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Hydrogeologic Mapping Needs For Ground-Water Protection And Management

Workshop Report
May 10-12, 1988

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Denver, Colorado

Table of Contents

	Page
Abstract	2
Executive summary	3
Preface	5
Introduction	6
Workshop structure	7
Definition of terms	8
Discussion topics	9
Hydrogeologic mapping needs, objectives and priorities	10
Mapping attributes--Needs and priorities	12
Map scale	13
Display and dissemination	15
Achieving greater consistency--technical and administrative considerations	16
Concluding comments	19
Appendix A--List of Attendees	21
Appendix B--List of Resource People	28
Appendix C--Questions and Issues for Discussion	30

U.S. Environmental Protection Agency
and U.S. Geological Survey
Workshop on Hydrogeologic
Mapping Needs for Ground-Water
Protection and Management
May 10-12, 1988

ABSTRACT

The U.S. Environmental Protection Agency and the U.S. Geological Survey conducted a joint workshop in May 1988. The workshop's purpose was to better define the hydrogeologic mapping needs of States and other organizations responsible for the protection and management of ground-water resources, and to identify areas in which more consistency in map content and design would be useful. Approximately 50 participants addressed mapping objectives and priorities, and discussed mapping attributes, scale, display and dissemination. Major results included definition of the types of information that are most needed, such as aquifer-system definition, and specific map attributes that are required such as transmissivity. Other identified needs included larger scale maps, consistency in the scales used and data format, and leadership by Federal, State, and professional organizations. Advantages and disadvantages of geographic information systems were identified.

EXECUTIVE SUMMARY

A 2 1/2 day workshop was held by the U.S. Environmental Protection Agency and the U.S. Geological Survey in Denver, Colorado, in May 1988. The goals of the workshop were to: 1) define the hydrogeologic mapping needs of the State agencies and other organizations responsible for the protection and management of ground-water resources, and 2) identify areas where more consistency in map content and design might be useful in those protection and management efforts. The conclusions reached by the workshop participants are summarized in the following paragraphs:

- The most needed types of information for management and protection of aquifers are: aquifer-system definition, flow-system definition, land use, vulnerability of aquifers to contamination, better well location information, delineation of wellhead protection areas, water-quality information, and delineation of ground-water classification areas.

- The most needed map attribute data for management and protection of aquifers in no particular order are: transmissivity and/or hydraulic conductivity, geology/lithology, hydrostratigraphy, aquifer boundaries, recharge/discharge areas, porosity, and water-quality attributes.

- Large-scale maps are desired to determine aquifer vulnerability and define flow systems.

- Vulnerability maps are most useful at the scales of 1:24,000 to 1:100,000, and local maps for site specific protection and management purposes are most desirable at the 1:24,000 scale or larger. Because of the wide range in the size of States and

complexity of hydrogeology, appropriate scales for maps used by States vary considerably.

- The major advantages of using geographic information systems (GIS) are: the ease in manipulating data to derive additional interpretive information from the data, data display, ability to change the scale of maps for analysis and display, and the ease of data transfer among different users. The major deterrents to use of GIS are: cost, personnel training, data availability, quality assurance and control (QA/QC), and the incompatibility of hardware, software and data sets from one type of installation to another.

- Increased consistency is desired for: certain map uses, the scale of certain maps, types of display and dissemination, and data set format.

- Voluntary guidelines for consistency would be helpful.

- Leadership in an effort to move towards more voluntary consistency could be taken by organizations such as the U.S. Geological Survey (USGS), Environmental Protection Agency (EPA), and the States. Professional groups such as the American Society for Testing & Materials (ASTM), National Water Well Association (NWWA), and American Water Works Association (AWWA) could assist in this effort.

- Further cooperation among States and among States and Federal agencies is encouraged.

PREFACE

On May 10-12, 1988, the U.S. Environmental Protection Agency (EPA) and the U.S. Geological Survey (USGS) jointly sponsored a workshop in Denver, Colorado, on hydrogeologic mapping needs for ground-water protection and management. Both agencies extend their appreciation to the individuals who attended and to the organizations represented. A list of the names and addresses of workshop participants (Appendix A) and workshop resource people (Appendix B) are included.

Personnel primarily responsible for planning the workshop and preparing workshop materials were Carey Carpenter (EPA), Jerry E. Carr (USGS), Marilyn Ginsberg (EPA), and David R. Soller (USGS). Todd W. Augenstein (USGS) also contributed to the initial stage of preparing workshop materials. Oversight was provided by Ron Hoffer (EPA), Marian Mlay (EPA) and David W. Moody (USGS). Jerry E. Carr, Marilyn Ginsberg, and David R. Soller prepared this workshop summary. The individuals listed above were present at the workshop as resource people, but were not active participants in the discussion groups.

Copies of the Discussion Guide and Workshop Report can be obtained from:

U.S. Environmental Protection Agency
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The reports can also be obtained through the National Technical Information Service.

INTRODUCTION

In mid-1987, the USGS and EPA initiated a joint project to investigate the need for and availability of hydrogeologic maps. As part of this effort to support local-, State-, and Federal-agency activities to protect and manage the Nation's ground-water resources at the State and local level, a 2 1/2 day workshop was held by EPA and USGS in Denver, Colo., in May 1988. The goals of the workshop were: 1) to define the hydrogeologic mapping needs of the state agencies and other organizations responsible for the protection and management of ground-water resources, and 2) to identify areas where more consistency in map content and design might be useful in those protection and management efforts. The purpose and content of the workshop are described in EPA-USGS Workshop on Hydrogeologic Mapping needs for Ground Water Protection and Management: Discussion Guide (2 volumes), and are quoted here:

"A goal of this workshop is to identify specific hydrogeologic mapping needs of states and other organizations that evaluate, protect, and manage ground-water resources, and to determine if more consistency in content and map scale is desired among agencies to support ground-water protection and management programs. The workshop will not focus on water allocation issues, but will address water quantity as it is related to water-quality issues."

"Attendees will explore the desirability of a consistent approach to hydrogeologic maps used in the protection and management of ground-water resources, particularly at the state level. During the workshop, the attendees will discuss hydrogeologic mapping issues, examine how maps can be used more effectively for ground-water protection and management, review new approaches to

gathering and interpreting hydrogeologic data, and discuss the desirability of achieving more consistency among hydrogeologic maps."

"Four major topics are presented for discussion at the workshop: (1) mapping needs, objectives, and priorities; (2) mapping attributes; (3) map scales, display and dissemination; and (4) achieving greater consistency."

The ideas and suggestions presented at the workshop are summarized here to provide input to future cooperative activities among Federal agencies and States.

Forty three participants of the workshop shared their ideas and suggestions from the perspectives of their organizations and backgrounds. They represented State governments, 21 participants (49 percent); federal agencies, 15 participants (35 percent); professional and private industry groups, 6 participants (14 percent); and local-government agencies, 1 participant (2 percent). In all, attendees came from 25 States (Appendix A).

Workshop Structure

The workshop included large-group (plenary) sessions to introduce the main topics. After each plenary session, participants attended one of four workgroups where in-depth discussion of the relevant topics ensued. Participants were provided with a list of questions to help guide the workshop sessions (see Appendix C). The results of each workgroups' discussion were reported at the next plenary session.

To help attendees visualize the variety of maps available for hydrogeologic purposes, 72 different maps were on display during the workshop. Brief descriptions

of these maps were included in the Discussion Guide. In addition, several computer-based GIS presentations demonstrated the capabilities and applications of GIS technology to ground-water investigations and hydrogeologic mapping.

Definition of Terms

At the workshop the maps and terms defined below were discussed in the framework of hydrogeologic mapping:

- Hydrogeologic maps -- maps showing information on the physical framework, hydraulic/hydrologic properties, and geochemistry (natural and human induced) of hydrogeologic systems. Hydrogeologic maps generally include information on such features as the elevations of the tops and bottoms, thickness, hydraulic conductivity, transmissivity, potentiometric surfaces, and/or geochemistry of aquifers or confining units.

- Supportive-data maps -- maps showing location of facilities, land use, topography, or other cultural or natural features, which support analysis of hydrogeologic systems for the purpose of aquifer protection and management.

- Geologic maps -- maps showing geologic information, such as the distribution and nature of rock units and unconsolidated sediments. Geologic maps generally include information on structural features, such as folds, and faults, and the geologic framework of an area in the form of cross sections, thickness, or subsurface structural contours or borehole data. Geologic maps provide a physical framework for some hydrogeologic maps.

- Very large-scale maps -- maps with scale larger that 1:24,000.

- Large-scale maps -- maps with scale from 1:24,000 to, but not including 1:100,000.

- Intermediate-scale maps -- maps with scale from 1:100,000 to, but not including, 1:250,000.

- Small-scale maps -- maps with scale of 1:250,000 and smaller.

- Derivative maps -- maps developed or aggregated from geologic, hydrogeologic, and supportive-data maps and which are used as interpretive and predictive tools. Derivative maps portray valuable information, such as ground-water availability, pollution potential, or vulnerability of aquifers to contamination.

- Attributes -- data that are depicted on any of the maps described above. Some examples of hydrogeologic attributes include depth to water table, water use, soil chemistry, and transmissivity. Well location, land-surface slope, and land use and land cover are examples of supportive attributes.

- Geographic Information System (GIS) -- a computer-based system used for storing, manipulating, and analyzing spatially-oriented data.

DISCUSSION TOPICS

The workshop participants undertook discussion of four topics: (1) mapping needs, objectives, and priorities; (2) mapping attributes; (3) map scales, and display

and dissemination of map data; and (4) technical and administrative considerations in achieving greater consistency among hydrogeologic maps. The close interrelation of these topics was reflected in the workshop discussions. The following summaries present the main points raised during the workgroup sessions, a consensus view if reached, and an indication of the diversity of opinions expressed within and among groups.

Hydrogeologic Mapping Needs, Objectives and Priorities

During the first workgroup session, attendees attempted to identify the relative importance of various hydrogeologic mapping needs. Attendees were provided with a list of seven example needs (Appendix C) and were asked to consider these and any others that they thought were important.

The groups identified the following information needs: (1) better definition (or characterization) of aquifers; (2) better definition of aquifer flow systems for ground-water protection and management purposes; (3) better land-use information; (4) better definition of aquifer vulnerability to contamination; (5) more accurate and better documented well-location information; (6) delineation of Wellhead Protection Areas (WHPAs); (7) water-quality information; (8) delineation of ground-water classification zones; and (9) better definition of temporal changes in hydrologic variables such as water quality.

Each workgroup made a distinction between regional and local aquifer systems. Although some workgroups felt that it was far more important to define either one or the other, others stressed that there is a great need to study both systems. It was noted that additional geologic and hydrogeologic data are needed to improve

characterization of regional aquifer systems. Mapping was frequently expressed as an iterative process, with regional mapping serving to focus attention on areas where more detailed mapping is needed. Detailed mapping then updates the regional map.

The relation between mapping needs and scales was emphasized. Some participants noted that, for example, maps at larger scales commonly are needed for site-specific regulatory purposes, particularly for the determination of aquifer vulnerability and for defining local flow systems. All participants agreed that large-scale vulnerability maps are useful for site-specific regulatory and environmental purposes, indeed some believe that small-scale maps were not useful for this purpose. Several attendees disagreed with this latter view, citing the usefulness of 1:500,000-scale vulnerability maps in determining areas where aquifers may be more vulnerable to contamination, and therefore, in need of additional study and environmental screening. Many participants noted, that in order to understand the local system, a knowledge of the regional system is desirable. They noted that some data are scale independent and can meet both local and regional mapping needs. It was concluded that in most places, the density of data is inadequate for a thorough understanding of geologic and hydrologic setting. Additional data would enhance the data base for making vulnerability and other types of assessments.

In summary, although the groups expressed themselves in different ways, there was a general consensus on priority needs. These needs are logically connected: (1) the physical and hydrogeologic framework of the regional and local aquifer systems need to be well mapped and understood; (2) the chemical characteristics of the water contained in the aquifer systems need to be assessed; and (3) supportive information--for example, sources of contamination, land use, and well locations, need to be gathered. Data on the physical framework, water, and supportive information can be

used to construct maps that may assist in evaluating the threat of potential sources of contamination to ground-water systems.

Mapping Attributes -- Needs and Priorities

In the second workgroup session, participants identified the attributes needed for the maps identified as primary mapping needs in the previous workgroup session. It was clear that there are many "important" attributes, and that those needed for a project vary according to the focus or theme of the map. The attributes generally considered to be of highest priority are shown below. These attributes have not been ranked, because they varied in priority among the participants; therefore, these attributes are listed in the approximate order necessary to evaluate a hydrogeologic system. Many of these attributes meet more than one of the mapping needs specified in the first workgroup session.

Geologic/lithologic framework

Hydrostratigraphic units

Aquifer boundaries

Recharge/Discharge areas

Water-quality attributes

(especially for synthetic organic compounds and similar indicators of human-induced contamination)

Porosity/effective porosity

Potentiometric surfaces

Transmissivity and hydraulic conductivity

Ground-water velocity

Location of wells and contamination sources

Land use

Vulnerability to contamination

Ground-water classification

Participants generally agreed that formal quality assurance/quality control (QA/QC) procedures need to be applied to the collection of attribute values, their use on maps, and their storage in digital data sets. The workgroups also addressed the question of "neutrality" of derivative maps. Theoretically, a "neutral" derivative map would display only data, with little suggestion as to the importance of particular breakpoints or class intervals of the variable being mapped. The groups concluded that a neutral or purely objective derivative map was neither possible nor necessarily desirable. Derivative maps represent the map makers weighting of attributes that give derivative maps their utility and subjectivity. Where map products are used to prioritize geographic areas for possible actions, the choice of breakpoints, class intervals, or colors used to display information need to be made in consultation with the policymakers and planners.

Map Scale

In the third workgroup session, attendees addressed questions about the choices of appropriate scales for various types of maps and the desirability of having a specific scale used for a specific type of map. Participants also discussed GIS applications, benefits, and problems.

Appropriate range of scales for several different types of maps proposed by the workgroups are listed below:

MAPS	SUGGESTED SCALE
Definition of Wellhead Protection Areas	1:24,000 or larger
Potential sources of contamination	1:24,000 or larger
Identification of water supply/ground-water withdrawal locations	1:24,000 - 1:100,000
General vulnerability of aquifers to contamination	1:24,000 - 1:100,000
Definition of aquifer flow systems	1:24,000 - 1:100,000
Definition of regional aquifer system	1:24,000 - 1:2,500,000

During the workgroup discussions, a wide range of scales was proposed for certain mapping needs. In some workgroups, there was a reluctance to suggest map scales because the factors that influence selection of appropriate map scales vary widely. Factors cited as influencing the choice of an appropriate map scale included: the nature of the geologic and hydrogeologic setting, density and availability of data, availability of base maps, and the size of area mapped. A particular difficulty for workgroups was to decide on an appropriate scale for the definition of regional aquifer systems because of the differing size of aquifer systems nationwide. In addition, some participants noted that consideration should be given to scale based on the size or other characteristics of the regulatory district for which ground-water protection and management decisions are being made.

However, there was a general consensus within a certain range for consistent maps scales for many types of map needs. For many local site-specific regulatory applications, 1:24,000 was selected as an appropriate scale, especially given the ready availability of this topographic map series from the USGS. Much larger scales appeared desirable in some cases, perhaps as large as 1:6,000, for such applications

as aquifer tests, monitor-well siting, contaminant-plume mapping, and waste-site investigations. When the need arises for maps with this level of detail, they usually are constructed as special-purpose products. A wide range of map scales was proposed for vulnerability maps, for maps defining ground-water flow systems, and especially for maps defining regional aquifer systems. Differences in the size of aquifer systems nationwide commonly dictate the appropriate map scale used to depict regional aquifer systems. In addition, there was general agreement that it is beneficial to allow the scale of maps of national coverage to range from perhaps 1:100,000 to 1:2,500,000. Maps of these scales are valuable for targeting or screening purposes to identify local areas where more detailed studies or data collection is needed and also for educational purposes.

Display and Dissemination

Participants generally agreed that computer-based GIS are useful tools for manipulation, storage, and exchange of data, especially those data types that are updated frequently. An informal survey of the workshop participants indicated that 12 of the States represented at the workshop had some type of GIS in place, 3 other States planned to have one in the next 2 years, and 2 other States planned to have a GIS at some undetermined date in the future. Interestingly, of the 12 States with GIS, representatives from only 3 were confident that the manpower would be available to manage the system for the next 10 years. Easy and rapid display of data, evaluation of data, particularly if frequent update occurs, and the display of the same data at different scales, were specified as advantages of using a GIS.

Concerns were expressed regarding the costs of GIS, the need for extensive training of users, manpower requirements, QA/QC of data, accessibility of data, and

incompatibility of hardware, software, and data sets among GIS installations. Other concerns included: the lack of an index to the spatial data that is available, the lack of standards for many aspects of GIS, the need for inter- and intra-agency cooperation, data security, and the time needed for data entry, particularly at GIS startup.

Achieving Greater Consistency -- Technical and Administrative Considerations

During the final workgroup session, attendees examined the feasibility and desirability of achieving greater consistency among attributes and scales of hydrogeologic maps. In addition, actions that could be taken by various agencies and organizations on suggested changes were discussed.

There was general agreement that consistency was desirable in many cases, although reservations were voiced regarding possible effects of imposing standards for all mapping needs. Participants noted that the benefits associated with increased consistency include better communication among State and Federal agencies, more efficient sharing of information among the states and with other organizations, and the cost savings that would result from increased consistency.

Technical Considerations

The groups discussed technical items from the previous sessions for which a consistent application and approach should be encouraged. The groups believed that the use of the high priority attributes as well as the scales suggested above should be encouraged to promote consistency in multiple-purpose hydrogeologic mapping. Items specifically mentioned in need of more consistency were map attributes or characteristics, such as map colors, aquifer names, aquifer boundaries and criteria for

their definition, symbols, patterns, units, scale, basic data-collection methods, and especially QA/QC procedures. Consistency of data-collection methods, data bases, and definitions was strongly encouraged. Considerable discussion ensued especially with regard to QA/QC aspects of field measurements, data-base management, and data portrayal on maps. Some workgroups suggested that more consistency is desirable in defining attributes to be included on derivative maps. Standards or guidelines to define consistency for digitized data, definitions, data-exchange formats, accuracy codes, and attribute codes in future GIS applications, were generally cited as desirable.

Some participants had reservations about overly restrictive Federal guidelines that could impair scientific flexibility, and lead to increased costs. Others stated that suggested guidance would be acceptable and that more consistency on the Federal level might be desirable.

Administrative Considerations

With regard to the overall roles that States, the Federal government, and other agencies should take to implement a consistent approach, many felt that the Federal Government should act by example rather than mandate. It was recognized that the Federal government does play a leadership role in mapping through its own mapping activities and its support of State and local programs. The groups suggested that Federal mapping agencies need to take the lead in encouraging more consistency in mapping and GIS by developing appropriate guidelines for voluntary standards. One group believed that no further definition of roles was needed and that, in some respects, consistency already exists for some technical and scientific aspects of mapping due to the activities of the USGS. Other groups stressed a need for

increased joint Federal and State cooperation to prioritize mapping needs and achieve greater consistency.

There was clear support for increased communication, along the lines of this workshop, with State or professional groups acting in cooperation with the Federal agencies to achieve more consistency. Such improved cooperation and communication could be at various levels: cooperation among States, States communicating their needs to Federal agencies, cooperation among States and/or among States and Federal agencies, States taking an active role in developing plans to increase the level of consistency, creation of an expanded process to further assess State mapping needs and communicate those needs to Federal agencies--especially the USGS and EPA--development of better State and interstate coordination methods.

Several actions to implement an approach to consistency of hydrogeologic maps were generally agreed upon. These actions are: setting of voluntary standards by suggested organizations or agencies, such as USGS and EPA; or standards being set in coordination with mapping agencies by a professional group, such as American Society for Testing and Materials (ASTM); holding additional workshops and meetings, possibly organized by a professional group; and initiating additional directives in EPA and USGS dealing with certain consistency issues. Efforts to develop and implement agreed-upon standards to improve the consistency of hydrogeologic maps will be undertaken within the authorities of the agencies involved.

Several organizations which were suggested as appropriate to assume roles in coordination with the USGS, EPA, and State agencies in efforts to increase consistency were: American Society for Testing and Materials (ASTM), American Water Works Association (AWWA), and National Water Well Association (NWWA). In

addition, some attendees thought members of workgroups such as this were in the best position to help encourage consistency.

Other related actions suggested for implementing increased consistency included: the creation of joint Federal/State groups to prioritize needs where increased consistency would be beneficial; environmental agencies developing a formal mechanism for identifying mapping priorities; the creation and maintenance of a forum to discuss issues related to consistency; Federal funding and planning for mapping oriented programs such as Wellhead Protection; DRASTIC[1] user-group meetings; national mapping of hydrostratigraphic units; the defining by EPA of its goals for GIS; construction of GIS hydrogeologic data bases by the USGS and EPA; more communications between EPA and USGS on this subject; and, the distribution of Federal funds to programs which encourage consistency.

CONCLUDING COMMENTS

Ron Hoffer (EPA) thanked all participants for their contributions, and noted some of the generally held views expressed by the participants: the gathering of traditional attribute information needs to be continued; derivative maps (for example, a map showing vulnerability attributes in a county or multicounty area) are useful, but traditionally have been produced at too small a scale for regulatory work; the commonality of certain attributes allows them to be used in a wide variety of applications and at a variety of scales; and, there is an increased need to represent temporal changes in attribute values.

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[1]DRASTIC is a method for assessing ground-water vulnerability to contamination.

David Moody (USGS) recognizec the high priority that needs to be placed on hydrogeologic and geologic data collection and expressed his enthusiasm for the future use of GIS technology. In addition, he indicated that hydrogeologic mapping programs would best be done by sharing resources among agencies. He also emphasized the need for continued communication among all concerned, with the lead for establishing GIS standards and encouraging consistency among hydrogeologic maps being taken by EPA and USGS.

Appendix A

USEPA-USGS HYDROGEOLOGIC MAPPING WORKSHOP

MAY 10-12, 1988

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Appendix B

USEPA-USGS HYDROGEOLOGIC MAPPING WORKSHOP

MAY 10-12, 1988

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Appendix C

WORKGROUP SESSION I

HYDROGEOLOGIC MAPPING NEEDS, OBJECTIVES, AND PRIORITIES

QUESTIONS AND ISSUES FOR DISCUSSION

1. In Table III-1 and throughout the discussion guide we have identified 7 example mapping "needs" for discussion purposes. These are not the only possible needs and others may have greater importance than those listed. These needs are as follows:

   - Better definition of regional aquifer systems
   - Better definition of vulnerability of aquifers
   - Location of potential sources of contamination in Wellhead Protection Areas
   - Location of suitable sites for waste disposal facilities
   - Location of ground-water withdrawals which impact ground-water quality
   - Delineation of ground-water classification zones
   - Better definition of aquifer flow systems for ground-water protection and management purposes

   In your working group meetings, please list additional ground-water protection and management needs.

   Of these needs, which are the most important to you?

2. For your most important needs, indicate whether existing maps are adequate. If existing maps are inadequate to support a need, indicate why. How may they be improved?

WORKGROUP SESSION II

MAPPING ATTRIBUTES--NEEDS AND PRIORITIES

QUESTIONS AND ISSUES FOR DISCUSSION

1. For each of your most important needs identified in the last session, list and rank the map attributes that would have to be determined to make the appropriate maps.

   -- Which attributes meet multiple needs?

   -- List the attributes which are not currently available but which would be essential for meeting the needs.

2. Identify a category of derivative maps which is needed to support one of your needs and is not commonly available. List the attributes required to prepare such a map.

3. How do you design derivative maps that are neutral in their display of such concepts as ground-water vulnerability and waste-disposal site suitability?

WORKGROUP SESSION III

MAP SCALE, DISPLAY AND DISSEMINATION

QUESTIONS FOR DISCUSSION

1. What scale, or range of scales, appear to meet the most important hydrogeologic mapping needs identified by your workgroup?

Use	Suggested scale(s)	Scale(s) in-use
Better definition of regional aquifer systems		
Better definition of vulnerability of aquifers		
Location of potential sources of contamination of WHPA's		
Location of suitable sites for waste disposal facilities		
Location of ground-water withdrawals which impact ground-water quality		
Delineation of ground-water classification zones		
Better definition of aquifer flow systems for protection and management purposes		
Others		

2. Would it be beneficial to have consistent scales for some needs at the national, regional, or local level? If so, please identify the needs and suggested scales.

3. For what uses will computer-based GIS techniques be most useful in the near and longer terms?

4. What are the critical factors for implementing GIS at the State and local levels?

WORKGROUP SESSION IV

ACHIEVING GREATER CONSISTENCY

DISCUSSION QUESTIONS

1. Is greater mapping consistency possible and desirable for some needs? At what cost? To whom?

2. What major technical changes would lead to improved consistency. For example, would it be important to:

   - define major attributes to be mapped for selected ground-water protection and management purposes?

   - define appropriate map scales for selected needs?

   - establish uniform definitions for mappable criteria on derivative maps?

3. What would be the overall roles of the States and other participants in carrying out a more consistent approach?

4. What administrative actions would support implementation? For example,

   - identification of a professional group to develop voluntary standards

   - joint Federal and State development of selected consistent maps

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