Appendix A1

State of Colorado Division of Water Resources
DWR Wells Database

(http://www.water.state.co.us/pubs/welldata.asp).

Well System Data Fields

Field Header	Definition
receipt	The receipt number is the number assigned when the fee is paid. The entire receipt number is eight numeric characters followed by one alphabetic character (if required).
div (Division)	Numeric identifier for Water Division (1-8) in which the well is located.
cty (County)	Numeric identifier for Colorado counties (1-63) in which the well is located:

COLORADO COUNTIES NUMERICAL CODE:

ADAMS	01
ALAMOSA	02
ARAPAHOE	03
ARCHULETA	04
BACA	05
BENT	06
BOULDER	07
CHAFFEE	08
CHEYENNE	09
CLEAR CREEK	10
CONEJOS	11
COSTILLA	12
CROWLEY	13
CUSTER	14
DELTA	15
DENVER	16
DOLORES	17
DOUGLAS	18
EAGLE	19
ELBERT	20
EL PASO	21
FREMONT	22
GARFIELD	23
GILPIN	24
GRAND	25
GUNNISON	26
HINSDALE	27
HUERFANO	28
JACKSON	29
JEFFERSON	30
KIOWA	31
KIT CARSON	32
LAKE	33
LA PLATA	34
LARIMER	35
LAS ANIMAS	36
LINCOLN	37
LOGAN	38
MESA	39
MINERAL	40
MOFFAT	41
MONTEZUMA	42
MONTROSE	43
MORGAN	44
OTERO	45
OURAY	46
PARK	47
PHILLIPS	48
PITKIN	49
PROWERS	50
PUEBLO	51
RIO BLANCO	52
RIO GRANDE	53
ROUTT	54
SAGUACHE	55
SAN JUAN	56
SAN MIGUEL	57
SEDGWICK	58
SUMMIT	59
TELLER	60
WASHINGTON	61
WELD	62
YUMA	63

permitno (Permit Number)	The well permit number (numeric).
permitsuf (Permit Suffix)	A character field for the well suffix code that follows the permit number.
Permitrpl	Identifier indicating a well's replacement.

actdate — Date well permit application received.

actcode — The activity code states status of permit application file:

Code	*Desc*
AP =	New application received.
AD =	Application denied. Denial number entered in permit number field and date entered in permit issued date field.
AW =	Application for a permit is withdrawn. Code and date also entered to status code and date fields.
AV =	Verbal approval granted to well construction contractor to construct a well without a permit in place (emergency only).
CA =	Canceled well permit. Code and date also entered to status code and date fields.
CD =	Change description of acres irrigated (designated basins). Entered to status and date fields of existing record upon receipt of application.
CO =	Application to commingle wells (designated basins). Entered to status and date fields of existing record upon receipt of application.
CP =	Amended household use permit to allow watering of user's noncommercial domestic animals.
EX =	Well permit expiration date extended.
MH =	Monitoring hole notice of construction. MH file number and date entered in permit number and permit date fields.
NP =	Well permit issued. Permit number and issue date entered in permit number and permit date fields.
TH =	Test hole notice. Replaced by MH notice in 1988.
TW =	Test well. Replaced by MH notice in 1988.

wd — A character field which indicates the Water District in which the well is located (1-80). Defined as a basin on minor drainage within the Water Division.

basin — When applicable, a character field indicating the Designated Groundwater Basin Number (1-8):

DESIGNATED BASINS	
NORTHERN HIGH PLAINS	01
KIOWA-BIJOU	02
SOUTHERN HIGH PLAINS	03
UPPER BLACK SQUIRREL CREEK	04
LOST CREEK	05
CAMP CREEK	06
UPPER BIG SANDY	07
UPPER CROW CREEK	08

md — A character field indicating the Designated Groundwater Basin Management District Number (1-13):

MANAGEMENT DISTRICTS (BASINS)	
PLAINS	01
SAND HILLS	02
ARIKAREE	03
FRENCHMAN	04
CENTRAL YUMA	05
W – Y	06
NORTH KIOWA-BIJOU	07
EASTERN CHEYENNE	08
LOST CREEK	09
SOUTHERH HIGH PLAINS	10
MARKS BUTTE	11
UPPER BLACK SQUIRREL	12
UPPER BIG SANDY	13

full name	Applicant name (character field).
address1	A character field for the street portion of the primary mailing address of the permit holder.
address2	A character field for the street portion of a secondary mailing address if submitted.
city	A character field for the City of the primary mailing address.
state	A character field for the State of the primary mailing address
zip1	A character field for the primary zip code.
zip2	A character field for a secondary zip code, if provided.
phone_number	A character field for Applicant's phone number.
pm	Principal Meridian in which well is located (S = Sixth, N = New Mexico, U = Ute, C = Costilla, B = Baca).
rng (Range)	Numeric field for the Range in which well is located.
Rnga	Identifies half ranges ("H")
Rdir	Identifies direction (E, W)
ts (Township)	Numeric field for Township in which well is located.
Tsa	Identifies half ranges ("H")
Tdir	Identifies direction (N, S)
sec (Section)	Numeric field for Section in which well is located (1-36).
Seca	Reserved for locations containing a U in the section number.
QTR160	Character field for quarter section (160 acre quarter) in which well is located.
QTR40	Character field for the quarter-quarter section (40 acre quarter of 160 acre quarter) in which well is located.
QTR10	Character field for the quarter-quarter section (10 acre quarter of 40 acre quarter) in which well is located.
coordsns	Distance (feet) from the north or south section line to the well location.
coordsns_dir	Identifies which section line (N,S) from which distance is measured.
coordsew	Distance (feet) from the east or west section line to the well location.

coordsew_dir Identifies which section line (E,W) from which distance is measured.

AQUIFER1 Aquifer in which well is located.

AQUIFER CODES:

GW	ALL UNNAMED AQUIFERS	
KA	ARAPAHOE	
UKA	UPPER ARAPAHOE	
LKA	LOWER ARAPAHOE	
JMB	BRUSHY BASIN	
KDB	BURRO CANYON	
KCH	CHEYENNE	
CON	CONFINED	SAN LUIS VALLEY
KD	DAKOTA	
TDW	DAWSON	
UTDW	UPPER DAWSON	
LTDW	LOWER DAWSON	
TKD	DENVER	
JE	ENTRADA	
TG	GREEN RIVER	
PH	HERMOSA	
KI	ILES	
KL	LARAMIE	
KLF	LARAMIE FOX HILLS	
ML	LEADVILLE LIMESTONE	
KM	MANCOS	
KMV	MESA VERDE GROUP	
JM	MORRISON	
TO	OGALLALA	
KP	PIERRE SHALE	
KPU	PURGATOIRE	
JMS	SALT WASH	
UNC	UNCONFINED	SAN LUIS VALLEY
TW	WASATCH	
TW	WHITE RIVER	
KW	WILLIAMS FORK	

AQUIFER2 name of second aquifer if well is known to be multiply completed.

subdiv_name Subdivision name.

lot Lot number in subdivision.

block Block number in subdivision.

filing Filing number.

engineer Engineer who approved permit.

well_name Owners's well designation number or name.

Use1 & Use2 Codes for well Uses:

Data Code	Use Description
1	Crop Irrigation
2	Municipal
3	COMMERCIAL
4	INDUSTRIAL
5	RECREATION
6	FISHERY
7	FIRE
8	DOMESTIC
9	LIVESTOCK
G	GEOTHERMAL
H	HOUSEHOLD USE ONLY

K	SNOWMAKING
O	OTHER
O	MONITORING HOLE/WELL
R	RECHARGE
E	EXCHANGE AND AUGMENTATION
Q	=O (Other, or Monitoring Hole/Well)

Use3

CODE	TYPE
A	AUGMENTATION. All wells in augmentation plans are coded with an "A" in the last position. First position is the actual use of the well.
M	MONITORING WELL (PERMITTED). The first position is "O" followed by "M" in the last position.
Z	HOUSEHOLD USE WELLS ISSUED PRIOR TO HB1111 THAT HAVE BEEN AMENDED PURSUANT TO (3)(b)(II)(b) BY $25.00 APPLICATION. First position code is "H" followed by "Z" in the last position.
L	PERMIT ISSUED UNDER PRESUMPTION (3)(b)(II)(A) FOR DOMESTIC/LIVESTOCK USES AS THE ONLY WELL ON 35 ACRES. First position is either "8" domestic or "9" livestock", or both 1st and 2nd followed by "L" in the last position.
	PERMITS ISSUED UNDER (3)(b)(I) WHERE WATER IS AVAILABLE ARE CODED FIRST POSITIONS AS NECESSARY WITH THE ACTUAL USE. HB1111 does not apply to these wells.
G	GRAVEL PIT WELL PERMIT. This application (PERMIT) is coded as "O" in the first position with "G" in the last position.
C	CLOSED LOOP GEOTHERMAL WELL. First position is codes as "G" for geothermal. Last position is "C".
P	GEOTHERMAL PRODUCTION WELL. First position is coded "G" for geothermal. Last position is "P".
S	OTHER TYPES OF HOLES CONSTRUCTED-ESPECIALLY FOR CATHODIC PROTECTION.
	IDENTIFIES THAT THE PERMIT WAS ISSUED PURSUANT TO SENATE BILL 5 (137 (4). First positions are for the actual use(s) of the well.

driller_lic Water well contractor's license number.

pump_lic Pump installation contractor's license number.

pidate Date the pump installation report is received by DWR.

statute Statute under which the permit was issued using the last four numbers of chapter and paragraph, i.e. 37-92-602(3)..602(3). (see www.intellinetusa.com/statmgr.htm)

statcode Interim status of the application or permit:

Code	*Desc*
AB =	Abandoned well.
AR =	Date application for permit resubmitted to DWR.
AU =	Date application returned to applicant for correction or additional information.
EP =	Expired well permit.
NS =	Exempt wells where no statement of use is required (no longer used).
PI =	Pump Installation Report received (no longer used).
PU =	Pump Installation Report returned to responsible party for correction.
RC =	Record change. A portion of the file was modified.
SA =	Statement of beneficial use accepted (no longer used in statute code).
SP =	Statement of beneficial use received (no longer used in statute code).
SR =	Statement of beneficial use resubmitted to DWR.
SU =	Statement of beneficial use returned to owner for correction.
WA =	Well construction report received (no longer used).

WU = Well construction report returned to responsible party for correction.
WR = Well construction report resubmitted to DWR.
ZZ = Transaction code indicates a portion of the file was updated with general review and update of records.

statdate	Date of the above status code action.
npdate	Date the permit, denial (AD) or monitoring hole was issued.
wadate	Date the Well Construction and Test Report was received in DWR.
trancode	Activity or status code. Last action updated.
trandate	Computer machine date of last update to the record.
sadate	Date of first beneficial use.
sbudate	Date statement of use received.
exdate	Expiration date of well permit.
abrdate	Date abandonment report received.
abcodate	Date well plugged and abandoned.
abreq	Flag if the well requires plugging and sealing upon construction of new well
acreft	Annual appropriation in acre feet.
tperf	Depth to top of first perforated casing.
bperf	Depth to base of last perforated casing.
case_no	Water court case number.
yield	Yield in gallons per minute.
depth	Total depth of well.
level	Depth to static water level.
elev	Ground surface elevation.
area_irr	Acres irrigated.
Irr_meas	Acre irrigated units
comment	Comment field
meter	Totalizing flow meter reqd., installed.
wellxno	Cross reference to another well or record.
Wellxsuf	Cross reference character field for well suffix code (follows the permit number).

Wellxrpl	Cross reference identifier indicates well replacement.
Nwcdate nontributary rules).	Notice of Well Construction Report received (Statewide
Nbudate	Notice of Commencement of Beneficial Use received (Statewide nontributary rules).
wcdate	Date well construction completed.
pcdate	Date pump installation completed
log	Flag to indicate if a geophysical is required and received.
qual	Water quality information available, y or n.
user1	Initials of last staff member to update file.
pyield	Proposed yield of well in gpm.
pdepth	Proposed depth of well.
pacreft	Proposed annual appropriation.
well_type	Calculated value to determine if record is exempt, non exempt or georthermal.
valid_permit	Calculated value to determine if a well permit is valid. (must be verified)
parcel_no	Parcel identifier
parcel_size	Parcel size in acres. Number of acres on well site.
noticedate	Notice sent to owner indicating permit about to expire. (Not yet used)
utm_x	A numeric field for the UTM-X coordinate. Note some UTM values are calculated from legal description. All UTM values are Zone 13 based on NAD 27 and Clark 1866 projections.
utm_x	A numeric field for the UTM-X coordinate. Note some UTM values are calculated from legal description. All UTM values are Zone 13 based on NAD 27 and Clark 1866 projections.
utm_y	A numeric field for the UTM-X coordinate. Note some UTM values are calculated from legal description. All UTM values are Zone 13 based on NAD 27 and Clark 1866 projections.
loc_source	Identifies source of UTM coordinates. If blank, the applicant provided the coordinates otherwise the version of the program used to determine the coordinates is given.

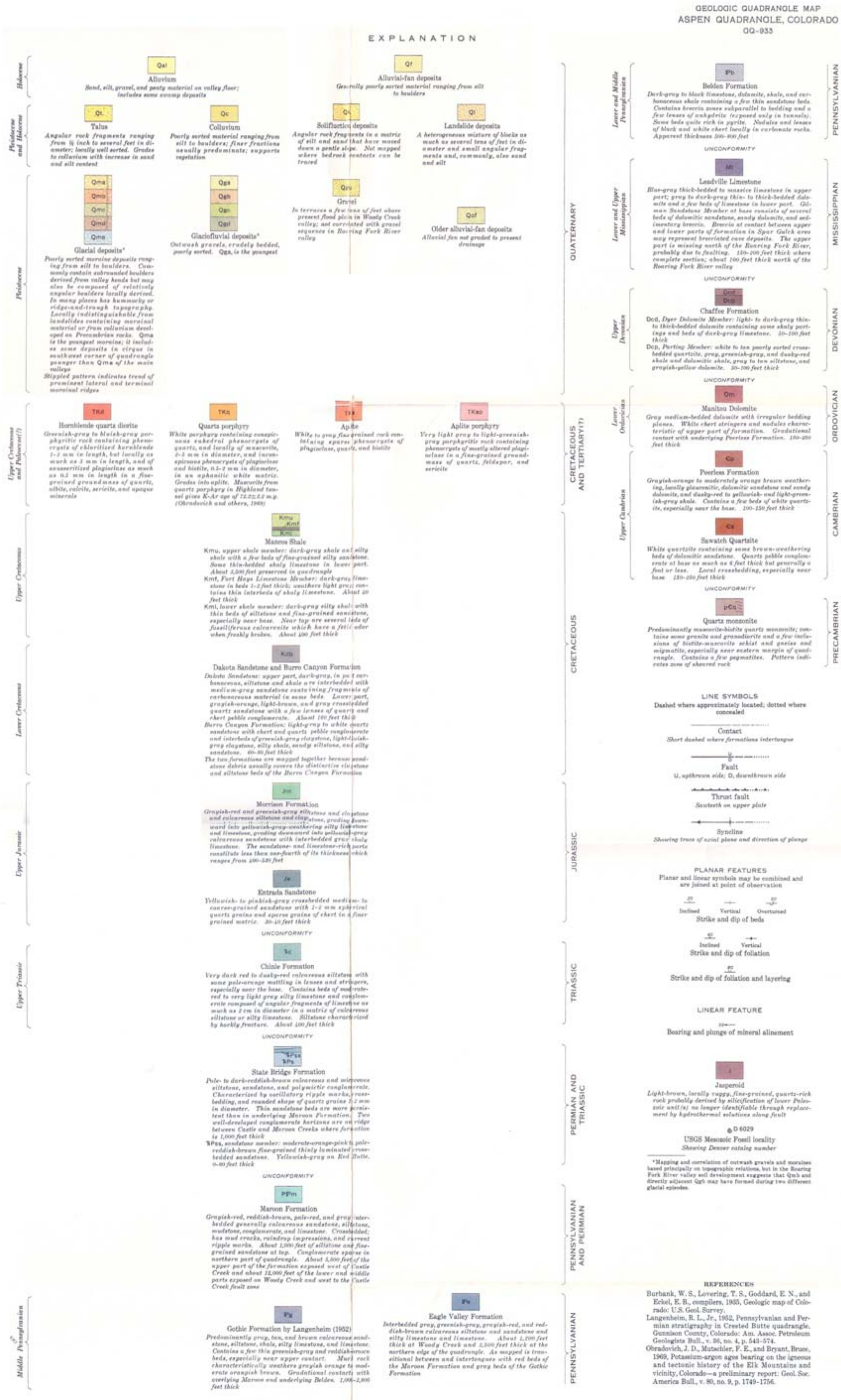
d:documents/word.Well_data fields.doc (6/25/01, ebt)
Modified from wellsys.doc 1/27/97 rab.
`c:officedoc.wellsys.doc`

Appendix A2

Geologic Quadrangle Map
Aspen Quadrangle
Colorado

U.S. Geological Survey
GQ-933

Legend


GEOLOGIC QUADRANGLE MAP
ASPEN QUADRANGLE, COLORADO
GQ-933
EXPLANATION
Alluvium
Alluvial-fan deposits
Talus
Colluvium
Solifluction deposits
Landslide deposits
Gravel
Older alluvial-fan deposits
Glacial deposits
Glaciofluvial deposits
Hornblende quartz diorite
Quartz porphyry
Aplite
Aplite porphyry
Mancos Shale
Dakota Sandstone and Burro Canyon Formation
Morrison Formation
Entrada Sandstone
UNCONFORMITY
Chinle Formation
State Bridge Formation
Maroon Formation
Gothic Formation by Langenheim (1952)
Eagle Valley Formation
Belden Formation
Leadville Limestone
Chaffee Formation
Manitou Dolomite
Peerless Formation
Sawatch Quartzite
Quartz monzonite
QUATERNARY
CRETACEOUS AND TERTIARY(?)
CRETACEOUS
JURASSIC
TRIASSIC
PERMIAN AND TRIASSIC
PENNSYLVANIAN AND PERMIAN
PENNSYLVANIAN
MISSISSIPPIAN
DEVONIAN
ORDOVICIAN
CAMBRIAN
PRECAMBRIAN
LINE SYMBOLS
Contact
Fault
Thrust fault
Syncline
PLANAR FEATURES
Strike and dip of beds
Strike and dip of foliation
Strike and dip of foliation and layering
LINEAR FEATURE
Bearing and plunge of mineral alinement
Jasperoid
USGS Mesozoic Fossil locality
REFERENCES

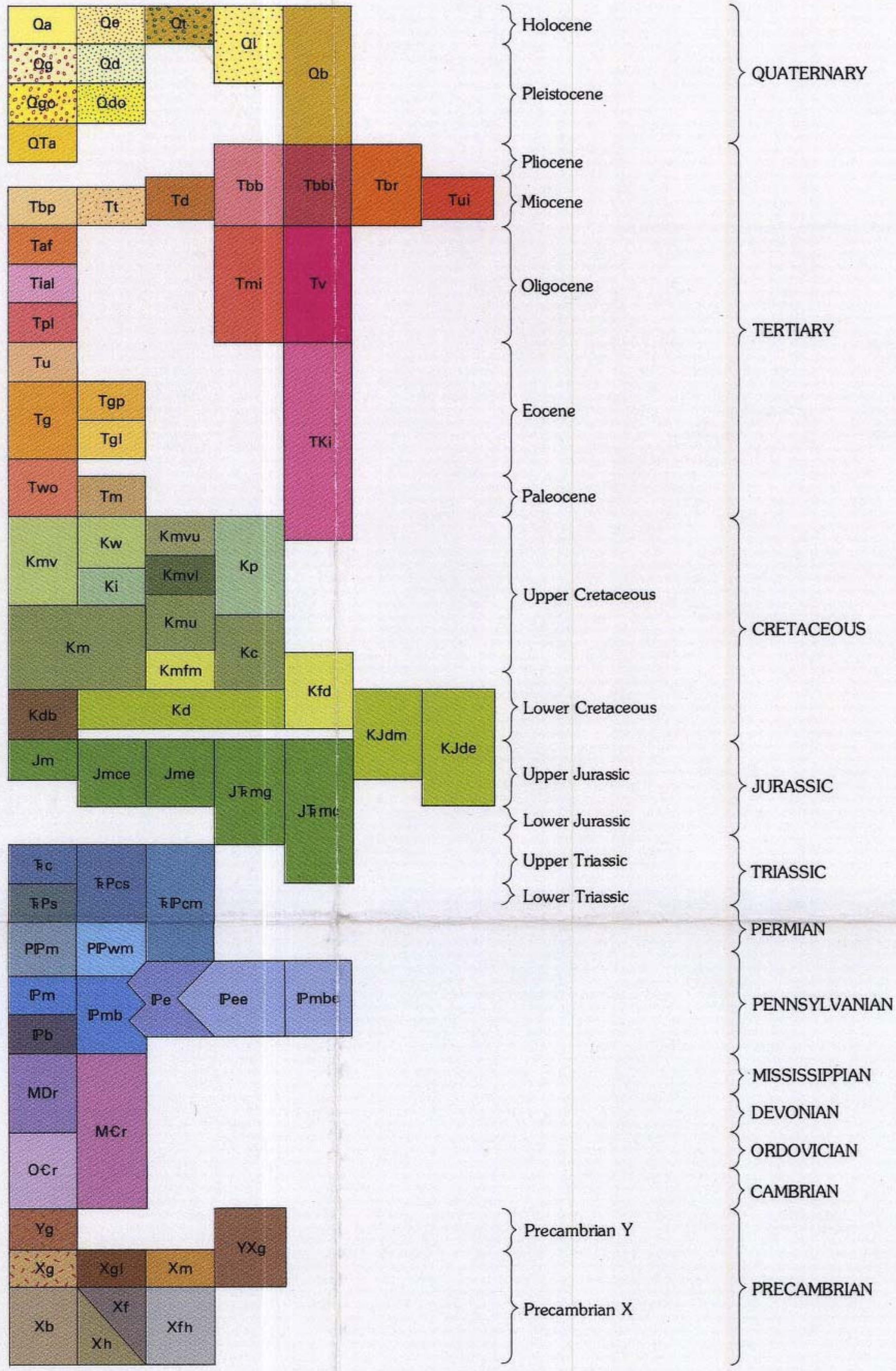
Appendix A3

Geologic Map
Leadville 1^o x 2^o Quadrangle
Colorado

U.S. Geological Survey
Miscellaneous Investigations Series Map I-999

Legend

CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

Formations for which no map symbol is shown are grouped with other stratigraphic units to form map units

UNCONSOLIDATED DEPOSITS (HOLOCENE):

- **Qa** Alluvium—Gravel, sand, and silt in stream valleys and alluvial fans
- **Qe** Eolian deposits—Windblown sand and silt
- **Qt** Talus deposits and rock glaciers

Ql LANDSLIDE DEPOSITS (HOLOCENE AND PLEISTOCENE)—On Grand and Battlement Mesas (southwestern corner of quadrangle), consist principally of large slump blocks of basalt irregularly veneered with young (Pinedale) glacial drift. Elsewhere, include mudflow and some talus deposits. Many small bodies not mapped

Qb YOUNG BASALT (HOLOCENE AND PLEISTOCENE)—In Roaring Fork valley north of Aspen, 1.5 m.y. (million years) old; along Rock Creek north of McCoy, 0.64 m.y. old (Larson and others, 1975, p. 166). Near Dotsero, 4,150 years old (Giegengack, 1962)

- Volcanic cinder cone or crater

UNCONSOLIDATED DEPOSITS (PLEISTOCENE):

- **Qg** Young gravels (Bull Lake and younger)—Stream, terrace, and outwash gravels
- **Qd** Young glacial drift (Bull Lake and younger)—Unsorted bouldery glacial deposits (till) and associated sand and gravel deposits
- **Qgo** Old gravels and alluviums (pre-Bull Lake)—Terrace, outwash, and pediment gravels
- **Qdo** Old glacial drift (pre-Bull Lake)—Unsorted bouldery glacial deposits (till); morainal form subdued or lacking

QTa HIGH-LEVEL ALLUVIUM (PLEISTOCENE AND/OR PLIOCENE)—Fine-grained to bouldery alluvial deposits and gravels; preserved mainly on ridge tops; may not all be of same age; in southwest part of quadrangle, characterized by abundant basalt boulders and in places has been mapped previously as basalt

Tbp BROWNS PARK FORMATION (MIOCENE)—Fluvial ashy siltstone, claystone, sandstone, conglomerate, and thin beds of air-fall ash; loosely consolidated; conglomerate at base. Locally interbedded with basalt (Tbb unit). Thickness >1,000 ft (305 m) south of State Bridge

Tt TROUBLESOME FORMATION (MIOCENE)—Chiefly siltstone; contains many beds of volcanic ash and some of sandstone and conglomerate. Thickness >500 ft (152 m) in Williams Fork valley. Term is used in Middle Park for Miocene rocks largely equivalent to Browns Park Formation west of the Gore Range

Td DRY UNION FORMATION (PLIOCENE AND MIOCENE)—Light-brown sandy siltstone and interbedded friable sandstone, conglomerate, and volcanic ash. Thickness >3,000 ft (915 m) in Arkansas River valley southwest of Leadville

Tbb BASALT OF BIMODAL SUITE (PLIOCENE AND MIOCENE)—Dense black resistant alkali basalt in lava-flow layers 5–200 ft (1.6–61 m) thick, and interbedded tuffs and volcanic conglomerates. Greatest preserved thicknesses are 900 ft (275 m) on White River Plateau and 800 ft (244 m) on Grand Mesa. Ages determined from several localities range from 8 to 23 m.y. (Larson and others, 1975)

Tbbi BASALTIC DIKES AND PLUGS (PLIOCENE AND MIOCENE)—Probable feeders of basalt flows of Tbb unit; also intrusive into the flows

- **Tbbi** Dike

Tbr RHYOLITIC ROCKS OF BIMODAL SUITE (PLIOCENE AND MIOCENE)—In plugs, dikes, and small flows

- **Tbr** Dike

Tui UPPER TERTIARY INTRUSIVE ROCKS (MIOCENE)—Sodic granite of Treasure Mountain south of Marble, and satellitic plugs and dikes. About 12.5 m.y. in age (Obradovich and others, 1969)

Taf ASH-FLOW TUFF (OLIGOCENE)—Dense silicic welded tuff and vitrophyre; principally in Grizzly caldera south of Independence Pass in Sawatch Range

Tial INTER-ASH FLOW ANDESITIC LAVAS AND BRECCIAS (OLIGOCENE)—Mapped only at Buffalo Peaks in southeast corner of quadrangle

Tpl PRE-ASH FLOW ANDESITIC LAVAS AND BRECCIAS (OLIGOCENE)—Mapped only in Grizzly caldera area south of Independence Pass in Sawatch Range

Tmi MIDDLE TERTIARY INTRUSIVE ROCKS (OLIGOCENE; 26–38 m.y.)—Granodiorite and quartz monzonite; generally porphyritic but equigranular in some large bodies; in stocks, dikes, sills, and irregular bodies

- **Tmi** Dike or sill

Tv VOLCANIC ROCKS OF GREEN MOUNTAIN AREA (OLIGOCENE)—Trachytic lavas related to Green Mountain intrusive and volcanic center in Blue River valley.dated by fission-track method at 30 m.y. (Naeser and others, 1973)

Tu UINTA FORMATION (EOCENE)—Siltstone, sandstone, and marlstone. Maximum preserved thickness on Battlement Mesa about 1,000 ft (305 m)

Tg GREEN RIVER FORMATION (EOCENE)—Marlstone, oil shale, siltstone, and sandstone. Undivided unit mapped only at depositional edge of formation in southwest corner of quadrangle

- **Tgp** Parachute Creek Member—Oil shale and marlstone. Thickness 1,200 ft (365 m) on Roan Plateau northwest of Rifle; thins southward to wedge edge near south boundary of quadrangle
- **Tgl** Lower part of Green River Formation—Shale, sandstone, and marlstone in the Anvil Points, Garden Gulch, and Douglas Creek Members. Thickness >2,000 ft (610 m) on Roan Plateau northwest of Rifle; thins southward to wedge edge near south boundary of quadrangle

Two WASATCH AND OHIO CREEK FORMATIONS:

- Wasatch Formation (Eocene and Paleocene)—Variegated claystone, siltstone, sandstone, and conglomerate; carbonaceous shale and lignite near base. Maximum thickness about 5,800 ft (1,770 m)
- Ohio Creek Formation (Paleocene)—Sandstone and conglomerate. Thickness 400 ft (122 m) near south boundary of quadrangle; thins northward to about 50 ft (15 m) along Grand Hogback north of Rifle

Tm MIDDLE PARK FORMATION-UPPER PART (PALEOCENE)—Arkosic grit, conglomerate, sandstone, and mudstone; contains abundant volcanic detritus. Preserved thickness at northeast corner of quadrangle >2,000 ft (610 m)

TKi LARAMIDE INTRUSIVE ROCKS (EOCENE, PALEOCENE, AND UPPER CRETACEOUS; 40–72(?) m.y.)—Quartz monzonite, granodiorite, and quartz diorite porphyries in stocks, sills, and dikes

- **TKi** Dike or sill

Kmv MESAVERDE GROUP UNDIVIDED OR MESAVERDE FORMATION (UPPER CRETACEOUS)

- **Kw** Williams Fork Formation—Light-brown to white sandstone, gray to black shale, and coal beds. Maximum thickness along Grand Hogback north of Rifle is 4,500 ft (1,372 m)
- **Ki** Iles Formation—Massive beds of light-brown to white sandstone and interbedded shale and coal. Trout Creek Sandstone Member at top. Maximum thickness along Grand Hogback north of Rifle is 1,600 ft (488 m)
- **Kmvu** Upper part of Mesaverde Formation—Sandstone, shale, and minor coal beds. Maximum thickness along Grand Hogback south of Colorado River is 2,700 ft (823 m)
- **Kmvl** Lower part of Mesaverde Formation—Sandstone, shale, and coal. Unit thins southward by wedging of lower sandstone beds into Mancos Shale. Thickness near Colorado River is 2,400 ft (732 m); near Carbondale, where Rollins Sandstone Member is at base, 1,400 ft (427 m)

Kp PIERRE SHALE (UPPER CRETACEOUS)—Dark-gray marine shale containing a few thick beds of fine-grained sandstone. Maximum preserved thickness 5,000–6,000 ft (1,525–1,830 m)

- CONTACT
- FAULT—Dotted where concealed. Bar and ball on downthrown side
- THRUST FAULT—Dotted where concealed. Sawteeth on upper plate
- INFERRED FAULT IN VALLEY-FILL DEPOSITS—Largely concealed; location approximate or conjectural. Bar and ball on downthrown side
- PRECAMBRIAN SHEAR ZONE—Dotted where concealed
- ANTICLINE—Showing crestline; dotted where concealed
- SYNCLINE—Showing troughline; dotted where concealed
- MONOCLINE—Showing anticlinal crestline of steep dip; dotted where concealed

Km MANCOS SHALE (UPPER AND LOWER CRETACEOUS)—Gray to dark-gray marine shale. Sandstone beds near the top. Calcareous sandstone of Upper Cretaceous Frontier Sandstone Member 300–400 ft (90–122 m) above base, overlain by calcareous shale zone equivalent to Niobrara Formation. Silver-gray siliceous shale of Lower Cretaceous Mowry Shale Member at base. Thickness north of Colorado River about 5,000 ft (1,525 m); south of river, >6,000 ft (1,820 m)

- **Kmu** Upper unit of Mancos Shale (Upper Cretaceous)—Mancos Shale above the Frontier Sandstone Member
- **Kmfm** Frontier Sandstone and Mowry Shale Members and intervening shale zone (Upper and Lower Cretaceous)—Thickness about 500 ft (152 m)

Kc COLORADO GROUP (UPPER AND LOWER CRETACEOUS)—Consists of Upper Cretaceous Niobrara Formation (calcareous shale and marly limestone) and Upper and Lower Cretaceous Benton Shale, which has calcareous sandstone equivalent to Frontier Sandstone Member of Mancos Shale at top and siliceous shale equivalent to Mowry Shale Member at base. Thickness 800–1,000 ft (244–305 m)

Kd DAKOTA SANDSTONE (LOWER CRETACEOUS)—Light-gray and tan sandstone or quartzite; some interbedded dark shale and shaly sandstone. Resistant, widely exposed unit but too thin to show separately at map scale in many areas. Thickness 125–225 ft (37–68 m)

Kdb DAKOTA SANDSTONE AND BURRO CANYON FORMATION (LOWER CRETACEOUS)—Mapped only in Aspen-Basalt area

- Burro Canyon Formation—Yellow sandstone and green claystone. Maximum thickness 225 ft (68 m)

Kfd FRONTIER SANDSTONE AND MOWRY SHALE MEMBERS OF MANCOS SHALE AND DAKOTA SANDSTONE

Jm MORRISON FORMATION (UPPER JURASSIC)—Variegated shale and mudstone, light-gray sandstone, and local beds of gray and green-gray limestone. Locally conglomeratic near base. Thickness about 500 ft (152 m) along Grand Hogback and along Colorado River near Burns; thins eastward and southeastward to <200 ft (60 m) in Blue River valley

CURTIS FORMATION (UPPER JURASSIC)—Yellowish-gray to pale-green glauconitic sandstone and oolitic limestone. Thickness <100 ft (30 m)

ENTRADA SANDSTONE (UPPER JURASSIC)—Light-gray to orange crossbedded sandstone. Thickness 75–150 ft (23–46 m) in northwest and central parts of quadrangle; wedges out southward in Aspen area and eastward at Gore Range

KJdm DAKOTA FORMATION AND MORRISON FORMATION

KJde DAKOTA, MORRISON, CURTIS, AND ENTRADA FORMATIONS ALONG COLORADO RIVER NEAR BURNS AND STATE BRIDGE; ELSEWHERE, DAKOTA, MORRISON, AND ENTRADA FORMATIONS

Jmce MORRISON, CURTIS, AND ENTRADA FORMATIONS

Jme MORRISON AND ENTRADA FORMATIONS

GLEN CANYON SANDSTONE (LOWER JURASSIC AND UPPER TRIASSIC)—Light-brown to light-gray crossbedded sandstone that closely resembles the overlying Entrada Sandstone, from which it is separated by a subtle unconformity. Maximum thickness 75 ft (23 m)

JTRmg MORRISON, ENTRADA, AND GLEN CANYON FORMATIONS

TRc CHINLE FORMATION (UPPER TRIASSIC)—Brownish- and purplish-red calcareous siltstone, mudstone, and sandstone; limestone-pellet conglomerate in lower part; Gartra Sandstone Member at base (pale-purple to white pebbly sandstone 25 ft or 8 m thick). Thickness 1,200 ft (365 m) near Brush Creek south of Eagle; thins from there in all directions; wedges out beneath pre-Entrada unconformity along west side of Gore Range and in Elk Mountains southwest of Aspen

JTRmc MORRISON, ENTRADA, AND CHINLE FORMATIONS—Along Grand Hogback south of T. 6 S., Chinle is represented only by the Gartra Member

TRPs STATE BRIDGE FORMATION (LOWER TRIASSIC AND PERMIAN)—Orange-red to red-brown siltstone and sandstone. Thickness at least 5,000 ft (1,525 m) in local depositional basin in Hardscrabble Mountain area south of Eagle. To the north, unit is 500 ft (152 m) thick and thins eastward to wedge out along west flank of Gore Range. To the southwest, unit is 2,400 ft (732 m) thick along Fryingpan River east of Basalt but absent beneath pre-Chinle and pre-Entrada unconformities at Grand Hogback and in Elk Mountains

TRPcs CHINLE AND STATE BRIDGE FORMATIONS

PPm MAROON FORMATION (PERMIAN AND PENNSYLVANIAN)—Maroon and grayish-red sandstone, conglomerate, and mudstone; lower part intertongues with Eagle Valley Formation or Evaporite which underlies the Maroon in places. Thickness >9,500 ft (2,900 m) in area southwest of Aspen; thins northeastward to depositional margin along west flank of Gore Range; thinning also due to pre-State Bridge unconformity

WEBER SANDSTONE (PERMIAN AND PENNSYLVANIAN)—Yellow-gray sandstone. Thickness about 100 ft (30 m) near northwest corner of quadrangle; thins toward depositional margin to south and east; present margin south of Glenwood Springs, east of Eagle, and east of Burns results in part from truncation beneath pre-State Bridge unconformity

PPwm WEBER SANDSTONE AND MAROON FORMATION

TRPcm CHINLE, STATE BRIDGE, AND MAROON FORMATIONS

Pm MINTURN FORMATION (PENNSYLVANIAN)—Gray, pale-yellow, and red sandstone, grit, conglomerate, and shale, and scattered beds and reefs of carbonate rocks. Includes rocks of Gothic Formation of Langenheim (1952). Thickness near Minturn >6,000 ft (1,830 m); thins abruptly eastward toward depositional margin along west flank of Gore Range and at Breckenridge. Thins westward and intertongues with Eagle Valley Evaporite in Eagle basin. Thickness on western side of basin, in Elk Mountains, about 3,000 ft (915 m). East and north of Sawatch Range, contact with overlying Maroon Formation is placed at top of highest marine limestone; west of Sawatch Range and White River Plateau, contact is at color change from predominantly gray (Minturn) below to predominantly red (Maroon) above

Pb BELDEN FORMATION (PENNSYLVANIAN)—Dark-gray to black shale, carbonate rocks, and sandstone. Map unit includes local thin lenses of Molas Formation (Pennsylvanian) at base. Maximum thickness in Elk Mountains and White River Plateau area about 900 ft (275 m); thins eastward to depositional margin along Gore Range and near Hoosier Pass

Pmb MINTURN AND BELDEN FORMATIONS

- **Pmbe** Evaporite-bearing facies of Minturn and Belden Formations—Mapped only in South Park, in southeast corner of quadrangle

Pe EAGLE VALLEY FORMATION (PENNSYLVANIAN)—Gray and reddish-gray siltstone, shale, sandstone, carbonate rocks, and local lenses of gypsum. Unit is transitional between the coarse clastic rocks of the Minturn and Maroon Formations and purely evaporitic rocks. Thickness variable, depending on intertonguing relations

Pee EAGLE VALLEY EVAPORITE (PENNSYLVANIAN)—Gypsum, anhydrite, and interbedded siltstone and minor dolomite; contains thick salt at depth in some places, as shown by wells drilled for oil and gas. Intertongues with Minturn, Belden, and Maroon Formations and grades into fine-grained clastic rocks of Eagle Valley Formation. Diapiric in structural configuration in many places, especially in large area in central part of quadrangle. Thickness indeterminate

MDr MISSISSIPPIAN AND DEVONIAN ROCKS—Includes rocks of, Leadville Limestone (or Dolomite) (Mississippian) and Chaffee Group (Mississippian? and Devonian). Leadville thickness variable beneath pre-Belden unconformity; maximum of about 275 ft (84 m) in Elk Mountains; truncated eastward along west flank of Gore Range and near Hoosier Pass. Chaffee Group consists of Gilman Sandstone (Mississippian or Devonian), Dyer Dolomite (Mississippian? and Devonian) and Parting Formation (Devonian). Maximum thickness of Chaffee Group 250 ft (76 m) in White River Plateau area; truncated beneath pre-Belden unconformity along west flank of Gore Range and near Hoosier Pass

OCr ORDOVICIAN AND CAMBRIAN ROCKS—Includes various combinations of: Fremont Limestone (Ordovician), Harding Sandstone (Ordovician), Manitou Dolomite (Ordovician), Dotsero Formation (Cambrian), Peerless Formation (Cambrian), and Sawatch Quartzite (Cambrian). Fremont is present beneath pre-Parting unconformity only in western Elk Mountains. Harding is present beneath pre-Parting and pre-Fremont unconformities only in western Elk Mountains and along Eagle River from Minturn area to Tennessee Pass. Manitou is widespread but in eastern part of quadrangle is absent beneath pre-Harding and younger unconformities from Pando and Breckenridge northward. Dotsero is mapped only in White River Plateau area. Peerless and Sawatch are widespread but are truncated beneath various unconformities along Gore Range and near Breckenridge. Maximum thickness of Ordovician and Cambrian rocks about 750 ft (230 m) in White River Plateau area

MCr MISSISSIPPIAN, DEVONIAN, ORDOVICIAN, AND CAMBRIAN ROCKS

Yg GRANITIC ROCKS (PRECAMBRIAN Y— 1,400 m.y. AGE GROUP)—Includes Silver Plume and St. Kevin Granites and equivalents

Xg GRANITIC ROCKS (PRECAMBRIAN X— 1,700 m.y. AGE GROUP)—Includes Cross Creek Granite of Gore and northern Sawatch Ranges, Denny Creek Granodiorite of central Sawatch Range, and equivalent rocks

Xgl LEUCOCRATIC GRANITIC ROCKS (PRECAMBRIAN X)—Includes trondhjemitic Kroenke Granodiorite in Sawatch Range, and granite at Taylor Pass southeast of Ashcroft Mountain in the Elk Mountains

YXg GRANITIC ROCKS UNDIVIDED (PRECAMBRIAN Y AND X)

Xm MAFIC INTRUSIVE ROCKS (PRECAMBRIAN X)—Noritic gabbro

Xb BIOTITIC GNEISSES AND MIGMATITE (PRECAMBRIAN X)—Unit contains minor interlayered hornblende gneiss and calc-silicate rocks. Parent materials mainly graywacke and shale

Xf FELSIC GNEISSES (PRECAMBRIAN X)—Parent materials probably igneous rocks of intermediate compositions

Xh HORNBLENDIC GNEISSES (PRECAMBRIAN X)—Parent materials probably mainly basaltic and andesitic igneous rocks; some of gneiss is closely associated with calc-silicate rocks and minor marble and probably is metasedimentary

Xfh INTERLAYERED FELSIC AND HORNBLENDIC GNEISSES (PRECAMBRIAN X)

Appendix A4

Summary of Hydrogeologic Units in Upper and Middle Roaring Fork Study Area Pitkin County, Colorado

Hydrogeological Units in Upper and Middle Roaring Fork Study Area
Pitkin County, Colorado

Hydrologic Systems Analysis, LLC., Golden, Colorado

1. Surficial Aquifer Materials

Modern Alluvium *(Qal; alluvium)*. Sand, silt, gravel and peaty material on valley floor [USGS GQ-933, 1971]. This material is primarily located along the modern streams, such as Owl Creek and Brush Creek, and rivers, such as the Roaring Fork. These materials usually are natural aquifers that have direct connection to and are sustained by the nearby surface water bodies, and are most likely vulnerable due to being prone to seasonal fluctuations and changes in surface water body use (withdrawal for irrigation, for example).

Terrace Gravels *(Q, Qg, Qf, and Qc; young terrace gravels, fans, colluvium)*. Combination of primarily glaciofluvial deposits (Qg, outwash gravels, crudely bedded, poorly sorted), and some alluvial fan deposits (Qf, poorly sorted material ranging from silt to boulders), and colluvium (Qc, poorly sorted material ranging from silt to boulders; finer fraction usually dominates) [USGS GQ-933, 1971]. This material is primarily located above the modern stream levels on the hillslopes. These materials usually are dry, or can be aquifers created and sustained by anthropogenic activity, such as irrigation ditches or irrigation return flow.

Moraines *(Qm; terminal and lateral moraines)*. Poorly sorted glacial deposits ranging from silt to boulders; locally indistinguishable from landslide deposits or colluvium [USGS GQ-933, 1971]. This material is primarily located at mountain canyon mouths, such as the Roaring Fork River, and Castle and Maroon Creek canyons, or along the higher hillslope locations near the high glacially carved hanging valleys and cirques, such as the slopes along Burnt Mountain near Snowmass Village. The moraines of the Roaring Fork River and Castle and Maroon Creeks are dry near the surface, but frequently contain natural ground water at depth. The moraines and associated mass wasting deposits of the Owl and Brush Creek areas also contain natural ground water at depth, and are sustained by natural climate and underlying Dakota Formation in some locations.

Landslides *(Ql, Qls, landslide deposits)*. A heterogeneous mixture of blocks as much as several tens of feet in diameter and smaller angular fragments and , commonly also sand and silt [USGS GQ-933, 1971]. This material is primarily located along the hillslopes surrounding the populated areas of Pitkin County. These materials are mostly dry, but in areas of irrigation ditches and other anthropogenic activity, may become aquifers.

Older terrace gravels and fans *(Ts, Qof; Tertiary/Pleistocene(?) deposits; see terrace gravels and fans)*. This material is primarily located along the hillslopes. These materials usually are dry, or can be aquifers created and sustained by anthropogenic activity, such as irrigation ditches or irrigation return flow.

These surficial materials, when saturated, will be primarily unconfined or water table systems. Therefore, the water table will fluctuate naturally with climate input (seasonal rainfall and snowmelt). In addition, these aquifers, in the absence of overlying low-

permeability units, will be vulnerable to contamination from land surface activity, such as irrigation, industrial, or urban uses.

2. Bedrock Aquifer Material

Dakota Sandstone *(Kd, Lower Cretaceous).* This unit is primarily a sandstone that may have either matrix or fracture permeability. Aquifer conditions may be unconfined or confined dependent on overlying geologic unit. Given the age of the unit, fracture permeability is likely to be most significant for water supply. Typically, this unit is located at a depth greater than 200 feet under most of the study area west of the City of Aspen.

Leadville Limestone *(Ml, Mississippian; Carbonates)* This unit is primarily a limestone that has mostly fracture and karst permeability. Aquifer conditions may be unconfined or confined dependent on overlying geologic unit. The unit is located a depths greater than 1,000 feet under most of the study area west of the City of Aspen.

Fractured Crystalline Material *(Granite, Gneiss, etc).* This unit is primarily igneous or metamorphic crystalline rocks that have mostly fracture permeability. The unit has vast thicknesses, however, the depth to which saturated thickness of this (mostly unconfined) unit is maintained is usually not greater than 500 feet. Note that the fractured crystalline material is found primarily beneath BLM and U.S. Forest Service lands, and is located in the upper Roaring Fork Drainage and North Star area.

For the current study area, only the surficial material, the Dakota Sandstone, and the fractured crystalline rocks are of interest. The Leadville Limestone is of interest when the study is extended to Aspen and nearby areas.

3. Bedrock Aquitard Material

Mancos Shale *(Km, Upper Cretaceous).* This unit consists of an upper and lower shale member of significant thickness, separated by an up to 40 ft thick limestone member (Fort Hays Limestone). This very low-permeability unit serves as a confining layer when present, primarily in the western half of the Middle Roaring Fork study area.

Appendix A5

Stepwise Approach to Assessing Ground Water Availability, Sustainability, and Vulnerability in Upper and Middle Roaring Fork Study Area, Pitkin County, Colorado

Stepwise Approach to Assessing Ground Water Availability, Sustainability, and Vulnerability in Upper and Middle Roaring Fork Study Area, Pitkin County, Colorado

Hydrologic Systems Analysis, LLC., Golden, Colorado

Steps 1 – 2 prompt the user to initiate the GIS and locate the site being evaluated.

Step 1. Start ARCMAP™ Version 8.3 (ESRI®, Redlands, California) or higher and load the Middle Roaring Fork (MRF) or Upper Roaring Fork (URF) annotated map dependent on the location of the site [*file: PitkinCounty_GWGIS_MRFannotated.mxd or PitkinCounty_GWGIS_URFannotated.mxd*].

Step 2. The precise location or platting of the permit site (PS) should be plotted on the URF or MRF map using the appropriate layers in the GIS (e.g., using site coordinates or location information on existing wells, roads, parcels, etc.). This location is used in conjunction with the hydrology and hydrogeology GIS layers to determine the presence of ground water (Steps 3 - 6). The succeeding tasks include determining the level of ground water sustainability as a resource at the site (Steps 7-9), and its vulnerability to contamination and subsequent loss of supply (Step 10). It should be noted that due to limitations in data availability and quality, this analysis is primarily qualitative in nature. It does not replace due diligence on the side of the permit applicant.

Steps 3 – 6 allow the user to determine the potential availability of ground water for water supply at the site by identifying the areas covered by hydrogeologic formations that may be an aquifer (either unconsolidated surficial materials or bedrock) and evaluating the presence or absence of ground water in these formations (see document *HSA_Hydrogeology_Legend.pdf* for descriptions of hydrogeological units).

Step 3. Determine the potential unconfined surficial aquifer material at the site. Check to see if the site is located in one of the following units:

> For Unit 1: Modern Alluvium (Qal; alluvium). *In the MRF GIS map, switch on layer S; in the URF GIS map, switch on layer Q or layer R.*
>
> For Unit 2: Terrace Gravels (Q or Qg; young terrace gravels, fans, colluvium). *In the MRF GIS map, switch on layer T; in the URF GIS map, switch on layer Q or layer R.*
>
> For Unit 3: Moraines (Qm; moraines). *In the MRF GIS map, switch on layer U; in the URF GIS map, switch on layer Q or layer R.*
>
> For Unit 4: Landslides (Qls). *In the MRF GIS map, switch on layer V; in the URF GIS map, switch on layer Q or layer R.*
>
> For Unit 5: Older terrace gravels and fans (Ts). *In the MRF GIS map, switch on layer W; in the URF GIS map, switch on layer Q or layer R.*

Step 4. Determine potential unconfined and confined bedrock aquifer material at site. Check to see if the site is located in one of the following units:

For Unit 7: Dakota Sandstone (unconfined or confined). *In the MRF GIS map, switch on layers Y and/or BB; in the URF GIS map, switch on layer Q or layer R.*

For Unit 8a: Leadville Limestone (Carbonates) (unconfined or confined). *In the MRF GIS map, switch on layers Y and/or BB; in the URF GIS map, switch on layer Q or layer R.*

For Unit 8b: Fractured Crystalline Material (Granite, Gneiss, etc) (unconfined). *In the MRF GIS map, switch on layers Y and/or BB; in the URF GIS map, switch on layer Q or layer R.*

Note that Hydrogeologic Unit 6 is Mancos Shale, a potential aquitard.

Alternatively, step 3 and 4 combined (MRF only); use: 1) Locate the site in a set of layers showing the outcrops of all hydrogeologic units combined: *switch on MRF layers R and EE together*; or 2) Locate site with respect to each of the unconsolidated hydrogeologic units (*switch on MRF layers S, T, U, V and W, separately)* and each of the potential bedrock aquifers (switch on *MRF layers BB and CC, separately).*

Step 5. Determine if the potential alluvial/colluvial aquifer is connected/not connected with a bedrock aquifer. This step determines if the alluvial/colluvial aquifer is sustained by a bedrock aquifer, or sustained solely by surface processes, such as a nearby river. For the MRF, presence of Mancos Shale indicates absence of connectivity; for the URF, additional professional judgment may be needed to interpret geologic map. Overlay the surficial layers over the bedrock layers to determine connectivity: *in the MRF GIS map, switch on layers R and EE and check presence of unit 6 (Mancos Shale); in the URF GIS map, switch on layer Q or layer R, determine geologic stack, and check for connectivity.*

Step 6. Determine if the alluvial/colluvial material is saturated or unsaturated. This step shows the availability of ground water for the site. Identify one or more relevant wells based on distance to PS and comparable hydrogeology (*switch on layer GG and combine with layers identified as relevant in steps 3-5)*. Using the accompanying attribute table in layer GG, well depth, depth to encountered water below the surface (and calculated saturated thickness, and well production (gal per minute yield) may be determined. This step could be used to quantitatively determine the amount of ground water available, but requires professional judgment using standard practices.

Steps 7 – 10 allow the user to determine the potential sustainability and vulnerability of ground water for use as a water supply for the site.

Step 7. Determine amount of direct infiltration of precipitation into the alluvial/colluvial aquifer or the bedrock aquifer. This step is performed to determine recharge to the aquifer from precipitation. To assess the recharge potential from precipitation in the vicinity of the site, a precipitation layer is included in the GIS maps *(layer C in both MRF and URF GIS maps)*. Calculation of actual recharge amounts (a fraction of precipitation) requires professional judgment using standard practices.

Step 8. Determine if the alluvial/colluvial aquifer is connected/not connected with a perennial stream. This step is performed to determine recharge to the aquifer from any nearby surface water system. The attribute table of Pitkin County's water GIS layer *(GIS layer F in both MRF and URF GIS maps)* contains, among others, a field in the attribute table indicating intermittent stream flow (ephemeral stream) or continuous stream flow (perennial stream). By combining hydrogeologic information from the alluvial aquifer layer (*layer O in both MRF and URF GIS maps*), or the information resulting from steps 3-6, with the county's streams layer F, the existence of a hydraulic connection can be established. Calculation of actual recharge amounts and effect of new well on stream requires professional judgment using standard practices.

Step 9. Determine if the saturated alluvial/colluvial aquifer is connected with an irrigation ditch or return flow of irrigation water. This step is performed to determine recharge to the aquifer from any irrigation practices, which may not sustain a ground water supply if water uses and water rights ownership change. In order to establish if the saturated portion of the potential aquifer of interest is connected with an irrigation ditch, hydrogeologic information from the alluvial aquifer layer (*layer O in both MRF and URF GIS maps*), or the information resulting from steps 3-6, is combined with the county's ditches layer (*layer H in both MRF and URF GIS maps*). The potential effect of the return flow of irrigated acreage on recharge can be evaluated by plotting the PS on the 2000 or 1993 irrigated acreage layer (*layer D and E, respectively*). Calculation of actual recharge amounts requires professional judgment using standard practices.

Step 10. Determine the vulnerability of ground water supplies to contamination from the surface for the site. Natural protection from overlying confining units, such as the Mancos Shale, is important for maintaining natural water quality, However, all ground water in the area shown in the MRF layers R (unconsolidated sediments), Y (Dakota Sandstone outcrops) & Z (Lower Bedrock outcrops) is vulnerable; natural protection is only available in areas shown by the MRF layer DD (extent Mancos Shale) for ground water in the Dakota Sandstone underneath the Mancos Shale. *In the MRF GIS map, switch on layer EE and check presence of unit 6 (Mancos Shale) at PS; in the URF GIS map, switch on layer Q or layer R and check geologic stack for presence of Mancos Shale (or other potentially confining layers).* If the Mancos Shale is present, determine if there is an underlying aquifer (Dakota) that may be a source of ground water: *in the MRF GIS map, switch on layer FF and check presence of unit 7 (Dakota Sandstone) at PS; in the URF GIS map, switch on layer Q or layer R and check geologic stack for presence of Dakota Sandstone underneath Mancos Shale.* Calculation of actual risk (both qualitatively and quantitatively) requires professional judgment using standard practices.