, than readily available alternatives. There is even stronger evidence that virtually any geologically-based screening process would have militated strongly against selection of the Pasco Basin, with its proximity to the Columbia River and extraordinary geotechnical complexity.

In addition, as discussed in YIN Comment # 2-5, the extremely limited investigations outside the Hanford Site do not remedy this defect, as they were superficial and clearly not designed to locate the best sites in basalt.

Because the result of the process which led to selection of the Hanford site as a candidate for a repository has never been evaluated against detailed geologic considerations, as required by section 112(a) of the NWPA, the selection is invalid under the Act and the guidelines. Even if Congress did not intend for DOE to start the site screening process from scratch following passage of the NWPA, it also did not intend for DOE to continue to consider sites which would not have been selected based primarily on geologic considerations.

<u>Recommendation:</u> Either demonstrate in the final EA that the Hanford site would have been selected under a geologically-based site screening process, or remove Hanford from the list of potentially acceptable sites.

CHAPTER 2

<u>YIN Comment #:</u> 2-1

EA Section: 2.1.1, Regional geology

Page 2-5, par. 1

<u>Statement of Issue:</u> The DEA incorrectly utilizes data from a reference.

<u>Discussion:</u> The EA states "that fracture abundances in core samples range from approximately 1 to 40 fractures per meter ... (Long and WCC, 1984, p. I-69) " (page 2-5, par. 1). However, Long and WCC (1984, p. I-69) state "fracture abundance versus position in flow from surface sections for the Rocky Coulee, Cohassett, McCoy Canyon, and Umtanum flows, respectively. The total range of fracture abundance for the four flows is from 1 to 37 fractures per meter".

Importance to EA findings/conclusions: The EA incorrectly quotes Long and WCC (1984) when they assign this data to core samples when the data was obtained from surface outcrops. Not only is this incorrect, but Long and WCC (1984, p. I-68) state "...fractures measured in surface outcrops probably do not reflect the rock mechanics characteristics of basalts at depth...."

<u>Recommendation:</u> The EA should change the statement "fracture abundances in core samples range from approximately 1 to 40 fractures per meter..." to "...fracture abundances in surface outcrops range...". Also, because fracturing is being discussed in this subsection, it seems reasonable to include a discussion on core disking which is directly related to fracturing (Kim, et.al., 1984).

<u>References:</u>

Kim, K., S.A. Dischler, J.R. Aggson, and M.P. Hardy, 1984. <u>The State of Insitu Stresses Determined by Hydraulic Fracturing at the Hanford Site</u>, SD-BWI-TD-014, Rockwell Hanford Operations, Richland, Washington.

Long, P.E. and Woodward-Clyde Consultants, 1984. <u>Repository Horizon Identification Report</u>, Volumes 1 and 2, Draft SP-BWI-TY-001, WCC for Rockwell Hanford Operations, Richland, WA.

<u>YIN Comment #:</u> 2-2

EA Section: 2.1.4

Page: 2-21, Regional ground-water hydrology

<u>Statement of Issue:</u> YIN exclusion from the Interagency Hydrology Working Group frustrates effective consultation and cooperation with respect to a key technical issue regarding the suitability of the Hanford Site for a repository.

<u>Discussion:</u> The Draft EA states: "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 Survey, Pacific Northwest Laboratory, and Basalt Waste Isolation Project who share data and conduct computer-model studies to examine hydrologic properties and ground-water flow dynamics within portions of the Columbia Plateau, particularly those areas surrounding the Pasco Basin."

As should be apparent from the comments here and those on earlier DOE work products, the question of regional groundwater movement is a major concern for the Yakima Indian Nation. Exclusion of YIN representatives from the activities of the IHWG constitutes a fundamental frustration of YIN cooperation and consultation with regard to these crucial hydrologic issues.

Importance to EA findings/conclusions - The YIN is unable to adequately exercise its legitimate review of DEA hydrologic conclusions because of YIN exclusion from the key forum for resolution of those issues. Exclusion of NRC, other affected Indian tribes, and Washington State from that forum are equally unacceptable.

<u>Recommendation:</u> In order to adequately fulfill their consultation and cooperation responsibilities, the YIN, other affected Indian tribes, the NRC, and Washington State should immediately be brought fully up-to-date on the past work of the IHWG, and should be included in all future IHWG sessions.

<u>YIN Comment #:</u> 2-3

EA Section: 2.1.4.1 Regional groundwater chemistry.

Page 2-31

<u>Statement of Issue:</u> The range in concentration of major chemical constituents presented in Table 2-1 of this section does not reflect the full range encountered in the Columbia River Basalt Group.

Discussion: Regional groundwater chemistry data compiled by DOE for the Pasco Basin is presented in a summarized form in Table 2-1, titled "Range in concentration and mean composition of major chemical constituents within groundwater of the Columbia River Basalt Group." The data presented is not representative of the whole Columbia River Basalt Group because very few wells penetrate the deep basalt flows. Most of the samples were taken from wells that penetrate multiple shallow aquifers (the unconfined aquifer and the Saddle Mountain and Wanapum Basalts). The samples are mixtures of distinct groundwaters and do not characterize the groundwater of any particular unit.

Importance to EA findings/conclusions - The results shown here indicate that very little is known about the regional groundwater chemistry in the Pasco Basin. It is not currently possible to evaluate the origin and evolution of the groundwaters. Groundwater evolution could provide a useful key to understanding groundwater flow paths in the region. An alternate of existing data is presented in the Technical Appendix.

Recommendation: Quality control for data used in the analysis of regional groundwater chemistry must be implemented by DOE. Composite samples (taken from a number of hydrogeologic units penetrated by open boreholes) are not useful in the characterization of the groundwater chemistry. Rather, data from deeper basalt horizons could be evaluated to postulate likely groundwater flow paths for the site.

YIN Comment #: 2-4

EA Section: 2.2

Page 2-38, Site Screening Process

Statement of Issue: The DEA incorrectly contends that the suitability of basalt as a repository host rock was a major consideration in the selection of the Hanford Site as potentially acceptable for a repository.

Discussion: The DEA states:

> 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 ... crystalline rock types in the U.S., 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.... 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.

If the suitability of basalt as a repository host rock had really played any significant role in the initial DOE screening decision, the area screened would not have been limited to the Hanford Site and immediately surrounding Pasco Basin. Rather, the entire Columbia Plateau and any other suitable basalt settings would have been screened. It cannot be seriously contended that Hanford is technically the best or even one of the better basalt locations, in light of its proximity to a major river system and its exceedingly complex geologic and hydrologic conditions.

On the contrary, it is almost universally acknowledged, and has even been noted by BWIP's own Hydrology Oversight Committee and the National Academy of Sciences, that the Hanford Site is a candidate for a repository for sociopolitical reasons, not because of its geologic suitability. (BWIP, 1980; NAS, 1983). DOE should not insult the intelligence of EA readers by suggesting otherwise.

Recommendation: Any pretense that the geologic suitability of basalt had any significant role in the selection of Hanford as a repository candidate site should be eliminated from the EA, and the entire Columbia Plateau and any other suitable basalt settings should be screened before a site is selected in basalt.

References:

BWIP Hydrology Overview Committee, Report on Hydrologic Studies Within the Columbia Plateau, RHO-BWI-LD-50, p. III-3 (1980).

National Research Council, A Study of the Isolation System for Geologic Disposal of Radioactive Wastes, National Academy Press, p. 155 (1983).

YIN Comment #: 2-5

EA Section: 2.2.1.1

Page 2-41 Identification of site localities

Statement of Issue: The extremely limited investigations outside the Hanford Site were superficial and clearly not designed to locate the best sites in basalt. The Hanford Site was not selected from the universe of potentially acceptable basalt sites on the basis of any legitimate screening whatsoever.

Discussion: The DEA states: "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 were located in a natural region outside, but contiguous to, the Hanford Site." By limiting the scope of screening to areas contiguous to Hanford, DOE probably excluded superior, structurally and hydrologically less complex areas within the Columbia Plateau, but farther from the river. Indeed, the very limited areas outside the boundaries of the Hanford Site which DOE purportedly considered (See Figures 2-20 and 2-21) were even closer to the Columbia River than is the RRL, thus prejudicing even the severely restricted "screening" that was done.

In addition, the "obviously superior" standard of comparison purportedly used by DOE is totally inappropriate for use in an actual initial screening. That standard has been used for comparison of a proposed action against alternatives where a license application has already been submitted to NRC for a nuclear power plant. It has no application in the initial site screening for a repository.

Once basalt was selected as a candidate geologic medium, and the Columbia Plateau was selected as a candidate geohydrologic setting, the entire Plateau should have been screened to attempt to locate--if not the best sites--then sites which are among the best which could be found in basalt. A minimum of two basalt sites within the entire Columbia Plateau should have been considered to ensure that the basalt site selected was not the worst possible basalt site. (There are many indications that the Hanford site is precisely that.)

The NWPA calls for sites to be selected as candidates for site characterization primarily on the basis of "detailed geologic considerations." (NWPA § 112(a)). The site screening process prescribed in DOE's recently promulgated general siting guidelines, 10 CFR Part 960, and now being implemented for the second repository candidate sites, is consistent with this NWPA requirement. The Hanford site was selected prior to enactment of the NWPA and promulgation of the guidelines, and DOE maintains that siting decisions which preceded the NWPA enactment were not intended by Congress to be revisited. Nevertheless, DOE concedes, the previously selected sites should satisfy the NWPA and the siting guidelines after the fact.

The selection of the Hanford Site as the beginning point for identifying a site in basalt does not satisfy the NWPA, as that selection was not based on "detailed geologic considerations", but rather on prior land-use. 49 Fed. Reg. 47716, Col. 2. No place in the NWPA does it state that land use (or convenience) is a legitimate starting consideration in the selection of candidate repository sites. Indeed, there is no statutory exception to the requirement that detailed geologic considerations constitute the primary criteria for site selection. Thus, the Hanford Site was not selected on the basis of any screening process which is legitimate under the NWPA, and its selection is therefore invalid.

Recommendation: Defer consideration of a basalt site for a repository until a statutorily legitimate screening of possible basalt sites based on their geologic characteristics has been completed.

CHAPTER 3

Introduction

Many matters discussed in Chapter 3 of the Draft EA are also discussed in other chapters, most notably Chapters 6 and 7. Because of insufficient time and resources, many Yakima Indian Nation concerns which pertain to Chapter 3 are commented upon not here, but rather in our comments on Chapters 6 and 7.

YIN Comment #: 3-1

EA Section: 3.3.1.3.3 Flood potential

Page 3-65, paragraph 1

Statement of Issue: Using 50% breach of Grand Coulee Dam as probable maximum flood is not realistic.

Discussion: Basing the maximum flood potential of the area on a partial dam failure appears unrealistic. A complete failure scenario should be studied.

Recommendation: Show an analysis of a 100% failure of Grand Coulee Dam.

YIN Comment #: 3-2

EA Sections: 3.3.2.2 Alternative groundwater flow concepts
6.4.2.3.5 Site subsystem performance

Pages 3-91, 6-77 par. 3, 6-264, 6-265 par. 3

Statement of Issue: The choice of Alternative Flow Concept B is premature and provides longer travel times than Concepts C and D in light of EPA's definition of accessible environment.

Discussion: The calculated groundwater travel time estimates presented in the EA are based on the assumption that groundwater flow away from the repository is confined to the adjacent flow top. In this assumption, travel times are based on a distance to the accessible environment of 10 kilometers. However, vertical flow needs to be taken into account, as demonstrated in the available data, especially in light of EPA's definition of the accessible environment. As shown on page 6-264 of the EA, the accessible environment may be as close as approximately 2 kilometers, or 5 times less than is now being assumed.

Recommendation: Vertical flow must be taken into account in travel time estimates to determine the fastest path to the accessible environment.

YIN Comment #: 3-3

EA Section: 3.4.1 Land Use

Pages 3-94 - 3-96

Statement of Issue: The discussion of land use on the Hanford Site is totally inadequate in that it fails to describe current institutional activities on the site.

Discussion: Section 3.4 of the EA purports to be a description of the environmental setting of the Hanford Site, and section 3.4.1 is supposed to be a description of land use in and around the site. The DEA notes that the Hanford Site

> was established in 1943 as a national security area for plutonium production. The Major activity on the Hanford Site continues to be nuclear materials production and activities related to nuclear energy. These activities are primarily carried out in the 100, 200, 300, and 400 Areas of the Hanford Site.

(p. 3-94). Except for showing the locations of these areas in Figure 3-38, and pointing out additional nuclear activities carried out within the Site boundaries by the State of Washington and WPPSS, that brief passage appears to be the EA's only description of the existing nuclear activities at Hanford.

* There is no mention of the 150 million gallons of defense high level wastes--some of which have already leaked into the ground and contaminated the shallow aquifer; nor is there any discussion of the implications for a repository of final disposition of those defense wastes.

* There is no mention of eight abandoned plutonium production reactors.

* There is no mention of the numerous cribs and trenches and ponds into which highly contaminated (both radiologically and chemically) materials have been dumped for 40 years, and which have also contaminated the shallow aquifer.

* There is no mention of the effluents from the PUREX Plant or the high and unexpected releases of radioactive and chemically toxic materials from that facility since it was restarted in the past couple of years.

Any objective observer of the present Hanford environment would have to note as its most salient feature the fact that it is one of the most intensively used nuclear parks on the Earth. *See* YIN Comment # 6-5, *infra*. Yet the DEA in its description of Hanford land use says virtually nothing about the institutional activities which have wrought changes in the natural environment at Hanford over the past 40 years. The discussion of radiological conditions in section 3.4.2.7 does not adequately remedy this omission in the DEA. [*See* YIN comment # 3-4, *infra*.]

Recommendation: Include descriptions of the current nuclear activities at the Hanford Site in the final EA.

YIN Comment #: 3-4

EA Section: 3.4.2.7 Radiological conditions

Pages 3-105 - 3-109

Statement of Issue: The DEA does not adequately discuss the radiological effects of past and current operations at the Hanford Site on the environment and on Yakima Nation resources, and does not adequately consider the effects of biological magnification.

Discussion: The DEA states:

> 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 doses resulting from ingestion of any of these wildlife forms that might migrate off the Hanford Site would be well below applicable federal radiation protection standards. Fish from the Hanford 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 quantification of any differences. Cesium-137 levels in Hanford Site deer over a recent 2-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.

(p.3-108). The statement that the radioactive contamination of fish and other animals in and around Hanford is sufficiently low is unacceptable. The Yakima Indian Nation does not accept any increase in the level of contamination in the fish which the Yakima people have Treaty-guaranteed rights to take from the river, nor in the plants or animals which they have Treaty-guaranteed rights to gather and hunt on Yakima Ceded Lands. When the ancestors of present-day Yakimas signed a Treaty with the government of the United States, they reserved to themselves the

Yakima Indian Reservation and the rights to fish in usual and accustomed places, and to hunt, gather natural foods, and graze animals on Ceded Lands.

At that time, none of those natural resources was contaminated by man-made effluents of any kind. If they had been known to be contaminated, they would have had little or no value to the Yakima people. In other words, what the Yakimas retained when they ceded most of their lands to the United States was the right to take uncontaminated fish and plants and animals. That Treaty, which remains as valid today as when it was signed in 1855, still guarantees the Yakima people the right to take uncontaminated fish at usual and accustomed places and to gather and hunt uncontaminated plants and animals. Consequently, the United States may not intentionally engage in activities which deny the Yakimas those rights.

Whether the levels of contamination are within present-day limits prescribed by the United States or the State of Washington is immaterial to this issue. What matters is the understanding of the Yakimas who entered into the Treaty. They can only have understood that the natural resources which they were retaining for themselves would be untainted and pure, as they were when the Creator put them on the Earth for the Yakimas to use.

Besides ignoring the implications for Yakima Nation Treaty rights from Hanford-related contamination, the EA lacks any study of the ecological factors involved in the uptake and accumulation of Hanford-produced discharges into the ecosystem. Section 3.4.2.7.5 does not cite or discuss studies of the concentration of radioactive materials in organisms. Fresh-water invertebrates of all classes studied in the Columbia River and White Oak Lake exhibited maximum concentration factors which ranged from less than 100 to more than 100,000. Bacteria have even a greater power for concentrating radioactive materials and their concentration factors may exceed 1,000,000. The following general statements briefly outline the contours of this issue:

A. Radioactive materials are taken into the body of an organism either through physiological processes and incorporated directly into the tissues or they are attached to the surfaces of the organisms through adsorption.

B. The concentration of certain radionuclides reaches a higher level in many of the lower plant and animal forms, such as bacteria, protozoa, and phytoplankton, than in higher forms such as vertebrates. In such instances, there is an inverse correlation between the complexity of body structure and the concentration of the radionuclide in question.

C. Certain plants and animals have a predilection for concentrating specific radionuclides in different tissues. For instance, iodine is concentrated in the thyroid tissues.

D. Although radionuclides may occur in amounts acceptable for drinking water, concentration of these elements in organisms, aquatic and terrestrial life may reach harmful levels.

Considering the large amount of fish used in the home by the members of the Yakima Indian Nation and the fact that they continue to rely heavily on a gathering economy in areas contiguous to the Hanford Site, a thorough study of the cumulative effects biological magnification of radioactivity in the ecosystem is called for.

Recommendation: The final EA must include a thorough discussion of the implications of all Hanford-related contamination on Reserved Treaty Rights of the Yakima Nation, as well as assess the implications of biological magnification in the ecosystem.

References:

National Academy of Sciences, Publication 551 (1957), The Effects of Atomic Radiation on Oceanography and Fisheries, pp. 28-103.

Davis, J.J., R.W. Coopey, D.G. Watson, C.C. Watson, C.C. Palmiter, and C.L. Cooper, 1952. The Radioactivity and Ecology of Aquatic Organisms of the Columbia River. USAEC Document HW 25021:19-29.

Washington State University, The Socio-economic Status of the Yakima Nation. Circular 397.

Pacific Northwest Laboratory, Yakima Indian Nation Report, Indian Household Survey, 1972.

Treaty with the Yakimas, 12 Stat. 951, 1859.

YIN Comment #: 3-5

EA Section: 3.4.6 Archaeological, cultural, and historical resources

Page 3-119

Statement of Issue: The EA ignores the fact that a major Yakima Indian cultural site (Gable Mountain) has already been damaged and desecrated by the BWIP project.

Discussion: As discussed in YIN comments # 6-6 and 6-8, the EA is deficient in its discussion of Indian religious and cultural sites, and cites references for conclusions which they do not support.

Recommendation: Site selection activities at Hanford should not proceed until Yakima sacred locations have been protected by agreement between the DOE and the Yakima Indian Nation.

CHAPTER 4

YIN Comment #: 4-1

EA Section: 4.1.1.5.1 Hydrochemical characterization, groundwater sampling.

Page 4-9

Statement of Issue: There is a need for a specific Quality Assurance/Quality Control plan that describes future groundwater sampling events to assure that the locations and parameters critical to the proper characterization of the site are properly measured.

Discussion: This section of the EA briefly outlines the parameters that will be evaluated to further characterize the in situ groundwater environment. Existing boreholes need to be re-sampled to check for temporal variations in chemical constituents and to determine if samples taken during well construction are representative of the formation groundwater. The EA does not specify which existing boreholes will be re-sampled.

To analyze the spatial variations in chemical constituents, new boreholes will be drilled. The EA does not specify the number or location of these new boreholes, nor does it identify areas that need further characterization. There is no provision to drill below the Grande Ronde Basalts in an effort to characterize groundwaters in the pre-Miocene sub-basalt sediments. The pre-Miocene sediments must be characterized to evaluate the possibility of upward migration of groundwater.

Importance to EA findings/conclusions - The EA lists only general groups of parameters to be analyzed in future sampling events. A detailed list of parameters should be included to determine if samples will be collected for organic compounds and dissolved methane gas concentrations.

Recommendation: Without full analysis of organic carbon and methane gas in the groundwater, compliance with favorable condition (2) of the geochemistry section of the DOE General Siting Guidleines (10 CFR 960.4-2-2) should not be claimed.

YIN Comment #: 4-2

EA Section: 4.1.1.5.2 Hydrochemical characterization, sampling techniques.

Page 4-9

Statement of Issue: The DOE effort to evaluate and improve sampling techniques and to estimate the effects of drilling mud on sample quality indicates that past samples have been subject to inadequate sampling techniques and possible contamination.

Discussion: The need for improvement in sampling techniques and estimation of the effects of drilling mud on sample quality indicates that the BWIP is concerned with the quality of their groundwater samples. Reviews by the USGS (USGS, 1983) and PNL (Burnham, 1983) specify a number of deficiencies in the DOE sampling program, particularly in the areas of quality control and data presentation. Sampling techniques can be significantly improved for dissolved gas measurements and redox conditions. Drilling muds were found to have a deleterious effect on carbon isotope and organic carbon data most prominently. In the sampling results for borehole RRL-2, the contamination of some samples was noted by high tritium concentrations from the Columbia River water used in the drilling mud. The DOE has not indicated how the USGS and PNL criticisms would affect the validity of past hydrochemical sampling results.

Importance to EA findings/conclusions - The evidence indicates that past sampling results are suspect because of inadequate sampling techniques and/or contamination. This uncertainty is not reflected in the assignment of favorable and potentially adverse conditions in the DOE General Siting Guidelines, 10 CFR 960.4-2-2.

Recommendation: The validity of past groundwater samples must be considered. The effects of drilling mud contamination of samples must also be determined. The results of past groundwater sampling must be scrutinized to determine if the samples are representative of the formation groundwater.

References:

Burnham, J.B., 1983. "Basalt Waste Isolation Project Review by Pacific Northwest Laboratory's Review Team," (letter from D.E. Oleson to A.G. Fremling, November 29, 1983), 216 pp.

U.S. Geological Survey, 1983. "Review Comments by the U.S. Geological Survey on Site Characterization Report for the Basalt Waste Isolation Project," DOE-RL-82-3, (letter from J.B. Robertson, Chief, Office of Hazardous Waste Hydrology, to O.L. Olson, Project Manager, BWIP, May 6, 1983), 60 pp.

<u>YIN Comment #:</u> 4-3

EA Section: 4.1.1.5.3 Hydrochemical characterization, radionuclide transport.

Pages 4-9, 4-10

<u>Statement of Issue:</u> The planned DOE radionuclide transport studies are described in a very vague manner and important points necessary to evaluate the validity of the experimental procedure are not included. These studies concern radionuclide transport in the near- and far-field environment.

<u>Discussion:</u>

1) The transport characteristics of "significant" radionuclides would be studied in these experiments, but the selection process for these significant radionuclides is not included.

2) DOE experimental procedures for sorption studies have had many deficiencies in the past (noted in comments for Section 6.3.1.2.1) and there is no evidence here that the DOE has corrected these deficiencies.

3) There has been no characterization of organic compounds in the groundwater, despite the fact that they would be important in the complexation and transport of radionuclides (Means et al., 1978, and many others).

4) The effect of high concentration of methane gas in the Grande Ronde groundwater is not addressed. Radiolysis of methane could cause the formation of organic compounds that would act as complexing ligands for radionuclides (Burnham, 1983).

5) The extrapolation of field sorption characteristics to other radionuclides using laboratory data is of questionable validity. There is no explanation of the assumptions and procedures necessary to accomplish this step. It is not explained how field sorption studies will be done.

6) A critical point not included in this discussion of radionuclide transport is the range of temperature, pressure, Eh, pH, and groundwater compositions to be covered by these experiments. As noted in the comments for Section 6.3.1.2.1, it is important to characterize the full range of geochemical conditions expected in the repository during waste-emplacement, containment, and isolation periods.

Importance to EA findings/conclusions - Presently, there is considerable uncertainty in the determination of radionuclide transport factors in the near- and far-field. These uncertainties are overlooked when determining the presence or absence of favorable and potentially adverse conditions from Section 960.4-2-2 of the DOE General Siting Guidelines.

Recommendation: The DOE should justify its assignment of favorable and potentially adverse conditions in light of these considerable uncertainties.

References:

Burnham, J.B., 1983. "Basalt Waste Isolation Project Review by Pacific Northwest Laboratory's Review Team," (letter from D.E. Oleson to A.G. Fremling, November 29, 1983), 216 pp.

Means, J.L., D.A. Crerar, and J.O. Duguid, 1978. "Migration of Radioactive Wastes: Radionuclide Mobilization by Complexing Agents," Science, Volume 200, pp. 1477-1481.

YIN Comment #: 4-4

EA Section: 4.1.1.6.4, Geomechanics characterization

Page 4-14

Statement of Issue: There is insufficient evidence to support a conclusion that the repository can be constructed and operated safely; in fact, there is considerable evidence that it may not be possible to do so. The technology for excavation has not been shown to be feasible at this stage. Even if drilling is possible, the induced effects on the state of the host rock and system performance are not known.

Discussion:

1) The opening and closing of existing fractures during the shaft and tunnel construction has not been addressed and quantified in the EA. The stress and strain redistribution in the surrounding rock due to drilling is not known at the present time, and simply cannot be ignored. Quantification of the stress and strain condition is necessary to assess rock stability during drilling operations, and is important for the design of the engineered barrier system and evaluation of the repository performance.

2) The excavation of shafts and tunnels causes the development of new fractures. The effect of these new

fractures on the hydraulic conductivity and the enhancement of interconnections between existing fracture conduits is not known. These fractures will directly affect the transport of radionuclides to the biosphere along cracks and fractures adjacent to the tunnels and the vertical shaft. The probability of transport in concentrations that would exceed NRC allowable thresholds will increase drastically.

3) The effect of rock thermal expansion on the opening and closing of existing fractures is not known. Such a thermal expansion of the rock will influence conductivity and porosity of the system.

4) The degree of fracturing due to thermal effects is not known. The effects of thermally induced fractures on the hydraulic conductivity of the host rock, the circulating flow and its heat carrying capacity, followed by the opening and closing of cracks and fractures must be considered. Therefore, radionuclide control cannot be established at this time.

5) The thermal spalling effect due to the thermal shock induced by the sudden temperature increase of a surface is not known.

6) The piping effect has not been investigated. Piping is known to enlarge the flow conduits for fluids in the damaged/disturbed/intact host rock, and is a combination of chemical, hydraulic, mechanical and thermal effects.

Importance to EA findings/conclusions - All of the above factors indicate that one cannot with confidence state that the technology exists to cope with all the listed problems.

Recommendation: The potentially adverse condition for rock characteristics that *could* require engineering measures beyond reasonably available technology is "present" for the Hanford site.

YIN Comment #: 4-5

EA Section: 4.1.2.6.1 Geochemistry studies, reduction/oxidation conditions and other groundwater characteristics in the waste package and adjacent rock.

Page 4-18

Statement of Issue: Experiments on radionuclide solubility do not cover the full range of reduction/oxidation conditions expected in the near-field over the life of the repository.

Discussion: - The EA acknowledges the importance of the redox condition on the oxidation states of multivalent radionuclides. However, solubility experiments performed in the past have simulated only the reducing conditions expected in the far-field. If a major breach were to occur during waste emplacement, the released radionuclides would be subjected to oxidizing conditions in the near-field host rock, due to high oxygen fugacity and radiolysis of water into hydrogen peroxide (Neretnieks, 1982). Under these conditions, radionuclide solubilities would be much greater and adsorption would be much lower than under reducing conditions. The planned experiments would not account for the possibility of a breach of the waste package during waste emplacement.

Importance to EA findings/conclusions - The results of solubility experiments conducted under oxidizing conditions should be considered as a indicating that Potentially Adverse Condition (1) of the Geochemistry section (10 CFR 960.4-2-2), "Groundwater conditions in the host rock that could affect the solubility or chemical reactivity of the engineered barrier system to the extent that repository performance would be compromised", is "present".

Recommendation: Radionuclide solubility under oxidizing conditions should be considered since oxidizing conditions are not expected in the repository during waste emplacement. The effect of a major breach during waste emplacement should be determined.

References:

Neretnieks, I., 1982. The Movement of a Redox Front Downstream from a Repository for Nuclear Waste, SKBF/KBS Teknisk Rapport, 82-16, Royal Institute of Technology, Stockholm, Sweden.

CHAPTER 5

YIN Comment #: 5-1

EA Section: 5.1 The repository

Page 5-6, Table 5-1, Design parameter #5

Statement of Issue: The variation in radiation effects due to the type of repository waste inventory is not clearly accounted for in the engineered barrier design.

Discussion: Contrary to what is claimed, there may be a change in the potential impact between the 1982 Conceptual Design and the current single-phase concept due to the unknown radiation effects arising from different types of repository waste inventory. This statement is based on the fact that characterization of the practical consequences of radiation effects are relatively well advanced for the borosilicate glass (which is one of the current reference candidates for commercial high level waste form), but remains in early stages for other waste forms and containment materials.

Importance to EA findings/conclusions - Allocation of the type of waste in the proportion of 50% spent fuel and 50% commercial high-level fuel may not be meaningful at this stage. No conclusive environmental impacts conclusions should be drawn.

Recommendation: Further testing on various waste forms of the commercial high-level waste should be conducted to examine the radiation effects on the selected type of cannister material. In the final EA, conclusions should be supported by more comprehensive analysis.

YIN Comment #: 5-2

EA Section: 5.2.1.3.1 Ecosystems impacts

Page 5-43

Statement of Issue: The DEA's conclusion concerning threatened and endangered species is contradicted by the evidence cited.

Discussion: With respect to threatened or endangered animal species, the DEA states that, "At this time, no federally recognized threatened or endangered animal species, or their critical habitats, are known to occur within the [RRL]." This conclusion is immediately followed by the admission that

> During recent field investigations, a threatened bird

> species, the bald eagle, and an endangered bird species, the peregrine falcon, were sighted infrequently within the [RRL] boundaries; however, their presence is not common. Three additional bird species that nest in the vicinity of the RRL are now being considered as potential candidates for protection on the federal threatened and endangered species list. These are the ferruginous hawk, the Swainson's hawk, and the long-billed curlew.

The sighting of the two threatened or endangered species within the RRL, however infrequent, obviously refutes any conclusion that they are not known to occur there. At the most, the DEA could conclude that those species are not known to nest within the RRL.

Also, the presence of three animal species being considered for "threatened" or "endangered" status that nest within the RRL and several plant species being similarly considered that occur in the vicinity are too lightly disposed of in the DEA. The facts cited in the DEA suggest that the repository site may in fact have significant impacts on sensitive plant and animal species.

Recommendation: The DEA should deal more forthrightly with the potential adverse impacts on sensitive species.

CHAPTER 6

<u>YIN Comment #:</u> 6-1

EA Sections: 6.2.1.1 Site ownership and control
6.2.1.3

Pages 6-8 - 6-9
6-15 - 6-16

<u>Statement of Issue:</u> DOE may not have unencumbered ownership and control of all lands at the RRL by virtue of the method of its acquisition and Yakima Indian Nation Reserved Treaty Rights.

<u>Discussion:</u> The DEA states (p. 6-8):

> The lands designated for the RRL consist of acquired lands plus section 10 and part of section 4, Township 12 North, Range 25 East of the Willamette Meridian, which is public domain (see Fig. 2-28). Sections 10 and 4 have been withdrawn from all forms of appropriation under the public land laws including the mining and mineral leasing laws and have been reserved for use by the AEC in connection with its Hanford Site operations. The pertinent part of the applicable Public Land Order 1273 (BLM, 1956) reads as follows:
>
>> Subject to valid existing rights, the following described public lands in Washington are hereby withdrawn from all forms of appropriation under the public land laws, including the mining and mineral-leasing laws, and reserved for use of the Atomic Energy Commission in connection with its Hanford Operations.

The lands designated for the RRL with the exception of section 10 and part of section 4, Township 12 North, Range 25 EWM, were acquired pursuant to the authorization contained in Title II of the Act of 27 March 1942 (Public Law 507, 77th Congress, 56 Stat. Chapter 1995, Sec. 201 et seq.) Book IV, File Project, <u>Manhattan District History</u>, page 1.3.

Authorization for acquisition is limited to lands "deemed necessary for military or other war purposes". The Department of Energy seeks to dedicate land so acquired for limited military purposes to civilian use. Such civilian use may not be permitted of said lands. Unencumbered ownership and control of these lands for civilian purposes has not been demonstrated.

Further, the Manhattan District History, supra, shows that the usage and possessory rights of the Yakima Indian Nation were not terminated by such acquisition. Likewise, the reservation of said section 10 and part of said section 4 for Hanford operations was explicitly subject to the existing reserved usage and possessory rights of the Yakima Indian Nation.

In addition, the Yakima Indian Nation asserts that the area may not be used in any manner that would threaten or diminish the value, availability, viability, production potential, accessibility, or usability of the treaty-reserved property, water, fishing, hunting, and gathering rights of the Yakima Indian Nation or its members, or diminish or impair the enjoyment of reserved treaty water and property rights of the Yakima Indian Nation or its members. The Yakima Indian Nation submits that the Department of Energy has not sought to meet its burden of persuasion regarding many environmental impacts and the potential diminution of treaty-reserved rights to these lands and their use.

The Yakima Indian Nation submits in raising these contentions that any diminution of these rights must be with the consent of the Yakima Indian Nation, which has not been obtained. The Yakima Indian Nation particularly cites the Northwest Ordinance which continues to be the law of the land. Our national policy is firmly established in the first great act of our Congress, the Northwest Ordinance of July 13, 1787, which declared:

> Art. 3 *** The utmost good faith shall always be observed toward the Indians; their land and property shall never be taken from them without their consent; and in their property, rights and liberty, they never shall be invaded or disturbed, unless in just and lawful wars authorized by Congress; but laws founded in justice and humanity shall from time to time be made, for preventing wrongs being done to them, and for preserving peace and friendship with them.

We further cite 25 USC Sec. 177, which provides, in part:

> No purchase, grant, lease or other conveyance of lands, or of any title or claim thereto from any Indian Nation or tribe of Indians, shall be of any validity under law or equity, unless the same be made by treaty or convention entered into pursuant to the Constitution.

We further call attention to 25 U.S.C. § 194, and *Wilson v. Omaha Indian Tribes*, 442 U.S. 653 (1979). 25 U.S.C. § 194 provides:

> In all trials about the right of property in which an Indian may be a party on one side, and a white person on the other, the burden of proof shall rest upon the white person, whenever the Indian shall make out a presumption of title in himself from the fact of previous possession or ownership.

Wilson, *supra*, holds that 25 USC Sec. 194 is triggered once a tribe makes out a prima facie case of prior possession or title to the particular area under dispute, and thereafter the plaintiffs would have not only the burden of producing evidence but the burden of persuasion as well. (422 U.S. at 668-669.)

The Department of Energy has failed to consider in a forthright and complete manner the magnitude and impact of these proceedings on the Yakima Indian Nation and its members. The Department of Energy, in a cursory manner, acknowledges the reserved fishing rights of the Yakima Indian Nation and its members and the right not to have the habitat of this reserved fishery impacted. However the Department of Energy has not addressed impacts to the reserved treaty rights of the Yakima Indian Nation and its members within the Hanford Reservation site area, Columbia and Yakima Rivers, and on the treaty-reserved rights of the Yakima Indian Nation and its members in their use and enjoyment of the 1,387,505-acre treaty-reserved Yakima Indian Reservation.

It is clear from available materials that the fourteen tribes and bands of people indigenous to their region in which the RRL is located is now the Yakima Indian Nation and its members. (*See* Basic Documents listed in Appendix F.)

It is clear from available materials that these indigenous people have owned, occupied, possessed, enjoyed the lands and resources of this entire region for thousands of years and continue, as the Yakima Indian Nation and its members, to rightfully own, occupy, possess and enjoy the lands and resources of this entire region except as limited by the Treaty With the Yakimas (12 Stat. 951) or where their rightful ownership use and enjoyment has unlawfully and improperly been withheld or diminished. Basic Documents (Appendix F), *United States v. Taylor*, 3 W.T. 88 (1887); *United States v. Winans*, 198 U.S. 371 (1905); Department of Interior, Federal Indian Law, Government Printing Office (1958), pp. 146, 495-500, 599, 662; *United States v. Oregon*, 302 F.Supp. 899 (D. Ore. 1969), 529 F.2d 570 (9th Cir. 1976); *Washington v. Washington State Commercial Passenger Fishing Vessel Ass'n*, 443 U.S. 658 (1979); *United States v. Washington*, 506 F.Supp. 187 (W.D. Wash. 1980); *United States v. Adair*, 478 F.Supp. 337 (D. Ore. 1979), 723 F.2d 1394 (1983), *cert. denied* June 1984; *Kittitas Reclamation District v. Sunnyside Valley Irrigation District*, Opinion, February 6, 1985, Court of Appeals, 9th Circuit Nos. 80-3505, 81-3002, 81- 3068, 81-3069.

The area over which these rights were established and continue to prevail are set out in the Treaty With the Yakimas (12 Stat. 951). As pertains to this proceeding this area encompasses the Hanford Reservation, the Yakima and Columbia Rivers and the Yakima Indian Reservation.

The Yakima Indians have reserved rights to hunt, fish, gather roots and berries, pasture their horses and cattle, and to further their culture and religion within the Hanford Reservation, site area, Columbia and Yakima Rivers. *See* Basic Documents in Appendix F. The Department of Energy has not addressed these rights and how they will be affected or protected by these proceedings or this project.

Recommendation: The treaty-reserved rights of the Yakima Indian Nation should be addressed and these rights classified as adverse to the Basalt Waste Isolation Project.

References:

See Basic Documents in Appendix F.

YIN Comment #: 6-2

EA Section: 6.2.1.2.2 Population density and distribution

Page 6-10

Statement of Issue: DOE does not define "vicinity" when it states that 3,500 workers work in the vicinity of the RRL.

Discussion: The DEA states: "Currently, DOE and its contractors employ approximately 12,000 workers at the Hanford Site, of which 3,500 work in the vicinity of the RRL."

Recommendation: Define "vicinity".

YIN Comment #: 6-3

EA Section: 6.2.1.2.4 Population potentially adverse condition 1

Page: 6-12

Statement of Issue: The potentially adverse condition for high daytime population density appears to be present for the Hanford site.

Discussion: Potentially adverse condition (1) states: "High residential, seasonal, or daytime population density within the projected site boundaries." The DEA states: "There are approximately 700 daytime individuals, and an additional 700 shift workers, working within the boundaries of the RRL, and 3,500 individuals employed in nuclear related jobs in the vicinity of the RRL." This would appear by most measures to constitute a high daytime population density within the site boundaries, and therefore this potentially adverse condition should be deemed "present". *See also* YIN comment # 6-5, *infra*.

Recommendation: Change the finding on this potentially adverse condition to "present".

YIN Comment #: 6-4

EA Section: 6.2.1.4 Meteorology

Pages: 6-17 - 6-19

Statement of Issue: The DEA understates the potential for adverse meteorological conditions at Hanford.

Discussion: The DEA states:

> Diffusion conditions at the Hanford Site are generally good, although poor diffusion circumstances can and do occur, particularly during the winter under a northwest airflow regime. The same conditions can be found during the summer, although they occur less frequently.

In fact, poor diffusion conditions are quite common in the Hanford region in the winter. This past winter, for example, experienced an inversion which lasted more than a month. The DEA itself concedes on page 3-113 that "[m]oderately stable and very stable conditions exist 66 percent of the time during the winter." The exception which the DEA acknowledges is sufficiently common to disprove the general conclusion reached.

In addition, potentially adverse condition (1), "prevailing meteorological conditions such that radioactive emissions from repository operation or closure could be preferentially transported toward localities in the vicinity of the repository with higher population densities than are the average for the region", is quite clearly "present" at the Hanford Site. Section 6.2.1.4.4 states disingenuously that this condition is not "substantively" present, although winds blow in the direction of Richland, 22 miles to the southeast, 16 percent of the time. The monthly wind roses in Figure 3-42, p. 3-111, clearly show that the prevailing winds are from the northwest. This fact is conceded in the DEA on page 3-109. The strongest prevalence of northwest winds is recorded in the winter months--significantly, at the same time as the poorest dispersion conditions. It is impossible to reach any conclusion other than that emissions from repository operation or closure could be preferentially transported toward the high population density Richland area.

Finally, this section too lightly dismisses the potential for snow, fog, windstorms, ice, and sandstorms in the Hanford region to significantly affect repository operation or closure.

Recommendation: Meteorology potentially adverse conditions (1) and (2) should be considered "present".

YIN Comment #: 6-5

EA Sections: 6.2.1.5. Offsite Installations and Operations
7.3.1.1.2 Population Density and Distribution

Pages 6-20 - 6-20
7-68 - 7-72

Statement of Issue: The location of a waste repository at Hanford poses conflicts with vital national security defense facilities existing on the site.

Discussion: The DEA states (p. 6-20):

> Screening guidelines were adopted that excluded to the extent possible, potential repository sites that were subject to the effects of manmade hazards. These guidelines addressed potentially adverse effects from...national defense and security facilities that were interpreted as attractive military targets. (Emphasis added.)

In addition, the guidelines contain the following disqualifying condition (p.6-24): "A site shall be disqualified if atomic energy defense activities in proximity to the site are expected to conflict irreconcilably with repository siting, construction, closure or decommissioning."

Further, the guidelines contain a potentially adverse condition for the presence of nearby potentially hazardous installations or operations that could adversely affect repository operation or closure. (p.6-23) DOE concedes that this condition is present at Hanford.

While admitting that the facilities at Hanford are "potential terrorist targets" (p.6-24) and that an accident at the defense facilities could disrupt operations at the repository (p.6-24 - 6-25), the DEA reaches the clearly unjustified conclusion that the disqualifying condition is not met. It does so on the basis of a deceptively incomplete and wholly uninformative discussion of the existing national defense-related facilities at Hanford which fails to disclose the nature of the activities performed there or the importance of these facilities to the U.S. defense program. The facts are as follows:

The reference repository location encompasses the 200 West area of the Hanford Reservation and is within 2000 meters of the 200 East area (pp 2-9. 2-22. 2-27). These two areas contain a host of facilities of great national importance and are prime military and terrorist targets.

Hanford Reservation is one of two principal production sites for plutonium for nuclear weapons (The Savannah River Plant is second.) The reactor (located in the 100 Area) is one of four operating plutonium production reactors in the United States. Approximately 600 kg of plutonium annually, or about one-fourth of the new plutonium currently produced for U.S. weapons, is produced by the N-Reactor at Hanford.

The 200 areas (East and West) are locations of the fuel processing and plutonium storage facilities for the nuclear weapons material production activities at Hanford. The PUREX processing plant is located in the 200 East area. The PUREX plant processes irradiated fuels from the N-Reactor to recover plutonium for weapons as well as uranium, neptunium, and by-product cesium and strontium. PUREX was placed on standby in 1972 and restarted in November 1983. In the year following restart, it processed 1046 MT of N-Reactor spent fuel, recovering about 900 kg of weapon-grade plutonium. In FY 1985, DOE plans to process about 1200 MT of N-Reactor spent fuel, recovering about 1000 kg of weapon-grade plutonium. By the time the waste repository becomes operational, assuming the N-Reactor is still operational (DOE is currently studying ways to prolong the life of the N-Reactor), or assuming a new production reactor is sited at Hanford, it is reasonable to assume that on average about 600-700 kg of weapon-grade plutonium will be recovered annually by the PUREX plant.

Supporting the N-Reactor and the PUREX plant are four fuel facilities located in the 200 West areas, namely the UO_3 Plant, the B-Plant, the Z-Plant, and the T-Plant. the UO_3 is used for conversion of uranyl nitrate (UNH) from the PUREX plant to uranium oxide (UO_3) powder for shipment to the Fernald Plant, where it is used in the fabrication of new N-Reactor fuel elements.

The B-Plant was an early processing plant for separating cesium and strontium from high-level waste for encapsulation and storage at the Waste Encapsulation and Storage Facility.

The Z-Plant (Plutonium Finishing Plant) is used as a storage site for PuO_2 to Pu metal.

The T-Plant is an old processing plant that is now used on an irregular basis for PUREX equipment decontanimation and repairs.

With regard to future activities at Hanford, it should be noted that Hanford is one of three alternative candidate sites for the New Production Reactor. This reactor may be postponed indefinitely as DOE is currently focusing on ways to prolong the life of the N-Reactor. Refurbishing the N-Reactor appears to be a less expensive alternative. DOE also plans to modify the PUREX plant by adding a chop-leach head-end, which will enable PUREX to process stainless steel fuel. This will give DOE a capability to process a wide variety of reactor fuels at PUREX, including (with minor hardware modifications) commercial reactor fuels. Processing fuel from NRC-licensed reactors for weapons purposes is not permitted under existing law.

DOE also announced in August 1983 plans for construction and full operation of a special isotope separation (SIS) production plant at Hanford by FY 1991 that would employ the atomic vapor laser isotope separation (AVLIS) process to purify plutonium for weapons. The Hanford SIS plant will be located in 231-Z Building (at the Z-Plant in 200 West area). DOE is moving forward with plans to have an SIS plant operational at Hanford in the early 1990s. The SIS plant capacity will probably be on the order of 2 MT Pu/year.

Few would argue that the U.S. nuclear weapons production facilities would not be prime military or terrorist targets. The plutonium production facilities at Hanford are a key component of U.S. nuclear weapons production. It is likely that the N-Reactor and the 200 East and 200 West areas would all be prime targets. The 200 areas would be more attractive targets than the N-Reactor because the plutonium in storage at the 200 West area and the plutonium recovered at PUREX from existing stocks of spent fuel represent the more accessible stocks of plutonium for weapons.

Since the 200 West area is a prime military target, the Reference Repository location is at ground zero. One can only speculate what kinds of warheads might be targeted against these facilities. It is perhaps worth noting that Soviet ICBMs are believed to carry some warheads as large as 5 or 6 megatons (on SS-17 Mod 2 and SS-19 Mod 2) although most Soviet ICBM warheads are believed to be in the 0.5 to 1.0 megaton range. The Soviet bomber force is believed to carry some bombs in the 5 to 10 megaton range, as well as bombs in the 0.2 to 0.5 megaton range.

Given that most of the fuel facilities are of thick concrete construction for shielding purposes, it is reasonable to assume that the 200 areas would be targeted with high-yield warheads fused for ground burst in order to maximize the damage to the facilities. A ground burst at the Z-Plant (200 West area) or at PUREX (200 East area) could be expected to spread huge quantities (several tons) of extremely toxic plutonium -- as well as some 283 millions of curies of strontium and cesium stored at B-Plant and other fission products -- around the Hanford site and in the downwind direction.

A large megaton ground burst in the 200 areas (the Reference Repository location) could also be expected to damage physically the engineered waste repository facility and possibly change the hydrology of the overlying formations. The spread of plutonium, strontium, and cesium around the area would make further use, including corrective actions, impossible for an indefinite period into the future.

It is also noteworthy that the repository itself would become an attractive ground burst target, since the spread of radioactivity at the repository could render the weapons program facilities useless indefinitely.

Finally, it should be noted that the U.S. and, presumably, the Soviet Union have contingency plans for fighting limited and protracted nuclear wars. It is reasonable to assume that Hanford could be an attractive target under such circumstances. It is U.S. policy to limit the damage to the homeland in the event of a nuclear war. Construction of a repository at the 200 area at Hanford is incompatible with such a policy.

Also, according to the FY 1984-88 Defense Guidance, U.S. strategic doctrine asserts that, "[s]hould deterrence fail and strategic nuclear war with the U.S.S.R. occur, the United States must prevail and be able to force the Soviet Union to seek earliest termination of hostilities on terms favorable to the United States." (New York Times, May 30, 1982). Thus, it would be inappropriate to conclude that targeting Hanford facilities need not be considered in siting a waste repository because the U.S. and its inhabitants would not survive any nuclear exchange with the Soviet Union.

DOE has virtually conceded, by virtue of the screening guidelines (p. 6-20) purportedly intended to exclude sites subject to the effects of man-made hazards -- specifically encompassing "attractive military targets" - that the Hanford site is unsuitable. If the guideline has any meaning at all, Hanford i the one site that should have been excluded.

In addition, while DOE concedes that "design basis accidents at nearby facilities could result in temporary disruption of repository operations or closure" (p. 6-23), it provides virtually no discussion of the nature of the accidents in question, the nature or degree of disruption that would ensue, the probability of such accidents nor what scenarios could cause repository closure. DOE asserts that the probability of such accidents is low (p. 6-23), 7-68-71) without providing any analysis whatever to establish how low it is. It is DOE's obligation to provide all of this information in order that the suitability of this site and its comparison with the other sites under consideration can be addressed in a rational manner.

Based upon the information currently available to the YIN, a criticality accident is a design basis accident (and thus not of exceedingly low probability) for the PUREX facility. It appears that such an accident could force emergency closure or abandonment of the repository while placing the workers in peril. By the nature of such an accident, it could occur at any time - perhaps at a time when abandonment of the work then going on at the repository, even if temporary, could itself pose grave risks. In addition, one could postulate fires at other of the facilities or a criticality accident at the plutonium storage facility.

It is irrational to locate the repository at a site where the potential for disruption is so severe. At the very least, DOE must provide a meaningful discussion of the nature of this problem so that the comparison among sites in Chapter 7 can be fairly made.

There are other related sections of the DEA which similarly manifest unwillingness to fully and candidly assess the conflicts and problems that would result from siting a waste repository in the midst of numerous highly sensitive and inherently dangerous atomic energy defense facilities. For example, the guidelines contain a disqualifying condition if an adequate emergency preparedness program could not be developed (p. 7-59). We have listed above the numerous national defense facilities in proximity to the RRL. At least some if not all of these facilities cannot be evacuated. They must be secured at all times. Moreover, an accident at the repository triggering emergency response at these facilities could obviously be severely disruptive of weapons production. An accident at the repository could force a Hobson's choice: either endanger the atomic energy defense facilities or place the workers there at great peril, or, as to the remaining security force, both.

It is apparent that the defense facilities and the repository pose each other unreasonable mutual risks. This constitutes an "irreconcilable conflict" and should, pursuant to the pertinent disqualifying condition (p. 6-24), disqualify BWIP as a repository location.

Finally, it should be noted that despite conceding that approximately 5000 people work at the facilities on or adjacent to the RRL, DOE concluded that the site does not have a "high . . . daytime population" by using the remarkable expedient of disregarding these workers on the grounds that they are "not members of the general public." (p. 7-59). There is no justification whatever for this semantic concoction. The fact is that Hanford alone among the sites under consideration has thousands of people in the near vicinity on a daily basis, many of whom, moreover, cannot be practically or quickly evacuated without endangering the defense facilities. This enhances the risk to them, rather than detracting from it. The failure of DOE to consider this fact fatally skews the site comparison.

Recommendation: The evidence supports the conclusion that the Hanford site should be disqualified because atomic energy defense activities in proximity to the proposed site conflict irreconcilably with the repository siting, construction, operation, closure, and decommissioning.

References:

Cochran, Thomas B., 1985. Memorandum (March 8, 1985) from Dr. Thomas B. Cochran, Senior Research Scientist, Natural Resources Defense Council, Inc., to Ellyn Weiss.

YIN Comment #: 6-6

EA Section: 6.2.1.6 Environmental Quality--American Indian religious sites

Table 6-2 Page 6-28

Statement of Issue: The repository and its support facilities have already had adverse effects on Yakima Indian sacred sites.

Discussion: Table 6-2 deals with the American Indian Religious Freedom Act together with environmental laws. In the table it is stated that no religious or sacred sites used by American Indians have been identified at the RRL. There is nothing in the American Indian Religious Freedom Act which suggests that the scope of the analysis should be limited to the RRL. Rather, the entire BWIP project must be assessed in light of its impacts or potential for impacts on Indian religious sites.

In addition, the DEA's treatment of this subject is insultingly deficient in that effects on Indian religious sites outside the boundaries of the RRL are not considered, and references cited by the DEA for the proposition that no religious sites would be affected do not support that conclusion. In fact, those references indicate that there have already been adverse impacts from BWIP activities (the Near Surface Test Facility and various boreholes) on known Indian religious sites on the Hanford Reservation. Neither the DEA nor the references describe either the sites or the impacts on them.

See Comment # 6-8 below.

<u>YIN Comment #:</u> 6-7

EA Section: 6.2.1.6 Environmental Quality--Wild and Scenic Rivers

Table 6-2 Page 6-30

<u>Statement of Issue:</u> A wild and scenic river, the Hanford Reach of the Columbia, may be adversely affected by the BWIP Project.

<u>Discussion:</u> The DEA dispenses with the Wild and Scenic Rivers Act merely by stating that wild and scenic rivers are not located at the RRL. The Hanford Reach of the Columbia is the last free-flowing stretch of the river in the U.S. It is presently being considered for protection under the Act. That the river is not at the RRL does not dispose of this issue. Ground-water discharge from the repository to the river, as well as intermittant surface run-off from the Cold Creek basin during repository construction, could adversely affect the river.

<u>Recommendation:</u> The EA should more thoroughly evaluate the potential for adverse impacts from BWIP on a potential wild and scenic river.

<u>YIN Comment #:</u> 6-8

EA Sections: 6.2.1.6.9 Significant Native American Resources
7.3.2.1.1

Pages 6-33 - 6-34, 7-78

<u>Statement of Issue:</u> The repository and its support facilities would have, and already have had, significant impacts on Yakima Indian religious sites and cultural resources. DOE is currently in violation of the American Indian Freedom of Religion Act.

<u>Discussion:</u> Potentially adverse condition (5) is "proximity to, and projected significant adverse environmental impact of the repository and its support facilities on, a significant Native American resource, such as a major Indian religious site, or other sites of unique cultural interest." The DEA concludes that

> This potentially adverse condition is not present at the RRL since there are (1) no known significant Native American resources within or immediately adjacent to the RRL, and (2) no significant adverse impacts are projected for resources distant from the RRL.
>
> In 1981 and 1982, archaeological field surveys were conducted to intensively investigate the RRL. These studies concluded that none of the repository undertakings would have an effect on significant Native American cultural resources

(Rice, 1984a, 1984b). Therefore, although there are areas of significant Native American resources on the Hanford Site, primarily along the Columbia River shorelands 7 kilometers (4 miles) from the RRL at the nearest point, the distance of the repository from these resources indicates there would be no projected significant adverse environmental impacts.

Contrary to these DEA findings, the Rice "studies" cited do not support a conclusion that repository undertakings would not have an effect on significant Native American cultural resources. On the contrary, one of the Rice reports (Rice, 1984a) clearly suggests that repository-related activities (at the Near Surface Test Facility) have already had impacts on a major Yakima Indian sacred site at Gable Mountain. Rice also states that testing boreholes have already had impacts on other sites of archaeological significance. Moreover, the limitations in scope and general inscrutability of the Rice reports make them of little use in addressing the questions posed.

Before discussing the Rice material in detail, it is necessary to place this matter in perspective. The Department of Energy has not acknowledged the importance of the area involved. The area involved in the construction of this project contains one of the remaining pristine remnants of a regionally dense settlement system which stretches along the middle Columbia. This area needs to be approached and systematically explored rather than excavating and seeing what is found, as the Department of Energy suggests. Construction excavators do not have the proper training to ascertain the worth of the area as they proceed.

The Middle Columbia Region in prehistoric and early historic times contained one of the highest population densities in the intermountain west. It achieved this dense settlement and aggregation by virtue of its geographic situation, resource abundance, and cultural endowment. Geographically this region is dominated by the junction of three major rivers--the Yakima, the Snake and the Columbia, within a 15-mile core area. These rivers functioned as travel routes linking the interior areas with areas on the lower Columbia and the coast. Most importantly they provided an unprecedented abundance of anadromous fish.

It is not chance that the three rivers intersect here for they meet in the geographically structured topographic low of the Columbia Plateau. This low point has a mild winter climate with relatively few days of deep snow pack or extreme cold, a fact which made it a major winter ground for migrating animal populations. Included in the prehistoric fauna are elk, deer, mountain sheep, bison and pronghorn. The shrub-steppe environment of this region not only provided the major forage for overwintering animals but also fostered a variety of smaller animals available year round including rabbits, sage hens, badger, etc. The river margins supported beaver, raccoons, otter, ducks, geese, and a wide variety of small animals and birds. The seasonal migration of ducks and geese provided still another major resource in the area. Within the shrub-steppe a number of food and medicinal plants were available including several varieties of "Lomatium" and "Balsamorhiza sagittata" (arrowleaf balsamroot). Bitterroot and onions occur on the higher ridges of the Hanford Reserve.

Within the context of the rich and nucleated resource mosaic it is not surprising to find the density of settlement and use by Native American people. It is not surprising to find sites lining the river banks and scattered among the shrub-steppe. It is not surprising to find extensive cemeteries on islands and throughout the area. It is not surprising to find special religious places. Gable Mountain is one of these special places and it has already been violated by the Department of Energy in this Basalt Isolation Waste Project without consultation with the Yakima Indian Nation.

Gable Mountain and the nearby areas have especially deep significance in Yakima religious beliefs. It is their belief that the first Yakima people were created in a location in the pristine area near the mountain precisely known to the elders of the tribe. In addition, young boys were sent alone by their parents to the mountain to learn of their quest or place in life. The experiences undergone there must always remain a secret, and cannot be described to any other persons. Youths were designated during these experiences and instructed in the ways to minister to future misfortunes or maladies which would befall the Yakima people.

Further, it is not surprising in view of the fact that Native Americans have lived out their lives in this region for more than 10,000 years that the Native American people feel a deep and intimate connection to this place. In view of the fact that Native American religions are closely tied to the lands upon which their life began and continued cultural survival depends on the maintenance of usual and accustomed places, the exclusion of the Yakimas from this core of their homeland is absolutely destructive of their religion and culture.

Exploration of the area to be disturbed requires a systematic exploration by trained persons in order to comply with the purposes of the national policy set forth regarding such areas in 16 U.S.C. § 470-1. Such a systematic exploration is necessary in recognition of the rights of the Yakima Indian Nation in this area so important to its culture and religion.

Ruth Fulton Benedict, noted anthropologist (1887-1948), conceived of cultures as "total constructs of intellectual, religious and aesthetic elements". Webster defines culture as "the enlightenment and refinement of taste acquired by intellectual and aesthetic training", or "a particular stage of advancement in civilization or the characteristic features of such a stage or state".

As can be best defined by a borrowed language, the Yakima Indian Nation is a culturally-oriented people much dependent upon the natural resources of the area specifically but not limited to the water, fish, the natural foods which grow out of the ground (at least 72 types), various animals which contribute to the food chain, and numerous natural medicines which are all obviously dependent upon a safe environment.

The practice of utilizing these resources at this particular stage of advancement is no different today than has been performed since time immemorial. Without understanding what the indigenous populace is trying to define to contemporary society as "culture", the main stem of society has gone through a form of culture shock.

Again Mrs. Benedict states, "The tough minded respect difference. Their goal is a world made safe for differences, where the United States may be American to the hilt without threatening peace, and France may be France and Japan may be Japan."

Then, also, allow Yakimas to be Yakimas.

The Yakima Indian Nation's right to practice their traditional religion is securely bound into the laws of the United States. This right to practice their religion without interference is specifically protected by the American Indian Religious Freedom Act, and also covered by the National Environmental Policy Act of 1969 (NEPA). Operations at the Hanford site must not infringe upon these right. Before choosing a reference repository location, DOE has a responsibility to comprehensively assess whether operations at the proposed site would infringe on the Yakima's right to practice their religion. However DOE, in the DEA, fails to fulfill its responsibility. The DEA reaches conclusions that no Native American religious sites have been found without offering evidence that a concerted effort was made to find them.

The American Indian Religious Freedom Act reaffirms the Yakima's inherent right to practice their traditional religion. As the legislative history demonstrates, this basic right is firmly grounded in U.S. law. The House report (95-1308) to this bill states

> Native Americans have an inherent right to the free exercise of their religion. This right is reaffirmed by the U.S. Constitution in the Bill of Rights, as well as by many State and tribal constitutions. The practice of traditional Native American religions, outside the Judeo-Christian

> mainstreasm or in combination with it, is further upheld in the 1968 Indian Civil Rights Act.

As the Congressional reports reveal, the primary purpose of the bill was to prevent the U. S. Government from infringing upon the right of Indian tribes to practice their traditional religion. The bill emphasizes the Indians' broadly based rights to practice their religion freely. House Report 95-1308 interprets the Act as prohibiting Federal agencies from interfering with the right of the Indians to practice their traditional religions. DOE thus has an affirmative responsiblity to ensure that its activites at Hanford do not interfere with the Yakima's ability to practice their religion.

The YIN's right to practice their religion is also protected under the National Environmental Policy Act of 1969 (NEPA). NEPA challenges the Federal Government to do its utmost to preserve the cultural wealth of our nation. 42 U.S.C. § 4331 provides, in part, that the Nation may

> preserve important historic, cultural, and natural aspects of our national heritage, and maintain, wherever possible, an environment which supports diversity and a variety of individual choice.

The YIN religious and cultural heritage falls under the protection of this Act. NEPA also recognizes that intangibles such as protection of culture be included in the decision making process. Thus, when making siting decisions, DOE is obligated to carefully consider the proposed repository's effects upon the Yakimas' religious freedom .

In the place of making a proper survey of the Yakimas' religious sites, DOE misinterprets and misapplies the results of several archaelogical studies to reach the conclusion that "no such sites have been identified at the reference repository location" (DEA,6-28). DOE is charged with attempting to find religious or sacred sites. Not one of the surveys cited by DOE constitutes a serious attempt to locate all Native American sites that could be damaged if a repository is built at Hanford.

To support its conclusions, DOE cites several surveys performed by Dr. David G. Rice. It is true that these surveys are the closest things cited by DOE to an attempt to locate Native American religious sites . These surveys, however, have three serious flaws when used to support DOE's conclusions . First, the surveys don't attempt to comprehensively cover the Hanford area.

In the first survey (Sept. 1981), Dr. Rice covered only a limited region on the Hanford site. While he tried to cover the area encompassed by regions designated A-H on the DOE map K-258817-I, but only about half of the region was actually surveyed. For "reasons of health and safety or security," the rest of of the areas were excluded (Rice, 1984a). In this survey, Rice declares that a more detailed descriptive report needs to be done.

A second survey, performed by Rice, does not purport to be a comprehensive archaelogical survey (1984b). Instead, the second survey examines only the selected areas around the shaft starter and surface facilities (1984b). Neither of the two reports mentioned here have a large enough scope to support DOE's conclusion that the repository activites would not significantly affect a major Indian resource.

In fact, Rice 's second report explicitly states its limitations. He concludes "no further archaeological work is recommended for the BWIP as described in DOE/EA-0168." (Rice, 1984b). DOE/EA-0168, in turn, describes the construction of an exploratory shaft. It does not describe further stages of work. A more careful reading of this report than that given by DOE would recognize that further site characterization is not included in this conclusion. Thus, the Hanford area has not been comprehensively surveyed.

Secondly, there are considerable questions about the breadth of Rice's surveys. DOE cites Rice's studies as an attempt to "identify potentially important archaeological, historical, or native American religious sites" (EA,3-119). Indeed, a survey of the type described by DOE would significantly assist the determination of the repository's impact upon the Yakima's relogious and sacred sites. However, it is not clear that Rice attempted to perform such a survey.

The 1981 survey makes no explicit mention of Native American religious sites. Dr. Rice does describe the study as an "archaeological survey." (Rice, 1984a). While it may be that Dr. Rice searched for Indian religious sites in his archaeological survey, his report of the study does not so state.

In the November 1982 report, Rice alludes cryptically to "areas of potential religious significance" in an area covered by his first survey. Neither the 1981 nor the 1982 surveys describe these potentially significant sites in any manner. Nor is there mention of any attempt to contact the local Indians to verify his evaluations.

Rice's November 1984 report cites an afternoon meeting with some of Rockwell's Hanford employees to discuss the Native American Religious Freedom Act as it pertains to religious sites on the Hanford reservation. Again, there is no mention of where these sites are, of their nature, or importance. Nor does he mention how he determined that they were religious sites.

One cannot conclude from these observations that Dr. Rice systematically attempted to locate Native American religious sites. Even if the intention was to search for Indian religious sights, two brief and cryptic references to Native American Religions hardly constitute a valid survey.

The third general difficulty with the Rice surveys is that it is impossible to tell from the reports what was actually done. This is especially true of the September 1981 report, which is in the form of a letter barely two pages in length. Because of the letter's brevity and lack of detail, it is virtually impossible to know what Dr. Rice was looking for or exactly what he found.

The letter's inadequacy for DOE's purported purpose becomes painfully obvious when one attempts to decipher his work. Rice states in the letter that four finds were made, three of which appeared to be already affected by boreholes. The letter mentions "impact" to these sites.No further elaboration is made. It is impossible to know from this material either what the nature was of the "finds" or in what manner they have been "impacted." Thus, the letter raises more questions than it answers.

This lack of description obviously calls for further work. Dr. Rice himself notes that the study finds "require more extensive documentation. To our knowledge, no further surveys or reports have been done on this subject. It is impossible to know from this material whether any Indian religious sites were among those damaged.

In fact, at least one was. The archaeological site descriptions are so patently sterile that they disguise possible major damage to Indian religious sites.
For example, Rice's survey mentions an

> Impact to the Gable Mountain archaeological locality by borehole DC-11 and the Near Surface Test Facility (NTSF).

This colorless description fails to reveal that there is a profoundly important Yakima Indian sacred site at Gable Mountain, discussed above. Apparently neither DOE nor Dr. Rice consulted with the Yakima people. DOE appears content to hide behind the emasculated language of Rice's reports. The other archaelological finds are described in similarly uninformative, abstract fashion.

In summary, the Rice "studies" fail to answer the most basic questions: 1) What are the Native American religious sites at risk from BWIP? 2) Of what significance are these sites? 3) In precisely what manner could these sites be damaged? 4) In what way have known sites (e.g., Gable Mountain) already been damaged?

<u>Recommendation:</u> The EA should conclude that there are significant Native American Religious sites and sites of unique

cultural importance in proximity to the RRL, and that repository-related activities have already had and will continue to have adverse impacts on these sites. The potentially adverse condition is "present" at Hanford.

References:

Reports of Morris Uebelacker

Tribal Interviews

16 U.S.C. § 470-1

USNRC Regulatory Guide Series NUREG-0099; Regulatory Guide 4.2, Revision 2.

Rice, D.G., 1984a. Archaeological Inventory of the Basalt Waste Isolation Project Hanford Reservation, Washington, RHO-BWI-ST-006, RHO, Richland, Washington.

Rice, D.G., 1984b. FY 83 Summary Report for Archaeological Survey and Monitoring of Initial Excavations within the Basalt Waste Isolation Reference Repository Site, Hanford Reservation Washington, SD-BWI-TA-007, RHO.

YIN Comment #: 6-9

EA Section: 6.2.1.6 Environmental Quality

pages 6-25 - 6-39; 7-73 - 7-80

Statement of Issue: Due to the unique relationship of The Yakima Indians to their land and natural resources, and judged by the special cultural and religious perspective of the Yakima Indian Nation, the risk to the quality of the environment in the affected area during this and future generations posed by construction, operation, closure, and decommissioning of the proposed repository is unacceptable.

Discussion: The guidelines contain the following qualifying condition (p. 6-25):

> The site shall be located such that (1) the quality of the environment in the affected area during this and future generations will be adequately protected during repository siting, construction, operation, closure, and decommissioning, and projected environmental impacts in the affected area can be mitigated to an acceptable degree, *taking into account* programmatic, technical, *social*, economic, and environmental *factors*; and, (2) the requirements specified in Section 960.5-1(a)(2) can be met."

(Emphasis added.) The related favorable condition is (p. 6-26):

> (2) Potential significant adverse environmental impacts to present and future generations can be mitigated to an insignificant level through the application of reasonable measures, *taking into account* technical, *social*, economic, and environmental *factors*."

(Emphasis added.) In addition the following is a disqualifying condition (p. 6-34):

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

By specifically providing that "social" factors are to be accounted for in assessing the nature and significance of environmental impact and in evaluating whether the mitigation of these impacts will be adequate, the guidelines implicitly incorporate the concept that the answers to these questions do not flow automatically from technical analyses but also depend upon the circumstances and heritage of those upon whom the risk will fall. The primary purpose of the National Environmental Policy Act of 1969 ("NEPA") is to "encourage productive and enjoyable harmony between man and his environment." (42 U.S.C. § 4321. *See also* § 4331). In order to carry out this policy, it is the obligation of the federal government, *inter alia*, to:

> (1) fulfill the responsibilities of each generation as trustee of the environment for succeeding generations;
>
> (4) preserve important historic cultural and natural aspects of our national heritage and maintain, wherever possible an environment which supports diversity and variety of individual choice;

42 U.S.C. § 4331(b)

Contrary to the intent of NEPA and the guidelines, the DEA for BWIP makes no attempt whatever to assess the risk associated with repository development from the cultural and religious viewpoint of the Yakima Indian Nation. The closest it approaches are the two perfunctory Rice "surveys" of archeological sites in the RRL vicinity. The severe limitations, and general inscrutability of these surveys are discussed in detail in YIN comment # 6-8, *supra*. The point addressed here is a broader one and requires consideration of the living heritage and future of the Yakima Indian Nation.

The Yakima Indians have inhabited this region for over 10,000 years; it is their belief that the first human beings were created on what is now the Hanford Site. It is their duty to protect and nurture this sacred land for their descendants beyond 10,000 years. For the Yakima Indians, 10,000 years is not unimaginably far in the future; they deeply feel their obligation to their descendants as well as their ancestors. The risk of contaminating their lands and natural resources, including both those on and outside of the YIN Reservation--even were that contamination to occur hundreds or thousands of years from now--is not acceptable to them. It is also within the living heritage of the Yakima Indians to foresee a time when the Hanford Reservation and its sacred sites will again be fully accessible for the practice of their religion. Their stewardship and concern is thus not limited to the current time frame.

In addition, the Indian religion is uniquely tied to the land and its natural resources, the water, fish, natural foods and medicines and animals. These resources are used today in the same way that they have been since time immemorial. The continued existence of the Yakima Indian Nation depends upon the vitality of the land and their continued access to the resources the Creator placed upon it for their use.

Finally, the Yakima Indian Nation is not free to move elsewhere should its land or resources be ruined. This concept may be particularly difficult for other cultures on the American continent to comprehend. Exclusion of the Yakimas from the core of their homeland would be absolutely destructive of their religion and culture. Were the chain to be broken, this culture would cease to exist.

For all of these reasons, the risks posed by locating a nuclear waste repository at the Hanford site are unacceptable. The projected environmental impacts cannot be mitigated to an acceptable degree. There are potential significant adverse environmental impacts and the quality of the environment cannot be adequately protected, taking into account the unique social factors present here. The views of the Yakima Indian Nation on this subject are further documented in the various tribal resolutions attached as Appendix G.

Recommendations: The EA should conclude that the disqualifying condition for environmental quality is present (p. 6-34), and that the qualifying condition (p. 6-25) and favorable condition (2) (p. 6-26) are not present.

YIN Comment #: 6-10

EA Section: 6.2.1.8.9 Transportation--Favorable Condition (7) Absence of Legal Impediments

Page 6-51

Statement of Issue: The DEA incorrectly takes credit for the absence of legal impediments to nuclear waste transportation for the Hanford Site, ignoring a Yakima Indian Nation ban on such transportation within the Yakima Indian Reservation.

Discussion: Transportation favorable condition (7) is "absence of legal impediment with regard to compliance with Federal regulations for the transportation of waste in or through the affected State and adjoining States". The DEA concludes: "Since no legal impediments with regard to waste transportation now exist within the State of Washington or adjoining states, this favorable condition is present for the [RRL]."

This conclusion is incorrect. Since June of 1979 the Yakima Indian Nation has had a complete ban on transportation of radioactive substances across its Reservation. *See* Yakima Tribal Council Resolution T-72-79, attached as Appendix ____. Since there clearly is a legal impediment to waste transportation within the State of Washington, this favorable condition is not present. This oversight is especially egregious because the Hanford Site alone among the five candidates for nomination is given credit for this favorable condition. The other four sites are all denied credit for this condition on the basis of various enacted local transportation restrictions or bans--sometimes in cities in adjoining states--that are clearly no more valid than the YIN ban. There is no basis for the Hanford site to be singled out for favor with respect to this condition.

Recommendation: The Final EA should acknowledge that this favorable condition is "not present" at the Hanford Site.

YIN Comment #: 6-11

EA Section: 6.2.1.8.10 Transportation--Favorable Condition (8) Emergency Response Procedures

Page 6-52

Statement of Issue: The discussion of transportation accident response procedures ignores the implications of Yakima Indian Nation sovereignty and Reserved Treaty Rights, as well as YIN resolution not to cooperate in radiological emergency response plans which might involve evacuation.

Discussion: The DEA cites the State of Washington's procedures and programs to support its favorable conclusion on this condition. It ignores the fact that a major part (the most populated part) of the Yakima Indian Reservation is within the 50-mile radius ingestion pathway planning zone for Hanford-related emergency response, and that the State's jurisdiction to enforce emergency response plans within the Yakima Reservation is strictly circumscribed by Yakima Nation sovereignty.

Also at risk from repository-related transportation accidents would be Yakima Reserved Treaty Rights to fish at usual and accustomed places and to graze animals and gather natural plants within the Ceded Lands, which include most of the lands in and around the Hanford Site. The DEA ignores the potential impacts of transportation accidents on these important Yakima Reserved Treaty Rights.

Finally, the DEA ignores the fact that the Yakima Tribal Council has in effect a legal resolution refusing the Yakima Nation's cooperation in emergency response procedures which might involve evacuation from Tribal Lands. *See* Yakima Tribal Council Resolution T-72-79, attached in Appendix G. For these reasons, the "plans, procedures and capabilities for response to radioactive waste transportation accidents" in Washington State are flawed by major omissions concerning implications for Yakima Nation sovereignty and Reserved Treaty Rights.

Recommendation: The final EA should acknowledge that this favorable condition is "not present" for the Hanford Site.

YIN Comment #: 6-12

EA Section: 6.2.1.8.11 Transportation--Favorable Condition (9) Meteorology

Page 6-52

Statement of Issue: The DEA gives none of the quantitative data about frequency or severity of potentially disruptive weather conditions necessary to support its favorable conclusion about this condition.

Discussion: This favorable condition states: "[a] regional meteorological history indicating that significant transportation disruptions would not be routine seasonal occurrences." The DEA concludes that this condition is present because "[d]isruptions to transportation due to weather conditions are uncommon in the region." The DEA concedes that transportation in the region can be disrupted by duststorms, snow, and ice, and that those conditions are seasonal, but concludes that they "do not cause highway closures with sufficient frequency to be considered routine."

No quantitative measures of the frequency of these disruptive conditions are given, so the validity of the DEA's conclusion cannot be verified. Section 3.4.3 is referred to for a description of Hanford area meteorology, but that section also lacks any discussion of the frequency of potentially disruptive weather events other than thunderstorms. There is no discussion at all of icestorms or heavy fog, which in our experience are not rare winter occurrences.

Recommendation: The favorable conclusion on this condition should be withheld until quantitative data on transportation-disruptive weather events are supplied to support it.

YIN Comment #: 6-13

EA Section: 6.3.1.1.3

Page 6-62, paragraph 6

Statement of Issue: DOE overstates the confidence in its calculation of groundwater travel time relative to the uncertainties recognized by the Interagency Hydrology Working Group ("IHWG").

Discussion: The IHWG was created to resolve differences and uncertainties in the hydrologic models for the Pasco Basin. As the findings by Wilson and Kanehiro (1983) are not referenced in the EA, nor are they conclusive, by the authors'own admission, the overconfidence in the calculated travel times is unjustified.

Importance to EA Findings - The EA states that a final conclusion cannot be made at this time, yet they also claim the presence of the 10,000 travel time as a favorable condition.

Relevance to Regulations - Questionable presence of favorable 10,000 travel time (b,2).

Recommendation: Change conclusion on geohydrology guideline b,2 to "not present."

References

Wilson, C.R., and B.Y. Kanehiro, 1983. Updated recommendations for standard problems and sensitivity studies for modeling the groundwater system in the Pasco Basin, DOE Accessions B031230, Report by Hydrotechnique Associates prepared for Rockwell Hanford Operations.

<u>YIN Comment #:</u> 6-14

EA Section: 6.3.1.1.3 Geohydrology - favorable condition

Pages 6-63, paragraph 3
6-65, paragraph 1

<u>Statement of Issue:</u> Reference to study of travel time estimates is incorrect.

<u>Discussion:</u> The reference in the EA to the study of travel time estimates is incorrect. On the above pages, reference is made to an important study that determined the travel time estimates used in the EA as evidence that groundwater travel times were in excess of 10000 years. The referenced document, Clifton et al. (1984a), should instead be Clifton et al. (1984b).

<u>Recommendation:</u> Change reference in Final EA.

<u>YIN Comment #:</u> 6-15

EA Sections: 6.3.1.1.3 Geohydrology - favorable condition
6.3.1.1.11 Geohydrology - disqualifying condition

Pages 6-63 paragraph 2
6-81 paragraphs 2, 4

<u>Statement of Issue:</u> Transient conditions of the groundwater flow system are not considered in travel time estimates.

<u>Discussion:</u> The groundwater travel time estimates are based on the assumption of steady-state flow conditions. Considering the large spatial and temporal scales that are being modeled, it seems likely that the steady-state assumption is not valid. In addition, incomplete field data exists to establish steady state conditions near the site.

<u>Recommendation:</u> The assumption of steady-state flow conditions used to estimate travel times requires justification. If further field data suggests that the system is not at steady-state, further modeling efforts must be based on transient conditions.

<u>YIN Comment #:</u> 6-16

EA Section: 6.3.1.1.3 Geohydrology - favorable condition
6.3.1.1.11 Geohydrology - disqualifying condition

Pages 6-63 paragraph 2
6-81 paragraphs 2, 4

<u>Statement of Issue:</u> Estimated travel times are non-conservative as a result of errors in the modeling approach used.

<u>Discussion:</u> This comment concerns the Monte Carlo simulation of groundwater travel times in basalt flow tops at the Hanford Site. The original work described in Clifton et al. (1983) has been extended to include uncertainty about the spatially uniform effective porosity assumed and the regional average gradient (Clifton et al, 1984).

The modeling approach is in question for the following reasons:

1) Neglected uncertainty of median transmissivity

2) Lack of sensitivity analysis for correlation assumptions

3) Lack of essential details

4) Inconsistency of the three modes used

A thorough mathematical discussion of these problems is found in Appendix A.

<u>Recommendation:</u> The estimated travel times are too high due to errors in the modeling approach. The above points must be considered in travel time estimates.

References:

Clifton, P.M., R.G. Baca, and R.C. Arnett, 1983. <u>Stochastic Analysis of Groundwater Traveltimes for Long-Term Repository Performance Assessment</u>, RHO-BW-SA-323 P, Rockwell Hanford Operations, Richland, Washington.

Clifton, P.M., R.C. Arnett, and N.W. Kline, 1984. <u>Preliminary Uncertainty Analysis of Pre-Waste-Emplacement Groundwater Travel Times for a Proposed Repository in Basalt</u>, SD-BWI-TA-013, Rockwell Hanford, Richland, Washington.

<u>YIN Comment #:</u> 6-16

EA Sections: 6.3.1.1.3 Geohydrology - favorable condition
6.3.1.1.11 Geohydrology - disqualifying condition
6.4.2.3.5 Site subsystem performance

Pages: 6-63 paragraph 2
6-81 paragraphs 2,4
6-267 paragraph 4

<u>Statement of Issue:</u> All of the factors that contribute to uncertainty in groundwater travel time estimates have not been considered.

<u>Discussion:</u> The Draft Environmental Assessment (EA) considers travel time analysis via the use of numerical simulation techniques. The EA states that "these numerical simulations represent the primary tools for predicting ground-water travel times". It follows then that the uncertainties of the predictions made by the simulators need to be quantified to be able to assess the site with some degree of confidence.

On page 6-261 the EA states that "The amount of uncertainty in a predicted travel time depends on how well the spatial variability of the hydraulic parameters and hydraulic gradients are known ...." This statement suggests that all of the uncertainty is associated with the data and that if the variability of the data base can be quantified, then the uncertainty of travel time estimates can be quantified. However, there are several other ways in which uncertainty is introduced into the prediction of groundwater travel times. The following discussion will examine these errors and discuss how they add uncertainty to the travel time estimates.

I. Numerical Error

Conventional finite element and finite difference techniques are subject to errors that are inherent in application of the numerical procedure, for example, roundoff error and discretization error. In the preliminary uncertainty analyses of pre-waste-emplacement travel times of Clifton et al. (1984), a conventional finite element technique (Baca, et al., 1983) is used to solve the flow equation. A flow top with a domain of 10 km by 20 km is discretized into 200 1 km square elements. Using Monte Carlo analysis, the input parameters are treated as random variables which accounts for uncertainty in the input data.

When applying finite element techniques to real-world situations, numerical accuracy can be lost if not properly used. In the study by Clifton et al. (1984) an unquantified amount of numerical error is introduced by allowing the transmissivity values to vary randomly over the solution domain. The cause of this numerical error can be seen by examining the final matrix equation of the solution of the flow equation

$$A(T)h = b \tag{1}$$

where (T) is the transmissivity matrix. Simply stated, values of transmissivity are added together, element by element, to form the (T) matrix. During the solution of the matrix equation (1), the large transmissivity values numerically overwhelm the smaller values, with a resulting loss of sensitivity to the smaller values (Hokkanen, 1984; Frind, 1984). This problem is usually controlled by adjusting the size of the grid elements. Grid adjustment in this case, because of the random treatment given to the transmissivity values, will not work.

Two important consequences of this type of error on the travel time estimates is that the amount of this error has not been quantified and, in addition, the error itself is random. To have any credibility, travel time estimates must account for this error.

II. Flow Equation

To compute travel times, Clifton et al. (1984) use Darcy's Law written for confined aquifers. Darcy's Law states that seepage velocity, q_s, is given by

$$q_s = - \frac{K \text{ grad}(h)}{n_e} \tag{2}$$

where K is the hydraulic conductivity matrix, grad(h) the hydraulic gradient and n_e the effective porosity. For confined aquifers q_s is given by

$$q_s = - \frac{T \text{ grad}(h)}{n_e \, b} \tag{3}$$

where T is the transmissivity matrix and b is the aquifer thickness. Transmissivity is related to hydraulic conductivity by

$$T = K\,b \tag{4}$$

Clifton et al. (1984) offer no explanation for assuming that the flow domain is a confined aquifer and are therefore not justified in using equation (3).

In addition, in Case 3 in Clifton et al. (1984) all three input parameters are considered to be spatially independent. However, a consequence of using equation (3) is that equation (4) must be used. This is important because equation (4) says that T and b are correlated which means that T and ne b (effective thickness) are correlated. This contradicts the assumption that transmissivity, effective thickness, and hydraulic gradient are uncorrelated. This contradiction must be explained and the error introduced by this approach needs to be quantified.

III. Model Uncertainty

There is also an underlying uncertainty associated with the conceptual modeling approach used by Clifton et al. (1984) to calculate groundwater velocities in fractured media.

There are currently several common approaches to modeling flow in fractured media: discrete fracture, dual porosity, and equivalent porous medium (continuum). Each method is an attempt to account for the complex nature of fractured systems in the context of a mathematical model.

The discrete fracture approach attempts to account for each individual feature in a rock mass. Flow is calculated through individual fractures. However, for most real-world problems the data requirements are too severe for practical usage.

The dual porosity approach treats the fracture network and the matrix blocks separately, assigning them different hydraulic properties. In this treatment the geometry of the fracture network is either simplified or not specified directly. Flow is calculated for each separately and added to obtain the resultant flow system. However, this method suffers from the oversimplification of the fracture network and the assignment of appropriate hydraulic parameters is problematic.

The third approach, used by Clifton et al. (1984), ignores the effect of individual fractures and lumps together the fracture system and rock matrix and treats the entire rock mass as an equivalent porous medium. The main advantage of this technique is that existing porous media flow codes can be used. The problem lies in the validity of conceptualizing a complex fractured system as a uniform porous medium and in the assignment of appropriate hydraulic parameters.

There is considerable uncertainty in the scientific community as to the general validity of the continuum approach to fractured media (i.e. fractured basalt flow tops) (Gale, 1982). It follows that no matter how well known the spatial variability of the data is, when using the continuum approach there will remain a degree of uncertainty which needs to be quantified. In this light, DOE must justify the use of the continuum approach and fully explain the simplifying assumptions associated with this method.

IV. Data Error/Spatial Variability

In the study of Clifton et al. (1984) the input parameters, transmissivity, hydraulic gradient, and effective thickness are treated as random variables. Transmissivity is assigned a log-normal probability distribution. However, hydraulic gradient and effective thickness are assigned uniform probability distributions. This means, for example, that for the regional gradient, any value between 10^{-4} and 10^{-3} has an equal probability of occurence. The problem here is that values outside of this range have a zero probability of occurance, which infers that the hydraulic gradient is explicitly known within the prescribed limits. Given this distribution for Case 2 (Clifton et al., 1984) a travel time of 86,000 years was determined. The gradient in Case 1 was set at 10^{-3}. Since the travel time varies directly with the hydraulic gradient, allowing the gradient to vary uniformly between the prescribed limits means that the calculated median travel time for Case 2 should be approximately 5 :: times that of Case 1 (since the median gradient is 5 X 10^{-3}). This result is seen when travel time increases from 17,000 years to 86,000 years from Case 1 to Case 2. This problem carries over into Case 3 when all three parameters are allowed to vary.

Great care must be exercised in assigning realistic and appropriate distribution functions to the input parameters. The travel time estimates are extremely sensitive to these parameters and improper input assignments will make the estimates meaningless.

V. Tortuosity/Travel Time

The travel time estimates of Clifton et al. (1984) are unrealistically high due to the use of tortuous pathlines in conjunction with the continuum approach. For each simulation, using random input parameters, a random hydraulic head field was calculated. Individual pathlines in each field do not follow straight lines but instead follow winding, tortuous paths. To calculate a travel time, one such pathline was traced until its linear distance from the starting point was 10 kilometers. The actual distance traveled was always greater than 10 kilometers, however. This causes the travel times to be much greater than if the calculation was based on a straight line distance. For example, in Case 3 a travel time of 81,000 years was calculated. The mean transmissivity was 0.153 square meters per day, the mean hydraulic gradient was 5.0×10^{-4}, and the mean effective thickness was 10^{-2} meters. Using these values and a straight pathline, a travel time of 3581 years is calculated. Clearly, Clifton et al. (1984) are overestimating the travel times. The use of tortuous pathlines must be justified.

Recommendation: Because groundwater travel time is a potential disqualifying factor in the DOE guidelines, all sources of error in the calculation of travel time must be examined and accounted for. There is a good possibility that the travel time disqualifying condition is present.

References:

Baca, R.G., R.C. Arnett, and D.W. Langford, 1983. Modeling Fluid Flow in Fractured-Porous Rock Masses by Finite Element Techniques, RHO-BW-SA-297 P, Rockwell Hanford Operations, Richland, Washington.

Clifton, P.M., R.C. Arnett, and N.W. Kline, 1984. Preliminary Uncertainty Analysis of Pre-Waste-Emplacement Groundwater Travel Times for a Proposed Repository in Basalt, SD-BWI-TA-013, Rockwell Hanford, Richland, Washington.

Frind, E.O., 1984. Personal Communication.

Gale, J.E., 1982. "Assessing the Permeability Characteristics of Fractured Rock," in Recent Trends in Hydrogeology, T.N. Narasinhan, ed., Geological Society of America, Special Paper 189, pp. 163-181.

Hokkanen, G.E., 1984. Application of the Alternating Direction Galerkin Technique to the Simulation of Contaminant Transport at the Borden Landfill, MSc thesis, University of Waterloo, Waterloo, Ontario, 64 p.

YIN Comment #: 6-17

EA Section: 6.3.1.1.4, Geohydrology - favorable condition (2)

Page 6-66, paragraph 4

Statement of Issue: The favorable condition does not exist at Hanford due to effects of probable catastrophic flooding within the next 100,000 years.

Discussion: Problem and basis - Favorable condition - "(2) The nature and rates of hydrologic processes operating within the geologic setting during the Quaternary Period would, if continued into the future, not affect or would favorably affect the ability of the geologic repository to isolate the waste during the next 100,000 years."

The climatic future of the Hanford site involves glaciation, possibly within 15,000 years (Craig,1983). The nature of hydrologic processes operating within the geologic setting during the Quaternary Period has been one of large flooding and ponding of water due to ice dams at Wallula gap. The last such period of flooding occurred 18,000-12,000 years BP (Baker, 1983, p.121).

These multiple floods were especially prevalent in the Pasco Basin due to ice damming of the Columbia River channel at Wallula Gap.

> At times, the ice dams [in the mountain valleys northeast of the reference repository] have failed by some mechanism, releasing enormous volumes of water that flowed over the Columbia Plateau..., converged at the Pasco Basin, were hydraulically ponded upstream from Wallula Gap, and produced huge amounts of erosion (and deposition) within the Pasco Basin.

(Craig, 1983). Umtanum Bar is a depositional feature of one of these great floods (Long and WCC, 1984).

Importance to EA findings/conclusions -

1) The stress changes resulting from loading/unloading due to ponded water weight (plus sediments) will undoubtedly affect the repository in an unfavorable manner, e.g., changes in hydraulic heads to increase flow through the repository, increased fracture width due to changes in loading and unloading, triggering of seismic events at a distance from the repository. The EA cannot assume that the depth of the repository will isolate it from the effects of these events.

2) These floods may decrease the travel time required for radionuclides to reach the accessible environment. A surge of floodwaters could conceivably recharge a stratigraphic unit creating an aquifer immediately above the repository (due to the basin nature of the subsurface). The EA's assertion that "...the hydrologic processes operating during the Quaternary Period are expected to have had mostly transient, local and shallow effects on the hydrologic systems..." (p.6-66) is not well founded.

3) Catastrophic floods will increase stress on structures; e.g., the EA states (p.3-49) that trenches in Gable Mountain exposed offsets (6 cm.) "along narrow fractures in glaciofluvial sediments that are continuous with a reverse fault in the basalt...Borehole data shows that the fault has much greater displacement in the basalt at depth (the top of the Esquatzel Member is offset approximately 50 meters (160 feet)". The dispacement is interpreted "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 " (EA, p.3-49). To state later that this catastrophic flooding will not affect the repository's ability to isolate the waste is not consistent with geologic evidence.

Brotchie and Sylvester (1969) maintain that stresses located away from the front of a continental glacier are responsible for the formation of the Great Lakes. Conceivably, fracturing associated with crustal loading from continental glaciation could affect the Hanford site within the next 100,000 years. Such fracturing could alter the geohydrologic system in an adverse manner.

Recommendation: This favorable condition does not exist at Hanford because catastrophic floods could very well adversely affect the ability of the geologic repository to isolate the waste during the next 100,000 years.

References:

Baker, V.R., 1983. "Late-Pleistocene Fluvial Systems" in The Late Pleistocene, S.C. Porter (ed.), Volume 1, pp. 115-129.

Brotchie, J.F. and R. Silvester, 1969. "On Crustal Flexure," Geophysical Research, Volume 74, pp. 5240 - 5252.

Craig, R.G., M.P. Singer, and G.L. Underberg, 1983. Analysis of Ice-Age Flooding from Lake Missoula, Kent State University, Kent, Ohio.

Long, P.E. and Woodward-Clyde Consultants, 1984. Repository Horizon Identification Report, Volumes 1 and 2, Draft SP-BWI-TY-001, WCC for Rockwell Hanford Operations, Richland, WA.

YIN Comment #: 6-18

EA Section: 6.3.1.1.5 Geohydrology - favorable condition (3)

Page 6-66, paragraph 4

Statement of Issue: "It should be recognized that no hydrologic model can directly address all of the uncertainties . . ."

Discussion: Basis - In an update report, Kanehiro and Wilson, 1983 (DOE ref. BO31230) have made the above statement (p.2, paragraph 2).

Importance to EA Findings - The EA reports that geohydrologic favorable condition b,2 (p. 7-6) is not present. Kanehiro and Wilson imply that no model can directly address the uncertainties. Thus, this would indicate that further characterization and modeling effort would be useless.

Relevance to Regulations - The site cannot be "readily modeled with reasonable certainty."

Recommendation: The utility of planned site characterization and uncertainty modeling activities should be re-evaluated in light of the likelihood that critical uncertainties cannot be resolved.

References:

Wilson, C.R., and B.Y. Kanehiro, 1983. Updated recommendations for standard problems and sensitivity studies for modeling the groundwater system in the Pasco Basin, DOE Accession B031230, Report by Hydrotechnique Associates prepared for Rockwell Hanford Operations.

YIN Comment #: 6-19

EA Section: 6.3.1.1.5 Geohydrology - favorable condition (3)

Page 6-66, paragraph 4

Statement of Issue: The DEA fails to account for ongoing activities of the Interagency Hydrology Working Group (IHWG) which document the degree of uncertainty and difficulty in developing a ground water model.

Discussion: The IHWG was created by Rockwell at the insistence of NRC to encourage Rockwell to provide a technical forum for identifying and resolving differences in previous ground water models, and yet its activities and preliminary conclusions are not included in the EA findings.

Importance to EA Findings - Kanehiro and Wilson have prepared at least 3 reports for Rockwell during CY 1983 and 1984. Two of these references are presented in the DOE accessions list. A third is mentioned in the one reference received from DOE. Mention of these reports should appear in the EA. These reports document the degree of uncertainty and differences in developing a consensus ground water model.

Relevance to Regulations - The EA understates the degree to which the favorable condition (system can be modeled with reasonable certainty; b,2) is not present.

Recommendation: Include reference to and discussion of ongoing PASCO Basin modeling activities of the IHWG.

References:

Kanehiro, 1984. Updated working group plans and rationales for addressing regional flow system characterization. DOE Accession B040441, Report by Hydrotechnique Associates, prepared for Rockwell Hanford Operations.

Wilson, C.R., and B.Y. Kanehiro, 1983. Updated recommendations for standard problems and sensitivity studies for modeling the groundwater system in the Pasco Basin, DOE Accession B031230, Report by Hydrotechnique Associates prepared for Rockwell Hanford Operations.

YIN Comment #: 6-20

EA Section: 6.3.1.1.5 Geohydrology - favorable condition (3)

Page 6-66, paragraph 4

Statement of Issue: Deliberations of the Interagency Hydrology Working Group (IHWG) were removed from the public record.

Discussion: A YIN request (Rockwell #85-06) for IHWG reports (DOE Accessions B040441 and B025789, Kanehiro, 1984 and Rockwell, 1983) made on January 7, 1985 was denied by the DOE Public Release System on January 28. These reports summarized the group's findings.

Importance to EA Findings - While these reports "are being used to develop the content of the Site Characterization Plan" (Jo Ludwick, DOE, January 28, 1985), the information contained therein is expected to be applicable for the EA.

Relevance to Regulations - DOE has not provided the affected Indian tribes with "timely and complete information regarding determinations or plans made with respect to siting, site characterization, . . . (960.3-3)."

Recommendation: Release reports as requested and do not remove any other items from DOE Accessions List.

References:

Kanehiro, 1984. Updated working group plans and rationales for addressing regional flow system characterization. DOE Accession B040441, Report by Hydrotechnique Associates, prepared for Rockwell Hanford Operations.

Rockwell, 1983. Summary of activities of BWIP Interagency Hydrology Working Group through July 1983. DOE Accession B02589.

YIN Comment #: 6-21

EA Section: 6.3.1.1.11.1

Page 6-74, paragraphs 1 and 8

Statement of Issue: There is evidence indicating that the Hanford site may not qualify, based on short ground water travel times to the accessible environment.

Discussion: The stochastic ground water travel time analyses upon which rejection of the disqualifying condition is based (see EA pages 6-266 through 6-269) consider the likely pathway to be horizontal through the Cohasset flow top. In contradiction, the head data in well DC-20 (Hydrology Workshop, Silver Spring, Maryland, December 12, 1984) show evidence of a strong interconnection between the Cohasset and Rocky Coulee flow tops. Neutron logs and TV cameras indicate that the interconnection may be a function of the degree to which the Rocky Coulee flow interior is incompetent at this location. RHO stated at the December, 1984 workshop that they believed the interconnections to be due to rock character rather than poor packer seals. Of the total six flow interiors spanned by DC19, DC20, and DC22, one strong interconnection between flow tops exists. Although this does not constitute a legitimate sampling population from which any probabilistic judgments could be made, it does demonstrate the real possibility that a vertical pathway may provide the most direct access to the accessible environment.

Importance to EA Findings/Conclusions -- As stated in the EA on page 6-79, paragraph 2, to date, a conclusion on this qualifying condition is not possible. However, the comments implying the high probability of the site qualifying are without basis.

Recommendation: The vertical connection possibilities in the system, as well as the complex heterogeneities in the flow tops, must be assessed. The necessary extent of a valid sampling population to define the system and whether the sampling needed to reasonably define the system falls within the realm of practicality deserves further consideration. Delete the conclusion that there is a high probability of the site qualifying.

YIN Comment #: 6-22

EA Section: 6.3.1.1.8 Geohydrology, potentially adverse condition (1)

Page 6-76, paragraph 3

Statement of Issue: Thermal loading originating from the decay of nuclear waste will change the geohydrologic conditions surrounding the repository by increasing vertical groundwater flux.

Discussion:: Problem and Basis - The thermal loading from the decay of nuclear waste will increase groundwater temperatures in an area extending "several hundred meters" from the repository. As seen in Figure 6-5 on page 6-108 of the EA, the thermal loading at distances about 100 to 700 meters above and below the repository will increase with time (St. John et al., 1981, p. I-102).

The potential for thermal convection can be evaluated by calculating the thermal Rayleigh number (R) and comparing it with the established criteria for monotonic instability and the onset of convection in a porous medium. The thermal Rayleigh number is a dimensionless parameter that is calculated with the following equation:

$$(\pi)2R = \frac{(\alpha)\ B\ g\ k\ d^2}{(\kappa)\ (\nu)} \qquad (1)$$

where (alpha) is the thermal expansion coefficient of the water, B is the thermal gradient imposed by the heat generated by the decay of radioactive waste in the repository, g is the gravitational acceleration constant, k is the vertical permeability of the porous medium, d is the thickness of the porous medium, (kappa) is the thermal diffusivity of the water, and (nu) is the kinematic viscosity of the water. Substituting for k and (nu) with

$$k = \frac{K\ (\mu)}{(\rho)\ g} \quad \text{and} \quad (\nu) = \frac{(\mu)}{g} \qquad (2) \text{ and } ($$

where K is the hydraulic conductivity, (mu) is the dynamic viscosity of the water, and (rho) is the mass density of the water, equation (1) is reduced to

$$R = \frac{(\alpha)\ B\ K\ d^2}{\pi^2\ (\kappa)} \qquad ($$

Using an imposed temperature gradient calculated from Figure 6-5 of the EA (p. 6-108), a thermal Rayleigh number is calculated that indicates the onset of thermal convection in the flow top overlying the repository if the value of the vertical hydraulic conductivity in the flow top is greater than 3.0 X 10^{-4} m/sec.

Importance to EA findings/conclusions - DOE presents no evidence in the EA that indicates thermal loading will not cause increased radionuclide transport to and heating of the overlying flow top.

Recommendation: DOE should conclude that it is likely that Potentially Adverse Condition (3) of the Geohydrology section (10 CFR 960.4-2-1) is present at the Hanford site because thermal loading will cause increased vertical flow to the flow top.

References:

St. John, C.M., J.R. Aggson, M.P Hardy, and G. Hocking, 1981. Evaluation of Geotechnical Surveillance Techniques for Monitoring High-Level Waste Repository Performance, NUREG/CR-2547, Appendix I, US Nuclear Regulatory Commission, p. I-102.

YIN Comment #: 6-23

EA Section: 6.3.1.1.8 Geohydrology, potentially adverse condition (1)
6.3.1.2.6 Geochemistry, favorable condition (4)

Pages 6-76, paragraph 3
6-92

Statement of Issue: The thermally-induced flow increases the potential for released radionuclides to be transported to the overlying flow top.

Discussion: Groundwater temperatures in the flow top will rise to temperatures greater than expected for the far-field environment because of the influx of thermally-affected groundwater. Higher groundwater temperatures in the far- field environment will cause increased solubility for many important radionuclides (e.g., uranium and plutonium) (Langmuir, 1978; Lemire and Tremain, 1982).

Because radionuclides attain greater solubility in higher temperature groundwater, a contradiction occurs in the application of the Postclosure Technical Guidelines (10 CFR 960.4-2). The important criteria in establishing compliance with the Geohydrlogy section (960.4-2-1) is a long pre-emplacement groundwater travel time to the accessible environment. Favorable Condition (1) is present if the travel time is greater than 10,000 years; and if the travel time is less than 1,000 years, the Disqualifying Condition (960.4-2-1d) would disqualify the Hanford site.

The Geochemistry section (960.4-2-2) grants Favorable Condition (4) for the site if the "geochemical conditions and volumetric flow rate in the host rock would allow less than 0.001 percent per year of the total radionuclide inventory in the repository at 1,000 years to be dissolved."

The contradiction in the regulations is this: longer groundwater travel time would be beneficial under the Geohydrology guidelines, but longer travel times would mean longer residence time in the thermally-affected host rock for radionuclides transported by the groundwater. Longer residence times would provide a longer time for the radionuclide dissolution reactions to reach equilibrium. The thermal loading is expected to increase radionuclide transport away from the repository and to increase the solubilities of the radionuclides. Greater radionuclide solubility increases the chance of dissolving the portion of the radionuclide inventory specified in the Geochemistry Favorable Condition (4).

Importance to EA findings/conclusions - There is a contradiction between the requirements of long groundwater travel time to the accessible environment and a limit on the amount of dissolution of the total radionuclide inventory because longer residence time enables dissolution reactions to proceed further toward equilibrium. The thermal loading increases the solubilities of radionuclides in the host rock.

Recommendation: The contradiction between the groundwater travel-time requirements of the Geohydrology guidelines (960.4-2-1) and the Geochemistry guidelines (960.4-2-2) should be eliminated.

References:

Langmuir, D., 1978. "Uranium Solution-Mineral Equilibria at Low Temperature with Applications to Sedimentary Ore Deposits," Geochim. Cosmochim. Acta, Volume 42, pp. 547-569.

Lemire, R.J. and P.R. Tremain, 1982. "Uranium and Plutonium Equilibria in Aqueous Solutions to 200 Degrees C," J. Chem. and Engr. Data, Volume 25, pp. 361-370.

<u>YIN Comment #:</u> 6-24

EA Section: 6.3.1.1.11

Page 6-79, paragraph 1

<u>Statement of Issue:</u> The Hanford site should be disqualified on the basis that pre-waste-emplacement ground water travel times are reasonably likely to be less than 1000 years.

<u>Discussion:</u> Clifton (1984) describes the sensitivities of the results of travel time uncertainties to the correlation range. As noted on page 56 of Clifton (1984), the uncertainty increases as the correlation factor increases. What is not made clear in the EA is the fact that when the correlation range varies from 0-10 km, the median travel time increases as the correlation range increases. Varying the correlation range between the possible values of 0 to 10 km gives travel times from 7,150 to 30,000 years. A correlation range of 5 results in the 21,500 year median travel time presented in Clifton et al, 1984.

Since there is absolutely no basis for the choice of 5 km as the correlation range, the travel time estimates are biased by this choice of an arbritrary correlation range and may be overestimated by a factor of 2 to 3. Adjusting the travel time studies presented in the EA to account for a factor of three overestimation would reduce the median travel times for the three studies from 17,000, 81,000, and 86,000 years to 5,667, 27,000, and 28,667 years respectively. If this overestimation is considered in conjunction with the factor of 23 overestimation of effective porosity (see comment 6-) it is fair to conclude that the three studies should have given median travel time results of 246, 1174, and 1246 years respectively. From this it can be stated that the site may be disqualified on the basis of a less then 1000 year travel time to the accessible enviroment.

Importance to EA findings--The EA findings are likely to be overestimating ground water travel times to the accesible environment by 20 to 30 times, which profoundly effects site rankings and strongly suggests that the site should be disqualified.

<u>Recommendation:</u> Disqualify the site on the grounds that the pre-waste-emplacement ground water travel times are reasonably likely to be less than 1000 years.

<u>References:</u>

Clifton, P.M., 1984. <u>Groundwater Travel Time Uncertainty Analysis--Sensitivity of Results to Model Geometry, and Correlations and Cross Correlations Among Input Parameters</u>, SD-BW-TI-256, Rockwell Hanford Operations, Richland, Washington.

Clifton, P.M., R.C. Arnett, and N.W. Kline, 1984. Preliminary Uncertainty Analysus of Pre-Waste-Emplacement Groundwater Travel Times for a Proposed Repository in Basalt, SD-BWI-TA-013, Rockwell Hanford Operations, Richland, Washington.

YIN Comment #: 6-25

EA Section: 6.3.1.1.11

Page 6-80, paragraph 4

Statement of Issue: The quote stating that ". . . in all probability, the Hanford site will demonstrate a pre-emplacement ground water travel time in excess of 1,000 years when fully characterized," is not supported by the data available for interpretation.

Discussion: The stochastic travel time analyses may be overestimating travel times by an order of magnitude or more for the following reasons:

1) the range of effective porosities for stochastic studies (EA pages 6-267 through 6-269 and Clifton, 1984) reflects the biases of RHO hydrologists;

2) the analysts charged with the task of evaluating independent hydrologists are including their own biases in the study;

3) consideration is given to series of lab test data which does not accurately reflect the flow structure at the megascale.

This overestimation implies that the stochastic analyses (pages 6-267 through 6-269) should have given mean values of between 740 years to 3740 years or less. The analysis would be performed using a median effective thickness based on a field derived effective porosity of a range of 1.6×10^{-4} to 2.7×10^{-4}, and an average flow top thickness of 8 m. A realistic variance should show a substantial probability of a pathway existing that does not satisfy to the 1000 year travel time condition.

Importance to EA Findings - The ground water travel time is a potential disqualifying factor if travel time from the disturbed zone to the accessible environment is less than 1,000 years.

Relevance to Regulations - The possibility of further characterization showing that travel times could be less than 1,000 years is not unlikely (960.4-2-1,d).

Recommendation: The likelihood that the Hanford site would not meet the 1000 year pre-emplacement ground water travel time requires that the site be disqualified.

References:

Clifton, P.M., 1984. Groundwater Travel Time Uncertainty Analysis--Sensitivity of Results to Model Geometry, and Correlations and Cross Correlations Among Input Parameters, SD-BW-TI-256, Rockwell Hanford Operations, Richland, Washington.

Loo, W.W., R.C. Arnett, L.S. Leonhart, S.P. Luttrell, W.R. McSpadden, and I. Wang, 1984. Effective Porosities of Basalt: A Technical Basis for Values and Probability Distributions Used in Preliminary Performance Assessments, SD-BWI-TI-254, Rockwell Hanford Operations, Richland Washington.

<u>YIN Comment #:</u> 6-26

EA Section: 6.3.1.1.11 Disqualifying condition

Pages 6-79, paragraph 1
6-80, paragraph 4

<u>Statement of Issue:</u> The evidence indicates that the Hanford site may not qualify, based on possible ground water travel times to the accessible environment.

<u>Discussion:</u> The stochastic ground water travel time analyses upon which rejection of the disqualifying condition is based (EA pages 6-266 through 6-269) consider the likely pathway to be horizontal through the Cohasset flow top. In contradiction, the head data in Well DC-20 (Hydrology Workshop, Silver Spring, Maryland, December 12, 1984) show evidence of a strong interconnection between the Cohasset and Rocky Coulee flow tops. Neutron logs and TV cameras indicate that the interconnection may be a function of the degree to which the Rocky Coulee flow interior is incompetent at this location. RHO stated at the December, 1984 workshop that they believed the interconnections to be due to rock character rather than poor packer seals. Of the total six flow interiors spanned by DC19, DC20, and DC22, one strong interconnection between flow tops exists. Although this does not constitute a legitimate sampling population from which any probabilistic judgments could be made, it does show the possibility that a vertical pathway may provide the most direct access to the accessible environment.

Importance to EA Findings - As stated in the EA on page 6-79, paragraph 2, to date, a conclusion on this qualifying condition is not possible. However, the comments implying the high probability of the site qualifying are without basis.

Relevance to Regulations - "A site shall be disqualified if the pre-waste-emplacement ground water travel time from the disturbed zone to accessible environment is expected to be less than 1000 years along any pathway of likely and significant radionuclide travel."

<u>Recommendation:</u> The vertical connection possibilities in the system, as well as the complex heterogeneities in the flow tops, must be assessed. The necessary extent of a valid sampling population to define the system and whether the sampling needed to reasonably define the system falls within the realm of practicality deserves further consideration.

YIN Comment #: 6-27

EA Section: 6.3.1.1.11 Geohydrology - disqualifying condition

Page 6-81 paragraphs 2,4

Statement of Issue: Reported travel time estimates are much lower than reported when effective thickness values measured in the field are used.

Discussion: In the travel time estimates of Clifton et al. (1983) and Clifton et al. (1984) three input parameters are used to calculate groundwater velocities to determine travel times. As discussed in these reports and in the EA the data base for these parameters is small.

In the study of Clifton et al. (1984) effective thickness is taken from the study of Loo et al. (1984). Loo et al. (1984) conducted a literature review and reported a range of effective porosity values for a typical basalt flow top of 10^{-4} to 10^{-2}. This validity of this range of values is questionable with respect to the Hanford site since it considered values from many different formations. However, two tracer tests have been conducted in the flow top of the McCoy Canyon flow and determined effective thickness values of $2X10^{-3}$ and $3X10^{-3}$ meters (reported on p. 3-89). It seems appropriate to rely more heavily on these values, even though they are not from the candidate repository flow top, since they are more representative of the basalt flows under Hanford than textbook numbers. It should be noted that this same rationale for using transmissivity values from a different flow top is given by Clifton et al. (1984).

In their model Clifton et al. (1984) use the mean of the range of values reported by Loo et al. (1984) to determine travel times for Case 1. The effective thickness value determined by Leonhart et al. (1982) of $2X10^{-3}$ meters corresponds to an effective porosity of $1.6X10^{-4}$. Using this value and a flow top thickness of 8 meters the calculated travel time would be approximately 550 years instead of 17,000 years. This was determined by direct ratio, since Clifton et al. (1983) reports that the groundwater travel time is directly proportional to effective thickness. The same argument holds for Cases 2 and 3, where shorter travel times would be calculated.

Recommendation: The estimated travel times are very sensitive to small changes in the input parameters. Considering the fact that travel time is a disqualifying condition, these input parameters should be chosen carefully. Actual effective thickness measurements from the Hanford site should be used, resulting in travel times that are much shorter than reported.

References:

Clifton, P.M., R.G. Baca, and R.C. Arnett, 1983. Stochastic Analysis of Groundwater Traveltimes for Long-Term Repository Performance Assessment, RHO-BW-SA-323 P, Rockwell Hanford Operations, Richland, Washington.

Clifton, P.M., R.C. Arnett, and N.W. Kline, 1984. Preliminary Uncertainty Analysis of Pre-Waste-Emplacement Groundwater Travel Times for a Proposed Repository in Basalt, SD-BWI-TA-013, Rockwell Hanford, Richland, Washington.

Leonhart, L.S., R.L. Jackson, D.L. Graham, G.M. Thompson, and L.W. Gelhar, 1982. Groundwater Flow and Transport Characteristics of Flood Basalts as Determined from Tracer Experiments, RHO-BW-SA-220 P, Rockwell Hanford Operations, Richland, Washington.

Loo, W.W., R.C. Arnett, L.S. Leonhart, S.P. Luttrell, W.R. McSpadden, and I. Wang, 1984. Effective Porosities of Basalt: A Technical Basis of Values and Probability Distributions Used in Preliminary Performance Assessments, SD-BWI-TI-254, Rockwell Hanford Operations, Richland, Washington.

YIN Comment #: 6-28

EA Section: 6.3.1.1.11 Geohydrology - disqualifying condition

Page 6-81 paragraph 2,4

Statement of Issue: Reported mean travel time values may be in error as a result of the use of the continuum approach and because of the use of vertically averaged input parameters.

Discussion: In the travel time study of Clifton et al. (1984) velocities are calculated to determine time of groundwater travel from the repository to the accessible environment. These travel times are questionable for the following reasons:

1) Freeze and Cherry (1979) point out that velocities determined by the equivalent porous medium (i.e. contimuum) approach are average velocities and provide no indication of the velocities in individual fractures. The actual velocities may deviate from the average by orders of magnitude. It is possible that significantly shorter groundwater travel times could be present along preferential pathways in the flow tops.

2) Clifton et al. (1984) assume that the flow tops are vertically homogeneous. However, the EA reports on page 3-88 that geophysical log traces have indicated that

ground water movement is sometimes channeled along narrow intervals of the flow top instead of being averaged across the entire effective thickness. These intervals would have a higher hydraulic conductivity than the "equivalent" value used for the entire flow top. Therefore, velocities along these preferentiaal pathways may be higher than reported in the EA and consequently travel times lower.

Recommendation: The above points suggests that the continuum approach using vertically averaged input parameters, may not yield realistic travel time estimates. The use of this modeling approach must be justified and the associated assumptions and simplifications fully explained.

References:

Clifton, P.M., R.C. Arnett, and N.W. Kline, 1984. Preliminary Uncertainty Analysis of Pre-Waste-Emplacement Groundwater Travel Times for a Proposed Repository in Basalt, SD-BWI-TA-013, Rockwell Hanford, Richland, Washington.

Freeze, R.A., and J.A. Cherry, 1979. Groundwater, Prentice-Hall, Inc.

YIN Comment #: 6-29

EA Section: 6.3.1.1.12

Page 6-85, paragraph 1

Statement of Issue: It is doubtful that RHO can characterize the site such as to reduce hydrologic system uncertainty to an acceptable level.

Discussion: Resolution of the geohydrology qualifying condition relies on being able to characterize the site. Given the extremely complex hydrologic nature of the site evidenced by extreme local heterogeneities, it is likely that compliance of the site with relevant regulations, even after site characterization, will not be possible to an acceptable degree considering reasonable time and budget constraints.

Recommendation: The Hanford site should be eliminated from consideration because characterization cannot resolve the uncertainty concerning the hydrologic system.

YIN Comment #: 6-30

EA Sections: 6.3.1.1.11
6.3.1.1.12

Page 6-79, paragraph 1
6-85, paragraph 3

Statement of Issue: The effective porosity distributions given by Rockwell hydrologists G and H (see SD-BWI-TA-011) in the expert opinion elicitation study is in contradiction to available data.

Discussion: The range of possible effective porosities used in stochastic analyses of travel time is based on sparse field test data, laboratory data and the elicitation of expert opinions based on two decision making analysis methodologies, the Delphi method and the SRI probability encoding method. The opinion analyses consisted of two studies, one using a panel of five expert hydrologists from universities and private consulting firms (Runchal et. al., 1984, SD-BWI-TA-011). The probable porosity ranges given by the RHO panel are notably higher than those of the non-RHO hydrologists.

A closer look at the ranges given by the RHO workers show that the upper value (90 percent probability) is inconsistent with data on the Grande Ronde flow tops (SD-BWI-TA-011, pg. 21). Rockwell hydrologists G and H indicate that the 90 percent probability level for Cohosset effective porosity would be .20 or .25 respectively. In Leonhart et al., 1984, (RHO-BW-SA-300, pg. 241), it is stated that for the Grande Ronde flow tops the major flow is through high conductivity zones occupying between 5 and 25 percent of the flow top. The upper value of effective porosity should be only a fraction of .25. By using .20 to .25 as their opinion of 90 percent probability level, RHO hydrologists G and H are biasing, and thus weighting, the results with totally unrealistic effective porosities which, although they may hold water, would never hold the overburden above.

Importance to EA Findings - The 10,000 year travel time favorable condition is "not present" and the disqualifying condition for travel time less than 1000 years has a very good chance of being present.

Relevance to Regulations - The use of RHO expert opinion to characterize hydrologic parameters may be misleading and incorrectly biases the effective porosity ranges for stochastic travel time analyses.

Recommendation: Consider the mean of field test derived effective porosities of 2.2×10^{-4} as a median value for stochastic travel time analyses and, as such, consider the favorable condition criteria to fail. The opinions of Rockwell hydrologists G and H should be disregarded and, in general, the use of expert opinions of characterization parameters should carry little weight.

References:

Leonhart, L.S., R.L. Jackson, D.L. Graham, L.W. Gelhar, G.M. Thompson, B.Y. Kauchiro, and C.R. Wilson, 1984. Analysis and Interpretation of a Decirculating Tracer Experiment Performed on a Deep Basalt Flow Top, RHO-BW-SA-300 P, Rockwell Hanford Operations, Richland, Washington.

Runchal, A.K., M.W. Merkhofer, E. Olmstead, and J.D. Davis, 1984b. Probability Encoding of Hydrologic Parameters for Basalt: Elicitation of Expert Opinion from a Panel of Three Basalt Waste Isolation Project Staff Hydrologists, SD-BWI-TA-011, Rockwell Hanford Operations, Richland, Washington.

YIN Comment #: 6-31

EA Sections: 6.3.1.1.11
6.3.1.1.12

Pages 6-79, paragraph 1
6-85, paragraph 3

Statement of Issue: The results of studies to elicit expert opinions of effective porosity from a panel of five hydrologists is unduly influenced by the bias of the contractor performing the study.

Discussion: To help derive plausible ranges of effective porosity values to be used in stochastic travel time analyses, a panel of hydrologic experts were questioned. The questioning was performed according to structural methodologies based on a combination of two decision analysis methodologies: the Delphi method and the SRI probability encoding method (Runchal et. al., 1984a, SD-BWI-TA-010). One of the stages of the methodology is the conditioning stage which is used to extract from the subjects' immediate consciousness all knowledge relevant to the uncertain parameter. In describing the conditioning phase, the analyst follows accepted methodology in a way that may bias the results toward his own way of thinking. In describing the conditioning state, the analyst states:

> The purpose of the conditioning stage is to draw out into the subject's immediate consciousness all relevant knowledge relating to the uncertain variable. Usually, the discussion will indicate that the subject is basing judgment concerning the variable on both specific information (relating to the specific quantity being assessed) and general information (relating to quantities similar to that being assessed).

> The first step in the conditioning phase, therefore, is to discuss the data and background knowledge available to the subject. In this discussion, the analyst must watch for signs of bias caused by focusing only on specific information. Empirical evidence shows that subjects often tend to attach less importance to general information. For example, if the specific test information is some recent data (such as the results of recent field tests), then the importance of that information might be overrated in the subject's mind. If the analyst suspects this may be the case, it is helpful to educate the subject on this effect (known as a lack of "motivation") and to use formal processing of probabilities where possible. A useful device here is to ask the subject to guess what estimate of the quantity would be given by another subject who does not have access to the specific information. This gives a prior probability for using Bayes' rule (Larson and Shubert 1979) to formally compute a posterior probability that properly weights both general and specific information.

Obviously, the analyst believes that weighting sparse, specific data more heavily than general data constitutes a bias. The weak point of this argument is the assumption that the general information given relates quantities that are similar to those being assessed. For example, comparison of a field test value of effective porosity with general information about porosities or apparent porosities derived from laboratory tests may contradict this assumption. When considering the complexity of basalt flow tops where the water of the pore structure is highly dependent on the initial content of dissolved volatiles, and lava viscosity due to the chemical composition, etc., comparison of general information based on field tests may not even be valid. In a flow top at the mega-scale, neither true porosities nor lab test based apparent porosities are indicative of the structure through which the water flows.

In summary, it is up to the panelist being questioned to consider whether or not the specific field test values may or may not be the only pore structure information that is reflective of the nature of ground water flow within the system. This is the nature of professional judgment that is the basis of expertise.

Relevance to Regulations - The favorable condition as indicated by stochastic analysis travel times of 17,000, 86,000, and 81,000 years (see EA pages 6-266 through 6-269) have been overestimated due to inherent bias in studies used to determine the effective porosities to be used in the travel time analysis.

Recommendation: Use the mean of field test effective thicknesses (effective porosity multiplied by unit thickness) as the basis for the median value in the stochastic analysis.

References:

Larson, H.J., and B.O. Shubert, 1979. Probabilistic Models in Engineering Sciences, Engineering Sciences, 1:91, John Wiley & Sons, Inc., New York.

Runchal, A.K., M.W. Merkhofer, E. Olmstead, and J.D. Davis, 1984a. Probability Encoding of Hydrologic Parameters for Basalt: Elicitation of Expert Opinions from a Panel of Five Consulting Hydrologists, SD-BWI-TA-010, Rockwell Hanford Operations, Richland, Washington.

YIN Comment #: 6-32

EA Sections: 6.3.1.1.11
6.3.1.1.12

Pages 6-79, paragraph 1
6-85, paragraph 3

Statement of Issue: The expected median travel time of 81,000 years through the Cohasset flow top is overestimated due to inconsistent consideration of hydraulic conductivity vs. effective porosity.

Discussion: The methodology used to elicit expert opinions of probable effective porosity ranges for flow tops is described in Runchal et. al., 1984a (SD-BWI-TA-011). The panel consisted of five well-known hydrologists who were chosen on the basis of knowledge and impartiality. The panelists were provided with pertinent data on the BWIP site (Appendix D of SD-BWI-TA-010) and asked to give a probable range of effective porosities to be used in stochastic travel time studies. The determined need for this information was based on the sparse field test data available and the inappropriateness of the laboratory determined parameters. The field test value of effective porosity was determined from borehole testing in the McCoy formation and was approximately 1.6×10^{-4} (Leonhart et al., 1984). This range was determined by taking the field test results for effective thickness and dividing by the approximate formation thickness of 11.3 meters.

As per definition, the effective porosity represents the ratio of pore space through which most of the water flows to the total volume of material in the formation. As described in Leonhart et al. (1984), the active pore space mainly resides in a zone of higher conductivity in the flow top that is probably less than 10 percent of the thickness of the whole flow top. In general, similar high conductivity zones also control flow in other flow tops. Borehole studies in other Grande Ronde flow tops indicate a general range of high conductivity zones of 5 to 25 percent of the unit thickness (Leonhart et al., 1984).

As noted in Appendix D of Runchal et. al., the panelists were give the results of the field test (i.e., 1.6×10^{-4}) and then told, "The effective porosity is somewhat higher, however, because of the presence of highly conductive zones." Although porosity in the narrow high conductivity zone is underestimated by this method, this definition of effective porosity is consistent with field derived transmissivity values that are used in travel time calculations and are considered to be due to water transmission allocated over the whole flow top thickness.

If the effective porosity of the high conductivity zone is to be used in calculations, then the transmissivity should be divided by the thickness of the high conductivity zone to derive the hydraulic conductivity, which is not the case for the stochastic analysis.

By indicating that the effective porosity is somewhat higher due to the high conductivity zone, the questioner is biasing the experts answers in a manner that is inconsistent with the methodology used in travel time analysis. For an unbiased parameter estimation of effective porosity, the questions should have been aimed at estimating ranges of effective thickness (effective porosity multiplied by formation thickness) given the field tests and high conductivity zone thickness ranges for other Grande Ronde flow tops.

Relevance to Regulations - This favorable condition cannot be accepted as present on the basis of studies performed (see EA pages 6-266 through 6-269). There is no basis for considering the McCoy Canyon field test effective thickness range as unreasonably high. The use of a mean value that is one order of magnitude greater than that indicated in field tests (which, although sparse, are the most accurate data available) biases the stochastic analyses such that a favorable finding is virtually guaranteed. The biases also hide the potential for disqualification based on a travel time of less than 1000 years.

Recommendation: Until further field data results are available, the mean of an effective porosity range of 1.6×10^{-4} to 2.7×10^{-4} as derived from the field tests should be considered the median value for use in preliminary travel time calculations, and it should be concluded that the favorable condition is not present.

References:

Leonhart, L.S., R.L. Jackson, D.L. Graham, L.W. Gelhar, G.M. Thompson, B.Y. Kauchiro, and C.R. Wilson, 1984. Analysis and Interpretation of a Decirculating Tracer Experiment Performed on a Deep Basalt Flow Top, RHO-BW-SA-300 P, Rockwell Hanford

Operations, Richland, Washington.

Runchal, A.K., M.W. Merkhofer, E. Olmstead, and J.D. Davis, 1984a. Probability Encoding of Hydrologic Parameters for Basalt: Elicitation of Expert Opinions from a Panel of Five Consulting Hydrologists, SD-BWI-TA-010, Rockwell Hanford Operations, Richland, Washington.

YIN Comment #: 6-33

EA Section: 6.3.1.2.2 Geochemistry -- evaluation process

Page 6-87, Paragraph 3

Statement of Issue: The methods and procedures that DOE has used to determine radionuclide sorption are not valid for evaluating individual radionuclide behavior under repository conditions.

Discussion: To date, all DOE radionuclide sorption data has been measured in static, batch experiments. In this type of experiment, a single averaged K_d value is determined for all species of a radionuclide, even though, in general, each species has a distinct K_d value. The sorption ratios developed by batch tests will not account for particular species of a radionuclide which could move more rapidly than predicted by the averaged value. DOE claims that future testing (for example, using flow-through column experiments) will address this problem, however, they give no details of experiments, not even in the referenced subsection (4.1.2.6) on future plans.

Importance to EA findings/conclusions - DOE concedes that their present method of study has inherent inadequacies. The K_d values they have determined are not representative of specific radionuclide species, and therefore are not accurate for radionuclide release modeling.

Recommendation: Conclusions as to the behavior of individual radionuclide species can not be made based on the present data; thus, the favorable condition cannot be considered present.

YIN Comment #: 6-34

EA Section: 6.3.1.2.3 Geochemistry -- favorable condition (1)

Page 6-89, paragraph 4

Statement of Issue: Information regarding radionuclide sorption has been incorrectly presented by DOE. Strong adsorption of radionuclides by basalt secondary phases has not been clearly demonstrated.

Discussion:: The experiments performed by BWIP to measure radionuclide sorption have not been conducted in representative repository conditions.

1) Many experiments have been conducted under oxidizing conditions rather than the reducing conditions that BWIP expects to be present in the repository environment. Sorption behavior is characteristic of a particular radionuclide species in solution, and many of the radionuclides change their valence (and therefore speciation) depending on the redox conditions present. Thus, under oxidizing conditions, DOE may be modeling different radionuclide species than would be found under the expected reducing conditions.

2) The reducing conditions used for a number of experiments were created by adding hydrazine, a highly reducing chemical which alters experimental conditions and does not produce defensible results (Kelmers, 1984).

3) The temperatures at which the experiments were conducted are not representative of expected near-field conditions after waste emplacement. Temperatures are expected to reach 250-300°C, but most experiments were run at 23 and 60°C. Because radionuclide sorption behavior is strongly influenced by many environmental parameters (Salter and Jacobs, 1982), radionuclide K_d values should be determined under conditions that simulate actual repository conditions as closely as possible.

4) Only static experiments were conducted, and equilibrium conditions were not shown to have been reached. Data that have been reported as distribution coefficients, therefore, are actually sorption ratios. These non-equilibrium values are generally higher (i.e. indicate greater retardation) than the equilibrium coefficients (Kelmers, 1984), and thus should not be used to evaluate repository performance.

Importance to EA findings/conclusions - BWIP presents the Hanford site as having very favorable geochemical conditions, yet there is not a well-established data base on which to base this conclusion. Defensible sorption studies demonstrating high radionuclide retardation have not been conducted, therefore, the favorable condition has not been shown to exist at the site.

Recommendation: Geochemical experimentation should be conducted at a full range of expected repository conditions. Equilibrium conditions must be proven, or the resulting distribution coefficients do not describe the true radionuclide behavior.

Flow-through column experiments should be considered as an alternative to static batch tests because equilibrium conditions would be easier to verify. Until the above are done, DOE should not conclude that the site has favorable geochemical conditions.

References:

Kelmers, A.D., 1984. Review and Assessment of Radionuclide Sorption Information for the Basalt Waste Isolation Project Site (1979 through May, 1983), NUREG/CR-3763, ORNL/TM-9191/V1.

Salter, P. F. and G.K. Jacobs, 1982. Evaluation of Radionuclide Transport: Effect of Radionuclide Sorption and Solubility, RHO-BW-SA-192 P.

YIN Comment #: 6-35

EA Section: 6.3.1.2.3 Geochemistry -- favorable condition (1)

Page 6-90, paragraph 1

Statement of Issue: Hydrazine is not an acceptable chemical reducing agent for geochemical sorption experiments. The conclusions regarding radionuclide sorption on the current data are not valid.

Discussion: Hydrazine is used in BWIP radionuclide sorption experiments to simulate the reducing conditions which are expected in the repository. However, there are many reasons why hydrazine should not be used in the laboratory experiments (Kelmers, 1984), including:

1) The reaction between hydrazine and any reducible radionuclide is unknown, therefore the effective redox condition is unknown.

2) Hydrazine hydrate dissociates to release hydroxide anions, which likely affect the groundwater pH, so the pH is no longer representative of in-situ conditions.

3) Hydrazine could react with bicarbonate in the groundwater to form the carbamate anion, which may form radionuclide complexes.

4) Hydrazine is an aggressive chemical and attacked polycarbonate test tubes used in the BWIP tests, causing failure of the test tubes or brown-colored degradation products in the groundwater.

5) Hydrazine may alter or disaggregate clay mineral structures and change the secondary minerals in the

test.

6) Uncertainty exists concerning the solid phase or solution species formed by the reaction of hydrazine with some radionuclides such as technetium.

As a result of the above problems, the sorption information collected in the presence of hydrazine is not defensible for modeling the radionuclide releases to the accessible environment.

The EA states that "experiments are under progress for key radionuclides under reducing conditions that do not rely on the presence of hydrazine." The methodology for these experiments is not presented.

Importance to EA findings/conclusions - The radionuclide sorption data is used as the basis for the Hanford site's favorable geochemistry rating. However, DOE does not have a sound data base on which a conclusion can be based, since its experimental methodology is not acceptable or defensible. The data collected in the experiments using hydrazine cannot be used to show compliance with the Favorable Condition (1), therefore, the DOE cannot show that the Favorable Condition is present at Hanford.

Recommendation: A more direct approach to creating reducing conditions would be to allow the basalt or interbed materials to establish a "natural" redox condition in the tests. This could be accomplished by conducting tests isolated from air in a suitable controlled atmosphere chamber. Another alternative would be to use methane-saturated groundwater (GR-2) which would closely simulate many Grande Ronde groundwaters. Currently, no conclusions can be drawn regarding radionuclide sorption behavior under repository conditions. It should not be concluded that this favorable condition is present.

References:

Kelmers, A.D., 1984. Review and Assessment of Radionuclide Sorption Information for the Basalt Waste Isolation Project Site (1979 through May, 1983), NUREG/CR-3763, ORNL/TM-9191/V1.

YIN Comment #: 6-36

EA Section: 6.3.1.2.4 Geochemistry - favorable condition (2)

Page 6-90, paragraph 4

Statement of Issue: The DEA incorrectly states that the Hanford geologic setting is unlikely to contain substantial concentrations of organic complexes. DOE claims that mud-drilled boreholes make it difficult to obtain "representative deep groundwater samples" for analysis of organic species. Consequently, DOE lacks the data on which to base its conclusion.

Discussion: Most boreholes installed at the Hanford site have been drilled using a drilling mud mixture including organic polymers, bentonite, and Columbia River water. There is always the possibility that the use of drilling mud can contaminate the groundwater and render samples non-representative. The measurement of tritium in the groundwater samples is used by DOE to determine if samples are acceptably free of drilling mud contamination. Samples with <1 tritium unit are considered acceptable. The DOE however, claims that its groundwater samples are not representative. This indicates poor quality control of the sampling program. If samples are non-representative, then DOE cannot reach a conclusion concerning the organic content of the groundwater.

Importance to EA findings/conclusions - The organic content of the Hanford groundwaters can greatly affect the radionuclide mobility. Organic species can form very strong, soluble radionuclide complexes which would therefore increase the transport rates.

Recommendation: An effort should be made to collect "representative" samples (with no drilling mud contamination), so that an accurate determination of the organic content of the groundwater can be made. If it is determined that the formation water cannot be cleansed of drilling mud, then:

1) Wells drilled in the future should use a different mud mixture which will not adversely affect the organic analysis.

2) All analyses conducted in the past should be reevaluated to determine whether other parameters have been adversely affected by the use of drilling mud. One check of the representativeness of samples is the anion-cation balance.

YIN Comment #: 6-37

EA Section: 6.3.1.2.5 Geochemistry -- favorable condition (3)

Page 6-91, paragraph 3

Statement of Issue: Hydrothermal conditions in the near field will likely cause alteration of the existing clays which fill basalt fractures. A significant alteration reaction will be the conversion of mixed layer smectite clays to non-sorptive illite clays.

Discussion: At the ambient repository temperature in the Grande Ronde (approximately 65°C), the clay fracture fillings are predominantly smectite. Eberl and Hower (1976) showed that at 60 °, the mixed layer clay is initially 75% smectite and 25% illite. At 100°C, hydrothermal alterations result in mixed layer clays which are 20% smectite and 80% illite. Because illite has a low sorptive capacity, this conversion will result in reduced radionuclide retardation.

Importance to EA findings/conclusions - One of the favorable conditions regards the capability of the basalt primary and secondary phases to retard radionuclide transport. The DOE has not considered all the hydrothermal reactions possibly resulting from waste emplacement. The conversion of smectite to illite is inconsistent with the presence of the favorable condition.

Recommendation: Elevated temperatures can cause irreversible alterations of the fracture filling clays, thus reducing the sorptive capacity of the repository. Therefore the favorable condition (3) is not present at the site, and the DOE conclusion should be changed.

References:

Eberl D. and J. Hower, 1977. "The Hydrothermal Transformation to Sodium and Potassium Smectite into Mixed layer clays," Clays and Clay Minerals, Volume 25, pp 215-228.

YIN Comment #: 6-38

EA Section: 6.3.1.2.6 Geochemistry -- favorable condition (4)

Page 6-92, first paragraph

Statement of Issue: Solubility and sorption data for radionuclides do not constitute a sufficient basis on which to calculate accurate release rates.

Discussion: The DOE data on radionuclide solubility are not sufficient for calculating release rates. Solubility estimates by Early (1982) determine solubilities from thermodynamic tables at 25°C. Thus, the solubilities calculated are strictly applicable only at 25°C, and may vary greatly with temperature increases to 250-300°C. At elevated temperatures, thermodynamic data exists for only a few radionuclides, and much of it is estimated. However, thermodynamic parameters available for uranium and plutonium at 50 to 60°C indicate that solubilities of these radionuclides at the higher temperatures are approximately one order of magnitude greater than their respective solubilities at

25°C. Solubilities would likely increase even more at temperatures above 60 degrees C.

Solubility determinations also show a strong dependence on Eh, by as much as 10 orders of magnitude. Since the Eh value has not been conclusively determined, solubilities of some radionuclides are not known to better than 10 orders of magnitude. During waste emplacement, the repository will be open to the atmosphere and oxidizing conditions are expected. The rate at which the system will return to the expected reducing conditions is not known. This further increases the uncertainty in the repository Eh, and thus the radionuclide solubilities.

Groundwater composition also greatly affects radionuclide solubilities. A study by Early (1982) showed that the range of observable compositions for Grande Ronde groundwater lead to calculated ranges of solubilities of two to three orders of magnitude for some radionuclides.

From the above limitations, it can be seen that the radionuclide solubilities for the repository conditions are not well known.

Importance to EA findings/conclusions - DOE currently believes that the solubility data supports the favorable condition. They have not considered all the limitations in the determination of radionuclide solubilities. Limitations in the thermodynamic data base, groundwater temperature, Eh, and chemical composition result in radionuclide solubilities defined at best within a range of two to three orders of magnitude. With this information, it is not possible to conclude that the favorable condition has been met.

Recommendation: Much more detailed thermodynamic measurements and solubility measurements need to be made for the radionuclides before reaching conclusions regarding the dissolution of the entire inventory. Solubility calculations must be relevant to the repository conditions.

References:

Early, T.O., G.K. Jacobs, D.R. Drewes, and R.C. Routson, 1982. Geochemical Controls of Radionuclide Releases from a Nuclear Waste Repository in Basalt: Estimated Solubilities for Selected Elements, RHO-BW-ST-39 P, Rockwell Hanford Operations, Richland, WA.

YIN Comment #: 6-39

EA Section: 6.3.1.2.7 Geochemistry -- favorable condition (5)

Page 6-93, first paragraph

Statement of Issue: DOE has not shown that the geologic repository will decrease radionuclide travel time by a factor of 10, because their sorption data is not representative of individual radionuclides for expected repository conditions.

Discussion:: In order for a radionuclide in the repository to be retarded by a factor of 10, the distribution coefficent for the radionuclide must be greater than or equal to 0.3 ml/g. The DOE reports that its measured sorption coefficients are greater than 0.3, and that the favorable condition is met. However, their information on sorption behavior is inadequate, and should not be used to assess the radionuclide potential for sorption and retardation for the following reasons:

1) No radionuclide sorption data has been collected under redox conditions which are relevant to the repository near-field or far-field. Much of the data was collected under oxic redox conditions. The remainder of the data was collected in the presence of added hydrazine hydrate. This data, however, has been shown to be unacceptable (Kelmers, 1984).

2) It was not established that sorption information was collected under steady-state conditions. Results of desorption experiments to test for sorption/desorption disequilibrium have not been reported. Where BWIP has reported values for distribution coefficients they have actually only measured sorption ratios, which may not have been collected at equilibrium.

3) Sorption information has not been collected at temperatures representative of the repository conditions. Temperatures in the near-field environment are expected to reach 200-300°C due to radioactive decay heat. Adsorption/desorption can be tremendously temperature sensitive (Maest and Crerar, 1984; Salter et al, 1981), and therefore sorption coefficients cannot be extrapolated from lower temperatures. Studies by Maest and Crerar (1984) show that for Uranium and Cesium, adsorption generally decreases with increasing temperature. Most BWIP sorption studies have been conducted at temperatures of 23 and 60°C and should not be used to evaluate radionuclide releases in the high-temperature repository conditions.

4) The effect of multiple speciation on the sorption information was not evaluated. Several radionuclides can exist as more than one solution species, due to multiple valences or complexes with other groundwater constituents. Each solution species may have a distinct sorption coefficient, and therefore BWIP batch tests, which calculate an average K_d value, may not account for a portion of the radionuclide which could move more rapidly than predicted.

5) The groundwater used in the sorption experiments was synthetic groundwater prepared to simulate the existing in-situ conditions. No consideration was given to the likely alteration of groundwater composition due to hydrothermal and radiolytic reactions with the engineered facility components. A change in groundwater composition can greatly affect the sorption behavior (Salter et al, 1981), since it can influence radionuclide speciation.

6) The BWIP sorption information is not adequate for several key radionuclides. For example, technetium is considered to be the most hazardous radionuclide in high-level waste (Barney and Wood, 1980). However, there has been no high-temperature data for technetium reported, and no sorption isotherms for technetium have been identified. Iodine, which is considered the second most hazardous radionuclide, is not expected to be adsorbed at all in the basalt environment, and therefore will not be retarded. Thus, for the two most hazardous radionuclides, DOE has not been able to meet the favorable condition.

Importance to EA findings/conclusions - The DOE has not shown experimentally that all radionuclides in the waste will have a distribution coefficient greater than 0.3 (mg/l), and thus will be favorably retarded. The EA even states that "several radionuclides ... do not adsorb in the basalt geochemical environment and will not be retarded." The DOE does not have sufficient basis to state that the favorable condition is met by the Hanford site.

Recommendation: The DOE must conduct sorption experiments under the conditions which they expect in the repository (i.e. reducing, high temperature conditions). The use of hydrazine to simulate reducing conditions is not aceptable. Complete sorption/desorption experiments must be conducted for all radionuclides, and equilibrium conditions must be established, before conclusions can be reached. The use of flow-through reactors is recommended for determining distribution coefficients for multiple radionuclide species.

References:

Barney G.S. and B.J. Wood, 1980. Identification of Key Radionuclides in a Nuclear Waste Repository in Basalt, RHO-BW-ST-9.

Early, T.O., G.K. Jacobs, D.R. Drewes, and R.C. Routson, 1982. Geochemical Controls of Radionuclide Releases from a Nuclear Waste Repository in Basalt: Estimated Solubilities for Selected Elements, RHO-BW-ST-39 P, Rockwell Hanford Operations, Richland, WA.

Eberl D. and J. Hower, 1977. "The Hydrothermal Transformation of Sodium and Potassium Smectite into Mixed Layer Clays," Clays and Clay Minerals, Volume 25, pp 215-228.

Kelmers, A.D., 1984. Review and Assessment of Radionuclide Sorption Information for the Basalt Waste Isolation Project Site (1979 through May 1983), NUREG/CR-3763, ORNL/TM-9191/V1.

Maest A.S., D.A. Crerar, E.C. Dillon, S.M. Trehu, and T.N. Rountree, 1984. "Effect of Temperature on the Sorption of Chelate Radionuclides," for 1984 Materials Research Society Meeting, Boston, and Symposium: Scientific Basis for Radionuclide Disposal (in review).

Salter, P.F., and G. K. Jacobs, 1982. Evaluation of Radionuclide Transport: Effect of Radionuclide Sorption and Solubility, Rockwell Hanford Operations, RHO-BW-SA-192 P.

<u>YIN Comment #:</u> 6-40

EA Section: 6.3.1.2.8 Geochemistry, potentially adverse condition (1)

Page 6-93, paragraph 3

<u>Statement of Issue:</u> High fluoride levels in the groundwater of the host rock will increase such that repository performance could be compromised.

<u>Discussion:</u> DOE claims the high fluoride concentrations (mean concentration 31 mg/l (Long and WCC, 1984) in the groundwater of the host rock will not increase the solubility of radionuclides, based on the study conducted by Early et al. (1982). However, an independent reviewer has compared the effects of various groundwaters on the solubility of plutonium. The study of Cleveland et al. (1983) shows that the high fluoride levels present in the Grande Ronde Basalts will greatly increase plutonium solubility by stabilizing Pu(IV) in solution as mono- or difluoro complexes or as hydroxyfluoro complexes.

DOE presents three objections to the study of Cleveland et al. (1983) in the EA:

1) the experiments were carried out in the absence of a basalt solid phase;

2) there was no mechanism to control Eh; and

3) the importance of colloids was not evaluated.

However, the DOE objections do not change the basic conclusions of this study. The presence of a basalt solid phase in the experiment would not affect the determination of Pu solubility in basalt groundwater. The inherent uncertainty in any Eh measurements makes it impossible to accurately evaluate the Eh of experiments and to use Eh as a control factor. The basalt groundwater used in the study was definitely reducing--nearly all the plutonium in solution was in reduced oxidation states, Pu(III) and Pu(IV)(Cleveland, personal communication, 1985). The study also examined the solubility of plutonium in filtered and unfiltered samples to check for plutonium sorption onto colloids and other particles. They found that the presence of colloids and smaller particles (>0.05 um) had no significant effect on the solubility of plutonium.

Importance to EA findings/conclusions - Fluoride complexation of plutonium was shown by Cleveland et al.(1983) to greatly increase the solubility of plutonium in basalt groundwaters. Plutonium is an important radionuclide in the inventory of the waste package. Therefore, high fluoride in the Grande Ronde groundwaters is considered as a "condition that could affect the solubility...to the extent that the expected repository performance could be compromised."

Recommendation: Potentially Adverse Condition (1) of the Geochemistry section (DOE General Siting Guidelines, 10 CFR 960.4-2-2) is present at the Hanford site because of the high fluoride concentrations in the Grande Ronde Basalts groundwater. All references to this condition in the EA should be changed from "not present (NP)" to "present (P)".

References:

Cleveland, J.M., T.F. Rees, and K.L. Nash, 1983. "Plutonium Speciation in Selected Basalt, Granite, Shale, and Tuff Groundwaters," Nuclear Technology, Volume 62, pp. 298-310.

Early, T.O., G.K. Jacobs, D.R. Drewes, and R.C. Routson, 1982. Geochemical Controls of Radionuclide Releases from a Nuclear Waste Repository in Basalt: Estimated Solubilities for Selected Elements, RHO-BW-ST-39 P, Rockwell Hanford Operations, Richland, WA.

Long, P.E. and Woodward-Clyde Consultants, 1984. Repository Horizon Identification Report, Volumes 1 and 2, Draft SP-BWI-TY-001, WCC for Rockwell Hanford Operations, Richland, WA.

YIN Comment #: 6-41

EA Section: 6.3.1.2.8 Geochemistry, potentially adverse condition (2)

Page 6-95, paragraph 1

Statement of Issue: Organic compounds, at concentrations found in the Grande Ronde groundwater, will reduce adsorption of americium and neptunium in the far-field environment.

Discussion: In the EA, DOE states that the geochemical conditions of the Grande Ronde Basalts produces an environment favorable for the adsorption of radionuclides in the far-field. However, naturally-occurring organic compounds with high metal-binding capabilities are present in the Grande Ronde groundwater. Means (1982) found approximately 0.3 mg/l of fulvic acids in a single sample. DOE reports in the EA that "groundwaters from extensively pumped horizons usually have total organic carbon concentrations of less than 1 mg/l...(p.6-94, paragraph 1)." It has been shown by Boggs and Seitz (1984) that the adsorption of americium and neptunium by crushed basalts was reduced by 25 to 50 percent by the addition of 1 mg/l of dissolved organic carbon at 22 and 90°C.

Importance to EA findings/conclusions - The presence of organic compounds with high metal-binding capacities (such as fulvic acids) in the Grande Ronde groundwater will reduce adsorption of americium and neptunium, two important radionuclides in the waste inventory.

Recommendation: Potentially Adverse Condition (2) of the Geochemistry section of the DOE General Siting Guidelines (10 CFR 960.4-2-2) is present at the Hanford site because the concentrations of organic compounds found in the Grande Ronde groundwater will decrease the sorption of americium and neptunium by basalt. All references to this condition in the EA should be changed to reflect a status of "present (P)" instead of "not present (NP)."

References:

Boggs, S. Jr., and M.G. Seitz, 1984. The Influence of Dissolved Organic Substances on Sorption Behavior of Americium and Neptunium, ANL-83-84, Argonne National Laboratory, Chemical Technology Division, Argonne, IL.

Means, J.L., 1982. The Organic Geochemistry of Deep Groundwaters, ONWI-268, Battelle Memorial Institute, Columbus, Ohio.

YIN Comment #: 6-42

EA Section: 6.3.1.2.9 Geochemistry -- Potentially adverse condition (2)

Page 6-96, first paragraph

Statement of Issue: The organic content, fluoride content and colloids in the basalt groundwater are all factors that could adversely affect radionuclide sorption.

Discussion: The DOE recognizes that the above factors can have an influence on radionuclide sorption, but gives no details as to how studies will progress to evaluate their significance. Subsection 4.1.1.5 is referenced, but there are no details given.

Importance to EA findings/conclusions - Factors such as fluoride and organic content, and colloids in the groundwater could lead to decreased radionuclide sorption and therefore could constitute a potentially adverse condition.

Recommendation: DOE must definitely study the affects of these factors on radionuclide sorption, and should make known their plans of study, before conclusions can be made.

YIN Comment #: 6-43

EA Section: 6.3.1.2.10 Geochemistry, potentially adverse condition (3)

Page 6-96, paragraph 2

Statement of Issue: The evidence that supports non-oxidizing conditions in the repository are based on the reactions between observed solid phases and the absence of specific solid phases and/or dissolved species in the Grande Ronde groundwater. The evidence is based on the incorrect assumption that equilibrium conditions exist in the Grande Ronde Basalt.

Discussion: The use of reactions involving solid phases present in the Grande Ronde Basalt to make thermodynamic calculations of the Eh is not valid because it is unlikely that the basalt-groundwater system is in equilibrium at the low temperatures found in the Grande Ronde. The thermodynamic calculations are based on the assumption of equilibrium conditions.The five points cited in the EA as evidence of a chemically - oxidizing environment are challenged in the following:

1) The reaction between magnetite and secondary iron- bearing minerals has been shown to be an effective buffer of oxygen fugacity in systems with temperatures below 400°C (Huebner, 1971).

2) In addition , Beuson and Teague (1979) report the existence of a ferric iron phase, possible hematite, in the smectite clays , the primary fracture - filling alteration mineral in the Grande Ronde Basalts. lack of hematite in the Grande Ronde Basalt is not a definite indicator of reducing conditions because reaction rates between magnetite, pyrite, other ferrous iron minerals and hematite are not well known at any temperatures.(Barton and Skinner, 1967). Therefore, calculations or assumptions based on equilibrium conditions are not valid.

3) The coexistence of sulfide and sulfate is not shown in any hydrochemical data published for the Hanford site. The presence of sulfide in the Grande Ronde groundwater does not definitely indicate reducing conditions because the aqueous sulfur species equilibrate extremely slowly at temperatures less than 100°C. (Ohmoto and LaSaga, 1982). Furthermore, Grandstaff et. al.(1983) concluded that the low sulfide : sulfate ratio in their experiments "may indicate that redox conditions are buffered to more oxidized values by the presence of spent fuel. The presence of methane coexisting with carbon dioxide is not a definite indicator of reducing conditions because reaction rates are expected be quite slow at the temperatures

expected in the repository. It is likely that both the hydrogen sulfide/sulfate and the methane/carbon dioxide speciation are not in equilibrium and the source of the sulfide and methane may be upwelling from deeper groundwaters (USGS, 1983; Burnham, 1983). DOE has not explored the effects of the deeper groundwaters.

4) As stated in the EA, Jantzen (1983) did achieve an Eh of -0.41 V at a pH of 8.44 at 60°C in a mixture of crushed basalt and deionized water. This experiment was designed to examine the ability of crushed basalt to impose reducing conditions in the near-field environment. When the experiment was conducted with a mixture of crushed basalt and simulated, deoxygenated Grande Ronde groundwater (GR3), the lowest Eh achieved was only about -0.1 V at a pH of 8.6 at 60°C. The Eh measured in these experiments was shown to be strongly dependent on the surface area/volume ratio (SA/V) of the crushed basalt. At greater SA/V ratios (finer mesh size of crushed basalt), Eh measurements were more reducing. To simulate the ability of basalt to influence the redox conditions of the groundwater in the far-field environment, uncrushed basalt (with a very low SA/V ratio relative to the crushed basalt) would be used. Such a basalt sample would not be expected to impose reducing conditions on the groundwater in this experiment.

Importance to EA findings/conclusions - The EA presents *no* evidence that establishes the existence of non-oxidizing conditions in the pre-waste-emplacement groundwater.

Recommendation: Because the EA has not sufficiently established the existence of non-oxidizing conditions in the groundwater at the Hanford site, Potentially Adverse Condition (3) of the Geochemistry section of the DOE General Siting Guidelines (10 CFR 960.4- 2-2) is considered to be present at the Hanford site.

References:

Barton, P.B., and B.J. Skinner, 1967. "Sulfide Mineral Stabilities," in H.L. Barnes, ed., Geochemistry of Hydrothermal Ore Deposits, Holt, Rhinehart and Winston, Inc., N.Y. pp.236-333.

Benson, L.V. and L.S. Teague, 1979. A Study of rock-water-nuclear waste interactions in the Paso Basin, Washington, University of California, Lawrence Berkely Laboratory Report LBL-9677.

Burnham, J.B., 1983. "Basalt Waste Isolation Project Review by Pacific Northwest Laboratory's Review Team," (letter from D.E. Oleson to A.G. Fremling, November 29, 1983), 216 pp.

Grandstaff, D.E., G.L. McKeen, E.G. Moore, and G.C. Ulmar, 1983. "Reactions in the System Basalt/ Simulated Spent Fuel/ Water." in Proceedings of the Materials Research Society Symposium Scientific Basis for Nuclear Waste Management, Boston, Ma, prepared for Rockwell Hanford Operations.

Huebner, J.S., 1971. "Buffering Techniques for Hydrostatic Systems at Elevated Pressures," G.C. Ulmer, (ed.), Research Techniques for High Temperature and High Pressure, pp. 123- 177.

Jantzen, C.M., 1983. Methods of Simulating Low Redox Potential (Eh) for a Basalt Repository, DP-MS-83-59X, E.I. DuPont de Nemours & Co., Savannah River Laboratory, Aiken, SC.

Ohmoto, H. and A.C. LaSaga, 1982. "Kinetics of Reactions Between Aqueous Sulfates and Sulfides in Hydrothermal Systems," Geochim. Cosmochim. Acta, Volume 46, pp. 1727-1745.

U.S. Geological Survey, 1983. "Review Comments by the U.S. Geological Survey on Site Characterization Report for the Basalt Waste Isolation Project," DOE-RL-82-3, (letter from J.B. Robertson, Chief, Office of Hazardous Waste Hydrology, to O.L. Olson, Project Manager, BWIP, May 6, 1983), 60 pp.

YIN Comment #: 6-44

EA Section: 6.3.1.3.3 Rock characteristics - favorable condition (1)

Page 6-99

Statement of Issue: This favorable condition is not met due to uncertainties in lateral variations in the Cohassett.

Discussion: Favorable Condition - "(1) A host rock that is sufficiently thick and laterally extensive to allow significant flexibility in selecting the depth, configuration, and location of the underground facility to ensure isolation."

The EA recognizes that this favorable condition is not present. Suggestions in the EA discussion of this favorable condition that significant lateral flexibility exists is not substantiated by evidence. Large variations in thickness of the flow components (e.g., flow top, colonnade, entablature, pillow zones) occur especially in the Umtanum, Rocky Coulee, and McCoy Canyon flows. These variations are observed within the Cohassett. The degree of variability of these components is unknown and would be difficult to characterize.

Importance to EA findings/conclusions: Characterization of the intraflow stratigraphy will be difficult due to lack of consistency in the lateral variation of the intraflow stratigraphy.

Recommendation: Site characterization will require drilling in advance of tunnel construction in the repository. Site characterization will not be readily accomplished due to the uncertainties in intraflow stratigraphy. The EA's overly optimistic discussion of this favorable condition must address the lack of lateral flexability more critically.

YIN Comment #: 6-45

EA Section: 6.3.1.3.4, Rock characteristics - favorable condition (2)

Page 6-102

Statement of Issue: This favorable condition is present for only one of three qualifying characteristics.

Discussion: Favorable Condition - "(2) A host rock with a high thermal conductivity, a low coefficient of thermal expansion, or sufficient ductility to seal fractures induced by repository construction, operation, or closure or by interactions among the waste, host rock, ground water, and engineered components."

The repository host rock, basalt, does not meet this favorable condition with respect to a) high thermal conductivity or b) a sufficient ductility to seal fractures induced by repository construction, operation, etc. The favorable condition may exist at Hanford due to the relatively low coefficient of thermal expansion of the host rock. However, what is debatable is what constitutes "a low coefficient of thermal expansion". The data presented in the EA (Table 6-7) is not complete in any respect. Also, the EA declares that data for Table 6-8 is taken from DOE (1979), vol. 1, pp. 7.2.17, 7.2.20,etc...). The reference should be volume 4.

The statement "...hydrothermal alteration of the basalt in the vicinity of the waste package is expected to seal fractures, resulting in improved host rock isolation characteristics" is questionable. Due to the low thermal conductivity of the basalt, temperatures can be expected to be quite high, thereby reducing or removing the sealing characteristics of the clays due to their decreased ability to adsorb radionuclides (Smyth, 1982).

Importance to EA findings/conclusions - The effects of those conditions that are not present for this favorable conditon (i.e., low thermal conductivity, brittle host rock) are quite important to repository performance. The structure of this guideline makes its application quite deceptive with respect to the BWIP site. Though this favorable condition is present due to the low coefficient of thermal expansion of basalt, it is important to note that the other two qulifying restrictions are not present.

Recommendation: A favorable condition implies that the repository site is "favorable" with respect to that condition. Since this favorable condition is present on only one count out of three, the EA should re-evaluate the presence of this favorable condition.

Also, more work is needed concerning the adsorbing characteristics of clays at high temperatures.

References:

DOE (U.S. Dept. of Energy), 1979. Technology for Commercial Radioactive Waste Management, DOE/ET-0028, Volume 1 and Volume 4, Washington, D.C.

Smyth, J.R., 1982. "Zeolite Stability Constraints on Radioactive Waste Isolation in Zeolite - Bearing Volcanic Rocks," Journal of Geology, Volume 90, pp. 195 - 202.

YIN Comment #: 6-46

EA Section: 6.3.1.3.6 Rock characteristics - potentially adverse conditon (2)

Page 6-106 to 6-109

Statement of Issue: Several statements made in the EA are based on insufficient evidence or do not directly apply here.

Discussion: Potentially Adverse Condition - "(2) Potential for such phenomena as thermally-induced fractures, the hydration or dehydration of mineral components, brine migration, or other physical, chemical, or radiation- related phenomena that could be expected to affect waste containment or isolation." The EA recognizes that this potentially adverse condition exists at Hanford. Several statements made in the discussion of this potentially adverse condition are nebulous. These will be summarized below.

1) On Page 6-106, par. 5, the EA asserts that "the potential for thermal-induced fracturing in the strata overlying the preferred candidate horizon is very low and hydration and dehydration of mineral components in the flow top is not expected to be significant". Firstly, the potential for thermally induced fracturing depends on many

rock characteristics (e.g., presence of water, degree of fracturing, thermal conductivity, etc...) of the host rock which are not well enough understood to make this statement.

Secondly, the USGS (1983, p.55) questioned BWIP's position regarding these minerals, especially the zeolite minerals and smectite clays. Smyth (1982) has shown that these minerals are unstable at elevated temperatures and at low water vapor pressures and may breakdown either by reversible dehydration or by irreversible mineralogical reactions. The behavior of these minerals is not well enough understood for the EA to make this statement.

2) Regarding thermal-induced fractures that will develop in the host rock upon emplacement of the repository, the EA notes three fracture mechanisms (p. 6-107, par. 2). Fractures by mechanism (3) ("due to the development of high deviatoric excavation-induced and thermal expansion-induced stresses) will be especially important in the repository due to the high in situ stresses. The present stress state is one of high horizontal compressive and low vertical stresses. The EA (Page 6-107, par. 2) notes that: "...large deviatoric stresses could develop due to the excavation-induced and thermal expansion-induced compressive tangential stresses, and the reduction in radial stress near the boundary of the excavation". The EA asserts "such fractures are not critical factors in the evaluation of postclosure effects".

To state that such fractures are not critical is premature and not based on conclusive evidence or models. The present in-situ stress state is quite capable of producing fracturing (see USGS, 1983, Page 11). Coupled with the stresses due to excavation, fracturing is definitely a critical factor in the evaluation of postclosure effects. The degree of fracturing produced in a sealed repository is important in order to model postclosure rock characteristics, hydrogeological conditions and geochemical conditions which are directly dependent on the fracturing system of the repository.

Importance to EA findings/conclusions - The EA statements discussed above fail to present a realistic assessment of this potentially adverse condition and its effects on the Hanford site.

<u>Recommendation:</u> The discussion of this potentially adverse condition in the EA does not address the importance of the above issues. The EA should recognize that these adverse conditions must be studied further.

References:

Smyth, J.R., 1982. "Zeolite Stability Constraints on Radioactive Waste Isolation in Zeolite - Bearing Volcanic Rocks," Journal of Geology, Volume 90, pp. 195 - 202.

U.S. Geological Survey, 1983. "Review Comments by the U.S. Geological Survey on Site Characterization Report for the Basalt Waste Isolation Project," DOE-RL-82-3, (letter from J.B. Robertson, Chief, Office of Hazardous Waste Hydrology, to O.L. Olson, Project Manager, BWIP, May 6, 1983), 60 pp.

YIN Comment #: 6-47

EA Section: 6.3.1.3.6 Rock characteristics - potentially adverse condition (2)

Page 6-107, paragraph 3

Statement of Issue: A major discrepancy exists in the EA text concerning initial waste emplacement thermal density.

Discussion: The caption for figure 6.5 reads "8.2 watts per cubic meter" while the text reads "8.2 watts per square meter".

Importance to EA findings/conclusions - There is a discrepancy between the text and the figure. Is one to assume an isotropic medium with respect to heat flow? If so, this is a generalization that is important to the description of the thermal modeling within the repository besides its importance to thermally-induced fractures. No mention is made in the EA as to how much waste "8.2 watts per square meter (?) /cubic meter (?)" represents.

Recommendation: The EA needs to explain how it obtains the unit "cubic meter" when the reference cited uses the unit "square meter". An explanation concerning how much waste this represents should be included in this section of the EA.

YIN Comment #: 6-48

EA Section: 6.3.1.3.6, Rock characteristics - potentially adverse condition (2)

Page 6-107, paragraph 4

Statement of Issue: A sentence in the EA regarding the Cohassett rock characterization cannot be substantiated.

Discussion: The EA statement: "There are no known physical, chemical, or radiation related phenomena that are expected to adversely affect the Cohassett flow dense interior capability to contain or isolate waste" (Page 6-107, paragraph 4) is not known with the degree of certainty required for the EA.

Importance to EA findings/conclusions - Due to the brittle nature of the pre-fractured Cohassett dense interior, the high in-situ stresses expected, the lack of knowledge regarding fracture abundance and reaction of thermal- induced fractures, this statement is open to question. Furthermore, the discussion in paragraph 4, Page 6-107, regarding rock temperature-mineral changes has been questioned (Smyth, 1982) and is not backed by sufficient evidence. The statement in the EA reflects a higher degree of confidence than is warranted by the current state of knowledge.

Recommendation: The EA should not include these optimistic comments regarding the a) physical, chemical, or radiation related phenomena and b) rock temperature-mineral changes when evidence supports the opposite view.

References:

Smyth, J.R., 1982. "Zeolite Stability Constraints on Radioactive Waste Isolation in Zeolite - Bearing Volcanic Rocks," Journal of Geology, Volume 90, pp. 195 - 202.

YIN Comment #: 6-49

EA Section: 6.3.1.3.7 Rock characteristics - potentially adverse condition (3)

Page 6-109

Statement of Issue: The EA's position that this potentially adverse condition is not present at the Hanford site is not justified by the available evidence. Heat generated by the waste could significantly decrease the isolation provided by the host rock. Thermally induced fractures and mineral alterations will result in increased permeabilities and reduced travel time to the accessible environment.

Discussion: The geologic structure, geochemical and thermal properties and hydrologic conditions in the host rock and surrounding units are such that the heat generated by the waste could significantly decrease the isolation provided by the host rock as compared with pre-waste-emplacement conditions.

1) Thermal fracturing resulting from post-emplacement heat generation will increase the permeability of the surrounding intact rock. This fracturing will result, in part, due to the low thermal conductivity of basalt.

2) Evaluation of the structural character of the Cohassett flow is not possible at this time. Only repository tunneling will reveal the intraflow stratigraphy and structure associated with the Cohassett.

3) The geochemical properties of the fracture filling secondary minerals (e.g., smectite-clays, zeolites) at high temperatures are not well understood. These minerals undergo a volume decrease due to loss of interlayer-water with increasing temperature thereby increasing permeability. This increased permeability significantly decreases the isolation capability of the host rock compared with pre-emplacement conditions.

Importance to EA - The increased permeability resulting from the above factors will decrease the travel time for radionuclides to reach the accessible environment compared to pre-emplacement conditions.

Recommendation: This potentially adverse condition should be assumed to be present at Hanford based on available data.

YIN Comment #: 6-50

EA Section: 6.3.1.4.3, Climatic changes - favorable condition (1)

Pages 6-115 to 6-117

Statement of Issue: This favorable condition is not present due to the repeated occurrence of large catastrophic floods.

Discussion: Favorable condition - "(1) A surface-water system such that expected climatic cycles over the next 100,000 years would not adversely affect waste isolation."

Based on Craig's (1983) model, the Pasco Basin will be subject to several (perhaps many) catastrophic floods within the next 100,000 years. The geomorphic effects may not be negligible with regard to waste isolation. Structural effects will adversely compromise the repository's ability to isolate waste. Loading and unloading from flooding will likely affect fracturing, may increase permeability, increase recharge and subsequently increase groundwater flux, reactivate or accelerate faulting or folding, etc. That these events can occur is indicated in the EA Subsection 3.2.3.2, "These data suggest that the central fault on Gable Mountain may still be active; however, the offsets may be due to other than tectonic processes, such as rapid loading and unloading during catastrophic flooding".

Importance to EA findings/conclusions - The EA asserts that "this favorable condition appears to be present" at the Hanford site based on a projected climatic model of Craig (1983). Craig's model predicts major glaciation and associated catastrophic flooding within the next 100,000 years. These floods could adversely affect waste isolation (loading/unloading causing perturbations in groundwater flow, increased fracturing and reactivation of existing structures, etc.). The EA conclusion that this favorable condition exists is incorrect.

Recommendation: This favorable condition is not present due to expected effects of catastrophic flooding.

References:

Craig, R.G., M.P. Singer, and G.L. Underberg, 1983. Analysis of Ice-Age Flooding from Lake Missoula, Kent State University, Kent, Ohio.

YIN Comment #: 6-51

EA Section: 6.3.1.4.6, Climatic - potentially adverse condition (2)

Page 6-118, paragraph 2

Statement of Issue: The EA's argument against the presence of this potentially adverse condition is inconsistent.

Discussion: In the discussion of this potentially adverse condition, the EA makes statements that are not justified by the evidence. Specifically: "The very short transient nature of catastrophic floods (i.e., less than 2 weeks)..." implies that all catastrophic floods are of a duration of less than 2 weeks. Baker (1973) was describing one flood when he assigned to it a duration of 2 weeks. Also, the EA uses the phrase "...estimated to be weeks or less..." elsewhere in the text. Why is a quantitative value "less than 2 weeks" used in this discussion whereas "weeks or less" is used elsewhere in the EA?

Importance to EA findings/conclusions - The exact nature of the effects these floods will have on the local recharge is unknown. But it has been reported that "...during these 14 hours [of ponding above Wallula Gap] 340 cubic miles of water moved through the system, leaving about 130 cubic miles to sustain the waning flows as the discharges subsided." (Baker, 1973, p. 21). Even with an order of magnitude uncertainty associated with these numbers, this is still a large amount of surface water to be introduced to the surface hydrologic system. Ground-water impacts from proglacial flooding (catastrophic floods) are not negligible especially when considered in conjunction with increased fracturing due to the loading and unloading associated with ponding, draining, and sediment aggradation/degradation. :: Recommendation: The EA should delete the phrase "less than 2 weeks" because this value is used out of context.

References:

Baker, V.R., 1973. "Paleohydrology and Sedimentology of Lake Missoula Flooding in Eastern Washington," Geo. Soc. Am., Special Paper 144.

YIN Comment #: 6-52

EA Section: 6.3.1.4.7, Climate - Conclusion on qualifying condition

Page 6-118, paragraph 4

Statement of Issue: The conclusion reached in the EA regarding this qualifying condition is based on incorrect assumptions made earlier in the EA. Many of the favorable conditions are not present at the Hanford site.

Discussion: Problem and basis - The EA cannot state "Significant erosion is not considered likely over the next 100,000 years based on the past geologic record" because the past geologic record has recorded huge amounts of erosion associated with these large catastrophic floods.

Importance to EA findings/conclusions - The increase in proglacial streams and occurrence of catastrophic floods would cause changes in the deep ground-water flow system (especially in conjunction with fracturing and effects of loading- and unloading-stress fluctuations), changes in recharge and groundwater heads in the host flow, etc.

Recommendation: The "Conclusion on qualifying condition" should be reassessed in light of corrected conclusions concerning potentially adverse and favorable conditions.

YIN Comment #: 6-53

EA Section: 6.3.1.5.6 Erosion - potentially adverse condition

Pages 6-121 to 6-122

Statement of Issue: As written, this Potentially Adverse Condition is present at the Hanford site.

Discussion: Potentially Adverse condition - "(1) A geologic setting that shows evidence of extreme erosion during the Quaternary Period." The geologic setting "means the geologic, hydrologic, and geochemical systems of the region in which a geologic-repository operations area is or may be located" (DOE Guidelines, 10 CFR 960, 49 Fed. Reg. 47753). "Regions are normally smaller than provinces, but may extend across several states " (DOE Guidelines, 10 CFR 960, 49 Fed. Reg. 47715).

Catastrophic floods have caused extreme erosion in the region (Bretz, 1969, Baker, 1973, 1983) within the Quaternary Period. Therefore, this potentially adverse condition is present.

Importance to EA findings/conclusions - As the DOE Guidelines now read, this potentially adverse condition is present at Hanford because of the extreme erosion caused by catastrophic flooding within the geologic setting during the Quaternary Period.

Recommendation: The EA should recognize that this potentially adverse condition exists at Hanford.

References:

Baker, V.R., 1973. "Paleohydrology and Sedimentology of Lake Missoula Flooding in Eastern Washington," Geo. Soc. Am., Special Paper 144.

Baker, V.R., 1983. "Late-Pleistocene Fluvial Systems," in The Late Pleistocene, S.C. Porter (ed.), Volume 1, pp. 115-129.

Bretz, J.H., 1969. "The Lake Missoula Floods and the Channeled Scablands," Journal of Geology, Volume 77, pp. 505 - 543.

<u>YIN Comment #:</u> 6-54

EA Section: 6.3.1.7.4, Tectonics potentially adverse condition (1)

Page 6-129, paragraph 3

<u>Statement of Issue:</u> Several statements in the EA regarding this potentially adverse condition are inappropiate and should be deleted.

<u>Discussion:</u> Potentially Adverse Condition - "(1) Evidence of active folding, faulting, diapirism, uplift, subsidence, or other tectonic processes or igneous activity within the geologic setting during the Quaternary Period." The EA considers this potentially adverse condition to be present at Hanford. Several statements in the EA's discussion are not appropiate and should be deleted. These statements are summarized below.

1) The EA states that "deformation appears to be concentrated on the steeper limbs of anticlinal folds with little or no deformation occurring in synclinal troughs like the Cold Creek syncline". That deformation in synclines is less than observed in the anticlines (in the Yakima fold province) is not disputed. However, the degree of deformation in synclines is not known with any certainty (due to few surface exposures). Deformation in a syncline has occurred; there could not be bending associated with a synclinal fold without some deformation.

   The Cold Creek syncline is located at depth. Data regarding its overall shape are obtained from borehole data and geophysical means. There is no evidence to indicate with certainty the degree of deformation at depth in the Cold Creek syncline. The USGS notes that "... such faults (in fold axes) are as common in synclinal areas as anticlinal areas and could occur in the Pasco Basin, including the Cold Creek syncline and repository...Unfortunately, most of these features occur as steeply dipping or narrow zones. Where they lie beneath the cover of younger sedimentary formations, they may be essentially (or completely) undetectable by geophysical methods.." (USGS, 1983, p.2). Caggiano and Duncan (1983) summarize thirty-three different tectonic conceptions of the Pasco Basin area. Some models include significant deformation within synclines.

   Therefore, the EA's statement "...with little or no deformation occurring in synclinal troughs like the Cold Creek syncline" is inappropiate because there is insufficient evidence to support it, and significant evidence contradicting it.

2) Page 6-129, paragraph 4

Catastrophic flooding may be assumed to reactivate shear and fault zones considering the volume of water that will affect the Pasco Basin. "These data suggest that the central fault on Gable Mountain may still be active: however, the offsets may be due to other than tectonic processes, such as rapid loading and unloading during catastrophic flooding (see Subsection 3.2.3.2)." Mention of this phenomenon should be included in the EA's discussion of this Potentially Adverse Condition.

3) Page 6-130, paragraph 3

"These [tectonic] rates, when projected 10,000 or more years into the future, would lead to increased elevation of Rattlesnake Mountain and the Saddle Mountains, and further subsidence of basalt strata in the Cold Creek syncline, neither of which would lead to increased potential for erosion of the candidate horizons in the Cold Creek syncline. Therefore, uplift and subsidence continuing along the extant pattern and rates would appear not to jeopardize isolation of radioactive waste at the reference repository location."

These two sentences are inconsistent. The statement that "Uplift and subsidence continuing along the extant pattern and rates would not appear to jeopardize isolation" is true only with respect to erosion. These sentences imply that uplift and subsidence, in themselves, would not affect repository performance, which has not yet been demonstrated.

Importance to EA findings/conclusions - The discussion of the Potentially Adverse Condition as it now exists creates an unjustifiably optimistic impression regarding the ramifications of this potentially adverse condition at the Hanford site.

Recommendation: The discussion in the EA, § 6.3.1.7.4, should not include the aforementioned statements in their present form and should include a discussion of tectonic effects of catastrophic flooding.

References:

Caggiano, J.A. and D.W. Duncan, (eds.), 1983. Preliminary Interpretation of the Tectonic Stability of the Reference Repository Location, Cold Creek Syncline, Hanford Site, RHO-BW-ST-19P, Rockwell Hanford Operations, Richland, Washington.

U.S. Geological Survey, 1983. "Review Comments by the U.S. Geological Survey on Site Characterization Report for the Basalt

<u>Waste Isolation Project</u>," DOE-RL-82-3, (letter from J.B. Robertson, Chief, Office of Hazardous Waste Hydrology, to O.L. Olson, Project Manager, BWIP, May 6, 1983), 60 pp.

<u>YIN Comment #:</u> 6-55

EA Section: 6.3.1.7.5, Tectonics - potentially adverse condition (2)

Page 6-130 to 6-131

<u>Statement of Issue:</u> Relative closeness of seismic activity to reference repository location and importance to presence of Potentially Adverse Condition.

<u>Discussion:</u> The EA dismisses earthquake activity near the repository as a minor concern. In fact, "...shallow earthquake swarm activity is concentrated in the central Columbia Plateau region, principally north and east of the Hanford site. In this region earthquakes greater than magnitude 3.0 also occur, including possibly the largest magnitude swarm-related earthquake. This was instrumentally recorded, 20 December 1973, as a magnitude 4.4 earthquake, located in the Royal Slope area [approx. 25 miles away]..." (p.2-15,paragraphl).

Importance to EA *findings/conclusions* - It is disturbing that earthquake swarm activity within the Columbia Plateau is concentrated less than 25 miles away from the repository. The resulting seismic energy could have significant implications for the repository.

<u>Recommendation:</u> A potentially adverse condition exists due to the relatively high seismic activity located in the vicinity of the repository. The EA should not attempt to qualify the repository as unaffected by nearby seismic activity without a more thorough understanding of the seismological character of the Pasco Basin.

<u>YIN Comment #:</u> 6-56

EA Section: 6.3.1.7.6 Tectonics - potentially adverse condition (3)

Page 6-131, paragraph 5

<u>Statement of Issue:</u> Perturbations in the stress field in the repository horizon could increase the potential for swarm earthquake activity in the rock adjacent to the repository.

Discussion: The probable cause of swarm earthquake activity in the Columbia basin is slippage along joint planes associated with columnar structures in basalt (Roth, 1978). Generally, the swarm earthquakes are found in the anticlinal areas where high compressive stresses found in conjunction with occurrance of columnar joints that are not interlocked to the extent found in other areas (i.e., synclines) and with the incidence of higher vertical mobility of water (Roth 1978). Because the RRL is located in a syncline, it is considered unlikely that the reference repository location is a candidate for swarm earthquake activity. Although swarm earthquakes tend to take place in areas weakened by previous deformation, it is possible that the stress release associated with repository excavation and the stress perturbations due to thermal loading and unloading may result in a weakened condition that could cause strain energy release along joint planes. Once initiated, earthquakes generated by motion along portions of joint planes tend to propagate and the area becomes more susceptible to seismic energy release.

Importance to EA Findings - "Indications based on correlations of earthquakes with tectonic processes and features, that either the frequency of occurrence or the magnitude of earthquakes within the geologic setting may increase," is a potentially adverse condition (960.4-2-7,C,2).

Recommendation: The potential for slippage along columnar joint planes due to the perturbation of the stress field due to post-excavation stress release, thermal expansion and (later) contraction during cooling and changes in pore pressure needs to be evaluated to see if a potentially adverse condition may exist.

References:

Rothe, G.H., 1978. Earthquake Swarms in the Columbia River Basalts, Ph.D. Thesis, University of Washington.

YIN Comment #: 6-57

EA Section: 6.3.1.7.6 Tectonics - potentially adverse condition

Page 6-131, paragraph 6

Statement of Issue: Based on current tectonic models, it is not possible to conclude that the frequency of occurrence or magnitude of earthquakes within the geologic setting will not increase.

Discussion: Caggiano, (1983), indicates several lines of evidence which support episodic movement and activity. Further, out of 33 possible tectonic models, several are indicative of a plate boundary. If these indications are correct, it is imprudent to locate a repository in an area associated with an episodically active plate boundary, when much more stable and more predictable sites can be found. DOE does not adequately discuss this possibility and its associated consequences in the EA. If it is a plate boundary situation, then potential exists for increased tectonism, especially episodic tectonism.

Recommendation: The potential for a plate boundary near the RRL should be discussed and the possibility of episodic tectonism admitted.

References:

Caggiano, J.A. and D.W. Duncan (eds) 1983. Preliminary Interpretations of the Tectonic Stability of the Reference Repository Location, Cold Creek Syncline, Hanford Site, RHO-BW-ST-19P, Rockwell Hanford Operations, Richland, Washington.

YIN Comment #: 6-58

EA Section: 6.3.1.7.6 Tectonics - potentially adverse condition

Page 6-131 through 6-132

Statement of Issue: The EA does not discuss geophysical anomalies and how they affect the position of the Columbia River.

Discussion: RHO-BW-ST-19P and RHO-BW-SA-289P discuss linears and gradients which are reflected in the basement structure. They relate some of these basement structures to surface structures such as the Umtanum Ridge and Snively Basin. However, any discussion of why these linears and gradients correspond to the positions of the Columbia and Yakima Rivers is absent. Earthquake swarms in the area also occur in the Columbia River channel both north and east of the RRL, as well as near the Rattlesnake-Wallula alignment and near the intersection of Cold Creek Syncline-Rattlesnake Hills trend. The explanation of these phenomena are conspicuously absent in ST-19P as well as the EA.

Additional similarity to basement structure can be seen from the two attached figures. This apparent correlation should be thoroughly discussed in the EA.

Recommendation: Discuss the implications of linears and earthquake swarms relative to the position of the Columbia and Yakima Rivers.

References:

Caggiano, J.A. and D.W. Duncan (eds) 1983. Preliminary Interpretations of the Tectonic Stability of the Reference Repository Location, Cold Creek Syncline, Hanford Site, RHO-BW-ST-19P, Rockwell Hanford Operations, Richland, Washington.

Rohay, A.C. and S.D. Malone, 1983. Crustal Structure of the Columbia Plateau Region, Washington, RHO-BW-SA-289P, Rockwell Hanford Operations, Richland, Washington, pp. 23.

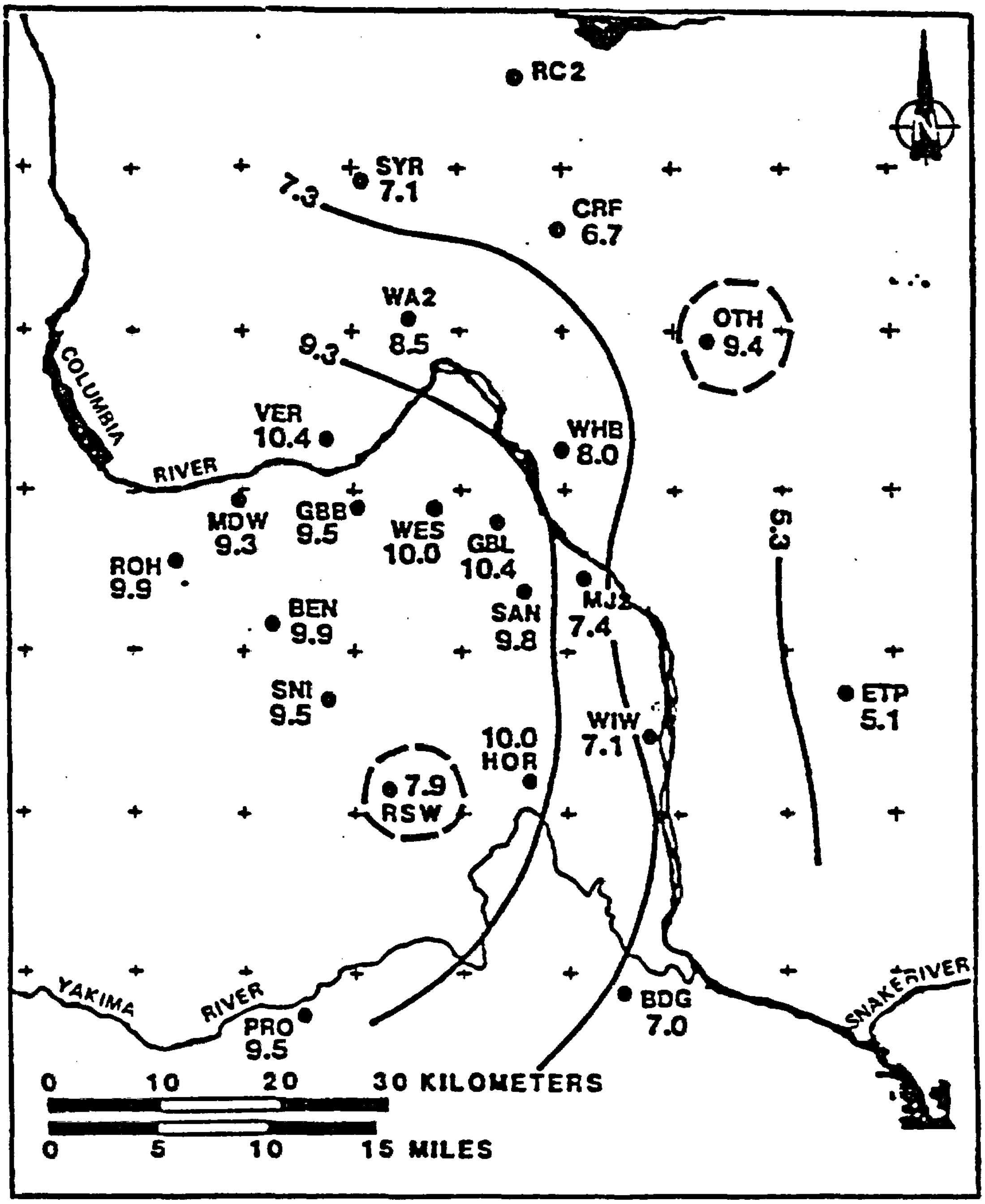

Figure Geographical Variation of Interpreted Depth to 6.0-Kilometers/Second Layer. Contours are the same as in Figure 10, but converted to depth.

Map represents depth to basement after RHO-BW-SA-239 P.

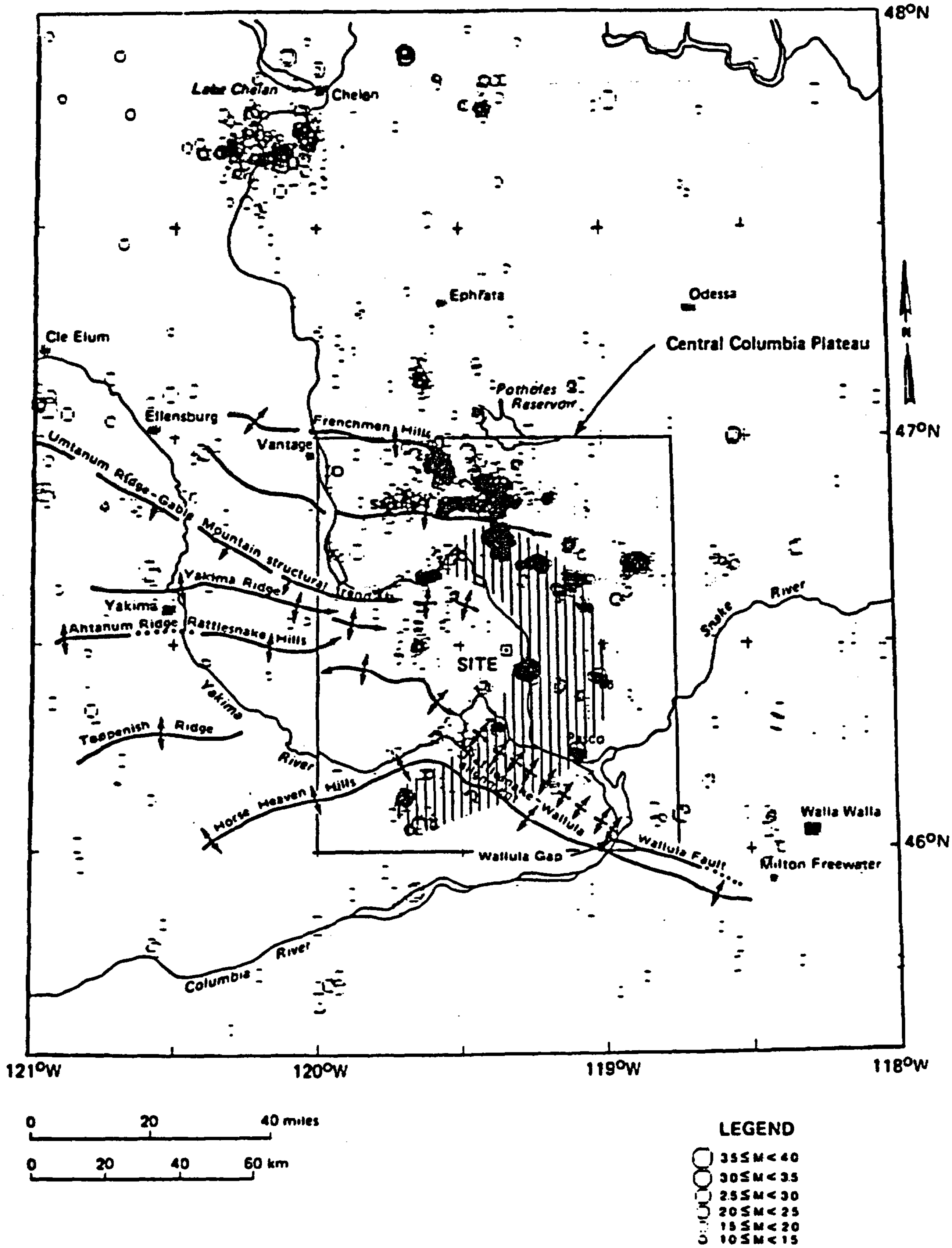

Figure Swarm earthquakes in the Pasco Basin region (Source: Washington Public Power System, Amendment No. 18)

The apparent trend of swarms is added to base map. Base

YIN Comment #: 6-59

EA Section: 6.3.1.7.11 Tectonics - conclusion on qualifying condition

Pages 6-136 to 6-137

Statement of Issue: In situ stress conditions are such that faulting on fracture and fault planes is likely to occur.

Discussion: The EA should note that the present in-situ stress regime is such that faulting is likely to continue, at least at present rates, and possibly increased rates.

Shallow earthquake swarms associated with reverse faulting have occurred with relative frequency in the Pasco Basin (Long and WCC, 1984, EA Subsection 2.1.1.3, Malone, et.al. 1975). There may exist a relation between the state of stress and the potential for reverse faulting such that high in-situ stresses may induce faulting.

Zoback and Hickman (1982) discuss the relationship of shallow reverse faults in regard to earthquakes at Monticello Reservoir, So. Carolina. The critical condition controlling the occurrence of such earthquakes is the ratio of the maximum effective horizontal stress (Shmax - P) to the effective vertical stress (Svmax-P) where P is the pore pressure. They show in eq. 2 (p.6962) that the critical effective stress ratio on well-oriented faults or fracture planes is a function of the coefficient of friction of the rock, F, such that

$$(Shmax-P)/(Svmax-P) = ((2F + 1) * 1/2 + F) * 2,$$

F = 0.6 to 1.0 for all rocks (Byerlee, 1976).

Reverse faulting is "potentially imminent" (USGS, 1983, p.11) when the critical effective stress ratio ranges from 3.12 (for F =0.6) to 5.83 (for F =1.0). Based on measurements from Hanford, (provided in USGS (1983)), the mean value of (Shmax - P/Svmax - P) is greater than the critical value for F = 0.6. Therefore, the ambient stress state is close to one which would continue to cause reverse faulting on well-oriented fracture and fault planes.

Importance to EA findings/conclusions - The stress tensor for the Hanford region may be sufficient to cause earthquakes and/or faulting that could adversely affect the repository's isolation performance in the future.

Recommendation: The Hanford tectonic and seismologic character must be examined further to determine if the tectonic-qualifying condition,-favorable condition, -potentially adverse conditions and -disqualifying condition are or are not present at the Hanford site. The EA recognizes that sufficient evidence is not yet available. Mention of the possible relationship between in situ stress conditions and earthquake swarms should be addressed in the EA as well as in future work at the Hanford site. In-situ stress conditions indicate likelihood of continued faulting which might affect the qualifying condition.

References:

Byerlee, J., 1978. "Friction of Rocks", Pure and Applied Geophysics, Volume 116, pp.615 - 626.

Long, P.E. and Woodward-Clyde Consultants, 1984. Repository Horizon Identification Report, Volumes 1 and 2, Draft SP-BWI-TY-001, WCC for Rockwell Hanford Operations, Richland, WA.

Malone, S.D., G.H. Rothe, and S.W. Smith, 1975. "Details of Micro-Earthquake in Columbia Basin, Bull. Seismol. Soc. Am., Volume 65, pp.855-864.

U.S. Geological Survey, 1983. "Review Comments by the U.S. Geological Survey on Site Characterization Report for the Basalt Waste Isolation Project," DOE-RL-82-3, (letter from J.B. Robertson, Chief, Office of Hazardous Waste Hydrology, to O.L. Olson, Project Manager, BWIP, May 6, 1983), 60 pp.

Zoback, M.D. and Hickman, 1982. "In Situ Study of the Physical Mechanisms Controlling Induced Seismicity at Monticello Reservoir, South Carolina," Jour. Geophys. Res., Volume 87, pp. 6959 - 6974.

YIN Comment #: 6-60

EA Section: 6.3.3.2.3 Rock characteristics - favorable condition (1)

Page 6-153, paragraph 1

Statement of Issue: Favorable Condition (1) of the Preclosure Rock Characteristics (DOE guidelines, 10 CFR 960.5-2-9) is not present at the Hanford site due to statements made in discussion of the Postclosure guidelines, Favorable Condition (1), Postclosure Rock Characteristics (DOE guidelines, 10 CFR 960.4-2- 3).

Discussion: Referring to Postclosure guideline, Rock Characteristics, Favorable Condition (1), p. 6-99, paragraph 1, EA Chapter 6.3.1.3.3, the EA supports "a conservative finding that this favorable condition is not present". However, in the discussion of Preclosure Technical guideline, Rock Characteristics, Favorable Condition (1), page 6-153, paragraph 1, EA chapter 6.3.3.2.3, the EA states "this favorable condition is present in the reference repository location".

Importance to EA findings/conclusions - The same uncertainties and rock charcteristics apply to these identically-worded favorable conditions, but the EA states the condition is present in one and not the other. The EA attributes this contradiction to differences in pre- and post- closure requirements (p. 6-99, paragraph 4), which is incorrect. The favorable conditions are identical in wording and content, except for the phrase "to ensure isolation" in the post-closure guideline. This phrase does not justify a different conclusion on the same facts.

Due to the variations in the flow top, flow thickness, presence of intraflow stratigraphy, etc., this favorable condition is not present in the reference repository location. The EA cannot state that this favorable condition is present for one purpose and not present for another. In addition, the DEA should not state that the presence of three other candidate horizons may provide further flexibility, since DOE has already rejected those other horizons precisely because of this very consideration, i.e., because of excessive variability in dense interior thickness.

Recommendation: The EA should state that this favorable condition (Preclosure Technical guidelines, Rock Characteristics, favorable condition (1), Page 6-153, EA chapter 6.3.3.2.3) is not present at the reference repository location because the identical favorable condition is found not present earlier.

YIN Comment #: 6-61

EA Section: 6.3.3.3.7 Disqualifying Condition

Page 6-207, paragraph 3

Statement of Issue: Given the possibility of massive dewatering being needed during construction and active life of the site, it may be disqualified.

Discussion: Information provided at the December 1984 NRC/DOE hydrology workshop indicated that head data for well DC-20 show evidence of a strong interconnection between the Cohasset and Rocky Coulee flow tops. Geophysical methods and packer seal testing indicate the interconnection is a function of the character of the rock at this location. The Rocky Coulee interior is likely to be similar in nature to the candidate Cohasset interior zone. The possiblity of strongly interconnected flow tops has major implications for the construction and utilization of the repository facility. The massive dewatering that would be needed to alleviate the water hazard of strongly connected aquifer zones may not fall within the realm of correctable to the extent needed to not present a significant risk.

Importance to EA findings: The EA does not contend with this possibility and on page 6-197 states that "while some water inflow into excavated openings is anticipated, the volumetric flow rate is expected to be minimal based on current knowledge."

Relevance to Regulations: The Hanford site may be disqualified because the geohydrologic setting may require engineering measures beyond reasonably available technology for repository construction, operation and closure (960.5-2-10d).

Recomendation: Reevaluate the possible disqualification of the site based on this consideration.

References:

Clifton, P.M., 1984. Groundwater Travel Time Uncertainty Analysis--Sensitivity of Results to Model Geometry, and Correlations and Cross Correlations Among Input Parameters, SD-BW-TI-256, Rockwell Hanford Operations, Richland, Washington.

Clifton, P.M., R.G. Baca, and R.C. Arnett, 1983. Stochastic Analysis of Groundwater Traveltimes for Long-Term Repository Performance Assessment, RHO-BW-SA-323, P, Rockwell Hanford Operations, Richland, Washington.

Clifton, P.M., R.C. Arnett, and N.W. Kline, 1984. Preliminary Uncertainty Analysis of Pre-Waste-Emplacement Groundwater Travel Times for a Proposed Repository in Basalt, SD-BWI-TA-013, Rockwell Hanford Operations, Richland, Washington.

Kanehiro, 1984. Updated working group plans and rationales for addressing regional flow system characterization. DOE Accession B040441, Report by Hydrotechnique Associates, prepared for Rockwell Hanford Operations.

Larson, H.J., and B.O. Shubert, 1979. "Probabilistic Models in Engineering Sciences", Engineering Sciences, 1:91, John Wiley & Sons, Inc., New York.

Leonhart, L.S., R.L. Jackson, D.L. Graham, L.W. Gelhar, G.M. Thompson, B.Y. Kauchiro, and C.R. Wilson, 1984. Analysis and Interpretation of a Decirculating Tracer Experiment Performed on a Deep Basalt Flow Top, RHO-BW-SA-300 P, Rockwell Hanford Operations, Richland, Washington.

Loo, W.W., R.C. Arnett, L.S. Leonhart, S.P. Luttrell, W.R. McSpadden, and I. Wang, 1984. Effective Porosities of Basalt: A Technical Basis for Values and Probability Distributions Used in

Preliminary Performance Assessments, SD-BWI-TI-254, Rockwell Hanford Operations, Richland Washington.

Rockwell, 1983. Summary of activities of BWIP Interagency Hydrology Working Group through July 1983. DOE Accession B02589.

Rothe, G.H., 1978. Earthquake Swarms in the Columbia River Basalts, Ph.D. Thesis, University of Washington.

Runchal, A.K., M.W. Merkhofer, E. Olmstead, and J.D. Davis, 1984a. Probability Encoding of Hydrologic Parameters for Basalt: Elicitation of Expert Opinions from a Panel of Five Consulting Hydrologists, SD-BWI-TA-010, Rockwell Hanford Operations, Richland, Washington.

Runchal, A.K., M.W. Merkhofer, E. Olmstead, and J.D. Davis, 1984b. Probability Encoding of Hydrologic Parameters for Basalt: Elicitation of Expert Opinion from a Panel of Three Basalt Waste Isolation Project Staff Hydrologists, SD-BWI-TA-011, Rockwell Hanford Operations, Richland, Washington.

Sonnichsen, J., 1984. Basalt Waste Isolation Project Performance Assessment Plan, SD-BWI-PAP-001, Rockwell Hanford Operations, Richland, Washington.

Wilson, C.R., and B.Y. Kanehiro, 1983. Updated recommendations for standard problems and sensitivity studies for modeling the groundwater system in the Pasco Basin, DOE Accession B031230, Report by Hydrotechnique Associates prepared for Rockwell Hanford Operations.

YIN Comment #: 6-62

EA Section: 6.3.3.4.4 Tectonics - potentially adverse condition

Page 6-211, paragraph 5

Statement of Issue: Statements regarding positions of active faults may be in error.

Discussion: DOE states that faults which may be active include the Central Fault on Gable Mountain and the area of Wallula Gap, eastward to the Hite Fault, which is located greater than 80 kilometers from the RRL. White, (1983), makes note of a fault which has minor displacement younger than 12,000 years 25 km to the southeast of the RRL. This fault should be discussed in the DEA.

Recommendation: Include a discussion of the faults 25 km or less from the RRL in the list of active or capable faults.

References:

White, Donald E, June, 1983. A Study of the Isolation System for Geologic Disposal of Radioactive Wastes, Waste Isolation Systems Panel, Board on Radioactive Waste Management, National Research Council, p. 5.

YIN Comment #: 6-63

EA Section: 6.4.2.3.1, Stochastic analysis methodology

Page 6-234, paragraphs 2 & 3

Statement of Issue: The use of an *a priori* specified distribution function for the parameters of the corrosion model leads to incorrect predictions of the onset of material failure. A specified distribution function, empirically derived from experiments performed under repository conditions, can only be used to describe the material behavior far from the critical point.

Discussion: A purely systems approach (i.e., Monte Carlo method) for modeling material response cannot be used to predict the onset of canister failure. More specifically, in the study of uniform corrosion, the model parameters should not be varied simply according to a specified probability distribution. A non-physically justified method of analysis cannot be valid when modeling a physical process and determining its critical behavior.

Importance to EA findings/conclusions - A physically-based derivation of the probability curve for waste package (e.g., canister) failure is the only reliable method for the study of containment time. The analysis should take into consideration the most relevant failure modes under the expected repository conditions. Since none of these aspects have been considered in Sagar's work (1984), it cannot be concluded that the containment time criterion can safely be met.

Assuming that a corrosion model is selected, its parameters must be varied in accordance to a relationship that would relate microscopic behavior to the macroscopic response of the solid canister material. This structural connection relating micro- and macroscopic scales can be derived using statistical mechanics (the approach being similar to that presented by Abi-Ghanem and Nguyen (1983) in the derivation of elastic moduli as a function of microstructural arrangement of a solid medium). In this manner, the method for analyzing failure incorporates a method based on the physics of the material. The final outcome is a more physically-based probability curve for canister failure.

Recommendation: The corrosion model's parameters must be varied to satisfy a relationship between the microscopic behavior and the macroscopic response of the sold canister material.

References:

Sagar, B., P.W. Eslinger, R.G. Baca, and R.P. Anantatmula, 1984. Probabilistic Modeling of Radionuclide Release at the Waste Package Subsystem Boundary of a Repository in Basalt, SD-BWI-TA-012, Rockwell Hanford Operations, Richland, Washington.

Abi-Ghanem, G.V. and V.V. Nguyen, 1983. Physical Review B, Volume 26, p.4321.

YIN Comment #: 6-64

EA Section: 6.4.2.3.1 Stochastic analysis methodology

Page 6-235, paragraph 1

Statement of Issue: Similar computer codes yield unexplainably different results.

Discussion: Ground water travel times to the accessible environment are calculated by stochastic modeling. In Clifton, (1984), PORMC and MAGNUM-MC (two codes for stochastic steady-state flow modeling) yield different calculated mean and distributions for ground water travel time. PORMC yields a larger mean 21,500 years and larger deviation 0.81 relative to MAGNUM-MC (17,000 years and 0.71).

Importance to EA Findings - The EA findings are based on Magnum-MC only. The conclusiveness of the reported ground water travel times is questionable.

Relevance to Regulations - The presence of the favorable condition for a 10,000 year travel time (960.4-2-1,b) is questionable.

Recommendation: Assess which model yields defensible results.

References:

Clifton, P.M., 1984. Groundwater Travel Time Uncertainty Analysis--Sensitivity of Results to Model Geometry, and Correlations and Cross Correlations Among Input Parameters, SD-BW-TI-256, Rockwell Hanford Operations, Richland, Washington.

YIN Comment #: 6-65

EA Section: 6.4.2.3.1. Stochastic analysis methodology

Page 6-235, paragraph 1

Statement of Issue: There exists evidence that Quality Assurance practices are not adhered to.

Discussion: Basis - DOE has formulated and documented Quality Assurance procedures. All contractors are required to conform. In Clifton, (1984), the code PORMC is used in travel time calculations, but the EA refers to MAGNUM-MC.

Importance to EA Findings - Traceability of QA records is questionable. If the name of the code used is incorrect, then the results presented lack credibility. Review procedures do not appear to be adhered to.

Relevance to Regulations - The defensibility of the favorable condition of a 10,000 year travel time (960.4-2-1,b) is questionable.

Recommendation: Clarify which code was actually used.

References:

Clifton, P.M., 1984. Groundwater Travel Time Uncertainty Analysis--Sensitivity of Results to Model Geometry, and Correlations and Cross Correlations Among Input Parameters, SD-BW-TI-256, Rockwell Hanford Operations, Richland, Washington.

YIN Comment #: 6-66

EA Section: 6.4.2.3.3, Waste package subsystem performance

Page 6-241, paragraph 1

Statement of Issue: The methodology used by DOE to determine radionuclide release rates from the waste package system is not supported by a valid physically-based argument. The analysis cannot lead to conservative release estimates at the boundary of the waste package subsystem.

Discussion: The problem approach followed by Sagar, et.al. (1984) is not reliable for the following reasons:

1) The only process that is taken into consideration is uniform corrosion. Nothing is mentioned about other

aspects of corrosion (i.e., pitting, crevice stress corrosion, hydrogen damage, etc.).

2) The data derived from short term experimentation cannot be extrapolated to arrive at a long-term prediction of failure. As indicated by Sagar, et.al. (1984), the models describing uniform corrosion were taken from preliminary work by Fish and Anantatmula (1983). These models, which were empirically derived from a short experimentation period (several weeks) have been used to obtain predictions on a much larger time scale (several thousands of years). Such predictions are not valid due to the following:

   a) these mathematical models do not necessarily hold if damage due to coupling of corrosion with other failure modes (e.g., with radiation and hydrogen damage, pitting and stress corrosion, rupture or fracture, plastic deformation, etc) becomes important;

   b) even if the mathematical form of the models remains valid, the variation of its phenomenological parameters according to an *a priori* specified probability distribution function leads to incorrect and false conclusions. The specified probability distribution function does not reflect the time scale or the microstructural irregularities occuring within the container, both of which must be considered in determining container failure.

3) The selected criterion of failure due to uniform corrosion has no valid physical basis and no mathematical foundation. Under repository conditions, release of radionuclides may occur much before the uniform corrosion penetration equals 3 inches, due to the coupling effects of other failure inducing processes. The manifestation of failure, in this case, may be due to localized effects.

Importance to EA findings/conclusions - Based on the above arguments, it can be concluded that the EA results (i.e., figure 6-16) concerning container failure are not sufficiently conservative in light of the uncertainty involved. Therefore, there is no indication that the NRC performance objectives will be met.

Recommendation: Experimentation under repository conditions followed by in-situ testing is needed in order to:

1) determine the most probable manifestations of failure,

2) determine the phenomenological models to be used,

3) define the relationship between the the microscopic characteristics of the material and the macroscopic material behavior.

By when these three aspects of the study become clear, can the Monte Carlo technique be applied on the parameters describing the microscopic behavior.

References:

Sagar, B., P.W. Eslinger, R.G. Baca, and R.P. Anantatmula, 1984. Probabilistic Modeling of Radionuclide Release at the Waste Package Subsystem Boundary of a Repository in Basalt, SD-BWI-TA-012, Rockwell Hanford Operations, Richland, Washington.

Fish, R.L., and R.P. Anantatmula, 1983. Preliminary Corrosion Models for BWIP Canister Materials, SD-BWI-TI-157, Rockwell Hanford Operations, Richland, Washington.

YIN Comment #: 6-67

EA Section: 6.4.2.3.3 Waste package subsystem performance

Page 6-243, paragraph 1

Statement of Issue: An average canister lifetime of 6300 years used in the Preliminary Performance Assessment may not be valid.

Discussion: The Preliminary Performance Assessment used a range of canister lifetimes which average to approximately 6300 years. As mentioned in earlier comments, thermal and lithostatic loadings may greatly reduce canister integrity. (The 6300 year value derives from corrosion failure only.)

Additionally, the NRC has asked BWIP to define how much "weight" is assigned to engineered barrier components in a performance assessment. It appears that BWIP has placed a high degree of confidence and weight on one waste barrier - 6,300 out of 10,000 years. The questions to be asked is "Will the NRC allow this much weight to be placed on the canister in the final analysis?" and "Is it valid for this analysis?". 10CFR60 states that the waste package must substantially contain the waste for 300 - 1000 years, with no mention of a longer time frame.

Recommendation: Redo the Preliminary Performance Assessment to reflect containment for 300 - 1000 years as opposed to 6300 years.

YIN Comment #: 6-68

EA Section: 6.4.2.3.3 Waste package subsystem performance

Page 6-246, Figure 6-17

Statement of Issue: Thickness and physical properties of the damaged and disturbed host rock layers are not known, and setting parameters to describe their characteristics greatly affect predictions of radionuclide transport.

Discussion: The boundaries delineating the disturbed and damaged host rock on one hand, and the disturbed and intact host rock on the other, cannot be determined before true excavation is performed due to unknown in situ rock characteristics (e.g., thermal, mechanical, hydraulic, etc.). At this stage, there is no reason to believe that the boundaries shown in figure 6-17 are reasonable, nor is there a reason to accept hypothetical values of rock characteristics near the repository environment as the ones that will be found at the time of waste emplacement.

Importance to EA findings/conclusions - The damaged, disturbed and intact host rock characteristics, as well as the delineation of their boundaries, will dictate the properties and thickness of the backfill. Also affected will be the spacing of the canisters and tunnels.

Recommendation: At the level of the EA, various scenarios of the type shown in figure 6-17 will still have to be performed. As the site characterization proceeds, extensive in-situ testing would be required prior to determining the final specifications of the backfill material. Currently, thicknesses of various engineered barrier components cannot be made as to the effectiveness of the barrier system unless these values reflect the actual repository thicknesses.

YIN Comment #: 6-69

EA Sections: 6.4.2.3.5 Site subsystem performance
6.4.2.3.1 Stochastic analysis methodology

Pages 6-262, paragraph 1
6-235, paragraph 1

Statement of Issue: Incorrect computer code reference.

Discussion: The EA discusses MAGNUM-MC as used in Clifton (1988) however, in Clifton, 1984 (SD-BW-TI-256), the code PORMC is presented. MAGNUM-MC is presented in Clifton, et al., (1983).

Importance to EA Findings - BWIP's records in travel time calculations are questionable.

Relevance to Regulations - The presence of the favorable condition for a 10,000-year travel time (960.4-2-1,b) is questionable.

Recommendation: Better records and review of modeling and reporting of modeling results are needed. Indicate which code is actually used in the analysis.

References:

Clifton, P.M., 1984. Groundwater Travel Time Uncertainty Analysis--Sensitivity of Results to Model Geometry, and Correlations and Cross Correlations Among Input Parameters, SD-BW-TI-256, Rockwell Hanford Operations, Richland, Washington.

Clifton, P.M., R.G. Baca, and R.C. Arnett, 1983. Stochastic Analysis of Groundwater Traveltimes for Long-Term Repository Performance Assessment, RHO-BW-SA-323, P, Rockwell Hanford Operations, Richland, Washington.

YIN Comment #: 6-70

EA Section: 6.4.2.3.5 Site subsystem performance

Page 6-266, paragraph 1

Statement of Issue: Ground water travel time calculations implicitly assume that flow will be contained in Grande Ronde Basalts.

Discussion: Ground water travel times are based on stochastic models of flow contained in GR basalts. Containment is based on previous studies. In Clifton, et al., (1984b), (SD-BWI-TA-013), a set of deterministic vertical cross-section models are used to assess the degree of potential vertical migration. In one of the cases, a particle enters the Vantage Interbed. The authors do not report the value, but indicate that such a path may result in a longer traveltime. It is unclear (or at least uncertain) that such vertical movement and transit through the Vantage Interbed would increase travel times to the accessible environment in excess of 10,000 years.

Importance to EA Findings - The EA fails to acknowledge the possibility of flow from the repository up to the Vantage Interbed and transit to the accessible environment.

Relevance to Regulations - Not all paths of travel for the favorable condition of the 10,000 year travel time (960.4-2-1,b) are addressed.

<u>Recommendation:</u> Present calculations for travel times in cases where vertical (dense interior) to horizontal (flow top) conductivities are less than 5×10^{-4}.

<u>References:</u>

Clifton, P.M., R.C. Arnett, and N.W. Cline, 1984. <u>Preliminary Uncertainty Analysis of Pre-Waste-Emplacement Groundwater Travel Times for a Proposed Repository in Basalt</u>, SD-BWI-TA-013, Richland, Washington.

<u>YIN Comment #:</u> 6-71

EA Section: 6.4.2.3.5 Site subsystem performance

Page 6-266, paragraph 2

<u>Statement of Issue:</u> Possible variations in ground water flow paths through the Grande Ronde Basalts.

<u>Discussion:</u> DOE has presented a limited number of calculations of ground water travel times. All values assume that travel will be confined in one basalt flow top. This is based on deterministic models (Clifton, et al, 1984). The authors have assumed a horizontal gradient of 5×10^{-4}, whereas Loo, et al., (1984) suggest a value on the order of 10^{-4}.

Importance to EA Findings - In the EA, stochastic analysis of travel time using probabilistic hydraulic gradients is presented. The relative importance of horizontal and vertical hydraulic gradients may lead to variations in the deterministic flow paths (i.e., more vertical movement). These alternate flow paths may indicate significantly reduced travel times to the accessible environment.

Relevance to Regulations - The calculated travel times are probably biased and the 10,000 year favorable condition (960.4-2-1,b) is probably not present.

<u>Recommendation:</u> Analyze variations in the deterministic flow paths using variations in the relative horizontal to vertical hydraulic flow gradients.

<u>References:</u>

Clifton, P.M., R.C. Arnett, and N.W. Cline, 1984. <u>Preliminary Uncertainty Analysis of Pre-Waste-Emplacement Groundwater Travel Times for a Proposed Repository in Basalt</u>, SD-BWI-TA-013, Richland, Washington.

Loo, W.W., R.C. Arnett, L.S. Leonhart, S.P. Luttrell, W.R. McSpadden, and I. Wang, 1984. Effective Porosities of Basalt: A Technical Basis for Values and Probability Distributions Used in Preliminary Performance Assessments, SD-BWI-TI-254, Rockwell Hanford Operations, Richland Washington.

YIN Comment #: 6-72

EA Section: 6.4.2.3.5 Site subsystem performance

Page 6-266, paragraph 4

Statement of Issue: Ground water travel to accessible environment is contained within Grande Ronde Basalt.

Discussion: The EA fails to recognize the uncertainty in the conclusion of containment of flow to the Grande Ronde in that hydraulic gradients (2×10^{-3} in GR and 10^{-3} in Wanapum) are not well known. In addition, the vertical conductivities (especially 3.0×10^{-13} m/s) are not defensible.

Importance to EA Findings - The travel times may be overestimated in that ground water may travel vertically and reach the Priest Rapids and quickly travel to the accessible environment.

Relevance to Regulations - The favorable condition of the 10,000 year travel time (960.4-2-1,b) may not be present.

Recommendation: Address alternative flow paths to accessible environment.

YIN Comment #: 6-73

EA Section: 6.4.2.3.5 Site subsystem performance

Page 6-270, paragraph 2

Statement of Issue: Insufficient documentation of radionuclide modeling.

Discussion: In the performance assessment plan (Sonnichsen, 1984), a limited description of the EPASTAT model is presented. Without more complete documentation (verification, benchmarking, user's manual, etc.), it is not possible to assess the findings presented in the EA.

Importance to EA Findings - It is not possible to confirm the findings regarding radionuclide release.

Relevance to Regulations - Inability to confirm the system guideline qualifying condition 960.4-1 that requires compliance with 40 CFR Part 191.

Recommendation: Complete documentation, verification, and benchmarking of EPASTAT.

References:

Sonnichsen, J., 1984. Basalt Waste Isolation Project Performance Assessment Plan, SD-BWI-PAP-001, Rockwell Hanford Operations, Richland, Washington.

YIN Comment #: 6-74

EA Section: 6.4.2.4.4 Performance of the total isolation system

Page 6-279 paragraph 2

Statement of Issue: Preliminary system performance assessment accounts for the combined performance of the three major repository subsystems but does not account for the error associated with transferring information between these subsystems.

Discussion: The multibarrier concept consists of three subsystems, waste package, repository seals, and the candidate site. The performance assessment for the proposed repository site combines performance evaluations for these subsystems. This is accomplished in a step-wise manner where the output from the innermost subsystem is used as the boundary condition for the adjacent subsystem, etc..

An important issue in determining the overall performance of the multibarrier system is how the errors within each subsystem are propagated when transfering data between subsystems. Nguyen and Lehman (1985) examined this problem in detail. Using the conventional one-dimensional transport equation they show how the uncertainty within each subsystem is propagated through the entire system. The uncertainty in the concentration exiting from the multibarrier system is not simply the additive combination of the uncertainties of the subsystems. Nguyen and Lehman (1985) find that the actual uncertainty is greater than the uncertainty calculated by the DOE performance assessment models due to differences in the spatial and temporal scales between the subsystems.

Recommendation: Before judgement can be made on the performance of the total isolation system, the type of error discussed above must be considered

References:

Nguyen, V.V., and L. Lehman, 1985. Interscale Transfer of Information in Nuclear Waste Repository Multibarrier Systems, Proceedings of the Western Regional Ground Water Conference of the NWWA Ground Water Technology Division, Reno, Nevada.

YIN Comment #: 6-75

EA Section: 6.4.2.6 Preliminary performance assessment findings

Page 6-284

Statement of Issue: Compliance with the Waste Package containment time cannot be determined because the principal computer codes used in the performance assessment completely ignore many aspects that can contribute to failure.

Discussion: The evaluation of the containment time requires an extensive knowledge of canister material behavior under repository conditions. All possible manifestations of failure should be considered such as (EWA/YIN, August, 1984):

1) Elastic deformation

2) Plastic deformation

3) Rupture or fracture

4) Material change

   a. metallurgical

   b. chemical

   c. nuclear

It is the coupling between various physical processes (i.e., corrosion, creep, temperature and radiation) that causes the container to fail more quickly than a solely corrosion-based analysis would predict.

Importance to EA findings/conclusions - Contrary to the conclusion of Sagar et. al. (1984), uniform corrosion is not the only mode of failure which might lead to breaching of the waste canister. Other modes of failure that may enhance canister degradation have not been adequately considered and therefore the preliminary DOE finding that "there is no evidence or indication that a 300 to 1000 year containment period could not be achieved" is too hasty. In actuality, there is no evidence that a 300 to 1000 year containment period can be achieved.

<u>Recommendation:</u> Preliminary containment time estimates should take into account all or some of the following degradation processes:

1. force- and/or temperature-induced elastic deformation
2. yielding
3. brinnelling
4. ductile rupture
5. brittle fracture
6. fatigue
    a. high-cycle fatigue
    b. low-cycle fatigue
    c. thermal fatigue
    d. surface fatigue
    e. impact fatigue
    f. corrosion fatigue
    g. fretting fatigue
7. corrosion
    a. direct chemical attack
    b. galvanic corrosion
    c. crevice corrosion
    d. pitting corrosion
    e. intergranular corrosion
    f. selective leaching
    g. erosion corrossion
    h. cavitation corrosion
    i. hydrogen damage
    j. biological corrosion

k. stress corrosion

8. wear

   a. adhesive wear

   b. abrasive wear

   c. corrosive wear

   d. surface fatigue wear

   e. deformation wear

   f. impact wear

   g. fretting wear

Only after considering all of the above processes can a conclusion regarding the containment time be reached.

References:

Sagar, B., P.W. Eslinger, R.G. Baca, and R.P. Anantatmula, 1984. Probabilistic Modeling of Radionuclide Release at the Waste Package Subsystem Boundary of a Repository in Basalt, SD-BWI-TA-012, Rockwell Hanford Operations, Richland, Washington.

EWA/YIN, August, 1984. The Barrier System and Waste Package Form: Review and Discussion of DOE General Approach and Work, EWA, Inc./Yakima Indian Nation, Minneapolis, MN.

CHAPTER 7

Introduction

Virtually all of the issues discussed in Yakima Indian Nation comments on any part of the Draft EA are reflected in the comparative analysis of Chapter 7. Due to insufficiency of time and resources, we do not point out each such connection in our comments on this chapter. Accordingly, each and every Yakima Indian Nation comment on EA Chapters 1-6 and the appendices which in any way bears on site suitability under the siting guidelines, the presence or not of favorable, potentially adverse, qualifying, or disqualifying conditions, or ranking of the sites, is hereby reaffirmed and incorporated by reference in these YIN comments on Chapter 7. For each and every YIN comment that recommends changes in DOE findings under the guidelines, these comments should be read to include the corresponding changes and any related implications in the comparative analysis of Chapter 7.

YIN Comment #: 7-1

EA Section: 7.2 and 7.3 Ratings according to DOE guidelines

Pages 7-5 to 7-118

Statement of Issue: The binary condition evaluations (the presence or absence of favorable or potentially adverse conditions) and the total scoring of a site are inconsistent.

Discussion: The DEA does not fully describe the procedures employed in transforming the binary condition evaluations into scores and ranks. It appears that there is no difference between 1) ranking sites on an individual guideline, based on components of that guideline, and 2) ranking sites overall based on a set of individual guidelines. Yet, in the first case rankings are derived using professional judgment, and in the second case they are given scores and weights. Because professional judgments do not take into account the larger set of guidelines, the ranking will be insensitive to the inherent uncertainty associated with each binary condition.

Recommendation: The EA should describe the procedures for transformation between binary condition evaluations and numerical scores.

YIN Comment #: 7-2

EA Section: 7.2.1.1 Geohydrology

Page 7-6, paragraph 2

Statement of Issue: Hanford may be the only site where the 10,000 year travel time condition is not met.

Discussion: Travel times in stochastic studies may have been overestimated by a factor of ten or more. The effective porosity range used in the stochastic travel time analyses (see pages 6-266 through 6-269) utilizes the most appropriate value of effective porosity (for the modeling methodology used) as the lower limit of the effective porosity range. By doing this, the studies bias the results needed for a favorable condition. If the sparse field data is given its proper weighting, especially given the bias of expert opinion, data and the inappropriateness of laboratory test data (the scale of the test rules out evaluating influence of the structures controlling the flow regime), the field test values of effective porosity should represent at best a mean for the range. This would yield travel times for the three stochastic analyses (pages 6-266 through 6-269) of less than 10,000 years.

Importance to EA Findings - The favorable condition for ground water travel time greater than 10,000 years (960.4-2-1b) is not present at Hanford.

Recommendation: Re-evaluate the relative merits of the sites given that unfavorable hydrologic conditions are likely at the Hanford site.

YIN Comment #: 7-3

EA Section: 7.2.1.8.1 Natural resources

Page 7-49, paragraph 2

Statement of Issue: The potential for exploitation of natural resources has been underestimated and the geothermal resource possibilities are ignored.

Discussion: DOE acknowledges the potential for exploration for natural gas and the possibility of ground water withdrawal for irrigation. However, DOE downplays the natural gas possibilities by stating that since the RRL is in a syncline, there is very little likelihood of exploratory drilling. White, (1983), states that "Only in recent years has natural gas alone perhaps justified deep exploration, so the mild interest of the past seems likely to increase." White also states that "nonelectrical geothermal heat at the Hanford site (approx. 57°C at 1 km and 96°C at 2 km) is a potential resource, especially if the thermal waters are sufficiently low in objectionable constituents for domestic and agricultural uses. Even if the waters are too high in some chemical constituents, they could be utilized for heating and then diluted by surface waters for other uses."

The growing interest in Columbia Plateau hydrocarbon exploration has also been noted in the petroleum industry trade press. (Shirley, 1984).

Recommendation: DOE should acknowledge the geothermal potential of the region and not underestimate the natural gas exploration attempts.

References:

Shirley, Cathy, 1984. "Columbia Plateau Activity Booms," AAPG Explorer (American Association of Petroleum Geologists), November 1984.

White, Donald E., June, 1983. A Study of the Isolation System for Geologic Disposal of Radioactive Wastes, Waste Isolation Systems Panel, Board of Radioactive Waste Management, National Research Council, p. 5.

YIN Comment #: 7-4

EA Section: 7.2.2 Postclosure System Guideline

Pages 7-53 - 7-55
7-120

Statement of Issue: The DEA's failure to compare the candidate sites on the basis of the postclosure system guideline hides the Hanford site's profoundly inferior projected performance relative to all the other candidate sites, thus invalidating the site selection process.

Discussion: With respect to the postclosure system guideline, the DEA states:

> The different approaches to the evaluation of waste-package performance, the conservative nature of these assessments, and the uncertainties in the parameters on which the analyses are based all limit the ability to rank the sites in terms of these results. Therefore, because of the preliminary nature of these performance assessments, it does not appear that a comparison between and among the sites on the basis of the system guideline is practicable at present.

(Hanford EA, 7-55).

DOE's failure to compare the projected overall performance of the candidate sites in Chapter 7 of the EAs hides the fact that the Hanford site is projected to perform many orders of magnitude more poorly than any of the other sites. The omission of this information from the EA is a fatal flaw which fundamentally distorts the decision-making process of selecting sites for characterization. Furthermore, it is inconsistent with DOE's general siting guidelines. 10 CFR § 960.3-2-2-3, Comparative evaluation of all site proposed for nomination, states:

> *Sixth*, for those potentially acceptable sites to be proposed for nomination ..., a reasonable comparative evaluation of each such site with all other such sites shall be made. For each site and for each guideline specified in Subparts C and D, the DOE shall summarize the evaluations and findings specified under § 960.3-2-2-1 and under the fourth and fifth provisions of § 960.3-2-2-2. Each such summary shall allow comparisons to be made among sites on this [sic] basis of each guideline.

(Emphasis added.) This guideline quite clearly requires that DOE compare the sites on the basis of each and every guideline, including the postclosure system guideline. The fifth provision of § 960.3-2-2-2, cited above, states:

> *Fifth*, each preferred site within a geohydrologic setting shall be evaluated as to whether such site is suitable for site characterization under the qualifying conditions of those guidelines specified in Subparts C and D that require characterization (i.e., subsurface geologic, hydrologic, and geochemical data gathering). Such guidelines include those specified in § 960.4-1(a) (postclosure system guideline)....

(Emphasis added.) Thus, comparison of the sites under the postclosure system guideline is explicitly required. Furthermore, section 960.3-1-5, Basis for site evaluations, provides:

> Comparisons between and among sites shall be based on the system guidelines, to the extent practicable and in accordance with the levels of relative significance specified above for the postclosure and the preclosure guidelines. Such comparisons are intended to allow comparative evaluations of sites in terms of the capabilities of the natural barriers for waste isolation and to identify innate deficiencies that could jeopardize compliance with such requirements. If the evidence for the sites is not adequate to substantiate such comparisons, then the comparisons shall be based on the groups of technical guidelines under the postclosure and the preclosure guidelines.... Comparative site evaluations shall place primary importance on the natural barriers of the site.

DOE cannot argue that the evidence is not adequate to substantiate comparison under the system guideline, since it has in fact completed preliminary performance assessments for each of the sites. [*See also*, YIN comment # 7-15, *infra*.] The arguments DOE presents in the DEA for not comparing the sites under the system guideline do not bear up under scrutiny. The "different approaches to evaluation of waste- package performance" are not controlling since, as quoted from the guidelines above, engineered barrier performance is not to play a significant role in comparisons of site performance. Sites are to be compared based on assumptions of identical engineered barrier performance at all the sites. And it does not logically follow from the purportedly "conservative nature" of the assessments that comparisons are impracticable. Comparable measures of conservatism should be achievable in the various assessments. Finally, if uncertainties in the parameters on which the analyses are based do not invalidate the individual preliminary performance assessments themselves, there is no reason why they should prevent comparisons. Indeed, uncertainties are if anything less problematic in comparative evaluations than they are in the absolute ones (i.e., whether a guideline is satisfied) which DOE has no apparent difficulty performing at this time.

Of course, any performance assessments are subject to considerable uncertainty at this time. Nevertheless, based on the available evidence, the projected performance of a repository at the Hanford site would be many orders of magnitude poorer than that at all of the other candidate sites. Even the DEA hints that this is the case, stating, e.g., that at Hanford the release rates from the engineered barrier system would be as much as a factor of 0.65 of the NRC release rate criterion for certain radionuclides (Iodine-129 and Carbon-14), whereas at Yucca Mountain the releases are calculated to be less than a factor of 0.00025 of the criterion, and at the salt sites the releases are calculated to be zero. Differences of several orders of magnitude are obviously significant for comparing sites even with the limited state of knowledge and large uncertainty which prevails today. The failure of the DEA to properly reflect these crucial differences precludes a meaningful comparative evaluation and frustrates the primary purpose of the site selection process: to identify sites which are among the best that can be found from the standpoint of geologic considerations.

It appears that DOE has declined to compare the sites on the basis of the postclosure system guideline specifically to avoid the bad light such a comparison would cast on its selection of the Hanford site as one of the top three. By thus reverting to the individual technical guidelines and "reaching" obviously incorrect conclusions on many of them [*See* YIN comments on Chapter 6, *supra*], and then using invalid methods to combine the incorrect conclusions [*See* YIN comments on Appendix B, *infra*] the DEA lamely attempts to paint a patina of technical legitimacy onto the sociopolitical decision DOE made years ago: that Hanford would be the most convenient place in the country to put a nuclear waste repository.

Appendix E of these comments presents a preliminary comparative performance assessment, performed by YIN technical consultants, of the Hanford site and a generic site in the Paradox Basin, which DOE does not propose to recommend for characterization. The EAs should include such a comparison of all of the candidate sites. The YIN Nuclear Waste Program lacks the resources and the time to do such a comprehensive study. Nevertheless, this limited comparison shows quite clearly the profound inferiority of the Hanford site for isolation of wastes.

Recommendation: Compare the sites based on the postclosure system guideline in the final EA, and give that comparison the predominance called for in the siting guidelines when making site selection decisions. Remove Hanford from the list of sites to be recommended for characterization.

YIN Comment #: 7-5

EA Section: 7.3.1.1.1 Population Potentially Adverse Condition 1

Page 7-59

Statement of Issue: The potentially adverse condition for high daytime population density is present at Hanford.

Discussion: Population density potentially adverse condition 1 is the presence of a high residential, seasonal, or daytime population within the boundaries of the site. The DEA states that this condition is not present at any site, although "[a]t Hanford, there may be up to 700 daytime workers and an additional 700 shift workers within the boundaries of the site and 3500 persons working in the vicinity of the site; however, because these persons are all currently employed in nuclear facilities, they are not members of the general public."

This casual and off-hand exclusion of at least 1400 potentially affected persons from the obvious intent of this guideline is patently unacceptable. There is nothing in general siting guideline 960.5-2-1(c)(1) which even remotely suggests that its effect should be limited to persons who are not "employed in nuclear facilities". Indeed, there would never be significant numbers of people within site boundaries at any site who were not employed in nuclear facilities, since access to the site will be strictly controlled during the pre-closure phase and generally limited to site workers.

What distinguishes the Hanford site from all the other candidate sites--and requires that this potentially adverse condition be deemed "present" for the site--is that the repository is proposed to be constructed directly beneath some of the nation's most important nuclear weapons facilities. As a consequence, the hundreds of workers who are employed at those weapons facilities must be within the repository site boundaries every day in addition to those who would be there at any site in order to construct and operate the repository.

There can be no question but that this situation constitutes a high daytime population density for the site--particularly relative to the other sites for which there would be no similar requirement for the regular presence of hundreds of non-repository-related workers within the site boundaries. The DEA takes copious credit for the advantages of siting a repository at a federal nuclear reservation. It does a much poorer job of acknowledging the disadvantages, of which this is a prime example.

Recommendation: Change the EA finding for this potentially adverse condition to "present".

YIN Comment #: 7-6

EA Section: 7.3.1.1.2 Site ownership and control

Page 7-61

Statement of Issue: DOE does not have clear ownership and control of all land and all surface and subsurface mineral and water rights at Hanford.

Discussion: The DEA states that "[t]he favorable condition--DOE ownership and control of all land and all surface and subsurface mineral and water rights--is met only at the Hanford site in the State of Washington. All land at this site has been either acquired by the DOE or withdrawn from all forms of appropriation under the public land laws." As discussed in YIN comment # 6-1, *supra*, DOE may not have control of all surface and water rights at the RRL because of prior existing Yakima Nation Reserved Treaty Rights.

In addition, the majority of the land at the RRL was acquired by the Federal Government under the Second War Powers Act of 1942 (Pub. L. 77-507) for military purposes. Its status has never been changed to authorize use for non-military purposes. Any such change in status would require full recognition of prior existing rights to the land, including those of the Yakima Nation.

For the same reasons, the potentially adverse condition--ownership conflicts that cannot be resolved through voluntary agreements, nondisputed agency-to-agency transfers of title, or legal means--is also present at Hanford. Resolution of the Yakima Treaty Rights is if anything more problematic than the inter-agency land transfers that would be required at Yucca Mountain and Davis Canyon.

Recommendation: Change the finding on the favorable condition to "not present" and the finding on the potentially adverse condition to "present" for the Hanford site.

YIN Comment #: 7-7

EA Section: 7.3.1.1.3 Meteorology

Page 7-66

Statement of Issue: Meteorology potentially adverse condition (1) is, contrary to the conclusion reached in § 6.2.1.4 of the DEA, quite clearly present for the Hanford site.

Discussion: As YIN Comment # 6-4 explains, the DEA's conclusion on this potentially adverse condition is quite clearly incorrect. Potentially adverse condition (1) is prevailing meteorological conditions that could allow radionuclide releases to be preferentially transported to localities with larger than average population densities for the region. The DEA concludes that the condition is not present at Hanford and Yucca Mountain, and states, at page 7-66: "The downwind population center closest to Hanford is Richland, 22 miles away [to the southeast]; however, the prevailing winds are not in its direction." This conclusion is flatly contradicted by the information provided in Chapter 3--specifically, the monthly wind roses in Figure 3-42 which show prevailing northwest winds in all months, and the statement on page 3-109 that, "Prevailing wind directions are from the northwest in all months."

Recommendation: Change the finding on this potentially adverse condition to "present".

YIN Comment #: 7-8

EA Section: 7.3.1.1.4 Offsite installations

Pages 7-68 - 7-72

Statement of Issue: The Hanford site should be either disqualified or severely penalized because of conflicts with nearby atomic energy defense activities.

Discussion: As discussed in YIN comment # 6-5, *supra*, the extremely close proximity of the RRL to numerous strategically vital and exceptionally hazardous nuclear weapons facilities requires the disqualification of the Hanford site because of the high likelihood of irreconcilable conflicts. Even if the site is not disqualified on this basis, it should be ranked far below Yucca Mountain, in last place, because the proximity to the atomic energy defense facilities is so much closer at Hanford, and the perpetual staffing requirements of the Hanford facilities generate much greater potential for conflicts. (The portions of the Air Force range near Yucca can be abandoned (they generally are); the PUREX plant and nuclear materials storage facilities right on top of the RRL, with their hundreds of daily employees, cannot be.)

Recommendation: Either disqualify the site, or, if conflicts are demonstrated not to be irreconcilable, heavily penalize it because of this condition. At the very least, the Hanford site must be ranked in distant last place for this guideline.

YIN Comment #:7-9

EA Section 7.3.2.1.1 . Environmental Quality.

Statement of the Issue: The Department of Energy is in major conflict with applicable nonradiological environmental requirements.

Discussion: The Department of Energy regularly introduces toxic substances into the environment at Hanford and refuses to comply with state environmental standards. It is very difficult to ascertain precisely what toxic substances are being introduced into the environment, or in what amounts, because of the Department of Energy's usual failure to report such releases and discharges. However, it has been reported that there are hundreds of locations of uncontained hazardous and toxic substances within the Hanford Reservation. The DEA does not discuss even one.

There is documentation of at least one discharge of a hazardous substance--not disclosed in the DEA--which supports the presence of a major conflict. This incident happened before the publication of the draft EA, yet no mention of this or other toxic discharges has been found in the DEA.

On September 26, 1984 approximately 1,175 gallons of 57% nitric acid were released into a ground disposal area by Rockwell Operations, which operates the PUREX plant for the Department of Energy. On receiving a notice of violation of the Revised Code of Washington promulgated pursuant to the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), 42 U.S.C. § 9601 *et seq.*, the Department of Energy took the position that the statutes are not applicable to the operations of the Department. According to the information we have received from the Department, no effort has been made to remove the hazardous substance from the ground or to prevent it from entering the ground water.

Recommendation: Projected major conflicts with applicable Federal, State or local environmental requirements should be considered "present". Projected significant adverse environmental impacts that cannot be avoided or mitigated should be considered "present".

References: Letter with enclosure from Richland Operations Office to Mr. Donald Dubois, Assistant Director, Washington Department of Ecology, dated February 28, 1985.

YIN Comment #: 7-10

EA Section: 7.3.2.1.1 Native American Resources

Page 7-78 and Table 7-13

Statement of Issue: DOE has not done the necessary work to determine whether significant Yakima Indian cultural or religious resources would be adversely affected by a repository, and has ignored the adverse impacts which have already been caused to a major Yakima religious site at Gable Mountain.

Discussion: As discussed in YIN comments # 6-6, 6-8, and 6-9, *supra*, the EA and its references are totally inadequate in their treatment of this issue. In light of the desecration which has already occurred to the Yakima religious site at Gable Mountain, and the possibility of further impacts alluded to in the references, environmental quality potentially adverse condition (5)--proximity to, and projected significant effects on, a significant Native American resource or other sites of unique cultural interest--must be considered "present" at the Hanford site.

Recommendation: Change the finding on this potentially adverse condition to "present".

YIN Comment #: 7-11

EA Section: 7.3.2.1.3 Transportation

Page 7-93

Statement of Issue: The DEA improperly gives only the Hanford site credit for transportation favorable condition (7) on the basis of the misimpression that there are no legal impediments to transportation of nuclear wastes in Washington or surrounding states.

Discussion: Transportation favorable condition 7--an absence of legal impediments to waste transportation within the affected or adjoining States--is stated to be present only at Hanford. As YIN comment # 6-10, *supra*, explains, this conclusion is incorrect because it ignores the nuclear materials transportation ban which the Yakima Indian Nation has had in effect on its Reservation since 1979. The YIN ban is no less valid or more avoidable than those at the other sites; therefore, there is no basis to single out Hanford for this favorable condition.

Recommendation: Change the finding for this favorable condition to "not present".

YIN Comment #: 7-12

EA Section: 7.3.3.1.1 Surface characteristics

Page 7-98

Statement of Issue: The conclusion that "[t]here are no existing surface-water impoundments whose failure could cause the surface facilities to be flooded at any of the sites" is questionable for the Hanford site because DOE did not consider the impacts of 100% failure of Grand Coulee Dam.

Discussion: DOE considers the impacts of only a 50% failure of Grand Coulee Dam. It is difficult to conceive of a failure of that magnitude that would stop at 50%.

Recommendation: The EA should consider the effects of 100% failure of Grand Coulee Dam on the repository surface facilities at Hanford before reaching the conclusion above.

YIN Comment #: 7-13

EA Section: 7.3.3.1.2 Rock characteristics (preclosure)

Pages 7-99 - 7-106 and Table 7-17

Statement of Issue: Hanford possesses most of the unfavorable rock characteristics. The evidence supports a finding that the site is not likely to meet the rock characteristics qualifying condition, and that the site should be disqualified on this basis.

Discussion: The rock characteristics qualifying condition requires (1) that the thickness, lateral extent, characteristics, and composition of the host rock be suitable for the underground facility and (2) that repository construction, operation, and closure not cause undue hazard to workers. The evidence presented in the DEA and elsewhere supports a finding that the Hanford site fails on both these counts. As discussed in YIN comment # 6-60, *supra*, the same questionable flow thickness conditions which are acknowledged at Hanford for postclosure purposes are equally troubling for preclosure purposes, and the finding on potentially adverse condition (1) should be changed to "present".

With respect to factor (2) above, although many of the adverse rock characteristics conditions are present at Hanford and acknowledged by DOE, what is not considered or factored into the comparative analysis is the combined effects of these adverse conditions. The following discussion on the most threatening effects of repository construction is excerpted from White, (1983):

Effects from Rock Bursting

> Special studies of the present stress environment by recognized experts are needed to establish the magnitude of the problems. Direct communication with permeable local aquifers may become established.

Changes in Altitude

> Inhomogeneities in Umtanum's central zone, with changes in altitude of its contact (initial and superimposed) as construction advances. The repository must remain nearly "centered" in this zone and must avoid permeable faults, fractures and primary flow structures. Advancing construction can tolerate slightly increased contact altitudes, thereby maintaining water drainage to central sumps, but declining altitudes will result in costly and troublesome drainage problems.

High In-Situ Temperatures

> Construction of the repository at very high in-situ temperatures, estimated by Rockwell to be 57°C, but possibly considerably higher. Refrigeration on a scale seldom if ever attempted in world mining may be necessary. The costs in time, money, energy and lives of men are likely to be high.
>
> Even if each of the above is individually tractable, all in combination may be intolerable. More satisfactory alternatives probably can be found elsewhere.

(Emphasis added.)

The discussion of changes in altitude is based on the Umtanum unit; however, it is also applicable to other candidate horizons. DOE should not conclude that the repository horizon will be at a consistent elevation over the large area required for constructing the underground facility.

Recommendation: DOE should acknowledge the combined effects of adverse rock characteristics at Hanford and disqualify the Hanford site based on preclosure rock characteristics considerations.

References:

White, Donald E., June, 1983. A Study of the Isolation System for Geologic Disposal of Radioactive Wastes. Waste Isolation Systems Panel, Board on Radioactive Waste Management, National Research Council, p. 25.

YIN Comment #: 7-14

EA Section: 7.3.3.1.3 Hydrology

Page 7-110

Statement of Issue: The potentially adverse condition for preclosure hydrology conditions is present, and the site may need to be disqualified on this basis. The Hanford site is ranked too high for this condition.

Discussion: As discussed in YIN comment # 6-61, *supra*, the potentially adverse condition for hydrology--"ground-water conditions requiring complex engineering measures that are beyond reasonably available technology for repository construction, operation, and closure"--is certainly present at the Hanford site. The actual wording of the potentially adverse condition is "groundwater conditions that could require measures beyond reasonably available technology." From the potential difficulties that are acknowledged in the EA and discussed in YIN comment # 6-61, it is apparent that the possibility of such measures being required at Hanford is very real, thus, the condition is present. The only difference between the potentially adverse condition and the disqualifying condition is that the former is expressed in terms that extraordinary measures "could" be required, whereas the latter speaks of them being "likely" to be required. Conwequently, the disqualifying condition may also be present.

Recommendation: The Hanford site should either be disqualified based on this consideration, or at the very least, it should be heavily penalized. Certainly, Hanford should not be ranked equal to Davis Canyon, Deaf Smith, and Richton on this consideration. The hydrologic conditions at the other three sites are not nearly as adverse as those at Hanford.

YIN Comment #: 7-15

EA Section: 7.4.1 PREFERRED SITES FOR RECOMMENDATION FOR CHARACTERIZATION--INTRODUCTION

Page 7-120

Statement of Issue: DOE improperly declines to compare the sites on the basis of the system guidelines.

Discussion: The DEA states:

> Sections 7.2.2, 7.3.1.2, 7.3.2.2, and 7.3.3.2 explain, however, that the evidence is not sufficient to substantiate comparisons or to discriminate among sites on the basis of the system guidelines. In such a circumstance, the implementation guidelines allow comparisons to be made by considering collectively the technical guidelines in the postclosure and the preclosure sets.

As discussed in YIN comment # 7- , the guidelines specify that "[c]omparisons between and among sites shall be based on the system guidelines, to the extent practicable...." 10 CFR § 960.3-1-5. In light of this requirement, DOE should meet a heavy burden to show that the evidence is not adequate to substantiate such comparisons before deciding to dispense with them.

The sections cited by DOE above do not meet this burden. In each case, DOE cites the large uncertainties of systems findings as the reason why it cannot do comparisons. However, the inability to compare the sites on the basis of the system guidelines does not follow from the uncertainties. If anything, the inherent uncertainties are less important for a comparative analysis than in the absolute analyses, i.e., whether the individual system guidelines are satisfied for each site. DOE even acknowledges that "relative analysis reduces the effect of uncertainties" in its discussion of transportation risks (EA p. A-16). For example, one can conclude with much greater certainty, that the Hanford site would be likely to perform many times more poorly than any other site in terms of the postclosure system guideline, than that any site will satisfy that guideline.

At the very least, systems comparisons at this stage could detect the likelihood of large differences between and among the sites based on the system guidelines. Their absence in the EA prevents an adequate "reasonable comparative evaluation."

Recommendation: Include comparisons based on system guidelines in the final EAs.

YIN Comment #: 7-16

EA Section: 7.4.2 Aggregation Methods

Pages 7-120 - 7-123

Statement of Issue: Giving equal weight to each guideline in a set invalidates the site comparisons.

Discussion: The DEA states:

> The DOE does recognize that the relative importance of any technical guideline to the corresponding system guideline is site specific. For example, for a site in basalt, the technical guidelines on geohydrology and geochemistry may be important to ensuring compliance with the postclosure system-guideline requirement for the radionuclide- release rate from the engineered barrier system. At a site in salt, where very little water is expected to be available for interation with the engineered barriers, these guidelines may be much less important to ensuring compliance with the same system guideline. However, the precise importance or weight that should be assigned to a particular site characteristic is not fully understood at this stage of site exploration. The weighting of the technical guidelines associated with a particular system guideline is likely to be refined in the future; however, at the present time, all the technical guidelines in a particular guideline set or group have been weighted equally for lack of a basis to do otherwise.

As DOE acknowledges, giving the guidelines on site ownership and climate the same weight as the guideline on geohydrology for the Hanford site is patently absurd. Giving equal weight to each guideline in a set results in comparisons which have little or no relationship to the actual relative worth of the sites. Combined with the methodological problems discussed above and in the YIN comments on Appendix B, and the incorrect DOE conclusions on many of the individual guidelines, this deficiency makes the comparative evaluation totally inadequate.

Recommendation: Amend the siting guidelines to more appropriately reflect the site-specific significance of each technical guideline to the system guidelines; then perform a new comparative evaluation on the basis of corrected guidelines findings, appropriate guideline weights, comparisons under the system guidelines, and proper aggregation methodologies.

YIN Comment #: 7-17

EA Sections: 7.4.2.1 and 7.4.2.2 Ranking Methods I & II

Pages 7-123 and 7-124

Statement of Issue: The validity of the "averaging" and "pairwise comparison" methods is questionable due to substantial uncertainties in the data base and in the technical aspects.

Discussion: The methods used to compute an overall ranking of the five selected sites aggregate scores given on individual guidelines and arrive at a single numerical value for a site. This procedure does not adequately address the uncertainty involved in the scoring process, the data base and the technical aspects. The final score received by a site does not have any statistical measure associated with it.

Recommendations: An explanation must be given regarding the absence of sensitivity analysis in the aggregation methods.

YIN Comment #: 7-18

EA Section: 7.4.3 Ranking Results

Pages 7-124 to 7-132

Statement of Issue: Incompleteness and redundancy present in the DOE guidelines invalidate the ranking results.

Discussion: As discussed in previous comments on other chapters of the DEA, the guidelines fail to anticipate possible adverse scenarios regarding disqualifying conditions. Consequently, the guidelines are incomplete when applied to performance assessments. There is also a large degree of dependency between components of both postclosure and preclosure guidelines, such as population density and socioeconomic impacts, rock characteristics and geohydrology, etc. This leads to a redundancy in the scoring associated with the ranking process. Incompleteness and redundancy can lead to incorrect results in scoring aggregation and overall ranking.

Recommendation: These flaws must be remedied to establish the credibility of the ranking results in the EAs.

COMMENTS ON EA APPENDIX A

YIN Comment #: A-1

EA Section: General

Statement of Issue: The assumption that all defense high level waste originates at Savannah River is a major defect in the transportation analysis.

Discussion: Since about 60% (by volume) of the nation's defense high-level waste (DHLW) is temporarily stored at Hanford, and another smaller percentage is stored at Idaho National Engineering Laboratory, failure to consider the implications of transportation of that waste is a major omission in the EA. The total amount of the nation's DHLW could require up to 20,000 shipments to dispose of instead of the 6,720 considered in the EAs. (Mitre, 1984.) It is notable that DOE considers the much smaller amount of waste at West Valley, NY separately throughout the analysis, but totally ignores the Hanford DHLW. This omission is significant for the transportation risk projections since the radiological unit factors for defense wastes are considerably higher than those for spent fuel (Tables A-4 and A-5).

We note with approval that the Transportation Appendix at least makes explicit the DOE assumption that Hanford DHLW will not be transported to a repository. That represents a slight improvement over earlier DOE documents--and the rest of the EA--which simply make the assumption without bothering to note it.

Recommendation: Include full consideration of the transportation of Hanford DHLW in the final EA.

References:

Mitre Corp., 1984. An Evaluation of Commercial Repository Capacity for Disposal of Defense High-Level Waste, DOE/DP-0020 (Draft).

YIN Comment #: A-2

EA Section: A.8.6 Intermediate Results for Population Risks

Page A-19

Statement of Issue: This section is insufficient for a comparative analysis of the sites with respect to transportation risks.

Discussion: To facilitate the comparative analysis which DOE claims is its purpose, the Transportation Appendix should include the final population risk values for all potentially acceptable sites, such as are presented in § 5.2.2 for Hanford only. It seems non-sensical to provide the intermediate results for all the sites in the common Appendix, but require reference to the individual EAs for the final results.

Recommendation: Include the final results for all sites in the Transportation Appendix for the final EA.

YIN Comment #: A-3

EA Section: General Implications of MRS and Second Repository

Statement of Issue: The EA Transportation Appendix fails to consider the implications of Monitored Retrievable Storage facilities or a second repository on transportation considerations

Discussion: The Transportation Appendix considers only the implications of moving wastes from commercial reactors, Savannah River, and West Valley to a first repository. The fact that there will almost certainly be a second repository, and the implications of that for transportation, are not considered. Neither is the fact that DOE is now actively planning to integrate either a Monitored Retrievable Storage facility or a similar facility into the waste management program considered.

These omissions are fundamental flaws in the transportation analysis. Obviously, the needs, impacts, and costs of nuclear waste transportation will be quite different from those assessed in the EAs if any of the above-mentioned facilities comes into existence.

Recommendation: Consider the impacts for transportation of a second repository and one or more intermediate storage or handling facilities in the final EA.

<u>YIN Comment #:</u> A-4

EA Section: General Proximity to Wastes

<u>Statement of Issue:</u> The EA does not adequately consider the proximity of proposed repository sites to the points of origin of wastes.

<u>Discussion:</u> Section 112(a) of the NWPA specifically provides:

> Such guidelines shall take into consideration the proximity to sites where high-level radioactive waste and spent nuclear fuel is generated or temporarily stored and the transportation and safety factors involved in moving such waste to a repository.

The EAs do not satisfy this requirement. As discussed in YIN comment # A-1, *supra*, they do not consider the location of defense waste at three sites. As discussed in YIN comment # A-3, *supra*, they do not consider the location of one or more Monitored Retrievable Storage facilities, which according to current DOE thinking will be an integral part of the repository system. They do not consider the locations of actual reactors, but rather only 21 artificially generated centroids.

In addition, the EAs do not adequately consider the added costs and risks involved in transporting all the wastes to the site which is farthest from their origin--Hanford. As noted in YIN comment # A-2, *supra*, the Transportation Appendix does not even report the final quantitative risk figures for the respective sites. There is no rational narrative discussion presented of the marginal risk associated with transporting the wastes all the extra miles to Hanford. Instead, the bulk of the section is devoted to relatively trivial matters such as the number of road cuts that would be required.

<u>Recommendation:</u> Redo the transportation analysis with the proper attention to the proximity of repository sites to points of origin of wastes, as required by the NWPA.

COMMENTS ON EA APPENDIX B

<u>YIN Comment #:</u> B-1

EA Section: Appendix B.3.2 Application

Pages B-9, B-10

<u>Statement of Issue:</u> Scales used for favorability ratings are misleading.

<u>Discussion:</u> DOE admits that Hanford has scored poorly with regard to geohydrology, rock characteristics and tectonics. However, scores indicated on a scale from 1 - 10 indicate Hanford rates higher than a 6 in all cases. If 5.5 and higher is considered favorable and less than 5.5 unfavorable on this scale, then Hanford looks favorable for all guidelines. Since this is not the case, then the scales should be revised to accurately reflect the unfavorable status of certain guidelines.

<u>Recommendation:</u> Revise scales to reflect relative unfavorability of geohydrology, rock characteristics and tectonics.

<u>YIN Comment #:</u> B-2

<u>EA Appendix</u> B.3.2, Application

Pages B-7, B-8, B-9, B-10

<u>Statement of Issue:</u> The application of the utility-estimation method is flawed due to the sensitivity of the ranking's response to changes in the rating variables.

<u>Discussion:</u> The results of the application of the utility-estimation method to the site ranking are not reliable for the following reasons:

1) The "independence assumptions" between the rating variables shown in Table B-2, are not valid. For example, the geohydrology and the geochemistry aspects of the site cannot be independent due to the coupling and interactions of various physical processes that describe them.

2) Even under the linear additive form assumption for the utility function, no mathematical formula is presented to estimate the method's sensitivity to the presence of the correlation between the rating variables.

3) The standard deviation (s.d.) of the choice of each rating variable shall reflect the s.d. of the value of the utility function (u.f.). Derivation of a mathematical expression of the s.d. of the u.f. has been avoided in the EA.

4) The ranking method used to arrive at the results shown on page B-8 is not rigorous. The aforementioned derivable mathematical expression can be used to show that the overall s.d. of the u.f. is on the order of 50 points. This implies that, given a probability distribution for the utility value for each site, the spreading of error about the average (not the mean) site u.f. estimate shown on page B-8 greatly overlaps the 2 sequentially located probability distributions.

Importance to EA findings/conclusions - Unless the uncertainty and ambiguity of the method can be justified, the validity of the ranking approach is questioned.

Recommendation:

1) The DOE should examine the effect of removing the "independence assumption".

2) The DOE should examine the sensitivity of their method to changes in weighting factors and the effect of these changes on the ranking of the various sites.

3) The DOE should compare the outcome of the present method with the results of other multicriteria/multiobjective methods.

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VOLUME 2 -- APPENDICES

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APPENDIX A

APPENDIX A

MATHEMATIC DISCUSSION OF TRAVEL TIME MODELING APPROACH

V.V. Nguyen
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APPENDIX A

Mathmatical Discussion of YIN Comment # 6-16

EA Sections: 6.3.1.1.3
6.3.1.1.11
6.4.2.3.5

Pages 6-63, 6-81, 6-267

Statement of Issue: Estimated travel times are questionable as a result of errors in the modeling approach used.

NEGLECTED UNCERTAINTY OF MEDIAN TRANSMISSIVITY

In Clifton et al. (1983) transmissivity is treated as a random parameter. Clifton et al. (1984) improve on this earlier effort by treating effective thickness and regional gradient as random parameters, but these cases (2 and 3) are still inadequate because they neglect the uncertainty of the median transmissivity. A more appropriate formulation would be a two- factor form such as the following.

$$T = T_m T_h \quad (1)$$

Here T is transmissivity, T_m is a spatially uniform median value, and T_h is a lognormal spatial stochastic process normalized to have a unit median. The cases presented so far effectively treat T_m as an exactly known number, which it is not. Clifton et al. (1984) lists 42 values of log10 (T). The sample mean and standard deviation of those values have been used to define the median and variance of T in cases 1, 2, and 3. That median is uncertain because the average of N random variables L_i is itself a random variable (L^{bar}). If these random variables are all independent and of the same variance, then the variance of the mean estimate is given by var(L)/N. If, however, the L_i are in fact positively correlated, this simplified form underestimates the true uncertainty of L^{bar}. Thus the average log10 (T) computed has a standard deviation of at least $1.83/42^{0.5}$. Expert opinion may reduce this uncertainty in a quantifiable way, but it certainly does not reduce the uncertainty to zero. Moreover, unquantified biases in measurement techniques add to the uncertainty.

LACK OF SENSITIVITY ANALYSIS FOR CORRELATION ASSUMPTIONS

Apparently cases 1, 2, and 3 all use the same correlation structure for T. Clifton et al. (1983) describes a correlation function that decays to zero beyond a radius of 5 km. The functional form of the correlation coefficient, based on the spherical semivariogram of Journel and Huijbregts (1978), is as follows.

$$\text{rho}(r) = 1 - (3r/d - (r/d)^3)/2 \quad (\text{for } r >= 0 \text{ and } =< d)$$
$$= 0 \quad (\text{for } r > d)$$

Shorter and longer correlations need to be used to see which one produces more conservative estimates.

A deterministic calculation based on the parameter values of case 1 and a uniform deterministic T of 0.153 meters²/day shows a travel time markedly shorter than the median.

$$t = bn_e\ D\ /\ (t\ \text{grad}\ h) = \frac{(0.04\ m)\ (10^4\ m)}{(0.153\ m^2/d \times 10^{-3})/365}$$

$$= 7.16 \times 10^3 \text{ years}$$

The discrepency between this value and the median of 17,000 years reported for case 1 is remarkable enough to be questionable. It appears that this discrepancy may be caused by circuitous flow paths or by flow through zones of low transmissivity. It is also unclear whether this may also be dependent on the correlation distance or on the coarse 1 km element size of the stochastic T process. These questions must be answered before realistic travel time estimates can be made.

LACK OF ESSENTIAL DETAILS

The description of the Monte Carlo runs of Clifton et al. (1984) lacks much of the quantitative information needed to critically evaluate them. The three cases need to be independently checked to verify their consistency with each other and the uncertainty of each traveltime statistic estimated. In order to accomplish this evaluation, the following information, at a minimum, must be provided:

1. Average of log traveltimes for each case
2. Higher moments of log traveltimes for each case
3. Number of realizations for each case
4. An accurately drawn cumulative distribution function, preferably not smoothed, for each case

CONSISTENCY OF THE THREE MODELS

The large variation in median traveltimes among the three cases is surprising in view of what can be derived analytically. The following notation will be used: for some uncertain parameter, P,

P_d denotes the deterministic value used in case 1 and $\langle P \rangle$ denotes the mean. The term "log" will mean log base 10. Here t denotes traveltime and $\langle \log t \rangle[1]$ denotes the mean of log t based on the assumptions of case 1. G will represent the regional gradient.

$$\langle \log t \rangle = \langle \log(bn_e) \rangle - \log(bn_e)d - \langle \log G \rangle + \log G_d + \langle \log t \rangle[1]$$

$$\mathrm{var}(\log t) = \mathrm{var}(\log(bn_e)) + \mathrm{var}(\log G) + \mathrm{var}(\log t)[1]$$

These relationships assume that the effective thickness and regional gradient are spatially uniform and independent of each other and the transmissivity. If $\langle \log t \rangle$ is close to the median, as it appears to be in the two distribution function graphs published, the numbers cited in table 6-33 can be approximately reproduced for cases 2 and 3 based on the results published for case 1. The mean of log t for case 1 was computed by reading values from the cumulative distribution function graph in Clifton et al. (1983) Figure 2 and performing a numerical integration. The result is $\langle \log t \rangle[1] = 4.34$ ($\log 2.2 \times 10^4$). To corroborate that result, the same numerical integration technique was used to compute a variance which produced a standard deviation of 0.72 for log t, which reasonably reproduces the reported 0.71 value. Note, however, that the graph shows a median of about 2.1×10^4, which is more than 20 percent greater than the reported median of 1.7×10^4.

Table 1. Analytical derivation of case 2 and case 3 results from those of case 1. Mean log t case 1 computed from Figure 2 of Clifton et al. (1983).

	mean	var
$\langle \log t \rangle[1]$	4.34	$0.5041 = 0.71^2$
G range 10^{-4} to 10^{-3}		
-log G	3.3232	0.0652
+log G_d	-3.	0
case 2 log t	$4.6632=\log(4.58 \times 10^4)$	$0.5693 = 0.75^2$
Eff. thick. range 10^{-3} to 10^{-1}		
+log(bn_e)	-1.4141	0.1478
-log(bn_e)d	1.3979	0
case 3 log t	$4.6470=\log(4.4 \times 10^4)$	$0.7171 = 0.85^2$

Having failed to reproduce the numbers in table 6-33, there is the possibility that G and bne might have been uniformly distributed on a log scale rather than a linear scale. In other words, their cumulative distribution functions might have been linear when plotted versus the log parameter rather than versus the parameter itself.

Table 2. Analytic derivation of case 2 and case 3 results from those of case 1 using alternative assumptions about the distributions of effective thickness and regional gradient.

	mean	var
<log t>[1]	4.34	$0.5041 = 0.71^2$
G range 10^{-4} to 10^{-3}		
-log G	3.5	0.0833
+log G_d	-3.	0
case 2 log t	$4.84 = \log(6.9 \times 10^4)$	$0.5874 = 0.77^2$
Eff. thick. range 10^{-3} to 10^{-1}		
+log(bn_e)	-2.	0.3333
-log(bn_e)d	1.3979	0
case 3 log t	$4.2379 = \log(1.7 \times 10^4)$	$0.9207 = 0.96^2$

Here the variances are correct, while the means are far from the medians reported in the EA.

To check these computations, another experiment to estimate medians was performed. From the case 1 distribution function of Figure 2 in Clifton et al. (1983), ten intervals of equal probability and a traveltime at the center of each were selected. In other words, the percentiles 0.05, 0.15, 0.25,..., 0.95 were used. For the regional gradient distribution, ten percentiles from a uniform distribution on the interval 10^{-4} to 10^{-3} were selected in a similar fashion. Dividing each traveltime percentile by the ratio of each gradient percentile produced a list of 100 numbers. Once sorted, these numbers form a rough distribution function for the case 2 traveltimes. The experiment was performed for both possible interpretations of the uniform distribution. Figure 1 shows the results. Items 50 and 51 in the sorted list give good estimates of the median. To simulate the case 3 distribution, an analogous procedure is performed considering ten percentiles of traveltime, ten of regional gradient, and ten of effective thickness. The results appear in Figure 2. This set of experiments suggests that some of the three cases contain significant errors of some type. The results of case 1 have not been verified, but this exercise shows the need to independently verify all Monte Carlo results before they are used in decision making. The verification should use different computer programs and be performed by different modelers.

ALTERNATIVE MODELS

Some variants on the three cases presented are instructive. Tables 1 and 2 are useful if one wishes to choose other distributions that have the same mean and variances as those shown. Lognormal distributions for regional gradients and effective thicknesses are considered and the means and variances of Table 2 are assumed. In view of the central value theorem, it is expected that the resulting traveltime distribution would be nearly lognormal. Accordingly, traveltime quantiles can be closely estimated.

Table 3. Analytic derivation of moments of log traveltime based moments of Table 2.

	mean	var
$\langle \log t \rangle$[1]	4.34	$0.5041 = 0.72^2$
G		
$-\log G$	3.5	0.0833
$+\log G_d$	-3.	0
cum. result 2	$4.84=\log(6.9\text{X}10^4)$	$0.5874 = 0.77^2$
Eff. thickness		
$+\log(bn_e)$	-2.	0.3333
$-\log(bn_e)$	1.3979	0
cum. result 3	$4.2379=\log(1.7\text{X}10^4)$	$0.9207 = 0.96^2$
$-\log T_m$	0.8153	0.0797
$+\log T_{md}$	-0.8153	0
cum. result 4	$4.2379=\log(1.7\text{X}10^4)$	$1.0004 = 1.00^2$

For random gradient and effective thickness, cumulative result 3 in Table 3 shows that the thousand year traveltime occurs about $(4.2379 - 3) / 0.96 = 1.29$ standard deviations below the mean. The probability of exceedance is about 90 percent.

A random median transmissivity T_m defined previously also needs to be considered. Suppose the median of log transmissivity has a normal distribution and a variance $1.83^2 / 42 = 0.0797$ as discussed above. Cumulative result 4 of Table 3 shows the thousand year traveltime event about $(4.2379 -3) / 1.00$ standard deviations below the mean with an exceedance probability of about 89 percent.

The use of lognormal parameters here is somewhat arbitrary, but so is the use of uniformly distributed parameters in the EA. The distributions of regional gradient and effective thickness are subjective distributions based on the modeler's uncertainty. Therefore, they cannot be readily confirmed or rejected. The choice here of lognormal distributions is motivated in part by convenient properties and in part by their compatibility with our own subjective uncertainty. The choice of uniform distributions in cases 2 and 3 is questionable because that hypothesis contends that values immediately inside the cutoff bounds have the same probability density as any other value inside while it treats values immediately outside the bounds as impossible ones. If a distribution with bounds is to be used, it is more appropriate to use one whose density approaches zero gradually at the bounds as a triangular distribution does and as some beta distributions do.

Recommendation:

The above points must be considered in travel time estimates. Judgments concerning the favorable condition and the disqualifying condition dealing with travel times cannot be made at this time.

References:

Clifton, P.M., R.G. Baca, and R.C. Arnett, 1983. Stochastic Analysis of Groundwater Traveltimes for Long-Term Repository Performance Assessment, RHO-BW-SA-323 P, Rockwell Hanford Operations, Richland, Washington.

Clifton, P.M., R.C. Arnett, and N.W. Kline, 1984. Preliminary Uncertainty Analysis of Pre-Waste-Emplacement Groundwater Travel Times for a Proposed Repository in Basalt, SD-BWI-TA-013, Rockwell Hanford, Richland, Washington.

Journel, A.G., and Ch.J. Huijbregts, 1978. Mining Geostatistics, Academic Press, 600 p.

FIGURE 1. Model 2

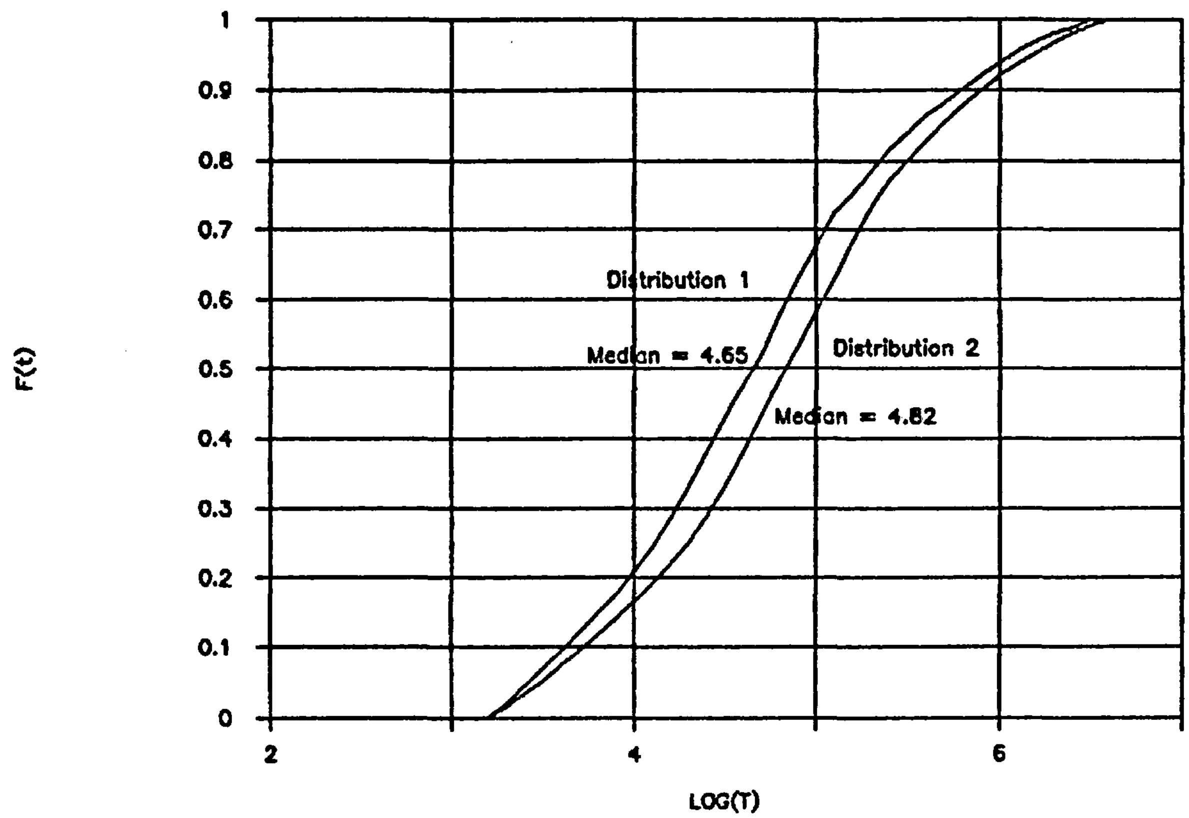
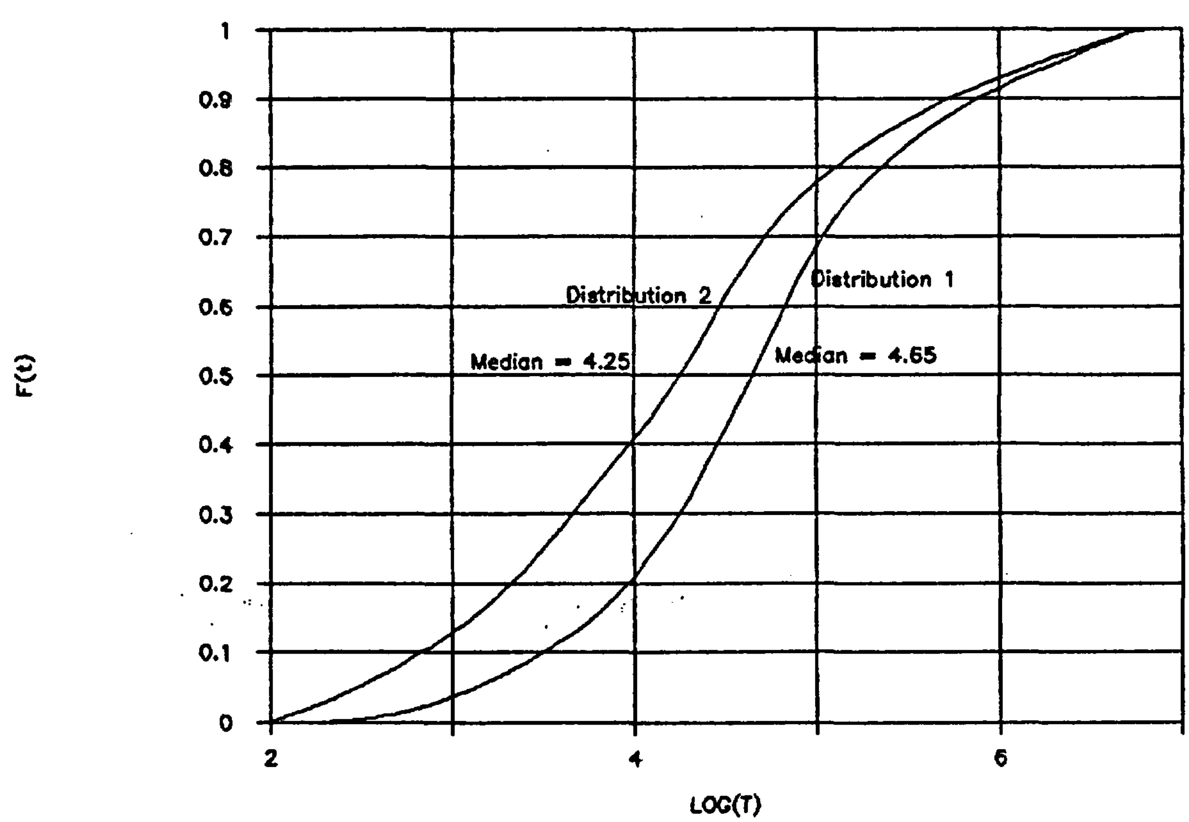


FIGURE 2. Model 3



APPENDIX B

APPENDIX B

FACTOR ANALYSIS OF GROUNDWATER FLOW PATHS IN THE CENTRAL COLUMBIA PLATEAU

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FACTOR ANALYSIS OF GROUNDWATER FLOW PATHS IN THE CENTRAL COLUMBIA PLATEAU

by

Linda Lehman

for the Yakima Indian Nation

Introduction

This report is essentially an update of work started in 1982 for the U.S. Nuclear Regulatory Commission. It is more detailed and uses more recent data; however, the same conclusions are still valid. The previous conclusion regarding upwelling of older water in the Pasco basin is better defined.

Description of the Study Area

The Pasco Basin study area is bounded by 121 degrees to 118.30 degrees east longitude and 45 degrees 45' to 47 degrees 30' north latitude.

The Pasco Basin is a structural and topographic basin of approximately 2000 square miles located within the Yakima Fold Belt Subprovince of the Columbia Plateau. It is structurally and topographically the lowest point in the Plateau. The basin consists of an undetermined thickness of lower Miocene and younger flood basalts with interbedded and overlying sedimentary units. This sequence rests upon an Eocene or older sedimentary sequence. The deeper basement is thought to be metamorphic or igneous rocks that are present in the Cascade Range and Okanogan Highlands regions (Rohay and Malone, 1983).

The basin is bounded on the north, south and west by east-west trending Yakima folds which, along with related folds within the basin, plunge to the east. Subsurface structures may be related to the intersection of both east-west trending and north-west trending structural features. Faults have been proposed to explain structural relationships at Wallula Gap and along the northeastern flank of Rattlesnake Hills. Two faults are present at Gable Mountain (Guzowski, 1982).

Formerly known as the Oregon River, the Columbia River flows through the center of the Pasco Basin from its origin in SE British Columbia over a thousand miles to the north. Through hydrologic connection with the water table, the position, stage and structural controls on the river must be understood. And specifically, in regard to siting nuclear facilities, if groundwater is discharging to the river, where and how is this taking place.

A large amount of data is available on the hydrology of the unconfined alluvial groundwater system; but deeper groundwater flow systems remain poorly understood. The location of regional recharge and discharge areas as well as ground water flow paths remain uncertain. In order to define the system, hydrochemical data was analyzed to determine patterns which may indicate areas of recharge and discharge. The analysis selected for use was a factor analysis.

Factor Analysis

A form of numerical analysis, factor analysis, was applied to the Columbia Plateau water chemistry data in order to determine intermediate and regional ground water flow patterns. Water chemistry data from 218 wells within the Columbia Plateau were used as the basis of this analysis. Water chemistry data was acquired from Battelle PNL, U.S.G.S. Watstore Water Quality File, and Rockwell Hanford Operations. The data is provided in the format used for input to Factor Analysis in the Raw Data Appendix.

The factor analysis subroutine Factor of the Statistical Package for the Social Sciences (Nie, et. al., 1975) was chosen to reduce the raw chemical data. The final method used was the PA1 or principal factoring with no iterations, and the final factor solution was the orthogonal Varimax rotated factor solution with Kaiser normalization.

Thirteen variables were used in the analysis. They were: HCO3 (mg/l), magnesium (mg/l), sodium (mg/l), potassium (mg/l), carbonate (ppm), sulfate (ppm), chloride (mg/l), fluoride (mg/l), calcium (mg/l), dissolved solids (mg/l), pH, temperature (degrees F) and depth (ft. above datum). The datum used was sea level.

Objectives of Factor Analysis

The principal concern of factor analysis is the linear resolution of a set of variables in terms of a small number of categories or "factors." This resolution can be accomplished by the analysis of the correlations among the variables. A satisfactory solution will yield factors which convey all the essential information of the original set of variables. Thus, the aim is to attain scientific frugality or the economy of description (Harman, 1976).

Description

Strictly speaking, factor analysis requires that the correlations be of a product-moment correlation type and no assumptions are made about the statistical distributions of variables. More precisely, the correlations among the variables for a given sample are treated as if they were the true correlations in the population, ignoring statistical variation. Various procedures are developed which operate on the mathematical correlations among a set of variables to produce solutions. However, when questions of statistical inference arise regarding the number of common factors or the significance of factor loadings, then specific assumptions on the distribution functions of the factors and the observed variables are introduced (Harman, 1976). A complete explanation of Factor Analysis is provided in Harman (1976).

Problems and Limitations Encountered in Analysis
==

Several problems were encountered in the analysis with respect to making a consistent representation of the available data.

1) Factor analysis requires a complete data set for all input variables, i.e., each well must have a value for each chemical constituent used in the analysis. If data are missing, factor loading scores will not be generated. Since the USGS and RHO data did not contain all the same variables, only the variables common to both data sets could be used. This amounted to the basic major ion chemistry.

2) The depth difference between the top of the Wanapum at central Pasco Basin and the northern end of the study area is approximately 2000 feet. The lowest elevation in the Pasco Basin is 1000 ft. BSL, and in the northern areas approximately 1000 ft. ASL. The units are not flat-lying over the study area, nor are they all present over the entire study area. Additionally, all geologic units are at higher elevations in the surrounding areas than in the Pasco Basin itself. Furthermore, the wells located in the surrounding areas do not penetrate to the great depths of the RHO exploratory wells. Thus there are a disproportionately large number of deep wells located in the Pasco Basin in comparison to the entire data set; and the water type present in the deeper layers under the northern and eastern boundaries is essentially unknown. In the earlier work of the writer, the wells were simply divided by depth using the arbitrary terms of shallow, intermediate, and deep. In this analysis, the sample points are identified by hydrostratigraphic unit.

3) A large portion of the wells in the USGS data set are true hydrologic composites of the Wanapum and Grande Ronde basalts, i.e., the wells are open to both layers. In contrast, the RHO data are generally distinct unit samples. To accommodate these sampling differences, certain RHO samples were considered to be part of the associated composite layer when so located. An explanation of the layering system follows.

4) In some cases the data provided were analyzed with inconsistent detection limits. This would tend to introduce an error into the calculations. To accommodate this error in a systematic manner, all sample values labeled "less than" a certain detection limit were considered equal to their detection limits. Only eight of the approximately 3000 values are so effected.

5) The USGS data were provided as a set of values which had been obtained over a period of several years. In some cases, as many as three values were provided at the same data point. The variation noted at individual sample points over the time frame of the USGS study was small compared to the variation noted between the total number of sample points. For this reason an arithmetic average was taken as being representative of the several values taken at a single data point. When the charge balance errors determined for the USGS data (averaged values) were compared to those determined for the RHO data it was found the values determined for the USGS were consistently smaller.

6) Factor Analysis can either be forced to a number of factors, or allowed to find its own number of factors by selecting an eigenvalue solution of 1.0. For this analysis, the later method was used; since it was felt inappropriate to predetermine the number of factors.

Description of Data and Methods of Data Presentation

Figure 1 is a map of the study area showing the distribution of wells which were used in the analysis. Most of the wells in the Pasco Basin provided samples which were collected at various depths within the same well. This generally was not the case in the wells surrounding the Pasco Basin.

Layering Scheme

In the technical reviews by the NRC and RHO of previous work done by the writer, a major issue was that it was not considered valid to compare water chemistries taken from different hydrostratigraphic units. In order to address this objection, a layer-by-layer presentation is used in this analysis (for illustrative purposes only). The manner in which the data is presented does not affect the outcome of the analysis; it merely is a means of presenting the data in an easily understood fashion.

The layering scheme devised, assigned all sample points to one of seven hydrostratigraphic units. This was done to help visualize the distribution of factors with depth. Although this layering was used as a tool for conceptualization, it did approximately conform to the RHO designated hydrostratigraphic units. No other meaning was intended by the layering. However, it is felt the layers also give one a better understanding of recharge and discharge areas.

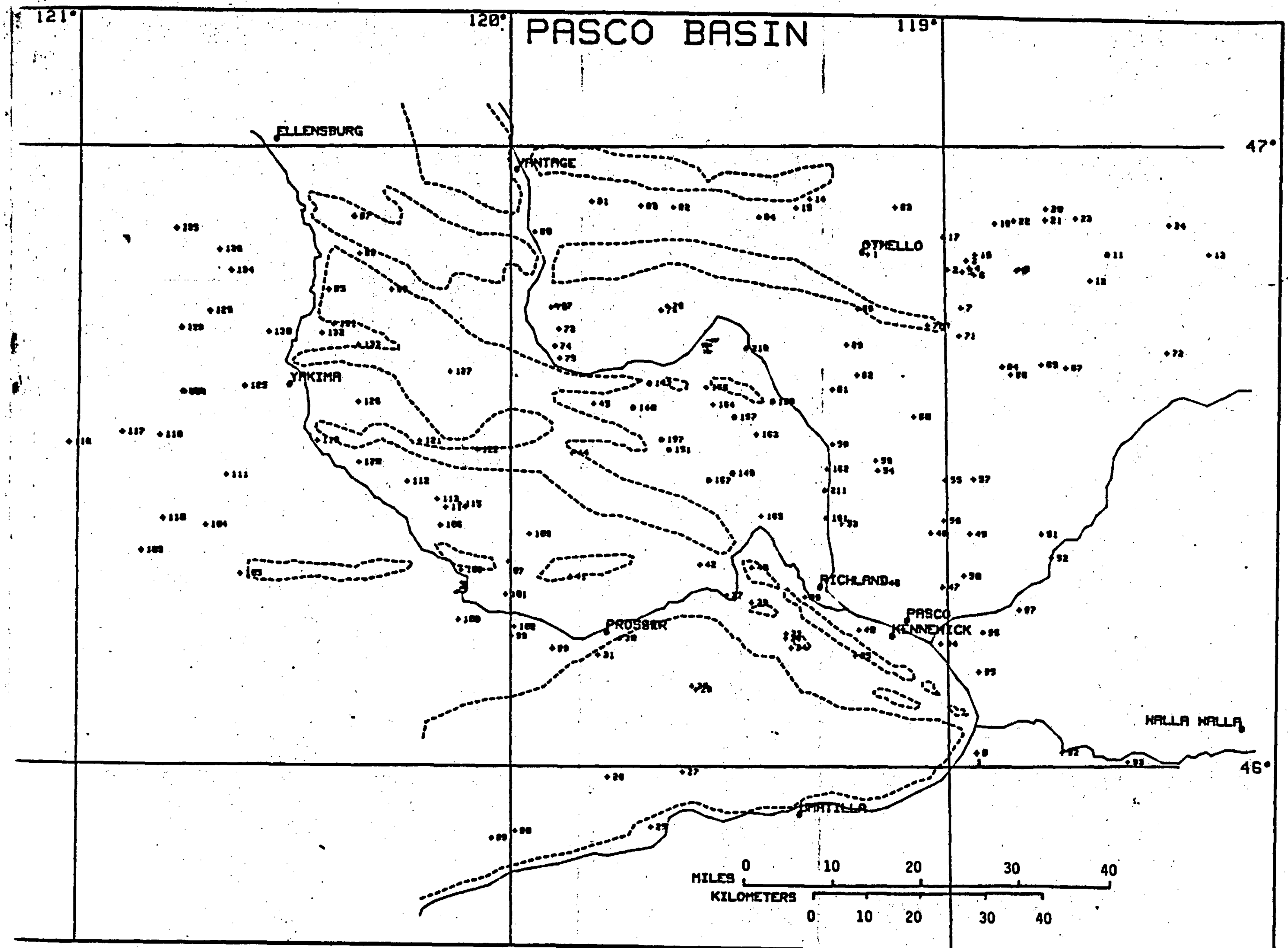


Figure 1. Sample Locations

In order to view the factor score distribution with depth, the Basalt sequence has been divided into 7 layers as follows:

Layer 1: Alluvium

Alluvium represents the alluvial aquifer which overlies the basalt. It includes the upper and middle Ringold and Hanford formations. Due to the fact that no water samples were obtained for this layer, it is not included in this analysis.

Layer 2: Composite Alluvium/Saddle Mountains

This layer is made up of the lower and Basalt Ringold and the Elephant Mountain Basalt. Because very few samples are taken in these units. This layer has also been omitted.

Layer 3: Saddle Mountains Basalt

This unit includes the Rattlesnake ridge interbed, Pomona basalt, Sela Interbed, Esquatzel Basalt, Cold Creek interbed and Umatilla Basalt.

Layer 4: Composite Saddle Mountain/Wanapum

This unit is comprised of samples in the Mabton Interbed.

Layer 5: Wanapum

This layer includes samples obtained from the Priest Rapids, Roza and Frenchman Springs basalts.

Layer 6: Composite Wanapum/Grande Ronde

This layer includes samples obtained from the Vantage Interbed and the Upper Sentinel bluffs units.

Layer 7: Grande Ronde

This includes samples from all units lower than the Upper Sentinel bluffs units.

Figure 2 graphically shows the division of units. It can be seen this division conforms to the three major hydrostratigraphic units as defined by RHO; and at the same time includes the units where breaks in trends are thought to occur by RHO (composite zones).

It should be noted the word 'composite' is not used in the strict hydrologic sense, i.e., the composite units do not necessarily contain composite water samples. For all Pasco Basin wells, the water sample is generally representative of a distinct unit within a given layer. However, for USGS well samples obtained from the surrounding basin, some samples are true hydrologic composites and are plotted in the composite layer representative of that sample, i.e., a sample labeled composite Wanapum - Grande Ronde would be placed in layer 6. The lack of consistent data is considered a major problem in any regional analysis. (See discussion of data limitations.)

Figures 3 - 7 show the actual data points available for each layer. The number of points in each layer varies; and this fact should be recalled when interpreting contour maps of factor loadings. The data points and the factor score value for each sample used are shown on the factor loading maps. In some cases in the Pasco Basin (RHO) wells, the data point is marked with an asterisk rather than a cross. This indicates several data points are collocated at this point, i.e. several samples were taken from the same well at several depths - all of which would be located in the same unit. The factor score listed at these points on the factor loading maps is the average of all the scores determined.

The data set used for this analysis is listed in the raw data. It is noted this is not the most up-to-date set of data, however, it is thought to be representative. The most up-to-date set of data was not obtained until late February. Unfortunately, this was too late to be of use in the EA review time period. It is not expected that the new data will make a significant difference in the interpretation since most new data points are located near the RRL, and a small area to the east of the RRL. This area is small with regard to the study area . Values in the new data were spot checked for consistency with those used in this interpretation. See Table 1. It appears on a preliminary basis that the use of the new data would not change the conclusions. However, the entire factor analysis will have to be repeated using the most up-to-date set of information and resubmitted at a later date.

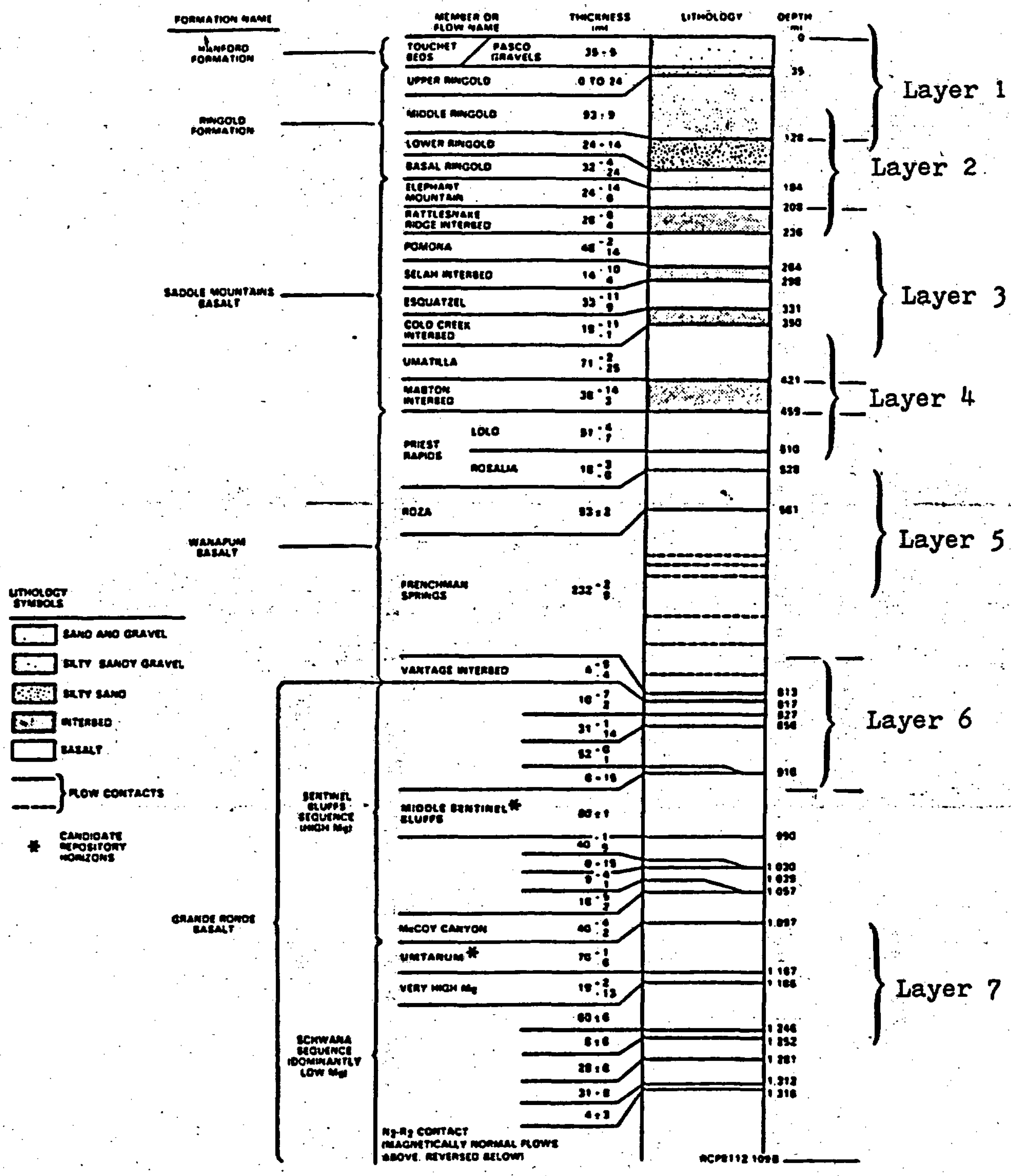
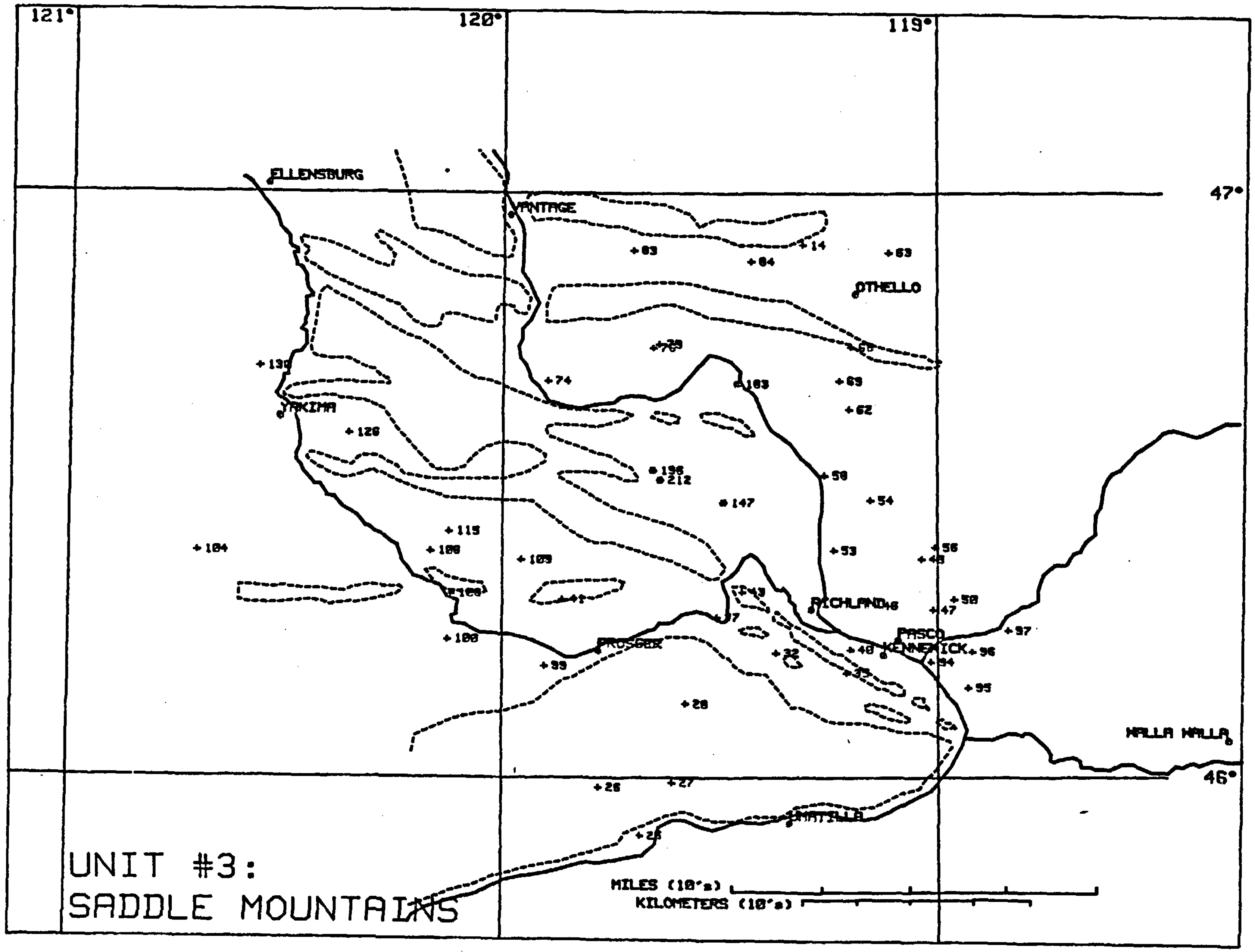


Figure 2: Generalized Strategraphic Column at Reference Repository Location (Modified to show layers)

Source: DOE/RL 82-3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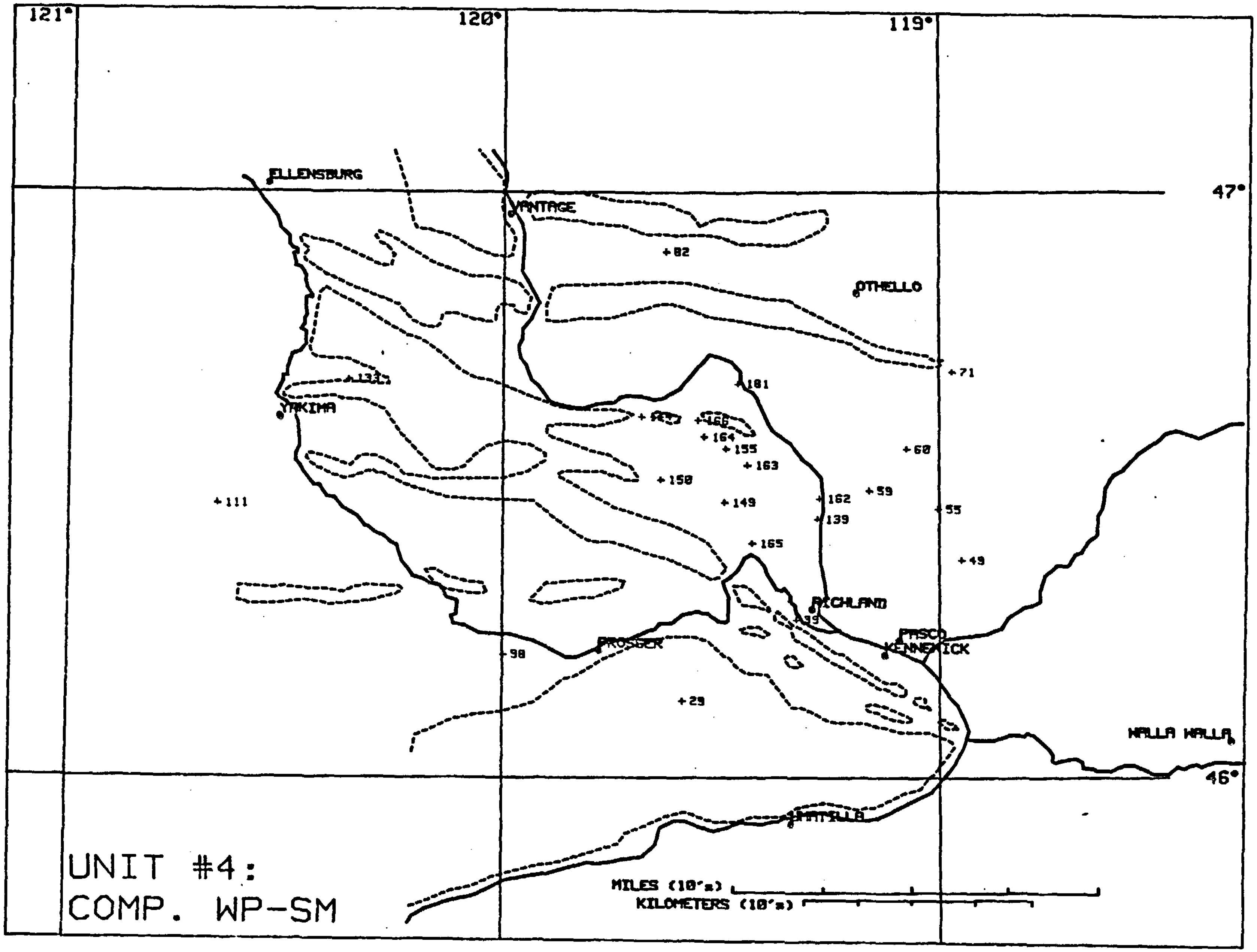
VANTAGE
OTHELLO
YAKIMA
RICHLAND
PASCO
KENNEWICK
PROSSER
WALLA WALLA
UMATILLA
UNIT #3:
SADDLE MOUNTAINS
MILES (10's)
KILOMETERS (10's)

Figure 3



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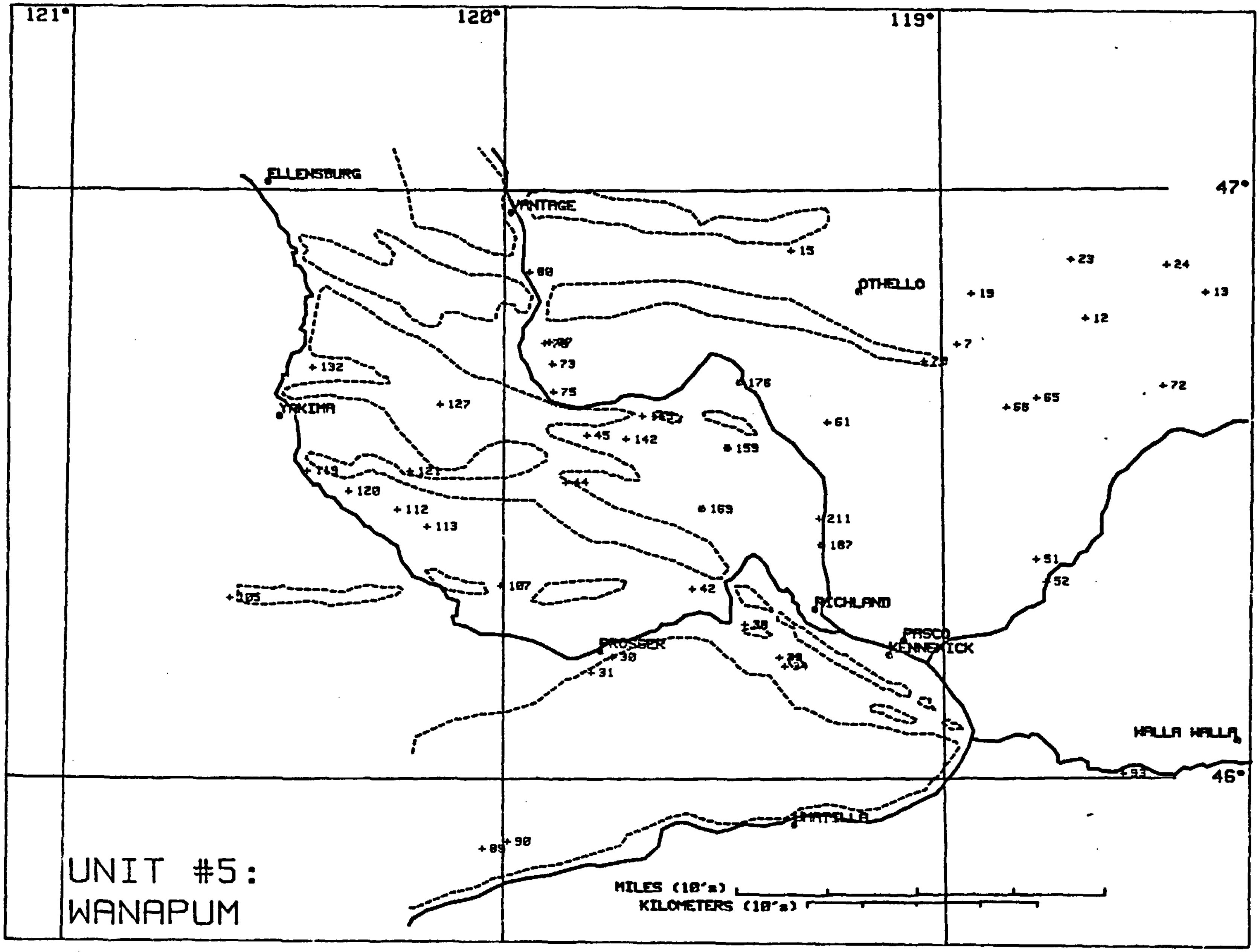
OTHELLO
YAKIMA
RICHLAND
PASCO
KENNEWICK
PROSSER
WALLA WALLA
UMATILLA
+82
+71
+181
+60
+164
+155
+163
+150
+59
+162
+139
+55
+149
+111
+165
+49
+98
+29
UNIT #4:
COMP. WP-SM
MILES (10's)
KILOMETERS (10's)

Figure 4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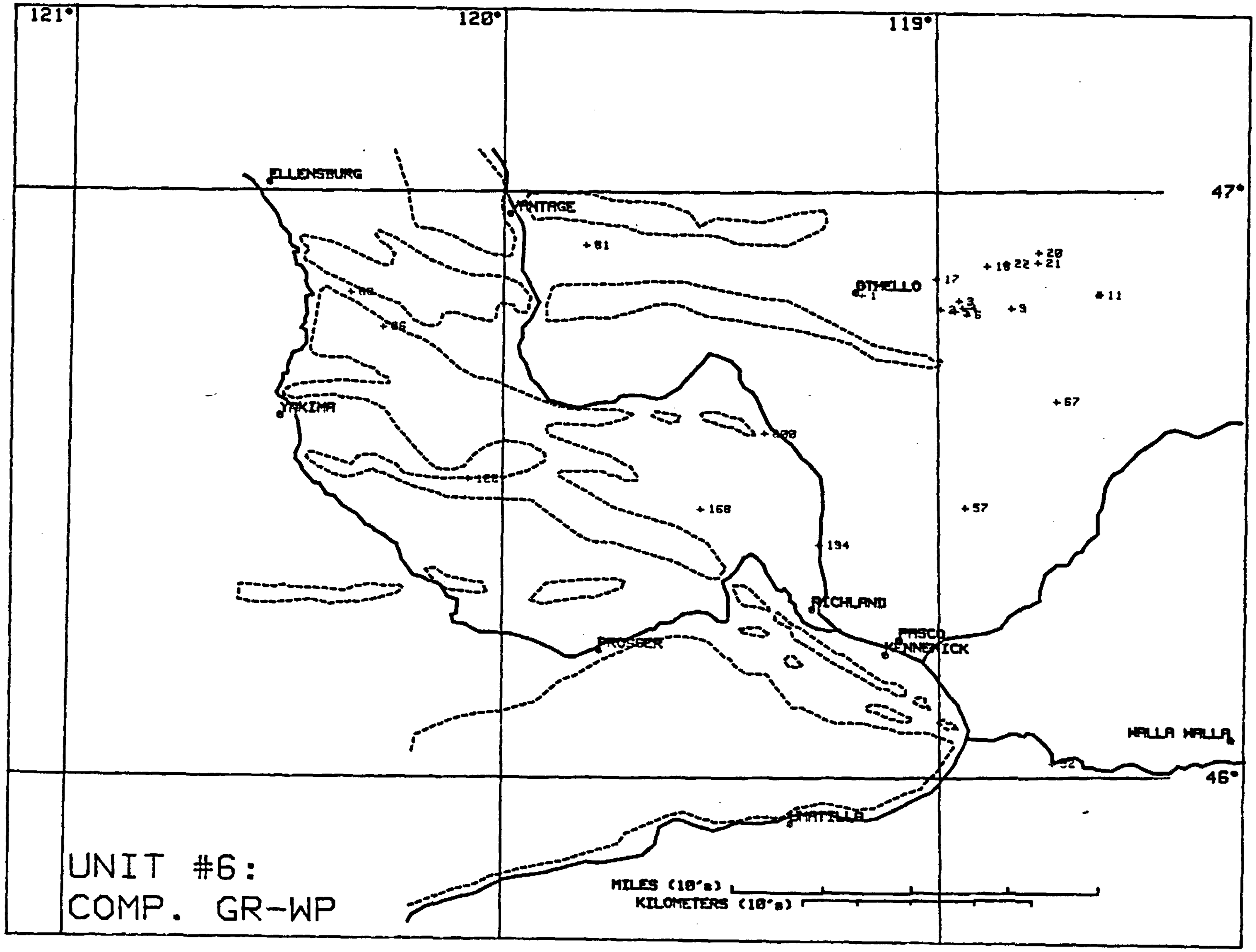
RICHLAND
PASCO
KENNEWICK
PROSSER
WALLA WALLA
UMATILLA
MILES (10's)
KILOMETERS (10's)
UNIT #5:
WANAPUM

Figure 5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PASCO
KENNEWICK
PROSSER
WALLA WALLA
UMATILLA
MILES (10's)
KILOMETERS (10's)
UNIT #6:
COMP. GR-WP

Figure 6

HEWLETT PACKARD

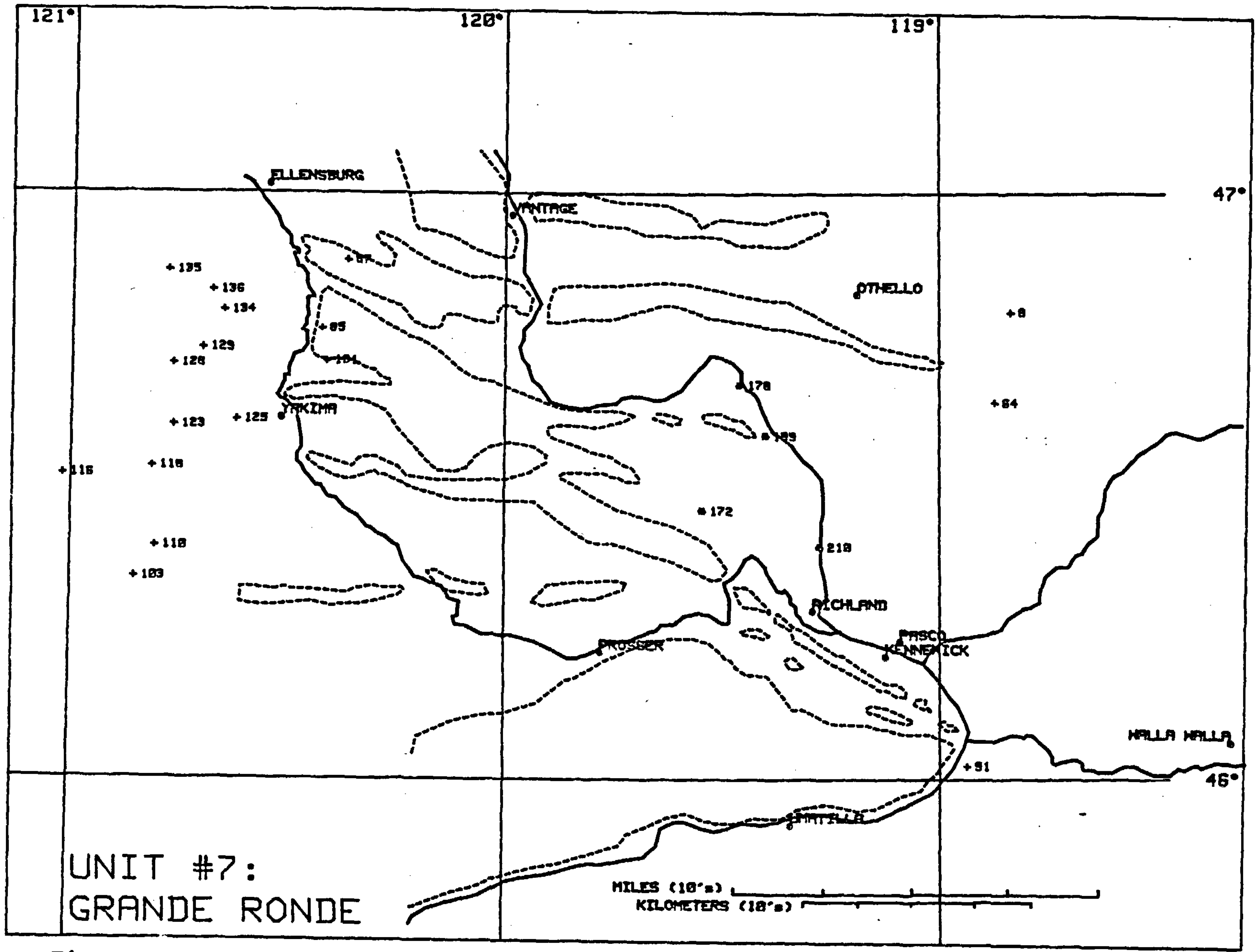


Figure 7

TABLE 1

(SAMPLE #), LAYER #	PH	T	NA	SOLIDS	CL	F	FACTOR SCORE
(82-65), 5	9.32	32.5	141	Missing	133	8.5	
(82-170), 5	8.3	43.3	282	Missing	122	8.6	
(82-122), 7	8.76	48.6	374	Missing	507	21.7	
(82-401), 7	9.7	53.67	337	Missing	403	20.	
(84-7), 7	9.6		353	Missing	416	14.	
(82-364), 7	9.4	56.9	355	Missing	451	18.2	
(82-309), 7	9.34	58.83	336	Missing	384	17.2	
(82-456), 7	9.78	56.2	364	Missing	455	20.1	
(168), 6	9.46	25.1	162.5	546.3	117.	10.7	1.52
(172), 7	9.52	41.7	161.4	526.56	130.6	12.9	1.61
(200), 6	9.62	21.	349.5	1123.99	296.8	22.4	3.31
(203), 7	9.4	37.5	359.7	1000.64	289.1	35.6	3.66

Table 1 lists the field measured values which are positively correlated to Factor 1. The first eight measurements are from well RRL-2. The last four are actual measurements in the Pasco Basin which reflect high Factor 1 scores. It can be seen that for the variables most important to Factor 1, the actual measured amount is greater in the RRL.

Results of Factor Analysis Run

The factor analysis yielded the following set of communalities which was placed in the matrix diagonal and solved for real eigenvalues and associated eigenvectors. Table (2) shows the communalities generated by the data. Table 3 lists the eigenvalue solutions obtained and the percent of the variance accounted for by each solution. Each eigenvector associated with an eigenvalue becomes a factor.

Table 2. Final communalities of variables in PA1 analysis.

TABLE 2

VARIABLE	COMMUNALITY
DATUM	.59409
PH	.85605
TEMP	.49761
CA	.88352
MG	.88675
NA	.89921
K	.78821
CL	.30147
HCO3	.76931
CO3	.67890
SO4	.85349
F	.86665
SOLIDS	.91991

Table 3: Eigenvalues and percent of variance accounted for by 13 factors with the PA1 analysis.

TABLE 3

FACTOR	EIGENVALUE	PCT OF VAR	CUM PCT
1	6.00757	46.2	46.2
2	2.57881	19.8	66.0
3	1.20879	9.3	75.3
4	0.89438	6.9	82.2
5	0.64595	5.0	87.2
6	0.54823	4.2	91.4
7	0.44488	3.4	94.8
8	0.31191	2.4	97.2
9	0.12679	1.0	98.2
10	0.08646	.7	98.9
11	0.06927	.5	99.4
12	0.05611	.4	99.8
13	0.02085	.2	100.0

The eigenvalue cutoff for factor extraction was 1.0, as a result the 13 variables were reduced to three factors, accounting for 75.3% of the total variability of the data.

Table 4 provides the final factor loading matrix obtained from the PA1 analysis. Factor loadings show the relationships of variables to principal factors. This table shows that the variables sodium, carbonate, chloride, fluoride, solids, pH, temperature datum and HCO3 group in Factor 1. Magnesium, sulfate, and calcium tend to group in Factor 2, and potassium and HCO3 group in Factor 3. A negative sign before a variable in a factor grouping indicates it is inversely related to the other variables in the grouping. Underlined loadings are considered significant (greater than .5).

Table 4. Varimax-rotated factor loading matrix.

TABLE 4

	FACTOR 1	FACTOR 2	FACTOR 3
HCO3	-.59284	.40473	.50403
SOLIDS	.87037	.35782	.18528
MG	-.24382	.90156	-.12039
NA	.93286	-.09907	.13847
K	.17241	-.22671	.84089
CO3	.72609	-.38067	.08233
SO4	.49954	.77452	-.06379
CL	.53577	-.05091	.10874
F	.91808	-.09211	-.12372
CA	-.29312	.88444	-.12400
PH	.80416	-.43400	.14497
TEMP	.54805	-.43243	.10125
DATUM	-.58139	.17887	-.47337

The three factors summarize the combination of variables used in the analysis. Each factor represents a chemically distinct water type. The contours drawn in Figures 9 through 13 and 15 through 26 are based on the solution of the linear factor equation with coefficients from the factor score coefficient matrix. (See Harman (1976) for a discussion of the Factor Analysis method.) From these coefficients, the value of each factor at each well location can be plotted (Klovan, 1975). The resulting factor scores are in standard form, i.e. a mean of 0.0 and a standard deviation of 1.0. These values should be considered to represent a normal distribution and a gradient of the water type. (Factor scores can be used as any other variable; and are plotted and manipulated in the same way.) The actual scores are provided in the Raw Data Appendix.

Interpretation of Factors

Factor 1 contains the variables sodium, carbonate, bicarbonate, chloride, fluoride, pH, temperature, solids and datum (Table 4). These are the chemical constituents one would expect to be found in water from a sedimentary sequence - such as the one thought to be below the Pasco Basin basalts. Newcomb (1972), recognized a water type similar to this and attributed it to a sedimentary origin. The distribution of Factor 1 indicates the greatest concentration is at wells DC-6 and DC-14, located at the north eastern side of the horn of the Columbia River south of Priest Rapids Dam. It is noted these two wells are flowing from depths greater than 1700 ft. below the surface (Fenix & Scisson, 1978). Potential upwelling is suggested by the depletion of this factor with decreasing depth. Since Factor 1 water is less significant in wells higher in the section, one could infer a mixing with younger water as it progresses toward the surface.

Factor 2 water contains the variables magnesium, sulfate and calcium. It is positively correlated to each of these variables. One interpretation is that Factor 2 water could be basalt equilibrated recharge water. The calcium/magnesium ratios of these water types is close to the ratios obtained for basalt as shown on Table II-1 in RHO-BWI-ST-4. Also, high sulfate values could be associated with irrigation practices. Hem (1970), states "When an area of low rainfall and accumulated solutes is reclaimed by irrigation, the increased water supply tends to leach away the solutes, and they appear in drainage water or return flow. The process is an acceleration of natural leaching and will increase the dissolved solids concentrations and loads in residual water of the affected area for a considerable period." The Factor 2 scores show a minor positive correlation to solids, indicating this could be the case. Therefore, this water can be thought of as recharge water, possibly basalt equilibrated.

Factor 3 water has positive correlations only to bicarbonate and potassium. The Factor 3 water has several possible interpretations. Bicarbonate can be picked up in the soil zone and is generally a near surface phenomenon. Also, the potassium could have several sources of origin: three of which are

1) clays from weathered feldspars (interbeds)
2) fertilizers
3) basalts

Since factor scores occur in the same areas where irrigation by canal water occurs, some possible connection may exist in the upper units (Figure 8). However, factor scores seem to increase with depth which gives rise to a different interpretation. An increased pH in the basalts could cause increased potassium values and therefore this water may be representative of areas where more potassium has been removed from the basalt, possibly due to higher pH.

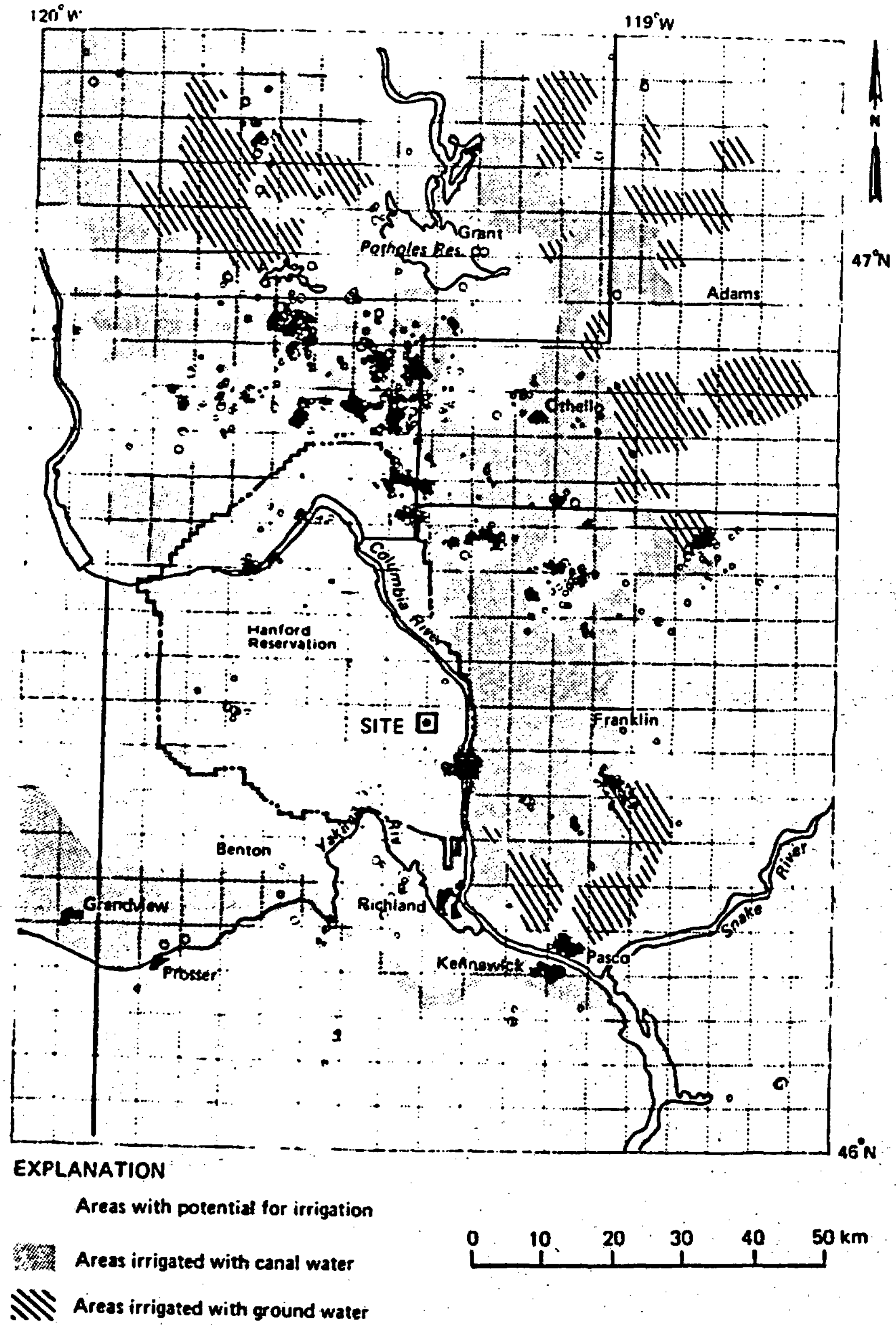


Figure 8 Swarm seismicity and areas of irrigation (Source: Washington Public Power System, Amendment No. 18)
(After NRC, 1983)

Factor Distributions

Factor distributions are presented with contour lines in Figures 9 through 13 and 15 through 26. All contours were done by computer using a plotting routine (Golden, 1984). The computer contouring is not influenced by surface structures or features which could interrupt these purely mathematical intervals. However, the main surface features which could influence the distribution of contour intervals are superimposed on the contours. For ease of interpretation, the more significant factor values have been shaded.

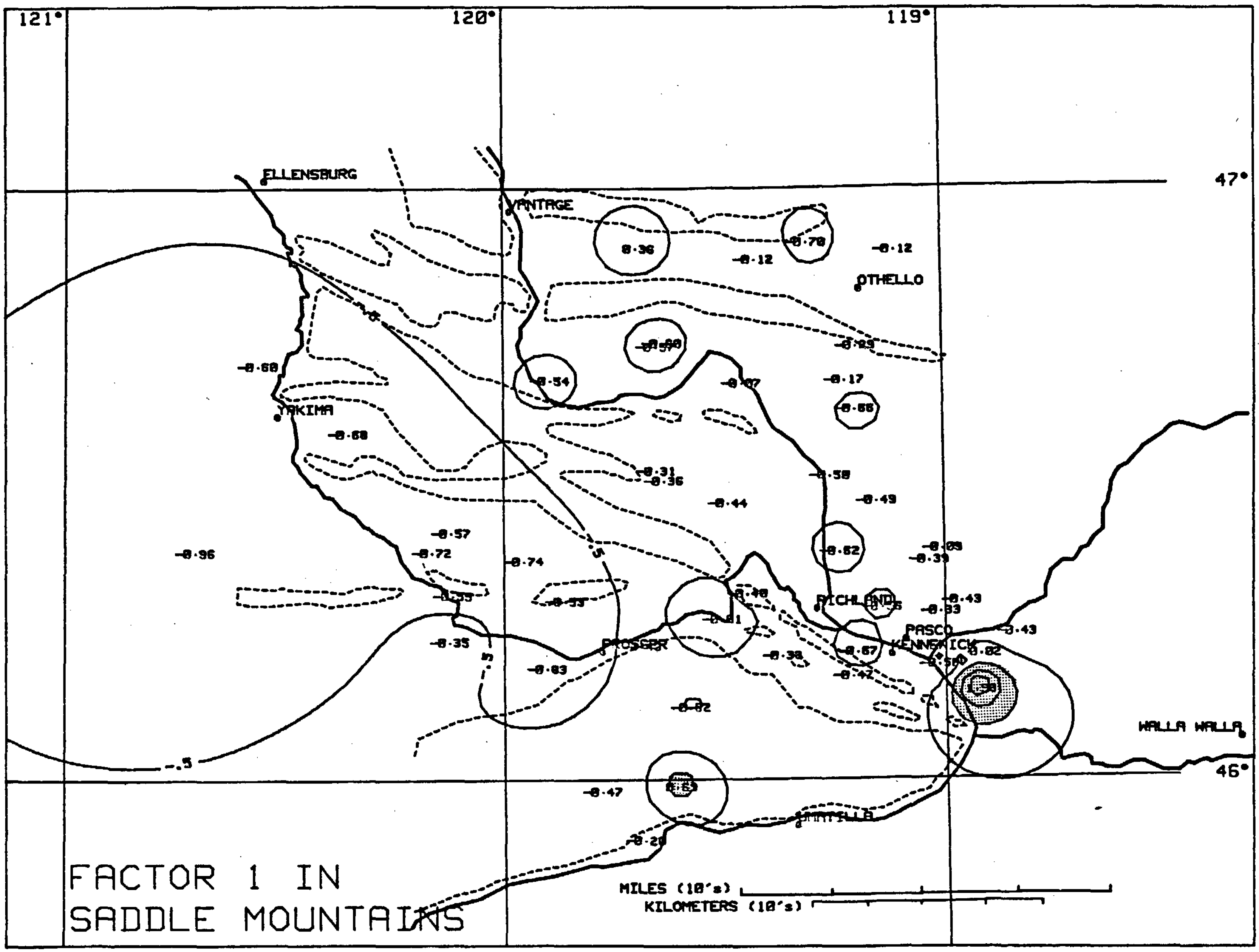
It should be noted that no data are shown in the RRL area. These data were not acquired in time to be useful in the analysis due to the severe time constraints placed on the EA comment period (90 days). See previous discussion regarding Table 1.

Factor 1

Figures 9 thru 13 represent the distribution of Factor 1 with depth in the study area. The Factor 1 distribution starts in the Saddle Mountains unit (Figure 9) in wells located near the confluence of the Snake, Walla Walla and Columbia Rivers. Very high scores are shown in this area. A somewhat weaker factor score is apparent in the lower reaches of the Columbia, just north of a northward jog in the river. Slightly lower in the section, (Figure 10), the composite Wanapum/Saddle Mountains unit starts to show Factor 1 water at significant levels in the Pasco Basin. Figures 11 thru 13 show that the factor scores generally increase and become more widespread in the deeper units within the Pasco Basin. The deep wells in the western part of the study area show negative correlations to Factor 1, as do most wells to the north and east of the Pasco Basin.

This distribution indicates that Factor 1 water is moving upward through the sections at certain sites which are not necessarily associated with anticlines, as is the RHO determination regarding upwelling. Rather, a strong correlation exists between the rivers and the distribution of Factor 1 water in the upper units. In the Wanapum and lower layers, a more widespread distribution occurs which indicates more numerous sources may be present at depth.

The origin of Factor 1 water is presently unknown. Some possibilities for sources of this water are Mesozoic and Tertiary sediments which may underlie the basalts. The distribution of these sediments is shown as Figure 14. Since the marine sediments appear closest to the Pasco Basin and have a relatively widespread distribution, these sediments are a likely source for the Factor 1 water. Hydraulic gradients are consistent with this interpretation. However, the composition of these sediments must be closely examined before any conclusions can be reached.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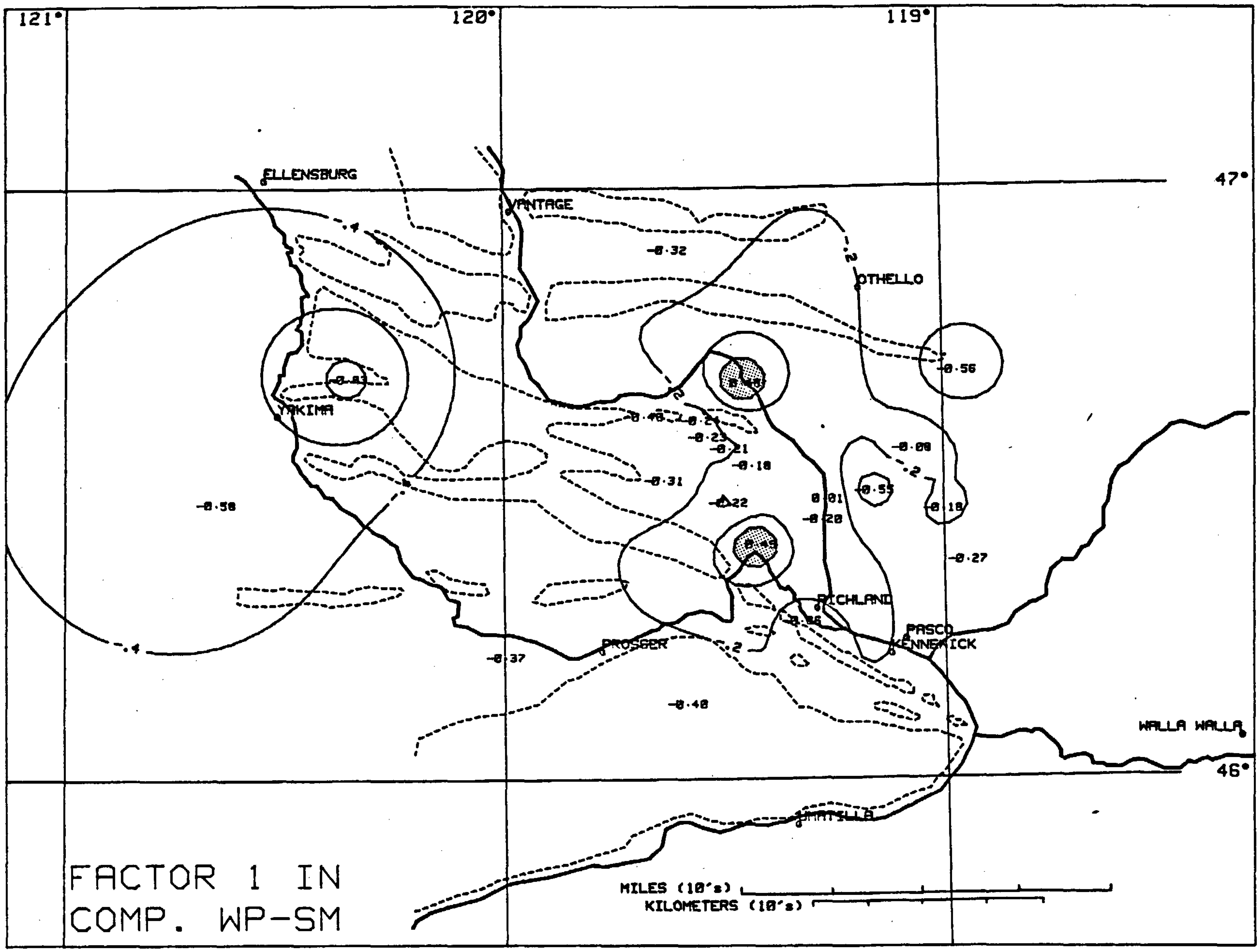
PROSSER
WALLA WALLA
FACTOR 1 IN
SADDLE MOUNTAINS
MILES (10's)
KILOMETERS (10's)

Figure 9



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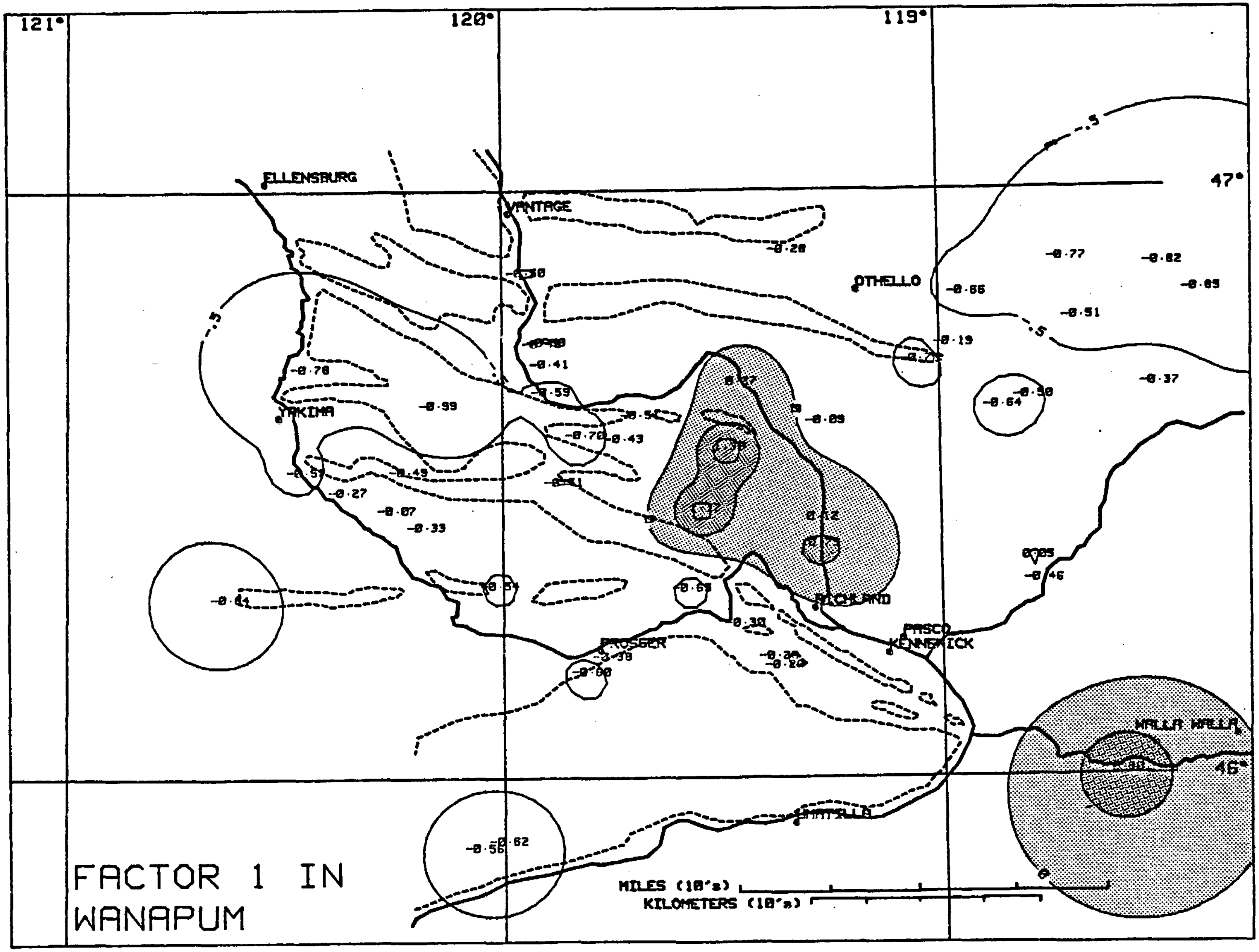
UMATILLA
FACTOR 1 IN
COMP. WP-SM
MILES (10's)
KILOMETERS (10's)

Figure 10



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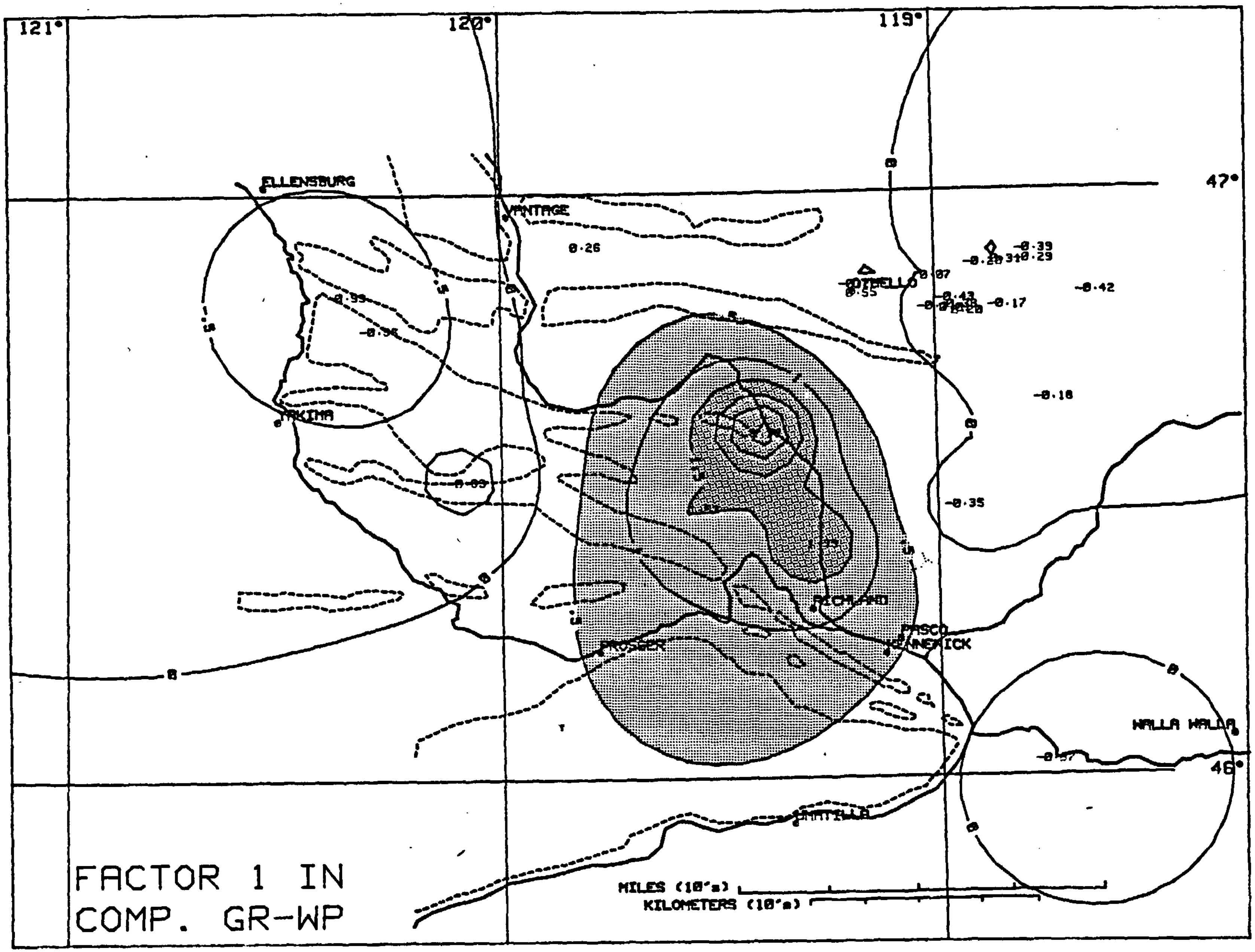
FACTOR 1 IN
WANAPUM
MILES (10's)
KILOMETERS (10's)

Figure 11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UMATILLA
0.26
-0.42
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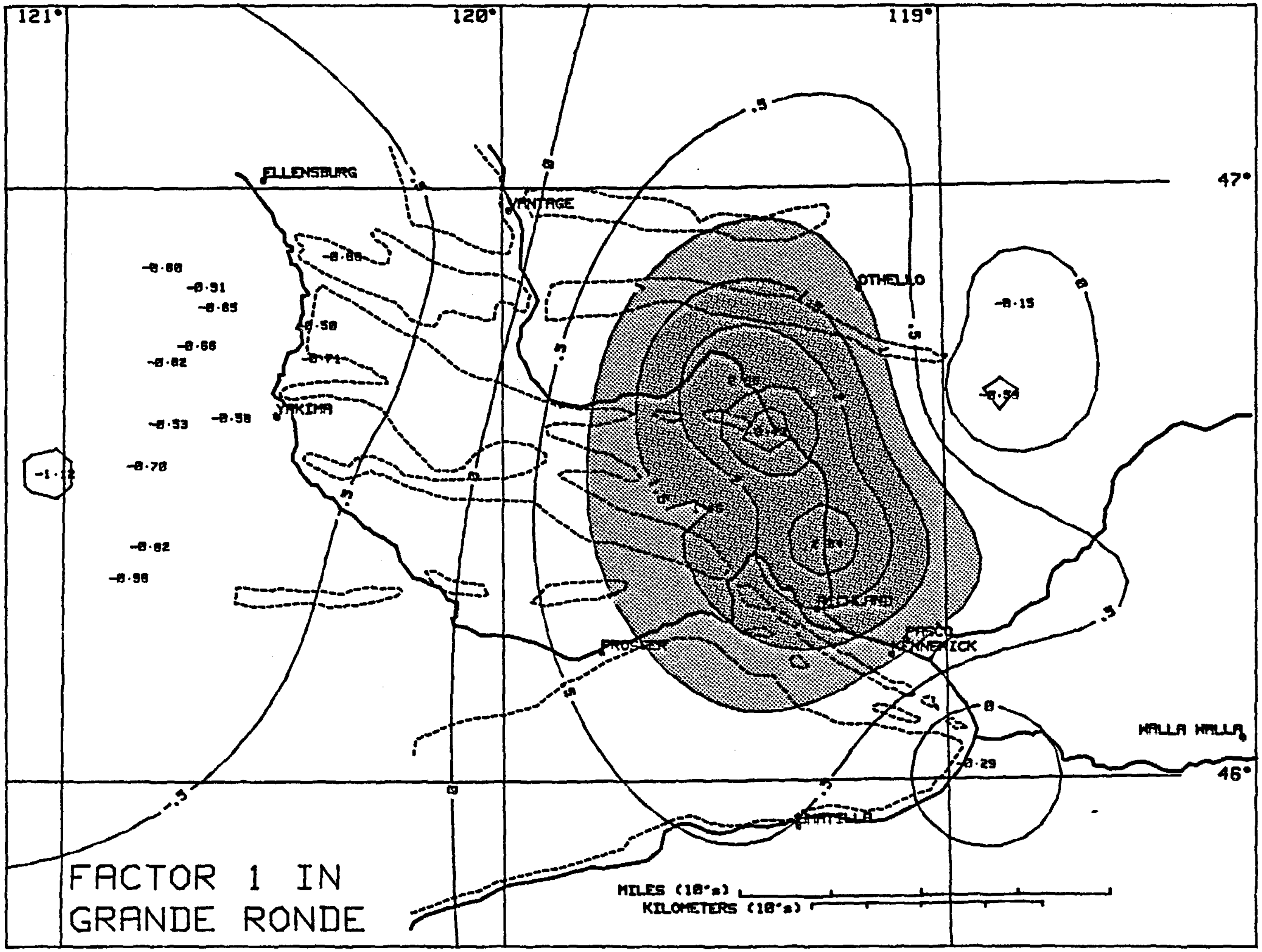
-0.35
-0.17
FACTOR 1 IN
COMP. GR-WP
MILES (10's)
KILOMETERS (10's)

Figure 12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UMATILLA
MILES (10's)
KILOMETERS (10's)
FACTOR 1 IN
GRANDE RONDE

Figure 13

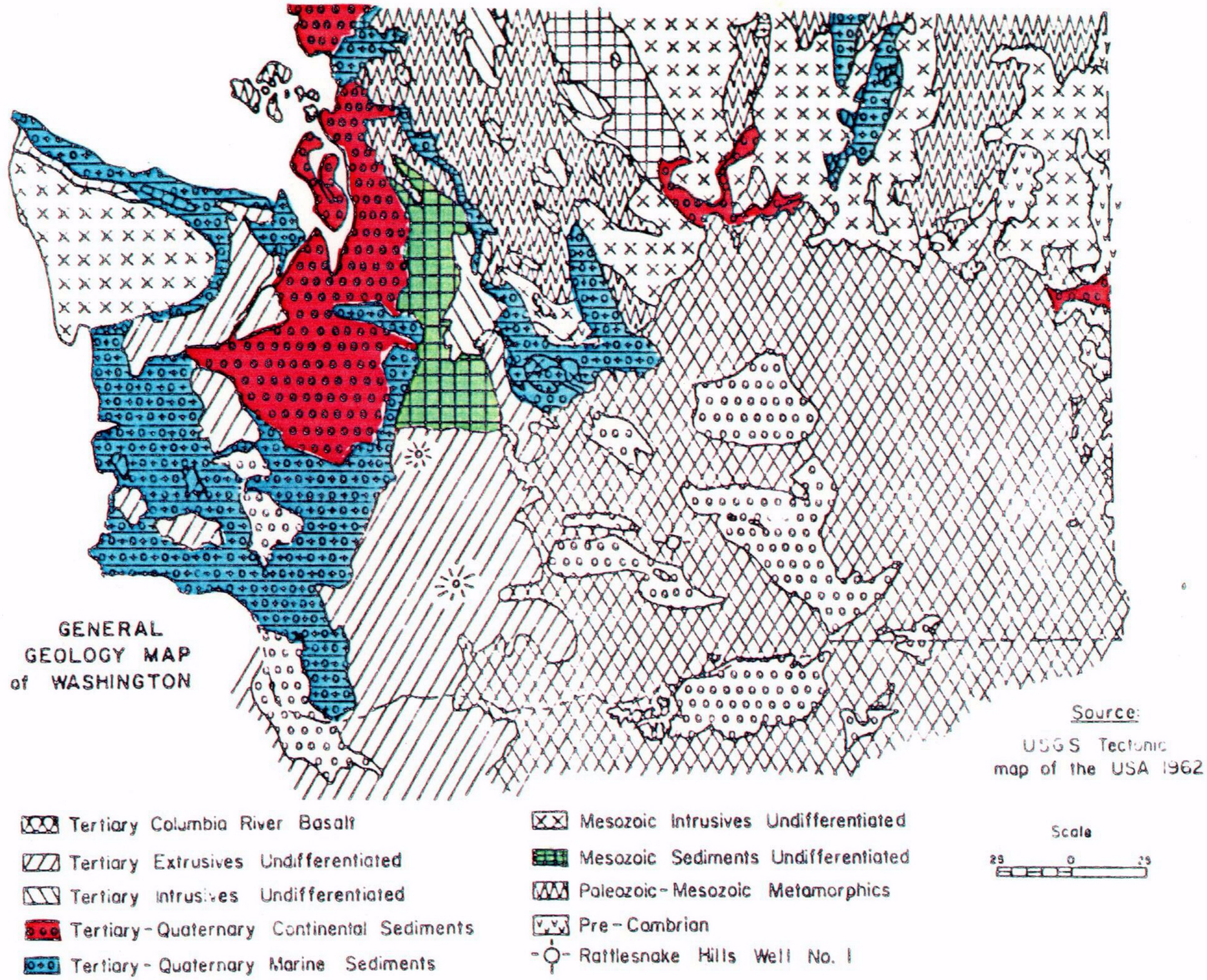


Figure 14

Possible Sediment Sources of Factor 1 Water

C01

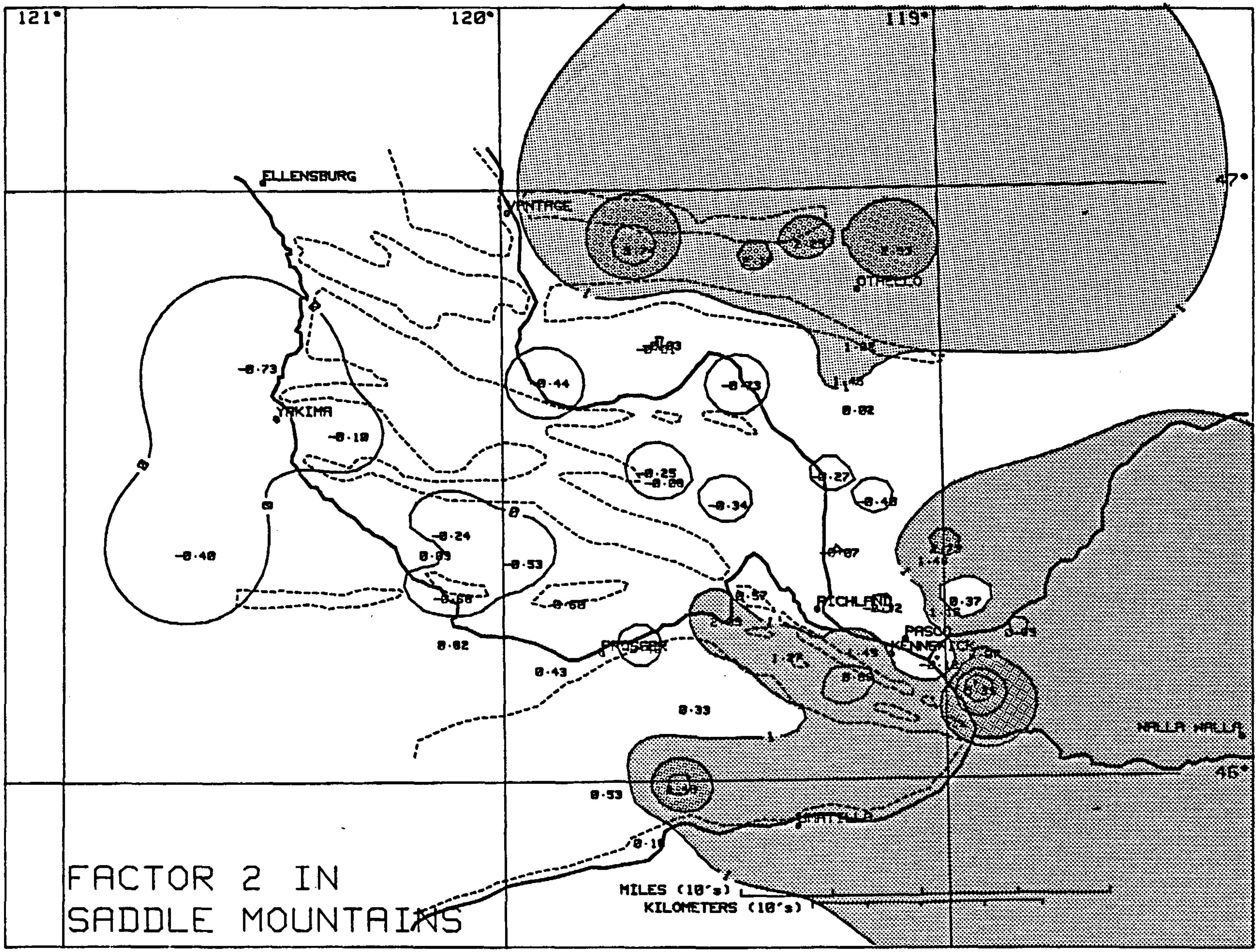
Factor 2

Figures 15 through 19 show the distribution of Factor 2 water. The patterns are not easily interpreted due to the relative lack of data at the various depths. However, several observations can be made. First, this factor is notably absent in the Pasco Basin except for one measuring point along the river. Secondly, this factor is present to the north, south and east of the Pasco Basin in varying amounts. Thirdly, water to the west of the Pasco Basin is not correlated to this factor.

These patterns indicate that Factor 2 water is basalt equilibrated recharge water moving toward the Pasco Basin through the various units from across the plateau. Some change occurs in water type in the Pasco Basin since Factor 2 water is essentially absent there.

Factor 3

The distribution of Factor 3 is shown in Figures 20 through 24. Figure 20 indicates there are a few areas containing this factor in the Saddle Mountains unit. These areas correspond to locations where canal water is used to irrigate. It is noted Factor 3 water spreads rapidly across the area in the composite SM/WP layer (layer 4), Figure 21. This could illustrate the transmissive nature of this layer. Factor 3 water is present in the Pasco Basin in the southern and central regions. The distribution of Factor 3 in the Wanapum (Figure 22) is more spacially confined than Factor 1; however, Factor 3 water is still evident in the Pasco Basin in significant amounts. The amount of Factor 3 water in the Pasco Basin becomes more significant in the Wanapum and is still present in the Grande Ronde/Wanapum composite unit. This distribution indicates that a mixture of Factor 1 and Factor 3 may be occurring in the Pasco Basin.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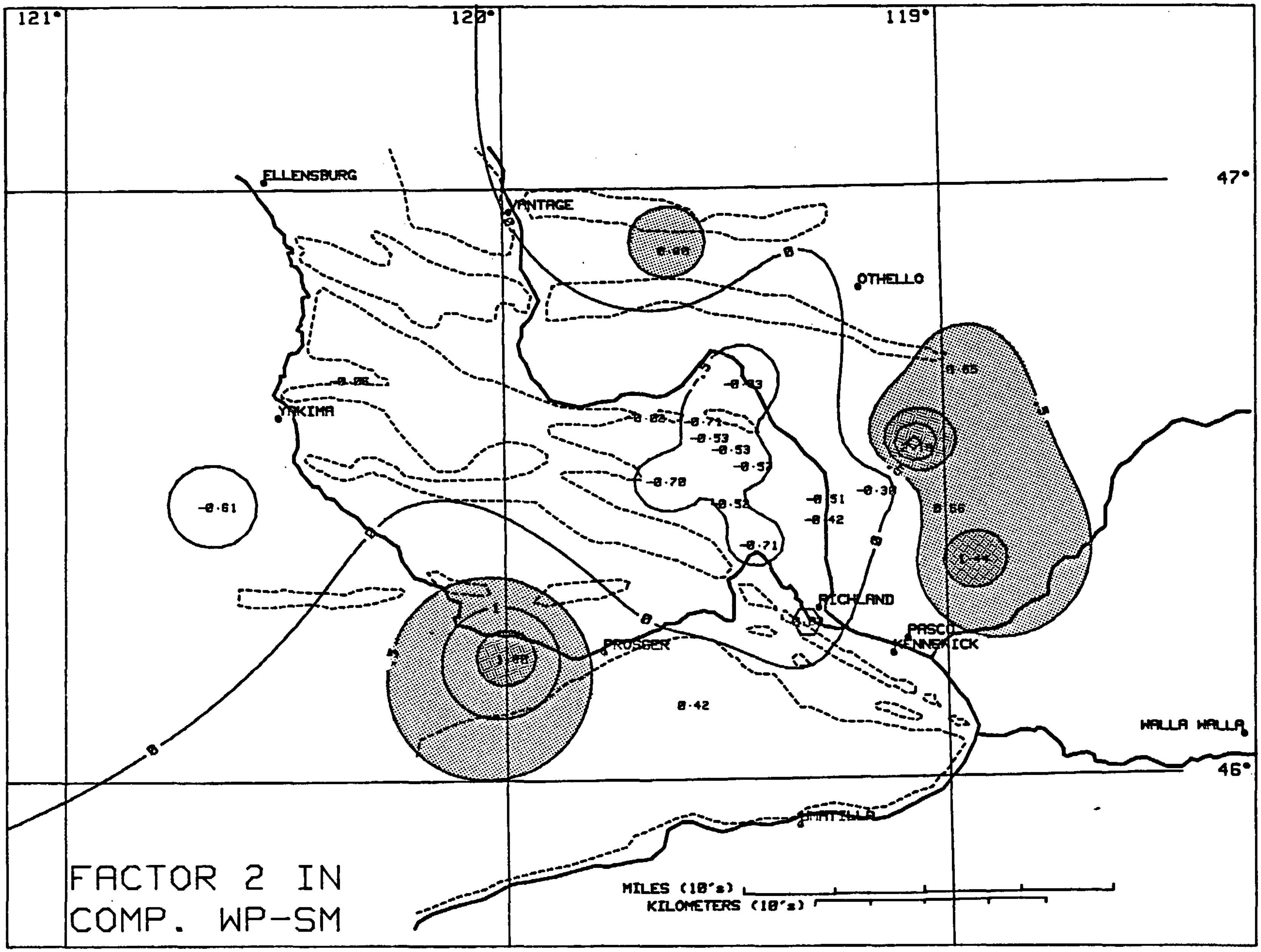
WALLA WALLA
UMATILLA
MILES (10's)
KILOMETERS (10's)
FACTOR 2 IN
SADDLE MOUNTAINS

Figure 15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UMATILLA
-0.61
-0.83
-0.71
-0.53
-0.53
-0.52
-0.78
-0.52
-0.71
-0.51
-0.42
-0.38
0.42
MILES (10's)
KILOMETERS (10's)
FACTOR 2 IN
COMP. WP-SM

Figure 16

HEWLETT PACKARD

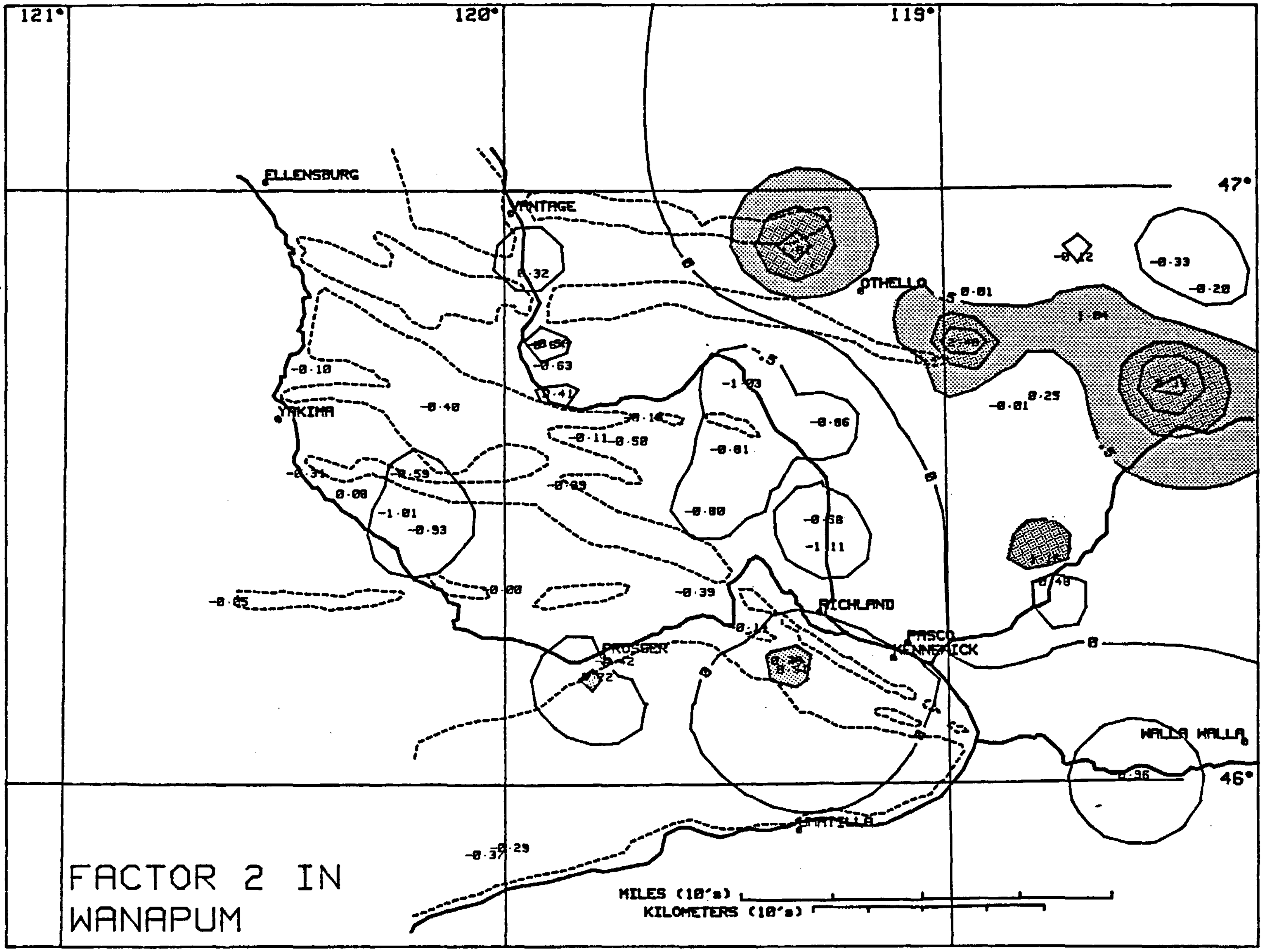
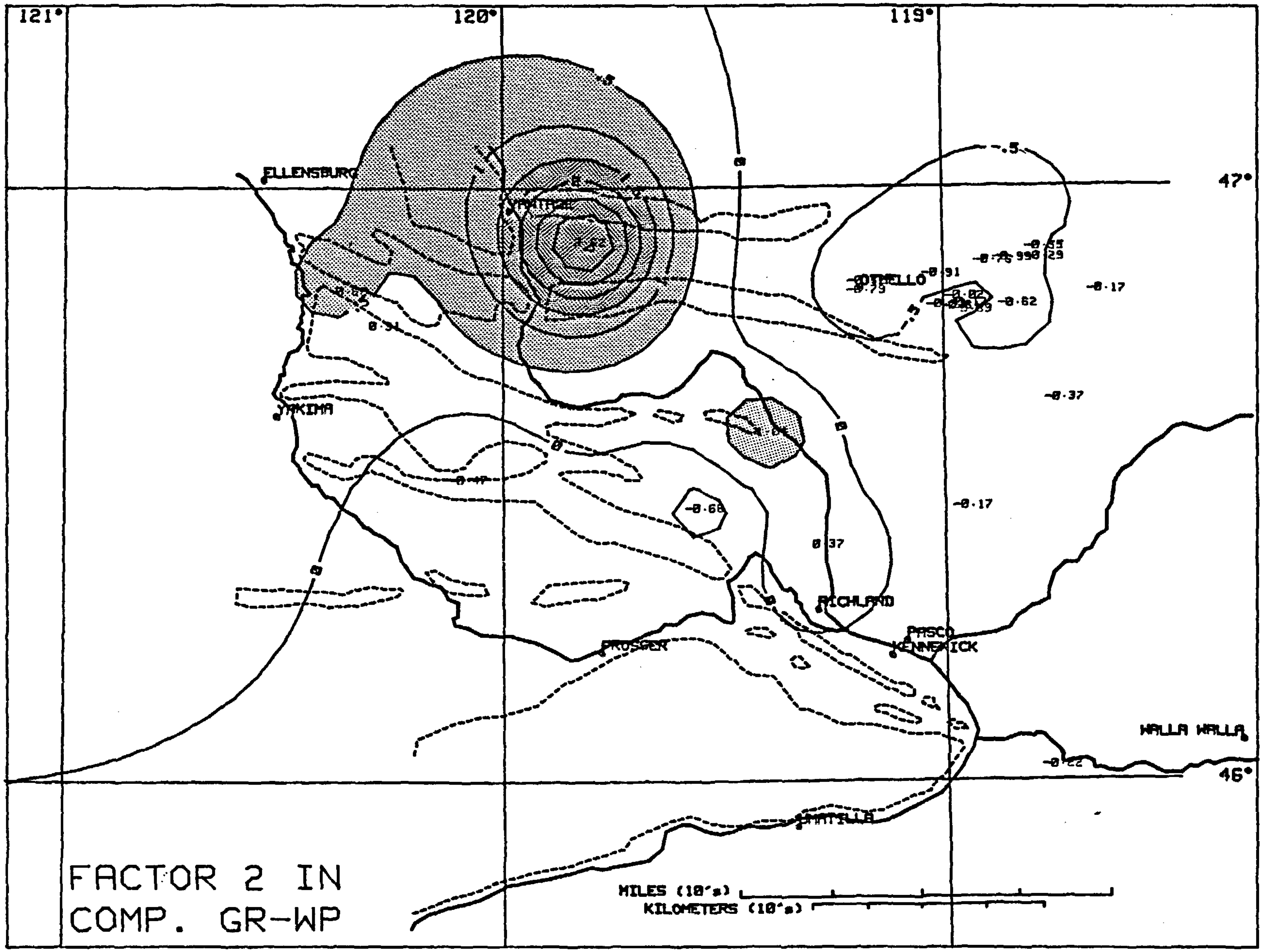


Figure 17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MILES (10's)
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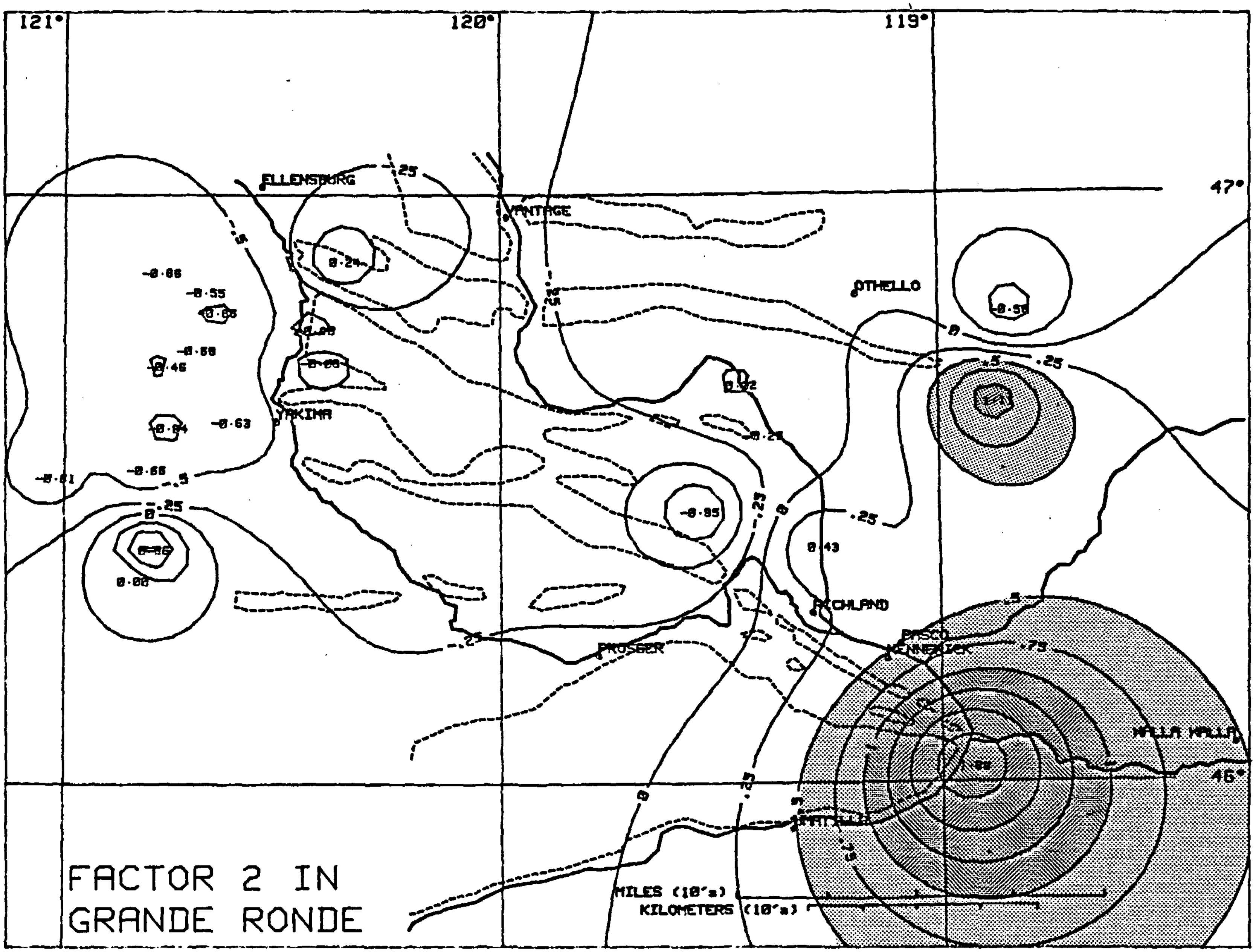
FACTOR 2 IN
COMP. GR-WP

Figure 18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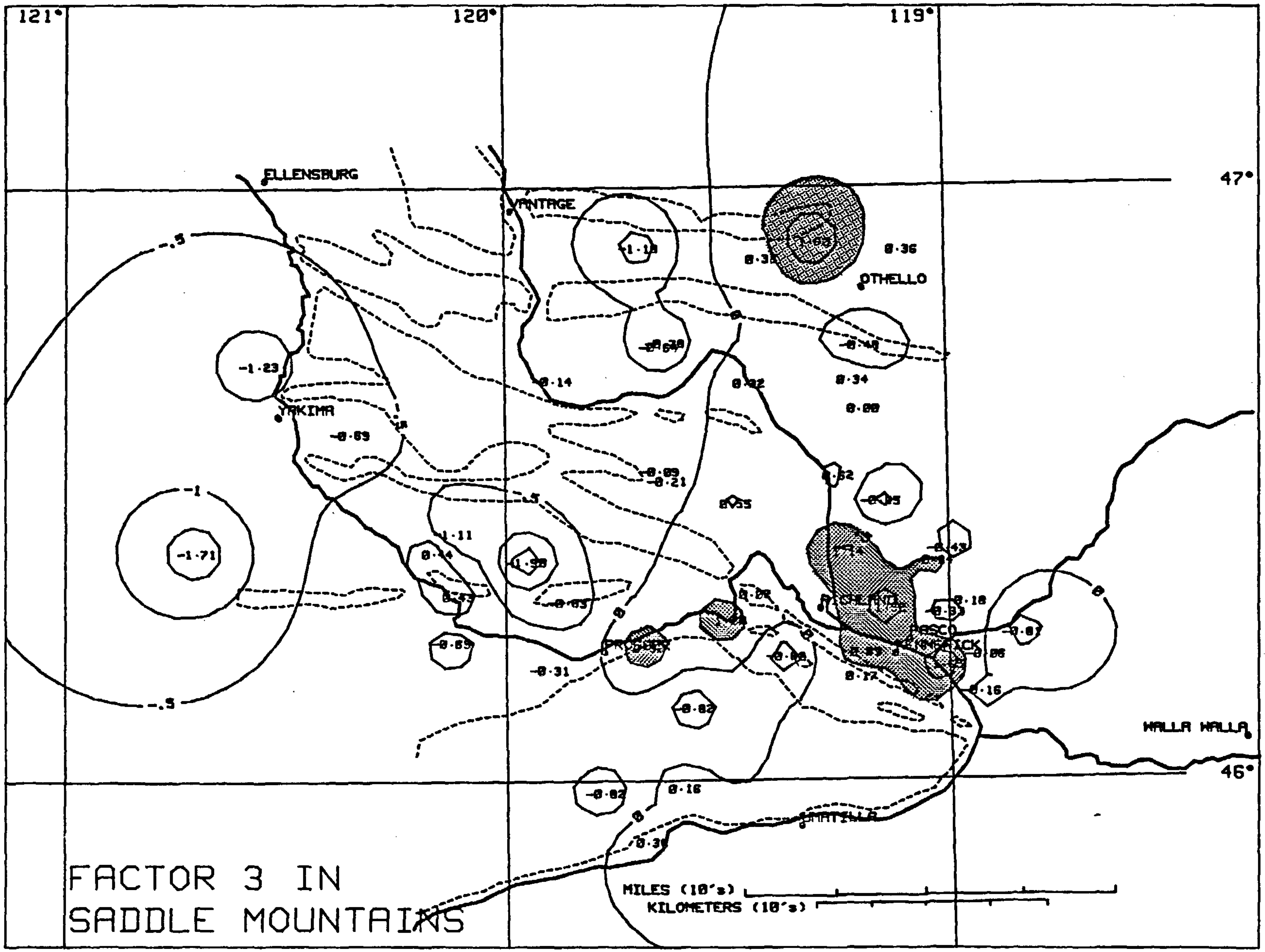
MILES (10's)
KILOMETERS (10's)
FACTOR 2 IN
GRANDE RONDE

Figure 19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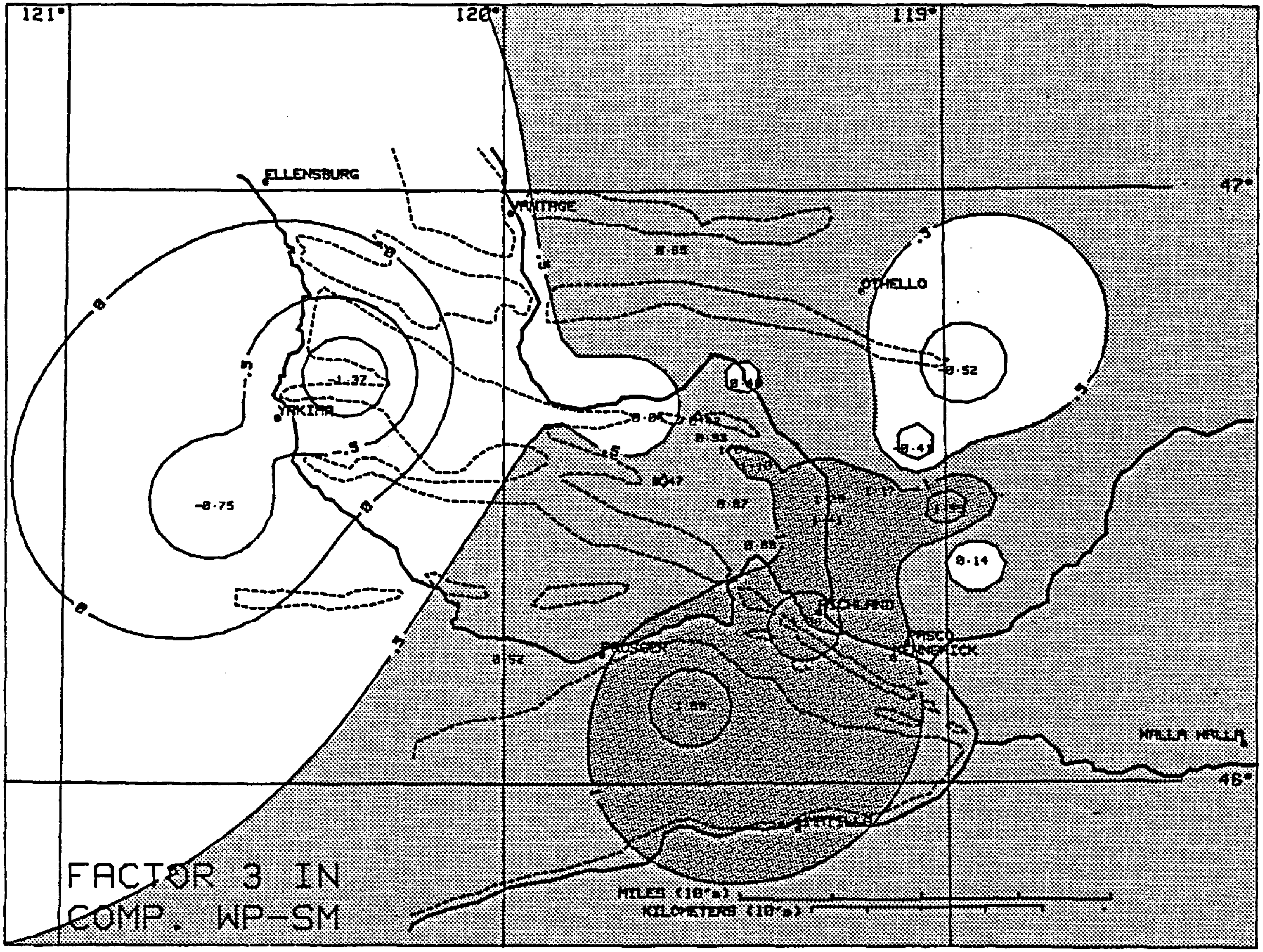
FACTOR 3 IN
SADDLE MOUNTAINS
MILES (10's)
KILOMETERS (10's)

Figure 20



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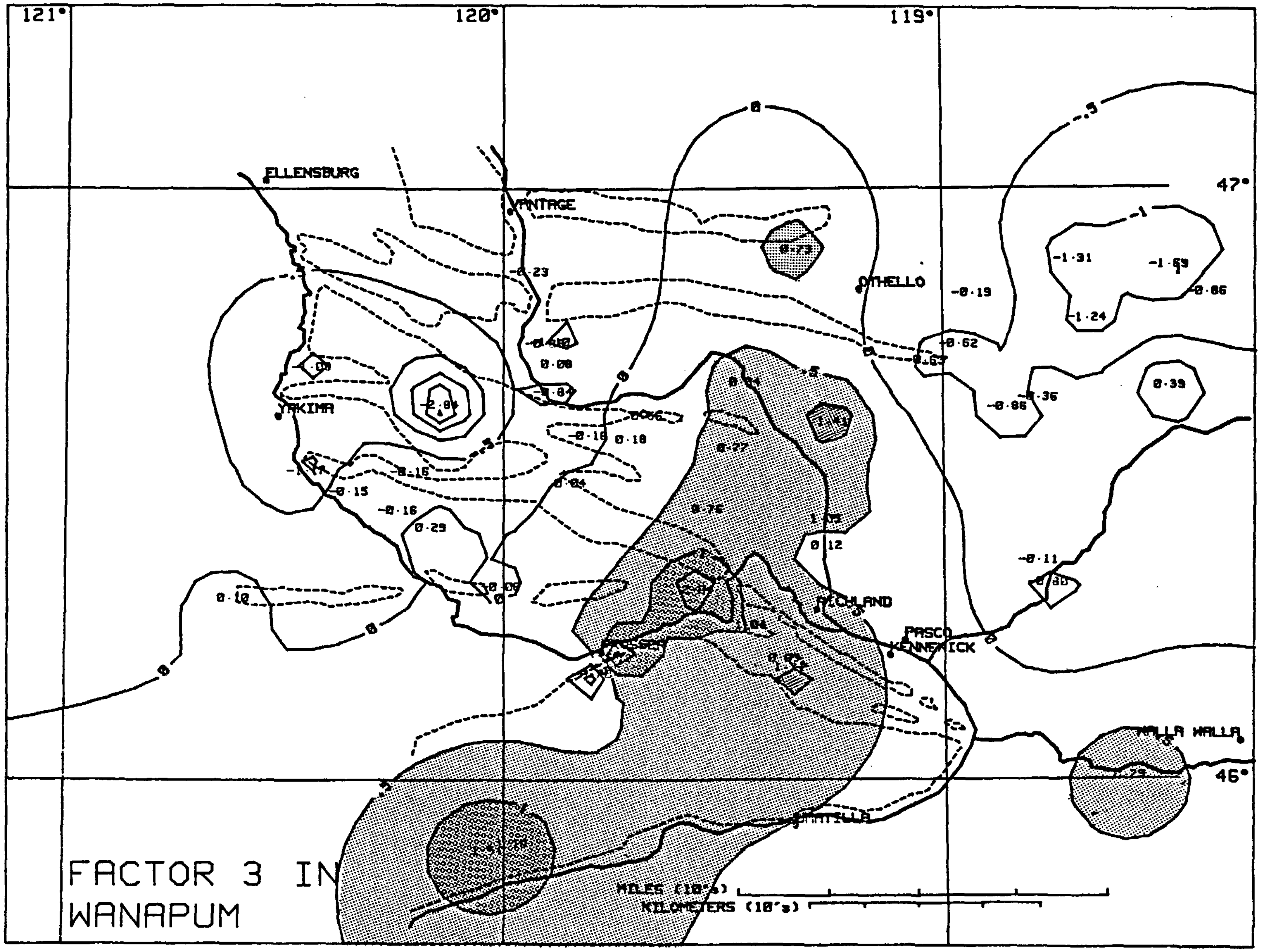
KENNEWICK
PROSSER
WALLA WALLA
-1.37
-0.75
0.52
0.14
0.85
0.87
0.52
FACTOR 3 IN
COMP. WP-SM
MILES (10's)
KILOMETERS (10's)

Figure 21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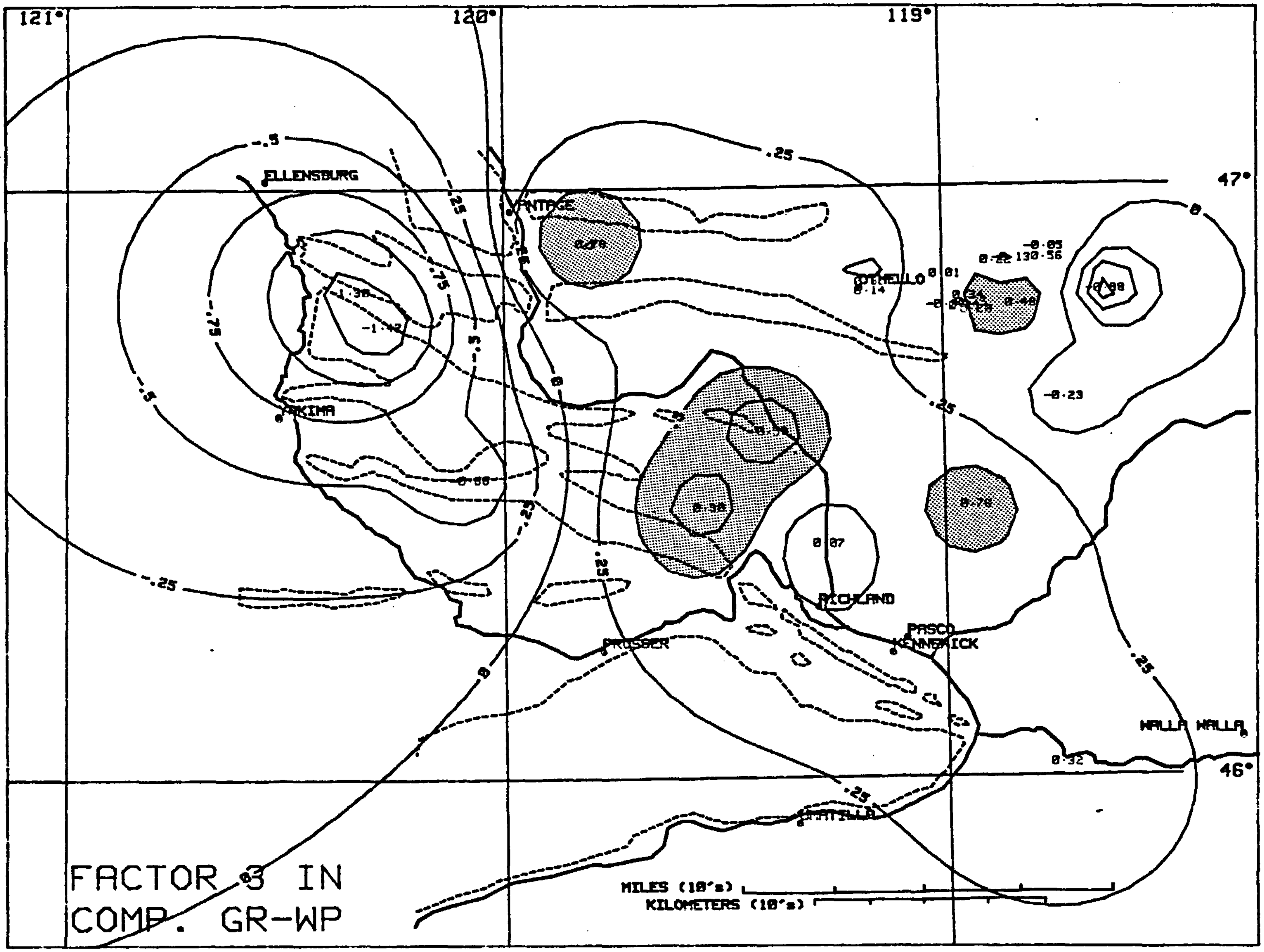
UMATILLA
FACTOR 3 IN
WANAPUM
MILES (10's)
KILOMETERS (10's)

Figure 22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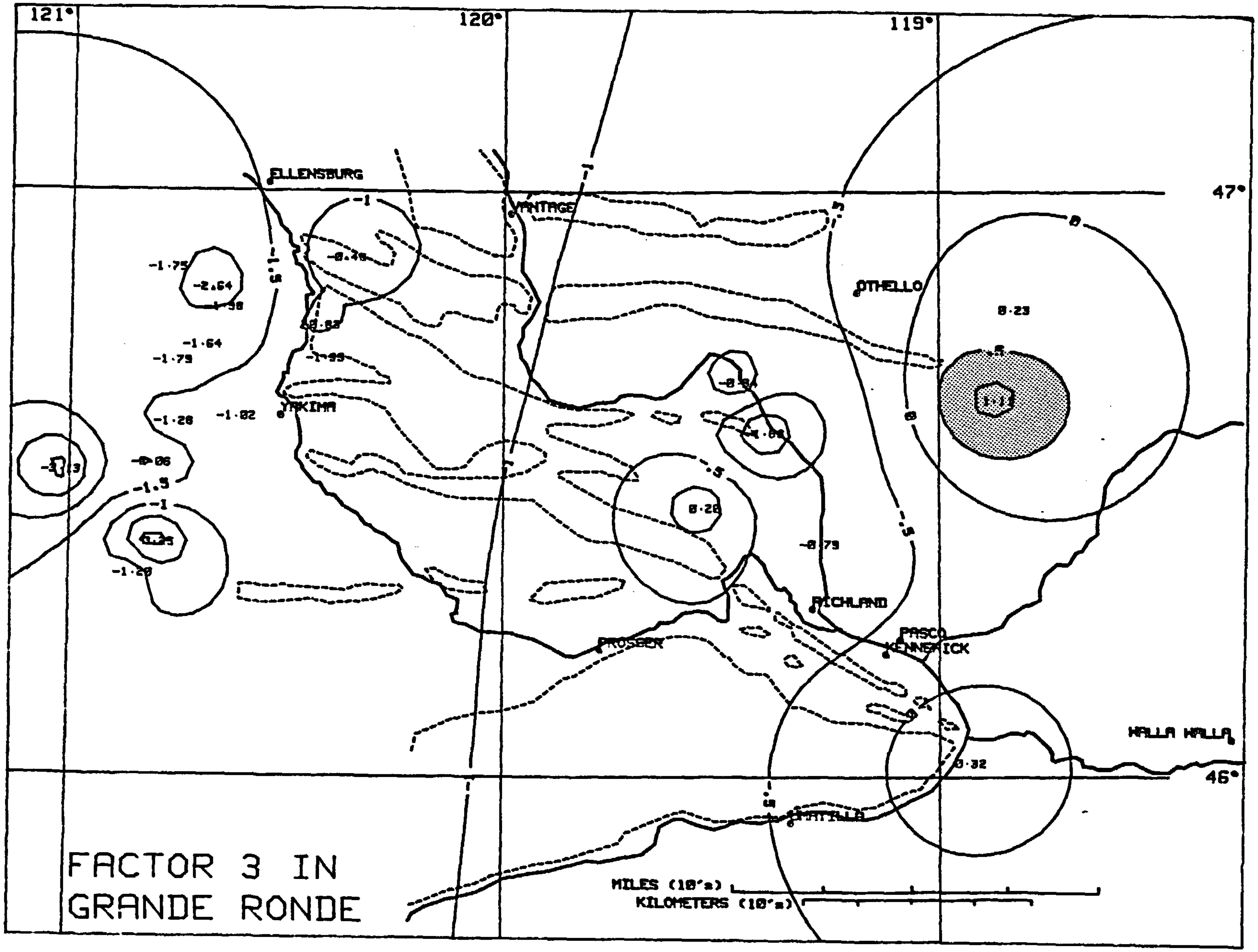
UMATILLA
MILES (10's)
KILOMETERS (10's)
FACTOR 3 IN
COMP. GR-WP

Figure 23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WALLA WALLA
UMATILLA
-1.75
-2.64
-1.38
-1.64
-1.79
-1.28
-1.02
-0.45
-0.06
-1.5
-1
-1.29
-0.79
0.23
0.28
0.32
MILES (10's)
KILOMETERS (10's)
FACTOR 3 IN
GRANDE RONDE

Figure 24

Piper Trilinear Diagrams

All the available water chemistry data with charge balance errors less than 5% were plotted on Piper trilinear diagrams. The data were plotted as two separate sets. Since the USGS data was all taken outside the Pasco Basin and the RHO data predominantly inside the Piper Basin, the RHO data and the USGS data are plotted separately by layer. In this fashion, if trends within the Pasco Basin are distinct from those outside the Basin, it should show up. Figures 25 through 30 represent the RHO data and figures 31 through 36 represent the USGS data.

Figures 25 and 26 in the composite Alluvium/Saddle Mountains and the Saddle Mountains (layers 2 and 3) in the Pasco Basin show a gradual change from a cation bicarbonate type to a sodium bicarbonate type. In layer 4, the change is more pronounced to the sodium bicarbonate type with a noticeable trend becoming apparent toward the sodium chloride position. In Layer 5 (Wanapum), this trend towards the sodium chloride type is more defined. There are no RHO samples in layer 6 which had charge balance errors less than 5%. (See Table RD-1 in Raw Data Appendix) This leaves a gap in the record. In Layer 7, the trend has continued to predominantly a sodium chloride water type. Outside the Pasco Basin, the trend in the upper layers (Figures 31 through 33) is toward the sodium bicarbonate type from a cation bicarbonate type. No trends toward a sodium chloride type are observed outside the Pasco Basin, even in the Grande Ronde units.

A comparison of factor plots with Piper plots indicates that the potential for mixing exists in the Pasco Basin with either the recharge water moving in laterally (Factor 2) or the Factor 3 water. The Piper plots show a distinct mixing trend is occurring.

HANFORD NUCLEAR RESERVATION

ROCKWELL DATA ONLY

MAJOR UNIT:
2 COMPOSITE SM-ALL

C.B.E. < 5%

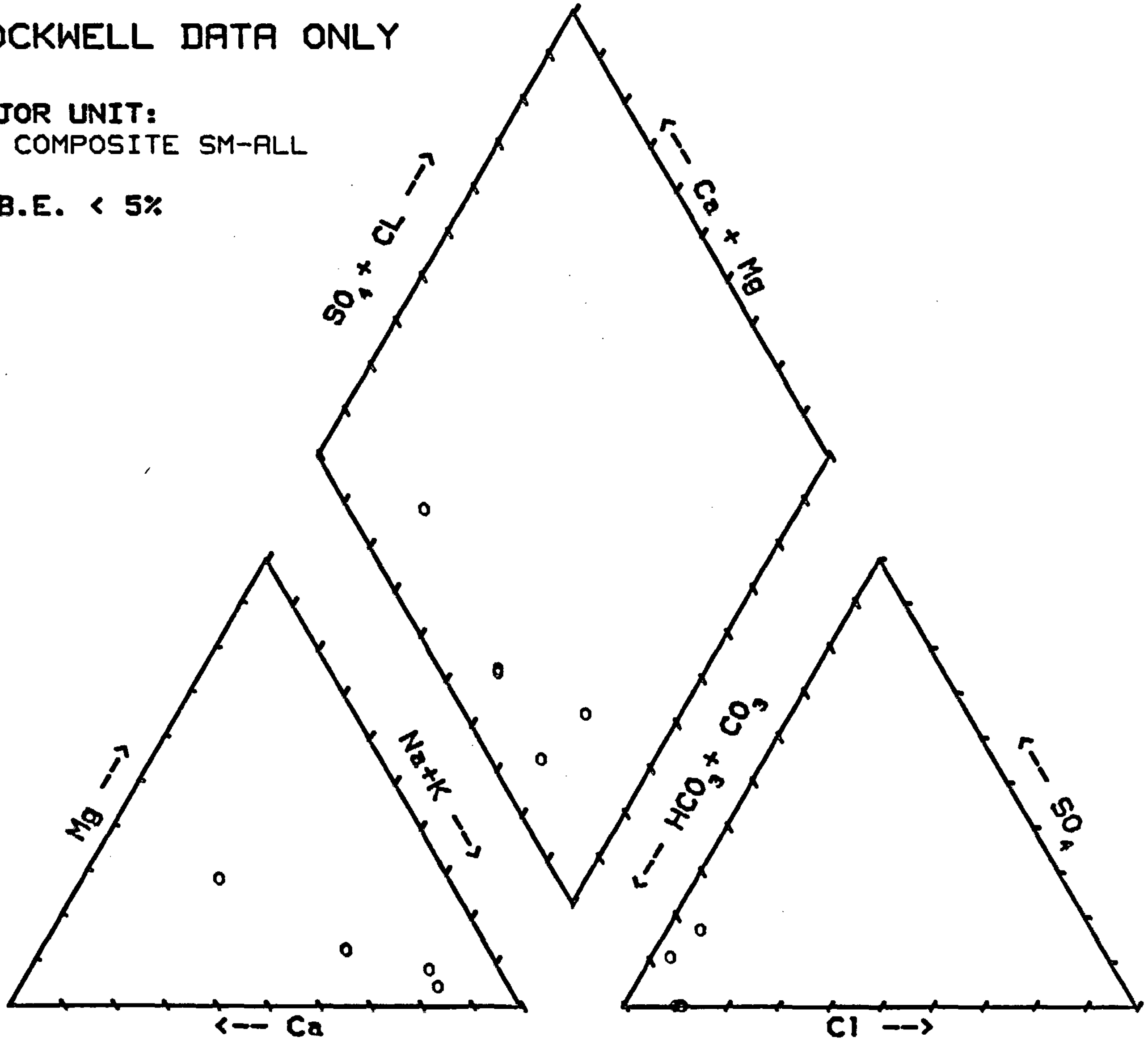

Figure 25

HANFORD NUCLEAR RESERVATION

ROCKWELL DATA ONLY

MAJOR UNIT:
3 SADDLE MOUNTAINS

C.B.E. < 5%

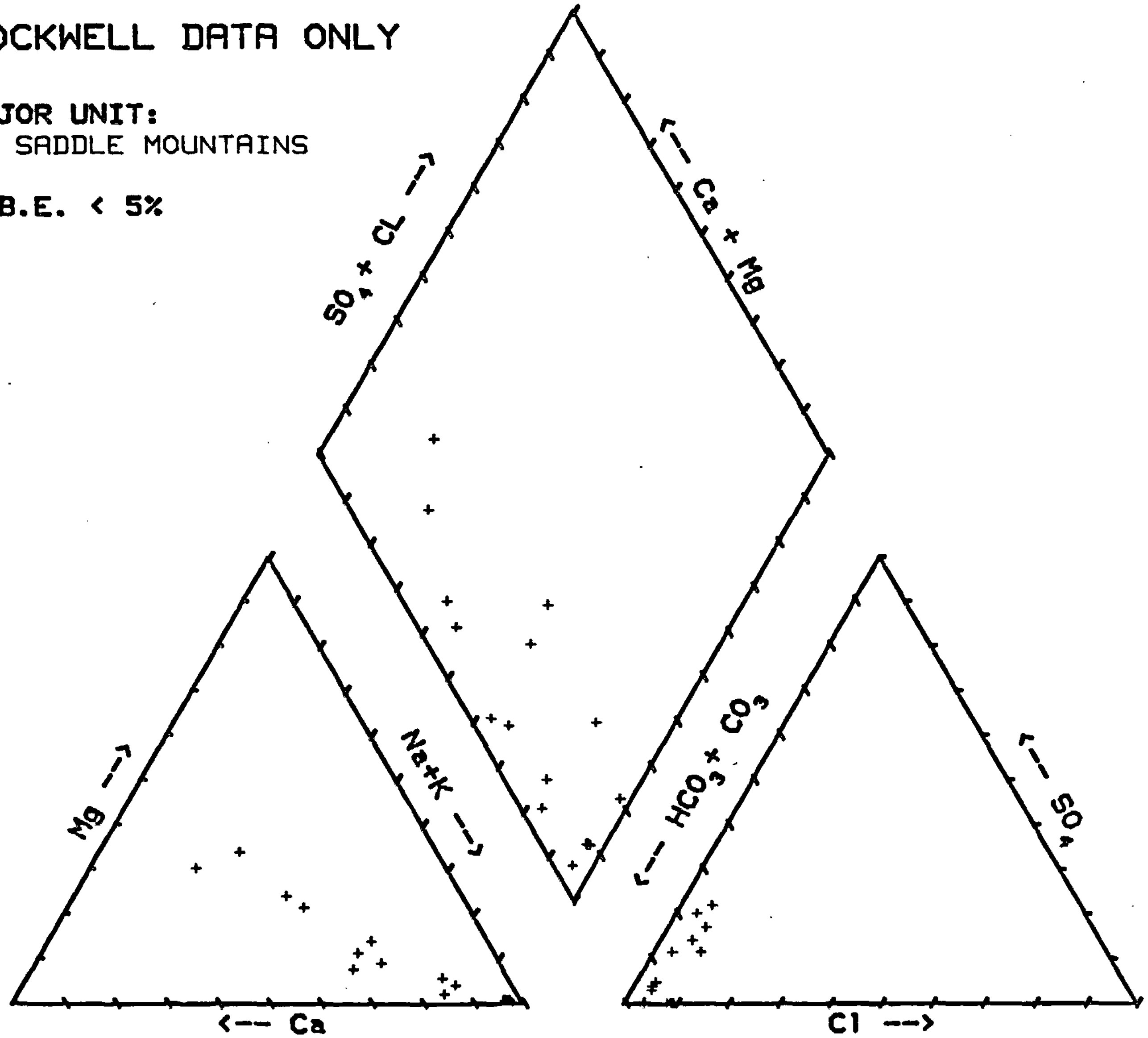

Figure 26

HANFORD NUCLEAR RESERVATION
ROCKWELL DATA ONLY

MAJOR UNIT:
4 COMPOSITE WP-SM

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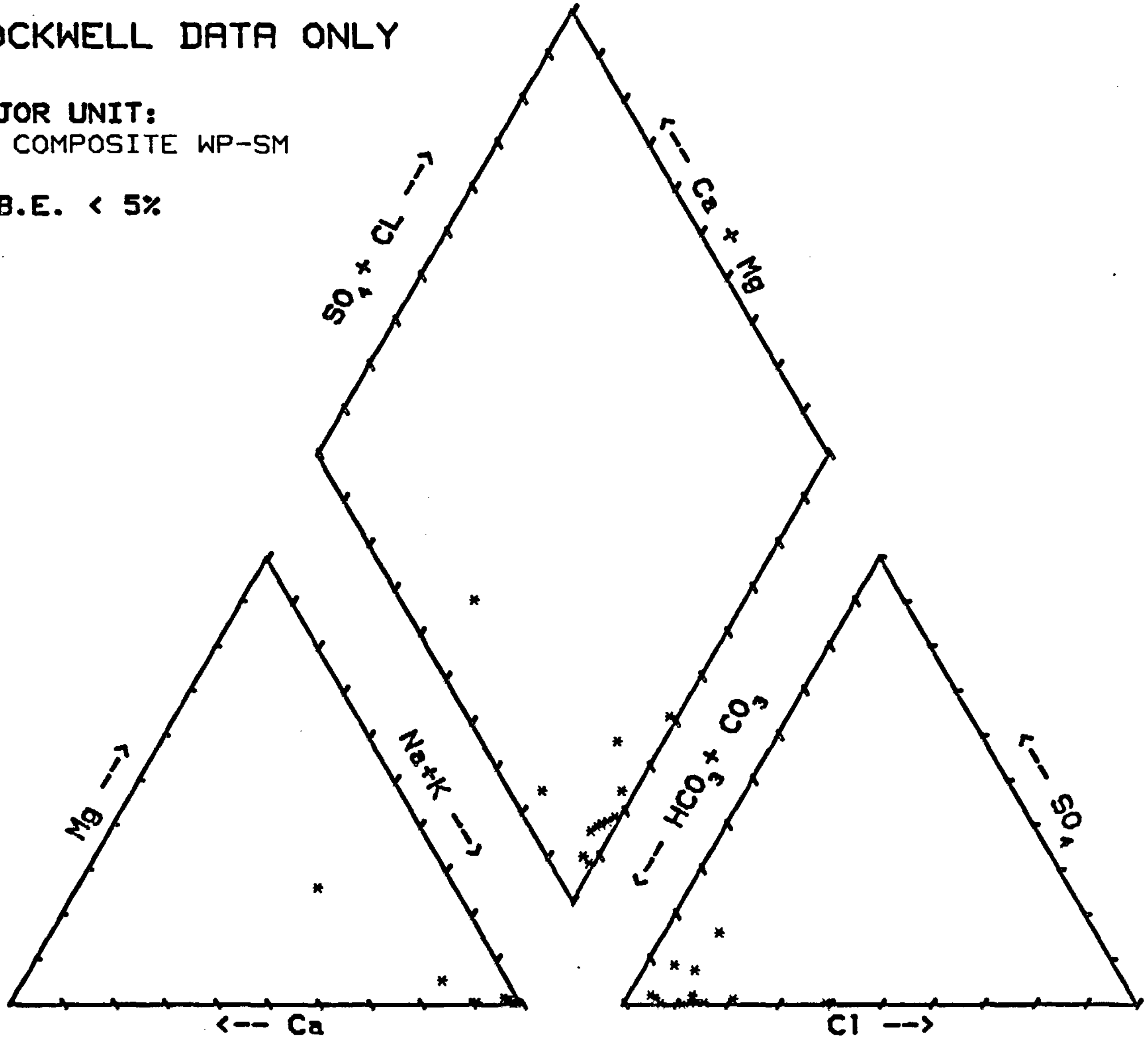

Figure 27

HANFORD NUCLEAR RESERVATION

ROCKWELL DATA ONLY

MAJOR UNIT:
5 WANAPUM

C.B.E. < 5%

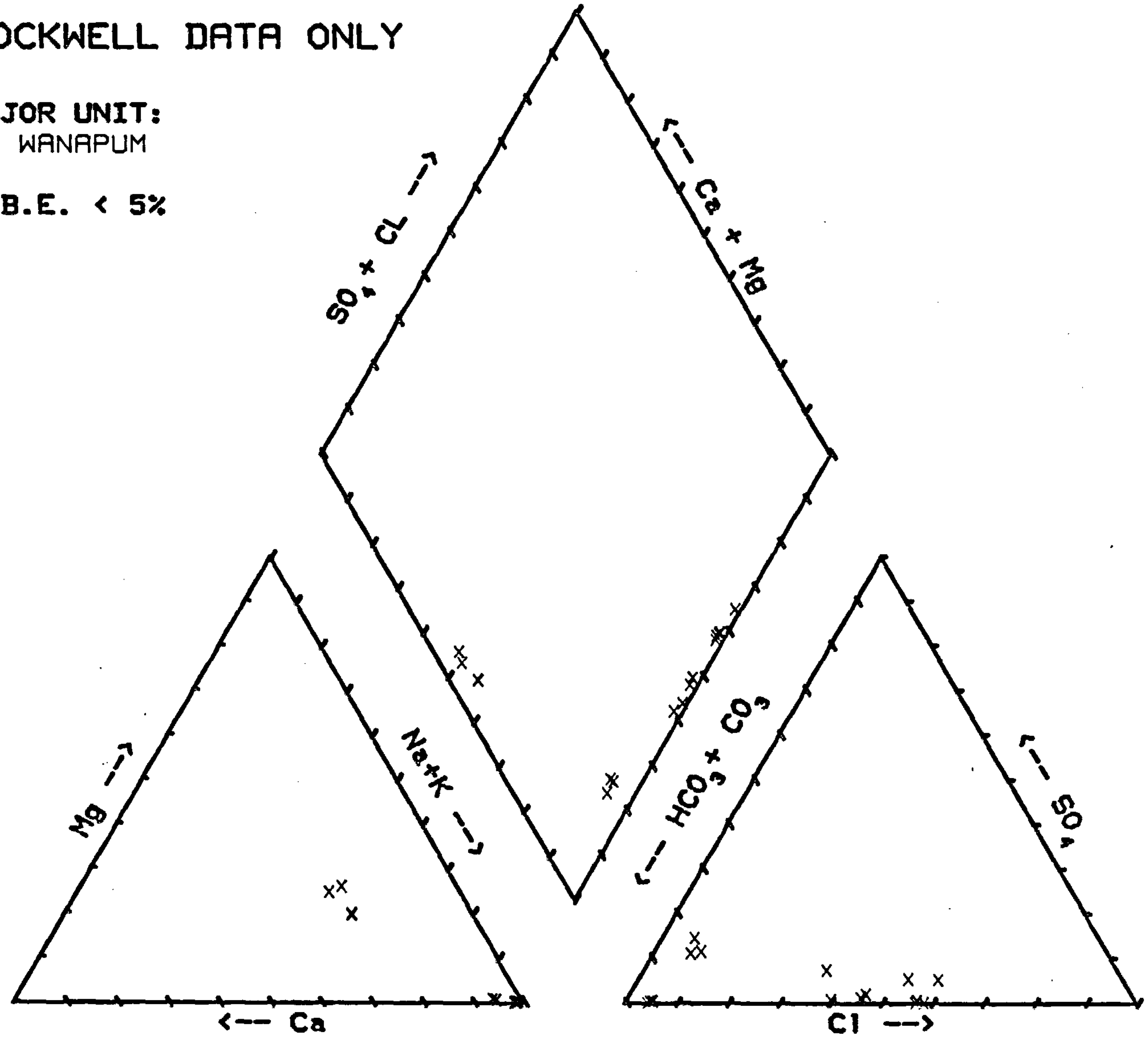

Figure 28

HANFORD NUCLEAR RESERVATION

ROCKWELL DATA ONLY

MAJOR UNIT:
6 COMPOSITE GR-WP

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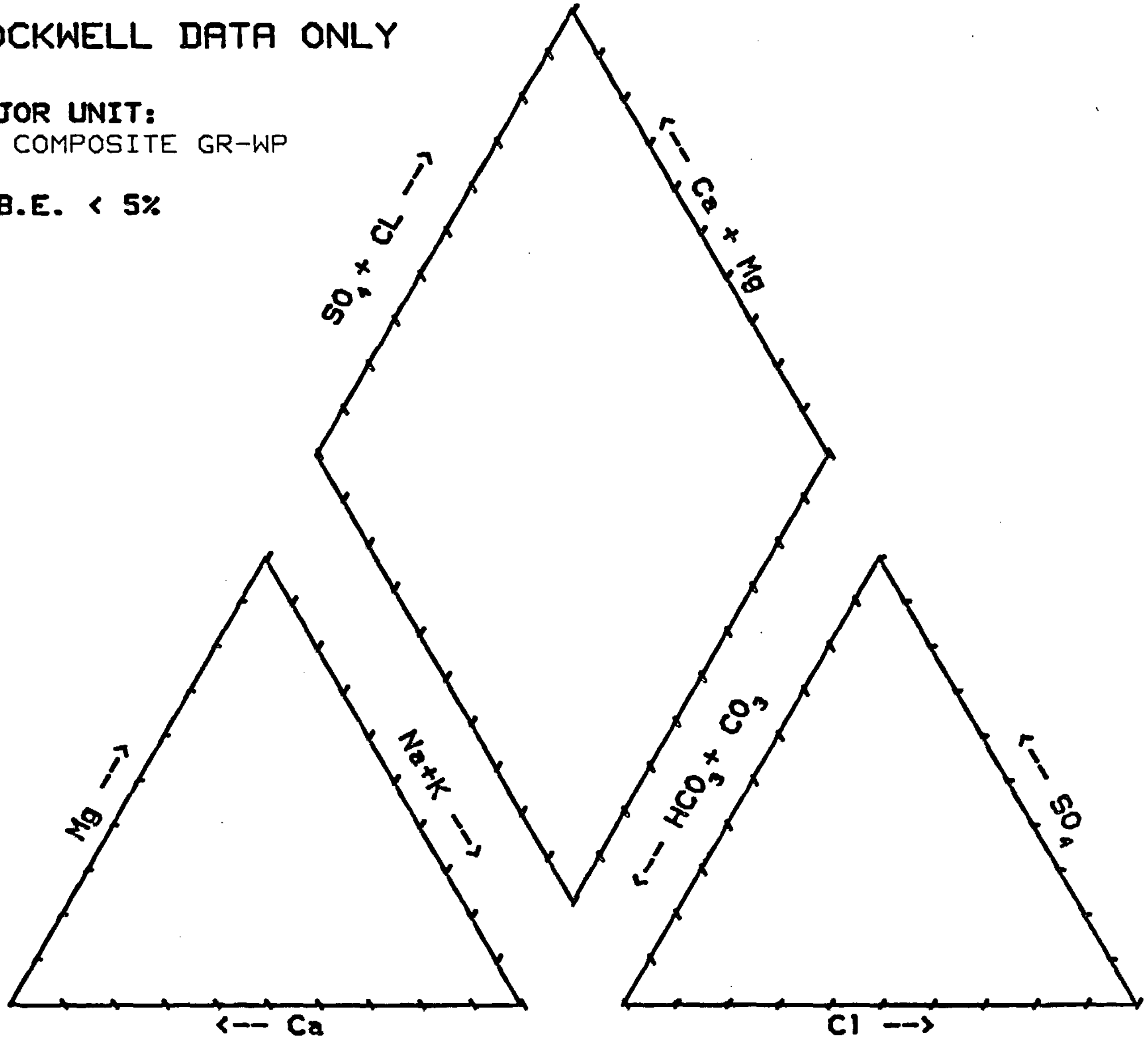

Figure 29

HANFORD NUCLEAR RESERVATION
ROCKWELL DATA ONLY

MAJOR UNIT:
7 GRANDE RONDE

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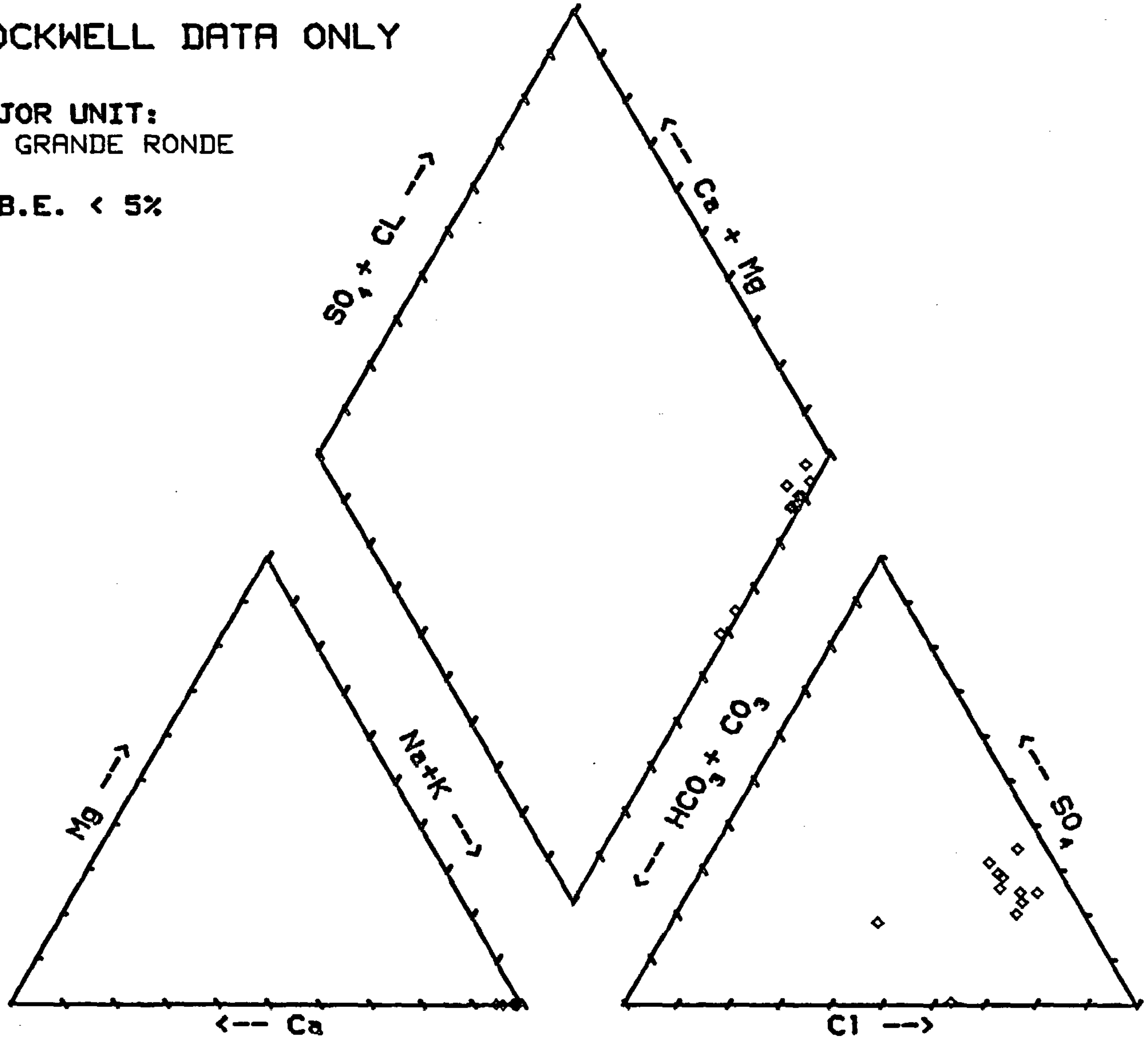

Figure 30

HANFORD NUCLEAR RESERVATION

USGS DATA ONLY

MAJOR UNIT:
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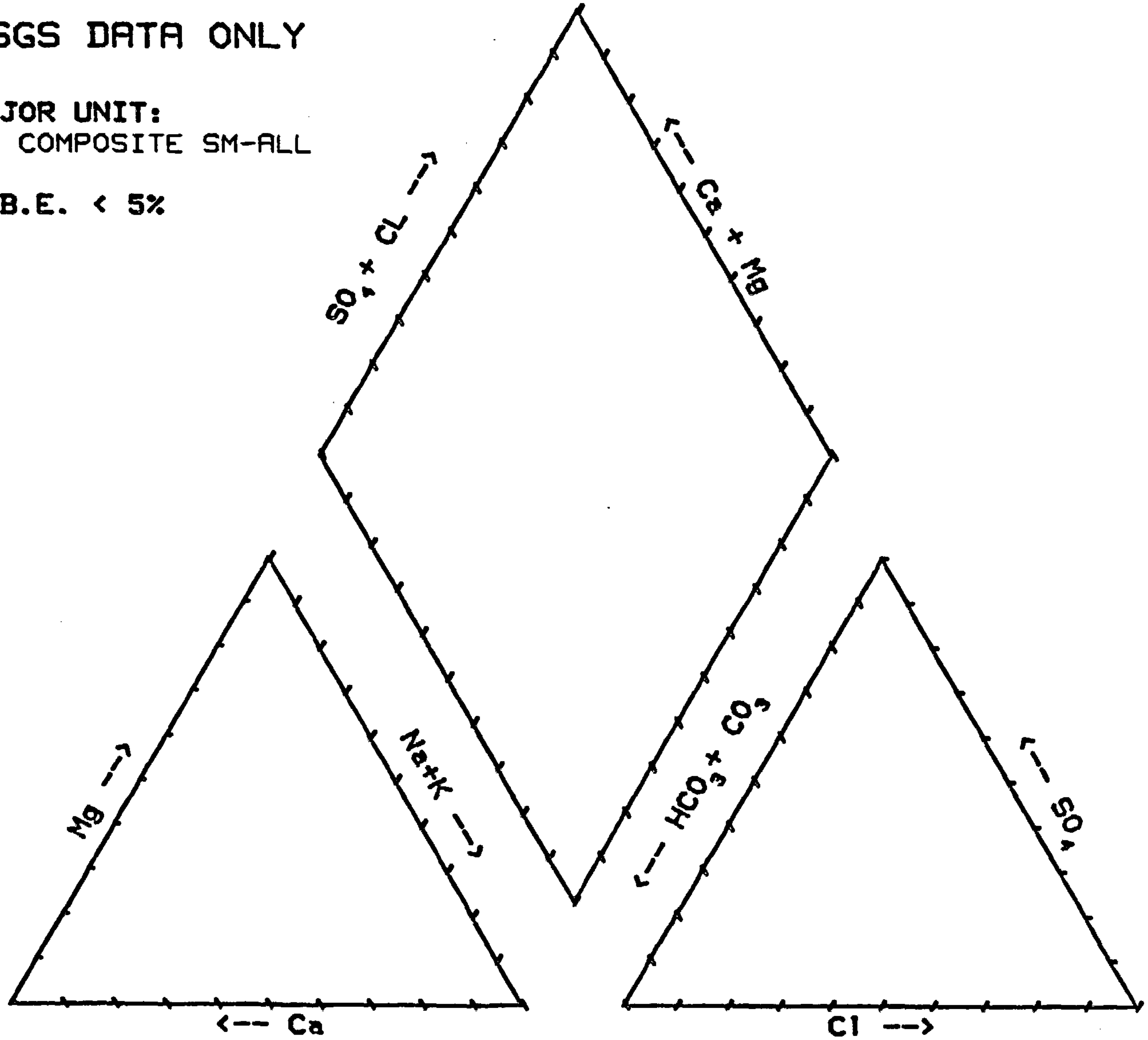

Figure 31

HANFORD NUCLEAR RESERVATION

USGS DATA ONLY

MAJOR UNIT:
3 SADDLE MOUNTAINS

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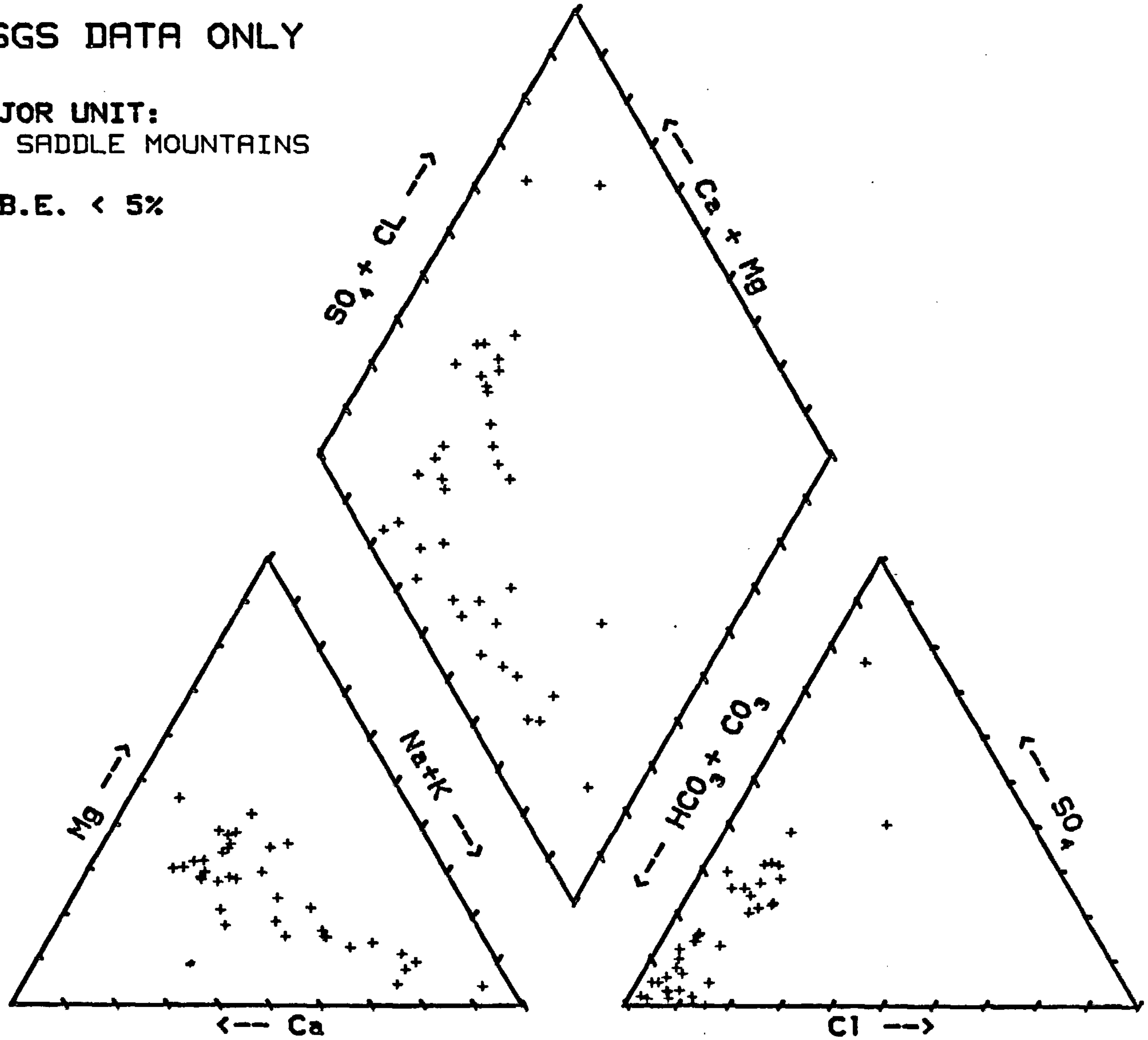

Figure 32

HANFORD NUCLEAR RESERVATION
USGS DATA ONLY

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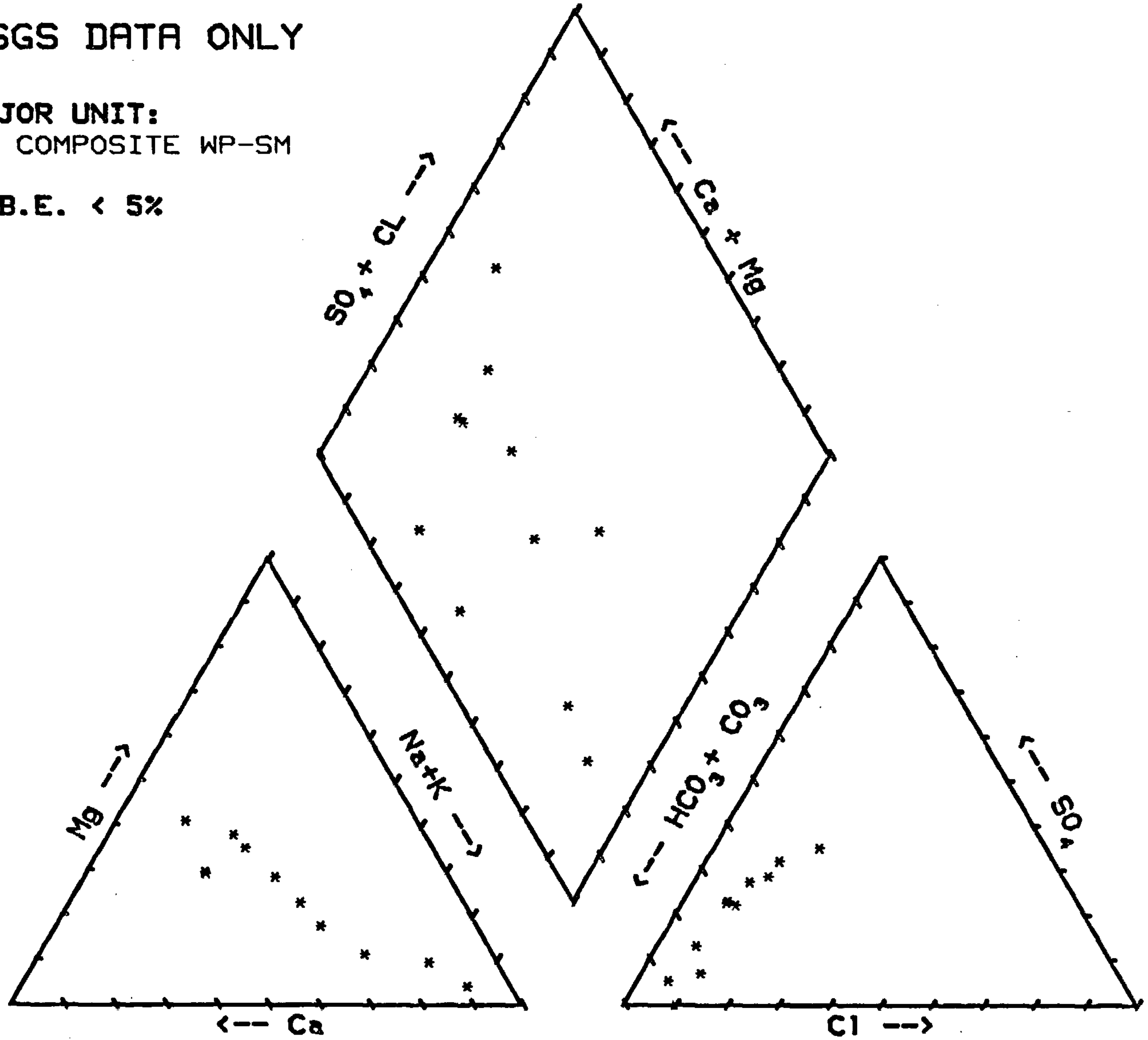

Figure 33

HANFORD NUCLEAR RESERVATION

USGS DATA ONLY

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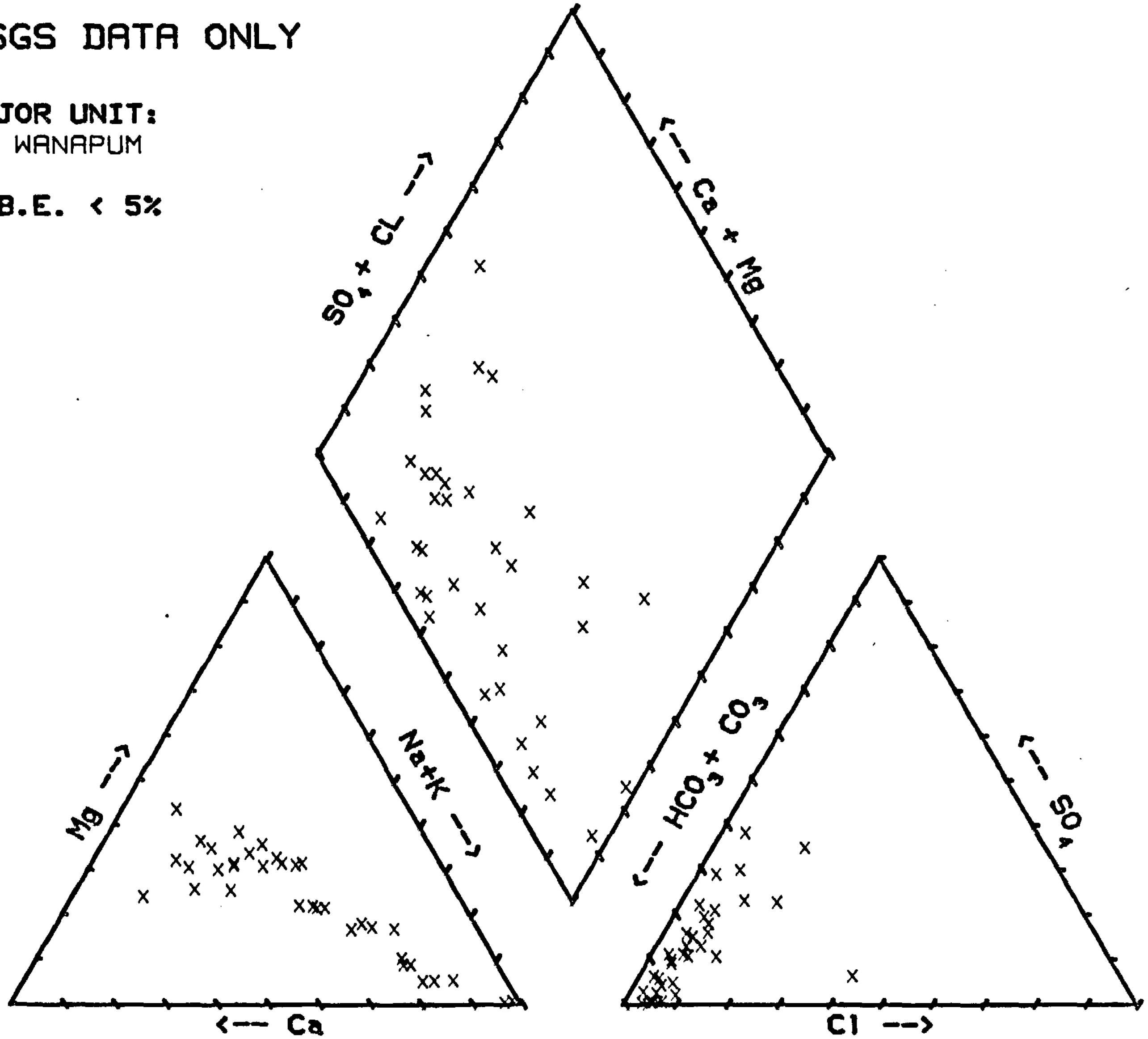

Figure 34

HANFORD NUCLEAR RESERVATION

USGS DATA ONLY

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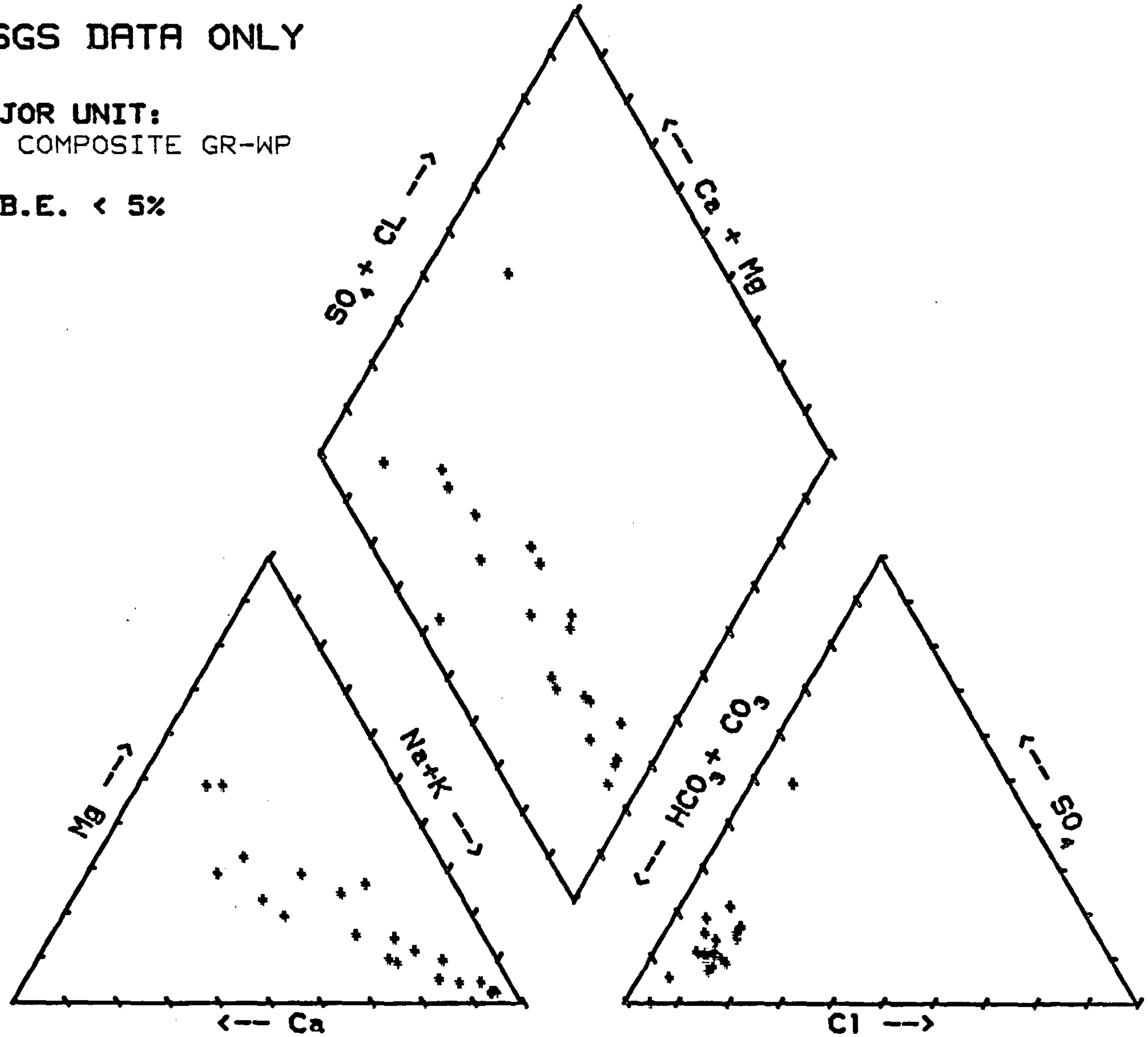

Figure 35

HANFORD NUCLEAR RESERVATION
USGS DATA ONLY

MAJOR UNIT:
7 GRANDE RONDE

C.B.E. < 5%

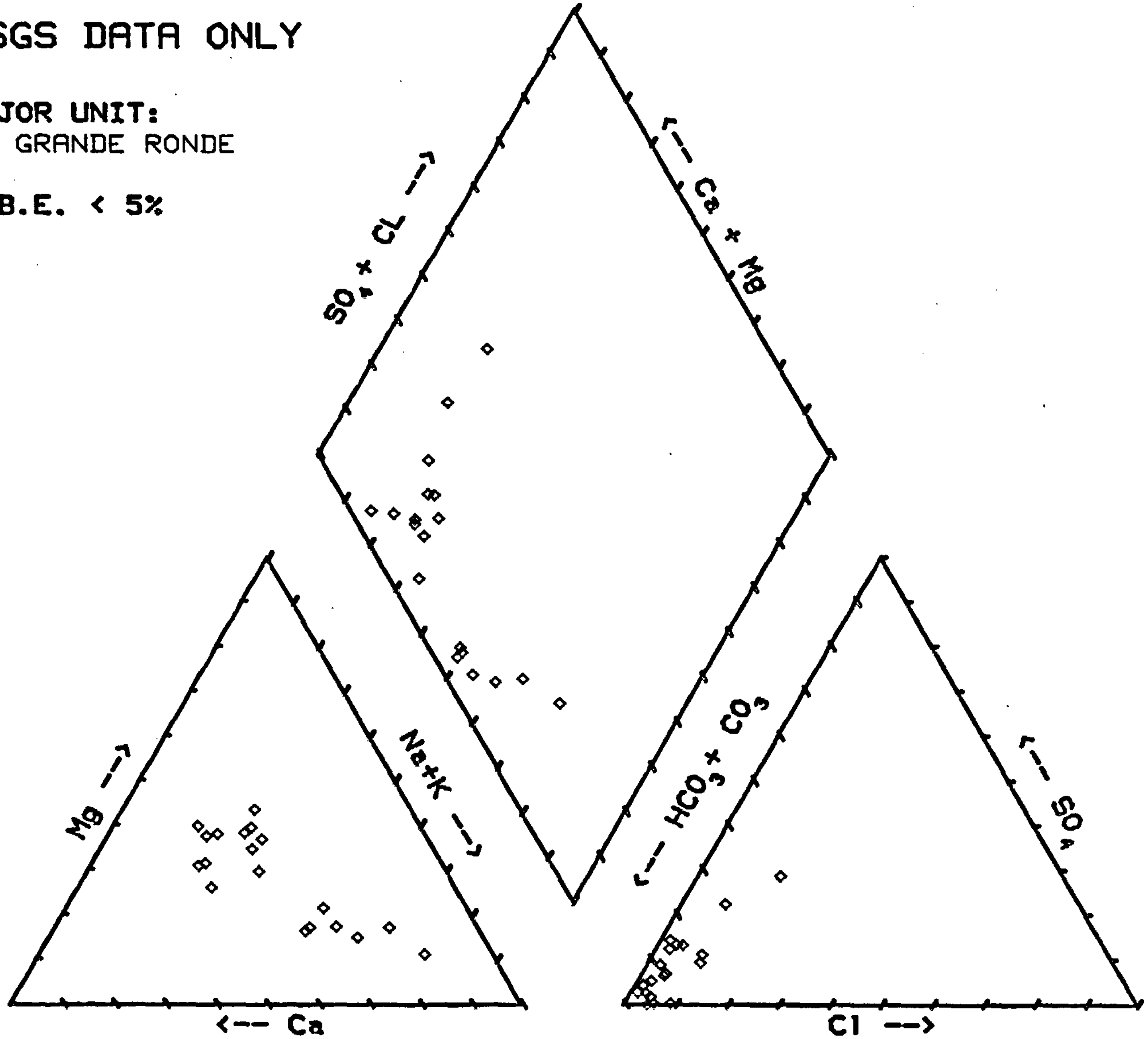

Figure 36

Conclusions

The hydrochemistry analysis indicates a significant amount of upward movement of Factor 1 water is occurring within the Pasco Basin. Actual rates of mixing and velocities, however, can not be established, but are supported by Piper plots.

The flow system as depicted through these analyses is not a simple stratified system as the origin of the Factor 1 water is not currently known. However, there is evidence this water comes from a sedimentary sequence underlying the miocene basalts.

The RHO flow path, as offered in the EA, is not supported by our geochemical interpretive model. In order for the flow path to be believable, it must be supported by all relevant data, including geochemistry.

These problems must be resolved in the final EA and a more open and cooperative effort between all affected parties must be instituted to resolve the actual flow paths.

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RAW DATA APPENDIX

INPUT DECK TO FACTOR ANALYSIS

```
/JOB
LLL(T20)
USER(ZYI6001,,CA)
RFL(57000)
SPSS.
RETAIN,OUTPUT=RUN.
RETAIN,BCDOUT=BCDOUT.
EXIT.
RETAIN,OUTPUT=BUST.
/EOR
RUN NAME        FACTOR ANALYSIS:  WATER CHEMISTRY, HANFORD NUCLEAR RESERVATI
FILE NAME       FINAL1 - WITHOUT SILICA OR NITROGEN
VARIABLE LIST   DATUM,PH,TEMP,CA,MG,NA,K,CL,HCO3,CO3,SO4,F,SIO2,SOLIDS,NITRG
INPUT MEDIUM    CARD
INPUT FORMAT    FIXED (T20,5F10.0/T20,5F10.0/T20,5F10.0)
N OF CASES      218
VAR LABELS      DATUM  -FEET ABOVE DATUM - NGVD/
                PH     -PH IN PH UNITS/
                TEMP   -DEGREES CENTIGRADE/
                CA     -CALCIUM  IN MG PER LITER/
                MG     -MAGNESIUM IN MG PER LITER/
                NA     -SODIUM IN MG PER LITER/
                K      -POTASSIUM IN MG PER LITER/
                CL     -CHLORIDE IN MG PER LITER/
                HCO3   -BICARBONATE IN MG PER LITER/
                CO3    -CARBONATE IN MG PER LITER/
                SO4    -SULFATE IN MG PER LITER/
                F      -FLUORIDE IN MG PER LITER/
                SIO2   -SILICA AS SIO2 IN MG PER LITER/
                SOLIDS -DISSOLVED SOLIDS MG PER LITER/
                NITRGN -NO2 AND NO3 MG PER LITER
MISSING VALUES  DATUM TO NITRGN (999)
COMMENT         COMPLETE DATA SET AS OF 12-10-84/
FACTOR          VARIABLES=DATUM TO F,SOLIDS/
                FACSCORE/
                TYPE=PA1/
                MINEIGEN=1.0/
                ROTATE=VARIMAX/
OPTIONS         2,11
STATISTICS      1,2,4,5,6,7,8
```

IDENTIFIER IDENTIFIER IDENTIFIER	FT ABOVE DATUM NA SULFATE	pH K F	TEMP C CL SILICA	CA HCO3 SOLIDS	MG CO3 NITRGN
**************	*******	******	******	******	******
15/29E-04A02	-157	9.2	26.3	5.3	2.5
15/29E-04A02	89	8.4	16	162	19
15/29E-04A02	32	4.5	85	361	16
15/30E-12L01	-128	8.7	18.4	13	12
15/30E-12L01	44	6.7	16	137	6
15/30E-12L01	29	1.2	55	255	16
15/31E-05L01	-70	8	19.3	19	12
15/31E-05L01	43	9.9	19	166	0
15/31E-05L01	32	0.65	48	264	19
15/31E-08J01D1	65	7.8	22.7	14	6.9
15/31E-08J01D1	54	13	11	168	0
15/31E-08J01D1	42	1.7	60	286	11
15/31E-08N01	190	8.8	23.6	8.7	4.6
15/31E-08N01	67	10	11	165	9
15/31E-08N01	27	2.5	65	297	11
15/31E-16D01	-140	9.1	28.7	3.7	1.1
15/31E-16D01	78	8.6	11	164	8
15/31E-16D01	21	2.8	83	306	11
15/31E-31R01	811	7.6	15.2	74	43
15/31E-31R01	18	4.2	48	214	0
15/31E-31R01	127	0.4	45	464	48
15/32E-07J01	-590	8.4	25.5	9.4	4.9
15/32E-07J01	57	7.1	9.5	168	2
15/32E-07J01	16	1.8	66	257	9.5
15/32E-08E01	-671	8.6	26	10	4.6
15/32E-08E01	50	8.6	8.8	164	0
15/32E-08E01	17	1.7	66	247	8.8
15/33E-02A01	665	8.5	17.9	31	12
15/33E-02A01	18	4	14	154	1.5
15/33E-02A01	16	0.4	46	219	14
15/33E-02A01D1	295	8.6	17	27	9.6
15/33E-02A01D1	27	4.8	15	147	4
15/33E-02A01D1	16	0.9	56	237	15
15/33E-15N02	940	7.9	16.8	72	24
15/33E-15N02	15	4	47	157	0
15/33E-15N02	27	0.23	41	307	47
15/35E-02D01	1368	8.1	14.8	17	12
15/35E-02D01	26	7.1	8	177	0
15/35E-02D01	7.6	0.4	43	205	8
16/28E-04B01	841	7.6	15.3	63	39
16/28E-04B01	32	11.5	74	340	0
16/28E-04B01	74	0.33	53	457	74
16/28E-05N01	710	7.9	15.8	48	33
16/28E-05N01	47	10.1	105	254	0
16/28E-05N01	105	0.65	55	445	105
16/29E-34D01	40	8.4	24.7	1.7	0.5
16/29E-34D01	79	12	26	192	1.5
16/29E-34D01	26	2.6	63	295	26
16/30E-26A02D1	315	9	27	3.6	1
16/30E-26A02D1	73	9.2	17	161	9
16/30E-26A02D1	17	2.2	88	302	17

IDENTIFIER IDENTIFIER IDENTIFIER	FT ABOVE DATUM NA SULFATE	pH K F	TEMP C CL SILICA	CA HCO3 SOLIDS	MG CO3 NITRGN
**************	*******	******	******	******	******
16/31E-14K01	75	8.6	25.8	6.9	1.8
16/31E-14K01	61	9.4	14	168	3
16/31E-14K01	14	1.7	72	263	14
16/31E-33P01	760	7.8	18.2	22	12
16/31E-33P01	32	9.1	25	176	0
16/31E-33P01	24	0.53	59	257	25
16/32E-11D01D1	75	8.2	23.1	13	3.5
16/32E-11D01D1	48	8.3	11	159	0
16/32E-11D01D1	14	1.5	67	242	11
16/32E-14D01	68	8.3	24.4	17	4.8
16/32E-14D01	57	11	18	178	0
16/32E-14D01	31	1.5	66	294	18
16/32E-18G01D2	40	9.3	26.2	2.9	1.1
16/32E-18G01D2	78	7.3	12	162	14.8
16/32E-18G01D2	13	3.3	91	317	12
16/33E-17B02	1055	7.9	17.3	23	13
16/33E-17B02	20	3.5	2.9	170	0
16/33E-17B02	9.1	0.43	47	203	2.9
16/34E-13R02	1295	8	17.1	25	9.3
16/34E-13R02	9.4	3.4	2.2	145	0
16/34E-13R02	3.6	0.2	49	173	2.2
05/25E-22M01	64	8.1	18.6	16	5.9
05/25E-22M01	82	8.5	17	199	0
05/25E-22M01	65	1.1	55	349	17
06/24E-23N01	383	7.6	18.2	42	15
06/24E-23N01	20	4.6	27	159	0
06/24E-23N01	48	0.3	58	294	27
06/26E-19K01	305	7.6	18.2	92	51
06/26E-19K01	91	9.2	120	163	0
06/26E-19K01	190	0.4	56	690	120
07/26E-04E01	835	8	15	32	13
07/26E-04E01	38	5.7	20	167	0
07/26E-04E01	42	0.5	54	285	20
07/26E-05B02D1	65	8	21.8	31	11
07/26E-05B02D1	51	17	19	211	0
07/26E-05B02D1	55	0.3	69	358	19
08/24E-01J01	-526	8.5	21.7	9.2	2.9
08/24E-01J01	77	15	10	244	3.7
08/24E-01J01	1.2	1.1	62	311	10
08/24E-15F01	790	7.7	20.3	47	18
08/24E-15F01	15	4.3	6	207	0
08/24E-15F01	49	0.33	52	293	6
08/27E-01A01D1	510	7.8	16.9	60	22
08/27E-01A01D1	23	3.5	22	186	0
08/27E-01A01D1	81	0.47	49	351	22
08/27E-01J01	210	7.9	18.8	41	17
08/27E-01J01	22	9.2	7	163	0
08/27E-01J01	87	0.5	61	325	7
08/28E-07P01	275	8.1	20.4	19	12
08/28E-07P01	81	16	15	230	0
08/28E-07P01	88	1.3	71	417	15

IDENTIFIER IDENTIFIER IDENTIFIER	FT ABOVE DATUM NA SULFATE	pH K F	TEMP C CL SILICA	CA HCO3 SOLIDS	MG CO3 NITRGN
***************	*******	******	******	******	******
08/29E-17G01D1	335	7.6	19.1	44	18
08/29E-17G01D1	32	7.8	29	210	0
08/29E-17G01D1	57	0.4	57	349	29
09/25E-33B01	-55	8.4	20.7	12	4.7
09/25E-33B01	48	12	5.6	193	1.3
09/25E-33B01	11	0.57	57	248	5.6
09/26E-12N01	460	7.5	15.7	71	30
09/26E-12N01	36	3.9	11	384	0
09/26E-12N01	46	0.73	46	434	11
09/27E-16M01	-125	8	22.6	14	4.9
09/27E-16M01	56	14	4.4	168	0
09/27E-16M01	57	0.7	61	295	4.4
09/28E-17A01	-535	8.1	26.4	14	6.1
09/28E-17A01	86	13	12	259	0
09/28E-17A01	34	1.6	73	366	12
09/29E-33M01	218	7.5	17.4	52	31
09/29E-33M01	32	7.5	27	291	0
09/29E-33M01	41	0.33	46	380	27
10/24E-31P01	741	7.9	16.3	46	16
10/24E-31P01	13	5.7	18	163	0
10/24E-31P01	50	0.33	57	287	18
10/26E-28L02	355	8.2	24.7	15	4.4
10/26E-28L02	57	19	5.6	226	0
10/26E-28L02	5	1.2	64	275	5.6
10/27E-28N01	245	7.8	18.9	28	19
10/27E-28N01	29	8.3	7	181	0
10/27E-28N01	66	0.7	59	306	7
12/24E-30B01	-185	8.1	26.3	19	12
12/24E-30B01	21	7.1	4.3	176	0
12/24E-30B01	0.2	0.55	61	212	4.3
13/24E-27M04	180	7.9	19.6	21	13
13/24E-27M04	26	5.9	5.5	199	0
13/24E-27M04	0.5	0.55	59	227	5.5
09/29E-02G02	-3	7.9	22.1	5.2	2.4
09/29E-02G02	90	12	26	262	0
09/29E-02G02	0.2	1.5	62	328	26
09/30E-02R01	304	7.9	17	47	25
09/30E-02R01	31	4.8	25	205	0
09/30E-02R01	74	0.53	41	351	25
10/30E-03Q01	410	7.9	17.4	44	36
10/30E-03Q01	35	11	39	233	0
10/30E-03Q01	68	0.57	56	404	39
10/31E-09D01	225	8	17.3	61	23
10/31E-09D01	31	6.6	31	220	0
10/31E-09D01	87	0.4	39	387	31
10/31E-32L02	190	7.8	19.1	24	19
10/31E-32L02	30	10	10	166	0
10/31E-32L02	52	0.87	58	286	10
10/32E-03R01	320	7.9	19.1	46	25
10/32E-03R01	61	9.4	74	139	0
10/32E-03R01	92	0.4	58	434	74

IDENTIFIER IDENTIFIER IDENTIFIER	FT ABOVE DATUM NA SULFATE	pH K F	TEMP C CL SILICA	CA HCO3 SOLIDS	MG CO3 NITRGN
**************	*******	******	******	******	******
10/32E-23J01	250	7.9	22.6	17	7.1
10/32E-23J01	24	6.5	7.2	120	0
10/32E-23J01	20	0.63	69	211	7.2
11/28E-36R01	99	7.7	24.4	20	7.6
11/28E-36R01	60	11	19	246	0
11/28E-36R01	4.2	0.83	69	313	19
11/29E-03A01	338	8	21.7	18	5.9
11/29E-03A01	32	6.3	6.4	146	0
11/29E-03A01	24	0.65	51	215	6.4
11/30E-12D01	215	8.3	17.2	31	8.5
11/30E-12D01	80	19	31	199	0
11/30E-12D01	94	0.33	35	397	31
11/30E-36M01	483	7.8	16.7	60	59
11/30E-36M01	26	2.1	55	249	0
11/30E-36M01	120	0.35	51	494	55
11/31E-04P01	-460	8	21.6	19	7.1
11/31E-04P01	46	11	8.4	168	0
11/31E-04P01	27	1	83	285	8.4
12/28E-23H01D1	-23	8.2	18.7	15	3.9
12/28E-23H01D1	62	9.5	19	205	0
12/28E-23H01D1	10.1	0.87	62	284	19
12/29E-34B01D1	-77	8.3	12.3	6.8	1.9
12/29E-34B01D1	72	13	14	204	0
12/29E-34B01D1	14	1.7	61	285	14
12/30E-05B01	456	7.7	17.4	69	38
12/30E-05B01	21	5.1	53	197	0
12/30E-05B01	123	0.3	56	464	53
13/28E-13N01	-158	8.4	29	0.8	0.4
13/28E-13N01	76	16	14	172	6
13/28E-13N01	20	2.4	65	290	14
13/29E-08H01	545	7.9	20.4	24	10.5
13/29E-08H01	39	7.3	11	214	0
13/29E-08H01	14	0.47	62	274	11
13/30E-31N01	655	7.7	15.7	81	40
13/30E-31N01	52	4.4	48	306	0
13/30E-31N01	140	0.47	48	564	48
13/31E-01E01	-460	7.6	20.3	53	22
13/31E-01E01	25	7.1	19	279	0
13/31E-01E01	31	0.33	54	350	19
13/32E-03C01	485	7.8	18.3	25	12
13/32E-03C01	50	5.7	10	199	0
13/32E-03C01	38	1.3	49	291	10
13/32E-07E02	418	8	14.4	26	12
13/32E-07E02	18	4.9	9.3	154	0
13/32E-07E02	20	0.53	48	216	9.3
13/33E-06M01D1	405	8.8	16.9	11.3	2.7
13/33E-06M01D1	73	6.9	8.5	182	6
13/33E-06M01D1	39	0.75	40	282	8.5
14/29E-05A01	795	8.1	17.1	39	32
14/29E-05A01	33	6	33	196	0
14/29E-05A01	79	0.6	57	375	33

IDENTIFIER IDENTIFIER IDENTIFIER ***************	FT ABOVE DATUM NA SULFATE *******	pH K F ******	TEMP C CL SILICA ******	CA HCO3 SOLIDS ******	MG CO3 NITRGN ******
14/29E-19Q01	665	7.7	21	50	28
14/29E-19Q01	42	11	30	191	0
14/29E-19Q01	107	0.53	61	422	30
14/30E-10P01	583	7.6	16	29	19
14/30E-10P01	21	4.9	8	191	0
14/30E-10P01	29	0.47	52	257	8
14/31E-19B01	795	7.8	17.4	34	21
14/31E-19B01	22	6.3	14	191	0
14/31E-19B01	51	0.47	60	302	14
14/34E-25P01D1	780	7.7	17.2	75	37
14/34E-25P01D1	41	5.8	55	295	0
14/34E-25P01D1	91	0.33	42	491	55
14/23E-13D01	-225	8.3	23.5	13	5.3
14/23E-13D01	30	9.1	2.7	142	0
14/23E-13D01	13	0.9	57	200	2.7
14/23E-26A01D1	218	8.1	20.7	18	5.5
14/23E-26A01D1	31	8.7	4.4	154	0
14/23E-26A01D1	15	0.87	51	210	4.4
14/23E-36L02	314	7.9	14.6	46	11
14/23E-36L02	9.9	4.1	10	164	0
14/23E-36L02	38	0.2	41	241	10
14/25E-02C01	235	7.8	20.1	30	11
14/25E-02C01	17	5.3	7.5	159	0
14/25E-02C01	23	0.3	62	234	7.5
15/23E-35J01	354	8.2	20.5	20	7
15/23E-35J01	12.9	5.5	3.3	113	0
15/23E-35J01	18	0.45	31	154	3.3
15/23E-35P01	-243	8.3	19.9	13	5.8
15/23E-35P01	21	7.9	1.8	126	0
15/23E-35P01	13	0.7	37.6	163	1.8
15/25E-35J01	300	7.8	18.8	27	11
15/25E-35J01	18	4.5	7.1	162	0
15/25E-35J01	23	0.3	57	227	7.1
16/23E-21J01	357	7.8	21.4	30	16
16/23E-21J01	30	6.4	8	193	0
16/23E-21J01	40	0.67	51	276	8
16/24E-04H01	419	7.5	17.4	69	59
16/24E-04H01	33	9.5	28	252	0
16/24E-04H01	230	0.53	54	607	28
16/25E-01Q01	123	7.9	19.9	37	19
16/25E-01Q01	41	10.5	20	202	0
16/25E-01Q01	71	0.57	51	349	20
16/25E-04N01	1110	7.7	14.4	96	61
16/25E-04N01	23	3.3	113	178	0
16/25E-04N01	200	0.43	37	622	113
16/27E-10N01	690	7.6	17.1	61	34
16/27E-10N01	39	9.6	34	221	0
16/27E-10N01	140	0.73	60	488	34
15/19E-22R01	190	7.9	27.3	15	7.1
15/19E-22R01	29	3.7	3.9	161	0
15/19E-22R01	0.5	0.9	71	210	3.9

IDENTIFIER	FT ABOVE DATUM	pH	TEMP C	CA	MG
IDENTIFIER	NA	K	CL	HCO3	CO3
IDENTIFIER	SULFATE	F	SILICA	SOLIDS	NITRGN
**************	*******	******	******	******	******
15/20E-23Q01	1565	7.3	12.1	29	15
15/20E-23Q01	23	4.1	13	182	0
15/20E-23Q01	20	0.57	48	241	13
16/20E-07Q01	1567	7.7	18.3	23	20
16/20E-07Q01	17	9.3	4.3	195	0
16/20E-07Q01	25	0.35	57	251	4.3
16/20E-32N01	1450	7.5	13.6	32	25
16/20E-32N01	12	2.2	8.5	221	0
16/20E-32N01	11	0.27	53	253	8.5
05/22E-27P02D1	298	8.2	24.3	13	4.1
05/22E-27P02D1	56	16	6.2	213	0
05/22E-27P02D1	18	0.7	59	277	6.2
05/23E-30D01	57	8	23.4	15	7.6
05/23E-30D01	45	13	6.8	213	0
05/23E-30D01	7.5	0.63	58	259	6.8
06/31E-04P01	254	7.5	18.1	71	28
06/31E-04P01	32	7.1	39	233	0
06/31E-04P01	96	0.4	43	429	39
06/32E-01R01D1	-685	8.1	21.5	24	7.6
06/32E-01R01D1	28	7.9	8.7	159	0
06/32E-01R01D1	18	0.55	76	248	8.7
06N/34E-07R01	-1140	9	40.7	14.1	3.2
06N/34E-07R01	86	9.9	72	133	15
06N/34E-07R01	16	2.4	99	397	72
08/30E-02R01	72	8.5	17.9	9.7	2.7
08/30E-02R01	74	11	27	303	1.7
08/30E-02R01	5.3	2.7	62	346	27
08/31E-21R01	245	8	22.2	96	61
08/31E-21R01	69	9.7	41	118	0
08/31E-21R01	490	0.7	61	888	41
09/31E-34P01	257	8	15.7	79	38
09/31E-34P01	38	8.4	100	159	0
09/31E-34P01	88	0.43	49	478	100
09/32E-20F01	425	7.8	18.7	46	29
09/32E-20F01	17	4.1	34	171	0
09/32E-20F01	38	0.55	59	311	34
08/22E-01G03	-282	7.8	15.3	68	26
08/22E-01G03	36	3.8	20	280	0
08/22E-01G03	73	0.53	50	415	20
08/23E-11M01D1	580	7.7	15.7	40	14
08/23E-11M01D1	19	4.9	3.7	227	0
08/23E-11M01D1	10	0.37	64	267	3.7
09/21E-25J03	393	7.9	17	47	19
09/21E-25J03	19	5.6	21	157	0
09/21E-25J03	71	0.3	51	310	21
09/22E-12P01	375	7.8	20.8	22	5.3
09/22E-12P01	24	11	6.7	171	0
09/22E-12P01	5	0.4	64	999	6.7
09/23E-31F01	297	8	19.1	24	7.1
09/23E-31F01	25	8.8	7.5	179	0
09/23E-31F01	5	0.4	64	999	7.5

IDENTIFIER IDENTIFIER IDENTIFIER **************	FT ABOVE DATUM NA SULFATE *******	pH K F ******	TEMP C CL SILICA ******	CA HCO3 SOLIDS ******	MG CO3 NITRGN ******
10/16E-20E01D1	1065	7.3	15.5	25	14
10/16E-20E01D1	8.6	4.3	1.1	172	0
10/16E-20E01D1	3.9	0.17	60	199	1.1
10/17E-04F01	827	7.1	13.7	15	8.9
10/17E-04F01	7.4	3.2	1.4	120	0
10/17E-04F01	1.7	0.2	54	145	1.4
10/18E-31N01	100	7.8	23.2	21	14
10/18E-31N01	31	6	3.4	220	0
10/18E-31N01	0.3	0.75	77	264	3.4
10/21E-03H01	150	7.9	22.9	39	8.6
10/21E-03H01	26	7.6	4.9	235	0
10/21E-03H01	2.7	0.3	44	248	4.9
10/22E-25F02	-415	7.6	21.1	32	9.9
10/22E-25F02	13	6.6	6.3	160	0
10/22E-25F02	20	0.33	70	236	6.3
10/22E-31F01	340	8.4	21.6	13	1.7
10/22E-31F01	43	12	14	164	0
10/22E-31F01	0.4	0.57	63	229	14
10/23E-08H01	953	7.8	16.8	20	5.4
10/23E-08H01	13	2.4	2.5	117	0
10/23E-08H01	5.4	0.47	47	158	2.5
11/16E-34K02	733	6.7	23.5	33	23
11/16E-34K02	32	6.9	2.7	265	0
11/16E-34K02	36	0.4	79	349	2.7
11/17E-02P01	180	7.9	26	19	8.3
11/17E-02P01	28	5.1	8.6	150	0
11/17E-02P01	0.2	0.75	42	141	8.6
11/21E-07F01	-430	8.9	27.6	1.8	0.1
11/21E-07F01	69	4.8	8.1	171.7	3.3
11/21E-07F01	3.3	1.5	57	235	8.1
11/21E-22G02	-540	8.4	27.8	8.5	1.6
11/21E-22G02	41	8.7	5.1	150	0
11/21E-22G02	0.4	0.7	53	192	5.1
11/21E-26F01	245	8.1	25.4	15	4.4
11/21E-26F01	33	8.8	8.7	161	0
11/21E-26F01	5	0.6	56	999	8.7
11/22E-19N01	407	7.8	20.3	26	10
11/22E-19N01	12	4.8	5.5	127	0
11/22E-19N01	20	0.47	57	199	5.5
12/14E-24L01	3110	7.9	10.4	13	6.4
12/14E-24L01	12	3.1	0.6	107	0
12/14E-24L01	3.9	0.27	50	142	.6
12/15E-13D01	1920	7.6	15.6	14	8
12/15E-13D01	6.8	2.6	1.3	104	0
12/15E-13D01	5	0.2	58	999	1.3
12/16E-15F01D1	1084	7.9	18.4	13	7.8
12/16E-15F01D1	11	2.7	1.1	102	0
12/16E-15F01D1	8.2	0.3	55	149	1.1
12/19E-16P01	670	8.3	19.5	24	12
12/19E-16P01	9.2	4.8	5.8	137	1
12/19E-16P01	15	0.3	40	181	5.8

IDENTIFIER IDENTIFIER IDENTIFIER	FT ABOVE DATUM NA SULFATE	pH K F	TEMP C CL SILICA	CA HCO3 SOLIDS	MG CO3 NITRGN
**************	*******	******	******	******	******
12/20E-31H01	-10	8.2	21.5	25	11.2
12/20E-31H01	43	6.9	17	166	0
12/20E-31H01	47	0.7	48	280	17
12/21E-17Q01	-68	8	26.9	13	6.5
12/21E-17Q01	37	6.1	4.9	178	0
12/21E-17Q01	0.4	0.8	57	215	4.9
12/22E-21N01	380	8	23.1	16	9.7
12/22E-21N01	24	5.2	4.4	169	0
12/22E-21N01	0.2	0.6	53	192	4.4
13/16E-24H01	482	7.8	27.7	14	4.1
13/16E-24H01	21	4.4	2.1	119	0
13/16E-24H01	1.9	0.65	66	172	2.1
13/17E-19E01	1065	8.1	28.1	14	4.5
13/17E-19E01	22	4.2	2.2	128	0
13/17E-19E01	0.2	0.7	72	999	2.2
13/18E-18K01	620	8	22.7	13	4.9
13/18E-18K01	34	4.5	6.6	154	0
13/18E-18K01	0.3	1.1	69	211	6.6
13/20E-29E01	765	7.6	23	24	12
13/20E-29E01	23	5.8	6.4	179	0
13/20E-29E01	14	0.5	70	245	6.4
13/21E-12D01	2425	7.5	13.5	18	8.5
13/21E-12D01	13	2.2	5.1	111	0
13/21E-12D01	11.3	0.53	50	162	5.1
14/16E-13B01	1101	7.5	17.3	15	10
14/16E-13B01	11	3.7	3.3	117	0
14/16E-13B01	6.6	0.27	55	163	3.3
14/17E-04H02	480	7.8	17.7	16	5.4
14/17E-04H02	8	3.7	2.4	92	0
14/17E-04H02	5.9	0.2	53	141	2.4
14/18E-15L01	792	8.1	23.4	14	4.2
14/18E-15L01	26	4.6	5.5	140	0
14/18E-15L01	1.9	0.67	57	182	5.5
14/19E-11L01	1377	8	19.9	22	16
14/19E-11L01	18	4.9	4.9	164	0
14/19E-11L01	21	0.45	44	210	4.9
14/19E-15M01	1140	8.1	16.9	21	14
14/19E-15M01	21	4.4	4.2	184	0
14/19E-15M01	8.9	0.5	49	214	4.2
14/20E-20N02D1	1425	7.9	17.8	24	14
14/20E-20N02D1	19	3.8	6.4	182	0
14/20E-20N02D1	8.7	0.53	46	212	6.4
15/17E-12N01	1170	8.1	17.5	6	3.6
15/17E-12N01	24	3.8	1.1	95	0
15/17E-12N01	11	0.47	49	146	1.1
16/16E-24D01D1	1470	7.7	19.4	12	4.6
16/16E-24D01D1	25	4.3	1.6	132	0
16/16E-24D01D1	2.7	0.45	66	182	1.6
16/17E-34J01D1	1744	6.8	18.6	15	8
16/17E-34J01D1	5.8	3.5	4.5	69	0
16/17E-34J01D1	18	0.2	49	138	4.5

IDENTIFIER IDENTIFIER IDENTIFIER **************		FT ABOVE DATUM NA SULFATE *******	pH K F ******	TEMP C CL SILICA ******	CA HCO3 SOLIDS ******	MG CO3 NITRGN ******
DB-15:	11/09/79	-26	9.44	25.1	1.3	0.11
DB-15:	11/09/79	164.2	17.7	105	113.59	15.24
DB-15:	11/09/79	9.4	19.8	97.54	595.74	999
DB-1:	02/02/81	93	8.24	999	1.8	0.49
DB-1:	02/02/81	100.6	13.2	16.1	228.96	2.3
DB-1:	02/02/81	0.3	3.6	59.71	527.06	999
DB-1:	07/20/78	93	8.36	22.2	2	0.55
DB-1:	07/20/78	94.8	12.7	16	237.15	3.6
DB-1:	07/20/78	0.5	3.1	68.22	444.3	999
DB-11:	12/27/77	471	8.26	999	14.3	9.98
DB-11:	12/27/77	31.8	9.6	4.36	172.17	1.73
DB-11:	12/27/77	0.04	0.45	69	313.43	999
DB-11:	04/13/78	471	8.11	999	14.2	7.2
DB-11:	04/13/78	33.6	9.9	4.7	172.76	1.73
DB-11:	04/13/78	0.5	0.67	75.5	320.76	999
DB-11:	07/14/78	471	8.2	26.7	14.7	7.49
DB-11:	07/14/78	34.5	10.1	4.6	174.14	1.75
DB-11:	07/14/78	0.5	0.7	63.8	312.28	999
DB-12:	04/20/78	999	8.05	15.8	25.3	13.5
DB-12:	04/20/78	16.8	7.1	4.6	176.9	1.29
DB-12:	04/20/78	19.1	0.03	31.9	296.9	999
DB-12:	05/11/78	352	8.27	19.6	20.1	11.88
DB-12:	05/11/78	36	7.9	6.6	188.32	2.32
DB-12:	05/11/78	15.8	0.4	56.44	351.1	999
DB-12:	05/23/78	307	8.23	19.7	17.7	10.29
DB-12:	05/23/78	33	10.7	5	194.23	1.95
DB-12:	05/23/78	0.5	0.6	55.84	329.81	999
DB-13:	06/13/78	462	8.29	999	32.2	12.4
DB-13:	06/13/78	18.54	6.2	4.1	180.26	2.33
DB-13:	06/13/78	18.9	0.4	60.5	339.7	999
DB-13:	06/23/78	426	8.1	21.3	22.1	9.38
DB-13:	06/23/78	26.7	7.2	3.8	183.05	0.75
DB-13:	06/23/78	7.9	0.4	64.5	327.1	999
DB-13:	08/05/78	302	8.28	25.3	10.9	0.95
DB-13:	08/05/78	63.9	14.68	3.9	200.17	2.52
DB-13:	08/05/78	0.6	0.5	66.9	369.2	999
DB-13:	09/21/78	199	8.6	26.7	10.1	2.52
DB-13:	09/21/78	67.1	11.1	4.9	209.46	3.1
DB-13:	09/21/78	3.8	0.6	72	389.9	999
DB-14:	12/28/78	318	8.4	22.2	1.39	0.23
DB-14:	12/28/78	70.8	10.6	15.5	182.06	3.02
DB-14:	12/28/78	3.2	0.4	60.7	352.9	999
DB-14:	09/10/78	540	8.5	18.9	42	15.75
DB-14:	09/10/78	17	6.4	5.4	175.89	3.7
DB-14:	09/10/78	38.6	0.3	67.1	384.1	999
DB-14:	10/16/78	472	8.23	21.5	21.6	8.73
DB-14:	10/16/78	31.2	8	4	176.13	4.54
DB-14:	10/16/78	6.45	0.2	72.1	341.2	999
DB-15:	04/26/79	413	7.06	17.4	18.9	4.9
DB-15:	04/26/79	44.4	10.4	7.7	153.4	0.12
DB-15:	04/26/79	37.1	999	53.5	337.5	999

IDENTIFIER IDENTIFIER IDENTIFIER **************	FT ABOVE DATUM NA SULFATE *******	pH K F ******	TEMP C CL SILICA ******	CA HCO3 SOLIDS ******	MG CO3 NITRGN ******
DB-15: 05/24/79	298	8.1	21.2	2	0.39
DB-15: 05/24/79	82.68	8.7	7.2	201.76	4.21
DB-15: 05/24/79	999	3	67.63	384.1	999
DB-15: 07/03/79	226	8.7	22.8	1.9	0.42
DB-15: 07/03/79	91.8	11	6.9	229.32	3.03
DB-15: 07/03/79	2.9	0.9	60.1	414.6	999
DB-15: 05/10/79	349	8.1	19.6	2.4	0.39
DB-15: 05/10/79	78.5	7.1	3.4	206.37	0.86
DB-15: 05/10/79	999	0.8	44.3	346.3	999
DB-15: 06/04/79	268	8.2	22	1.6	0.46
DB-15: 06/04/79	89.9	10.6	8.8	225.56	2.98
DB-15: 06/04/79	999	3	62.9	410.5	999
DB-15: 08/13/79	191	9.5	21.4	2.08	0.06
DB-15: 08/13/79	171.2	14.8	117	114.52	18.34
DB-15: 08/13/79	10.9	21.8	114	584.7	999
DB-15: 09/27/79	67	9.31	22.4	1.11	0.23
DB-15: 09/27/79	166	14.7	94.6	140.22	13.64
DB-15: 09/27/79	19.8	16.8	113.58	623.36	999
DB-15: 10/15/79	16	9.36	23.1	1.4	0.19
DB-15: 10/15/79	162	18.6	102	148.01	16.18
DB-15: 10/15/79	18.4	17.4	93.26	618.81	999
DB-15: 10/18/79	37	9.53	25.4	1.3	0.06
DB-15: 10/18/79	159.9	18.5	108	109.4	20.5
DB-15: 10/18/79	17.5	19.5	91.98	604.49	999
DB-2: 07/25/78	140	8.57	24.6	1.2	0.37
DB-2: 07/25/78	106.8	12.2	16.9	237.38	5.85
DB-2: 07/25/78	0.5	5.5	61.6	457.2	999
DB-4: 07/25/78	122	8.47	24.8	0.5	0.14
DB-4: 07/25/78	84	11.1	8.4	227.8	4.44
DB-4: 07/25/78	0.5	1.3	91.1	437.2	999
DB-5: 07/18/78	295	8.42	19.7	1.4	0.52
DB-5: 07/18/78	90.5	12.6	28.8	194.77	3.36
DB-5: 07/18/78	2.4	1.5	71.3	413	999
DB-7: 07/24/78	318	9.09	22.4	1.4	0.12
DB-7: 07/24/78	121.8	13.9	62.7	172.76	14.13
DB-7: 07/24/78	1.2	7.6	82.9	505.4	999
DB-9: 07/17/78	281	8.41	22.2	0.5	0.11
DB-9: 07/17/78	72.9	11.2	11.1	164.44	2.79
DB-9: 07/17/78	12.5	0.7	62.85	344	999
DC-12: 05/09/80	-114	9.38	24.1	1.16	0.078
DC-12: 05/09/80	135.1	16.3	102.3	117.53	14.29
DC-12: 05/09/80	999	10.3	75.33	472.39	999
DC-12: 09/10/80	-347	9.46	25.1	1.64	0.16
DC-12: 09/10/80	162.5	13	117	123.24	14.98
DC-12: 09/10/80	4	10.7	99.08	546.3	999
DC-12: 01/23/80	139	9.21	22	1.08	0.09
DC-12: 01/23/80	142.4	15.2	103	115.09	15.44
DC-12: 01/23/80	3.3	10.3	69.73	475.63	999
DC-12: 02/07/80	105	9.4	23	1.31	0.046
DC-12: 02/07/80	123	13.8	96.5	115.09	15.44
DC-12: 02/07/80	999	8.9	72.94	447.03	999

IDENTIFIER IDENTIFIER IDENTIFIER		FT ABOVE DATUM NA SULFATE	pH K F	TEMP C CL SILICA	CA HCO3 SOLIDS	MG CO3 NITRGN
**************		*******	******	******	******	******
DC-12:	02/25/80	52	9.46	22.6	1.6	0.098
DC-12:	02/25/80	125.9	13.8	105	118.47	17.21
DC-12:	02/25/80	1.4	8.2	66.95	458.63	999
DC-12:	04/20/80	-718	9.52	41.7	1.07	0.02
DC-12:	04/20/80	161.4	7.62	130.6	74.12	17.12
DC-12:	04/20/80	4.2	12.9	117.53	526.56	999
DC-14:	07/14/80	-117	9.57	24.7	2.1	0.1
DC-14:	07/14/80	80.1	11.6	5.6	109.66	19.04
DC-14:	07/14/80	26.1	1.8	82.8	338.9	999
DC-14:	07/29/80	-146	9.44	30.3	1.01	0.02
DC-14:	07/29/80	74.7	11.8	5.8	102.27	15.03
DC-14:	07/29/80	22.9	2.3	73.63	309.46	999
DC-14:	07/07/80	-95	9.41	30.7	1.17	0.05
DC-14:	07/07/80	76.1	11.9	6.9	111.91	16.45
DC-14:	07/07/80	20.5	2.2	90.6	337.78	999
DC-14:	06/11/80	-7	8.75	28.3	3.15	0.2
DC-14:	06/11/80	61.3	20.4	6.9	147.45	4.53
DC-14:	06/11/80	16.6	0.9	63.8	325.23	999
DC-14:	05/19/80	26	8.8	23.5	3.42	0.29
DC-14:	05/19/80	64.5	20.6	6.3	155.77	4.79
DC-14:	05/19/80	24.2	1	57.76	338.63	999
DC-14:	09/09/80	-270	9.69	27.9	1.32	0.05
DC-14:	09/09/80	161	9.6	70.6	113.35	26.15
DC-14:	09/09/80	18.7	24.4	161.8	586.97	999
DC-14:	01/22/80	265	8.35	18.9	9.59	1.87
DC-14:	01/22/80	58.5	9.95	5.9	155.08	2.29
DC-14:	01/22/80	28.1	1.1	59.25	335.7	999
DC-14:	01/18/80	239	8.1	16.7	6.5	1.44
DC-14:	01/18/80	48.8	13.1	6.5	129.98	1.08
DC-14:	01/18/80	23.5	0.8	68.02	301.9	999
DC-14:	04/07/80	81	9.44	17.7	7.03	0.26
DC-14:	04/07/80	79.6	12.7	11.8	123.57	22.56
DC-14:	04/07/80	29.1	1.5	55.84	387	999
DC-14:	03/14/80	122	9.41	19.3	1.46	0.08
DC-14:	03/14/80	79	12.8	7.4	120.42	20.47
DC-14:	03/14/80	18.8	2.9	53.48	352.2	999
DC-14:	02/05/80	174	7.65	20	16	2.6
DC-14:	02/05/80	31.9	13	5	130.23	0.38
DC-14:	02/05/80	18.1	0.6	72.51	293.8	999
DC-14:	12/23/80	-552	9.59	19.8	4.14	0.04
DC-14:	12/23/80	315.6	8.08	231.4	70.66	6.87
DC-14:	12/23/80	144.8	40.6	119.84	942.03	999
DC-14:	01/19/81	-582	9.72	14.2	4.52	0.09
DC-14:	01/19/81	325	8.1	237.9	90.91	9.94
DC-14:	01/19/81	135.5	47.1	103.79	962.85	999
DC-15:	07/15/80	-75	999	27	1.33	0.05
DC-15:	07/15/80	101.7	15.9	44.5	145.06	9.21
DC-15:	07/15/80	1.3	10.9	80.7	410.65	999
DC-15:	08/04/80	-142	9.39	27.7	0.96	0.03
DC-15:	08/04/80	117.3	13.6	64.7	100.38	17.42
DC-15:	08/04/80	7.5	11.8	120.1	453.77	999

IDENTIFIER IDENTIFIER IDENTIFIER **************	FT ABOVE DATUM NA SULFATE *******	pH K F ******	TEMP C CL SILICA ******	CA HCO3 SOLIDS ******	MG CO3 NITRGN ******
DC-15: 05/05/80	19	9.35	24.7	1.07	0.03
DC-15: 05/05/80	91.3	11	46.9	106.3	14.42
DC-15: 05/05/80	2.4	11.4	70.17	354.99	999
DC-15: 01/04/80	307	7.8	17	10.5	3.8
DC-15: 01/04/80	60.3	12.6	11.2	202.09	0.84
DC-15: 01/04/80	999	1.2	49.41	353.2	999
DC-15: 01/23/80	263	8.25	18	8.97	2.45
DC-15: 01/23/80	58.2	12.6	8.4	186.81	2.19
DC-15: 01/23/80	999	1	54.55	338.7	999
DC-15: 03/25/80	173	8.06	20.6	3.08	0.51
DC-15: 03/25/80	112.3	12.1	15.5	297.66	2.27
DC-15: 03/25/80	999	1.1	70.17	517.9	999
DC-15: 04/14/80	85	8.27	19.7	2.58	0.95
DC-15: 04/14/80	108.5	13.6	17.9	275.24	3.4
DC-15: 04/14/80	999	2	60.97	490.2	999
DC-15: 02/17/81	-524	9.46	37.5	2.08	0.02
DC-15: 02/17/81	259.4	5.84	189	50.78	7.55
DC-15: 02/17/81	131.8	32.6	110.28	789.35	999
DC-15: 12/10/80	-414	9.27	24.1	10.4	0.08
DC-15: 12/10/80	229.2	11.9	183.4	64.62	4.1
DC-15: 12/10/80	139.6	17.5	81.96	737.76	999
DC-15: 04/10/81	-621	8.8	32.8	2.21	0.14
DC-15: 04/10/81	276.6	4.01	210.29	84.33	3.32
DC-15: 04/10/81	171.99	22.74	84.16	859.79	999
DC-16: 09/23/81	395	8.32	21	10.82	4.87
DC-16: 09/23/81	104	4.2	3.62	263.85	3.66
DC-16: 09/23/81	22.09	0.48	47.6	470.36	999
DC-16: 10/21/81	328	8.04	24.1	14.94	3.51
DC-16: 10/21/81	46.6	6.44	3.58	168.63	1.22
DC-16: 10/21/81	4.43	0.47	21.21	272.7	999
DC-6: 08/02/79	-728	10	41.4	1.12	0.008
DC-6: 08/02/79	211.7	1.49	108.3	16.66	13.96
DC-6: 08/02/79	81.4	30.6	131.4	596.64	999
DC-6: 05/27/80	-523	9.71	16.5	1.66	0.012
DC-6: 05/27/80	310.2	6.7	166.1	61.52	17.07
DC-6: 05/27/80	190.6	42.2	107	903.06	999
DC-6: 08/14/80	-374	9.62	21	4.51	0.17
DC-6: 08/14/80	349.5	15.9	296.8	84.56	22.21
DC-6: 08/14/80	197.4	22.4	135	1123.99	999
DC-6: 02/08/80	-719	10.4	44.7	0.97	0.006
DC-6: 02/08/80	218.5	0.34	96.3	16.98	31.33
DC-6: 02/08/80	79	39	111.01	727.29	999
DC-6: 01/02/80	-895	10.6	43.2	0.95	0.005
DC-6: 01/02/80	241.5	1.9	76.9	14.38	38.43
DC-6: 01/02/80	157	40	110.37	681.43	999
DC-6: 02/24/81	-630	9.4	37.5	2.7	0.001
DC-6: 02/24/81	359.7	3.38	289.1	41.57	8.98
DC-6: 02/24/81	177.2	35.6	82.41	1000.64	999
S11-E12A: 03/20/80	291	8.15	15.5	22.4	6.05
S11-E12A: 03/20/80	50.3	8.7	13.8	203.23	1.9
S11-E12A: 03/20/80	999	0.7	45.37	35.24	999

IDENTIFIER IDENTIFIER IDENTIFIER	FT ABOVE DATUM NA SULFATE	pH K F	TEMP C CL SILICA	CA HCO3 SOLIDS	MG CO3 NITRGN
**************	*******	******	******	******	******
DC-12: 07/14/80	-224	9.57	20.8	1.17	0.051
DC-12: 07/14/80	148.2	15	127.6	114.2	16.8
DC-12: 07/14/80	1.7	13.6	999	500.1	999
DC-12: 11/04/81	-837	9.52	28	1.28	0.01
DC-12: 11/04/81	167.1	7.6	123	103.7	7.8
DC-12: 11/04/81	3.3	13.7	999	562.4	999
DC-14: 03/26/80	105	9.22	23.8	1.14	0.074
DC-14: 03/26/80	73.6	10.4	6.5	146	12.5
DC-14: 03/26/80	19.8	2.8	999	327.6	999
DC-14: 02/11/81	-612	9.39	31.3	1.7	0.03
DC-14: 02/11/81	149.6	8.2	66.4	138.1	13.4
DC-14: 02/11/81	58	15	999	535.6	999
DC-15: 01/08/81	-30	9.13	28.5	7.9	0.03
DC-15: 01/08/81	234.7	14.8	206.2	36.7	1.9
DC-15: 01/08/81	198.8	22.9	999	817.9	999
DC-15: 11/05/81	-875	9.81	18.6	1.8	0.1
DC-15: 11/05/81	271.2	2.9	137.2	83.4	8.2
DC-15: 11/05/81	107.2	46.3	999	783.3	999
DB-1: 11/10/81	50	8.67	19.9	0.43	0.1
DB-1: 11/10/81	99.7	15.3	46.6	154.3	3.1
DB-1: 11/10/81	16.3	7.1	999	418.9	999
DB-14: 10/30/78	421	8.19	23.4	14.09	5.23
DB-14: 10/30/78	40.45	7.8	3.6	177.7	1.8
DB-14: 10/30/78	0.5	0.4	999	313.3	999
S11-E12A: 07/24/80	123	8.04	17.1	21.6	5.9
S11-E12A: 07/24/80	48.2	7.8	14.9	207	2.1
S11-E12A: 07/24/80	0.05	0.77	999	367.8	999
DB-15: 08/27/79	142	9.63	26.9	2	0.3
DB-15: 08/27/79	170.8	14.9	104.8	66.6	17.4
DB-15: 08/27/79	6.8	19	999	526.9	999
DC-15: 06/30/80	-53	9.43	27.2	1.67	0.04
DC-15: 06/30/80	97.8	13.3	39.7	118.4	17.4
DC-15: 06/30/80	0.05	9.3	999	378.3	999
DC-15: 08/12/80	-164	9.63	29	1.6	0.032
DC-15: 08/12/80	122	12.8	70.7	112.5	26
DC-15: 08/12/80	4.8	8.6	999	483	999
DC-15: 06/12/80	-17	9.31	26.6	1.06	0.034
DC-15: 06/12/80	97.7	14.2	35.9	123.5	13.5
DC-15: 06/12/80	0.5	9	999	364.5	999
DC-14: 06/23/80	-63	9.46	20.1	3.99	0.39
DC-14: 06/23/80	72.5	13.1	7	130.89	15.91
DC-14: 06/23/80	18.9	2.2	42.37	307.25	999

FACTOR ANALYSIS COMPUTER OUTPUT

UNIVERSITY COMPUTER CENTER
UNIVERSITY OF MINNESOTA

S P S S -- STATISTICAL PACKAGE FOR THE SOCIAL SCIENCES

VERSION 9.0 (NOS) -- MARCH 6, 1984

377700 CM MAXIMUM FIELD LENGTH REQUEST

RUN NAME	FACTOR ANALYSIS: WATER CHEMISTRY, HANFORD NUCLEAR RESERVATION
FILE NAME	FINAL1 - WITHOUT SILICA OR NITROGEN
VARIABLE LIST	DATUM,PH,TEMP,CA,MG,NA,K,CL,HCO3,CO3,SO4,F,SIO2,SOLIDS,NITRGN
INPUT MEDIUM	CARD
INPUT FORMAT	FIXED (T20,5F10.0/T20,5F10.0/T20,5F10.0)

ACCORDING TO YOUR INPUT FORMAT, VARIABLES ARE TO BE READ AS FOLLOWS

VARIABLE	FORMAT	RECORD	COLUMNS
DATUM	F10. 0	1	20- 29
PH	F10. 0	1	30- 39
TEMP	F10. 0	1	40- 49
CA	F10. 0	1	50- 59
MG	F10. 0	1	60- 69
NA	F10. 0	2	20- 29
K	F10. 0	2	30- 39
CL	F10. 0	2	40- 49
HCO3	F10. 0	2	50- 59
CO3	F10. 0	2	60- 69
SO4	F10. 0	3	20- 29
F	F10. 0	3	30- 39
SIO2	F10. 0	3	40- 49
SOLIDS	F10. 0	3	50- 59
NITRGN	F10. 0	3	60- 69

THE INPUT FORMAT PROVIDES FOR 15 VARIABLES. 15 WILL BE READ.
IT PROVIDES FOR 3 RECORDS ("CARDS") PER CASE.
A MAXIMUM OF 69 "COLUMNS" ARE USED ON A RECORD.

N OF CASES	218	
VAR LABELS	DATUM	-FEET ABOVE DATUM - NGVD/
	PH	-PH IN PH UNITS/
	TEMP	-DEGREES CENTIGRADE/
	CA	-CALCIUM IN MG PER LITER/
	MG	-MAGNESIUM IN MG PER LITER/
	NA	-SODIUM IN MG PER LITER/
	K	-POTASSIUM IN MG PER LITER/
	CL	-CHLORIDE IN MG PER LITER/
	HCO3	-BICARBONATE IN MG PER LITER/

CO3	-CARBONATE IN MG PER LITER/
SO4	-SULFATE IN MG PER LITER/
F	-FLUORIDE IN MG PER LITER/
SIO2	-SILICA AS SIO2 IN MG PER LITER/
SOLIDS	-DISSOLVED SOLIDS MG PER LITER/

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                    NITRGN -NO2 AND NO3 MG PER LITER
MISSING VALUES      DATUM TO NITRGN (999)
COMMENT             COMPLETE DATA SET AS OF 12-10-84/
```

CPU TIME REQUIRED.. .085 SECONDS

```
FACTOR              VARIABLES=DATUM TO F,SOLIDS/
                    FACSCORE/
                    TYPE=PA1/
                    MINEIGEN=1.0/
                    ROTATE=VARIMAX/
OPTIONS             2,11
STATISTICS          1,2,4,5,6,7,8
READ INPUT DATA
```

00054500 CM NEEDED FOR FACTOR

OPTION - 2
PAIRWISE DELETION OF MISSING DATA

OPTION -11
WRITE SEQUENCE INFORMATION WITH FACSCORES

FILE FINAL1 (CREATION DATE = 85/01/13.) - WITHOUT SILICA OR NITROGEN

VARIABLE	MEAN	STANDARD DEV	CASES
DATUM	264.3687	563.1874	217
PH	8.3218	.6967	217
TEMP	21.5280	5.4906	214
CA	20.4217	20.6972	218
MG	9.6977	12.1575	218
NA	67.6453	66.7227	218
K	8.7589	4.1908	218
CL	78.6204	241.4701	218
HCO3	167.6701	56.9221	218
CO3	4.0525	6.9088	218
SO4	38.3913	56.7743	208
F	4.2390	8.9147	217
SOLIDS	365.0711	174.4115	213

FILE FINAL1 (CREATION DATE = 85/01/13.) - WITHOUT SILICA OR NITROGEN

CORRELATION COEFFICIENTS..

	DATUM	PH	TEMP	CA	MG	NA	K	CL	HCO3
DATUM	1.00000	-.59869	-.60187	.32126	.34830	-.57503	-.35747	-.23220	.18
PH	-.59869	1.00000	.60010	-.59440	-.55391	.76991	.35603	.41662	-.56
TEMP	-.60187	.60010	1.00000	-.48050	-.44879	.48189	.17193	.22847	-.42
CA	.32126	-.59440	-.48050	1.00000	.92969	-.44598	-.36829	-.18774	.44
MG	.34830	-.55391	-.44879	.92969	1.00000	-.40467	-.34076	-.15929	.43
NA	-.57503	.76991	.48189	-.44598	-.40467	1.00000	.28270	.48097	-.46
K	-.35747	.35603	.17193	-.36829	-.34076	.28270	1.00000	.22467	.06
CL	-.23220	.41662	.22847	-.18774	-.15929	.48097	.22467	1.00000	-.29
HCO3	.18056	-.56483	-.42171	.44442	.43082	-.46367	.06501	-.29400	1.00
CO3	-.44826	.87185	.54571	-.48057	-.42796	.64527	.30025	.36852	-.51
SO4	-.13415	.04677	-.02647	.50038	.54943	.37280	-.08438	.08293	-.09
F	-.47708	.72511	.43849	-.36511	-.33046	.90811	.05794	.46052	-.57
SOLIDS	-.44919	.54356	.29522	-.00770	.04506	.85659	.22680	.43218	-.23

	CO3	SO4	F	SOLIDS
DATUM	-.44826	-.13415	-.47708	-.44919
PH	.87185	.04677	.72511	.54356
TEMP	.54571	-.02647	.43849	.29522
CA	-.48057	.50038	-.36511	-.00770
MG	-.42796	.54943	-.33046	.04506
NA	.64527	.37280	.90811	.85659
K	.30025	-.08438	.05794	.22680
CL	.36852	.08293	.46052	.43218
HCO3	-.51263	-.09886	-.57306	-.23978
CO3	1.00000	.02129	.63243	.48589
SO4	.02129	1.00000	.34100	.68142
F	.63243	.34100	1.00000	.76382
SOLIDS	.48589	.68142	.76382	1.00000

FILE FINAL1 (CREATION DATE = 85/01/13.) - WITHOUT SILICA OR NITROGEN

VARIABLE	EST COMMUNALITY	FACTOR	EIGENVALUE	PCT OF VAR	CUM PCT
DATUM	1.00000	1	6.00757	46.2	46.2
PH	1.00000	2	2.57881	19.8	66.0
TEMP	1.00000	3	1.20879	9.3	75.3
CA	1.00000	4	.89438	6.9	82.2
MG	1.00000	5	.64595	5.0	87.2
NA	1.00000	6	.54823	4.2	91.4
K	1.00000	7	.44488	3.4	94.8
CL	1.00000	8	.31191	2.4	97.2
HCO3	1.00000	9	.12679	1.0	98.2
CO3	1.00000	10	.08646	.7	98.9
SO4	1.00000	11	.06927	.5	99.4
F	1.00000	12	.05611	.4	99.8
SOLIDS	1.00000	13	.02085	.2	100.0

FILE FINAL1 (CREATION DATE = 85/01/13.) - WITHOUT SILICA OR NITROGEN

FACTOR MATRIX USING PRINCIPAL FACTOR, NO ITERATIONS

	FACTOR 1	FACTOR 2	FACTOR 3
DATUM	-.67017	-.04007	-.37862
PH	.92289	-.06562	-.00547
TEMP	.68472	-.16820	-.02175
CA	-.64182	.68552	.04054
MG	-.60380	.72143	.04155
NA	.90206	.29135	.02487
K	.37862	-.20967	.77517
CL	.52022	.17003	.04390
HCO3	-.61922	.06823	.61744
CO3	.82116	-.04465	-.05103
SO4	.12611	.91520	.00133
F	.84493	.31569	-.23039
SOLIDS	.66794	.67273	.14563

VARIABLE	COMMUNALITY
DATUM	.59409
PH	.85605
TEMP	.49761
CA	.88352
MG	.88675
NA	.89921
K	.78821
CL	.30147
HCO3	.76931
CO3	.67890
SO4	.85349
F	.86665
SOLIDS	.91991

FILE FINAL1 (CREATION DATE = 85/01/13.) - WITHOUT SILICA OR NITROGEN

VARIMAX ROTATED FACTOR MATRIX
AFTER ROTATION WITH KAISER NORMALIZATION

	FACTOR 1	FACTOR 2	FACTOR 3
DATUM	-.58139	.17887	-.47337
PH	.80416	-.43400	.14497
TEMP	.54805	-.43243	.10125
CA	-.29312	.88444	-.12400
MG	-.24382	.90156	-.12039
NA	.93286	-.09907	.13847
K	.17241	-.22671	.84089
CL	.53577	-.05091	.10874
HCO3	-.59284	.40473	.50403
CO3	.72609	-.38067	.08233
SO4	.49954	.77452	-.06379
F	.91808	-.09211	-.12372
SOLIDS	.87037	.35782	.18528

TRANSFORMATION MATRIX

	FACTOR 1	FACTOR 2	FACTOR 3
FACTOR 1	.90074	-.40525	.15633
FACTOR 2	.42186	.90191	-.09267
FACTOR 3	-.10344	.14943	.98335

FILE FINAL1 (CREATION DATE = 85/01/13.) - WITHOUT SILICA OR NITROGEN

FACTOR SCORE COEFFICIENTS

	FACTOR 1	FACTOR 2	FACTOR 3
DATUM	-.07464	-.01561	-.32401
PH	.12811	-.08588	.02192
TEMP	.07701	-.10770	.00617
CA	.01244	.28806	-.00836
MG	.02393	.29818	-.00784
NA	.18078	.04412	.03323
K	-.04386	-.00305	.64799
CL	.10206	.02980	.04314
HCO3	-.13452	.14196	.48372
CO3	.12018	-.07732	-.01854
SO4	.16851	.31174	-.02852
F	.19804	.02493	-.17678
SOLIDS	.19773	.20823	.11168

FILE FINAL1 (CREATION DATE = 85/01/13.) - WITHOUT SILICA OR NITROGEN

3 FACTOR SCORES WERE WRITTEN ON FILE BCDOUT FOR 218 UNWEIGHTED CASES.
1 RECORDS OUTPUT PER CASE

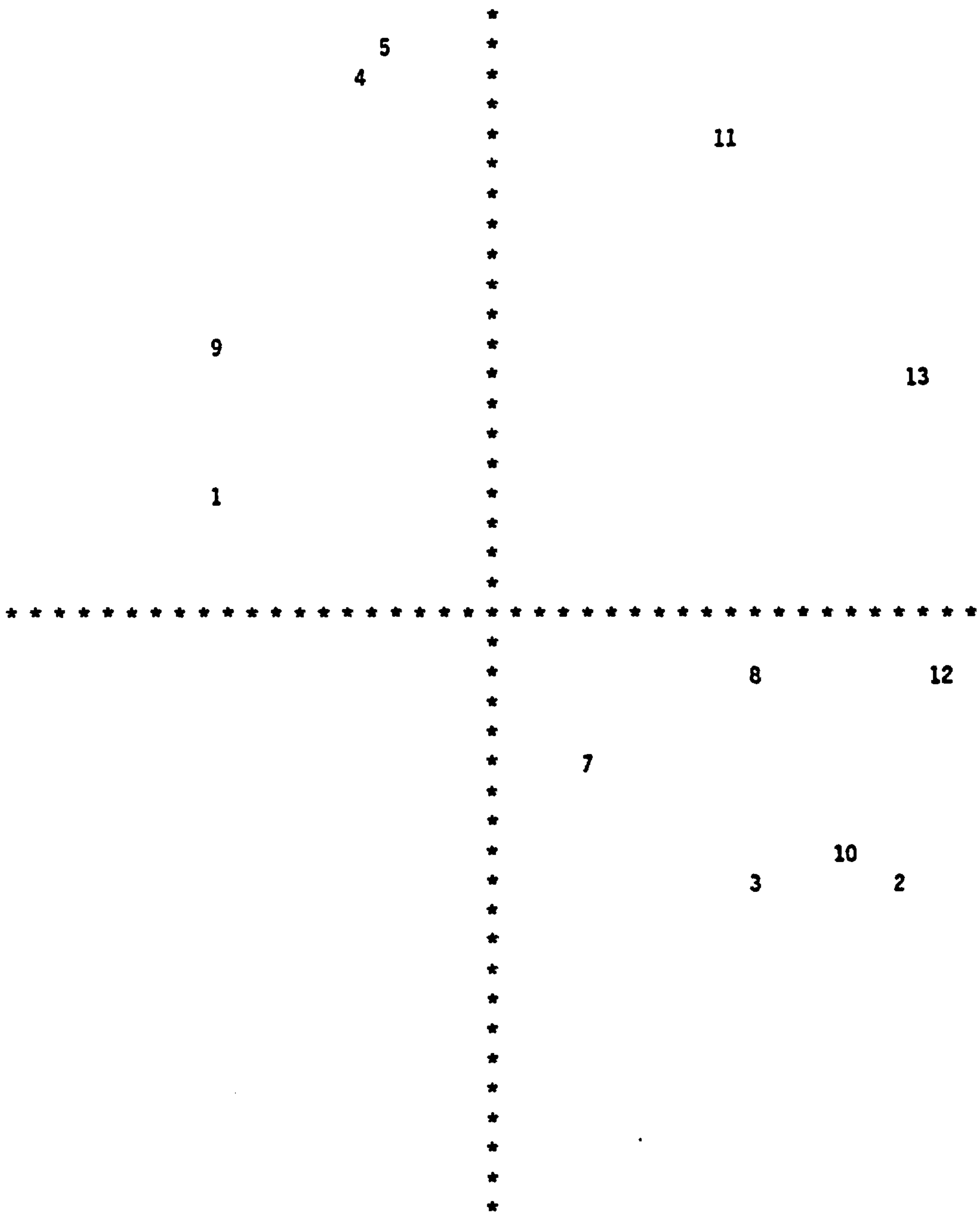
OUTPUT FORMAT IS ...
(F8.0,F2.0,1X,A8,1X,6F10.6). RECORD NUMBER APPEARS LEFT-ZERO-FILLED.

MISSING FACTOR SCORES ARE OUTPUT AS 999.0
NON-MISSING BUT EXTREME FACTOR SCORES ARE TRUNCATED TO +99.0 OR -99.0

FACTORS FROM VARIABLE LIST	FACTOR NUMBER	OUTPUT RECORD NUMBER PER CASE	RECORD COLUMNS	UNWEIGHTED NUMBER OF MISSING CASES
SEQNUM		1	1- 8	
RECORD NUMBER		1	9-10	
SUBFIL		1	12-15	
1	1	1	21-30	22
1	2	1	31-40	22
1	3	1	41-50	22

FILE FINAL1 (CREATION DATE = 85/01/13.) - WITHOUT SILICA OR NITROGEN

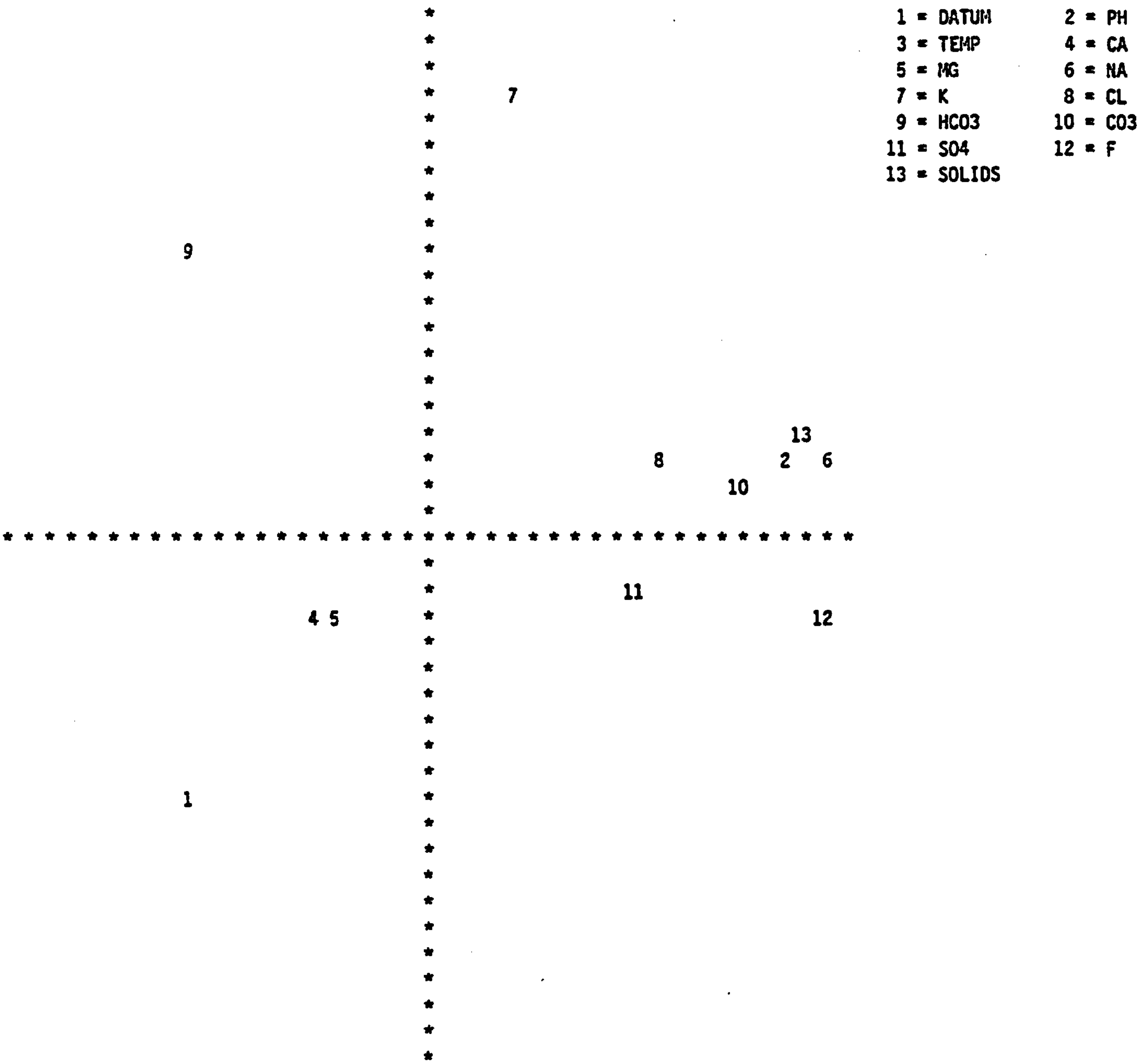
HORIZONTAL FACTOR 1 VERTICAL FACTOR 2



1 = DATUM	2 = PH
3 = TEMP	4 = CA
5 = MG	6 = NA
7 = K	8 = CL
9 = HCO3	10 = CO3
11 = SO4	12 = F
13 = SOLIDS	

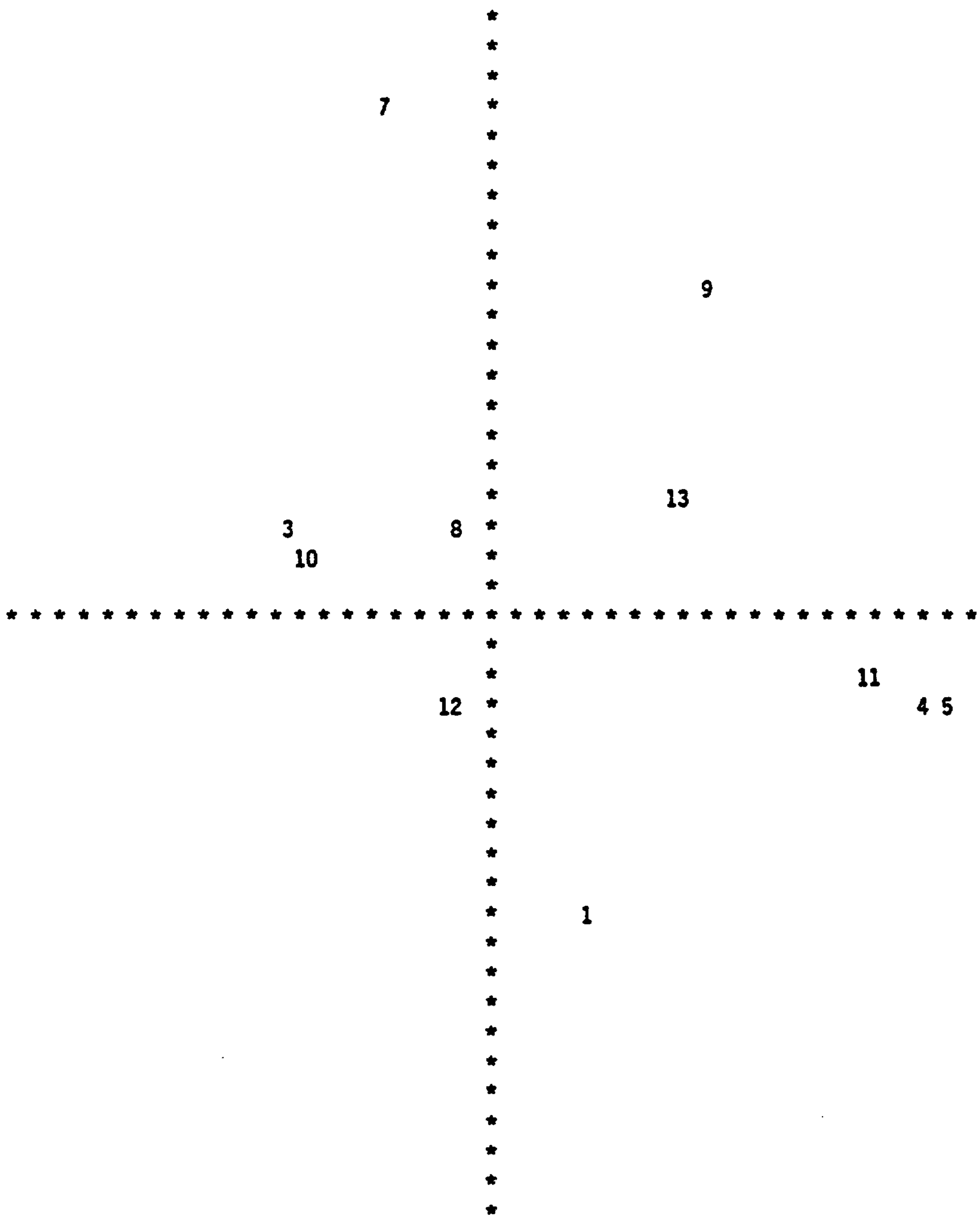
FILE FINAL1 (CREATION DATE = 85/01/13.) - WITHOUT SILICA OR NITROGEN

HORIZONTAL FACTOR 1 VERTICAL FACTOR 3



FILE FINAL1 (CREATION DATE = 85/01/13.) - WITHOUT SILICA OR NITROGEN

HORIZONTAL FACTOR 2 VERTICAL FACTOR 3



1 = DATUM 2 = PH
3 = TEMP 4 = CA
5 = MG 6 = NA
7 = K 8 = CL
9 = HCO3 10 = CO3
11 = SO4 12 = F
13 = SOLIDS

CPU TIME REQUIRED.. 1.481 SECONDS

TOTAL CPU TIME USED.. 1.569 SECONDS

RUN COMPLETED

NUMBER OF CONTROL CARDS READ 31
NUMBER OF ERRORS DETECTED 0
S

101	FINAL1	.551792	-.791176	.137259
201	FINAL1	-.105052	-.332847	-.377027
301	FINAL1	-.426180	-.019778	.338692
401	FINAL1	-.379007	-.167102	.752468
501	FINAL1	.009217	-.606088	.208341
601	FINAL1	.198237	-.893770	.203663
701	FINAL1	-.186011	2.481937	-.622949
801	FINAL1	-.153087	-.584311	.230579
901	FINAL1	-.169684	-.615663	.478756
1001	FINAL1	-.501770	-.109164	-1.122265
1101	FINAL1	-.346118	-.225168	-.840331
1201	FINAL1	-.514431	1.035047	-1.236766
1301	FINAL1	-.854942	-.199776	-.860156
1401	FINAL1	-.695116	2.249764	1.601539
1501	FINAL1	-.279259	1.807751	.732945
1601	FINAL1	-.220675	-.620181	.853460
1701	FINAL1	.072906	-.914644	.011469
1801	FINAL1	-.203131	-.757871	.220206
1901	FINAL1	-.663450	.011568	-.188760
2001	FINAL1	-.391687	-.551673	-.053978
2101	FINAL1	-.285582	-.294090	.561627
2201	FINAL1	.312494	-.994922	-.131008
2301	FINAL1	-.770937	-.120956	-1.309281
2401	FINAL1	-.817576	-.334954	-1.688056
2501	FINAL1	-.203379	.179340	.381057
2601	FINAL1	-.468659	.527108	-.817851
2701	FINAL1	.689307	3.425921	.161090
2801	FINAL1	-.518014	.326867	-.824508
2901	FINAL1	-.395685	.419817	1.799402
3001	FINAL1	-.377110	-.416405	2.122728
3101	FINAL1	-.596059	.723880	-.696912
3201	FINAL1	-.322282	1.265864	-.821353
3301	FINAL1	-.284109	.775484	.029862
3401	FINAL1	-.197799	.608529	1.706797
3501	FINAL1	-.471937	.860602	.171259
3601	FINAL1	-.491089	-.455155	.904400
3701	FINAL1	-.810823	2.085454	1.001546
3801	FINAL1	-.297718	-.143489	1.041740
3901	FINAL1	-.257200	.019876	1.958421
4001	FINAL1	-.671288	1.490641	.892768
4101	FINAL1	-.528284	.603814	-.825869
4201	FINAL1	-.647570	-.387173	2.044261

4301	FINAL1	-.403189	.565740	.022362
4401	FINAL1	-.510075	-.392589	.038990
4501	FINAL1	-.695868	-.113020	-.164206
4601	FINAL1	-.562854	-.317747	1.517169
4701	FINAL1	-.332107	1.163762	-.326951
4801	FINAL1	-.391838	1.481149	.843874
4901	FINAL1	-.269804	1.444375	.143572
5001	FINAL1	-.434318	.369784	.183119
5101	FINAL1	.049076	1.163715	-.112627
5201	FINAL1	-.459859	-.484557	-.796572
5301	FINAL1	-.617739	-.065210	1.140346
5401	FINAL1	-.488678	-.400211	-.650676
5501	FINAL1	-.178132	.657659	1.947623
5601	FINAL1	-.085622	2.726725	-.429252
5701	FINAL1	-.347729	-.170803	.764501
5801	FINAL1	-.496332	-.273942	.622588
5901	FINAL1	-.547559	-.296522	1.173189
6001	FINAL1	-.075665	2.181382	-.406781
6101	FINAL1	-.092306	-.860102	1.409219
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7501	FINAL1	-.593433	.405815	-.841615
7601	FINAL1	-.566628	-.009638	-.639456
7701	FINAL1	-.525595	-.548016	-1.102726
7801	FINAL1	-.476686	-.639045	-.264551
7901	FINAL1	-.599390	-.027375	-.779358
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8101	FINAL1	.264526	3.619817	.777146
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8701	FINAL1	-.875254	.242281	-.481187
8801	FINAL1	-.987157	.602773	-1.301003
8901	FINAL1	-.558009	-.371396	1.507545
9001	FINAL1	-.618655	-.293087	1.161732
9101	FINAL1	-.294052	1.884592	.316876
9201	FINAL1	-.370519	-.219986	.319678
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10401	FINAL1	-.957503	-.400810	-1.708141
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10801	FINAL1	-.553198	-.684350	.428913
10901	FINAL1	-.743067	-.534129	-1.899977
11001	FINAL1	-.819236	.863006	.254212
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15901	FINAL1	1.149264	-.506093	.796626
16001	FINAL1	1.544382	-.433230	1.639861
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20801	FINAL1	1.365162	-.580670	.124372
20901	FINAL1	2.378284	.653246	-.013908
21001	FINAL1	2.875187	.295266	-1.409429

21101	FINAL1	.117598	-.577919	1.046120
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21301	FINAL1	-.486209	-.068293	.329397
21401	FINAL1	1.417496	-1.023568	.068772
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21801	FINAL1	.293019	-.967397	.576120

Table RD-1

****

POINTS WITH CHARGE BALANCE ERRORS GREATER THAN 5 %

****

REF. NO.	IDENTIFIER	MAJOR UNIT#	ERROR (%)
14	16/28E-04B01	3	6.90
27	06/26E-19K01	3	12.81
56	11/30E-36M01	3	5.07
69	14/29E-19Q01	3	5.10
94	08/30E-02R01	3	17.97
96	09/31E-34P01	3	10.18
97	09/32E-20F01	3	9.40
182	DC-14: 03/14/80	3	6.21
196	DC-16: 09/23/81	3	5.09
12	15/33E-15N02	5	17.07
15	16/28E-05N01	5	11.52
19	16/31E-33P01	5	5.24
51	10/32E-03R01	5	6.93
137	DB-15: 11/09/79	5	7.66
158	DB-15: 08/13/79	5	5.03
159	DB-15: 09/27/79	5	6.74
169	DC-12: 01/23/80	5	5.73
173	DC-14: 07/14/80	5	9.42
174	DC-14: 07/29/80	5	10.09
175	DC-14: 07/07/80	5	8.10
187	DC-15: 08/04/80	5	6.38
214	DB-15: 08/27/79	5	15.77
215	DC-15: 06/30/80	5	6.14
217	DC-15: 06/12/80	5	8.12
16	16/29E-34D01	6	8.73
168	DC-12: 09/10/80	7	7.38
172	DC-12: 04/20/80	7	7.64
178	DC-14: 09/09/80	7	6.78
198	DC-6: 08/02/79	7	13.47
201	DC-6: 02/08/80	7	10.58
202	DC-6: 01/02/80	7	7.83
206	DC-12: 11/04/81	7	9.46
210	DC-15: 11/05/81	7	8.08

* Note: Major Unit # refers to Layer #

APPENDIX C

Examination of the BWIP Hydrochemistry Data for Concurrence with Flow Path Conceptualizations

Prepared for

Yakima Indian Nation
Nuclear Waste Program

Submitted by

GeoTrans, Inc.
209 Elden Street
Herndon, Virginia 22070

March 16, 1985

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Examination of the BWIP Hydrochemistry Data for
Concurrence with Flow Path Conceptualizations

Introduction

An important part of any complete hydrogeologic study is the examination of hydrochemical data for indicators of system behavior. Not only are elements of the water-rock reaction process exposed, but indicators of the nature and direction of water travel are also revealed. While the information derived is not wholly conclusive, it can often delimit a range of realistic conceptual views. Analysis methods typically involve examination of both the water-rock reactions suggested by the individual analyses and the interrelated possible cause-effect relationships that create down-gradient differences in composition. The complexity of a system may prevent the development of a complete, unique, hydrochemical conceptualization. Nonetheless, hydrochemical study of such complex systems is often critical because the complexity can be a geohydrologic event such as the mixing of different waters that is effectively examined by chemical differences.

The BWIP EA presents no hydrochemical indications in support of the ground-water flow conceptualization used in the travel time calculations. Presumably, the EA-relevant, DOE understanding of the hydrochemistry resides in the frequently-cited Site Characterization Report (SCR) released by DOE in 1982. Perhaps criticisms for relying too heavily on hydrochemistry in the SCR has led to lack of consideration of hydrochemistry in the EA.

This report tries to determine the ground-water flow conceptualization best supported by the BWIP hydrochemistry data. Such a conceptualization would likely be that most supported for use in a travel time analysis. This work is considered preliminary because, having received the magtape of the DOE data base output in mid-February and being constrained by the 90-day review period of the EA, we have not developed our ideas as fully as we would like.

Geologic Setting

The BWIP site is located in the Pasco Basin which is a part of the Columbia Plateau (Figure 1). The Columbia Plateau consists of extremely voluminous basalt layers extruded in Miocene time. The Pasco Basin, located in the northern portion of the Plateau, is a long-standing structural and topographic low. The basalt layers in the Pasco Basin have a total thickness greater than 1500 meters and are overlain by lacustrine and fluvial deposits. Subtle differences in the mineralogy and bulk chemical composition, as well as downhole logs and magnetic-polarity stratigraphy, are used to differentiate between the various basalt units (Figure 2).

Mineralogy

A study of the mineralogy and alteration products can provide information about reactants and products to be considered in the chemical equations of the reaction model. The mineralogies and bulk chemistries of the Columbia Plateau have been studied extensively by various authors. The primary basaltic minerals consist of plagioclase feldspar with labradorite to slightly andesine compositions, pyroxenes generally with subcalcic augite compositions, and minor iron-titanium oxides with compositions in the ilmenite-magnetite solid solution. The accessory minerals include apatite, occasional olivine, a minor Fe-Co-Ni sulfide, and an unidentified Fe-rich mineraloid (Ames, 1980). The primary and secondary minerals are contained within a groundmass of basaltic glass.

Fractures and vesicles contain complex assemblages of alteration products that have been identified in core samples with petrographic microscopy, x-ray diffraction, electron microprobe analysis and scanning electron microscopy (Ames, 1980; Benson et al., 1978; Benson and Teague, 1977; BWIP and Colorado School of Mines, 1979; Teague, 1980; and Hearn et al., 1985). Table 1 compares the results of many of these authors with the equilibria-speciation results obtained by Deutsch et al. (1982). In reporting their findings a few of the authors (Benson and Teague, 1979; Ames, 1980; and Hearn et al., 1985) noted significant differences between those alteration products found in vesicles and those found along fractures in core.

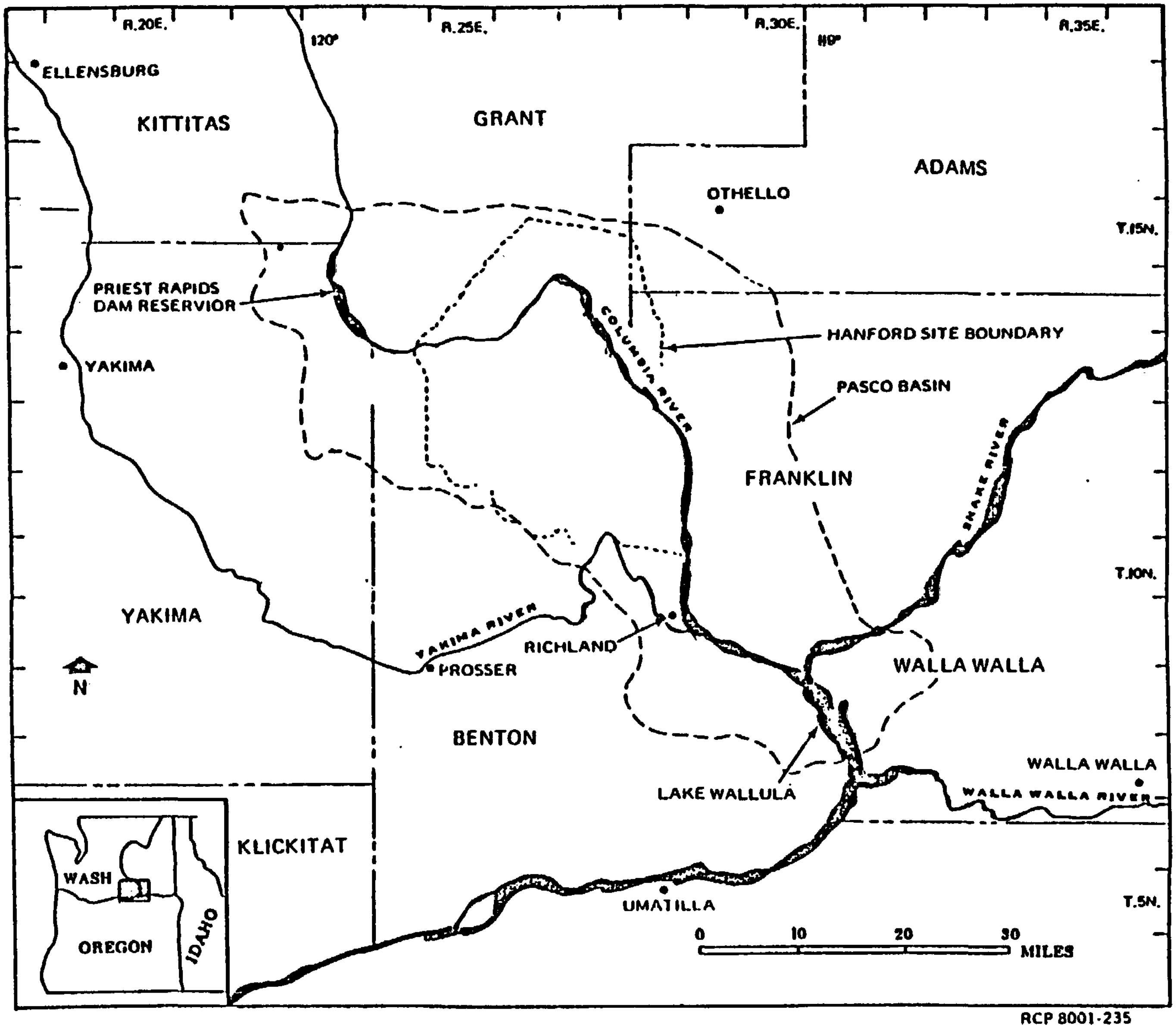

Figure 1. Hanford Site Location (from Gephart,1979)

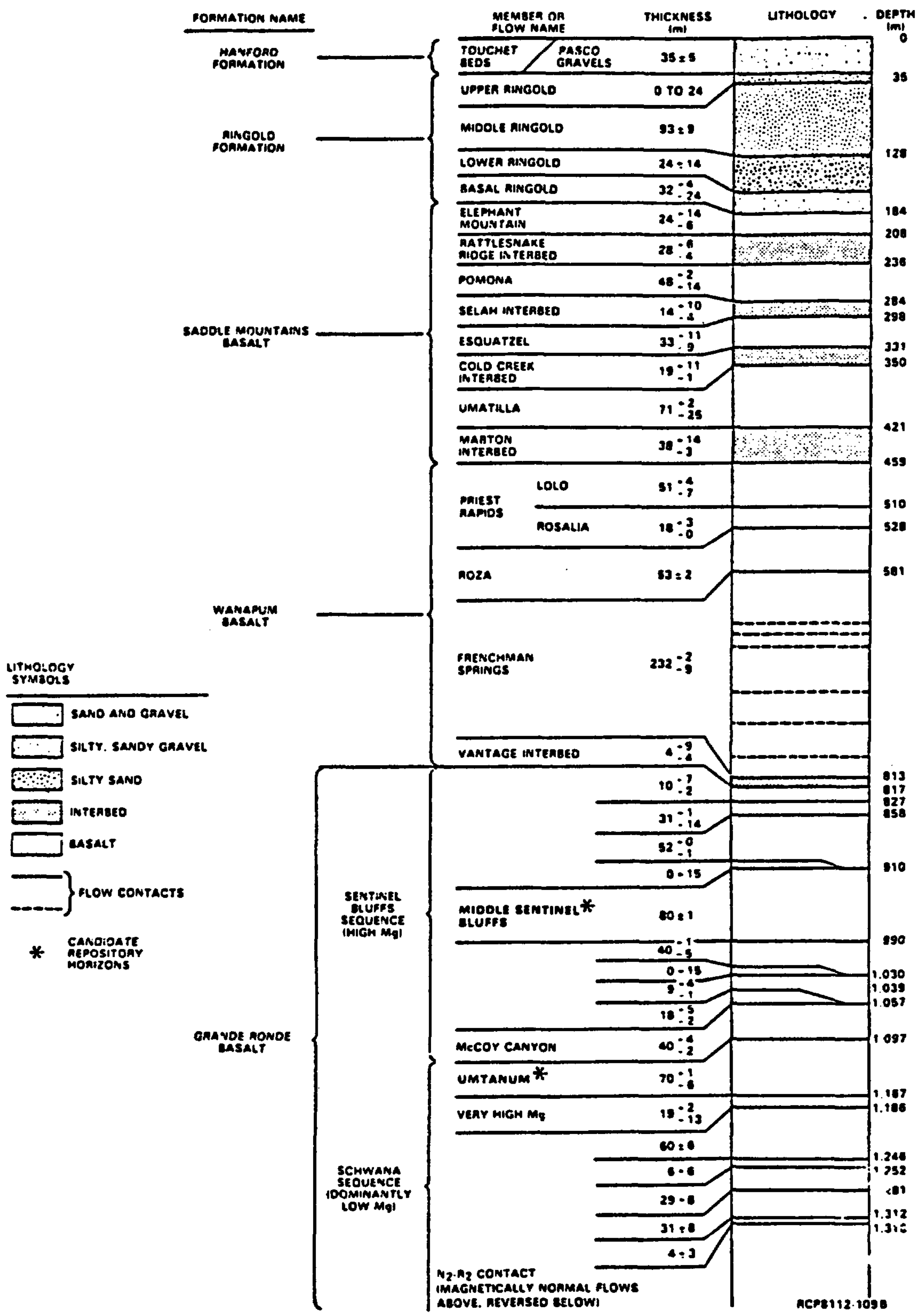

FIGURE 2 Stratigraphic Column, Reference Repository Location. (from SCR, 1982)

TABLE 1. Solid phases calculated by WATEQ2 to be in equilibrium with the ground waters or identified to be alteration products of the Columbia Plateau Basalts (modified from Deutsch et al., 1982)

	Calculated equilibrium phases	Observed alteration products				
Solid Phases	Deutsch et al. (1982)	Ames (1980)	Benson et al. (1978)	Benson and Teague (1979)	BWIP & CSM Staff (1979)	Teague (1980)
Minerals						
*Analcime	X		X	X		X
+Calcite	X	X		X		
*Chabazite		X		X		
Chlorite		X				
+Clinoptilolite (b)		X	X	X	X	X
+Cristobalite (b)		X	X	X	X	X
Dolomite	X					
*Erionite		X	X	X		
Gmelinite		X				
*Gypsum		X		X		
Halloysite	X					
Harmotome		X				
Heulandite		X			X	
+Illite (celadonite)			X	X		X
Laumontite		X				
Mordenite		X	X	X	X	X
Opal (c)		X	X	X		X
*Phillipsite		X		X		
+Pyrite		X	X	X	X	X
+Quartz (b)		X		X	X	X
Sepiolite	X					
+Smectite Clay (b)	X	X	X	X	X	X
+Tridymite			X	X		X
*Vermiculite		X	X	X		
Wairakite	X		X	X		
Other Solids						
Allophane	X					
Ferric Hydroxide (amorphic)	X					
Iron Oxides		X				
$MnHPO_4$	X					
SiO_2 (A,gl)	X					

(a) Rhodocrosite and fluorite calculated to be at equilibrium solubility in a very limited number of samples.
(b) Major solid phases reported.
(c) Poorly-ordered cristobalite and tridymite.
* Seen only in vesicles.
\+ Principle components in fractures.

Vesicles were found to contain a complex mineralogy including phases such as chabazite and erionite that are zeolites not known to be characteristic of those found in open ground-water systems. The presence of these minerals in some vesicles may be due to isolation of the vesicle from the moving ground water, in which case diffusive mass transport processes would become more important than advective processes.

The chemical composition of the basalt flows also varies as a function of cooling rate. Basalts that have been chilled rapidly will have much greater glass contents and tend to be more vesicular due to rapid degassing. Rapid cooling occurs primarily in flow tops and flow bottoms and in situations where the basalt flowed into standing bodies of water. Flows into water are marked by pillow palagonite structures that have been noted in the Pasco Basin. Thin flows reflect a more rapid cooling rate than thicker flows regardless of total volume extruded.

Hydrology

In order to study a system hydrochemically, it is first necessary to formulate a rough conceptual view that directs organization of the data. Data organization is particularly important in complicated scenarios such as BWIP. Because the flow system and the development of a hydrochemical conceptual model are interrelated, a general understanding of the flow system can be applied as a conceptual view of the geochemical system. This is an iterative process since the flow system is not clearly defined and description of the flow system is of major importance to a hydrochemical conceptualization.

The ground-water hydrology of this region has been studied by Gephart et al. (1979) and others and is discussed in the SCR (1982). Direct recharge of the basalt aquifer occurs primarily as a result of rainfall infiltrations through the weathered basalt surface northeast of the study area where rainfall is relatively high. In addition to direct recharge, the basalt aquifers may be recharged by percolation from alluvial aquifers that, in turn, are recharged by infiltration from rainfall and irrigation water. There is debate about the occurrence of interbasin flow, but if such flow were occurring, additional recharge would result. Ground-water flow through the basalt is thought to parallel the flow units because the most permeable portion of the flows are generally along the fractured contact zones between flows. There are also sedimentary interbeds between many flows. These interbeds can serve as aquifers where their lithologies are conducive; they otherwise serve as semi-confining beds. Because of the occurrence of some relatively impermeable layers and the presence of joints and fractures related to structural features, there is question as to the extent and location of vertical flow.

Data Presentation

The DOE BWIP program provided on magnetic tape a data base output of water analyses taken from springs, surface water, and confined and unconfined geologic units in the BWIP study area. For this preliminary work, the major ion chemistries from the confined and unconfined units were the primary considerations. Data locations for the 470 confined and 127 unconfined samples considered are shown in Figures 3 and 4, respectively.

An indication of the unit sampled was provided with each of the confined unit analyses. Because more than fifty different expressions of geologic unit were noted, a more general layer representation method was employed to facilitate comparative examination. The stratigraphic section was considered to be six confined unit layers and one unconfined layer, as shown in Figure 5. Each of the geologic units was assigned to a depth layer based on stratigraphy. Division of the depth layers was based on the occurrence of samples, formation stratigraphy, and depths at which changes in hydrochemical character might be noted. A few of the samples were taken in intervals that span the utilized depth layer divisions. In these cases, the depth layer was assigned according to the layer which contained a majority of the sample interval.

All confined sample wells contained more than one sample in a given depth layer. To further consolidate for illustrative purposes, the duplicate samples were averaged and the average is considered. Before averaging, all samples for both confined and unconfined units

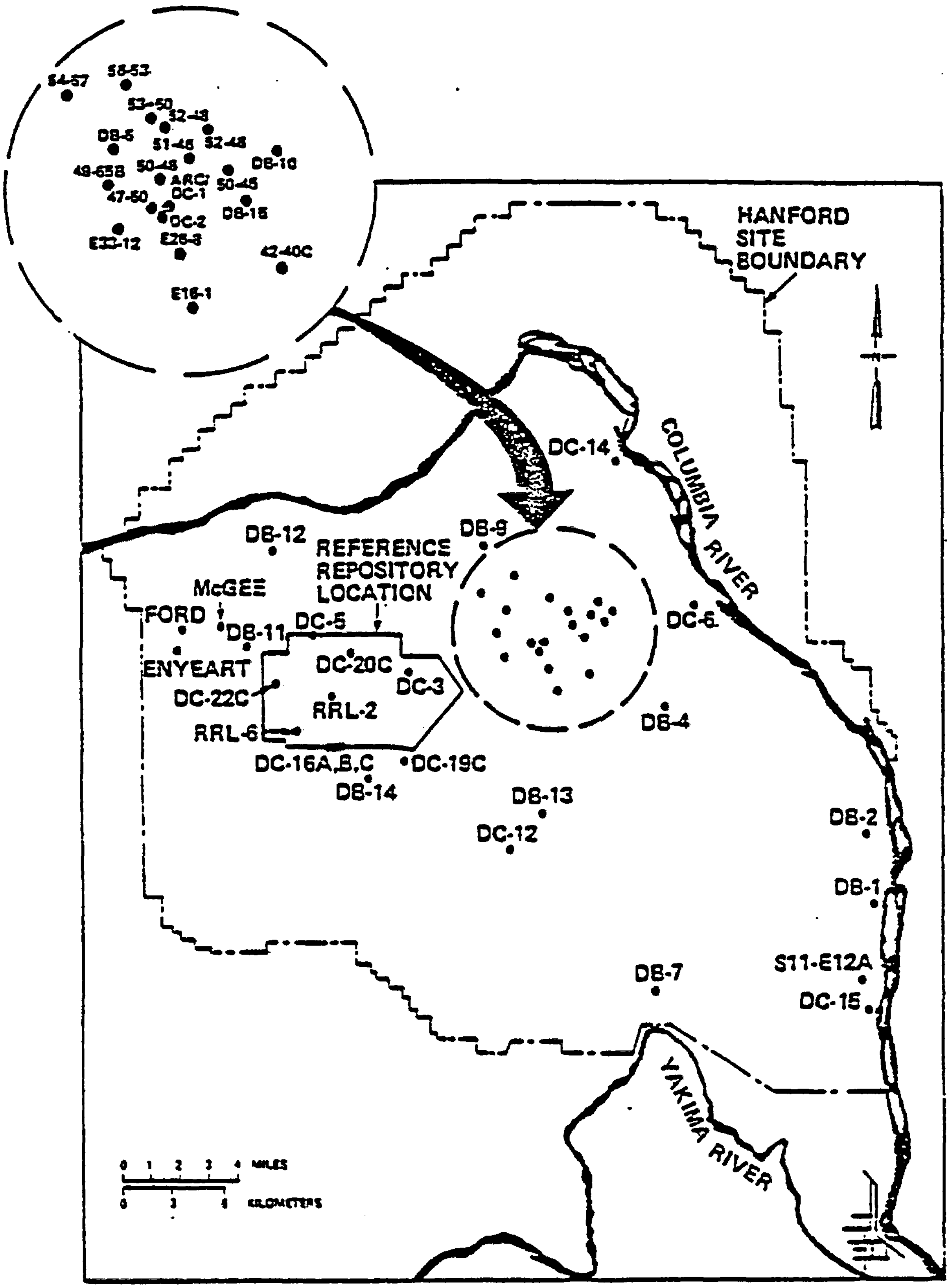

FIGURE 3 Location of Sampling Boreholes for the Confined Aquifers. (from Early, T.O, R.D. Mudd, G.D. Spice, D.L. Starr, 1985. A hydrochemical data base for the Hanford Site, Rockwell Report DE-AC06-77RL01030.)

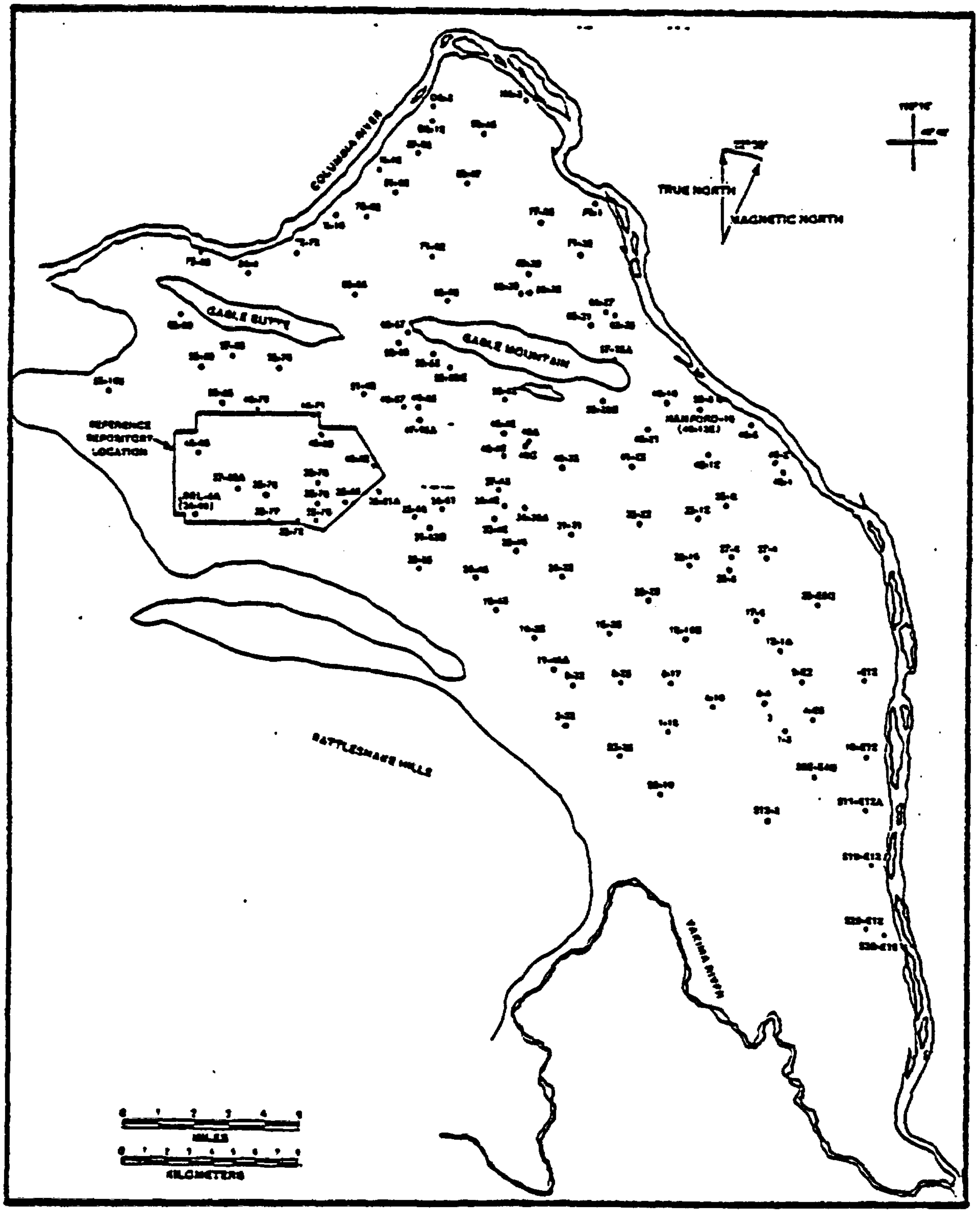

FIGURE 4. Locations of Sampling Wells for the Unconfined Aquifer. (from Early, T.O., R.D. Mudd, G.D. Spice, D.L. Starr, 1985. A hydrochemical data base for the Hanford Site, Rockwell Report DE-AC06-77RL01030.)

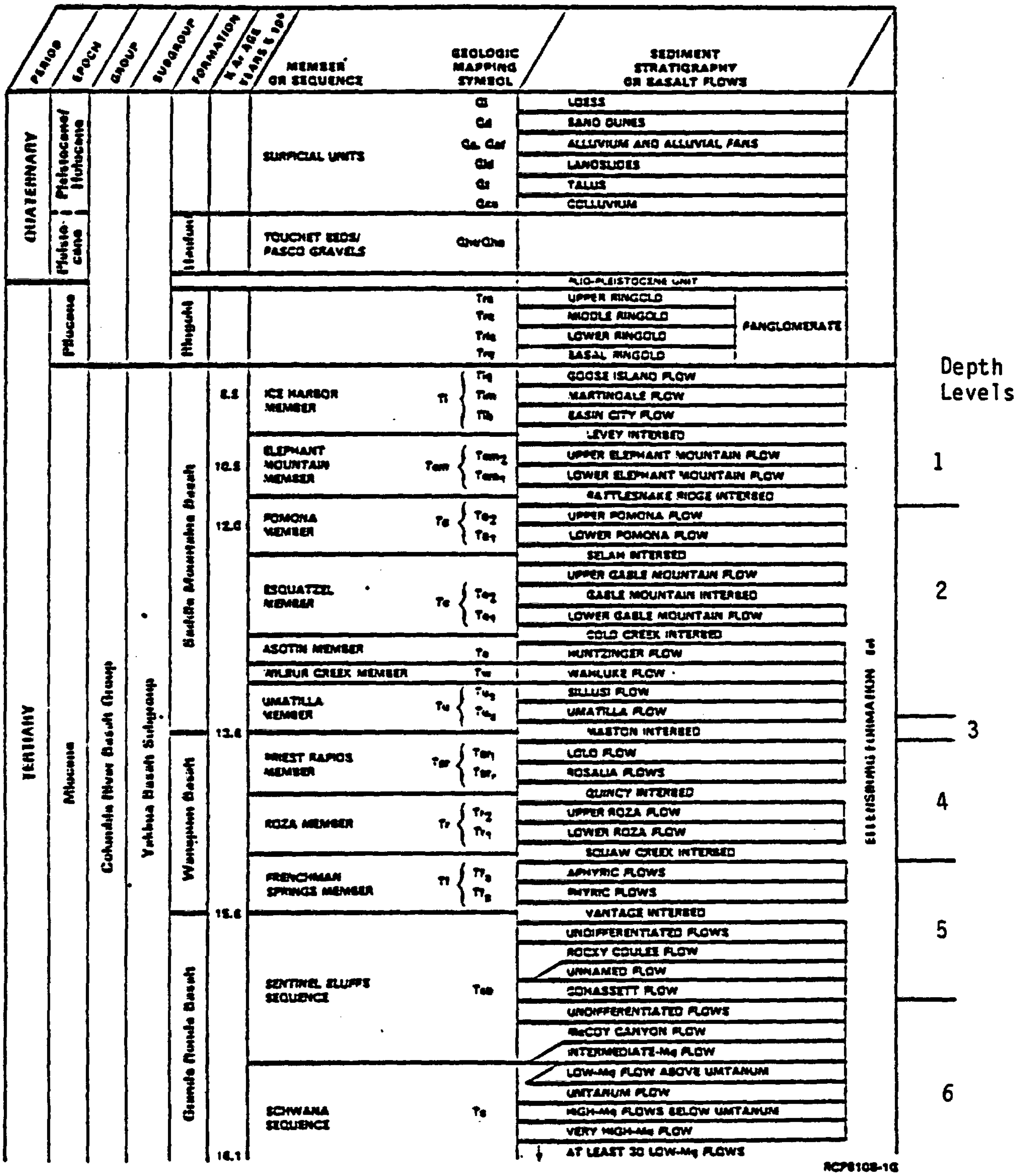

FIGURE 5. Stratigraphic Units Present in the Pasco Basin.
(modified from Early, T.O, R.D. Mudd, G.D. Spice, D.L. Starr, 1985. A hydrochemical data base for the Hanford Site, Rockwell Report DE-AC06-77RL01030.)

with an electrical balance greater than five were removed from consideration. Although five is fairly conservative, there were few data in the five to eight range that would have been retained by using a larger balance check and the additive effects by such analyses on the balances of the averages was undesirable. After averaging, averaged samples with an electrical balance greater than ten were removed from further consideration, narrowing the number of averaged analyses to 80 for the confined units. Tables of the averaged and unaveraged analyses and a definition of the well numbering used are given in the data appendix of this report.

The averaged analyses have been plotted on Durov diagrams (Zaporozec, 1972) in order to graphically examine the hydrochemical character of the waters at BWIP. The plots show the fairly detailed changes in character both downhole and areally that are indicative of important processes occurring at the site. Durov diagrams are similar to better known Piper diagrams (Piper, 1944) with the advantage of allowing the user to plot two parameters in addition to relative concentrations of common ions. For this work, pH and sample temperature were chosen as the additional parameters. The diagram then shows: the relative concentrations of all common ions in the center square, the relative concentrations of common cations in the left triangle, the relative concentrations of common anions in the upper triangle, the pH relative to the relative concentrations of all common ions in the bottom rectangle, and the sample temperature relative to the relative concentration of all common ions in the right rectangle. The reader is referred to Freeze and Cherry (1979 p. 249-251) for a further description of the diagram and discussion on its uses.

The Durov plots of the analyses are presented in the data appendix of this report. Both the unconfined and confined units are plotted with respect to depth layer; the confined units also have been plotted with respect to well number.

Processes

Various processes are indicated by the Durov plots of the analyses at BWIP, many of which are associated with the basalt mineralogy. The chemical character of water reacting with basalt trends from mixed cation bicarbonate to sodium carbonate with age. This trend is observed in the Durov plots by following the changes in hydrochemical character from the unconfined and layer 1 plots to the layer 2 and layer 3 plots. The trend is due to the dissolution of silicic minerals in the basalt by hydrolysis and carbonic acid and the precipitation of alteration minerals (Jones 1966; Hearn et al., 1984). The primary components of the basalt react with ground water in this order: glass, pyroxene, titano-magnetite, and plagioclase feldspar. These dissolutions add Na, Ca, Si, K, Fe, Ai, and Mg cations to the system. Initially, the system is very undersaturated with respect to alteration products (Deutsch et al., 1982), and the Mg and Ca dominate the solution cation assemblage. Concurrently, the reactions are generating -OH, raising the pH, inducing greater amounts of carbonate species. Eventually, the water becomes saturated with respect to alteration products and some ions start to drop out. Mg and Al precipitate in smectite clays and Fe precipitates as amorphous or mineraloid iron and oxide. As the bicarbonate is still being produced by the dissolution of the primary minerals, calcite becomes saturated and precipitates, lowering the quantities of calcium in solution dramatically. The system also becomes saturated with clinoptilolite and silica which precipitate removing K and Si, respectively. Much more sodium is dissolved than precipitated, and it is left as the dominant cation. Ion exchange on the precipitated smectite clays is also possible, enhancing the high sodium levels even further.

Basalt water interactions can also explain the behavior of ions associated with accessory minerals. Fluoride, for example, is introduced by the dissolution of glass or minor primary minerals, such as fluorapatite, that contain significant quantities of fluoride in their structure. Initially, the fluoride is probably removed by precipitation of small amounts of fluorite, but as the easily precipitated calcite starts to compete for the available carbonate, this removal would be greatly slowed, creating an increase in dissolved fluoride. Sulfate is possibly introduced by the dissolution and oxidation of accessory basaltic sulfides at relatively shallow depths, but other sources also exist.

In addition to basalt interactions, some mixing processes clearly are occurring at the site. Although some chloride can be admitted to the system by dissolution of accessory minerals or glasses that have chloride trapped in their structure, this process cannot account for the large chloride values at the site observed with increasing depth. The Durov plots of layers 5 and 6 show that higher sulfate, sodium and dissolved solids are associated with this chloride occurrence. The assemblage clearly indicates a sedimentary origin, a hypothesis supported by the isotope data. The origin of these waters is apparently upwelling from the Eocene sedimentary units that underlie the basalts.

The Durov plot of the unconfined layer shows that another observable mixing process is occurring in the shallow regions of the system. High sulfate waters not associated with chloride are observed and are apparently due to an influx of irrigation waters. In areas where higher sodium waters are used to irrigate, the soil becomes less friable as the clays absorb the sodium, and gypsum is sometimes applied to counter this effect. This seems a sensible hypothesis as to the origin of the shallow high sulfate waters and probably is a significant factor. However, the shallow high sulfate waters are sometimes associated with a relatively high pH, which would not be expected. Therefore, the sodium is probably also associated with the dissolution of basalt sulfides, or the presence of concentrated flood waters. This last possibility would be consistent with occurrences of other areas of shallow high sulfate waters that exist in the general region. The waters that have drained into the Columbia have, in the past, been high in sulfates. During Pleistocene floods, these waters have been left in places as bodies of water that, when evaporated, become alkalai lakes. These lakes, such as Moses Lake, contain both high sulfate and high pH values. Perhaps there was a similar occurrence at some time in the BWIP site history.

Discussion

The question we are attempting to answer is, "How do the described processes relate to a conceptualization of ground-water flow at the BWIP site?" First, consider the DOE BWIP conceptualization. DOE suggests that the most likely flow path is one of purely horizontal flow through a relatively permeable flow top. If questioned as to how the hydrochemistry at the site relates to this proposed flow path, DOE would most likely point back to the work presented in the SCR and suggest that the sudden changes in geochemical nature from bicarbonate to chloride that occur downhole, indicate an overall extremely dominant horizontal component of flow. The upwelling would be explained as occurring so slowly at the present time as to be insignificant. While it is true that the sudden shifts in geochemical nature observed are best explained by a dominance of horizontal flow at that point, the data suggests that vertical flow has been extremely significant overtime and still is most likely occurring in recent time.

The concept of vertical flow is supported by the variability in the depth at which the hydrochemical shifts take place and the typically consistent nature of the water in a given well below that depth. If horizontal flow was the extremely dominant flow component, the downhole geochemistry shifts would tend to occur at similar depths and the wells would likely have a series of shifts at similar depths relating to horizontal flow in the many units. Instead, the flow appears to be both horizontal and vertical, creating a step-like pattern as the vertical flow is point specifically inhibited by the occurrence of laterally discontinuous non-fractured confining beds.

Examining the data tables, the RRL area has the highest chloride values found at depth in the area. In contrast, the wells west of the postulated hydraulic barrier west of RRL and the wells north of the Gable Butte flow divide have the lowest chlorides at depth. This indicates the flow barrier is possibly a fault that allows significant upward flow bringing the high chloride waters into the Grande Ronde. From that point, the depth at which shifts in the chloride concentrations occur seems to shallow toward both wells DB-7 and DC-6. Waters from depth discharging into the Columbia River seems well within the range of reasonable possibility.

Conclusion

The geochemistry clearly indicates the need for consideration of vertical leakage through local heterogeneities in any ground-water flow path conceptualization. The path best supported by the geochemistry data is a step-like path to the east or southeast of the RRL. Upward leakage into the Columbia River from depth appears to be likely and should be carefully considered in any conceptualization regarding the BWIP site.

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DATA APPENDIX

DATA TABLES

Well locations and well numbers.

Well	Well No.
299-E16-1	1
299-E26-8	2
299-E33-12	3
699-42-40C	4
699-47-50	5
699-49-55B	6
699-50-45	7
699-50-48	8
699-51-46	9
699-52-46A	10
699-52-48	11
699-53-50	12
699-54-57	13
699-56-53	14
DB-01	15
DB-02	16
DB-04	17
DB-05	18
DB-07	19
DB-09	20
DB-10	21
DB-11	22
DB-12	23
DB-13	24
DB-14	25
DB-15	26
DC-01	27
DC-02	28
DC-03	29
DC-05	30
DC-06	31
DC-07	32
DC-12	33
DC-14	34
DC-15	35
DC-16A	36
DC-16B	37
DC-16C	38
DC-19C	39
DC-20C	40
DC-22C	41
ENYEART	42
FORD	43
MCGEE	44
RRL-02	45
RRL-06	46
RRL-14	47
S11-E12A	48

CONFINED UNITS AVERAGE VALUES

CA	MG	NA	K	ALK	SO4	CL	PH	TEMP	W#	U#
27.00	9.75	31.00	10.20	144.50	33.00	1.10	8.70	23.00	1	1
20.00	9.20	18.50	9.90	103.50	27.50	7.85	8.30	20.05	2	1
15.30	8.20	29.80	10.00	126.50	17.00	4.55	8.00	18.80	4	1
46.00	18.50	22.00	7.20	95.00	100.00	31.00	7.80	19.40	5	1
38.00	12.05	11.50	6.85	121.00	20.50	13.15	7.60	18.25	6	1
19.00	6.20	33.00	11.00	114.00	31.00	26.00	8.20	19.80	8	1
30.00	10.90	21.00	7.30	114.00	29.00	21.00	7.60	17.20	12	1
1.69	0.46	97.57	12.97	199.00	0.40	16.30	8.42	20.83	15	3
0.48	0.12	100.17	15.62	134.00	16.35	47.25	8.81	21.90	15	4
1.15	0.36	105.05	12.20	207.00	0.50	16.85	8.57	24.60	16	3
0.67	0.21	101.27	16.77	134.20	37.00	30.85	8.55	18.70	16	4
0.77	0.19	65.20	11.20	190.96	0.67	7.40	8.31	24.75	17	3
1.41	0.49	94.72	13.52	173.92	1.75	28.82	8.32	20.12	18	3
1.42	0.11	117.45	13.02	172.50	1.27	59.37	9.27	23.50	19	3
0.49	0.11	72.89	11.09	140.31	12.59	10.38	8.46	22.09	20	3
1.80	0.22	100.60	9.45	193.00	0.25	37.55	9.61	18.50	21	3
14.79	8.26	33.60	10.06	144.71	0.30	4.53	8.19	11.40	22	4
25.30	13.50	16.80	7.10	145.00	19.10	4.60	8.05	15.80	23	2
20.95	12.12	36.90	7.80	159.00	16.95	6.80	8.12	18.60	23	3
17.72	9.97	33.75	9.89	164.70	1.30	5.17	8.28	18.30	23	4
26.62	10.70	23.56	6.70	152.75	13.62	3.90	8.11	10.35	24	1
8.65	1.09	63.22	11.74	165.00	3.55	3.80	8.31	24.65	24	2
9.62	2.24	61.75	10.50	166.00	1.75	4.60	6.27	26.55	24	3
42.45	15.84	17.05	6.40	152.00	39.15	5.30	8.41	18.90	25	1
17.45	6.71	36.19	7.70	153.25	3.54	3.65	8.60	22.30	25	2
2.09	0.58	71.37	10.77	158.00	2.97	11.33	8.13	23.03	25	3
1.97	0.02	133.95	16.98	128.40	0.50	129.00	9.31	0.00	25	4
19.25	5.00	43.20	11.00	98.40	38.40	7.75	7.00	17.40	26	1
1.97	0.43	87.44	9.14	186.12	0.90	4.96	8.20	21.22	26	2
1.91	0.42	92.85	11.05	194.70	2.85	6.90	8.70	22.80	26	3
2.11	0.46	166.39	16.74	155.34	14.31	104.07	9.47	23.97	26	4
2.37	0.47	89.00	9.50	169.29	4.77	22.40	2.60	21.54	27	2
2.45	0.10	141.50	10.50	171.00	3.70	84.00	9.59	26.75	27	3
3.90	0.20	168.00	12.33	159.33	8.00	116.67	10.05	28.80	27	4
0.62	0.08	154.33	4.80	189.67	12.27	76.83	9.58	53.23	27	6
337.00	0.15	4330.00	734.00	143.00	162.00	7392.00	10.80	0.00	29	6
0.81	0.01	221.33	3.34	165.43	63.73	84.67	10.17	42.67	31	5
1.91	0.03	280.22	5.30	142.69	149.11	166.75	10.02	32.01	31	6
2.62	0.14	166.00	5.07	159.30	51.40	68.70	8.45	21.20	32	5
6.48	0.50	330.00	4.96	152.60	144.45	243.20	9.34	24.64	32	6
1.34	0.09	131.80	15.50	141.46	0.87	99.12	9.38	22.66	33	4
1.48	0.10	151.80	13.44	157.09	1.04	113.50	9.35	24.08	33	5
2.44	0.06	162.17	10.34	169.47	7.25	121.00	9.71	31.93	33	6
7.95	1.64	53.85	11.60	120.85	25.92	6.20	8.22	17.80	34	1
5.65	0.71	68.90	12.82	142.17	18.11	6.07	8.98	20.67	34	2
7.01	0.26	79.50	12.75	151.80	29.10	11.85	9.44	17.70	34	3
2.13	0.16	76.17	15.61	149.26	17.92	5.67	9.21	28.46	34	4
2.57	0.07	208.25	13.90	178.75	93.10	144.95	9.65	24.95	34	5
1.74	0.06	312.37	6.38	113.64	130.05	230.90	9.39	31.51	34	6
9.83	3.15	59.70	12.55	162.70	0.00	9.60	8.02	17.55	35	1
3.26	0.53	117.65	12.50	248.60	0.00	12.65	8.06	20.60	35	2
2.58	0.95	109.50	13.70	232.60	0.00	17.85	8.27	19.70	35	3
1.24	0.04	102.71	13.77	150.71	2.86	50.88	9.45	26.47	35	4
6.60	0.24	214.67	12.42	86.31	132.83	191.33	9.25	24.30	35	5
3.49	0.05	278.82	7.55	90.84	165.93	213.73	9.38	27.53	35	6
10.45	4.73	101.10	4.03	229.00	21.95	3.59	8.69	21.00	36	1

CONFINED UNITS AVERAGE VALUES PAGE 2

CA	MG	NA	K	ALK	SO4	CL	PH	TEMP	W#	U#
14.95	3.50	46.70	6.43	141.00	4.45	3.57	8.04	24.10	36	2
5.97	1.48	68.65	11.60	184.00	4.60	5.00	8.86	25.40	36	3
3.20	0.10	226.64	26.00	103.94	3.22	270.07	7.81	26.90	36	4
2.70	0.10	352.25	22.12	139.50	6.98	418.50	9.25	24.20	36	5
4.81	1.46	56.45	11.45	135.00	0.00	7.36	7.20	29.40	37	3
1.56	0.10	298.50	8.97	118.00	3.99	365.50	8.76	29.70	36	5
1.68	0.10	160.00	17.30	126.00	1.58	188.00	8.40	30.50	38	6
1.89	0.15	190.50	20.15	135.50	15.73	179.00	8.75	0.00	39	4
1.88	0.20	192.00	11.80	116.00	14.80	202.00	8.75	24.40	39	5
1.99	0.29	177.00	6.27	111.00	4.60	185.00	9.05	23.30	39	6
1.56	0.10	171.00	17.40	132.50	7.79	164.00	9.05	0.00	40	5
1.83	0.10	125.50	16.90	125.00	2.18	105.00	9.15	0.00	41	5
18.02	11.10	27.07	6.45	148.25	0.45	4.88	8.11	11.00	42	4
18.50	11.50	26.50	7.90	151.50	1.00	5.10	7.90	24.05	43	4
16.96	8.70	29.16	7.95	142.62	0.40	4.60	7.60	27.40	44	4
1.31	0.13	94.79	8.51	184.80	1.02	15.48	9.30	21.60	44	5
1.01	0.10	128.00	10.02	185.00	6.24	48.60	9.31	0.00	44	6
4.47	0.17	195.33	23.90	129.33	8.20	197.00	8.88	19.13	45	4
2.48	0.10	355.17	17.56	128.67	2.20	443.33	9.27	16.77	45	5
2.11	0.12	350.50	7.91	133.33	2.57	429.17	9.48	25.87	45	6
2.14	0.10	336.45	24.60	182.00	16.80	356.50	9.40	22.90	47	5
22.40	6.05	50.30	8.70	170.50	0.00	13.80	8.15	15.50	48	1

CONFINED UNITS UNAVERAGED VALUES

CA	MG	NA	K	ALK	SO4	CL	PH	TEMP	W#	U#
28.00	9.60	31.00	10.20	144.00	31.00	1.20	8.80	22.80	1	1
26.00	9.90	31.00	10.20	145.00	35.00	1.00	8.60	23.20	1	1
21.00	9.20	18.00	9.90	103.00	18.00	7.60	8.30	19.50	2	1
19.00	9.20	19.00	9.90	104.00	37.00	8.10	8.30	20.60	2	1
10.00	4.60	35.00	13.60	125.00	16.00	4.00	8.20	19.60	4	1
26.60	11.80	24.60	6.40	128.00	18.00	5.10	7.80	18.00	4	1
46.00	18.50	22.00	7.20	95.00	100.00	31.00	7.80	19.40	5	1
38.00	11.90	11.00	6.90	120.00	20.00	16.70	7.60	18.10	6	1
38.00	12.20	12.00	6.80	122.00	21.00	9.60	7.60	18.40	6	1
19.00	6.20	33.00	11.00	114.00	31.00	26.00	8.20	19.80	8	1
30.00	10.90	21.00	7.30	114.00	29.00	21.00	7.60	17.20	12	1
2.00	0.55	94.80	12.70	202.00	0.50	16.00	0.00	22.20	15	3
1.30	0.41	96.90	13.00	202.00	0.50	16.20	0.00	22.20	15	3
1.78	0.49	101.00	13.20	193.00	0.21	16.70	8.55	18.10	15	3
0.49	0.15	101.00	16.00	132.00	16.30	47.50	8.95	23.90	15	4
0.50	0.15	100.00	15.90	132.00	16.20	47.40	8.95	23.90	15	4
0.43	0.10	99.70	15.30	136.00	16.30	46.60	0.00	19.90	15	4
0.49	0.10	100.00	15.30	136.00	16.60	47.50	0.00	19.90	15	4
1.10	0.35	103.30	12.20	207.00	0.50	16.80	0.00	24.60	16	3
1.20	0.37	106.80	12.20	207.00	0.50	16.90	0.00	24.60	16	3
0.74	0.29	98.70	17.00	134.20	35.60	29.70	0.00	16.50	16	4
0.75	0.36	99.40	17.30	134.20	35.70	29.90	0.00	16.50	16	4
0.59	0.09	103.00	16.30	134.20	38.20	31.90	0.00	20.90	16	4
0.60	0.09	104.00	16.50	134.20	38.50	31.90	0.00	20.90	16	4
1.50	0.30	88.00	11.00	194.84	0.50	6.00	0.00	26.40	17	3
0.50	0.14	84.00	11.10	197.00	0.50	8.40	0.00	24.80	17	3
0.50	0.14	84.00	11.10	197.00	0.50	8.00	0.00	24.80	17	3
0.60	0.18	84.80	11.60	175.00	1.20	7.20	0.00	23.00	17	3
1.40	0.52	90.50	12.60	167.00	2.40	28.80	0.00	19.70	18	3
1.40	0.54	94.40	12.90	167.00	2.30	28.10	0.00	19.70	18	3
1.46	0.46	95.60	14.00	174.00	1.10	18.10	0.00	20.10	18	3
1.40	0.43	98.40	14.60	187.70	1.20	40.30	0.00	21.00	18	3
1.40	0.12	117.00	13.30	175.00	2.10	61.20	0.00	22.40	19	3
1.40	0.12	121.80	13.90	175.00	1.20	62.70	0.00	22.40	19	3
1.46	0.10	117.00	12.60	170.00	0.90	56.50	9.45	24.60	19	3
1.43	0.10	114.00	12.30	170.00	0.89	57.10	9.45	24.60	19	3
0.40	0.10	73.30	11.30	141.80	12.56	10.09	0.00	0.00	20	3
0.50	0.12	71.20	11.00	142.38	11.70	12.30	0.00	0.00	20	3
0.50	0.11	72.90	11.20	141.00	12.50	11.10	0.00	22.20	20	3
0.60	0.12	76.60	11.09	141.00	12.90	10.80	0.00	22.20	20	3
0.56	0.12	74.30	12.00	140.00	9.60	8.10	0.00	20.80	20	3
0.45	0.10	70.90	10.52	138.00	14.50	10.20	8.50	22.40	20	3
0.45	0.10	71.00	10.50	138.00	14.40	10.10	8.50	22.40	20	3
1.90	0.22	98.70	9.50	193.00	0.30	35.30	0.00	18.50	21	3
1.70	0.22	102.50	9.40	193.00	0.20	39.80	0.00	18.50	21	3
14.30	9.98	31.80	9.60	145.00	0.04	4.36	0.00	0.00	22	4
14.60	10.20	32.80	9.80	145.00	0.04	4.38	0.00	0.00	22	4
14.20	7.20	33.60	9.90	145.00	0.50	4.70	0.00	0.00	22	4
14.60	7.40	34.20	10.10	145.00	0.50	4.80	0.00	0.00	22	4
14.70	7.49	34.50	10.10	146.00	0.50	4.60	0.00	26.70	22	4
15.80	8.02	35.00	11.00	146.00	0.50	4.30	0.00	26.70	22	4
15.30	7.50	33.30	9.92	141.00	0.00	4.60	0.00	26.40	22	4
25.30	13.50	16.80	7.10	145.00	19.10	4.60	0.00	15.80	23	2
21.80	12.37	37.80	7.70	159.00	18.10	7.00	0.00	17.60	23	3
20.10	11.88	36.00	7.90	159.00	15.80	6.60	0.00	19.60	23	3
17.70	10.29	33.00	10.70	162.00	0.50	5.00	0.00	19.70	23	4

CA	MG	NA	K	ALK	SO4	CL	PH	TEMP	W#	U#
15.50	9.00	39.10	10.30	153.00	3.10	5.10	0.00	19.30	23	4
18.80	10.30	31.40	9.24	171.90	0.81	5.30	0.00	17.10	23	4
18.90	10.30	31.50	9.31	171.90	0.79	5.30	0.00	17.10	23	4
32.20	12.40	18.54	6.20	153.00	18.90	4.10	0.00	0.00	24	1
31.40	11.78	22.30	6.20	156.00	20.10	4.00	0.00	20.10	24	1
22.10	9.38	26.70	7.20	152.00	7.90	3.80	0.00	21.30	24	1
21.60	9.25	26.70	7.20	150.00	7.60	3.70	0.00	0.00	24	1
6.40	1.23	62.54	8.80	160.00	6.50	3.70	0.00	24.00	24	2
10.90	0.95	63.90	14.68	170.00	0.60	3.90	0.00	25.30	24	2
10.30	2.40	70.70	10.50	178.00	2.90	4.30	0.00	24.50	24	3
10.10	2.52	67.10	11.10	178.00	3.80	4.90	0.00	26.70	24	3
9.00	2.03	54.20	10.10	154.00	0.14	4.59	8.35	27.50	24	3
9.08	2.02	55.00	10.30	154.00	0.16	4.62	8.35	27.50	24	3
42.00	15.75	17.00	6.40	152.00	38.60	5.40	0.00	18.90	25	1
42.90	15.93	17.10	6.40	152.00	39.70	5.20	0.00	18.90	25	1
20.10	7.69	32.50	7.20	159.00	6.50	3.30	0.00	0.00	25	2
21.60	8.73	31.20	8.00	155.00	6.45	4.00	0.00	21.50	25	2
14.09	5.23	40.45	7.80	149.00	0.50	3.60	0.00	23.40	25	2
14.02	5.20	40.60	7.80	150.00	0.70	3.70	0.00	23.00	25	2
1.39	0.23	70.80	10.60	156.00	3.20	15.50	0.00	22.20	25	3
2.17	0.71	67.90	10.00	159.00	2.40	10.90	0.00	23.90	25	3
2.70	0.79	75.40	11.70	159.00	3.30	7.60	0.00	23.00	25	3
2.03	0.02	137.00	17.60	128.40	0.50	129.00	0.00	0.00	25	4
1.91	0.02	130.90	16.37	128.40	0.50	129.00	0.00	0.00	25	4
18.90	4.90	44.40	10.40	98.40	37.10	7.70	0.00	17.40	26	1
19.60	5.10	42.00	11.60	98.40	39.70	7.80	0.00	17.40	26	1
2.36	0.39	78.40	7.12	171.50	1.20	3.50	7.80	19.60	26	2
2.29	0.39	80.70	7.05	171.50	1.20	3.40	7.80	19.60	26	2
2.04	0.39	83.00	8.17	174.00	1.20	7.40	0.00	21.20	26	2
2.00	0.40	82.10	8.16	174.00	1.20	7.20	0.00	21.20	26	2
1.62	0.46	89.90	10.60	191.30	1.20	8.80	0.00	22.00	26	2
1.63	0.47	90.70	10.60	191.30	1.20	9.40	0.00	22.00	26	2
1.90	0.46	97.10	10.60	207.70	0.00	0.00	0.00	22.10	26	2
1.90	0.47	97.60	10.80	207.70	0.00	0.00	0.00	22.10	26	2
1.90	0.42	91.80	11.00	194.70	2.90	6.90	0.00	22.80	26	3
1.93	0.43	93.90	11.10	194.70	2.80	6.90	0.00	22.80	26	3
2.08	0.06	171.00	14.80	154.20	10.90	117.00	0.00	24.00	26	4
1.97	0.07	170.00	14.30	154.20	9.40	107.00	0.00	24.00	26	4
2.98	0.82	179.00	15.40	156.65	9.60	105.00	0.00	24.00	26	4
3.04	0.55	176.00	15.60	156.65	10.20	105.00	0.00	24.00	26	4
1.50	0.34	171.00	15.80	149.60	6.80	104.00	0.00	26.90	26	4
1.90	0.30	170.00	14.70	149.60	6.80	104.00	0.00	26.90	26	4
2.20	0.24	155.00	14.50	146.80	20.10	97.80	0.00	20.60	26	4
2.40	0.30	160.00	17.00	146.80	20.10	98.00	0.00	20.60	26	4
1.11	0.23	168.00	14.70	161.20	19.80	94.60	0.00	22.40	26	4
2.70	0.40	164.00	16.60	161.20	19.80	96.80	0.00	22.40	26	4
4.30	2.20	170.00	18.60	158.60	16.30	109.00	0.00	24.20	26	4
3.90	2.00	169.00	18.10	158.60	16.50	103.00	0.00	24.20	26	4
1.30	0.06	163.00	19.30	154.20	17.80	111.00	0.00	25.40	26	4
1.30	0.06	158.00	19.20	154.20	17.50	108.00	0.00	25.40	26	4
1.40	0.19	162.00	19.20	168.60	18.40	102.00	0.00	23.10	26	4
1.40	0.18	161.00	18.30	168.60	18.70	101.00	0.00	23.10	26	4
1.30	0.11	164.00	17.70	148.20	9.40	105.00	0.00	25.10	26	4
1.20	0.10	164.00	17.60	148.20	9.40	105.00	0.00	25.10	26	4
4.70	1.20	60.00	8.80	122.00	19.00	11.00	0.00	0.00	27	2
2.20	0.30	79.00	8.00	180.00	0.40	3.90	0.00	0.00	27	2

UNAVERAGED VALUES PAGE 3

CA	MG	NA	K	ALK	SO4	CL	PH	TEMP	W#	U#
2.00	0.40	124.00	9.60	168.00	0.40	68.00	0.00	0.00	27	2
2.20	0.30	77.00	8.40	161.00	12.00	7.70	0.00	0.00	27	2
2.10	0.30	79.00	7.80	130.00	0.00	4.20	0.00	0.00	27	2
1.70	0.40	90.00	9.90	192.00	0.00	13.00	0.00	0.00	27	2
1.70	0.40	114.00	14.00	182.00	1.60	49.00	0.00	0.00	27	2
2.40	0.10	142.00	10.00	171.00	1.80	85.00	0.00	0.00	27	3
2.50	0.10	141.00	11.00	171.00	5.60	83.00	0.00	0.00	27	3
0.90	0.40	164.00	10.00	157.00	2.00	120.00	0.00	0.00	27	4
5.80	0.10	177.00	12.00	153.00	10.00	120.00	0.00	0.00	27	4
5.00	0.10	163.00	15.00	168.00	12.00	110.00	0.00	0.00	27	4
1.20	0.20	87.00	8.00	179.00	3.60	13.00	0.00	0.00	27	6
0.80	0.00	182.00	3.30	208.00	13.00	98.00	0.00	0.00	27	6
0.70	0.10	181.00	3.90	208.00	12.00	94.00	0.00	0.00	27	6
0.60	0.10	176.00	5.90	202.00	10.00	98.00	0.00	0.00	27	6
0.20	0.10	166.00	4.70	180.00	14.00	90.00	0.00	0.00	27	6
0.20	0.00	134.00	3.00	161.00	21.00	68.00	0.00	0.00	27	6
337.00	0.15	4330.00	734.00	143.00	162.00	7392.00	0.00	0.00	29	6
0.00	0.00	233.00	3.20	163.10	96.00	125.00	10.10	46.00	31	5
1.17	0.01	217.00	3.26	166.60	95.20	129.00	0.00	41.00	31	5
1.27	0.02	214.00	3.56	166.60	0.00	0.00	0.00	41.00	31	5
4.51	0.17	350.00	15.90	137.00	197.00	296.00	0.00	21.00	31	6
4.32	0.17	365.00	16.30	137.00	194.00	290.00	0.00	21.00	31	6
1.60	0.03	270.00	6.18	163.70	163.00	145.00	0.00	19.80	31	6
1.67	0.03	269.00	6.20	163.70	161.00	146.00	0.00	19.80	31	6
1.66	0.01	310.00	6.72	114.40	190.00	166.00	0.00	16.50	31	6
1.49	0.01	310.00	6.50	114.40	193.00	152.00	0.00	16.50	31	6
2.64	0.00	359.00	3.35	83.00	177.00	289.00	9.70	37.50	31	6
2.70	0.01	360.00	3.38	83.00	177.00	289.00	9.70	37.50	31	6
0.95	0.01	209.10	1.65	151.80	79.50	96.30	0.00	44.70	31	6
0.97	0.01	218.00	0.34	151.80	79.00	96.30	0.00	44.70	31	6
1.12	0.01	212.00	1.49	155.50	81.40	108.00	0.00	41.40	31	6
1.20	0.01	208.00	2.40	155.50	81.60	105.00	0.00	41.40	31	6
0.95	0.00	242.00	1.90	173.40	157.00	76.90	0.00	43.20	31	6
0.93	0.00	241.00	1.90	173.40	157.00	79.00	0.00	43.20	31	6
2.90	0.22	133.00	5.20	177.40	23.40	40.90	0.00	19.40	32	5
2.80	0.21	134.00	5.00	177.40	26.00	39.60	0.00	19.40	32	5
2.40	0.06	199.00	5.00	141.20	78.70	97.50	0.00	23.00	32	5
2.40	0.06	198.00	5.10	141.20	77.50	96.80	0.00	23.00	32	5
3.73	0.10	235.00	3.06	158.00	74.00	126.00	9.15	25.30	32	6
3.82	0.10	226.00	2.81	158.00	74.50	126.00	9.15	25.30	32	6
3.46	0.10	259.00	3.33	141.00	83.00	137.00	9.26	26.00	32	6
3.47	0.10	258.00	3.31	141.00	83.00	136.00	9.26	26.00	32	6
7.28	1.20	312.00	8.65	158.40	225.00	171.00	0.00	19.00	32	6
5.25	1.24	303.00	4.82	158.40	232.00	180.00	0.00	19.00	32	6
4.54	0.02	416.00	5.80	108.00	173.00	418.00	0.00	26.50	32	6
4.60	0.02	433.00	5.50	108.00	175.00	420.00	0.00	26.50	32	6
11.00	0.91	438.00	6.08	197.60	172.00	386.00	0.00	26.40	32	6
17.70	1.20	420.00	6.25	197.60	153.00	332.00	0.00	26.40	32	6
1.08	0.09	142.00	15.20	137.10	3.30	103.00	0.00	22.00	33	4
1.09	0.10	145.00	15.10	137.10	2.80	104.00	0.00	22.00	33	4
1.31	0.05	123.00	13.80	139.70	0.00	96.50	0.00	23.00	33	4
1.38	0.05	123.00	16.30	139.70	0.00	95.60	0.00	23.00	33	4
1.60	0.10	126.00	13.80	143.40	1.40	105.00	0.00	22.60	33	4
1.56	0.09	123.00	13.70	143.40	1.20	103.00	0.00	22.60	33	4
1.54	0.12	135.00	17.10	147.40	0.00	89.50	0.00	21.60	33	4
1.52	0.12	135.00	17.40	147.40	0.00	89.60	0.00	21.60	33	4

UNAVERAGED VALUES PAGE 4

CA	MG	NA	K	ALK	SO4	CL	Ph	TEMP	W#	U#
1.16	0.08	135.00	16.30	139.70	0.00	102.00	0.00	24.10	33	4
1.12	0.07	131.00	16.80	139.70	0.00	103.00	0.00	24.10	33	4
1.17	0.05	148.00	15.00	144.65	1.70	127.00	0.00	20.80	33	5
1.40	0.05	165.00	13.00	163.00	2.20	110.00	0.00	24.70	33	5
1.40	0.05	169.00	12.50	163.00	0.00	101.00	0.00	24.70	33	5
1.64	0.16	138.00	13.00	157.40	0.00	116.20	0.00	25.10	33	5
1.77	0.17	139.00	13.70	157.40	1.30	113.30	0.00	25.10	33	5
5.00	0.05	159.00	16.00	210.60	15.40	104.00	0.00	26.10	33	6
4.96	0.05	157.00	15.70	210.60	13.50	103.00	0.00	26.10	33	6
1.07	0.02	161.00	7.62	146.00	4.20	130.00	9.44	41.70	33	6
1.05	0.01	163.00	7.58	146.00	4.20	130.00	9.44	41.70	33	6
1.28	0.10	166.00	7.53	151.80	2.96	127.00	0.00	28.00	33	6
1.28	0.10	167.00	7.61	151.80	3.25	132.00	0.00	28.00	33	6
9.59	1.87	58.50	9.95	132.40	28.10	5.90	0.00	18.90	34	1
9.00	1.78	58.30	9.95	132.40	28.10	5.70	0.00	18.90	34	1
6.70	1.47	49.80	13.40	109.30	24.00	6.70	0.00	16.70	34	1
6.50	1.44	48.80	13.10	109.30	23.50	6.50	0.00	16.70	34	1
15.10	2.47	30.50	12.00	107.80	17.60	4.90	0.00	20.00	34	2
16.00	2.60	31.90	13.00	107.80	18.10	5.00	0.00	20.00	34	2
1.45	0.08	78.00	13.10	144.60	17.60	5.90	0.00	19.30	34	2
1.46	0.08	79.00	12.80	144.60	18.80	7.40	0.00	19.30	34	2
4.67	0.14	83.20	13.10	166.70	19.60	7.00	0.00	19.60	34	2
4.60	0.14	83.30	13.30	166.70	19.60	5.90	0.00	19.60	34	2
0.95	0.08	81.80	12.20	149.60	14.30	7.00	0.00	23.80	34	2
0.96	0.08	83.50	13.10	149.60	19.30	5.50	0.00	23.80	34	2
7.00	0.26	79.40	12.80	151.80	29.10	11.90	0.00	17.70	34	3
7.03	0.26	79.60	12.70	151.80	29.10	11.80	0.00	17.70	34	3
2.44	0.25	64.00	20.00	134.20	21.80	6.20	0.00	24.10	34	4
2.74	0.29	65.60	20.40	134.20	21.20	6.30	0.00	24.10	34	4
3.53	0.30	65.50	22.10	140.80	24.20	6.20	0.00	23.50	34	4
3.42	0.29	64.50	20.60	140.80	24.20	6.30	0.00	23.50	34	4
3.19	0.21	62.70	21.30	134.20	16.60	6.60	0.00	28.30	34	4
3.15	0.20	61.30	20.40	134.20	16.60	6.90	0.00	28.30	34	4
3.99	0.38	72.50	13.10	145.20	0.00	7.00	0.00	20.10	34	4
4.10	0.40	71.90	13.20	145.20	0.00	7.00	0.00	20.10	34	4
1.17	0.05	76.10	11.90	145.75	20.50	6.90	0.00	30.70	34	4
1.23	0.05	79.20	12.70	145.75	20.50	6.90	0.00	30.70	34	4
0.95	0.02	73.20	11.30	146.30	16.60	0.00	0.00	30.30	34	4
1.01	0.02	74.70	11.80	146.30	17.80	0.00	0.00	30.30	34	4
0.86	0.01	79.30	13.60	160.00	18.60	5.10	0.00	34.50	34	4
0.66	0.02	78.20	14.10	160.00	18.60	5.10	0.00	34.50	34	4
0.71	0.02	114.00	11.70	187.60	24.80	7.00	0.00	36.20	34	4
0.72	0.02	116.00	11.50	187.60	24.70	7.20	0.00	36.20	34	4
1.25	0.05	148.00	9.60	206.60	18.70	70.20	0.00	27.90	34	5
1.32	0.05	151.00	9.62	206.60	18.70	70.60	0.00	27.90	34	5
3.82	0.10	264.00	18.00	150.90	169.00	222.00	0.00	22.00	34	5
3.89	0.10	270.00	18.40	150.90	166.00	217.00	0.00	22.00	34	5
4.25	0.04	316.00	8.26	109.00	145.00	231.00	0.00	19.80	34	6
4.14	0.04	316.00	8.08	109.00	144.00	231.00	0.00	19.80	34	6
4.52	0.09	325.00	8.10	124.00	135.00	237.00	0.00	14.20	34	6
1.82	0.09	344.00	7.32	106.43	112.00	258.00	0.00	0.00	34	6
1.89	0.03	162.00	9.10	156.00	58.40	67.10	9.68	31.30	34	6
1.91	0.03	162.00	9.01	156.00	57.10	65.80	9.68	31.30	34	6
1.67	0.07	267.00	6.60	123.00	105.00	185.00	9.72	36.60	34	6
1.66	0.06	265.00	6.56	123.00	105.00	186.00	9.72	36.60	34	6
1.66	0.04	294.00	6.38	112.00	122.00	214.00	9.72	37.20	34	6

CA	MG	NA	K	ALK	SO4	CL	PH	TEMP	W#	U#
1.67	0.04	298.00	6.54	112.00	122.00	214.00	9.72	37.20	34	6
1.54	0.02	306.00	6.30	109.00	130.00	224.00	9.74	37.50	34	6
1.56	0.02	303.00	6.29	109.00	129.00	224.00	9.74	37.50	34	6
1.30	0.10	323.00	5.77	109.00	134.00	249.00	0.00	28.50	34	6
1.27	0.10	316.00	5.56	109.00	134.00	247.00	0.00	28.50	34	6
1.29	0.01	337.00	5.81	103.00	141.00	253.00	9.21	31.20	34	6
1.27	0.10	336.00	5.78	103.00	147.00	253.00	9.21	31.20	34	6
1.56	0.01	336.00	5.73	110.00	141.00	254.00	9.15	29.40	34	6
1.54	0.10	332.00	5.81	110.00	141.00	254.00	9.15	29.40	34	6
1.32	0.01	338.00	5.90	114.00	140.00	254.00	9.19	30.00	34	6
2.07	0.10	337.00	5.88	114.00	140.00	254.00	9.19	30.00	34	6
1.28	0.10	327.00	5.69	114.00	140.00	254.00	9.20	29.70	34	6
1.28	0.01	328.00	5.71	114.00	140.00	253.00	9.20	29.70	34	6
1.29	0.10	331.00	5.85	107.00	141.00	254.00	9.14	30.20	34	6
1.29	0.01	330.00	5.88	107.00	141.00	254.00	9.14	30.20	34	6
1.32	0.01	336.00	5.73	110.00	141.00	254.00	9.10	30.20	34	6
1.30	0.10	335.00	5.76	110.00	140.00	254.00	9.10	30.20	34	6
1.29	0.10	334.00	5.66	108.00	140.00	253.00	9.20	30.50	34	6
1.41	0.01	335.00	5.77	108.00	140.00	253.00	9.20	30.50	34	6
1.30	0.10	336.00	5.82	110.00	140.00	252.00	9.10	30.50	34	6
1.30	0.10	326.00	5.66	110.00	140.00	251.00	9.10	30.50	34	6
1.33	0.10	332.00	5.87	109.00	138.00	251.00	9.20	36.10	34	6
1.35	0.10	333.00	5.86	109.00	138.00	251.00	9.20	36.10	34	6
10.50	3.80	60.30	12.60	167.50	0.00	11.20	0.00	17.00	35	1
10.70	3.34	61.30	12.40	167.50	0.00	11.30	0.00	17.00	35	1
8.97	2.45	58.20	12.60	157.90	0.00	8.10	0.00	18.10	35	1
9.17	2.50	59.00	12.60	157.90	0.00	7.80	0.00	18.10	35	1
3.08	0.51	112.30	12.10	248.60	0.00	15.50	0.00	20.60	35	2
3.44	0.55	123.00	12.90	248.60	0.00	9.80	0.00	20.60	35	2
2.58	0.95	109.00	13.60	232.60	0.00	17.90	0.00	19.70	35	3
2.59	0.95	110.00	13.80	232.60	0.00	17.80	0.00	19.70	35	3
1.08	0.03	89.10	11.10	130.10	2.00	46.80	0.00	24.70	35	4
1.07	0.03	91.30	11.00	130.10	2.40	46.90	0.00	24.70	35	4
1.04	0.03	97.50	14.20	138.60	0.00	38.60	0.00	26.60	35	4
1.06	0.03	97.70	14.20	138.60	0.00	35.90	0.00	26.60	35	4
1.54	0.04	98.10	14.50	148.50	2.70	40.10	0.00	27.20	35	4
1.67	0.04	97.80	13.30	148.50	0.00	39.70	0.00	27.20	35	4
1.33	0.05	102.00	15.90	162.25	1.30	44.50	0.00	23.60	35	4
1.33	0.05	100.00	15.40	162.25	1.30	44.50	0.00	23.60	35	4
0.95	0.03	111.00	14.00	151.80	7.50	66.00	0.00	27.70	35	4
0.96	0.03	117.00	13.60	151.80	7.50	64.70	0.00	27.70	35	4
1.45	0.03	118.00	14.70	173.00	4.80	70.70	0.00	29.00	35	4
1.40	0.03	113.00	13.30	173.00	4.80	72.20	0.00	29.00	35	4
3.49	0.23	199.00	10.60	94.40	140.00	170.00	0.00	28.60	35	5
3.49	0.22	200.00	10.80	94.40	141.00	165.00	0.00	28.60	35	5
5.89	0.08	213.00	14.60	86.24	119.00	224.00	0.00	20.20	35	5
6.05	0.78	217.00	14.90	86.24	119.00	224.00	0.00	20.20	35	5
10.40	0.08	229.00	11.90	78.30	139.00	183.00	0.00	24.10	35	5
10.30	0.08	230.00	11.70	78.30	139.00	182.00	0.00	24.10	35	5
7.90	0.03	235.00	14.80	52.30	198.00	206.00	0.00	28.50	35	6
7.77	0.03	252.00	23.60	52.30	198.00	205.00	0.00	28.50	35	6
2.12	0.02	264.00	5.72	108.00	131.00	189.00	9.70	37.50	35	6
2.11	0.02	262.00	5.64	108.00	133.00	190.00	9.70	37.50	35	6
4.30	0.09	362.00	8.14	66.00	214.00	308.00	9.16	23.30	35	6
4.18	0.08	355.00	8.01	66.00	214.00	308.00	9.16	23.30	35	6
2.03	0.04	267.00	3.86	88.00	175.00	222.00	9.23	32.80	35	6

UNAVERAGED VALUES PAGE 6

CA	MG	NA	K	ALK	SO4	CL	PH	TEMP	W#	U#
2.22	0.03	271.00	3.94	83.00	175.00	224.00	9.16	27.10	35	6
2.11	0.03	263.00	3.69	83.00	175.00	224.00	9.16	27.10	35	6
1.79	0.10	265.00	12.74	146.30	105.00	138.00	0.00	18.60	35	6
1.84	0.10	271.00	2.88	146.30	107.20	137.00	0.00	18.60	35	6
10.80	4.90	104.00	4.20	229.00	22.10	3.62	8.69	21.00	36	1
10.10	4.57	98.20	3.87	229.00	21.80	3.57	8.69	21.00	36	1
14.90	3.51	46.60	6.44	141.00	4.43	3.58	8.04	24.10	36	2
15.00	3.50	46.80	6.42	141.00	4.47	3.57	8.04	24.10	36	2
5.97	1.47	68.60	11.60	184.00	4.60	5.10	0.00	25.40	36	3
5.97	1.49	68.70	11.60	184.00	4.60	4.90	0.00	25.40	36	3
2.02	0.10	165.00	17.00	146.00	2.00	146.00	9.38	28.70	36	4
2.00	0.10	166.00	16.90	146.00	2.00	147.00	9.38	28.70	36	4
1.67	0.10	180.00	18.20	145.00	1.20	170.00	9.09	21.50	36	4
1.67	0.10	180.00	18.30	145.00	1.20	172.00	9.09	21.50	36	4
1.67	0.10	142.00	20.30	142.00	1.90	110.00	9.05	23.80	36	4
1.67	0.10	140.00	20.10	142.00	1.90	109.00	9.05	23.80	36	4
4.83	0.10	232.00	34.40	96.00	6.70	308.00	9.11	22.40	36	4
4.90	0.10	232.00	34.60	96.00	6.51	309.00	9.11	22.40	36	4
3.87	0.10	217.00	30.20	107.60	6.10	263.00	0.00	31.60	36	4
4.06	0.10	227.00	31.50	107.60	5.95	265.00	0.00	31.60	36	4
3.89	0.10	324.00	32.00	91.00	2.26	442.00	8.95	34.20	36	4
3.82	0.10	320.00	31.60	91.00	2.26	438.00	8.95	34.20	36	4
4.36	0.10	323.00	29.40	0.00	2.60	451.00	0.00	26.10	36	4
4.31	0.10	325.00	29.50	0.00	2.52	451.00	0.00	26.10	36	4
2.74	0.10	346.00	20.00	138.00	8.42	414.00	9.32	23.40	36	5
2.81	0.10	355.00	20.40	138.00	8.42	411.00	9.32	23.40	36	5
2.63	0.10	355.00	24.30	141.00	5.50	422.00	9.18	25.00	36	5
2.62	0.10	353.00	23.80	141.00	5.60	427.00	9.18	25.00	36	5
4.80	1.46	56.30	11.40	135.00	0.00	7.36	7.20	29.40	37	3
4.82	1.46	56.60	11.50	135.00	0.00	7.36	7.20	29.40	37	3
1.53	0.10	300.00	9.05	118.00	3.98	367.00	8.76	29.70	38	5
1.60	0.10	297.00	8.90	118.00	4.00	364.00	8.76	29.70	38	5
1.63	0.10	180.00	17.30	126.00	1.58	188.00	8.40	30.50	38	6
1.74	0.10	180.00	17.30	126.00	1.58	188.00	8.40	30.50	38	6
1.72	0.16	188.00	19.40	127.00	21.90	180.00	8.50	0.00	39	4
1.76	0.15	190.00	19.70	127.00	21.40	175.00	8.50	0.00	39	4
2.04	0.13	191.00	20.70	144.00	9.89	181.00	9.00	0.00	39	4
2.05	0.13	193.00	20.80	144.00	9.75	180.00	9.00	0.00	39	4
1.89	0.21	194.00	12.00	116.00	14.80	202.00	8.75	24.40	39	5
1.87	0.19	190.00	11.60	116.00	14.80	202.00	8.75	24.40	39	5
2.00	0.31	177.00	6.34	111.00	4.63	185.00	9.05	23.30	39	6
1.99	0.27	177.00	6.20	111.00	4.58	185.00	9.05	23.30	39	6
1.56	0.10	171.00	17.40	132.50	7.79	164.00	9.05	0.00	40	5
1.56	0.10	171.00	17.40	132.50	7.79	164.00	9.05	0.00	40	5
1.85	0.10	126.00	17.00	125.00	2.16	103.00	0.00	0.00	41	5
1.81	0.10	125.00	16.80	125.00	2.20	107.00	0.00	0.00	41	5
18.00	11.00	29.00	6.70	151.00	1.80	5.40	0.00	0.00	42	4
18.00	11.00	27.00	6.40	150.00	0.00	4.80	0.00	0.00	42	4
18.10	11.20	26.30	6.41	146.00	0.00	4.67	8.13	22.00	42	4
18.00	11.20	26.00	6.30	146.00	0.00	4.65	8.13	22.00	42	4
19.00	12.00	27.00	8.50	155.00	1.80	5.80	0.00	23.90	43	4
18.00	11.00	26.00	7.30	148.00	0.20	4.40	0.00	24.20	43	4
16.50	8.50	29.50	7.50	146.70	2.00	4.82	0.00	26.80	44	4
15.90	8.40	28.30	7.56	140.00	0.00	4.40	6.88	26.10	44	4
15.60	8.26	27.70	7.31	140.00	0.00	4.60	6.88	26.10	44	4
16.60	9.29	29.70	8.85	142.40	7.20	5.00	0.00	26.30	44	4

UNAVERAGED VALUES PAGE 7

CA	MG	NA	K	ALK	SO4	CL	PH	TEMP	W#	U#
16.60	9.26	29.40	8.31	142.40	0.00	4.80	0.00	26.30	44	4
16.40	8.77	30.80	8.44	139.00	0.00	4.10	8.11	24.30	44	4
16.90	9.05	31.50	8.55	139.00	0.00	4.15	8.11	24.30	44	4
17.10	9.50	31.20	8.31	138.00	0.00	4.10	8.09	25.00	44	4
16.72	9.00	31.40	8.42	138.00	0.00	4.15	8.09	25.00	44	4
16.80	8.81	29.90	8.10	134.00	0.00	4.80	6.60	26.30	44	4
16.60	8.71	29.70	8.04	134.00	0.00	4.70	6.60	26.30	44	4
16.40	8.60	27.00	7.01	143.00	0.00	4.12	7.37	26.70	44	4
16.70	8.70	27.40	7.09	143.00	0.00	4.12	7.37	26.70	44	4
16.40	8.90	28.30	7.43	148.00	0.00	4.82	7.10	28.20	44	4
16.50	9.00	28.60	7.53	148.00	0.00	4.94	7.10	28.20	44	4
17.30	9.50	28.10	7.66	139.00	0.00	5.07	7.40	30.50	44	4
17.60	9.60	28.10	7.69	139.00	0.00	4.89	7.40	30.50	44	4
17.20	9.20	28.20	7.77	143.00	0.20	4.20	8.11	31.70	44	4
17.40	9.30	28.30	7.79	143.00	0.20	4.30	8.11	31.70	44	4
17.70	8.50	27.40	7.77	144.00	0.09	4.60	7.65	20.40	44	4
17.90	8.50	27.70	7.80	144.00	0.09	4.60	7.65	20.40	44	4
17.60	9.16	28.50	7.68	151.00	0.05	5.00	7.60	31.80	44	4
18.00	9.30	28.70	7.80	151.00	0.05	5.00	7.60	31.80	44	4
17.70	5.80	31.70	9.11	148.00	0.00	4.80	7.98	31.80	44	4
17.80	5.80	31.80	9.20	148.00	0.00	4.90	7.98	31.80	44	4
2.67	0.25	85.60	8.15	189.00	1.66	6.82	9.40	27.30	44	5
2.66	0.26	85.40	8.12	189.00	1.66	6.82	9.40	27.30	44	5
1.06	0.10	87.10	8.06	177.00	1.62	7.49	8.90	27.80	44	5
1.04	0.10	88.60	8.14	177.00	1.63	7.60	8.90	27.80	44	5
0.82	0.10	89.10	8.17	194.00	0.26	7.06	9.25	26.30	44	5
0.81	0.10	90.70	8.27	194.00	0.24	7.06	9.25	26.30	44	5
0.87	0.10	90.50	8.32	188.00	0.45	7.60	9.40	26.60	44	5
0.87	0.10	90.90	8.36	188.00	0.45	7.57	9.40	26.60	44	5
1.17	0.10	120.00	9.71	176.00	1.11	48.40	9.55	0.00	44	5
1.18	0.10	120.00	9.82	176.00	1.14	48.40	9.55	0.00	44	5
1.03	0.10	130.00	10.17	185.00	6.23	48.40	9.31	0.00	44	6
1.00	0.10	126.00	9.87	185.00	6.25	48.80	9.31	0.00	44	6
1.98	0.20	162.00	20.90	156.00	1.60	133.00	9.09	6.50	45	4
2.02	0.19	162.00	20.90	156.00	1.60	133.00	9.09	6.50	45	4
1.94	0.10	141.00	15.50	144.00	2.00	122.00	8.94	21.80	45	4
1.86	0.10	139.00	15.40	144.00	2.00	123.00	8.94	21.80	45	4
9.60	0.23	286.00	35.60	88.00	21.00	346.00	8.60	29.10	45	4
9.40	0.23	282.00	35.10	88.00	21.00	325.00	8.60	29.10	45	4
2.88	0.10	374.00	25.30	81.00	1.40	507.00	8.60	26.90	45	5
2.88	0.10	379.00	25.60	81.00	1.50	508.00	8.60	26.90	45	5
2.22	0.10	337.00	13.80	159.00	4.20	403.00	9.60	23.40	45	5
2.19	0.10	337.00	13.90	159.00	4.20	406.00	9.60	23.40	45	5
2.36	0.10	351.00	13.40	146.00	0.97	420.00	9.60	0.00	45	5
2.35	0.10	353.00	13.50	146.00	0.95	416.00	9.60	0.00	45	5
1.63	0.10	355.00	9.39	131.00	1.70	451.00	9.38	29.40	45	6
1.72	0.10	361.00	9.61	131.00	1.70	448.00	9.38	29.40	45	6
2.84	0.15	336.00	8.46	134.00	3.54	384.00	9.30	25.90	45	6
2.80	0.15	329.00	8.36	134.00	3.68	383.00	9.30	25.90	45	6
1.85	0.10	358.00	5.77	135.00	2.40	454.00	9.75	22.30	45	6
1.83	0.10	364.00	5.87	135.00	2.40	455.00	9.75	22.30	45	6
2.10	0.10	336.90	24.70	182.00	16.80	357.00	9.40	22.90	47	5
2.19	0.10	336.00	24.50	182.00	16.80	356.00	9.40	22.90	47	5
22.40	6.05	50.30	8.70	170.50	0.00	13.80	0.00	15.50	48	1

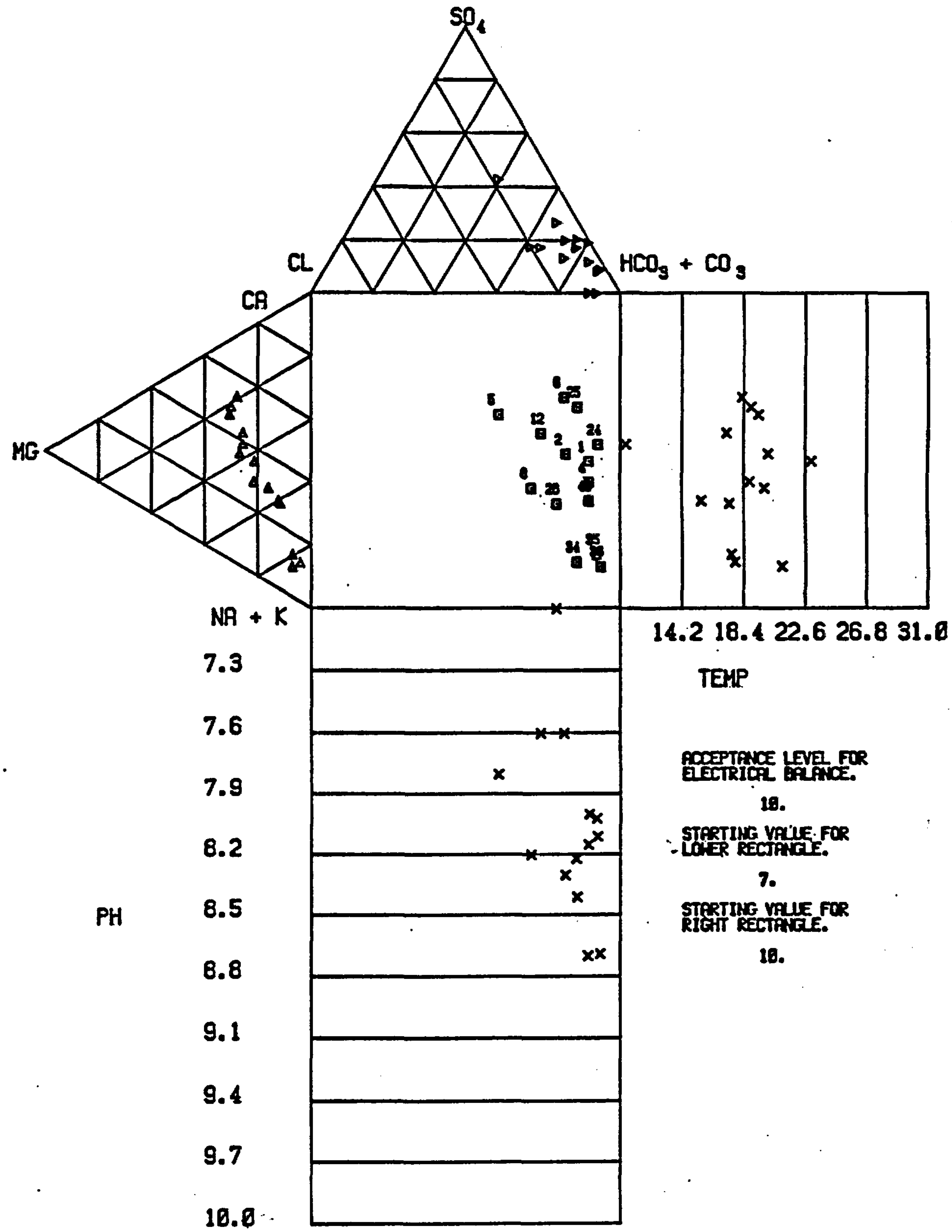
UNCONFINED VALUES

CA	MG	NA	K	ALK	SO4	CL	PH	TEMP	W#	U#
43.00	5.90	10.00	4.90	98.00	42.00	6.60	7.60	39.10	1	0
39.00	8.40	12.00	4.10	90.00	46.00	16.00	7.70	24.20	2	0
46.00	6.90	5.20	5.00	70.00	51.00	11.00	7.80	32.50	3	0
34.00	4.50	4.40	2.70	98.00	14.00	2.60	7.80	20.60	4	0
50.00	7.50	700.00	10.00	196.00	160.00	8.80	7.90	22.40	5	0
34.00	4.30	3.40	1.90	72.00	42.00	2.60	8.10	22.20	6	0
27.00	4.60	2.90	2.40	62.00	16.00	2.50	7.90	20.70	7	0
25.80	10.70	15.60	5.00	69.00	29.00	9.50	7.70	0.00	8	0
33.00	5.50	21.00	3.10	77.00	25.00	31.00	8.00	15.90	10	0
29.00	5.80	22.00	3.90	90.00	27.00	12.00	7.50	17.50	11	0
35.00	7.20	17.00	4.60	120.00	23.00	8.60	7.60	16.60	12	0
46.00	11.00	23.00	6.60	120.00	67.00	9.90	8.20	19.10	13	0
45.00	14.00	19.00	5.50	160.00	29.00	8.20	7.80	19.30	14	0
33.00	8.90	11.00	4.60	120.00	18.00	5.20	7.70	19.30	15	0
33.00	13.00	22.00	6.50	130.00	39.00	7.70	7.80	17.40	16	0
34.00	11.00	17.00	6.00	140.00	20.00	4.20	7.80	19.00	17	0
30.00	9.40	17.00	5.70	148.00	21.00	4.00	7.90	19.10	18	0
41.00	9.30	20.00	7.20	123.00	57.00	6.00	7.70	0.00	19	0
54.00	11.00	20.00	6.40	120.00	84.00	6.70	7.90	19.40	20	0
46.00	12.00	22.00	7.30	124.00	57.00	9.80	7.90	18.50	21	0
48.00	12.00	23.00	6.30	130.00	60.00	9.90	7.90	18.80	22	0
61.00	11.00	12.00	6.40	106.00	53.00	14.00	7.80	16.20	23	0
43.00	11.00	18.00	5.70	110.00	67.00	6.90	7.80	18.10	25	0
44.00	10.00	19.00	5.60	115.00	71.00	7.40	7.60	17.50	26	0
44.00	11.00	19.00	6.30	126.00	48.00	8.90	7.90	0.00	27	0
35.00	11.00	13.00	4.40	140.00	34.00	5.60	7.80	19.20	28	0
42.00	11.00	12.00	4.40	130.00	36.00	5.80	7.70	19.30	29	0
53.00	11.00	20.00	8.00	116.00	51.00	14.00	7.90	17.50	30	0
35.00	9.50	13.00	5.90	110.00	24.00	6.40	8.00	19.30	31	0
47.00	13.00	25.00	7.60	135.00	64.00	9.20	7.90	19.40	32	0
32.00	12.00	16.00	6.00	156.00	22.00	3.40	7.90	20.50	33	0
50.00	12.00	10.00	5.10	146.00	34.00	7.00	8.00	18.10	34	0
48.00	11.00	23.00	7.10	120.00	55.00	13.00	8.00	17.20	35	0
50.00	10.00	10.00	5.70	131.00	27.00	6.80	8.00	17.50	36	0
56.00	12.00	19.00	6.40	119.00	46.00	13.00	8.00	16.50	37	0
54.00	11.00	19.00	6.90	122.00	50.00	13.00	8.00	16.30	38	0
48.00	12.00	21.00	6.40	123.00	56.00	13.00	7.90	16.60	41	0
40.00	12.00	23.00	6.70	140.00	55.00	7.50	7.90	19.20	42	0
37.00	11.00	30.00	6.90	109.00	58.00	11.00	8.00	19.40	44	0
38.00	12.00	21.00	4.90	164.00	33.00	6.30	8.00	21.10	45	0
53.00	14.00	31.00	7.00	105.00	66.00	17.00	7.70	18.50	46	0
53.00	13.00	29.00	7.20	113.00	65.00	17.00	8.00	18.20	47	0
51.00	13.00	29.00	6.50	110.00	64.00	28.00	7.90	18.40	48	0
40.00	13.00	29.00	6.60	115.00	66.00	15.00	8.00	18.70	50	0
37.00	12.00	18.00	4.50	110.00	25.00	13.00	7.70	20.80	51	0
32.00	9.80	19.00	4.30	123.00	24.00	12.00	7.80	20.80	52	0
34.00	11.00	18.00	4.10	120.00	25.00	12.00	7.70	21.20	53	0
28.00	12.00	16.00	4.30	115.00	27.00	16.00	7.80	20.50	54	0
30.00	7.00	25.00	3.20	106.00	20.00	11.00	8.00	16.60	55	0
38.00	12.00	29.00	7.00	117.00	60.00	11.00	7.90	19.60	57	0
37.00	12.00	29.00	5.30	110.00	55.00	12.00	7.80	19.80	58	0
38.00	13.00	29.00	6.40	110.00	52.00	14.00	7.90	19.70	59	0
35.00	12.00	31.00	6.20	115.00	59.00	16.00	7.90	20.00	60	0
42.00	13.00	27.00	5.80	167.00	36.00	7.60	7.70	0.00	61	0
41.00	12.00	25.00	6.10	171.00	30.00	7.30	7.80	21.70	62	0
CA	MG	NA	K	ALK	SO4	CL	PH	TEMP	W#	U#

CA	MG	NA	K	ALK	SO4	CL	PH	TEMP	W#	U#
46.00	14.00	24.00	5.70	170.00	34.00	7.70	7.70	21.50	63	0
47.00	14.00	24.00	6.00	170.00	33.00	7.80	7.80	21.20	64	0
41.00	12.00	25.00	5.70	160.00	32.00	7.60	7.80	21.50	65	0
32.00	11.00	31.00	6.80	115.00	50.00	11.00	7.90	21.50	66	0
37.00	11.00	32.00	7.30	113.00	54.00	11.00	7.90	20.60	67	0
32.00	9.90	28.00	6.10	110.00	45.00	11.00	7.90	20.30	68	0
50.00	15.00	21.00	5.90	160.00	47.00	8.20	7.80	21.10	69	0
43.00	13.00	20.00	5.90	140.00	27.00	11.00	7.80	21.20	70	0
40.00	11.00	23.00	5.60	147.00	28.00	14.00	7.90	21.20	71	0
51.00	16.00	28.00	6.60	184.00	26.00	16.00	7.70	20.40	72	0
19.00	6.40	23.00	3.20	98.00	13.00	6.90	8.00	15.00	73	0
40.00	9.50	19.00	5.50	131.00	30.00	8.70	8.00	17.30	74	0
30.00	10.00	10.00	5.50	131.00	38.00	11.00	7.90	17.50	75	0
40.00	13.00	21.00	5.60	148.00	32.00	7.70	7.80	22.20	76	0
25.00	7.90	41.00	8.40	151.00	45.00	3.60	8.00	21.00	77	0
62.00	29.00	57.00	8.70	106.00	305.00	19.00	7.75	21.00	78	0
50.00	0.40	22.00	8.00	50.00	59.00	13.00	10.70	18.00	79	0
92.00	29.00	21.00	7.30	126.00	24.00	32.00	7.60	20.70	80	0
38.00	11.00	17.00	6.00	122.95	40.00	7.10	0.00	17.00	81	0
40.00	11.00	17.00	6.00	120.00	26.00	6.90	7.70	0.00	82	0
50.00	11.00	10.00	5.80	123.00	31.00	9.30	8.10	17.30	83	0
14.00	3.90	52.00	7.50	160.00	2.70	3.60	8.00	18.10	84	0
43.00	15.00	17.00	5.30	140.00	39.00	8.30	7.70	21.40	85	0
48.00	15.00	30.00	7.30	108.00	77.00	15.00	7.70	17.70	86	0
42.00	12.00	29.00	6.70	114.00	61.00	9.60	8.00	18.00	87	0
41.00	14.00	24.00	5.40	118.00	49.00	13.00	8.00	17.50	88	0
43.00	15.00	26.00	5.40	120.00	60.00	12.00	7.90	17.60	89	0
41.00	12.00	19.00	5.30	120.00	38.00	11.00	7.90	17.80	90	0
22.00	12.40	25.00	4.30	106.00	29.00	6.70	0.00	0.00	92	0
50.00	14.00	24.00	5.80	114.00	57.00	14.00	8.00	17.20	93	0
42.00	6.30	14.00	4.60	60.00	57.00	21.00	7.70	18.00	94	0
25.00	11.00	18.00	4.50	98.00	29.00	3.80	8.00	18.80	95	0
41.00	17.00	14.00	3.80	98.00	62.00	20.00	8.00	20.00	96	0
40.00	16.00	21.00	4.90	120.00	54.00	12.00	8.00	17.20	97	0
42.00	14.00	21.00	4.70	123.00	61.00	17.00	7.80	16.90	98	0
70.00	20.00	35.00	10.30	104.00	209.00	21.00	8.15	0.00	10	0
44.00	12.00	13.00	5.70	119.00	52.00	11.00	7.90	17.20	10	0
32.00	13.00	10.00	3.60	98.00	24.00	11.00	7.90	19.30	10	0
55.00	15.00	41.00	7.70	94.00	150.00	24.00	8.10	0.00	10	0
57.00	12.00	39.00	10.00	93.00	150.00	23.00	8.20	17.00	10	0
63.00	15.00	43.00	11.00	82.00	190.00	23.00	8.20	17.40	10	0
62.00	7.70	42.00	12.00	57.00	180.00	25.00	9.40	17.60	10	0
58.00	7.70	45.00	13.00	72.00	170.00	28.00	9.20	18.20	10	0
64.00	1.40	41.00	12.00	26.00	210.00	26.00	10.00	17.00	10	0
67.00	8.30	45.00	13.00	40.00	230.00	22.00	8.80	18.30	10	0
85.00	25.00	53.00	9.70	113.00	99.00	9.20	7.60	16.40	11	0
44.00	15.00	8.70	4.20	94.00	45.00	11.00	7.60	0.00	11	0
31.00	11.00	22.00	4.20	130.00	28.00	8.40	7.80	19.20	11	0
31.00	12.00	18.00	5.90	106.00	39.00	11.00	7.80	0.00	11	0
17.00	5.00	16.00	4.60	42.00	39.00	12.00	7.70	16.70	11	0
42.00	12.00	22.00	6.90	130.00	45.00	11.00	8.00	18.20	11	0
38.00	12.00	10.00	3.90	123.00	21.00	11.00	8.00	20.00	11	0
32.00	12.00	12.00	4.10	114.00	22.00	9.50	8.00	17.80	11	0
17.00	9.20	29.00	7.80	140.00	1.40	4.50	8.00	26.80	11	0
29.00	2.50	6.00	4.70	110.00	12.00	2.70	7.90	16.40	11	0
41.00	8.10	14.00	5.90	46.00	85.00	21.00	8.50	17.70	12	0
34.00	5.20	10.00	5.50	29.00	83.00	17.00	9.10	17.90	12	0

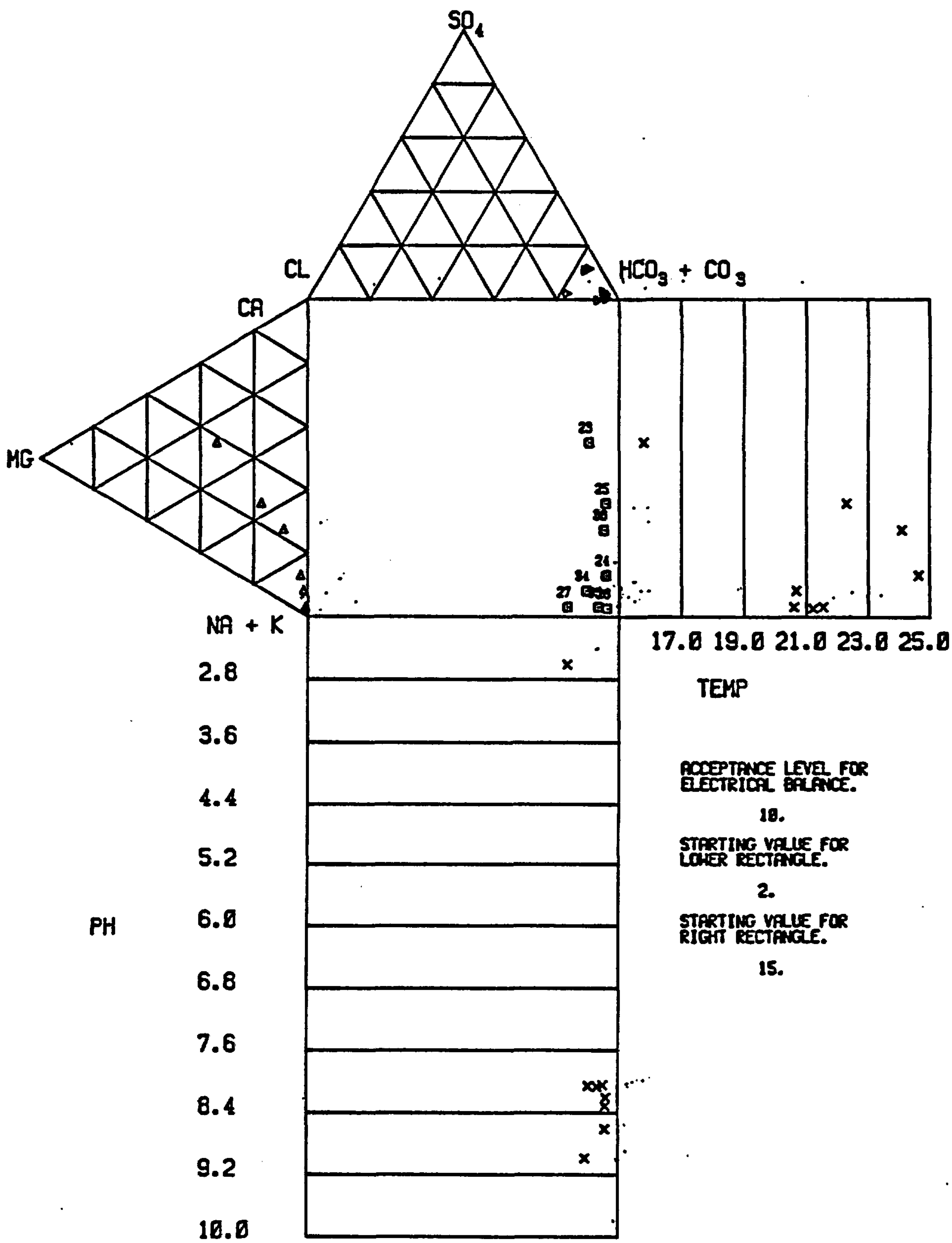
CA	MG		K	ALK	SO4	CL	PH	TEMP	WR	OR
28.00	4.90	9.60	4.80	43.00	46.00	17.00	7.70	17.00	12	0
33.00	12.00	10.00	4.40	131.00	19.00	7.50	8.10	17.70	12	0
25.00	10.50	8.50	5.40	107.00	8.40	3.70	7.25	14.40	12	0
30.00	7.10	31.00	6.60	131.00	24.00	6.10	8.10	18.30	12	0
30.00	12.00	7.60	3.50	115.00	20.00	7.50	7.70	17.30	12	0
16.00	6.50	38.00	7.80	155.00	1.80	13.00	7.95	18.50	13	0
36.00	8.10	20.00	5.20	139.00	31.00	5.30	7.30	17.50	13	0
64.00	13.00	24.00	5.20	156.00	80.00	11.00	7.80	16.80	13	0
36.00	13.00	11.00	4.70	120.00	28.00	9.10	7.80	17.40	13	0
34.00	12.00	11.00	4.40	123.00	30.00	21.00	7.80	17.00	13	0
91.00	21.00	48.00	7.10	150.00	190.00	30.00	7.80	17.70	13	0
26.00	9.20	19.00	5.40	110.00	15.00	6.30	8.00	0.00	13	0
24.00	8.20	19.00	5.00	115.00	16.00	7.20	8.00	18.00	13	0
9.30	1.30	61.00	1.30	31.00	100.00	21.00	9.60	17.50	13	0
27.00	8.40	14.00	5.40	107.00	20.00	6.20	7.90	16.90	14	0
27.00	8.30	16.00	5.50	123.00	17.00	5.00	7.90	17.40	14	0
72.00	8.80	64.00	13.00	258.00	64.00	14.00	7.50	14.50	14	0
56.00	14.00	39.00	6.20	196.00	57.00	16.00	7.80	16.70	14	0
30.00	10.00	22.00	5.50	107.00	45.00	7.30	7.90	17.50	14	0
33.00	7.50	9.30	4.50	98.00	42.00	3.90	7.50	21.20	14	0
70.00	30.00	69.00	7.10	230.00	44.00	12.00	7.80	16.60	14	0
35.00	10.00	15.00	5.10	114.00	47.00	4.30	8.10	16.50	14	0
46.00	11.00	22.00	7.30	121.00	61.00	11.00	8.00	18.40	14	0
46.00	12.00	22.00	7.30	126.00	66.00	8.50	8.00	18.50	15	0
40.00	10.00	18.00	5.90	123.00	45.00	5.50	7.80	0.00	15	0
29.00	7.40	4.00	2.60	96.00	15.00	1.30	8.00	16.60	15	0
31.00	11.00	18.00	4.40	114.00	46.00	4.30	8.10	17.10	15	0
26.00	9.60	16.00	3.50	98.00	25.00	3.80	8.00	16.90	15	0
24.00	9.70	30.00	6.90	131.00	28.00	3.50	7.80	17.90	15	0
35.00	11.00	16.00	5.70	156.00	23.00	3.70	7.40	16.50	15	0
31.00	7.10	25.00	5.40	137.70	20.00	3.10	0.00	17.50	15	0
39.00	11.00	16.00	4.60	126.00	25.00	5.80	8.00	17.50	15	0
43.00	9.80	23.00	5.60	120.00	43.00	18.00	7.90	17.30	15	0
42.00	9.60	24.00	5.80	130.00	44.00	17.00	7.90	17.70	16	0
40.00	11.00	22.00	6.00	131.00	41.00	24.00	7.90	17.10	16	0
44.00	8.80	21.00	6.50	157.00	24.00	8.10	7.80	16.70	16	0
51.00	14.00	26.00	7.30	125.00	81.00	23.00	7.90	18.50	16	0
62.00	15.00	26.00	7.70	140.00	99.00	22.00	7.80	18.90	16	0
26.00	3.10	17.00	7.00	82.00	25.00	3.70	9.40	16.80	16	0
24.00	8.10	13.00	4.70	98.00	15.00	4.60	8.30	0.00	16	0
60.00	12.00	17.00	6.00	200.00	18.00	4.10	7.50	16.60	16	0
41.00	9.50	32.00	7.60	160.00	12.00	22.00	7.80	18.00	16	0
36.00	8.90	36.00	7.80	172.00	13.00	22.00	8.00	18.20	17	0
41.40	14.50	20.20	4.40	13.80	0.00	4.14	0.00	17.90	17	0

DUROV PLOTS

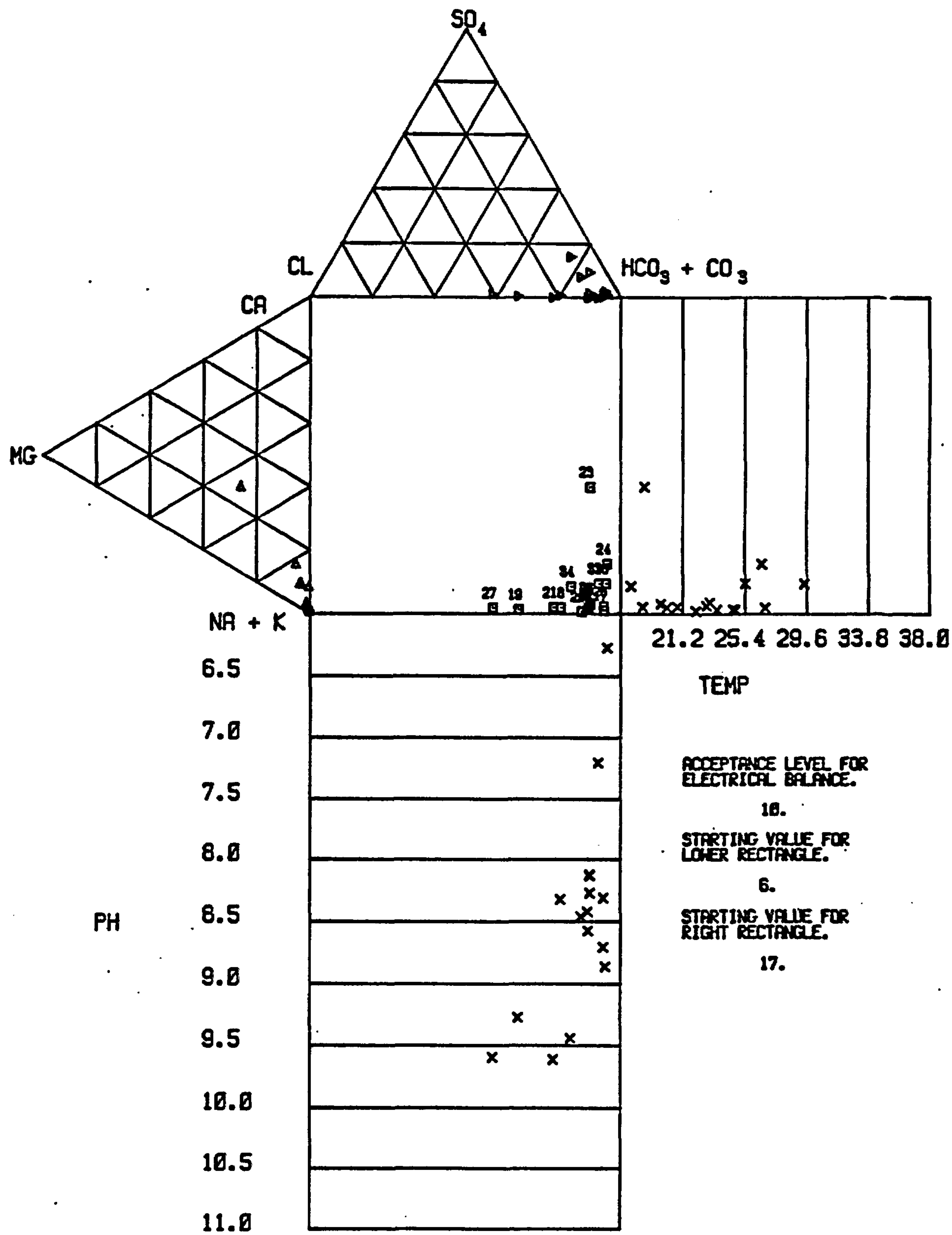


SO4
CL
HCO3 + CO3
CA
MG
NA + K
14.2 18.4 22.6 26.8 31.0
TEMP
7.3
7.6
7.9
8.2
8.5
8.8
9.1
9.4
9.7
10.0
PH
ACCEPTANCE LEVEL FOR ELECTRICAL BALANCE.
10.
STARTING VALUE FOR LOWER RECTANGLE.
7.
STARTING VALUE FOR RIGHT RECTANGLE.
10.

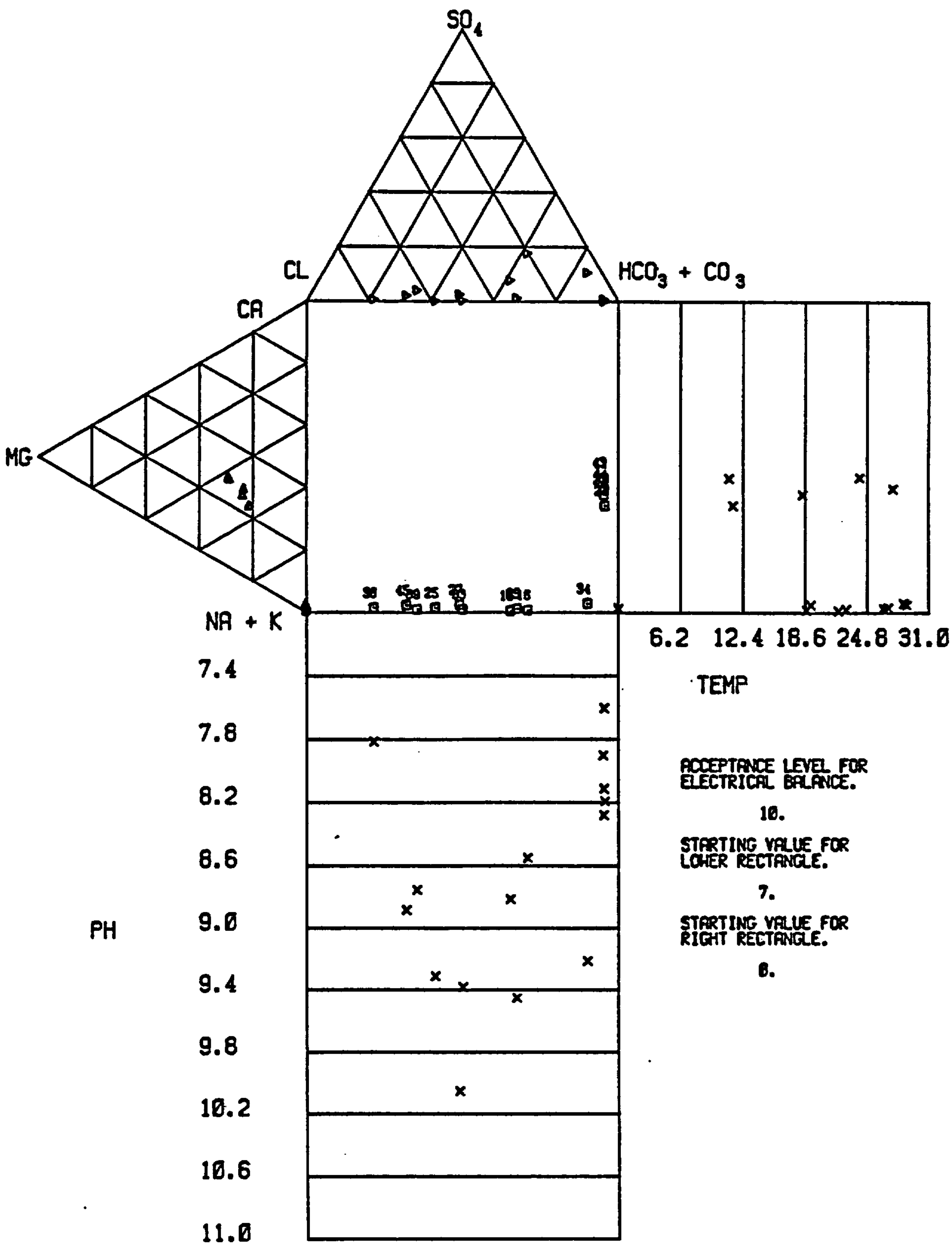
UNIT 1


SO4
CL
HCO3 + CO3
CA
MG
NA + K
17.0 19.0 21.0 23.0 25.0
TEMP
2.8
3.6
4.4
5.2
6.0
6.8
7.6
8.4
9.2
10.0
PH
ACCEPTANCE LEVEL FOR ELECTRICAL BALANCE.
10.
STARTING VALUE FOR LOWER RECTANGLE.
2.
STARTING VALUE FOR RIGHT RECTANGLE.
15.

UNIT 2

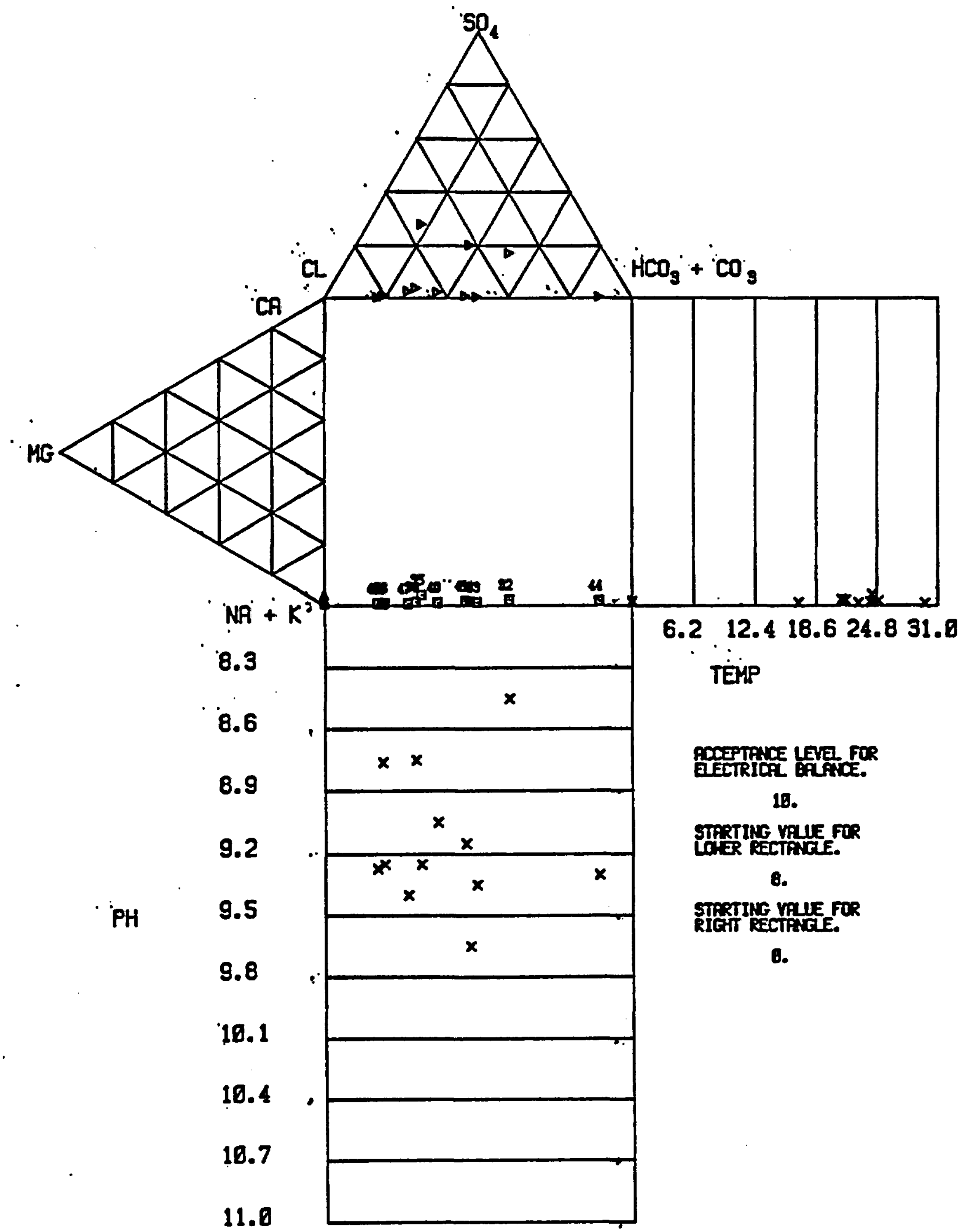

SO4
CL
HCO3 + CO3
CA
MG
NA + K
21.2 25.4 29.6 33.8 38.0
TEMP
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
10.5
11.0
PH
ACCEPTANCE LEVEL FOR ELECTRICAL BALANCE.
10.
STARTING VALUE FOR LOWER RECTANGLE.
6.
STARTING VALUE FOR RIGHT RECTANGLE.
17.

UNIT 3



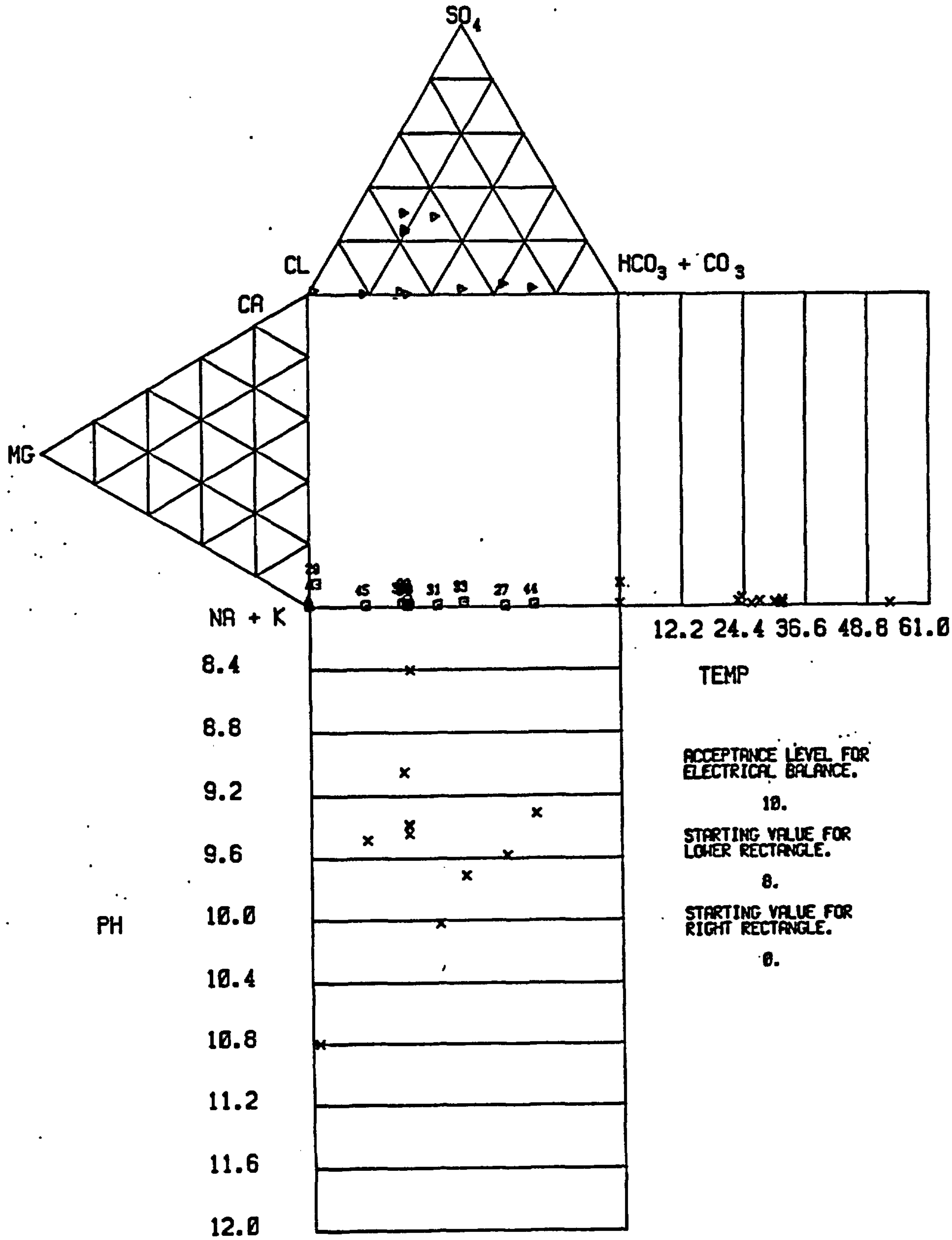
SO4
CL
HCO3 + CO3
CA
MG
NA + K
6.2 12.4 18.6 24.8 31.0
TEMP
7.4
7.8
8.2
8.6
9.0
9.4
9.8
10.2
10.6
11.0
PH
ACCEPTANCE LEVEL FOR ELECTRICAL BALANCE.
10.
STARTING VALUE FOR LOWER RECTANGLE.
7.
STARTING VALUE FOR RIGHT RECTANGLE.
0.

UNIT 4



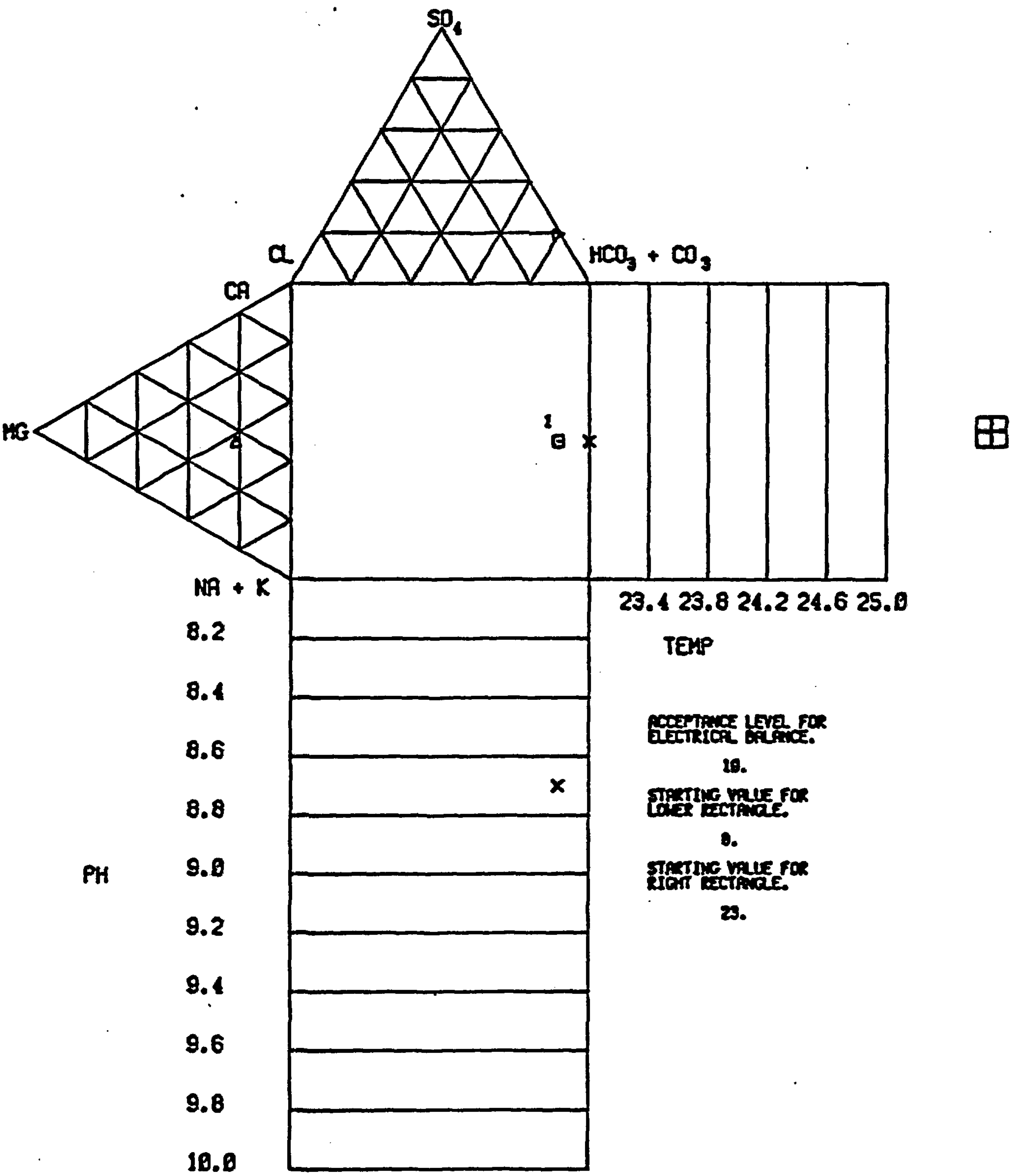
SO4
CL
HCO3 + CO3
CA
MG
NA + K
6.2 12.4 18.6 24.8 31.0
TEMP
8.3
8.6
8.9
9.2
9.5
9.8
10.1
10.4
10.7
11.0
PH
ACCEPTANCE LEVEL FOR ELECTRICAL BALANCE.
10.
STARTING VALUE FOR LOWER RECTANGLE.
8.
STARTING VALUE FOR RIGHT RECTANGLE.
0.

UNIT 5

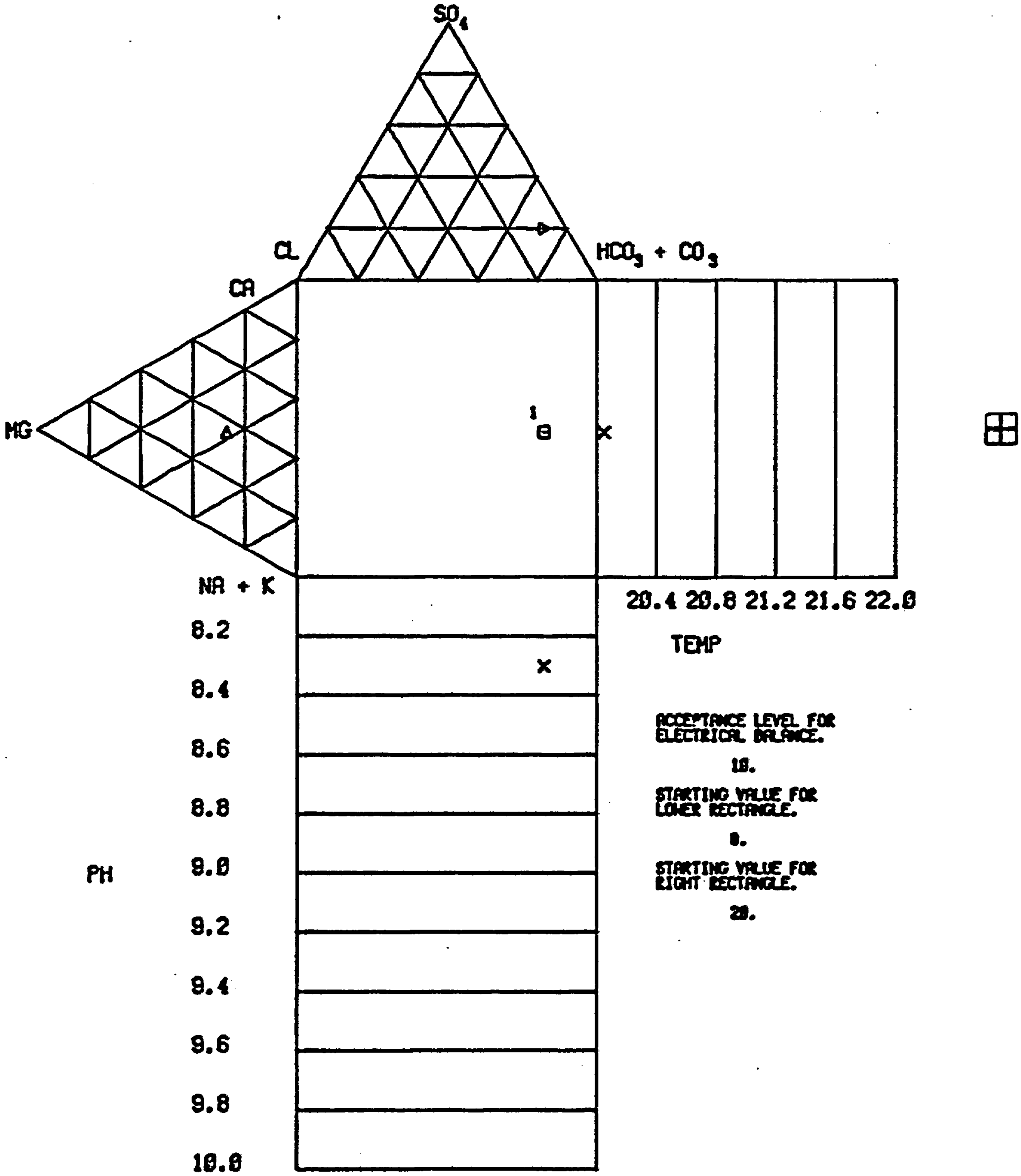


SO4
CL
HCO3 + CO3
CA
MG
NA + K
12.2 24.4 36.6 48.8 61.0
TEMP
8.4
8.8
9.2
9.6
10.0
10.4
10.8
11.2
11.6
12.0
PH
ACCEPTANCE LEVEL FOR ELECTRICAL BALANCE.
10.
STARTING VALUE FOR LOWER RECTANGLE.
8.
STARTING VALUE FOR RIGHT RECTANGLE.
0.

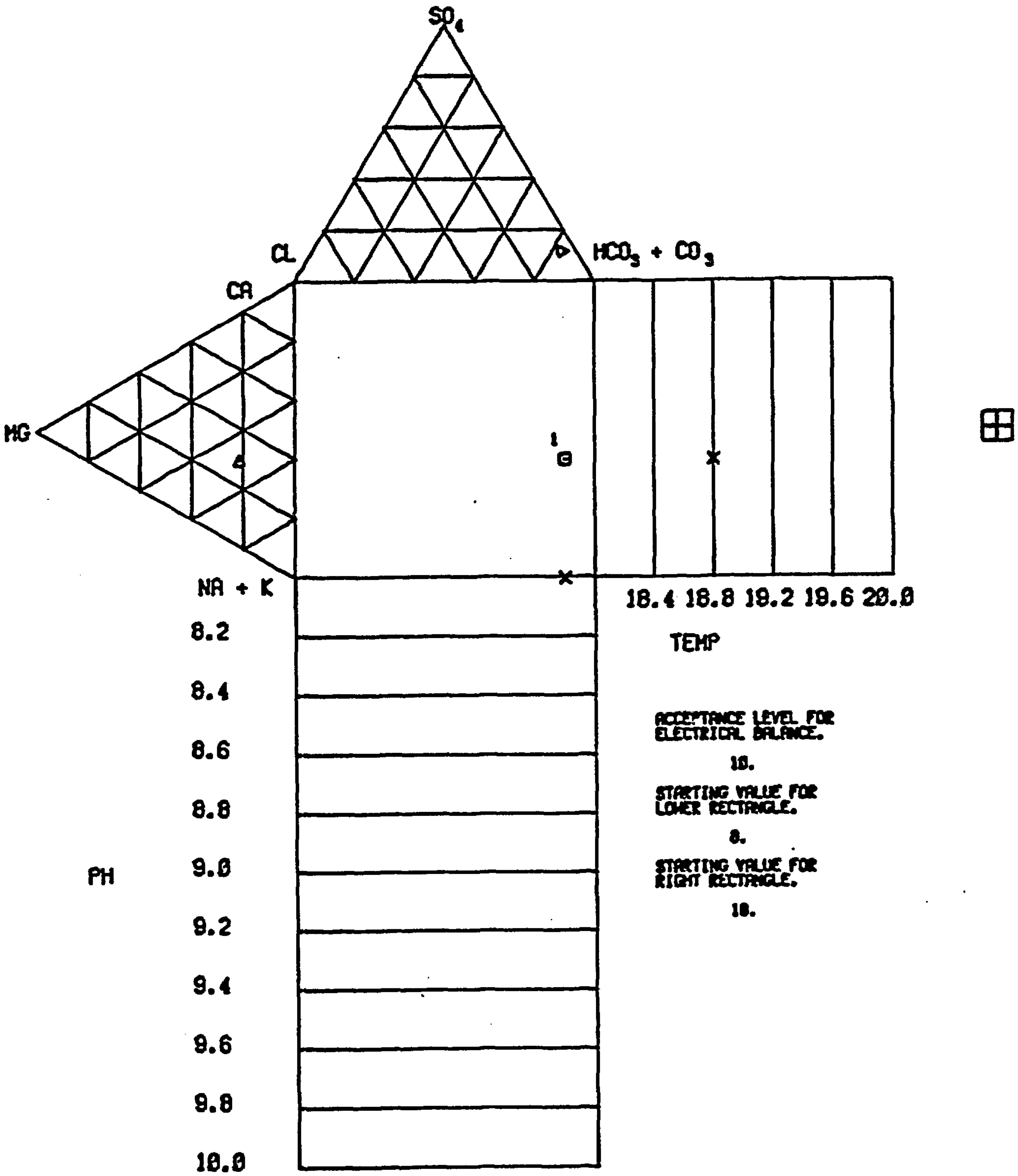
UNIT 6



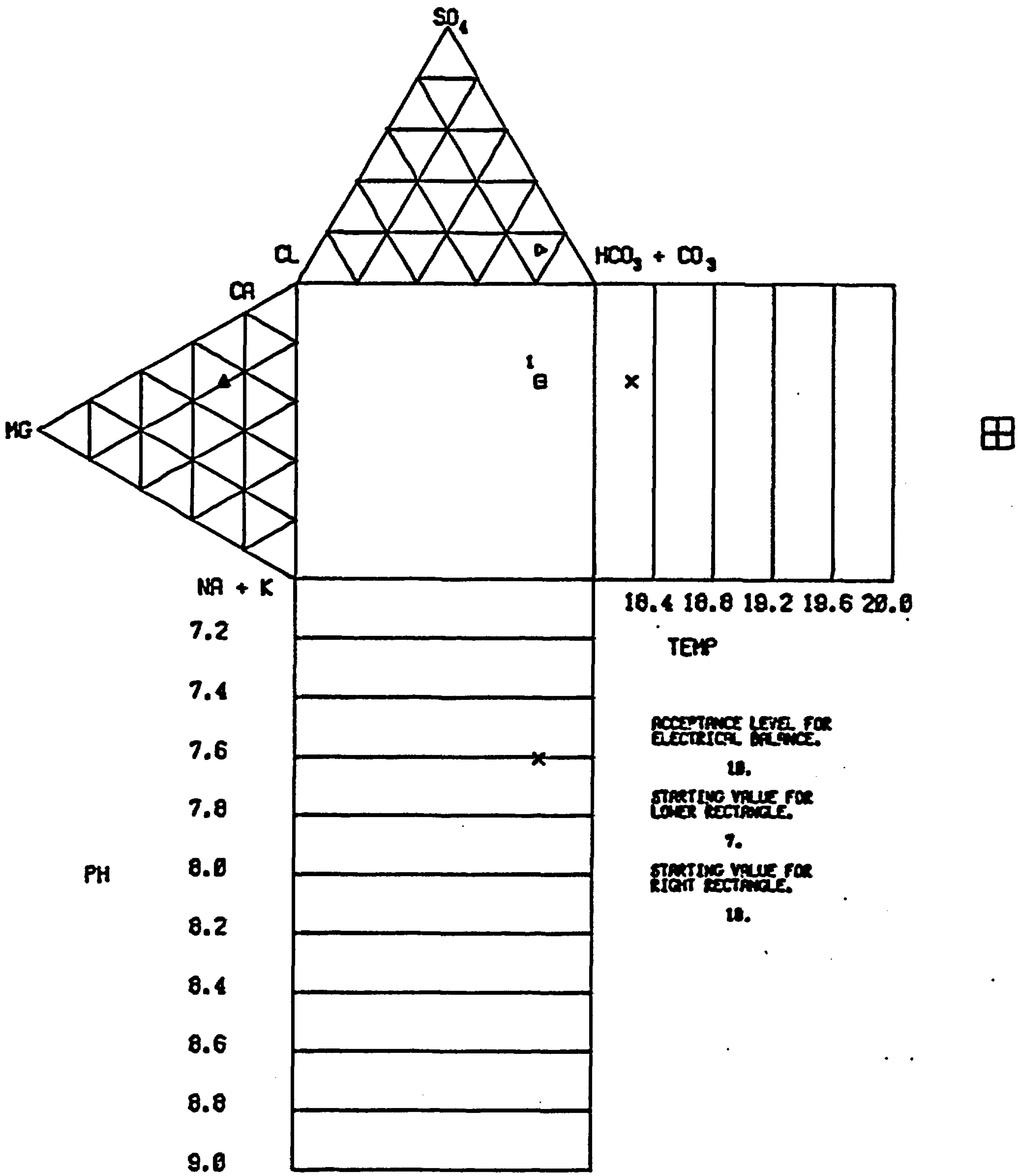
WELL 299-E16-1 (1)



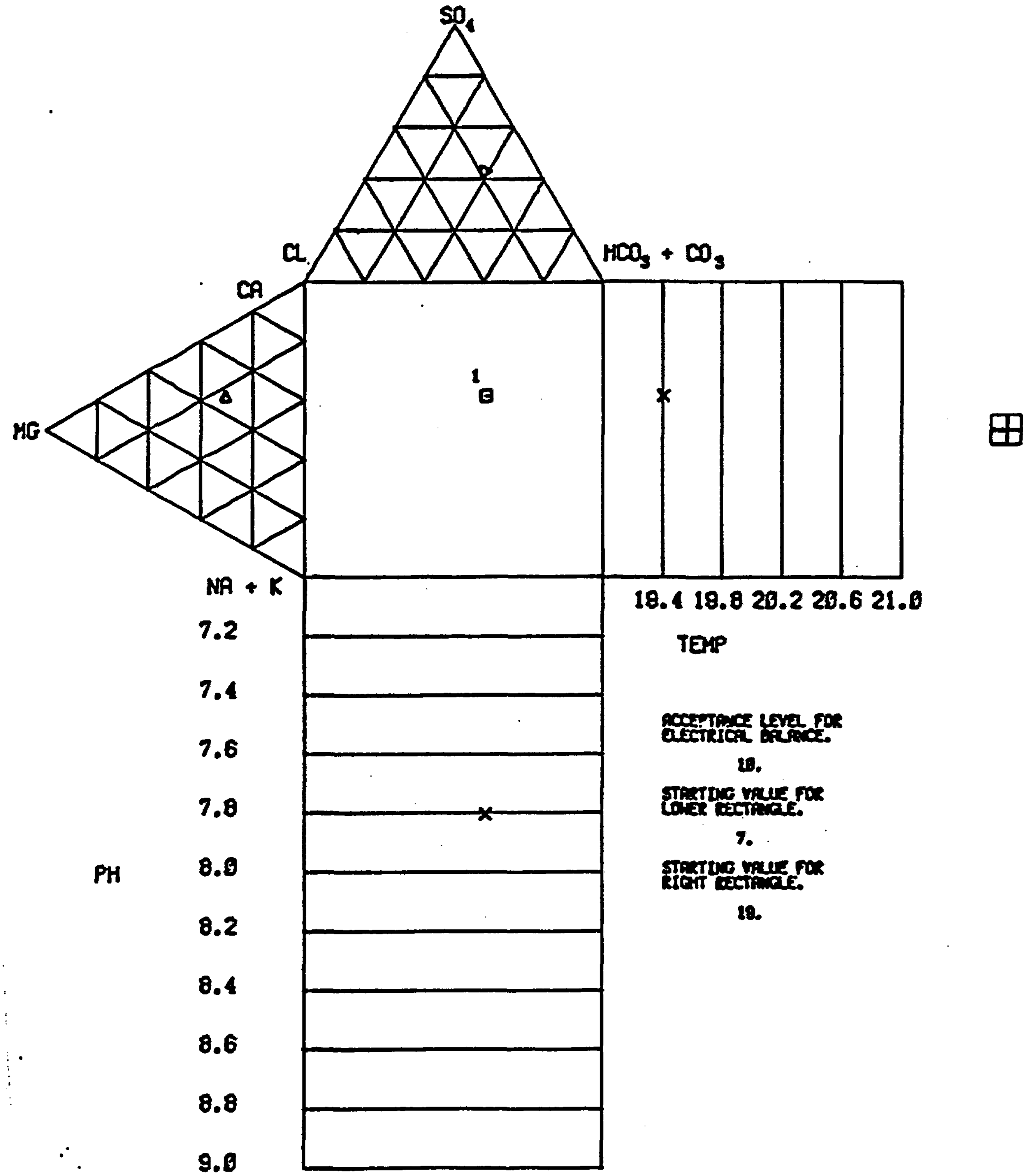
WELL 299-E26-8 (2)



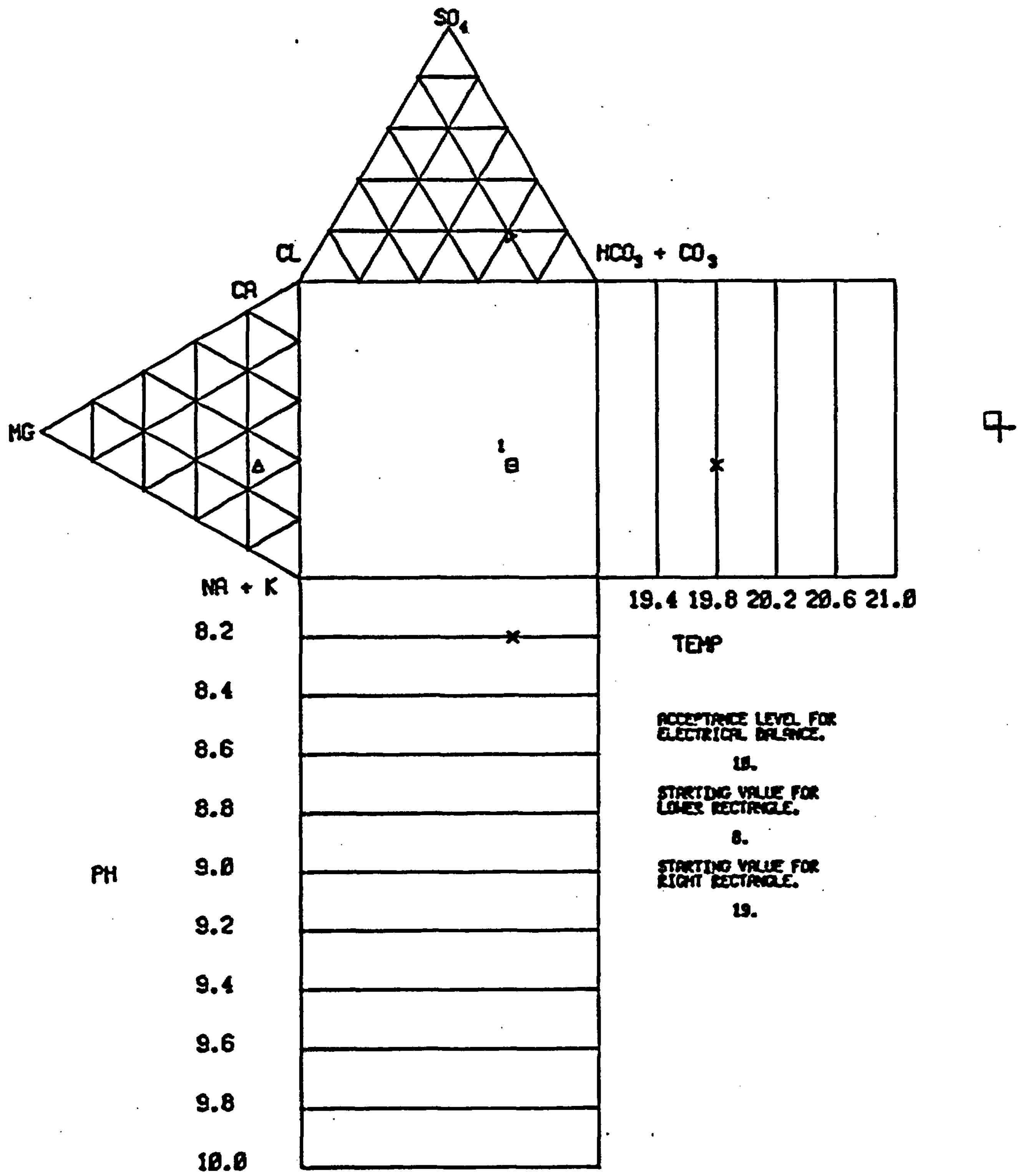
WELL 699-42-40C (4)



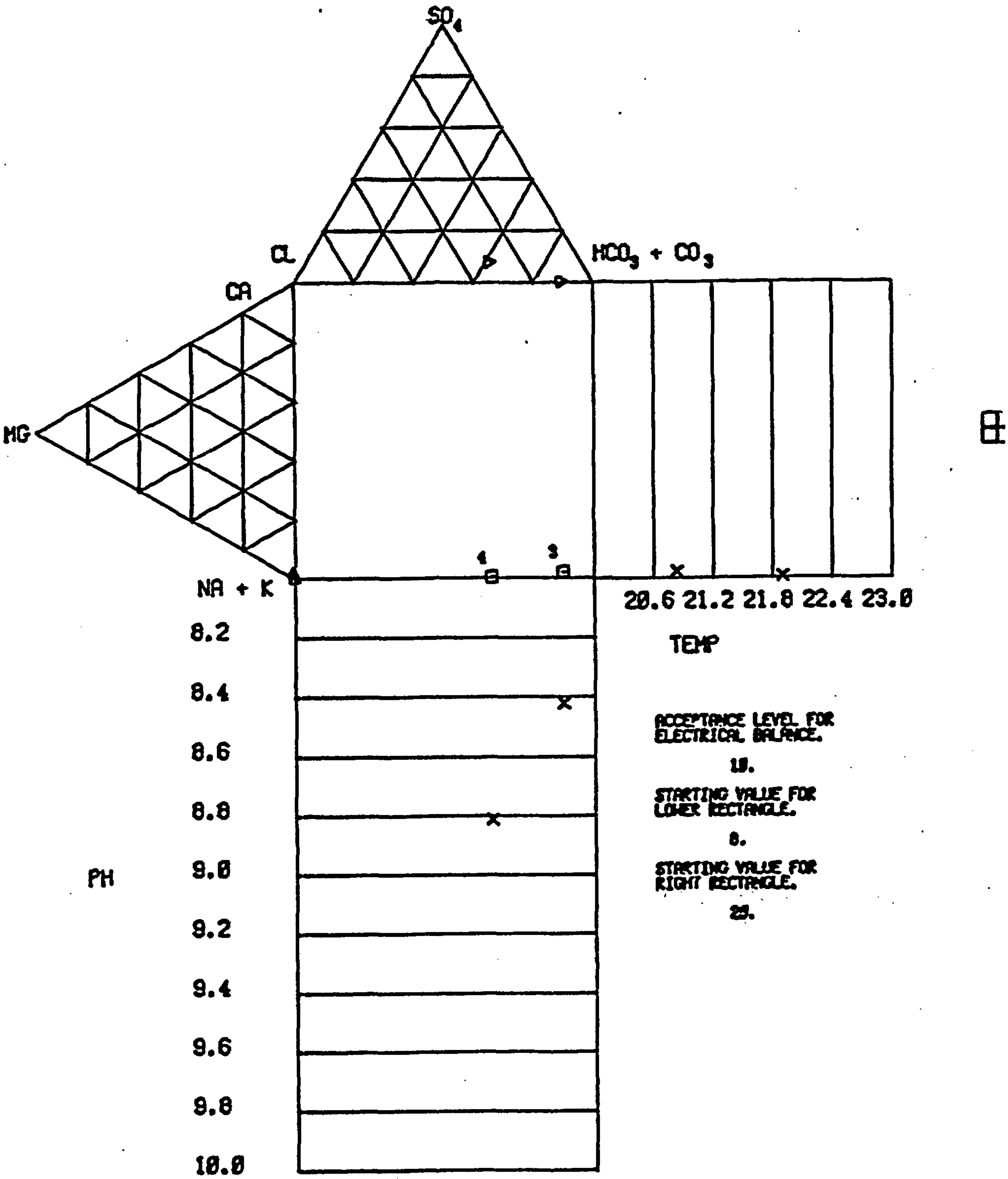
WELL 699-49-55B (6)



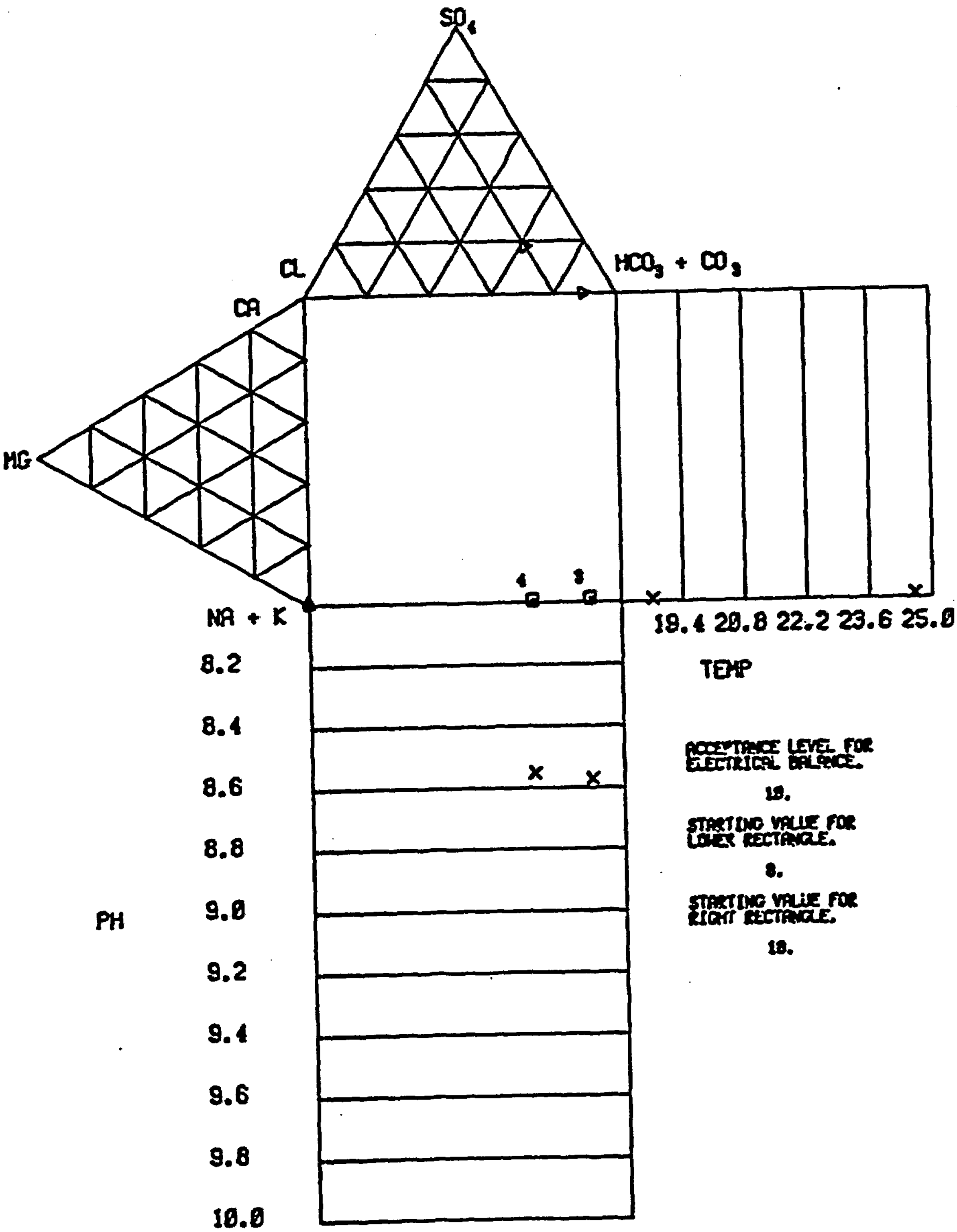
WELL 699-47-50 (5)



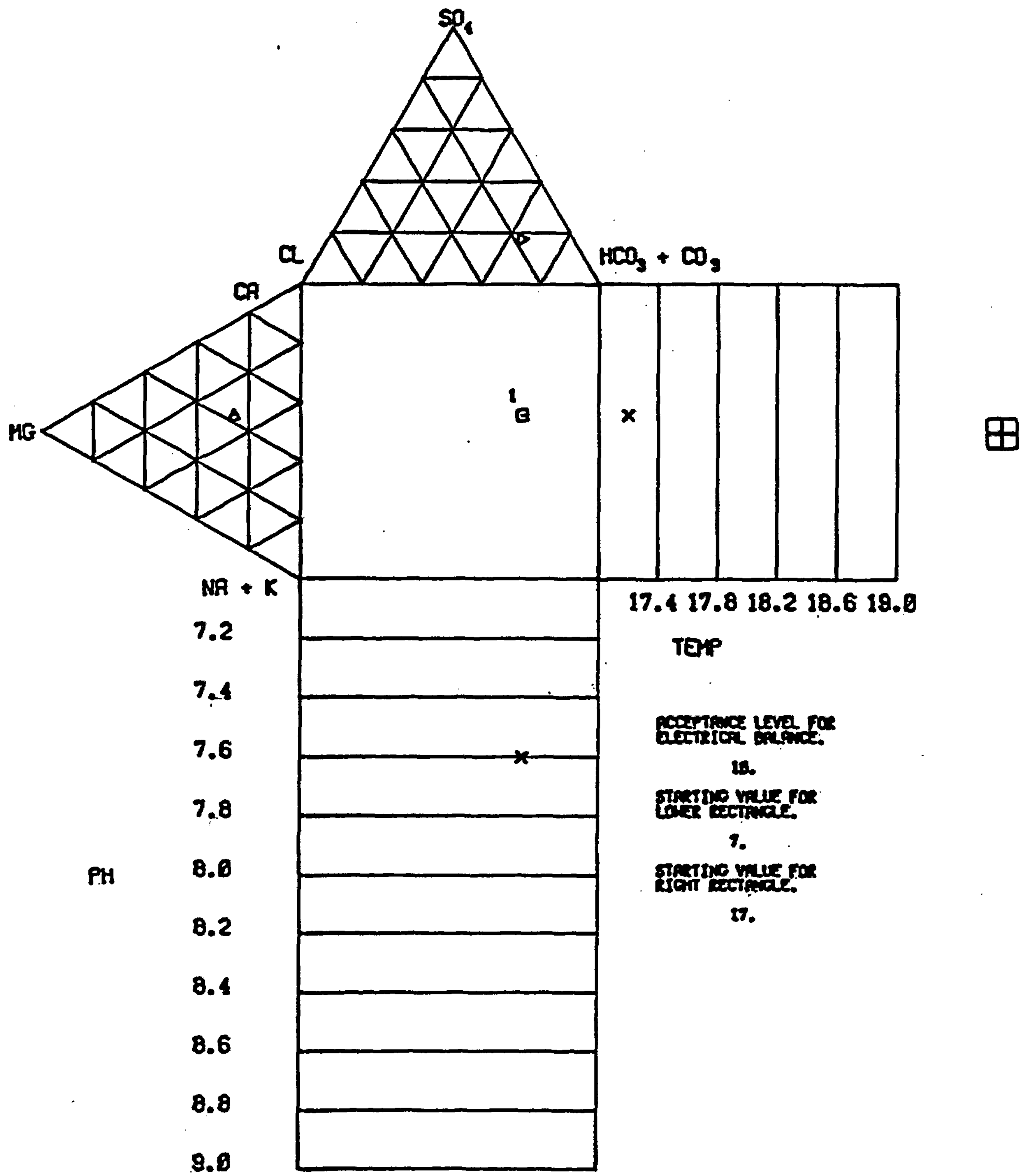
WELL 699-50-48 (8)


SO4
CL
HCO3 + CO3
CA
MG
NA + K
4
3
20.6 21.2 21.8 22.4 23.0
TEMP
8.2
8.4
8.6
8.8
9.0
9.2
9.4
9.6
9.8
10.0
PH
ACCEPTANCE LEVEL FOR ELECTRICAL BALANCE.
10.
STARTING VALUE FOR LOWER RECTANGLE.
8.
STARTING VALUE FOR RIGHT RECTANGLE.
20.

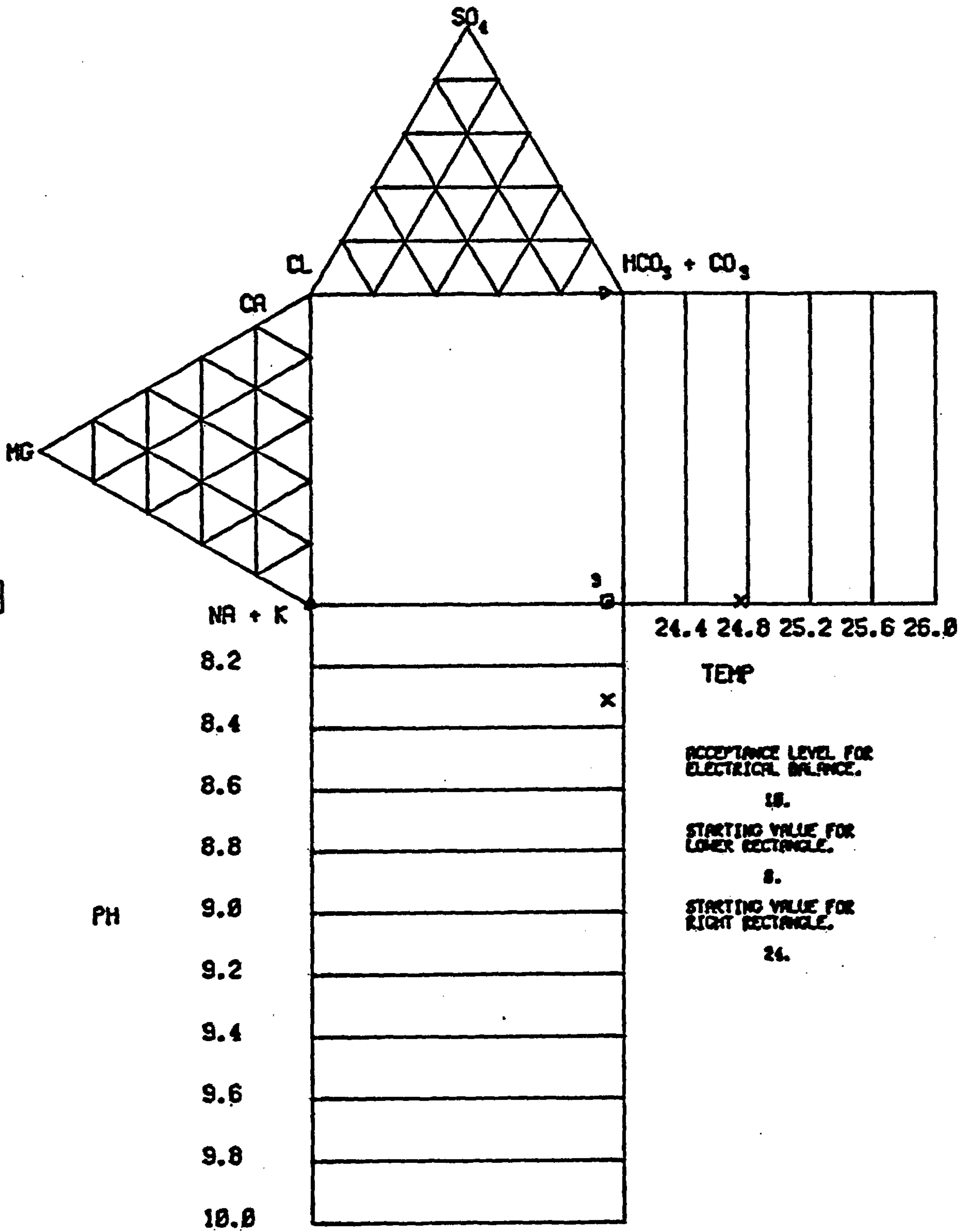
WELL DB-Ø1 (15)


SO4
CL
HCO3 + CO3
CA
MG
NA + K
4
3
19.4 20.8 22.2 23.6 25.0
TEMP
8.2
8.4
8.6
8.8
9.0
9.2
9.4
9.6
9.8
10.0
PH
ACCEPTANCE LEVEL FOR ELECTRICAL BALANCE.
10.
STARTING VALUE FOR LOWER RECTANGLE.
8.
STARTING VALUE FOR RIGHT RECTANGLE.
18.

WELL DB-02 (16)

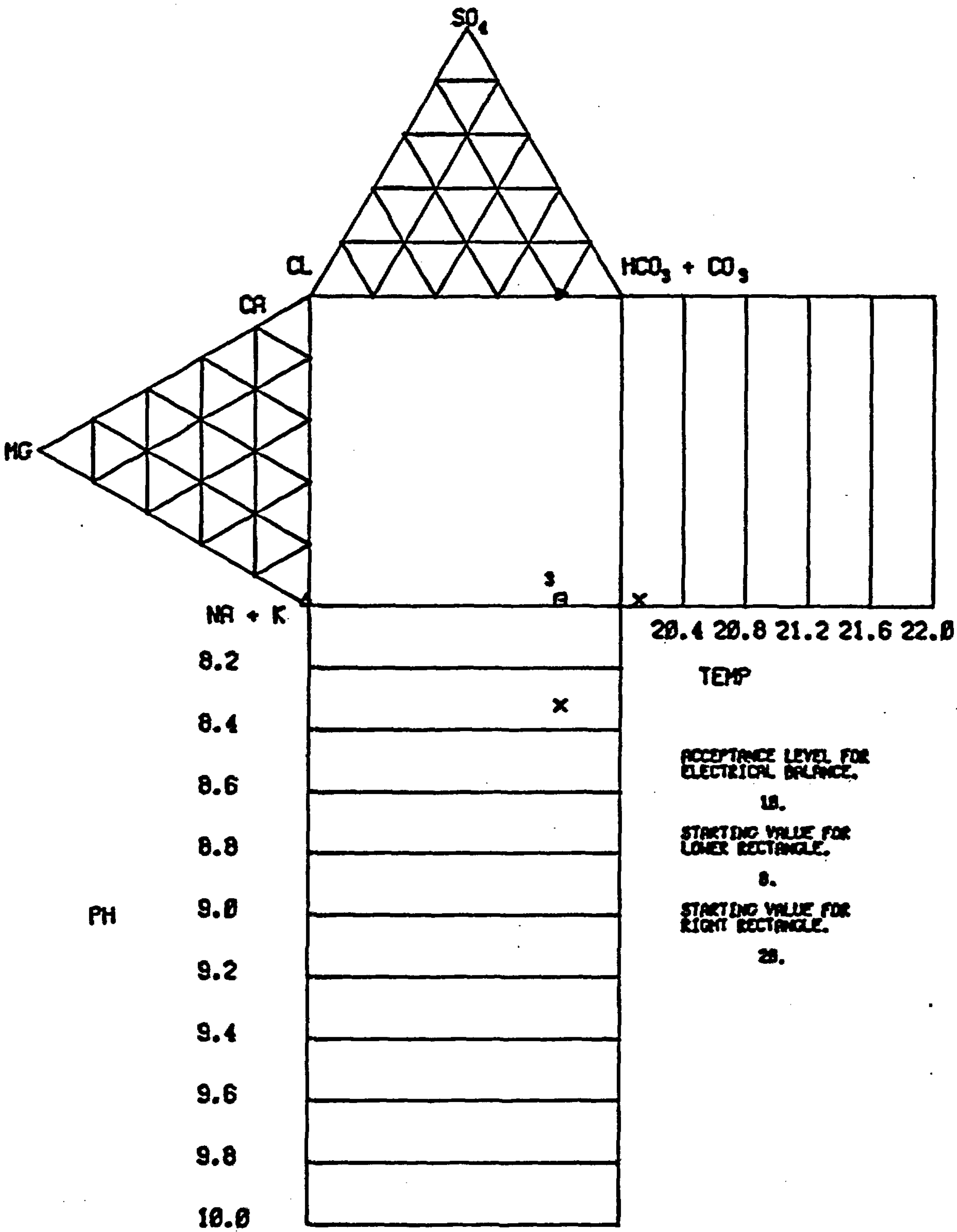


WELL 699-53-50 (12)

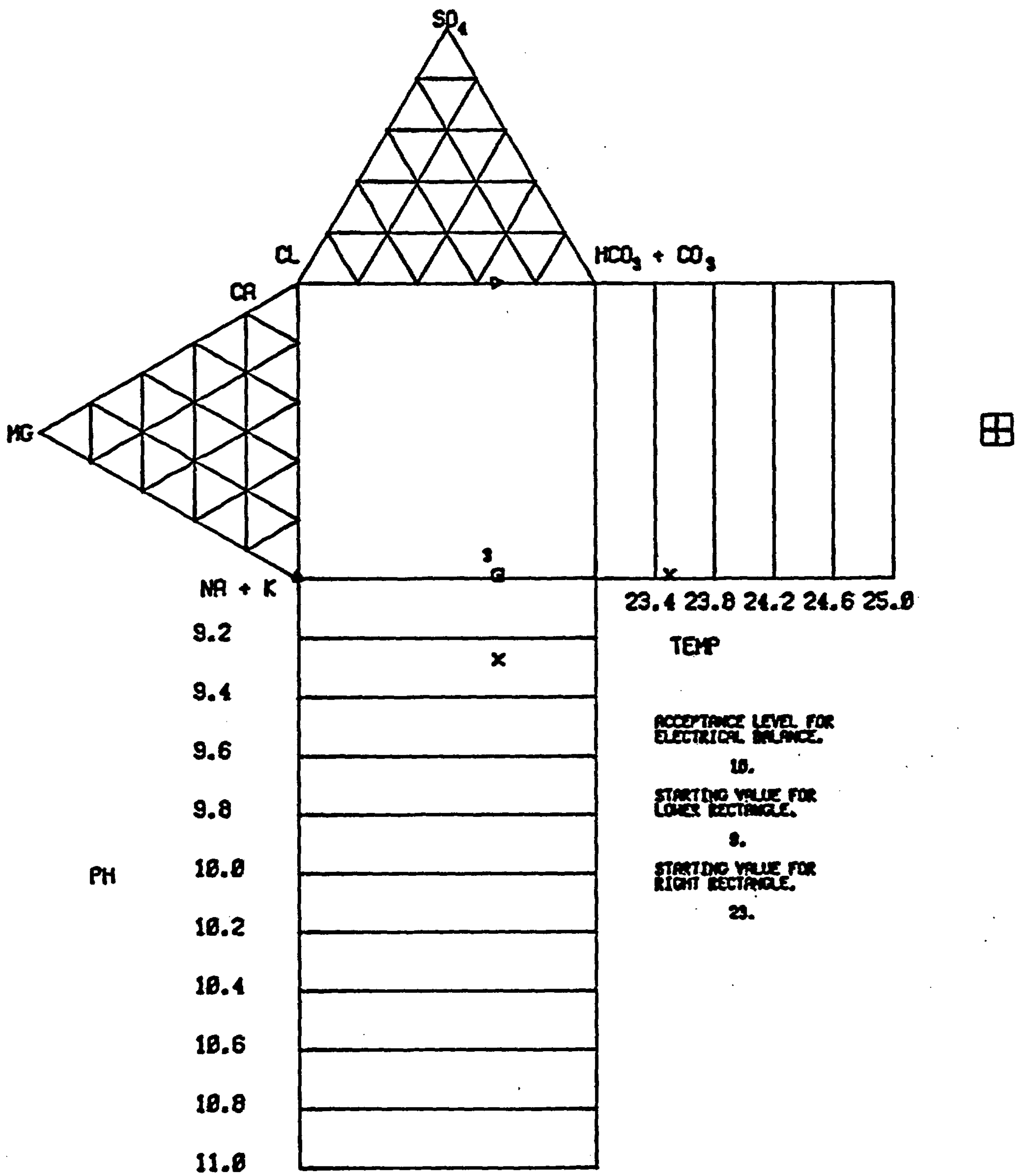


SO4
CL
HCO3 + CO3
CA
MG
NA + K
24.4 24.8 25.2 25.6 26.0
TEMP
8.2
8.4
8.6
8.8
9.0
9.2
9.4
9.6
9.8
10.0
PH
ACCEPTANCE LEVEL FOR ELECTRICAL BALANCE.
10.
STARTING VALUE FOR LOWER RECTANGLE.
8.
STARTING VALUE FOR RIGHT RECTANGLE.
24.

WELL DB-04 (17)

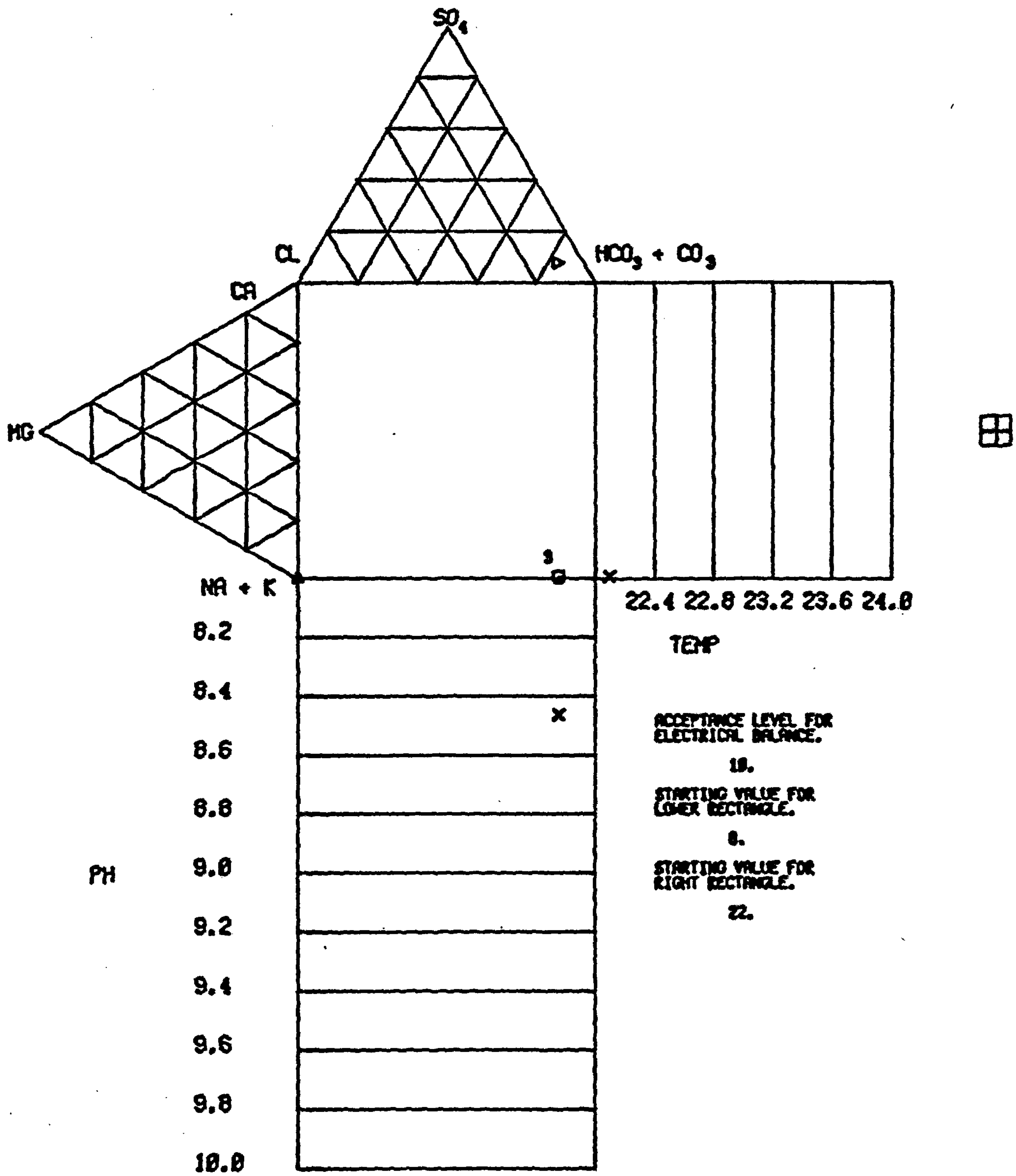

SO4
CL
HCO3 + CO3
CA
MG
NA + K
20.4 20.8 21.2 21.6 22.0
TEMP
8.2
8.4
8.6
8.8
PH
9.0
9.2
9.4
9.6
9.8
10.0
ACCEPTANCE LEVEL FOR ELECTRICAL BALANCE.
10.
STARTING VALUE FOR LOWER RECTANGLE.
8.
STARTING VALUE FOR RIGHT RECTANGLE.
20.

WELL DB-05 (18)



SO4
CL
HCO3 + CO3
CA
MG
NA + K
23.4 23.8 24.2 24.6 25.0
TEMP
9.2
9.4
9.6
9.8
PH
10.0
10.2
10.4
10.6
10.8
11.0
ACCEPTANCE LEVEL FOR ELECTRICAL BALANCE.
10.
STARTING VALUE FOR LOWER RECTANGLE.
9.
STARTING VALUE FOR RIGHT RECTANGLE.
23.

WELL DB-07 (19)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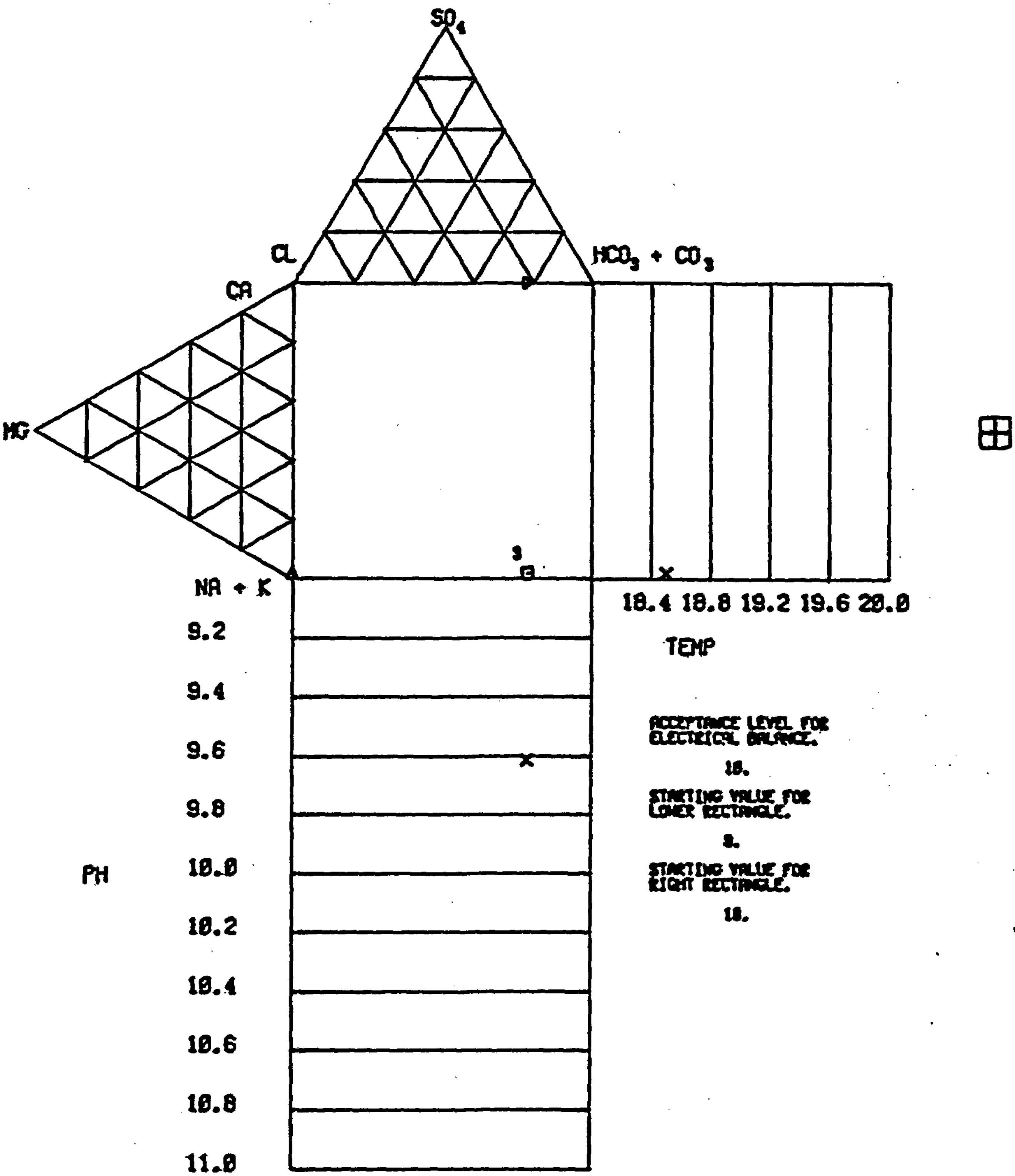
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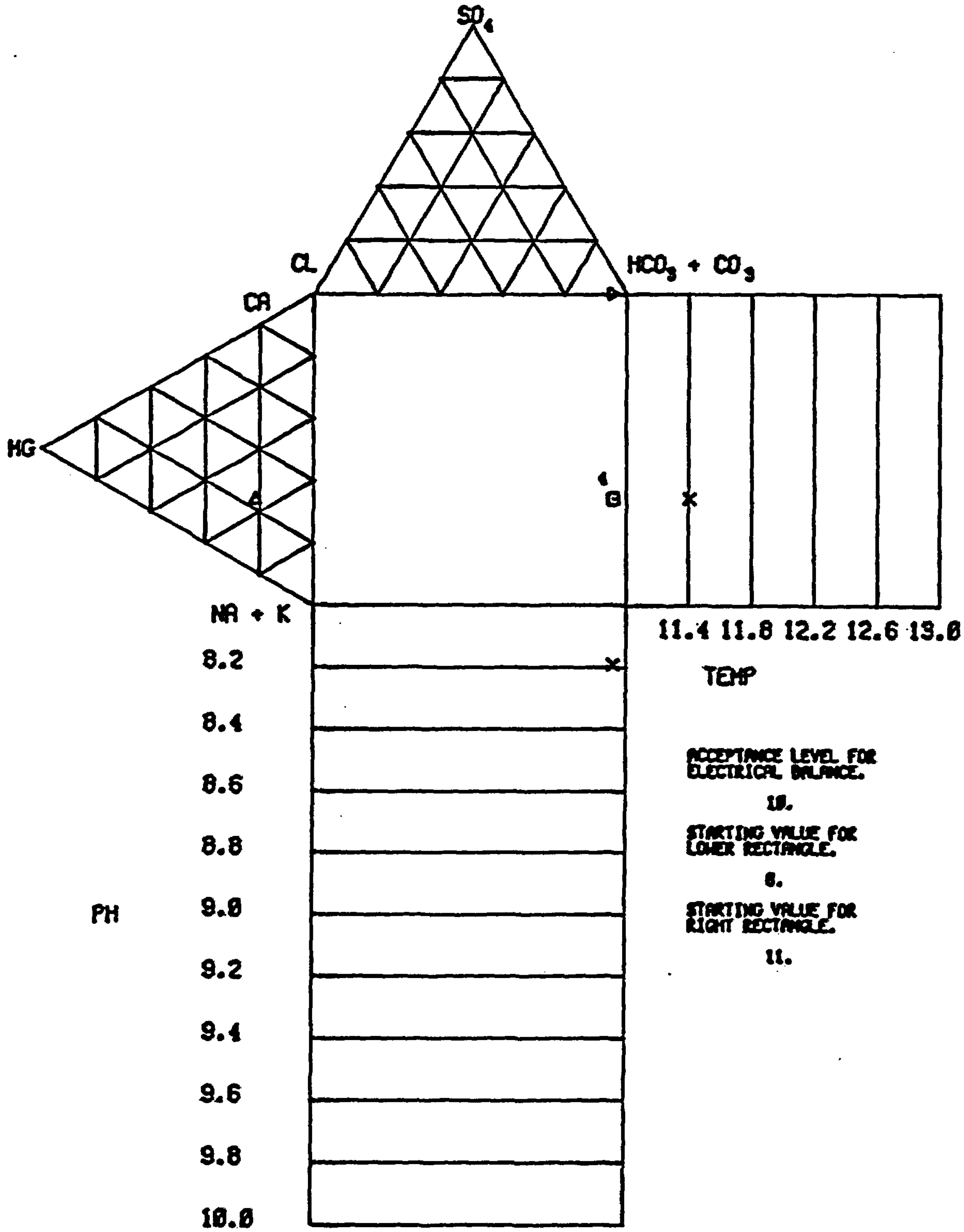
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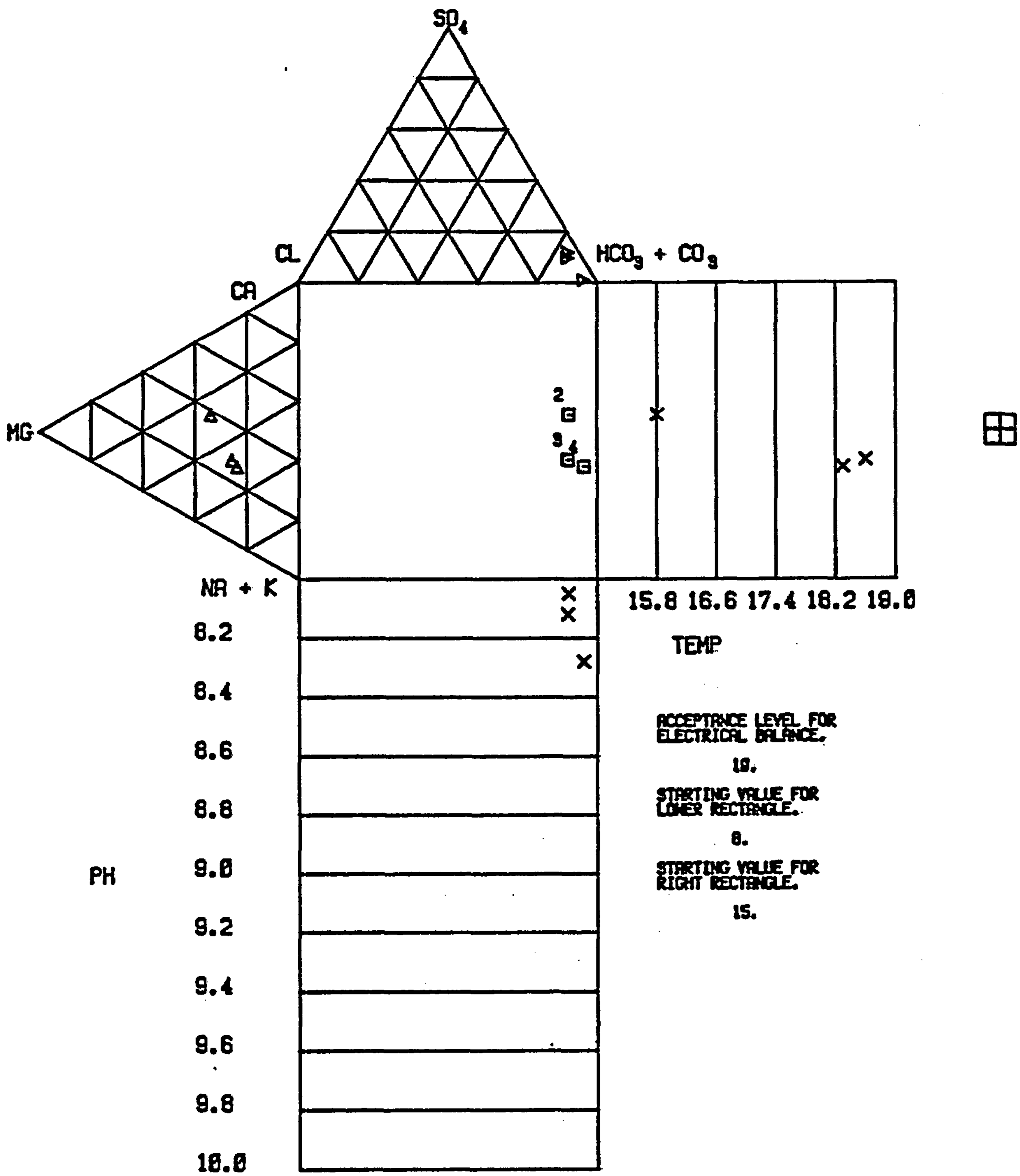
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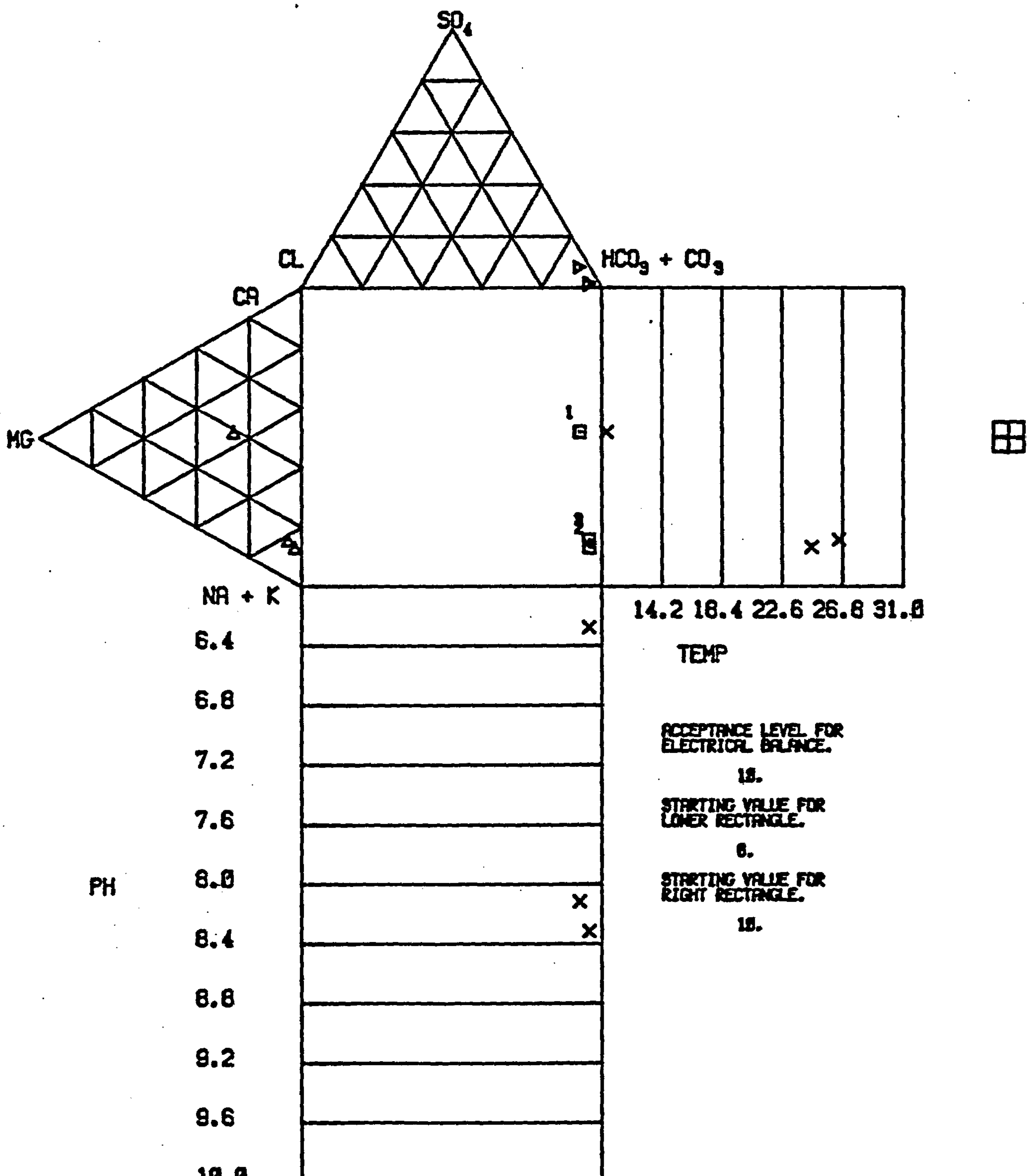

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8.8
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10.0
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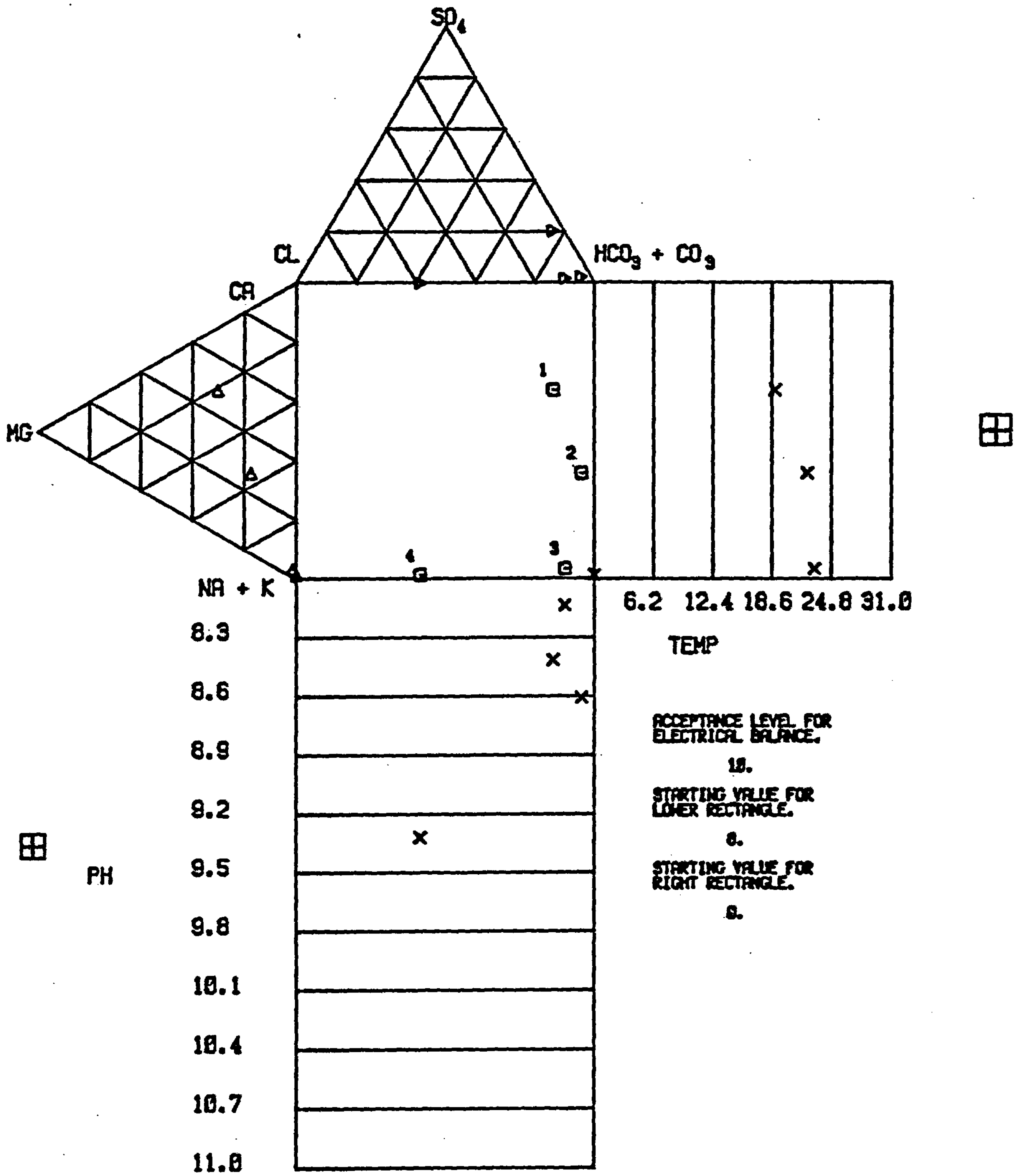
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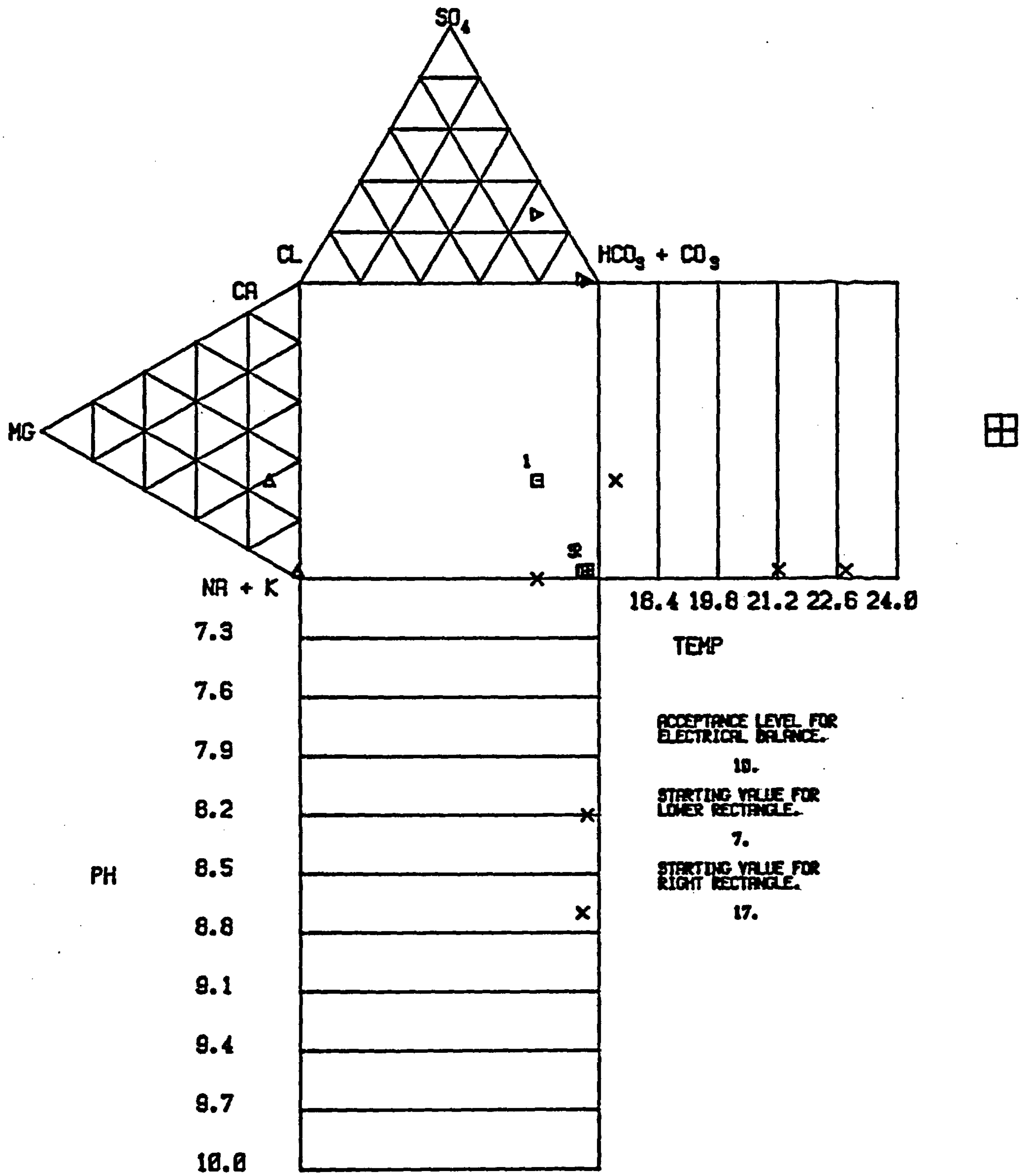
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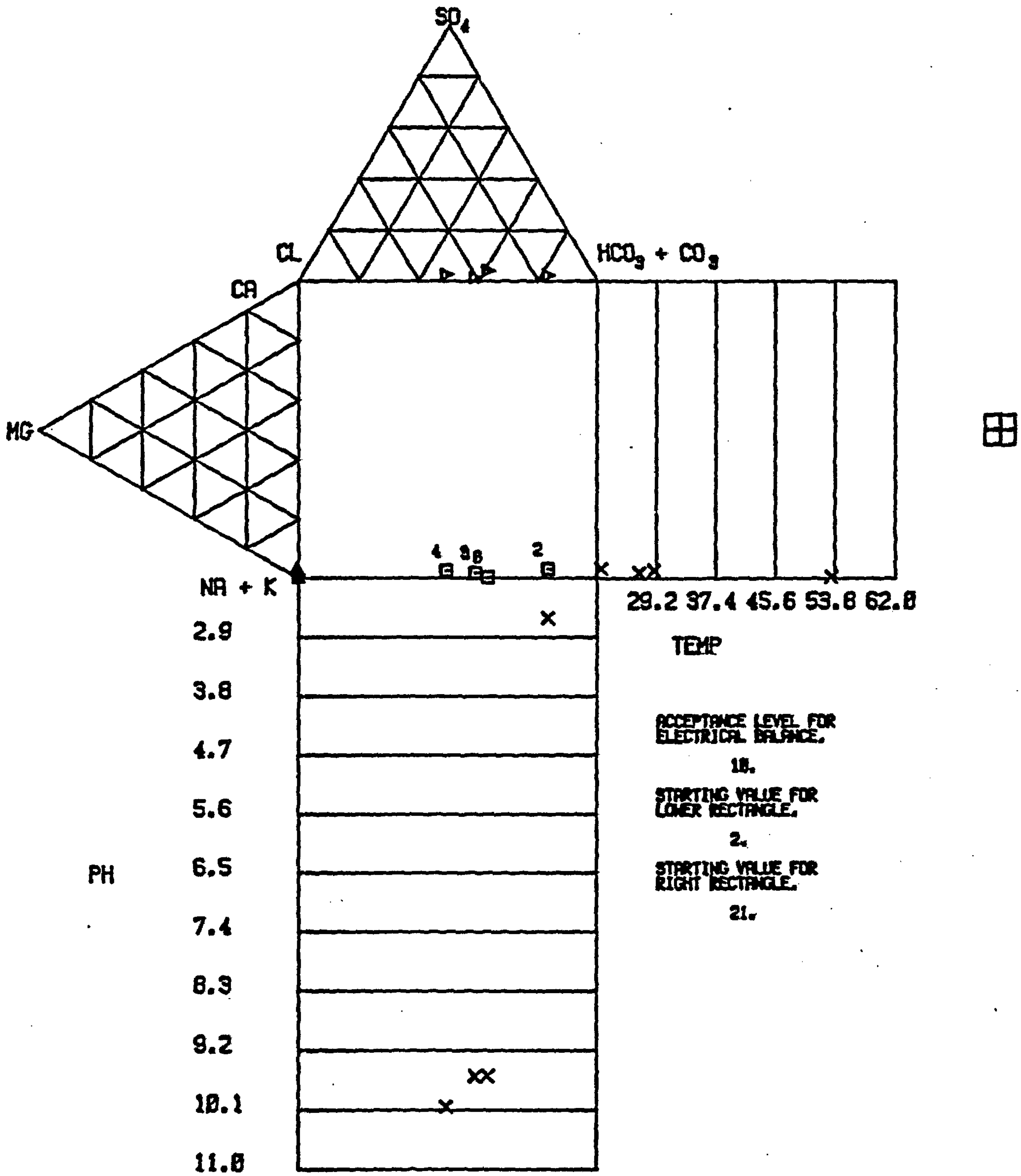
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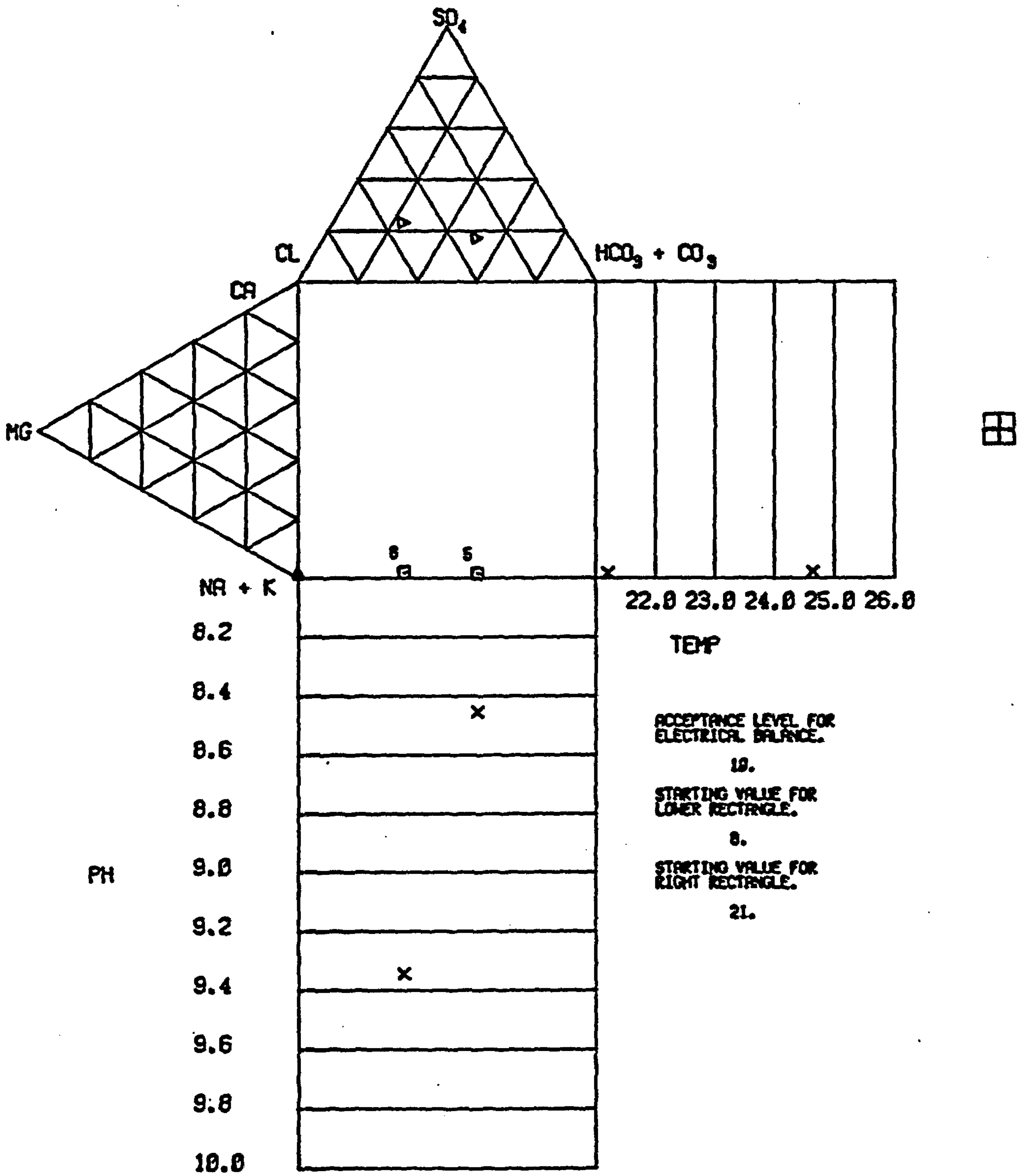
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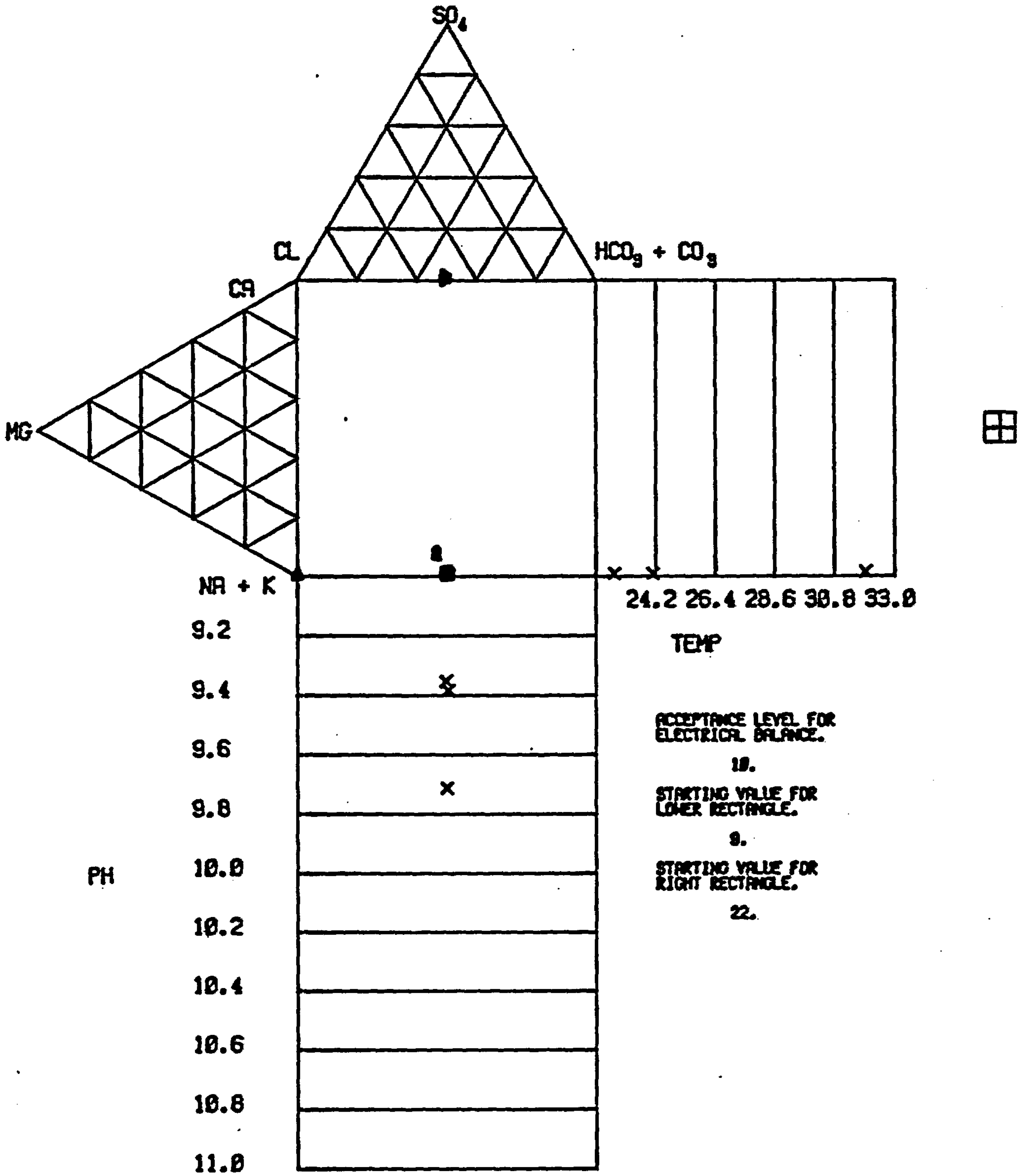
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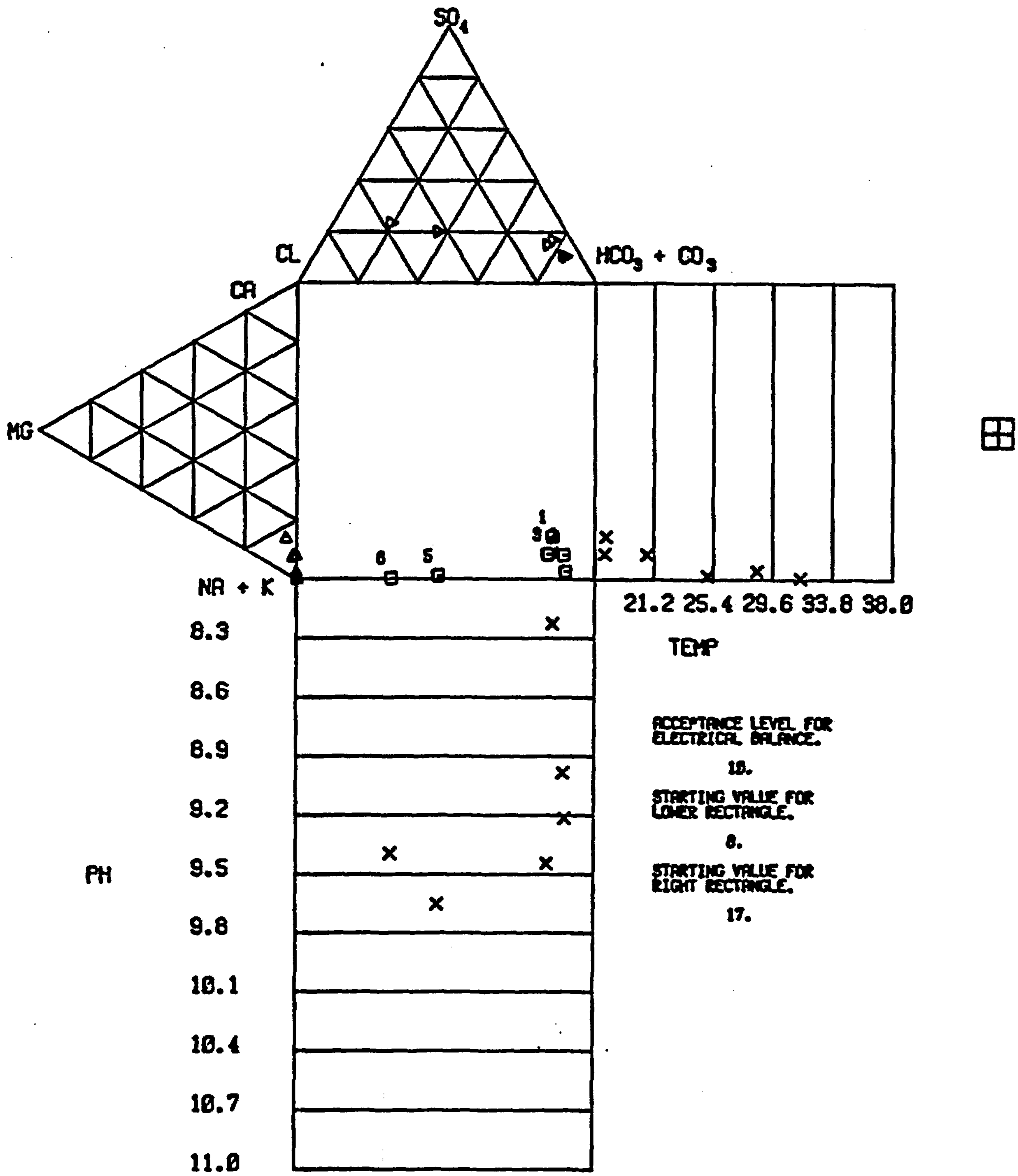
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MG
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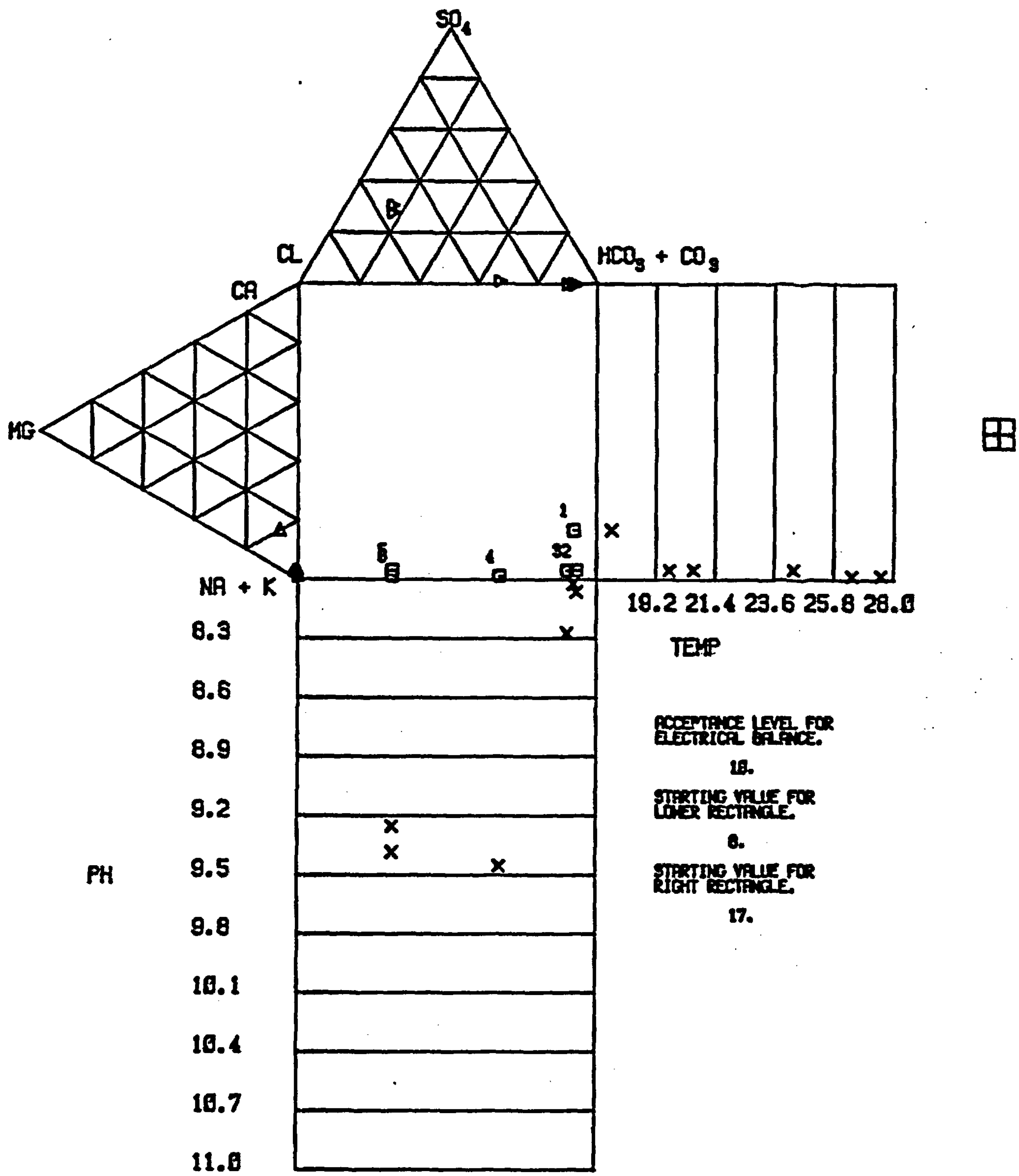
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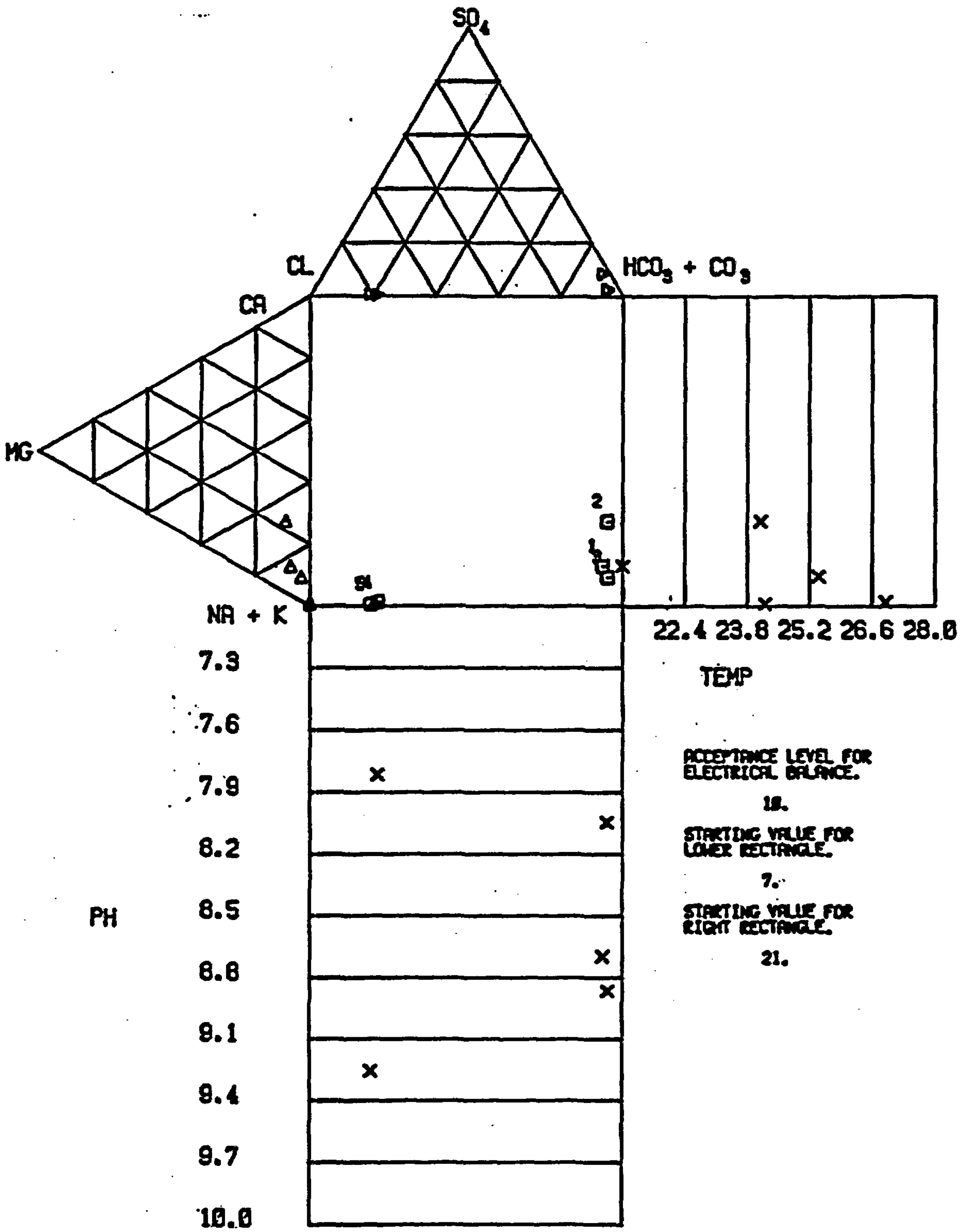

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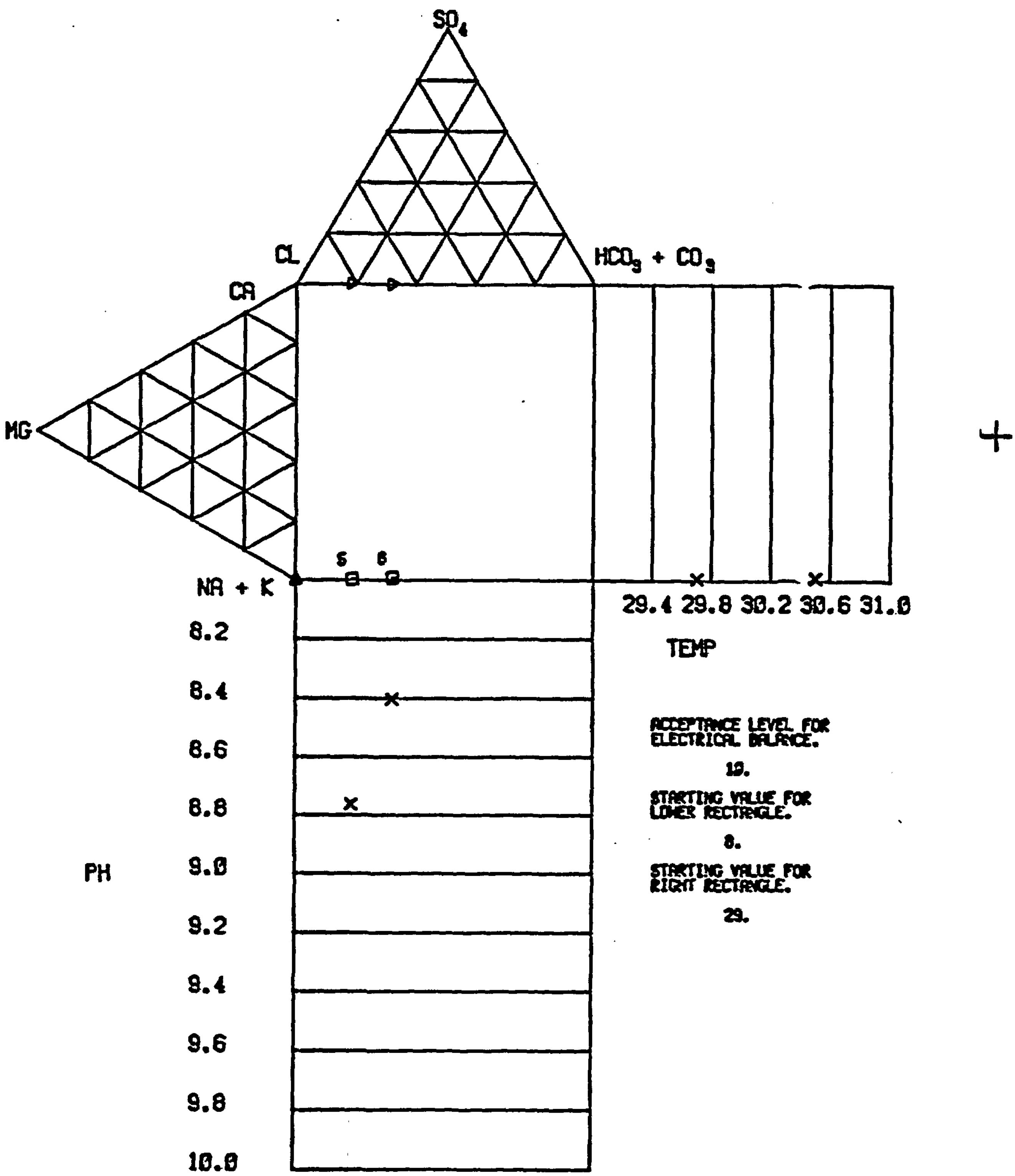

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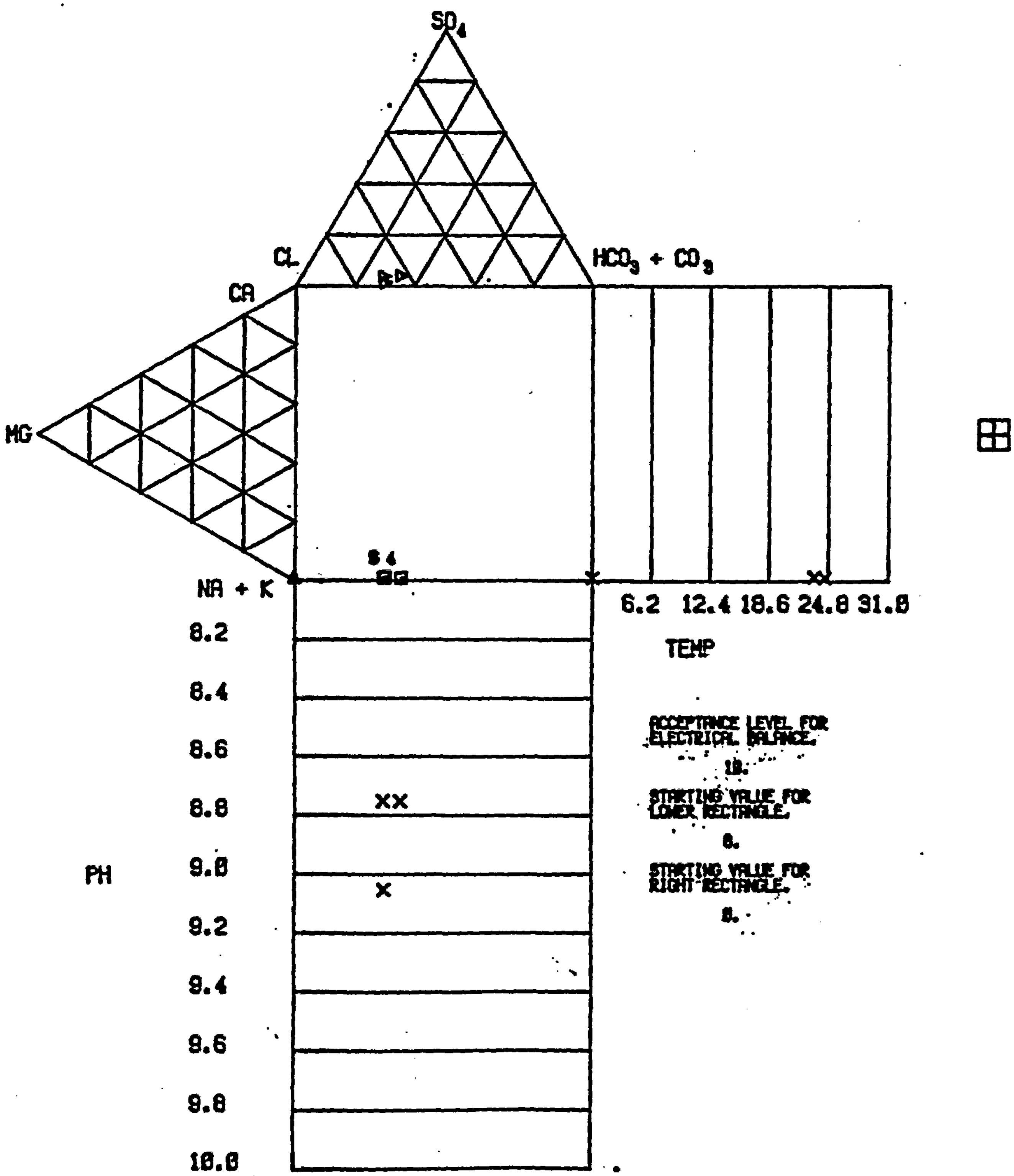

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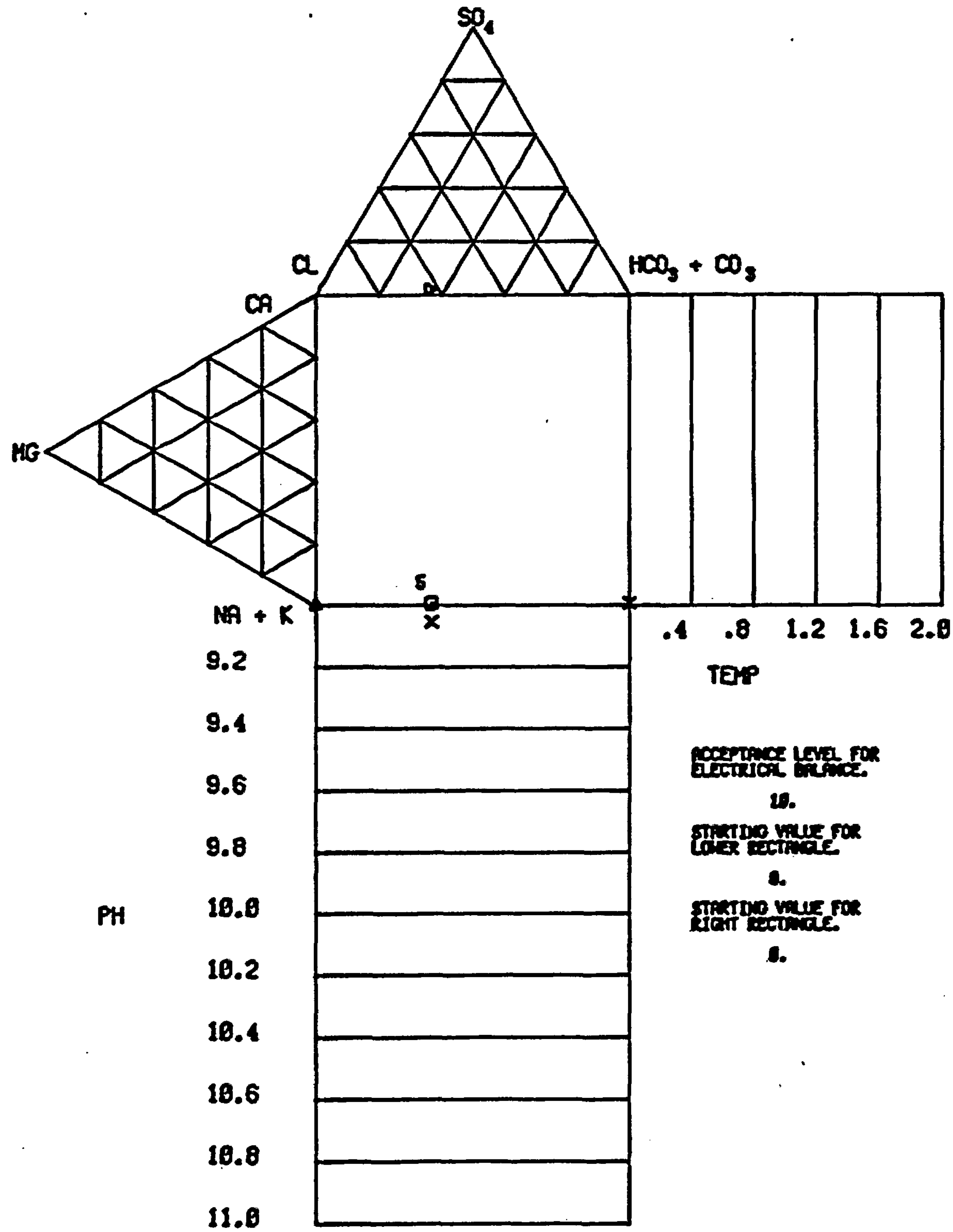

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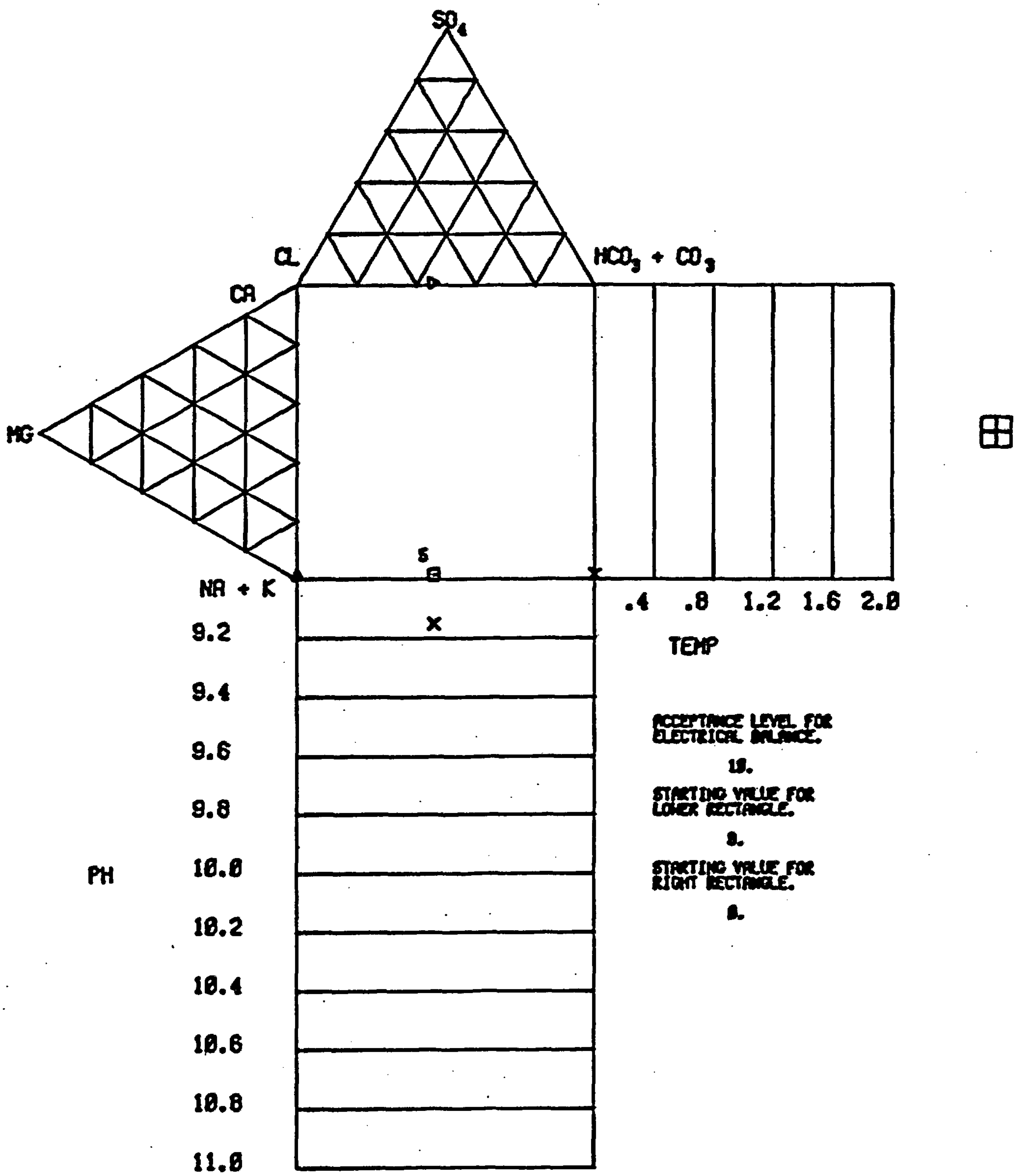

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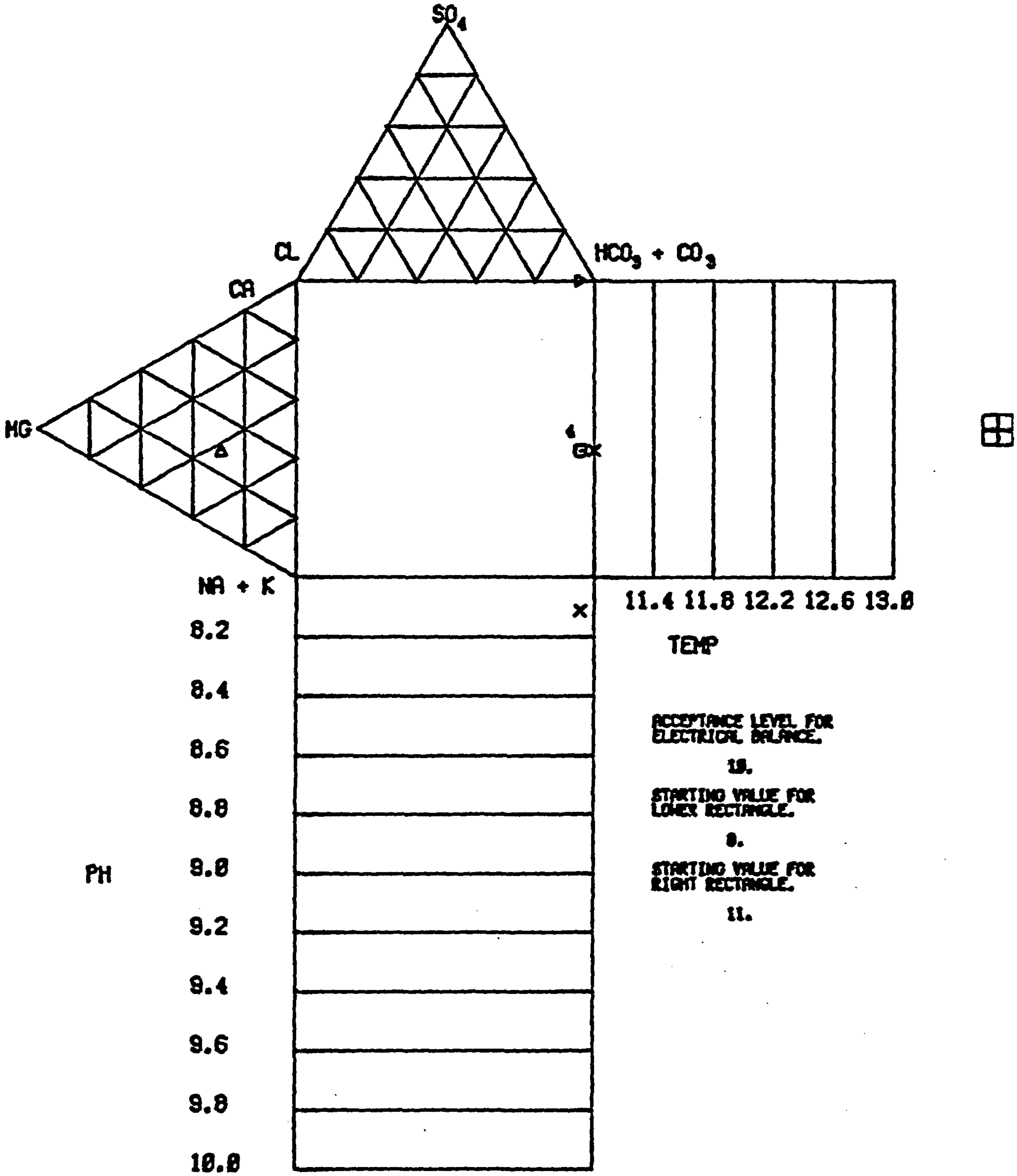

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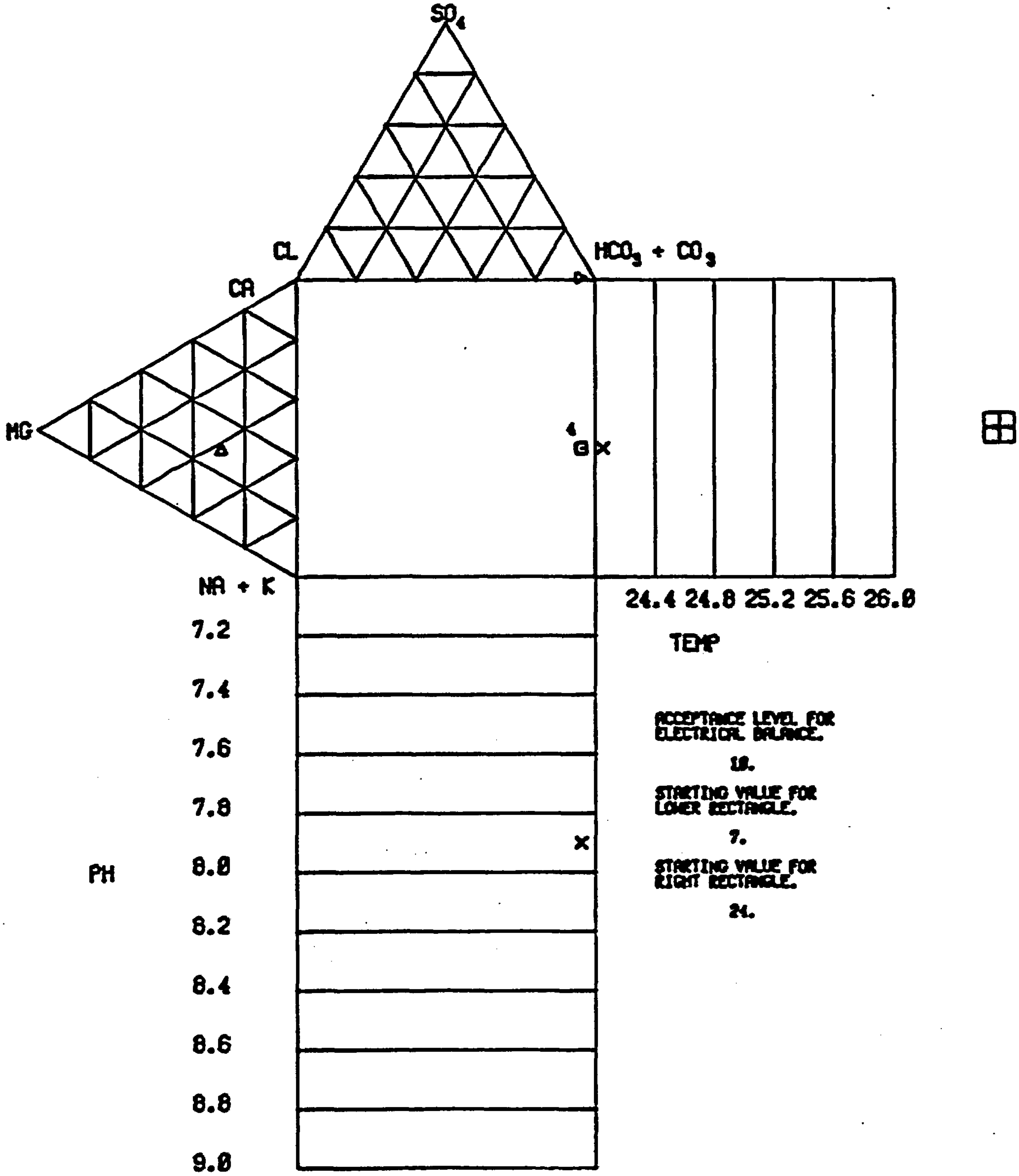
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STARTING VALUE FOR RIGHT RECTANGLE.
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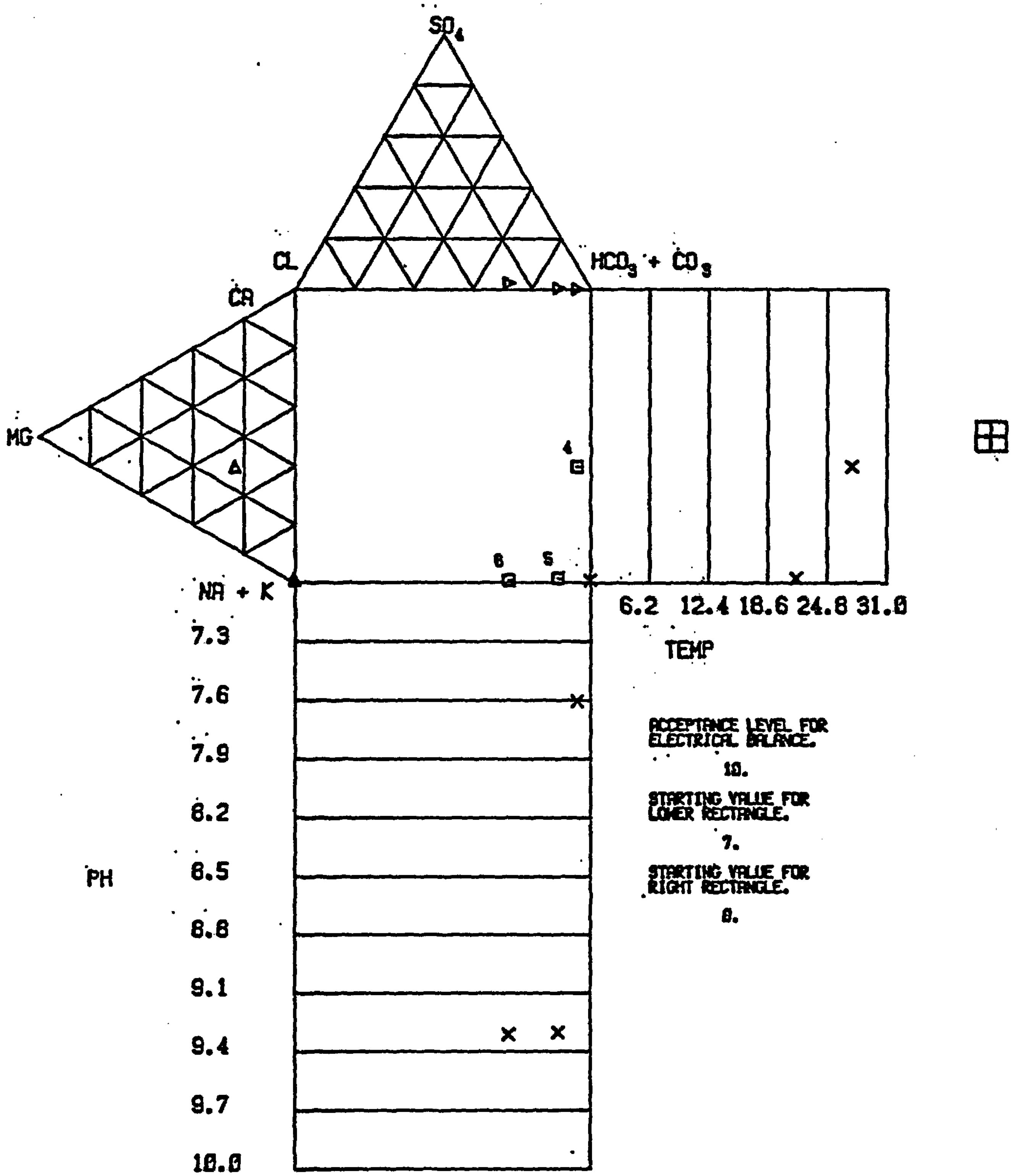

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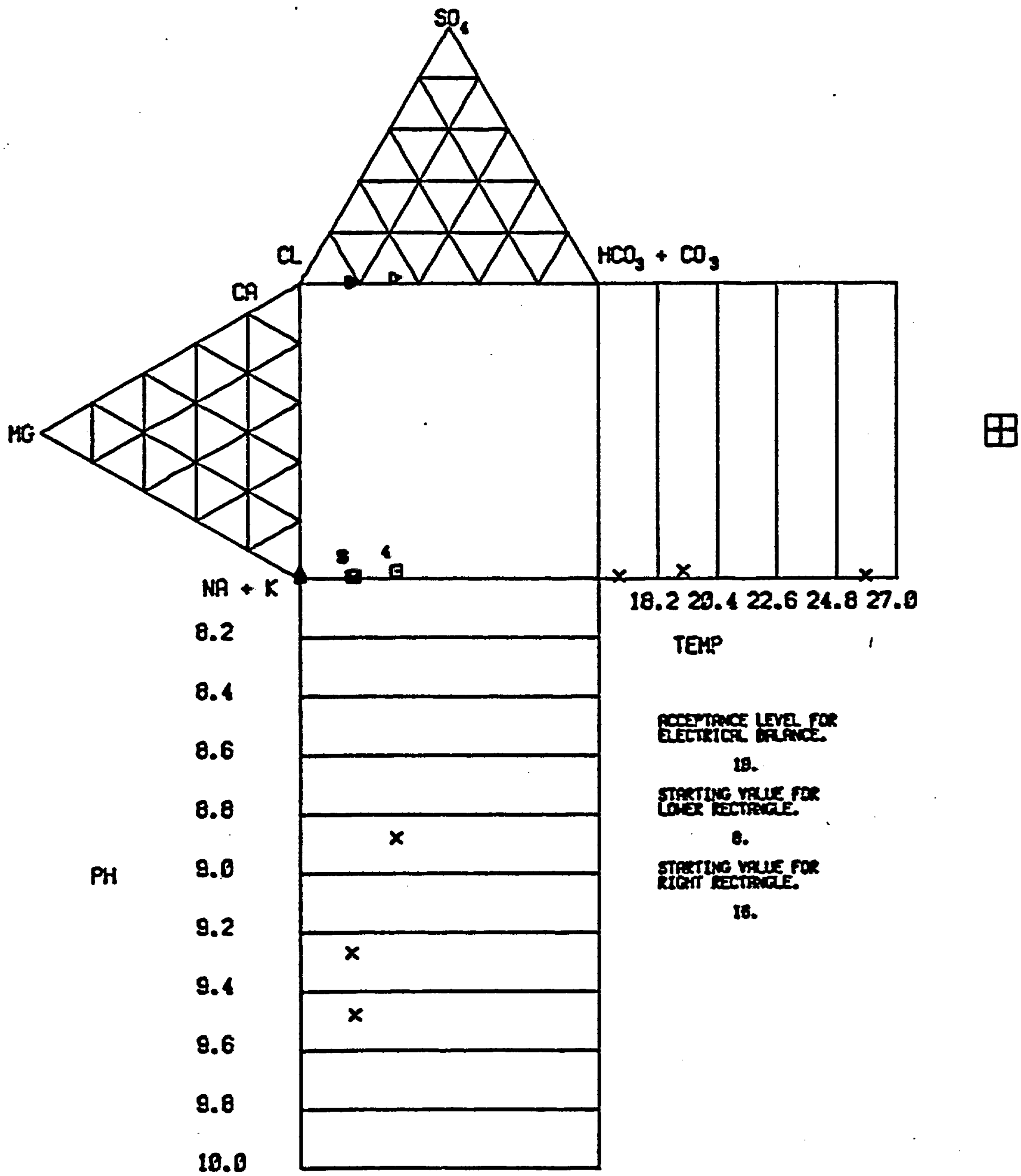

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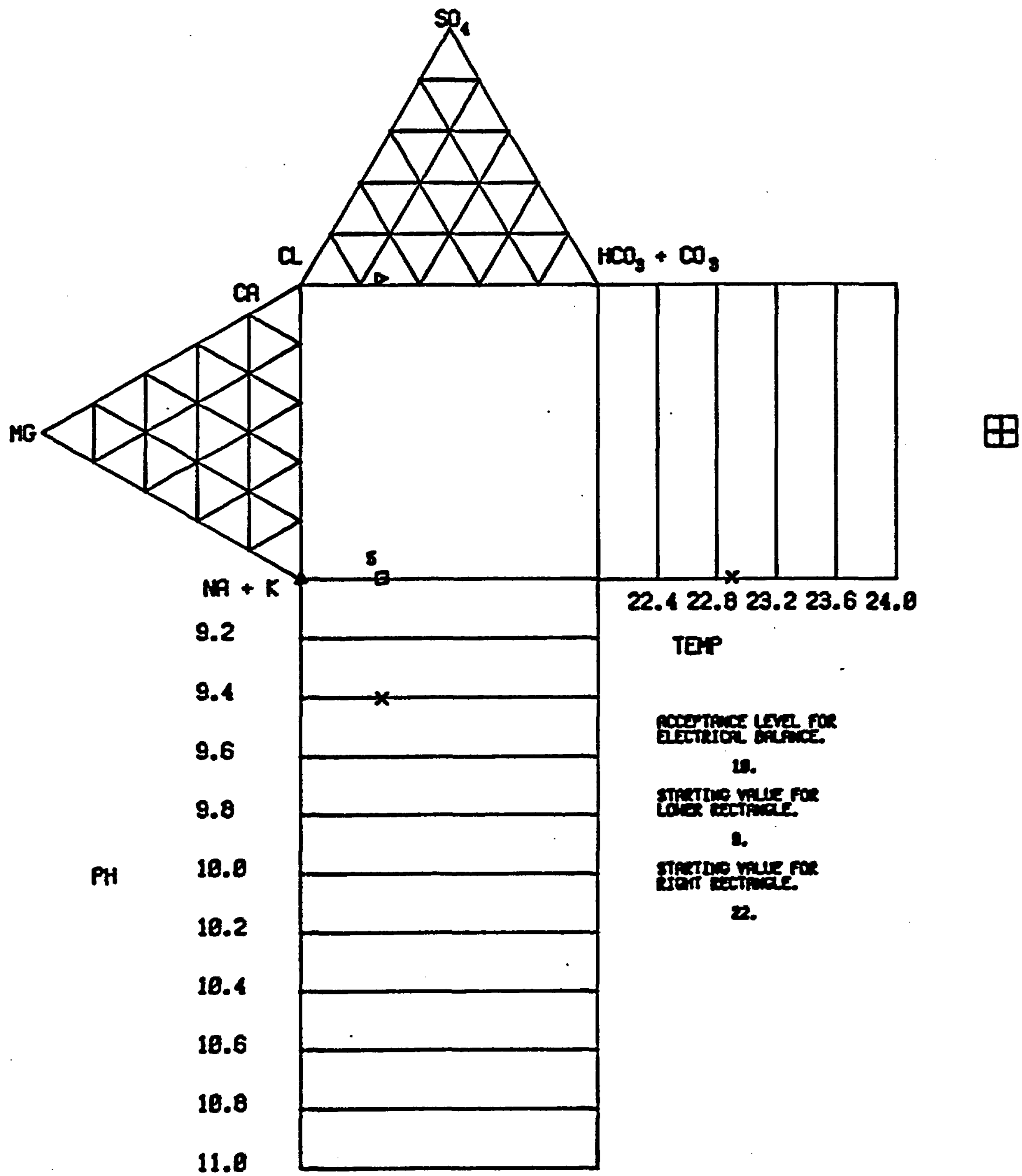

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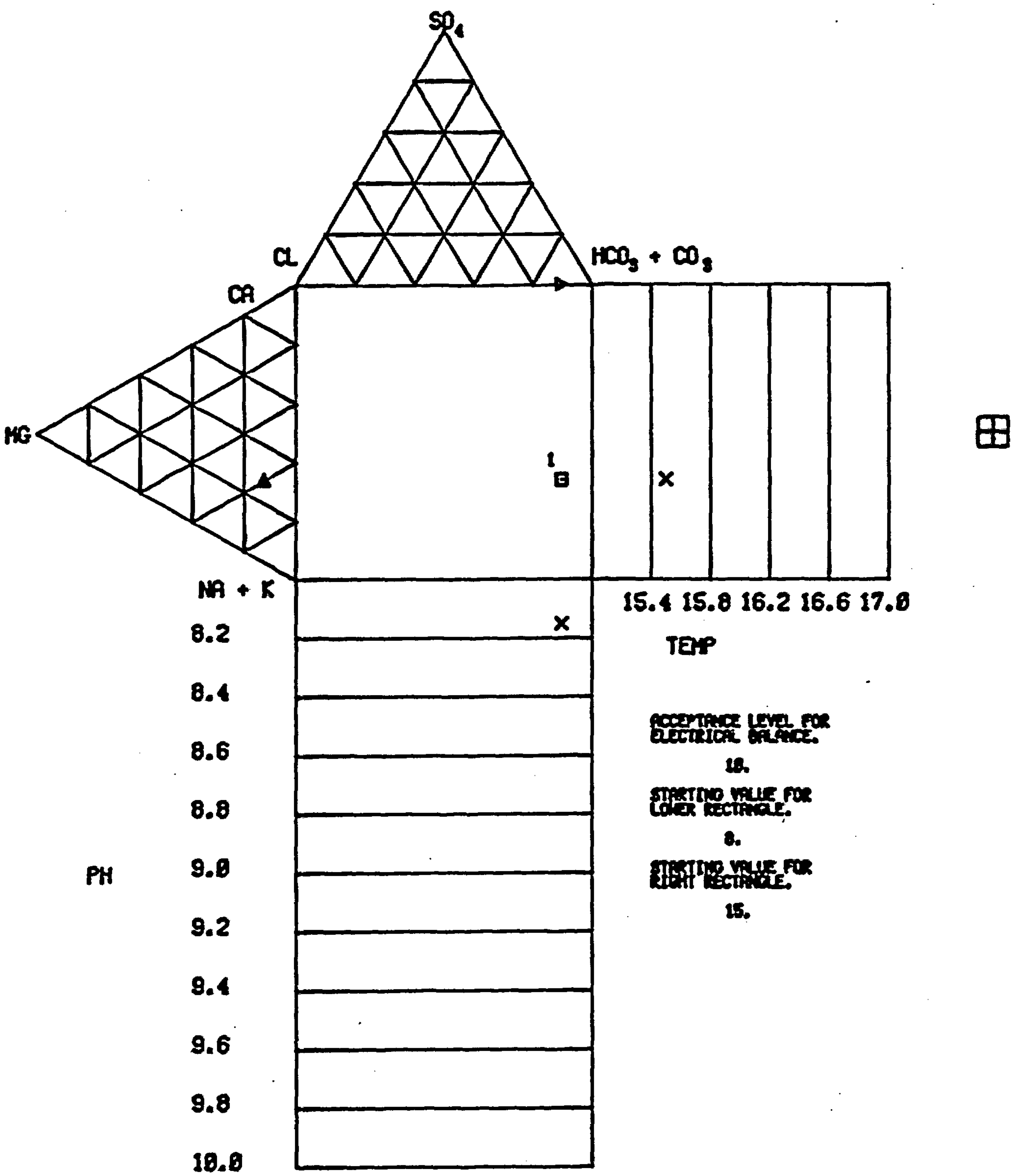

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APPENDIX D

APPENDIX D

PRELIMINARY SENSITIVITY ANALYSIS OF ROCKWELL FLOW PATH USING SWIFT

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PRELIMINARY SENSITIVITY ANALYSIS OF ROCKWELL FLOW PATH USING SWIFT

by

Linda Lehman and GeoTrans, Inc.

for

the Yakima Indian Nation

INTRODUCTION

The EA presents a hydrologic model of RHO's preferred flow path in the Pasco Basin. The model yields a very long travel time to the accessible environment. As part of the Yakima Indian Nation (YIN) review, a preliminary sensitivity analysis was done on the model RHO used to generate this flow path for the purposes of:

1. Observing changes in flow path due to inclusion of hydrologic barrier in western Cold Creek Syncline,

2. Testing sensitivity of flow path to local variations in vertical permeability,

3. Assessing agreement of flow model with geochemical model, and

4. Recommending changes in the overall approach to the modeling and testing effort.

The conclusions resulting from this preliminary analysis are that there are severe problems with 1) the boundary conditions assigned to the model, 2) the vertical conductivity values used, 3) the lack of consistency with geochemical models, and 4) the overall approach to determining boundary conditions and permeabilities.

Background

It has been pointed out to DOE and RHO that boundary pressures used in the models which predict flow paths are of critical importance to the model's validity (Lehman and Quinn, 1982). The boundary conditions used in the RHO model cited in the EA were extrapolated from a very small number of point measurements taken in the center of the basin (Arnett, 1981). There is no factual basis for these boundary conditions in the form of direct field measurements. As a result, the DOE is including the Hanford Site as a highly ranked contender in the First Repository Program on the weight of a flow path derived from a hydrologic model which essentially uses guesswork for boundary conditions. Furthermore, there are no current plans to conduct field work to directly measure boundary pressures.

Lehman and Quinn (1982) also note that the next most critical piece of information for flow path determination is the degree of vertical permeability. This is because very small changes in Kv/Kh ratio can alter travel paths significantly. However, as with boundary conditions, no field measurements of this parameter have been made, not even in areas which are suspected to have vertical connection; nor is there any provision made in the RHO model to accomodate local variations in the KV/Kh ratio.

SENSITIVITY ANALYSIS

Methods

The code used by the YIN to perform the sensitivity analysis was SWIFT. The grid structure and parameter values used in the analysis are basically the same as in Lehman and Quinn (1982). A few minor changes in grid-block elevations were made in the center of the Pasco Basin; these were based on RHO structure contour maps. See Figure 1 (Grid Block Elevations). The pressure boundary conditions are those published in Arnett (1981), with one exception. The exception is based on recent hydraulic head data provided by the USGS in Horseheaven Hills. The new data reflect higher heads than were previously used by RHO. See Figure 2 (Boundary Conditions). The SWIFT code was run in the steady state mode.

Hydrologic Barrier in Cold Creek Syncline

One purpose of running the analyses was to determine the effect of the hydrologic barrier thought to exist to the west of the RRL, in the Cold Creek Syncline. The barrier was simulated by imposing a constant head of 415 feet ASL in the vicinity of the barrier and by decreasing the horizontal transmissivity in those grid blocks by a factor of 100. The grid blocks to the immediate west of the barrier in the Wanapum were shut off; thereby using only the pressures in the Grande Ronde in that location. No recharge or pressure from the Wanapum in that area is used by the model. It should be noted new information by RHO has shown that a complex hydrologic condition exists west of the barrier in the Wanapum units, i.e., flowing wells exist at high elevations, 2) St. Michele vineyards are pumping considerable amounts of water, and 3) springs are discharging water through the Vantage interbed. However, in order to simplify the model (which is mainly concerned with flow paths in the Grand Ronde) these effects were not simulated.

YAKIMA MODEL

GRID BLOCK ELEVATIONS

(R1 - 26)

	1	2	3	4	5	6	7	8	9	10
1	2000	500	1800	1800	1800	1800	1800	1000	1000	1000
2	2000	500	650	550	500	500	900	900	900	1100
3	2000	2000	550	500	500 / -200	500 / -100	700	700	900	1000
4	2000	2000	1500	600	600	500 / 400	700	700	900	1000
5	2000	2300	1500	550	550	500	500	700	900	1000
6	2000	1800	1800	600	600	500 / -100	400	700	700	1000
7	x	x	3000	1800	1800	500 / 100	400	700	700	900
8	x	x	x	x	1800	500	450	500	500	850
9	x	x	x	x	x	1000	500	500	600	850
10	x	x	x	x	x	x	1400	1200	700	700

Figure 1

BOUNDARY CONDITIONS

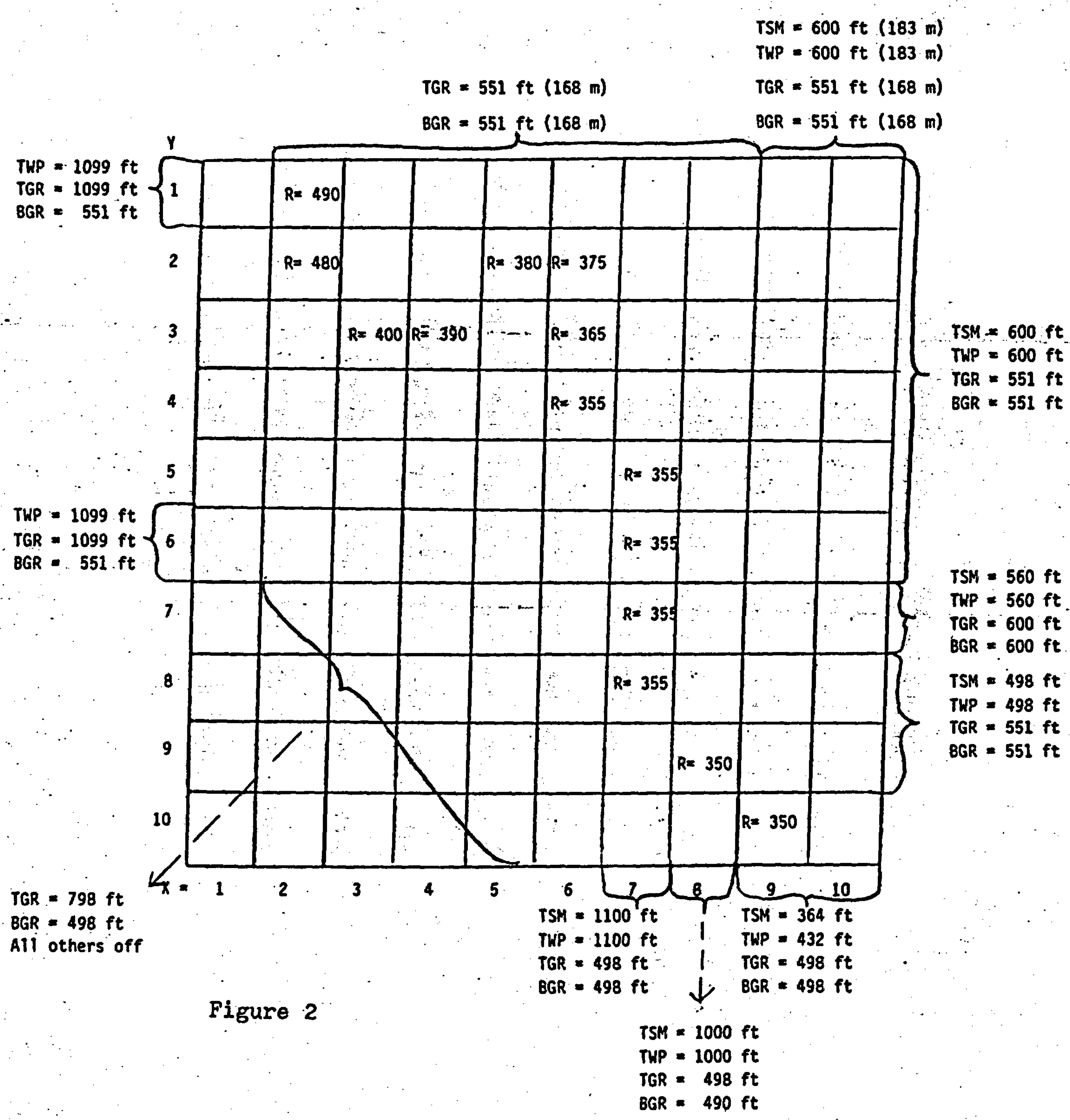

Figure 2

Results

When the Cold Creek barrier was simulated, actual field measured values were imposed within the boundary conditions of the overall model, i.e. the changes were internal and the RHO boundary pressures were maintained. The effect was to create a hydraulic low in the vicinity of the barrier. As a result, particles released in the repository block traveled downward initially, then traveled towards the barrier in a northwesterly direction, and ultimately moved upward in the vicinity of the barrier.

In short, the simulation could not reproduce the RHO flow path; and, in fact, showed particle movement in the opposite direction. It is believed the flow path obtained is the result of the higher heads assigned by RHO along the western boundaries; and illustrates the importance of using actual values for boundary conditions in any model which predicts travel time. The pressure boundaries assigned by RHO, by their own admission, are arbitrary. Since the inclusion of field verified data in the RHO model results in a radically different flow path than originally predicted by RHO, the entire RHO conceptual model is very questionable. Furthermore, in the absense of actual field measurements to obtain boundary conditions, the flow path in the Pasco Basin can not be confidently predicted at all.

Local Vertical Permeability

In order to test for the effect of local changes in permeability, changes in the vertical permeability were imposed. To do this in a realistic sense, changes were imposed only at grid cells where earthquake swarms were known to exist. It has been generally accepted that swarms occur over 2 - 5 mile square areas, and that they result in increased permeability. Five swarms occur in the area being modeled (Figure 3). At these locations in the corresponding grid cell, the vertical permeability assigned to each layer was multiplied by a factor of 10.

Results

The pressure profiles generated by these runs indicate that since pressures are higher at depth, small local changes in vertical permeability (such as those thought to be caused by earthquake swarms) will cause vertical gradients to occur which can channel flow upward at these locations. This has the effect of shortening flow paths to the accessible environment. This may be very significant since an actual swarm is located to the south of the RRL near Rattlesnake Hills, and another swarm is within five miles of the RRL to the north. The potential for upward flow in these areas is not accounted for in the flow paths generated by RHO.

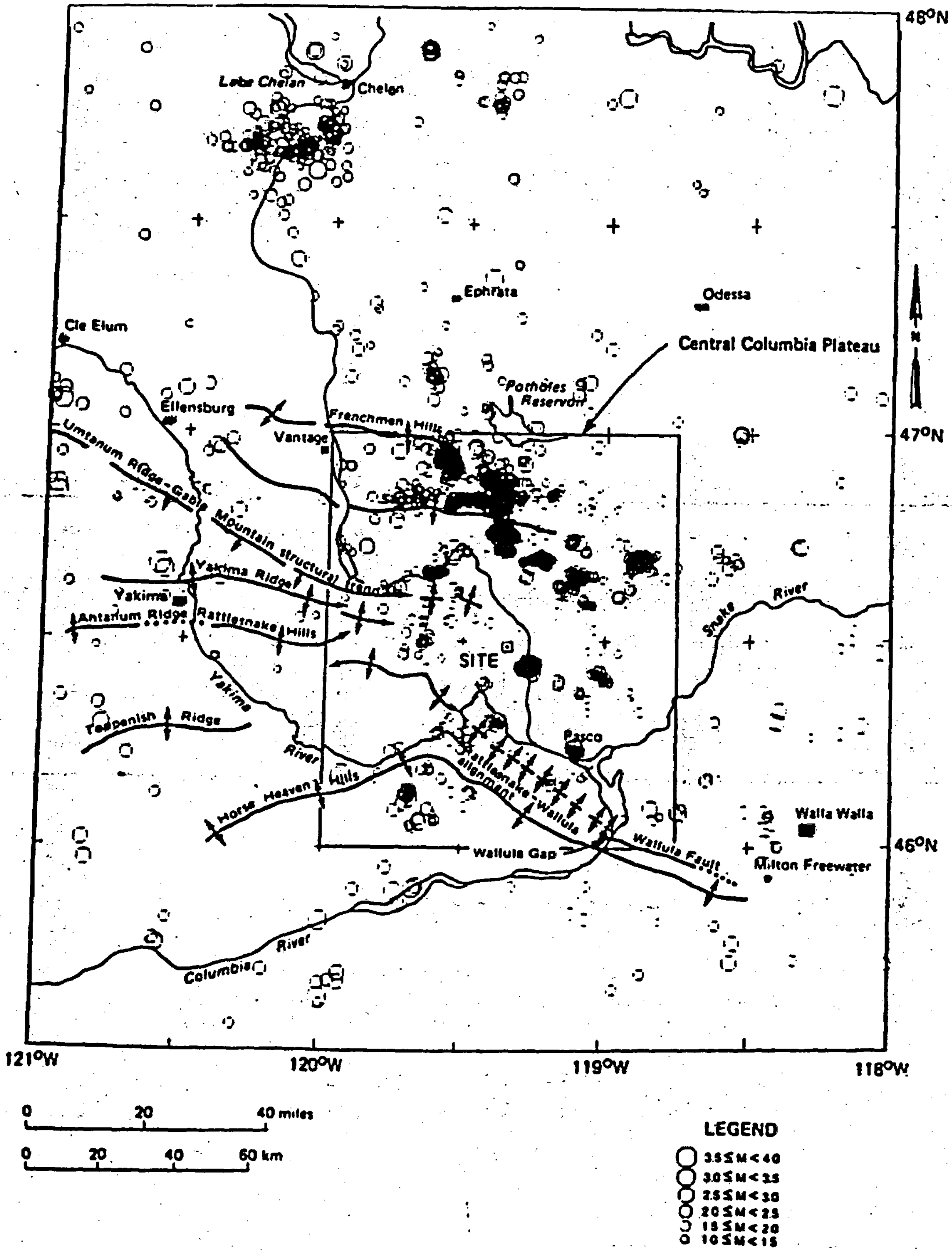

Figure 3 Swarm earthquakes in the Pasco Basin region (Source: Washington Public Power System, Amendment No. 18) (After NRC, 1983)

COMPARISON TO GEOCHEMICAL INTERPRETATIONS

The geochemical interpretations presented in Appendices B and C indicate that the chemical constituents of the water in the Pasco Basin are significantly different from water encountered in the surrounding areas. Moreover, the water in the Pasco Basin is characteristic of water types resident in a sedimentary rock sequence. Such water could only originate from a rock layer located beneath the Grande Ronde. This means that the water is coming in from below (i.e. vertical flow), and this interpretation is supported by the hydraulic data. This fact is not consistent with the RHO flow paths used in the EA.

Another piece of information generated by the geochemistry interpretation in Appendix B is that the water to the west (in the Yakima Valley) is not related to any of the water types seen to the east of the Yakima Ridge Fold Belt. This discovery is relevant to the Interagency modeling task force efforts. The task force has expanded the model boundaries to include the Yakima Valley to help generate boundary conditions for flow paths within Pasco Basin. Based on the geochemical interpretations, however, the two basins may not be hydraulically connected.

CONCLUSIONS

1. The current RHO hydrologic model does not consistently predict the same flow path when actual field verified pressures are included. Since the proposed RHO flow model can not accomodate known field data, it must be concluded the model is inaccurate. The error could result from inaccurate assessment of model boundary pressures, permeability ratios, an incorrect conceptual model, or all of these.

2. The current RHO hydrologic model does not acknowledge the probability of local increased Kv/Kh ratios in the Pasco Basin. This is a critical omission because the pressure boundaries assumed by RHO would cause vertical channeling of water in these areas; thereby drastically shortening the flow path to the accessible environment.

3. The geochemical interpretations proposed by the YIN indicate vertical flow is occurring throughout the Pasco Basin. This undermines the entire basis of the RHO flow model, which assumes no vertical flow is occurring.

RECOMMENDATIONS

The accurate characterization of Hanford as a repository site will require a very large amount of additional data. Accurate boundary conditions for the Pasco Basin must be determined before any confidence can be placed in a numerical flow model. This will entail drilling wells outside the Hanford boundaries, especially along the western, eastern and southeastern basin boundaries. There currently are no plans to obtain this data. It is therefore recommended:

1. Field verified boundary pressures be determined for the Pasco Basin.

2. The current RHO conceptual flow model be discarded and replaced with a realistic model which accomodates the extremely complex geohydrologic conditions in the Pasco Basin.

REFERENCES CITED

Arnett, R.C., et al, 1981. Pasco Basin Hydrologic Modeling and Far-Field Radionuclide Migration Potential, RHO-BWI-LD-44, pp 68.

Lehman, L. L. and E. J. Quinn, 1982. Comparison of Model Studies: The Hanford Reservation, USNRC Public Document Room, PDR Waste WM-1, 8204200365 820330.

NRC (U.S. Nuclear Regulatory Commission), 1983. Draft Site Characterization Analysis of the Site Characterization Report for the Basalt Waste Isolation Project, Hanford, Washington Site, NUREG-0960.

APPENDIX E

APPENDIX E

MODEL COMPARISON

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MODEL COMPARISON

by

Linda Lehman

for

the Yakima Indian Nation

INTRODUCTION

The Draft Environmental Assessments (EA) rank the Hanford site as one of the top three contenders in the First Repository Program. The Nuclear Waste Policy Act (NWPA) requires the ranking process to weigh the geophysical, geochemical, and hydrologic characteristics of the nine sites to determine which sites were best, with the primary criterion being isolation potential. The actual process, however, contained no meaningful analyses of isolation potential using flow field and geochemical characteristics. A quantitative approach to estimating the overall system guidelines should have been undertaken using these most critical parameters. Since this was not done, the Hanford Site - which easily is the worst site hydrologically - is still a contender. It has survived because of an optimistic ranking of geochemical potential, which has not been substantiated, and because of a perception that the near-term socioeconomic impacts at this site would be relatively small. The Yakima Indian Nation (YIN) considers the ranking process used by DOE to be extremely weak and inappropriate. An alternative method of ranking is recommended which makes a more meaningful judgment of isolation potential from a hydrologic perspective.

The YIN has conducted a comparative analysis between the Hanford site and the sites in the Paradox Basin that DOE would reject. The computer code chosen for this analysis was NWFT/DVM (Campbell, et al, 1981). This code was developed for the U.S. Nuclear Regulatory Commission by Sandia National Laboratories, and was designed to assess long-term radioactive releases from a repository. The simulation was carried out over 100,000 years in order to see the very long-term effects. The results of this comparison indicate that the long-term radioactive releases and the potential public health impact that could be expected from the Hanford site are much higher than the projected releases from the Paradox Basin sites. This is the case even though the release mechanism for the Paradox Basin sites is probably overconservative, and engineered barriers as good as those called for by 10 CFR Part 60 are assumed. Less Optimistic assumptions about the engineered barriers would make the differences between Hanford and the Paradox Basin sites even greater. These comparative analyses were carried out for "expected repository performance" over a 100,000-year period after disposal - the same comparative framework established in the site selection guidelines (10 CFR Part 960).

METHOD OF ANALYSIS

As mentioned earlier, the computer code NWFT/DVM was selected for the analysis. Hydrological, geological and geochemical parameters were taken from the modeling studies performed for the U.S. Environmental Protection Agency by Arthur D. Little (ADL 1980, 1982, 1984, 1984a). The actual configuration and geometry of each of the models, i.e., Hanford and Paradox are different but the release scenario for the cannisters is the same. Releases are to occur in all cannisters beginning at 300 years after permanent closure when the waste package fails. The wastes are then leached out of the failed cannisters and carried away at solubility limited rates that are no greater than one part in 100,000 per year. The model setups are discussed separately.

Hanford

The model was constructed from data provided in ADL 1984. The flow field is assumed to be upward through the repository to the first interflow zone. The interflow zone channels the flow horizontally to a distance of two kilometers. Figure 1 provides a graphic description of the model setup. Three "legs" are used to simulate the flow field. Leg 1 is assumed to be a vertical leg through the repository. It is also the source for radionuclides. Leg 2 simulates the vertical flow path through the basalt up to the interflow zone. Leg 3 simulates the interflow zone. Table 1 describes the leg lengths, conductivities and cross sectional areas assigned to each leg.

TABLE 1 MODEL PARAMETERS

Leg Number	Length (ft)	Conductivity (ft/day)	Cross Sectional Area (sq. ft)
1	16.41	2.8E-4	8.0E7
2	66.00	2.8E-4	8.0E7
3	6562.00	2.8	1.2E6

The releases are measured at the end of Leg 3. To arrive at integrated curies released at this point, four radionuclide chains plus the remaining inventory were used in the calculations. All radionuclides used are listed in Table 2. This table also lists the solubility limit assigned to each radionuclide.

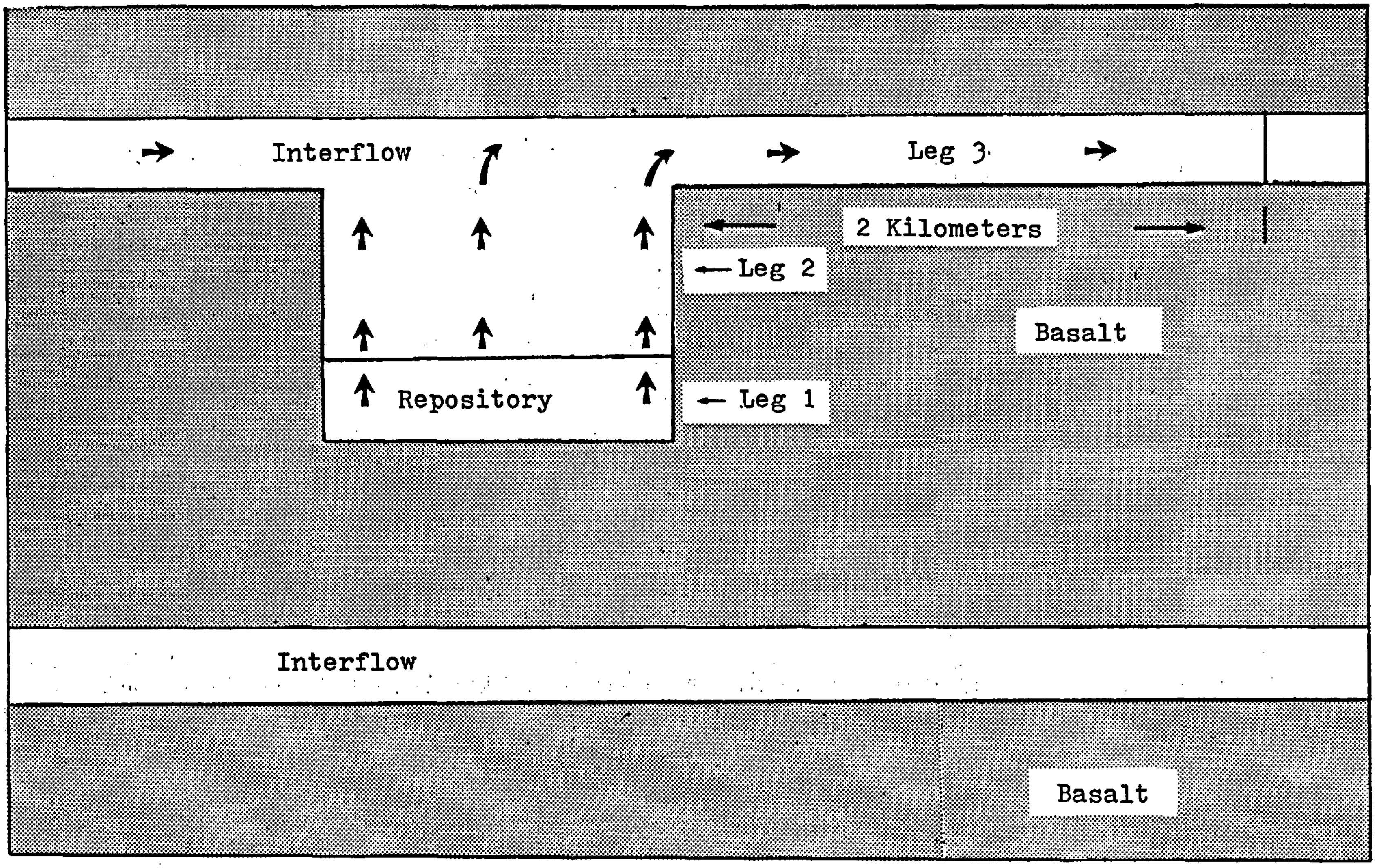


Figure 1: Hanford Model Set Up

TABLE 2 BASALT SOLUBILITIES

RADIONUCLIDE	SOLUBILITY gms/gm
CHAIN 1	
PU 240	1.0E-11
U 236	1.0E-9
TH 232	1.0E-10
RA 228	1.0E-9
CHAIN 2	
CM 245	1.0E-9
PU 241	1.0E-11
AM 241	1.0E-9
NP 237	1.0E-10
U 233	1.0E-9
TH 229	1.0E-10
CHAIN 3	
CM 246	1.0E-9
PU 242	1.0E-11
U 238	1.0E-9
PU 238	1.0E-11
U 234	1.0E-9
TH 230	1.0E-10
RA 226	1.0E-9
PB 210	1.0E-7
CHAIN 4	
AM 243	1.0E-9
PU 239	1.0E-11
U 235	1.0E-9
PA 231	1.0E 0
AC 227	1.0E 0
OTHER RADIONUCLIDES	
TC 99	1.0E-9
I 129	1.0E 0
SN 126	1.0E-10
CS 135	1.0E 0
C 14	1.0E 0
SR 90	6.3E-7
CS 137	1.0E 0

Paradox

The Paradox model was also constructed from data provided in ADL 1980, 1982, 1984a. A U-tube flow scenario was chosen because this is much more reasonable than the assumption of darcy flow through "porous" salt that is considered in the EAs. (It is not presently known whether or not darcy flow occurs in salt.) A U-tube scenario occurs when the repository shaft seals fail and water is channeled down one shaft, through the repository, and then upward through another shaft. This scenario has been widely used by the NRC when considering repository disruptions. However, the scenario may be overconservative because careful repository design might prevent any significant gradient between potentially leaky shafts. It has been used in this comparison since it appears to be the most likely way in which "expected performance" in a salt repository might lead to any releases.

Three "legs" are also used to simulate the flow field in the Paradox model. Leg one is assumed to be horizontal and goes through the repository. This leg is the source for radionuclides. Leg 2 is the down gradient side of the "U" which channels flow upward to intersect an overlying aquifer. Leg 3 simulates the overlying aquifer. Figure 2 is a graphic presentation of the Paradox Basin model setup. Again, releases of radionuclides are measured at the end of Leg 3 at a two-kilometer distance. Table 3 describes the leg lengths, conductivities and cross sectional areas assigned to each leg.

TABLE 3 MODEL PARAMETERS

Leg Number	Length (ft)	Conductivity (ft/day)	Cross Sectional Area (sq. ft)
1	16.41	2.8E-4	538.0
2	2067.00	2.8E-4	538.0
3	6562.00	6.8E-2	5.9E4

The same radionuclides are used in the Paradox Basin simulation as were used in the Hanford simulation. Table 4 lists these radionuclides, and the solubilities assigned.

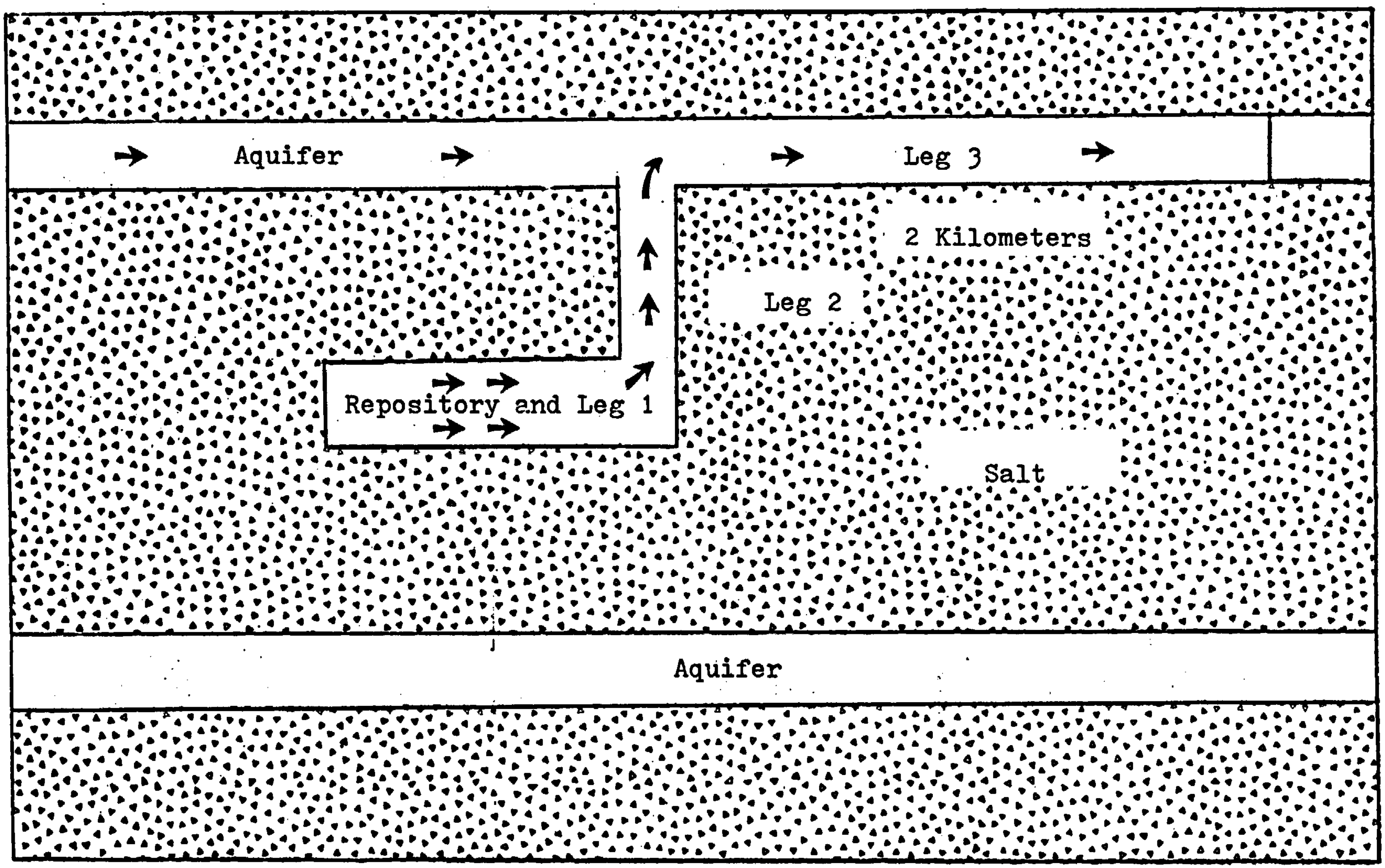


Figure 2: Paradox Model Set Up

TABLE 4 PARADOX BASIN SOLUBILITIES

RADIONUCLIDE	SOLUBILITY gms/gm
CHAIN 1	
PU 240	1.0E-9
U 236	1.0E-9
TH 232	1.0E-9
RA 228	1.0E-8
CHAIN 2	
CM 245	1.0E-9
PU 241	1.0E-9
AM 241	1.0E-8
NP 237	1.0E-9
U 233	1.0E-9
TH 229	1.0E-9
CHAIN 3	
CM 246	1.0E-9
PU 242	1.0E-9
U 238	1.0E-9
PU 238	1.0E-9
U 234	1.0E-9
TH 230	1.0E-9
RA 226	1.0E-8
PB 210	1.0E-7
CHAIN 4	
AM 243	1.0E-8
PU 239	1.0E-9
U 235	1.0E-9
PA 231	1.0E 0
AC 227	1.0E 0
OTHER RADIONUCLIDES	
TC 99	1.0E 0
I 129	1.0E 0
SN 126	1.0E-9
CS 135	1.0E 0
C 14	1.0E 0
SR 90	1.0E 0
CS 137	1.0E 0

RESULTS

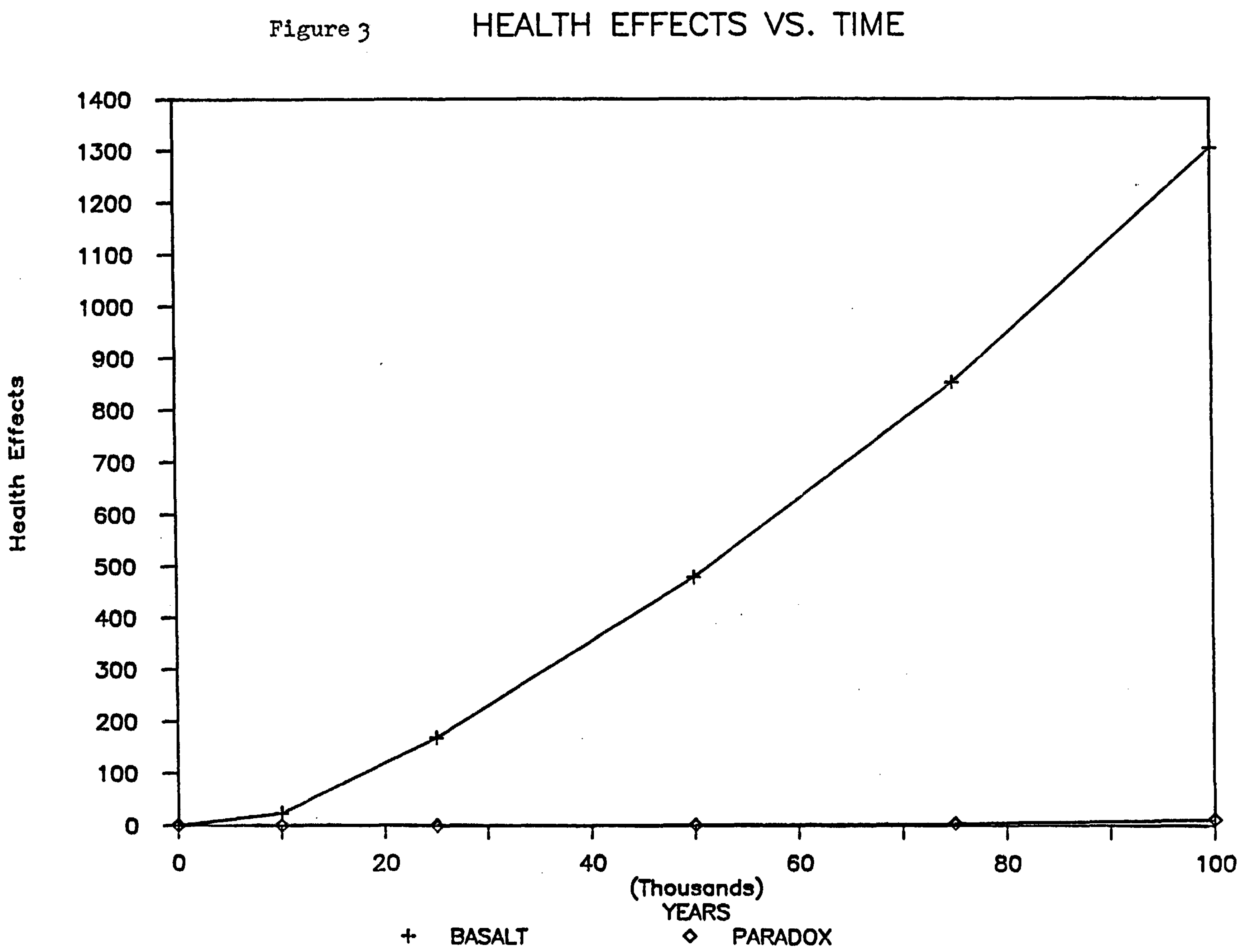
The results of the model runs were first calculated as the integrated number of curies of each radionuclide released over time. The total for each radionuclide was then multiplied times a "fatal cancers per curie released" term derived from a draft of the Final EPA Standards (Working Draft 4, May 21, 1984). The release limit for each radionuclide in Table 1 of this draft corresponds to 10 fatal cancers, and the resulting health impact term for each nuclide is shown in Table 5. Figure 3 is a plot of the integrated health effects over a 100,000 year time period for Hanford and Paradox. It can be seen from this plot that the potential impacts from Hanford are much higher than for the Paradox Basin. When one considers that in order to get releases from Paradox, shaft leakage and poor shaft locations must be assumed, the releases to be expected from such salt media repositories could be far less than shown in this comparison. What this means is that Hanford, under the best of conditions, will release far more radionuclides and cause far more health impacts than will unlikely scenarios in the Paradox.

The reason the release rates in the Hanford model are so much higher than Paradox are twofold; the length of the flowpath to the accessible environment is shorter at Hanford, and the cross sectional area is larger. (It is noted, however, the solubilities at Paradox are generally higher than at Hanford due to the salt present in the water). A possible criticism of the Hanford model would concern the vertical path assumed from the repository to the flowtop. The criticism would spring from the fact that DOE has repeatedly stated the groundwater flow in the area of the proposed repository is horizontal. The actual direction of groundwater flow, however, has not been conclusively determined. There are geochemical indications there is already a large vertical component to groundwater flow in the Grande Ronde (Lehman and Quinn, 1982). Furthermore, as a result of the high temperatures, there is every reason to suspect vertical flow in the immediate vicinity of the proposed Hanford repository due to convection. The use of the entire cross sectional area of the repository for transport could also be questioned. In this regard, the assumption made in the Hanford model is that the transport is through a heterogeneous porous medium using darcy flow. This should be acceptable since it is the same assumption DOE makes in its own modeling efforts.

TABLE 5 HEALTH EFFECTS PER CURIE
(IMPLIED FROM EPA WORKING DRAFT #4)

RADIONUCLIDE	SOLUBILITY gms/gm
CHAIN 1	
PU 240	0.1
U 236	0.1
TH 232	0.1
RA 228	0.1
CHAIN 2	
CM 245	0.1
PU 241	0.01
AM 241	0.1
NP 237	0.1
U 233	0.1
TH 229	0.1
CHAIN 3	
CM 246	0.1
PU 242	0.1
U 238	0.1
PU 238	0.1
U 234	0.1
TH 230	0.1
RA 226	0.1
PB 210	0.1
CHAIN 4	
AM 243	0.1
PU 239	0.1
U 235	0.1
PA 231	0.1
AC 227	0.1
OTHER RADIONUCLIDES	
TC 99	0.001
I 129	0.1
SN 126	0.01
CS 135	0.01
C 14	0.1
SR 90	0.01
CS 137	0.01

Figure 3


HEALTH EFFECTS VS. TIME
Health Effects
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
0
20
40
60
80
100
(Thousands)
YEARS
+ BASALT
◇ PARADOX

CONCLUSIONS

It is obvious from this preliminary model comparison study that the Hanford Site should be ranked lower than those in the Paradox Basin and most, if not all, of the other salt sites as well. It simply does not make sense to score Hanford higher than the Paradox. The EA fails to do adequate comparative analysis against the system guidelines. The ranking system that has been used instead overemphasizes short-term considerations and factors that have relatively little bearing on long-term protection of the environment. As this comparison shows, the EA ranking system results in selecting a site for characterization (Hanford) that is clearly far inferior in terms of the system guidelines to sites that would not be characterized (Paradox). A more meaningful comparative methodology will have to be developed by DOE in order to adequately assess the isolation potential of the nine candidate sites. Rock type diversity should not be used as a justification for characterizing an obviously inferior site.

REFERENCES CITED

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DOE (U.S. Department of Energy), 1984. Nuclear Waste Policy Act of 1982: General Guidelines for the Recommendation of Sites for Nuclear Waste Repositories, 10CFR Part 960, Washington, D.C.

EPA (U.S. Environmental Protection Agency), 1984. Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes, Working Draft No. 4, 40CFR part 191, Washington, D.C.

Lehman, L.L. and E.J. Quinn, 1982. Comparison of Model Studies: The Hanford Reservation, U.S. NRC Public Document Room, PDR Waste WM-1.

Little, Arthur D., March, 1980. "Technical Support of Standards for High-Level Radioactive Waste Management," Release Mechanisms, EPA 520/4-79-007D, Volume D, Report for the U.S. Environmental Protection Agency, Washington, D.C.

Little, Arthur D., March, 1982. "Technical Support of Standards for High-Level Radioactive Waste Management," EPA-520/4-79-007E, Addendum Volume C and D, Report for the U.S. Environmental Protection Agency, Washington, D.C.

Little, Arthur D., August, 1984. "Conceptual Model of a Basalt Repository at the Hanford Reservation, Richland, Washington," EPA-68-01-6628, Report for the U.S. Environmental Protection Agency, Washington, D.C.

Little, Arthur D., August, 1984a. "Draft Conceptual Model of a Bedded Salt Repository in the Paradox Basin, Utah," EPA-68-01-6628, Report for the U.S. Environmental Protection Agency, Washington, D.C.

Appendix F

APPENDIX F

DOCUMENTATION OF RESERVED TREATY RIGHTS

OF THE YAKIMA INDIAN NATION

The following historical material, public documents, anthropology reports and other writings show that the Department of Energy's submission concerning Hanford Site ownership vis-a-vis YIN Reserved Treaty Rights is inadequate and misleading.

American Indians, North of Mexico
Edited by: Frederick Webb Hodge
Published by: Smithsonian Institution,
  Bureau of American Ethnology
Bulletin No. 30
Subject: Shahaptian Family
Pages: 519, 520 and 983
Dated: October, 1912

Intergroup Relations in the Southern Plateau
By: Angelo Anastasio
Ph.D. Dissertation, University of Chicago, 1955

Barnaby, J.T.
Dams and the Columbia River Salmon
Presented at the meeting of the American
  Society of Ichthyologists and Herpetologists,
  Western Division, San Diego, California
Date: Wednesday, June 18, 1947. Symposium of
  "Overcoming Obstructions to Movements of
  Fishes in Rivers"

Bureau of Ethnology
Fourteenth Annual Report to the Secretary of
  The Smithsonian Institution, 1892-93
By: J. W. Powell, Director
Part 2, Published by: Government Printing Office,
  1896

Bureau of Ethnology
Eighteenth Annual Report to the Secretary of
  The Smithsonian Institution, 1896-97
By: J. W. Powell, Director
Government Printing Office, 1899
Pages: 944-1006

Bureau of Indian Affairs
Records of the Treaty File. Letters received, 1856 - Washington Superintendency, W-537. Letter of Governor Isaac I. Stevvens to George W. Mannypenny
The National Archives

Bureau of Indian Affairs
Records of the Treaty File. Minutes of proceedings leading up to Treaty of Point No Point
Date: January 26, 1855
The National Archives

Bureau of Indian Affairs, Records of the
Wilber, James H., letter dated November 17, 1881 from H. Price, Commissioner
Subject: Trouble between the Indians and whites at the Tumwater Fisheries
Records of the Bureau of Indian Affairs (RG 75).
Letters sent: Land Division Letter, Book 87
The National Archives

Bureau of Indian Affairs, Records of the
Letter dated February 21, 1884, to Honorable C. Delano, Secretary of the Interior, from E. P. Smith, Commissioner of Indian Affairs.
Record copies of letters sent, Volume 24
The National Archives

Chief Sluskin's True Narrative
By: Luculus V. McWhorter
Published: Washington State Historian
Volume VIII, No. 2, April 1917

Commission, Appointment of
Subject: Bonneville Dam and protection of the Columbia River Fisheries
Document No. 87
Seventy-Fifth Congress, First Session

Commissioner of Indian Affairs, Report 1897
Fifty-Fifth Congress, Second Session
Pages 93, 94, 298
Contents: Fisheries in Washington, Irrigation, Fisheries

Condition of the Indian Tribes
Report of the Joint Special Committee appointed under Joint Resolution of March 3, 1865
Pages 8, 9, 424, 425, 440, 441

Craig, Joseph A., and R. L. Hacker
History and Development of Fisheries of the Columbia River
Bulletin of U.S. Bureau of Fisheries, 1940
Pages 133-216

Davidson, F. A.
Historical evidence of the use and occupancy of the Yakima Indians of their usual and accustomed fishing locations at Celilo Falls and the Dalles on the Columbia River
Date: August 15, 1953

Doty, James
Extracts from the journal of Mr. James Doty, Secretary for treaties in Washington Territory and the Blackfoot country, showing his proceedings in assembling for a council at the Walla Walla valleys, the Cayuse, Walla Walla, Nez Perce, Palouse, Oakinakans, Pisquose and Yakima tribes of Indians under the directions of Governor Isaac I. Stevens, Superintendent of Indian Affairs, Washington Territory

Doty, James
A true copy of the record of the official proceedings at the Council in the Walla Walla Valley, held jointly by Isaac I. Stevens, Governor and Superintendent, Washington Territory, and Joel Palmer, Superintendent, Indian Affairs, Oregon Territory, on the part of the United States, with the tribes of Indians named in the treaties made at that Council
Date: May 28, 1855 - June 11, 1855

Doty, James
Secretary of Treaties for Washington Territory under Isaac I. Stevens, Governor and Commissioner of Indian Affairs
Covering the period January 20, 1855 to January 4, 1856
The notification by Gov. Stevens to the Indian tribes that a treaty council will be held at Walla Walla in June
Yakima Indian Nation Archives, Box 10-1

Executive Document No. 38
Indian war in Oregon and Washington Territories
Letter from the Secretary of the Interior transmitting in compliance with the resolution of the House of the 15th instant, the report of J. Ross Browne, on the subject of the Indian war in Oregon and Washington Territories
Thirty-Fifth Congress, First Session
Date: January 25, 1858

Executive Document No. 39
Indian Affairs on Oregon and Washington Territories
Thirty-Fifth Congress, First Session
Date: 1857

Executive Document No. 78
Explorations and surveys, reports to ascertain the most practicable and economic route for a railroad from the Mississippi River to the Pacific Ocean
Thirty-Third Congress, Second Session
Volume 1, 1853-54

Executive Document No. 91
Report of explorations and surveys to ascertain the most practical and economic route for a railroad from the Mississippi River
Thirty-Third Congress, Second Session

Findings, U.S. v. Washington
384 F.Supp. 312

Fisheries on the Columbia River, Washington Territory
Secretary of the Interior Report, 1886-87
Forty-Ninth Congress, Second Session

Fisheries on the Columbia River, Washington Territory
Secretary of the Interior Report, 1887-88
Fiftieth Congress, First Session

Fisheries, Right of the Indiians in the Wisham Fishery Case
Commissioner of Indian Affairs Report, 1897
Fifty-Fifth Congress, Second Session

Gibbs, George
Indian Tribes of Washington Territory
Published: Ye Galleon Press (reprint) 1972

Gibbs, George
Railroad Survey Report
Geology of Central Washington Territory
Volume 1
Dated: 1855
Pages 477-482

Gordon Report
In the United States Court for the
District of Oregon
United States v. Seufert Brothers
Filed in U.S. District Court March 6, 1917
District of Oregon

Griswold, Gillett
Aboriginal Patterns of Trade between the Columbia
River and the Northern Plains
M.A. thesis, Montana State University, 1953

Hewes, Gordon
Aboriginal Use of Fishery Resources in North-
western North America
Ph.D. dissertation, University of California, 1947

Railroad Survey Report
Indian Tribes of Washington Territory
Dated: 1854
Volume 1
Pages: 402-428

Railroad Survey Report (Stevens)
Narrative of 1855
Dated: 1860
Volume XII
Pages: 222-225

Railroad Survey Report (Gibbs)
Geology of Central Washington Territory
Dated: 1855
Volume 1
Pages: 477-482

Ray, Dr. Vern
Native Villages and Groupings of the
Columbia River Basin
Published: Pacific Northwest Quarterly
Dated: 1936

Ray, Dr. Vern
Tribal Distribution in Eastern Oregon and Adjacent Regions
Published: American Anthropologist
Volume 40
Dated: 1938

Relander, Click
Drummers and Dreamers
Published: Caxton Printers, Ltd.
Dated: 1956
Subject: Smowhalla, The Prophet
Pages: 286 through 311 inclusive

Relander, Click
Strangers on the Land
Published: Yakima Indian Nation
Dated: December 1962
A historiett - of a longer story of the Yakima Indian Nation's efforts to survive against great odds

Report on the Condition of the Yakima Indian Reservation - Washington
Submitted by the Secretary of the Interior
Sixty-Second Congress, Third Session
Dated: January 23, 1913
Document No. 1299

Secretary of the Interior Report
Dated: 1884-85
Forty-Eighth Congress, Second Session
Pages: 216-219
Subject: Condition, Habits and Dispositions - Progress Made - Industrial Boarding Schools - A Mistaken and Pernicious Policy - Conflict of Departments - The Indian Police - Piutes - Fisheries

Secretary of the Interior Report
Dated: 1886-87
Forty-Ninth Congress, Second Session
Pages: 129, 130, 131
Subject: Joseph's Band of Nez Perce, Washington Territory - Fisheries on the Columbia River, Washington Territory

Secretary of the Interior Report
Dated: 1887-88
Fiftieth Congress, First Session
Pages: 80, 81, 303
Subjects: Fisheries on the Columbia River, Washington Territory - Condition of Agency - Civilization and Morals - Agency Stock

Secretary of the Interior Report
Dated: 1892-93
Fifty-Second Congress, Second Session
Page: 423
Subjects: Census - Indians Living Along the Columbia - Agriculture - Improvements and Repairs - Allotments of Lands in Severalty - Reservation Schools

Secretary of the Interior Report
Dated: 1897
Fifty-Fourth Congress, Second Session
Pages: 98,99, 100, 319
Subjects: Wisham and Tumwater Fisheries on the Columbia River - Fishery, Tumwater - Commission - Health - Census

Snowden, Clinton A.
History of Washington - The Rise and Progress of an American State
Published: 1909
Volume 3
Pages 254-375
Chapter XLIII - Treaties With the Indians

Social Economic Status of the Yakima Nation, Washington State University Circular 397, 1961.
Particularly from page 31 regarding tribal dependence on fisheries

Swindell, Edward G.
Report on source, nature and extent of fishing, hunting and miscellaneous related rights of certain Indian tribes in Washington and Oregon
Office of Indian Affairs, 1942

Treaty, Preliminary Proceedings
By: James Doty, Secretary of Treaties for Governor Stevens
Extracts from the journal of Mr. James Doty, Secretary for Treaties in Washington Territory and the Blackfoot Country, showing his proceedings in assembling for a council in the Walla Walla valleys, the Cayuse, Walla Walla, Nez Perce, Palouse, Oakinakans, Pisquose and Yakima Tribes of Indians under the directions of Governor Isaac I. Stevens, Superintendent of Indian Affairs, Washington Territory

Treaty Proceedings of the Yakima Indian Nation
By: James Doty, Secretary of Treaties for Governor Stevens
A true copy of the record of the official proceedings at the council in the Walla Walla Valley held jointly by Isaac I. Stevens, Governor and Superintendent, Washington Territory, and Joel Palmer, Superintendent of Indian Affairs, Oregon Territory, on the part of the United States with the tribes of Indians named in the treaties made at that Council
Dated: May 28, 1855 - June 11, 1855

Treaty With the Yakimas
12 Stat. 951, 2 Kap. 524

Walker, Deward
Mutual Cross Utilization of Economic Resources of the Plateau
Washington State University, Laboratory of Anthropology
Report of Investigations No. 41, 1967

Yakima Indian Nation Primer
The Yakima Indian Nation, Retention of Customs and Beliefs, Tribal Government and Membership Operations of the Yakima Agency
Published: Circa 1960

Yakima Tribes v. United States
Docket 161, Indian Claims Commission,
An unconscionable consideration claim
regarding in part the area herein involved

APPENDIX G

YAKIMA TRIBAL COUNCIL RESOLUTIONS

RESOLUTION T-72-79

WHEREAS, the Yakima Indian Nation and its governing bodies have the responsibility for preserving the health and welfare of citizens within its boundaries, at its usual and accustomed hunting and fishing sites and various other locations described herein; and

WHEREAS, the President of the United States through the Secretary of the Interior for the United States has on official record the legal description of said boundaries and areas mentioned herein; and

WHEREAS, nuclear wastes, residues, fuels, products and by-products from nuclear material have a real and distinct health hazard to all the residents within and at the areas mentioned herein; including hazards to traditional, cultural, and religious sites throughout the Yakima Indian Nation and at its usual and accustomed hunting and fishing sites; and

WHEREAS, the Yakima Indian Nation, pursuant to its Treaty of 1855 with the United States (ratified) possesses sovereign authority to exercise control and dominion within its said boundaries and at its usual and accustomed hunting and fishing sites and other sites mentioned herein.

NOW, THEREFORE, BE IT RESOLVED that nuclear wastes,residues, fuels, products and by-products from nuclear material are, from this day forward NOT PERMITTED within the borders of the Yakima Indian Nation; nor are said nuclear material permitted to cross said lands by any conveyance, whether by land, rail, air, or water;.

BE IT FURTHER RESOLVED that because of Treaty and court case rights to access, ingress and egress, as to hunting, fishing, relgious, and food gathering sites in the various Treaty Ceded areas of the Yakima Indian Nation and because of the Yakima Indian Nation's concern for the health, welfare, and safety of their people when using said ceded sites and areas, the Yakima Indian Nation records this day their concern over any nuclear wastes,residues, fuels, products and by-products from nuclear material being introduced by whatever method or manner into the Yakima Indian Nation various Treaty ceded areas.

DONE AND DATED on this 6th day of June, 1979 by the Yakima Tribal Council, meeting in regular session at the Governmental Offices of the Confederated Tribes and Bands of the Yakima Indian Nation, Toppenish, Washington, by a vote of 9 for and none against (1 not voting).

Watson Totus, Chairman,
Yakima Tribal Council

ATTEST:

Joe Sampson, Secretary,
Yakima Tribal Council

Tribal Council   General Council Office
Supt's Office
Archives
T.A.D.

RESOLUTION   T-17-83

WHEREAS, the establishment of nuclear facilities and nuclear waste facilities on the Hanford Reservation will affect the lives, the health and safety of the Yakima Indian Nation and its members and will affect the use and enjoyment of the Yakima Indian Reservation; and

WHEREAS, the Yakima Indian Nation is a Sovereign Nation, by right of the Treaty of June 9, 1855, over the Totally Reserved Lands, and in its Reserved Usage Rights over all Ceded Land; and

WHEREAS, the Yakima Indian Nation has the right and obligation to protect from environmental harm all Yakima Indian Nation Ceded and Totally Reserved Lands; and

WHEREAS, said nuclear facilities and nuclear waste facilities will have a detrimental effect to the Treaty reserved hunting, fishing and gathering rights together with sacred and archaeological sites within the area Ceded in the Treaty of 1855; and

WHEREAS, no agency of man can guarantee the Yakimas that emergency measures can be devised or carried out which will protect the Yakima Indian Nation from nuclear contamination originating from the Hanford Reservation.

NOW, THEREFORE, BE IT RESOLVED by the Yakima General Council meeting in its annual session, at the Wapato Longhouse, Wapato, Washington, a quorum being present, does take a stand against the establishment of nuclear facilities and nuclear waste facilities on the Hanford Reservation.

BE IT FURTHER RESOLVED that the Yakima Indian Nation shall refuse to participate in any proposed emergency response plans that would require the evacuation of our Reserved Lands under the Treaty of June 9, 1855.

DONE AND DATED on this 7th day of December, 1982 by the Yakima General Council of the Yakima Indian Nation by a vote of 132 for and 10 against.

Walter J. Speedis, Chairman
Yakima General Council
Yakima Indian Nation

ATTEST:

Virginia Beavert, Secretary
Yakima General Council
Yakima Indian Nation