STATE OF COLORADO

BOARD OF EXAMINERS OF WATER WELL CONSTRUCTION AND PUMP INSTALLATION CONTRACTORS
Division of Water Resources

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BOARD POLICY NO. 2003-3

Construction Standards for Wells in the Unconfined Sediments of the Alamosa Formation in the San Luis Valley

INTRODUCTION:

The sedimentary basin-fill materials of the unconfined section of the Alamosa Formation in the San Luis Valley have similar characteristics and are generally indistinguishable from the alluvial sediments of the Rio Grande and Conejos rivers and the alluvial fan materials that overlie the formation at the basin margins. Due to the inability to distinguish between the detrital sediments of the uppermost part of the Alamosa Formation and the alluvial deposits of the modern stream systems, confusion has arisen regarding the type of aquifer present and the associated construction standards that apply to wells constructed in the unconfined aquifer of the San Luis Valley. The generally shallow water table in much of the unconfined aquifer and hydraulic interconnection between the basin-fill sediments and the alluvium adds to the difficulty in determining which construction standards apply.

DISCUSSION:

The Board of Examiners adopted Rules that establish construction standards in three basic types of aquifers. The aquifer types are generally defined according to the hydrologic and geologic characteristics of the water bearing strata. In simplest terms, Type I aquifers are confined aquifers, Type II aquifers consist of unconfined bedrock, and Type III aquifers are composed of modern stream alluvium and similar recent deposits. Well construction standards developed by the Board for each aquifer type are intended to afford the greatest reasonable protection to the ground water resource contained in the aquifer.

The geology of Colorado reflects a wide variety of structural events and depositional environments over eons of time. Descriptions of the geology in the state are documented in volumes of scientific literature and the terms and definitions of geologic description are well established in the geologic community. However, applying reasonable construction practices and requirements to the diverse geologic and hydrologic conditions is the sole responsibility of the Board. To arrest the confusion generated by retrofitting aquifer type definitions to a complex depositional setting, and to address the sedimentary and hydraulic characteristics of the uppermost part of the Alamosa Formation, the Board has determined that it is reasonable to apply construction standards for a Type III aquifer to the unconfined portion of the Alamosa Formation in the San Luis valley ("unconfined aquifer").

POLICY:

In order to provide consistency and adequacy in the construction of water wells into the unconfined aquifer of the San Luis Valley, and to acknowledge the hydraulic interconnectedness and similarity of the basin-fill sediments and recent stream alluvium in the basin, the Board hereby adopts the following policy:

Water wells constructed into the unconfined aquifer of the San Luis Valley may be constructed in accordance with the construction standards for Type III aquifers found in Rule 10.4.7 without the necessity for requesting a variance from the minimum standards of Rule 10.4.6 (Type II aquifer construction standards). This policy shall not apply to or supercede any construction requirements specified in the conditions of approval of a valid well permit. Any deviation from the requirements of Rule 10.4.7 or other applicable standards of the Water Well Construction Rules shall be accomplished only after obtaining approval from the Board.

Dated this 5th day of August, 2003

Halsey R. Newmyer

Halsey R. Newmyer, Chairman
Board of Examiners of Water Well Construction
and Pump Installation Contractors

TYPE III AQUIFER (Alluvial aquifers)

June 16, 2003

Introduction

At the June 3, 2003 meeting of the Board of Examiners, Board member Ray Newmyer questioned the designation of the unconfined aquifer of the San Luis Valley as a Type II aquifer. Mr. Newmyer suggested that the designation of the aquifer had been changed since the Board's adoption of the Rules that established construction standards for Type I, II, and III aquifers. In about August of 2000 a similar misunderstanding of the aquifer designations was expressed by contractors constructing wells in the High Plains area of eastern Colorado regarding the Ogallala aquifer. An attempt to address the aquifer type question and misunderstanding of the geologic terminology was provided in a discussion of the aquifer types provided to the contractors in November 2000 (see Exhibit G).

The problem stems from the incorrect use of the term "alluvium". Many drilling contractors apply the term to any unlithified material that they encounter in the drilling process. However, the term alluvium is restricted in geologic terminology to a specific veneer of sedimentary deposits that are confined to stream valleys of modern origin. The terminology is further explained in the following paragraphs.

Definitions - Water Well Construction Rules (2000)

The following definitions were adopted in the Water Well Construction Rules and have been used consistently by the Board's staff since the Rules became effective on June 1, 2000. The designation of an aquifer as Type I, II, or III is based on the commonly accepted geologic terms, definitions and designations utilized by the Geotechnical Branch of the State Engineer's office. The characteristics of the various sedimentary deposits that compose the aquifer systems have been well documented by research, mapping, and investigations conducted by numerous geological entities including universities, the U.S. Geological Survey, Colorado Geological Survey, Colorado Oil and Gas Conservation Commission, the State Engineer's office and others. The designations for "alluvium" and the alluvial aquifer (Type III aquifers) have been and are currently consistent with the generally accepted definitions for the terms. The paragraphs from the Statement of Basis and Purpose of the Water Well Construction Rules illustrate that intent to designate Type II and Type III aquifers according to the accepted usage of the term "alluvium" by omitting "recently deposited unconsolidated alluvial and/or colluvial materials" from the designation of Type II aquifers and by specifically designating Type III aquifers to be "recently deposited material located adjacent to river and stream channels or unconsolidated materials emplaced by gravity (slope wash)".

5.2.2.1 **"Type I Aquifer"** means a **confined aquifer** as defined in these Rules.

5.2.12 **"Confined Aquifer"** means an aquifer consisting of unconsolidated or consolidated rock material or crystalline rocks below a confining layer. Confined aquifers are designated in these Rules as **"Type I aquifers"**.

5.2.2.2.1 **"Type II Aquifer"** means an **unconfined bedrock aquifer** as defined in these Rules.

5.2.52 **"Unconfined Bedrock Aquifer"** means an aquifer consisting of consolidated rock material or crystalline rocks that is not overlain by a confining layer. Unconfined bedrock aquifers are designated in these Rules as **"Type II aquifers"**.

5.2.5 **"Bedrock"** means consolidated crystalline or sedimentary rock.

5.2.2.3 **"Type III Aquifer"** means an aquifer that consists of unconsolidated rock material including alluvial and/or colluvial deposits and severely weathered (decomposed) crystalline rocks.

<u>Statement of Basis and Purpose – Water Well Construction Rules (2000)</u>

<u>Rule 10.4.6</u> establishes minimum standards for the intervals of grout and watertight casing in wells constructed into **Type II** (unconfined bedrock) aquifers such as the unconfined portion of a Denver Basin aquifer (Dawson, Denver, Arapahoe, Laramie-Fox Hills), the fractured granite common in mountain locations, and other water bearing formations that are neither under confined conditions *nor consist of recently deposited unconsolidated alluvial and/or colluvial materials*. The required minimum depths of watertight casing and grout placement will afford reasonable protection from surface and near surface contamination of wells constructed into unconfined bedrock. Because the standards of this Rule may not be adequate in all cases, a contractor is responsible for exceeding the standards of this Rule in those instances where it is obvious or expected that the minimum requirements of this Rule are inadequate to protect the well and the ground water resource from contamination. Figure 2c is included in this Rule to illustrate the necessary elements of well construction in Type II aquifers.

<u>Rule 10.4.7</u> establishes minimum standards for wells constructed into **Type III** aquifers (unconfined, unconsolidated material) such as *recently deposited material located adjacent to river and stream channels or unconsolidated materials emplaced by gravity (slope wash)*. The vulnerability to contamination of wells constructed into Type III aquifers is well recognized. The standards adopted in this Rule recognize that most wells constructed into Type III aquifers are shallow with a static water level near the land surface and that often, little natural protection from contamination is found between the land surface and the water table. The minimum depth of steel casing, solid casing, and grout interval reflect consideration of these factors. Contractors are encouraged to exceed these minimum standards in instances where the installation of additional grout is practical and may afford the well a greater degree of protection from contamination.

Figure 2d is included in this Rule to illustrate the necessary elements of construction of wells completed into Type III aquifers.

Geological definitions for alluvium/alluvial

"alluvial" pertaining to alluvium. Formerly used as a term for recent unconsolidated sediments [Dictionary of Geological Terms].

"alluvium" a general term for all detrital deposits resulting from the operations of modern rivers, thus including the sediments laid down in river beds, flood plains, lakes, fans at the foot of mountain slopes, and estuaries. The rather constant usage of the term throughout its history makes it quite clear that alluvium is intended to apply to stream deposits of comparatively recent time, that the subaqueous deposits of seas and lakes are not intended to be included, and that permanent submergence is not a criterion. Alluvium may become lithified, as has happened frequently in the past, and then may be termed ancient alluvium [Dictionary of Geological Terms].

"alluvium" (a) a general term for clay, silt, sand, gravel, and similar unconsolidated detrital material deposited during comparatively recent geologic time by a stream or other body of running water as a sorted and semisorted sediment on the bed of the stream of on its flood plain or delta, or as a cone or fan at the base of a mountain slope; esp. such a deposit of fine-grained texture (silt and silty-clay) deposited during time of flood. The term formerly included (but is not now intended to include) subaqueous deposits in seas, estuaries, lakes, and ponds. Syn. Alluvial, alluvial deposits, alluvion. **(b)** A driller's term used "incorrectly" for the broken, earthy rock material directly below the soil layer and above the solid, unbroken bed or ledge rock. [Glossary of Geology, 2nd Edition]

"alluvium" a general term for clay, silt, sand, gravel, and similar unconsolidated material deposited during comparatively recent geologic time by a stream or other body of running water as a sorted and semisorted sediment in the bed of the stream of on its floodplain or delta, or as a cone or fan at the base of a mountain slope [Groundwater and Wells, 2nd Edition].

Other relevant definitions – recent / Holocene epoch, consolidation, compaction

"Recent" see Holocene [Dictionary of Geological Terms].

"Holocene" Recent; that period of time (an epoch) since the last ice age (Wisconsin in North America; Wurm in Europe); also the series of strata during the epoch [Dictionary of Geologic Terms].

"Holocene" an epoch of the Quaternary period, from the end of the Pleistocene, approximately 8 thousand years ago, to the present time; also the corresponding series of rocks and deposits. When the Holocene is designated as an era, the Holocene is considered to be a period. Syn: Recent. [Glossary of Geology, 2nd Edition]

"consolidation" any or all of the processes whereby loose, soft, or liquid earth materials become firm and coherent [Dictionary of Geological Terms].

"compaction" decease in the volume of sediments, as a result of compressive stress, usually resulting from continued deposition above them, but also from drying and other causes [Dictionary of Geological Terms].

Summary of Geologic Terminology

As is stated in the above definitions, the term "alluvium" is used to describe the sediments deposited by **modern streams** during relatively recent time. The same processes that transport and deposit sediments in Colorado's stream valleys today have deposited "alluvial" sediments for millions of years and have been a primary means for basin filling since the uplift of the Rocky Mountains some 65 million years ago. Much of the older sedimentary rock deposited prior to that time is associated with deposition in shallow seas (marine sediments).

Thus, fluvial processes have resulted in the deposition of thousands of feet of clay, silt, sand, and gravel (alluvial sediments) in the intermontane and foreland basins of Colorado. Because the sediments were transported and deposited by streams, they are all considered to be "alluvial" deposits. With time and depending on conditions in the subsurface, alluvial deposits become consolidated (lithified – cemented by chemical processes, or simply compacted). The lithification process is evident in the conglomerates, sandstones, siltstones, and claystones that comprise the Arapahoe, Denver, and Dawson aquifers of the foreland Denver Basin, the Troublesome and North Park formations of the North and Middle Park intermontane basins, and the White River Formation of the eastern plains. These deposits are considered to be "bedrock", based on their relative age, not their degree of induration or lithification. Likewise, the Ogallala Formation, which is compacted but largely unconsolidated in many locations, and the Alamosa Formation (Pliocene – Pleistocene age; i.e. approximately 2 m.y. ago) of the San Luis Valley are fluvial deposits of ancient alluvium and considered to be bedrock.

The upper portion of the Alamosa Formation (geologic map symbol, Qa) composes the bulk of surficial deposits in the San Luis Valley and is commonly referred to as the unconfined aquifer. Though these materials are fluvial sediments from ancient rivers, they are not considered to be "alluvium" according to accepted geologic terminology. The disassociation of the clastic materials of the Ogallala and Alamosa Formations from a modern river depositional system places the materials in the Type II aquifer category.

Possible Solution

To remedy the problem for those contractors constructing wells in the High Plains area, the Staff has granted variances to Rule 10.4.6.1 (30 continuous feet of grout from a depth of at least 39 feet upward) on a case-by-case basis so that the maximum amount of grout possible is placed in each well to afford the greatest amount of protection to the well and the aquifer. Similar variances have been granted to contractors constructing wells in the unconfined aquifer of the San Luis Valley when such variances have been requested.

At the direction of the Board, requests for variance from minimum construction standards are evaluated on a case-by-case basis. The Board could consider a regional exemption to the minimum construction standards for some wells constructed into Type II aquifers, however, the variation of thickness and associated water levels of the Ogallala aquifer of the High Plains and the unconfined aquifer of the San Luis Valley may not promote development of a regional exemption from minimum standards (see Exhibit H).

Exhibits and Additional Information

Attached as **Exhibit A** is a map of the Alluvial Deposits from the Colorado Geological Survey's Ground Water Atlas of Colorado. The High Plains (Ogallala aquifer) and San Luis Valley are outlined in red.

Exhibit B, also from the Colorado Geological Survey's Ground Water Atlas of Colorado, shows the extent of the "Alluvial aquifers" throughout the state. The designation of the alluvial aquifers is consistent with the geological usage of the term "alluvium" that has been applied to such deposits for the duration of modern science. The atlas prepared by the Colorado Geological Survey is a compilation of ground water and aquifer information derived largely from previous investigations. No new or altered aquifer designations are offered in the publication.

Exhibit C is a Geologic Column for the geologic time scale. The recent period (Holocene epoch) has been added in red at the top of the column.

Exhibit D combines a portion of the geologic time scale with the equivalent stratigraphic sequence for the San Luis Valley (from the Colorado Geological Survey's Ground Water Atlas of Colorado).

Exhibit E again shows the extent of the alluvial aquifer ("Quaternary alluvium") in the San Luis Valley (Colorado Geological Survey; Ground Water Atlas of Colorado).

Exhibit F is a cross section of the central part of the San Luis Valley that shows the Alamosa Formation (Qa) at the top of the sedimentary sequence throughout the basin (Colorado Geological Survey; Ground Water Atlas of Colorado).

Exhibit G - The designation of the Ogallala aquifer of the High Plains and the unconfined aquifer of the San Luis Valley as Type II aquifers was presented to all contractors in an earlier discussion of aquifer types. The discussion was mailed to all contractors with their license renewal packet in November of 2000 and an abbreviated version was subsequently printed in the Drillstem (November 2000 - attached).

Exhibit H is the map currently used by the Geotechnical Branch to determine the depth to the confining clay series in the San Luis Valley. The map shows the variation of thickness of the unconfined aquifer in the valley.

Dave McElhaney, Professional Geologist
Division of Water Resources
Geotechnical Branch

ALLUVIAL DEPOSITS

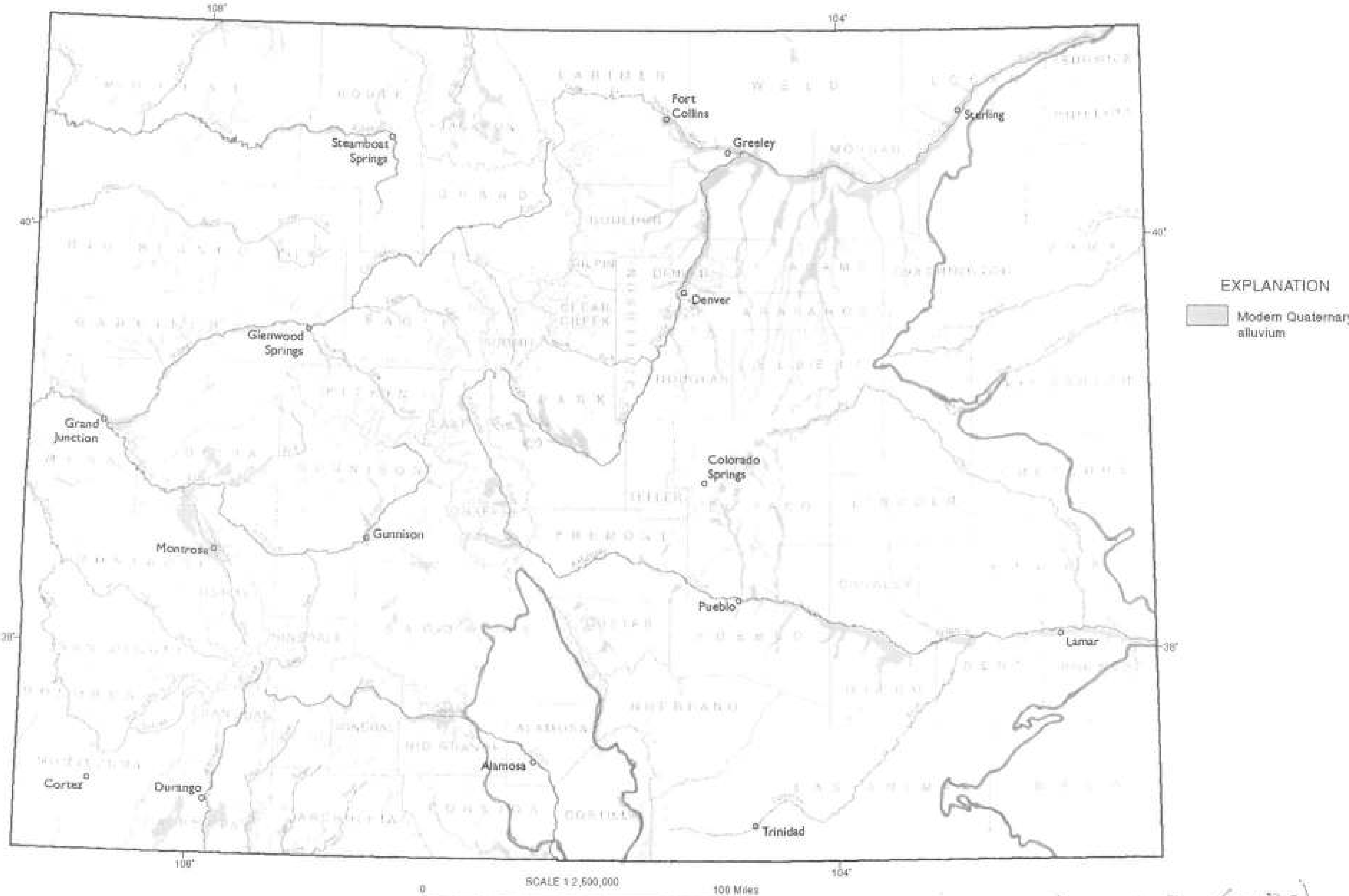
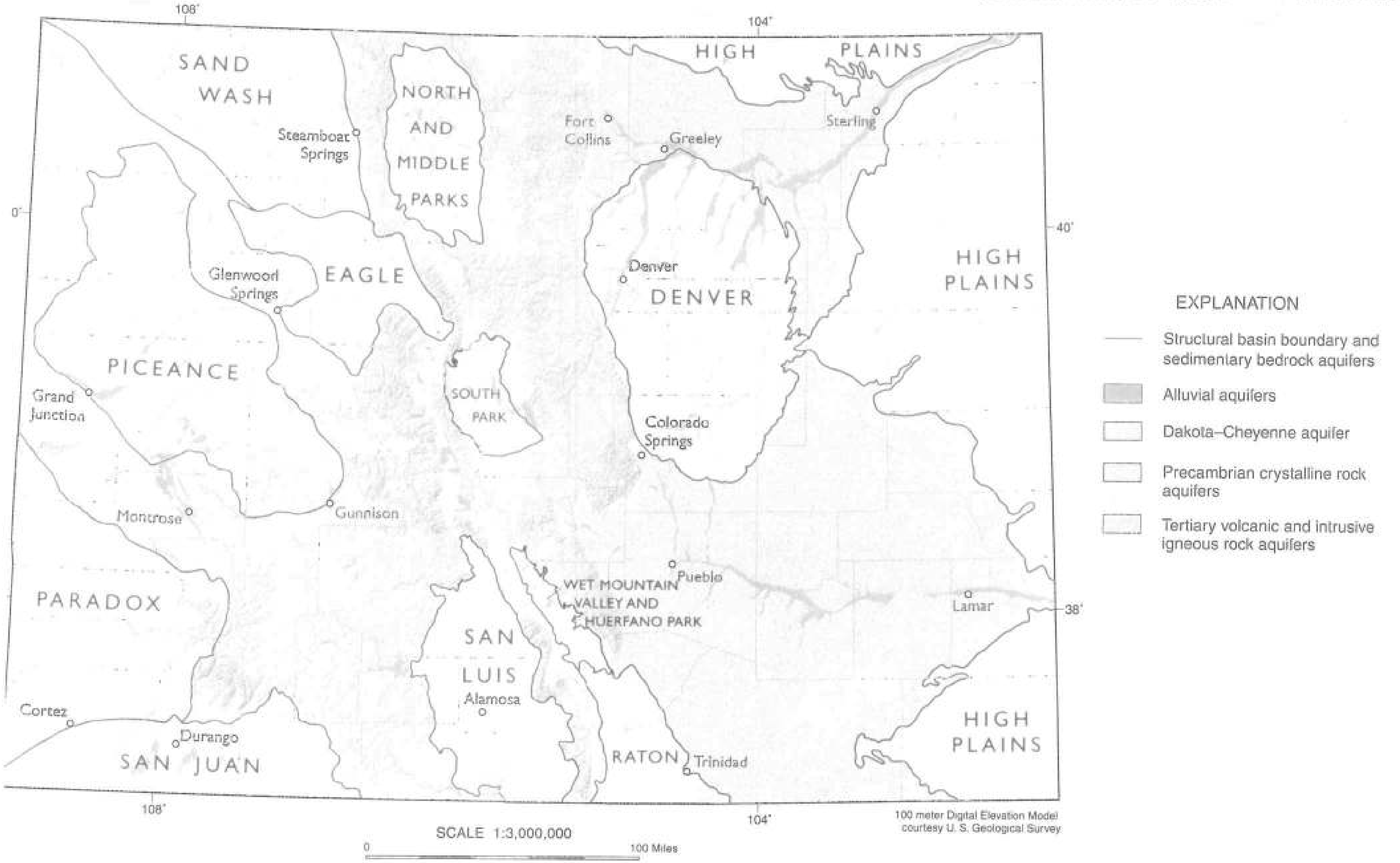


Figure 4-3 (pg 33)

EXHIBIT A

Ground Water Atlas of Colorado



gure 1-4. **Principal aquifers and structural basins of Colorado.**

Ex B

Table 5-2

The Geologic Column

Major Worldwide Subdivisions, Selected Events in Physical and Biological Earth History

Uniform Time Scale: 570 m.y. — 1 B.y. (1000 m.y.) — 2 — 3 — 4 — 4650 m.y.

Eon	Era	System/ Period	Series/ Epoch	Radiometric Dates (millions of yrs. before present)	Outstanding Events: Physical	Outstanding Events: Biological
Phanerozoic	Cenozoic		Holocene	.008	Recent glacial advances 'Great Lakes, Missouri, Ohio R.	Homo Sapiens
		Quaternary	Pleistocene	2		
		Tertiary	Pliocene	5	Beginning of Colorado River	Homo erectus Modern great apes Primitive hominids
			Miocene	25	Basin and Range formation, Utah, Nevada	Grasses
			Oligocene	36		
			Eocene	58	Beginning of volcanic activity at Yellowstone	Complete mammalian-dominated ecosystems Radiation of mammals
			Paleozoic	63	Beginning of Rocky Mountains	Dinosaurs disappear Flowering plants
	Mesozoic	Cretaceous	(many)	135	Beginning of Lower Mississippi	Climax of dinosaurs
		Jurassic		181		Birds
		Triassic		230	Beginning of Atlantic Ocean basin	Mammals, Dinosaurs, Conifers
	Paleozoic	Permian			Climas of Applachian orogeny	"Coal" forests, insects, reptiles, amphibians
		Pennsylvanian		280		
				340	Earliest economic coal deposits	Land plants & animals
		Mississippian		365		
		Devonian		405		
		Silurian		425		Primitive fishes
		Ordovician		500	Beginning of Appalachians	Marine animals abundant
		Cambrian			Earliest of land Gas fields	
	ERA			Age of Boundary (in Ma) 570 (Approximate)		Primitive aquatic animals and algae Diversity of bacteria, blue-green
Proterozoic	Proterozoic III			900	Oldest dated earth rocks	Diversity of Bacteria photosynthesis
	Proterozoic II			1,600	Formation of continents	
	Proterozoic I			2500		No life known
	Archaeozoic			4650	Oldest dated rocks (Moon)	

EXHIBIT C

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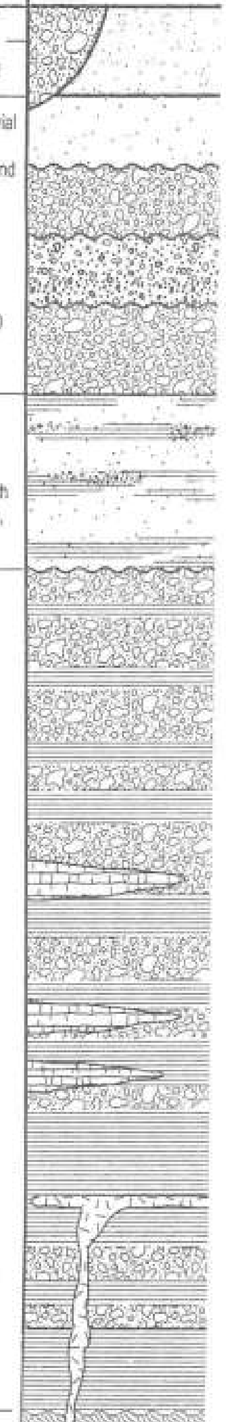
Era	System	Series	Stratigraphic Unit	Physical Cha ...eristics		Hydrogeologic Unit	Saturated thickness (feet)	Hydrologic characteristics
Cenozoic	Quaternary	Holocene	Stream deposits	Well to poorly sorted, uncemented, sands, silts, and gravels		Qal		Permeability controlled by reworked older alluvial materials
			Eolian sands	Well-rounded sands forming active and stabilized dunes	Unconfined aquifer (HRS unit 1)	Qs		Hydraulic conductivity ranges from 0.020 to 0.072 cm/sec, with an average of 0.042 cm/sec
			Alluvial fan 4	Poorly sorted, rounded to sub-angular gravels, sands, and silts; forms small, steeply-sided undissected alluvial fans, standing at modern stream level; found only as small cones at the mouths of small canyons and at the toes of older alluvial fans		Qf_4		Hydraulic conductivities in the alluvial fans ranged from 0.033 to 1.333 centimeters per second (cm/sec), and averaged 0.225 cm/sec
		Pleistocene	Alluvial fan 3	Poorly sorted, rounded to sub-angular gravels, sands, and silts; forms large gently sloped relatively undissected alluvial fans, standing (8–12 feet) above modern stream level		Qf_3		
			Alluvial fan 2	Poorly sorted, rounded to sub-angular gravels, sands, and silts, forming large intermediate-sloped moderately dissected alluvial fans, standing (40 feet) above modern stream levels		Qf_2		Pumping tests in Qf_3 produced permeabilities of 3.8×10^{-3} to 2.8×10^{-2} cm / sec and transmissivities of 2,400 to 11,600 gpd / ft
			Alluvial fan 1	Poorly sorted, rounded to sub-angular gravels, sands, and silts, forming large steeply sloped strongly dissected alluvial fans, standing (60–90 feet) above modern stream level; characterized by a caliche layer near upper fan surface		Qf_1		
			Alamosa Formation	Interbedded, discontinous, blue, gray, and green clays and dark sands; sands are dominantly fine-grained; uppermost clay layers divide valley into an upper unconfined aquifer and lower confined aquifers; 0–20,000 feet		HRS unit 2	0–200	Unconfined aquifer has transmissivities ranging from 5,000 to 225,000 gpd/ft; specific yield estimated to be 0.20; yields as much as 3,000 gpm (Emery and others, 1971)
	Tertiary	Pliocene	Vallejo-Santa Fe Formation	Red to maroon shales, siltstones, and poorly sorted sandstones and conglomerates, with interbedded volcanic flows of the San Juan Mountains; top of the unit is dominantly conglomerates and sandstones, while bottom is dominantly siltstones and shales; deposits are cross-bedded and channel cut; Oligocene sills are found in section	Confined aquifer	HRS unit 3	4,050–14,500	Confined aquifer has transmissivities ranging from 4,000 to 300,000 gpd/ft; storage coefficient estimated to be 0.0001; water under artesian pressure; yields as much as 4,000 gpm (Emery and others, 1971)
		Miocene						Interbedded volcanic flows have different aquifer characteristics from the valley-fill deposits

Lithology



EX. D

Colorado Geol[illegible]al Survey
Ground Water Atlas of Colorado
(pg 158)

…ll data from the Colorado … Water Resources (DWR) …eological Survey (USGS) …er Digital Elevation Model …e U.S. Geological Survey

EXPLANATION

Water Division Office
Water Division 3 boundary
Rio Grande Watershed
Conejos River Watershed
Quaternary alluvium
Wells used in USGS related investigations
Wells of record in DWR permit database

EX. E

…1a. Location and extent of the …e Basin in Colorado showing …ution of permitted water wells

ars, the valley or
:n has continued to
en due to displacement
; bounding faults,
: contemporaneously
; with sediments and
s of volcanic rock shed
the surrounding
ıtains and carried by
iver systems. A
natic block diagram
:ting the structure of
an Luis Valley is pre-
:d as **Figure 7.1-2**. The
ness of the basin-fill
sits is estimated to be
uch as 30,000 feet in the
Luis Valley (Robson and
a, 1995). The San Luis
y is bounded on the
ı and west by Tertiary
ınic rocks, and on the
by igneous, metamor-
and sedimentary rock
ecambrian, Paleozoic,
Mesozoic age (see
oter 1).

Conejos and underlie the Miocene-Pliocene age Santa Fe and Los Pinos Formations. The Santa Fe and Los Pinos

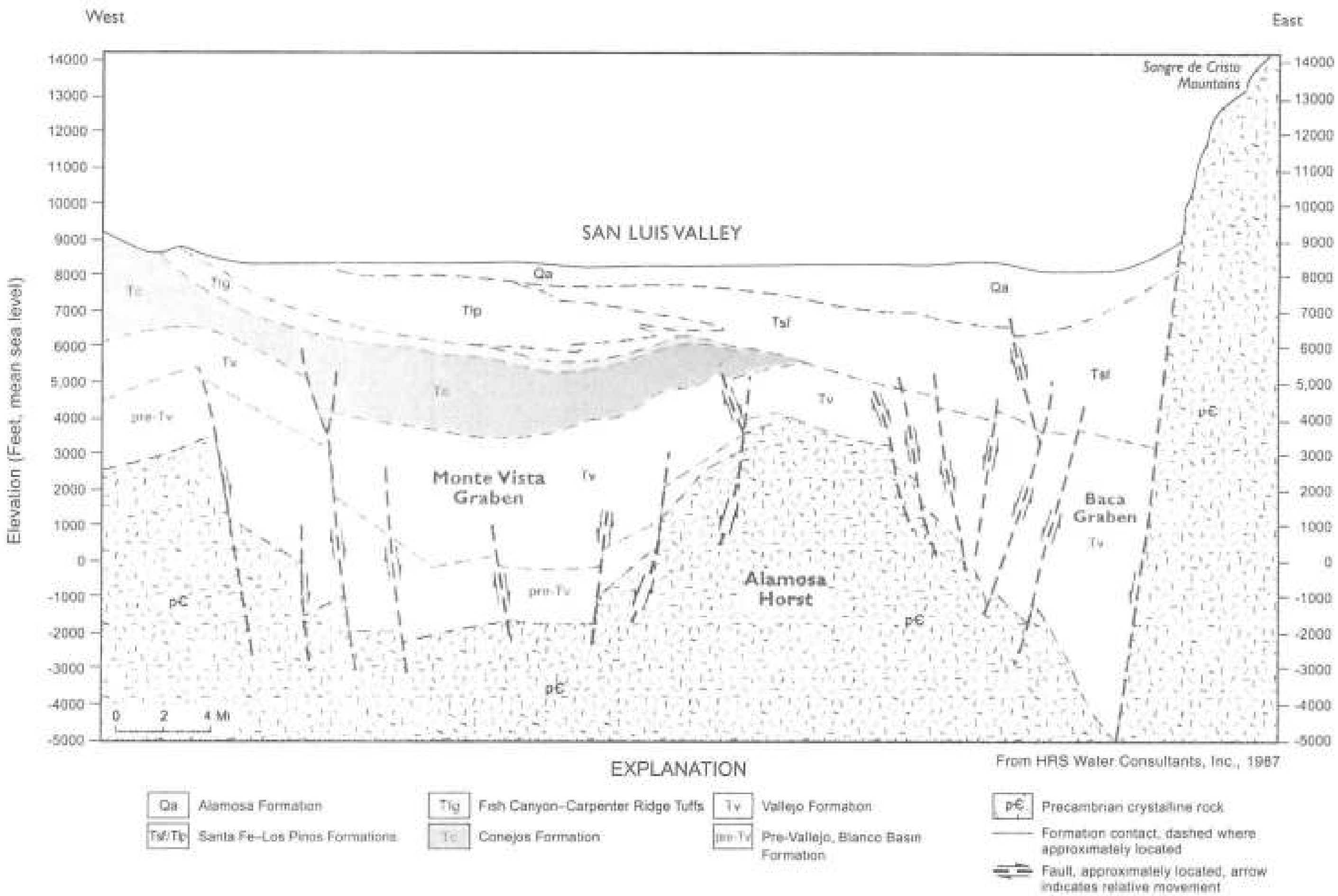


Figure 7.1-3. Generalized geologic cross-section in the central part of the San Luis Valley.

Colorado Geological Survey
Ground Water Atlas of Colorado
(Pg 159)

EX, F

Discussion of Aquifer "Types"

-Dave McElhaney, P.G.

The Board of Examiners of Well Construction and Pump Installation Contractors has adopted Rules that identify three general "types" of aquifers into which wells are constructed to withdraw ground water. The minimum construction standards for grouting are different for each type of aquifer. There has been confusion among some drilling contractors regarding which type of aquifer is being utilized in their specific area and what grouting standards are applicable. The following discussion is presented to try to clarify the Board of Examiners' intent when the aquifer types were developed for their Well Construction Rules.

The aquifer types adopted by the Board are Type I, II, and III aquifers. The aquifer types can be visualized as an ascending group of aquifers with a Type I aquifer (deepest) underlying a Type II aquifer, which in turn is overlain by a Type III aquifer (shallowest). The aquifer model is best represented in the Denver Basin where all three aquifer types can be found at many locations, but is also adaptable to areas of Colorado where the Dakota, Cheyenne, Manitou Springs, Entrada, or other confined aquifers are utilized as a source of ground water. An example of the Denver Basin situation can be found at any location that the South Platte River has deposited alluvial material at the surface (Type III aquifer – unconfined, unconsolidated aquifer material of recent origin) over the sediments that compose the Arapahoe aquifer (Type II aquifer – unconfined bedrock material) which is underlain at some depth by the Laramie-Fox Hills aquifer (Type I aquifer – confined aquifer). The terms "confined aquifer" and "bedrock" are defined in the Water Well Construction Rules and were developed to distinguish between the two general conditions under which ground water is found (unconfined "water table" conditions and confined "artesian" conditions) and two broad categories of material in which the water is stored and transmitted (unconsolidated "alluvial" sand and gravel material and consolidated "cemented, compacted, or crystalized" bedrock material of ancient age).

The applicable construction standards are dependant on the type of material and/or storage conditions into which the well is constructed to withdraw ground water. Type I aquifers are most easily identified and the contractors that work in an area where confined aquifer conditions are found are generally familiar with the geology and the aquifers available. The State Engineer has identified the confined aquifers that are administered as separate sources of water and the well permit will identify a specific aquifer and the interval in which the well can be completed. Type II and Type III aquifers can be more difficult to distinguish because the difference is determined by the type and age of aquifer material in which the water to be withdrawn is stored.

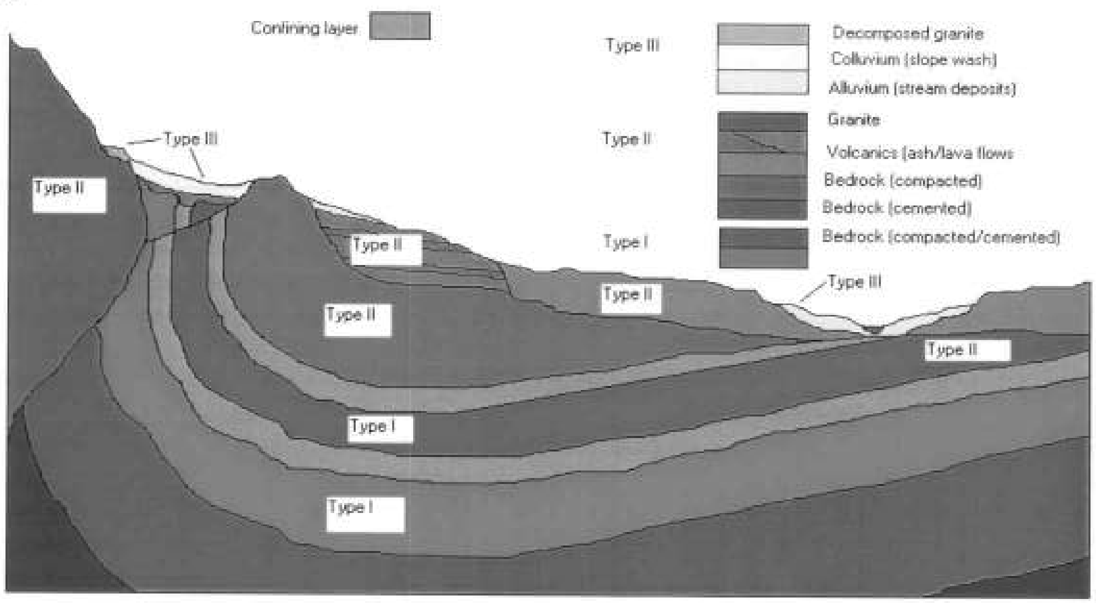
It is very common to penetrate several feet or, in some instances, tens of feet of unconsolidated material before encountering consolidated bedrock material (i.e. shale, sandstone, conglomerate, limestone or granite). If the well terminates in and is constructed to withdraw any water from a zone in the bedrock aquifer, it is a well constructed into a Type II aquifer and must be constructed and grouted in accordance with the standards for wells in Type II aquifers. If the well terminates in and withdraws water from the unconsolidated alluvial material of recent origin, it is constructed into a Type III aquifer and the standards for construction in Type III aquifers apply. The standards for wells constructed into Type III aquifers were developed to alleviate the necessity for obtaining a construction variance when the top of the saturated zone is encountered very near the surface; as is typical in alluvial aquifers.

Some unique situations are encountered in areas where a relatively thin layer of unconsolidated material overlies a thick layer of shale or other impermeable bedrock. Wells constructed in these areas are often drilled into the bedrock to provide a volume of casing storage for the well.

Ex. G

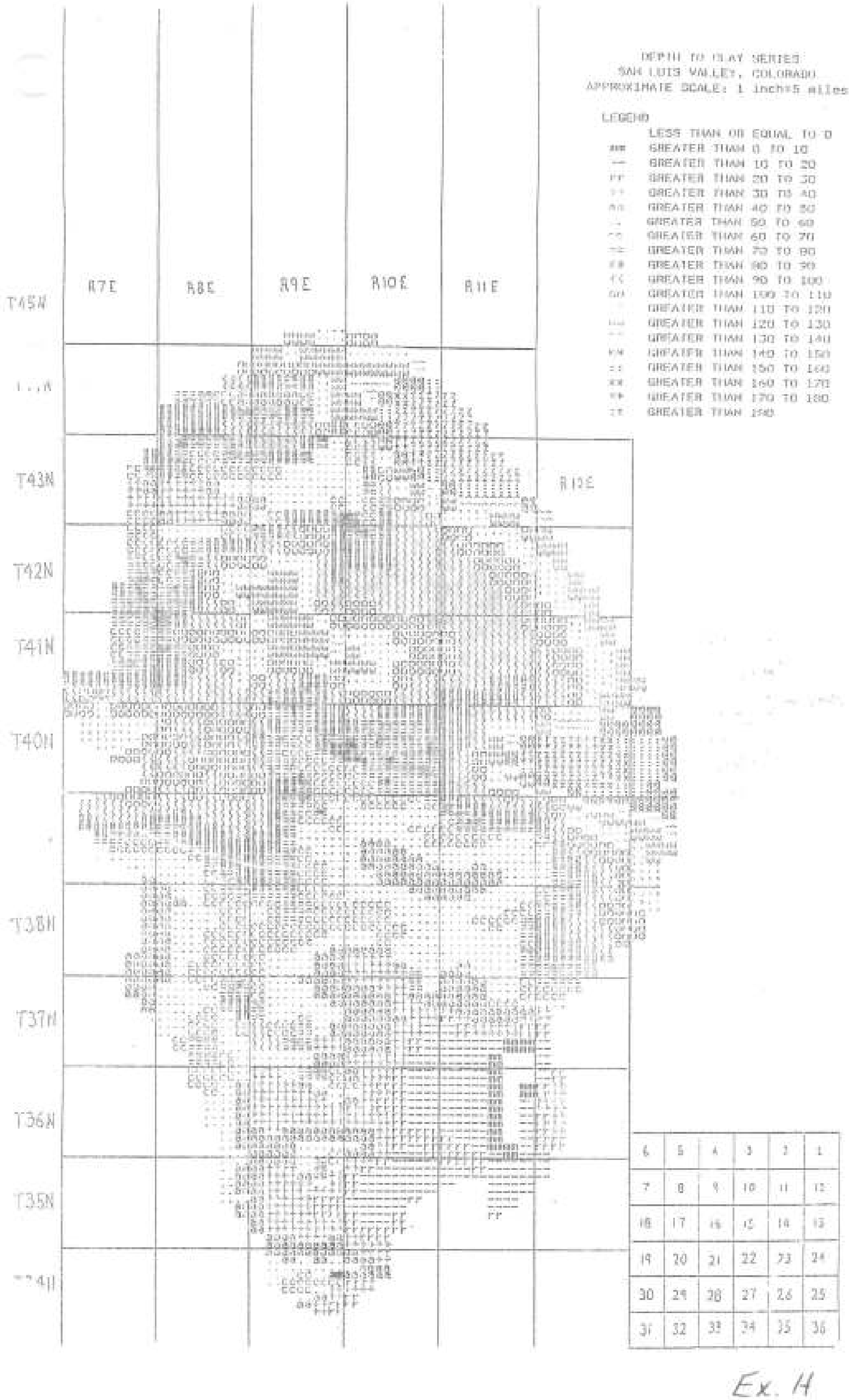
Although the water produced is from the unconsolidated alluvial material, it may enter the well through perforations located near the bottom of the well in the bedrock interval. Because the ground water is actually produced from the unconsolidated material, it is considered to be constructed into a Type III aquifer. If any measurable portion of the water produced originated from the bedrock (compacted or cemented material of older age), the well would be considered to be constructed into a Type II aquifer. To utilize waters from both the bedrock and unconsolidated material, (if the unconsolidated material does not extend to a depth greater than 39 feet - the required depth for grout in a Type II aquifer) a variance would be needed to construct the well to produce water from both sources. Similarly, to construct a well to withdraw water from a thin, unconsolidated material in conjunction with water from a saturated sandstone or other unconfined bedrock source near the surface requires obtaining a variance from the Board (if the well will not be grouted to at least 39 feet); even if the two types of aquifer materials are so interconnected that they have a common water level. An example of the described situation would be where the Ogallala aquifer of the eastern plains (a Type II aquifer consisting of compacted sand and gravel of older age) is overlain with recent stream deposits (alluvial sand and gravel of recent age deposited in a stream valley or flood plain). A similar example is where recent stream deposits overlie the unconfined aquifer of the San Luis Valley.

The following is an illustration of various aquifer types. It is important to note that Type III aquifer deposits are not laterally extensive as compared to Type I and II aquifers and are confined to active stream/river valleys and flood plains. Thus, Type III aquifer materials are limited to areas of decomposition and deposition by weathering, slope wash and stream deposition of recent age (generally considered to be from the present to about 10,000 years in age). Glacial deposits and aquifers associated with a named formation or identified as a member of a named formation (i.e. Ogallala Formation, Arapahoe Formation, Dakota Sandstone, etc.) all exceed the "recent" age.



Schematic cross-section of various types of aquifers

These simple descriptions are not intended to cover all possible scenarios. Contractors who encounter unique situations and/or conditions are encouraged to contact Dave McElhaney or Jack Byers at the Division of Water Resources if they have any question as to the type of aquifer in which a well is to be completed.


DEPTH TO CLAY SERIES
SAN LUIS VALLEY, COLORADO
APPROXIMATE SCALE: 1 inch=5 miles
LEGEND
LESS THAN OR EQUAL TO 0
GREATER THAN 0 TO 10
GREATER THAN 10 TO 20
GREATER THAN 20 TO 30
GREATER THAN 30 TO 40
GREATER THAN 40 TO 50
GREATER THAN 50 TO 60
GREATER THAN 60 TO 70
GREATER THAN 70 TO 80
GREATER THAN 80 TO 90
GREATER THAN 90 TO 100
GREATER THAN 100 TO 110
GREATER THAN 110 TO 120
GREATER THAN 120 TO 130
GREATER THAN 130 TO 140
GREATER THAN 140 TO 150
GREATER THAN 150 TO 160
GREATER THAN 160 TO 170
GREATER THAN 170 TO 180
GREATER THAN 180
R7E
R8E
R9E
R10E
R11E
R12E
T45N
T43N
T42N
T41N
T40N
T38N
T37N
T36N
T35N
6 5 4 3 2 1
7 8 9 10 11 12
18 17 16 15 14 13
19 20 21 22 23 24
30 29 28 27 26 25
31 32 33 34 35 36

Ex. H