Research Technical Completion Report

EVALUATION OF HYDROGEOLOGIC SITING CRITERIA FOR SITING HAZARDOUS WASTE MANAGEMENT FACILITIES IN IDAHO

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ABSTRACT

The Idaho Legislature addressed the issue of land disposal of hazardous wastes by adopting the Hazardous Waste Facility Siting Act in 1985. This Act established a committee charged with developing the Idaho Hazardous Waste Management Plan. The plan was formulated and passed the State Legislature in early 1987.

Hazardous waste facility siting criteria, included in the plan, were developed for siting future land disposal hazardous waste management facilities in Idaho. The siting criteria address depth to water, depth to fractured rock, thickness of unconsolidated fine-grained sediments beneath the proposed site, minimum distance to water supply wells, distance to surface water and location outside of a 500-year recurrence interval floodplain.

Two standardized methods for comparing and ranking the hydrogeology at a waste management facility were reviewed. The standard methods of DRASTIC and Harry E. LeGrand were analyzed to determine their effectiveness of siting new facilities within Idaho.

Hydrogeologic siting criteria from the States of New Jersey, New York, Arizona, and California were evaluated and compared to the Idaho criteria. New Jersey, California, and Idaho addressed the most comprehensive range of hydrogeologic issues; however, Idaho's criteria are the most stringent.

A preliminary application of the Idaho hydrogeologic siting criteria using existing available public information is presented for a portion of southwestern Idaho. The depth to fractured rock and depth to water criteria are the most restrictive in limiting potential sites.

CHAPTER 1

INTRODUCTION

Statement of the Problem

The land disposal of hazardous waste has created potential environmental and health risks on a national scale. Environmental ramifications of the land disposal of hazardous wastes have become a major issue in Idaho. Envirosafe Services Inc. (ESI) owns and operates a hazardous waste management facility near Grandview, Idaho. The disposal practices at ESI have raised public concern regarding potential long term health and environmental impacts.

The Idaho legislature addressed this issue by adopting the Hazardous Waste Facility Siting Act in 1985. Among other actions, this Act established a committee to develop a state management plan for hazardous wastes within Idaho. Seventeen Idaho citizens were appointed by the Governor and approved by the Idaho Senate in early 1986 to serve on this committee. The committee worked through the summer of 1986 to formulate a Plan and adopted the Idaho Hazardous Waste Management Plan on December 17, 1986. The plan was presented and approved by the Idaho legislature in early 1987.

The plan consists of policy statements, rationale for each statement, and recommended implementation methods. The plan also contains hydrogeologic and demographic technical siting criteria. These criteria were developed by the committee to guide the screening procedure for siting potential new land disposal waste management facilities. Hydrogeologic criteria include: minimum depth to water, depth to fractured rock, thickness of unconsolidated fined-grained sediments, distance to surface water, distance to water supply wells and location outside of a 500-year floodplain. The purpose of these hydrogeologic criteria are to exclude portions of the State of Idaho that obviously are not amenable to the operation of hazardous waste management facilities because of their lack of natural hydrogeologic barriers that would limit contaminant movement into usable water resource systems.

The ramification of these exclusionary siting criteria on locating hazardous waste management facilities in Idaho are not understood. This research is directed toward examining the criteria in light of regulations from other states and two classification systems. The criteria are tested by an example application to a portion of southwestern Idaho.

Purpose and Objectives

The purpose of this research is to explore the utilization of Idaho's hydrogeologic siting criteria for siting future commercial hazardous waste management facilities. The general objective is to analyze and evaluate the application of hydrogeologic siting criteria for siting future hazardous waste management facilities within southwestern Idaho. The specific objectives are: (1) review the applicability of existing methodologies for evaluating and comparing the hydrogeology at waste management facilities. The standard methodologies reviewed include DRASTIC (Aller and others, 1985) and LeGrand (1983), and a method for conducting a hydrogeologic field investigation (Williams and Osiensky, 1983), (2) compare the Idaho hydrogeologic siting criteria with those developed by the States of New Jersey, New York, Arizona, and California, (3) determine and compare the physical implications of the hydrogeologic siting criteria developed by Idaho and the other states, (4) regionally delineate locations within southwestern Idaho that might satisfy the Idaho hydrogeologic siting criteria, (5) select two specific areas to illustrate the application of the Idaho hydrogeologic siting criteria based on existing available public information, (6) compare the application of the hydrogeologic siting criteria with the application of DRASTIC to the same areas, and (7) draw conclusions and recommendations regarding the application of the Idaho hydrogeologic siting criteria.

Method of Study

The Hazardous Waste Management Planning Committee convened during the summer of 1986. I researched, collected and compiled various state and federal regulations governing the disposal of hazardous wastes while serving as staff member to the committee.

The applicability of standardized methodologies to evaluate and compare the hydrogeology at waste management facilities were reviewed. The standardized systems of DRASTIC and LeGrand were reviewed and compared evaluating their effectiveness for siting waste management facilities in Idaho.

A detailed literature review of hydrogeologic siting criteria adopted by other states was conducted. Siting criteria from the States of New Jersey, New York, Arizona, and California were compared to the Idaho criteria and major differences were noted.

As part of a regional evaluation, locations within southwestern Idaho were delineated that might satisfy the Idaho hydrogeologic siting criteria. The areas were determined by applying two preliminary criteria (i.e., depth to fractured rock and depth to water) on a regional reconnaissance basis.

Two small areas delineated by the regional analysis were selected to illustrate the application of the Idaho hydrogeologic siting criteria using existing available public information. The application of the criteria to these smaller areas was then compared with the application of DRASTIC. The application and comparison of DRASTIC to the criteria demonstrates the effectiveness and limitations of interpreting the hydrogeology using only existing available information.

CHAPTER 2

STANDARDIZED SYSTEMS FOR HYDROGEOLOGIC EVALUATION OF A WASTE MANAGEMENT FACILITY

Understanding the hydrogeology of a proposed or existing waste management facility (WMF) is imperative for siting new facilities. The State of Idaho is currently at the stage of hazardous waste management to address the industry needs for new waste management facilities. Natural hydrogeologic conditions provide the primary protection for the environment against long term disposal of hazardous wastes.

Two standardized systems for evaluating and comparing the hydrogeology of a WMF and one methodology for conducting a hydrogeologic investigation are reviewed in this chapter. The National Water Well Association in conjunction with the Environmental Protection Agency developed the system DRASTIC (Aller et. al., 1985). This standardized system was developed for evaluating the ground water pollution potential for any hydrogeologic setting using seven DRASTIC factors. This system focuses upon evaluating large scale areas (i.e., greater than 100 acres), thereby limiting its use for site-specific locations. Harry E. LeGrand (1983) developed a standardized system for evaluating and comparing site-specific waste disposal locations based upon four hydrogeologic factors. Williams and Osiensky (1983) developed a logical sequence of procedures to properly conduct a hydrogeologic field investigation. Each system is outlined and discussed in this section regarding their application and usefulness for siting new hazardous waste management facilities in Idaho.

DRASTIC: A System for Evaluating Ground Water Pollution Potential using Hydrogeologic Settings

The purpose of this system is to create a methodology that permits the ground water pollution potential of any hydrogeologic setting to be systematically evaluated using existing information (Aller and others, 1985). This system focuses upon the designation of the general hydrogeologic setting, and the relative ranking of the area based upon seven hydrogeologic DRASTIC factors. These factors are: (1) depth to water, (2) net recharge, (3) aquifer media, (4) soil media, (5) topography, (6) impact of vadose zone, and (7) hydraulic conductivity of the aquifer (Aller and others, 1985, p.7).

The ground water pollution potential using the DRASTIC factors is categorized into weights, ranges, and ratings. DRASTIC factors are weighted with respect to their relative importance in determining the pollution potential (Table 1). Each DRASTIC factor is divided into a range for rating their impact on pollution potential (Table 2). Each range has been evaluated to determine the relative significance of each to the pollution potential, and assigned a rating between 1 and 10 (Table 2).

This system of weights, ranges, and ratings allows the user to determine a numerical rating value (i.e., DRASTIC index) for any hydrogeologic setting using the following equation. The DRASTIC index is: where r= rating
w= weight

Dr+Dw+Rr+Rw+Ar+Aw+Sr+Sw+Tr+Tw+Ir+Iw+Cr+Cw= Pollution Potential.

The higher the DRASTIC index for an area the greater the potential for ground water pollution. Proposed or existing locations can then be ranked and compared by their DRASTIC indices. The reader is referred to

Table 1: Assigned Weights for each DRASTIC Factor
(Modified after Aller and Others, 1985)

Feature	Weight
Depth to Water Table	5
Net Recharge	4
Aquifer Media	3
Soil Media	2
Topography	1
Impact of the Vadose Zone	5
Hydraulic Conductivity of the Aquifer	3

Table 2: Range and Ratings for each DRASTIC Factor for Rating their Impact on Determining the Pollution Potential of a Site. (Modified from Aller and Others, 1985)

Depth to Water (feet)

Range	Rating
0-5	10
5-10	9
15-30	7
30-50	5
50-75	3
75-100	2
100+	1
Weight:5	

Topography (percent slope)

Range	Rating
0-2	10
2-6	9
6-12	5
12-18	3
18+	1
Weight:1	

Net Recharge (inches)

Range	Rating
0-2	1
2-4	3
4-7	6
7-10	8
10+	9
Weight:4	

Impact of Vadose Zone

Range	Rating
Silt and Clay	1-2
Sand and Gravel with silt and clay	4-8
Sand and Gravel	6-9
Metamorphic/Igneous	2-8
Basalt	2-10
Weight:5	

Aquifer Media

Range	Rating
Massive Shale	1-3
Metamorphic/Igneous	2-5
Sand and Gravel	6-9
Basalt	2-10
Weight:3	

Hydraulic Conductivity (GPD/FT2)

Range	Rating
100-300	2
300-700	4
700-1000	6
1000-2000	8
2000+	10
Weight:3	

Soil Media

Range	Rating
Thin or Absent	10
Gravel	10
Sand	9
Sandy Loam	6
Silty Loam	4
Weight:2	

Aller and others (1985) for a complete description of the steps to evaluate a waste management facility site location.

LeGrand: A Standardized system for Evaluating Waste Disposal Sites

This system focuses on weighting four hydrogeologic factors of a site. These factors are: (1) distance to point of water use, (2) depth to water, (3) water table gradient, and (4) permeability-sorption (LeGrand, 1983). Each hydrogeologic factor is assigned a numerical value which comprise a standard numerical rating for each disposal site.

The development and interpretation of the numerical rating system is divided into ten steps within four stages (Table 3). Stage 1 (steps 1-7) provides a standard hydrogeologic description of the site. Stage 2 (step 8) indicates the degree of seriousness for contamination by comparing the degree of aquifer sensitivity with contaminant severity. Stage 3 (step 9) describes the relative probability of contamination and development of a final grade for comparison of each site. Stage 4 (step 10) recesses the site by considering engineering modifications to prevent contamination (LeGrand, 1983). The first seven steps of the system concentrate on developing a standardized hydrogeologic numerical description of a site (Table 4). Steps 8 and 9 focus on the nature of the contaminant, aquifer sensitivity and develop a final grade for comparison. Proposed or existing locations can then be compared and evaluated by their final grade. The reader is referred to LeGrand (1983) for a complete description of the steps to evaluate a waste management facility site location.

Table 3: Development of the LeGrand Numerical Rating System for Comparing the Hydrogeology at a Waste Management Facility (Modified from LeGrand, 1983)

STAGE 1: Numerical Description for Each Site

- Step 1: Determine the distance on ground between the contamination source and water supply.
- Step 2: Estimate the depth to the water table below base of contamination source more than 5% of the year.
- Step 3: Estimate water table gradient from contamination site.
- Step 4: Estimate the character of the earth materials in terms of permeability and sorption.
- Step 5: Determine the Degree of Confidence in the accuracy of values.
- Step 6: Add any miscellaneous site identifiers.
- Step 7: Completion of the site numerical description.

STAGE 2: Determination of Degree of Seriousness

- Step 8: Determine degree of seriousness by comparing the aquifer sensitivity with contaminant severity.

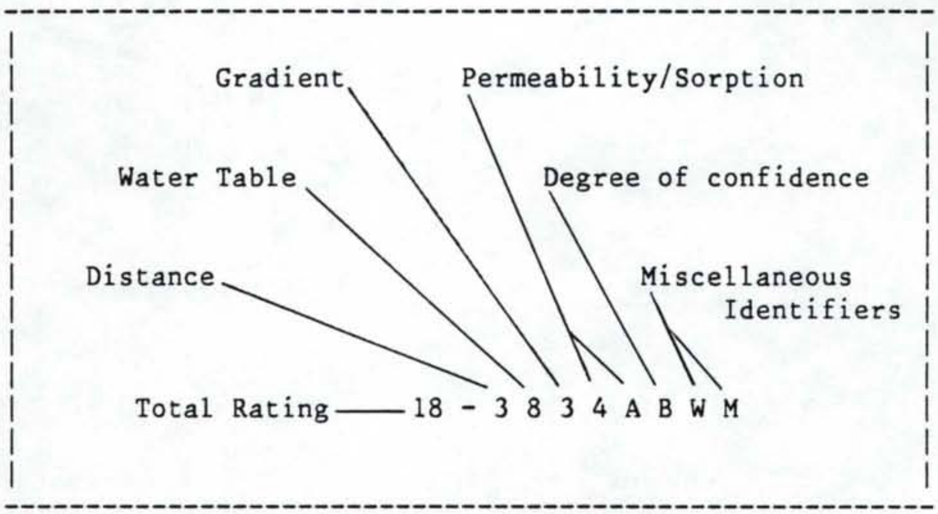
Stage 3: Grading and Evaluating the Hazard Potential and Probability of Contamination

- Step 9: Describes the relative probability of contamination by comparing the site numerical description to a standardized rating (PAR) to develop a final grade for comparison.

Stage 4: Grading and Evaluating the Hazard Potential for a Modified Site

- Step 10: Reacess the site by considering engineering modifications to prevent contamination.

Table 4: An Example of a LeGrand Hydrogeologic Numerical Site Description Code (Modified after LeGrand, 1983)



Williams and Osiensky: Hydrogeologic Analysis of a Waste Management Facility

Williams and Osiensky (1983) developed a methodology for evaluating the site-specific hydrogeology of a proposed or existing waste management facility. This system outlines the logical sequence of procedures for designing and implementing a hydrogeologic field investigation. The system is very useful as a guide for conducting a site-specific field investigation.

The methodology developed by Williams and Osiensky (1983) was not intended to rank and compare a site's hydrogeology, but rather provide guidelines to ensure that sufficient site-specific field data are collected. A complete review of the methodology is provided in Appendix A.

Advantages and Limitations of the Standardized Systems

The DRASTIC and LeGrand systems for evaluating and comparing the hydrogeology at waste management facilities have advantages and limitations regarding their application and usefulness for siting new facilities in Idaho. Advantages for using these systems are: (1) the systems allow for alternate waste management facilities sites to be rated and evaluated using the same comparative methodology, (2) the systems allow for a preliminary rating of each site location which should flag both strong and weak points of the hydrogeology, and (3) the systems allow partially trained personnel to evaluate and compare proposed waste management site locations. However, both systems oversimplify the hydrogeologic comparative analysis. This oversimplification is a major limitation. The LeGrand system is based only on four hydrogeologic factors and the process for numerically rating each factor has many generalizations and assumptions. DRASTIC incorporates more hydrogeologic information in its evaluation, but still may not accurately represent a complex hydrostratigraphic environment.

Utilization of either of these systems to compare and evaluate the hydrogeology of a proposed waste management facility in Idaho must be done with caution. DRASTIC (Aller and others, 1985) is most effective when used for broad regional scale comparisons (e.g., county or geographic region) to illustrate areas which might be suitable for siting a waste management facility. LeGrand (1983) was developed to evaluate, rank, and compare the hydrogeology of specific WMF site locations. However, the geotechnical generalizations inherent in this system probably are too great to effectively evaluate, compare and rank potential WMF site locations.

CHAPTER 3

COMPARISON OF HAZARDOUS WASTE MANAGEMENT FACILITY HYDROGEOLOGIC SITING CRITERIA

The need for siting new hazardous waste management facilities across the nation has intensified due to the continued increase in production of hazardous wastes. The production of hazardous wastes in Idaho nearly doubled during the two year period of 1983 to 1985 (U. S. Environmental Protection Agency, 1985). Many states, including Idaho, have addressed this issue by adopting hazardous waste facility siting legislation.

The primary purpose for developing hazardous waste facility siting criteria is to ensure that new facilities are located in areas which are amenable to the operation of a waste management facility. The general objective of hydrogeologic siting criteria is to locate waste management facilities where the natural hydrogeologic conditions provide sufficient secondary protection for both public safety and the environment. The Idaho Hazardous Waste Management Plan contains technical siting criteria for new commercial hazardous waste land disposal facilities (Idaho Hazardous Waste Management Planning Committee, 1986). These criteria are intended to exclude major portions of the state where the operation of a hazardous waste management facility is not appropriate.

Siting criteria from the States of New Jersey, New York, Arizona, and California were analyzed and compared during the development of the Idaho technical siting criteria. Criteria from these specific states were reviewed because: (1) no state in the Rocky Mountain Northwest had adopted hydrogeologic hazardous waste facility siting criteria, and (2) criteria from these states were the only ones obtainable within the time limit of the Committee meeting schedule. Hydrogeologic siting criteria from New Jersey, New York, Arizona, California, and Idaho are presented, discussed, and compared in this chapter.

WMF Hydrogeologic Siting Criteria from the States of New Jersey, New York, Arizona, California, and Idaho

WMF hydrogeologic siting criteria from the States of New Jersey, New York, Arizona, California, and Idaho range from specific numerical requirements to advisory policy statements. Numerical requirements are criteria that minimize the uncertainty and judgement with respect to the suitability of a proposed site location. Advisory policy statements are criteria that address a given policy issue, but only make a general statement regarding the suitability of a proposed site. These types of criteria represent political advice for locating a proposed site, however they may be ambiguous and do not explicitly exclude any areas from potential site consideration.

The criteria from the five states address a wide range of hydrogeologic issues; however, not every issue is addressed by each state. The criteria can be divided into eight principal categories: (1) depth to water, (2) distance to surface water, (3) distance to water supply wells, (4) depth to fractured rock, (5) lithologic controls, (6) flood plain restriction, (7) location over mining activities, and (8) geologically unstable areas.

The criteria presented from each state are not reproduced verbatim from their respective texts in order to create continuity and organization for comparison. In general, concise paraphrases of the originals are presented.

New Jersey

The hydrogeologic siting criteria adopted by the State of New Jersey are comprised of both specific numerical requirements and advisory policy statements (Table 5). They address a comprehensive range of hydrogeologic issues including: depth to water, direction of ground water flow, ground water travel time, distance to a well or well field, flood plain restriction, areas underlain by specific lithologic formations, and areas overlying subsurface mining activities.

The New Jersey hydrogeologic siting criteria provide exclusionary requirements to control the location of hazardous waste management facilities within the state. However, some of the numerical requirements (e.g., depth to water) are not very restrictive. New Jersey is a highly industrialized state and is faced with the problem of providing sufficient waste management facilities to properly handle their large generation of hazardous wastes. Therefore, the criteria adopted by New Jersey are not very restrictive in limiting potential locations for siting new facilities.

New York

The hydrogeologic siting criteria adopted by the State of New York are comprised entirely of qualitative advisory policy statements (Table 6). The hydrogeologic issues addressed include: siting locations near recharge zones, surface water, aquifers, fractured rock, poor soil conditions, and areas adjacent to mining activities. The criteria are limited in scope and effectiveness for siting new facilities because only general statements regarding each hydrogeologic issue are stated.

Table 5: Hydrogeologic siting criteria from the State of New Jersey (after New Jersey Hazardous Waste Management Commission, 1985) (emphasis is added with capital letters)

1) Depth to Water:

All new Hazardous waste facilities shall be prohibited in areas where the depth to the seasonally high water table in the uppermost saturated unit will rise to within ONE FOOT of the ground surface. (Section 7:26-13.12)

2) Direction of Ground Water Flow:

New major commercial hazardous waste facilities may only be sited where, prior to construction, the flow of ground water in the uppermost saturated unit is predominantly parallel to or upwards toward the water table and the predominant ground water flow direction is toward a nearby surface water body without any intermediate withdrawls from the uppermost saturated zone for public or private water supply and there is no significant recharge to deep aquifers. (Section 7:26-13.12)

3) Ground Water Travel Time:

Land emplacement and impoundment type of new major commercial hazardous waste facilities (e.g., landfills, holding or storage lagoons) shall be prohibited in areas where the ground water travel time, within the uppermost saturated unit from the outermost edge of the containment structure to the site boundary, or to a surface water body...within the site boundary, is LESS THAN TEN YEARS. (Section 7:26-13.12)

4) Distance to Water Supply:

Land emplacement and impoundment type of new major commercial hazardous waste facilites shall be prohibited in areas within ONE MILE of a water supply well or well field producing over 100,000 gallons per day, unless it can be demonstrated...that natural hydrologic barriers isolate the site from the aquifer being pumped. (Section 7:26-13.12)

5) Flood Plain Restrictions:

No new major commercial hazardous waste facility shall be sited in a riverine flood hazard area..., or in areas shown to be within the area subject to inundation by the 100-YEAR design flood... (Section 7:26-13.12)

6) No type of new major commercial hazardous waste facility shall be sited in:

A) A coastal flood hazard area...
B) Areas underlain by cavernous limestone, dolomite, and marble
C) Areas overlying past or present subsurface mining activities

Table 6: Hydrogeologic siting criteria from the State of New York (after New York Hazardous Waste Management Committee,1981)

1) Geologic/Hydrologic:

A) The site is optimally located: it is not in close proximity to...: wetlands, recharge zones, surface waters, subsurface fracture zones, and aquifers. (page 29)

B) (the site is considered least favorable if)...The site's locational characteristics associated with one or more of the following factors (including close proximity to): wetlands, recharge zones, surface waters, subsurface fracture zones, aquifers; present severe problems with respect to water contamination. Extensive efforts would be required to overcome these natural conditions. (page 30)

2) Soil Characteristics:

A) (the site location is most favorable if)...the natural soil conditions at the site are optimal; the soil structure would impede any ground water contamination. (page 30)

B) (the site location is least favorable if)...the subsurface conditions at the site are not desirable; extensive site modifications would be required to reduce the risk of ground water contamination. (page 31)

3) Areas of Mineral Development:

...areas of concern are those where mineral resources of solid form have been removed by various procedures. Such areas commonly present limitations to land disposal facilities due to: escavation close to or into the ground water, avenues of rapid transmittal of contaminants should leakage or spillage occur through either boreholes or improperly or uncased wells, and structural instability and possibility of subsidence due to extensive subsurface removal of mineral resources. (page 36)

The State of New York has made the political decision to take a "hands off" policy with respect to influencing where future waste management facilities might be located. The hydrogeologic siting criteria only provide qualitative advisory policy statements and do not necessarily exclude any part of the state from potential site consideration.

Arizona

The hydrogeologic siting criteria adopted by the State of Arizona include both advisory policy statements and specific numerical requirements (Table 7). The only hydrogeologic issues addressed are: depth to water, distance to water supply, and flood plain restriction.

The Arizona hydrogeologic siting criteria are limited in scope, but emphasize the protection of their ground water resources. The depth to water criterion is the most stringent of all the reviewed states. Arizona's criteria reflect the political decision to protect ground water, since the state depends both economically and socially upon that resource.

California

The hydrogeologic siting criteria adopted by the State of California include both specific numerical requirements and advisory policy statements (Table 8). A comprehensive range of hydrogeologic issues are addressed including: depth to water beneath the wastes, fractured rock, protection of surface water, minimum permeability requirement of natural geologic materials, distance from known active faults, areas subject to rapid geologic change, and flood plain restrictions.

Table 7: Hydrogeologic siting criteria from the State of Arizona (after Arizona Department of Health Services, 1981) (emphasis is added with capital letters)

1) Depth to Ground Water:

A hazardous waste site...shall not be located within an area where up to ONE MILE from the perimeter of the site the depth to ground water level is LESS THAN 150 FEET. (page VI-3)

2) Distance to Water Supply:

A hazardous waste site...shall not be located within an area so close to public roads, residences and public water wells and water supplies as to constitute a threat to human health and the environment. (page VI-3)

3) Flood Plain Restriction:

A hazardous waste site...shall not be selected within a 100-YEAR flood plain... (page VI-3)

4) A hazardous waste site shall not be located within:

A) An area where the hydrology and geology is incompatible with such use.

B) An area where subsidence has occured or is likely to occur. (page VI-3)

Table 8: Hydrogeologic Siting Criteria from State of California (after California Administration Code, 1984) (emphasis is added with capital letters)

1) Depth to Water:

All new landfills, waste piles, and subsurface impoundments, shall be sited, designed, constructed, and operated to ensure that wastes will be a minimum of FIVE FEET above the highest anticipated elevation of underlying ground water. (page 3.1)

2) Geologic Setting:

A) New and existing Class I units (i.e., hazardous waste management units) shall be immediately underlain by natural geologic materials which have a permeability of not more than 1x10 -7 CM/SEC and which are of sufficient thickness to prevent vertical movement of fluid, including waste and leachate, from waste management units to waters of the state as long as wastes in such units pose a threat to water quality. Class I units shall not be located where areas of primary (porous) or secondary (rock opening) permeability greater than 1x10 -7 CM/SEC could impair the competence of natural geologic materials to act as a barrier to vertical fluid movement... (page 3.3)

B) New and existing Class I units...shall have a 200 FOOT setback from any known Holocene fault... (page 3.3)

C) New and existing Class I units...shall be located outside areas of potential rapid geologic change... (page 3.3)

3) Flood Plain Requirement:

New disposal and existing Class I units..., shall be located outside of flood plains subject to inundation by floods with 100-YEAR return periods... (page 3.3)

4) Class I disposal units shall be located where natural geologic features provide optimum conditions for isolation of wastes from waters of the state. (page 3.3)

California is a highly industrialized and populated state with an economic need to site new facilities. Their siting criteria are comprehensive and provide exclusionary requirements which restrict potential site locations within the state. California was able to adopt such strict legislation because it has extremely diverse hydrogeologic, topographic, and climatic conditions which create areas that might be amenable to the operation of a WMF.

Idaho

The Idaho hydrogeologic siting criteria are comprised of both specific numerical requirements and advisory policy statements (Table 9). A comprehensive range of hydrogeologic issues are addressed including: depth to ground water and fractured rock beneath the wastes, minimum thickness of fine grained sediments, distance to surface water and water supply wells, proximity to known active faults and geologically unstable areas, flood plain restriction, and areas overlying subsurface mining.

The Idaho hydrogeologic siting criteria provide strict exclusionary requirements which minimize the location of new hazardous waste management facilities within the state. The numerical requirements for distance to water supply, depth to fractured rock, and flood plain restriction are the most stringent of all the states reviewed.

Idaho is a non-industrialized state that generates only small quantities of hazardous waste. The siting criteria are comprehensive and provide exclusionary requirements which minimize the potential locations of waste management facilities within the state. Idaho can afford to adopt such strict legislation since it generates small quantities of hazardous wastes and has diverse hydrogeology, climate and topography.

Table 9: Hydrogeologic siting criteria from State of Idaho (after Idaho Hazardous Waste Management Committee, 1986) (emphasis is added with capital letters)

1) Depth to Water:

No new hazardous waste land disposal facility shall be sited where the seasonal-high depth of the ground water, beneath the proposed site, is LESS THAN 100 FEET below the lowest point of disposal. Perched zones may be exempt from exclusionary criterion if it can be demonstrated that the saturated zone has no economic or consumptive useable purpose.

2) Depth to Fractured Rock:

No hazardous waste land disposal facility shall be sited where the depth to fractured rock (e.g., basalt, rhyolite, limestone, dolomite) is LESS THAN 100 FEET below the lowest point of disposal.

3) Minimum Thickness of Fine Grained Sediments:

No new hazardous waste land disposal facility shall be sited where the thickness of fine-grained (predominantly clay and silt) unconsolidated sediments above the water table is LESS THAN 25 FEET.

4) Distance to Surface Water:

No new hazardous waste land disposal facility shall be sited within 2500 FEET of surface water bodies (e.g., lakes and perennial rivers and streams).

5) Distance to Water Supply Wells:

No new hazardous waste land disposal facility shall be sited within 1000 FEET of existing public or private or irrigation water supply wells, unless it can be demonstrated that natural hydrogeologic barriers isolate the site location from the aquifer being pumped.

6) Flood Plain Restriction:

No new hazardous waste land disposal facility shall be sited within a floodplain of a 500-YEAR (recurrence interval) flood.

7) No new hazardous waste land disposal facility shall be sited within:

   A) areas that are in close proximity of active fault zones (i.e., displacement within Holocene time) or other tectonically active or unstable areas (e.g., paleo-landslides, etc.).

   B) areas overlying any subsurface mining.

Physical Implication of the Hydrogeologic Siting Criteria

The general physical meaning of each hydrogeologic siting criteria is important with respect to siting a WMF. The physical meaning and qualitative rationale for each of the eight principal hydrogeologic categories are discussed below.

Depth to Water

Each state addresses this issue either by an advisory statement or numerical requirement (Table 10). Idaho and California require a minimum depth to water beneath the disposed wastes, while New Jersey and Arizona require a minimum depth to water below the land surface. The physical implication of this criterion is markedly different by comparing the language between these four states. The statement of "below land surface" may allow the disposed, buried wastes to be submerged within the water table and still satisfy the siting criterion. For example, wastes may be below the water table and still satisfy New Jersey's depth to water requirement of only one foot below land surface. None of the states directly address the issue of defining the term "depth to water." Depth to water may mean the level of the first water encountered below land surface or the highest water level elevation measured in a well. Hydrologically there can be a marked difference between depth to water in an unconfined and confined aquifer depending upon the definition used. The depth to water in an unconfined aquifer is represented by the water table where the fluid pressure is atmospheric (Freeze and Cherry, 1979). However, water levels in wells may also vary in unconfined aquifers if there is a significant vertical gradient depending upon the depth of the well. The depth to water in a confined aquifer is represented by a

Table 10: Comparison of the Hydrogeologic Siting Criteria from the States of New Jersey, New York, Arizona, California and Idaho

Hydrogeologic Issue	NJ	NY	AZ	CA	ID
Depth to Water	1 ft.	adv	150 ft.	5 ft.	100 ft.
Distance to Surface Water	--	adv	--	adv	2500 ft.
Distance to Water Supply Wells	5280 ft.	--	adv	adv	1000 ft.
Depth to Fractured Rock	--	adv	--	adv	100 ft.
Lithologic Controls	10 yr. travel time	adv	--	10x-7 cm/sec	25 ft. fine-grain
Flood Plain (recurrence interval)	100 yr.	--	100 yr.	100 yr.	500 yr.
Locations over Mining activities	adv	adv	--	--	adv
Geologically unstable areas	adv	--	adv	200 ft. setback	adv

-- : state did not address issue
adv : state addressed issue with an advisory policy statement

potentiometric surface which may be significant distance above the aquifer. For example, the depth to water in a well can be only a few feet below land surface while the aquifer may be actually hundreds of feet below the land surface.

The rationale for each state to address a depth to water criterion is two fold. First, saturated ground water flow is the primary mechanism for lateral contaminant movement (Freeze and Cherry, 1979). Therefore, the greater the distance between the wastes and ground water systems, the less chance of contaminant migration off site. Second, the thickness of the unsaturated zone is directly related to the depth to water. A thick unsaturated zone can provide a degree of treatment (e.g., retardation) depending upon the type of contaminant and geologic media.

Retardation, in general, is many different processes that effect the migration of contaminant movement. An example list of the various processes that might slow down or stop contaminant movement are adsorption, chemical reactions, and biological transformations (Freeze and Cherry, 1979).

Distance to Surface Water

Idaho, California, and New York address this issue, but only Idaho requires a minimum numerical distance (Table 10). The physical implication and rationale for this criterion is two fold. The greater the distance between waste and surface water the less probability of contaminating the water supply, and providing a mechanism for waste removal via flooding (i.e., buffer zone).

Distance to Water Supply Wells

Idaho, California, New Jersey, and Arizona address this issue. Both Idaho and New Jersey require a minimum numerical distance (Table 10). This criterion is addressed primarily to protect the ground water users. The probability of well contamination is directly related to the distance a water supply well is located from a waste management facility. In addition, poorly constructed water wells may provide a pathway for contaminants to migrate quickly downward into usable ground water systems. Therefore, the greater the lateral distance between a water well and wastes, the less chance a well might become contaminated.

Depth to Fractured Rock

Idaho, California, and New York address this issue, but only Idaho requires a minimum numerical depth (Table 10). A minimum depth to fractured rock is important for three primary reasons: (1) fractures provide preferential conduits for water and contaminants to move at greater velocities than the average ground water velocity, (2) flow through consolidated fractured rock provides little, if any, retardation to contaminants and (3) fractured rock environments are difficult to characterize hydrogeologically because of the variability of fracture patterns, spacing, and apertures. Therefore, monitoring ground water for contamination in fractured rock environments is difficult. The rationale for addressing this hydrogeologic issue is to provide a buffer zone of unconsolidated material underneath a WMF. Unconsolidated material may provide a degree of treatment (e.g., retardation). This criterion is important in states with extensive areas of near surface consolidated (possibly fractured) rock units.

Lithologic Controls

Idaho, California, New Jersey, and New York addressed this issue, but with three different physical implications (Table 10). New Jersey addressed this issue by adopting a minimum ground water travel time. The higher the porosity within a ground water flow system, the lower the ground water travel time (Freeze and Cherry, 1979). Requiring a minimum ground water travel time would delay the effects of contaminant movement away from a site. However, it does not necessarily provide any retardation of contaminant movement. California addressed retardation by adopting a minimum fine-grained sediment restriction (i.e., vertical hydraulic conductivity) beneath a WMF. Unconsolidated low permeability sediments generally increase the probability of retardation. However, measuring and quantifying both ground water travel time and vertical hydraulic conductivity may be difficult. Idaho addressed this problem including retardation by adopting a minimum thickness of unconsolidated fine-grained sediments beneath a WMF. This criterion provides for possible retardation and is relatively easy to determine from a geologic log of a borehole.

Each of these siting criteria are directed toward slowing the migration of contaminants away from a hazardous waste management facility. The rationale for addressing this hydrogeologic issue is obvious. Unconsolidated low permeable sediments beneath a proposed facility is the most important natural protection against the migration of wastes away from a waste management facility.

Flood Plain Restriction

Idaho, California, New Jersey, and Arizona addressed this issue (Table 10). California, New Jersey, and Arizona require that all waste management facilities be located outside a flood plain of a 100-year recurrence interval flood. Idaho requires that all facilities are located outside a 500-year recurrence interval flood plain. The physical implication of this criterion is to minimize the chance of a waste management facility being innundated by a flood. The rationale for this criterion is flooding a waste management facility could facilitate the movement of contaminates off the site.

Location over Mining Activities

Idaho, New Jersey, and New York all addressed this issue by advisory policy statements (Table 10). The physical implication of this criterion is subsurface mining may provide preferential pathways for contaminant movement both through the unsaturated and saturated zones. The rationale for this criterion is to minimize the chance of contaminant movement away from a WMF.

Geologically Unstable Areas

Idaho, California, New Jersey and Arizona addressed this issue, but only California requires a minimum distance from known active faults (Table 10). The physical implication of this criterion is to locate waste management facilities away from areas that are subject to rapid geologic change (e.g., fault zones, paleo-landslides). The rationale for this criterion is to ensure the structural integrity of a waste management facility by locating them within areas that are not directly subjected to rapid geologic change.

Discussion of the Political Decisions Involved in the Development of Hazardous Waste Facility Siting Criteria

The development of hazardous waste facility siting criteria is a process which addresses political, economic, social, and environmental issues. An example list of these issues include: (1) the willingness of a state to politically address their social, economic, and environmental concerns, (2) the industry needs for new facilities to properly dispose of hazardous wastes, (3) education of the public regarding the generation of wastes and the social responsibility to manage hazardous wastes, and (4) the availability of suitable hydrogeologic environments to provide natural environmental protection.

The hydrogeologic siting criteria from the five states analyzed in this report represent a range of management tools reflecting political compromises on the various policy issues. These compromises can be best illustrated by comparing the political, economic, social and environmental arenas of the States of New Jersey, Arizona and Idaho. New Jersey is an industrialized state which generates large quantities of hazardous wastes. Adequate waste management facilities are needed to preserve the industrial economy of the state. New Jersey probably has relatively few ideal hydrogeologic environments to locate waste management facilities (i.e., relatively high precipitation and shallow depth to water). As a result, the New Jersey hydrogeologic siting criteria are not very restrictive reflecting a political decision to preserve the economic integrity of the state by providing hydrogeologic environments to site new facilities that would not be allowed in other states. Arizona, on the other hand, is a rapidly growing state that depends upon ground water as its primary source of water. The desert regions of Arizona provide plenty of hydrogeologic environments potentially suitable for the operation of a waste management facility. Therefore, the Arizona hydrogeologic siting criteria reflect the political, economic and social decision to protect their ground water resources by being more restrictive on WMF siting. By contrast, Idaho is a non-industrialized state which generates relatively small quantities of hazardous wastes. The political and economic atmosphere within Idaho is to provide sufficient waste management facilities for Idaho's industries, but not become a "dumping ground" for wastes generated out of the state. Idaho has diverse hydrogeologic environments which may provide suitable locations for the operation of a waste management facilities. Therefore, the Idaho hydrogeologic siting criteria are very strict and comprehensive reflecting the political decision to minimize the location of waste management facilities within the state.

CHAPTER 4

APPLICATION OF THE IDAHO HYDROGEOLOGIC SITING CRITERIA

The purpose of this chapter is to delineate regional areas in the general vicinity of Boise that might satisfy the Idaho hydrogeologic siting criteria as an example application of the siting criteria (Figure 1). A two step process is followed to identify areas that might satisfy the Idaho hydrogeologic siting criteria. The first step is to utilize information on the regional hydrostratigraphy and hydrogeology of a portion of southwestern Idaho to select areas which might satisfy the siting criteria. The second step is to utilize more detailed available information to delineate areas that might serve as possible WMF sites.

Regional Hydrogeology of a Portion of Southwestern Idaho

The USGS has studied the hydrogeology of the Snake River plain as part of a nation-wide study of the major aquifer systems in the United States. Geologic and hydrogeologic characteristics divide the Snake River plain into eastern and western regions with King Hill approximately the dividing point (Whitehead, 1984). Boise lies in the western portion of the Snake River plain. The western Snake River plain consists primarily of Cenozoic rocks which are divisible into broad geologic units that differ in lithology, age, geographic distribution, and degree of deformation (Malde and Powers, 1962). The generalized stratigraphy and water-yielding characteristics of the western Snake River plain is presented in Table 11. The depositional environments of these units are extremely complex with contrasting lithologies intertonguing with one another.

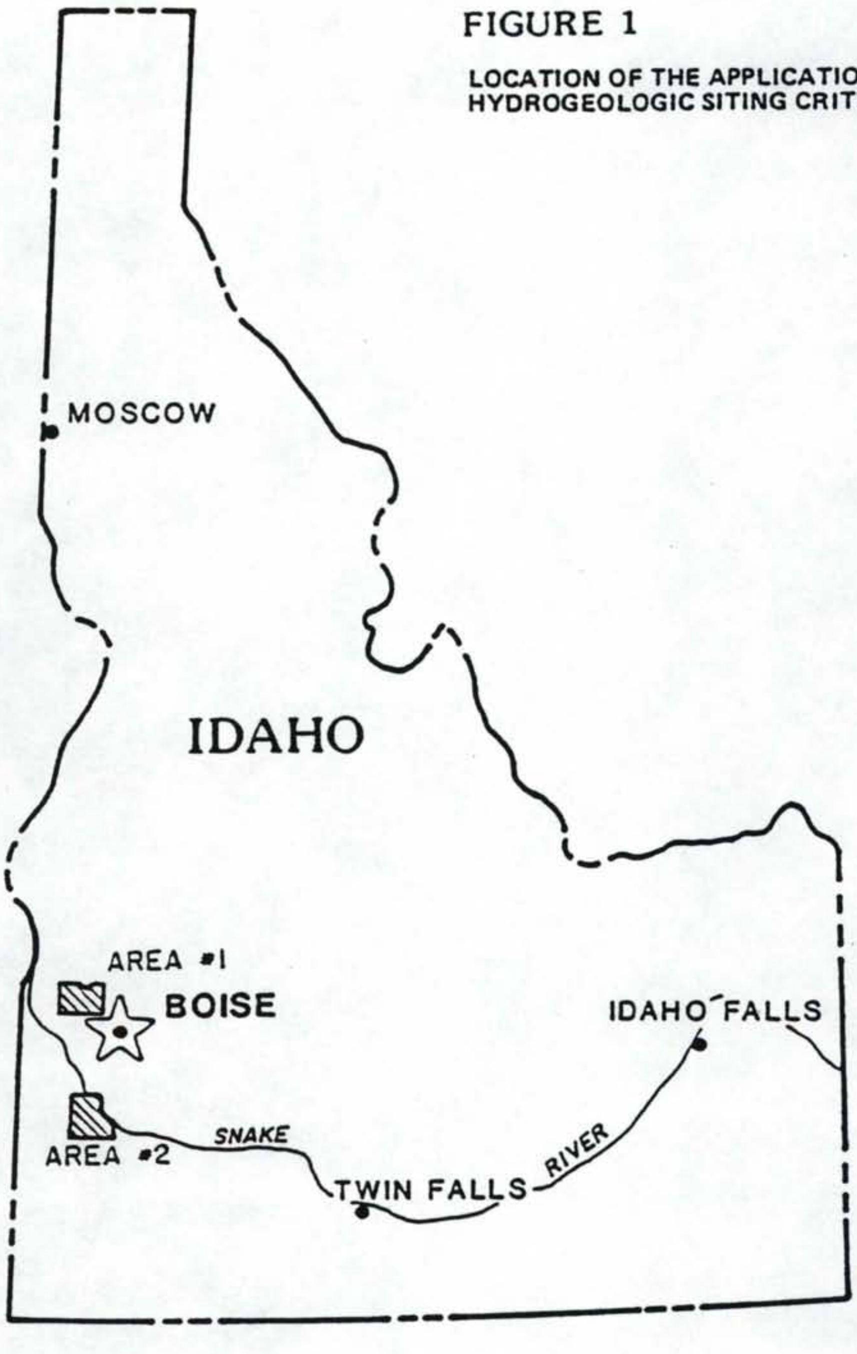


FIGURE 1

LOCATION OF THE APPLICATION OF THE IDAHO HYDROGEOLOGIC SITING CRITERIA

Table 11: Generalized Stratigraphy and Water-Yielding Characteristics of the western Snake River plain (modified from Whitehead (1984), Young and Whitehead (1975), and Savage (1961))

FORMATION OR UNIT	DESCRIPTION	WATER-YIELDING CHARACTERISTICS
Recent Alluvium	Chiefly flood plain deposits. Clay, sand, gravel and bouldes. Forms the alluvium floors of tributary valleys and flood plains.	Hydraulic conductivity is variable, moderately high in coarse-grained deposits. Sandy and gravely alluvium yields moderately to large quantities of water to wells. An important aquifer.
Snake River Group	Consists of boulders,cobbles, and pebbles. Gravel units occur in widely scattered outcrops and appear to be remanants of both pediments and river terraces.	These surficialdeposits appear to be very permeable, but they generally occur above the regional water table.
Pleistocene Sediments Caldwell-Nampa sediments, Ten Mile gravel undifferetiated	Terrace gravels; clay, silt, sand and gravel, unconlolidated to poorly consolidated. Some caliche. Lacustrine and fluviatile deposits with some cross-bedding and stratification.	These surficial deposits appear to be very permeable, are not as important as aquifers.
Black Mesa Gravel	Consists of gravel and sand up to 25 feet thick. Remnants of a widely preserved pediment surface.	This unit generally occurs above the water table and is (??)
Bruneau Formation	Consists primarily of underformed, unconsolidated, detrital material dominated by massive lake beds of clay, silt, sand and pebbles. Interbedded with basaltic lava flows.	Hydraulic conductivity is variable but typically low. Sedimentary units yield small quantities of water to domestic and stock wells. May be an important aquifer.
Tuana Gravel	Consists of pebble and cobble gravel interbedded with layers of massive sand and silt. Capped by a caliche layer several feet thick.	Generally occurs above the water table. Not important as an aquifer.
Glenns Ferry Formation	Consists of basin-fill, poorly consolidated detrital material interbedded with minor basalt flows. Includes fluvial and lacustrine deposits characterized by abrupt facies change. Facies include: massive silt layers, cemented sand beds, thin beds of clay, silt, sand, and gravel.	Hydraulic conductivity highly variable. Yields to wells are extremely variable. Generally yields are low, but sand zones may produce large quantities of water. An important aquifer.
Chalk Hills Formation	Consists of basin-fill consolidated, locally indurated, clastic deposits. Interbedded with minor basalt flows.	Hydraulic conductivity is generally low. Yields small quantities of water to stock and domestic wells.

Table 11 (cont'd)

FORMATION OR UNIT	DESCRIPTION	WATER-YIELDING CHARACTERISTICS
Banbury Basalt	Basaltic lava flows, interbedded locally with minor amounts of stream and lake deposits. Lava flows are mostly vesicular and less than 15 feet thick.	Hydraulic conductivity is highly variable, generally contains water under confined artesian conditions. Yields small to moderate amounts of water. An important aquifer.
Poison Creek Formation	Consists of consolidated fine-grained, tuffaceous, detrital material in massive beds. Including layers of locally derived sand and gravel.	Hydraulic conductivity is variable but generally low. Generally contains water under confined artesian conditions. Yields small quantities of water.
Idavada Volcanics	Consists of latitic and andesitic, of massive, dense lava flows with minor amounts of rhyolitic lava flows. These rocks are highly jointed and fractured.	Fractures allow vertical and horizontal movement ground water. Generally under confined artisian conditions, geothermal water. An important aquifer.
Columbia River Volcanics and Payette Formation	Columbia River volcanics consist of fine-grained basalt to coarse-grained diabase. Flows are either vesicular or massive. Payette formation consists of clay, silt, ash, arkosic sand of both fluvial and lacustrine origin. Payette formation stratigraphically lies between Columbia River volcanic sequences.	Hydraulic conductivity is highly variable.
Idaho Batholith	Granitic type rocks. Grayish to light dark mottled; equigranular quartz diorite. Local variations with porphyritic and gneissic facies.	Hydraulic conductivity is generally low. Faults, and fractures, and weathered zones may yield small quantities of water to wells. Not important as an aquifer.

The stratigraphy of the western Snake River plain is discussed relative to satisfying the Idaho hydrogeologic siting criteria. Each stratigraphic unit or formation is compared regarding how its lithology and general hydraulic characteristics would satisfy each siting criteria (Table 12). The Glenns Ferry, Chalk Hills, Poison Creek Formations of the Idaho Group, and Caldwell-Nampa sediments, generally satisfy the criteria pertaining to depth to fractured rock and minimum thickness of unconsolidated fine-grained sediments. However, the lithology of each formation varies widely throughout the western Snake River plain due to the complex depositional histories. The Snake River Basalts, Bruneau Formation, Banbury Basalt and Idavada volcanics contain fractured rock and probably would not satisfy the criteria pertaining to depth to fractured rock. However, the sedimentary sequences of the Bruneau Formation may satisfy the criteria. The Black Mesa Gravel, Ten Mile Gravel and Tuana Gravel Formations generally do not contain sufficient fine-grained sediments and probably would not satisfy the criteria pertaining to minimum fine-grained thickness of unconsolidated sediments.

Ground water within the western Snake River plain generally is divided into an unconfined shallow system and a confined deep system (Thomas and Dion, 1974). The shallow system is within the sand and gravel layers of the Recent Alluvium and Snake River Group. Recharge to this aquifer system is from downward percolation of precipitation and irrigation. Application of irrigation water has drastically altered ground water conditions in this aquifer. Water levels have risen to above river level causing ground water flow towards the Boise River

Table 12: Comparison of the Western Snake River Plain Stratigraphy Relative to Satisfying the Idaho Hydrogeologic Siting Criteria

	Formation or Unit	Relative Importance to Siting Criteria
	Recent Alluvium	Usually found within 500-year flood plain
	Snake River Group	Lithology indicates high permeability. Probably consists of of insufficient unconsolidated fine grained sediments to satisfy criteria.
	Pleistocene Sediments (Caldwell-Nampa Sediments, Ten Mile Gravel undefferentiated)	Lithology indicates variation of fine and coarse grained sediments which may consist of sufficient unconsolidated fine-grained sediments to satisfy criteria. Coarse-grained layers have a very high permeability.
Idaho Group	Black Mesa Gravel	Lithology indicates very high permeability. Probably consists of insufficient unconsolidated fine grained sediments to satisfy criteria.
	Bruneau Formation	Lithology indicates sedimentary sequences may provide sufficient unconsolidated fine-grained sediments to satisfy criteria. Basaltic lava flows may be fractured.
	Tuana Gravel	Lithology indicates very high permeability. Probably consists of insufficient unconsolidated fine-grained sediments to satisfy criteria.
	Glenns Ferry Formation	Lithology indicates sufficient fine-grained sediments may exist to satisfy criteria. Minor basalt flows may be fractured.
	Chalk Hills Formation	Lithology indicates sufficient unconsolidated fine-grained sediments may exist to satisfy criteria. Minor basalt flows may be fractured.
	Poison Creek Formation	Lithology indicates sufficient unconsolidated fine-grained sediments may exist to satisfy criteria. Massive sandstone layers may be fractured.
	Idavada Volcanics	Lithology indicates jointed and fractured undifferentiated volcanic lava flows.
	Columbia River and Payette Formation	Lithology indicates jointed and fractured volcanic lava flows. Sedimentary sequences may consist of sufficient unconsolidated fine-grained sediments to satisfy criteria.
	Idaho Batholith	Lithology indicates jointed and fractured granitic rock.

(Thomas and Dion, 1974). Discharge from this aquifer system is from: (1) flow into the Boise River, (2) evapotranspiration, (3) flow from seeps and springs, and (4) ground water pumpage (Thomas and Dion, 1974). Regional ground water flow in this system is either in a northwesterly direction parallel to the Boise River, or southwesterly towards the Snake River (Mink, 1976). Depth to water in this aquifer is highly variable and is dependant upon seasonal variations and climatic occurrences.

The deep aquifer system is within the sand and gravel layers and volcanic lava flows of the Idaho Group. Recharge to this aquifer system is primarily from precipitation and snow melt along the Boise Ridge and Owyhee Mountains (Mitchell, 1981). Discharge from the deep aquifer is to the Snake River and ground water pumpage. Regional ground water flow in the deep aquifer is away from the mountain fronts towards the Snake and Payette Rivers.

Regional Selection of Locations to Illustrate the Application of the Idaho Hydrogeologic Siting Criteria

Screening criteria are applied to a portion of southwestern Idaho around Boise to illustrate the first step in application of the Idaho hydrogeologic siting criteria (Figure 1). The preliminary screening criteria are: (1) areas are excluded where fractured rock (e.g., volcanic lava flows) are exposed at land surface or mapped at less than 100 feet below land surface, and (2) areas are excluded where the depth to water is mapped less than 100 feet below land surface.

The preliminary screening criteria are individually applied on a reconnaissance basis starting with the minimum depth to fractured rock criterion. A preliminary screening map illustrates the progressive application of the criteria to a portion of southwestern Idaho

(Figure 2). The depth to fractured rock criterion excludes a majority of the western Snake River plain and adjacent mountains (Figure 2). A U. S. Geological Survey geologic map (Mitchell and Bennett, 1979) and a depth to volcanic rock map (Whitehead, 1984) were used to delineate areas that would not satisfy this criterion. Areas that remain after the application of this criterion includes portions of the foothills south of the Snake River and north of Boise between the Boise and Payette Rivers.

The minimum depth to water criterion was applied to the remaining portion of the western Snake River plain and adjacent foothills. The general depth to water was estimated by subtracting water level elevations (Lindholm and others, 1983) from topographic elevations (Mitchell and Bennett, 1979). This criterion excludes the remaining western Snake River plain west of Nampa including the Payette River drainage near Emmett (Figure 2).

The preliminary screening map illustrates the application of the depth to fractured rock and depth to water criterion to southwestern Idaho. These two criteria practically eliminate the entire western Snake River Plain. Two general areas are selected from the map for a more detailed examination of the application of the siting criteria (Figure 2). These areas were selected because they represent two contrasting hydrogeologic environments each having a different level of available information.

A qualitative confidence rating scale is utilized to relate the extent to which each criterion can be satisfied with the existing available information. A low confidence level indicates that insufficient data exist to confidently apply the siting criterion. Conversely, a high rating indicates that the criterion can be applied confidently with the available information. The standardized method of DRASTIC (Aller and others, 1985) also is applied to the same two areas. The applicability of using these two methods to evaluate potential waste management facilities in Idaho is accessed.

Application of the Idaho Hydrogeologic Siting Criteria to Two Selected Areas

Area #1

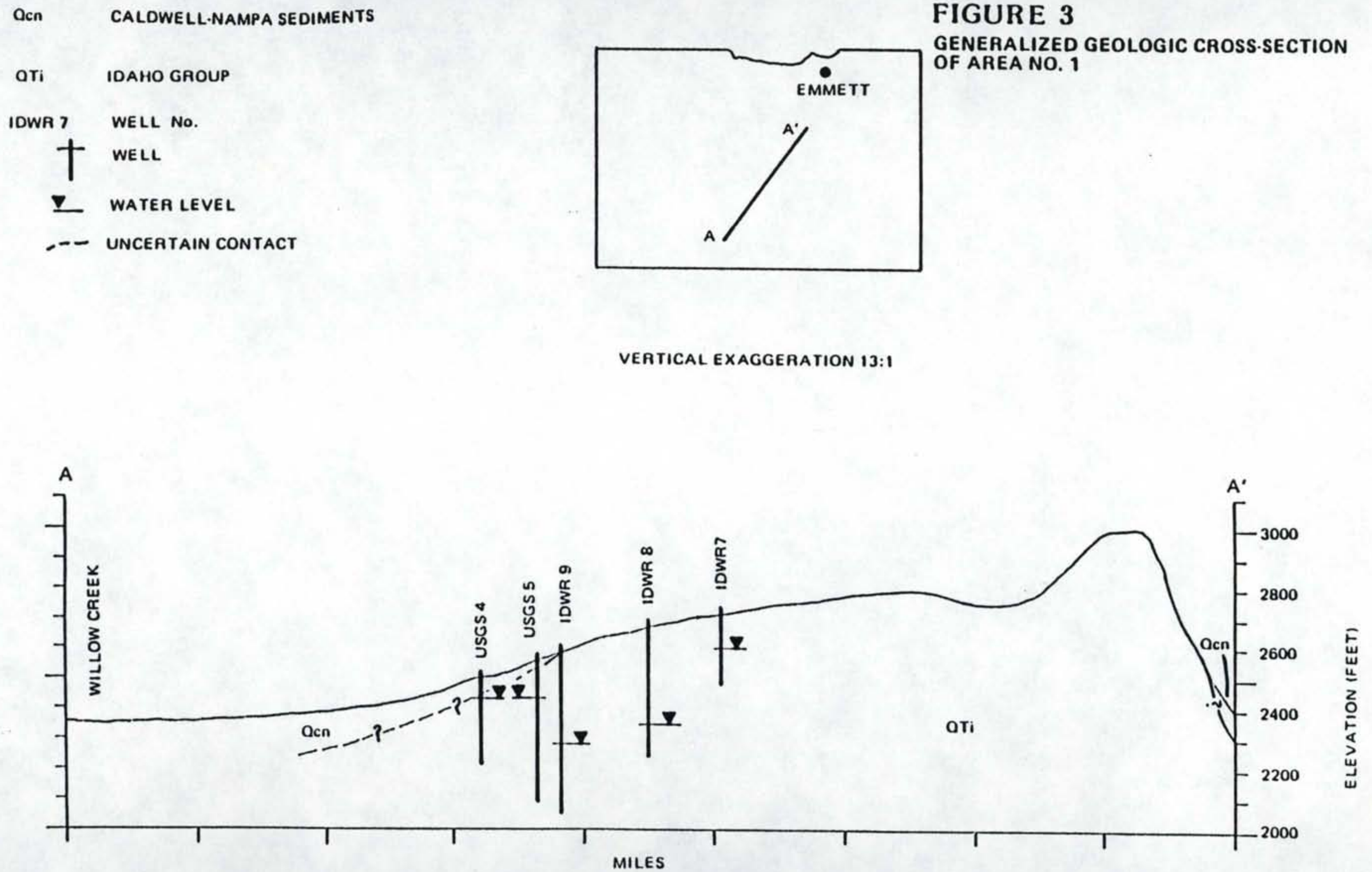
Area #1 includes the dryland highlands between the Boise and Payette Rivers northeast of Boise. The area is relatively unpopulated and is approximately six square-miles in size. Area #1 is semi-arid and receives approximately 11 to 12 inches of rainfall per year (NOAA, 1977).

The example application of the Idaho hydrogeologic siting criteria to Area #1 was conducted with relatively little hydrogeologic information. A summary of the available information used for this area includes: geologic maps (Savage, 1958 and 1960), geologic and hydrologic data from selected driller's logs from the Idaho Department of Water Resources (IDWR), and depth to water measurements from U. S. Geological Survey observation wells (Appendix B). Little information has been published regarding the hydrogeology of this area.

A detailed application of the depth to fractured rock criterion to Area #1 is difficult. Most of the area is mapped as the Idaho Group. Driller's log information is sparse for this relatively unpopulated area. The geology can be inferred using available information to evaluate the depth to fractured rock criterion. A generalized cross-section illustrates the topography and geology of Area #1 (Figure 3). The erosional patterns of consolidated fractured rock (i.e., cliff-forming)

FIGURE 3

GENERALIZED GEOLOGIC CROSS-SECTION OF AREA NO. 1

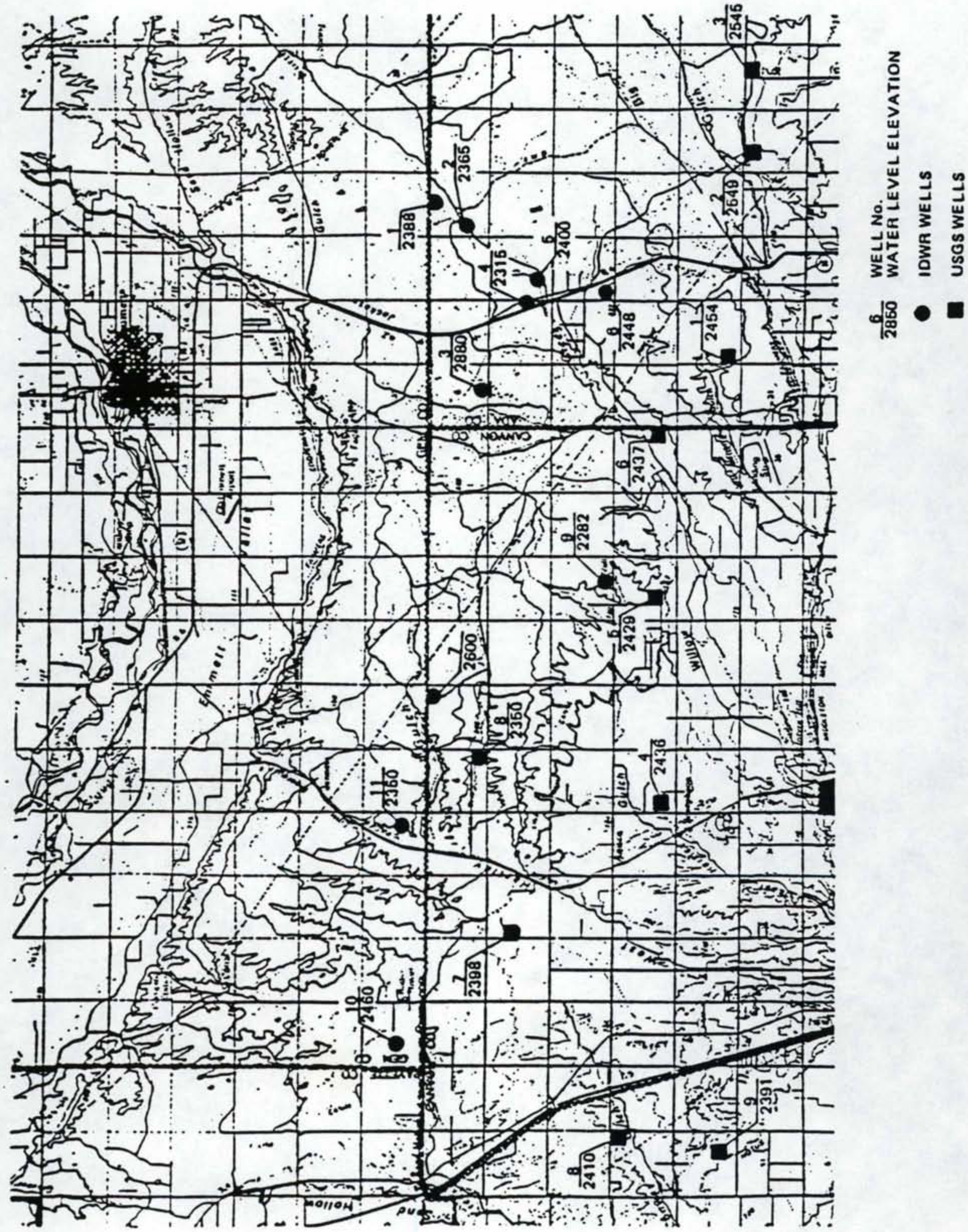


are markedly different than unconsolidated soft rock (i.e., slope-forming). An analysis of the topography of Area #1 indicates that there is only one abrupt cliff mapped towards the northern boundary of the area (Mitchell and Bennett, 1979). This cliff is probably due to the erosional nature of the Payette River and not necessarily a reflection of consolidated fractured rock. Therefore, the geology can be inferred not to consist of significant consolidated fractured rock formations to a depth of 300 to 600 feet (i.e., above 2400 ft. elevation). The analysis of the erosional patterns in conjunction with driller's log information indicate that there probably is not fractured rock within 100 feet of the land surface. The confidence level for satisfying the depth to fractured rock criterion based upon the topographic analysis and limited available information is moderate.

Application of the depth to water criterion using existing available information is difficult because of the apparent complexity of the ground water flow system. To help understand the hydrogeology, a water elevation map was constructed from 20 depth to water measurements on IDWR driller's logs and U. S. Geological Survey observation wells (Figure 4). The water level elevations appear to be in the range of 2300 and 2450 feet. The 20 wells used to construct the water level elevation map are completed generally at a depth of 2200 to 2300 feet. These similar well depths indicate that there is a water producing zone at this general elevation. No springs are mapped within Area #1 at an elevation above 2450 feet. Based on the water level data, the depth to water criterion probably can be satisfied above the land surface elevation of 2550 feet (i.e., 100 feet above the regional water level). Areas below the elevation of 2600 feet were excluded from further consideration.

FIGURE 4

WATER ELEVATION MAP FOR AREA NO. 1



However, IDWR wells 3 and 7, and USGS wells 2 and 3 have water level above the regional water level of 2300 to 2450 feet. These wells are completed between the elevations of 2450 and 2500 feet (except IDWR 3 is completed at 2700 feet). The high water levels in these wells may be attributed to a perched saturated zone, downward gradient within the ground water system, or the regional water level interpretation of 2450 feet may be incorrect due to the limited available hydrogeologic information. Areas that might satisfy the depth to water criterion are outlined in Figure 5.

The confidence level for the areas above the elevation of 2600 feet satisfying the depth to water criterion is moderate. This confidence rating can be attributed to the limitations of the hydrogeologic interpretation using available data. These limitations are: (1) water level elevation measurements from the driller's logs may not be accurate, (2) water level elevation data is generally 10 years old or more and may not represent current hydrogeologic conditions, (3) using existing data may not allow for the delineation of potential perched water tables (i.e., water above the regional water level elevation), and (4) difficulty in correlating water level elevations over such a large area with a limited data base.

Application of the minimum thickness of unconsolidated fine-grained sediments criterion in Area #1 is based upon areas that are mapped geologically as the Idaho Group (Figure 6). Several formations within the Idaho Group contain sufficient fine-grained sediments to satisfy this criterion (Table 11). Selected portions of the Caldwell-Nampa Sediments may also contain sufficient fine-grained sediments.

The confidence level for areas mapped as Idaho Group and Caldwell-Nampa sediments to satisfy the criterion is high to moderate. This is justified by the selected driller's logs indicating, in general, that sufficient fine-grained unconsolidated sediments exist throughout Area #1.

Application of the minimum distance to surface water criterion does not exclude any area within Area #1. This is because the closest perennial water bodies are the Boise and Payette Rivers. Areas near these rivers are already excluded by the depth to water criterion.

Application of the minimum distance to water wells must be based on site-specific field investigation. The available well log data suggest that a number of sites in Area #1 would meet this criterion.

The 500-year flood plain criterion can not be evaluated in Area #1. No information regarding a 500-year recurrence interval flood exists for this portion of Idaho. However, the topographic variability of Area #1 suggests that selected sites might meet this criterion.

Locations within Area #1 that might satisfy the Idaho hydrogeologic siting criteria (except for the floodplain and distance to water well criteria) are outlined in Figure 7. The application of these criteria using existing available information illustrate general locations that probably would satisfy the criteria. These general locations are controlled primarily by the depth to water criterion.

The application of DRASTIC to Area #1 is illustrated in Figure 8. The DRASTIC index (i.e., numerical rating) associated with each generalized area indicates the relative pollution potential of that area (Table 13). The figure illustrates that the majority of the central highlands of Area #1 have a relatively low pollution potential (i.e., area C). However, areas towards the Boise and Payette Rivers to the south and north respectively, have a higher DRASTIC index rating due to the shallow depth to water. A small strip within the center of Area #1 also has a relatively high index rating due to the shallow depth to water measurements in three wells. The relatively high DRASTIC indices are controlled primarily by the depth to water DRASTIC factor (Table 13).

The application of DRASTIC to Area #1 delineates, in general, similar areas as the Idaho hydrogeologic siting criteria that might be favorable to locate a WMF. This can be attributed to the influence of depth to water on the application of both the siting criteria and DRASTIC. The DRASTIC application was relatively easy except for the depth to water explanation from the three wells located in the center of Area #1.

Area #2

Area #2 is located in the Owyhee foothills south of the Snake River near Oreana. This area is sparsely populated and is approximately 5.5 square-miles in size. Area #2 is semi-arid and receives approximately 7 to 8 inches of rainfall per year (USGS, 1957).

The example application of the Idaho hydrogeologic siting criteria to Area #2 was conducted with relatively little detailed information. Several hydrogeologic investigations have been conducted throughout the region. The information available used for this area includes: U. S. Geological Survey geologic map (Ekren and others, 1981), selected driller's logs from the Idaho Department of Water Resources (IDWR), and depth to water measurements from U. S. Geological Survey observation

Table 13: Calculations of DRASTIC Indices for Area #1

Feature	Range	Weight	Rating	Number A	Number B	Number C
	<10 feet	5	9	45		
Depth to	<50 feet	5	5		25	
Water	>100 feet	5	1			5
Recharge	2"-4"	4	3	12	12	12
Aquifer	sand and		8	24	24	24
Media	gravel	3				
Soil Media*	silt-loam	2	5		10	10
	sandy-loam	2	6	12		
Topography	0-2%	1	10			10
	2-6%	1	9	9	9	
Vadose Zone	sand & gravel with silt & clay	5	5	25	25	25
Hydraulic Conductivity	1-100 GPD/FT2	3	1	3	3	3
			DRASTIC Index:	130	108	89

* Information from U.S.D.A., 1972
and U.S.D.A., 1965

wells (Appendix C), and a ground water resource report on northern Owyhee county (Ralston and Chapman, 1969).

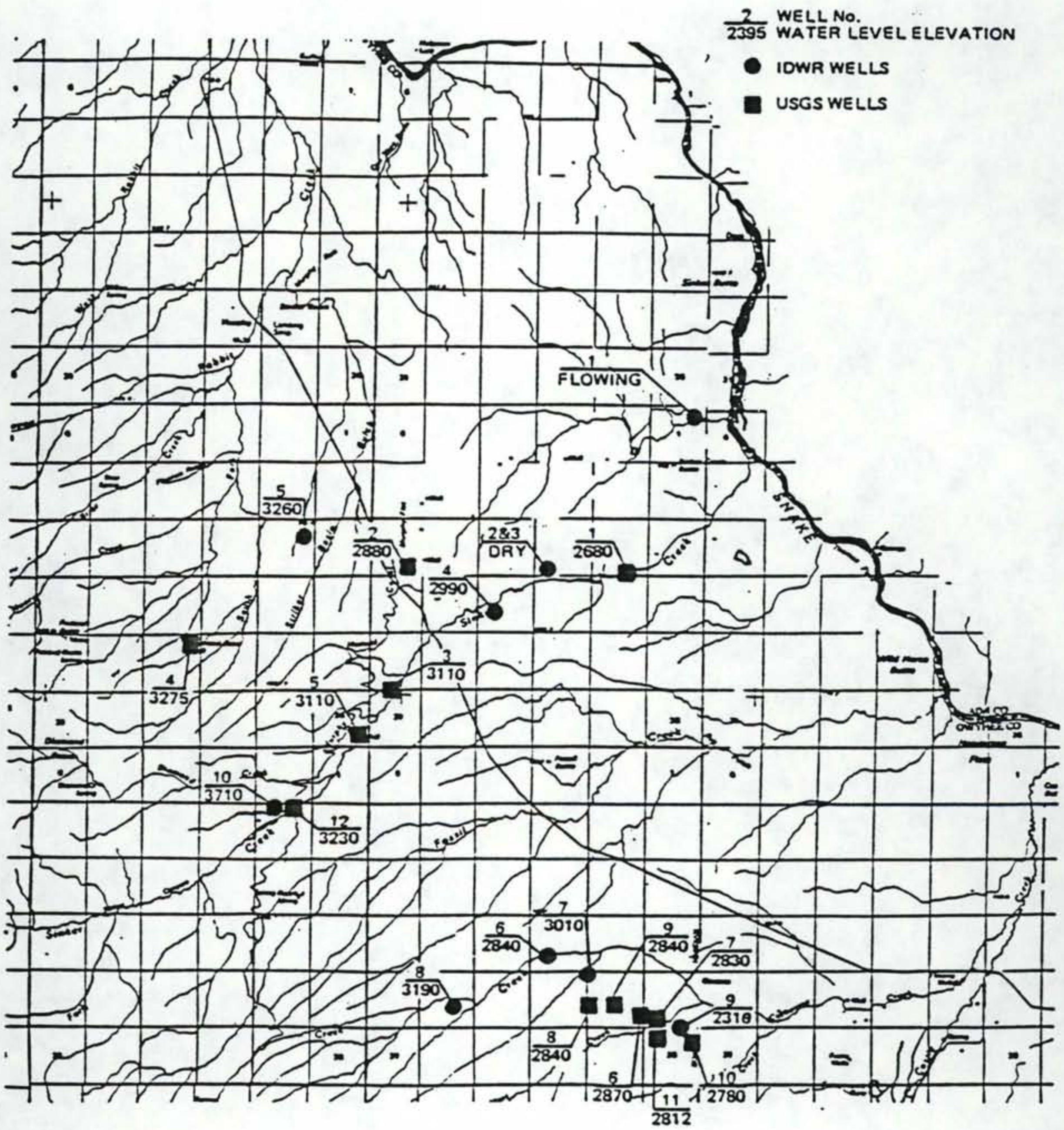
The siting criteria were applied to Area #2 in the same order as Area #1, starting with the minimum depth to fractured rock. Application of the depth to fractured rock criterion excludes large areas within Area #2 (Figure 9). This criterion was applied by excluding areas where basalt and rhyolite lava flows of the Bruneau, Chalk Hills, Banbury Basalt, and Poison Creek Formations are exposed at land surface. Other areas excluded were undifferentiated basalt, rhyolite, and granitic volcanic rocks exposed at land surface (Ekren and Others, 1981).

The confidence level for the application of the depth to fractured rock criterion based upon the available data is moderate to high. This rating is based on the availability of a relatively detailed geologic map of the area, and makes the delineation of where fractured rock exists at land surface relatively easy. However, areas adjacent to exposed fractured rock may not necessarily satisfy this criterion (i.e., fractured rock may exist less than 100 feet below land surface). These locations were assumed to satisfy the siting criterion since there is insufficient driller's log information to determine otherwise.

Application of the depth to water criterion using existing available information is very complex. A water elevation map was constructed from 22 depth to water measurements on IDWR driller's logs and U. S. Geological Survey observation wells (Figure 10). The 22 wells are completed over a wide range of elevations. Water levels in this region are highly variable and difficult to correlate areally. The variable water level elevations, well depths and complex stratigraphy are illustrated in the generalized geologic cross-section (Figure 11). A

FIGURE 10

WATER ELEVATION MAP FOR AREA NO. 2



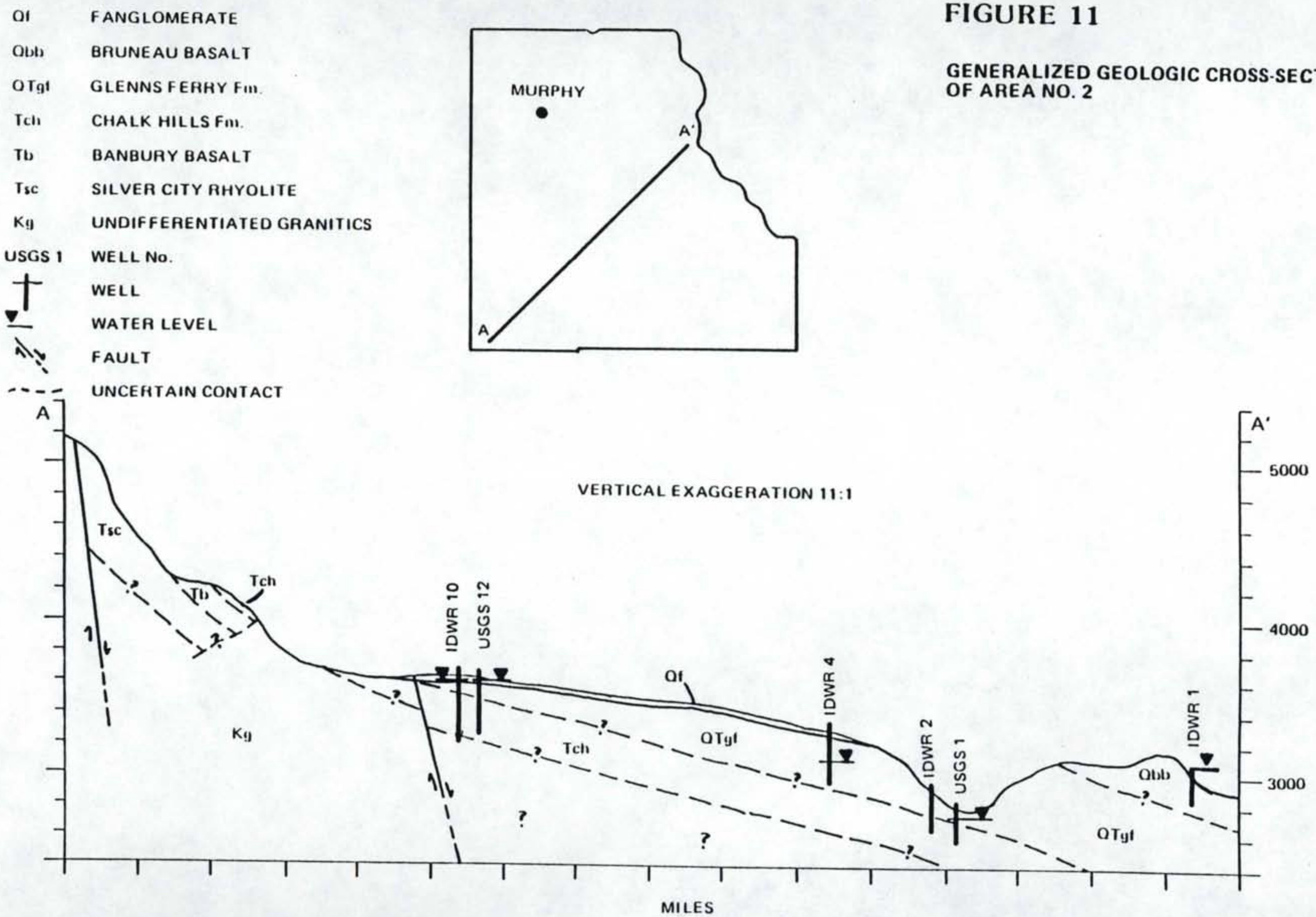


FIGURE 11

GENERALIZED GEOLOGIC CROSS-SECTION OF AREA NO. 2

marked water level elevation difference exists between wells along Sinker Creek and wells in the Oreana area. The complex hydrogeology of the region probably hosts a ground water system with significant vertical and horizontal gradients.

Ralston and Chapman (1969) state that there are four important aquifer systems within this region. The Glenns Ferry Formation comprises a shallow sedimentary aquifer within Area #2. This shallow aquifer appears to be of local lateral extent around the Oreana area (Ralston and Chapman, 1969). Three deeper aquifers exist within the basalts of the Poison Creek Formation, Banbury Basalt Formation and Bruneau Basalt Formation (Ralston and Chapman, 1969). The only spring mapped in Area #2 is along Castle Creek at an elevation of 2600 feet; it appears to discharge from the Glenns Ferry Formation and probably represents discharge from the shallow sedimentary aquifer (Ekren and Others, 1981). Understanding the water level elevations in Area #2 using existing available information is very difficult. Existing hydrologic data are not sufficient to evaluate Area #2 with respect to the depth to water criterion. However, there are locations that are 100 feet above the highest water level elevation suggesting the criterion may be satisfied to portions of Area #2.

Application of the minimum thickness of unconsolidated fine grained sediments criterion in Area #2 is based upon delineation of areas that are mapped geologically as the Glenns Ferry, Chalk Hills and Poison Creek Formations of the Idaho Group (Figure 12). These formations contain sufficient fine-grained sediments to satisfy this criterion (Table 11). Areas are excluded where mapped geologically as pediment gravel, fan alluvium and fanglomerate deposits (Ekren and Others, 1981).

The confidence level for areas mapped as the Glenns Ferry Formation, Chalk Hills Formation and Poison Creek Formation to satisfy this criterion is moderate to high. This is justified from the driller's log information indicating that, in general sufficient fine-grained unconsolidated sediments exist within those areas. Application of the minimum distance to surface water criterion excludes a small strip of area within 2500 feet of the Snake River. There are no other perennial creeks within Area #2.

Application of the minimum distance to water wells must be determined from site-specific field investigations due to the limited available water well data. However, the majority of the wells around Sinker Creek and Oreana are within the low lying areas adjacent to the stream drainages. Therefore, highland areas probably would meet this criterion. Application of the 500-year flood plain criterion has little impact in Area #2. Although no information regarding a 500-year recurrence interval flood exists for this portion of Idaho, several general statements can be made. The majority of the major ephemeral streams within Area #2 are located in deep canyons. A 500-year flood event probably would not breech the top of these canyon walls. Therefore, this criterion probably excludes all of the deep canyons and the majority of the lowlands towards the mouths of these ephemeral streams.

Locations within Area #2 that might satisfy the Idaho hydrogeologic siting criteria (except depth to water, distance to water wells and flood plain criteria) are outlined in Figure 13. The application of these criteria using available existing information illustrate general locations that probably would satisfy the criteria. These general locations are controlled primarily by the depth to fractured rock and minimum thickness of fine-grained sediment criteria. The application of

DRASTIC to Area #2 illustrates that the majority of the area has a relatively high pollution potential (Figure 14). The high DRASTIC indices are controlled primarily by the vadose zone DRASTIC factor (i.e., exposed fractured rock and high permeable surficial sediments) (Table 14). However, these DRASTIC indices are in general, less than Area #1 indicating this area has a lower overall pollution potential by the DRASTIC analysis. The application of DRASTIC delineates, in general, similar areas as the Idaho hydrogeologic siting criteria. This can be attributed to the influence of exposed fractured rock on the application of both the siting criteria and DRASTIC. The application of DRASTIC to Area #2 was very difficult due to the complex hydrogeology and water level interpretation.

Table 14: Calculations of DRASTIC Indices for Area #2

Feature	Range	Weight	Rating	Number A	Number B
Depth to Water	confined aquifer	5	1	5	5
Recharge	0-2"	4	1	4	4
Aquifer Media	sand & gravel	3	8	24	
	igneous/basalt	3	8		24
Soil Media*	loam	2	6	12	12
Topography	2-6%	1	9	9	9
Vadose Zone	sand & gravel with silt & clay	5	5		25
	igneous/basalt	5	9	45	
Hydraulic Conductivity (GPD/FT2)	1-100	3	1		3
	700-1000	3	6	18	
		DRASTIC Index:		117	82

* Information from U.S.D.A., 1968

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The Idaho hydrogeologic siting criteria appear to be effective management tools for siting new waste management facilities within the State of Idaho. The criteria effectively exclude major portions of the State that obviously are not amenable to the operation of a waste management facility but provide limited opportunities for possible site development. The specific conclusions of this research are:

1. The use of DRASTIC (Aller and others, 1985) and LeGrand (1983) as tools for siting and evaluating the hydrogeology at waste management facilities in Idaho are limited. These standardized methods oversimplify the hydrogeologic evaluation. However, DRASTIC might be used effectively as a preliminary investigative tool to categorize broad regions and identify areas that might warrant further detailed site investigations. DRASTIC should be used only on a broad regional scale to delineate areas that have the lowest pollution potential. LeGrand (1983) was developed for comparing the hydrogeology of site-specific locations. However, this hydrogeologic evaluation method also is too simplified to accurately characterize, rank and compare site hydrogeology. The methodology presented by Williams and Osiensky (1983) is a very useful guide to properly conduct a hydrogeologic field investigation. Careful planning and organization may ensure

that all necessary field data are collected to evaluate and understand the hydrogeology at a waste management facility.

2. Two primary types of hydrogeologic siting criteria are evident from evaluating criteria from the States of New Jersey, New York, Arizona, California, and Idaho. Qualitative advisory criteria offer guidelines for siting new waste management facilities. They reflect a political position without necessarily restricting areas from potential site locations. Numerical requirements, however can be very effective in eliminating areas from potential site consideration. Numerical requirements allow little subjectivity in the selection of potential site locations. The States of New Jersey, California and Idaho address the most comprehensive range of hydrogeologic issues. The Idaho criteria are the most stringent of all of the states reviewed. The criteria from each state reflect an unique political, social, and economic atmosphere.

3. The physical implication of each hydrogeologic siting criteria is dependant upon how the criteria is written. It is important to define the technical aspect first, then write the criteria accordingly. None of the states addressed the exact definition of depth to water. Depth to water has a different physical meaning depending upon the hydrogeology. The physical implication of depth to water is different between an unconfined aquifer system and a confined aquifer system.

4. General areas have been defined that might satisfy the Idaho hydrogeologic siting criteria within the western Snake River plain by regionally applying two preliminary siting criteria.

The depth to water and depth to fractured rock criteria essentially eliminate the mountainous and lowland portions of the western Snake River plain. The remaining portions that might satisfy the criteria include the highlands to the northwest of Boise and south of the Snake River in the Owyhee mountain foothills.

5. Application of the Idaho hydrogeologic siting criteria to two areas based on an evaluation of existing data shows that there are potential locations that might satisfy the criteria. Insufficient information is available to illustrate confidently the application of most of the hydrogeologic siting criteria to Area #1. A detailed geologic map and more water level data would help delineate potential outcrops of fractured rock and supplement the limited water level information.

   The application of the siting criteria to Area #2 using existing available information was very difficult. Insufficient information is available to illustrate confidently where all of the criterion might be satisfied. The hydrogeology is too complex to effectively apply the depth to water criterion. Site-specific evaluations are needed to ensure that the area would satisfy the criterion.

6. The application of DRASTIC to both Areas #1 and #2 delineated in general, similar areas to the siting criteria that might be amenable to the operation of a WMF. The application of DRASTIC to both areas was limited by the existing available information. The application to Area #1 was relatively simple and influenced primarily by the depth to water and vadose zone

DRASTIC factors. The application to Area #2 was difficult due to the complex hydrogeology and water level interpretation and was influenced primarily by the impact of the vadose zone DRASTIC factor.

Recommendations

The selection process for new hazardous waste management facilities within the western Snake River plain should focus further site evaluations in the foothills to the northwest of Boise and south of the Snake River in the Owyhee Mountain foothills. The specific recommendations are:

1. The State of Idaho should encourage the mapping of potential areas to locate future WMF.
2. New hazardous waste management facilities (i.e., not only land disposal facilities) should be located within areas that provide sufficient natural protection against ground water contamination. Man-made engineering structures should not replace the proper hydrogeologic location to minimize the potential of contamination to the environment.
3. The State of Idaho should define the exact physical meaning of depth to water as stated in the Idaho Hazardous Waste Management Plan.

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APPENDIX A

HYDROGEOLOGIC ANALYSIS OF A HAZARDOUS WASTE MANAGEMENT FACILITY

The methodology developed by Williams and Osiensky for evaluating the hydrogeology at waste management facilities is divided into two parts. The first focuses on existing facilities and the second on proposed facilities. Each part is divided into six main categories. A discussion of each category includes a synopsis of the data that should be collected and the rational for collecting them.

Part One

Literature Review: A literature review is essential prior to any field investigation. A detailed review will familiarize investigators with any previous knowledge and minimize potential costly field duplications. The literature review should begin with local hydrogeology, including federal, state, local, and private literature (Williams and Osiensky, 1983). If this review determines that the site is underlain by aquifers then the review should be expanded. This expansion should include relationships between local and regional ground water gradients, geologic structures, and hydrostratigraphy (Williams and Osiensky, 1983).

Data collected should include: well logs, geophysical logs, geologic maps, hydrogeologic reports, and aerial photographs (Williams and Osiensky, 1983).

Detailed Surface Hydrogeological Investigation: Preliminary field boundaries should be defined surrounding the site. These boundaries should include the furthest extent of known contamination and be within natural hydrologic boundaries (e.g., ground water divides, recharge-discharge areas). Surface water divides should not be considered to represent ground water divides unless sufficient data are available to support that conclusion (Williams and Osiensky, 1983).

A detailed hydrogeologic map should be constructed of the area under investigation. All identified hydrogeologic and geomorphologic features need to be field checked. Such features include: streams, terraces, escarpments, geologic structures, outcrops of hydrostratigraphic units, ground water recharge-discharge areas, and any active or inactive water supply wells (Williams and Osiensky, 1983). Surface extent of various hydrostratigraphic units should be delineated. Alluvial deposits should be differentiated into at least the basic lithologic descriptions (e.g., clay, sand, and gravel). Understanding the paleo-depositional environment of each hydrostratigraphic unit will assist in developing a hydrogeologic conceptual model of the site.

All active, in-active, abandon test holes or wells should be mapped. Information regarding each test hole or well should be compiled. This information includes: hydrostratigraphic unit penetrated (i.e., screened interval), well depth and diameter, method of construction, static water level, pumping schedule (e.g., irrigation purposes), and use of water (Williams and Osiensky, 1983).

All springs and streams should be mapped and information regarding them should be compiled and evaluated. Field measurements should be collected if no data exist. The objective of spring and stream measurements is to evaluate relationships between hydrostratigraphy, ground water flow, and stream flow (Williams and Osiensky, 1983). Stream flow should be measured at several different sites along the length of each stream and during the period of low flow. This measurement schedule will help determine if the stream is influent or effluent (i.e., recharging to or discharging from the ground water, respectively) (Williams and Osiensky, 1983). Water quality samples should be collected from all wells, springs and selected locations along each stream. Selection of stream sampling locations should be based upon knowledge of the hydrogeology and discharge measurements (Williams and Osiensky, 1983). Water quality samples should be analyzed for background quality and contamination.

A preliminary hydrogeologic conceptual model of the site location now can be developed. Understanding of this conceptual model is imperative to the development of any exploration, testing, and monitoring program.

Hydrogeologic Exploration Program: The purpose and objective of any exploration program must be defined prior to drilling. The objectives of an exploration program are generally site-specific. Williams and Osiensky (1983) state that there is at least one primary objective that is common to all exploration programs at waste management facilities. This objective is to delineate the hydrogeology and/or geometry of a contaminant plume to the degree that is adequate to answer the purpose of the analysis (Williams and Osiensky, 1983).

It is necessary to pre-determine which data must be collected during each phase of the exploration program. Test holes and wells should be constructed one at a time and only after all necessary data have been collected and analyzed (Williams and Osiensky, 1983). There is no standard exploration program for all site-specific conditions, however, many data needed to delineate the hydrogeology and/or contaminant plume are identical. These data include: detailed hydrostratigraphic data, water quality data, ground water potential data, and hydrogeologic characteristics of individual hydrostratigraphic units (e.g., vertical and horizontal hydraulic conductivity, specific storage and transmissivity coefficients).

The exploration program outlined by Williams and Osiensky (1983) is divided into three categories: surface and borehole geophysics, drilling of test holes and wells, and the location, design and construction of test holes and wells. Surface and Borehole Geophysical Techniques: There are many surface and borehole geophysical techniques that may help to delineate the hydrogeology or a contaminant plume. If a contaminant plume is suspected at a WMF, a detailed surface electrical resistivity survey may help to define the lateral extent of contamination (Williams and Osiensky, 1983). The degree of success of a resistivity survey in defining the hydrostratigraphy or geometry of a contaminant plume is dependant upon several factors. These factors are: (1) the degree of resistivity contrast between the contaminant plume, native ground water and subsurface geologic media, (2) degree to which the depth and extent of the plume are within the limitations of equipment used, (3) the relative homogeniety of the subsurface materials, (4) presence of low resistivity clay layers, and (5) degree of cultural interference that exists at the site (Williams and Osiensky, 1983).

Geophysical logs are a valuable tool for collecting pertinent data from each borehole. When correctly interpreted Williams and Osiensky (1983) state that geophysical logs serve the following purposes: (1) guide the location, drilling and construction of future wells, (2) allow for the extrapolation of vertical and horizontal data from boreholes, and (3) they may provide for estimation of the lithology, geometry, resistivity, bulk density, porosity, permeability, moisture content, and specific yield of water bearing units, and the source, movement, chemical and physical characteristics of water (Keys and MacCray, 1976).

Geophysical logs provide continuous objective records of the subsurface materials penetrated by the borehole. Geophysical logs when recorded along with a driller's or hydrogeologist's log significantly add to the data base at each borehole. A detailed discussion of each type of geophysical log are discussed in Keys and MacCray (1976). Test Hole and Well Drilling: Exploratory drilling is the only direct method available for collecting subsurface hydrogeologic data. It is very important that the objectives for drilling each test hole or well be defined prior to drilling. Accurate definitions of each objective will maximize the amount of data that can be collected at each borehole (Williams and Osiensky, 1983). General and specific objectives should be ranked in order of importance so that the optimal methods of drilling and data collection can be chosen logically.

Hydrogeologic data that can be collected from a borehole during and after drilling may vary considerably with the type of drilling method used. This may be of major significance with respect to satisfying the purpose and objective of each borehole. Williams and Osiensky (1983) list some of the pertinent hydrogeologic data that can be collected with several commonly used drilling methods (Table 15).

Location, Design, and Construction of Test Holes and Wells: The degree to which the purpose and objective of each borehole can be satisfied depends upon several factors in addition to the drilling method. Williams and Osiensky (1983) state that the three most important factors are location, design, and construction of each bore hole.

Table 15: Examples of hydrogeologic data that can be collected during drilling (modified after Williams and Osiensky, 1983)

	HYDROGEOLOGIC DATA					
Drilling Method	Formation samples (lithology)	Formation samples (water)	Field Analysis of water samples	Groundwater potential	Water table depth	Estimated Hydraulic Conductivity
Mud Rotary	Samples by core drilling or coring.	Drilling to sampling depth, pull drill string set temporary well screen.	no	no	no	Set temporary well screen & test, pull drive screen, drill to next horizon.
Air Rotary	Samples by core drilling or drive core.	Drive casing to sampling depth bail or pump	Mixed samples during drilling.	Relative measurement.	yes	Packing off intervals.
Cable Tool	Samples from bailer.	Drive casing to sampling depth and bail.	Yes, mixing minimized in cased holes.	Relative measurement.	yes	Same as Air Rotary.
Double-Wall Reverse Circulation	Samples same as Air Rotary.	Same as Mud or Air Rotary.	Mixed samples during drilling.	Relative measurement.	yes	Same as Mud or Air Rotary.
Hollow Stem Continous Flight Auger	Core samples only.	no	no	no	Difficult at depth.	Yes, if hole is screened or cased.

However, relative importance of each factor varies with the purpose for drilling.

Test hole and well location is extremely important to the delineation of the hydrogeology and geometry of a contaminant plume. Erroneous conclusions may be drawn if test holes do not intersect specific hydrostratigraphic units. This is of major significance where the migration characteristics of a contaminant plume are within a complex hydrogeologic environment (Williams and Osiensky, 1983).

The design and construction of test holes and wells are very important to the success of a ground water monitoring program. Design specifications including bore hole diameter, depth, screened interval, and casing requirements are important for the proper construction and operation of monitor wells and piezometers (Williams and Osiensky, 1983). The design and construction technique of each test hole should be well documented.

Boreholes should be completed according to their design specifications after all necessary data have been collected during and after drilling. All boreholes should be completed as wells or piezometers, or plugged with bentonite, cement or other suitable material (Williams and Osiensky, 1983). For information on well construction and piezometer installation the reader is referred to the following publications: U. S. Environmental Protection Agency (1986), U. S. Department of Interior (1981), Driscoll (1986), and U. S. Environmental Protection Agency (1980).

Hydraulic Property Testing Program: The migration of non-reactive contaminants in ground water is controlled by two processes, advection and dispersion (Gillham and Cherry, 1982). Advection (i.e., the average linear pore water velocity) is controlled by natural ground water gradients. Dispersion is a function of mechanical mixing and molecular diffusion (Gillham and Cherry, 1982). Man-made influences such as pumping wells, excavations, and irrigation practices may markedly alter natural ground water movement. The fundamental relationship of ground water flow through a porous media is defined by Darcy's Law (Freeze and Cherry, 1979).

$$Q=KiA$$

Where:

Q = discharge per unit time (units: length cubed /time)

K = hydraulic conductivity (constant of proportionality, units: length/time)

i = hydraulic gradient (potential energy loss per unit length, units: length/length)

A = unit area (units: length squared)

It is evident from this relationship that the primary factors which control the rate of ground water movement through porous media are hydraulic conductivity and hydraulic gradient. Several laboratory and field methods have been developed for measuring hydraulic conductivity. Williams (1982) provides an in depth discussion of the advantages and disadvantages of some of these methods.

The general objective of hydraulic property testing is to define the hydraulic characteristics of subsurface materials. Knowledge of these characteristics is important to define or predict the rate and direction of contaminant migration (Williams and Osiensky, 1983).

A standard testing program for any site should include data collection for the evaluation of: the hydraulic conductivity of individual hydrostratigraphic units, aquifer boundary conditions and their influence on ground water flow, degree of hydraulic continuity between wells, degree of hydraulic interconnection between different hydrostratigraphic units, and the velocity of ground water flow through individual hydrostratigraphic horizons (Williams and Osiensky, 1983).

Designing a hydraulic testing program should be based upon the hydrogeologic conceptual model of the site. Williams and Osiensky (1983) have divided a testing program into two main steps. Step one includes long term aquifer pump tests to evaluate the hydraulic response of selected hydrostatigraphic units. The purpose for conducting a series of long term aquifer tests is to stress hydraulically a large volume of the contaminated hydrostratigraphic units. These tests should be designed to permit the evaluation for the degree of hydraulic continuity between monitoring wells, observation wells, and pumping wells which intersect the same hydrostratigraphic units. This information is important for evaluating the hydraulic continuity between contaminated and uncontaminated wells, and potential aquifer boundary conditions that may influence ground water flow (Williams and Osiensky, 1983).

Values of transmissivity and storativity should be estimated from the data for each monitor and observation well that responds to the pumpage of the pumping well. Data for wells that do not respond predictably to pumpage should be analyzed for boundary conditions, partial penetration, or other hydraulic analytical techniques to explain the data response. Monitor or observation wells that do not respond predictably to pumpage should be tested individually.

The second step of the testing program is to estimate hydraulic conductivity. Hydraulic conductivity can be tested using one or more of the methods presented in Figure 13. There are advantages and disadvantages to each of these methods. Many factors must be considered in selecting which method to use, including: purpose of testing, reliability of test method, cost, time required, skill required, hydrogeologic setting, desired results and whether or not the results will be representative of the area being tested (Williams, 1982).

A major disadvantage of testing the hydraulic conductivity from individual single well tests is that the results represent only a small volume of the subsurface media adjacent to the well screen. Extrapolation of hydraulic conductivity estimations between single well tests is not valid, especially in complex hydrostratigraphic environments (Williams and Osiensky, 1983). It is also not valid to average single well tests in order to estimate an overall hydraulic conductivity for the hydrostatigraphic unit. A multiple well aquifer test stresses hydraulically a much larger portion of the unit and gives a much more representative value for hydraulic conductivity for the entire unit.

Water Quality Monitoring Program: The first step to implementing a water quality monitoring program is to define the objectives clearly. The general objective of a water quality monitoring program should be to ascertain: (1) whether contamination is present at depth discrete sampling locations, and (2) the concentration of contamination, if present, to be able to delineate temporal changes in the geometry of a contaminant plume (Williams and Osiensky, 1983). Several possible purposes for conducting a ground water monitoring program are: (1) identifying the source of contamination, (2) identify the chemical constituents within a contaminant plume, and (3) comply with federal and state regulations.

It is necessary to identify the data that must be collected at each monitoring location to minimize insufficient, or inaccurate information.

The monitoring program should begin with the collection of representative ground water samples from each monitor well. Accurate and consistent sampling procedures, preservation methods, and analytical techniques are necessary to provide reliable water quality data. The same sampling procedures, including pumping rate and length of pumping for each sample should be consistent from one sampling period to the next. The same certified laboratory should perform the analyses for all samples (Williams and Osiensky, 1983). Independent analysis should be performed periodically for quality assurance. The reader is referred to American Public Health Association (1976) and U. S. Environmental Protection Agency (1979) for additional information pertaining to water quality sample collection and analysis.

Part Two

Williams and Osiensky (1983) developed part two as an outline of procedures to evaluate whether a proposed site is suitable for the construction and operation of a waste management facility. The purpose of a hydrogeologic investigation at a proposed WMF is to evaluate whether the site complies with federal and state regulations rather than searching for potential contamination. Most of the hydrogeologic data in part one are recommended in part two. The primary difference between each part is the purpose for collecting the data (Williams and Osiensky, 1983).

Most methods for data collection that are described for part one are applicable directly to part two (Williams and Osiensky, 1983).

Discussion of the data collection methods that are the same are not repeated in this part. However, differences between the two are discussed in this section.

Literature Review: A literature review is essential prior to any field investigation. A detailed literature review may eliminate the expense of a field investigation if the site is found to be unsuitable for the operation of a WMF. Details of the literature review are described in Part One - Literature Review.

Detailed Surface Hydrogeologic Investigation: A detailed field investigation should incorporate the entire proposed facility location. Data collected during this stage are important to accurately evaluate the hydrogeology. A detailed discussion of the procedures are outlined in Part One-Detailed Surface Hydrogeologic Investigation.

Hydrogeologic Exploration Program: The objectives for conducting a hydrogeologic exploration program are essentially the same for existing and proposed WMF sites (Williams and Osiensky, 1983). The methods for data collection that are described in Part One - Hydrogeologic Exploration Program, are applicable to conditions that exist at proposed facilities except: (1) collection of data regarding an existing contaminant plume, and (2) utilization of an electrical resistivity survey. This data is limited only to the evaluation of natural resistivity variations and not for the delineation of a contaminant plume (Williams and Osiensky, 1983).

Hydraulic Property Testing Program: The general objective of hydraulic property testing at a proposed facility is to define the hydraulic characteristics of the subsurface media beneath the site (Williams and Osiensky, 1983). This information is important in determining the rate of leakage to an underlying ground water system in the event of an accident or spill. The type of data that must be collected depends upon: (1) whether or not aquifers exist beneath the proposed site, and (2) whether or not aquifers are separated from the proposed site by a continuous hydrostratigraphic unit of low hydraulic conductivity to mitigate the downward migration of contaminants. A detailed discussion of procedures are outlined in Part One - Hydraulic Property Testing Program.

Water Quality Monitoring Program: The primary purpose of developing a ground water monitoring program at a proposed site is to comply with federal and state regulations. The objective of a program is to detect potential contamination prior to contamination of the underlying ground water system. Details of a water quality monitoring program are outlined in Part One - Water Quality Monitoring Program.

APPENDIX B

U. S. GEOLOGICAL SURVEY OBSERVATION WELL WATER LEVEL DATA AND SELECTED IDAHO DEPARTMENT OF WATER RESOURCES DRILLER'S LOGS FOR AREA #1

U. S. Geological Survey Observation Wells

1) County: Ada
Well Number: 05N 01W 29CBA1
Altitude: 2630 feet
Well Depth: 332 feet
Depth to First Perforations: 272 feet
Depth to Static Water Level: 175.7 feet
Water Level Elevation: 2454 feet
Date of Measurement: March 20, 1980

2) County: Ada
Well Number: 05N 01W 35BAA1
Altitude: 2610 feet
Well Depth: 153 feet
Depth to First Perforations: 49 feet
Depth to Static Water Level: 60.8 feet
Water Level Elevation: 2549 feet
Date of Measurement: April 10, 1980

3) County: Ada
Well Number: 05N 01W 36ABB1
Altitude: 2620 feet
Well Depth: 105 feet
Depth to First Perforations: ?
Depth to Static Water Level: 75.1 feet
Water Level Elevation: 2545 feet
Date of Measurement: June 28, 1983

4) County: Canyon
Well Number: 05N 02W 19CBA1
Altitude: 2480 feet
Well Depth: 260 feet
Depth to First Perforations: 254 feet
Depth to Static Water Level: 43.9 feet
Water Level Elevation: 2436 feet
Date of Measurement: March 13, 1980

5) County: Canyon
Well Number: 05N 02W 22CAD1
Altitude: 2610 feet
Well Depth: 450 feet
Depth to First Perforations: 279 feet
Depth to Static Water Level: 180.6 feet
Water Level Elevation: 2429 feet
Date of Measurement: March 17, 1981

6) County: Canyon
Well Number: 05N 02W 24DAB1
Altitude: 2600 feet
Well Depth: 320 feet
Depth to First Perforations: 280 feet

Depth to Static Water Level: 162.8 feet
Water Level Elevation: 2437 feet
Date of Measurement: March 12, 1980

7) County: Canyon
Well Number: 05N 03W 11BCA1
Altitude: 2590 feet
Well Depth: 304 feet
Depth to First Perforations: 311 feet
Depth to Static Water Level: 192.1 feet
Water Level Elevation: 2398 feet
Date of Measurement: November 30, 1981

8) County: Canyon
Well Number: 05N 3W 19AAD1
Altitude: 2440 feet
Well Depth: 136 feet
Depth to First Perforations: 131 feet
Depth to Static Water Level: 30.1 feet
Water Level Elevation: 2410 feet
Date of Measurement: March 12, 1980

9) County: Canyon
Well Number: 05N 03W 30DAA1
Altitude: 2470 feet
Well Depth: 149 feet
Depth to First Perforations: 149 feet
Depth to Static Water Level: 79 feet
Water Level Elevation: 2391 feet
Date of Measurement: March 13, 1980

Summary of Idaho Department of Water Resources
Driller's Log Information

(altitudes and water level elevations are approximated)

1) County: Ada
Well Number: 05N 01W 3BA1
Altitude: 2740 feet
Well Depth: 421 feet
Depth to First Perforations: ?
Depth to Static Water Level: 352 feet
Water Level Elevation: 2388 feet
Date of Measurement: August 31, 1979

2) County: Ada
Well Number: 05N 01W 3CB1
Altitude: 2740 feet
Well Depth: 440 feet
Depth to First Perforations: 432 feet
Depth to Static Water Level: 375 feet
Water Level Elevation: 2365 feet
Date of Measurement: November 1970

3) County: Ada
Well Number: 05N 01W 6DC1
Altitude: 2900 feet
Well Depth: 124 feet
Depth to First Perforations: open hole
Depth to Static Water Level: 20 feet
Water Level Elevation: 2880 feet
Date of Measurement: September 9, 1978

4) County: Ada
Well Number: 05N 01W 8DA1
Altitude: 2700 feet
Well Depth: 430 feet
Depth to First Perforations: 420 feet
Depth to Static Water Level: 385 feet
Water Level Elevation: 2315 feet
Date of Measurement: June 24, 1968

5) County: Ada
Well Number: 05N 01W 9DB1
Altitude: 2700 feet
Well Depth: 450 feet
Depth to First Perforations: open hole
Depth to Static Water Level: 300 feet
Water Level Elevation: 2400 feet
Date of Measurement: October 14, 1966

6) County: Ada
Well Number: 05N 01W 16CC1
Altitude: 2700 feet

Well Depth: 303 feet
Depth to First Perforations: 263 feet
Depth to Static Water Level: 252 feet
Water Level Elevation: 2448 feet
Date of Measurement: May 15, 1971

7) County: Canyon
Well Number: 05N 02W 5AA1
Altitude: 2700 feet
Well Depth: 232 feet
Depth to First Perforations: open hole
Depth to Static Water Level: 100 feet
Water Level Elevation: 2600 feet
Date of Measurement: August 29, 1977

8) County: Canyon
Well Number: 05N 02W 6DD1
Altitude: 2600 feet
Well Depth: 401 feet
Depth to First Perforations: ?
Depth to Static Water Level: 315 feet
Water Level Elevation: 2350 feet
Date of Measurement: March 29, 1972

9) County: Canyon
Well Number: 05N 02W 15CD1
Altitude: 2500 feet
Well Depth: 508 feet
Depth to First Perforations: 270 feet
Depth to Static Water Level: 218 feet
Water Level Elevation: 2282 feet
Date of Measurement: March 8, 1980

10) County: Gem
Well Number: 06N 03W 33CA1
Altitude: 2500 feet
Well Depth: 175 feet
Depth to First Perforations: open hole
Depth to Static Water Level: 40 feet
Water Level Elevation: 2460 feet
Date of Measurement: January 28, 1978

11) County: Gem
Well Number: 06N 03W 36DA1
Altitude: 2620 feet
Well Depth: 528 feet
Depth to First Perforations: 272 feet
Depth to Static Water Level: 268 feet
Water Level Elevation: 2350 feet
Date of Measurement: May 5, 1979

APPENDIX C

U. S. GEOLOGICAL SURVEY OBSERVATION WELL WATER LEVEL DATA

AND SELECTED IDAHO DEPARTMENT OF WATER RESOURCES

DRILLER'S LOGS FOR AREA #2

U.S. Geological Survey Observation Wells

1) County: Owyhee
   Well Number: 03S 01W 15DCC1
   Altitude: 2736 feet
   Well Depth: 250 feet
   Depth to First Perforations: ?
   Depth to Static Water Level: 57.6 feet
   Water Level Elevation: 2678 feet
   Date of Measurement: March 13, 1980

2) County: Owyhee
   Well Number: 03S 01W 18DCC1
   Altitude: 3240 feet
   Well Depth: 738 feet
   Depth to First Perforations: 260 feet
   Depth to Static Water Level: 360 feet
   Water Level Elevation: 2880 feet
   Date of Measurement: March 13, 1980

3) County: Owyhee
   Well Number: 03S 01W 31BCC1
   Altitude: 3130 feet
   Well Depth: 23.3 feet
   Depth to First Perforation: ?
   Static Depth to Water: 22.2 feet
   Water Level Elevation: 3108 feet
   Date of Measurement: September 22, 1977

4) County: Owyhee
   Well Number: 03S 02W 28AAC1
   Altitude: 3524 feet
   Well Depth: 355 feet
   Depth to First Perforations: 277 feet
   Depth to Static Water Level: 250 feet
   Water Level Measurement: 3274 feet
   Date of Measurement: February 16, 1979

5) County: Owyhee
   Well Number: 03S 02W 36DBB1
   Altitude: 3131 feet
   Well Depth: ?
   Depth to First Perforations: ?
   Depth to Static Water Level: 19.4 feet
   Water Level Elevation: 3112 feet
   Date of Measurement: January 8, 1979

6) County: Owhyee
   Well Number: 04S 01W 25CCC1
   Altitude: 2880 feet
   Well Depth: ?
   Depth to First Perforations: ?
   Depth to Static Water Level: 6.4 feet

Water Level Elevation: 2874 feet
Date of Measurement: June 20, 1978

7) County: Owhyee
Well Number: 04S 01W 25CDC1
Altitude: 2856 feet
Well Depth: 335 feet
Depth to First Perforations: 250 feet
Depth to Static Water Level: 31.5 feet
Water Level Elevation: 2825 feet
Date of Measurement: March 22, 1978

8) County: Owyhee
Well Number: 04S 01W 26CBD1
Altitude: 3024 feet
Well Depth: 318 feet
Depth to First Perforations: 166 feet
Depth to Static Water Level: 182.4 feet
Water Level Elevation: 2842 feet
Date of Measurement: March 22, 1978

9) County: Owyhee
Well Number: 04S 01W 26DBD1
Altitude: 2940 feet
Well Depth: 334 feet
Depth to First Perforations: 166 feet
Depth to Static Water Level: 97.8 feet
Water Level Elevation: 2842 feet
Date of Measurement: March 22, 1978

10) County: Owhyee
Well Number: 04S 01W 36ADB1
Altitude: 2820 feet
Well Depth: 507 feet
Depth to First Perforations: 158 feet
Depth to Static Water Level: 38.5 feet
Water Level Elevation: 2781 feet
Date of Measurement: March 23, 1978

11) County: Owyhee
Well Number: 04S 01W 36BDB1
Altitude: 2868 feet
Well Depth: 348 feet
Depth to First Perforations: 168 feet
Depth to Static Water Level: 56.3 feet
Water Level Elevation: 2812 feet
Date of Measurement: March 23, 1978

12) County: Owyhee
Well Number: 04S 02W 11ABA1
Altitude: 3250 feet
Well Depth: 419 feet
Depth to First Perforation: 20 feet
Static Depth to Water: 24.3 feet

Water Level Elevation: 3226 feet
Date of Measurement: March 21, 1978

Summary of Department of Water Resources
Driller's Log Information

(altitudes and water level elevations are approximated)

1) County: Owyhee
   Well Number: 03S 01W 1AA1
   Altitude: 2900 feet
   Well Depth: 106 feet
   Depth to First Perforations: ?
   Depth to Static Water Level: flowing
   Water Level Elevation: flowing
   Date of Measurement: July 1, 1971

2) County: Owyhee
   Well Number: 03S 01W 15DC1
   Altitude: 2750 feet
   Well Depth: 285 feet
   Depth to First Perforations: 0
   Depth to Static Water Level: dry
   Water Level Elevation: dry
   Date of Measurement: ?

3) County: Owyhee
   Well Number: 03S 01W 15DC2
   Altitude: 2750 feet
   Well Depth: 90 feet
   Depth to First Perforations: 0
   Depth to Static Water Level: dry
   Water Level Elevation: dry
   Date of Measurement: ?

4) County: Owhyee
   Well Number: 03S 01W 21AC1
   Altitude: 3100 feet
   Well Depth: 298 feet
   Depth to First Perforations: 265 feet
   Depth to Static Water Level: 109 feet
   Water Level Measurement: 2990 feet
   Date of Measurement: August 25, 1984

5) County: Owhyee
   Well Number: 03S 02W 14CD1
   Altitude: 3280 feet
   Well Depth: 125 feet
   Depth to First Perforations: open hole
   Depth to Static Water Level: 17.7 feet
   Water Level Elevation: 3262 feet
   Date of Measurement: March 21, 1972

6) County: Owhyee
   Well Number: 04S 01W 22AC1
   Altitude: 3000 feet

Well Depth: 307 feet
Depth to First Perforations: open hole
Depth to Static Water Level: 165 feet
Water Level Elevation: 2835 feet
Date of Measurement: July 27, 1984

7) County: Owyhee
Well Number: 04S 01W 26BB1
Altitude: 3025 feet
Well Depth: 318 feet
Depth to First Perforations: 166 feet
Depth to Static Water Level: 13 feet
Water Level Elevation: 13 feet
Date of Measurement: February 22, 1967

8) County: Owyhee
Well Number: 04S 01W 29BD1
Altitude: 3300 feet
Well Depth: 377 feet
Depth to First Perforations: 157 feet
Depth to Static Water Level: 108 feet
Water Level Elevation: 3192 feet
Date of Measurement: January 22, 1969

9) County: Owhyee
Well Number: 04S 01W 36AA1
Altitude: 2825 feet
Well Depth: 326 feet
Depth to First Perforations: 158 feet
Depth to Static Water Level: 12 feet
Water Level Elevation: 2813 feet
Date of Measurement: March 17, 1967

10) County: Owyhee
Well Number: 04S 02W 11AB1
Altitude: 3725 feet
Well Depth: 430 feet
Depth to First Perforations: open hole
Depth to Static Water Level: 18 feet
Water Level Elevation: 3707 feet
Date of Measurement: 1964

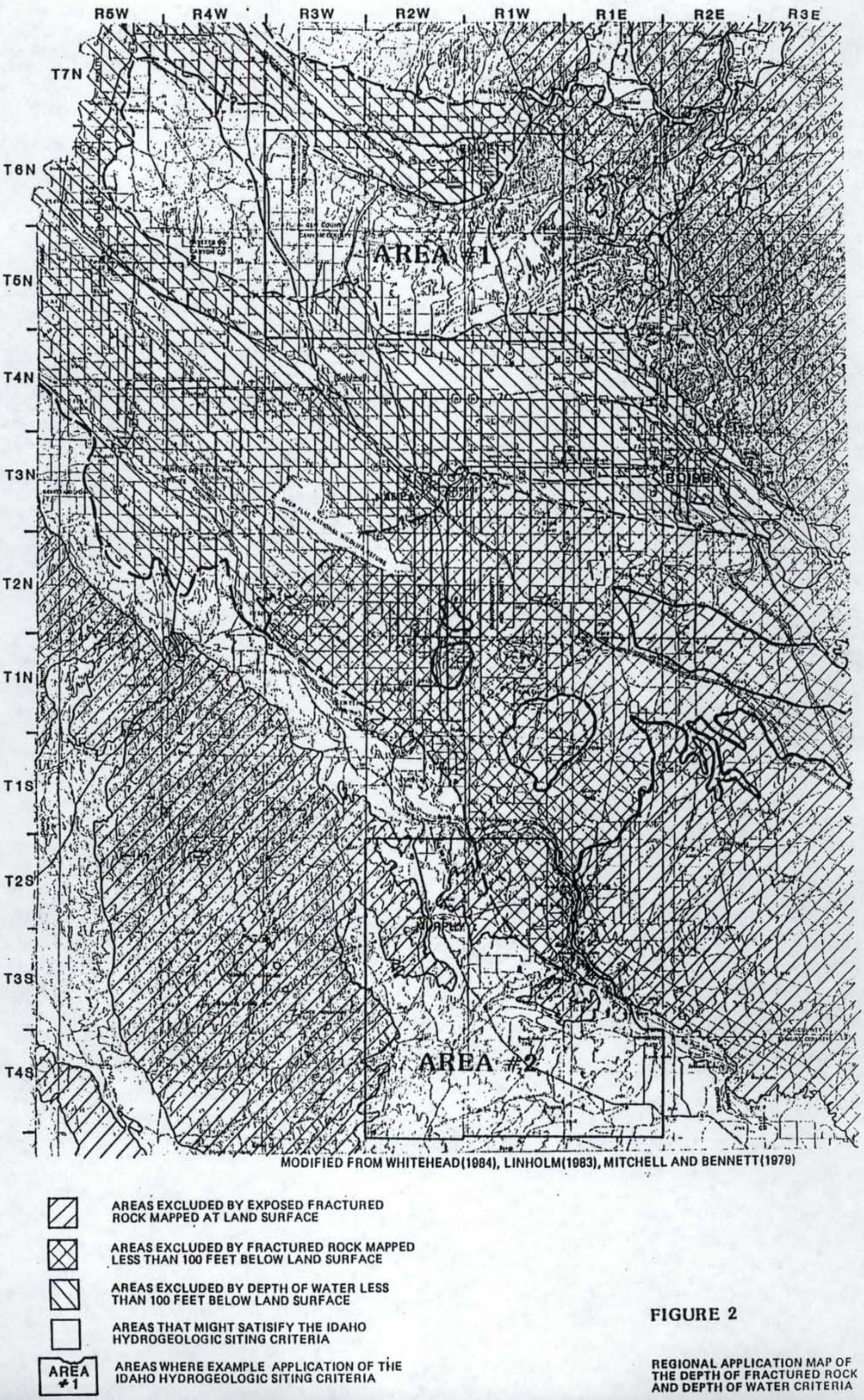
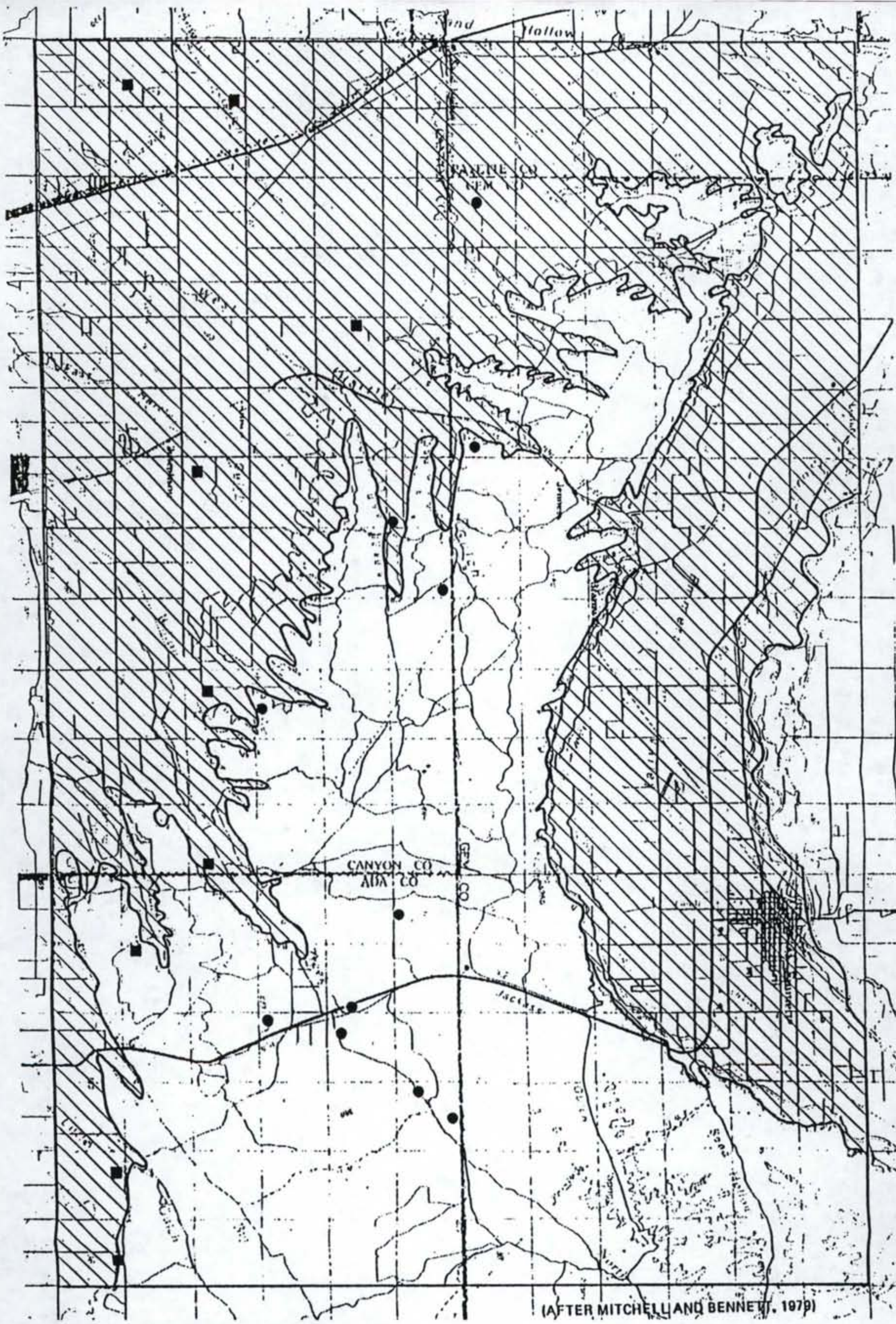


FIGURE 2

REGIONAL APPLICATION MAP OF THE DEPTH OF FRACTURED ROCK AND DEPTH OF WATER CRITERIA



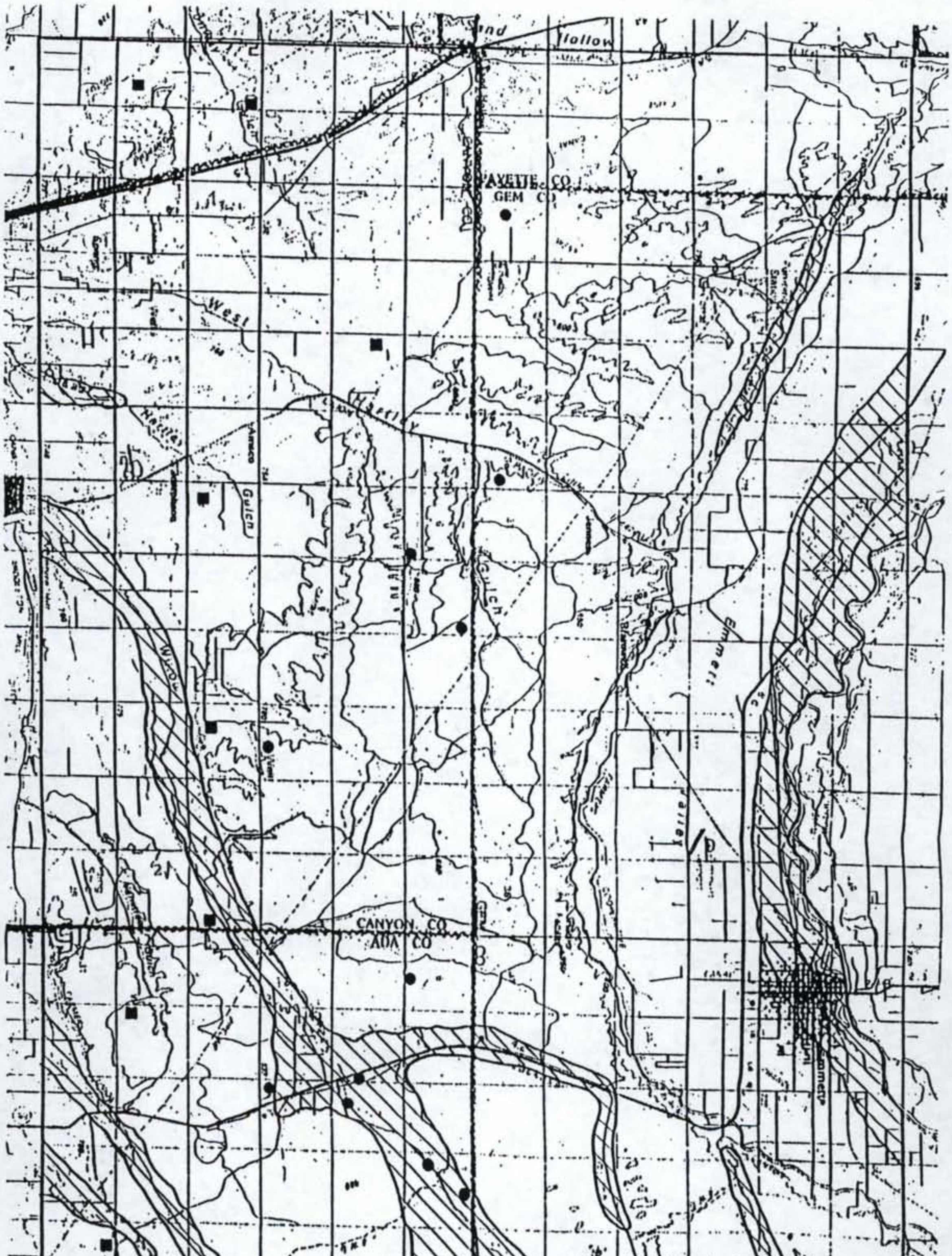
AREAS EXCLUDED BY DEPTH TO WATER CRITERION (IE, BELOW 2600 FT. ELEV.)

● IDWR WELLS

■ USGS WELLS

FIGURE 5

APPLICATION OF THE MINIMUM DEPTH TO WATER SITING CRITERION TO AREA NO. 1



(MODIFIED AFTER MITCHELL AND BENNETT, 1979)

▧ AREAS EXCLUDED BY MINIMUM THICKNESS OF FINE GRAINED SEDIMENTS (IE, AREAS MAPPED AS ALLUVIUM AND TEN MILE GRAVEL)

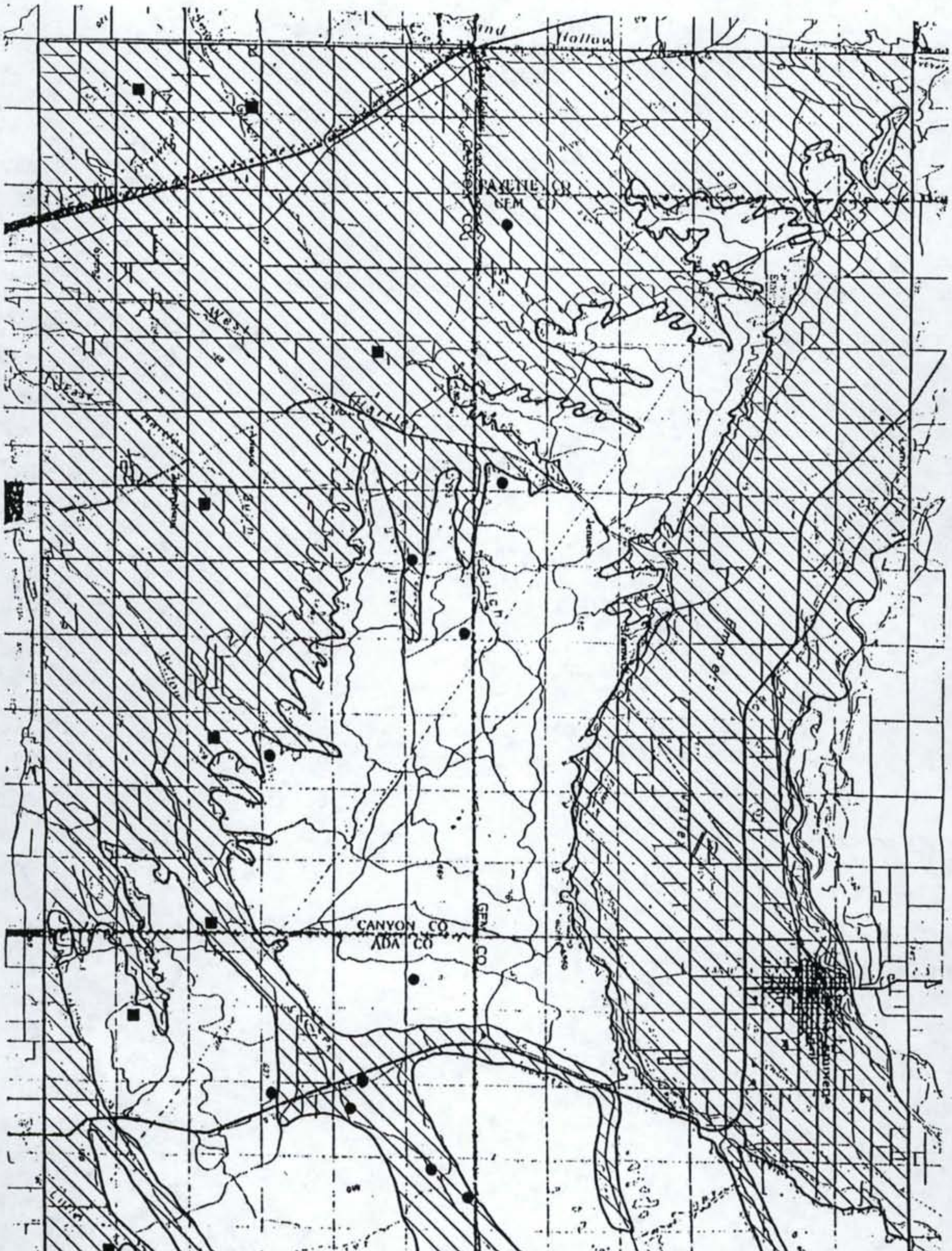
□ AREAS MAPPED AS IDAHO GROUP AND CALDWELL-NAMPA SEDIMENTS

● IDWR WELLS

■ USGS WELLS

FIGURE 6

APPLICATION OF THE MINIMUM THICKNESS OF UNCONSOLIDATED FINE-GRAIN SEDIMENTS SITING CRITERION TO AREA NO. 1



AREAS THAT MIGHT SATISFY THE IDAHO HYDROGEOLOGIC SITING CRITERIA

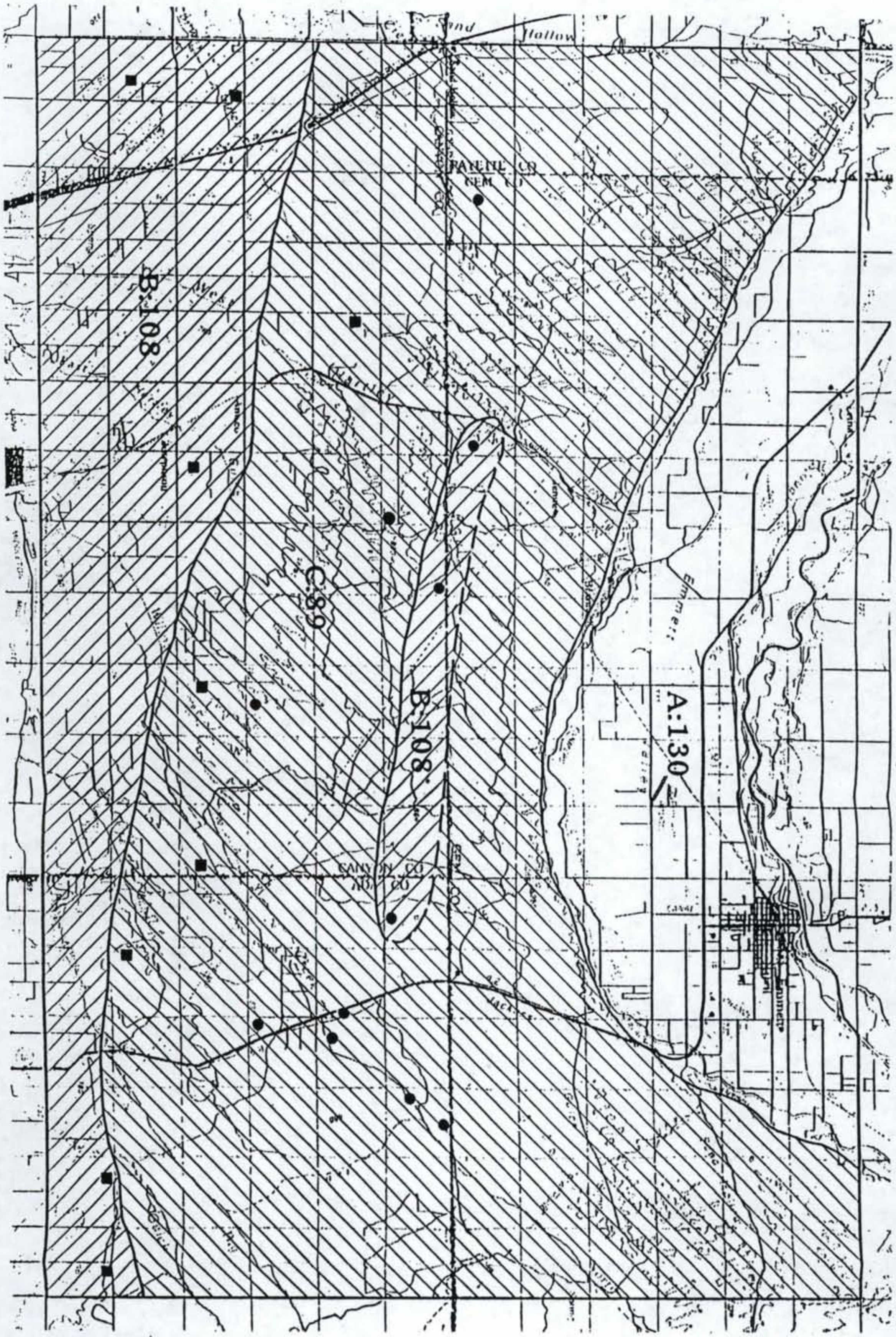
AREAS EXCLUDED BY THE IDAHO HYDROGEOLOGIC SITING CRITERIA

● IDWR WELLS

■ USGS WELLS

FIGURE 7

APPLICATION OF THE IDAHO HYDROGEOLOGIC SITING CRITERIA TO AREA NO. 1 (EXCEPT 500-YR FLOOD PLAIN AND DISTANCE TO WATER WELLS CRITERIA)



130 AREA A: DRASTIC INDEX

108 AREA B: DRASTIC INDEX

89 AREA C: DRASTIC INDEX'

● IDWR WELLS

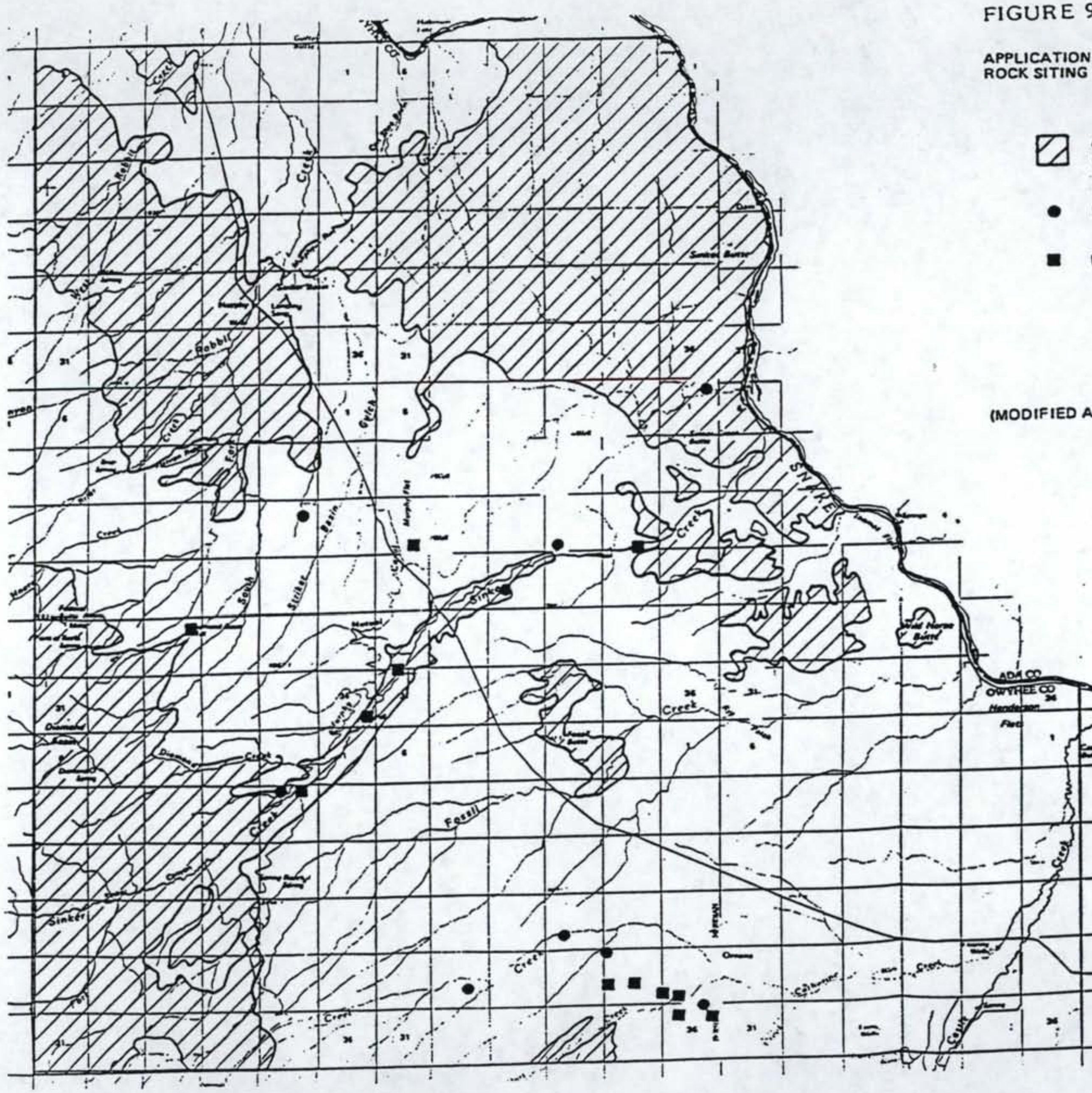
■ USGS WELLS

FIGURE 8

APPLICATION OF DRASTIC TO AREA NO. 1

FIGURE 9

APPLICATION OF THE DEPTH TO FRACTURED ROCK SITING CRITERION TO AREA NO. 2

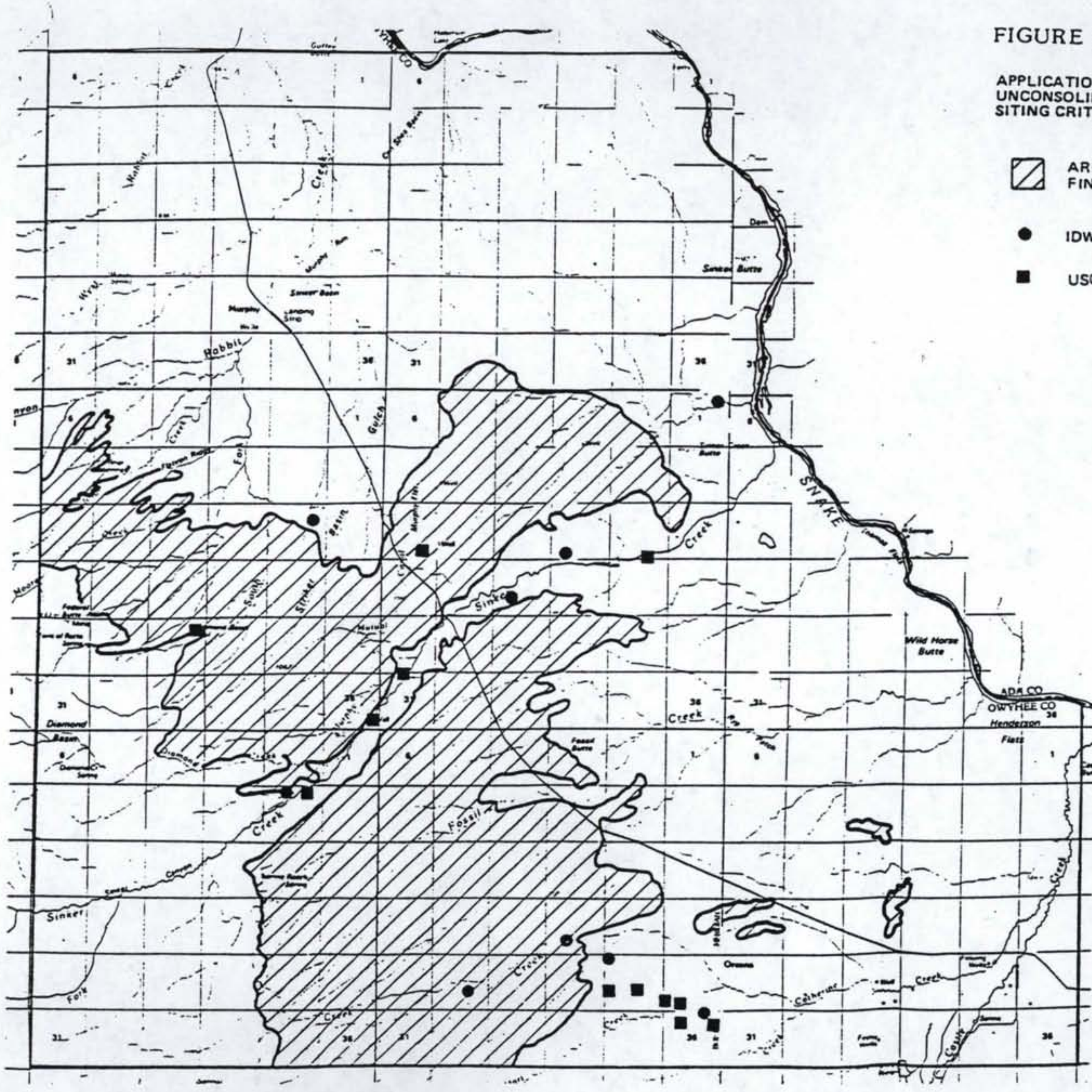


- AREAS EXCLUDED BY EXPOSED FRACTURED ROCK MAPPED AT LAND SURFACE
- ● IDWR WELLS
- ■ USGS WELLS

(MODIFIED AFTER EKREN AND OTHERS, 1981)

FIGURE 12

APPLICATION OF THE MINIMUM THICKNESS OF UNCONSOLIDATED FINE-GRAIN SEDIMENTS SITING CRITERION TO AREA NO. 2



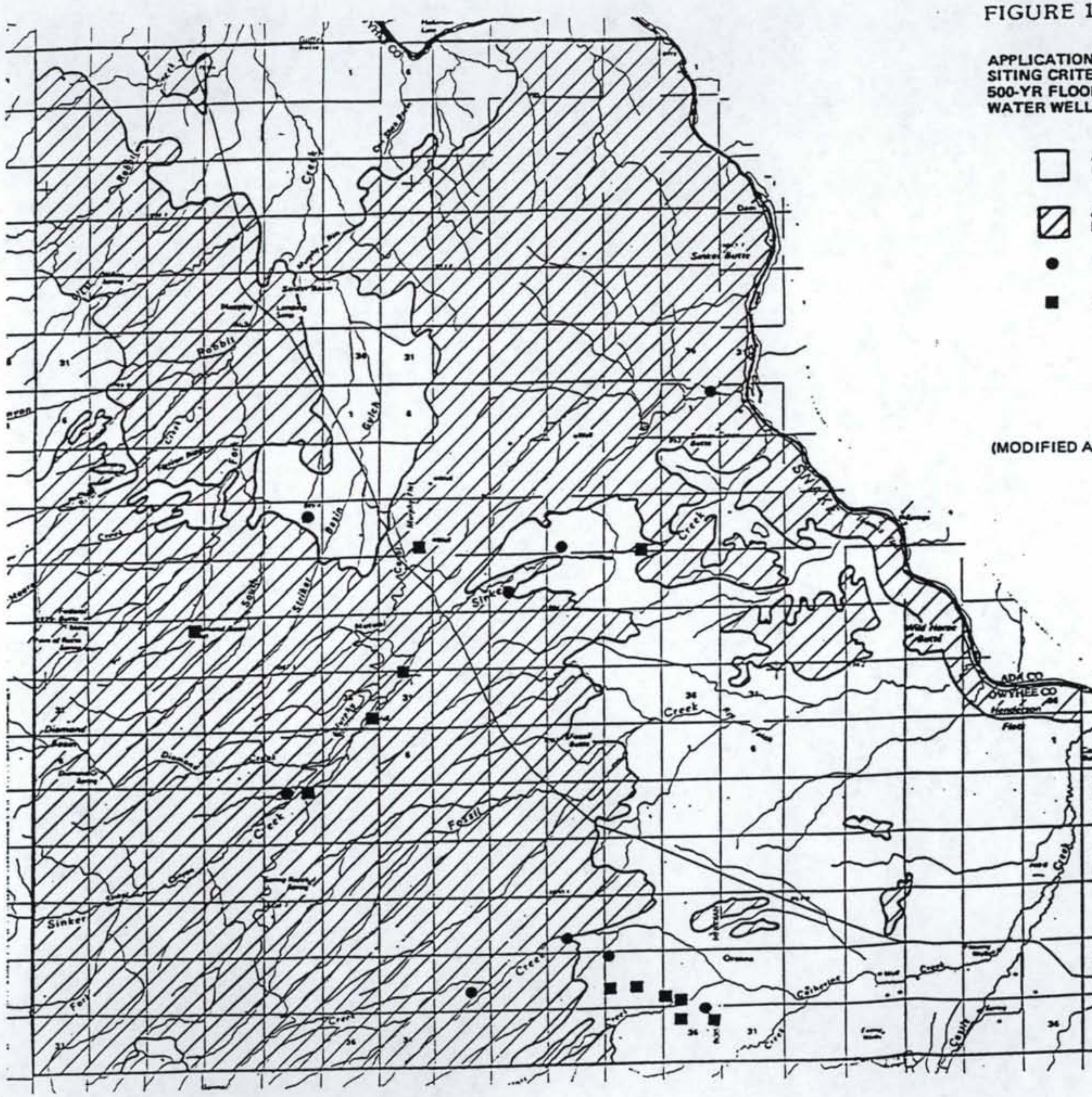
AREAS EXCLUDED BY THE MINIMUM THICKNESS OF FINE GRAINED-SEDIMENTS CRITERION

● IDWR WELLS

■ USGS WELLS

FIGURE 13

APPLICATION OF THE IDAHO HYDROGEOLOGIC SITING CRITERIA TO AREA NO. 2 (EXCEPT 500-YR FLOOD PLAIN AND DISTANCE TO WATER WELLS CRITERIA)



AREAS THAT MIGHT SATISFY THE IDAHO HYDROGEOLOGIC SITING CRITERIA

AREAS EXCLUDED BY THE IDAHO HYDROGEOLOGIC SITING CRITERIA

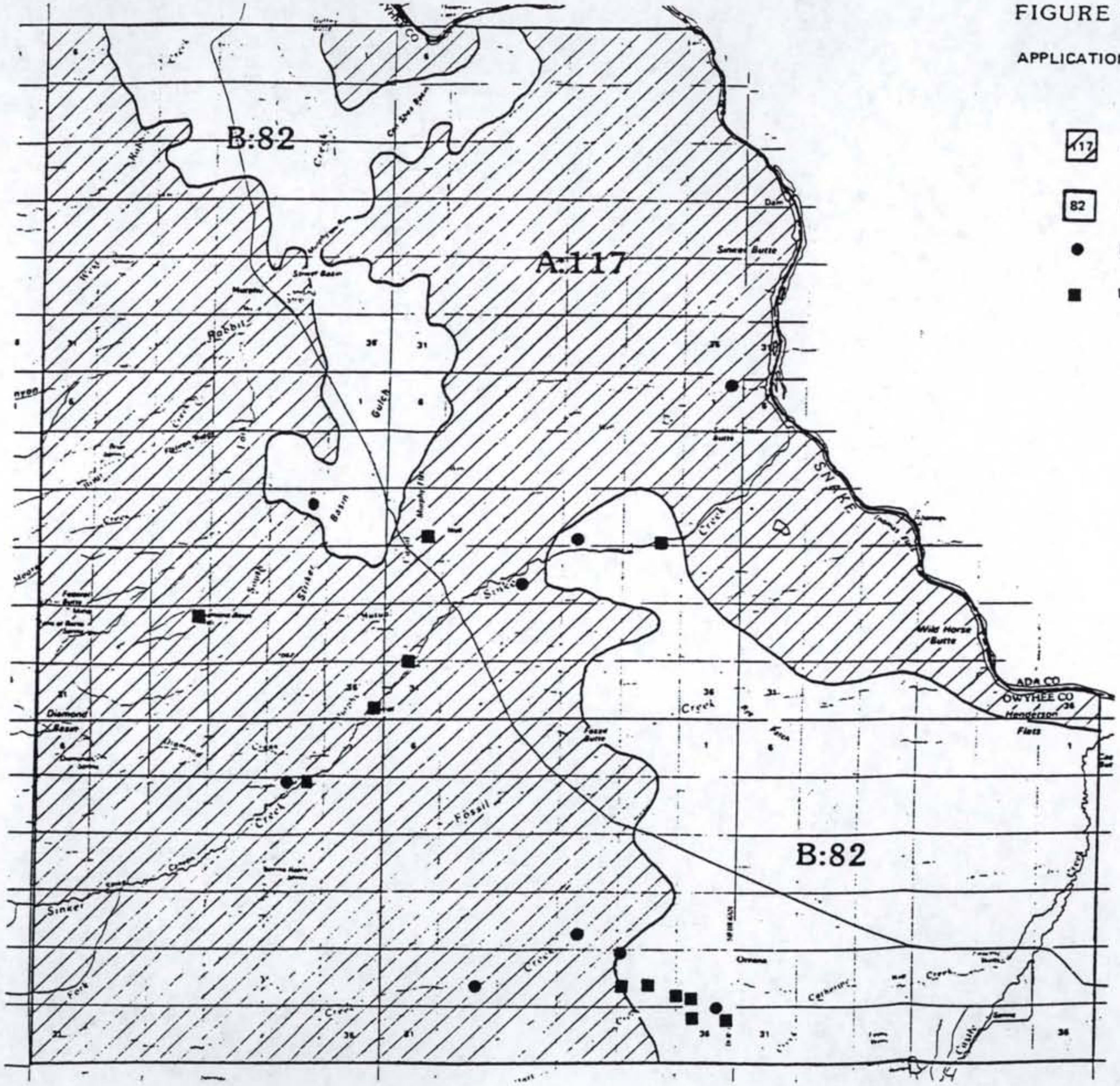
● IDWR WELLS

■ USGS WELLS

(MODIFIED AFTER EKREN AND OTHERS, 1981)

FIGURE 14

APPLICATION OF DRASTIC TO AREA NO. 2



117 (hatched)	AREA A: DRASTIC INDEX
82	AREA B. DRASTIC INDEX
●	IDWR WELLS
■	USGS WELLS