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Standard Guide for Establishing Nomenclature of Ground-Water Aquifers[1]

This standard is issued under the fixed designation D 6106; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide covers a series of options but does not specify a course of action. It should not be used as the sole criterion or basis of comparison and does not replace or relieve professional judgement.

1.2 This guide contains instructions and suggestions for authors of ground-water (hydrogeologic) reports in assigning appropriately derived and formatted aquifer nomenclature. Discussed are the water-bearing units that may require name identification, which are, ranked from largest to smallest, aquifer system, aquifer, and zone. Guidance is given on choosing the source of aquifer names, those are from lithologic terms, rock-stratigraphic units, and geographic names.

1.3 Included are examples of comparison charts and tables that can be used to define the hydrogeologic framework. Illustrations of eleven different hypothetical aquifer settings are presented to demonstrate the naming process.

1.4 Categories of items not suggested as a source of aquifer names are reviewed because, although they should be avoided, they occur in published documents. These categories are the following: time-stratigraphic names, relative position, alphanumeric designations, depositional environment, depth of occurrence, acronyms, and hydrologic conditions.

1.5 Confining units are discussed with the suggestion that these units should not be named unless doing so clearly promotes an understanding of a particular aquifer system. Suggested sources of names for confining units correspond to those for aquifer names, which are lithologic terms, rock-stratigraphic units, and geographic names.

1.6 It is suggested that in reports that involve hydrogeology, the author should consider first not naming aquifers (see 6.2).

1.7 Format and expression styles are assessed along with the general cautions related to name selection of aquifers and confining units.

1.8 This guide is a modification of a previously published report **(1)**.[2]

1.9 *This guide offers an organized collection of information or a series of options and does not recommend a specific course of action. This guide cannot replace education or experience and should be used in conjunction with professional judgment. Not all aspects of this guide may be applicable in all circumstances. This guide is not intended to represent or replace the standard of care by which the adequacy of a given professional service must be judged, nor should this guide be applied without consideration of a project's many unique aspects. The word "Standard" in the title of this document means only that the document has been approved through the ASTM consensus process.*

2. Referenced Documents

2.1 *ASTM Standards:* [3]

D 653 Terminology Relating to Soil, Rock, and Contained Fluids
D 1129 Terminology Relating to Water
D 5409 Guide for Set of Data Elements to Describe a Ground-Water Site; Part Two—Physical Descriptors
D 5434 Guide for Field Logging of Subsurface Explorations of Soil and Rock
D 5474 Guide for Selection of Data Elements for Ground-Water Investigations

3. Terminology

3.1 *Definitions:* Except as discussed as follows, all definitions are in accordance with Terminologies D 653 and D 1129. The following terms are examined in detail in order to clarify the method of assigning nomenclature to the aquifers and associated units:

3.2 *Introduction*—Aquifers do not lend themselves to brief, neat, and simple definitions; therefore, a flexible hierarchy of terms is used in these guidelines. The terms that are used for water-yielding rocks from largest to smallest are: aquifer system **(2)**, aquifer **(3)**, and zone **(4)**. Confining units **(3)** are discussed because of the stratigraphic relationship with the water-bearing units.

[1] This guide is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is under the direct responsibility of Subcommittee D18.21 on Ground Water and Vadose Zone Investigations.

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[2] The boldface numbers in parentheses refer to the list of references at the end of this standard.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

3.2.1 Parallelism between the hierarchy of terms for water-yielding rocks and rock-stratigraphic terms, namely, aquifer system (group), aquifer (formation), and zone (member), should be avoided because water-yielding rocks can cross the boundaries of geologic units or constitute only part of a geologic unit. The scale of the study also may determine the best usage. For example, at the local scale, an aquifer system could be defined totally within a single formation, and at the regional scale, a formation or group could be totally within and only a part of a single aquifer or an aquifer system. Again, the guidelines for aquifer nomenclature must remain flexible to meet a variety of hydrogeologic scales and settings.

3.2.2 A discussion of the terms aquifer, aquifer system, zone, and confining unit is provided here to give authors a common reference base. Although complete agreement on these definitions has not been achieved, the terms are adequate to transfer knowledge from authors to readers of reports. It is not the purpose of these guidelines to formally redefine the terms or to define new terms to take their place.

3.3 *Definitions of Terms Specific to This Standard*:

3.3.1 *aquifer, n*—This term probably has more shades of meaning than any other term in hydrology **(5)**, see Terminology D 653. It can mean different things to different people and different things to the same person at different times.

3.3.1.1 *Discussion*—Meinzer **(5)** defined an aquifer as "a rock formation or stratum that will yield water in sufficient quantity to be of consequence as a source of supply is called an *aquifer*, or simply a *water-bearing formation*, *water-bearing stratum*, or *water-bearer*. It is water-bearing, not in the sense of holding water, but in the sense of carrying or conveying water."

3.3.1.2 Lohman and others **(3)** refined Meinzer's definition of an aquifer as "a formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs."

3.3.1.3 Both of these definitions imply that the aquifer is bounded by or is included within the formation(s) (or stratum), but the concept of the aquifer extending across formational boundaries is not indicated explicitly. In many local studies covering a few tens to a few hundred square miles, the aquifer and the formation may be the same. In these studies, few problems may exist in defining the aquifer. However, since the late 1970s, studies of regional aquifers that may cover hundreds of thousands of square miles have been made under the Regional Aquifer-System Analysis (RASA)[4] Program. Results from several of the RASA studies have shown that regional aquifers may include numerous formations and rock types and that the aquifers cut across formational and lithologic boundaries so that no one formation is completely representative of the aquifer.

3.3.1.4 In studies of regional scope, the shape and the boundaries of the permeable rocks that form the aquifer have greater importance to understanding the flow system than do the individual formational boundaries. A definition that places less emphasis on the formal term *formation* **(6)** and more on *permeable rocks* has merit. For example, aquifer is defined in the Glossary of Geology **(7)** as "a body of rock that is sufficiently permeable to conduct ground water and to yield economically significant quantities of water to wells and springs."

3.3.1.5 Regardless of the fine points in any definition, delineating permeable rocks should be the major goal of hydrogeologists in mapping and describing an aquifer. By the same token, detailed knowledge of the stratigraphic units and post-depositional processes, such as solution, cementation, folding, and faulting, are essential in determining where the boundaries of the aquifer are located and in understanding the flow system. In addition, hydraulic properties (hydraulic conductivity and storage coefficient) throughout the aquifer usually are not determined directly but are estimated by indirect means, such as aquifer tests, analyses of drill cuttings and cores, borehole geophysical logging, and surface geophysical surveys.

3.3.1.6 In many situations, hydrologic estimates and extrapolations can be made on the basis of rock type alone without any determination of hydrologic properties. For example, a wide-spread, thick clay separating two sand units tentatively could be designated as a confining unit on the basis of geologists' logs and borehole geophysical logs alone without any hydrologic data.

3.3.2 *aquifer system, n*—Poland and others **(2)** define an aquifer system as "a heterogeneous body of intercalated permeable and poorly permeable material that functions regionally as a water-yielding hydraulic unit; it comprises two or more permeable beds (aquifers) separated at least locally by aquitards (confining units) that impede ground-water movement but do not greatly affect the regional hydraulic continuity of the system."

3.3.2.1 *Discussion*—The definition could be more general if the term *aquifers* were used in place of *permeable beds*. *Bed* implies a single stratigraphic unit, whereas, the individual aquifer could include or cross many *beds*.

3.3.2.2 *Confining unit* should be used instead of *aquitard* because the definition of confining unit is broad enough to include varying degrees of *leakiness*.

3.3.2.3 The hierarchy of aquifer and aquifer-system names may not always be consistent in practice. Because of differences in scales of investigations, individual aquifers may be combined into a single aquifer system, which may be only a part of another aquifer system over a larger area. Authors have the responsibility to explain these relationships clearly with comparison charts and descriptions in the text.

3.3.3 *confining unit, n*—confining bed was defined by Lohman and others **(3)** as " . . . a term which will now supplant the terms *aquiclude*, *aquitard*, and *aquifuge* in reports of the U.S. Geological Survey and is defined as a body of *impermeable* material stratigraphically adjacent to one or more aquifers. In nature, however, its hydraulic conductivity may range from nearly zero to some value distinctly lower than that of the aquifer. Its conductivity relative to that of the aquifer it confines should be specified or indicated by a suitable modifier, such as slightly permeable or moderately permeable."

[4] RASA, Regional Aquifer-System Analysis Program, a systematic study of a number of regional ground-water systems that represent a significant part of the water supply of the United States. These studies are managed by the Water Resources Division of the U.S. Geological Survey.

3.3.3.1 *Discussion*—Although the Lohman and others **(3)** definition of *confining bed* is descriptive and should be used, the term *confining unit* is more general and appropriate than *confining bed*, especially where more than a single bed makes up the confining unit.

3.3.3.2 The term *bed* is not correct usage for a thick sequence of stratigraphic units that could be of member or formation rank. *Bed* is particularly inappropriate when used for intrusive igneous rocks beneath an aquifer. The term *bed* has a formal definition in the 1983 North American Stratigraphic Code **(6)** and should not be used in definitions of aquifer nomenclature.

3.3.3.3 Many confining units are leaky and in some areas, under natural conditions, may contribute significant amounts of water to the aquifers they confine, and even larger quantities of water as heads are lowered in the aquifer by pumping. In areas where withdrawals from aquifers have caused large declines in head, considerable amounts of water may be derived from water stored in the confining unit.

3.3.3.4 Poland and others **(2)** retained the terms *aquiclude* and *aquitard* in their definitions related to studies of the mechanics of aquifer systems and land subsidence due to fluid withdrawal. An aquiclude was defined as a body of saturated but relatively impermeable material that is characterized by very low values of *leakance* (the ratio of vertical hydraulic conductivity to thickness) and transmits negligible interaquifer flow.

3.3.3.5 An aquitard is a saturated poorly permeable bed that has values of leakance that range from relatively low to relatively high. Where an aquitard is sufficiently thick, it may form an important ground-water storage unit.

3.3.3.6 The general term *confining unit* is preferable to aquitard, aquiclude, and aquifuge, as recommended by Lohman and others **(3)**.

3.3.3.7 Estimation of the *leakiness* of the confining unit should be discussed if this hydrologic information is available.

3.3.4 *erathem, n*—a geologic time term, used in this guide, is defined as the largest formal chronostratigraphic unit generally recognized, next in rank above system; the rocks formed during the era of geologic time, such as the Mesozoic Erathem composed of the Triassic System, the Jurassic System, and the Cretaceous System **(7)**.

3.3.5 *zone, n*—the term zone may be used to subdivide an aquifer for the purpose of delineating a particular hydrologic characteristic that is not typical of the entire aquifer. For example, the *Fernandina permeable zone* is a high-permeability subunit of the Lower Floridan aquifer **(4)**. The zone consists of vuggy, locally cavernous limestone and is traceable for as much as 100 miles in coastal Georgia and Florida. The permeability of the zone greatly exceeds that of most of the Lower Floridan aquifer.

3.4 *Terms to Be Avoided*—The use of terms that are intended to be synonymous with *aquifer* or aquifer system should be avoided. Terms, such as *hydrofer* or *aquiformation* should not be used in lieu of aquifer; *aquigroup* should not be used in place of aquifer system.

3.4.1 The term *aquifer* may be less precise than we would like, but it has been used and accepted widely in the hydrologic literature since it was defined originally.

3.4.2 Coining new terms for aquifer and aquifer system that either are synonyms or defined with slightly different meaning is not an advancement. It only creates confusion especially among people who are not hydrogeologists. Use of the term *aquiformation* also infers an equivalence between aquifer and formation that is not always correct.

4. Significance and Use

4.1 An essential requirement of hydrogeologists in evaluating the hydraulic properties of a segment of earth materials is to define and map hydrogeologic units, aquifers, and confining units, which are determined on the basis of relative permeability. Discussion of the hydrogeologic units is facilitated by individual designations (see Practices D 5409, D 5434, and D 5474).

4.2 Determinations of hydrogeologic units are based on indirect methods, knowledge of the geologic materials (geologic mapping, surface geophysical surveys, borehole geophysical logs, drill-cuttings and core descriptions, and so forth), and hydraulic testing (aquifer tests, laboratory permeability tests on core samples, and so forth).

4.3 The physical properties of all rock units will change if traced laterally and vertically. The rock units are broken by unconformities and faults, which may or may not affect the flow of ground-water. The process of designating and naming aquifers and confining units, therefore, is a somewhat subjective undertaking, and, if not thoroughly documented, can lead to confusion.

4.4 Guidelines for naming aquifers can help avoid some of the confusion and problems associated with hydrogeologic studies if the guidelines are straight forward to apply, flexible, and applicable to studies of a variety of scales from site-specific to regional.

4.5 The guidelines that follow include discussions of the terminology of aquifer nomenclature, the definition of the hydrogeologic framework, the suggested procedures for naming aquifers, and examples of naming aquifers.

4.6 These guidelines have resulted from numerous discussions on the subject of aquifer nomenclature among hydrogeologists. Although unanimous agreement on these proposals has not been achieved, the exercises provided an extremely useful purpose in creating additional thought and discussion.

5. Documentation for Defining the Hydrogeologic Framework

5.1 *Introduction*—In hydrogeologic studies, as in purely geologic investigations, the orderly, consistent designation of pertinent parts of the geologic framework is essential to a clear reporting and understanding of the study results.

5.1.1 In ground-water studies, this involves definition and correlation of water-yielding rock materials and relating those rock materials to established rock-stratigraphic units.

5.1.2 Generally, authors of reports on ground-water resources are required to follow the same rules and guidelines for designating rock-stratigraphic units as are authors of purely geologic reports, that is, they should follow the guidelines and rules in the North American Stratigraphic Code **(6)**.

5.1.3 The authors of ground-water reports, however, have an additional requirement to identify significant water-yielding parts of the geologic framework. Commonly, the water-yielding parts do not correspond exactly to named geologic units and, therefore, present additional nomenclatural problems.

5.1.4 Although exhaustive systematic guidelines for the complex task of naming geologic units have been developed over several decades **(6)**, there were no comparable guidelines for naming water-yielding units until publication of *Aquifer-Nomenclature Guidelines* in 1986 **(1)**. For example, see the fifth edition of *Suggestions to Authors of the Reports of the U.S. Geological Survey* **(8)**; the sixth edition **(9)**; the seventh edition **(10)** in 1991 includes the complete *Aquifer-Nomenclature Guidelines* **(1)**; and the *Water-Resources Division Publications Guide* **(11)**.

5.1.5 The proper designation of hydrogeologic units involves the consistent use of ground-water terms, as well as actual naming of the units.

5.1.6 One of the first considerations in describing an aquifer in a report is mappability. The aquifer should be mappable at the map scale used in the report of the study area. Exceptions to this rule may occur in areas where thin, highly transmissive aquifers could not be easily mapped at the principal map scale of the study but would still be important hydrologically.

5.1.7 The report should contain comparison charts; maps of the top, thickness, and geographic extent of the aquifers; and hydrogeologic cross sections. Hydraulic characteristics should be discussed to show how the aquifer differs from the underlying and overlying confining units.

5.1.8 If the author believes that additional information on the hydraulic characteristics of the aquifer in the vertical dimension is necessary, a type area, type locality, a type well, or a combination thereof, can be described.

5.1.9 Several surface exposures and wells may be required to describe the characteristics of the aquifer if the hydraulic properties of the aquifer change greatly vertically and laterally. In this case, selected surface exposures and wells can be used to illustrate important hydrologic aspects of the aquifer. For example, the surface exposures can show effects of fracturing or solution, grain size, bedding thickness, faulting, folding, and so forth, all of which may affect movement and storage of ground-water.

5.1.10 Borehole geophysical logs, cuttings and core descriptions, driller's and geologist's logs for wells can be used to illustrate hydraulic properties in the subsurface.

5.1.11 A comparison chart is one of the most essential parts of a report that involves a description of a ground-water flow system and aquifer names. The comparison charts consist of three major components:

5.1.11.1 *Component 1*—a correlation chart that shows rock- and time-stratigraphic (geologic) units for the water-bearing materials described in the report.

5.1.11.2 *Component 2*—A comparison of hydrogeologic units to layers used in digital flow model, if one is used.

5.1.11.3 *Component 3*—A comparison of hydrogeologic units of the report with those in previous reports.

5.1.12 The amount of detail in the comparison chart will be determined by the scale and complexity of the investigation. If the report contains only a few geologic and hydrogeologic units, all of the comparisons may be shown in one illustration. For complicated investigations that involve many geologic and hydrogeologic units, two or three illustrations may be required to show the comparisons.

5.1.12.1 An example of a comparison chart that shows the relation of geologic units, hydrogeologic units, and model layers is shown in Fig. 1.

5.1.12.2 Fig. 2 shows a comparison of geologic and hydrologic units with those in previous reports. A chart like that in Fig. 2 is especially important in reports where aquifers are redefined and renamed.

5.1.12.3 Fig. 3 shows an example of a correlation chart where the hydrogeologic units are made up of many rock-stratigraphic units. Unlike the chart shown in Fig. 1, the hydrogeologic units are on the left side and the rock-stratigraphic units are combined on the right side of the chart. This chart emphasizes primarily hydrogeologic units and secondarily rock-stratigraphic-units, although considerable analysis of rock-stratigraphic data from throughout the study area was required to develop the chart.

5.1.12.4 This analysis of time-stratigraphic units and rock-stratigraphic units in a correlation chart should be shown as a separate illustration because of the great number of rock-stratigraphic units to be considered. The comparison chart should make completely clear to the reader the relationships of the hydrogeologic units to the geologic units and to equivalent layers in the computer flow models, if one is included in the study.

5.1.13 Preparation of a comprehensive comparison chart requires a thorough search of the literature for all previous studies in the project area that contain rock-stratigraphic names and aquifer names. The comparison chart should contain the following items:

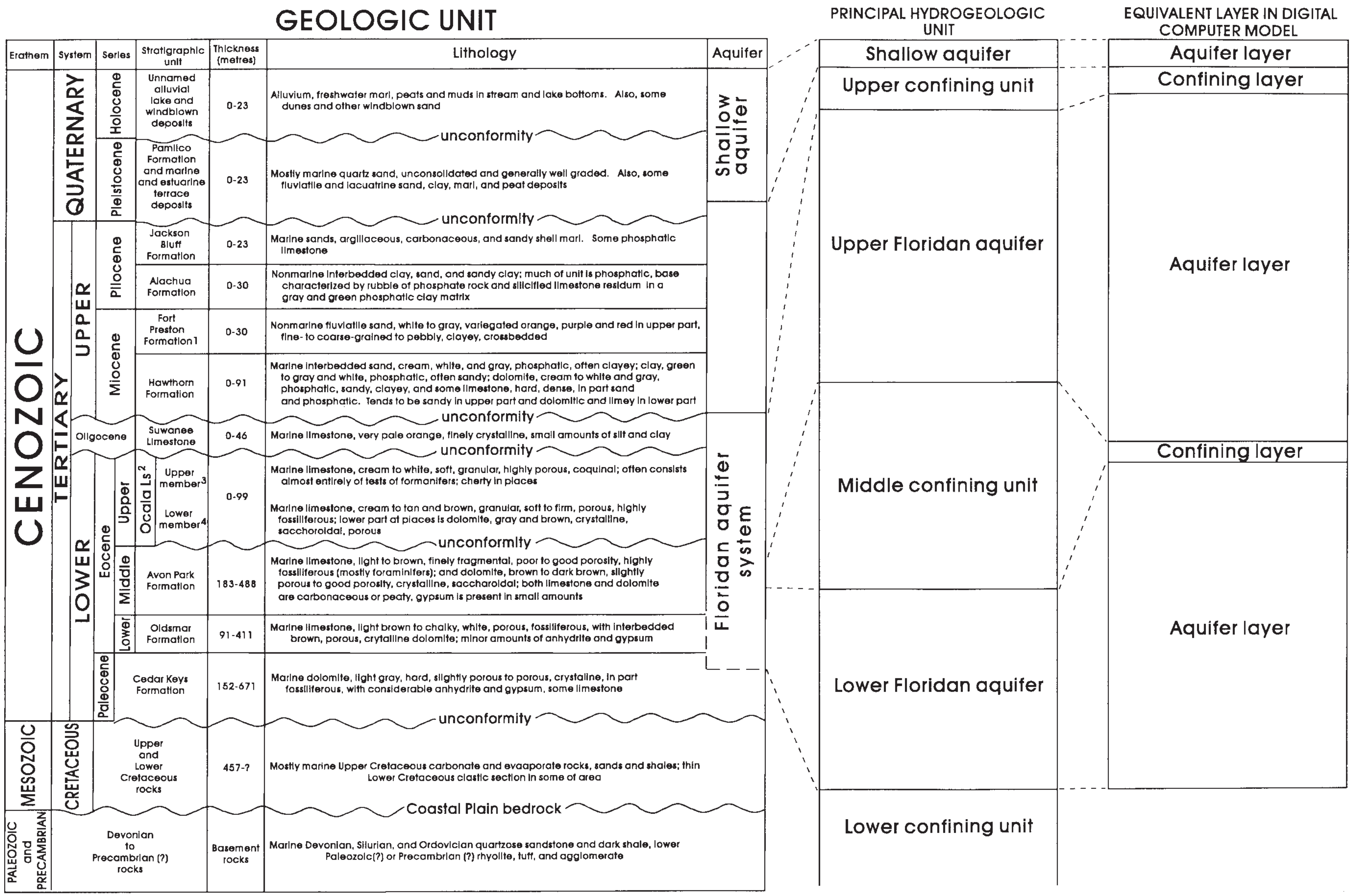
5.1.13.1 Headings entitled: Erathem, system, series, rock-stratigraphic unit, thickness, lithology, hydrogeologic unit, and hydraulic characteristics.

5.1.13.2 The geologic units that are pertinent to the hydrology under study.

5.1.13.3 The hydrogeologic units that the author is using and how they relate to geologic units and previously named hydrogeologic units.

5.1.13.4 A column that shows relations of hydrogeologic units to layers in the flow model, if one is included in the study.

5.1.14 Only the part of the geologic column that pertains to the hydrology under study should be discussed and shown in detail. The amount of discussion of the geology should be limited mainly to those aspects that affect the movement and storage of ground-water. An exception would be a situation where the details of the stratigraphy were not well known prior to the hydrologic study, and as a result of determining the hydrogeologic units a clearer understanding of the stratigraphy was achieved.



[1] Usage of Bureau of Geology, Florida Department of Natural Resources
[2] Ocala Group of Bureau of Geology, Florida Department of Natural Resources
[3] Crystal River Formation of Ocala Group
[4] Inglis Formation and Williston Formation (older to younger) of Ocala Group

FIG. 1 Example of a Chart Showing Comparison of Geologic Units, Hydrogeologic Units, and Equivalent Units in a Digital Ground-Water Flow Model (13)

EPOCH		Stringfield (1936) Formation	Stringfield (1936) Aquifer	Parker & others (1955) Formation	Parker & others (1955) Aquifer	Stringfield (1966) Formation	Stringfield (1966) Aquifer	Miller, in Franks (1982) Formation	Miller, in Franks (1982) Aquifer	Miller (1982 a, c) Formation	Miller (1982 a, c) Aquifer	This Report Formation	This Report Aquifer
MIOCENE	Middle	Hawthorn Formation	Principal artesian formation	Hawthorn Formation	Where Permeable	Hawthorn Formation	Principal artesian aquifer	Hawthorn Formation	Where Permeable	Hawthorn Formation		Hawthorn Formation	
MIOCENE	Early	Tampa Limestone		Tampa Limestone	Floridan aquifer system	Tampa Limestone		Tampa Limestone		Tampa Limestone	Where Permeable	Tampa Limestone	Where Permeable
OLIGOCENE		Oligocene Limestone		Suwannee Limestone		Suwannee Limestone		Suwannee Limestone	Floridan aquifer system	Suwannee Limestone	Tertiary limestone aquifer system	Suwannee Limestone	Floridan aquifer system
EOCENE	Late	Ocala Limestone		Ocala Limestone		Ocala Limestone		Ocala Limestone		Ocala Limestone		Ocala Limestone	
EOCENE	Middle			Avon Park Limestone		Avon Park Limestone		Avon Park and Lake City Limestone		Avon Park and Lake City Limestone		Avon Park Formation	
EOCENE	Middle			Lake City Limestone		Lake City Limestone							
EOCENE	Early					Oldsmar Limestone		Oldsmar Limestone		Oldsmar Limestone		Oldsmar Limestone	
PALEOCENE								Cedar Keys Limestone		Cedar Keys Limestone		Cedar Keys Limestone	

FIG. 2 Example of Chart Showing Comparisons of Geologic and Hydrogeologic Units with Those in Previous Reports (4)

	HYDROGEOLOGIC UNIT	THICKNESS IN FEET	LITHOLOGY AND HYDROLOGIC CHARACTERISTICS	ROCK-STRATIGRAPHIC UNIT	TIME-STRATIGRAPHIC UNIT
	Western Interior Plains confining unit	0-6,000	Shale layer of very low permeability separated by permeable limestones and sandstones. Leakage through shale is slow.	Marmaton Group, Cherokee Group, Atokan rocks, Bloyd Shale, Hale Formation, Morrowan rocks, Pitkin Limestone, Fayetteville Shale, and Batesville Sandstone	Middle Pennsylvanian through Upper Mississippian (Chesterian)
Ozark Plateaus aquifer system	Springfield Plateau aquifer	0-1,500	Permeable limestone, fractured and solutioned locally. Well yields range from 1 to 300 gallons per minute, but typical yields are of 5-10 gallons per minute.	Moorefield Formation, St. Louis Limestone, Salem Limestone, Warsaw Limestone, Boone Formation, including St. Joe Limestone Member, Keokuk Limestone, Burlington Limestone, and Fern Glen Limestone	Upper Mississippian and Lower Mississippian
Ozark Plateaus aquifer system	Ozark confining unit	0-1,500	Shale of very low permeability; however, at most locations thickness of shale is less than 20 feet. Thus, unit is moderately leaky.	Chouteau Group (Limestone) and Chattanooga Shale	Lower Mississippian and Upper Devonian
Ozark Plateaus aquifer system	Ozark aquifer	0-4,000	Mostly dolostone with limestone and sandstone layers. Dolostone highly fractured with very permeable zones of fractured and solutioned dolostone. Well yields range from 2 to 2000 gallons per minute, but typical yields are 200-400 gallons per minute.	Clifty Limestone, Penters Chert, Lafferty Limestone, St. Clair Limestone, Brassfield Limestone, Cason Shale, Fernvale Limestone, Kimmswick Limestone, Plattin Limestone, Joachim Dolomite, St. Peter Sandstone, Everton Formation, Powell Dolomite, Smithfield Formation, Cotter Dolomite, Jefferson City Dolomite, Roubidoux Formation, Gasconada Dolomite, including Gunter Sandstone Member, Eminence Dolomite, and Potosi Dolomite	Middle Devonian through uppermost Cambrian
Ozark Plateaus aquifer system	St. Francois confining unit	0-730	Shale, siltstone, dolostone, and limestone, all of low permeability. Unit is leaky to slightly leaky.	Elvins Group Derby-Doe Run Dolomite, Davis Formation	Upper Cambrian
Ozark Plateaus aquifer system	St. Francois aquifer	0-500	Fractured and permeable dolostone and sandstone. Well yields range from 1 to 500 gallons per minute, but typical yields are 50-200 gallons per minute.	Bonneterre Dolomite and Lamotte Sandstone	
	Basement confining unit		Mostly igneous and metamorphic ricks. Rocks are fractured and locally will yield small quantities of water to wells. No known aquifers beneath these rocks; thus, unit is the basal confining unit.	Mostly igneous and metamorphic rocks	Precambrian

FIG. 3 Example of a Chart Showing Comparison of Hydrogeologic Units, Rock-Stratigraphic Units, and Time-Stratigraphic Units (12)

5.1.15 Differences in opinions between hydrogeologists as to what should constitute the aquifer(s) and confining unit(s) may still exist after the report is published. No uncertainty should exist, however, as to what the author included in the definition of the aquifer(s) and confining unit(s) and the relationships to geologic units and hydrogeologic units in previous investigations.

5.2 *Naming Aquifers, General Discussion*—Aquifer names have been derived from a variety of sources:

5.2.1 Rock-stratigraphic terms (Sparta aquifer);

5.2.2 Geographic features (High Plains aquifer; Floridan aquifer);

5.2.3 Time-stratigraphic terms (Cambrian-Ordovician aquifer);

5.2.4 Lithology (limestone aquifer);

5.2.5 Depth of occurrence (500-ft sand in the Memphis area);

5.2.6 Depositional environment (shallow marine aquifer, glacial aquifer);

5.2.7 Alphanumeric designations for model layers (A1 aquifer layer, C1 confining layer, etc.);

5.2.8 Relative position (upper carbonate aquifer);

5.2.9 Unusual locations (Clinton Street-Ballpark aquifer); and,

5.2.10 Unusual geologic features of rock exposures (bird's nest aquifer).

5.2.11 The variety of ways in which aquifers have been named is one of the causes of the confusion associated with aquifer nomenclature. The problem is compounded by the various scales of hydrologic investigations. Until the advent of the RASA program (see 3.3.1.3), few ground-water studies were large enough to encounter the problems that arise when one attempts to extend local aquifer and stratigraphic nomenclature to a regional scale.

5.2.12 The gradational changes that are commonplace in geologic materials complicate the work of hydrogeologists who are trying to define aquifers and related confining units. At the scale of a study concerning a few tens to a few hundred square miles, gradations in the physical properties of the rocks are often not obvious.

5.2.13 Generally, it is straightforward to apply names of rock-stratigraphic units to aquifers because of the relative uniformity of the rocks within the study area where a stratigraphic unit may make up the entire aquifer. At the scale of many of the RASA studies, the problem is that of differentiating regionally extensive units of relatively high or relatively low permeability within a group of rock units whose relations and variability are frequently complex, and whose names may change at political boundaries.

5.2.14 It is suggested that in reports that involve hydrogeology, the author should consider first not naming aquifers. If aquifers are already named in the area, or if the extent of the aquifer is reasonably well known, or both, aquifer names should be derived from the following sources:

5.2.14.1 Lithologic terms (sand and gravel aquifer);

5.2.14.2 Rock-stratigraphic names (Sparta aquifer after the Sparta Sand); and

5.2.14.3 Geographic names (High Plains aquifer for the permeable parts of the Ogallala Formation and overlying and underlying hydrologically continuous deposits in parts of eight states **(13)**; Floridan aquifer system for permeable parts of several Tertiary carbonate formations in the Southeastern United States **(14)**).

5.2.15 It is further suggested that aquifer or aquifer-system names not be derived from the following sources:

5.2.15.1 Time-stratigraphic names (Cretaceous aquifer);

5.2.15.2 Relative position names (upper carbonate aquifer);

5.2.15.3 Alphanumeric designations for model layers (A1 aquifer layer, C1 confining layer, etc.);

5.2.15.4 Depositional environment (shallow marine aquifer, glacial aquifer, etc.);

5.2.15.5 Depth of occurrence (500-ft sand);

5.2.15.6 Acronyms (The first letter of each formation in a multiaquifer system); and,

5.2.15.7 Hydrologic condition (principal artesian aquifer).

Each of these sources of aquifer names is discussed in the following sections.

5.3 *Suggested Sources for Aquifer Names*:

5.3.1 *Introduction*—Authors of reports on hydrogeology have the following two options in dealing with aquifer nomenclature:

5.3.1.1 *Option 1*—do not name the aquifers, or

5.3.1.2 *Option 2*—name the aquifers using lithologic, rock-stratigraphic, or geographic names.

5.3.2 *Aquifers Not Named*—If Option 1 is chosen where the aquifers are not named, use the following guidelines:

5.3.2.1 The water-bearing properties of rocks can be described in many investigations without naming aquifers. Each rock unit, and its water-bearing properties, can be described in comparison charts and tables.

5.3.2.2 The principal difference between a report of this kind and one describing named aquifers would be in phraseology. Although this approach could be used in studies involving both formal and informal rock-stratigraphic names, it would have particular application in areas where no formal rock-stratigraphic-units had been designated or where both the stratigraphy and hydrology of the particular rocks are poorly known, or both.

5.3.2.3 There is an advantage to not cluttering up the literature with aquifer names in areas where the hydrogeology has not been studied in great detail, where the present study describes the area in only a cursory or reconnaissance fashion, or where the size of the study area is so small that only a small part of the aquifer is investigated. This option should be considered to avoid the unnecessary coining of new aquifer names.

5.3.3 *Aquifers Named*—If Option 2 is chosen where the aquifers are to be named from lithologic, rock-stratigraphic, or geographic nomenclature, use the following guidelines:

5.3.3.1 *General Guidelines*—If aquifers are to be named, lithologic names or rock-stratigraphic names, or both, should be used to the extent that permeability distribution and hydrologic continuity permit. If in a larger area these terms are inappropriate, geographic names should be used. For example, in a local study where the aquifer consists of a single rock-stratigraphic unit, the name of the rock-stratigraphic unit may be used for the aquifer name. If at a later time, another study was done that included a larger area than the first, a judgment would have to be made to determine if the rock-stratigraphic name was still appropriate.

5.3.3.2 If the aquifer in the larger area still consisted of the same rock-stratigraphic unit, its name could be retained as the aquifer name. If the aquifer was made up of several units, none of which would be appropriate to name the aquifer, or if the aquifer extended across rock-unit boundaries, a name based on a geographic feature should be used. These relations should be shown clearly in the comparison charts of the report. If an aquifer is named after a rock-stratigraphic unit or geographic feature, rules of priority should be followed. A thorough literature search should be made to avoid duplication of aquifer names. The name should not be preempted by a rock-stratigraphic name. Additional guidelines are in Section 6.

5.3.3.3 *Lithologic Names*—Lithology-derived aquifer names are useful in some investigations to define water-bearing materials where formal rock-stratigraphic units do not exist. The adjectives for lithologic aquifer names may be based on lithologic terms, such as, sand and gravel aquifer, granite aquifer, limestone aquifer, etc. If uncertainty exists about a lithologic term being consistent throughout the extent of the aquifer, a geographic name could be used. Lithologic names are especially useful for naming aquifers in glacial deposits. If several aquifers are discussed in a report describing ground-water in glacial deposits, lithologic terms might be similar. In these situations, local geographic names may be more appropriate.

5.3.3.4 *Rock-Stratigraphic Names*—Rock-stratigraphic names may be used as the basis for aquifer names for studies that generally cover a state or parts of a state and an adjacent state. At the scale of these studies, the rock-stratigraphic unit and the aquifer commonly are equivalent. In addition to the criteria for defining the hydrologic framework, the following guidelines should be used, as appropriate, for assigning names and using or modifying existing aquifer names that are based on rock-stratigraphic names.

5.3.3.5 Through the use of comparison charts, maps, and cross sections, it should be shown clearly how much of the rock-stratigraphic unit is included in the aquifer. In some areas, aquifers have been named for, but consist of only a part of, the rock-stratigraphic unit. Geologic units in the coastal plain of Atlantic and Gulf coasts generally thicken in an oceanward direction, and the units may become less permeable in the same direction because of an increase in fine-grained materials in the sediments. Thus, the aquifer may thin as the formation thickens, for example, the Tuscaloosa Formation (Group) and the Tuscaloosa aquifer of Alabama. Similar problems of the aquifer not corresponding with the rock-stratigraphic unit of the same name can exist at any scale when the formation name is used automatically for the aquifer name and little consideration is given to how much of the formation actually constitutes the aquifer.

5.3.3.6 The binomial name of the rock-stratigraphic unit should be shortened for use as the aquifer name:

(1) Madison aquifer, after the Madison Group;

(2) Edwards aquifer, after the Edwards Limestone; and,

(3) Sparta aquifer, after the Sparta Sand.

The argument is made that including the full rock-stratigraphic name provides additional information, for example, Edwards Limestone aquifer. If the aquifer is described adequately in the comparison table, the text, maps, and so forth, then it is redundant, and in many situations incorrect where additional rock types are included in the aquifer to have the modifier in the aquifer name. In addition, including all the modifiers in some rock-stratigraphic names can result in long, awkward aquifer names. Lithologic modifiers for existing entrenched aquifer names should not be capitalized, for example, Burnam limestone aquifer, not Burnam Limestone aquifer. Do not use the name of a rock-stratigraphic unit for an aquifer name unless the unit is part of the aquifer.

5.3.3.7 For aquifer names based on multiple stratigraphic units use the following guidelines:

(*1*) If an aquifer includes all or part of two superimposed rock-stratigraphic units, the aquifer name is hyphenated with the younger unit first; for example, the lower Hell Creek-Fox Hills aquifer consists of the lower part of the Upper Cretaceous Hell Creek Formation and underlying Fox Hills Sandstone. This usage conforms to map explanations, tables, sections, and the U.S. Geological Survey's computerized National Water Information System II (NWIS-II), which all show units in chronologic sequence youngest to oldest. An aquifer name consisting of units in order of decreasing age, however, may be used if its use is entrenched in an area or has been used in legal terminology. For example, the oldest to youngest named Potomac-Raritan-Magothy aquifer in the Cretaceous Potomac Group and overlying Raritan and Magothy Formations is of longtime usage in New Jersey.

(*2*) If an aquifer includes three or more superimposed rock-stratigraphic units, the aquifer name may include all units youngest to oldest (hyphenated), or only the youngest and oldest units. For example, the Galena-Platteville aquifer that is used locally in Wisconsin is in the Galena Dolomite (youngest), Decorah Formation, and Platteville Formation. Giving an aquifer an appropriate geographic name would be a desirable alternative to a cumbersome hyphenated rock-stratigraphic name.

(*3*) If the middle rock-stratigraphic unit is the primary aquifer, that name may be used, provided that the overlying and underlying stratigraphic units are identified clearly. For example, the Edwards aquifer in Texas is in the Georgetown Limestone (youngest), Edwards Limestone, and Comanche Peak Limestone.

(d) An aquifer that includes many rock-stratigraphic units that are water bearing and hydraulically connected vertically and laterally should have a name that is not based on any of the individual rock-stratigraphic names. A geographic name would be appropriate. For example, the Floridan aquifer system includes the Tampa Limestone, Suwanee Limestone, Ocala Limestone, Avon Park Formation, Oldsmar Formation, and part of the Cedar Keys Formation.

5.3.3.8 An abandoned rock-stratigraphic name should not be used for an aquifer name; the newly assigned stratigraphic name should be used instead. If the usage of the abandoned name is entrenched in the area or is a legal term in state regulations, however, the author may use the term but should describe the stratigraphic change in the introduction of the report and show the correlation in a chart so that the reader is aware of the new terminology.

5.3.3.9 *Geographic Names*—Geographic names could be the basis for aquifer names where no rock-stratigraphic names are available, no single rock-stratigraphic name or combination of rock-stratigraphic names (or lithologic names) would be appropriate, or the use of previously named aquifers in small-area studies would not be appropriate or correct. Geographic names also include names of physiographic regions or subregions.

5.3.3.10 In addition to geographic names, a regional aquifer name could be derived from a geologic structural feature, for example a basin that has relevance in the area underlain by the aquifer. Physiographic names should be from a well-known source **(12)**. The High Plains aquifer and the Floridan aquifer system are two examples of regional aquifer names that are derived from geographic names. Geographic names could be used for aquifers of subregional extent where the location of the aquifer might provide more meaningful information than its physical characteristics, or no rock-stratigraphic name is available for derivation of the aquifer name, or both.

5.4 *Sources Not Recommended for Aquifer Names*:

5.4.1 *Introduction*—The following types of aquifer name options are presented to help clarify the use of names that are not suggested, however, examples of these can be found in the literature.

5.4.1.1 *Time-Stratigraphic Names*—Time-stratigraphic boundaries do not necessarily coincide with rock-stratigraphic boundaries or other physical changes in the hydraulic characteristics of rocks, and as a result, should not be used as a basis for aquifer boundaries or naming individual aquifers.

5.4.1.2 Aquifers have been named after time-stratigraphic terms; later studies and more detailed mapping have shown that some parts of the aquifer are older or younger than that of the time-stratigraphic unit in the aquifer name. For example, several years after the aquifer was originally named, the Tertiary limestone aquifer in the southeastern United States was found to contain Upper Cretaceous rocks.

5.4.1.3 Another possible complication is that long-standing time-stratigraphic boundaries have been changed in the United States to agree with boundaries developed under international geologic agreements, for example, the change in the Miocene-Pliocene boundary from 10 to 5 million years. Also, terms such as *Cretaceous aquifers*, are not strictly correct. The aquifer is not of Cretaceous age, but consists of rocks of Cretaceous age whose hydraulic properties are not now the same as when the rocks were first formed. *Aquifers in rocks of Cretaceous age* is correct and should be used instead.

5.4.1.4 Aquifer names based on time-stratigraphic names currently are in the literature and are commonly used, for example, the Cambrian-Ordovician aquifer of the north-central United States. Other aquifers in the country have similar time-stratigraphic names that are entrenched in local usage. Time-stratigraphic nomenclature should not be used for newly named aquifers, and existing time-stratigraphically based aquifer names should not be extended from local use to aquifers of regional scale.

5.4.1.5 *Relative Position*—If a layer of saturated permeable rock overlies another layer of saturated permeable rock, regardless of differences in lithology, they form one aquifer and should not be designated upper and lower aquifers. If they are separated at most locations by mappable distinctly less permeable material (confining units) they are two separate aquifers. The terms *upper, lower*, and so forth may be used where parts of the aquifer are separated by confining units and the full extent of the aquifer or aquifer system is reasonably well known. For example, the Floridan aquifer system was described as the Upper Floridan aquifer and Lower Floridan aquifer in the part of the area where the two units are separated by a regional confining unit. In other parts of the area where the confining unit is not present, the term *Floridan aquifer system* is used.

5.4.1.6 In reality, considering the definition of "aquifer system," it is also the "Floridan aquifer system" throughout the extent of the area, including places where the two parts are separated by the confining unit. When referring to parts of the same aquifer that have some distinctive difference, use of the term *zone* is preferred. For example, use upper zone of the Chicot aquifer, not upper Chicot aquifer. Use lower zone of the Chicot aquifer, not lower Chicot aquifer.

5.4.1.7 *Alphanumeric Designations*—Alphanumeric designations, such as A1 aquifer layer, C1 confining layer, and so forth are useful in discussing layers of a numerical groundwater flow model. They should not be used, however, as aquifer names. A clear distinction always should be made in a report between the real flow system and the simulated flow system. Illustrations, such as Fig. 1, help differentiate these distinctions and relations.

5.4.1.8 *Depositional Environment*—Names based on depositional environment can be misleading and should not be used for aquifer names. For example, *shallow marine aquifer* may be totally unclear as to what it includes and means. Even if it is described as consisting of sand deposited in a shallow sea, problems and additional confusion may arise if the rocks of the aquifer grade into hydrologically continuous deposits from a different depositional environment or into different rocks in a similar depositional environment. Likewise, the term *glacial aquifer* may contain or be hydrologically continuous with other deposits or rocks that are not of glacial origin. Lithologic terms or geographic locations would be more appropriate.

5.4.1.9 *Depth of Occurrence*—Aquifers should not be named after depth of occurrence. The aquifer named after the 2000-ft sand may well be present at a depth of about 2000 ft at a given location where it was named in a local study. On a regional scale, however, the sand may be present elsewhere at a greater or lesser depth and have no relationship to the name derived from the local study. Established local usage may require the continued use of these names at the local level, but the name should not be extended to studies of larger areas.

5.4.1.10 *Acronyms*—Aquifers or aquifer systems should not have acronyms for names, such as, an aquifer name derived from the first letter of each rock-stratigraphic unit that makes up the aquifer. In this situation, if many rock-stratigraphic units make up the aquifer, a geographic name unrelated to any of the rock-stratigraphic names should be used.

5.4.1.11 *Hydrologic Condition*—Terms, such as water-table aquifer and artesian aquifer are not suggested because they are names that are based on hydrologic conditions that can change as outside stresses change, such as pumping and climatic change. Hydrologic conditions also can vary from place to place in the aquifer's area of occurrence. For example, an artesian aquifer can be dewatered by pumping, and an aquifer that is considered to be under artesian conditions within the study area may be under water-table conditions in a recharge area inside or outside the study area.

5.5 *Suggestions for Naming Confining Units*:

5.5.1 Confining units should not be named unless a clear-cut need exists for understanding a complex aquifer system. In studies where several aquifers and confining units are discussed, the confining units could be given individual names, but a hierarchy of terms for confining units comparable to aquifer system, aquifer, and zone is not necessary.

5.5.2 If names are applied to confining units, they should be derived in a similar manner as aquifer names, that is, after lithologic terms, rock-stratigraphic names, or geographic names.

5.5.3 If the confining unit consists of one rock-stratigraphic unit, the confining unit may be named after the rock-stratigraphic unit.

5.5.4 If the confining unit consists of several rock-stratigraphic units, it could be given a hyphenated name of the youngest and oldest unit, or probably more preferable, a geographic name.

5.5.5 A confining unit could be named after the aquifer it confines, but two potential situations may cause confusion if confining units are named in this manner.

5.5.5.1 In the first situation, determine what name should be given to a confining unit that separates two aquifers. It confines both. A logical order of naming confining units should be followed. For example, confining units could be named after the aquifers they overlie. In areas where crystalline basement rocks or other rocks having low hydraulic conductivity form the lowest confining unit, a name unrelated to an aquifer name should be chosen. The term *basal confining unit* could be used for the lower-most confining unit of the known flow system.

5.5.5.2 In the second situation, if an aquifer is named after a rock-stratigraphic unit that forms all or a major part of an aquifer, this name should not be used to name the confining unit that overlies or underlies the aquifer. In other words, the confining unit should not be named after a rock-stratigraphic unit that is not part of the confining unit. For example, in western South Dakota, the upper part of the Minnelusa Formation is an aquifer named the Minnesula aquifer. This aquifer is overlain by a confining unit that consists of six formal rock-stratigraphic units. The confining unit should not be called the Minnelusa confining unit because the Minnelusa Formation is not a part of the confining unit. The options are not to name the confining unit, name it after an appropriate combination of rock-stratigraphic units that are in the confining unit, or name the confining unit after a geographic feature. The lower part of the Minnelusa Formation is a confining unit and could be named the Minnelusa confining unit.

5.5.6 In summary, it is suggested that confining units not be named unless a serious potential exists for confusing such units in the text. If the confining units are named, they could be named after the rock-stratigraphic unit or units that compose them, after the aquifers they confine, unless the aquifers are named after rock-stratigraphic units, or after a geographic feature.

6. General Procedures, Style, and Expression

6.1 *Cautions in Using Rock-Stratigraphic Names for Aquifer Names*—The use of rock-stratigraphic names for aquifer names is simple in concept, but has some risk for confusion if not done carefully.

6.1.1 When using a rock-stratigraphic name for an aquifer name, the author should make the distinction throughout the text and illustrations of the report between the rock-stratigraphic unit and the aquifer.

6.1.1.1 In writing reports, authors have a tendency, not necessarily incorrect, to shorten the name of both rock-stratigraphic and aquifer names after they have been described by their full name a few times. For example, if the Baker aquifer makes up a large part, but not all, of the Baker Formation, confusion may be caused by using the expression "the Baker is 450 ft thick south of the Possum River." Is this the Baker Formation or the Baker aquifer? If situations such as this arise, the term *aquifer* always should be included when discussing the aquifer.

6.1.2 Lithologic modifiers in rock-stratigraphic names should not be used in aquifer names. Not only will this avoid unnecessarily long names, it also will help keep clear the distinction between the aquifer and rock-stratigraphic unit. If an aquifer is made up largely of the Jacob Sand Member of the Blackjack Formation, the aquifer should be called the Jacob aquifer, not the Jacob Sand Member aquifer.

6.1.2.1 Lithologic modifiers are often used in aquifer names because the author believes that the modifiers add additional information to the aquifer name. If the aquifer is clearly defined in the comparison charts, there should be no problem in knowing what constitutes the aquifer. A reader who desires information on the characteristics of the water-bearing units in an area will know what makes up the aquifer, regardless of its name, after reading a comparison chart(s) that is clearly constructed. In addition, a single lithologic modifier may be incorrect if more than one rock type makes up the aquifer.

6.1.3 Descriptions of aquifers and rock-stratigraphic units should be clearly separated or distinguished in the text and illustrations. For example, hydraulic information on potentiometric surface, storage coefficient, and specific yield, describes the aquifer not the rock-stratigraphic unit. Geologic information on dip, strike, plunge, and deposition of sediments describes the rock-stratigraphic unit, not the aquifer. Terms, such as porosity and permeability could refer to either the aquifer or the rock-stratigraphic unit.

6.2 *Redefining and Renaming Previously Named Aquifers*—A previously named aquifer can be redefined and renamed, and the approach is the same as naming an aquifer for the first time. All the guidelines that are given in the previous sections apply also to redefining and renaming aquifers. The comparison charts are particularly important in this endeavor, especially the one represented in Fig. 2 that shows the relation of the renamed aquifer(s) to the previously named aquifer(s).

6.2.1 Redefining and renaming an aquifer should not be done casually or done just to change the name. No hard, fast rules, however, will be given here as to what constitutes justification for redefining and renaming an aquifer, except that it should be the result of a thorough analysis of the hydrogeology of the area and represent an improvement in the understanding of the hydrology.

6.2.2 Technical review should be used to judge the merit of the nomenclature changes. The work of Miller **(4)** is an example of a detailed hydrogeological analysis that resulted in redefining and renaming the water-bearing units of the Floridan aquifer system.

6.2.3 In reality, all aquifer names are informal names **(6)** that might be changed with additional study. It is more important to represent clearly the hydrology of a particular area than to retain old or introduce new naming conventions.

6.3 *Format Conventions for Aquifer Names*—The following format conventions are suggested for reports that name aquifers or contain discussions of aquifer names:

6.3.1 The terms aquifer, aquifer system, zone, and confining unit are not capitalized.

6.3.2 Terms, such as sand and gravel aquifer, and limestone aquifer, etc., are not capitalized or hyphenated.

6.3.3 Adjective modifiers, except parts of formal geographic names, are not capitalized, such as, Mississippi River alluvial aquifer.

6.3.4 Relative-position terms, that is, upper, middle, and lower, are not capitalized. The terms may be capitalized, however, if they represent parts of a regional aquifer system that are separated by a major confining unit. For example, Miller **(4)** formally divided the Floridan aquifer system into an Upper Floridan aquifer and a Lower Floridan aquifer in all Florida and parts of adjacent states.

6.3.5 Quotation marks are not used for aquifer names unless the term is a misnomer. The “500-ft” sand is in quotes because it is not at 500 ft below land surface everywhere. As mentioned in the section on not recommended criteria, depth of occurrence should not be used for new aquifer names.

6.3.6 Usage of hydrologic and geologic terminology will vary depending on context and structure of the sentence, but certain distinctions between the two should be kept clear:

6.3.6.1 Water from the Madison aquifer, not Madison water.

6.3.6.2 Wells completed in Madison Limestone (or aquifer), not Madison wells.

7. Keywords

7.1 aquifer nomenclature; aquifer systems; confining units; geological names; ground-water; hydrogeology; rock-stratigraphic units

APPENDIX

(Nonmandatory Information)

X1. EXAMPLES OF DESIGNATING AND NAMING AQUIFERS

X1.1 *Introduction*—Eleven examples of designating and naming aquifers are shown in Fig. X1.1. The examples are hypothetical and generalized for convenience, but they illustrate characteristics of hydrologic settings throughout the United States. Even though most of the examples use rock-stratigraphic names, it should be remembered that the two options for naming aquifers in order of consideration are: (1) do not name the aquifers, and (2) name the aquifers using lithologic, rock-stratigraphic or geographic names.

X1.2 *Example 1—Aquifer and Rock-Stratigraphic Unit Coincide*—Fig. X1.1, example 1 shows an aquifer that coincides with the rock-stratigraphic unit and is confined above and below by much less permeable material. The aquifer probably would be named the Johnsville aquifer even though the full lateral extent of the aquifer may not be known.

X1.3 *Example 2—Aquifer Consists of One Rock-Stratigraphic Unit and Part of an Adjacent Rock-Stratigraphic Unit*—The aquifer shown in Fig. X1.1, example 2 is made up of the lower two-thirds of Whiskey Creek Formation (sandy silt and clayey sand) and the moderately cemented Devils Lake Sandstone. Hydrologically, the two units are continuous and form a single aquifer. The aquifer is confined above and below. The name of the aquifer could be taken from the rock-stratigraphic name, Whiskey Creek-Devils Lake aquifer. Likewise, if a prominent geographic feature were near where the aquifer was described, by wells or outcrops, it could be the basis of the aquifer name. The description of the aquifer in the text, comparison chart, and illustrations carefully should describe the reasoning for the selection of the upper and lower boundaries of the aquifer. In addition, it should be made clear that the upper formation and aquifer are not totally coincidental.

X1.4 *Example 3—Aquifer Consists of a Small Part of Two Major Rock-Stratigraphic Units*—The aquifer in Fig. X1.1, example 3 consists mostly of the Murphy Member of the Ringer Formation, and probably would be called the Murphy aquifer. If the Murphy Member had not been named, the aquifer might be called the Bell-Ringer aquifer. The aquifer makes up only a small part of each formation, however, especially the Bell Formation. In this case, a local geographic name might be more appropriate.

X1.5 *Example 4—Aquifer and Aquifer System*—The cross section in Fig. X1.1, example 4 represents an aquifer system consisting of three permeable carbonate formations and the

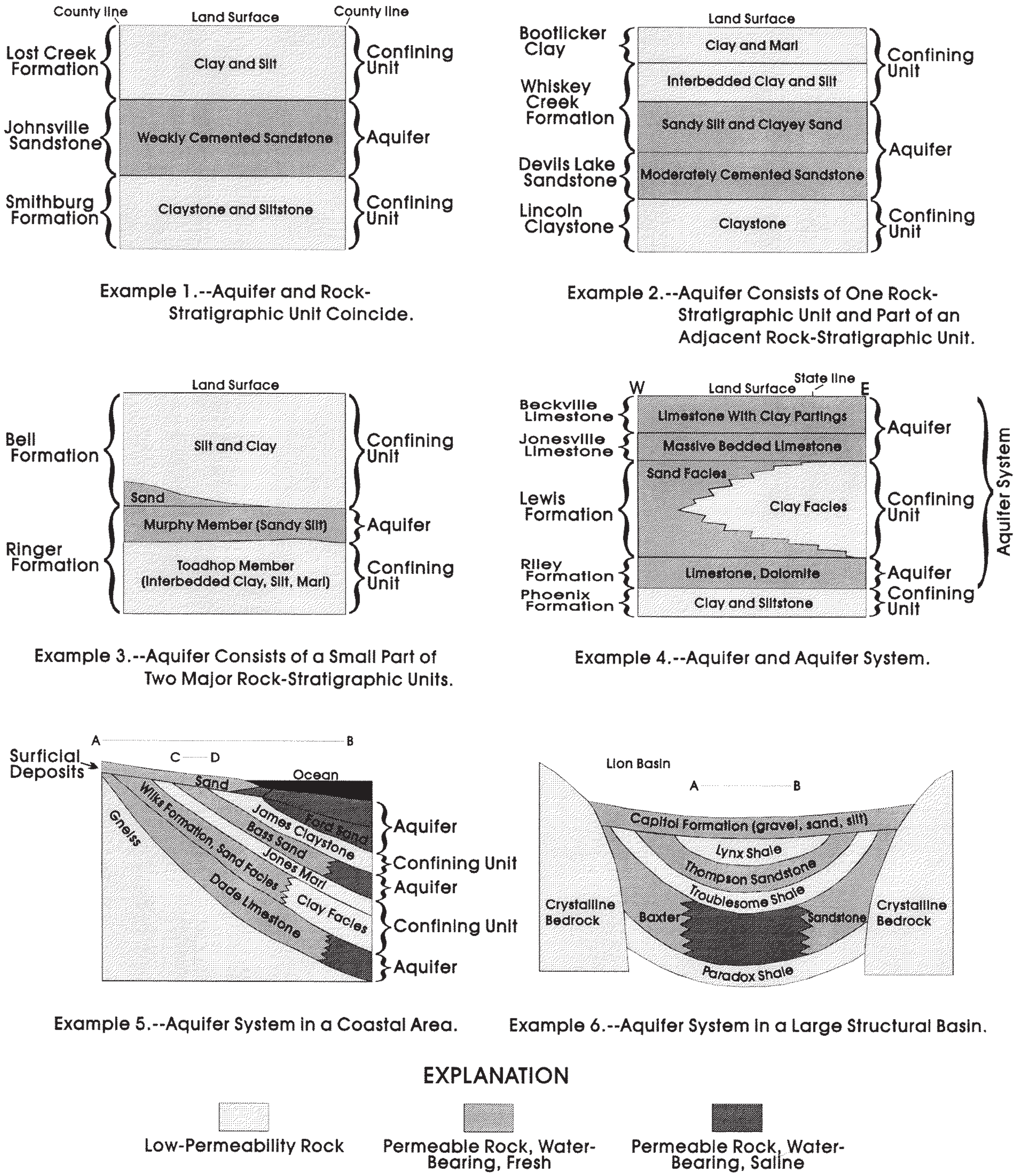
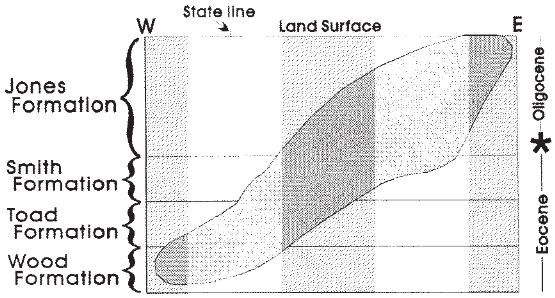
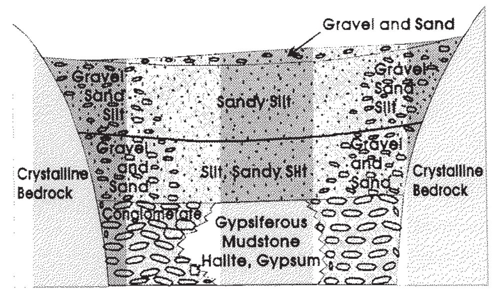


FIG. X1.1 Examples of Designating and Naming Aquifers

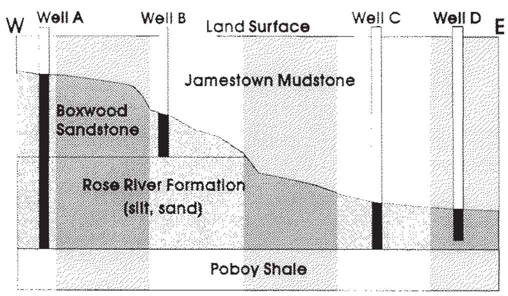
sand facies of a clastic formation. The clay facies forms a confining unit over part of the area. If the study had included only the area east of the stateline, two separate aquifers could have been defined, the Beckville-Jonesville aquifer and the Riley aquifer, or two aquifers named for geographic locations. If the study included only the area west of the Stateline, the following options could be considered for naming the aquifer: (1) the aquifer might be called the Lewis aquifer if the sand was significantly more permeable than the limestone units, or (2) if the permeability of the four units was not greatly different, the aquifer might be called the Beckville-Riley aquifer or could be named after an appropriate geographic feature. If the study area included all the units shown on the cross section, no individual rock-stratigraphic unit would be representative everywhere, and a geographic name should be used to name the aquifer system. If the sketch represented the full extent of the aquifer, and the aquifer was given a name, say the Williamsburg aquifer, the parts above and below the confining unit could be named the Upper Williamsburg aquifer and the Lower Williamsburg aquifer in a manner similar to the



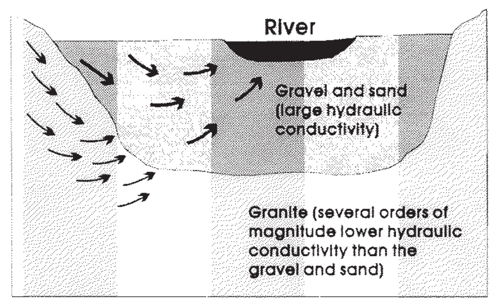
Example 7.--Aquifer Crosses Boundaries of Rock-Stratigraphic Units and Time-Stratigraphic Units.



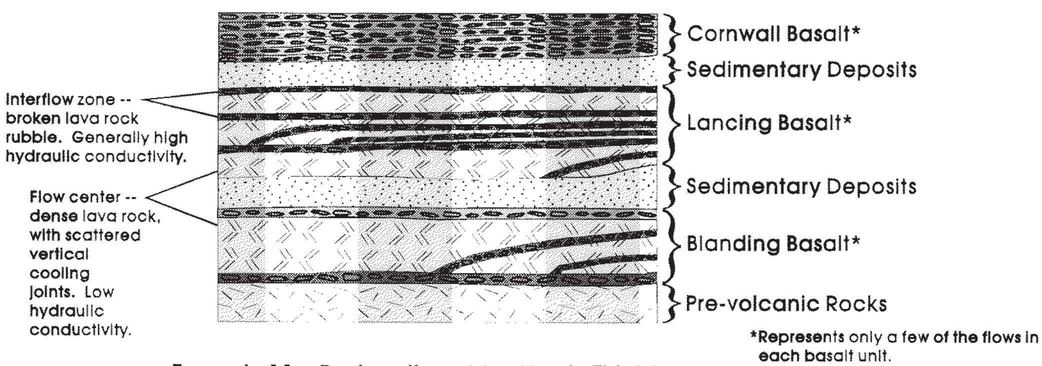
Example 8.--Aquifers in an Alluvial Basin in the West or Southwest.



Example 9.--Use of Aquifer Terminology Where Rock-Stratigraphic Units are Discontinuous.



Example 10.--Designation of Aquifers and Confining Units for Different Purposes and Scales of Investigations.



Example 11.--Designation of Aquifers in Thick Lava-Flow Sequences.

FIG. X1.1 Examples of Designating and Naming Aquifers *(continued)*

Floridan aquifer System of Miller **(4)**. For local studies on either side of the stateline, the local aquifer name could still be used if the names were entrenched in usage, but the authors of local reports should clearly show and explain the broader relationships, if known.

X1.6 *Example 5—Aquifer Systems in a Coastal Area*—In hydrologic studies of coastal areas shown in Fig. X1.1, example 5, the tendency has been to give hydrologically contiguous rock-stratigraphic units separate aquifer names. For example, in a study area represented by section A-B, the aquifers from youngest to oldest are surficial aquifer (the sand unit), Ford aquifer, Bass aquifer, Wilks aquifer, and Dade aquifer. In reality, all these units form a single aquifer system that should be named after a physiographic or geographic feature. In a local-scale study represented by section C-D, the surficial deposits and the Bass Sand form one aquifer that should have a single name. It could be called the Bass aquifer as long as it was explained clearly that this name also included the surficial deposits. The second aquifer under C-D would be the Wilks-Dade aquifer.

X1.6.1 It should be noted that the aquifer materials that contain saline water are part of the same aquifer that contains fresh water. Interfaces between saltwater and freshwater are subject to movement depending on the hydrologic conditions of the area and should not be used as aquifer boundaries. The boundary between the saltwater and freshwater and its apparent stability (or instability), however, should be defined as clearly as possible in the report.

X1.7 *Example 6—Aquifer System in a Large Structural Basin*—The sketch for Fig. X1.1, example 6 represents an aquifer system in a large structural basin. The aquifer system should be named after a physiographic, geographic, or in this case perhaps, a geologic structural name after the basin, such as, the Lion aquifer system. If the tops and bottoms of the Capitol Formation, Thompson Sandstone, and Baxter Sandstone are all well defined, and if it is known that the boundaries of these units largely correspond to the boundaries of the aquifers of the system, then the rock-stratigraphic names could be used for individual aquifer names in the Lion aquifer system. If the subsurface extent and boundaries of the rock-stratigraphic units are not well known, however, or if the individual aquifers consist of several rock-stratigraphic units, or both, names unrelated to rock-stratigraphic terms should be assigned to the individual aquifers. If considerable uncertainty exists in defining the boundaries of the aquifers, this should be indicated in the comparison charts and text. If the aquifer is well-defined, it could be subdivided into the Upper Lion aquifer, Middle Lion aquifer, and Lower Lion aquifer in a manner similar to that done for the Floridan aquifer system. In local studies preceding the regional evaluation, such as in the area represented by the section A-B, individual aquifers might have been designated such as, the Capitol aquifer, the Thompson aquifer, and the Baxter aquifer.

X1.7.1 In local studies subsequent to the regional study, the Lion aquifer system names could be used for individual aquifers unless the rock-stratigraphic names were entrenched or otherwise advantageous. If the rock-stratigraphic names are used as the basis for aquifer names, their corresponding equivalents in the regional aquifer system should be discussed and shown in the comparison table of the report.

X1.8 *Example 7—Aquifer Crosses Boundaries of Rock-Stratigraphic Units and Time-Stratigraphic Units*—Fig. X1.1, example 7 shows an aquifer that crosses the boundaries of and comprises parts of four rock-stratigraphic units. East of the stateline the aquifer could be named the Jones-Smith aquifer and west of the stateline it could be called Toad-Wood aquifer. The boundaries of the aquifer bear no relation to the time-stratigraphic boundaries. In studies involving the entire aquifer, a single rock-stratigraphic name is not appropriate. A geographic name should be used for the basis of the aquifer name. Of course, a geographic name rather than a rock-stratigraphic name could be selected for the aquifer name at the local scale.

X1.9 *Example 8—Aquifers in an Alluvial Basin of the West and Southwest*—In Fig. X1.1, example 8, the sedimentary units shown in the sketch are representative of closed-basin deposits. Generally in such a setting, the grain size decreases basinward from the source areas, and the amount of cementation increases downward in the deposits. Hydraulic conductivity likewise decreases in the same directions. Even though the hydraulic conductivity generally is lower in the deeper units, a large part of the deposits in the upper part of the basin are hydraulically connected and consist of one aquifer. Most of the deposits do not have formal rock-stratigraphic names, but may have informal names, such as, basin fill, valley fill, cemented gravel, playa deposits, lake deposits, etc. Other rock units, such as volcanic flows may be interbedded with the basin deposits, complicating the picture.

X1.9.1 Well-defined confining clay units may be present in some basins, making it convenient to subdivide the materials into two or more aquifers. In other basins, however, well-defined clay layers are absent, or clay deposits form plugs at depth in the centers of the basins. The gravel, sand, silt, and conglomerate areas of the sketch could be considered one aquifer unless well-log data or hydraulic-head data indicate a significant discontinuity with depth. The first option to consider is to not name an aquifer, but describe the water-bearing characteristics of the informally named deposits. Informal rock names could be retained for the aquifer name, for example, valley-fill aquifer, or if necessary, the aquifer could be named for a geographic feature, such as the name of the basin or valley. Zones could be designated for hydraulic features that require emphasis or separation.

X1.10 *Example 9—Use of Aquifer Terminology Where Rock-Stratigraphic Units are Discontinuous*—In Fig. X1.1, example 9, the aquifer in the study area represented by the sketch could be called the Boxwood-Rose River aquifer. The upper boundary of the aquifer coincides with an erosional discontinuity, and the Boxwood Sandstone is not present in the eastern part of the area. Within the study area the aquifer name, Boxwood-Rose River aquifer, would be used in the report even though the Boxwood Sandstone is not present throughout. Use of the aquifer name is illustrated by the wells in the sketch: Well A completely penetrates the Boxwood-Rose River aquifer; Well B partially penetrates the Boxwood-Rose River aquifer; Well C completely penetrates the Boxwood-Rose River aquifer; and, Well D partially penetrates the Boxwood-Rose River aquifer.

X1.10.1 If a study were done in an area represented by Wells C and D on the sketch, the aquifer could be called the Rose River aquifer in the report because the Boxwood Sandstone is not present in that study area. If the study area represented by the entire sketch were completed and the Boxwood-Rose River aquifer already named, however, the later report should contain statements in the text and show on the comparison charts that the Rose River aquifer thickens west of the study area to include the overlying Boxwood Sandstone and forms the Boxwood-Rose River aquifer.

X1.11 *Example 10—Designation of Aquifers and Confining Units for Different Purposes and Scales of Investigations*—The sketch in Fig. X1.1, example 10 represents a highly permeable deposit of gravel and sand in a valley occupied by a major perennial stream. The bedrock is granite that is several orders of magnitude less permeable than the gravel and sand.

X1.11.1 Based on the large contrast in permeability, the gravel and sand is the aquifer and the granite is the confining unit. In an investigation to evaluate the potential for developing ground-water supplies from the gravel and sand, or to evaluate interaction between ground-water and surface-water, the granite might be considered effectively impermeable and the flow in the granite ignored. In an evaluation of the potential for establishing a repository for high-level radioactive wastes in the granite, the designations of the aquifer and confining unit would not necessarily change, but the flow system through both units would have to be considered. The rate of flow through the granite into the gravel and sand would be slow, but could not be ignored in evaluating minimum travel times of radionuclides that the ground-water might transport through the granite. This situation is similar to an aquifer overlain by a confining unit for example, clay over sand, that contributes water to the aquifer by leakage. A small to large part of the water withdrawn from the aquifer could come from the confining unit, but the designations of the aquifer and confining unit would not change. The purpose of an investigation in a given area, therefore, should not affect the designations of aquifers and confining units.

X1.11.2 Aquifers and confining units may be designated differently in two or more investigations because of differences in scale or areal extent of the study area, or both. If a water-resources investigation were undertaken of just the granitic terrain in the sketch, for example, an evaluation of ground-water availability for domestic use, the granite would be the aquifer because it is the only water-bearing unit in the study area. If the report were completed and published, on the larger area that included the gravel, it would provide information to the reader to mention the other report and show the relation between the two studies and how the hydrogeologic units were selected. A similar situation could arise where a unit of low hydraulic conductivity is utilized for domestic water supplies, and locally is considered an aquifer, and an evaluation from a regional perspective shows that the same unit is a regional confining unit. Again, it is the responsibility of the author to discuss these relationships in the comparison charts and text so that this apparent anomaly is explained.

X1.12 *Example 11—Designation of Aquifers and Confining Units in Thick Lava-Flow Sequences*—Thick lava-flow sequences, such as in the Columbia Lava Plateau **(15)**, require special consideration in the designation of aquifers and confining units. These sequences are as much as several hundred to a few thousand feet thick and consist of individual flows that range from a few feet to a few hundred feet in thickness. The most permeable parts of the sequence are the interflow zones that consist of a few feet of broken lava-rock rubble that formed at the top of a flow during deposition and a thinner rubbly zone at the base of the overlying flow (see sketch for Fig. X1.1, example 11). The interflow zones are interrupted laterally or terminate; therefore, continuous aquifers are identifiable for only a few miles **(16)**. The part of the flow between interflow zones, the flow center, cooled more slowly and consists of dense vertically jointed lava rock. The interflow zones may account for 1 to 30 % of the volume of the rock, but the lateral hydraulic conductivity of the interflow zones may be several orders of magnitude greater than the vertical hydraulic conductivity of the dense zone unless the top of the flow has been subjected to a long period of subaerial weathering. If the top of a flow was extensively weathered before being covered by another lava flow, the minerals in the lava rock may be altered to clay minerals that reduce the permeability of the interflow zone. The flows may contain discontinuous deposits of fine-grained sediments in the interflow zones that have little effect on the hydrologic properties of the flow sequence or may grade into, or be divided by, widespread sedimentary deposits, or both. The hydraulic conductivity of the widespread sedimentary deposits is variable but usually is much less than that of a rubbly interflow zone.

X1.12.1 Designation of aquifers may be governed by the scale of the study and the thickness of the individual lava flows. For example, where individual flows are several hundred feet thick (the middle and lower part of the sketch) the interflow zones are easily recognized as individual aquifers and the dense rock between interflow zones are confining units. The part of the flow sequence consisting of several permeable interflow zones separated by dense, much thicker lava would be an aquifer system. At the other extreme, a sequence of flows where the individual flows are only a few feet thick (the upper part of the sketch) the designation of aquifer versus aquifer system may not be as clear cut. At some point, the ratio of interflow zone to dense zone may become large enough that the multiple thin-flow sequence could be considered a single aquifer. A comparison can be made to that of sandstone interbedded with shale, which taken as a whole, might behave hydrologically as a single aquifer and not an aquifer system, even though thin continuous confining units are part of the aquifer. Other information, such as head measurements versus depth in areas where the aquifer is under stress, might be used to determine whether the sequence under study behaves as a single aquifer or as several aquifers separated by confining units.

X1.12.2 Assuming that the thin-bedded flows in the upper part of the sketch behave as a single aquifer, the hypothetical lava-flow sequence consists of an aquifer and two aquifer systems all of which constitute an even larger aquifer system. It might appear that a larger category than aquifer system is needed in the hierarchy of nomenclature to classify the water-bearing rocks in this example. The term *aquifer system*, however, is adequate to encompass the example shown here (see Section 3). An appropriate geographic name should be used for the entire hydrologic system represented by the sketch, such as the Rome River aquifer system after a major river in the area. The individual parts of the system could be called the Upper, Middle, and Lower Rome River aquifer in a similar manner as was done for the Floridan aquifer system. An alternate method of naming consists of giving the upper, middle, and lower parts individual names based on the rock-stratigraphic units (or appropriate geographic names) that make up the aquifers as follows:

Rome River aquifer system	Cornwall aquifer (after Cornwall Basalt) Lancing aquifer (after Lancing Basalt) Blanding aquifer (after Blanding Basalt

X1.12.3 As in any other aquifer description, the characteristics of the dense, less permeable parts of the aquifer versus the very permeable interflow zones should be described carefully in the comparison tables and text.

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