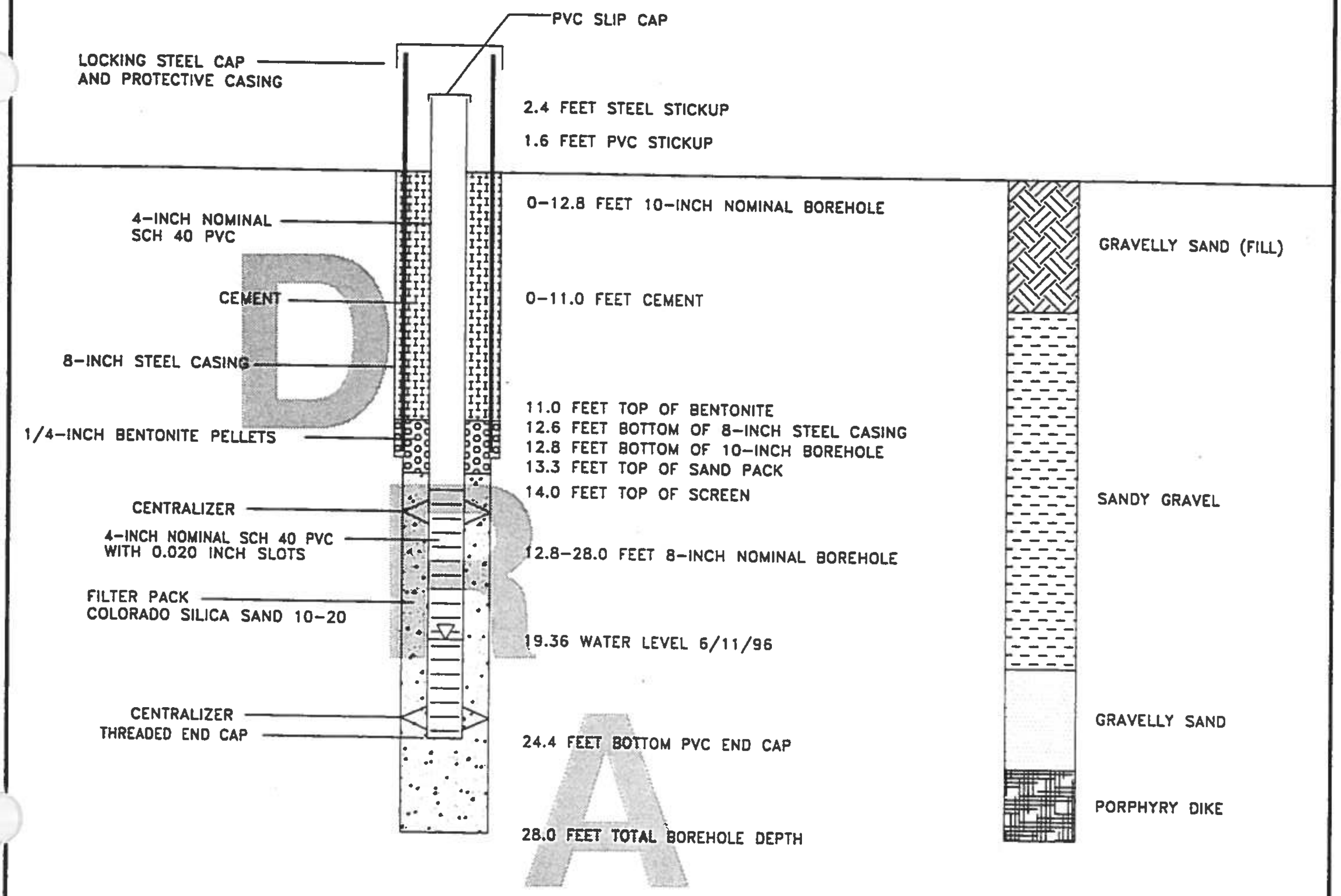
ATTACHMENT F.2
MONITORING WELL BOREHOLE LOGS AND COMPLETION DIAGRAMS

▨	gravelly Sand (fill)
░	gravelly Sand
▤	sandy Gravel
▨	clayey Sand
▧	Shale
▦	Limestone
▨	Dolomite
▦	Porphyry dike

SHEPHERD MILLER
INCORPORATED

KEY TO HATCH PATTERNS

Date: AUGUST 1996
Project: 12–475
File: KEY



PERMIT NUMBER M-8235
ALL DEPTHS BELOW GROUND SURFACE

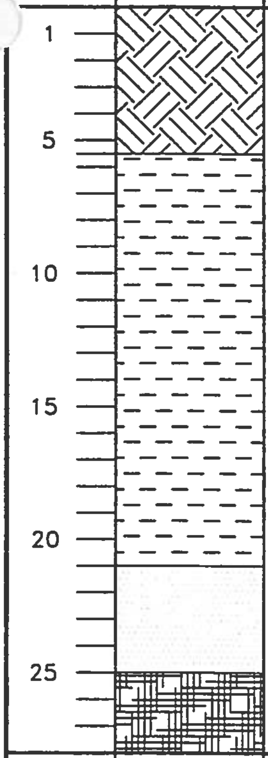
WATER LEVEL DATA 6/11/96

SHEPHERD MILLER
INCORPORATED

MW-19
MONITORING WELL CONSTRUCTION INFORMATION

Date:	AUGUST 1996
Project:	12-475
File:	MW-19

DEPTH (FT)	LITHOLOGY	DESCRIPTION



0.0 Feet – gravelly Sand (SW) brown, 10yr 5/3, 50% fine to coarse sand, 40% fine gravel, 10% silt, trace of clay, angular to very angular, very slightly plastic, medium dense, very slightly moist, very slight acid reaction (fill)

5.5 Feet – sandy Gravel (GW) dark reddish brown, 5yr 3/3, 50% fine gravel, 45% fine to coarse sand, 5% silt, trace of clay, sub–angular to very angular, very slightly plastic, medium dense, very slightly moist, very slight acid reaction, some root/organic material

11.0 Feet – sandy Gravel (GP) yellowish brown, 10yr 5/4, 70% fine gravel, 25% fine to coarse sand, <5% silt, trace of clay, rounded to angular, very slightly plastic, medium dense, very slightly moist, very slight acid reaction

16.5 Feet – sandy Gravel (GW) olive, 5y 5/4, 50% fine gravel, 45% sand, 5% silt, fine to coarse sand, angular, dry, no acid reaction

21.0 Feet – gravelly Sand (SP) olive, 5y 5/4, 50% sand, 45% gravel, 5% silt, fine to coarse sand, angular, dry, no acid reaction

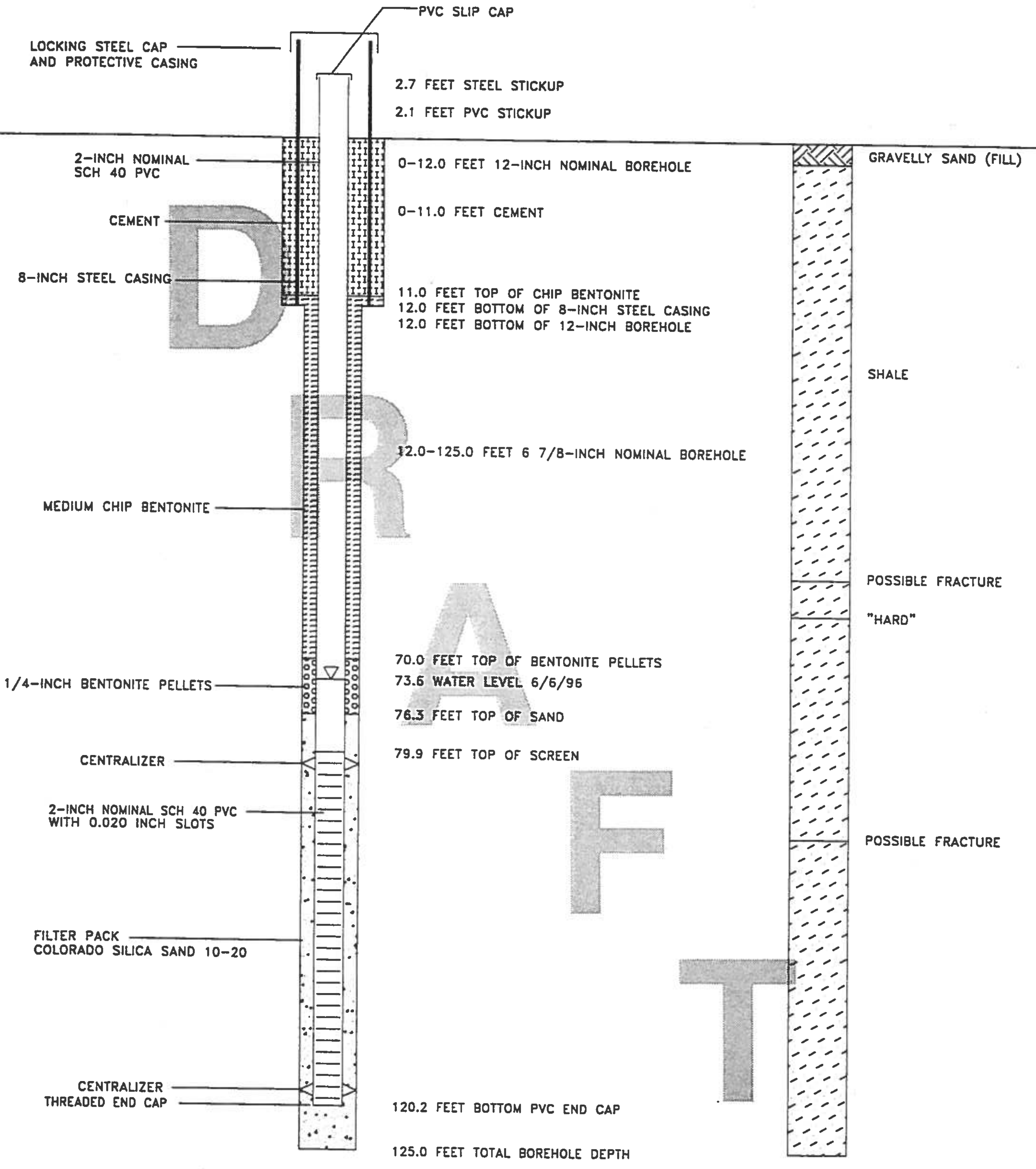
25.0 Feet – Bedrock, olive gray, 5y 4/1, porphyry dike, no acid reaction

28.0 Feet – Total borehole depth

SHEPHERD MILLER
INCORPORATED

MW–19 FIELD BORING LOG

Date:	5/21/96
Project:	12–475
File:	B–MW–19



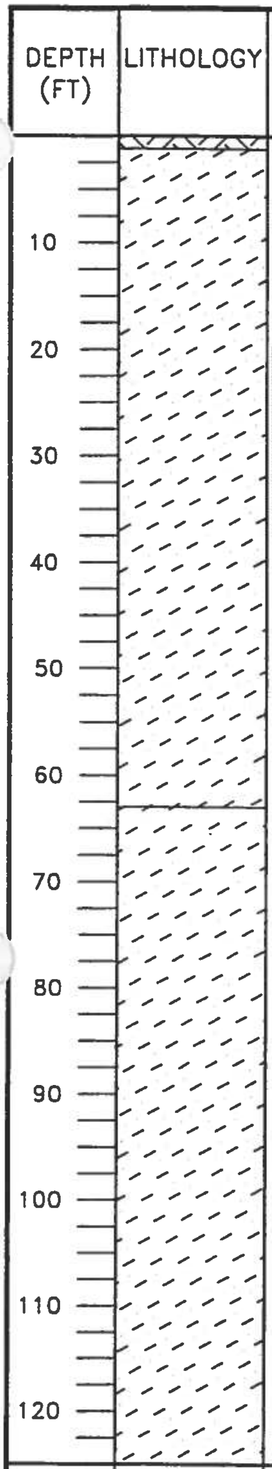
PERMIT NUMBER M-8236
ALL DEPTHS BELOW GROUND SURFACE

WATER LEVEL DATA 6/6/96

SHEPHERD MILLER
INCORPORATED

MW-20
MONITORING WELL CONSTRUCTION INFORMATION

Date: AUGUST 1996
Project: 12-475
File: MW-20



DESCRIPTION

0.0 Feet – Fill

0.5 Feet – Bedrock, brownish black, 5yr 2/1, no acid reaction, highly weathered shale, soft–degree of weathering decreases with depth

63.0 Feet – Possible fracture

65.0 Feet – Drilling harder

80.0 Feet – Dark greenish gray, 5gy 4/1, pyrite, cherty, shale

85.0 Feet – Possible fracture

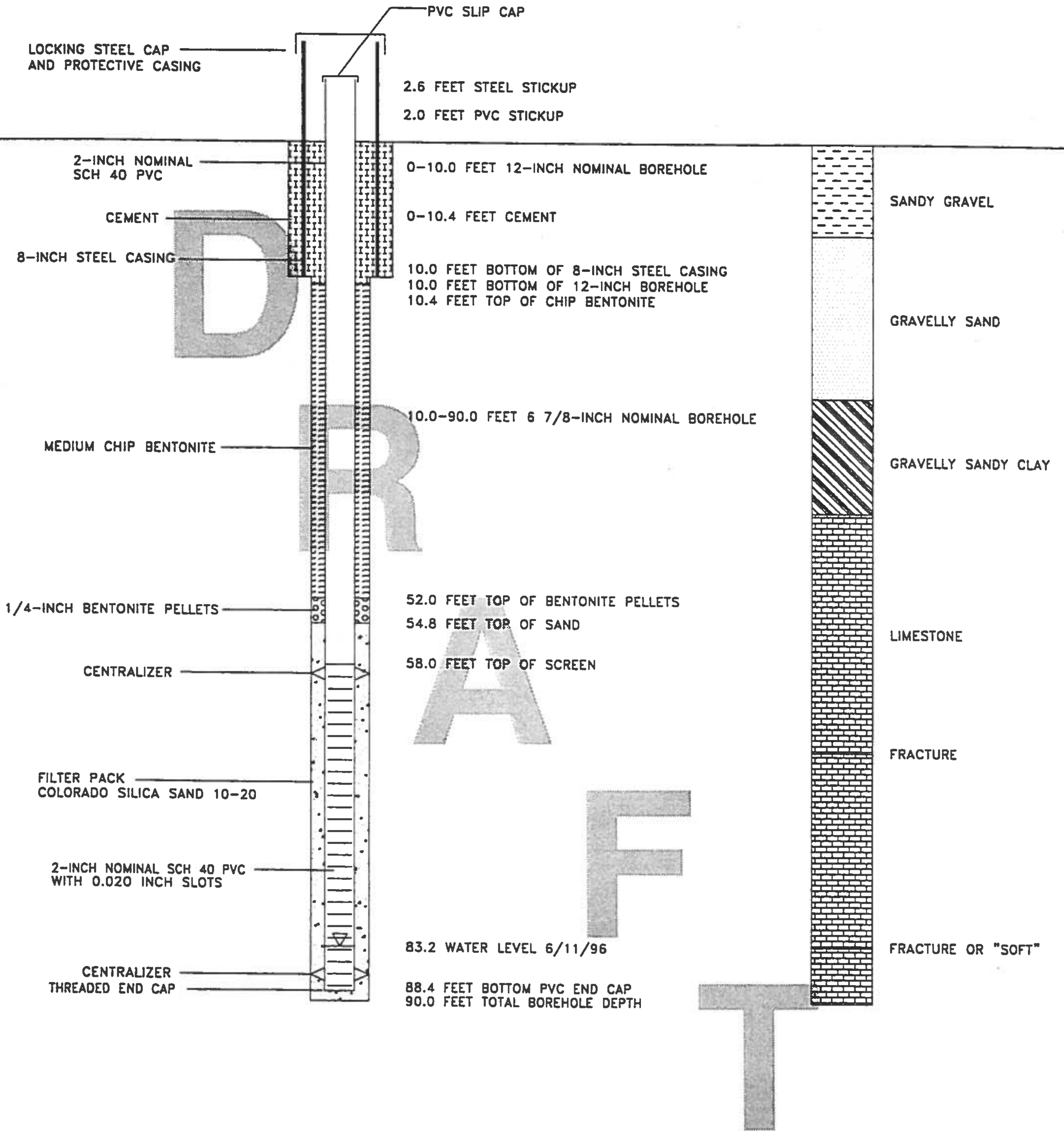
100.0 Feet – Dark greenish gray, 5gy 4/1, cherty, shale

125.0 Feet – Total borehole depth

SHEPHERD MILLER
INCORPORATED

MW–20 FIELD BORING LOG

Date:	5/24/96
Project:	12–475
File:	B–MW–20



PERMIT NUMBER M-8234
ALL DEPTHS BELOW GROUND SURFACE

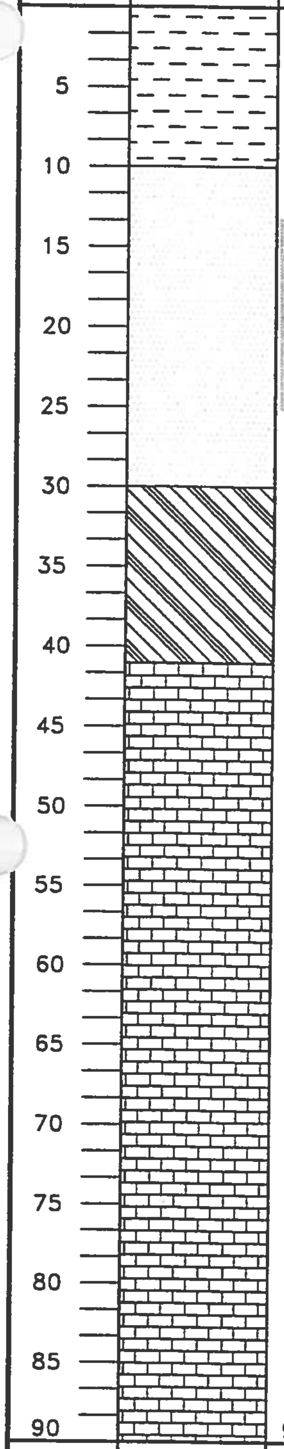
WATER LEVEL DATA 6/11/96

SHEPHERD MILLER
INCORPORATED

MW-21
MONITORING WELL CONSTRUCTION
INFORMATION

Date:	AUGUST 1996
Project:	12-475
File:	MW-21

DEPTH (FT) | LITHOLOGY | DESCRIPTION



0 Feet – sandy Gravel (GP) light bluish gray, Gley #2 8/1, 65% fine gravel, 30% fine to medium sand, <5% silt, sub-rounded to angular, medium dense, dry

10.0 Feet – gravelly Sand with silt, strong brown, 7.5yr 4/6, 50% coarse and fine sand, 40% fine gravel, 10% silt, rounded to angular, no plasticity, slightly moist, wood chips

30.0 Feet – clayey Sand with gravel and silt (SC), dark brown, 10yr 3/3, fine to coarse sand, fine gravel, slightly moist, slightly plastic, soft

40.0 Feet – Bedrock, medium bluish gray, 5B 5/1, strong acid reaction, limestone

52.0 Feet – White, N9, strong acid reaction, limestone

57.0 Feet – Medium bluish gray, 5B 5/1, limestone

63.0 Feet – Fracture, very light gray, 5B N8, strong acid reaction, limestone softer than above

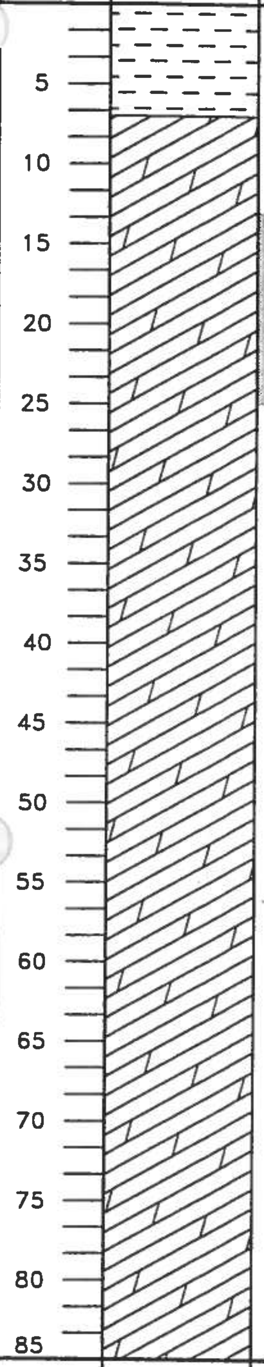
65.0 Feet – Medium bluish gray, 5B 5/1, strong acid reaction, limestone

90.0 Feet – Total borehole depth

SHEPHERD MILLER
INCORPORATED

MW-21 FIELD BORING LOG

Date:	5/23/96
Project:	12-475
File:	B-MW-21



DEPTH (FT)	LITHOLOGY	DESCRIPTION
		0.0 Feet – sandy Gravel (GW), dark reddish brown, 5yr 3/3, 50% fine gravel, 45% fine to coarse sand, 5% silt, trace of clay, sub–angular to very angular, very slightly plastic, medium dense, dry, no acid reaction
		7.0 Feet – Bedrock, greenish black, 5G 2/1, no acid reaction, pyrite, mottled dolomite
		85.0 Feet – Total borehole depth

SHEPHERD MILLER
INCORPORATED

MW–22 FIELD BORING LOG

Date:	5/28/96
Project:	12–475
File:	B–MW–22

ATTACHMENT F.3
FEBRUARY 1996 SURFACE WATER ANALYTICAL DATA

Accu-Labs® Research, Inc.

Table Mountain Drive   Golden, Colorado 80403-1650
(277-9514   FAX (303) 277-9512

Date: 04/22/96
Page 1

REPORT OF ANALYSIS
ADDITIONAL

Mr Walt Niccoli
Shepard-Miller Inc
3801 Automation Way Suite 100
Fort Collins, CO 80525

Lab Job Number: 007343   SHE002
Date Samples Received: 02/27/96

ALR Designation:	96-A3653	96-A3654
Client Designation:	SMI-TAIL-1B	SMI-GAP-1
Sample Location:		
Location II:		
Date/Time Collected	02/24/96 17:40	02/24/96 15:30
Aluminum, Total (mg/L)	0.080	0.24
Aluminum, Dissolved (mg/L)	< 0.050	< 0.050
Antimony, Total (mg/L)	< 0.05	< 0.05
Antimony, Dissolved (mg/L)	< 0.05	< 0.05
Arsenic, Total (mg/L)	< 0.05	< 0.05
Arsenic, Dissolved (mg/L)	< 0.05	< 0.05
Boron, Total (mg/L)	0.2	0.1
Boron, Dissolved (mg/L)	< 0.1	< 0.1
Cadmium, Total (mg/L)	< 0.005	< 0.005
Cadmium, Dissolved (mg/L)	< 0.005	< 0.005
Calcium, Total (mg/L)	580	73
Calcium, Dissolved (mg/L)	640	75
Chromium, Total (mg/L)	< 0.005	< 0.005
Chromium, Dissolved (mg/L)	< 0.005	< 0.005
Cobalt, Total (mg/L)	< 0.005	< 0.005
Cobalt, Dissolved (mg/L)	< 0.005	< 0.005
Copper, Total (mg/L)	0.012	0.006
Copper, Dissolved (mg/L)	0.009	< 0.005
Iron, Total (mg/L)	0.16	0.26
Iron, Dissolved (mg/L)	0.01	0.02
Lead, Total (mg/L)	< 0.05	< 0.05
Lead, Dissolved (mg/L)	< 0.05	< 0.05
Magnesium, Total (mg/L)	47	36
Magnesium, Dissolved (mg/L)	50	35
Manganese, Total (mg/L)	0.27	0.029
Manganese, Dissolved (mg/L)	0.29	0.013
Mercury, Total (mg/L)	< 0.0001	< 0.0001
Mercury, Dissolved (mg/L)	< 0.0001	< 0.0001
Molybdenum, Total (mg/L)	0.66	< 0.005
Molybdenum, Dissolved (mg/L)	0.71	< 0.005
Nickel, Total (mg/L)	< 0.02	< 0.02
Nickel, Dissolved (mg/L)	< 0.02	< 0.02
Potassium, Total (mg/L)	26	0.7

REPORT OF ANALYSIS
ADDITIONAL

Mr Walt Niccoli
Shepard-Miller Inc

Lab Job Number: 007343 SHE002
Date Samples Received: 02/27/96

Potassium, Dissolved (mg/L)	29	0.8
Selenium, Total (mg/L)	< 0.05	< 0.05
Selenium, Dissolved (mg/L)	< 0.05	< 0.05
Silicon, Total (mg/L)	3.8	31
Silicon, Dissolved (mg/L)	3.9	32
Sodium, Total (mg/L)	100	13
Sodium, Dissolved (mg/L)	110	13
Vanadium, Total (mg/L)	< 0.005	0.017
Vanadium, Dissolved (mg/L)	< 0.005	0.015
Zinc, Total (mg/L)	0.070	< 0.005
Zinc, Dissolved (mg/L)	0.051	< 0.005

REPORT OF ANALYSIS
ADDITIONAL

Mr Walt Niccoli
Shepard-Miller Inc

Lab Job Number: 007343 SHE002
Date Samples Received: 02/27/96

ALR Designation:	96-A3655	96-A3656
Client Designation:	SMI-GRP-1	SMI-PS-1
Sample Location:		
Location II:		
Date/Time Collected	02/25/96 16:25	02/24/96 14:08
Aluminum, Total (mg/L)	< 0.050	< 0.050
Aluminum, Dissolved (mg/L)	< 0.050	< 0.050
Antimony, Total (mg/L)	< 0.05	< 0.05
Antimony, Dissolved (mg/L)	< 0.05	< 0.05
Arsenic, Total (mg/L)	< 0.05	< 0.05
Arsenic, Dissolved (mg/L)	< 0.05	< 0.05
Boron, Total (mg/L)	0.1	0.1
Boron, Dissolved (mg/L)	< 0.1	< 0.1
Cadmium, Total (mg/L)	< 0.005	< 0.005
Cadmium, Dissolved (mg/L)	< 0.005	< 0.005
Calcium, Total (mg/L)	50	68
Calcium, Dissolved (mg/L)	51	70
Chromium, Total (mg/L)	< 0.005	< 0.005
Chromium, Dissolved (mg/L)	< 0.005	< 0.005
Cobalt, Total (mg/L)	< 0.005	< 0.005
Cobalt, Dissolved (mg/L)	< 0.005	< 0.005
Copper, Total (mg/L)	< 0.005	< 0.005
Copper, Dissolved (mg/L)	< 0.005	< 0.005
Iron, Total (mg/L)	0.08	< 0.01
Iron, Dissolved (mg/L)	0.02	< 0.01
Lead, Total (mg/L)	< 0.05	< 0.05
Lead, Dissolved (mg/L)	< 0.05	< 0.05
Magnesium, Total (mg/L)	26	34
Magnesium, Dissolved (mg/L)	25	33
Manganese, Total (mg/L)	0.019	< 0.005
Manganese, Dissolved (mg/L)	0.019	< 0.005
Mercury, Total (mg/L)	< 0.0001	< 0.0001
Mercury, Dissolved (mg/L)	< 0.0001	< 0.0001
Molybdenum, Total (mg/L)	< 0.005	< 0.005
Molybdenum, Dissolved (mg/L)	< 0.005	< 0.005
Nickel, Total (mg/L)	< 0.02	< 0.02
Nickel, Dissolved (mg/L)	< 0.02	< 0.02
Potassium, Total (mg/L)	1.4	< 0.5
Potassium, Dissolved (mg/L)	1.2	0.9
Selenium, Total (mg/L)	< 0.05	< 0.05
Selenium, Dissolved (mg/L)	< 0.05	< 0.05
Silicon, Total (mg/L)	21	30

REPORT OF ANALYSIS
ADDITIONAL

Mr Walt Niccoli
Shepard-Miller Inc

Lab Job Number: 007343 SHE002
Date Samples Received: 02/27/96

Silicon, Dissolved (mg/L)	22	31
Sodium, Total (mg/L)	13	13
Sodium, Dissolved (mg/L)	12	13
Vanadium, Total (mg/L)	0.007	0.016
Vanadium, Dissolved (mg/L)	0.007	0.015
Zinc, Total (mg/L)	< 0.005	< 0.005
Zinc, Dissolved (mg/L)	< 0.005	< 0.005

REPORT OF ANALYSIS
ADDITIONAL

Mr Walt Niccoli
Shepard-Miller Inc

Lab Job Number: 007343 SHE002
Date Samples Received: 02/27/96

ALR Designation:	96-A3657	96-A3658
Client Designation:	SMI-SBG-1	SMI-BG-11
Sample Location:		
Location II:		
Date/Time Collected	02/23/96 12:35	02/23/96 13:05
Aluminum, Total (mg/L)	< 0.050	< 0.050
Aluminum, Dissolved (mg/L)	0.070	< 0.050
Antimony, Total (mg/L)	< 0.05	< 0.05
Antimony, Dissolved (mg/L)	0.07	< 0.05
Arsenic, Total (mg/L)	< 0.05	< 0.05
Arsenic, Dissolved (mg/L)	< 0.05	< 0.05
Boron, Total (mg/L)	0.1	< 0.1
Boron, Dissolved (mg/L)	< 0.1	< 0.1
Cadmium, Total (mg/L)	< 0.005	< 0.005
Cadmium, Dissolved (mg/L)	< 0.005	< 0.005
Calcium, Total (mg/L)	640	630
Calcium, Dissolved (mg/L)	630	660
Chromium, Total (mg/L)	< 0.005	< 0.005
Chromium, Dissolved (mg/L)	< 0.005	< 0.005
Cobalt, Total (mg/L)	< 0.005	< 0.005
Cobalt, Dissolved (mg/L)	< 0.005	< 0.005
Copper, Total (mg/L)	< 0.005	0.013
Copper, Dissolved (mg/L)	< 0.005	0.015
Iron, Total (mg/L)	< 0.01	< 0.01
	<0.005	<0.005
Iron, Dissolved (mg/L)	< 0.01	< 0.01
	<0.005	<0.005
Lead, Total (mg/L)	< 0.05	< 0.05
Lead, Dissolved (mg/L)	< 0.05	< 0.05
Magnesium, Total (mg/L)	86	93
Magnesium, Dissolved (mg/L)	80	89
Manganese, Total (mg/L)	< 0.005	0.089
Manganese, Dissolved (mg/L)	< 0.005	0.089
Mercury, Total (mg/L)	< 0.0001	< 0.0001
Mercury, Dissolved (mg/L)	< 0.0001	< 0.0001
Molybdenum, Total (mg/L)	0.014	0.015
Molybdenum, Dissolved (mg/L)	0.007	0.013
Nickel, Total (mg/L)	< 0.02	< 0.02
Nickel, Dissolved (mg/L)	< 0.02	< 0.02
Potassium, Total (mg/L)	4.8	4.1
Potassium, Dissolved (mg/L)	4.2	4.1
Selenium, Total (mg/L)	< 0.05	< 0.05

REPORT OF ANALYSIS
ADDITIONAL

Mr Walt Niccoli
Shepard-Miller Inc

Lab Job Number: 007343 SHE002
Date Samples Received: 02/27/96

Selenium, Dissolved (mg/L)	0.06	< 0.05
Silicon, Total (mg/L)	15	13
Silicon, Dissolved (mg/L)	15	14
Sodium, Total (mg/L)	42	48
Sodium, Dissolved (mg/L)	40	44
Vanadium, Total (mg/L)	0.005	0.005
Vanadium, Dissolved (mg/L)	< 0.005	< 0.005
Zinc, Total (mg/L)	0.008	0.093
Zinc, Dissolved (mg/L)	0.008	0.10

REPORT OF ANALYSIS
ADDITIONAL

Mr Walt Niccoli
Shepard-Miller Inc

Lab Job Number: 007343 SHE002
Date Samples Received: 02/27/96

ALR Designation:	96-A3659	96-A3660
Client Designation:	SMI-WBG-1	SMI-EBG-5
Sample Location:		
Location II:		
Date/Time Collected	02/23/96 11:50	02/23/96 11:10
Aluminum, Total (mg/L)	< 0.050	< 0.050
Aluminum, Dissolved (mg/L)	< 0.050	< 0.050
Antimony, Total (mg/L)	< 0.05	< 0.05
Antimony, Dissolved (mg/L)	< 0.05	< 0.05
Arsenic, Total (mg/L)	< 0.05	< 0.05
Arsenic, Dissolved (mg/L)	< 0.05	< 0.05
Boron, Total (mg/L)	0.2	0.2
Boron, Dissolved (mg/L)	< 0.1	< 0.1
Cadmium, Total (mg/L)	< 0.005	< 0.005
Cadmium, Dissolved (mg/L)	< 0.005	< 0.005
Calcium, Total (mg/L)	620	590
Calcium, Dissolved (mg/L)	660	640
Chromium, Total (mg/L)	< 0.005	0.005
Chromium, Dissolved (mg/L)	< 0.005	< 0.005
Cobalt, Total (mg/L)	< 0.005	< 0.005
Cobalt, Dissolved (mg/L)	< 0.005	< 0.005
Copper, Total (mg/L)	0.005	0.058
Copper, Dissolved (mg/L)	0.005	0.058
Iron, Total (mg/L)	0.03	0.02
	0.029	0.020
Iron, Dissolved (mg/L)	< 0.01	< 0.01
	<0.005	<0.005
Lead, Total (mg/L)	< 0.05	< 0.05
Lead, Dissolved (mg/L)	< 0.05	< 0.05
Magnesium, Total (mg/L)	110	120
Magnesium, Dissolved (mg/L)	110	130
Manganese, Total (mg/L)	0.11	0.65
Manganese, Dissolved (mg/L)	0.10	0.71
Mercury, Total (mg/L)	< 0.0001	< 0.0001
Mercury, Dissolved (mg/L)	< 0.0001	< 0.0001
Molybdenum, Total (mg/L)	0.009	0.007
Molybdenum, Dissolved (mg/L)	0.006	0.011
Nickel, Total (mg/L)	< 0.02	< 0.02
Nickel, Dissolved (mg/L)	< 0.02	< 0.02
Potassium, Total (mg/L)	1.9	0.6
Potassium, Dissolved (mg/L)	1.4	0.9
Selenium, Total (mg/L)	< 0.05	< 0.05

REPORT OF ANALYSIS
ADDITIONAL

Mr Walt Niccoli
Shepard-Miller Inc

Lab Job Number: 007343 SHE002
Date Samples Received: 02/27/96

Selenium, Dissolved (mg/L)	< 0.05	< 0.05
Silicon, Total (mg/L)	9.8	14
Silicon, Dissolved (mg/L)	10	18
Sodium, Total (mg/L)	60	70
Sodium, Dissolved (mg/L)	65	76
Vanadium, Total (mg/L)	< 0.005	< 0.005
Vanadium, Dissolved (mg/L)	< 0.005	< 0.005
Zinc, Total (mg/L)	0.034	0.75
Zinc, Dissolved (mg/L)	0.030	0.82

REPORT OF ANALYSIS
ADDITIONAL

Mr Walt Niccoli
Shepard-Miller Inc

Lab Job Number: 007343 SHE002
Date Samples Received: 02/27/96

ALR Designation:	96-A3661	96-A3662
Client Designation:	SMI-TAIL-1A	SMI-HSN-1
Sample Location:		
Location II:		
Date/Time Collected	02/24/96 17:13	02/24/96 11:20
Aluminum, Total (mg/L)	< 0.050	1.2
Aluminum, Dissolved (mg/L)	< 0.050	< 0.050
Antimony, Total (mg/L)	< 0.05	< 0.05
Antimony, Dissolved (mg/L)	< 0.05	< 0.05
Arsenic, Total (mg/L)	< 0.05	0.06
Arsenic, Dissolved (mg/L)	< 0.05	0.06
Boron, Total (mg/L)	0.2	0.2
Boron, Dissolved (mg/L)	< 0.1	< 0.1
Cadmium, Total (mg/L)	< 0.005	< 0.005
Cadmium, Dissolved (mg/L)	< 0.005	< 0.005
Calcium, Total (mg/L)	< 0.1	56
Calcium, Dissolved (mg/L)	< 0.1	61
Chromium, Total (mg/L)	< 0.005	< 0.005
Chromium, Dissolved (mg/L)	< 0.005	< 0.005
Cobalt, Total (mg/L)	< 0.005	0.15
Cobalt, Dissolved (mg/L)	< 0.005	0.16
Copper, Total (mg/L)	< 0.005	0.088
Copper, Dissolved (mg/L)	< 0.005	0.024
Iron, Total (mg/L)	< 0.01	60
Iron, Dissolved (mg/L)	< 0.01	55
Lead, Total (mg/L)	< 0.05	< 0.05
Lead, Dissolved (mg/L)	< 0.05	< 0.05
Magnesium, Total (mg/L)	< 0.05	44
Magnesium, Dissolved (mg/L)	< 0.05	46
Manganese, Total (mg/L)	< 0.005	2.9
Manganese, Dissolved (mg/L)	< 0.005	3.1
Mercury, Total (mg/L)	< 0.0001	< 0.0001
Mercury, Dissolved (mg/L)	< 0.0001	< 0.0001
Molybdenum, Total (mg/L)	< 0.005	< 0.005
Molybdenum, Dissolved (mg/L)	< 0.005	< 0.005
Nickel, Total (mg/L)	< 0.02	0.11
Nickel, Dissolved (mg/L)	< 0.02	0.13
Potassium, Total (mg/L)	< 0.5	4.0
Potassium, Dissolved (mg/L)	< 0.5	3.9
Selenium, Total (mg/L)	< 0.05	< 0.05
Selenium, Dissolved (mg/L)	< 0.05	< 0.05
Silicon, Total (mg/L)	< 0.5	12

REPORT OF ANALYSIS
ADDITIONAL

Mr Walt Niccoli
Shepard-Miller Inc

Lab Job Number: 007343   SHE002
Date Samples Received: 02/27/96

Silicon, Dissolved (mg/L)	< 0.5	11
Sodium, Total (mg/L)	0.2	12
Sodium, Dissolved (mg/L)	< 0.1	13
Vanadium, Total (mg/L)	< 0.005	< 0.005
Vanadium, Dissolved (mg/L)	< 0.005	< 0.005
Zinc, Total (mg/L)	< 0.005	1.3
Zinc, Dissolved (mg/L)	< 0.005	1.4

REPORT OF ANALYSIS
ADDITIONAL

Mr Walt Niccoli
Shepard-Miller Inc

Lab Job Number: 007343 SHE002
Date Samples Received: 02/27/96

ALR Designation:	96-A3663	96-A3664
Client Designation:	SMI-HSN-2	SMI-ZH-1
Sample Location:		
Location II:		
Date/Time Collected	02/24/96 10:46	02/23/96 16:40
Aluminum, Total (mg/L)	0.060	< 0.050
Aluminum, Dissolved (mg/L)	< 0.050	< 0.050
Antimony, Total (mg/L)	< 0.05	< 0.05
Antimony, Dissolved (mg/L)	< 0.05	< 0.05
Arsenic, Total (mg/L)	< 0.05	< 0.05
Arsenic, Dissolved (mg/L)	< 0.05	< 0.05
Boron, Total (mg/L)	0.2	< 0.1
Boron, Dissolved (mg/L)	< 0.1	< 0.1
Cadmium, Total (mg/L)	< 0.005	0.021
Cadmium, Dissolved (mg/L)	< 0.005	0.021
Calcium, Total (mg/L)	49	550
Calcium, Dissolved (mg/L)	51	560
Chromium, Total (mg/L)	< 0.005	0.005
Chromium, Dissolved (mg/L)	< 0.005	< 0.005
Cobalt, Total (mg/L)	< 0.005	< 0.005
Cobalt, Dissolved (mg/L)	< 0.005	< 0.005
Copper, Total (mg/L)	0.054	0.010
Copper, Dissolved (mg/L)	< 0.005	< 0.005
Iron, Total (mg/L)	0.17	0.11
Iron, Dissolved (mg/L)	0.08	< 0.01
Lead, Total (mg/L)	< 0.05	< 0.05
Lead, Dissolved (mg/L)	< 0.05	< 0.05
Magnesium, Total (mg/L)	29	78
Magnesium, Dissolved (mg/L)	31	81
Manganese, Total (mg/L)	0.23	0.15
Manganese, Dissolved (mg/L)	0.24	0.14
Mercury, Total (mg/L)	< 0.0001	< 0.0001
Mercury, Dissolved (mg/L)	< 0.0001	< 0.0001
Molybdenum, Total (mg/L)	< 0.005	0.006
Molybdenum, Dissolved (mg/L)	< 0.005	0.010
Nickel, Total (mg/L)	< 0.02	< 0.02
Nickel, Dissolved (mg/L)	< 0.02	< 0.02
Potassium, Total (mg/L)	1.2	3.4
Potassium, Dissolved (mg/L)	1.6	4.3
Selenium, Total (mg/L)	< 0.05	< 0.05
Selenium, Dissolved (mg/L)	< 0.05	< 0.05
Silicon, Total (mg/L)	9.3	5.6

REPORT OF ANALYSIS
ADDITIONAL

Mr Walt Niccoli
Shepard-Miller Inc

Lab Job Number: 007343 SHE002
Date Samples Received: 02/27/96

Silicon, Dissolved (mg/L)	9.7	5.8
Sodium, Total (mg/L)	16	34
Sodium, Dissolved (mg/L)	16	32
Vanadium, Total (mg/L)	< 0.005	< 0.005
Vanadium, Dissolved (mg/L)	< 0.005	< 0.005
Zinc, Total (mg/L)	0.023	5.2
Zinc, Dissolved (mg/L)	0.020	5.5

REPORT OF ANALYSIS
ADDITIONAL

Mr Walt Niccoli
Shepard-Miller Inc

Lab Job Number: 007343 SHE002
Date Samples Received: 02/27/96

ALR Designation:	96-A3665	96-A3666
Client Designation:	SMI-ZH-2	SMI-FS-1
Sample Location:		
Location II:		
Date/Time Collected	02/23/96 17:14	02/24/96 9:30
Aluminum, Total (mg/L)	< 0.050	< 0.050
Aluminum, Dissolved (mg/L)	< 0.050	< 0.050
Antimony, Total (mg/L)	< 0.05	< 0.05
Antimony, Dissolved (mg/L)	< 0.05	< 0.05
Arsenic, Total (mg/L)	< 0.05	< 0.05
Arsenic, Dissolved (mg/L)	< 0.05	< 0.05
Boron, Total (mg/L)	0.2	0.2
Boron, Dissolved (mg/L)	< 0.1	< 0.1
Cadmium, Total (mg/L)	0.016	< 0.005
Cadmium, Dissolved (mg/L)	0.014	< 0.005
Calcium, Total (mg/L)	590	60
Calcium, Dissolved (mg/L)	620	57
Chromium, Total (mg/L)	< 0.005	< 0.005
Chromium, Dissolved (mg/L)	< 0.005	< 0.005
Cobalt, Total (mg/L)	< 0.005	< 0.005
Cobalt, Dissolved (mg/L)	0.007	< 0.005
Copper, Total (mg/L)	< 0.005	< 0.005
Copper, Dissolved (mg/L)	< 0.005	< 0.005
Iron, Total (mg/L)	0.01	< 0.01
Iron, Dissolved (mg/L)	< 0.01	< 0.01
Lead, Total (mg/L)	< 0.05	< 0.05
Lead, Dissolved (mg/L)	< 0.05	< 0.05
Magnesium, Total (mg/L)	65	23
Magnesium, Dissolved (mg/L)	70	21
Manganese, Total (mg/L)	0.024	< 0.005
Manganese, Dissolved (mg/L)	0.013	< 0.005
Mercury, Total (mg/L)	< 0.0001	< 0.0001
Mercury, Dissolved (mg/L)	< 0.0001	< 0.0001
Molybdenum, Total (mg/L)	< 0.005	< 0.005
Molybdenum, Dissolved (mg/L)	< 0.005	< 0.005
Nickel, Total (mg/L)	< 0.02	< 0.02
Nickel, Dissolved (mg/L)	< 0.02	< 0.02
Potassium, Total (mg/L)	3.6	2.4
Potassium, Dissolved (mg/L)	2.8	1.9
Selenium, Total (mg/L)	< 0.05	< 0.05
Selenium, Dissolved (mg/L)	< 0.05	< 0.05
Silicon, Total (mg/L)	3.6	7.7

Date: 04/22/96
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REPORT OF ANALYSIS
ADDITIONAL

Mr Walt Niccoli
Shepard-Miller Inc

Lab Job Number: 007343 SHE002
Date Samples Received: 02/27/96

Silicon, Dissolved (mg/L)	3.9	8.2
Sodium, Total (mg/L)	21	20
Sodium, Dissolved (mg/L)	22	15
Vanadium, Total (mg/L)	< 0.005	< 0.005
Vanadium, Dissolved (mg/L)	< 0.005	< 0.005
Zinc, Total (mg/L)	7.2	0.12
Zinc, Dissolved (mg/L)	7.9	0.015

REPORT OF ANALYSIS
ADDITIONAL

Mr Walt Niccoli
Shepard-Miller Inc

Lab Job Number: 007343 SHE002
Date Samples Received: 02/27/96

ALR Designation:	96-A3667	96-A3668
Client Designation:	SMI-MDD-1	SMI-MDD-2
Sample Location:		
Location II:		
Date/Time Collected	02/25/96 13:35	02/25/96 13:15
Aluminum, Total (mg/L)	< 0.050	< 0.050
Aluminum, Dissolved (mg/L)	< 0.050	< 0.050
Antimony, Total (mg/L)	< 0.05	< 0.05
Antimony, Dissolved (mg/L)	< 0.05	< 0.05
Arsenic, Total (mg/L)	< 0.05	< 0.05
Arsenic, Dissolved (mg/L)	< 0.05	< 0.05
Boron, Total (mg/L)	0.2	0.2
Boron, Dissolved (mg/L)	< 0.1	< 0.1
Cadmium, Total (mg/L)	< 0.005	< 0.005
Cadmium, Dissolved (mg/L)	< 0.005	< 0.005
Calcium, Total (mg/L)	560	570
Calcium, Dissolved (mg/L)	570	540
Chromium, Total (mg/L)	< 0.005	< 0.005
Chromium, Dissolved (mg/L)	0.005	< 0.005
Cobalt, Total (mg/L)	< 0.005	< 0.005
Cobalt, Dissolved (mg/L)	< 0.005	0.007
Copper, Total (mg/L)	0.008	0.024
Copper, Dissolved (mg/L)	0.006	0.017
Iron, Total (mg/L)	0.10	0.04
Iron, Dissolved (mg/L)	< 0.01	0.02
Lead, Total (mg/L)	< 0.05	< 0.05
Lead, Dissolved (mg/L)	< 0.05	< 0.05
Magnesium, Total (mg/L)	220	210
Magnesium, Dissolved (mg/L)	240	190
Manganese, Total (mg/L)	< 0.005	0.037
Manganese, Dissolved (mg/L)	< 0.005	0.031
Mercury, Total (mg/L)	< 0.0001	< 0.0001
Mercury, Dissolved (mg/L)	< 0.0001	< 0.0001
Molybdenum, Total (mg/L)	0.13	0.091
Molybdenum, Dissolved (mg/L)	0.12	0.10
Nickel, Total (mg/L)	< 0.02	< 0.02
Nickel, Dissolved (mg/L)	< 0.02	< 0.02
Potassium, Total (mg/L)	7.4	7.7
Potassium, Dissolved (mg/L)	6.3	6.9
Selenium, Total (mg/L)	0.06	< 0.05
Selenium, Dissolved (mg/L)	< 0.05	0.09
Silicon, Total (mg/L)	10	11

REPORT OF ANALYSIS
ADDITIONAL

Mr Walt Niccoli
Shepard-Miller Inc

Lab Job Number: 007343 SHE002
Date Samples Received: 02/27/96

Silicon, Dissolved (mg/L)	9.8	11
Sodium, Total (mg/L)	160	120
Sodium, Dissolved (mg/L)	160	74
Vanadium, Total (mg/L)	< 0.005	< 0.005
Vanadium, Dissolved (mg/L)	0.006	< 0.005
Zinc, Total (mg/L)	0.024	0.058
Zinc, Dissolved (mg/L)	0.023	0.061

REPORT OF ANALYSIS
ADDITIONAL

Mr Walt Niccoli
Shepard-Miller Inc

Lab Job Number: 007343 SHE002
Date Samples Received: 02/27/96

ALR Designation:	96-A3669	96-A3670
Client Designation:	SMI-TPS-1	SMI-TPS-3
Sample Location:		
Location II:		
Date/Time Collected	02/25/96 10:00	02/25/96 11:25
Aluminum, Total (mg/L)	< 0.050	< 0.050
Aluminum, Dissolved (mg/L)	< 0.050	< 0.050
Antimony, Total (mg/L)	< 0.05	< 0.05
Antimony, Dissolved (mg/L)	< 0.05	< 0.05
Arsenic, Total (mg/L)	< 0.05	< 0.05
Arsenic, Dissolved (mg/L)	< 0.05	< 0.05
Boron, Total (mg/L)	< 0.1	0.1
Boron, Dissolved (mg/L)	< 0.1	< 0.1
Cadmium, Total (mg/L)	< 0.005	< 0.005
Cadmium, Dissolved (mg/L)	< 0.005	< 0.005
Calcium, Total (mg/L)	590	560
Calcium, Dissolved (mg/L)	600	560
Chromium, Total (mg/L)	< 0.005	< 0.005
Chromium, Dissolved (mg/L)	< 0.005	< 0.005
Cobalt, Total (mg/L)	0.012	< 0.005
Cobalt, Dissolved (mg/L)	0.013	< 0.005
Copper, Total (mg/L)	0.025	0.033
Copper, Dissolved (mg/L)	0.024	0.028
Iron, Total (mg/L)	0.11	0.02
Iron, Dissolved (mg/L)	< 0.01	< 0.01
Lead, Total (mg/L)	< 0.05	< 0.05
Lead, Dissolved (mg/L)	< 0.05	< 0.05
Magnesium, Total (mg/L)	130	160
Magnesium, Dissolved (mg/L)	140	180
Manganese, Total (mg/L)	5.5	0.50
Manganese, Dissolved (mg/L)	5.6	0.52
Mercury, Total (mg/L)	< 0.0001	< 0.0001
Mercury, Dissolved (mg/L)	< 0.0001	< 0.0001
Molybdenum, Total (mg/L)	0.35	0.49
Molybdenum, Dissolved (mg/L)	0.33	0.49
Nickel, Total (mg/L)	< 0.02	< 0.02
Nickel, Dissolved (mg/L)	< 0.02	< 0.02
Potassium, Total (mg/L)	27	16
Potassium, Dissolved (mg/L)	21	15
Selenium, Total (mg/L)	< 0.05	< 0.05
Selenium, Dissolved (mg/L)	< 0.05	< 0.05
Silicon, Total (mg/L)	8.1	5.8

REPORT OF ANALYSIS
ADDITIONAL

Mr Walt Niccoli
Shepard-Miller Inc

Lab Job Number: 007343 SHE002
Date Samples Received: 02/27/96

Silicon, Dissolved (mg/L)	8.2	5.9
Sodium, Total (mg/L)	94	90
Sodium, Dissolved (mg/L)	85	84
Vanadium, Total (mg/L)	< 0.005	< 0.005
Vanadium, Dissolved (mg/L)	0.005	< 0.005
Zinc, Total (mg/L)	0.56	0.50
Zinc, Dissolved (mg/L)	0.58	0.51

REPORT OF ANALYSIS
ADDITIONAL

Mr Walt Niccoli
Shepard-Miller Inc

Lab Job Number: 007343 SHE002
Date Samples Received: 02/27/96

ALR Designation:	96-A3671
Client Designation:	SMI-TPS-2
Sample Location:	
Location II:	
Date/Time Collected	02/25/96 10:50
Aluminum, Total (mg/L)	< 0.050
Aluminum, Dissolved (mg/L)	< 0.050
Antimony, Total (mg/L)	< 0.05
Antimony, Dissolved (mg/L)	< 0.05
Arsenic, Total (mg/L)	< 0.05
Arsenic, Dissolved (mg/L)	< 0.05
Boron, Total (mg/L)	0.2
Boron, Dissolved (mg/L)	< 0.1
Cadmium, Total (mg/L)	< 0.005
Cadmium, Dissolved (mg/L)	< 0.005
Calcium, Total (mg/L)	580
Calcium, Dissolved (mg/L)	600
Chromium, Total (mg/L)	< 0.005
Chromium, Dissolved (mg/L)	< 0.005
Cobalt, Total (mg/L)	< 0.005
Cobalt, Dissolved (mg/L)	< 0.005
Copper, Total (mg/L)	0.10
Copper, Dissolved (mg/L)	0.090
Iron, Total (mg/L)	0.06
Iron, Dissolved (mg/L)	< 0.01
Lead, Total (mg/L)	< 0.05
Lead, Dissolved (mg/L)	< 0.05
Magnesium, Total (mg/L)	150
Magnesium, Dissolved (mg/L)	160
Manganese, Total (mg/L)	2.2
Manganese, Dissolved (mg/L)	2.4
Mercury, Total (mg/L)	< 0.0001
Mercury, Dissolved (mg/L)	< 0.0001
Molybdenum, Total (mg/L)	0.42
Molybdenum, Dissolved (mg/L)	0.42
Nickel, Total (mg/L)	< 0.02
Nickel, Dissolved (mg/L)	< 0.02
Potassium, Total (mg/L)	24
Potassium, Dissolved (mg/L)	19
Selenium, Total (mg/L)	< 0.05
Selenium, Dissolved (mg/L)	< 0.05
Silicon, Total (mg/L)	5.5

REPORT OF ANALYSIS
ADDITIONAL

Mr Walt Niccoli
Shepard-Miller Inc

Lab Job Number: 007343 SHE002
Date Samples Received: 02/27/96

Silicon, Dissolved (mg/L)	5.6
Sodium, Total (mg/L)	91
Sodium, Dissolved (mg/L)	77
Vanadium, Total (mg/L)	< 0.005
Vanadium, Dissolved (mg/L)	< 0.005
Zinc, Total (mg/L)	0.74
Zinc, Dissolved (mg/L)	0.77

NOTES: When present, *** indicates that the analyte in question was not requested for that sample.

Scheduled sample disposal/return date: May 22, 1996.

Carl R. Ray

Carl R. Ray
Laboratory Manager

CASE NARRATIVE

Re: 007343

Samples EBG-5, WBG-1, SBG-1 and BG-11 were not analyzed for iron by ICP-MS. Due to the concentration of calcium, a 0.001 mg/L detection limit was difficult to achieve. The lower values for iron were achieved by ICP. The ICP MDL is 0.005 mg/L.

All blanks and laboratory control samples were evaluated on the original data. The values reported reflect the concentration in the samples.

Accu-Labs® Research, Inc.
53 Table Mountain Drive Golden, Colorado 80403-1650
(303) 277-9514 FAX (303) 277-9512

Date: 03/14/96
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REPORT OF ANALYSIS

Mr Walt Niccoli
Shepard-Miller Inc
3801 Automation Way Suite 100
Fort Collins, CO 80525

Lab Job Number: 007343 SHE002
Date Samples Received: 02/27/96

ALR Designation:	96-A3653	96-A3654
Client Designation:	SMI-TAIL-1B	SMI-GAP-1
Sample Location:		
Location II:		
Date/Time Collected	02/24/96 17:40	02/24/96 15:30
Alkalinity, Total (mg/L CaCO3)	22	280
Bicarbonate (as HCO3-) (mg/L HCO3-)	27	340
Carbonate (as CO3=) (mg/L CO3=)	< 5	< 5
Chloride (mg/L)	190	3
Cyanide, Total (mg/L)	< 0.005	< 0.005
Fluoride (mg/L)	< 0.5	< 0.5
Hydroxide (as OH-) (mg/L OH-)	< 5	< 5
Nitrate plus Nitrite (mg/L)	6.7	< 0.05
Sulfate (as SO4) (mg/L)	1600	69
TDS (at 180 C) (mg/L)	2600	400
pH ()	7.2 ▲	8.3 ▲

ALR Designation:	96-A3655	96-A3656
Client Designation:	SMI-GRP-1	SMI-PS-1
Sample Location:		
Location II:		
Date/Time Collected	02/25/96 16:25	02/24/96 14:08
Alkalinity, Total (mg/L CaCO3)	200	260
Bicarbonate (as HCO3-) (mg/L HCO3-)	240	310
Carbonate (as CO3=) (mg/L CO3=)	< 5	< 5
Chloride (mg/L)	5	4
Cyanide, Total (mg/L)	< 0.005	< 0.005
Fluoride (mg/L)	< 0.5	< 0.5
Hydroxide (as OH-) (mg/L OH-)	< 5	< 5
Nitrate plus Nitrite (mg/L)	< 0.05	0.69
Sulfate (as SO4) (mg/L)	58	64
TDS (at 180 C) (mg/L)	310	370
pH ()	7.3 ▲	7.3 ▲

REPORT OF ANALYSIS

Mr Walt Niccoli
Shepard-Miller Inc

Lab Job Number: 007343 SHE002
Date Samples Received: 02/27/96

ALR Designation:	96-A3657	96-A3658
Client Designation:	SMI-SBG-1	SMI-BG-11
Sample Location:		
Location II:		
Date/Time Collected	02/23/96 12:35	02/23/96 13:05
Alkalinity, Total (mg/L CaCO3)	220	220
Bicarbonate (as HCO3-) (mg/L HCO3-)	270	270
Carbonate (as CO3=) (mg/L CO3=)	< 5	< 5
Chloride (mg/L)	93	87
Cyanide, Total (mg/L)	< 0.005	< 0.005
Fluoride (mg/L)	< 0.5	< 0.5
Hydroxide (as OH-) (mg/L OH-)	< 5	< 5
Nitrate plus Nitrite (mg/L)	0.56	0.31
Sulfate (as SO4) (mg/L)	1700	1700
TDS (at 180 C) (mg/L)	2600	2800
pH ()	8.0 ▲	8.0 ▲

ALR Designation:	96-A3659	96-A3660
Client Designation:	SMI-WBG-1	SMI-EBG-5
Sample Location:		
Location II:		
Date/Time Collected	02/23/96 11:50	02/23/96 11:10
Alkalinity, Total (mg/L CaCO3)	240	220
Bicarbonate (as HCO3-) (mg/L HCO3-)	290	270
Carbonate (as CO3=) (mg/L CO3=)	< 5	< 5
Chloride (mg/L)	69	35
Cyanide, Total (mg/L)	< 0.005	< 0.005
Fluoride (mg/L)	< 0.5	< 0.5
Hydroxide (as OH-) (mg/L OH-)	< 5	< 5
Nitrate plus Nitrite (mg/L)	< 0.05	< 0.05
Sulfate (as SO4) (mg/L)	1800	1900
TDS (at 180 C) (mg/L)	2900	2800
pH ()	7.8 ▲	7.6 ▲

REPORT OF ANALYSIS

Mr Walt Niccoli
Shepard-Miller Inc

Lab Job Number: 007343 SHE002
Date Samples Received: 02/27/96

ALR Designation:	96-A3661	96-A3662
Client Designation:	SMI-TAIL-1A	SMI-HSN-1
Sample Location:		
Location II:		
Date/Time Collected	02/24/96 17:13	02/24/96 11:20
Alkalinity, Total (mg/L CaCO3)	< 5	6
Bicarbonate (as HCO3-) (mg/L HCO3-)	< 5	7
Carbonate (as CO3=) (mg/L CO3=)	< 5	< 5
Chloride (mg/L)	< 1	5
Cyanide, Total (mg/L)	< 0.005	< 0.005
Fluoride (mg/L)	< 0.5	< 0.5
Hydroxide (as OH-) (mg/L OH-)	< 5	< 5
Nitrate plus Nitrite (mg/L)	< 0.05	0.06
Sulfate (as SO4) (mg/L)	< 10	440
TDS (at 180 C) (mg/L)	12	600
pH ()	5.9 ▲	5.4 ▲

ALR Designation:	96-A3663	96-A3664
Client Designation:	SMI-HSN-2	SMI-ZH-1
Sample Location:		
Location II:		
Date/Time Collected	02/24/96 10:46	02/23/96 16:40
Alkalinity, Total (mg/L CaCO3)	48	160
Bicarbonate (as HCO3-) (mg/L HCO3-)	58	190
Carbonate (as CO3=) (mg/L CO3=)	< 5	< 5
Chloride (mg/L)	8	50
Cyanide, Total (mg/L)	< 0.005	< 0.005
Fluoride (mg/L)	< 0.5	0.6
Hydroxide (as OH-) (mg/L OH-)	< 5	< 5
Nitrate plus Nitrite (mg/L)	< 0.05	0.28
Sulfate (as SO4) (mg/L)	210	1500
TDS (at 180 C) (mg/L)	350	2300
pH ()	6.6 ▲	8.1 ▲

REPORT OF ANALYSIS

Mr Walt Niccoli
Shepard-Miller Inc

Lab Job Number: 007343 SHE002
Date Samples Received: 02/27/96

ALR Designation:	96-A3665	96-A3666
Client Designation:	SMI-ZH-2	SMI-FS-1
Sample Location:		
Location II:		
Date/Time Collected	02/23/96 17:14	02/24/96 9:30
Alkalinity, Total (mg/L CaCO3)	95	220
Bicarbonate (as HCO3-) (mg/L HCO3-)	110	270
Carbonate (as CO3=) (mg/L CO3=)	< 5	< 5
Chloride (mg/L)	28	10
Cyanide, Total (mg/L)	< 0.005	< 0.005
Fluoride (mg/L)	0.6	< 0.5
Hydroxide (as OH-) (mg/L OH-)	< 5	< 5
Nitrate plus Nitrite (mg/L)	0.06	0.47
Sulfate (as SO4) (mg/L)	1600	45
TDS (at 180 C) (mg/L)	2300	290
pH ()	8.0 ▲	7.2 ▲

ALR Designation:	96-A3667	96-A3668
Client Designation:	SMI-MDD-1	SMI-MDD-2
Sample Location:		
Location II:		
Date/Time Collected	02/25/96 13:35	02/25/96 13:15
Alkalinity, Total (mg/L CaCO3)	200	200
Bicarbonate (as HCO3-) (mg/L HCO3-)	240	240
Carbonate (as CO3=) (mg/L CO3=)	< 5	< 5
Chloride (mg/L)	270	150
Cyanide, Total (mg/L)	< 0.005	< 0.005
Fluoride (mg/L)	1.1	0.6
Hydroxide (as OH-) (mg/L OH-)	< 5	< 5
Nitrate plus Nitrite (mg/L)	< 0.05	0.09
Sulfate (as SO4) (mg/L)	2000	2000
TDS (at 180 C) (mg/L)	3500	3400
pH ()	7.5 ▲	7.5 ▲

REPORT OF ANALYSIS

Mr Walt Niccoli
Shepard-Miller Inc

Lab Job Number: 007343 SHE002
Date Samples Received: 02/27/96

ALR Designation:	96-A3669	96-A3670
Client Designation:	SMI-TPS-1	SMI-TPS-3
Sample Location:		
Location II:		
Date/Time Collected	02/25/96 10:00	02/25/96 11:25
Alkalinity, Total (mg/L CaCO3)	120	120
Bicarbonate (as HCO3-) (mg/L HCO3-)	150	150
Carbonate (as CO3=) (mg/L CO3=)	< 5	< 5
Chloride (mg/L)	160	180
Cyanide, Total (mg/L)	< 0.005	< 0.005
Fluoride (mg/L)	0.6	< 0.5
Hydroxide (as OH-) (mg/L OH-)	< 5	< 5
Nitrate plus Nitrite (mg/L)	2.0	4.6
Sulfate (as SO4) (mg/L)	1800	1800
TDS (at 180 C) (mg/L)	2800	2900
pH ()	7.7 ▲	7.6 ▲

ALR Designation:	96-A3671
Client Designation:	SMI-TPS-2
Sample Location:	
Location II:	
Date/Time Collected	02/25/96 10:50
Alkalinity, Total (mg/L CaCO3)	150
Bicarbonate (as HCO3-) (mg/L HCO3-)	180
Carbonate (as CO3=) (mg/L CO3=)	< 5
Chloride (mg/L)	150
Cyanide, Total (mg/L)	< 0.005
Fluoride (mg/L)	0.5
Hydroxide (as OH-) (mg/L OH-)	< 5
Nitrate plus Nitrite (mg/L)	0.49
Sulfate (as SO4) (mg/L)	1800
TDS (at 180 C) (mg/L)	3000
pH ()	7.9 ▲

REPORT OF ANALYSIS

Mr Walt Niccoli
Shepard-Miller Inc

Lab Job Number: 007343 SHE002
Date Samples Received: 02/27/96

NOTES: When present, *** indicates that the analyte in question was not requested for that sample.
▲ Indicates that samples were received and analyzed past holding time.

Scheduled sample disposal/return date: April 13, 1996.

for Carl R. Ray
Laboratory Manager

ATTACHMENT F.4
FEBRUARY 1996 GROUND WATER ANALYTICAL DATA

Accu-Labs® Research, Inc.

Table Mountain Drive Golden, Colorado 80403-1650
(303) 277-9514 FAX (303) 277-9512

Date: 04/02/96
Page 1

REPORT OF ANALYSIS
ADDITIONAL

Mr Walt Niccoli
Shepard-Miller Inc
3801 Automation Way Suite 100
Fort Collins, CO 80525

Lab Job Number: 007410 SHE002
Date Samples Received: 03/01/96

ALR Designation:	96-A3862	96-A3863
Client Designation:	SMI-MW-7A	SMI-MW-1
Sample Location:		
Location II:		
Date/Time Collected	02/28/96 11:49	02/28/96 11:08
Aluminum, Total (mg/L)	0.90	0.20
Aluminum, Dissolved (mg/L)	< 0.050	< 0.050
Antimony, Total (mg/L)	< 0.05	< 0.05
Antimony, Dissolved (mg/L)	< 0.05	< 0.05
Arsenic, Total (mg/L)	< 0.05	< 0.05
Arsenic, Dissolved (mg/L)	< 0.05	< 0.05
Boron, Total (mg/L)	< 0.1	0.3
Boron, Dissolved (mg/L)	< 0.1	0.3
Cadmium, Total (mg/L)	< 0.005	< 0.005
Cadmium, Dissolved (mg/L)	< 0.005	< 0.005
Calcium, Total (mg/L)	210	2.8
Calcium, Dissolved (mg/L)	220	2.7
Chromium, Total (mg/L)	0.006	< 0.005
Chromium, Dissolved (mg/L)	< 0.005	< 0.005
Cobalt, Total (mg/L)	< 0.005	< 0.005
Cobalt, Dissolved (mg/L)	< 0.005	< 0.005
Copper, Total (mg/L)	0.12	0.022
Copper, Dissolved (mg/L)	< 0.005	< 0.005
Iron, Total (mg/L)	2.0	0.05
Iron, Dissolved (mg/L)	0.63	< 0.01
Lead, Total (mg/L)	< 0.05	< 0.05
Lead, Dissolved (mg/L)	< 0.05	< 0.05
Magnesium, Total (mg/L)	33	0.14
Magnesium, Dissolved (mg/L)	34	0.08
Manganese, Total (mg/L)	0.80	< 0.005
Manganese, Dissolved (mg/L)	0.81	< 0.005
Mercury, Total (mg/L)	< 0.0001	< 0.0001
Mercury, Dissolved (mg/L)	< 0.0001	< 0.0001
Molybdenum, Total (mg/L)	0.38	0.006
Molybdenum, Dissolved (mg/L)	0.38	< 0.005
Nickel, Total (mg/L)	0.03	< 0.02
Nickel, Dissolved (mg/L)	0.02	< 0.02
Potassium, Total (mg/L)	3.5	1.4
Potassium, Dissolved (mg/L)	3.1	1.4
Selenium, Total (mg/L)	< 0.05	< 0.05

REPORT OF ANALYSIS
ADDITIONAL

Mr Walt Niccoli
Shepard-Miller Inc

Lab Job Number: 007410 SHE002
Date Samples Received: 03/01/96

Selenium, Dissolved (mg/L)	< 0.05	< 0.05
Silicon, Total (mg/L)	16	5.1
Silicon, Dissolved (mg/L)	15	4.9
Sodium, Total (mg/L)	37	58
Sodium, Dissolved (mg/L)	38	65
Vanadium, Total (mg/L)	0.005	< 0.005
Vanadium, Dissolved (mg/L)	< 0.005	< 0.005
Zinc, Total (mg/L)	0.087	< 0.005
Zinc, Dissolved (mg/L)	0.007	< 0.005

REPORT OF ANALYSIS
ADDITIONAL

Mr Walt Niccoli
Shepard-Miller Inc

Lab Job Number: 007410 SHE002
Date Samples Received: 03/01/96

ALR Designation:	96-A3864	96-A3865
Client Designation:	SMI-MW-1A	SMI-MW-7B
Sample Location:		
Location II:		
Date/Time Collected	02/28/96 10:40	02/28/96 11:49
Aluminum, Total (mg/L)	< 0.050	0.46
Aluminum, Dissolved (mg/L)	< 0.050	< 0.050
Antimony, Total (mg/L)	< 0.05	< 0.05
Antimony, Dissolved (mg/L)	< 0.05	< 0.05
Arsenic, Total (mg/L)	< 0.05	< 0.05
Arsenic, Dissolved (mg/L)	< 0.05	< 0.05
Boron, Total (mg/L)	< 0.1	< 0.1
Boron, Dissolved (mg/L)	< 0.1	< 0.1
Cadmium, Total (mg/L)	< 0.005	< 0.005
Cadmium, Dissolved (mg/L)	< 0.005	< 0.005
Calcium, Total (mg/L)	90	220
Calcium, Dissolved (mg/L)	95	220
Chromium, Total (mg/L)	< 0.005	0.005
Chromium, Dissolved (mg/L)	< 0.005	< 0.005
Cobalt, Total (mg/L)	< 0.005	< 0.005
Cobalt, Dissolved (mg/L)	< 0.005	< 0.005
Copper, Total (mg/L)	< 0.005	0.061
Copper, Dissolved (mg/L)	< 0.005	< 0.005
Iron, Total (mg/L)	0.27	1.2
Iron, Dissolved (mg/L)	0.26	0.44
Lead, Total (mg/L)	< 0.05	< 0.05
Lead, Dissolved (mg/L)	< 0.05	< 0.05
Magnesium, Total (mg/L)	46	33
Magnesium, Dissolved (mg/L)	49	34
Manganese, Total (mg/L)	0.36	0.80
Manganese, Dissolved (mg/L)	0.38	0.81
Mercury, Total (mg/L)	< 0.0001	< 0.0001
Mercury, Dissolved (mg/L)	< 0.0001	< 0.0001
Molybdenum, Total (mg/L)	< 0.005	0.38
Molybdenum, Dissolved (mg/L)	< 0.005	0.38
Nickel, Total (mg/L)	< 0.02	0.02
Nickel, Dissolved (mg/L)	< 0.02	0.02
Potassium, Total (mg/L)	4.5	3.1
Potassium, Dissolved (mg/L)	4.2	3.2
Selenium, Total (mg/L)	< 0.05	< 0.05
Selenium, Dissolved (mg/L)	< 0.05	< 0.05
Silicon, Total (mg/L)	8.8	15
Silicon, Dissolved (mg/L)	9.3	15
Sodium, Total (mg/L)	28	37

REPORT OF ANALYSIS
ADDITIONAL

Mr Walt Niccoli
Shepard-Miller Inc

Lab Job Number: 007410 SHE002
Date Samples Received: 03/01/96

Sodium, Dissolved (mg/L)	29	38
Vanadium, Total (mg/L)	< 0.005	< 0.005
Vanadium, Dissolved (mg/L)	< 0.005	0.005
Zinc, Total (mg/L)	0.014	0.049
Zinc, Dissolved (mg/L)	0.014	< 0.005

REPORT OF ANALYSIS
ADDITIONAL

Mr Walt Niccoli
Shepard-Miller Inc

Lab Job Number: 007410 SHE002
Date Samples Received: 03/01/96

ALR Designation:	96-A3866	96-A3867
Client Designation:	SMI-MW-10	SMI-EDSN-1
Sample Location:		
Location II:		
Date/Time Collected	02/27/96 18:15	02/26/96 17:55
Aluminum, Total (mg/L)	1.6	< 0.050
Aluminum, Dissolved (mg/L)	< 0.050	< 0.050
Antimony, Total (mg/L)	< 0.05	0.06
Antimony, Dissolved (mg/L)	< 0.05	< 0.05
Arsenic, Total (mg/L)	< 0.05	< 0.05
Arsenic, Dissolved (mg/L)	< 0.05	< 0.05
Boron, Total (mg/L)	< 0.1	< 0.1
Boron, Dissolved (mg/L)	< 0.1	< 0.1
Cadmium, Total (mg/L)	< 0.005	< 0.005
Cadmium, Dissolved (mg/L)	< 0.005	< 0.005
Calcium, Total (mg/L)	210	540
Calcium, Dissolved (mg/L)	210	570
Chromium, Total (mg/L)	0.007	< 0.005
Chromium, Dissolved (mg/L)	< 0.005	< 0.005
Cobalt, Total (mg/L)	0.007	< 0.005
Cobalt, Dissolved (mg/L)	0.006	< 0.005
Copper, Total (mg/L)	0.30	0.19
Copper, Dissolved (mg/L)	0.12	0.19
Iron, Total (mg/L)	2.1	< 0.01
Iron, Dissolved (mg/L)	< 0.01	< 0.01
Lead, Total (mg/L)	< 0.05	< 0.05
Lead, Dissolved (mg/L)	< 0.05	< 0.05
Magnesium, Total (mg/L)	39	300
Magnesium, Dissolved (mg/L)	39	310
Manganese, Total (mg/L)	1.2	0.41
Manganese, Dissolved (mg/L)	1.2	0.42
Mercury, Total (mg/L)	< 0.0001	< 0.0001
Mercury, Dissolved (mg/L)	< 0.0001	< 0.0001
Molybdenum, Total (mg/L)	0.045	0.013
Molybdenum, Dissolved (mg/L)	0.044	0.013
Nickel, Total (mg/L)	< 0.02	0.03
Nickel, Dissolved (mg/L)	< 0.02	0.04
Potassium, Total (mg/L)	7.2	8.4
Potassium, Dissolved (mg/L)	6.9	9.7
Selenium, Total (mg/L)	< 0.05	< 0.05
Selenium, Dissolved (mg/L)	< 0.05	0.07
Silicon, Total (mg/L)	15	15
Silicon, Dissolved (mg/L)	13	16
Sodium, Total (mg/L)	37	130

REPORT OF ANALYSIS
ADDITIONAL

Mr Walt Niccoli
Shepard-Miller Inc

Lab Job Number: 007410 SHE002
Date Samples Received: 03/01/96

Sodium, Dissolved (mg/L)	37	130
Vanadium, Total (mg/L)	0.009	< 0.005
Vanadium, Dissolved (mg/L)	< 0.005	< 0.005
Zinc, Total (mg/L)	0.52	1.0
Zinc, Dissolved (mg/L)	0.44	1.1

REPORT OF ANALYSIS
ADDITIONAL

Mr Walt Niccoli
Shepard-Miller Inc

Lab Job Number: 007410 SHE002
Date Samples Received: 03/01/96

ALR Designation:	96-A3868	96-A3869
Client Designation:	SMI-MW-5	SMI-MW-4
Sample Location:		
Location II:		
Date/Time Collected	02/26/96 15:15	02/26/96 18:17
Aluminum, Total (mg/L)	< 0.050	0.080
Aluminum, Dissolved (mg/L)	< 0.050	< 0.050
Antimony, Total (mg/L)	< 0.05	< 0.05
Antimony, Dissolved (mg/L)	< 0.05	< 0.05
Arsenic, Total (mg/L)	< 0.05	< 0.05
Arsenic, Dissolved (mg/L)	< 0.05	< 0.05
Boron, Total (mg/L)	< 0.1	< 0.1
Boron, Dissolved (mg/L)	< 0.1	< 0.1
Cadmium, Total (mg/L)	< 0.005	< 0.005
Cadmium, Dissolved (mg/L)	< 0.005	< 0.005
Calcium, Total (mg/L)	200	73
Calcium, Dissolved (mg/L)	200	72
Chromium, Total (mg/L)	< 0.005	< 0.005
Chromium, Dissolved (mg/L)	< 0.005	< 0.005
Cobalt, Total (mg/L)	< 0.005	< 0.005
Cobalt, Dissolved (mg/L)	< 0.005	< 0.005
Copper, Total (mg/L)	< 0.005	< 0.005
Copper, Dissolved (mg/L)	< 0.005	< 0.005
Iron, Total (mg/L)	0.09	3.6
Iron, Dissolved (mg/L)	< 0.01	3.4
Lead, Total (mg/L)	< 0.05	< 0.05
Lead, Dissolved (mg/L)	< 0.05	< 0.05
Magnesium, Total (mg/L)	13	100
Magnesium, Dissolved (mg/L)	13	100
Manganese, Total (mg/L)	< 0.005	0.073
Manganese, Dissolved (mg/L)	< 0.005	0.067
Mercury, Total (mg/L)	< 0.0001	< 0.0001
Mercury, Dissolved (mg/L)	< 0.0001	< 0.0001
Molybdenum, Total (mg/L)	< 0.005	0.024
Molybdenum, Dissolved (mg/L)	< 0.005	0.023
Nickel, Total (mg/L)	< 0.02	< 0.02
Nickel, Dissolved (mg/L)	< 0.02	< 0.02
Potassium, Total (mg/L)	2.3	3.6
Potassium, Dissolved (mg/L)	2.5	4.2
Selenium, Total (mg/L)	< 0.05	< 0.05
Selenium, Dissolved (mg/L)	< 0.05	< 0.05
Silicon, Total (mg/L)	8.2	14
Silicon, Dissolved (mg/L)	8.6	14
Sodium, Total (mg/L)	10	3.8

REPORT OF ANALYSIS
ADDITIONAL

Mr Walt Niccoli
Shepard-Miller Inc

Lab Job Number: 007410 SHE002
Date Samples Received: 03/01/96

Sodium, Dissolved (mg/L)	10	4.0
Vanadium, Total (mg/L)	< 0.005	< 0.005
Vanadium, Dissolved (mg/L)	< 0.005	< 0.005
Zinc, Total (mg/L)	0.051	0.039
Zinc, Dissolved (mg/L)	0.050	< 0.005

REPORT OF ANALYSIS
ADDITIONAL

Mr Walt Niccoli
Shepard-Miller Inc

Lab Job Number: 007410 SHE002
Date Samples Received: 03/01/96

ALR Designation:	96-A3870	96-A3871
Client Designation:	SMI-MW-2	SMI-MW-3
Sample Location:		
Location II:		
Date/Time Collected	02/26/96 18:46	02/27/96 17:20
Aluminum, Total (mg/L)	< 0.050	0.10
Aluminum, Dissolved (mg/L)	< 0.050	< 0.050
Antimony, Total (mg/L)	< 0.05	< 0.05
Antimony, Dissolved (mg/L)	< 0.05	< 0.05
Arsenic, Total (mg/L)	< 0.05	< 0.05
Arsenic, Dissolved (mg/L)	< 0.05	< 0.05
Boron, Total (mg/L)	0.2	< 0.1
Boron, Dissolved (mg/L)	0.1	< 0.1
Cadmium, Total (mg/L)	< 0.005	< 0.005
Cadmium, Dissolved (mg/L)	< 0.005	< 0.005
Calcium, Total (mg/L)	340	220
Calcium, Dissolved (mg/L)	330	220
Chromium, Total (mg/L)	< 0.005	0.005
Chromium, Dissolved (mg/L)	< 0.005	0.005
Cobalt, Total (mg/L)	< 0.005	< 0.005
Cobalt, Dissolved (mg/L)	< 0.005	< 0.005
Copper, Total (mg/L)	< 0.005	< 0.005
Copper, Dissolved (mg/L)	< 0.005	< 0.005
Iron, Total (mg/L)	0.31	6.5
Iron, Dissolved (mg/L)	0.10	2.7
Lead, Total (mg/L)	< 0.05	< 0.05
Lead, Dissolved (mg/L)	< 0.05	< 0.05
Magnesium, Total (mg/L)	110	85
Magnesium, Dissolved (mg/L)	110	84
Manganese, Total (mg/L)	0.038	0.50
Manganese, Dissolved (mg/L)	0.034	0.49
Mercury, Total (mg/L)	< 0.0001	< 0.0001
Mercury, Dissolved (mg/L)	< 0.0001	< 0.0001
Molybdenum, Total (mg/L)	0.11	0.080
Molybdenum, Dissolved (mg/L)	0.10	0.072
Nickel, Total (mg/L)	< 0.02	< 0.02
Nickel, Dissolved (mg/L)	< 0.02	< 0.02
Potassium, Total (mg/L)	8.9	3.7
Potassium, Dissolved (mg/L)	9.4	4.0
Selenium, Total (mg/L)	< 0.05	< 0.05
Selenium, Dissolved (mg/L)	0.05	< 0.05
Silicon, Total (mg/L)	9.2	13
Silicon, Dissolved (mg/L)	9.1	13
Sodium, Total (mg/L)	59	34

REPORT OF ANALYSIS
ADDITIONAL

Mr Walt Niccoli
Shepard-Miller Inc

Lab Job Number: 007410 SHE002
Date Samples Received: 03/01/96

Sodium, Dissolved (mg/L)	59	35
Vanadium, Total (mg/L)	< 0.005	< 0.005
Vanadium, Dissolved (mg/L)	< 0.005	0.006
Zinc, Total (mg/L)	< 0.005	0.018
Zinc, Dissolved (mg/L)	< 0.005	< 0.005

NOTES: When present, *** indicates that the analyte in question was not requested for that sample.

Scheduled sample disposal/return date: May 2, 1996.

Carl R. Ray

Carl R. Ray
Laboratory Manager

Accu-Labs® Research, Inc.

563 Table Mountain Drive Golden, Colorado 80403-1650
03) 277-9514 FAX (303) 277-9512

Date: 03/14/96
Page 1

REPORT OF ANALYSIS

Mr Walt Niccoli
Shepard-Miller Inc
3801 Automation Way Suite 100
Fort Collins, CO 80525

Lab Job Number: 007410 SHE002
Date Samples Received: 03/01/96

ALR Designation:	96-A3862	96-A3863
Client Designation:	SMI-MW-7A	SMI-MW-1
Sample Location:		
Location II:		
Date/Time Collected	02/28/96 11:49	02/28/96 11:08
Alkalinity, Total (mg/L CaCO3)	280	120
Bicarbonate (as HCO3-) (mg/L HCO3-)	340	120
Carbonate (as CO3=) (mg/L CO3=)	< 5	12
Chloride (mg/L)	11	1
Cyanide, Total (mg/L)	< 0.005	< 0.005
Fluoride (mg/L)	< 0.5	1.4
Hydroxide (as OH-) (mg/L OH-)	< 5	< 5
Nitrate plus Nitrite (mg/L)	< 0.05	< 0.05
Sulfate (as SO4) (mg/L)	420	18
TDS (at 180 C) (mg/L)	930	160
pH ()	7.2 ▲	9.2 ▲

ALR Designation:	96-A3864	96-A3865
Client Designation:	SMI-MW-1A	SMI-MW-7B
Sample Location:		
Location II:		
Date/Time Collected	02/28/96 10:40	02/28/96 11:49
Alkalinity, Total (mg/L CaCO3)	300	290
Bicarbonate (as HCO3-) (mg/L HCO3-)	360	350
Carbonate (as CO3=) (mg/L CO3=)	< 5	< 5
Chloride (mg/L)	28	11
Cyanide, Total (mg/L)	< 0.005	< 0.005
Fluoride (mg/L)	< 0.5	< 0.5
Hydroxide (as OH-) (mg/L OH-)	< 5	< 5
Nitrate plus Nitrite (mg/L)	< 0.05	< 0.05
Sulfate (as SO4) (mg/L)	160	420
TDS (at 180 C) (mg/L)	530	940
pH ()	7.1 ▲	7.1 ▲

Date: 03/14/96

REPORT OF ANALYSIS

Mr Walt Niccoli
Shepard-Miller Inc

Lab Job Number: 007410 SHE002
Date Samples Received: 03/01/96

ALR Designation:	96-A3866	96-A3867
Client Designation:	SMI-MW-10	SMI-EDSN-1
Sample Location:		
Location II:		
Date/Time Collected	02/27/96 18:15	02/26/96 17:55
Alkalinity, Total (mg/L CaCO3)	290	280
Bicarbonate (as HCO3-) (mg/L HCO3-)	350	340
Carbonate (as CO3=) (mg/L CO3=)	< 5	< 5
Chloride (mg/L)	64	180
Cyanide, Total (mg/L)	< 0.005	< 0.005
Fluoride (mg/L)	< 0.5	0.8
Hydroxide (as OH-) (mg/L OH-)	< 5	< 5
Nitrate plus Nitrite (mg/L)	0.32	2.7
Sulfate (as SO4) (mg/L)	390	2500
TDS (at 180 C) (mg/L)	910	4000
pH ()	7.5 ▲	7.7 ▲

ALR Designation:	96-A3868	96-A3869
Client Designation:	SMI-MW-5	SMI-MW-4
Sample Location:		
Location II:		
Date/Time Collected	02/26/96 15:15	02/26/96 18:17
Alkalinity, Total (mg/L CaCO3)	340	440
Bicarbonate (as HCO3-) (mg/L HCO3-)	410	530
Carbonate (as CO3=) (mg/L CO3=)	< 5	< 5
Chloride (mg/L)	19	10
Cyanide, Total (mg/L)	< 0.005	< 0.005
Fluoride (mg/L)	< 0.5	0.8
Hydroxide (as OH-) (mg/L OH-)	< 5	< 5
Nitrate plus Nitrite (mg/L)	5.6	< 0.05
Sulfate (as SO4) (mg/L)	180	180
TDS (at 180 C) (mg/L)	650	640
pH ()	7.0 ▲	7.3 ▲

REPORT OF ANALYSIS

Mr Walt Niccoli
Shepard-Miller Inc

Lab Job Number: 007410 SHE002
Date Samples Received: 03/01/96

ALR Designation:	96-A3870	96-A3871
Client Designation:	SMI-MW-2	SMI-MW-3
Sample Location:		
Location II:		
Date/Time Collected	02/26/96 18:46	02/27/96 17:20
Alkalinity, Total (mg/L CaCO3)	85	200
Bicarbonate (as HCO3-) (mg/L HCO3-)	100	240
Carbonate (as CO3=) (mg/L CO3=)	< 5	< 5
Chloride (mg/L)	100	30
Cyanide, Total (mg/L)	< 0.005	< 0.005
Fluoride (mg/L)	< 0.5	< 0.5
Hydroxide (as OH-) (mg/L OH-)	< 5	< 5
Nitrate plus Nitrite (mg/L)	< 0.05	0.05
Sulfate (as SO4) (mg/L)	1100	710
TDS (at 180 C) (mg/L)	1900	1300
pH ()	8.0 ▲	7.3 ▲

NOTES: When present, *** indicates that the analyte in question was not requested for that sample.
▲ Indicates that samples were received and analyzed past holding time.

Scheduled sample disposal/return date: April 13, 1996.

Fryda Hergenreder
for
Carl R. Ray
Laboratory Manager

ATTACHMENT F.5
JUNE 1996 GROUND WATER ANALYTICAL DATA

Accu-Labs® Research, Inc.
4 Table Mountain Drive Golden, Colorado 80403-1650
(3 277-9514 FAX (303) 277-9512

Date: 06/28/96
Page 1

REPORT OF ANALYSIS

Mr Walt Niccoli
Shepard-Miller Inc
3801 Automation Way Suite 100
Fort Collins, CO 80525

Lab Job Number: 009317 SHE002
Date Samples Received: 06/13/96

		Duplicate
ALR Designation:	96-A11219	96-A11220
Client Designation:	MW-19-01-960611	MW-19-02-960611
Sample Location:	GRAB	GRAB
Location II:		
Date/Time Collected	06/11/96 12:30	06/11/96 12:35
Alkalinity, Total (as CaCO3) (mg/L)	180	180
Bicarbonate (as HCO3-) (mg/L)	220	220
Carbonate (as CO3=) (mg/L)	< 5	< 5
Chloride (mg/L)	92	95
Cyanide, Total (mg/L)	< 0.005	< 0.005
Fluoride (mg/L)	< 0.5	< 0.5
Hydroxide (as OH-) (mg/L)	< 5	< 5
Sulfate (as SO4) (mg/L)	1500	1300
TDS (at 180 C) (mg/L)	2500	2500
pH ()	6.9 ▲	6.9 ▲

	Field Blank	Rinsate
ALR Designation:	96-A11221	96-A11222
Client Designation:	MW-19-03-960611	MW-19-04-960611
Sample Location:	GRAB	GRAB
Location II:		
Date/Time Collected	06/11/96 13:05	06/11/96 11:30
Alkalinity, Total (as CaCO3) (mg/L)	< 5	6
Bicarbonate (as HCO3-) (mg/L)	< 5	7
Carbonate (as CO3=) (mg/L)	< 5	< 5
Chloride (mg/L)	< 1	< 1
Cyanide, Total (mg/L)	< 0.005	< 0.005
Fluoride (mg/L)	< 0.5	< 0.5
Hydroxide (as OH-) (mg/L)	< 5	< 5
Sulfate (as SO4) (mg/L)	< 10	< 10
TDS (at 180 C) (mg/L)	20	18
pH ()	5.4 ▲	6.4 ▲

REPORT OF ANALYSIS

Mr Walt Niccoli
Shepard-Miller Inc

Lab Job Number: 009317 SHE002
Date Samples Received: 06/13/96

ALR Designation:	96-A11223	96-A11224
Client Designation:	MW-20-01-960611	MW-21-01-960611
Sample Location:	GRAB	GRAB
Location II:		
Date/Time Collected	06/11/96 14:15	06/11/96 15:00
Alkalinity, Total (as CaCO3) (mg/L)	180	270
Bicarbonate (as HCO3-) (mg/L)	220	330
Carbonate (as CO3=) (mg/L)	< 5	< 5
Chloride (mg/L)	340	23
Cyanide, Total (mg/L)	< 0.005	< 0.005
Fluoride (mg/L)	< 0.5	1.5
Hydroxide (as OH-) (mg/L)	< 5	< 5
Sulfate (as SO4) (mg/L)	1100	3000
TDS (at 180 C) (mg/L)	2500	4500
pH ()	6.3 ▲	6.2 ▲

NOTES: When present, *** indicates that the analyte in question was not requested for that sample.
▲ Indicates that samples were received and analyzed past holding time.

Scheduled sample disposal/return date: July 28, 1996.

Eyda Hergenreder
Trudy L. Scott
Laboratory Managers

Accu-Labs® Research, Inc.

4 Table Mountain Drive Golden, Colorado 80403-1650
(303) 277-9514 FAX (303) 277-9512

Date: 06/28/96
Page 1

REPORT OF ANALYSIS

Mr Walt Niccoli
Shepard-Miller Inc
3801 Automation Way Suite 100
Fort Collins, CO 80525

Lab Job Number: 009317 SHE002
Date Samples Received: 06/13/96

ALR Designation:	96-A11219	96-A11220
Client Designation:	MW-19-01-960611	MW-19-02-960611
Sample Location:	GRAB	GRAB
Location II:		
Date/Time Collected	06/11/96 12:30	06/11/96 12:35
Aluminum, Total (mg/L)	< 0.10	< 0.10
Aluminum, Dissolved (mg/L)	< 0.10	< 0.10
Antimony, Total (mg/L)	< 0.05	< 0.05
Antimony, Dissolved (mg/L)	< 0.05	< 0.05
Arsenic, Total (mg/L)	< 0.005	< 0.005
Arsenic, Dissolved (mg/L)	0.003	0.003
Boron, Total (mg/L)	< 0.1	< 0.1
Boron, Dissolved (mg/L)	< 0.1	< 0.1
Cadmium, Total (mg/L)	< 0.005	< 0.005
Cadmium, Dissolved (mg/L)	< 0.005	< 0.005
Calcium, Total (mg/L)	420	420
Calcium, Dissolved (mg/L)	450	350
Chromium, Total (mg/L)	< 0.005	< 0.005
Chromium, Dissolved (mg/L)	< 0.005	< 0.005
Cobalt, Total (mg/L)	< 0.005	< 0.005
Cobalt, Dissolved (mg/L)	< 0.005	< 0.005
Copper, Total (mg/L)	0.038	0.039
Copper, Dissolved (mg/L)	0.042	0.029
Iron, Total (mg/L)	< 0.01	< 0.01
Iron, Dissolved (mg/L)	< 0.01	< 0.01
Lead, Total (mg/L)	< 0.005	< 0.005
Lead, Dissolved (mg/L)	< 0.005	< 0.005
Magnesium, Total (mg/L)	100	100
Magnesium, Dissolved (mg/L)	110	88
Manganese, Total (mg/L)	0.28	0.28
Manganese, Dissolved (mg/L)	0.31	0.24
Mercury, Total (mg/L)	< 0.0001	< 0.0001
Mercury, Dissolved (mg/L)	< 0.0001	< 0.0001
Molybdenum, Total (mg/L)	0.080	0.085
Molybdenum, Dissolved (mg/L)	0.080	0.067
Nickel, Total (mg/L)	0.01	< 0.01
Nickel, Dissolved (mg/L)	< 0.01	0.01
Potassium, Total (mg/L)	6.8	6.8
Potassium, Dissolved (mg/L)	7.8	5.7

REPORT OF ANALYSIS

Mr Walt Niccoli
Shepard-Miller Inc

Lab Job Number: 009317
Date Samples Received: 06/13/96

ALR Designation:	96-A11219	96-A11220
Client Designation:	MW-19-01-960611	MW-19-02-960611
Sample Location:	GRAB	GRAB
Location II:		
Date/Time Collected	06/11/96 12:30	06/11/96 12:35
Selenium, Total (mg/L)	< 0.050 Higher DL due to matrix	< 0.050 Higher DL due to matrix
Selenium, Dissolved (mg/L)	< 0.010 Higher DL due to matrix	< 0.010 Higher DL due to matrix
Silicon, Total (mg/L)	12	12
Silicon, Dissolved (mg/L)	13	10
Sodium, Total (mg/L)	67	68
Sodium, Dissolved (mg/L)	76	58
Vanadium, Total (mg/L)	0.005	0.005
Vanadium, Dissolved (mg/L)	0.006	0.005
Zinc, Total (mg/L)	0.28	0.28
Zinc, Dissolved (mg/L)	0.32	0.26

REPORT OF ANALYSIS

Mr Walt Niccoli
Shepard-Miller Inc

Lab Job Number: 009317 SHE002
Date Samples Received: 06/13/96

ALR Designation:	96-A11221	96-A11222
Client Designation:	MW-19-03-960611	MW-19-04-960611
Sample Location:	GRAB	GRAB
Location II:		
Date/Time Collected	06/11/96 13:05	06/11/96 11:30
Aluminum, Total (mg/L)	< 0.10	< 0.10
Aluminum, Dissolved (mg/L)	< 0.10	< 0.10
Antimony, Total (mg/L)	< 0.05	< 0.05
Antimony, Dissolved (mg/L)	< 0.05	< 0.05
Arsenic, Total (mg/L)	< 0.005	< 0.005
Arsenic, Dissolved (mg/L)	< 0.001	< 0.001
Boron, Total (mg/L)	< 0.1	< 0.1
Boron, Dissolved (mg/L)	< 0.1	< 0.1
Cadmium, Total (mg/L)	< 0.005	< 0.005
Cadmium, Dissolved (mg/L)	< 0.005	< 0.005
Calcium, Total (mg/L)	0.6	1.2
Calcium, Dissolved (mg/L)	< 0.1	1.0
Chromium, Total (mg/L)	< 0.005	< 0.005
Chromium, Dissolved (mg/L)	< 0.005	< 0.005
Cobalt, Total (mg/L)	< 0.005	0.006
Cobalt, Dissolved (mg/L)	< 0.005	< 0.005
Copper, Total (mg/L)	< 0.005	0.085
Copper, Dissolved (mg/L)	< 0.005	0.059
Iron, Total (mg/L)	< 0.01	0.02
Iron, Dissolved (mg/L)	< 0.01	< 0.01
Lead, Total (mg/L)	< 0.005	< 0.005
Lead, Dissolved (mg/L)	< 0.005	< 0.005
Magnesium, Total (mg/L)	0.12	0.05
Magnesium, Dissolved (mg/L)	< 0.05	< 0.05
Manganese, Total (mg/L)	< 0.005	0.005
Manganese, Dissolved (mg/L)	< 0.005	< 0.005
Mercury, Total (mg/L)	< 0.0001	< 0.0001
Mercury, Dissolved (mg/L)	< 0.0001	< 0.0001
Molybdenum, Total (mg/L)	< 0.005	< 0.005
Molybdenum, Dissolved (mg/L)	< 0.005	< 0.005
Nickel, Total (mg/L)	< 0.01	< 0.01
Nickel, Dissolved (mg/L)	< 0.01	0.01
Potassium, Total (mg/L)	< 0.5	< 0.5
Potassium, Dissolved (mg/L)	< 0.5	< 0.5
Selenium, Total (mg/L)	< 0.050 Higher DL due to matrix	< 0.050 Higher DL due to matrix
Selenium, Dissolved (mg/L)	< 0.010 Higher DL due to matrix	< 0.010 Higher DL due to matrix
Silicon, Total (mg/L)	< 0.5	< 0.5
Silicon, Dissolved (mg/L)	< 0.5	< 0.5

REPORT OF ANALYSIS

Mr Walt Niccoli
Shepard-Miller Inc

Lab Job Number: 009317
Date Samples Received: 06/13/96

ALR Designation:	96-A11221	96-A11222
Client Designation:	MW-19-03-960611	MW-19-04-960611
Sample Location:	GRAB	GRAB
Location II:		
Date/Time Collected	06/11/96 13:05	06/11/96 11:30
Sodium, Total (mg/L)	0.1	0.4
Sodium, Dissolved (mg/L)	< 0.1	0.3
Vanadium, Total (mg/L)	< 0.005	< 0.005
Vanadium, Dissolved (mg/L)	< 0.005	< 0.005
Zinc, Total (mg/L)	< 0.005	0.051
Zinc, Dissolved (mg/L)	< 0.005	0.040

REPORT OF ANALYSIS

Mr Walt Niccoli
Shepard-Miller Inc

Lab Job Number: 009317 SHE002
Date Samples Received: 06/13/96

ALR Designation:	96-A11223	96-A11224
Client Designation:	MW-20-01-960611	MW-21-01-960611
Sample Location:	GRAB	GRAB
Location II:		
Date/Time Collected	06/11/96 14:15	06/11/96 15:00
Aluminum, Total (mg/L)	4.0	0.60
Aluminum, Dissolved (mg/L)	< 0.10	0.30
Antimony, Total (mg/L)	< 0.05	< 0.05
Antimony, Dissolved (mg/L)	< 0.05	< 0.05
Arsenic, Total (mg/L)	< 0.005	< 0.005
Arsenic, Dissolved (mg/L)	0.002	0.002
Boron, Total (mg/L)	< 0.1	0.2
Boron, Dissolved (mg/L)	< 0.1	< 0.1
Cadmium, Total (mg/L)	< 0.005	0.14
Cadmium, Dissolved (mg/L)	< 0.005	0.15
Calcium, Total (mg/L)	470	560
Calcium, Dissolved (mg/L)	390	590
Chromium, Total (mg/L)	0.007	< 0.005
Chromium, Dissolved (mg/L)	< 0.005	< 0.005
Cobalt, Total (mg/L)	0.005	1.9
Cobalt, Dissolved (mg/L)	< 0.005	2.0
Copper, Total (mg/L)	0.014	13
Copper, Dissolved (mg/L)	< 0.005	14
Iron, Total (mg/L)	2.7	0.43
Iron, Dissolved (mg/L)	< 0.01	< 0.01
Lead, Total (mg/L)	< 0.005	< 0.005
Lead, Dissolved (mg/L)	< 0.005	< 0.005
Magnesium, Total (mg/L)	120	230
Magnesium, Dissolved (mg/L)	96	250
Manganese, Total (mg/L)	0.30	130
Manganese, Dissolved (mg/L)	0.22	140
Mercury, Total (mg/L)	< 0.0001	< 0.0001
Mercury, Dissolved (mg/L)	< 0.0001	< 0.0001
Molybdenum, Total (mg/L)	0.058	< 0.005
Molybdenum, Dissolved (mg/L)	0.051	< 0.005
Nickel, Total (mg/L)	< 0.01	0.41
Nickel, Dissolved (mg/L)	< 0.01	0.41
Potassium, Total (mg/L)	8.8	2.3
Potassium, Dissolved (mg/L)	7.6	2.6
Selenium, Total (mg/L)	< 0.050 Higher DL due to matrix	< 0.050 Higher DL due to matrix
Selenium, Dissolved (mg/L)	< 0.010 Higher DL due to matrix	< 0.010 Higher DL due to matrix
Silicon, Total (mg/L)	19	13
Silicon, Dissolved (mg/L)	14	14

REPORT OF ANALYSIS

Mr Walt Niccoli
Shepard-Miller Inc

Lab Job Number: 009317
Date Samples Received: 06/13/96

ALR Designation:	96-A11223	96-A11224
Client Designation:	MW-20-01-960611	MW-21-01-960611
Sample Location:	GRAB	GRAB
Location II:		
Date/Time Collected	06/11/96 14:15	06/11/96 15:00
Sodium, Total (mg/L)	36	50
Sodium, Dissolved (mg/L)	31	56
Vanadium, Total (mg/L)	0.011	< 0.005
Vanadium, Dissolved (mg/L)	0.005	< 0.005
Zinc, Total (mg/L)	0.016	50
Zinc, Dissolved (mg/L)	0.010	53

NOTES: When present, *** indicates that the analyte in question was not requested for that sample.

Scheduled sample disposal/return date: July 28, 1996.

Eyda Hergenreder
Trudy L. Scott
Laboratory Managers

ATTACHMENT F.6
CHAIN OF CUSTODY RECORDS AND QA/QC ANALYTICAL DATA

Westech of Texas, Inc.
The Quality People
Since 1955

4725 Ripley Drive, Suite A
El Paso, Texas 79922-1028
(915) 585-3443 • fax 585-4944

CHAIN OF CUSTODY RECORD

Page____ of ____

CLIENT Shepherd Miller Inc.	ADDRESS 3801 Automation Way Suite 100
CONTACT PERSON Walt Niccoli	Fort Collins, CO. 80525
TELEPHONE ~~9~~ 970-2239600	PROJECT 12-475
FAX	WESTECH QUOTE / CONTRACT NO.: JOB / P.O. NO.:

• SEE FEE SCHEDULE •

SAMPLER (SIGNATURE) Joseph L. Reed

PRINT NAME Joseph L. Reed

SAMPLE TYPE CODES
A WATER S SOIL O OIL G SLUDGE
D DRINKING WATER T TRAVEL BLANK
W WASTEWATER F FIELD BLANK
X OTHER (SPECIFY): ______

REQUESTED ANALYSES: Reference Fax 6/11/96

SAMPLE / COOLER TEMPERATURE:

SAMPLE IDENTIFICATION	DATE	TIME	SAMPLE LOCATION	NO. CONTAINERS	COMPOSITE	GRAB	SAMPLE TYPE	CONTAINERS (FOR LAB USE ONLY) UNPRESERVED	HNO$_3$	NaOH	H$_2$SO$_4$	HCl	HOLD (DO NOT ANALYZE)	COMMENTS (DWR / PWS / ETC.)	LABORATORY IDENTIFICATION
MW-19-01-960611	6/11/96	1230		4		x	A	1	2	1					
MW-19-02-960611	↓	1235		↓		↓	↓	↓	↓	↓					
MW-19-03-960611	↓	1305		↓		↓	↓	↓	↓	↓					
MW-19-04-960611	↓	1130		↓		↓	↓	↓	↓	↓					
MW-20-01-960611	↓	1415		↓		↓	↓	↓	↓	↓					
MW-21-01-960611	↓	1500		↓		↓	↓	↓	↓	↓					

JLR

RELINQUISHED BY (SIGNATURE)	PRINT NAME	RECEIVED BY (SIGNATURE)	PRINT NAME	DATE / TIME
Joseph L. Reed	Joseph L. Reed			6/12/96 0800
		Teena Ray	Teena Ray	6/13/96 11:10

REMARKS See Fax (6/11/96) for parameter List

☐ Fax Results ☐ Special Detection Limits / Requirements

SAMPLE PROCESS TURNAROUND TIME:

☒ Standard ☐ Other (specify) ______

WHITE - LABORATORY; YELL WORK FILE; PINK - CLIENT

623 ©94 WTI
110396

Accu-Lab Research, Inc.
4663 Table Mountain Drive
Golden, CO 80403-1650
(303 277-9514
FAX (303) 277-9512

CHAIN OF CUSTODY AND SAMPLE TRANSMITTAL FORM

ALR Job #: 007343

PLEASE FILL OUT COMPLETELY.
BE SURE SAMPLE ID# MATCHES SAMPLE LABEL

Page ____ of ____

non-filtered

ALR Use Only	Date Of Collection	Time Of Collection	Sample Type	Sample Identification SMI-	Total Number of Bottles Per Sample	Bottle Size & Preservation: 500 ml poly HNO3 Filtered	500 ml poly HNO3 non filtered	1 Liter poly Non Pres	500 ml poly H2SO4	500 ml poly NaOH		Analyses Requested (Attach Additional Pages if Necessary)
	2/24/96	1740	Water	Tail-1B		X	X	X	X	X		
	2/24/96	1530	"	GAP-1		X	X	X	X	X		
	2/25/96	1625	"	GRP-1		X	X	X	X	X		
	2/24/96	1408	"	BS-1			X	X	X	X		

Client Name Shepherd Miller Inc
Client Contact Walt Niccoli (for report)
Phone (970) 223-9600 FAX (____)
Sampler (Print Name): Walter L. Niccoli
Sampler (Signature): Walter L Niccoli

APPLICABLE REGULATION:
SDWA ____ NPDES ____
CWA ____ RCRA ____
Other ____ N/A ____
Notify Lab of any special turnaround time or QA Requirements

1) Relinquished By: Walt Niccoli	Date and Time 2/26 1000	Received By:
2) Relinquished By:	Date and Time	Received By:
3) Relinquished By:	Date and Time 2/27/96 10:40	Received for ALR By: Ellen Puls

Project or PWSID #: 12-479-02
Purchase Order #:
Invoice To: Walt Niccoli

ALR Contact: Debbie Updike
Remarks

LAB RESERVES THE RIGHT TO RETURN UNUSED PORTION OF SAMPLES TO CLIENT.

F8291 Rev. E

Accu-Labs® Research, Inc.
4663 Table Mountain Drive
(303 277-9514
Golden, CO 80403-1650
FAX (303) 277-9512

CHAIN OF CUSTODY AND SAMPLE TRANSMITTAL FORM

ALR Job #: 007343

non filtered.

ALR Use Only	Date Of Collection	Time Of Collection	Sample Type	Sample Identification	Total Number of Bottles Per Sample	500 ml poly HNO_3 Filtered	500 ml poly HNO_3 Non filtered	1 liter poly Non Pres	500 ml poly H_2SO_4	500 ml poly NaOH		Analyses Requested (Attach Additional Pages if Necessary) Page 1 of 1
	2/23/96	1235	Water	SBG-1		X	X	X	X	X		
	"	1305	"	BG-11		X	X	X	X	X		
	"	1150	"	WBG-1		X	X	X	X	X		
	"	1110	"	EBG-5		X	X	X	X	X		
	2/24/96	1213	"	Tail-1A		X	X	X	X	X		

PLEASE FILL OUT COMPLETELY.
BE SURE SAMPLE ID# MATCHES SAMPLE LABEL

Client Name Shepherd Miller Inc
Client Contact Walter Niccoli (for report)
Phone (970) 223-9600 FAX (____)

Sampler (Print Name): Walter L. Niccoli
Sampler (Signature): Walt Niccoli

APPLICABLE REGULATION:
SDWA ____ NPDES ____
CWA ____ RCRA ____
Other ____ N/A ____

Notify Lab of any special turnaround time or QA Requirements

Relinquished By	Date and Time		Received By
1) Relinquished By: Walt Niccoli	2/26	1030	Received By:
2) Relinquished By:			Received By:
3) Relinquished By:	2/27/96	10:40	Received for ALR By: Ellen Puls

Project or PWSID #: 12-479-02
Purchase Order #:
Invoice To: Walt ccoli

ALR Contact:
Remarks

F8291 Rev. E

Accu-Labs® Research, Inc.
4663 Table Mountain Drive
(303 277-9514
Golden, CO 80403-1650
FAX (303) 277-9512

CHAIN OF CUSTODY AND SAMPLE TRANSMITTAL FORM

ALR Job #: 007343
12-479-02

Page 1 of 1

PLEASE FILL OUT COMPLETELY.
BE SURE SAMPLE ID# MATCHES SAMPLE LABEL

ALR Use Only	Date Of Collection	Time Of Collection	Sample Type	Sample Identification	Total Number of Bottles Per Sample	Bottle Size & Preservation: 1500 ml Poly Filtered HNO_3	1500 ml Poly non-filtered HNO_3	1 L poly non-filtered	1x500 ml H_2SO_4	1x500 ml NaOH		Analyses Requested (Attach Additional Pages if Necessary)
	2/24/96	1120	Water	SMI HSN-1	5	X	X	X	X	X		
	2/24/96	1046		SMI-HSN-2	5	X	X	X	X	X		
	2/23/96	1640		SMI-ZH-1	5	X	X	X	X	X		
	2/23/96	714		SMI-ZH-2		X	X	X	X	X		
	2/24/96	0930		SMI-FS-1		X	X	X	X	X		

Client Name Shepherd Miller
Client Contact Walt Niccoli (for report)
Phone (970) 223-9600 FAX (970) 223- ?

Sampler (Print Name): Walter L. Niccoli
Sampler (Signature): Walter L. Niccoli

APPLICABLE REGULATION:
SDWA ____ NPDES ____
CWA ____ RCRA ____
Other ____ N/A X

Notify Lab of any special turnaround time or QA Requirements

1) Relinquished By: Walter L. Niccoli	Date and Time: 2/26/96	1200	Received By:
2) Relinquished By:	Date and Time:		Received By:
3) Relinquished By:	Date and Time: 2/27/96	10:40	Received for ALR By: Ellen Puls

Project or PWSID #: 12-479-02
Purchase Order #:
Invoice To: Walt Niccoli

ALR Contact: Debbie Updike
Remarks

Accu-Labs® Research, Inc.

4663 Table Mountain Drive
(303 277-9514
Golden, CO 80403-1650
FAX (303) 277-9512

CHAIN OF CUSTODY AND SAMPLE TRANSMITTAL FORM

filtered non-filtered.

ALR Job #: 007410

Page 1 of 1

PLEASE FILL OUT COMPLETELY.
BE SURE SAMPLE ID# MATCHES SAMPLE LABEL

ALR Use Only	Date Of Collection	Time Of Collection	Sample Type	SMI- Sample Identification	Total Number of Bottles Per Sample	Bottle Size & Preservation: 600 ml poly HNO3 filtered	500 ml poly HNO3 Non-filtered	1 liter poly Non-pres	500 ml poly NaOH	500 ml poly H2SO4		Analyses Requested (Attach Additional Pages if Necessary)
	2/28/96	1149	Water	MW-7A	5	X	X	X	X	X		See Proposal.
	2/28/96	1108	"	MW-1	5	X	X	X	X	X		plus
	2/28/96	1010	"	MW-1A	5	X	X	X	X	X		
	"	1149	"	MW-7B	5	X	X	X	X	X		
	2/27/96	1815	"	MW-10	5	X	X	X	X	X		

Client Name Shepherd Miller Inc
Client Contact Walter Niccoli (for report)
Phone (970) 223-9600 FAX (____)

Sampler (Print Name): Walt Niccoli
Sampler (Signature): Walter L. Niccoli

APPLICABLE REGULATION:
SDWA ______ NPDES ______
CWA ______ RCRA ______
Other ______ N/A ______

Notify Lab of any special turnaround time or QA Requirements

	Date and Time		Received By:
1) Relinquished By: Walt Niccoli	2/28	0130	Received By:
2) Relinquished By:	Date and Time		Received By:
3) Relinquished By:	Date and Time 3/1/96	10:15	Received for ALR By: Veera Ray

Project or PWSID #: 12-479-02
Purchase Order #:
Invoice To: Walt Niccoli

ALR Contact: Debbie Updike
Remarks

Accu-Labs Research, Inc.

QA/QC DATA SHEET

ALR ID: 007343

Date Received: 02/27/96

Analyte*	Date of Analysis	Time of Analysis	Analyst	Replicate		Spike		CV	Calibration Blank	Method
				ALR #	% RPD	ALR #	% Rec	% Rec		
Al (D)	02/28/96	18:05	JO	96-A3659 96-A3669	0 0	96-A3661 96-A3669	103 112	102 100	<0.05 <0.05	200.7 200.7
Sb (D)	02/28/96	18:05	JO	96-A3659 96-A3669	±DL 0	96-A3661 96-A3669	110 114	106 104	<0.05 <0.05	200.7 200.7
As (D)	02/28/96 02/29/96	18:05 13:58	JO MG	96-A3659 96-A3669 96-A3669	0 -- 0	96-A3661 96-A3669 --	105 88 --	97 98 92	<0.05 <0.05 <0.05	200.7 200.7 200.7
B (D)	02/28/96	18:05	JO	96-A3659 96-A3669	0 0	96-A3661 96-A3669	98 103	101 101	<0.1 <0.1	200.7 200.7
Cd (D)	02/28/96	18:05	JO	96-A3659 96-A3669	0 0	96-A3661 96-A3669	108 108	102 101	<0.005 <0.005	200.7 200.7
Ca (D)	02/28/96	18:05	JO	96-A3659 96-A3669	2 0	96-A3661 96-A3669	103 0	106 107	<0.1 <0.1	200.7 200.7
Cr (D)	02/28/96	18:05	JO	96-A3659 96-A3669	-- --	96-A3661 96-A3669	102 106	98 97	<0.005 <0.005	200.7 200.7

Comments:

Approved: EH

±DL = Plus or minus detection limit.

Date: 3/14/96

* mg/L unless otherwise noted.

Accu-Labs Research, Inc.

QA/QC DATA SHEET

ALR ID: 007343

Date Received: 02/27/96

Analyte*	Date of Analysis	Time of Analysis	Analyst	Replicate		Spike		CV	Calibration Blank	Method
				ALR #	% RPD	ALR #	% Rec	% Rec		
Cr (D)	02/29/96	13:58	MG	96-A3659	0	--	--	92	<0.005	200.7
				96-A3669	0	--	--	92	<0.005	200.7
Co (D)	02/28/96	18:05	JO	96-A3659	--	96-A3661	106	104	<0.005	200.7
				96-A3669	--	96-A3669	106	103	<0.005	200.7
	02/29/96	13:58	MG	96-A3659	0	--	--	98	<0.005	200.7
				96-A3669	0	--	--	98	<0.005	200.7
Cu (D)	02/28/96	18:05	JO	96-A3659	--	96-A3661	97	99	<0.005	200.7
				96-A3669	±DL	96-A3669	127	102	<0.005	200.7
	02/29/96	13:58	MG	96-A3659	0	--	--	94	<0.005	200.7
Fe (D)	02/28/96	18:05	JO	96-A3659	--	96-A3661	98	102	<0.01	200.7
				96-A3669	0	96-A3669	98	100	<0.01	200.7
	02/29/96	13:58	MG	96-A3659	0	--	--	94	<0.01	200.7
Pb (D)	02/28/96	18:05	JO	96-A3659	--	96-A3661	110	102	<0.05	200.7
				96-A3669	--	96-A3669	79	104	<0.05	200.7
	02/29/96	13:58	MG	96-A3659	0	--	--	100	<0.05	200.7
				96-A3669	0	--	--	100	<0.05	200.7

Comments:

Approved: EH

±DL = Plus or minus detection limit.

Date: 3/14/96

* mg/L unless otherwise noted.

Accu-Labs Research, Inc.

QA/QC DATA SHEET

ALR ID: 007343

Date Received: 02/27/96

				Replicate		Spike		CV		
Analyte*	Date of Analysis	Time of Analysis	Analyst	ALR #	% RPD	ALR #	% Rec	% Rec	Calibration Blank	Method
Mg (D)	02/28/96	18:05	JO	96-A3659	5	96-A3661	103	100	<0.05	200.7
				96-A3669	7	96-A3669	10**	103	<0.05	200.7
Mn (D)	02/28/96	18:05	JO	96-A3659	0	96-A3661	104	104	<0.005	200.7
				96-A3669	0	96-A3669	2**	104	<0.005	200.7
Mo (D)	02/28/96	18:05	JO	96-A3659	--	96-A3661	109	108	<0.005	200.7
				96-A3669	6	96-A3669	126	109	<0.005	200.7
	02/29/96	13:58	MG	96-A3659	±DL	--	--	102	<0.005	200.7
Ni (D)	02/28/96	18:05	JO	96-A3659	0	96-A3661	96	103	<0.02	200.7
				96-A3669	0	96-A3669	96	102	<0.02	200.7
K (D)	02/28/96	18:05	JO	96-A3659	0	96-A3661	104	101	<0.5	200.7
				96-A3669	10	96-A3669	82	103	<0.5	200.7
Si (D)	02/28/96	18:05	JO	96-A3659	0	96-A3661	103	108	<0.5	200.7
				96-A3669	0	96-A3669	104	107	<0.5	200.7

Comments:

Approved:

Date: 3/14/96

±DL = Plus or minus detection limit.
**%RPD - Sample concentration 4 times greater than spike.

* mg/L unless otherwise noted.

Accu-Labs Research, Inc.

QA/QC DATA SHEET

ALR ID: 007343

Date Received: 02/27/96

Analyte*	Date of Analysis	Time of Analysis	Analyst	Replicate		Spike		CV	Calibration Blank	Method
				ALR #	% RPD	ALR #	% Rec	% Rec		
Na (D)	02/28/96	18:05	JO	96-A3659	9	96-A3661	98	104	<0.1	200.7
				96-A3669	16	96-A3669	85	104	<0.1	200.7
V (D)	02/28/96	18:05	JO	96-A3659	--	96-A3661	106	98	<0.005	200.7
				96-A3669	--	96-A3669	118	100	<0.005	200.7
	02/29/96	13:58	MG	96-A3659	0	--	--	96	<0.005	200.7
				96-A3669	0	--	--	96	<0.005	200.7
Zn (D)	02/28/96	18:05	JO	96-A3659	--	96-A3661	109	103	<0.005	200.7
				96-A3669	3	96-A3669	2	102	<0.005	200.7
	02/29/96	13:58	MG	96-A3659	6	--	--	100	<0.005	200.7
Al (T)	03/05/96	21:06	JO	96-A3653	0	96-A3662	0**	100	<0.05	200.7
	03/08/96	11:30	MM	96-A3663	0	96-A3671	101	99	<0.05	200.7
Sb (T)	03/05/96	21:06	JO	96-A3653	0	96-A3662	94	97	<0.05	200.7
	03/08/96	11:30	MM	96-A3663	0	96-A3671	95	96	<0.05	200.7
As (T)	03/05/96	21:06	JO	96-A3653	0	96-A3662	100	95	<0.05	200.7
	03/08/96	11:30	MM	96-A3663	0	96-A3671	99	102	<0.05	200.7

Comments:

Approved: EH

**%RPD - Sample concentration 4 times greater than spike.

Date: 3/14/96

* mg/L unless otherwise noted.

Accu-Labs Research, Inc.

QA/QC DATA SHEET

ALR ID: 007343

Date Received: 02/27/96

				Replicate		Spike		CV		
Analyte*	Date of Analysis	Time of Analysis	Analyst	ALR #	% RPD	ALR #	% Rec	% Rec	Calibration Blank	Method
B (T)	03/05/96 03/08/96	21:06 11:30	JO MM	96-A3653 96-A3663	0 0	96-A3662 96-A3671	106 106	100 106	<0.1 <0.1	200.7 200.7
Cd (T)	03/05/96 03/08/96	21:06 11:30	JO MM	96-A3653 96-A3663	0 0	96-A3662 96-A3671	102 98	100 102	<0.005 <0.005	200.7 200.7
Ca (T)	03/05/96 03/08/96	21:06 11:30	JO MM	96-A3653 96-A3663	0 1	96-A3662 96-A3671	95 96	105 106	<0.1 <0.1	200.7 200.7
Cr (T)	03/05/96 03/08/96	21:06 11:30	JO MM	96-A3653 96-A3663	0 0	96-A3662 96-A3671	94 102	96 100	<0.005 <0.005	200.7 200.7
Co (T)	03/05/96 03/08/96	21:06 11:30	JO MM	96-A3653 96-A3663	0 0	96-A3662 96-A3671	88 102	102 102	<0.005 <0.005	200.7 200.7
Cu (T)	03/05/96 03/08/96	21:06 11:30	JO MM	96-A3653 96-A3663	±DL 0	96-A3662 96-A3671	95 94	98 97	<0.005 <0.005	200.7 200.7
Fe (T)	03/05/96 03/08/96	21:06 11:30	JO MM	96-A3653 96-A3663	0 0	96-A3662 96-A3671	0** 90	100 100	<0.01 <0.01	200.7 200.7

Comments:

Approved:

±DL = Plus or minus detection limit.
**%RPD - Sample concentration 4 times greater than spike.

Date: 3/14/96

* mg/L unless otherwise noted.

Accu-Labs Research, Inc.

QA/QC DATA SHEET

ALR ID: 007343

Date Received: 02/27/96

Analyte*	Date of Analysis	Time of Analysis	Analyst	Replicate		Spike		CV	Calibration Blank	Method
				ALR #	% RPD	ALR #	% Rec	% Rec		
Pb (T)	03/05/96	21:06	JO	96-A3653	0	96-A3662	105	102	<0.05	200.7
	03/08/96	11:30	MM	96-A3663	0	96-A3671	93	100	<0.05	200.7
Mg (T)	03/05/96	21:06	JO	96-A3653	0	96-A3662	96	99	<0.05	200.7
	03/08/96	11:30	MM	96-A3663	1	96-A3671	90	94	<0.05	200.7
Mn (T)	03/05/96	21:06	JO	96-A3653	4	96-A3662	80	102	<0.005	200.7
	03/08/96	11:30	MM	96-A3663	1	96-A3671	80	102	<0.005	200.7
Mo (T)	03/05/96	21:06	JO	96-A3653	0	96-A3662	98	106	<0.005	200.7
	03/08/96	11:30	MM	96-A3663	0	96-A3671	101	108	<0.005	200.7
Ni (T)	03/05/96	21:06	JO	96-A3653	0	96-A3662	92	100	<0.02	200.7
	03/08/96	11:30	MM	96-A3663	0	96-A3671	91	104	<0.02	200.7
K (T)	03/05/96	21:06	JO	96-A3653	4	96-A3662	90	96	<0.5	200.7
	03/08/96	11:30	MM	96-A3663	0	96-A3671	100	100	<0.5	200.7
Si (T)	03/05/96	21:06	JO	96-A3653	3	96-A3662	110	106	<0.5	200.7
	03/08/96	11:30	MM	96-A3663	1	96-A3671	98	108	<0.5	200.7

Comments:

Approved: EH

Date: 3/14/96

* mg/L unless otherwise noted.

Accu-Labs Research, Inc.

QA/QC DATA SHEET

ALR ID: 007343

Date Received: 02/27/96

Analyte*	Date of Analysis	Time of Analysis	Analyst	Replicate		Spike		CV	Calibration Blank	Method
				ALR #	% RPD	ALR #	% Rec	% Rec		
Na (T)	03/05/96 03/08/96	21:06 11:30	JO MM	96-A3653 96-A3663	4 3	96-A3662 96-A3671	90 92	96 101	<0.1 <0.1	200.7 200.7
V (T)	03/05/96 03/08/96	21:06 11:30	JO MM	96-A3653 96-A3663	±DL 0	96-A3662 96-A3671	108 110	98 104	<0.005 <0.005	200.7 200.7
Zn (T)	03/05/96 03/08/96	21:06 11:30	JO MM	96-A3653 96-A3663	0 0	96-A3662 96-A3671	80 89	102 103	<0.005 <0.005	200.7 200.7
Hg (D)	03/06/96	10:23	KT	96-A3653 96-A3663	0 0	96-A3662 96-A3862	100 104	100 99	<0.0001 <0.0001	245.1 245.1
Hg (T)	03/01/96	12:45	KT	96-A3348 96-A3660	0 0	96-A3659 96-A3669	112 113	104 103	<0.0001 <0.0001	245.1 245.1

Comments:

Approved: EH

Date: 3/14/96

±DL = Plus or minus detection limit.

* mg/L unless otherwise noted.

Accu-Labs Research, Inc.

QA/QC DATA SHEET

ALR ID: 007343

Date Received: 02/27/96

				Replicate		Spike		CV		
Analyte*	Date of Analysis	Time of Analysis	Analyst	ALR #	% RPD	ALR #	% Rec	% Rec	Calibration Blank	Method
Alk.	02/28/96	10:25	AKW	96-A3649	0	96-A3653	96	100	<5	310.1
	02/28/96	10:25	AKW	96-A3662	0	96-A3663	96	98	<5	310.1
Cl	03/06/96	13:45	LMH	96-A3355	18	--	--	102	<1	325.2
	03/06/96	13:45	LMH	96-A3661	0	--	--	100	<1	325.2
	03/06/96	16:17	LMH	--	--	96-A3660	100	102	<1	325.2
	03/06/96	16:17	LMH	--	--	96-A3670	110	102	<1	325.2
CN	03/01/96	06:30	AKW	96-A3653	0	96-A3654	97	96	<0.005	335.2
	03/01/96	06:30	AKW	96-A3662	0	96-A3663	94	97	<0.005	335.2
	03/05/96	11:10	AKW	96-A3670	0	96-A3671	90	93	<0.005	335.2
F	03/04/96	11:15	AKW	96-A3649	0	96-A3653	122	103	<0.5	340.2
	03/04/96	11:15	AKW	96-A3662	0	96-A3663	101	97	<0.5	340.2
$NO_3 + NO_2$	03/01/96	11:43	LMH	96-A3649	0	96-A3661	96	100	<0.05	353.2
	03/01/96	11:43	LMH	96-A3662	0	96-A3671	122	96	<0.05	353.2
	03/01/96	15:52	LMH	--	--	--	--	113	<0.05	353.2

Comments:

Approved: Fdb

Date: 3/14/96

* mg/L unless otherwise noted.

Accu-Labs Research, Inc.

QA/QC DATA SHEET

ALR ID: 007343

Date Received: 02/27/96

Analyte*	Date of Analysis	Time of Analysis	Analyst	Replicate		Spike		CV	Calibration Blank	Method
				ALR #	% RPD	ALR #	% Rec	% Rec		
SO_4	03/07/96	15:00	AB	96-A3653 96-A3662	6 0	96-A3654 96-A3663	95 85	92 96	< 10 < 10	375.4 375.4
TDS	02/29/96	14:00	JK	96-A3662 96-A3732	8 5	NA NA	NA NA	96 94	<5 <5	160.1 160.1
pH	02/27/96	08:00	TM	96-A3649 96-A3662	0 0	NA NA	NA NA	100 102	5.8 5.5	150.1 150.1

Comments:

Approved: FGH

Date: 3/14/96

* mg/L unless otherwise noted.

Accu-Labs Research, Inc.

QA/QC DATA SHEET

ALR ID: 007343

Date Received: 02/27/96

Page 1 of 1

Analyte*	Date of Analysis	Time of Analysis	Analyst	Replicate		Spike		CV	Calibration Blank	Method
				ALR #	% RPD	ALR #	% Rec	% Rec		
Se (T)	03/05/96 03/08/96	21:06 11:30	JO MM	96-A3653 96-A3663	0 0	96-A3662 96-A3671	103 106	96 103	<0.05 <0.05	200.7 200.7
Se (D)	02/28/96	18:05	JO	96-A3659 96-A3669	0 0	96-A3661 96-A3669	102 83	98 95	<0.05 <0.05	200.7 200.7

Comments:

Approved:

Date: 4/22/96

* mg/L unle rwise noted.

F8291 Rev. E

Accu-Labs® Research, Inc.

4663 Table Mountain Drive
(303) 277-9514

Golden, CO 80403-1650
FAX (303) 277-9512

CHAIN OF CUSTODY AND SAMPLE TRANSMITTAL FORM

non filt.

ALR Job #: 007410

Page 1 of 1

PLEASE FILL OUT COMPLETELY.
BE SURE SAMPLE ID# MATCHES SAMPLE LABEL

ALR Use Only	Date Of Collection	Time Of Collection	Sample Type	Sample Identification	Total Number of Bottles Per Sample	Bottle Size & Preservation: 500ml HNO3 filtered	500ml poly HNO3	1 liter poly no pres	500ml poly H2SO4	500ml poly NaOH		Analyses Requested (Attach Additional Pages if Necessary)
	2/26/96	1755	Water	EDS No1	5	X	X	X	X	X		See Proposal
	"	1515	"	MW-5	"	X	X	X	X	X		plus. C, As, Mo, Sb, V
	"	1817	"	MW-4	"	X	X	X	X	X		
	"	1846	"	MW-2	"	X	X	X	X	X		
	2/27/96	1720	"	MW-3	"	X	X	X	X	X		

Client Name ~~Po~~ Shepherd Miller Inc
Client Contact Walt Niccoli (for report)
Phone (970) 223-9600 FAX ( )

Sampler (Print Name): Walt Niccoli
Sampler (Signature): Walter L Niccoli

APPLICABLE REGULATION:
SDWA ___ NPDES ___
CWA ___ RCRA ___
Other ___ N/A X

Notify Lab of any special turnaround time or QA Requirements

1) Relinquished By:	Date and Time		Received By:
2) Relinquished By:	Date and Time		Received By:
3) Relinquished By:	Date and Time 3/1/96	10:15	Received for ALR By: Verna Ray

Project or PWSID #: 12-479-02
Purchase Order #:
Invoice To: Walt Niccoli

ALR Contact: Debbie Updike.
Remarks

LAB RESERVES THE RIGHT TO RETURN UNUSED PORTION OF SAMPLES TO CLIENT

Accu-Labs Research, Inc.
1663 Table Mountain Drive
303 277-9514
Golden, CO 80403-1650
FAX (303) 277-9512

CHAIN OF CUSTODY AND SAMPLE TRANSMITTAL FORM

non filtered

ALR Job #: 007343

Page ______ of ______

PLEASE FILL OUT COMPLETELY.
BE SURE SAMPLE ID# MATCHES SAMPLE LABEL

ALR Use Only	Date Of Collection	Time Of Collection	Sample Type	SMI Sample Identification	Total Number of Bottles Per Sample	Bottle Size & Preservation 500ml poly HNO_3 Filtered	500ml poly HNO_3 Non-Filtered	1 liter poly Non Pres.	500ml poly H_2SO_4	500ml poly NaOH		Analyses Requested (Attach Additional Pages if Necessary)
	2/25/96	1335	Water	MDD-1	5	X	X	X	X	X		
	"	1315	"	MDD-2	5	X	X	X	X	X		
	"	1000	"	TPS-1	5	X	X	X	X	X		
	2/25/96	1125	"	TPS-3	5	X	X	X	X	X		
	"	1050	"	TPS-2	5	X	X	X	X	X		

Client Name Shepherd Miller Inc
Client Contact Walt (for report)
Phone (970) 223-9600 FAX (____) ______

Sampler (Print Name): Walter L. Niccoli
Sampler (Signature): Walt L Niccol

APPLICABLE REGULATION:
SDWA ______ NPDES ______
CWA ______ RCRA ______
Other ______ N/A ______

Notify Lab of any special turnaround time or QA Requirements

1) Relinquished By: Walt Niccol	Date and Time 3/26	1020	Received By:
2) Relinquished By:	Date and Time		Received By:
3) Relinquished By:	Date and Time 2/27/96	10:40	Received for ALR By:

Project or PWSID #: 12-479-02
Purchase Order #: ______
Invoice To: W. Niccoli

ALR Contact: Debbie Updike
Remarks ______

Accu-Labs search, Inc.

QA/QC A SHEET

ALR ID: 007410

Date Received: 03/01/96

Analyte*	Date of Analysis	Time of Analysis	Analyst	Replicate		Spike		CV	Calibration Blank	Method
				ALR #	% RPD	ALR #	% Rec	% Rec		
Al (T)	03/11/96	20:34	JO	96-A3862	0	96-A3871	114	100	<0.05	200.7
Sb (T)	03/11/96	20:34	JO	96-A3862	0	96-A3871	101	96	<0.05	200.7
As (T)	03/11/96	20:34	JO	96-A3862	0	96-A3871	102	100	<0.05	200.7
B (T)	03/11/96	20:34	JO	96-A3862	0	96-A3871	104	103	<0.1	200.7
Cd (T)	03/11/96	20:34	JO	96-A3862	0	96-A3871	104	102	<0.005	200.7
Ca (T)	03/11/96	20:34	JO	96-A3862	0	96-A3871	102	105	<0.1	200.7
Cr (T)	03/11/96	20:34	JO	96-A3862	0	96-A3871	96	98	<0.005	200.7
Co (T)	03/11/96	20:34	JO	96-A3862	0	96-A3871	106	102	<0.005	200.7
Cu (T)	03/11/96	20:34	JO	96-A3862	0	96-A3871	98	96	<0.005	200.7
Fe (T)	03/11/96	20:34	JO	96-A3862	0	96-A3871	115	98	<0.01	200.7
Pb (T)	03/11/96	20:34	JO	96-A3862	0	96-A3871	3**	102	<0.05	200.7
Mg (T)	03/11/96	20:34	JO	96-A3862	0	96-A3871	103	96	<0.05	200.7
Mn (T)	03/11/96	20:34	JO	96-A3862	0	96-A3871	99	100	<0.005	200.7
Mo (T)	03/11/96	20:34	JO	96-A3862	3	96-A3871	104	106	<0.005	200.7
Ni (T)	03/11/96	20:34	JO	96-A3862	0	96-A3871	97	102	<0.02	200.7

Comments:

Approved:

Date: 3-14-96

**%RPD - Sample concentration 4 times greater than spike.

* mg/L unless otherwise noted.

Accu-Lab search, Inc.

QA/QC TA SHEET

ALR ID: 007410

Date Received: 03/01/96

Analyte*	Date of Analysis	Time of Analysis	Analyst	Replicate		Spike		CV	Calibration Blank	Method
				ALR #	% RPD	ALR #	% Rec	% Rec		
K (T)	03/11/96	20:34	JO	96-A3862	6	96-A3871	100	106	<0.5	200.7
Si (T)	03/11/96	20:34	JO	96-A3862	0	96-A3871	108	107	<0.5	200.7
Na (T)	03/11/96	20:34	JO	96-A3862	2	96-A3871	98	106	<0.1	200.7
V (T)	03/11/96	20:34	JO	96-A3862	0	96-A3871	112	102	<0.005	200.7
Zn (T)	03/11/96	20:34	JO	96-A3862	1	96-A3871	97	103	<0.005	200.7
Hg (T)	03/05/96	12:27	MM	96-A3862	0	96-A3863	120	98	<0.0001	245.1
Al (D)	03/11/96	22:03	JO	96-A3862	0	96-A3871	102	100	<0.05	200.7
Sb (D)	03/11/96	22:03	JO	96-A3862	0	96-A3871	103	96	<0.05	200.7
As (D)	03/11/96	22:03	JO	96-A3862	0	96-A3871	110	100	<0.05	200.7
B (D)	03/11/96	22:03	JO	96-A3862	0	96-A3871	104	104	<0.1	200.7
Cd (D)	03/11/96	22:03	JO	96-A3862	0	96-A3871	106	104	<0.005	200.7
Ca (D)	03/11/96	22:03	JO	96-A3862	0	96-A3871	106	105	<0.1	200.7
Cr (D)	03/11/96	22:03	JO	96-A3862	0	96-A3871	104	98	<0.005	200.7
Co (D)	03/11/96	22:03	JO	96-A3862	0	96-A3871	108	102	<0.005	200.7

Comments:

Approved:

Date: 3-14-96

* mg/L unless otherwise noted.

Accu-Lab search, Inc.

QA/QC TA SHEET

ALR ID: 007410

Date Received: 03/01/96

Analyte*	Date of Analysis	Time of Analysis	Analyst	Replicate		Spike		CV	Calibration Blank	Method
				ALR #	% RPD	ALR #	% Rec	% Rec		
Cu (D)	03/11/96	22:03	JO	96-A3862	0	96-A3871	99	96	<0.005	200.7
Fe (D)	03/11/96	22:03	JO	96-A3862	2	96-A3871	120	98	<0.01	200.7
Pb (D)	03/11/96	22:03	JO	96-A3862	0	96-A3871	107	102	<0.05	200.7
Mg (D)	03/11/96	22:03	JO	96-A3862	0	96-A3871	118	95	<0.05	200.7
Mn (D)	03/11/96	22:03	JO	96-A3862	0	96-A3871	107	100	<0.005	200.7
Mo (D)	03/11/96	22:03	JO	96-A3862	0	96-A3871	108	106	<0.005	200.7
Ni (D)	03/11/96	22:03	JO	96-A3862	±DL	96-A3871	98	108	<0.02	200.7
K (D)	03/11/96	22:03	JO	96-A3862	6	96-A3871	103	98	<0.5	200.7
Si (D)	03/11/96	22:03	JO	96-A3862	0	96-A3871	102	107	<0.5	200.7
Na (D)	03/11/96	22:03	JO	96-A3862	3	96-A3871	100	100	<0.1	200.7
V (D)	03/11/96	22:03	JO	96-A3862	0	96-A3871	102	102	<0.005	200.7
Zn (D)	03/11/96	22:03	JO	96-A3862	0	96-A3871	108	104	<0.005	200.7
Hg (D)	03/06/96	11:29	KT	96-A3863	0	96-A3862	104	100	<0.0001	245.1

Comments:

Approved:

±DL = Plus or minus detection limit.

Date: 3-14-96

* mg/L unless otherwise noted.

Accu-Labs earch, Inc.

QA/QC A SHEET

ALR ID: 007410

Date Received: 03/01/96

Analyte*	Date of Analysis	Time of Analysis	Analyst	Replicate		Spike		CV	Calibration Blank	Method
				ALR #	% RPD	ALR #	% Rec	% Rec		
Alk.	03/05/96	08:30	TM	96-A3862	1	96-A3863	91	96	<5	310.1
Cl	03/06/96	13:45	LMH	96-A3789 96-A3869	0 0	96-A3868 96-A3880	110 90	100 102	<1 <1	325.2 325.2
CN	03/05/96	11:10	AKW	96-A3868	0	96-A3869	93	87	<0.005	335.2
F	03/04/96	11:15	AKW	96-A3862	0	96-A3863	95	97	<0.5	340.2
$NO_3 + NO_2$	03/01/96	15:52	LMH	96-A3862	0	96-A3871	106	113	<0.05	353.2
SO_4	03/07/96	15:00	AB	96-A3790 96-A3871	1 1	96-A3791 96-A3874	85 108	88 88	<10 <10	375.4 375.4
TDS	03/01/96	14:30	JK	96-A3871	0	NA	NA	106	<5	160.1
pH	03/01/96	12:50	BSG	96-A3862	1	NA	NA	101	6.1	150.1

Comments:

Approved:

Date: 3-14-96

* mg/L unless otherwise noted.

Accu-Lab search, Inc.

QA/QC A SHEET

ALR ID: 007410

Date Received: 03/01/96

Page 1 of 1

Analyte*	Date of Analysis	Time of Analysis	Analyst	Replicate		Spike		CV	Calibration Blank	Method
				ALR #	% RPD	ALR #	% Rec	% Rec		
Se (T)	03/11/96	20:34	JO	96-A3862	0	96-A3871	105	100	<0.05	200.7
Se (D)	03/11/96	22:03	JO	96-A3862	0	96-A3871	119	101	<0.05	200.7

Comments:

Approved:

Date: 4/2/96

* mg/L unless otherwise noted.

Accu-Labs Research, Inc.

QA/QC DATA SHEET

ALR ID: 009317

Date Received: 06/13/96

Page 1 of 4

Analyte*	Date of Analysis	Time of Analysis	Analyst	Replicate		Spike		CV	Calibration Blank	Method
				ALR #	% RPD	ALR #	% Rec	% Rec		
Al	06/24/96	20:44	DE	96-A11219	0	96-A11224	120	98	<0.1	200.7
Sb	06/24/96	20:44	DE	96-A11219	0	96-A11224	94	96	<0.05	200.7
B	06/24/96	20:44	DE	96-A11219	0	96-A11224	97	95	<0.1	200.7
Cd	06/24/96	20:44	DE	96-A11219	0	96-A11224	104	98	<0.005	200.7
Ca	06/24/96	20:44	DE	96-A11219	2	96-A11224	12**	99	<0.1	200.7
Cr	06/24/96	20:44	DE	96-A11219	0	96-A11224	78	96	<0.005	200.7
Co	06/24/96	20:44	DE	96-A11219	0	96-A11224	5**	100	<0.005	200.7
Cu	06/24/96	20:44	DE	96-A11219	5	96-A11224	7**	97	<0.005	200.7
Fe	06/24/96	20:44	DE	96-A11219	0	96-A11224	106	100	<0.01	200.7
Mg	06/24/96	20:44	DE	96-A11219	10	96-A11224	8**	97	<0.05	200.7
Mn	06/24/96	20:44	DE	96-A11219	0	96-A11224	0**	98	<0.005	200.7
Mo	06/24/96	20:44	DE	96-A11219	2	96-A11224	91	96	<0.005	200.7
Ni	06/24/96	20:44	DE	96-A11219	±DL	96-A11224	88	96	<0.01	200.7
K	06/24/96	20:44	DE	96-A11219	1	96-A11224	99	96	<0.5	200.7
Si	06/24/96	20:44	DE	96-A11219	0	96-A11224	106	101	<0.5	200.7

Comments:

±DL = Plus or minus detection limit.

**%RPD - Sample concentration 4 times greater than spike.

Approved: Eoh

Date: 7/1/96

* mg/L unless otherwise noted.

Accu-Labs arch, Inc.

QA/QC D A SHEET

ALR ID: 009317

Date Received: 06/13/96

Analyte*	Date of Analysis	Time of Analysis	Analyst	Replicate		Spike		CV	Calibration Blank	Method
				ALR #	% RPD	ALR #	% Rec	% Rec		
Na	06/24/96	20:44	DE	96-A11219	3	96-A11224	102	102	<0.1	200.7
V	06/24/96	20:44	DE	96-A11219	0	96-A11224	96	98	<0.005	200.7
Zn	06/24/96	20:44	DE	96-A11219	0	96-A11224	4**	98	<0.005	200.7
Al (D)	06/24/96	21:31	DE	96-A11219	0	96-A11224	92	100	<0.1	200.7
Sb	06/24/96	21:31	DE	96-A11219	0	96-A11224	93	97	<0.05	200.7
B	06/24/96	21:31	DE	96-A11219	0	96-A11224	101	96	<0.1	200.7
Cd	06/24/96	21:31	DE	96-A11219	0	96-A11224	90	100	<0.005	200.7
Ca	06/24/96	21:31	DE	96-A11219	4	96-A11224	5**	101	<0.1	200.7
Cr	06/24/96	21:31	DE	96-A11219	0	96-A11224	70	96	<0.005	200.7
Co	06/24/96	21:31	DE	96-A11219	0	96-A11224	10**	100	<0.005	200.7
Cu	06/24/96	21:31	DE	96-A11219	7	96-A11224	15**	98	<0.005	200.7
Fe	06/24/96	21:31	DE	96-A11219	0	96-A11224	82	100	<0.01	200.7
Mg	06/24/96	21:31	DE	96-A11219	0	96-A11224	13**	99	<0.05	200.7
Mn	06/24/96	21:31	DE	96-A11219	7	96-A11224	15**	99	<0.005	200.7

Comments:

Approved:

**%RPD - Sample concentration 4 times greater than spike.

Date: 7/1/96

* mg/L unless otherwise noted.

QA/QC D SHEET

ALR ID: 009317

Date Received: 06/13/96

Analyte*	Date of Analysis	Time of Analysis	Analyst	Replicate		Spike		CV	Calibration Blank	Method
				ALR #	% RPD	ALR #	% Rec	% Rec		
Mo	06/24/96	21:31	DE	96-A11219	5	96-A11224	89	96	<0.005	200.7
Ni	06/24/96	21:31	DE	96-A11219	0	96-A11224	87	98	<0.01	200.7
K	06/24/96	21:31	DE	96-A11219	5	96-A11224	11**	98	<0.5	200.7
Si	06/24/96	21:31	DE	96-A11219	1	96-A11224	75	106	<0.5	200.7
Na	06/24/96	21:31	DE	96-A11219	2	96-A11224	88	102	<0.1	200.7
V	06/24/96	21:31	DE	96-A11219	±DL	96-A11224	86	98	<0.005	200.7
Zn	06/24/96	21:31	DE	96-A11219	6	96-A11224	10**	98	<0.005	200.7
As (T)	06/20/96	06:21	MM	96-A11219	0	96-A11224	123	100	<0.005	206.2
(D)	06/19/96	12:50	MM	96-A11219	0	96-A11224	109	97	<0.001	206.2
Hg (T)	06/27/96	14:18	KT	96-A11933	0	96-A11224	96	108	<0.0001	206.2
(D)	06/26/96	11:55	KT	96-A11066	0	96-A11224	92	92	<0.0001	245.1
Pb (T)	06/20/96	10:06	MM	96-A11219	0	96-A11224	93	95	<0.005	239.2
(D)	06/20/96	12:24	MM	96-A11219	0	96-A11224	96	94	<0.005	239.2
Se (T)	06/27/96	21:33	DE	96-A11219	0	96-A11224	86	100	<0.005	270.2
(D)	06/27/96	12:57	MM	96-A11219	0	96-A11224	84	95	<0.005	270.2

Comments:
±DL = Plus or minus detection limit.
**%RPD - Sample concentration 4 times greater than spike.

Approved:

Date: 7/1/96

* mg/L unless otherwise noted.

Accu-Labs Research, Inc.

QA/QC DATA SHEET

ALR ID: 009317

Date Received: 06/13/96

Page 4 of 4

Analyte*	Date of Analysis	Time of Analysis	Analyst	Replicate		Spike		CV	Calibration Blank	Method
				ALR #	% RPD	ALR #	% Rec	% Rec		
Alk.	06/17/96	13:15	AKW	96-A11219	3	96-A11220	89	100	<5	340.1
Cl	06/20/96	15:39	LMH	96-A11220	2	96-A11219	80	100	<1	325.4
CN (T)	06/18/96	14:30	AKW	96-A11096	0	96-A11204	91	101	<0.005	335.2
F	06/17/96	08:55	AKW	96-A11205	0	96-A11206	101	100	<0.5	340.2
SO_4	06/18/96	10:30	CM	96-A11219	6	96-A11219	125	100	<10	375.4
TDS	06/18/96	14:00	BSG	96-A11222	0	NA	NA	110	<5	160.1
pH	06/14/96	08:00	SC	96-A11219	1	NA	NA	100	5.7	150.1

Comments:

Approved:

Date: 7/1/96

* mg/L unless otherwise noted.

ATTACHMENT F.1
STANDARD OPERATING PROCEDURES

STANDARD OPERATING PROCEDURE #1

EQUIPMENT DECONTAMINATION

Prepared by:
Shepherd Miller, Inc.
3801 Automation Way, Suite 100
Fort Collins, CO 80525

May 17, 1996

SHEPHERD MILLER
INCORPORATED

TABLE OF CONTENTS

1.0 PURPOSE AND SCOPE

The purpose of this document is to define the standard procedure for decontamination. The American Society for Testing and Materials (ASTM) Standard Practice for Decontamination of Field Equipment Used at Nonradioactive Waste Sites (D 5088-90) was used as a guide in preparing this Standard Operating Procedure (SOP).

The overall objective of multimedia sampling programs is to obtain samples that accurately depict the chemical, physical, and/or biological conditions at the sampling site. Extraneous contaminants can be brought onto the sampling location and/or be introduced into the medium of interest during the sampling program (e.g., by bailing or pumping ground water with equipment that was previously contaminated at another site). Trace quantities of these contaminants can thus infect a sample and lead to false positive analytical results and, ultimately, to an incorrect assessment of the contaminant conditions at the site. Decontamination of sampling equipment (e.g., bailers, pumps, tubing, and soil and sediment sampling equipment) and field support equipment (e.g., drill rigs and vehicles) is therefore required to ensure that sampling cross-contamination is prevented and that on-site contaminants are not carried off-site.

2.0 RELATED STANDARD OPERATING PROCEDURES

This procedure is intended to be used with the following SOP:

SOP #	Title
7	Sample Documentation, Handling, Packaging, and Chain of Custody

3.0 EQUIPMENT NECESSARY FOR DECONTAMINATION

The following equipment may be needed to perform decontamination:

- Brushes
- Wash tubs (plastic)
- Buckets (plastic)
- Scrapers
- Steam cleaner or hot water washer
- Paper towels
- Liquinox detergent (or equivalent)
- Potable water
- Deionized water
- Garden type water sprayers
- Laboratory wash bottles
- Clean plastic sheeting and/or trash bags.

4.0 DECONTAMINATION PROCEDURES

4.1 General Decontamination Procedures for All Equipment

Decontaminate all equipment that will contact a sampled media. General procedures that apply to most specific decontamination procedures are listed below.

- Dress in suitable safety equipment to reduce personal exposure.

- Wear clean or new rubber or latex gloves during decontamination activities and when handling decontaminated equipment.

- Do not decontaminate new equipment, such as disposable filters and silicon tubing, that is certified clean by the manufacturer.

- Decontaminate all wash/rinse tubs before intial use and between boreholes.

- Replace rinse and detergent waters, unless in garden sprayers, with new solutions between borings or sample locations. In some cases, new solutions may be needed between samples in the same location.

- Following decontamination, place equipment in a clean area or on clean plastic sheeting to prevent contact with contaminated soil. If the equipment will not be used immediately, cover the equipment or wrap it in plastic sheeting or heavy duty trash bags to minimize potential airborne contamination.

4.2 Decontaminating Sampling Equipment

Decontaminate sampling equipment as follows:

1. Scrape off gross contamination from equipment at the sampling or construction site.

2. For equipment that water will not damage, place the equipment in a wash tub containing Liquinox and potable water or spray the equipment with a Liquinox/potable water solution contained within a garden type sprayer, and scrub the equipment with a bristle brush or similar utensil (if possible).

3. In a second wash tub or using a second garden sprayer, triple rinse equipment with potable water to remove the Liquinox solution.

4. Triple rinse the equipment with deionized water from a garden sprayer or laboratory wash bottles, and let the equipment air dry (if possible).

4.3 Decontaminating Submersible Pumps

Decontaminate the insides of an electric submersible pump and discharge hose (e.g., a Redi-Flo 2 pump) as follows:

1. Before performing internal decontamination, remove the Redi-Flo2 internal pump fluid and replace it with deionized water
2. Pump Liquinox/potable water solution through the pump and hose. Be sure that the volume of solution used is not less than one volume of fluid contained in the pump and hose. (Note that a Redi-Flo2 pump with 250 feet of 0.5-inch inner-diameter hose contains 2.55 gallons of fluid.)
3. Pump potable rinse water through the pump and hose. Be sure that the volume of solution used is not less than three times the volume of fluid contained in the pump and hose.
4. Pump deionized rinse water through the pump and hose. Be sure that the volume of solution used is not less than three times the volume of fluid contained in the pump and hose.

Decontaminate the outside of the pump and discharge hose as follows:

1. When removing the pump and hose from the well, place the hose reel 10 to 20 feet away from the well to allow the hose to be decontaminated before placing it on the reel. Do not let decontamination fluids enter the well.
2. While removing the pump from the well, wash the outside of the pump and hose with Liquinox/potable water solution and triple rinse it with potable water.
3. Triple rinse the hose with deionized water before placing the hose on the reel and/or triple rinse the hose with deionized water while lowering the pump into the next well. If the pump and hose are exposed to airborn contaminants (e.g., dust and mud), rinse the pump and hose while lowering the pump down the next well.

4.4 Decontaminating Water Level Probes

Decontaminate water level probes by using the general decontamination procedures for sampling equipment (Section 4.2) or by wiping them successively with paper towels wetted with Liquinox solution, potable water, and deionized water. Rinse the water level probe with deionized water before use. Store the water level probe in a plastic bag after decontamination.

4.5 Decontaminating Delicate Equipment

Carefully wipe clean equipment that water will damage successively with paper towels wetted with Liquinox solution, potable water, and deionized water. Be sure to avoid damaging the equipment.

4.6 Decontaminating Drilling and Heavy Equipment

Decontaminate drilling and heavy equipment as follows:

- Dress in suitable safety equipment to reduce personal exposure.
- With a flat-bladed scraper, scrape gross contamination or drill cuttings off equipment at the sampling or construction site.
- Spray equipment, such as drill rigs, augers, drill bits, and shovels, with a Liquinox/potable water solution using a hot water washer. Be sure to adequately clean the insides of the hollow-stem augers and backhoe buckets.
- Rinse the equipment with potable water.
- Place drilling equipment on the clean drill rig and move it to a clean area. If the equipment will not be re-used immediately, store it in a designated clean area.

4.7 Disposing of Decontamination Solution

Dispose of used wash and rinse solutions at a location that will not bias subsequent samples.

5.0 DOCUMENTATION

Be sure to document the decontamination of sampling and drilling equipment. Record the documentation with black waterproof ink in the sampler's field notebook with consecutively numbered pages. This documentation should include the following:

- The personnel who performed the decontamination
- Date
- Decontamination procedures and observations
- Rinsate sample collection procedure (if collected).

6.0 QUALITY ASSURANCE REQUIREMENTS

To verify the effectiveness of the decontamination procedures, collect equipment rinsate samples from the decontaminated sampling equipment as follows:

- Run deionized water through or over a representative decontaminated sampling tool (such as a split spoon sampler or bailer) and collect the rinsate water in sample bottles.
- Filter, preserve, handle, and analyze rinsate samples for the same parameters as primary samples collected at the site. Refer to SOP #7 for sample documentation, handling, packaging, and chain-of-custody procedures.

- Record the rinsate procedure, including the sample number, in the field notebook.
- Send the bottles to the laboratory for analysis.

Collect equipment rinsate samples at the following frequencies:

- If more than 20 field samples were collected, collect one rinsate sample per 20 field samples collected.
- If less than 20 field samples were collected in the sampling event, collect at least one rinsate sample per sampling method used.
- When using more than one sampling method or type of equipment, collect at least one rinsate sample from each type of device that was used to obtain samples (e.g., if both a bailer and a electric submersible pump were used to collect ground water samples, collect a rinsate sample from both devices at a minimum frequency of 1 each per 20 samples).

7.0 REFERENCES

ASTM D-5088 - 84, Standard Practice for Decontamination of Field Equipment Used at Nonradioactive Waste Sites, *1995 Annual Book of ASTM Standards*, Vol. 04.08.

STANDARD OPERATING PROCEDURE #2

MONITORING WELL WATER LEVEL MEASUREMENT

Prepared by:
Shepherd Miller, Inc.
3801 Automation Way, Suite 100
Fort Collins, CO 80525

May 17, 1996

SHEPHERD MILLER
INCORPORATED

TABLE OF CONTENTS

1.0 PURPOSE AND SCOPE

The purpose of this document is to define the standard procedure for measuring water levels in wells, piezometers, and boreholes. This Standard Operating Procedure (SOP) describes equipment and field procedures necessary to collect water level measurements.

2.0 RELATED STANDARD OPERATING PROCEDURES

This procedure is intended to be used with the following SOP:

SOP #	Title
1	Equipment Decontamination

3.0 NECESSARY EQUIPMENT

The equipment necessary to measure water levels includes:

- Electric water level probe capable of producing measurements to the nearest 0.01 foot
- Replacement batteries for water level probe
- Field logbook, field data sheets, and black pen
- Engineers tape (marked in increments of 10ths and 100ths of a foot)
- Additional stainless steel weight
- Paper cups and/or turkey baster
- Paper towels
- Liquinox soap
- Potable water

- Sprayer filled with deionized water
- Appropriate health and safety equipment, including at least safety glasses and latex gloves.

4.0 WATER LEVEL MEASUREMENT PROCEDURES

This section gives the sequence of events to follow when measuring water levels.

- Before mobilization to the site, obtain the following:
    - previous water level data and survey data if available (data should include description of measurement point location and survey point description)
    - well completion data, including total depth, well casing stickup, and protective casing stickup
    - if wells are locked, obtain the appropriate key.
- Wear appropriate health and safety equipment, as described in the Health and Safety Plan when opening and measuring wells and performing decontamination. At a minimum, wear safety glasses and latex gloves. (Latex gloves are required to prevent cross contamination.)
- To minimize potential cross contamination, measure the wells in order of cleanest to most contaminated.
- Before taking measurements, decontaminate the water level probe according to SOP #1 and Section 5 of this SOP.
- Unlock and open the well. If the water level is above the top of the well and cap, evacuate the water with a paper cup or a turkey baster. Follow all health and safety procedures and if necessary, let the well vent any gasses that may be present in the well casing. If you observe either a negative or positive pressure when opening the well, let the well stabilize before measuring the water level. Stabilization could take several minutes, hours, or days, depending on well characteristics.
- Test the water level probe to verify that it is working properly. Push the circuit test button to verify that the light/buzzer is working. This button tests only the light/buzzer and does not test the other parts of the water level probe. Dip the tip of

the water level probe into water to verify that the water level probe is working properly. Note that deionized water, due to its low conductivity, will not trigger a response.

- After opening the well cover, locate the measuring point for water level measurements. The measuring point for the water level is usually the top of the well casing, not the protective casing, but it can vary between wells and programs. Some programs will specify on which side of the well casing (i.e., the north side) to locate the measuring point or will specify the highest point of the casing if it is not cut evenly. If not already marked and described, the measuring point should be marked and described for easy identification. If possible, the measuring point should be the same as the survey point.

- To measure the static water level, lower the water level probe into the well until the buzzer/light indicates that the probe tip has contacted water. By raising and lowering the water level probe and adjusting the sensitivity to indicate when the probe is contacting the water, the depth to water should be measured to the nearest 0.01 foot. Record the water level depth below the measuring point in the field book or data sheet. Then recheck the measurement before removing the water level probe from the well. Compare the most recent measurement with past measurements and verify that the new measurement is reasonable before leaving the well. If the measurement does not seem reasonable, measure the water level again.

- If the well is dry, record the maximum depth measured (e.g., dry to 44.34 feet).

- Measuring the total well depth will help identify the well, indicate if there is well damage or accumulated sediment in the well, and provide data to calculate saturated borehole volume prior to purging the well. If water contacts cuts or nicks in the line and causes a "short" in the line, you may need to repair and/or clean and dry the line before reuse. (Note: Because measuring total depth in deep wells with high water levels can force water around seals in tips and may cause shorting, the tip may need to be disassembled and dried.) The total well depth should be measured unless a recent total depth measurement has been fully documented. If the measuring point on the well probe is not at the tip of the probe, adjust the total depth measurement to account for the distance between the water measurement point and the tip of the probe.

- When raising or lowering the water level probe from the well, exercise great care to avoid pulling the probe wire over the well casing or the protective casing. Even PVC pipe can damage the water level probe if it is not handled properly.

- Especially on deep wells, you may need an additional weight to lower the water level probe to the water level. A non-contaminating, long, narrow weight (e.g., a stainless steel rod) should be used. Tape the weight to the water level probe line with plastic electrical tape only when not measuring organics, and remove the weight prior to decontamination. Excessive weight could damage the water level probe by stretching or even breaking the line.

- Measure the distance that the protective casing sticks up above ground level and the distance from the measuring point on the top of the well casing to the top of the protective casing.

- Wells with submersible pumps or other installed equipment probably should not be measured unless a tube specifically designed for water level measurements is present. The risk of losing the water level probe and/or damaging equipment installed in the well is considerable. Before attempting to measure a water level in a well with <u>any</u> installed equipment, obtain the project manager's approval.

5.0 DECONTAMINATION

Decontaminate the water level indicator before measuring the water level in the first well and after measuring the levels in all wells. Decontaminate the probe according to SOP #1. Decontamination requirements will vary depending on the contaminants present and their concentrations, and some sites may require decontamination of the probe between measurements at each well.

At mining sites where low-level inorganic background parameters are being monitored, the decontamination procedure may consist of the following: (1) wiping the well probe line, as it is removed from the well, successively with paper towels that have been wetted with Liquinox solution, potable water, and deionized water and (2) rinsing the entire reel with deionized water before use. Although this method is efficient, it may not be acceptable at all sites. Other acceptable decontamination procedures are specified in SOP #1. The decontamination procedure used should be approved by the project manager before use.

Once decontaminated, the water level probe should be either placed in a clean plastic bag or used immediately.

If the water level probe has contacted especially corrosive fluids (e.g., water with high or low pH values, high chlorides concentrations, or high TDS concentrations), at a minimum, thoroughly rinse the water level probe immediately after use to protect the water level probe from damage.

6.0 DOCUMENTATION

This section describes the documentation necessary for water level monitoring. Record at least the following information in the field book or on the ground water data sheets for each well:

- Personnel who performed the measurement
- Date
- Time
- Well number
- Depth to water from measurement point
- Depth to well bottom from measurement point
- Distance from the well probe's water level measurement point to the well probe tip to correct total depth measurements
- Distance from top of protective casing to ground surface
- Distance from measuring point on top of the well casing to the top of protective casing
- Description of the measurement point location
- Description of the decontamination procedure
- Well probe's identification number
- All calculations performed.

The field notebook used during water level measurement activities will include any other observations made while measuring water levels.

7.0 CALIBRATION

The water level measurement probe cord should be calibrated at least annually or more often as needed to ensure the desired accuracy. The calibration check consists of laying out 100 feet of steel tape next to 100 feet of the probe cord. At 2-foot intervals, note any measurement discrepancies between the two. The probe cord shall be rechecked if it may have been stretched or damaged during water level measurements.

Document the procedures followed while calibrating and verifying equipment in the field notebook, along with any calculations. If a correction is required, tag the probe to indicate the correction.

STANDARD OPERATING PROCEDURE #3

GROUND WATER MONITORING WELL INSTALLATION

Prepared by:
Shepherd Miller, Inc.
3801 Automation Way, Suite 100
Fort Collins, CO 80525

May 17, 1996

SHEPHERD MILLER
INCORPORATED

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1.0 PURPOSE AND SCOPE

The purpose of this document is to define the standard operating procedure (SOP) for installing ground water monitoring wells. This SOP will explain the necessary equipment and procedures for well installation. The well installation procedures in this SOP are not specific to a particular drilling method or formation.

This is a generalized SOP that presents several options for procedures, equipment, and materials. Site-specific conditions must be evaluated to select the most appropriate options. When referencing this SOP, also specify the site-specific procedure, equipment, and materials that have been selected for the site.

Due to the variability of site-specific conditions, well designs, and drilling methods, a complete description of all procedures and options for well installation are beyond the scope of this SOP. For more detailed well installation procedures, refer to the National Water Well Association (NWWA) "Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells," "Groundwater and Wells" (Second Edition), and The American Society for Testing and Materials (ASTM) Design and Installation of Ground Water Monitoring Wells in Aquifers (D 5092-90).

2.0 RELATED STANDARD OPERATING PROCEDURES

This procedure is intended to be used with the following SOPs:

SOP #	Title
1	Equipment Decontamination
2	Monitoring Well Water Level Measurement
10	Visual Description and Classification of Unconsolidated Samples Obtained During Drilling
11	Visual Description and Classification of Bedrock Samples Obtained During Drilling

3.0 GENERAL DRILLING PROCEDURES

Boreholes can be drilled using various methods and equipment depending on the conditions and requirements of specific projects. The general drilling and well construction procedures listed below will apply to most drilling methods.

3.1 Premobilization Activities

Before mobilizing the drill rig to the site, do the following:

- Inspect the site for buried utilities and overhead power lines and obtain clearances from the appropriate companies and government agencies.
- Determine the applicable state and/or county regulations regarding borehole drilling and well construction.
- Obtain state and/or county well permits (if required) and ensure they will be available for inspection at the site.
- If a licensed well driller is required by the state, obtain the driller's license number.
- Verify that the drilling company has appropriate insurance as Shepherd Miller, Inc. (SMI) or the client requires (i.e., obtain copies of their insurance certificates).
- Verify that drilling personnel have appropriate (OSHA or MSHA) safety training and that their certifications are up to date (i.e., obtain copies of their certifications).
- Obtain copies of applicable plans, which may include SOPs, the Scope of Work (SOW), the Sampling and Analysis Plan (SAP), the Quality Assurance Project Plan (QAPP), and the Health and Safety Plan (HASP).
- Obtain all appropriate Material Safety Data Sheets (MSDS).
- Determine the types of lubricants and drilling fluids to be used and verify that they will not bias resulting data.

3.2 Pre-Drilling Site Activities

Perform the following site activities on-site before drilling:

- Conduct a health and safety meeting before performing any work. Document the health and safety meeting and have all drill company personnel sign to acknowledge the meeting and plan.
- Decontaminate all downhole equipment as specified in SOP #1. To prevent cross-contamination, perform the decontamination at a location other than the drill site. Once at the drill site, inspect equipment to verify that decontamination has been properly performed.
- Perform a safety check of the drill rig (see the HASP).
- Verify that oil/fuel spill containment equipment is available.

3.3 Preventing Cross Contamination

The most important aspect of drilling and completing monitoring wells is to ensure that representative samples will be obtained and that the samples will not be significantly biased due to the procedure, equipment, or materials used to drill or complete the well. Carefully evaluate all procedures, equipment, and materials used as a potential source of contamination. Proper equipment decontamination as specified in SOP #1 is essential in preventing cross-contamination. Common sources of contamination encountered during drilling and well installation include:

- Pipe lubricants that are used should not introduce contaminants into the borehole. Lubricants that are environmentally acceptable include Green Stuff, King Stuff, Crisco, and some Teflon-based lubricants. Lubricants that are not acceptable include petroleum and most metal-based lubricants. SMI will pre-approve lubricants that will be used and the MSDS sheets for these lubricants shall be provided for approval.
- Drilling fluids, if used, should not introduce contaminants into the borehole. Drilling fluids that are acceptable include air and potable water. When possible, only air or air/mist should be used during drilling. The use of bentonite or other

drilling fluids will result in significantly increased development times and possible contamination, so these fluids should not be used if possible. The project manager shall approve the use of bentonite or other drilling fluids.

- Oil from air compressors can contaminate the borehole when drilling with air. Use in-line air filters that remove air compressor oil.
- Obtain water to be used during drilling from a potable source. Before use, flush water tanks that will be used to transport the water to remove accumulated sediments and contamination.
- Wear clean gloves, preferably rubber or latex (clean cotton gloves are acceptable), when handling decontaminated equipment. Change or decontaminate gloves frequently, and always after contacting contaminated material.
- Dirty tools can be a source of contamination. Keep all tools that contact downhole drilling equipment clean and off the ground.
- Take great care when fueling equipment to prevent spillage.
- Do not use contaminated downhole drilling equipment.

3.4 Necessary Equipment

The following equipment is necessary to drill boreholes and install wells:

- Drill rig capable of installing wells to the desired depth in the expected formation materials and subsurface conditions
- Well casing, well screen and end caps
- Bentonite pellets and bentonite chip
- Cement and powdered bentonite for grouting
- Stainless steel centralizers
- Protective well casing with locking cap
- Steel guard post (optional)
- Gallon ziploc freezer bags

- Self-adhesive labels
- Weighted tape measure
- Appropriate health and safety equipment
- Log book
- Boring log sheets.

The following equipment is necessary to measure water levels:

- Electric water level probe capable of producing measurements to a precision of 0.01 ft
- Replacement batteries for water level probe
- Field logbook, field data sheets, and black pen
- Engineers tape (10ths, 100ths feet)
- Additional stainless steel weight
- Paper cups and/or turkey baster
- Appropriate health and safety equipment, minimum of safety glasses and latex gloves.

The following equipment may be needed to perform decontamination:

- Brushes
- Wash tubs (plastic)
- Buckets (plastic)
- Scrapers
- Steam cleaner or hot water washer

- Paper towels
- Liquinox detergent (or equivalent)
- Potable water
- Deionized water
- Garden-type water sprayers
- Laboratory wash bottles
- Clean plastic sheeting and/or trash bags.

3.5 Drilling and Well Installation Procedures

3.5.1 Drilling Techniques

SMI typically uses the following three types of drilling systems:

- Auger rigs
- Casing advance
- Dual tube reverse.

Conductor casing must sometimes be installed to isolate shallow aquifers, contamination, or to stabilize the borehole. In some cases, it may be necessary to install a bentonite plug in the end of the conductor casing to keep shallow contamination out of the conductor casing. Drive the conductor casing into a confining layer and/or cement it inplace with cement/bentonite.

The minimum borehole diameter shall be at least 4 inches greater than the diameter of the casing installed. This applies to both the conductor casing and the well casing/screen.

Water production and water level measurements that are collected during drilling are a very important part of a monitoring well program. Generally, monitoring wells are designed to be screened in the upper 10 to 20 feet of the aquifer, so it is important to accurately determine the top of the aquifer. Determine the upper aquifer water level by air lifting, measuring water levels within the drill string and in nearby piezometers, or inspecting split barrel core samples for saturation. When drilling with air, the borehole will be air lifted until water production stabilizes at the depths determined by the on-site SMI employee. Air lifting will sometimes be performed as frequently as every 10 feet near the top of the aquifer. It may occasionally be necessary to cease drilling, air lift the borehole, allow the aquifer to recover, and measure the depth to water.

Record observations made by the driller, because they can provide valuable information regarding borehole conditions. These observations can include the following:

- Depth to competent bedrock
- Depth to water
- Location of voids and fractures
- Location of boulders
- Loss of circulation
- Drilling rates and “soft” or “hard” drilling
- Zones of water production and production rates
- Changes in formations.

3.5.2 Stratigraphic Logging

Log the borehole stratigraphy by examining the sample cuttings, undisturbed split barrel samples (in soil), or core samples, as described in SOP #10 or #11.

Collect cuttings at a minimum of 5-foot intervals or at changes in lithology, and the field geologist or engineer will describe them. Archive a portion of each sample in sealed and labeled plastic bags and/or plastic chip trays.

When performing hollow stem augering, collect soil samples using a split-barrel sampler according to ASTM Method D-1586. Describe the samples on the data sheets and archive them in sealed and labeled plastic bags. Split-barrel samplers may fitted with 6-inch long brass sleeves that are capped and sealed on-site for later geotechnical analysis.

3.5.3 Field Notes

Logging will be performed on borehole log forms or in the field book. Data recorded in the field book shall include the following information:

- Project name and number
- Drilling company name
- Date drilling started and finished
- Type of bit and size
- Casing sizes and depths
- Well completion details
- Driller's name
- Geologist's name
- Type of drill rig
- Boring number
- Surface elevation (if available)
- Sample depths and times
- Water levels
- Drilling observations
- Other pertinent information.

3.5.4 Well Materials Specifications

The following subsections describe well material specifications in general terms. Site-specific material specifications will be presented in the project scope of work or project work plan.

3.5.4.1 Well Casing and Screen

Well casing (riser pipe) and screens will consist of new, threaded, flush-joint pipe. Typically, 2- or 4-inch inner diameter (ID), Schedule 40 or 80 PVC casing is used. The casing diameter is usually based on sampling/testing equipment that will be used. Smaller diameter wells are preferred due to cost savings, but larger diameter wells are sometimes required to accommodate standard-size electric submersible pumps that may be required due to water depths or the quantity of water required.

Casing thickness (e.g., Schedule 40 or 80) is determined based on the expected well depths and hydrostatic heads. Carefully review technical specifications of the casing in order to select the appropriate size and strength casing. Tensile strength, compressive strength, and collapse strength shall be considered when evaluating casing strength.

Well screen can be constructed from factory-machined slotted casing or specially manufactured continuous slot well screen. The continuous slot well screen has significantly more open area and is preferred for production wells or wells designed for aquifer tests. The well screen slot size is determined based on the gradation of the filter pack material, which is based on the gain size analysis of the formation material present at the completion interval. Generally, a 0.020-inch slot (20 slot) is acceptable with a 16-30 Colorado Silica Sand.

If the well casing is not certified clean by the manufacturer, delivered, and maintained clean at the site, clean the casing immediately prior to installation using potable water with a steam cleaner or a high pressure washer.

3.5.4.2 Casing Centralizers

Evaluate the use of casing centralizers on a well by well basis. Although casing centralizers do help center well casings within the borehole, they can interfere with the tremmie pipe and with placing materials within the annulus. In some cases, centralizers will not fit within the annulus. Some states/counties require centralizers at specific intervals.

Casing centralizers will consist of stainless steel or PVC and will be firmly attached to the casing. When used, attach centralizers at the base and top of the well screen and at minimum 40-foot intervals on the blank casing, or at intervals specified by state/county regulations.

3.5.4.3 Filter Pack

The filter pack will consist of a clean silica sand of selected grain size and gradation, and in most cases will extend approximately 3 feet above the top of the screen. Unless the well is less than 30 feet deep, install the filter pack through a tremmie pipe. Water can be used to facilitate placement if its quality is known. To demonstrate the absence or presence of voids, monitor the volume of filter pack installed and compare it to the calculated volume.

Before well installation, pour a small amount of filter pack over the well screen. Observe the amount of filter pack that passes through the well screen to verify that the sand size is not too small for the selected well screen.

3.5.4.4 Bentonite Seal

Install a bentonite seal above the filter pack. The seal will consist of a layer of commercially available 1/4-inch bentonite pellets or medium chip bentonite that is approximately 3 to 5 feet thick as measured immediately after placement, without allowance for swelling. Specially manufactured 1/4-inch bentonite pellets that are coated to retard swelling are now available. The coated bentonite pellets will fall further through water before swelling and are less likely to bridge. Depending on borehole conditions, install bentonite pellets or chip bentonite by gravity feed directly down the annulus or through a tremmie pipe installed to above the water level. Add at least 5 gallons of potable water to the bentonite, and let the bentonite hydrate for 1 hour or until a retained sample hydrates.

Use bentonite slurry seals only when bentonite pellets or chips cannot be placed in the annulus. The bentonite slurry will be 20% to 30% solids by weight and will be weighed with a mud scale before placement. The bentonite slurry seal will extent at least 10 feet and preferably longer above the filter pack. Install slurry seals with a side discharge tremmie pipe and let them hydrate for at least 2 hours before continuing. Slurry seals that are longer than 100 feet may cause collapse of PVC casing. The collapse strength of the casing should be evaluated before placing seals longer than 100 feet.

Fine sand (80 or 100 mesh) may be installed on top of the filter pack to prevent infiltration of the bentonite into the filter pack. Fine sand may also be installed on top of the bentonite slurry to facilitate measuring the top of the bentonite slurry. Monitor the volume of bentonite installed and compare it to the calculated volume to demonstrate the absence or presence of voids. Note that bentonite slurries sometimes lose significant amounts to the formation and fractures.

3.5.4.5 Cement/Bentonite Grout

Grout the annular space between the well casing and the borehole from the top of the bentonite seal to the ground surface. If the grout seal will be placed on top of a bentonite slurry seal, wait 2 hours between placing the bentonite and the grout seal. If bentonite pellets or chips were used to make the seal, do not implace cement/bentonite grout on the seal for at least 1 hour or until a retained bentonite sample hydrates at the surface. The grout mixture will consist of 10 parts cement to a maximum one-half part bentonite (equivalent to one 94-pound bag of cement to about 4½ pounds of bentonite powder); the bentonite powder should not exceed 5 percent of total weight with approximately 8 gallons of potable water per 94-pound bag of cement. The slurry should be made as thick as possible while still being able to be pumped.

Prepare the grout in an above-ground rigid container by <u>first</u> mixing the bentonite powder thoroughly with the water and then mixing in the cement. For deep holes where large volumes of grout are necessary, the grout may be mixed off-site and transported to the site by truck. Specific state/county well construction standards may dictate minimum depth requirements for the grout seal or may specify a neat cement grout (i.e., cement with no added bentonite) of a minimum density.

Place grout in the well annulus with a side discharge tremmie pipe located within about 10 feet of the top of the bentonite seal. Keep the tremmie submerged within the grout throughout the grouting process. Pump the grout through the tremmie pipe, which will be removed incrementally, until undiluted grout flows from the annular space at ground surface.

Let the initial batch of grout set for at least 12 hours before placing the next grout batch in the annulus or until a retained grout sample has setup. Measure the depth to the top of each batch. For PVC casing, no batch will exceed more than 100 feet of annulus displacement.

Do not mix additives, such as calcium chloride, with the grout mixture to accelerate cement set time. The excess heat generated can melt PVC casing.

Monitor the volume of installed cement and compare it to the calculated volume to demonstrate the absence or presence of voids.

3.5.4.6 Above Ground Completion

Determine the above ground completion based on the well location and site-specific needs. After initial annular grout placement, install a protective steel casing over the portion of the monitoring well casing that projects above the ground surface. The casing will have a lockable steel cap, will be at least 5 feet long (depending on the depth of frost), and will have a diameter of at least 8 inches for 4-inch wells or 6 inches for 2-inch wells. Set the protective casing before the final set of the grout approximately 6 inches above the top of the well casing. Fill the annular space to immediately above ground level with cement grout, mortar mix, or dry bentonite. Drill a 1/4-inch weep hole in the protective casing immediately above the annular seal. Install sand or pea gravel in the annulus to above the weep hole to prevent insects from entering.

Depending on site requirements, a 0.5-foot thick coarse gravel (3/4-inch to 3-inch particle size) blanket or cement pad will extend approximately 4 feet radially from the protective casing.

Four 3-inch diameter steel posts or four 4- by 4-inch wooden posts may be installed around the well. Locate the posts approximately 4 feet from the center of the well casing and approximately 2.5 feet below the ground surface, and be sure the posts extend at least 2.5 feet above ground exposure. In areas of high vegetation, flag the posts.

3.5.4 Measurements

Take and record measurements of the boring during drilling and well construction and of well construction materials. Measure the depth to the top of the sand pack, the top of the bentonite seal, and the top of each cement/bentonite grout batch to confirm volume and placement depth to the nearest 0.1 foot. Measure PVC casing and screen to the nearest 0.01 foot.

After construction, survey the horizontal location to the nearest 0.1 foot in reference to local, documentable coordinates. Survey the elevations of the top of the protective casing, ground surface, and water level measuring point to the nearest 0.01 foot in reference to a documentable bench mark.

3.5.5 Borehole Drilling and Well Installation Procedure

Use the following procedure to install alluvial wells using hollow stem augers or the dual tube method:

1. Decontaminate all drilling equipment according to SOP #1.
2. Before drilling begins, inventory all materials on-site and record the totals in the field book. Measure bits, augers, dual-tube pipes, or drill rods before they go down the borehole. Keep a running total in the field book of the drilling equipment that is downhole.
3. Advance the boring to the planned depth using hollow stem augers, dual tube reverse circulation, or other applicable method. Collect drill cuttings at 5-foot intervals when using the dual tube and other applicable method, or when encountering changes in lithology. Collect split barrel soil samples at minimum intervals of 5 feet or when encountering changes in lithology. Collect split barrel samples according to ASTM Method D-1586 when using hollow stem augers. Describe samples as specified in SOPs #10 and #11.
4. Measure depth of completed boring using a weighted tape or measured tremmie pipe.
5. Decontaminate all well casing, screen, and centralizers according to SOP #1 unless they have been certified clean by the manufacturer, delivered, and maintained clean at the site .
6. Measure each joint of casing, screen, and cap to nearest 0.01 foot.

7. Assemble screen and casing as it is lowered into the borehole. Verify that o-rings are present at each casing union. Attach centralizers as required. When tightening a threaded joint, do not use a conventional pipe wrench. The jagged edge of the pipe wrench's jaws can cut deep scars on the outside of the casing that could cause cracks and failure in the future. Careful use of a strap or chain wrench when tightening will prevent this. In many cases, hand tightening will be sufficient.

8. Lower screen and casing until they are installed at the proper interval. Do not allow the full weight of casing/screen to support itself. Casing must be suspended, when possible, throughout well construction.

9. Record level of top of casing and calculate the screened interval. Adjust the screen interval by raising or lowering the assembly to the desired interval, if necessary, and add sand to come to the base of the cap.

10. Calculate the volume of filter pack, bentonite seal, and grout required for idealized borehole conditions, and record the volume.

11. Begin adding filter pack around the annulus of the casing through the tremmie pipe (if depth to bottom of sand is greater than 50 feet) in 5-foot increments. Take repeated depth soundings to monitor the level of the sand. In very muddy water or when using fine sand, sand should be added slowly. If present, remove hollow stem augers or other temporary casing incrementally throughout the well construction procedure. Remove the hollow stem augers or temporary casing to prevent or minimize exposure of the well casing/screen to the open borehole.

12. Before measuring the sand level, allow sufficient time for the filter sand to settle through the water column outside the casing.

13. In most cases, extend the filter pack to approximately 3 feet above the top of the well screen. In some cases with very long screened intervals, the filter pack should extend longer than 3 feet to allow for settlement during development.

14. Following sand pack placement, install a minimum 3-foot-thick seal of bentonite pellets (preferred), chips, or slurry. Install bentonite slurries through a tremmie pipe. Install bentonite pellets/chips through a tremmie pipe or by gravity feed directly down the annulus, depending on water level and borehole conditions. Measure the thickness of the completed bentonite seal before the bentonite hydrates. Before proceeding with the grouting operation, let the completed bentonite seal hydrate for at least 1 hour if pellets or chips are used or for at least 2 hours if a slurry is used. In some cases, bentonite will extend to 5 to 10 feet from the ground surface.

Slurry seals that are longer than 100 feet may cause collapse of PVC casing. The collapse strength of the casing should be evaluated before placing seals longer than 100 feet.

Fine sand (80 or 100 mesh) may be installed on top of the filter pack to prevent infiltration of the bentonite into the filter pack. Fine sand may also be installed on top of the bentonite slurry to facilitate measuring the top of the bentonite slurry. Monitor the volume of bentonite installed and compare it to the calculated volume to demonstrate the absence or presence of voids. Note that bentonite slurries sometimes lose significant amounts to the formation and fractures.

15. After placing the bentonite seal, grout the remaining annulus from the top of the bentonite seal to the ground surface. If this distance is more than 100 feet, a second grout pour will be required. Pour the grout through the tremmie pipe (if depth to top of bentonite is greater than 35 feet) into the borehole until the annulus is completely filled. Place the base of the tremmie pipe approximately 10 feet above the bentonite seal.

16. Before the grout sets, center the protective steel casing on the well casing and insert it into the grouted annulus. Insert a temporary spacer between the protective casing locking lid and the well cap to prevent the protective casing from settling onto the well cap. Place the well number on the well casing and on the cap.

17. Wait until either the last grout that was poured has set for 12 hours or a retained sample has setup, and then check the grout for settlement. If necessary, add grout to top off the annulus.

18. After 12 hours, install the mortar collar, weep hole, gravel blanket, and guard posts according to Section 3.5.4. Paint the protective casing and posts red, write the well designation with white paint, and lock.

19. Do not begin development activities for at least an additional 24 hours.

4.0 DOCUMENTATION

Record observations and data acquired in the field during drilling and installation of wells to provide a permanent record. Record these observations with waterproof black ink in a bound weatherproof field book with consecutively numbered pages. Record notes daily when in the field. Include at least the following information:

- Project name and number
- Location
- Observer's name
- Drilling company name
- Driller's and helper's names
- Type of drill rig
- Date drilling started and finished
- Type of bit used and its size
- Casing sizes and depths
- Drilling and well installation observations as described in this section
- Problems encountered and resolution
- Decontamination observations
- Weather conditions
- Inventory of materials on site.

Complete a boring log for each boring with the observations recorded in the field book. Fill out a well completion form for monitoring wells and record the data in the field book.

Draw the well installation specifics in a diagram in the field book. Include the following information in each well diagram (denoted by depth from ground surface):

- Bottom of the boring
- Surface casing depth (if intermediate casing is left in the hole)
- Borehole diameter(s)
- Screen location(s)
- Filter pack
- Bentonite seal(s)
- Cave-in locations
- Centralizers
- Height of riser without cap (above ground surface)
- Protective casing detail.

Additional documentation for well construction in the field book will include the following:

- Grout, sand, and bentonite volume calculations prior to well installation
- The quantity and composition of the grout, seals, and filter pack actually used during construction
- All measurements made to top of filter pack, seal, grout batches and other depths
- Screen slot size (in inches), slot configuration, outside diameter, inside diameter, schedule/thickness, composition, and manufacturer
- Coupling/joint design and composition
- Protective casing composition and nominal inside diameter
- Start and completion dates
- Discussion of all procedures and any problems encountered during drilling and well construction
- Surface completion information and date.

5.0 REFERENCES

ASTM D-1586 - 84, Test Method for Penetration Test and Split-Barrel Sampling of Soils, *1995 Annual Book of ASTM Standards*, Vol. 04.08.

ASTM D-5092 - 90, Design and Installation of Ground Water Monitoring Wells in Aquifers, *1995 Annual Book of ASTM Standards*, Vol. 04.08.

National Water Well Association (NWWA), "Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells."

Driscoll, F.G., 1986, *Groundwater and Wells*, Second Edition, H.M. Smyth Co., Inc., Johnson Division, St. Paul, Minnesota.

STANDARD OPERATING PROCEDURE #4

MONITORING WELL DEVELOPMENT

Prepared by:
Shepherd Miller, Inc.
3801 Automation Way, Suite 100
Fort Collins, CO 80525

May 17, 1996

SHEPHERD MILLER
INCORPORATED

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LIST OF APPENDICES

1.0 PURPOSE AND SCOPE

This document defines the standard operating procedure (SOP) for developing ground water monitoring wells and piezometers. This SOP explains the necessary equipment and procedures for developing wells in both bedrock and alluvium.

This is a generalized SOP that presents several options for procedures, equipment, and materials. Site-specific conditions must be evaluated to select the most appropriate options. When referencing this SOP, also specify the site-specific procedure, equipment, and materials that have been selected for the site.

Due to the variability of site-specific conditions, well designs, and drilling methods, a complete description of all procedures and options for development are beyond the scope of this SOP. For more detailed development procedures, refer to the National Water Well Association (NWWA) "Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells," "Groundwater and Wells" (Second Edition), and The American Society for Testing and Materials (ASTM) Design and Installation of Ground Water Monitoring Wells in Aquifers (D 5092-90).

2.0 RELATED STANDARD OPERATING PROCEDURES

This procedure is intended to be used with the following SOPs:

SOP #	Title
1	Equipment Decontamination
3	Ground Water Monitoring Well Installation
9	Field Parameter Instrument Calibration and Measurement

3.0 NECESSARY EQUIPMENT

A combination of the following items are required to properly develop ground water monitoring wells:

- Calculator
- Field notebook
- Waterproof pen
- Stainless steel submersible pump
- Gas-powered electric generator
- PVC hand pump
- PVC or stainless steel bailer (sized appropriately for well)
- Nylon rope or wireline (deep wells) for bailing
- Surge block (sized appropriately for well)
- PVC or stainless steel pipe for operating surge block (sized appropriately for well)
- 5-gallon bucket
- Appropriate health and safety equipment
- Alconox soap (or equivalent).

The following equipment is necessary to measure water levels:

- Electric water level probe capable of producing measurements to a precision of 0.01 foot

- Replacement batteries for water level probe
- Field logbook, field data sheets, and black pen
- Engineers tape (10ths, 100ths feet)
- Additional stainless steel weight
- Paper cups and/or turkey baster
- Paper towels
- Liquinox soap
- Potable water
- Sprayer or laboratory wash bottle filled with deionized water
- Appropriate health and safety equipment, including at least safety glasses and latex gloves.

The following equipment may be needed to perform decontamination:

- Brushes
- Wash tubs (plastic)
- Buckets (plastic)
- Scrapers
- Steam cleaner or hot water washer
- Paper towels
- Liquinox detergent (or equivalent)
- Potable water

- Deionized water
- Garden type water sprayers
- Laboratory wash bottles
- Clean plastic sheeting and/or trash bags.

4.0 WELL DEVELOPMENT PROCEDURES

The purpose of well development is to repair damage done to the formation during drilling. Development removes well drilling fluids, solids, or other particulates that may be introduced or deposited on the borehole wall during drilling and construction activities. Development also may be performed on older or improperly developed wells that are suspected of not providing representative ground water samples. Development thus restores the natural hydraulic conductivity and geochemical equilibrium of the aquifer material surrounding the well to near pre-well installation conditions. Properly developed monitoring wells allow ground water samples to be collected that represent the aquifer of concern.

Develop a newly installed monitoring well only after the cement/bentonite grout has been allowed to set for at least 24 hours. Complete monitoring well development activities before collecting water samples for analytical testing. Before using development equipment and between uses at wells, decontaminate the equipment according to SOP #1.

Monitoring well development will be affected by the well completion method, open area and slot configuration, slot size, type of drilling fluid, filter pack size and thickness, and type of formation. Consider all these factors when developing wells.

4.1 Well Development Methods

Well development methods include mechanical surging, backwashing, and overpumping. Methods that involve adding water to the well or using air can potentially alter ground water quality. Therefore, do not use jetting, airlift pumping, or air surging for developing wells.

4.1.1 Mechanical Surging

Mechanical surging forces water to flow into and out of the screen by running a plunger up and down the well. A surge block is usually used to produce the surging action. A heavy bailer may be used, but the bailer is not as effective as the surge block in creating flow reversals. A dual wiper surge block with a bypass valve is most effective in reversing flows.

Begin mechanical surging immediately below the static water level and relatively gently. Move progressively downward to prevent the tool from becoming sand locked and steadily increase the force of surging. Surging may force fine material back into the formation before the fines are removed from the well. To minimize this problem, bail fine material from the borehole as often as possible.

In formations with many clay streaks, do not use surge blocks, because they may cause the clay to plug the formation. In formations with large amounts of mica, surge gently in order to minimize mica clogging, because vigorous surging may cause the screen to clog. In low-permeability formations, vigorous surging can cause screens to collapse. The hydraulic conductivity of the formation must be capable of yielding sufficient water to keep pressure differentials within reasonable limits. Surge silt and sandy formations with 0.010-inch or smaller slot screen only with great caution.

4.1.2 Backwashing

Backwashing is accomplished by starting the pump and, as soon as water reaches the surface, shutting off the pump to let the water flow back into the well (the check valve must be removed). This flow reversal breaks down the bridging, and the pumping then carries the fine material toward the screen and into the well. During backwashing, occasionally let the pump discharge to remove the sand that has been brought in by the surging action. As with overpumping, backwashing is most effective when the pump intake is raised and lowered throughout the saturated screen interval.

4.1.3 Overpumping

Overpumping involves purging the well at a higher rate than the well will be purged during sample collection. Although this is the easiest development method, it seldom produces complete development by itself. Overpumping will more fully develop the more-permeable zones and is less effective in the less-permeable zones. In some cases, overpumping may compact finer sediments around the borehole and thereby restrict flow into the screen. Overpumping is most effective in filter-packed wells located in competent, relatively homogenous formations because flow toward the well bore is more or less uniform. Overpumping is most effective when the pump intake is raised and lowered throughout the saturated screen interval.

Overpumping may be performed with either electric submersible pumps, hand pumps, or peristaltic pumps. Do not use air lift development, unless a dual wall system with a check valve to prevent aerated water from entering the well is specified. A bailer can be used, but it can cause overdevelopment of parts of high producing zones.

Record the maximum pumping rate that occurs during overpumping. Pumping rates during sample collection purging will be less than the maximum pumping rate recorded during overpumping.

4.2 Calculating Saturated Borehole Volume

Figure 1 presents the saturated borehole volume calculation formula. Figure 2 presents a sample saturated borehole volume calculation and a blank form to calculate specific saturated borehole volume. The basic formula is volume equals pi times the radius squared times depth ($V=\pi r^2 d$). To calculate the saturated borehole volume, the casing and borehole radii and the height of water in the casing and filter pack must be known. Measure the water level in the field and obtain the borehole and casing radii from the well completion data.

Figure 2 presents a sample saturated borehole volume calculation, as described below:

- Equation (a) shows how to calculate the casing radius in feet by dividing the nominal casing diameter in inches by 2 (to convert the diameter to a radius) and dividing the result by 12 (to convert inches to feet).
- Equation (b) shows how to calculate the borehole radius in feet by dividing the nominal borehole diameter in inches by 2 (to convert the diameter to a radius) and dividing the result by 12 (to convert inches to feet).
- Equation (c) shows how to calculate the casing volume, given the casing radius and height of water in the casing.
- Equation (d) shows how to calculate the annular volume, given the annular radius and the height of water in the filter pack.
- Equation (e) shows how to calculate the saturated annulus volume by subtracting the casing volume from the borehole volume and multiplying the result by the assumed effective porosity of the annulus.
- Equation (f) shows how to calculate the saturated borehole volume by adding the casing volume to the saturated annulus volume and converting cubic feet to gallons.

In confined wells and unconfined wells that are screened and filter packed below the water table, the height of water in the casing will exceed the height of water in the filter pack (i.e., $h_1 > h_2$).

In these cases, calculate the height of water in the filter pack based on the top of the filter pack interval, and not the top of the screen interval. To calculate the saturated borehole volume in these cases, substitute the appropriate height of water in feet into Equations C and D.

Note that wells have variable amounts of filter pack below the bottom of the screen. The volume of water below the bottom of the screen may be a significant portion of the total saturated borehole volume if there is only a few feet of measurable water in the screen and several feet of filter pack below the bottom of the screen. The saturated borehole volume calculation presented in Figure 2 does not account for the volume of water in the borehole below the screen. For wells with only minimal amounts of water in the screen, evaluate the amount of water within the borehole below the screen and consider it when purging the well.

4.3 Field Parameter Measurement

Although development is a physical process of removing fines from the borehole, measuring water quality is a useful tool to help assess the development procedure. During overpumping, monitor water quality parameters at least every one-half saturated borehole volume. These parameters include temperature, pH, specific conductivity, and turbidity. Regardless of the development method used, record final water quality parameter measurements to provide background data for collecting water samples.

4.4 Generalized Development Procedure

A generalized monitoring well development procedure consists of surging, backwashing, and then overpumping the well, as described below:

- Before mobilization, obtain the following well construction data: well depth, screen length and type (e.g., slotsize), filter pack interval, water production during drilling, description of measuring point, borehole diameter, and well casing diameter.

- Before mobilization, obtain the following well construction data: well depth, screen length and type (e.g., slotsize), filter pack interval, water production during drilling, description of measuring point, borehole diameter, and well casing diameter.

- Install plastic sheeting on the ground around the well to keep equipment clean.

- Decontaminate all downhole equipment as specified in SOP #1.

- Measure the static water level and total well depth as specified in SOP #2.

- Starting at the top of the water table, surge the well with either a surge block or a bailer. Surge throughout the entire screened saturated interval. Initial surging should be gentle, but surging energy should be gradually increased throughout development.

- Frequently purge the monitoring well to remove fines pulled into the well. At this stage of development, bailing the well is probably most effective due to the amount of fines and sand that will probably be present. Pumps can be damaged by sand and so pumps should probably not be used at this stage. Continue surging and bailing until sand production ceases or stabilizes.

- Install a submersible pump without a check valve. Starting at the top of the water table, backwash the well by running the pump to near surface discharge, turning the pump off, and letting the water surge back down the well. Continue backwashing the well throughout the saturated screened interval while occasionally pumping some water to remove fine materials pulled into the well. Continue backwashing the well until sand production stabilizes or ceases.

- Gradually increase the pumping cycle as the well cleans up until the pumping eventually becomes continuous (overpumping).

- During well construction and surging, debris can be deposited on the casing above the normal water level. Rinse the inside of the well casing with clean formation water during development. Rinse the well casing early in the development procedure to ensure that debris washed down the well casing will be removed during development.

- If measurable amounts of water are added during well construction, purge approximately five times that amount of water during overpumping in addition to purging a minimum of three saturated borehole volumes.

- During development, carefully monitor well characteristics (e.g., pumping rates and recovery rates) to help develop a purging/sample collection strategy. Determine the recommended sample collection pumping rate and pump placement during development, and carefully document these values.

- Continue development until sand production ceases or stabilizes and the turbidity stabilizes. Continue development as long as water quality (e.g., pH, conductivity, and temperature) continues to change. Depending on specific well characteristics, some monitoring wells may not clean up and will only produce highly turbid water. Most wells can be developed to yield representative formation water.

4.5 Development of Low-Yielding Wells

Developing low-yielding wells can be very time consuming, may take several days, and the development methods previously discussed may not be effective. In some cases, there may be no choice but to follow the procedures described in Section 4.4 (except for overpumping) and let the well recover between efforts. Do not overpump low-yielding wells because these wells cannot produce water steadily. Surging/bailing and backwashing will develop low-yielding wells with minimal purging. After a well has been surged and backwashed, purge it dry at least three times.

In extreme cases where wells are dry or nearly dry, water of known quality may need to be added to wells during development. Add water to facilitate development only if all other procedures fail. You may also circulate clean water down to the well casing and back up through the annulus before installing the annular seal. Because of the relatively low hydraulic conductivity of such formations, a negligible amount of water will penetrate the formation. Immediately following the procedure, install the annular seal and pump the well to remove, as much as possible, the water used in the development process.

5.0 DOCUMENTATION

Document field observations and data to provide information on well development and to keep a permanent record. Record these observations and data with waterproof ink either in a bound, weatherproof field book with consecutively numbered pages or on well development forms (Appendix A).

As part of the development process, record the following information in the field book:

- Person performing the development
- Well designation
- Well location
- Date(s) and time of well development
- Decontamination procedure
- Static water level from top of well casing before and after development
- Instrument calibration record
- Volume of water in the well before development
- Total well depth
- Screen length
- Depth from top of well casing to top of sediment inside well, before and after development, if present
- Volume of water removed and time of removal

- Field measurements of pH, specific conductance, temperature, and turbidity taken during and after development
- Physical character of water removed throughout development (color, odor, and turbidity)
- Type and size/capacity of pump and/or bailer
- Description of development technique.

6.0 REFERENCES

ASTM D-5092 - 90, Design and Installation of Ground Water Monitoring Wells in Aquifers, *1995 Annual Book of ASTM Standards*, Vol. 04.08.

National Water Well Association (NWWA), "Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells."

Driscoll, F.G., 1986, *Groundwater and Wells*, Second Edition, H.M. Smyth Co., Inc., Johnson Division, St. Paul, Minnesota.

APPENDIX A

MONITORING WELL DEVELOPMENT DATA SHEET

MONITORING WELL DEVELOPMENT DATA SHEET

IDENTIFICATION

Project Number____________________

Location____ Date __________ Time _____Page__of_

ersonnel ____

WEATHER CONDITIONS

Ambient Air Temperature: _____ °C ☐ °F ☐ Not Measured ☐ **Wind:** Heavy ☐ Moderate ☐ Light ☐

Precipitation: None ☐ Rain ☐ Snow ☐ Heavy ☐ Moderate ☐ Light ☐ Sunny ☐ Partly Cloudy ☐

INITIAL WELL MEASUREMENTS (Measurements in feet made from top of well casing)

Static Water Level_____ Total Depth______Top of Screen______ Filter Pack Interval_______ Borehole Diameter(inches)

Well Casing ID_____ Well Casing OD_____ Protective Casing Stickup____ Well Casing Stickup_____ Feet of Water

FINAL WELL MEASUREMENTS

Static Water Level___ Total Depth___ Total Volume Purged___ Saturated Borehole Volume (gal)___ Max Pumping Rate _____

INSTRUMENT CALIBRATION

pH Meter: Meter Number______________ **Conductivity Meter:** Meter Number________________

Buffer___ Measured Value_____ Temp.____ °C Standard______mS/cm Measured Value__________mS/cm Temp.___°C

Buffer___ Measured Value_____ Temp.____ °C Standard______mS/cm Measured Value__________mS/cm Temp.___°C

Turbidity Meter:_____ Standard ____NTU Measured Value_______NTU Standard ____NTU Measured Value_______NTU

DEVELOPMENT PROCEDURES

Surging Procedure/Equipment____

Backwashing Procedure/Equipment____

Overpumping Procedure/Equipment____

econtamination Procedure____

FIELD PARAMETER MEASUREMENTS DURING PURGING

Time	Volume (gallons)	pH	Cond. (µS/cm)	Temp. °C ☐ °F ☐	Turbidity Visual Est.☐ Measured☐	Comments

Notes ____

STANDARD OPERATING PROCEDURE #5

GROUND WATER SAMPLE COLLECTION

Prepared by:
Shepherd Miller, Inc.
3801 Automation Way, Suite 100
Fort Collins, CO 80525

May 17, 1996

SHEPHERD MILLER
INCORPORATED

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1.0 PURPOSE AND SCOPE

The purpose of this document is to define the standard procedure for collecting ground water samples from wells. This Standard Operating Procedure (SOP) gives descriptions of equipment, field procedures and quality assurance/quality control (QA/QC) procedures necessary to collect ground water samples from wells.

2.0 RELATED STANDARD OPERATING PROCEDURES

This procedure is intended to be used with the following SOPs:

SOP #	Title
1	Equipment Decontamination
2	Monitoring Well Water Level Measurement
7	Sample Documentation, Handling, Packaging, and Chain of Custody
8	Quality Assurance/Quality Control Sample Collection
9	Field Parameter Instrument Calibration and Measurement

3.0 NECESSARY EQUIPMENT

3.1 General Equipment Requirements

Equipment that may be used for measuring water levels includes:

- Electric water level probe capable of producing measurements to a precision of 0.01 foot
- Replacement batteries for water level probe
- Field logbook, field data sheets, and black pen
- Well keys

- Engineers tape (10ths, 100ths feet)
- Additional stainless steel weight
- Paper cups and/or turkey baster
- Paper towels
- Liquinox soap
- Potable water
- Sprayer filled with deionized water
- Appropriate health and safety equipment, including at least safety glasses and latex gloves.

Use the following equipment for sample collection, sample labeling, filtering, packing, documentation, and performing chain-of-custody procedures:

- Sample bottles. Obtain sample bottles and preservatives from the selected analytical laboratory, including several extra sample bottles in case breakage or other problems occur. Sample bottles can be either pre-preserved or preservatives can be added in the field.
- Sample labels
- Appropriate preservatives
- Field book and data forms
- Chain of Custody Form
- Black permanent markers and pens
- Clear plastic tape
- Fiber tape
- Custody seals
- Large (30 gallon) trash bag
- Gallon ziplock freezer bags

- Ice
- Shipping documentation
- Disposable 0.45-micron filters
- Silicon or Tygon® tubing
- Peristaltic pump.

The following equipment may be used during well evacuation and sampling:

- Assorted tools (knife, screwdriver, etc.)
- PVC, teflon, or stainless steel bailer (bottom filling)
- PVC hand pump
- PVC pump discharge hose
- Braided nylon rope
- Bailer tripod
- Gas-powered electric generator
- Stainless steel submersible pump
- Plastic sheeting (for placing around well)
- pH meter (with automatic temperature compensation)
- Specific conductivity meter
- Plastic squeeze bottle filled with deionized water
- Polyethylene or glass container (for field parameter measurements)
- Chemical-free paper towels or Kimwipes
- Calculator
- Field notebook
- Black waterproof pen
- Appropriate health and safety equipment.

Use the following equipment for performing decontamination:

- Alconox or Liquinox soap (or equivalent)
- Potable water
- Deionized water
- Decontamination buckets/pails
- Paper towels
- Plastic brushes
- Sprayers
- Plastic sheeting.

3.2 Field Parameter Measurements

Use the following apparatus and supplies for measuring pH in the field:

- Portable Hach One pH Meter Model 43800-00 with Hach One Combination pH Electrode Model 48600 or the EC10 Portable pH/mV/Temperature Meter Model 50050 with the Combination pH Electrode with Temperature (Gel-filled) Model 50200
- Spare electrolyte cartridge, if required
- Hach pH Electrode Storage Solution, Catalog No. 50301-49
- Extra batteries
- Beakers
- Buffer solutions of pH 4, 7, and 10
- Deionized or distilled water and wash bottle
- Kimwipes or equivalent.

Use the following apparatus and supplies for measuring conductivity in the field:

- Hach CO150 Conductivity Meter Model 50150 or Hach Conductivity/TDS Meter Model 44600
- Extra battery
- Calibration solutions which bracket expected range of measurements
- Deionized water
- Wash bottle
- Kimwipes
- Beakers.

Use the following apparatus and supplies for measuring turbidity in the field:

- Hach Portable Turbidimeter Model 2100P
- Extra battery
- Calibration solutions which bracket expected range of measurements
- Silicone oil
- Deionized water
- Wash bottle
- Liquinox solution
- Kimwipes
- Beakers.

4.0 WATER SAMPLING PROCEDURES

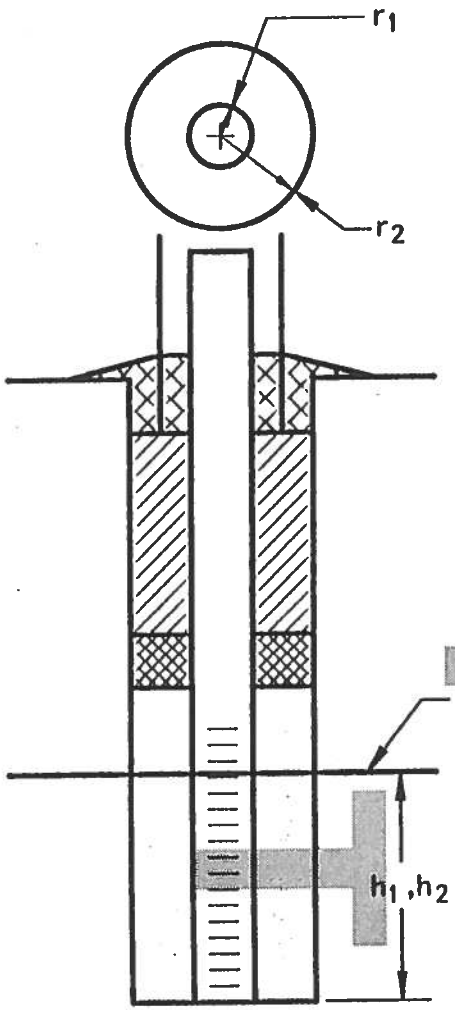
4.1 Well Purging Strategy

The objective of purging before sample collection is to thoroughly flush the static ground water from the well and filter pack (i.e., saturated borehole volume) and provide representative formation water for sample collection. The amount of water that that needs to be purged and how to determine that the resulting sample will be representative of the formation is a frequently debated issue. The two most common methods are purging a set number of saturated borehole volumes and/or casing volumes, usually between 3 and 10, and demonstrating the stability of field parameters (e.g., pH, conductivity, temperature, and turbidity) over a specified volume. Although this SOP discusses a minimum purge volume and stability of field parameters, the best procedure to help collect a representative sample requires on-site evaluation of all field conditions, which includes purge volume, stabilization of field parameters, well construction, hydrologic properties of the formation, and parameters of interest. Due to the variability of site conditions, no one procedure can ensure that a representative sample will be collected without the possibility of over- or under-purging some wells.

4.2 Calculating Saturated Borehole Volume

Monitoring wells should be purged before sampling so that representative ground water is sampled, not the potentially biased water stored in the well casing and filterpack. Because the representativeness of stored water is questionable, stored water should be purged from the monitoring well before collecting samples. Removing all stored water in most cases is not feasible or practical. Therefore, before collecting ground water samples, purge an undetermined amount of water from the monitoring well until representative formation water can be sampled.

The amount of water to purge will vary from well to well based on specific well characteristics. No one method of calculating the required purge volume will always work. The usual method to estimate purge volumes is to calculate a number of casing volumes or saturated borehole volumes.



$V_1 = \pi r_1^2 h_1$

$V_2 = \pi r_2^2 h_2$

$V_A = (V_2 - V_1)\ P$

$V_T = (V_1 + V_A)\ 7.48$ gallons/ft^3

V_1 = Casing Volume $(ft)^3$

V_2 = Annulus Volume $(ft)^3$

V_A = Saturated Annulus Volume (ft^3)

V_T = Total Saturated Borehole Volume (gallons)

r_1 = Casing Radius (ft)

r_2 = Borehole Radius (ft)

h_1 = Water in Casing (ft)

h_2 = Water in Filter Pack (ft)

P = Effective Porosity of Annulus *

$1 ft^3 = 7.48$ gallons

In Confined Wells, if $h_1 > h_2$, then

$V_T = [V_2 - (\pi r_1^2 h_2)]\ P$

* Assume $P = 0.45$ if no other data is available

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FIGURE 1
SATURATED BOREHOLE
VOLUME CALCULATION

Date: MAY, 1994
Project: 00-000
File: BH-VOL

Figure 2 **Saturated Borehole Volume Calculation (Blank Form and Example)**

Project Number: ____________________

Date: ____________________

Personnel: ____________________

Blank Form

Well:	________		Nominal Casing Diameter:	________	inches
Total Depth:	________	ft.	Nominal Borehole Diameter:	________	inches
Water Level:	________	ft.	Height of Water in Casing (h_1):	________	feet
Height of Water:	________	ft.	Height of Water in Filter Pack (h_2):	________	feet

a. Casing Radius (r_1) = ________ inches ÷ 2 ÷ 12 = ________ feet = r_1

b. Borehole Radius (r_2) = ________ inches ÷ 2 ÷ 12 = ________ feet = r_2

c. Casing Volume (V_1) = π [(________ (r_1))^2] ________ h_1) = ________ feet^3 = V_1

d. Annulus Volume (V_2) = π [(________ (r_2))^2] ________ h_2) = ________ feet^3 = V_2

e. Saturated Annulus Volume (V_A) = [________ (V_2) - ________ (V_1)] 0.45 = ______ feet^3 = V_A

f. Saturated Borehole Volume (V_T) = [________ (V_1) + ________ (V_A)] 7.48 = ______ gallons = V_T

Example

Well:	MW-1		Nominal Casing Diameter:	2	inches
Total Depth:	35	ft.	Nominal Borehole Diameter:	6.25	inches
Water Level:	20	ft.	Height of Water in Casing (h_1):	15	feet
Height of Water:	15	ft.	Height of Water in Filter Pack (h_2):	15	feet

a. Casing Radius (r_1) = 2 inches ÷ 2 ÷ 12 = 0.083 feet = r_1

b. Borehole Radius (r_2) = 6.25 inches ÷ 2 ÷ 12 = 0.260 feet = r_2

c. Casing Volume (V_1) = π [(0.083 (r_1))^2] 15 h_1) = 0.32 feet^3 = V_1

d. Annulus Volume (V_2) = π [(0.260 (r_2))^2] 15 h_2) = 3.18 feet^3 = V_2

e. Saturated Annulus Volume (V_A) = [3.18 (V_2) - 0.32 (V_1)] 0.45 = 1.287 feet^3 = V_A

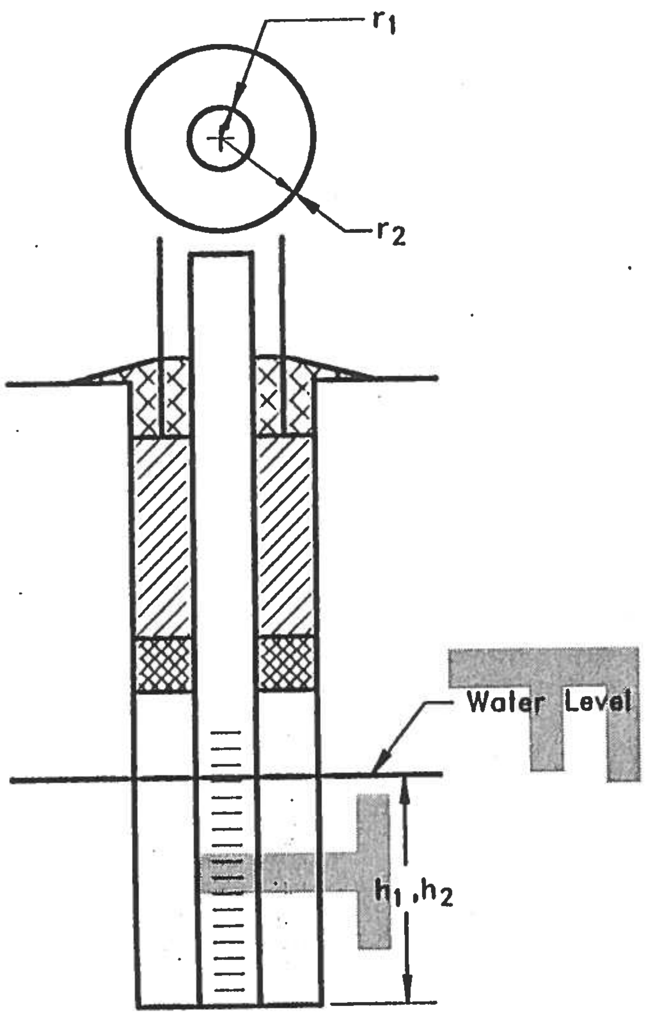
f. Saturated Borehole Volume (V_T) = [0.32 (V_1) + 1.287 (V_A)] 7.48 = 12.02 gallons = V_T

Casing volumes account for only the water in the well casing and does not account for the water in the annular borehole space, which is independent of the casing size. Calculating the saturated borehole volume accounts for all the water within the borehole and casing. If purging procedures were completely efficient, the saturated borehole volume would be the minimum volume of water to purge to remove the potentially biased water from the borehole. Because mixing does occur, the minimum purge volume must be greater than one saturated borehole volume. The degree of mixing within the borehole during purging is difficult to estimate and, therefore, the range of recommended purge volumes varies from 3 to 10 saturated borehole volumes. Three saturated borehole volumes has been selected as the best way to estimate purge volumes. Some wells will require purging more than three saturated borehole volumes and some less.

The saturated borehole volume calculation formula is presented in Figure 1. Figure 2 presents a sample saturated borehole volume calculation and a blank form to calculate specific saturated borehole volume. The basic formula is volume equals pi times the radius squared times depth ($V=\pi r^2 d$). To calculate saturated borehole volume, the casing and borehole radii and the height of water in the casing and the filter pack must be known. Measure the water level in the field, and obtain the borehole and casing radii from the well completion data.

Figure 2 presents a sample saturated borehole volume calculation, as described below:

- Equation (a) shows how to calculate the casing radius in feet by dividing the nominal casing diameter in inches by 2 (to convert the diameter to a radius) and dividing the result by 12 (to convert inches to feet).
- Equation (b) shows how to calculate the borehole radius in feet by dividing the nominal borehole diameter in inches by 2 (to convert the diameter to a radius) and dividing the result by 12 (to convert inches to feet).
- Equation (c) shows how to calculate the casing volume, given the casing radius and height of water in the casing.
- Equation (d) shows how to calculate the annular volume, given the annular radius and the height of water in the filter pack.
- Equation (e) shows how to calculate the saturated annulus volume by subtracting the casing volume from the borehole volume and multiplying the result by the assumed effective porosity of the annulus.



$V_1 = \pi r_1^2 h_1$

$V_2 = \pi r_2^2 h_2$

$V_A = (V_2 - V_1) P$

$V_T = (V_1 + V_A)$ 7.48 gallons/ft^3

V_1 = Casing Volume (ft)^3

V_2 = Annulus Volume (ft) ^{3}

V_A = Saturated Annulus Volume (ft^3)

V_T = Total Saturated Borehole Volume (gallons)

r_1 = Casing Radius (ft)

r_2 = Borehole Radius (ft)

h_1 = Water in Casing (ft)

h_2 = Water in Filter Pack (ft)

P = Effective Porosity of Annulus *

1ft^3 = 7.48 gallons

In Confined Wells, if $h_1 > h_2$, then

$V_T = [V_2 - (\pi r_1{}^2 h_2)] P$

* Assume P = 0.45 if no other data is available

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FIGURE 1
SATURATED BOREHOLE
VOLUME CALCULATION

Date: MAY, 1994
Project: 00-000
File: BH-VOL

Figure 2 **Saturated Borehole Volume Calculation (Blank Form and Example)**

Project Number: ____________
Date: ____________
Personnel: ____________

Blank Form

Well:	________	Nominal Casing Diameter:	________ inches
Total Depth:	________ ft.	Nominal Borehole Diameter:	________ inches
Water Level:	________ ft.	Height of Water in Casing (h_1):	________ feet
Height of Water:	________ ft.	Height of Water in Filter Pack (h_2):	________ feet

a. Casing Radius (r_1) = ________ inches ÷ 2 ÷ 12 = ________ feet = r_1
b. Borehole Radius (r_2) = ________ inches ÷ 2 ÷ 12 = ________ feet = r_2
c. Casing Volume (V_1) = π [(________ (r_1))^2] ________ h_1) = ________ feet^3 = V_1
d. Annulus Volume (V_2) = π [(________ (r_2))^2] ________ h_2) = ________ feet^3 = V_2
e. Saturated Annulus Volume (V_A) = [________ (V_2) - ________ (V_1)] 0.45 = ________ feet^3 = V_A
f. Saturated Borehole Volume (V_T) = [________ (V_1) + ________ (V_A)] 7.48 = ________ gallons = V_T

Example

Well:	MW-1	Nominal Casing Diameter:	2 inches
Total Depth:	35 ft.	Nominal Borehole Diameter:	6.25 inches
Water Level:	20 ft.	Height of Water in Casing (h_1):	15 feet
Height of Water:	15 ft.	Height of Water in Filter Pack (h_2):	15 feet

a. Casing Radius (r_1) = 2 inches ÷ 2 ÷ 12 = 0.083 feet = r_1
b. Borehole Radius (r_2) = 6.25 inches ÷ 2 ÷ 12 = 0.260 feet = r_2
c. Casing Volume (V_1) = π [(0.083 (r_1))^2] 15 h_1) = 0.32 feet^3 = V_1
d. Annulus Volume (V_2) = π [(0.260 (r_2))^2] 15 h_2) = 3.18 feet^3 = V_2
e. Saturated Annulus Volume (V_A) = [3.18 (V_2) - 0.32 (V_1)] 0.45 = 1.287 feet^3 = V_A
f. Saturated Borehole Volume (V_T) = [0.32 (V_1) + 1.287 (V_A)] 7.48 = 12.02 gallons = V_T

- Equation (f) shows how to calculate the saturated borehole volume by adding the casing volume to the saturated annulus volume and converting cubic feet to gallons.

In confined wells and unconfined wells that are screened and filter packed below the water table, the height of water in the casing will exceed the height of water in the filter pack (i.e., $h_1 > h_2$). In these cases, calculate the height of water in the filter pack based on the top of the filter pack interval, and not the top of the screen interval. To calculate the saturated borehole volume in these cases, substitute the appropriate height of water in feet into Equations C and D.

Note that wells have variable amounts of filter pack below the bottom of the screen. The volume of water below the bottom of the screen may be a significant portion of the total saturated borehole volume if there is only a few feet of measurable water in the screen and several feet of filter pack below the bottom of the screen. The saturated borehole volume calculation presented in Figures 1 and 2 does not account for the volume of water in the borehole below the screen. For wells with only minimal amounts of water in the screen, evaluate the amount of water within the borehole below the screen and consider it when purging the well.

4.3 Stability of Field Parameters

To demonstrate that you have collected a representative ground water sample, measure field parameters during purging and purge the well until these parameters stabilize. The field parameters measured may include pH, conductivity, temperature, turbidity, Eh, and dissolved oxygen. However, these parameters tend to stabilize at different rates, and field parameters generally stabilize before the chemical parameters that are being sampled. Therefore, the purge volume required for field parameters to stabilize should be considered a minimum purge volume, and laboratory parameters may stabilize only with continued purging.

In order to demonstrate that parameters have stabilized, establish the acceptable range of field parameter values and the volume of water between field parameter measurements. The acceptable range for most field parameter measurements is generally 10 percent of the value for conductivity, temperature, turbidity, Eh, and dissolved oxygen, and 0.1 units for pH. Demonstrate stabilization over a minimum volume of one saturated borehole volume. Document that the measurements do not fluctuate more than 10 percent or 0.1 pH units between the end points. Collect as many field parameter readings as practical between the end points (i.e., one reading at every 1/4 to 1/2 saturated borehole volume).

Calibrate the pH and conductivity meters before use every day. Record calibration times and appropriate readings in the field notebook. Refer to SOP #9 for specific instructions on calibrating the pH and conductivity meters.

4.4 Purge Rates and Pump Placement

Do not let the purge rate exceed the development rate. If possible, purge wells at or below their recovery rates in order to minimize turbidity and drawdowns. The purge rate should not result in excessive drawdown. Excessive drawdowns can cause water to cascade into the well, resulting in a significant sample bias, excessive turbidity, and entrapment of air in the filter pack, which will cause long-term sample bias.

When purging wells in shallow water tables, locate the pump intake near the top of the water table. Water will enter throughout the screen interval and move toward the pump, flushing all stagnant water from the borehole. If bailers are used, remove the water from the top of the water level.

4.5 Purging Low-Yielding Wells

Monitoring wells incapable of yielding three saturated borehole volumes within 24 hours are considered low-yielding wells. Low-yielding wells may be pumped at or below their recovery rates or purged to practical dryness. Purging the well to practical dryness will evacuate the stagnant water in the borehole, but cascading water and exposing the filter pack to air may bias subsequent samples.

Preferably, purge low-yielding wells at or below the recovery rate so that the saturated filter pack is not exposed to air. Purging at or below the recovery rate can take a considerable amount of time and may not be practical in some cases. Purge volume requirements and stabilization of field parameters criteria cannot always be applied to low-yielding wells. However, you should still perform saturated borehole volume calculations and field parameter measurement. Purging low-yielding wells can be time-consuming. Identify low-yielding wells during well development so that careful planning and scheduling may be performed to increase efficiency in the field. Based on site-specific conditions and project objectives, evaluate whether to purge a well over an extended period of time or to purge it to dryness and collect a sample when there is sufficient recovery. Purging over time is preferred over dryness if at all practical. Development should provide enough site-specific information to allow the best method to purge a well to be assessed and to acquire representative samples before mobilizing to the field.

5.0 SAMPLING PROCEDURES

This section gives the step-by-step procedures for collecting samples in the field. Record observations made during sample collection in the field notebook and field data sheet, as specified in Section 6 of this SOP.

5.1 Evacuating Well

As stated previously, the purpose of well purging is to (1) remove stagnant water from the well and (2) obtain representative water samples from the geologic formation while minimizing disturbance to the collected samples. In most cases, purge the well three saturated borehole volumes and until field parameters stabilize. If the well has been pumped or bailed dry twice, it has been completely purged.

Before purging a well, perform the following procedures:

- Before evacuating or sampling, decontaminate all well probes, bailers, and other sampling devices as specified in SOP #1. Do not decontaminate dedicated downhole pumps.
- Place clean plastic sheeting around the well.
- Open the well and measure static water level following SOP #2.
- Calculate the saturated borehole volume as specified in Section 4.2.
- Calibrate field parameter measurement equipment as specified in SOP #9.
- Obtain an initial sample from the bailer or purge pump for field measurements (e.g., temperature, conductivity, and pH measurements) and observation of water quality.
- Begin purging three saturated borehole volumes of water with a bailer or pump. Take temperature, specific conductance, and pH measurements after evacuating each 1/4 to 1/2 (if practical) saturated borehole volume. Generally, pH values within ±0.1 pH unit and conductivity within ±10 percent throughout one saturated borehole volume indicate good stability of the water chemistry. If the chemistry is not stable, continue purging.
- When evacuating a well using a pump, place the pump intake as follows:
  - for low recovery wells (wells that pump dry at low rates), place the pump intake at the bottom of the screened interval
  - for high recovery wells (wells that experience little drawdown with pumping), place the pump near the top of the water level to ensure the removal of stagnant water from the well bore. Purge the well at a rate that will not significantly draw down the well.
- Bail or pump dry low-yielding wells during evacuation. If possible, let low-yielding wells recover before purging them dry again. If recovery is very slow, obtain samples as soon as sufficient water is available, but samples must be collected within 24 hours.

5.2 Obtaining Water Samples

Ground water sample documentation, preservation, handling, packaging, and chain-of-custody procedures are specified in SOP #7. Collect ground water samples as follows:

1. Obtain samples for chemical analysis within two hours after purging is completed, if possible. For slow recovering wells, collect the sample immediately after a sufficient volume of water is available. Collect the water quality samples from within the well screen interval.
2. Assemble decontaminated sampling equipment. If bailers are used, use new nylon rope for each well for each sampling episode. Assemble the filtering apparatus.
3. Make sure that sample labels have been filled out for each sample bottle as specified in SOP #7.
4. Place labels on bottle and tape over.
5. Lower the bailer slowly and gently into contact with the water in the well. Lower the bailer to the same depth in the well each time, within the screened interval. If submersible or bladder pumps are used to collect samples, reduce the discharge rate to about 100 milliliters per minute or as low as possible (Note: Some pumps may overheat at 100 milliliters per minute). Before collecting samples, pump the well at the reduced rate until the volume of water in the discharge hose has been purged.
6. Retrieve the bailer smoothly and empty the water in a slow, steady stream into the sample containers or direct the pump discharge into the sample containers.
7. Retrieve additional samples and slowly fill the sample bottles for all other analyses and QA/QC samples. Cap the sample bottles quickly.
8. Filter samples that require filtration with a disposable filter apparatus and peristaltic pump or electric submersible pump, as specified in SOP #7.
9. Slowly pour an unfiltered portion into the sample container for field parameter (e.g., pH, specific conductance, and temperature) analyses, perform the in-field analyses, and record the results.

1\. Preserve samples as specified in SOP #7.

2\. Place samples in baggies.

3. Place samples on ice in a cooler.
4. Record time of sampling.
5. Replace and lock well cap.
6. Complete field documentation and chain of custody record.

5.3 Field Quality Assurance/Quality Control Procedures and Samples

Collect QA/QC samples during ground water sampling, as specified in the project planning documents. All QA/QC samples should be analyzed at the same time and in the same batches as the primary samples.

QA/QC samples help identify potential sources of sample contamination and help evaluate potential error introduced by sample collection and handling. Label all field QA/QC samples with QA/QC identification numbers (i.e., "02" for duplicate samples, "03" for field blanks, "04" for rinsate samples, and "MS" for matrix spike samples) and send them to the laboratory with the other samples for analyses.

Duplicate Samples

To check for the natural sample variance and the consistency of field techniques and laboratory analysis, collect duplicate samples side-by-side with primary samples. For ground water sampling, collect a duplicate sample while collecting the primary sample. Fill the primary sample bottle(s) first and the duplicate sample bottle(s) for the same analysis second until all necessary sample bottles for both the primary and duplicate samples have been filled. Use different filter and tubing for the primary and duplicate samples. Handle the duplicate ground water sample in the same manner as the primary sample. Assign the duplicate sample the QA/QC identification number "02"; follow SOP #7 for documentation, preservation, handling, packaging, and chain-of-custody procedures; store the sample in an iced cooler; and ship it promptly to the laboratory so that analyses can be performed within required holding times.

Collect one duplicate sample for every 20 primary samples collected so that a rate of at least 5 percent of primary samples collected is achieved. For example, if you collect from 1 to 20 primary samples during a sampling event, collect one duplicate sample, and if you collect from 21 to 40 primary samples during a sampling event, collect two duplicate QA/QC samples.

Collect duplicate QA/QC samples so that they represent the time of collection, different sampling teams, field conditions, and sampling equipment variability. For example, if ambient conditions are altered that could impact sample quality, the QA/QC sampling frequency may be increased. Collect duplicate samples throughout the sampling event, not just at the end.

Field Blanks

Collect field blanks by filling sample containers in the field with deionized water from the same source that is used for decontamination. Assign the sample the QA/QC identification number "03"; follow SOP #7 for documentation, preservation, handling, packaging, and chain-of-custody procedures; store the sample in an iced cooler; and ship it promptly to the laboratory so that analyses can be performed within required holding times.

Collect one field blank sample for every 20 samples primary collected, so that a rate of at least 5 percent of primary samples collected is achieved. For example, if you collect from 1 to 20 primary samples during a sampling event, collect one field blank sample; and if you collect from 21 to 40 primary samples during a sampling event, collect two field blank samples.

Rinsate Samples

An equipment rinsate sample of sampling equipment is intended to be used to check if decontamination procedures have been effective. For the well sampling operation, collect a rinsate sample from the decontaminated sampling equipment (bailer or pump) and filter equipment before using it to obtain the sample. To collect a rinsate sample from a bailer, rinse deionized water over the decontaminated bailer and transfer it to the sample bottles. To collect a rinsate sample from an electric submersible pump, transfer the final deionized water rinse that is pumped through the discharge hose to sample bottles. The same parameters that will be analyzed in the ground water samples will be analyzed in the rinsate samples. Assign the rinsate sample the QA/QC sample identification number "04"; follow SOP #7 for documentation, preservation, handling, packaging, and chain-of-custody procedures; store the sample in an iced cooler; and ship it promptly to the laboratory so that analyses can be performed within required holding times.

Collect one rinsate sample for every 20 primary water samples collected so that a rate for rinsate samples of at least 5 percent of primary samples collected is achieved. For example, if you collect from 1 to 20 primary samples during a sampling event, collect one rinsate blank sample, and if you collect from 21 to 40 samples during a sampling event, collect two rinsate blank samples.

Collect rinsate blank samples so that they represent the time of collection, different sampling teams, field conditions, and sampling equipment variability. For example, if ambient conditions are altered that could impact sample quality, the QA/QC sampling frequency may be increased. Collect rinsate blank samples throughout the sampling event, not just at the end. Collect one rinsate blank sample for each type of sampling equipment used if less than 20 samples are collected (e.g., if 10 samples are collected by a bailer and 10 samples are collected by a submersible pump, you would collect two rinsate samples — one from the bailer and one from the pump).

Matrix Spike Samples

Matrix spike (MS) samples are required to evaluate potential matrix effects on sample analyses for all inorganic parameters. The laboratory will spike matrix spike samples for the inorganic parameters. Depending on the specific laboratory and sample volume collected, the matrix spike samples may be split from an existing sample or may require a separate sample. To samples that you collect specifically for matrix spike analysis, assign the QA/QC identification "MS"; follow SOP #7 for documentation, preservation, handling, packaging, and chain-of-custody procedures; store the sample in an iced cooler; and ship it promptly to the laboratory so that analyses can be performed within required holding times. The samplers will identify all samples selected for matrix spike split analysis on the Chain of Custody Form. Specify one matrix spike sample for each sample shipment group of 20 samples or less.

Laboratory Replicate

Depending on the laboratory conducting the analysis, laboratory replicate samples may be required. Laboratory replicate samples are split from the primary sample in the laboratory and analyzed as part of the laboratory's QA/QC program. The laboratory replicate does not require a separate sample volume. The sample that the laboratory splits must be identified by the samplers on the Chain of Custody Form. One laboratory replicate sample will be specified for each sample shipment group of 20 samples or less.

5.4 Sample Documentation, Preservation, Handling, Packaging, and Chain of Custody

The project work plan specifies sample containers and preservatives. Label and handle samples as described in SOP #7.

6.0 DOCUMENTATION

6.1 Ground Water Data Sheet

Complete a ground water data sheet for ground water samples (Appendix A) at each sampling location. Be sure to completely fill in the data sheet. If items on the sheet do not apply to a specific location, label the item as not applicable (NA). The information on the data sheet includes the following:

- Well number
- Date and time of sampling
- Person performing sampling
- Depth to water before sampling
- Volume of water purged before sampling
- Conductivity, temperature, pH, and turbidity during evacuation (note number of well volumes)
- Time samples are obtained
- Sample identification number(s)
- QA/QC samples taken (if any)
- How the samples were collected (i.e., bailer and pump).

6.2 Field Notes

Keep field notes in a bound field book. Record the following information using waterproof ink:

- Names of personnel
- Weather conditions
- Date and time of sampling
- Location and well number
- Condition of the well
- Decontamination information
- Initial static water level and total well depth
- Calculations (e.g., calculation of evacuated volume)

- Calibration information, sample methods used, or reference to the appropriate SOP
- Final sample parameters
- Sample control number.

7.0 REFERENCES

ASTM D-4448 - 85a, Standard Guide for Sampling Groundwater Monitoring Wells, *1995 Annual Book of ASTM Standards*, Vol. 04.08.

APPENDIX A

GROUND WATER SAMPLING DATA SHEET

GROUND WATER SAMPLING DATA SHEET

IDENTIFICATION

Project Number: ______________

Sample Location____________________________ Date __________ Start Time ______ Stop time_____ Page__of__

ample Control Number_______________________________ Samplers ______________________________

WEATHER CONDITIONS

Ambient Air Temperature: __________ °C☐ °F☐ Not Measured ☐ **Wind:** Heavy☐ Moderate☐ Light☐

Precipitation: None☐ Rain☐ Snow☐ Heavy☐ Moderate☐ Light☐ Sunny☐ Partly Cloudy☐

INITIAL WELL MEASUREMENTS (Measurements in feet made from top of well casing)

Static Water Level_____ Total Depth_____Top of Screen_____ Filter Pack Interval_______ Borehole Diameter(inches)_____

Well Casing ID_____ Well Casing OD_____ Protective Casing Stickup____ Well Casing Stickup_____ Feet of Water________

Well purged with: ____

FINAL WELL MEASUREMENTS

Static Water Level___ Total Depth___ Total Volume Purged___ Saturated Borehole Volume (gal)___ Max Pumping Rate _____

INSTRUMENT CALIBRATION

pH Meter: Meter Number____________

Buffer___ Measured Value_____ Temp.____ °C

Buffer___ Measured Value_____ Temp.____ °C

Conductivity Meter: Meter Number____________

Standard_____mS/cm Measured Value_________mS/cm Temp.___°C

Standard_____mS/cm Measured Value_________mS/cm Temp.___°C

Turbidity Meter:_____ Standard ____NTU Measured Value______NTU Standard ____NTU Measured Value______NTU

FIELD PARAMETER MEASUREMENTS DURING PURGING

Time	Volume (gallons)	pH	Cond. (µS/cm)	Temp. °C☐ °F☐	Turbidity Visual Est.☐ Measured☐	Comments

FINAL SAMPLE PARAMETERS

Sample Date	Sample Time	Discharge cfs☐ gpm☐	pH	Cond. (µS/cm)	Temp. (°C)	Turbidity Visual Est.☐ Measured☐		

Duplicate Sample-02 (sample control number/time______________________________)

Field Blank-03 (sample control number/time______________________________)

Rinsate Sample-04 (sample control number/time______________________________)

Matrix Spike-MS (sample control number/time______________________________)

__________ (sample control number/time______________________________)

otes:____

____

____

Sampler's Signature ____

STANDARD OPERATING PROCEDURE #6

SURFACE WATER SAMPLE COLLECTION AND DISCHARGE MEASUREMENT

Prepared by:
Shepherd Miller, Inc.
3801 Automation Way, Suite 100
Fort Collins, CO 80525

May 17, 1996

SHEPHERD MILLER
INCORPORATED

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1.0 PURPOSE AND SCOPE

This document defines the standard operating procedure (SOP) for collecting surface water samples. This SOP describes equipment, field procedures, and quality assurance/quality control (QA/QC) procedures necessary to collect surface water samples.

2.0 RELATED STANDARD OPERATING PROCEDURES

This procedure is intended to be used with the following SOPs:

SOP #	Title
1	Equipment Decontamination
7	Sample Documentation, Preservation, Handling, Packaging, and Chain of Custody

3.0 NECESSARY EQUIPMENT

Before beginning the monitoring program, obtain the equipment listed in the following sections for performing decontamination, surface water sampling, and sample filtration.

3.1 General Equipment Requirements

Use the following general equipment to collect surface water samples:

- Watch
- Backpack
- Field logbook
- Pens, permanent pens, and pencils
- Surface water data sheets (see Appendix A)
- Mobile telephone or radio

- Sampling plan
- Appropriate health and safety equipment
- Camera
- Plastic flagging
- Wood stakes.

3.2 Field Parameter Measurements

Use the following apparatus and supplies to measure pH in the field:

- Portable Hach One pH Meter Model 43800-00 with Hach One Combination pH Electrode Model 48600 or the EC10 Portable pH/mV/Temperature Meter Model 50050 with the Combination pH Electrode with Temperature (Gel-filled) Model 50200
- Spare electrolyte cartridge, if required
- Hach pH Electrode Storage Solution, Catalog No. 50301-49
- Extra batteries
- Beakers
- Buffer solutions of pH 4, 7, and 10
- Deionized or distilled water and wash bottle
- Kimwipes or equivalent.

Use the following apparatus and supplies to measure conductivity in the field:

- Hach CO150 Conductivity Meter Model 50150, Hach Conductivity/TDS Meter Model 44600, or Hach High Range Conductivity Meter Model {????}
- Extra battery
- Calibration solutions which bracket expected range of measurements

- Deionized water
- Wash bottle
- Kimwipes
- Beakers.

Use the following equipment for decontamination activities:

- Liquinox detergent
- Potable water
- Deionized, metal-analyte-free water
- Decontaminated buckets, pails, and sprayers
- Chemical-free paper towels (Kimwipes or equivalent)
- Plastic brushes
- Disposable latex gloves.

Use the following equipment for sampling surface water:

- Nalgene (or equivalent) beakers of assorted sizes
- Churn splitter or composite sample container
- Peristaltic pump and battery
- Silicon or Tygon® tubing
- 0.45-micron filter.

Equipment used for sample filtration should include the following:

- Disposable filterware with a 0.45-micron filter

- Peristaltic pump
- Silicon or Tygon® tubing.

Equipment for measuring stream discharge shall include the following:

- Cutthroat flume with assorted throat sizes
- Small line level
- Shovel
- Marsh-McBirney flow meter or equivalent and top setting rod
- Fiberglass tape (50 foot)
- Calibrated containers (2 cup and up to 2.5 gallon) to measure flow
- Stop watch
- Rubber boots
- Calibrated buckets (5 and 2.5 gallon) to measure discharge
- Engineers tape, 25 feet long, marked in 10ths and 100ths of a foot.

Other field measurements may be needed (e.g., iron and sulfate). The manufacturer's manual should be consulted for equipment needed.

Use the following equipment for sample labeling, packing, documentation, and performing chain-of-custody procedures:

- Sample bottles
- Sample labels
- Appropriate preservatives
- Data forms
- Chain of custody document
- Black permanent markers and pens

- Clear plastic tape
- Fiber tape
- Custody seals
- Large (30 gallon) trash bag
- Gallon ziplock freezer bags
- Sample shipment coolers
- Ice
- Shipping documentation.

4.0 SURFACE WATER SAMPLING

This section discusses the criteria for selecting sampling methods and equipment. These criteria are based on sample type, flow conditions, and data quality objectives stated in the work plan. Select sampling methods and equipment based on flow conditions as follows:

- If the stream is less than 3 feet wide, collect samples from the center of the flow. Use a dipper or a beaker to collect samples directly into sample containers or into intermediate containers for homogenization.
- If the stream is 3 to 5 feet wide, use the horizontal areal composite method and collect aliquots of sample from three stations spaced evenly across the stream. If the stream is from 5 to 10 feet wide, collect samples at five evenly spaced stations. If the stream is too deep to wade, collect a grab sample from the bank. Combine these aliquots in a decontaminated container or churn splitter, as described below.

The churn splitter is a device that mixes sample aliquots to form a sample composite and then splits the composite into discrete samples. You may take samples from the churn splitter for analysis of all dissolved and suspended inorganic constituents, except for total organic carbon (TOC), fecal coliform, volatile organic analyses (VOAs), and oil and grease (O&G). Do not use the churn bucket as a direct sampling device; instead, collect water in a dipper or beaker and pour it into the churn splitter. Then use the churn splitter to mix the composited liquid while splitting the total volume into the various analyte samples.

4.1 Sampling Procedures

This section gives the step-by-step procedures for collecting surface water samples in the field. Record observations made during sample collection in the field notebook and on the field data collection note (Appendix A).

4.1.1 Decontamination

Before beginning a sampling event and between collecting individual samples, decontaminate sample collection equipment as specified in SOP #1. Wash sampling equipment with Liquinox solution, triple rinse with potable water, triple rinse with deionized water, and let air dry if possible.

4.1.2 Instrument Calibration

Calibrate the pH and conductivity meters before use every day. Record calibration times and appropriate readings in the field notebook. Refer to SOP #9 for specific instructions on calibrating the pH and conductivity meters.

4.1.3 Obtaining Water Samples

Select sampling methods and equipment based on flow conditions as follows:

- If the stream is less than 3 feet wide, collect samples from the center of the flow. Use a decontaminated dipper or a beaker to collect samples directly into sample containers (grab sample) or into an intermediate container for homogenization (composite sample).
- If the stream is from 3 to 5 feet wide, use the horizontal areal composite method and collect aliquots of sample from three stations spaced evenly across the stream. If the

stream is from 5 to 10 feet wide, then composite five evenly spaced stations. If the stream is too deep to wade, collect a sample from the bank. Combine these aliquots in a decontaminated container or churn splitter.

Collect surface water samples as follows:

1. Obtain all necessary sample collection and filtering equipment.

2. Decontaminate sampling equipment as specified in SOP #1.

3. Make sure that the sample labels have been filled out for the sampling location. Obtain bottles for filling.

4. Make sure that no activities are occurring or have recently occurred immediately upstream that would affect the integrity of the sample. Wade to the sample collection point from a downstream location. To avoid disturbing stream sediments or otherwise contaminating samples, stand downstream of the water that you collect. When collecting samples in succession, always proceed from downstream to upstream locations.

5. Rinse the water collection device (i.e., beaker, dipper, and_churn splitter with sample water.

6. Collect samples from streams,_using horizontal composites if appropriate. If grab samples are specified, then fill the sample bottles directly if possible. If composited samples are specified, use a beaker to collect and transfer the sample aliquots into the compositing container. If bottles or beakers cannot be filled due to low water depth, you may use the peristaltic pump and tubing to pump sample water into the appropriate container. Wear clean latex gloves at all times when collecting samples.

7. For composited samples, fill sample bottles by dispensing the composited water from the compositing container. Fill all bottle sets, such as for the primary, field duplicate, matrix spike, and laboratory replicate samples, for a particular analysis from the same composited sample.

8. Measure field parameters that are not measured in situ from a portion of the unpreserved composite taken from the churn splitter before samples are dispensed.

9. Preserve bottles if they are not pre-preserved.

10. Record time of sampling and complete field documentation.

11. Follow SOP #7 for the remaining procedure.

If discharge will subsequently be measured, collect samples from the same cross section of the stream that will be used to measure discharge. Always collect samples before measuring discharge.

4.1.4 Filtering Samples

Analyses for total metals and other parameters are performed on unfiltered samples. Analyses for cations and dissolved metals are performed on samples that have been filtered in the field. Filter samples in the field with a disposable 0.45-µm membrane filter apparatus and peristaltic pump. Collect filtered samples as follows:

- Assemble the filter device according to manufacturer's instructions.
- Filter the sample by pumping it through an in-line filter with a peristaltic pump. Composited sample remaining in the churn splitter may be used for filtered samples.
- Transfer filtered samples to appropriate preservative-containing sample bottles or unpreserved bottles. Then add preservatives to the bottle.

4.1.5 Field Quality Assurance/Quality Control Samples

Collect quality assurance/quality control (QA/QC) samples during surface water sampling as specified in the project planning documents. All QA/QC samples should be analyzed at the same time and in the same batches as the primary samples.

QA/QC samples are designed to help identify potential sources of sample contamination and evaluate potential error introduced by sample collection and handling. Label all QA/QC samples with QA/QC identification numbers (i.e., "02" for duplicate samples, "03" for field blanks, "04" for rinsate samples, and "MS" for matrix spike samples) and send them, with the other samples, to the laboratory for analysis.

Duplicate Samples

Duplicate samples are collected side-by-side with primary samples to check for natural sample variance and consistency of field techniques and laboratory analysis. When collecting primary surface water samples, collect duplicate sample at the same time. Fill the primary sample bottles first and the duplicate sample bottles for the same analysis second, and so on until all necessary sample bottles for both primary and duplicate samples have been filled. Use different filter and tubing for the primary and duplicate samples. Handle duplicate surface water samples in the same manner as primary samples. Assign duplicate samples the QA/QC identification number "02," store it in an iced cooler, and ship it promptly to the laboratory so that analyses can be performed within required holding times.

Collect at least one duplicate sample for every 20 samples, for a minimum rate of 5 percent duplicate to primary samples. For example, if you collect from 1 to 20 primary samples during a sampling event, collect one duplicate sample; and if you collect from 21 to 40 primary samples during a sampling event, collect two duplicate samples.

Field Blanks

Collect field blank samples by filling sample containers in the field with deionized water. Assign the sample the QA/QC identification number "03," store it in an iced cooler, and ship it to the laboratory with the other samples. Collect one field blank per sampling event for each medium sampled.

Collect at least one field blank sample for every 20 samples collected, for a minimum rate of 5 percent field blank to primary samples. For example, if you collect from 1 to 20 primary samples during a sampling event, collect one field blank sample; and if you collect from 21 to 40 samples during a sampling event, collect two field blank samples.

Rinsate Samples

An equipment rinsate sample of sampling equipment is intended to check if decontamination procedures have been effective. Before collecting surface water samples, collect a rinsate sample from the decontaminated sampling equipment and filter equipment. To collect a rinsate sample, rinse deionized water over the decontaminated equipment and transferred the water to the sample bottles. The surface water samples and rinsate samples will be analyzed for the same parameters. Assign the rinsate sample the QA/QC identification number "04," store it in an iced cooler, and ship it promptly to the laboratory so that analyses can be performed within the required holding times.

Collect at least 1 rinsate sample for every 20 water samples collected, for a minimum rate of 5 percent rinsate samples to primary samples. For example, if you collect from 1 to 20 primary samples during a sampling event, collect one rinsate blank sample; and if you collect from 21 to 40 samples during a sampling event, collect two rinsate blank samples.

Collect rinsate blank QA/QC samples so that they represent the time of collection, different sampling teams, field conditions, and sampling equipment variability. For example, if ambient conditions are altered that could impact sample quality, you may increase the QA/QC sampling frequency.

Matrix Spike Samples

Matrix spike (MS) samples are used to evaluate potential matrix effects on sample analysis for all inorganic parameters. The matrix spike samples will be spiked by the laboratory for the inorganic parameters. Depending on the specific laboratory and sample volume collected, the matrix spike samples may be split from an existing sample or may require a separate sample. Assign samples collected specifically for matrix spike analysis the QA/QC identification "MS," store it in an iced cooler, and ship it promptly to the laboratory so that analyses can be performed within required holding times. Identify all samples selected for matrix spike analysis on the

Chain of Custody Form. Specify one matrix spike sample for each sample shipment group of 20 samples or less.

Laboratory Replicate Samples

Depending on the laboratory conducting the analysis, laboratory replicate samples may be required. Laboratory replicate samples are split from the primary sample in the laboratory and analyzed as part of the laboratory's QA/QC program. The laboratory replicate does not require a separate sample volume. The sample that will be split by the laboratory must be identified by the samples on the Chain of Custody Form. One laboratory replicate sample will be specified for each sample shipment group of 20 samples or less.

4.2 Sample Handling

Sample containers and preservatives are specified in the project work plan. Label and handle samples as described in SOP #7.

5.0 DISCHARGE MEASUREMENT

Depending on the magnitude of the discharge and the physical conditions at the measurement site, discharge can be measured with a flow meter, cutthroat flume, stopwatch and a bucket, or stopwatch and a tape. When possible, use a cutthroat flume with interchangeable throat widths to measure discharge, provided that the flow is within the measurement parameters of the flume. Measure higher discharges with a flow meter.

The following sections discuss methods for obtaining point-flow measurements in streams, the equipment used to measure the discharge, and the calculations required to determine the total discharge.

5.1 Location of Stream Measurement Sites

The selection of the site to measure stream discharge depends on a number of factors, including data acquisition requirements, site accessibility, and stream flow characteristics. After selecting the site, take all subsequent stream flow measurements at the same site. When flow is measured in conjunction with water-quality sampling, take flow measurements as close as possible to the site of the water-quality samples. To avoid disturbing the sediments or otherwise contaminating samples, measure flow after collecting water-quality samples and immediately downstream of the sample collection point. Stream flow characteristics will determine the exact point where the discharge measurements will be made and the method used for measuring discharge; these characteristics include ease of measurement, channel alignment, flow regime, flow depth, and velocity. Consider the following factors when selecting a site:

1. Ease of measurement. The site should be accessible to wading, and flow should be confined to a definable channel. Because the field sampling team members will wade in the stream to measure the flow, be sure that the flow depth and velocity are sufficiently low to permit safe crossing.
2. Flow regime. Stream flow should be steady and uniform, the stream-bed gradient in the site vicinity should be relatively constant, and flow-lines should be parallel.
3. Backwater effects. The site should be free from backwater caused by downstream obstructions or by the confluence of the stream with a major tributary or other body of water.

5.2 Flow Meters

Before taking discharge measurements with a flow meter, establish intervals at which to measure the area of the cross-section and the flow velocity. Calculate the stream discharge by multiplying the average velocity by the cross-sectional flow area measured at each interval. Calculate the total discharge for the stream by summing the calculated discharge for the individual intervals. The average velocity is typically measured with a current or magnetic velocity meter. Calculate the cross-sectional area for each interval by multiplying the measured flow depth for each interval by the width of the interval.

Equipment that is required to measure stream flows includes a top-setting wading rod, water-velocity meter, and a fiberglass measuring tape long enough to span the stream.

Use the top-setting wading rod to measure the depth of water and adjust the position of the velocity flow meter. Attach the velocity flow meter to the top-setting wading rod on a movable mount so that the sensor can be set at the appropriate depth for velocity measurements. The wading rod should be made of stainless steel and marked with permanent grooves at intervals of 0.1 foot.

A Marsh-McBirney magnetic current meter is recommended for measuring water velocity. The Marsh-McBirney meter provides a direct velocity reading in feet per second, is durable, and rugged for field use. A pygmy meter may also be used, but it is not as user-friendly.
Use a fiberglass measuring tape to measure the distance across the stream at which velocity measurements are taken and as a guide along the stream cross-section. Anchor the fiberglass tape to the stream banks to mark the location of the station. The tape should be marked in intervals of 0.1 foot.

5.2.1 Flow Meter Measurement Procedures

When determining the flow velocity, the field sampling team shall perform the following steps:

1. Suspend the tape across the channel perpendicular to the direction of flow.
2. Measure the top width of the stream.
3. Determine suitable increments at which to measure velocity (see below).
4. Measure the flow depth at each increment with the wading rod.

4. Measure the flow depth at each increment with the wading rod.

5. Determine the appropriate depth or depths (see below) at which velocity measurements are to be taken, and adjust the flow sensor on the wading rod to the proper depth.

6. Measure the flow velocity using the appropriate method (see below). In general, the sampler should do the following:

    - Measure flow velocity while wading in the stream, if the depth and velocity of water are sufficiently low

    - Stand downstream of the measurement point and in a position that least affects the measurements; that is, the sampler should face the bank so that the water flows against the side of the leg

    - While measuring the velocity, hold the wading rod vertically against the tape and position the meter parallel to the direction of flow.

7. Record the distance from the tape, flow depth, depth of velocity measurement, and velocity.

8. Repeat Steps 4 through 7 at each increment.

9. Repeat Steps 2 through 8 if, during the measurements, the gage height readings change more than 10 percent for depths of flow less than 1 foot or 5 percent for depths greater than 1 foot.

10. Calculate the discharge using the methods described in Section 5.2.2.

The number of increments across the stream at which velocity measurements are performed, as listed in Step 3 above, will depend on the width and flow characteristics of the stream. The number of increments will usually determine the precision and accuracy of the flow measurements. In addition, increasing the number of increments will usually increase the accuracy of the flow measurement. Measurements are usually taken at equal intervals across the stream, such as every 1 or 2 feet. However, if the majority of flow is confined to one section of the stream, such as at the center or to one side of the stream, take the measurements at closer intervals in the majority of the flow and at larger intervals elsewhere across the stream.

Individual intervals should not contain more than 10 percent of the total flow and, ideally, less than 5 percent.

For the streams at the site, measure depth and velocity across the stream at intervals of less than 1 foot, and at smaller intervals where the flow is concentrated. You may measure depth and flow at any point or interval in the stream to account for specific conditions; for example, to avoid taking measurements on top of a boulder where the wading rod cannot be properly placed. Record the point at which you take measurements according to the distance shown on the tape line that is suspended across the stream. Take at least 10 measurements in the stream.

As listed in Step 4, measure the depth of flow at each increment with the wading rod. Place the rod vertically in the stream at a specific location along the tape line so that the base plate of the rod rests on the stream bed. Read the depth of water on the graduated rod to the nearest 0.05 foot. The sampler who holds the wading rod should stand downstream in a position that least affects the flow at the sensor.

Several different velocity methods can be used to determine the average flow velocity at a point. Two methods that are appropriate for measuring the average velocity for the streams in the area are the six-tenths depth method and the 2-point method. The selection of the specific method depends on the depth of flow.

The six-tenths method is the preferred method for measuring average velocity whenever the depth of flow is less than 2.5 feet. In this method, place the velocity sensor on the wading rod at a depth below the surface of 0.6 times the depth of the stream, or placing the rod at a depth above the bottom of the stream of 0.4 times. The velocity at this depth is assumed to represent the mean velocity in the horizontal direction.

The 2-point method is used to determine the average velocity when the depth of flow exceeds 2.5 feet. In the 2-point method, measure velocity at locations below the water surface of both 0.2

and 0.8 times the depth of the stream. The average of the two observations represents the mean velocity for the interval.

Record depth measurement data on a Steam Discharge Measurement Data Sheet (Appendix B).

5.2.2 Discharge Calculations

Referring to Figure 1, calculate the partial discharge for any partial section as follows:

$$q_x = V_x \, d_x \left(\frac{b_x - b_{(x-1)}}{2} + \frac{b_{(x+1)} - b_x}{2} \right)$$

$$= V_x \, d_x \left(\frac{b_{(x+1)} - b_{(x-1)}}{2} \right)$$

where:

q_x = discharge through partial section x

V_x = mean velocity at location x

b_x = horizontal distance from initial point to location x

$b_{(x-1)}$ = horizontal distance from initial point to preceding location

$b_{(x+1)}$ = horizontal distance from initial point to next location

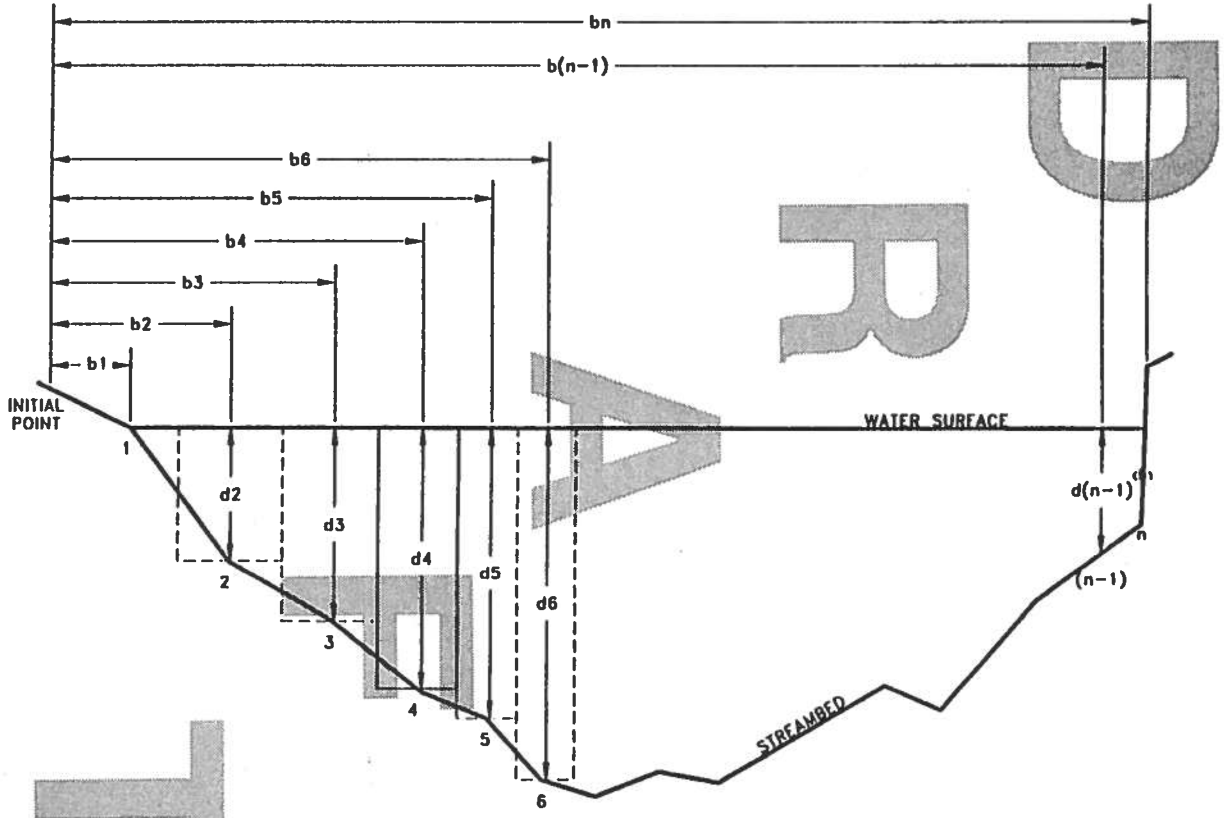
d_x = depth of water at location x.

For example, the discharge through partial section 4 would be:

$$q_4 = V_4 \, d_4 \left(\frac{b_5 - b_3}{2} \right)$$

The procedure is similar when the location x is at a beginning or end section. The "preceding location" at the beginning of the cross-section is the location x. The "next location" at the end of the cross-section is the location n.

Calculate the partial discharge for beginning or end sections as follows:



EXPLANATION

1,2,3,.........,n	Observation verticals
b1,b2,b3,...,bn	Distance, in feet or meters, from the initial point to the observation vertical
d1,d2,d3,...,dn	Depth of water, in feet or meters, at the observation vertical
DASHED LINES	Boundaries of subsections; one heavily outlined is discussed in text

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FIGURE 1
DEFINITION SKETCH OF MIDSECTION METHOD OF COMPUTING CROSS-SECTIONAL AREA FOR DISCHARGE MEASUREMENTS

Date: MAY 1996
Project: 00-100
File: 485\COMPXSEC

$$q_1 = V_1 \; d_1 \left(\frac{b_2 - b_1}{2} \right)$$

$$q_n = V_n \; d_n \left(\frac{b_n - b_{(n-1)}}{2} \right)$$

Use the above formula for q_n whenever there is water on only one side of an observation point, such as at piers, abutments, and islands. It will usually be necessary to estimate the velocity at an end section as a percentage of the adjacent section, because it is normally impossible to measure the velocity accurately with the current meter close to a boundary.

Calculate the total discharge by summing up the flow through all the partial sections:

$$q_T = \sum_{x=1}^{n} q_x$$

where: q_T = total discharge for stream

q_x = discharge through section x

n = number of sections.

5.3 Portable Cutthroat Flumes

Use a portable cutthroat flume with interchangeable throat widths typically ranging from 1 to 8 inches to measure most discharges. Set-up and measurement with the cutthroat flume are significantly easier and faster than with a flow meter, and the flume is more accurate when installed properly.

Place a portable cutthroat flume in a section of the stream channel with a bed slope of less than approximately 1 percent for a distance of 4 to 6 feet upstream of the flume. When the proper throat width is used, a pool of water at least twice the front width of the flume should form upstream of the flume. Install, level, plumb, and square the flume. Divert all the flow into the flume inlet. Be careful to ensure that water does not run underneath the flume. After the flow has equilibrated, read the staff gage provided in the flume and record the flow depth. Take and record two identical staff gage measurements 5 minutes apart to demonstrate that the flow has equilibrated. Install the flume so that free-flow occurs (that is, the flow through the flume reaches critical depth) near the minimum width in the flume.

If any leakage occurs through or around the dike, estimate the amount of leakage as a percentage of the total measured flow and then add the estimated leakage to the measured flow in order to calculate the total flow.

5.4 Time and Volume

The time and volume method consists of capturing flow in a container and measuring the time required to fill the container. When using this method, divert the flow through a culvert and measure the discharge at the point of outflow. Alternatively, a small earthen dike can be built to divert spring flow into a container with a known volume through a pipe that has been temporarily placed in the channel. Record the time required to fill the container with a stopwatch.

Repeat the measurement at least three times and average the resulting values. If the variance between the time measurements exceeds 10 percent, repeat the measurement procedure. If any leakage occurs through or around the dike, estimate the amount of leakage as a percentage of the total measured flow and then add the estimated leakage to the measured flow in order to calculate the total flow.

5.5 Time and Distance

In extreme cases where other measurement procedures fail or are not available, stream discharge may be estimated by measuring the time a floating object takes to travel a known distance through a stream section of known volume. In this method, measure or estimate the area of an average cross section with the procedures described in Section 5.2.1. Measure the time required for a floating object to travel a measured distance (e.g., 10 feet) of a uniform stream section. If possible, select an object that will float immediately below the water surface, because such an object will travel at approximately 90 percent of the actual water velocity. Given the time, distance, cross-sectional area, and the 90 percent correction factor, calculate the discharge.

6.0 DOCUMENTATION

This section provides forms to document the chemical and physical parameters that are measured during sample collection. These parameters include pH, temperature, specific conductivity, and discharge. In this documentation, include the conditions for which the various instruments were calibrated and the conditions in which the measurements were made.

Appendix A presents a Surface Water Data Sheet for spring and surface-water sample collection activities. Field personnel shall use this form to document the following information:

1. Sample identification and location
2. Sample collection date and time
3. Sample party members
4. Weather conditions
5. Stream or spring conditions
6. pH meter used, its calibration, and pH measurements
7. Water temperature
8. Conductivity meter used, its calibration, and conductivity measurement

9. The volume of sample collected and its relative location
10. Whether QA/QC samples were collected at this site (Quality assurance is discussed in Section 4.1.5.)
11. Any additional notes or observations pertinent to this sample, including treatment, preservation, and any deviations from established procedures.

For every sample collected, fill out this form, which provides a checklist of tasks to be accomplished for each sample. This form is a generic form and all spaces may not apply to the site. Fill in all applicable spaces clearly in black ink. If you make an incorrect entry, draw a single heavy line through the entry, make the correct entry, and initial and date the correction. Keep the completed forms in a 3-ring notebook and order the forms chronologically by station.

APPENDIX A

SURFACE WATER SAMPLING DATA SHEET

SURFACE WATER SAMPLING DATA SHEET

IDENTIFICATION

Project Number: ________________

Sample Location________________________________ Date ___________ Start Time _______ Stop time______ Page___of__

Sample Control Number______________________________________ Samplers ______________________________________

WEATHER CONDITIONS

Ambient Air Temperature: _____________ °C ☐ °F ☐ Not Measured ☐ **Wind:** Heavy ☐ Moderate ☐ Light ☐

Precipitation: None ☐ Rain ☐ Snow ☐ Heavy ☐ Moderate ☐ Light ☐ Sunny ☐ Partly Cloudy ☐

INSTRUMENT CALIBRATION

pH Meter: Meter Number______________ **Conductivity Meter:** Meter Number________________

Buffer___ Measured Value_____ Temp.____ °C Standard______mS/cm Measured Value_________mS/cm Temp.___°C

Buffer___ Measured Value_____ Temp.____ °C Standard______mS/cm Measured Value_________mS/cm Temp.___°C

Turbidity Meter:_____ Standard ____NTU Measured Value_______NTU Standard ____NTU Measured Value_______NTU

SAMPLE LOCATION DESCRIPTION

Notes: ____

____

SAMPLE COLLECTION PROCEDURE Fill bottles directly in stream ☐ Fill bottles with beaker ☐ Number of bottles _____

Filter with peristaltic pump: Directly from stream ☐ From intermediate sample bottle ☐ From beaker ☐

Decontamination Procedure: ____

Notes: ____

____

DISCHARGE MEASUREMENT Cutthroat Flume: 1"☐ 2"☐ 4"☐ 8"☐ Marsh McBirney☐ Volume/Time☐ Estimate☐

Discharge _______ cfs☐ gpm☐ Initial staff gauge _______ Final staff gauge (after 5 minutes) _______ Photos _________

Notes: ____

____

FINAL SAMPLE PARAMETERS

Sample Date	Sample Time	Discharge cfs☐ gpm☐	pH	Cond. (µS/cm)	Temp. (°C)	Turbidity Visual Est.☐ Measured☐		

Duplicate Sample-02 (sample control number/time________________________________)

Field Blank-03 (sample control number/time________________________________)

Rinsate Sample-04 (sample control number/time________________________________)

Matrix Spike-MS (sample control number/time________________________________)

______________ (sample control number/time________________________________)

Notes:____

____

____

____

Sampler's Signature ____

APPENDIX B

STREAM DISCHARGE MEASUREMENT DATA SHEET

STREAM DISCHARGE MEASUREMENT DATA SHEET

Distance From Initial Point (feet)	Width (feet)	Depth (feet)	Observation Depth (feet)	Time (seconds)	Velocity (ft/sec)	Area (feet^2)	Discharge (cfs)

STANDARD OPERATING PROCEDURE #7

SAMPLE DOCUMENTATION, PRESERVATION, HANDLING, PACKAGING, AND CHAIN OF CUSTODY

Prepared by:
Shepherd Miller, Inc.
3801 Automation Way, Suite 100
Fort Collins, CO 80525

May 17, 1996

SHEPHERD MILLER
INCORPORATED

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1.0 PURPOSE AND SCOPE

This document defines the standard operating procedure (SOP) for sample documentation, handling, packaging, and chain of custody procedures. The American Society for Testing and Materials (ASTM) Standard Practice for Sampling Chain of Custody Procedures (D 4840-88) was used to prepare this SOP.

2.0 RELATED STANDARD OPERATING PROCEDURES

This SOP supplements and is referenced by other SOPs; however, it does not reference any other SOP.

3.0 NECESSARY EQUIPMENT

The following equipment may be used for sample labeling, filtering, packing, documentation, and chain-of-custody procedures:

- Sample bottles
- Sample labels
- Appropriate preservatives
- Field book and data forms
- Chain of custody document
- Black permanent markers, black pens, pencils
- Clear plastic tape
- Fiber tape

- Custody seals
- Large (30 gallon) trash bags
- Gallon ziplock freezer bags
- Ice
- Sample shipment coolers
- Shipping labels
- Federal Express or UPS airbills
- Disposable 0.45-micron filters
- Silicon or Tygon® tubing
- Peristaltic pump
- Watch
- Mobile phone or radio.

4.0 PROCEDURES FOR SAMPLE DOCUMENTATION

4.1 Sample Identification

Assign unique sample identification numbers to collected samples in order to identify the sampling location and sampling sequence for each sample and sample date. These numbers are required for tracking the handling, analysis, and verification or validation status of all samples collected during monitoring. In addition, input the sample identification numbers into the project database to identify analytical results received from the laboratory.

Divide sample identification numbers that are assigned into three fields, as shown in the following examples:

- SMI-01-01-960414 (primary sample at SMI-01)
- CCS-03-02-950318 (duplicate sample at Cottonwood Creek Surface Water Station 03)
- MW-01-3.5-4.0-01-960216 (primary sample at MW-01 from 3.5 to 4.0 feet).

The first field (e.g., SMI-01, CCS-03, or MW-01-3.5-4.0) uniquely identifies the specific sample and is usually tied to the location, matrix sampled, and/or specific sample depths. If required, any additional site-specific identification can be encoded within the sample location field. The second field identifies whether the sample is a primary (01), a field duplicate (02), field blank (03), equipment rinsate (04), or matrix spike (MS) sample. The third and final field contains the date in a year-month-day format to allow data in the analytical database to be sorted easily. For example, the first sample identified above was collected on April 14, 1996.

4.2 Sample Labeling

Label each sample that is collected in the field for future identification. Before collecting the sample, a member of the sampling team will fill out sample labels as completely as possible with black waterproof ink. In most cases, sample labels need to be obtained from the analytical company. Each label will contain at least the following information:

- Sampler's company affiliation
- Unique identification number
- Date and time of sample collection
- Analyses required

- Method of preservation used
- Sampler's signature.

After the label is completed and attached to the sample container, place clear tape over the label to protect and secure it to the bottle.

4.3 Sample Containers, Preservatives, Filtration, and Holding Times

4.3.1 Sample Containers

Observe proper sample preparation practices (Section 4.5) to minimize sample contamination and potential repeat analyses due to anomalous analytical results. Before sampling, obtain commercially-cleaned sample containers from the analytical laboratory. Keep all documentation regarding sample bottle decontamination. Label the bottles as described in the Section 4.2. If sample bottles have not been pre-preserved from the laboratory, add preservatives in the field after sample collection.

4.3.2 Sample Preservation

Samples are preserved to prevent or minimize chemical changes that could occur during transit and storage. Preservation methods include placing samples on ice and adding certain chemicals. If sample bottles are not pre-preserved, preserve samples immediately after collecting them to ensure that laboratory results are not compromised by improper coordination of preservation requirements and holding times. If sample bottles are pre-preserved, allow the sample to free fall into the container and do not allow it to overflow. Store samples on ice in coolers before and during shipping. Specific sample preservation requirements will be specified in the project work plan or sample plan and should be discussed with the laboratory before performing the sampling episode.

Verify the proper pH of the sample after preservation. Use disposable pH test strips to quickly and conveniently verify proper preservation. Do not immerse the pH test strips directly into the sample bottle; instead, wet the strips with a small aliquot of the sample.

4.3.3 Sample Filtration

Filter samples that will be tested for dissolved cations and metals through a 0.45-micron filter. Two common filtration methods use either disposable filter cartridges or disposable filters in a reusable filter holder. If possible, use disposable filter cartridges, because these will eliminate both decontamination and the possibility of cross-contamination. Attach the disposable filter cartridge to disposable silicon or Tygon® tubing and connect the combination to a peristaltic pump or directly to the electric submersible pump discharge.

If reusable filter holders are used, be sure to decontaminate the filtration apparatus to avoid cross-contamination. Decontaminate filter holders as specified in SOP #1. Follow manufacturer's operating directions when operating filter holders and/or peristaltic pumps.

Regardless of the filtration method used, flush the filter and tubing with at least 100 milliliters of sample water before collecting samples. An intermediate container may be required to hold the unfiltered sample. For the intermediate container, use a new, unused sample bottle or a container that has been decontaminated before use as specified in SOP #1. Filter samples that require chemical preservation before preserving them.

4.3.4 Sample Holding Times and Analyses

Sample holding times are established to minimize chemical changes in a sample before analysis and/or extraction. A holding time is defined as the maximum allowable time between sample collection and analysis and/or extraction, based on the nature of the analyte of interest and chemical stability factors. Holding times will be specified in the project work plan or sample plan and should be discussed with the laboratory before performing the sampling episode. To minimize the possibility of exceeding holding times, send samples to the laboratory as soon as possible after collection by hand delivery or an overnight courier service.

The chemical constituents, preservation, and holding times for samples will be summarized in the project work plan or sample plan.

4.4 Sample Packaging for Shipping

To maintain the required storage temperature, ship the samples by the quickest route. Do not allow travel time to exceed 24 hours. Inform the analyzing laboratory of the shipment and of the carrier handling the shipment. Ship the samples in a sealed, ice-filled cooler of good quality. Place the appropriate completed chain-of-custody (COC) forms in each cooler.

The field sampling team shall pack non-hazardous samples for shipment as follows:

1. Obtain an appropriately sized cooler of good quality to pack the samples.
2. Line the cooler with a large plastic trash bag.
3. Place each sample bottle in a appropriately sized freezer zip-lock plastic bag, and place the bottle upright in the large plastic trash bag lining the cooler.
4. Double-bag ice in 1-gallon freezer zip-lock plastic bags. Use enough ice to keep the samples cool until they are received by the laboratory. Use more ice in the summer time.
5. If required, use vermiculite or a similar absorbent material to fill voids in the cooler.
6. Verify that all samples in the cooler have been documented on the COC form. Record the number of the Federal Express Air Bill or other shipping record document on the COC form. Sign and date the COC form and retain a copy of it.

Place the COC form in a 1-gallon zip-lock plastic bag and tape the COC form to the inside lid of the shipping cooler.

7. Seal the plastic trash bag liner with a signed custody seal. This will maintain the chain-of-custody if the cooler is inadvertently opened during shipment.
8. Seal the cooler and drainhole with plastic or fiber tape.
9. Attach signed custody seals across two sides of the cooler top.
10. Attach an address label with the laboratory address and phone number and with a return address and phone number.
11. Attach a Federal Express Air Bill or another shipping document. Retain a copy of shipping documents with the COC form.
12. Notify the laboratory of the sample shipment.
13. Verify that the laboratory receives the samples and that the samples were received in good condition and were sufficiently cool.

Transfer the samples in a timely fashion. Holding times and instructions for preservation for the parameters to be analyzed will be specified in the work plan. The laboratory must receive the samples as soon as possible to ensure that analysis and, if the need arises, re-analysis can be performed within the required holding time.

Carefully evaluate samples collected at hazardous waste sites to determine if they should be classified as dangerous goods. If they are hazardous, contact the shipping company to determine the proper shipping procedure. In some cases, state department of transportation laws may apply and should be considered.

4.5 Sample Handling

General sample handling procedures will include the following:

- Always make field measurements on a separate sub-sample, not on the sample that is sent to the laboratory for analysis, and discard it after the measurements have been made.
- Sample bottles shall be properly decontaminated if they are not certified clean by the manufacturer or have not been pre-preserved by the laboratory.
- Do not use bottles that have been used in the laboratory to store concentrated reagents as sample bottles.
- Do not allow the inner portion of sample containers and caps to come into contact with bare hands, gloves, or other objects.
- If contact with air would change the concentration or characteristics of a constituent to be determined, secure the sample without contacting it with air and completely fill the container.
- Keep sample containers in a clean environment away from dust, dirt, fumes, and grime. Keep vehicles clean to help eliminate contamination problems.
- Field personnel shall wear disposable latex or nitril gloves when collecting samples.
- Do not let foreign and metal objects contact acids and water samples.
- Do not measure electrical conductivity on a sample that was first used to measure pH. Potassium chloride that diffuses from the pH probe can alter the conductivity of the sample.
- Do not let samples stand in the sun. Store them in a cool place, preferably in ice chests with ice.
- Ship samples to the laboratory without delay.

5.0 SAMPLE DOCUMENTATION AND CHAIN OF CUSTODY

Documentation of the conditions and procedures used to collect, calibrate, treat, and handle samples and field data is one of the most important aspects of any monitoring program. Proper documentation provides sources to determine the integrity and applicability of the data. Carefully document all field activities in a logbook or on data sheets. Logbooks shall be bound with numbered pages and shall be written in with permanent black ink only. Record field activities in sufficient detail so that field activities can later be reconstructed from the notes. Any changes to the notes in the field book shall be made by drawing a single line through the incorrect material and initialing the markout.

The following sections provide procedures and formats for documenting the field data and conditions at the time of sample collection, shipment to the laboratory, and laboratory analysis. While forms are provided to document specific tasks, the field sampling team shall maintain a field book for recording all other events, conditions, and observations during sampling.

5.1 Field Notes

Documentation of observations and data acquired in the field provide information on sample acquisition, field conditions at the time of sampling, and a permanent record of field activities. Record field observations and data collected during routine monitoring activities with waterproof ink in a permanently bound weatherproof field log book with consecutively numbered pages or on field data sheets.

Field notebook and data sheet entries will include at least the following information. Consult relevant sampling and decontamination SOPs to supplement this list.

- Project name

- Location of sample
- Sampler's printed name and signature
- Data and time of sample collection
- Sample identification numbers
- Description of sample (matrix sampled)
- Sample depth (if applicable)
- Number and volume of samples
- Sample methods, or reference to the appropriate SOP
- Sample handling including filtration and preservation, as appropriate for separate sample aliquots
- Field observations
- Results of any field measurements, such as depth to water, pH, temperature, specific conductance
- Personnel present
- Decontamination procedures.

Strike out changes or deletions in the field book or on the data sheets with a single strike mark and be sure that the original information remains legible. Record enough information to allow the sampling event to be reconstructed from the notes alone.

Completely fill out field data sheets and do not leave blank lines. Write "Not Applicable" or "NA" on blank lines.

All field books will be signed daily by the person who made the entries.

5.2 Chain Of Custody Procedures

The custody of all samples shall be documented on COC forms provided by the laboratory. The COC forms will document possession of the sample from collection through laboratory analysis.

Follow appropriate sample custody and documentation procedures precisely to preserve sample integrity and to ensure the validity of field and laboratory data. As a result, all sample data will be traceable from the time and location of sample collection through chemical analyses and to the time when data are used. As described above, record initial information concerning sample collection in the field log book or on data sheets. Information on the custody, transfer, handling, and shipping of samples will be recorded on a Chain-of-Custody (COC) Form.

The objective of the custody identification and control system for the samples is to ensure, to the extent practicable, that the following occur:

- All samples scheduled for collection are uniquely identified.
- The correct samples are analyzed and are traceable to their records.
- Important sample characteristics are preserved.
- Samples are protected from loss or damage.
- Any alteration of samples (e.g., filtration, preservation, and dilution) is documented.
- A forensic record of sample integrity is established.
- Legally traceable custody and possession records are maintained.

For this project, a sample is defined as being in an individual's custody if the following conditions occur:

- The sample is in that individual's actual physical possession.
- The sample is in that individual's view after being in their physical possession.
- The sample is in that individual's physical possession and then locked or otherwise sealed so that tampering will be evident.
- The sample is maintained in a secure area that is restricted to authorized personnel only.

General field custody procedures include the following:

- As few people as possible should handle samples.
- The field sampler is personally responsible for the care and custody of the samples collected until they are properly transferred.
- When transferring the samples, the individuals relinquishing and receiving the samples will document the transfer by signing, dating, and writing the time of the transfer on the COC form.
- The person responsible for delivering the samples to the laboratory or to the shipping carrier will sign the COC form, retain the third copy of the form, document the method of shipment, and send the original and the second copy of the form with the samples. Upon arrival at the laboratory, the person receiving the samples will sign the COC form and return the second copy to the Project Manager.
- Custody seals must be attached so that it is necessary to break the seal to open the shipping container. The person affixing the custody seal will sign and date the seal.

Observe general documentation rules, including the use of black ink. Make any changes to the COC form by drawing a single line through the incorrect material and initialing the markout. Put a line through and initial blank lines on the COC form.

Upon receiving the samples, the laboratory's representative shall do the following:

- Sign and keep copies of the air bill.
- Sign the COC form.
- Measure and document the temperature of the samples.
- Document the condition of the sample.
- Notify the project manager if any breakage or improper preservation has occurred or if there is a discrepancy between the COC form, sample labels, and requested analyses.
- Provide copies of the above documentation to the project manager with the final laboratory data package.

6.0 REFERENCES

ASTM D-4840 - 88, Standard Practice for Sampling Chain of Custody Procedures, *1995 Annual Book of ASTM Standards*, Vol. 04.08.

STANDARD OPERATING PROCEDURE #8

MINI-PIEZOMETER INSTALLATION, WATER LEVEL MEASUREMENT, AND SAMPLING

Prepared by:
Shepherd Miller, Inc.
3801 Automation Way, Suite 100
Fort Collins, CO 80525

May 17, 1996

SHEPHERD MILLER
INCORPORATED

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LIST OF APPENDICES

1.0 PURPOSE AND SCOPE

This document defines the standard operating procedure (SOP) for installing mini-piezometers, measuring water levels, and sampling mini-piezometers. This SOP describes the equipment, field procedures, and quality assurance/quality control (QA/QC) procedures for installing mini-piezometers, measuring water levels, and collecting ground water samples from mini-piezometers.

2.0 RELATED STANDARD OPERATING PROCEDURES

This procedure is intended to be used with the following SOPs:

SOP #	Title
1	Equipment Decontamination
2	Monitoring Well Water Level Measurement
3	Ground Water Monitoring Well Installation
4	Monitoring Well Development
5	Ground Water Sample Collection
7	Sample Documentation, Preservation, Handling, Packaging, and Chain of Custody
9	Field Parameter Instrument Calibration and Measurement

3.0 MINI-PIEZOMETER INSTALLATION

This section describes the equipment, methods, and documentation to use for installing mini-piezometers.

3.1 Required Installation Equipment

Use the following equipment to install mini-piezometers:

- Mini-piezometer screen, riser pipe, and locking cap
- Fence post driver
- Pipe wrenches
- Level
- Sledge driver
- Engineers tape
- Cheese cloth, string, and steel rod.

3.2 Mini-Piezometer Design

Mini-piezometer design will be specified in the appropriate project document. Design criteria will include the following:

- Screen length and slot size
- Stainless steel or carbon steel riser pipe
- Installation depth.

3.3 Required Decontamination Equipment

The following equipment may be needed to perform decontamination:

- Brushes
- Wash tubs (plastic)

- Buckets (plastic)
- Steam cleaner or hot water washer
- Paper towels
- Liquinox detergent (or equivalent)
- Potable water
- Deionized water
- Garden type water sprayers
- Laboratory wash bottles
- Clean plastic sheeting and/or trash bags.

Before installation, decontaminate the mini-piezometers as specified in SOP #1. Wash mini-piezometers with Alconox solution, triple rinse them with potable water, and triple rinse them with deionized water.

3.4 Mini-Piezometer Installation

Install mini-piezometers as follows:

1. Assemble all equipment and materials.
2. Decontaminate mini-piezometer.
3. Drive mini-piezometer to design depth with fence post driver and/or sledge hammer. Protect threads on the mini-piezometer with a threaded drive plug. With a level, frequently verify that the mini-piezometer is vertical.
4. If driving the piezometer is unsuccessful, drill a pilot hole with a hand or powered auger or a post hole digger. Install the mini-piezometer as specified in SOP #3 by adding a filter pack and a bentonite seal.

5. If the surface material does not create a seal around the mini-piezometer, bentonite may need to be installed to seal the mini-piezometer at the ground surface.
6. Soft soils may squeeze into the mini-piezometer during installation and plug the mini-piezometer. To prevent this, install wet cheese cloth (tied to a string for easy removal) in the screen and then drive the mini-piezometer to total depth.

3.5 Mini-Piezometer Development

Develop mini-piezometers by using a bailer and peristaltic pump (in place of a submersible pump) with silicon tubing as specified in SOP #4. Use the bailer to surge and remove accumulated sediments and the peristaltic pump to overpump the mini-piezometer. Do not use the bailer to surge mini-piezometers installed in fine-grained sediments because the bailer can pull the fine-grained sediments into the mini-piezometer. Purging with a peristaltic pump will adequately develop mini-piezometers installed in fine-grained sediments.

4.0 WATER LEVEL MEASUREMENT PROCEDURE

Measure mini-piezometer static water levels as specified in SOP #2.

For mini-piezometers that have been installed adjacent to a stream or body of water, measure the distance from the top of the mini-piezometer to the highest flow in the stream. Wrap a string around the mini-piezometer and run it over the top of the casing at the measuring point. Attach a line level to the string and stretch the string across the stream. Attach the free end of the string to a steel or wooden rod and adjust the string until it is level. Measure the perpendicular distance from the string to the area of highest flow. Compare the water level in the mini-piezometer and the stream.

5.0 MINI-PIEZOMETER WATER SAMPLING PROCEDURE

If necessary, decontaminate equipment as specified in SOP #1. Perform field parameter instrument calibration and measurement procedures as specified in SOP #9. Sample mini-piezometers as specified in SOP #5. Purge mini-piezometers with a peristaltic pump and silicon tubing. Purge three mini-piezometer volumes (if not purged dry), based on the diameter of the mini-piezometer, from the mini-piezometer before sampling. Perform sample documentation, handling, packaging, and chain-of-custody (COC) documentation as specified in SOP #7.

5.1 Equipment List

Obtain sample bottles from the analytical laboratory, including several extra sample bottles in case breakage or other problems occur. If sample bottles are not pre-preserved, add preservatives in the field.

The following equipment may be used during mini-piezometer evacuation:

- Assorted tools (knife, screwdriver, etc.)
- Peristaltic pump with battery
- Silicon tubing
- Plastic squeeze bottle filled with deionized water
- Chemical-free paper towels or Kimwipes
- Calculator
- Field notebook
- Waterproof pen.

The following equipment may be used during mini-piezometer sampling:

- Peristaltic pump with battery
- Silicon or Tygon® tubing
- Thermometer (if meters are not equipped with a temperature readout)
- pH meter (with automatic temperature compensation)
- Specific conductivity meter
- Plastic squeeze bottle filled with deionized water
- Sample bottles
- Preservatives
- Dedicated jug for holding sample for filtering
- Cooler with ice
- Polyethylene or glass jar for field measurement samples
- Sample labels.

Use the following equipment during sample filtration:

- Disposable in-line filter assembly with 0.45-micron filter
- Hand or electric peristaltic pump
- Silicon or Tygon® tubing (2- to 4-foot lengths).

Use the following equipment during decontamination:

- Disposal container for decontamination solutions
- Liquinox soap (or equivalent)

- Potable water
- Deionized water
- Decontamination buckets/pails
- Plastic brushes
- Paper towels
- Garden-type sprayers.

5.2 Sampling Procedure

This section gives the step-by-step procedures for collecting samples in the field. Record observations made during sample collection in the field notebook and on field data sheets.

5.2.1 Equipment Decontamination

Before beginning any evacuation or sampling activities, decontaminate the peristaltic pump, Tygon® tubing, and other sampling devices. If dedicated equipment is used, rinse it with deionized water. Use mobile decontamination supplies so that equipment can be decontaminated with clean solutions (i.e., Liquinox solution and rinse water) between use at each mini-piezometer.

5.2.2 Instrument Calibration

Before going into the field, the sampler shall verify that the field test equipment (including the pH meter with automatic temperature calibration and the conductivity meter) is operating properly. Calibrate the pH and conductivity meters before use every day, and record calibration times and readings in a notebook that the field sampler keeps. Refer to SOP #9 for calibration instructions.

Since some pH meters may introduce sodium chloride into the sample, take specific conductivity measurements before taking pH measurements.

5.2.3 Evacuating Mini-Piezometers

Purge mini-piezometers with a peristaltic pump and silicon or Tygon® tubing or a bailer. Purge three mini-piezometer volumes (if not purged dry), from the mini-piezometer before sampling. The mini-piezometer's volume equals pi times the radius in feet squared times the depth to water in feet times 7.481 gallons per cubic foot ($V=\pi r^2 d$ [in ft^3]* 7.481 gal/ft^3). Perform field parameter measurements throughout purging as described in SOP #5.

5.2.4 Collecting Samples

Collect samples using either the peristaltic pump or bailer. Follow ground water sampling procedures as specified in SOP #5. Filter samples as necessary following procedures specified in SOP #7.

5.2.5 Field Quality Assurance/Quality Control Procedures and Samples

QA/QC samples help identify potential sources of sample contamination and help evaluate potential error introduced by sample collection and handling. Label all QA/QC samples with QA/QC identification numbers (i.e., "02" for duplicate samples, "03" for field blanks, "04" for rinsate samples, and "MS" for matrix spike samples) and send them to the laboratory with the other samples for analyses. All QA/QC samples should be analyzed at the same time and in the same batches as the primary samples.

Duplicate Samples

To check for the natural sample variance and the consistency of field techniques and laboratory analysis, collect duplicate samples side-by-side with primary samples. For ground water sampling, collect a duplicate sample while collecting the primary sample. Fill the primary sample bottle(s) first and the duplicate sample bottle(s) for the same analysis second until all necessary sample bottles for both the primary and duplicate samples have been filled. Use different filter and tubing for the primary and duplicate samples. Handle the duplicate ground water sample in the same manner as the primary sample. Assign the duplicate sample the QA/QC identification number "02"; follow SOP #7 for documentation, preservation, handling, packaging, and chain-of-custody procedures; store the sample in an iced cooler; and ship it promptly to the laboratory so that analyses can be performed within required holding times.

Collect one duplicate sample for every 20 primary samples collected so that a rate of at least 5 percent of primary samples collected is achieved. For example, if you collect from 1 to 20 primary samples during a sampling event, collect one duplicate sample, and if you collect from 21 to 40 primary samples during a sampling event, collect two duplicate QA/QC samples.

Collect duplicate QA/QC samples so that they represent the time of collection, different sampling teams, field conditions, and sampling equipment variability. For example, if ambient conditions are altered that could impact sample quality, the QA/QC sampling frequency may be increased. Collect duplicate samples throughout the sampling event, not just at the end.

Field Blanks

Collect field blanks by filling sample containers in the field with deionized water from the same source that is used for decontamination. Assign the sample the QA/QC identification number

"03"; follow SOP #7 for documentation, preservation, handling, packaging, and chain-of-custody procedures; store the sample in an iced cooler; and ship it promptly to the laboratory so that analyses can be performed within required holding times. Collect one field blank per sampling episode and per medium sampled.

Collect one field blank sample for every 20 samples primary collected, so that a rate of at least 5 percent of primary samples collected is achieved. For example, if you collect from 1 to 20 primary samples during a sampling event, collect one field blank sample; and if you collect from 21 to 40 primary samples during a sampling event, collect two field blank samples.

Rinsate Samples

An equipment rinsate sample of sampling equipment is intended to be used to check if decontamination procedures have been effective. For the well sampling operation, collect a rinsate sample from the decontaminated sampling equipment (bailer or pump) and filter equipment before using it to obtain the sample. To collect a rinsate sample from a bailer, rinse deionized water over the decontaminated bailer and transfer it to the sample bottles. To collect a rinsate sample from an electric submersible pump, transfer the final deionized water rinse that is pumped through the discharge hose to sample bottles. The same parameters that will be analyzed in the ground water samples will be analyzed in the rinsate samples. Assign the rinsate sample the QA/QC sample identification number "04"; follow SOP #7 for documentation, preservation, handling, packaging, and chain-of-custody procedures; store the sample in an iced cooler; and ship it promptly to the laboratory so that analyses can be performed within required holding times.

Collect one rinsate sample for every 20 primary water samples collected so that a rate for rinsate samples of at least 5 percent of primary samples collected is achieved. For example, if you collect from 1 to 20 primary samples during a sampling event, collect one rinsate blank sample, and if you collect from 21 to 40 samples during a sampling event, collect two rinsate blank samples.

Collect rinsate blank samples so that they represent the time of collection, different sampling teams, field conditions, and sampling equipment variability. For example, if ambient conditions are altered that could impact sample quality, the QA/QC sampling frequency may be increased. Collect rinsate blank samples throughout the sampling event, not just at the end. Collect one rinsate blank sample for each type of sampling equipment used if less than 20 samples are collected (e.g., if 10 samples are collected by a bailer and 10 samples are collected by a submersible pump, you would collect two rinsate samples — one from the bailer and one from the pump).

Matrix Spike Samples

Matrix spike (MS) samples are required to evaluate potential matrix effects on sample analyses for all inorganic parameters. The laboratory will spike matrix spike samples for the inorganic parameters. Depending on the specific laboratory and sample volume collected, the matrix spike samples may be split from an existing sample or may require a separate sample. To samples that you collect specifically for matrix spike analysis, assign the QA/QC identification "MS"; follow SOP #7 for documentation, preservation, handling, packaging, and chain-of-custody procedures; store the sample in an iced cooler; and ship it promptly to the laboratory so that analyses can be performed within required holding times. The samplers will identify all samples selected for matrix spike analysis on the Chain of Custody Form. Specify one matrix spike sample for each sample shipment group of 20 samples or less.

Laboratory Replicate Samples

Depending on the laboratory conducting the analysis, laboratory replicate samples may be required. Laboratory replicate samples are split from the primary sample in the laboratory and analyzed as part of the laboratory's QA/QC program. The laboratory replicate does not require a separate sample volume. The sample that the laboratory splits must be identified by the samplers on the Chain of Custody Form. One laboratory replicate sample will be specified for each sample shipment group of 20 samples or less.

APPENDIX A

MINI-PIEZOMETER SAMPLING DATA SHEET

MINI-PIEZOMETER SAMPLING DATA SHEET

IDENTIFICATION

Project Number: ________________

Sample Location________________________________ Date ___________ Start Time _______ Stop time______ Page___of__

ample Control Number______________________________________ Samplers ______________________________________

WEATHER CONDITIONS

Ambient Air Temperature: _____________ °C☐ °F☐ Not Measured ☐ **Wind:** Heavy☐ Moderate☐ Light☐

Precipitation: None☐ Rain☐ Snow☐ Heavy☐ Moderate☐ Light☐ Sunny☐ Partly Cloudy☐

INITIAL MINI-PIEZOMETER MEASUREMENTS (Measurements in feet made from top of casing)

Static Water Level______ Depth to Stream________Total Depth_______Top of Screen________ Filter Pack Interval__________

Borehole Diameter(inches)______________Mini-piezometer Casing ID_____________ Mini-piezometer Casing OD_____________

Mini-piezometer Casing Stickup_____ Feet of Water_______Mini-piezometer purged with: ______________________________

FINAL MINI-PIEZOMETER MEASUREMENTS

Static Water Level___ Total Depth___ Total Volume Purged___ Saturated Borehole Volume (gal)___ Max Pumping Rate ______

INSTRUMENT CALIBRATION

pH Meter: Meter Number_______________

Buffer___ Measured Value_____ Temp.____ °C

Buffer___ Measured Value_____ Temp.____ °C

Conductivity Meter: Meter Number_________________

Standard______mS/cm Measured Value__________mS/cm Temp.___°C

Standard______mS/cm Measured Value__________mS/cm Temp.___°C

Turbidity Meter:_____ Standard ____NTU Measured Value_______NTU Standard ____NTU Measured Value_______NTU

FIELD PARAMETER MEASUREMENTS DURING PURGING

Time	Volume (gallons)	pH	Cond. (µS/cm)	Temp. °C☐ °F☐	Turbidity Visual Est.☐ Measured☐	Comments

FINAL SAMPLE PARAMETERS

Sample Date	Sample Time	Discharge cfs☐ gpm☐	pH	Cond. (µS/cm)	Temp. (°C)	Turbidity Visual Est.☐ Measured☐		

Duplicate Sample-02 (sample control number/time____)

Field Blank-03 (sample control number/time____)

Rinsate Sample-04 (sample control number/time____)

Matrix Spike-MS (sample control number/time____)

______________ (sample control number/time____)

otes:____

____

____

Sampler's Signature ____

STANDARD OPERATING PROCEDURE #9

FIELD PARAMETER INSTRUMENT CALIBRATION AND MEASUREMENT

Prepared by:
Shepherd Miller, Inc.
3801 Automation Way, Suite 100
Fort Collins, CO 80525

May 17, 1996

SHEPHERD MILLER
INCORPORATED

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1.0 PURPOSE AND SCOPE

This document defines the standard operating procedure (SOP) for field parameter instrument calibration and measurement. This SOP describes the equipment and field procedures necessary to measure field parameters.

Whenever water samples are collected, measure field parameters on a separate aliquot of the sample immediately after collecting the sample. This SOP describes how to properly calibrate instruments and measure pH, temperature, conductivity, and turbidity in the field.

Many types of meters and methods are used to measure field parameters. The following sections: (1) list specific equipment requirements, (2) clarify the objectives of measuring field parameters to help the samplers obtain the proper equipment, and (3) describe the required apparatus for performing the measurements.

2.0 RELATED STANDARD OPERATING PROCEDURES

This procedure is intended to be used with the following SOPs:

SOP #	Title
1	Equipment Decontamination

3.0 pH METER CALIBRATION AND MEASUREMENT

3.1 Required pH Measurement Equipment

Use the following apparatus and supplies for measuring pH in the field:

- Portable Hach One pH Meter Model 43800-00 with Hach One Combination pH Electrode Model 48600 or the EC10 Portable pH/mV/Temperature Meter Model 50050 with the Combination pH Electrode with Temperature (Gel-filled) Model 50200

- Spare electrolyte cartridge, if required
- Hach pH Electrode Storage Solution, Catalog No. 50301-49
- Extra batteries
- Beakers
- Buffer solutions of pH 4, 7, and 10
- Deionized or distilled water and wash bottle
- Kimwipes or equivalent.

Many chemical reactions are pH-dependent; therefore, pH is an important indicator of the state of the water. If possible, determine the pH in situ; if this is not possible, determine the pH from a water sample as soon as possible. Determine the pH by the electrometric method using standard buffer solutions. The electrometric method is the preferred method because of its greater accuracy and ease of measurement. A combination electrode, which combines the glass membrane electrode and the reference electrode, may also be used.

Many portable battery-powered pH meters are available with a variety of features and abilities. The meter selected for field use should be rugged and it should be carried and stored in a foam-lined, water-resistant carrying case. The carrying case should have sufficient room to store extra pH buffers, electrode filling solution, spare electrodes, cables, and batteries.

Meters recommended should automatically compensate for temperature and be capable of calibration with a two-point (two buffers) slope adjustment method. The meter should have a precision of ±0.05 units.

3.2 pH Meter Calibration Procedures

Before collecting samples, calibrate the pH using calibration solutions. The field sampling team shall record all pH measurement data, including calibration dates, readings, SMI meter number, and temperatures, on a data sheet or in a field notebook.

The field sampling team shall be familiar with the meter and shall follow the manufacturer's instructions for calibrating and using the meter Calibrate the pH meter at the start of each sampling day and, as needed, when measuring waters with different pH values. Thoroughly document all calibrations, including the buffer readings and temperatures in the field book or data sheets. The field sampling team shall do the following when calibrating the meter according to the manufacturer's procedures:

- Condition new pH electrodes by soaking them for one hour in Hach pH Electrode Storage Solution. Do not condition pH electrodes that have been properly stored in Hach pH Electrode Storage Solution.
- One of the buffer solutions used for the slope adjustment should bracket the anticipated pH of the sample, and the other buffer should always have a pH of 7. Ensure that the buffer solutions are at the same temperature and are as close as practical to the temperature of the water to be measured. Use buffer solutions once and then discarded them.
- Before immersing the probe into the buffer or sample, rinse the probe with deionized or distilled water and blot it dry with a clean wipe. Protect the glass tip of the probe from abrasion and scratching.
- Adjust the slope of the meter with two buffer solutions (2-point slope adjustment) at least daily, and preferably twice per day to account for changes in conditions of the probe and meter and, as needed, when measuring waters with different pH values.
- If the slope deviates significantly from its theoretical value, search for a potentially defective electrode or contaminated buffer solution.

3.3 pH Measurement

The sampler shall measure pH in the field as follows:

1. Thoroughly check the pH meter, including the battery, and then calibrate the meter in the laboratory before taking it to the field. The buffers used for calibration should bracket the anticipated pH values to be measured.

2. Recalibrate the meter in the field before use.

3. If the pH is measured in a container, rinse the sample container with deionized water and then rinse it three times with the sample water prior to measurement. Rinse the pH probe with deionized water and, if possible, blot the probe dry with a clean wipe. Be sure to protect the fragile glass bulb at the end of the probe from damage.

4. Immerse the electrode into the water, allow the pH reading to stabilize, and monitor the drift of the instrument. Do not immerse the electrode above the top of the pH probe. When the pH reading stabilizes, record the temperature and the pH reading to the nearest 0.01 unit.

5. Between measurements, store the electrode in pH Electrode Storage Solution.

6. Measure samples within a short period of time after sampling and on a separate aliquot of the sample.

7. For the Hach One Combination pH Electrode Model 48600, dispense electrolyte if the reading becomes unstable, erratic, or if stabilization takes too long. An unstable reading may also indicate an air bubble in the reference line. Depress the dispenser button repeatedly until the bubble is expelled (5 to 10 clicks should be sufficient). Note that it is not necessary to refresh the electrolyte gel at the reference outlet between readings unless the reading is not stable.

8. Short-term electrode storage (between measurements/up to one week) will be in the Hach pH Electrode Storage Solution or cotton soaked in the Hach pH Electrode Storage Solution. Do not store in deionized water, as this will shorten the electrode life.

4.0 CONDUCTIVITY METER CALIBRATION AND MEASUREMENT

Electrical conductivity, or specific conductance, is the ability of water to conduct an electric current and depends on the concentration of ions in solution. The relationship between conductivity and the concentration of dissolved solids is approximately linear for most natural waters. Changes in this relationship indicate changes in the proportions of different salts and, therefore, changes in the sources of dissolved substances that enter the water body.

Conductivity is usually measured in the field with a hand-held meter that is equipped with a conductivity cell and temperature probe. The meter measures the ability of water to conduct electricity across a specified distance and cross-sectional area.

Numerous types of conductivity meters are available with various features and accessories. For measuring conductivity in the field, use a meter that can also measure temperature, has either a manual or automatic temperature compensator, and that displays conductivity directly in units of microsiemens per centimeter (μS/cm), corrected to a temperature of 25 degrees Centigrade (°C). Carry and store the meter in a foam-lined, water-resistant carrying case. The carrying case should have sufficient room to store extra calibration solution, spare probes, and batteries.

4.1 Conductivity Measurement Equipment

Use the following apparatus and supplies for measuring conductivity in the field:

- Hach CO150 Conductivity Meter Model 50150, Hach Conductivity/TDS Meter Model 44600, or Oakton® WD-35607-10 Hand-Held Conductivity Meter
- Extra battery
- Calibration solutions which bracket expected range of measurements
- Deionized water
- Wash bottle
- Kimwipes
- Beakers.

4.2 Conductivity Meter Calibration

Before collecting samples, calibrate the conductivity meter using calibration solutions . The sampler shall record all conductivity measurement data, including calibration dates, readings, SMI meter number, and temperatures, on a data sheet or in a field notebook.

Reagent-grade potassium chloride (KCl) or other equivalent solutions are universally used as reference solutions to calibrate conductivity (specific conductance) equipment. The reference solutions are also used to check the accuracy of the meter, usually on a daily basis or, as necessary, at more frequent intervals.

The conductivity of the reference solutions that are used to calibrate the meter should bracket the expected range of the conductivity of the water samples. Commercially prepared calibration standards are available from laboratory suppliers at many standard concentrations.

The sampler shall calibrate the meter as follows:

1. Calibrate the meter according to the manufacturer's instructions.
2. Prepare or obtain standard reference solutions of a known value at a known temperature. Adjust the meter or the calibration solution to the correct temperature.
3. Adjust the meter to read the reference conductivity. Rinse the probe with deionized water and blot the probe dry. Re-immerse the probe in the reference solution and read the measured value to validate the corrected conductivity.

4.3 Conductivity Measurement

Whenever possible, measure conductivity in situ or immediately after a sample is collected. If conductivity is measured within 24 hours, do not filter the conductivity sample beforehand. Record conductivity readings to the nearest 0.1 μS/cm, corrected to 25°C .

The sampler shall measure conductivity as follows:

1. Check the meter, including the battery, and calibrate the meter before taking it to the field. Buffer solutions used for calibration should bracket the expected conductivity values to be measured.

2. Recalibrate the meter in the field before use.

3. Rinse the probe with deionized water and blot the probe dry with a clean wipe, without wiping the plating on the cell.

4. Insert the probe into the sample solution. Immerse the tip to or beyond the vent holes and agitate the probe vertically. Make sure that air bubbles are not trapped near the temperature sensor. Allow the reading to stabilize before recording measurements. Measure and record the temperature of the sample.

5. During normal use, rinse the probe thoroughly with deionized water between measurements to minimize the buildup of interfering substances on the probe element.

6. Because the Model 44600 Conductivity Meter does not automatically turn itself off, verify that the unit is off before storing it.

5.0 TURBIDITY METER CALIBRATION AND MEASUREMENT

One of the most sensitive and, therefore, the most representative field parameter measured during ground water sample collection is turbidity. Measure turbidity in the field with the Hach Portable Turbidimeter Model 2100P.

5.1 Turbidity Measurement Equipment

Use the following apparatus and supplies for measuring turbidity in the field:

- Hach Portable Turbidimeter Model 2100P
- Extra battery
- Calibration solutions which bracket expected range of measurements
- Silicone oil
- Deionized water

- Wash bottle
- Liquinox solution
- Kimwipes
- Beakers.

5.2 Turbidity Meter Calibration and Measurements

Calibrate the turbidimeter before mobilizing to the field. Once in the field, check the calibration by measuring standards of known turbidity. The field sampling team shall record calibration checks, dates, and the SMI meter number on a field data sheet or in the field book.

Note the following operational considerations:

- Avoid prolonged exposure to ultraviolet light and sunlight.
- Do not hold the instrument during measurements; place the instrument on a flat, steady surface.
- Measure samples immediately to prevent temperature changes and settling. Avoid sample dilution when possible. Particles suspended in the original sample may dissolve or otherwise change characteristics when the sample temperature changes or when the sample is diluted, resulting in a non-representative sample measurement.
- Handle measurement cells only by the top to minimize dirt, scratches, and fingerprints in the light path.
- Always cap the sample cell to prevent spillage of sample into the instrument.
- Always close the sample compartment lid during measurement and storage.
- When oiling the sample cells, use only a thin coat of oil. Do not use excessive amounts of oil.

The sampler shall measure turbidity as follows:

1. Thoroughly check the meter, including the battery, and then calibrate the meter in the laboratory before taking it to the field.
2. Measure the turbidity of the standard and compare it to its certified value.
3. Clean the sample cell.
4. Fill the sample cell with sample.
5. Clean and oil the sample cell.
6. Place the cell in the meter.
7. Select the range.
8. Signal average the sample (if necessary).
9. Read and record the turbidity to 0.01, 0.1, or 1.0 NTU, depending on the range of the sample.
1. Empty and clean the sample cell.

6.0 HACH DR 100 COLORIMETER OPERATION

Hach DR 100 Colorimeter is used to measure both iron and dissolved oxygen in the field.

6.1 Iron Test

The hach DR 100 Colorimeter Model 41100-10

STANDARD OPERATING PROCEDURE #10

VISUAL DESCRIPTION AND CLASSIFICATION OF UNCONSOLIDATED SAMPLES OBTAINED DURING DRILLING

Prepared by:
Shepherd Miller, Inc.
3801 Automation Way, Suite 100
Fort Collins, CO 80525

May 17, 1996

SHEPHERD MILLER
INCORPORATED

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1.0 PURPOSE AND SCOPE

This Standard Operating Procedure (SOP) defines standard information for SMI personnel to record when describing unconsolidated subsurface samples obtained during drilling.

2.0 RELATED STANDARD OPERATING PROCEDURES

This procedure is intended to be used with the following SOPs:

SOP #	Title
1	Equipment Decontamination
3	Ground Water Monitoring Well Installation

3.0 REQUIRED EQUIPMENT

Use the following equipment to collect, describe, and preserve unconsolidated material samples obtained during drilling:

- Hand lens, magnification 10X
- Grain size comparator (not included in this document)
- Munsell Soil Color chart
- Knife
- 10% hydrochloric acid
- Tweezers
- Stainless steel spatula
- Probe
- Chip trays

- Gallon ziplock freezer bags
- Spot plates
- Nitrile or latex surgical gloves
- Calibrated 5-gallon buckets
- Food strainers
- Wrist watch
- Stop watch
- Supply of boring log forms
- Field book
- Permanent-ink black pens
- Engineers tape (marked in increments of 10ths and 100ths of a foot).

4.0 PROCEDURES FOR COLLECTING, DESCRIBING, AND CLASSIFYING UNCONSOLIDATED SUBSURFACE MATERIALS

4.1 Introduction

Subsurface samples can be obtained from various types of drilling/sampling methods, including:

- Reverse circulation rotary, cutting sampling method
- Hollow-stem auger, split spoon sampling method.

Methods of sample collection may vary between samples; however, describe samples in a standard manner using a logging form identified for the specific project.

4.2 Drilling/Sampling Methods

4.2.1 Reverse Circulation Rotary

Selected exploration borings and monitoring wells may be drilled using a dual-tube rotary reverse circulation drilling rig. In this drilling method, use air as the primary drilling fluid. The return fluid will consist of air, drill cuttings, and ground water, which will be routed through a cyclone to separate out the air. Soil and water will then be collected in a contained area, where the water will be decanted into mobile tanks. Collect representative samples of cuttings and ground water by routing a portion of the cuttings/ground water discharge stream from the cyclone into a 5-gallon bucket or food strainer. Replace the bucket or food strainer at every 5-foot interval.

The field geologist is responsible for doing the following: collecting the cuttings samples, describing and classifying the samples using Appendix A, preserving representative portions of each sample for archive and future analysis, and recording appropriate chemical and geotechnical sample numbers on the borehole log.

The field geologist will also record drilling operational information, including the following: drilling depths, amount of temporary casing installed in the borehole, drilling rates, drilling delays, and drill stem pressures. Sample recovery, sample descriptions, and drilling operational data will also be recorded.

Collect representative samples in chip trays for every 5-foot interval that is drilled. At the field geologist's discretion, increase the sampling interval to ensure representative sampling.

Record production rates, as measured with a 5-gallon bucket and watch, on the borehole log. Record flow rates in gallons per minute.

4.2.2 Hollow-Stem Auger

Obtain split-spoon samples from hollow stem auger borings. Perform split spoon sampling according to ASTM D-1586. Record sample recovery, sample descriptions, and drilling operational data either in the field book or on data sheets. Measure and record recovery as actual recovery length in the recovery column. Record blow counts for each 6-inch interval of a drive not to exceed 2 feet. Retain the entire recovered sample and place it in plastic bags.

4.3 Description of Unconsolidated Materials

A primary borehole logging objective is to describe pertinent lithologic parameters necessary to geologically characterize the site. When detailed textural and compositional aquifer descriptions are integrated into the hydrogeologic framework, interpretations regarding aquifer geometries will be augmented.

Classify and describe all unconsolidated materials, including alluvium, colluvium, and fill, using the Unified Soil Classification System (USCS) and enhance these descriptions using ASTM D-2488, "Description and Identification of Soils (Visual-Manual Procedure)."

4.4 Description of Unconsolidated Materials

Describe all unconsolidated materials according to ASTM D-2488 (Appendix A) and the Unified Soil Classification System (USCS). Describe the materials in the following order, including only applicable items:

> Group Name, Group Symbol, Color, Grain Size Distribution, Grain Mineralogy, Grain Angularity and Shape, Plasticity, Density, Moisture Content, Structure, Acid Reaction, Percentage Range of Constituents

(For Intact Samples: Consistency, Structure, Cementation, and Other Comments [odor, description of inclusions, description of organic matter])

Some sample descriptions follow:

- Well-graded SAND (SW), light yellow-brown (10YR 5/2), medium to coarse, quartz, subangular to angular quartz, dense, wet, homogeneous, no acid reaction, black staining from 5.0 to 5.4 feet, 90-95% sand, 5-10% silt,
- CLAY (CL), stiff, red (2.5YR 4/6), slightly plastic, moderately stiff, moist, blocky, no acid reaction.

Group Name

Describe and classify unconsolidated materials according to the USCS described in ASTM D-2488. A summary of the USCS is shown in Table 1.

Describe the coarse-grained fraction as gravel or sand according to the grain sizes listed in Table 2. The grading of the sample is included as part of the name when fines are less than 5 percent; "poorly-graded" indicates that mostly one grain size is present and "well-graded" indicates that a range of grain sizes are present.

Classify the fine-grained fraction as silt or clay. Silt is generally non-plastic and exhibits little strength when dried. Clay can generally be made to exhibit plastic properties and strength when dried.

Estimate the content of each material type to the nearest 5 percent. Classify combinations of material types as follows:

- Small amount of material present (less than 5 percent) — use the word "contains" in the description (e.g., "SAND, contains silt").
- Approximately 5 to 15 percent of material present — use the word "with" in the description (e.g., "SAND with silt").

- More than 15 percent of material present — use the suffix “y” or “ey” in the description (e.g., “silty SAND”).

Group Symbol

Assign the appropriate USCS symbol.

Color

Use the Munsell Soil Color charts when comparing and describing colors. Record the color designation and hue/value/chroma values. Colors may be described as mottled with other color(s) named. Note any staining or alteration.

Grain Size Distribution

Estimate the grain size distribution of the coarse fraction of the sample using a grain size chart. Table 2 lists USCS size classes.

Grain Mineralogy

If possible, describe the mineralogy of larger grains (e.g., quartz, feldspar, mica, pyrite, and granite). In addition, describe visible staining of the coarse fraction.

Grain Angularity and Shape

Based on ASTM D 2488, describe the angularity of the coarse fraction as angular, subangular, subrounded, or rounded. Describe the shape of the grains as flat if the width to thickness ratio is greater than 3 or as elongated if the length to width ratio is greater than 3.

Density or Stiffness

Only report the in-situ density (coarse-grained) or consistency (fine-grained) of the sample if supporting information has been acquired. A correlation between blow counts and density/stiffness is presented in Table 3.

Plasticity

To determine group type, test fine-grained fractions for plasticity as follows:

- If a 1/8-inch diameter thread cannot be rolled at any water content, the material is <u>non-plastic</u>.
- If a 1/8-inch diameter thread can barely be rolled without crumbling, the material has <u>low plasticity</u>.
- If a 1/8-inch diameter thread can easily be rolled without crumbling and not much time is required to roll-dry the thread to the crumbling point (plastic limit), the material is of <u>medium plasticity</u>.
- If a 1/8-inch diameter thread can be easily rolled without crumbling and considerable time is required to roll-dry the thread to the crumbling point (plastic limit), the material is <u>highly plastic</u>.

Moisture Content

Only report moisture content for samples that are unaffected by drilling fluids. Describe such samples as dry, moist, or wet.

Structure

Only report soil structure for intact core or split spoon samples. Use the descriptive terms cited in ASTM D-2488 (Table 4).

Acid Reaction

Test samples for reaction to a weak solution of hydrochloric acid (HCl). Describe the reaction as no [none], weak, moderate, or strong.

Other Descriptive Items

Many collected samples will likely fit the same general classification with only subtle differences. To fully describe these subtle differences, make detailed observations with a hand lens and microscope. If present, describe the following items:

- Description of alteration, coating, or staining of grains
- Description of cementing
- Odor, if unusual
- Description of inclusions
- Description of organic matter
- Radioactivity screening data (if applicable).

Limit descriptions to the observations made, such as color, texture, and extent. Do not use mineralogical terms if they are unknown (e.g., terms such as "iron" staining should be recorded as staining with a color descriptor.

5.0 DOCUMENTATION

Record the following information on boring logs:

- Sampled interval
- Sample type and number (for archive and analytical)
- Blows on sampler (for split spoons only)
- Recovery (for split spoon and core samples only)
- Visual description (see Sections 2.3 and 2.4)
- Drilling rate (or time of day per depth)
- Delays in drilling
- Drilling pressure
- First encounter with ground water

- Ground water flow rate.

Record the following information in the field book:

- Project name and number
- Name of drilling company and driller
- Name of field geologist (person describing samples)
- Type of drilling rig and drilling method
- Boring number
- Borehole diameter/temporary casing diameter
- Total depth
- Date and time started, date and time completed
- Sampling method(s)
- Names of all personnel directly involved in work and important visitors
- Date and time
- Weather conditions
- Location of boring
- Layout of equipment at drilling location
- Details of cuttings and fluid management system setup
- Nature of any equipment breakdowns
- Decontamination documentation
- Other operational information.

6.0 REFERENCES

The following ASTM standards describe the details of the Unified Soil Classification System and the Standard Penetration Test:

D-1586 - 84 Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils, 1995 Annual Book of ASTM Standards, Vol. 04.08.

D-2487 - 93 Standard Classification of Soils for Engineering Purposes (Unified Soil Classification System), 1995 Annual Book of ASTM Standards, Vol. 04.08.

D-2488 - 93 Standard Practice for Description and Identification of Soils (Visual-Manual Procedure), 1995 Annual Book of ASTM Standards, Vol. 04.08.

Table 1 Unified Soil Classification System

Major Division			Group Symbols	Group Name
Coarse-grained fraction greater than 50%	Gravel fraction greater than 50%	Clean Gravels, less than 5% fines	gw	Well-graded gravel
			gp	Poorly-graded gravel
		Gravels with Fines, more than 15% fines	gm	Silty gravel
			gc	Clayey gravel
	Sand fraction greater than 50%	Clean Sands, less than 5% fines	sw	Well-graded sand
			sp	Poorly-graded sand
		Sands with Fines, more than 15% fines	sm	Silty sand
			sc	Clayey sand
Fine-grained fraction greater than 50%	Silts and Clays, liquid limit 50% of less		ml	Silt
			cl	Lean Clay
			ol	Organic Silt and Organic Clay
	Silts and Clays, liquid limit 50% or greater		mh	Elastic Silt
			ch	Fat Clay
			oh	Organic Silt and Organic Clay
Highly Organic			pt	Peat

Table 2 USCS Size Classes

Size Class		Diameter, millimeters	Diameter, inches
Boulder		> 300	> 12
Cobble		75 - 300	3 - 12
Gravel	Coarse	19 - 75	3/4 - 3
	Fine	4.75 - 19	1/5 - 3/4
Sand	Coarse	2 - 4.75	1/12 - 1/5
	Medium	0.425 - 2	1/60 - 1/12
	Fine	0.074 - 0.425	1/340 - 1/60
Silt or clay		< 0.074	< 1/340

Table 3 Chart for Stiffness and Density Classification

Clay and Silt			Sand and Gravel		
Per 6"	**Per Foot**	**Stiffness**	**Per 6"**	**Per Foot**	**Density**
1	0-2	very soft	0-2	0-4	very loose
1-2	2-4	soft	2-5	4-10	loose
2-4	4-8	mod. stiff	5-15	10-30	mod. dense
4-8	8-16	stiff	15-25	30-50	dense
8-16	16-32	very stiff	>25	>50	very dense
>16	>32	hard			

Note: Based on blow counts in Standard Penetration Test

Table 4 Stratification

Stratification	Description
Laminated	Alternating layers of varying material or color with layers less than 6 mm (1/4 inch) thick
Stratified	Alternating layers of varying material or color with layers greater than 6 mm (1/4 inch) thick
Lensed	Inclusion of small pockets of a different material
Fissured	Breaks along planes of fracture with little resistance
Slickensided	Fracture planes appear polished or glossy, sometimes striated
Blocky	Cohesive material that can be broken down into small angular lumps which resist further breakdown
Homogeneous	Same color and appearance throughout

APPENDIX A

ASTM D-2488

Designation: D 2488 – 93

Standard Practice for
Description and Identification of Soils (Visual-Manual Procedure)[1]

This standard is issued under the fixed designation D 2488; 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.

This standard has been approved for use by agencies of the Department of Defense. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

1. Scope

1.1 This practice covers procedures for the description of soils for engineering purposes.

1.2 This practice also describes a procedure for identifying soils, at the option of the user, based on the classification system described in Test Method D 2487. The identification is based on visual examination and manual tests. It must be clearly stated in reporting an identification that it is based on visual-manual procedures.

1.2.1 When precise classification of soils for engineering purposes is required, the procedures prescribed in Test Method D 2487 shall be used.

1.2.2 In this practice, the identification portion assigning a group symbol and name is limited to soil particles smaller than 3 in. (75 mm).

1.2.3 The identification portion of this practice is limited to naturally occurring soils (disturbed and undisturbed).

NOTE 1—This practice may be used as a descriptive system applied to such materials as shale, claystone, shells, crushed rock, etc. (See Appendix X2).

1.3 The descriptive information in this practice may be used with other soil classification systems or for materials other than naturally occurring soils.

1.4 *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For specific precautionary statements see Section 8.

1.5 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 *ASTM Standards:*

D 653 Terminology Relating to Soil, Rock, and Contained Fluids[2]
D 1452 Practice for Soil Investigation and Sampling by Auger Borings[2]
D 1586 Method for Penetration Test and Split-Barrel Sampling of Soils[2]
D 1587 Practice for Thin-Walled Tube Sampling of Soils[2]
D 2113 Practice for Diamond Core Drilling for Site Investigation[2]
D 2487 Classification of Soils for Engineering Purposes (Unified Soil Classification System)[2]
D 4083 Practice for Description of Frozen Soils (Visual-Manual Procedure)[2]

3. Terminology

3.1 *Definitions:*

3.1.1 Except as listed below, all definitions are in accordance with Terminology D 653.

NOTE 2—For particles retained on a 3-in. (75-mm) US standard sieve, the following definitions are suggested:

Cobbles—particles of rock that will pass a 12-in. (300-mm) square opening and be retained on a 3-in. (75-mm) sieve, and

Boulders—particles of rock that will not pass a 12-in. (300-mm) square opening.

3.1.1.2 *clay*—soil passing a No. 200 (75-μm) sieve that can be made to exhibit plasticity (putty-like properties) within a range of water contents, and that exhibits considerable strength when air-dry. For classification, a clay is a fine-grained soil, or the fine-grained portion of a soil, with a plasticity index equal to or greater than 4, and the plot of plasticity index versus liquid limit falls on or above the "A" line (see Fig. 3 of Test Method D 2487).

3.1.1.3 *gravel*—particles of rock that will pass a 3-in. (75-mm) sieve and be retained on a No. 4 (4.75-mm) sieve with the following subdivisions:

coarse—passes a 3-in. (75-mm) sieve and is retained on a ¾-in. (19-mm) sieve.

fine—passes a ¾-in. (19-mm) sieve and is retained on a No. 4 (4.75-mm) sieve.

3.1.1.4 *organic clay*—a clay with sufficient organic content to influence the soil properties. For classification, an organic clay is a soil that would be classified as a clay, except that its liquid limit value after oven drying is less than 75 % of its liquid limit value before oven drying.

3.1.1.5 *organic silt*—a silt with sufficient organic content to influence the soil properties. For classification, an organic silt is a soil that would be classified as a silt except that its liquid limit value after oven drying is less than 75 % of its liquid limit value before oven drying.

3.1.1.6 *peat*—a soil composed primarily of vegetable tissue in various stages of decomposition usually with an organic odor, a dark brown to black color, a spongy consistency, and a texture ranging from fibrous to amorphous.

3.1.1.7 *sand*—particles of rock that will pass a No. 4

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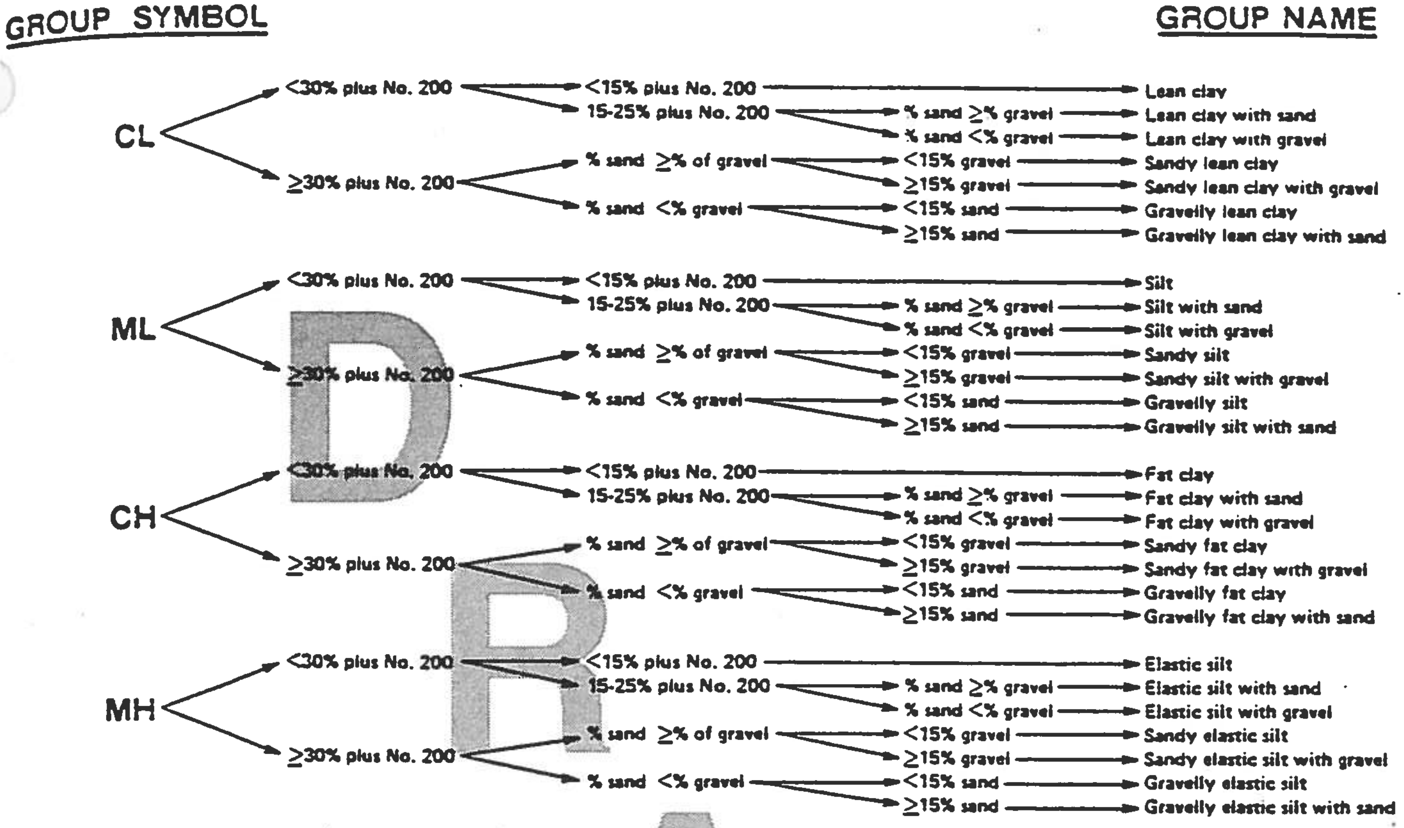
[1] This practice is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.07 on Identification and Classification of Soils.

Current edition approved Sept. 15, 1993. Published November 1993. Originally published as D 2488 – 66 T. Last previous edition D 2488 – 90.

[2] *Annual Book of ASTM Standards*, Vol 04.08.



NOTE—Percentages are based on estimating amounts of fines, sand, and gravel to the nearest 5 %.

FIG. 1a Flow Chart for Identifying Inorganic Fine-Grained Soil (50 % or more fines)

(4.75-mm) sieve and be retained on a No. 200 (75-µm) sieve with the following subdivisions:

coarse—passes a No. 4 (4.75-mm) sieve and is retained on a No. 10 (2.00-mm) sieve.

medium—passes a No. 10 (2.00-mm) sieve and is retained on a No. 40 (425-µm) sieve.

fine—passes a No. 40 (425-µm) sieve and is retained on a No. 200 (75-µm) sieve.

3.1.1.8 *silt*—soil passing a No. 200 (75-µm) sieve that is nonplastic or very slightly plastic and that exhibits little or no strength when air dry. For classification, a silt is a fine-grained soil, or the fine-grained portion of a soil, with a plasticity index less than 4, or the plot of plasticity index versus liquid limit falls below the "A" line (see Fig. 3 of Test Method D 2487).

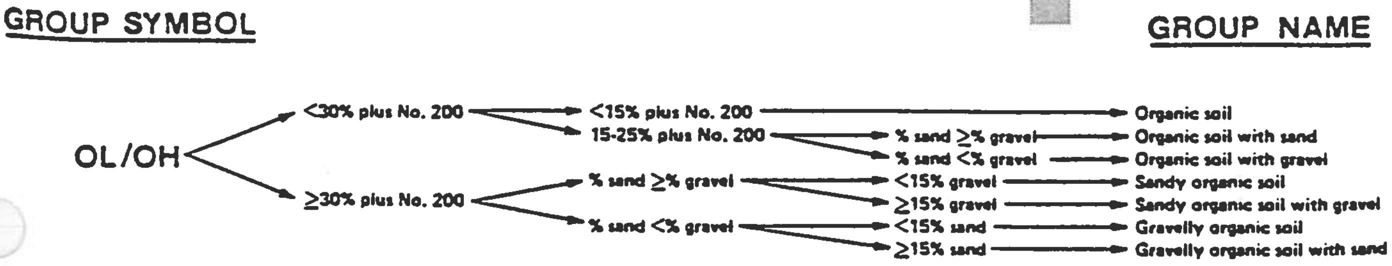
4. Summary of Practice

4.1 Using visual examination and simple manual tests, this practice gives standardized criteria and procedures for describing and identifying soils.

4.2 The soil can be given an identification by assigning a group symbol(s) and name. The flow charts, Figs. 1a and 1b for fine-grained soils, and Fig. 2, for coarse-grained soils, can be used to assign the appropriate group symbol(s) and name. If the soil has properties which do not distinctly place it into a specific group, borderline symbols may be used, see Appendix X3.

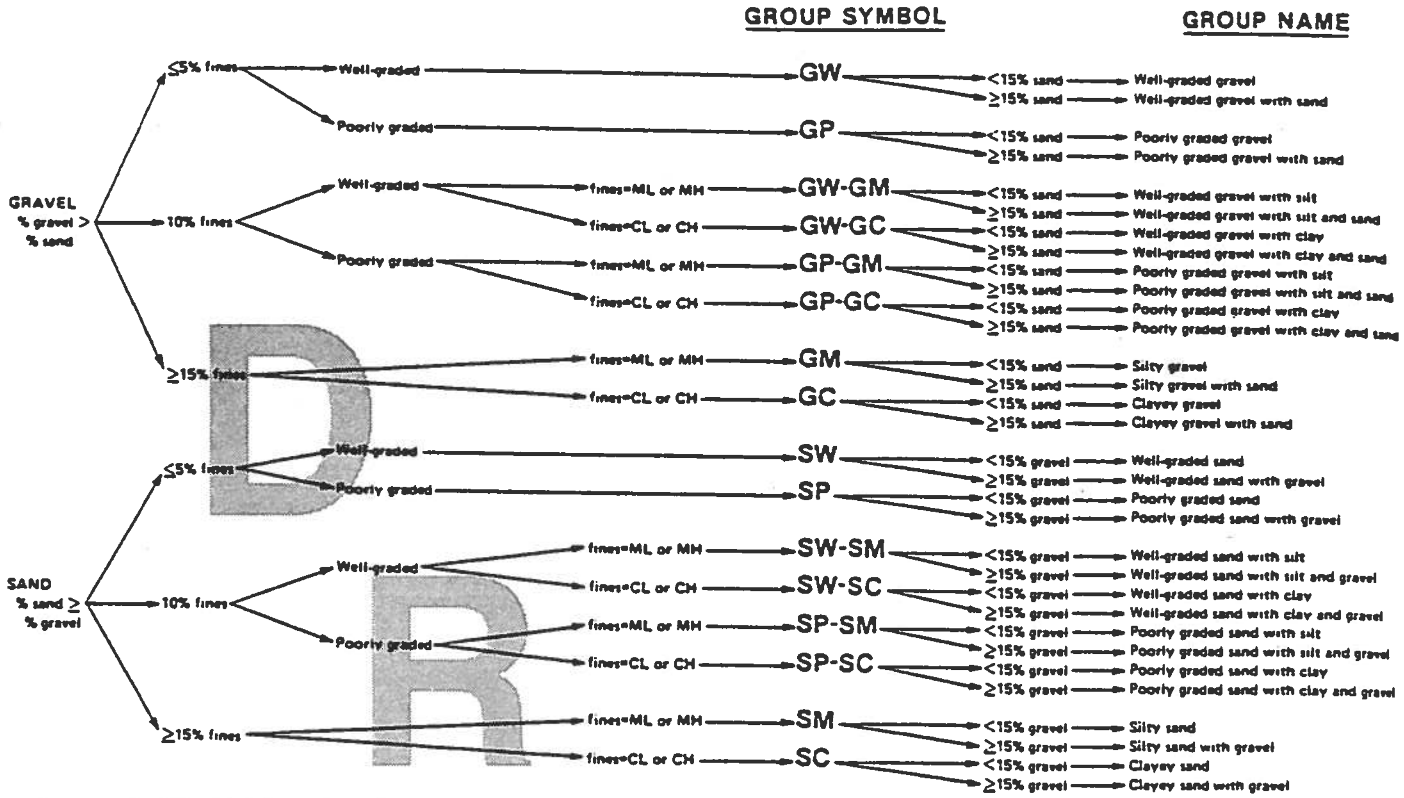
NOTE 3—It is suggested that a distinction be made between *dual symbols* and *borderline symbols.*

Dual Symbol—A dual symbol is two symbols separated by a hyphen, for example, GP-GM, SW-SC, CL-ML used to indicate that the soil has been identified as having the properties of a classification in accordance with Test Method D 2487 where two symbols are required. Two symbols are required when the soil has between 5 and 12 % fines or



NOTE—Percentages are based on estimating amounts of fines, sand, and gravel to the nearest 5 %.

FIG. 1b Flow Chart for Identifying Organic Fine-Grained Soil (50 % or more fines)



NOTE—Percentages are based on estimating amounts of fines, sand, and gravel to the nearest 5 %.

FIG. 2 Flow Chart for Identifying Coarse-Grained Soils (less than 50 % fines)

when the liquid limit and plasticity index values plot in the CL-ML area of the plasticity chart.

Borderline Symbol—A borderline symbol is two symbols separated by a slash, for example, CL/CH, GM/SM, CL/ML. A borderline symbol should be used to indicate that the soil has been identified as having properties that do not distinctly place the soil into a specific group (see Appendix X3).

5. Significance and Use

5.1 The descriptive information required in this practice can be used to describe a soil to aid in the evaluation of its significant properties for engineering use.

5.2 The descriptive information required in this practice should be used to supplement the classification of a soil as determined by Test Method D 2487.

5.3 This practice may be used in identifying soils using the classification group symbols and names as prescribed in Test Method D 2487. Since the names and symbols used in this practice to identify the soils are the same as those used in Test Method D 2487, it shall be clearly stated in reports and all other appropriate documents, that the classification symbol and name are based on visual-manual procedures.

5.4 This practice is to be used not only for identification of soils in the field, but also in the office, laboratory, or wherever soil samples are inspected and described.

5.5 This practice has particular value in grouping similar soil samples so that only a minimum number of laboratory tests need be run for positive soil classification.

NOTE 4—The ability to describe and identify soils correctly is learned more readily under the guidance of experienced personnel, but it may also be acquired systematically by comparing numerical laboratory test results for typical soils of each type with their visual and manual characteristics.

5.6 When describing and identifying soil samples from a given boring, test pit, or group of borings or pits, it is not necessary to follow all of the procedures in this practice for every sample. Soils which appear to be similar can be grouped together; one sample completely described and identified with the others referred to as similar based on performing only a few of the descriptive and identification procedures described in this practice.

5.7 This practice may be used in combination with Practice D 4083 when working with frozen soils.

6. Apparatus

6.1 *Required Apparatus:*

6.1.1 *Pocket Knife or Small Spatula.*

6.2 *Useful Auxiliary Apparatus:*

6.2.1 *Small Test Tube and Stopper* (or jar with a lid).

6.2.2 *Small Hand Lens.*

7. Reagents

7.1 *Purity of Water*—Unless otherwise indicated, references to water shall be understood to mean water from a city water supply or natural source, including non-potable water.

7.2 *Hydrochloric Acid*—A small bottle of dilute hydrochloric acid, HCl, one part HCl (10 *N*) to three parts water (This reagent is optional for use with this practice). See Section 8.

(a) Rounded (b) Angular

(c) Subrounded (d) Subangular

FIG. 3 Typical Angularity of Bulky Grains

8. Safety Precautions

8.1 When preparing the dilute HCl solution of one part concentrated hydrochloric acid (10 N) to three parts of distilled water, slowly add acid into water following necessary safety precautions. Handle with caution and store safely. If solution comes into contact with the skin, rinse thoroughly with water.

8.2 Caution—Do not add water to acid.

9. Sampling

9.1 The sample shall be considered to be representative of the stratum from which it was obtained by an appropriate, accepted, or standard procedure.

NOTE 5—Preferably, the sampling procedure should be identified as having been conducted in accordance with Practices D 1452, D 1587, or D 2113, or Method D 1586.

9.2 The sample shall be carefully identified as to origin.

NOTE 6—Remarks as to the origin may take the form of a boring number and sample number in conjunction with a job number, a geologic stratum, a pedologic horizon or a location description with respect to a permanent monument, a grid system or a station number and offset with respect to a stated centerline and a depth or elevation.

9.3 For accurate description and identification, the minimum amount of the specimen to be examined shall be in accordance with the following schedule:

Maximum Particle Size, Sieve Opening	Minimum Specimen Size, Dry Weight
4.75 mm (No. 4)	100 g (0.25 lb)
9.5 mm (⅜ in.)	200 g (0.5 lb)
19.0 mm (¾ in.)	1.0 kg (2.2 lb)
38.1 mm (1½ in.)	8.0 kg (18 lb)
75.0 mm (3 in.)	60.0 kg (132 lb)

NOTE 7—If random isolated particles are encountered that are significantly larger than the particles in the soil matrix, the soil matrix can be accurately described and identified in accordance with the preceding schedule.

9.4 If the field sample or specimen being examined is smaller than the minimum recommended amount, the report shall include an appropriate remark.

10. Descriptive Information for Soils

10.1 *Angularity*—Describe the angularity of the sand (coarse sizes only), gravel, cobbles, and boulders, as angular, subangular, subrounded, or rounded in accordance with the criteria in Table 1 and Fig. 3. A range of angularity may be stated, such as: subrounded to rounded.

10.2 *Shape*—Describe the shape of the gravel, cobbles, and boulders as flat, elongated, or flat and elongated if they meet the criteria in Table 2 and Fig. 4. Otherwise, do not mention the shape. Indicate the fraction of the particles that have the shape, such as: one-third of the gravel particles are flat.

10.3 *Color*—Describe the color. Color is an important property in identifying organic soils, and within a given

TABLE 1 Criteria for Describing Angularity of Coarse-Grained Particles (see Fig. 3)

Description	Criteria
Angular	Particles have sharp edges and relatively plane sides with unpolished surfaces
Subangular	Particles are similar to angular description but have rounded edges
Subrounded	Particles have nearly plane sides but have well-rounded corners and edges
Rounded	Particles have smoothly curved sides and no edges

TABLE 2 Criteria for Describing Particle Shape (see Fig. 4)

The particle shape shall be described as follows where length, width, and thickness refer to the greatest, intermediate, and least dimensions of a particle, respectively.

Flat	Particles with width/thickness > 3
Elongated	Particles with length/width > 3
Flat and elongated	Particles meet criteria for both flat and elongated

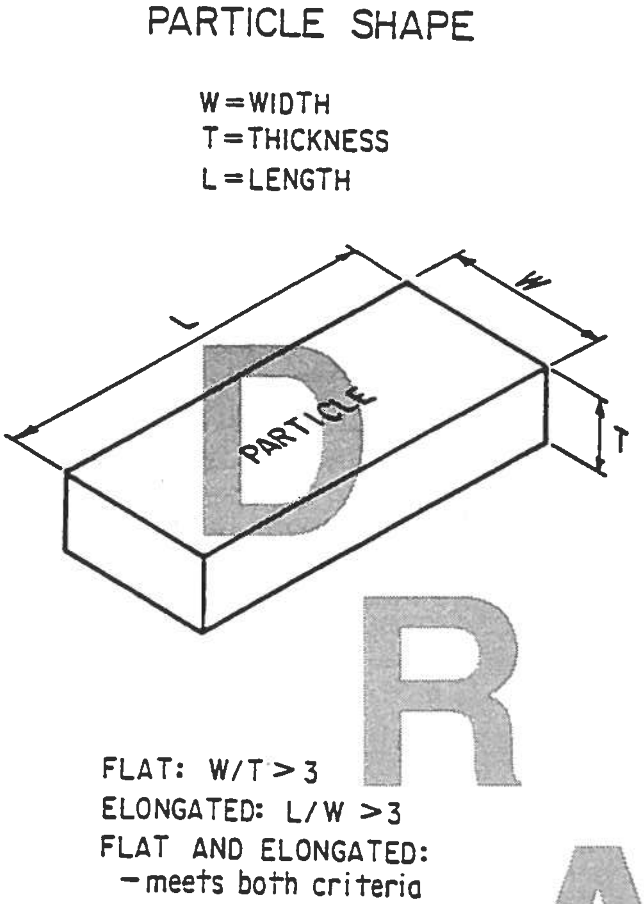


FIG. 4 Criteria for Particle Shape

TABLE 3 Criteria for Describing Moisture Condition

Description	Criteria
Dry	Absence of moisture, dusty, dry to the touch
Moist	Damp but no visible water
Wet	Visible free water, usually soil is below water table

locality it may also be useful in identifying materials of similar geologic origin. If the sample contains layers or patches of varying colors, this shall be noted and all representative colors shall be described. The color shall be described for moist samples. If the color represents a dry condition, this shall be stated in the report.

10.4 *Odor*—Describe the odor if organic or unusual. Soils containing a significant amount of organic material usually have a distinctive odor of decaying vegetation. This is especially apparent in fresh samples, but if the samples are dried, the odor may often be revived by heating a moistened sample. If the odor is unusual (petroleum product, chemical, and the like), it shall be described.

10.5 *Moisture Condition*—Describe the moisture condition as dry, moist, or wet, in accordance with the criteria in Table 3.

10.6 *HCl Reaction*—Describe the reaction with HCl as none, weak, or strong, in accordance with the critera in Table 4. Since calcium carbonate is a common cementing agent, a report of its presence on the basis of the reaction with dilute hydrochloric acid is important.

TABLE 4 Criteria for Describing the Reaction With HCl

Description	Criteria
None	No visible reaction
Weak	Some reaction, with bubbles forming slowly
Strong	Violent reaction, with bubbles forming immediately

TABLE 5 Criteria for Describing Consistency

Description	Criteria
Very soft	Thumb will penetrate soil more than 1 in. (25 mm)
Soft	Thumb will penetrate soil about 1 in. (25 mm)
Firm	Thumb will indent soil about ¼ in. (6 mm)
Hard	Thumb will not indent soil but readily indented with thumbnail
Very hard	Thumbnail will not indent soil

10.7 *Consistency*—For intact fine-grained soil, describe the consistency as very soft, soft, firm, hard, or very hard, in accordance with the criteria in Table 5. This observation is inappropriate for soils with significant amounts of gravel.

10.8 *Cementation*—Describe the cementation of intact coarse-grained soils as weak, moderate, or strong, in accordance with the criteria in Table 6.

10.9 *Structure*—Describe the structure of intact soils in accordance with the criteria in Table 7.

10.10 *Range of Particle Sizes*—For gravel and sand components, describe the range of particle sizes within each component as defined in 3.1.2 and 3.1.6. For example, about 20 % fine to coarse gravel, about 40 % fine to coarse sand.

10.11 *Maximum Particle Size*—Describe the maximum particle size found in the sample in accordance with the following information:

10.11.1 *Sand Size*—If the maximum particle size is a sand size, describe as fine, medium, or coarse as defined in 3.1.6. For example: maximum particle size, medium sand.

10.11.2 *Gravel Size*—If the maximum particle size is a gravel size, describe the maximum particle size as the smallest sieve opening that the particle will pass. For example, maximum particle size, 1½ in. (will pass a 1½-in. square opening but not a ¾-in. square opening).

10.11.3 *Cobble or Boulder Size*—If the maximum particle size is a cobble or boulder size, describe the maximum dimension of the largest particle. For example: maximum dimension, 18 in. (450 mm).

10.12 *Hardness*—Describe the hardness of coarse sand and larger particles as hard, or state what happens when the particles are hit by a hammer, for example, gravel-size particles fracture with considerable hammer blow, some gravel-size particles crumble with hammer blow. "Hard" means particles do not crack, fracture, or crumble under a hammer blow.

10.13 Additional comments shall be noted, such as the presence of roots or root holes, difficulty in drilling or augering hole, caving of trench or hole, or the presence of mica.

10.14 A local or commercial name or a geologic interpre-

TABLE 6 Criteria for Describing Cementation

Description	Criteria
Weak	Crumbles or breaks with handling or little finger pressure
Moderate	Crumbles or breaks with considerable finger pressure
Strong	Will not crumble or break with finger pressure

TABLE 7 Criteria for Describing Structure

Description	Criteria
ratified	Alternating layers of varying material or color with layers at least 6 mm thick; note thickness
Laminated	Alternating layers of varying material or color with the layers less than 6 mm thick; note thickness
Fissured	Breaks along definite planes of fracture with little resistance to fracturing
Slickensided	Fracture planes appear polished or glossy, sometimes striated
Blocky	Cohesive soil that can be broken down into small angular lumps which resist further breakdown
Lensed	Inclusion of small pockets of different soils, such as small lenses of sand scattered through a mass of clay; note thickness
Homogeneous	Same color and appearance throughout

tation of the soil, or both, may be added if identified as such.

10.15 A classification or identification of the soil in accordance with other classification systems may be added if identified as such.

11. Identification of Peat

11.1 A sample composed primarily of vegetable tissue in various stages of decomposition that has a fibrous to amorphous texture, usually a dark brown to black color, and an organic odor, shall be designated as a highly organic soil and shall be identified as peat, PT, and not subjected to the identification procedures described hereafter.

12. Preparation for Identification

12.1 The soil identification portion of this practice is ased on the portion of the soil sample that will pass a 3-in. (75-mm) sieve. The larger than 3-in. (75-mm) particles must be removed, manually, for a loose sample, or mentally, for an intact sample before classifying the soil.

12.2 Estimate and note the percentage of cobbles and the percentage of boulders. Performed visually, these estimates will be on the basis of volume percentage.

NOTE 8—Since the percentages of the particle-size distribution in Test Method D 2487 are by dry weight, and the estimates of percentages for gravel, sand, and fines in this practice are by dry weight, it is recommended that the report state that the percentages of cobbles and boulders are by volume.

12.3 Of the fraction of the soil smaller than 3 in. (75 mm), estimate and note the percentage, by dry weight, of the gravel, sand, and fines (see Appendix X4 for suggested procedures).

NOTE 9—Since the particle-size components appear visually on the basis of volume, considerable experience is required to estimate the percentages on the basis of dry weight. Frequent comparisons with laboratory particle-size analyses should be made.

12.3.1 The percentages shall be estimated to the closest 5 %. The percentages of gravel, sand, and fines must add up to 100 %.

12.3.2 If one of the components is present but not in sufficient quantity to be considered 5 % of the smaller than 3-in. (75-mm) portion, indicate its presence by the term *trace*, for example, trace of fines. A trace is not to be considered in the total of 100 % for the components.

13. Preliminary Identification

13.1 The soil is *fine grained* if it contains 50 % or more fines. Follow the procedures for identifying fine-grained soils of Section 14.

13.2 The soil is *coarse grained* if it contains less than 50 % fines. Follow the procedures for identifying coarse-grained soils of Section 15.

14. Procedure for Identifying Fine-Grained Soils

14.1 Select a representative sample of the material for examination. Remove particles larger than the No. 40 sieve (medium sand and larger) until a specimen equivalent to about a handful of material is available. Use this specimen for performing the dry strength, dilatancy, and toughness tests.

14.2 *Dry Strength:*

14.2.1 From the specimen, select enough material to mold into a ball about 1 in. (25 mm) in diameter. Mold the material until it has the consistency of putty, adding water if necessary.

14.2.2 From the molded material, make at least three test specimens. A test specimen shall be a ball of material about ½ in. (12 mm) in diameter. Allow the test specimens to dry in air, or sun, or by artificial means, as long as the temperature does not exceed 60°C.

14.2.3 If the test specimen contains natural dry lumps, those that are about ½ in. (12 mm) in diameter may be used in place of the molded balls.

NOTE 10—The process of molding and drying usually produces higher strengths than are found in natural dry lumps of soil.

14.2.4 Test the strength of the dry balls or lumps by crushing between the fingers. Note the strength as none, low, medium, high, or very high in accorance with the criteria in Table 8. If natural dry lumps are used, do not use the results of any of the lumps that are found to contain particles of coarse sand.

14.2.5 The presence of high-strength water-soluble cementing materials, such as calcium carbonate, may cause exceptionally high dry strengths. The presence of calcium carbonate can usually be detected from the intensity of the reaction with dilute hydrochloric acid (see 10.6).

14.3 *Dilatancy:*

14.3.1 From the specimen, select enough material to mold into a ball about ½ in. (12 mm) in diameter. Mold the material, adding water if necessary, until it has a soft, but not sticky, consistency.

14.3.2 Smooth the soil ball in the palm of one hand with the blade of a knife or small spatula. Shake horizontally, striking the side of the hand vigorously against the other hand several times. Note the reaction of water appearing on

TABLE 8 Criteria for Describing Dry Strength

Description	Criteria
None	The dry specimen crumbles into powder with mere pressure of handling
Low	The dry specimen crumbles into powder with some finger pressure
Medium	The dry specimen breaks into pieces or crumbles with considerable finger pressure
High	The dry specimen cannot be broken with finger pressure. Specimen will break into pieces between thumb and a hard surface
Very high	The dry specimen cannot be broken between the thumb and a hard surface

TABLE 9 Criteria for Describing Dilatancy

Description	Criteria
None	No visible change in the specimen
Slow	Water appears slowly on the surface of the specimen during shaking and does not disappear or disappears slowly upon squeezing
Rapid	Water appears quickly on the surface of the specimen during shaking and disappears quickly upon squeezing

TABLE 10 Criteria for Describing Toughness

Description	Criteria
Low	Only slight pressure is required to roll the thread near the plastic limit. The thread and the lump are weak and soft
Medium	Medium pressure is required to roll the thread to near the plastic limit. The thread and the lump have medium stiffness
High	Considerable pressure is required to roll the thread to near the plastic limit. The thread and the lump have very high stiffness

the surface of the soil. Squeeze the sample by closing the hand or pinching the soil between the fingers, and note the reaction as none, slow, or rapid in accordance with the criteria in Table 9. The reaction is the speed with which water appears while shaking, and disappears while squeezing.

14.4 *Toughness:*

14.4.1 Following the completion of the dilatancy test, the test specimen is shaped into an elongated pat and rolled by hand on a smooth surface or between the palms into a thread about ⅛ in. (3 mm) in diameter. (If the sample is too wet to roll easily, it should be spread into a thin layer and allowed to lose some water by evaporation.) Fold the sample threads and reroll repeatedly until the thread crumbles at a diameter of about ⅛ in. The thread will crumble at a diameter of ⅛ in. when the soil is near the plastic limit. Note the pressure required to roll the thread near the plastic limit. Also, note the strength of the thread. After the thread crumbles, the pieces should be lumped together and kneaded until the lump crumbles. Note the toughness of the material during kneading.

14.4.2 Describe the toughness of the thread and lump as low, medium, or high in accordance with the criteria in Table 10.

14.5 *Plasticity*—On the basis of observations made during the toughness test, describe the plasticity of the material in accordance with the criteria given in Table 11.

14.6 Decide whether the soil is an *inorganic* or an *organic* fine-grained soil (see 14.8). If inorganic, follow the steps given in 14.7.

14.7 *Identification of Inorganic Fine-Grained Soils:*

TABLE 11 Criteria for Describing Plasticity

Description	Criteria
Nonplastic	A ⅛-in. (3-mm) thread cannot be rolled at any water content
Low	The thread can barely be rolled and the lump cannot be formed when drier than the plastic limit
Medium	The thread is easy to roll and not much time is required to reach the plastic limit. The thread cannot be rerolled after reaching the plastic limit. The lump crumbles when drier than the plastic limit
High	It takes considerable time rolling and kneading to reach the plastic limit. The thread can be rerolled several times after reaching the plastic limit. The lump can be formed without crumbling when drier than the plastic limit

14.7.1 Identify the soil as a *lean clay*, CL, if the soil has medium to high dry strength, no or slow dilatancy, and medium toughness and plasticity (see Table 12).

14.7.2 Identify the soil as a *fat clay*, CH, if the soil has high to very high dry strength, no dilatancy, and high toughness and plasticity (see Table 12).

14.7.3 Identify the soil as a *silt*, ML, if the soil has no to low dry strength, slow to rapid dilatancy, and low toughness and plasticity, or is nonplastic (see Table 12).

14.7.4 Identify the soil as an *elastic silt*, MH, if the soil has low to medium dry strength, no to slow dilatancy, and low to medium toughness and plasticity (see Table 12).

NOTE 11—These properties are similar to those for a lean clay. However, the silt will dry quickly on the hand and have a smooth, silky feel when dry. Some soils that would classify as MH in accordance with the criteria in Test Method D 2487 are visually difficult to distinguish from lean clays, CL. It may be necessary to perform laboratory testing for proper identification.

14.8 *Identification of Organic Fine-Grained Soils:*

14.8.1 Identify the soil as an *organic soil*, OL/OH, if the soil contains enough organic particles to influence the soil properties. Organic soils usually have a dark brown to black color and may have an organic odor. Often, organic soils will change color, for example, black to brown, when exposed to the air. Some organic soils will lighten in color significantly when air dried. Organic soils normally will not have a high toughness or plasticity. The thread for the toughness test will be spongy.

NOTE 12—In some cases, through practice and experience, it may be possible to further identify the organic soils as organic silts or organic clays, OL or OH. Correlations between the dilatancy, dry strength, toughness tests, and laboratory tests can be made to identify organic soils in certain deposits of similar materials of known geologic origin.

14.9 If the soil is estimated to have 15 to 25 % sand or gravel, or both, the words "with sand" or "with gravel" (whichever is more predominant) shall be added to the group name. For example: "lean clay with sand, CL" or "silt with gravel, ML" (see Figs. 1a and 1b). If the percentage of sand is equal to the percentage of gravel, use "with sand."

14.10 If the soil is estimated to have 30 % or more sand or gravel, or both, the words "sandy" or "gravelly" shall be added to the group name. Add the word "sandy" if there appears to be more sand than gravel. Add the word "gravelly" if there appears to be more gravel than sand. For example: "sandy lean clay, CL", "gravelly fat clay, CH", or "sandy silt, ML" (see Figs. 1a and 1b). If the percentage of sand is equal to the percent of gravel, use "sandy."

15. Procedure for Identifying Coarse-Grained Soils (Contains less than 50 % fines)

15.1 The soil is a *gravel* if the percentage of gravel is estimated to be more than the percentage of sand.

TABLE 12 Identification of Inorganic Fine-Grained Soils from Manual Tests

Soil Symbol	Dry Strength	Dilatancy	Toughness
ML	None to low	Slow to rapid	Low or thread cannot be formed
CL	Medium to high	None to slow	Medium
MH	Low to medium	None to slow	Low to medium
CH	High to very high	None	High

15.2 The soil is a *sand* if the percentage of gravel is estimated to be equal to or less than the percentage of sand.

The soil is a *clean gravel* or *clean sand* if the percentage of fines is estimated to be 5 % or less.

15.3.1 Identify the soil as a *well-graded gravel*, GW, or as a *well-graded sand*, SW, if it has a wide range of particle sizes and substantial amounts of the intermediate particle sizes.

15.3.2 Identify the soil as a *poorly graded gravel*, GP, or as a *poorly graded sand*, SP, if it consists predominantly of one size (uniformly graded), or it has a wide range of sizes with some intermediate sizes obviously missing (gap or skip graded).

15.4 The soil is either a *gravel with fines* or a *sand with fines* if the percentage of fines is estimated to be 15 % or more.

15.4.1 Identify the soil as a *clayey gravel*, GC, or a *clayey sand*, SC, if the fines are clayey as determined by the procedures in Section 14.

15.4.2 Identify the soil as a *silty gravel*, GM, or a *silty sand*, SM, if the fines are silty as determined by the procedures in Section 14.

15.5 If the soil is estimated to contain 10 % fines, give the soil a dual identification using two group symbols.

15.5.1 The first group symbol shall correspond to a clean gravel or sand (GW, GP, SW, SP) and the second symbol shall correspond to a gravel or sand with fines (GC, GM, SC, SM).

15.5.2 The group name shall correspond to the first group symbol plus the words "with clay" or "with silt" to indicate the plasticity characteristics of the fines. For example: "graded gravel with clay, GW-GC" or "poorly graded with silt, SP-SM" (see Fig. 2).

15.6 If the specimen is predominantly sand or gravel but contains an estimated 15 % or more of the other coarse-grained constituent, the words "with gravel" or "with sand" shall be added to the group name. For example: "poorly graded gravel with sand, GP" or "clayey sand with gravel, SC" (see Fig. 2).

15.7 If the field sample contains any cobbles or boulders, or both, the words "with cobbles" or "with cobbles and boulders" shall be added to the group name. For example: "silty gravel with cobbles, GM."

16. Report

16.1 The report shall include the information as to origin, and the items indicated in Table 13.

NOTE 13—*Example: Clayey Gravel with Sand and Cobbles, GC*—About 50 % fine to coarse, subrounded to subangular gravel; about 30 % fine to coarse, subrounded sand; about 20 % fines with medium plasticity, high dry strength, no dilatancy, medium toughness; weak reaction with HCl; original field sample had about 5 % (by volume) subrounded cobbles, maximum dimension, 150 mm.

In-Place Conditions—Firm, homogeneous, dry, brown

Geologic Interpretation—Alluvial fan

NOTE 14—Other examples of soil descriptions and identification are given in Appendixes X1 and X2.

NOTE 15—If desired, the percentages of gravel, sand, and fines may be stated in terms indicating a range of percentages, as follows:

Trace—Particles are present but estimated to be less than 5 %
Few—5 to 10 %
Little—15 to 25 %
Some—30 to 45 %
Mostly—50 to 100 %

16.2 If, in the soil description, the soil is identified using a classification group symbol and name as described in Test Method D 2487, it must be distinctly and clearly stated in log forms, summary tables, reports, and the like, that the symbol and name are based on visual-manual procedures.

17. Precision and Bias

17.1 This practice provides qualitative information only, therefore, a precision and bias statement is not applicable.

18. Keywords

18.1 classification; clay; gravel; organic soils; sand; silt; soil classification; soil description; visual classification

TABLE 13 Checklist for Description of Soils

1. Group name
2. Group symbol
3. Percent of cobbles or boulders, or both (by volume)
4. Percent of gravel, sand, or fines, or all three (by dry weight)
5. Particle-size range:
   Gravel—fine, coarse
   Sand—fine, medium, coarse
6. Particle angularity: angular, subangular, subrounded, rounded
7. Particle shape: (if appropriate) flat, elongated, flat and elongated
8. Maximum particle size or dimension
9. Hardness of coarse sand and larger particles
10. Plasticity of fines: nonplastic, low, medium, high
11. Dry strength: none, low, medium, high, very high
12. Dilatancy: none, slow, rapid
13. Toughness: low, medium, high
14. Color (in moist condition)
15. Odor (mention only if organic or unusual)
16. Moisture: dry, moist, wet
17. Reaction with HCl: none, weak, strong

For intact samples:

18. Consistency (fine-grained soils only): very soft, soft, firm, hard, very hard
19. Structure: stratified, laminated, fissured, slickensided, lensed, homogeneous
20. Cementation: weak, moderate, strong
21. Local name
22. Geologic interpretation
23. Additional comments: presence of roots or root holes, presence of mica, gypsum, etc., surface coatings on coarse-grained particles, caving or sloughing of auger hole or trench sides, difficulty in augering or excavating, etc.

APPENDIXES

(Nonmandatory Information)

X1. EXAMPLES OF VISUAL SOIL DESCRIPTIONS

X1.1 The following examples show how the information required in 16.1 can be reported. The information that is included in descriptions should be based on individual circumstances and need.

X1.1.1 *Well-Graded Gravel with Sand (GW)*—About 75 % fine to coarse, hard, subangular gravel; about 25 % fine to coarse, hard, subangular sand; trace of fines; maximum size, 75 mm, brown, dry; no reaction with HCl.

X1.1.2 *Silty Sand with Gravel (SM)*—About 60 % predominantly fine sand; about 25 % silty fines with low plasticity, low dry strength, rapid dilatancy, and low toughness; about 15 % fine, hard, subrounded gravel, a few gravel-size particles fractured with hammer blow; maximum size, 25 mm; no reaction with HCl (Note—Field sample size smaller than recommended).

In-Place Conditions—Firm, stratified and contains lenses of silt 1 to 2 in. (25 to 50 mm) thick, moist, brown to gray; in-place density 106 lb/ft^3; in-place moisture 9 %.

X1.1.3 *Organic Soil (OL/OH)*—About 100 % fines with low plasticity, slow dilatancy, low dry strength, and low toughness; wet, dark brown, organic odor; weak reaction with HCl.

X1.1.4 *Silty Sand with Organic Fines (SM)*—About 75 % fine to coarse, hard, subangular reddish sand; about 25 % organic and silty dark brown nonplastic fines with no dry strength and slow dilatancy; wet; maximum size, coarse sand; weak reaction with HCl.

X1.1.5 *Poorly Graded Gravel with Silt, Sand, Cobbles and Boulders (GP-GM)*—About 75 % fine to coarse, hard, subrounded to subangular gravel; about 15 % fine, hard, subrounded to subangular sand; about 10 % silty nonplastic fines; moist, brown; no reaction with HCl; original field sample had about 5 % (by volume) hard, subrounded cobbles and a trace of hard, subrounded boulders, with a maximum dimension of 18 in. (450 mm).

X2. USING THE IDENTIFICATION PROCEDURE AS A DESCRIPTIVE SYSTEM FOR SHALE, CLAYSTONE, SHELLS, SLAG, CRUSHED ROCK, AND THE LIKE

X2.1 The identification procedure may be used as a descriptive system applied to materials that exist in-situ as shale, claystone, sandstone, siltstone, mudstone, etc., but convert to soils after field or laboratory processing (crushing, slaking, and the like).

X2.2 Materials such as shells, crushed rock, slag, and the like, should be identified as such. However, the procedures used in this practice for describing the particle size and plasticity characteristics may be used in the description of the material. If desired, an identification using a group name and symbol according to this practice may be assigned to aid in describing the material.

X2.3 The group symbol(s) and group names should be placed in quotation marks or noted with some type of distinguishing symbol. See examples.

X2.4 Examples of how group names and symbols can be incororated into a descriptive system for materials that are not naturally occurring soils are as follows:

X2.4.1 *Shale Chunks*—Retrieved as 2 to 4-in. (50 to 100-mm) pieces of shale from power auger hole, dry, brown, no reaction with HCl. After slaking in water for 24 h, material identified as "Sandy Lean Clay (CL)"; about 60 % fines with medium plasticity, high dry strength, no dilatancy, and medium toughness; about 35 % fine to medium, hard sand; about 5 % gravel-size pieces of shale.

X2.4.2 *Crushed Sandstone*—Product of commercial crushing operation; "Poorly Graded Sand with Silt (SP-SM)"; about 90 % fine to medium sand; about 10 % nonplastic fines; dry, reddish-brown, strong reaction with HCl.

X2.4.3 *Broken Shells*—About 60 % gravel-size broken shells; about 30 % sand and sand-size shell pieces; about 10 % fines; "Poorly Graded Gravel with Sand (GP)."

X2.4.4 *Crushed Rock*—Processed from gravel and cobbles in Pit No. 7; "Poorly Graded Gravel (GP)"; about 90 % fine, hard, angular gravel-size particles; about 10 % coarse, hard, angular sand-size particles; dry, tan; no reaction with HCl.

X3. SUGGESTED PROCEDURE FOR USING A BORDERLINE SYMBOL FOR SOILS WITH TWO POSSIBLE IDENTIFICATIONS.

X3.1 Since this practice is based on estimates of particle size distribution and plasticity characteristics, it may be difficult to clearly identify the soil as belonging to one category. To indicate that the soil may fall into one of two possible basic groups, a borderline symbol may be used with the two symbols separated by a slash. For example: SC/CL or CL/CH.

X3.1.1 A borderline symbol may be used when the ercentage of fines is estimated to be between 45 and 55 %. e symbol should be for a coarse-grained soil with fines d the other for a fine-grained soil. For example: GM/ML or CL/SC.

X3.1.2 A borderline symbol may be used when the percentage of sand and the percentage of gravel are estimated to be about the same. For example: GP/SP, SC/GC, GM/SM. It is practically impossible to have a soil that would have a borderline symbol of GW/SW.

X3.1.3 A borderline symbol may be used when the soil could be either well graded or poorly graded. For example: GW/GP, SW/SP.

X3.1.4 A borderline symbol may be used when the soil could either be a silt or a clay. For example: CL/ML, CH/MH, SC/SM.

X3.1.5 A borderline symbol may be used when a fine-grained soil has properties that indicate that it is at the boundary between a soil of low compressibility and a soil of high compressibility. For example: CL/CH, MH/ML.

X3.2 The order of the borderline symbols should reflect similarity to surrounding or adjacent soils. For example: soils in a borrow area have been identified as CH. One sample is considered to have a borderline symbol of CL and CH. To show similarity, the borderline symbol should be CH/CL.

X3.3 The group name for a soil with a borderline symbol should be the group name for the first symbol, except for:

CL/CH lean to fat clay
ML/CL clayey silt
CL/ML silty clay

X3.4 The use of a borderline symbol should not be used indiscriminately. Every effort shall be made to first place the soil into a single group.

X4. SUGGESTED PROCEDURES FOR ESTIMATING THE PERCENTAGES OF GRAVEL, SAND, AND FINES IN A SOIL SAMPLE

X4.1 *Jar Method*—The relative percentage of coarse- and fine-grained material may be estimated by thoroughly shaking a mixture of soil and water in a test tube or jar, and then allowing the mixture to settle. The coarse particles will fall to the bottom and successively finer particles will be deposited with increasing time; the sand sizes will fall out of suspension in 20 to 30 s. The relative proportions can be imated from the relative volume of each size separate. is method should be correlated to particle-size laboratory determinations.

X4.2 *Visual Method*—Mentally visualize the gravel size particles placed in a sack (or other container) or sacks. Then, do the same with the sand size particles and the fines. Then, mentally compare the number of sacks to estimate the percentage of plus No. 4 sieve size and minus No. 4 sieve size present. The percentages of sand and fines in the minus sieve size No. 4 material can then be estimated from the wash test (X4.3).

X4.3 *Wash Test (for relative percentages of sand and fines)*—Select and moisten enough minus No. 4 sieve size material to form a 1-in (25-mm) cube of soil. Cut the cube in half, set one-half to the side, and place the other half in a small dish. Wash and decant the fines out of the material in the dish until the wash water is clear and then compare the two samples and estimate the percentage of sand and fines. Remember that the percentage is based on weight, not volume. However, the volume comparison will provide a reasonable indication of grain size percentages.

X4.3.1 While washing, it may be necessary to break down lumps of fines with the finger to get the correct percentages.

X5. ABBREVIATED SOIL CLASSIFICATION SYMBOLS

X5.1 In some cases, because of lack of space, an abbreviated system may be useful to indicate the soil classification symbol and name. Examples of such cases would be graphical logs, databases, tables, etc.

X5.2 This abbreviated system is not a substitute for the full name and descriptive information but can be used in supplementary presentations when the complete description is referenced.

X5.3 The abbreviated system should consist of the soil classification symbol based on this standard with appropriate lower case letter prefixes and suffixes as:

Prefix:	Suffix:
s = sandy	s = with sand
g = gravelly	g = with gravel
	c = with cobbles
	b = with boulders

X5.4 The soil classification symbol is to be enclosed in parenthesis. Some examples would be:

Group Symbol and Full Name	Abbreviated
CL, Sandy lean clay	s(CL)
SP-SM, Poorly graded sand with silt and gravel	(SP-SM)g
GP, poorly graded gravel with sand, cobbles, and boulders	(GP)scb
ML, gravelly silt with sand and cobbles	g(ML)sc

X6. RATIONALE

Changes in this version from the previous version, D 2488 – 90, include the addition of X5 on Abbreviated Soil Classification Symbols.

APPENDIX B

WENTWORTH GRAIN-SIZE SCALE

Wentworth Grain-Size Scale

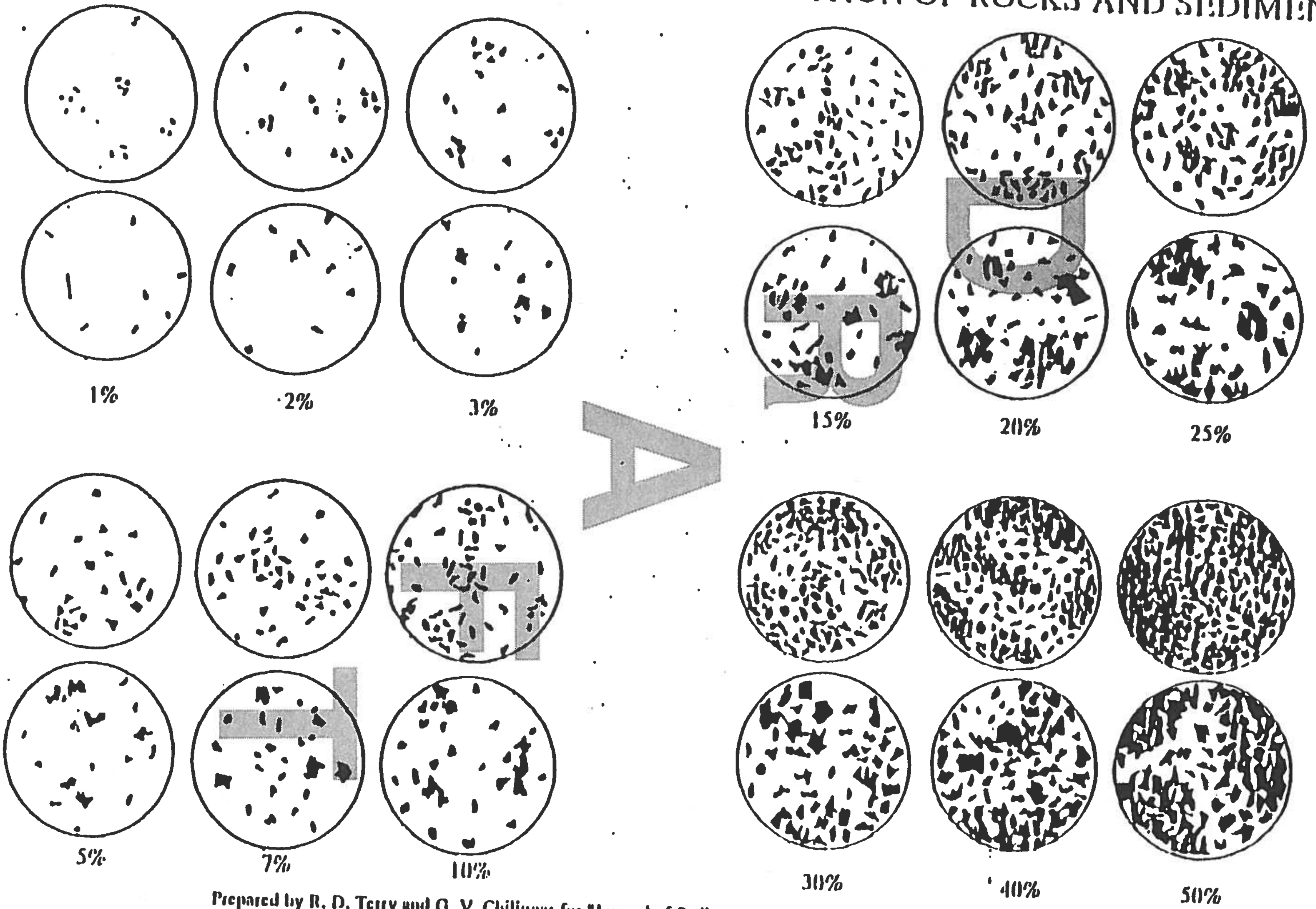
The Wentworth grade scale, which originated in 1922, is most commonly used for sediments and sedimentary rocks. It is a logarithmic scale in that each grade limit is twice as large as the next smaller grade limit. The table below presents the Wentworth size classes along with the U. S. sieve mesh sizes, and the Phi Scale.

U. S. Standard Sieve Mesh #		Millimeters (10^{-3}m)	Microns (10^{-6}m)	Phi	Wentworth Size Class	
		4096		-12		GRAVEL
		1024		-10	Boulder (-8 to -12φ)	
Use		256		- 8		
wire		64		-6	Cobble (-6 to -8φ)	
squares		16		-4	Pebble (-2 to -6φ)	
5		4		-2		
6		3.36		-1.75		
7		2.83		-1.5	Granule	
8		2.38		-1.25		
10		2.00		-1.0		
12		1.68		-0.75		SAND
14		1.41		-0.5	Very coarse sand	
16		1.19		-0.25		
18		1.00		0.0		
20		0.84		0.25		
25		0.71		0.5	Coarse sand	
30		0.59		0.75		
35	1/2	0.50	500	1.0		
40		0.42	420	1.25		
45		0.35	350	1.5	Medium sand	
50		0.30	300	1.75		
60	1/4	0.25	250	2.0		
70		0.210	210	2.25		
80		0.177	177	2.5	Fine sand	
100		0.149	149	2.75		
120	1/8	0.125	125	3.0		
140		0.105	105	3.25		
170		0.088	88	3.5	Very fine sand	
200		0.074	74	3.75		
230	1/16	0.0625	62.5	4.0		
270		0.053	53	4.25		MUD
325		0.044	44	4.5	Coarse silt	
		0.037	37	4.75		
	1/32	0.031	31	5.0		
	1/64	0.0156	15.6	6.0	Medium silt	
Analyzed	1/128	0.0078	7.8	7.0	Fine silt	
by	1/256	0.0039	3.9	8.0	Very fine silt	
		0.0020	2.0	9.0		
Pipette		0.00098	0.98	10.0	Clay	
		0.00049	0.49	11.0		
or		0.00024	0.24	12.0		
		0.00012	0.12	13.0		
Hydrometer		0.00006	0.06	14.0		

APPENDIX C

CHARTS FOR ESTIMATING PERCENTAGE COMPOSITION OF ROCKS AND SEDIMENT

CI TS FOR ESTIMATING PERCENTAGE COMPOSITION OF ROCKS AND SEDIMENT



Prepared by R. D. Terry and G. V. Chilingar for "Journal of Sedimentary Petrology" (v. 25, pp. 229-234, 1955); reprinted as 'Data Sheet 6' of "Geotimes" available from the American Geological Institute, 2101 Constitution Ave., N.W., Washington, D. C. Reprinted here by permission of the authors and the Society of Economic Paleontologists and Mineralologists. Taken from Compton, 1962.

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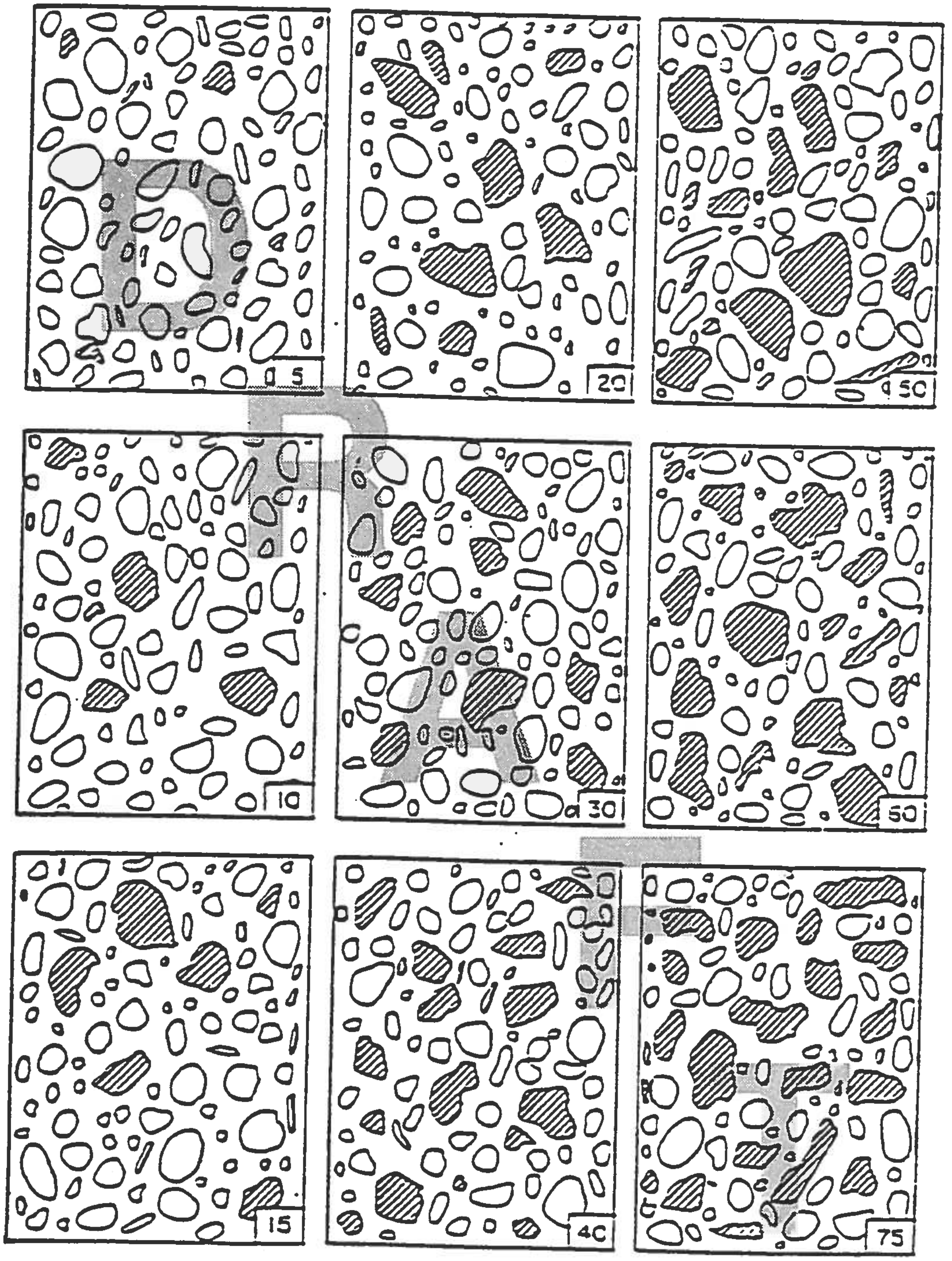
APPENDIX D

CHART FOR ESTIMATING PERCENTAGE OF A GIVEN ROCK TYPE IN A TRAY OF CUTTINGS

CHART FOR ESTIMATING PERCENTAGE OF A GIVEN ROCK TYPE IN A TRAY OF CUTTINGS



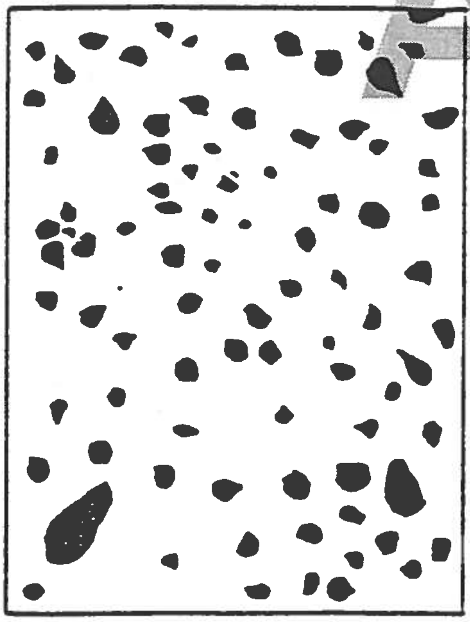
APPENDIX E

CHARTS FOR ESTIMATING PARTICLE PERCENTAGES

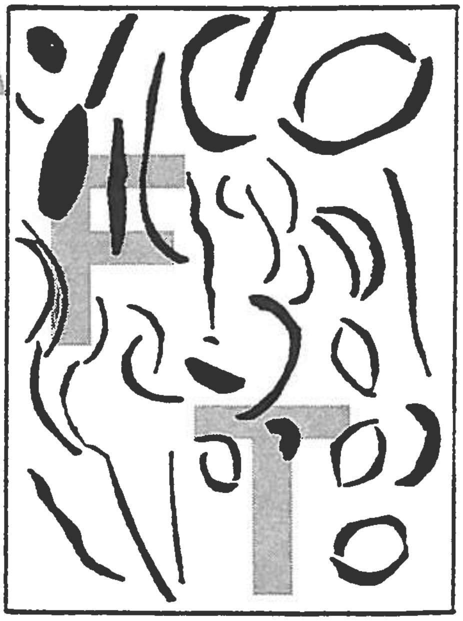
CHART FOR ESTIMATING PARTICLE PERCENTAGES

Chart I

11%



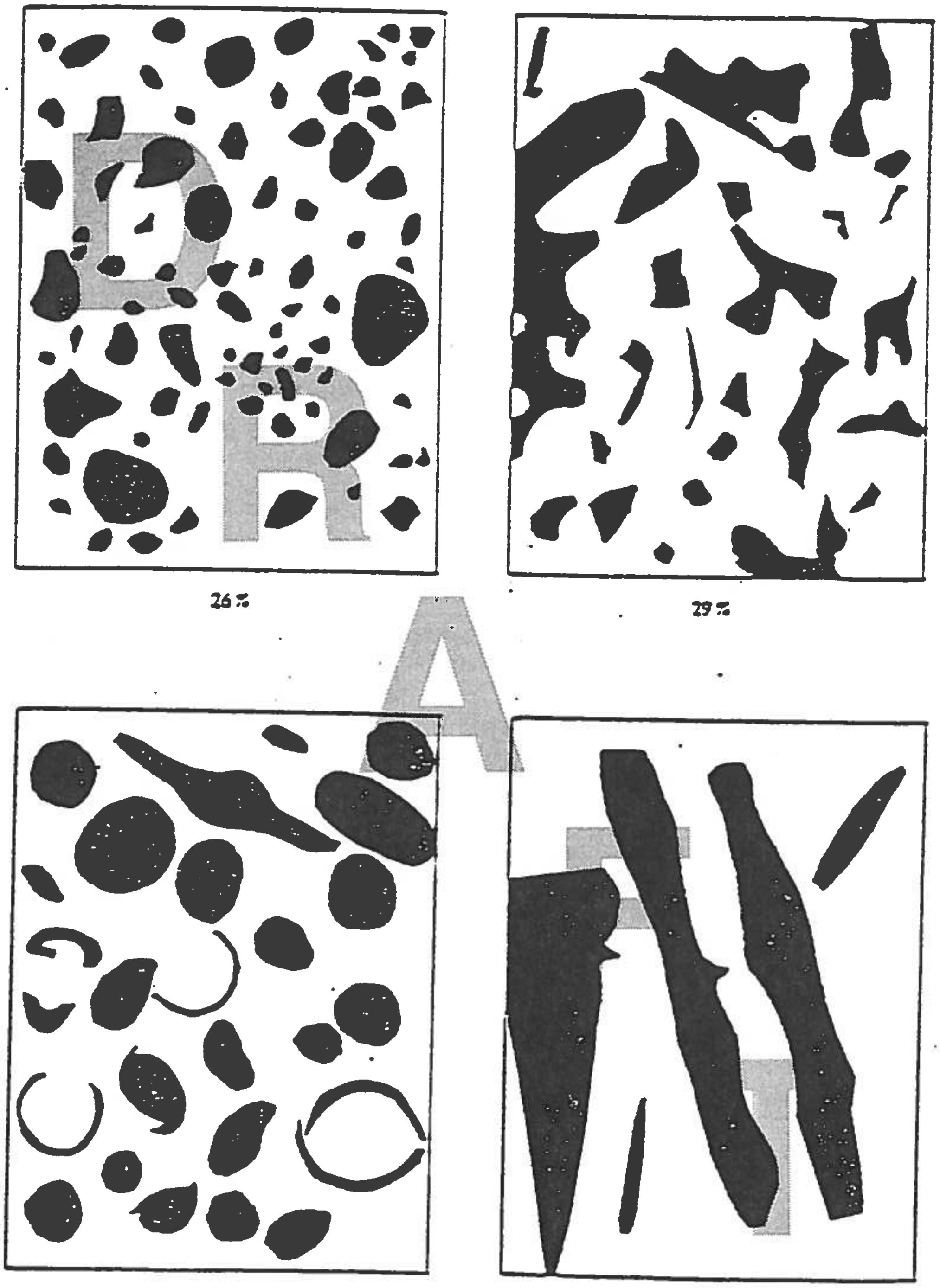
13%



18%

CHART FOR ESTIMATING PARTICLE PERCENTAGES

Chart II



26 %

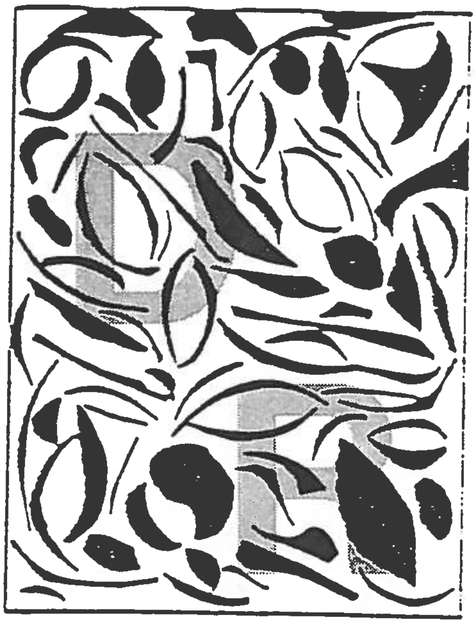
29 %

34 %

36 %

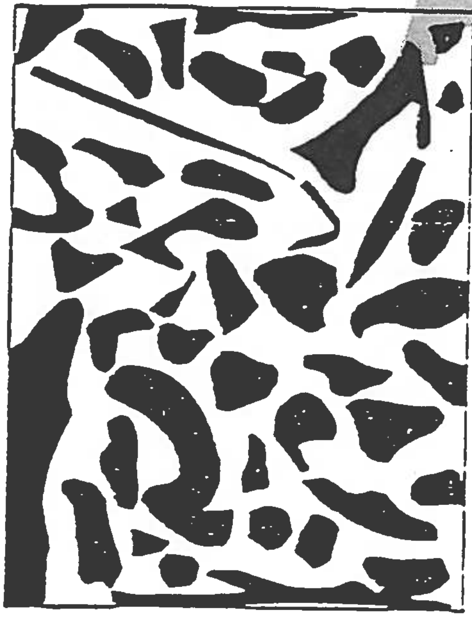
CHART FOR ESTIMATING PARTICLE PERCENTAGES

Chart III

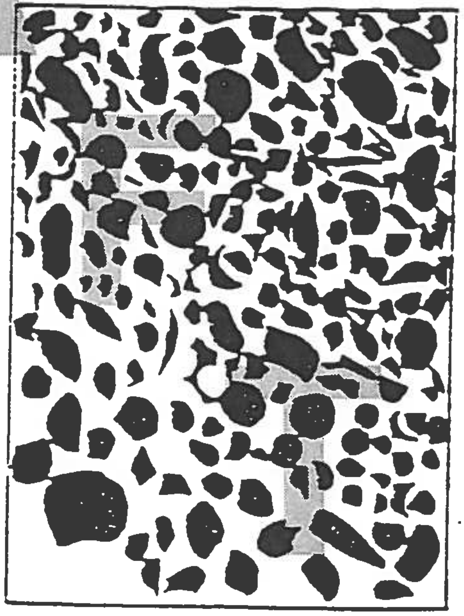


40 %

40 %



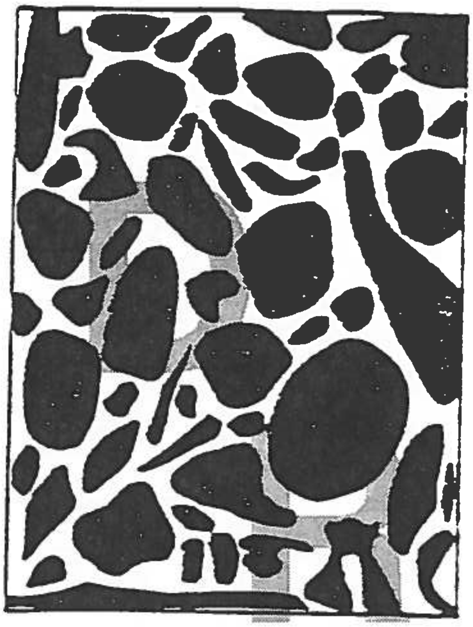
50 %



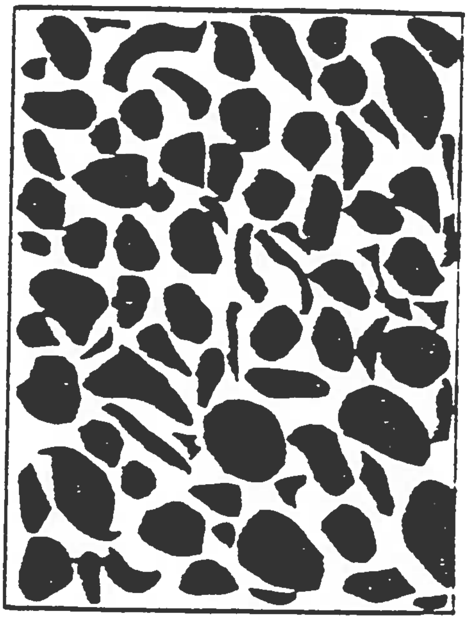
56 %

CHART FOR ESTIMATING PARTICLE PERCENTAGES

Chart IV



60 %



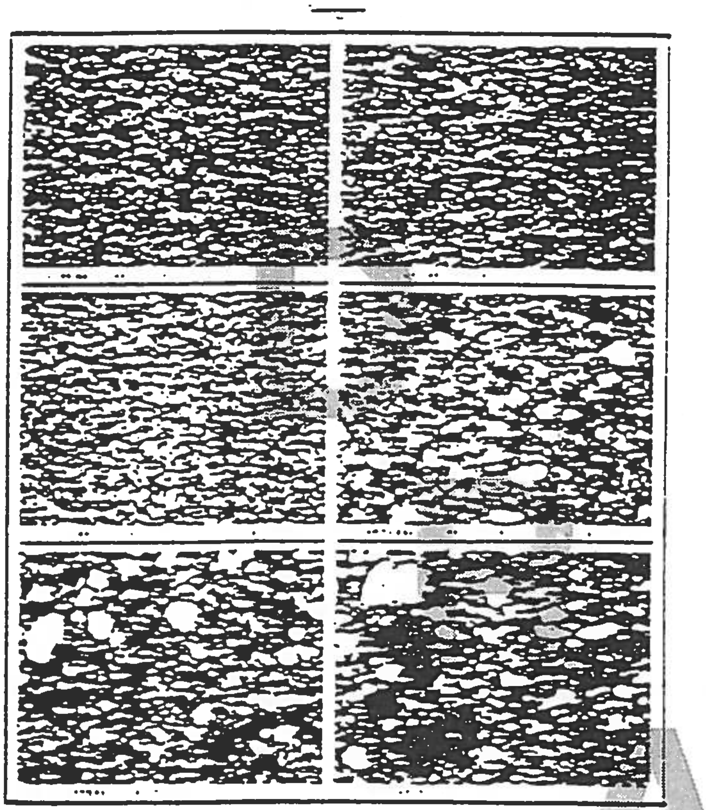
69 %

APPENDIX F

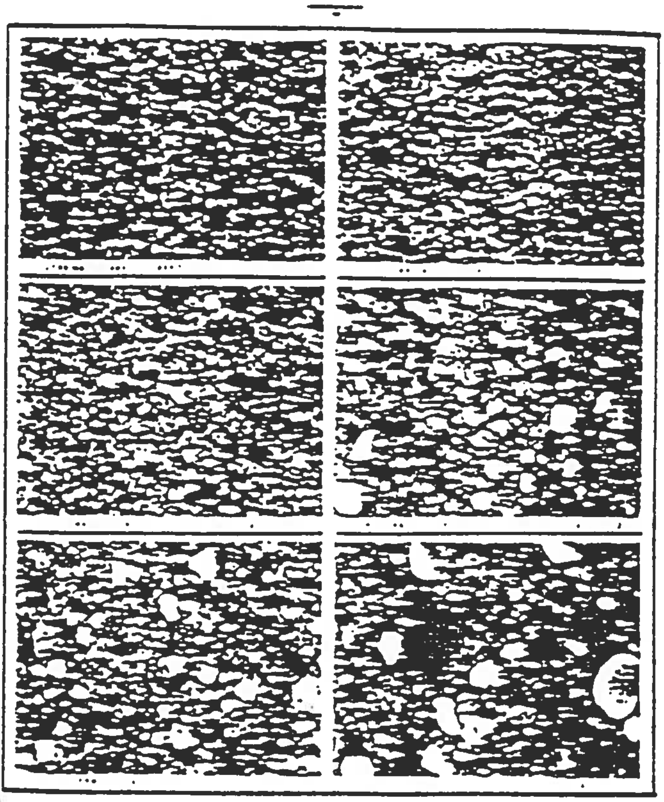
GRAIN SIZE AND SORTING COMPARATORS

Grain Size and Sorting Comparators (Photomicrographs of Thin Sections)

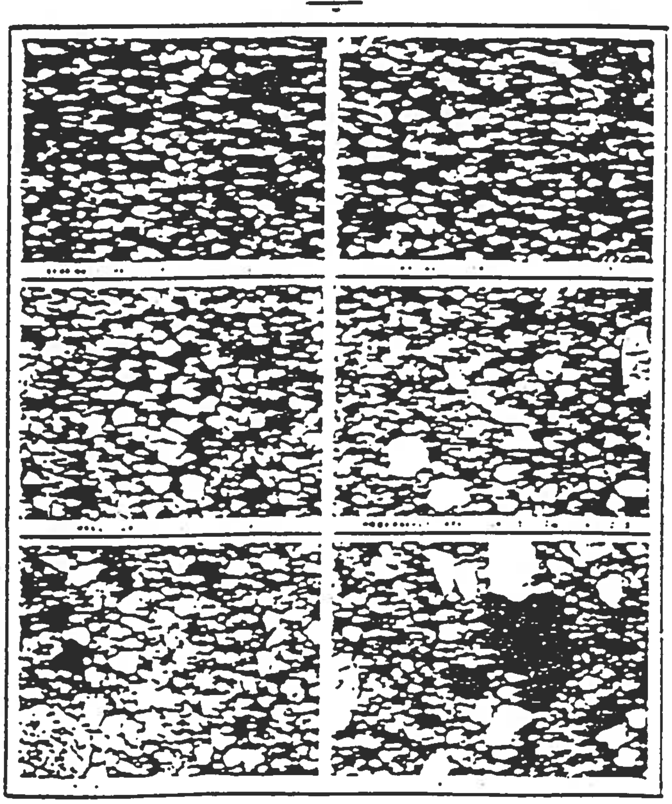
Lower Very Fine Grain Size
Median Diameter 0.074 mm



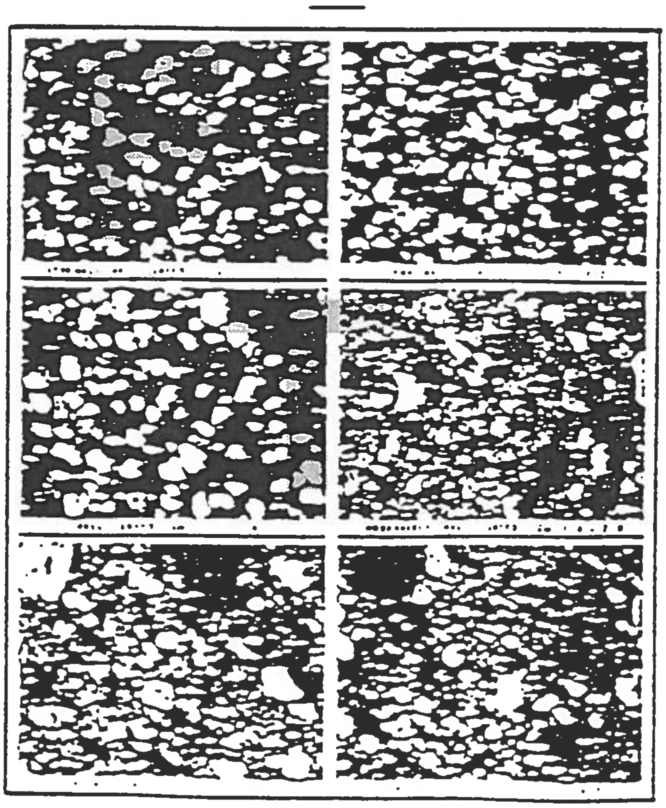
Upper Very Fine Grain Size
Median Diameter 0.105 mm



Lower Fine Grain Size
Median Diameter 0.149 mm



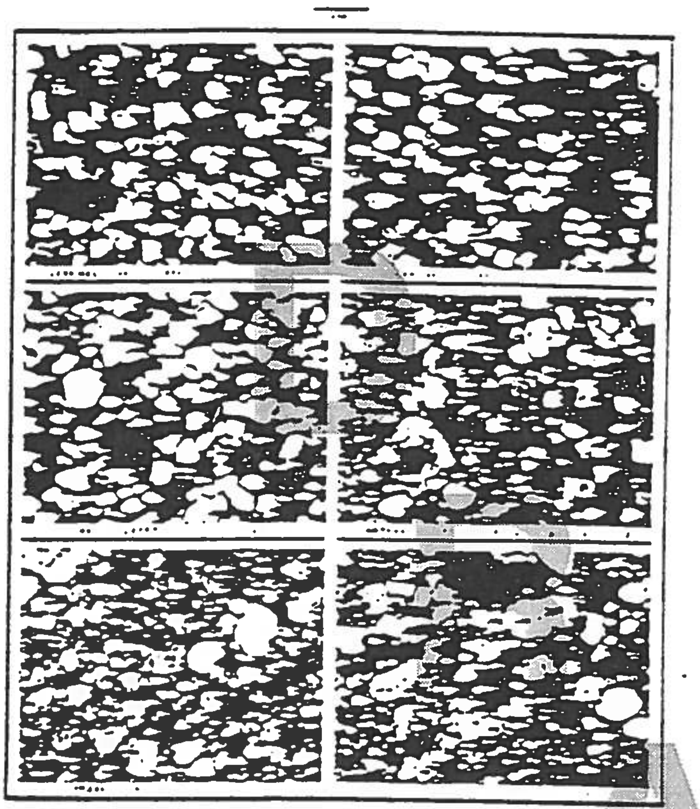
Upper Fine Grain Size
Median Diameter 0.210 mm



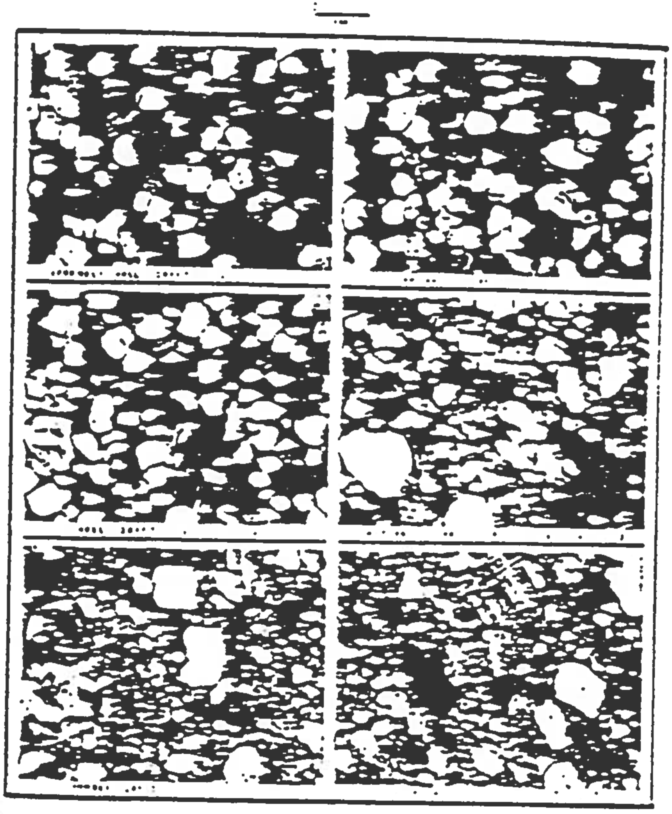
(from Beard and Weyl)

Grain Size and Sorting Comparators (Photomicrographs of Thin Sections)

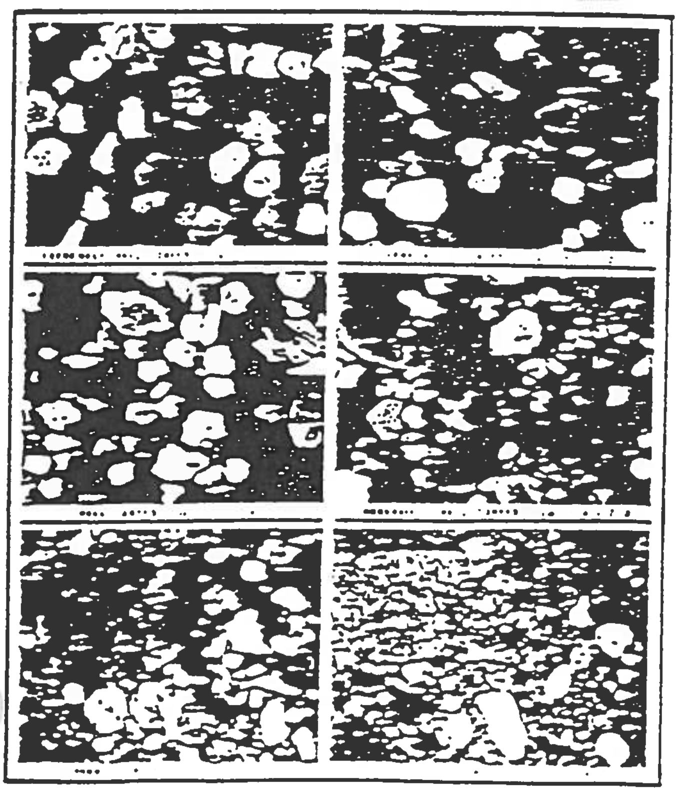
Lower Medium Grain Size
Median Diameter 0.297 mm ●



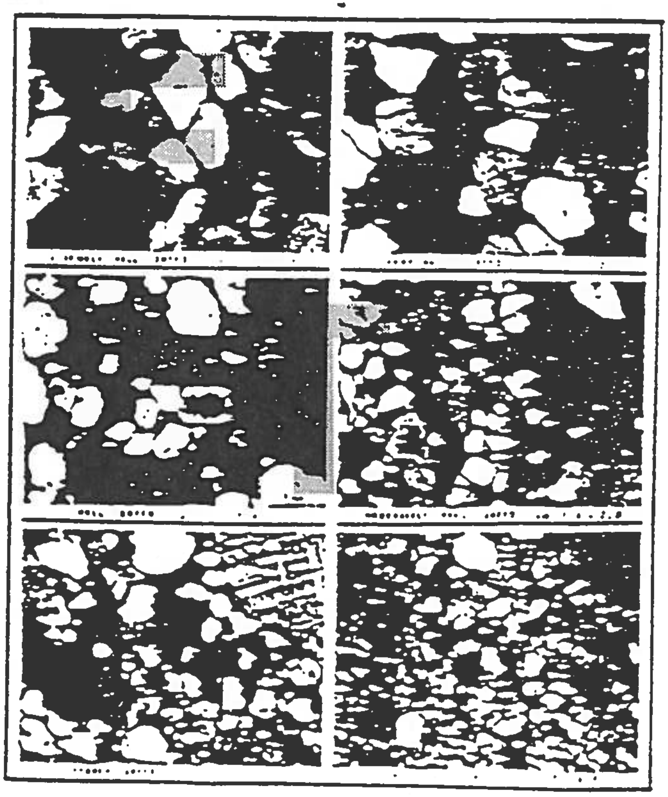
Upper Medium Grain Size
Median Diameter 0.420 mm ●



Lower Coarse Grain Size
Median Diameter 0.590 mm ●



Upper Coarse Grain Size
Median Diameter 0.840 mm ●



(from Beard and Weyl)

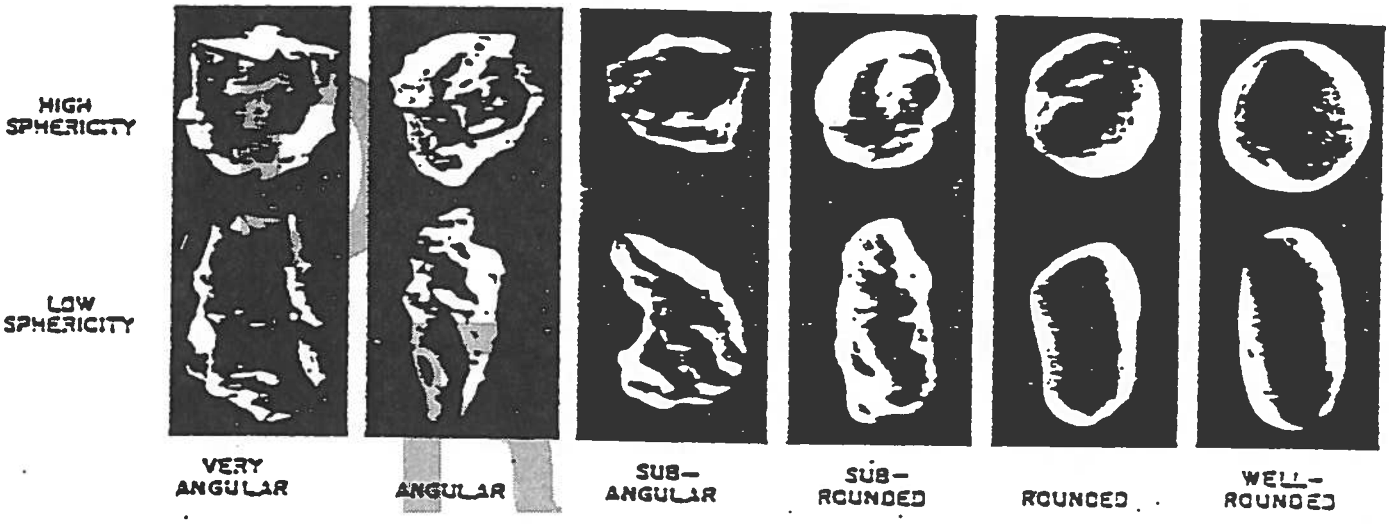
APPENDIX G

ROUNDNESS AND SPHERICITY COMPARATORS

Roundness and Sphericity Comparators

Roundness refers to the roughness of the surface; Sphericity refers to the shape of the grain. These parameters can be expressed by words or by numerical values as shown in the two charts below.

DEGREES OF ROUNDNESS



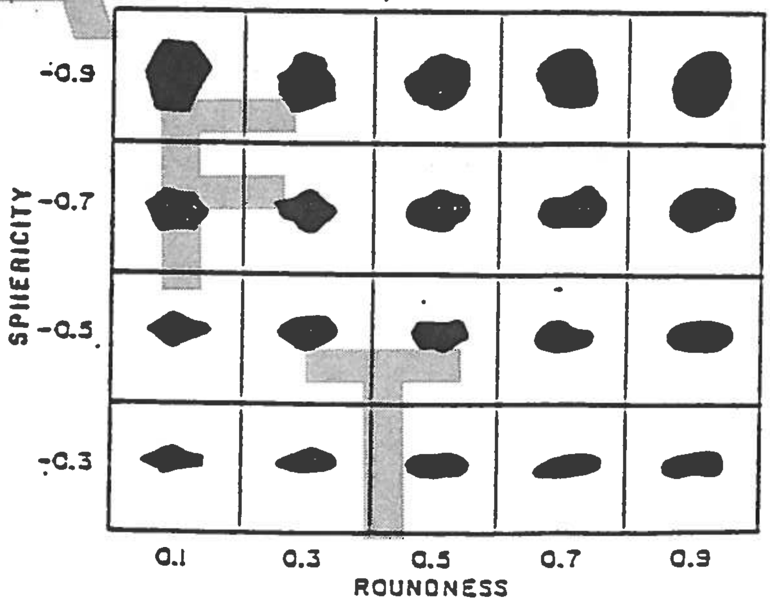
(from Powers, 1953)

SPHERICITY

0.3	LOW
0.5 & 0.7	MODERATE
0.9	HIGH

ROUNDNESS

0.1	ANGULAR
0.3	SUBANGULAR
0.5	SUBROUNDED
0.7	ROUNDED
0.9	WELL ROUNDED



STANDARD OPERATING PROCEDURE #11

VISUAL DESCRIPTION AND CLASSIFICATION OF BEDROCK SAMPLES OBTAINED DURING DRILLING

Prepared by:
Shepherd Miller, Inc.
3801 Automation Way, Suite 100
Fort Collins, CO 80525

May 17, 1996

SHEPHERD MILLER
INCORPORATED

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<u>Section</u> <u>Page</u>

LIST OF APPENDICES

1.0 PURPOSE AND SCOPE

This Standard Operating Procedure (SOP) defines standard information for SMI personnel to record when describing bedrock samples obtained during drilling.

2.0 RELATED STANDARD OPERATING PROCEDURES

This procedure is intended to be used with the following SOPs:

SOP #	Title
1	Equipment Decontamination
3	Ground Water Monitoring Well Installation

3.0 REQUIRED EQUIPMENT

Use the following equipment to collect, describe, and preserve unconsolidated and consolidated material samples obtained during drilling:

- Hand lens, magnification 10X
- Grain size comparator (not included in this document)
- Geological Society of America (GSA) Rock Color Chart or Munsell Soil Color Chart
- Knife
- 10% hydrochloric acid
- Tweezers
- Stainless steel spatula
- Probe
- Chip trays

- Gallon ziplock freezer bags
- Spot plates
- Nitrile or latex surgical gloves
- Calibrated 5-gallon buckets
- Food strainers
- Wrist watch
- Stop watch
- Supply of boring log forms
- Field book
- Permanent-ink black pens
- Engineers tape (marked in intervals of 10ths and 100ths of a foot).

4.0 PROCEDURES FOR COLLECTING, DESCRIBING, AND CLASSIFYING BEDROCK MATERIALS

4.1 Introduction

Subsurface samples can be obtained from various types of drilling/sampling methods, including:

- Reverse circulation rotary, cutting sampling method
- Normal circulation rotary, core sampling method, cutting sample method
- Hollow-stem auger, split spoon sampling method.

Methods of sample collection may vary between samples; however, describe samples in a standard manner.

4.2 Drilling/Sampling Methods

4.2.1 Reverse Circulation Rotary

Exploration borings and monitoring wells may be drilled using a dual-tube rotary reverse circulation drilling rig. In this drilling method, air and air/mist are the primary drilling fluids. The return fluid will consist of air, drill cuttings, and ground water, which will be routed through a cyclone to separate out the air. Collect representative samples of cuttings by routing a portion of the cuttings from the cyclone into a 5-gallon bucket or food strainer. Replace the bucket or food strainer at every 5-foot interval.

The field geologist is responsible for doing the following: collecting the cuttings samples, describing and classifying the samples, preserving representative portions of each sample for archive and future analysis, and recording appropriate chemical and geotechnical sample numbers on the borehole log.

The field geologist will also record drilling operational information, including the following: drilling depths, amount of temporary casing installed in the borehole, drilling rates, drilling delays, and drill stem pressures. Sample recovery, sample descriptions, and drilling operational data will also be recorded.

Collect representative samples in chip trays for every 5-foot interval that is drilled. At the field geologist's discretion, increase the sampling interval to ensure representative sampling.

Record the first encountered water levels and ground water production rates, as measured with a 5-gallon bucket and watch, on the borehole log. Record flow rates in gallons per minute.

4.2.2 Rotary Core

Core drilling may be performed to acquire intact subsurface samples. Because drilling will be performed using a bentonite mud, do not test ground water quality parameters during drilling. Sample recovery, sample descriptions, and drilling operational data will be recorded on the borehole log form.

The field geologist will record cored interval depths and core recoveries and label core depths with wooden blocks. Recoveries will be measured and recorded as the actual recovery length. Place recovered cores first in plastic bags or core sleeves and then in core boxes with the top of each run at front right. Label each core box with appropriate core depths.

4.2.3 Hollow-Stem Auger

Obtain standard-sized (1.5-inch diameter and 18- to 30-inch long) split-spoon samples from hollow stem auger borings at intervals specified in the Sampling and Analysis Plan. Perform split spoon sampling according to ASTM D-1586. Record sample recovery, sample descriptions, and drilling operational data on the borehole log form. Measure and record recovery as a percentage of each driven interval in the recovery column. Record blow counts for each 6-inch interval of a drive not to exceed 2 feet. Retain the entire recovered sample and place it in gallon zip-lock plastic bags.

Between sampling intervals, decontaminate all sampling equipment as specified in SOP #15.

4.3 Description of Bedrock Materials

4.3.1 Basis of Classification

A primary borehole logging objective is to describe pertinent lithologic parameters necessary to geologically characterize the site. When detailed textural and compositional aquifer descriptions are integrated into the hydrogeologic framework, interpretations regarding aquifer geometries will be augmented.

With an emphasis on textural classification, describe all consolidated rock materials with respect to the following:

1. Gross lithology and formation identification
2. Color
3. Grain-size distribution
4. Median grain size
5. Sorting
6. Rounding
7. Sphericity
8. Friability
9. Porosity
10. Sediment or rock name
11. Mineralogic composition
12. Matrix and secondary cement (particularly the reaction to dilute acid)

13 Moisture content

14. Other distinguishing characteristics.

Some comparison techniques are used for classification. These techniques are described in *Sample Examination Manual* by R. G. Swanson, which is published by the AAPG.

4.3.2 Borehole Logging Responsibilities

The field geologist will log the cuttings using a hand lens, a grain-size comparator, a Munsell Color Chart or GSA Rock Color Chart, and a bottle of hydrochloric acid.

4.3.3 Gross Lithology and Formation Identification

The lithologic classification of geologic materials for logging purposes is textural. The logger will classify all consolidated materials according to most frequent grain size using the Wentworth scale (Appendix C). The logging geologist will record a formation name if one is determined.

The logger will represent gross lithologies graphically on the logging form. If 80 percent of the logged material is composed of one grain size (i.e., sand, gravel, or clay), log it graphically as a single lithology and assign it the appropriate symbol. If the recovered material contains more than 20 percent of other-sized constituents, the second most abundant size should be used as a modifier. For example, if a rock is composed of 70% sand, 20% gravel, and 10% clay, it should be assigned the symbol of a conglomeratic sandstone.

4.3.4 Color

Color can convey a great deal of information. It helps to identify mineral components and cement. Color also indicates the current chemical environment from which the sample was taken. To ensure that the color descriptions are accurate and standardized, the logger will describe each wet sample by comparing it with the GSA's Rock Color Chart or the Munsell Soil Color Chart. Record both the color name and number on the logging form. If the sample has dried, it should be moistened with clean water from a squirt bottle. Be sure to remove sunglasses when determining color.

4.3.5 Texture

Texture refers to the shape and arrangement of the component elements of a sediment, soil, or rock. Size grades and sorting of sediments are important attributes, in that they have a direct bearing on porosity and permeability and may reflect the environment of deposition. Size classifications, based on a Wentworth scale, are shown as Appendix C. The logger will record grain sizes with reference to a standard comparator.

1. Grain Size Distribution and Grain Size Mode

The logger will make visual estimates of the percentages of major size classes (i.e., gravel, sand, silt, and clay) and record these in the appropriate columns on the logging form, normalizing all percentages to 100 percent. In addition, the logger will record the Wentworth size class of the grain size mode (e.g., very fine sand or fine sand). All grain size determinations pertaining to sand-sized and finer materials will be made with the aid of a grain-size comparator; the field geologist will use a hand lens. Useful visual aids for estimating percentages of abundance (Swanson, 1981) are provided as Appendices E through G.

2. Sorting

Sorting is a measure of size frequency distribution dispersion. It involves shape, roundness, specific gravity, and mineral composition as well as size; however, for these logging purposes, size dispersion is the most important. Use the classification below (Payne, 1942):

Sorting	Logging

Good Sorting:	90% of grains in 1 or 2 Wentworth size classes
Fair Sorting:	90% of grains in 3 or 4 Wentworth size classes
Poor Sorting:	90% of grains in 5 or more Wentworth size classes

The logging geologist will enter the appropriate logging symbol in the sorting column of the logging form. For example, if a sediment were composed of 20% clay, 30% silt, and 50% very fine sand, it would have fair sorting. Make all sorting determinations with a hand lens. The photomicrographs, included as Appendix H from Swanson (1981), are useful comparators for determining the degree of sorting.

3. Grain Shape

Because grain shape is a measure of grain abrasion, it is often used to decipher the history of sedimentary deposits. However, grain shape is only meaningful for sediments that are sand-sized and larger. Fine-grained sediments commonly undergo elastic collisions during sediment transport, and consequently these grains are not abraded. If rock materials are mechanically broken during the drilling process, grain shape is not significant. Shape involves both roundness and sphericity. The logger will determine and record both characteristics.

a. Roundness

Roundness refers to the sharpness of the edges and corners of a fragment. Five degrees of rounding are distinguished, as shown in Appendix I. These degrees are described below:

Degree	Description
Angular	Faces and corners are sharp; surface shows little or no evidence of abrasion
Subangular	Faces are untouched, but edges and corners are rounded
Subrounded	Edges and corners are rounded to smooth curves; areas of the original faces are reduced
Rounded	Original faces are almost completely destroyed, but some comparatively flat faces are present; all original edges and corners are smoothed off to broad curves
Well Rounded	No original faces, edges, or corners remain; entire surface consists of broad curves; flat areas are absent.

The logger will determine roundness by visual comparison and record a roundness code in the appropriate column of the logging form.

b. Sphericity

Sphericity is determined by comparing the surface area of a grain to that of a sphere of equal volume. The logger will determine the grain sphericity by visual comparison with the chart included in Appendix I and record sphericity as Low Sphericity, Moderate Sphericity, or High Sphericity, as described in Appendix F.

4.3.6 Friability

The tendency of a rock to crumble is related to how well it is cemented and the extent to which it has been altered. The logger will determine the friability, as defined below, and enter the appropriate code on the logging form.

Term	Definition
Unconsolidated	Material recovered from drilling is totally desegregated
Highly Friable	Material crumbles easily into individual grains upon minor disturbance
Moderately Friable	Material will crumble into individual grains with extensive rubbing
Slightly Friable	Material can be broken into individual grains by scraping it with a pocket knife
Non-Friable	Material cannot be broken into individual grains by any of the methods described above.

4.3.7 Classification of Sediment or Rock Materials

The logger will classify the recovered material and record the name on the logging form. Classify clastics according to the most frequent grain size (i.e., gravel, sand, silt, or clay). If one size faction makes up the bulk of the material (80% or more), it should be described as that lithology (e.g., sand or silt) without a modifier. If the most frequent grain-size constituent comprises less than 80 percent of the recovered material, the name should be assigned a modifier to represent the second most frequent grain size. However, the sediment or rock name can be assigned only one modifier. Less frequent constituents will follow the primary name using a statement beginning with the word "with". Use the division of abundance table below to qualify these constituents. For example, if a sediment is comprised of 25% gravel, 50% sand, 20% silt, and 5% clay, describe it as a "gravelly sand." The silt and clay components can be added using a "with" statement. Therefore, the full name will be "gravelly sand with some silt and a trace of clay."

The following describes the division of abundance and the range of percentages for each division:

Division of Abundance	Range of Percentages
Trace	>0 to 5
Some	6 to 25
Abundant	26 to 100

4.3.8 Mineralogy

Record the dominant grain mineralogy in the description column of the logging form (Appendix A). In addition, the logger should note distinguishing trace minerals. Also, record the composition of cement and matrix. The most common cementing materials are silica and calcite; the logger should consistently test for the reaction of the material to dilute hydrochloric acid (HCl). In addition, several different cements or generations of cement may occur in a given rock. The logger should be particularly aware of grain coatings and unusual mineral alterations. These could provide valuable clues relative to ground water migration pathways.

4.3.9 Moisture Content

The logger will record moisture content and ground water production rates on the logging form. The recovered material will be described as dry, moist, or wet. Also, the static water level will be recorded.

4.3.10 Bedding and Structure (Core samples only)

For cored samples, the logger will describe gross features, such as bedding characteristics (thickness and shape), sedimentary structures, the nature of bedding contacts (transitional or abrupt), fracturing, and slickensides. Criteria for describing stratification are provided below. Cored materials should be carefully described with respect to thin aquitards and aquicludes.

Stratification

Stratification	Description
Laminated	Alternating layers of varying material or color with layers less than 6 mm (1/4 inch) thick
Stratified	Alternating layers of varying material or color with layers greater than 6 mm (1/4 inch) thick
Lensed	Inclusion of small pockets of a different material
Fissured	Breaks along planes of fracture with little resistance
Slickensided	Fracture planes appear polished or glossy, sometimes striated
Blocky	Cohesive material that can be broken down into small angular lumps which resist further breakdown
Homogeneous	Same color and appearance throughout

4.3.11 Other Distinguishing Characteristics

The logger will describe any unusual odor, the occurrence of organic matter, and (if measured) radioactivity screening information.

5.0 DOCUMENTATION

Record the following information on boring logs:

<u>Header</u>
Name of drilling company and driller
Name of field geologist (person describing samples)
Type of drilling rig and drilling method
Boring number
Borehole diameter/temporary casing diameter
Total depth
Date and time started, date and time completed.

<u>Logged by depth (feet)</u>
Sampled interval
Sample type and number (for archive and analytical)
Blows on sampler (for split spoons only)
Recovery (for split spoon and core samples only)
Visual description (see Sections 2.3 and 2.4)
Drilling rate (or time of day per depth)
Delays in drilling
Drilling pressure
First encounter with ground water
Ground water flow rate.

Record the following information in the field book:

Project name and number
Name of drilling company and driller
Name of field geologist (person describing samples)
Type of drilling rig and drilling method
Boring number
Borehole diameter/temporary casing diameter
Total depth
Date and time started, date and time completed
Names of all personnel directly involved in work and important visitors
Date and time
Weather conditions
Location of boring
Layout of equipment at drilling location

Details of cuttings and fluid management system setup
Nature of any equipment breakdowns
Decontamination documentation
Other operational information.

6.0 REFERENCES

ASTM D-1586 - 84, Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils, *1995 Annual Book of ASTM Standards*, Vol. 04.08.

Swanson, R. G., *Sample Examination Manual*, 1981, Methods in Exploration Series, The American Association of Petroleum Geologists, Tulsa, Oklahoma.

APPENDIX A

WENTWORTH GRAIN-SIZE SCALE

Wentworth Grain-Size Scale

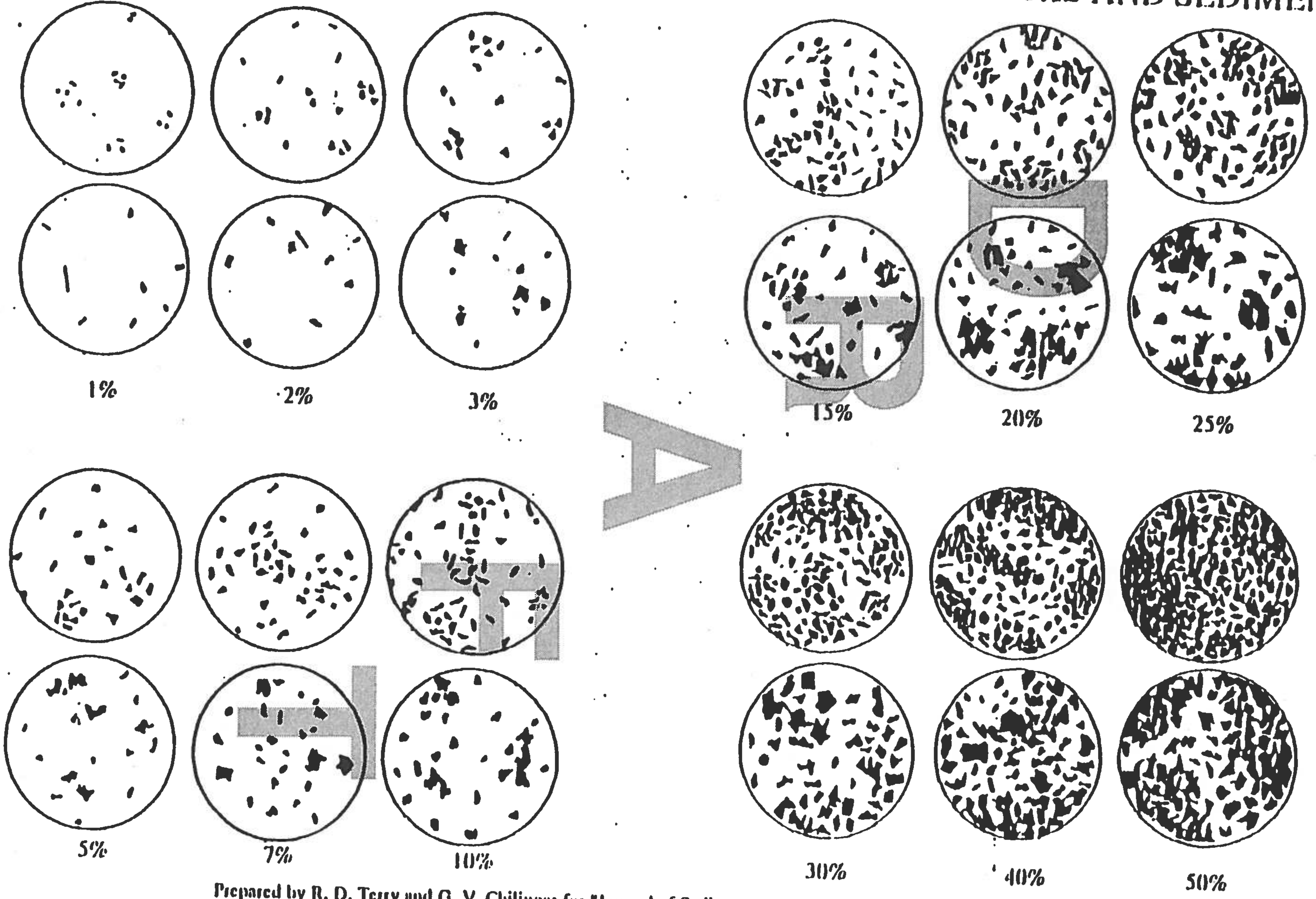
The Wentworth grade scale, which originated in 1922, is most commonly used for sediments and sedimentary rocks. It is a logarithmic scale in that each grade limit is twice as large as the next smaller grade limit. The table below presents the Wentworth size classes along with the U. S. sieve mesh sizes, and the Phi Scale.

U. S. Standard Sieve Mesh #		Millimeters (10^{-3}m)	Microns (10^{-6}m)	Phi	Wentworth Size Class	
		4096		-12		GRAVEL
		1024		-10	Boulder (-8 to -12φ)	
Use		256		-8		
wire		64		-6	Cobble (-6 to -8φ)	
squares		16		-4	Pebble (-2 to -6φ)	
5		4		-2		
6		3.36		-1.75		
7		2.83		-1.5	Granule	
8		2.38		-1.25		
10		2.00		-1.0		
12		1.68		-0.75		SAND
14		1.41		-0.5	Very coarse sand	
16		1.19		-0.25		
18		1.00		0.0		
20		0.84		0.25		
25		0.71		0.5	Coarse sand	
30		0.59		0.75		
35	1/2	0.50	500	1.0		
40		0.42	420	1.25		
45		0.35	350	1.5	Medium sand	
50		0.30	300	1.75		
60	1/4	0.25	250	2.0		
70		0.210	210	2.25		
80		0.177	177	2.5	Fine sand	
100		0.149	149	2.75		
120	1/8	0.125	125	3.0		
140		0.105	105	3.25		
170		0.088	88	3.5	Very fine sand	
200		0.074	74	3.75		
230	1/16	0.0625	62.5	4.0		
270		0.053	53	4.25		MUD
325		0.044	44	4.5	Coarse silt	
		0.037	37	4.75		
	1/32	0.031	31	5.0		
	1/64	0.0156	15.6	6.0	Medium silt	
Analyzed	1/128	0.0078	7.8	7.0	Fine silt	
by	1/256	0.0039	3.9	8.0	Very fine silt	
		0.0020	2.0	9.0		
Pipette		0.00098	0.98	10.0	Clay	
		0.00049	0.49	11.0		
or		0.00024	0.24	12.0		
		0.00012	0.12	13.0		
Hydrometer		0.00006	0.06	14.0		

APPENDIX B

CHARTS FOR ESTIMATING PERCENTAGE COMPOSITION OF ROCKS AND SEDIMENT

CHA[illegible]S FOR ESTIMATING PERCENTAGE COMPOSITION OF ROCKS AND SEDIMENT



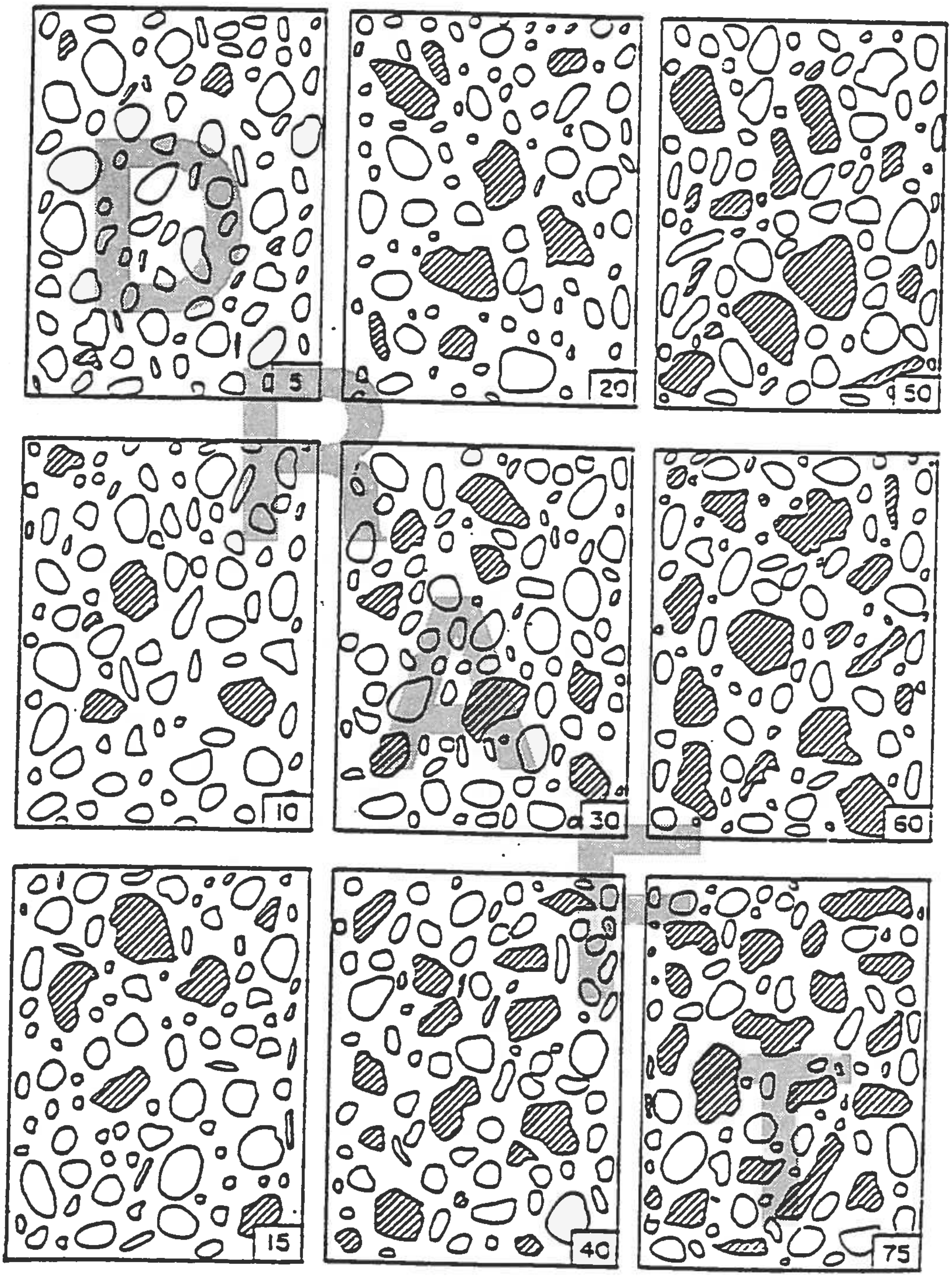
Prepared by R. D. Terry and G. V. Chilingar for "Journal of Sedimentary Petrology" (v. 25, pp. 229-234, 1955); reprinted as 'Data Sheet 6' of "Geotimes" available from the American Geological Institute, 2101 Constitution Ave., N.W., Washington, D. C. Reprinted here by permission of the authors and the Society of Economic Paleontologists and Mineralogists. Taken from Compton, 1962.

[illegible]

APPENDIX C

CHART FOR ESTIMATING PERCENTAGE OF A GIVEN ROCK TYPE IN A TRAY OF CUTTINGS

CHART FOR ESTIMATING PERCENTAGE OF A GIVEN ROCK TYPE IN A TRAY OF CUTTINGS

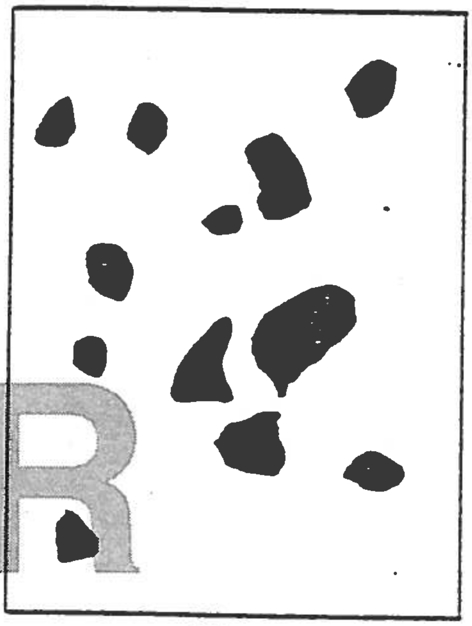


APPENDIX D

CHARTS FOR ESTIMATING PARTICLE PERCENTAGES

CHART FOR ESTIMATING PARTICLE PERCENTAGES

Chart I



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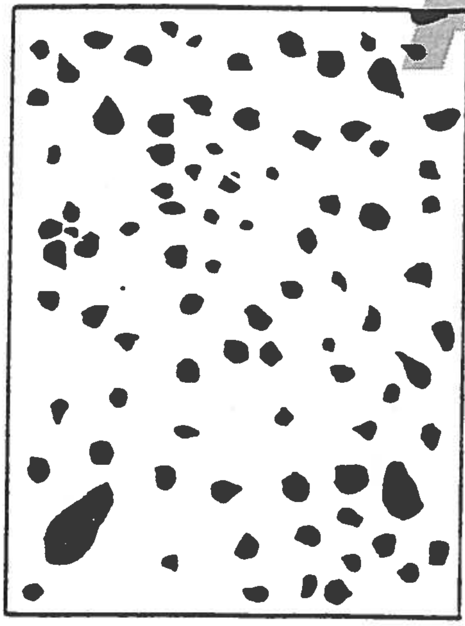
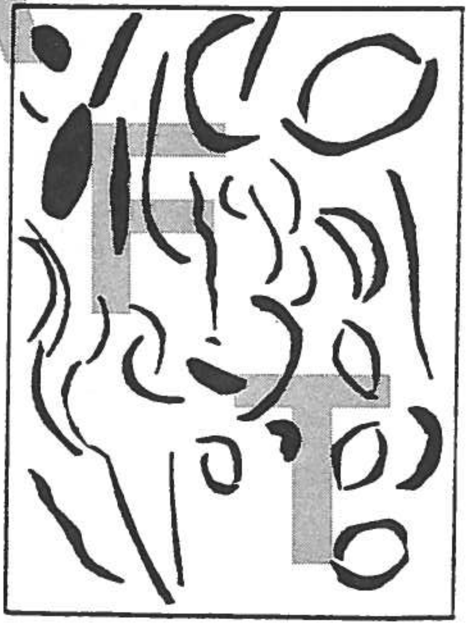


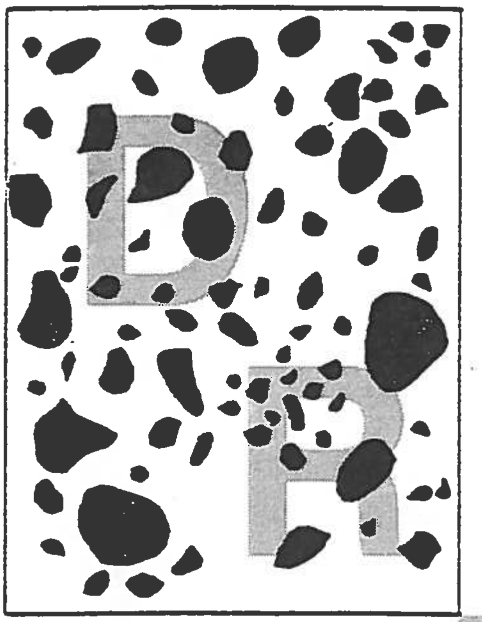
13%



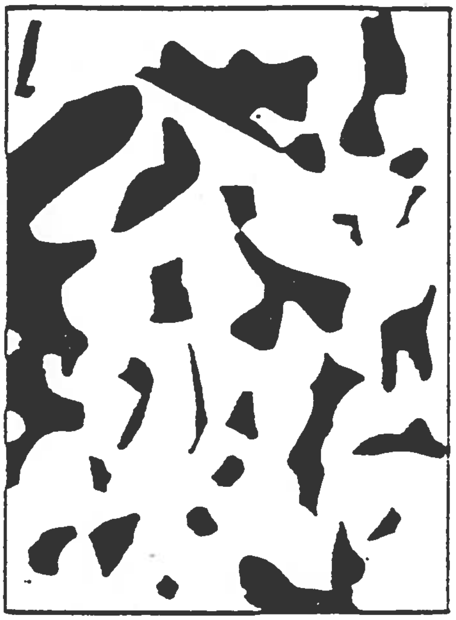
18%

CHART FOR ESTIMATING PARTICLE PERCENTAGES

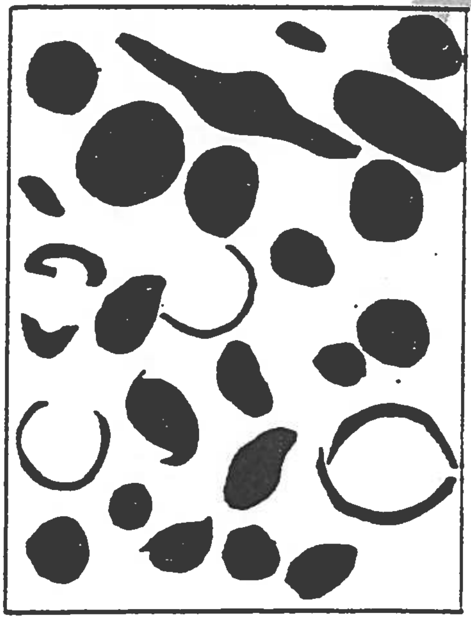
Chart II



26 %



29 %



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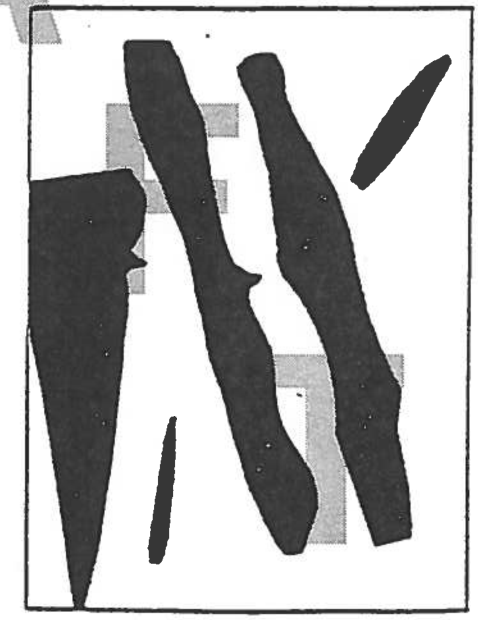
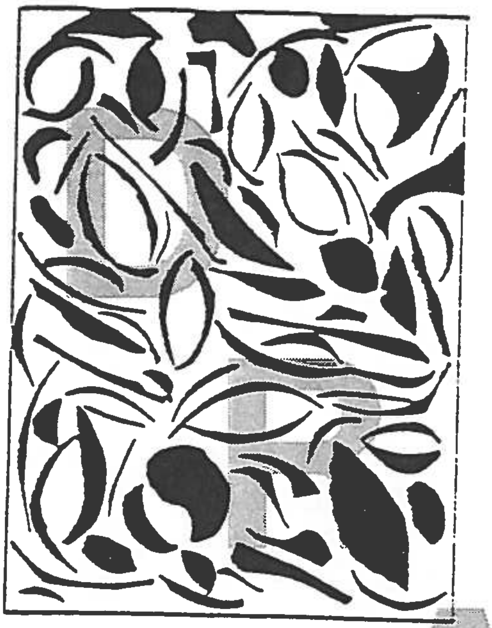


36 %

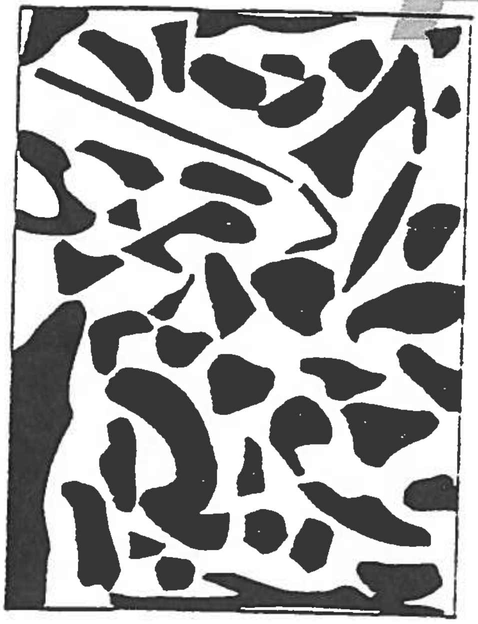
CHART FOR ESTIMATING PARTICLE PERCENTAGES

Chart III



40 %

40 %



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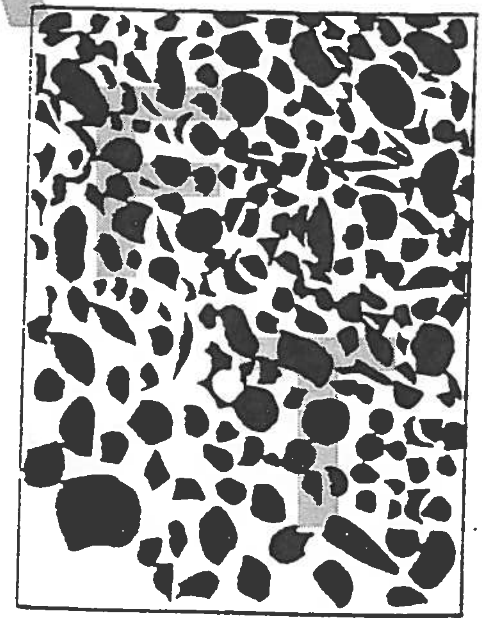
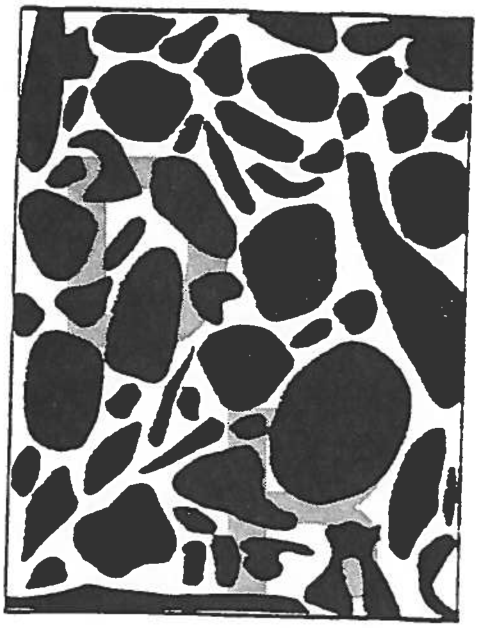


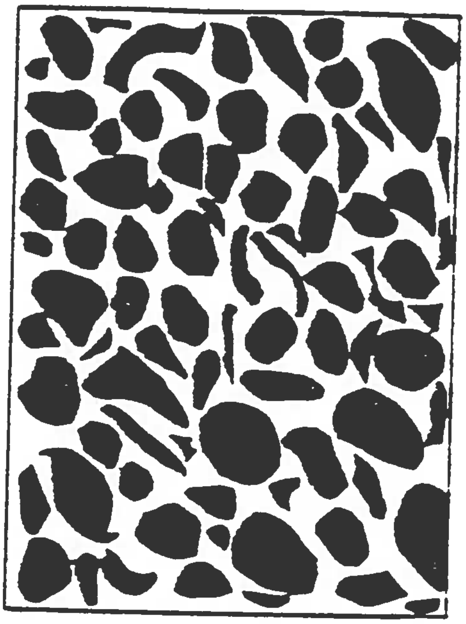
56 %

CHART FOR ESTIMATING PARTICLE PERCENTAGES

Chart IV



60%



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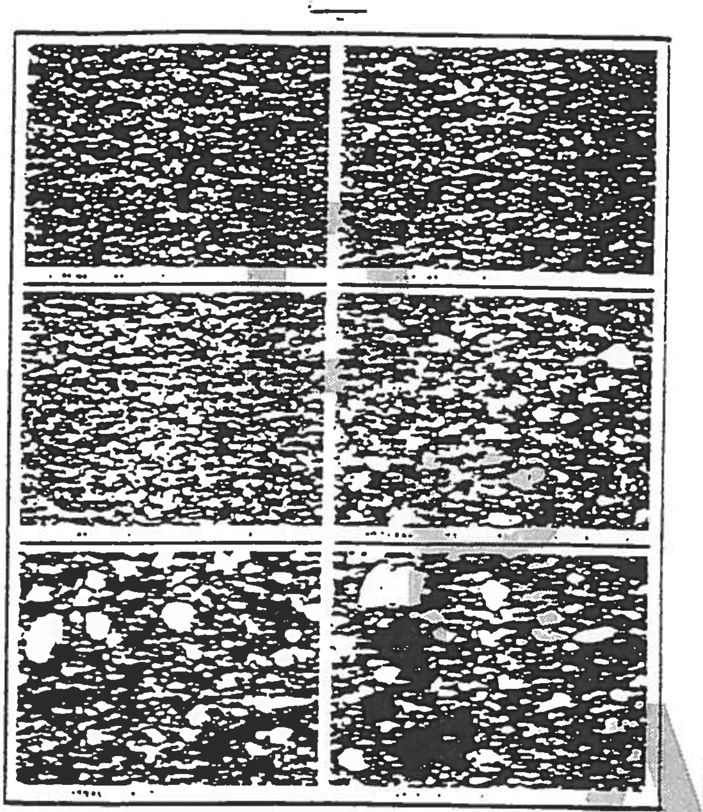
APPENDIX E

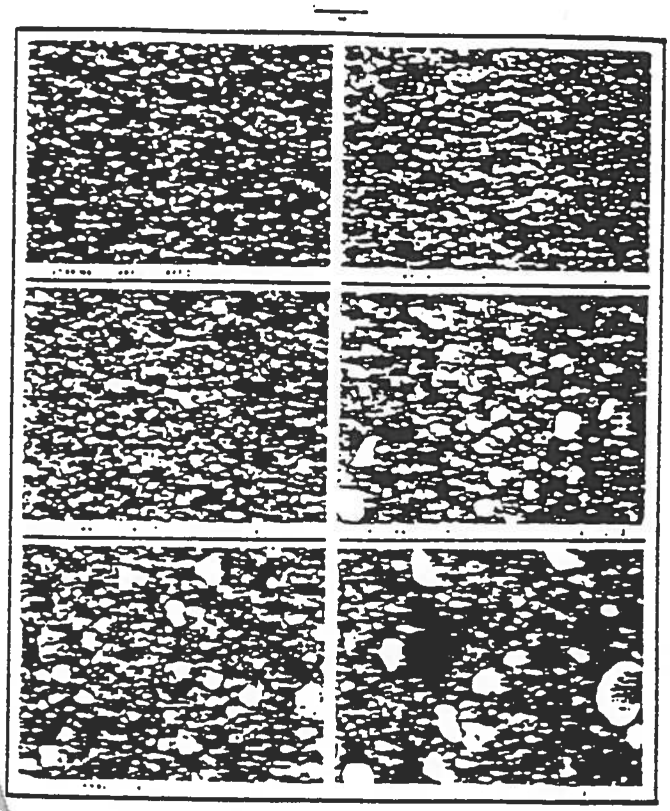
GRAIN SIZE AND SORTING COMPARATORS

Grain Size and Sorting Comparators (Photomicrographs of Thin Sections)

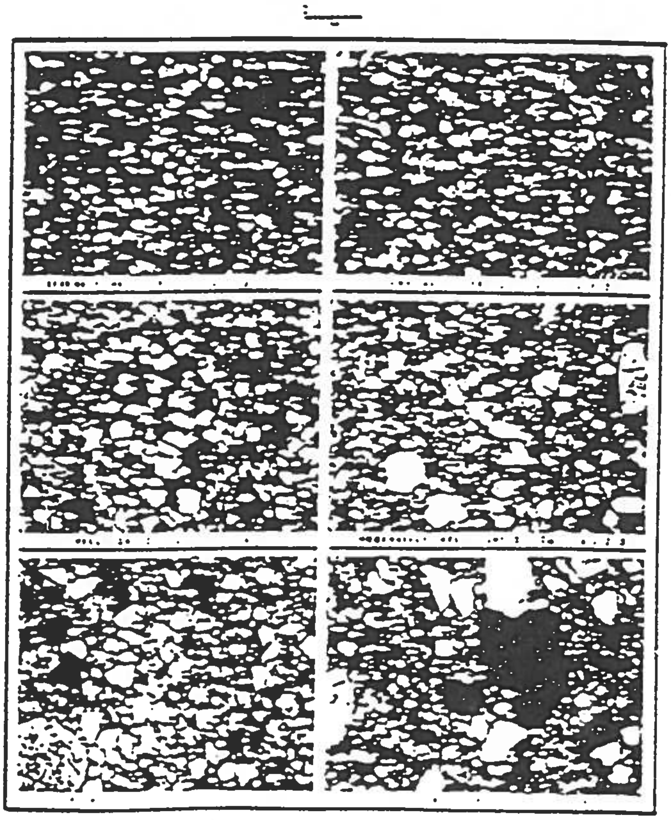
Lower Very Fine Grain Size
Median Diameter 0.074 mm



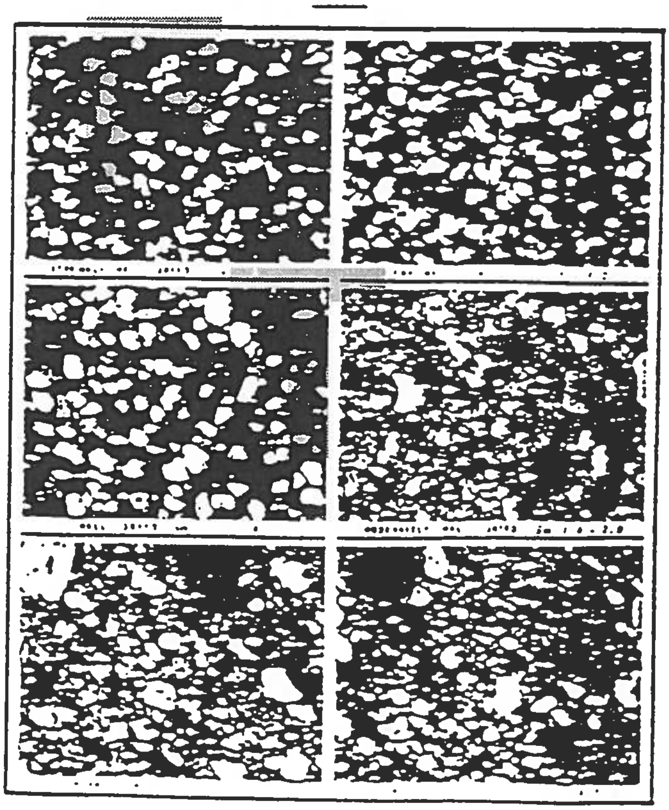
Upper Very Fine Grain Size
Median Diameter 0.105 mm



Lower Fine Grain Size
Median Diameter 0.149 mm



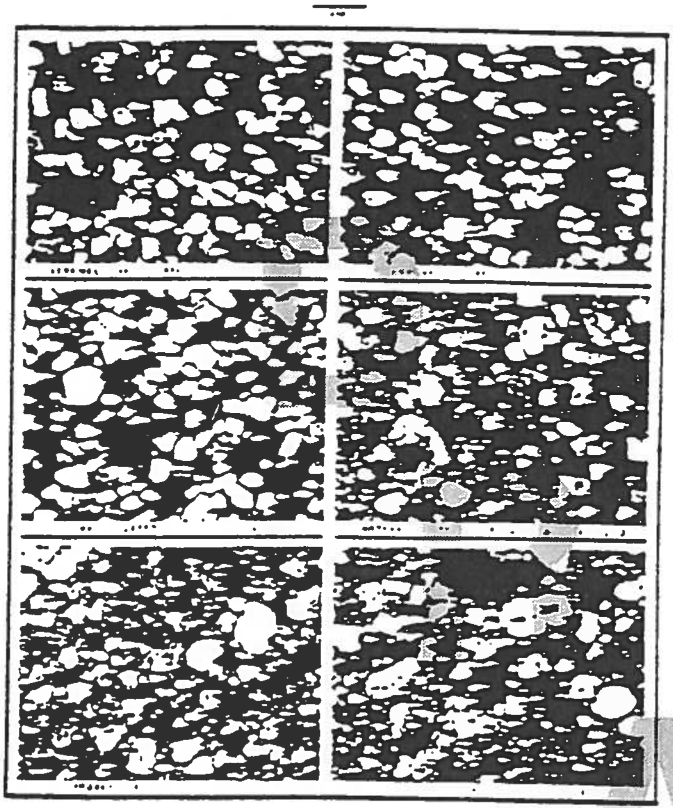
Upper Fine Grain Size
Median Diameter 0.210 mm



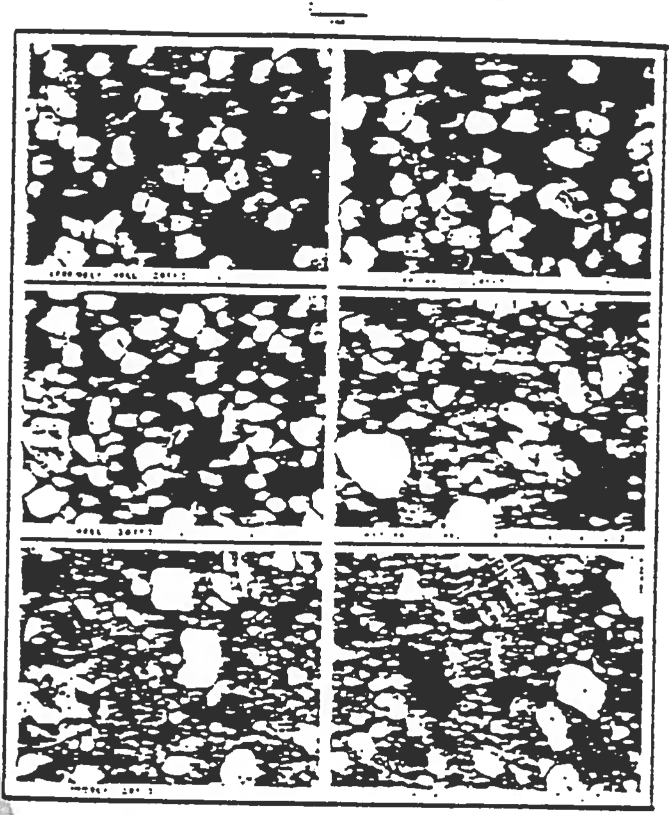
(from Beard and Weyl)

Grain Size and Sorting Comparators (Photomicrographs of Thin Sections)

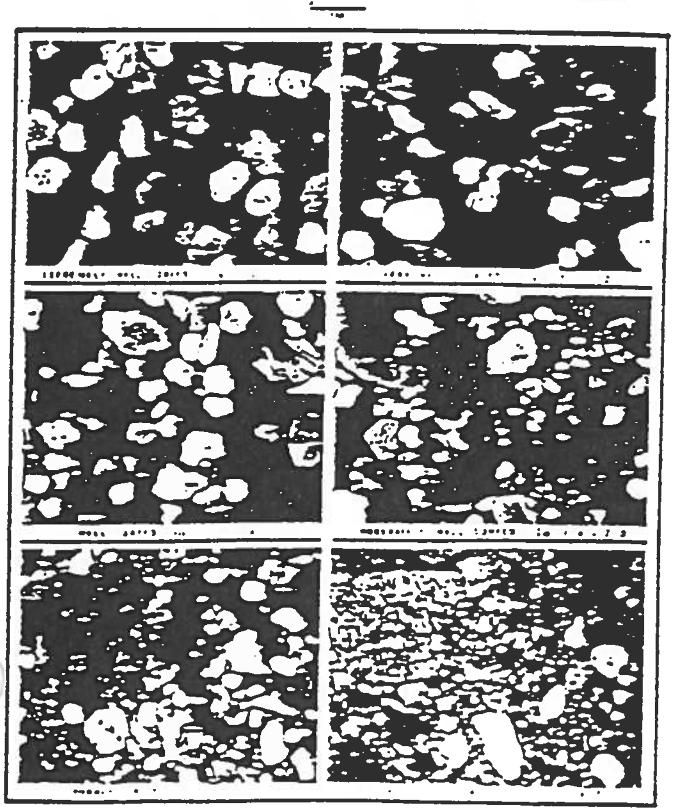
Lower Medium Grain Size
Median Diameter 0.297 mm



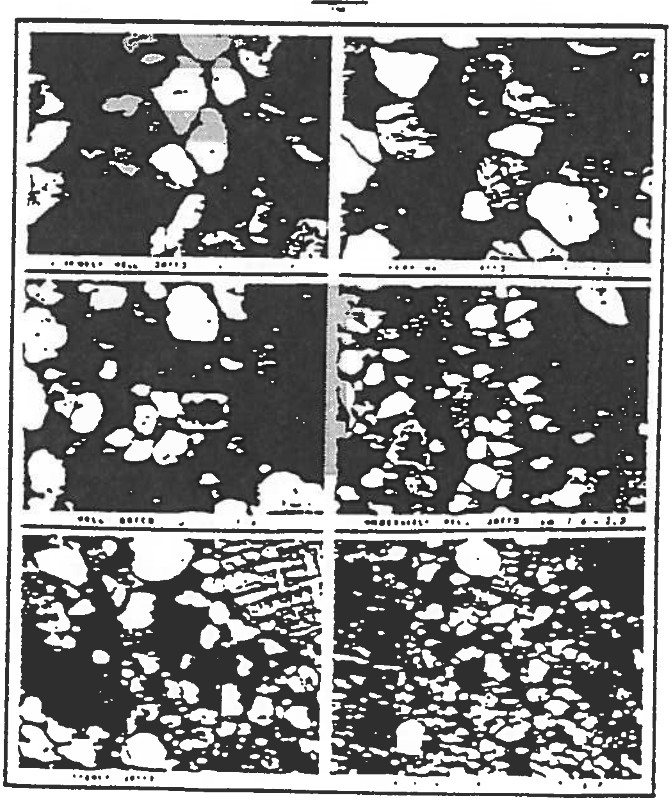
Upper Medium Grain Size
Median Diameter 0.420 mm



Lower Coarse Grain Size
Median Diameter 0.590 mm



Upper Coarse Grain Size
Median Diameter 0.840 mm



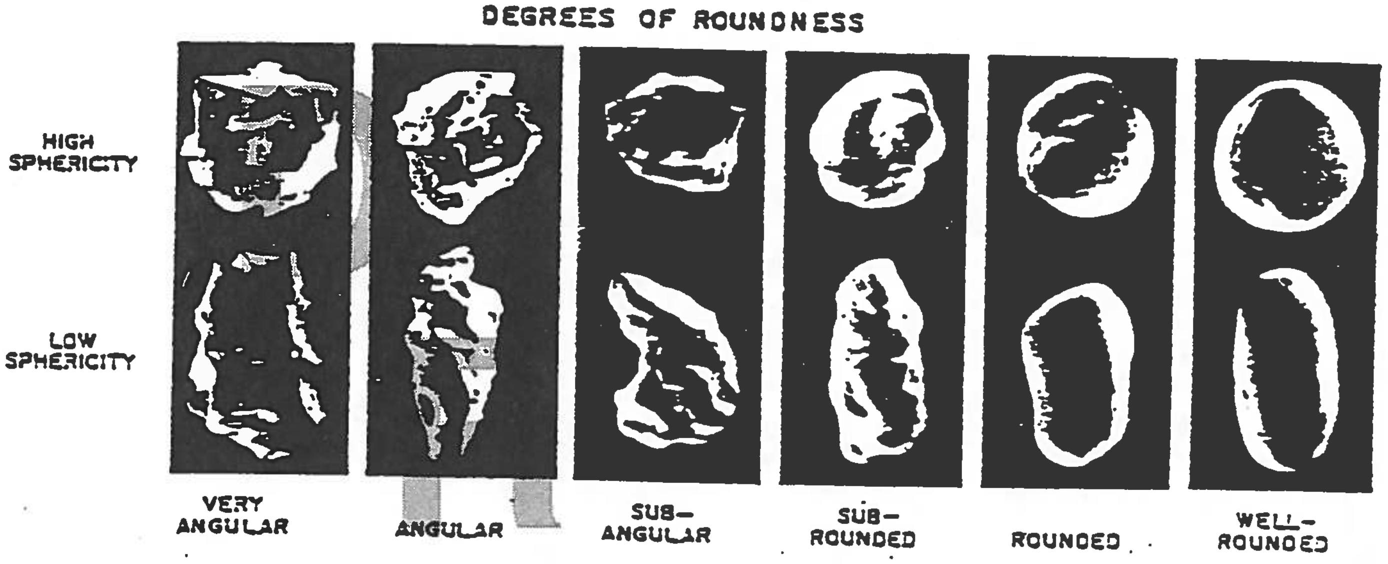
(from Beard and Weyl)

APPENDIX F

ROUNDNESS AND SPHERICITY COMPARATORS

Roundness and Sphericity Comparators

Roundness refers to the roughness of the surface; Sphericity refers to the shape of the grain. These parameters can be expressed by words or by numerical values as shown in the two charts below.



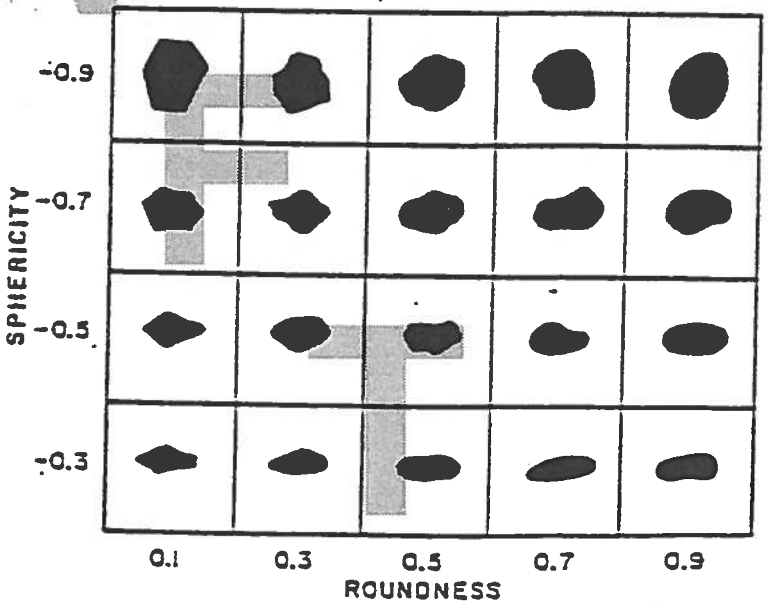
(from Powers, 1953)

SPHERICITY

0.3	LOW
0.5 & 0.7	MODERATE
0.9	HIGH

ROUNDNESS

0.1	ANGULAR
0.3	SUBANGULAR
0.5	SUBROUNDED
0.7	ROUNDED
0.9	WELL ROUNDED



Index

STANDARD OPERATING PROCEDURE #12

PNEUMATIC PIEZOMETER INSTALLATION AND MEASUREMENT

Prepared by:
Shepherd Miller, Inc.
3801 Automation Way, Suite 100
Fort Collins, CO 80525

May 17, 1996

SHEPHERD MILLER
INCORPORATED

TABLE OF CONTENTS

Section Page

1.0 PURPOSE AND SCOPE

This document defines the standard operating procedure (SOP) for installing and measuring pneumatic piezometers. This SOP describes the equipment and field procedures for installing and measuring pneumatic piezometers.

2.0 RELATED STANDARD OPERATING PROCEDURES

This procedure is intended to be used with the following SOPs:

SOP #	Title
3	Ground Water Monitoring Well Installation

3.0 PNEUMATIC PIEZOMETER INSTALLATION

This section describes the equipment, methods, and documentation to use for installing pneumatic piezometers.

3.1 Required Installation Equipment

Use the following equipment to install pneumatic piezometers:

- Pneumatic piezometer and tubing
- 1½-inch flush threaded schedule 80 polyvinyl chloride (PVC)
- Steel protective casing with locking cap
- Small cotton socks

- Fine quartz sand
- Engineers tape
- Plastic tape.

3.2 Pneumatic Piezometer Design

Pneumatic piezometer design will be specified in the appropriate project document. Design criteria will include number and depths of pneumatic piezometers.

3.3 Pneumatic Piezometer Installation

Install pneumatic piezometers as follows:

1. Assemble all equipment and materials.
2. Use an existing borehole or drill a new borehole following procedures described in SOP #3.
3. Remove red cap from pneumatic piezometer and place piezometer in small cotton sock. Add fine quartz sand (frac sand) to sock and secure top of sock to piezometer tubing with plastic tape. Secure the top and bottom of the piezometer assembly to the 1½-inch PVC with plastic tape. Secure the piezometer tubing to the 1½-inch PVC at regular intervals with plastic tape.
4. Carefully measure the location of the pneumatic piezometer's measurement point and lengths of PVC pipe to determine the piezometer's installation depth.
5. Repeat Steps 3 and 4 for multiple pneumatic piezometers installed in a single borehole.
6. Once the piezometers have been suspended in the borehole at the proper depth, install cement-bentonite grout through the 1½-inch PVC or a tremmie pipe. Grout the pneumatic piezometers with a cement-bentonite grout (98% Portland Type V cement/2% bentonite powder by weight). Before placement, weigh the grout with a mud scale to document grout densities. To prepare the grout, mix

bentonite and water together; add cement; and thoroughly mix the resulting grout.

4.0 PNEUMATIC PIEZOMETER MEASUREMENT PROCEDURE

Measure pneumatic piezometers following the manufacturer's instructions

FIGURES

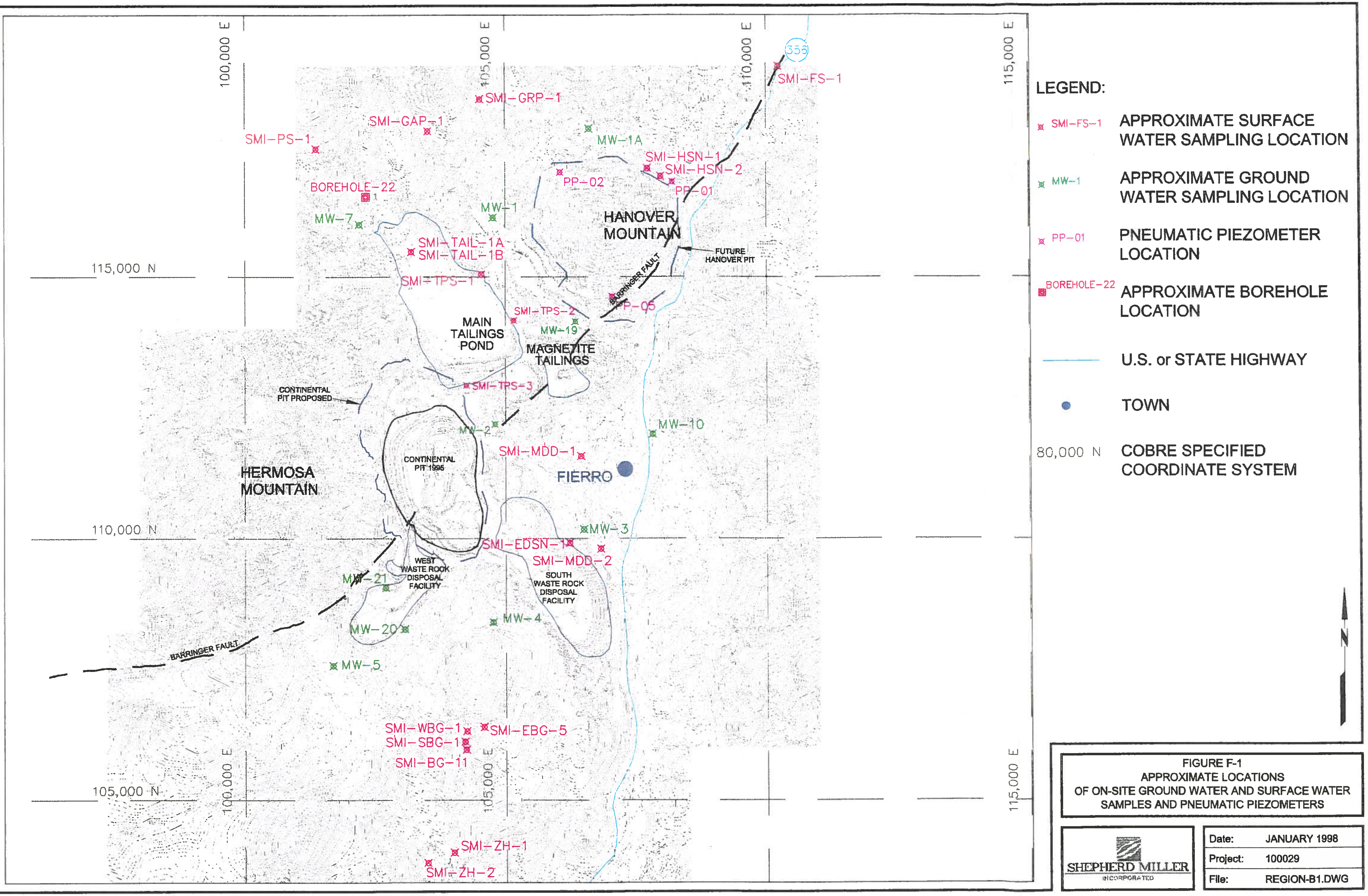


FIGURE F-1
APPROXIMATE LOCATIONS
OF ON-SITE GROUND WATER AND SURFACE WATER
SAMPLES AND PNEUMATIC PIEZOMETERS

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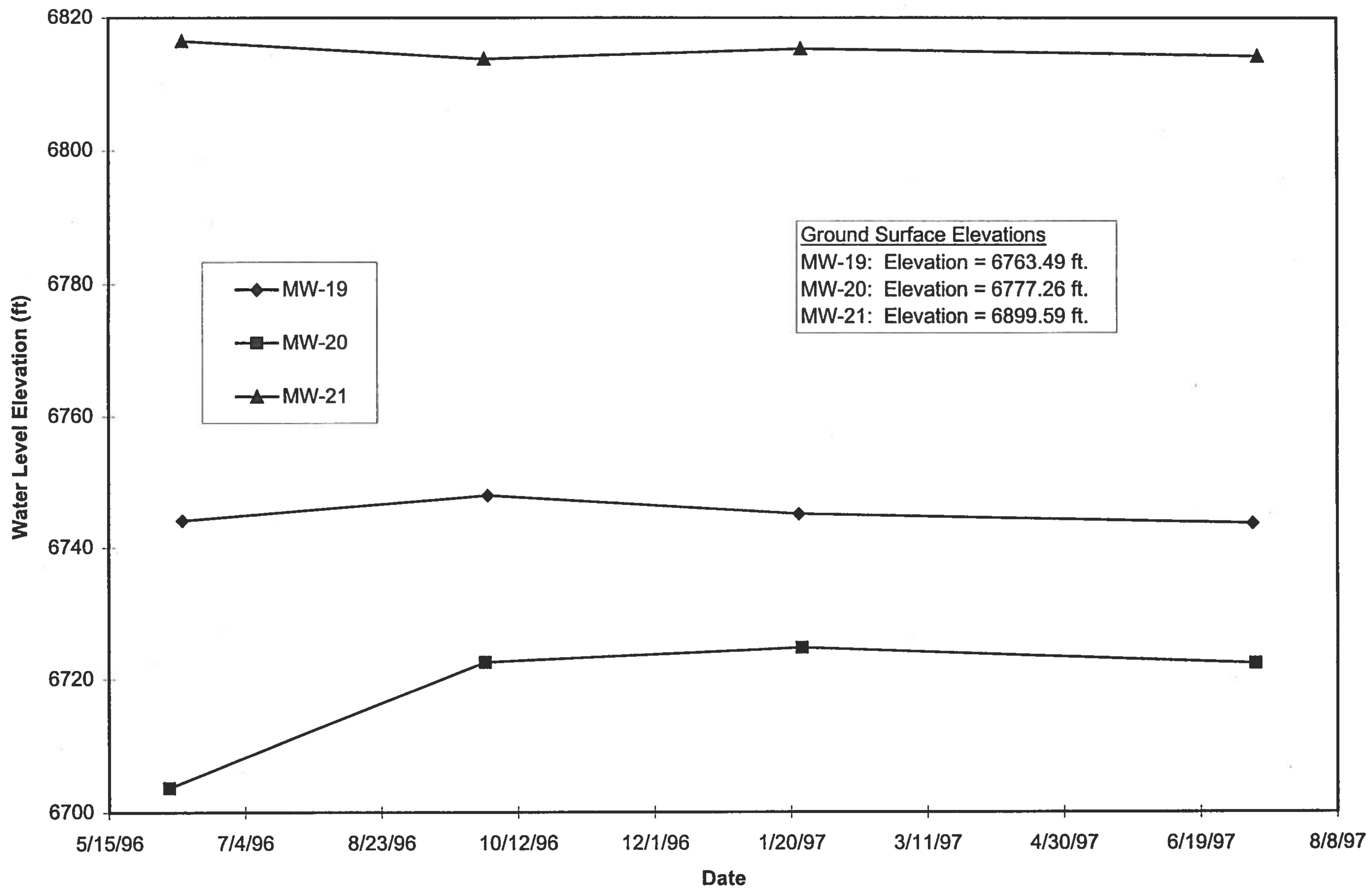
INCORPORATED

Date:	JANUARY 1998
Project:	100029
File:	REGION-B1.DWG



Ground Surface Elevations
MW-19: Elevation = 6763.49 ft.
MW-20: Elevation = 6777.26 ft.
MW-21: Elevation = 6899.59 ft.

SHEPHERD MILLER
INCORPORATED

FIGURE F-2
WATER LEVEL ELEVATION VERSUS DATE
MONITORING WELLS MW-19, MW-20, AND MW-21

Date:	JANUARY 1998
Project:	100029
File:	DTWFIG.DOC

TABLES

Table F-1 Monitoring Well Survey Data

Well	Easting	Northing	Elevation Top of PVC	PVC Stickup (feet)
MW-1	104,764	116,128	6,889.7	2.67
MW-1A	106,584	117,818	7,003.9	2.71
MW-2	104,795	112,188	6,658.1	1.31
MW-3	106,469	110,174	6,541.8	2.52
MW-4	104,753	108,396	6,768.2	2.42
MW-5	101,686	107,571	6,844.3	2.04
MW-7	102,106	115,977	7,000.2	2.35
MW-10	107,747	111,968	6,650.6	2.15
MW-19	106,318	114,148	6,763.5	1.60
MW-20	103,064	108,264	6,777.3	2.10
MW-21	102,697	109,056	6,899.6	2.00

Table F-2 Surface Water Station Locations and Descriptions

Station Identification	Station Location	Description
SMI-EBG-5	East Fork Buckhorn	Grab sample from pool, composited from East Fork, Buckhorn Gulch
SMI-WBG-1	West Buckhorn Gulch	Grab sample from pool, composited from West Fork Buckhorn Gulch
SMI-SBG-1	West Buckhorn Gulch	Grab sample composited from seep at south end of west side Buckhorn Gulch
SMI-BG-11	Buckhorn Gulch	Grab sample composited from main stream of Buckhorn Gulch
SMI-ZH-1	Zinc Hill	Grab sample composited from south bank of East Zinc Pit
SMI-ZH-2	Zinc Hill	Grab sample composited from east bank of West Zinc Pit
SMI-FS-1	Fierro Spring	Grab sample composited from cement structure at Fierro Spring
SMI-HSN-1	Northside Hanover Mountain	Uphill of SMI-HSN-02, red staining at pool and many yards downstream
SMI-HSN-2	Northside Hanover Mountain	Grab sample composited from pool, drainage south of Fierro Spring
SMI-PS-1	Poison Spring	Grab sample composited directly from pipe
SMI-GAP-1	Gap Gulch	Grab sample composited from tiny fall in pool below
SMI-GRP-1	Grape Gulch	Grab sample composited from pool beneath tiny fall
SMI-TAIL-1A	Tailings Pond	Field blank
SMI-TAIL-1B	Tailings Backwater	Grab sample composited from south bank of tailings backwater in mouth of Poison Spring
SMI-TPS-1	Northside Tailings Pond	Grab sample composited from seep located on the north side of tailings pond near haul road
SMI-TPS-2	Tailings Seep near Vent Shaft	Grab sample composited from seep on northeast side of tailings pond near vent shaft
SMI-TPS-3	Tailings Pond	Grab sample composited from HDPE pipe coming from tailings pond
SMI-MDD-1	Drainage below Magnetite Dam	Grab sample composited from pool above swamp, upstream from SMI-MDD-02
SMI-MDD-2	Drainage below Magnetite Dam	Grab sample composited from middle of spring
SMI-EDSN-1	East Waste Rock Disposal Facility	Grab sample composited from seep flowing from northern side of east waste rock dump

Table F-3 Standard Operating Procedures

SOP #	Title
1	Equipment Decontamination
2	Monitoring Well Water Level Measurement
3	Ground Water Monitoring Well Installation
4	Monitoring Well Development
5	Ground Water Sample Collection
6	Surface Water Sample Collection and Discharge Measurement
7	Sample Documentation, Preservation, Handling, Packaging, and Chain of Custody
8	Mini-Piezometer Installation, Water Level Measurement, and Sampling
9	Field Parameter Instrument Calibration and Measurement
10	Visual Description and Classification of Unconsolidated Samples Obtained During Drilling
11	Visual Description and Classification of Bedrock Samples Obtained During Drilling
12	Pneumatic Piezometer Installation and Measurement

Table F-4 Monitoring Well Construction Summary

Well	Borehole Depth (feet)[1]	Bottom of Screen (feet)[1]	Top of Screen (feet)[1]	Top of Filter Pack (feet)[1]	Top of Bentonite Pellets (feet)[1]	Top of Bentonite Chip (feet)[1]	PVC Stickup (feet)[2]	Steel Casing Stickup (feet)[2]
MW-1	300	230	210	205	200	NA	2.67	2.67
MW-1A	80	70	40	37	35	NA	2.71	3.62
MW-2	235	230	210	205	200	NA	1.31	2.04
MW-3	155	150	130	125	124	NA	2.52	3.17
MW-4	225	200	175	170	167.5	NA	2.42	3.04
MW-5	255	250	230	225	221	NA	2.04	2.81
MW-7	70	70	51	47	44	NA	2.35	3.08
MW-10	40	40	10	8	6	NA	2.15	2.90
MW-19	28	24.4	14.0	13.3	11.0	N/A	1.60	2.40
MW-20	125	120.2	79.9	76.3	70.0	11.0	2.10	2.70
MW-21	90	88.4	58.0	54.8	52.0	10.4	2.00	2.60

Notes:

[1] Below ground surface

[2] Above ground surface

Table F-5 Water Level Measurement Data

Well	Date	Elevation Top of PVC	Depth To Water Below Top of PVC (feet)	Elevation of Water Table (feet)
MW-1	2/25/96	6,889.7	12.67	6,877
MW-1A	2/25/96	7,003.9	150.02	6,853.8
MW-2	2/25/96	6,658.1	29.8	6,628.3
MW-3	2/25/96	6,541.8	2.49	6,539.3
MW-4	2/25/96	6,768.2	158.2	6,610
MW-5	2/25/96	6,844.3	181.05	6,663.2
MW-7	2/25/96	7,000.2	21.92	6,978.2
MW-10	2/25/96	6,650.6	19.95	6,630.6
MW-19	6/11/96	6,763.5	19.36	6,744.1
MW-20	6/6/96	6,777.3	73.6	6,703.7
MW-21	6/11/96	6,899.6	83.2	6,816.4

Table F-6 June 1996 Ground Water Field Parameter Measurements

Well	Sample Date	Sample Time	pH	Conductivity (µS/cm)	Temperature (°C)	Turbidity (NTU)	Purge Volume (gallons)
MW-19	6/11/96	1230	6.90	2530	19.3	0.56	45
MW-20	6/11/96	1415	7.50	3000	17.2	95.1	24
MW-21	6/11/96	1500	6.33	4020	17.6	26.7	2

Table F-7 February 1996 Ground Water Field Parameter Measurements

Well	Sample Date	Sample Time	pH	Conductivity (µS/cm)	Temperature (°C)	Dissolved O_2 (mg/L)	Fe^{2+} (mg/L)	Eh (mV)	Turbidity (NTU)	Purge Volume (gallons)
MW-1	2/28/96	1108	9.28	280	13.4	2.0	0	90	4	Purged dry with dedicated pump
MW-1A	2/28/96	1040	7.27	860	14.9	1.5	0.02	70	1	Purged dry with dedicated pump
MW-2	2/26/96	1846	7.35	2310	7.2	1.5	0.23	-35	3	Purged dry with dedicated pump
MW-3	2/27/96	1720	7.06	1670	11.4	4.0	3.23	-35	37	Purged dry with dedicated pump
MW-4	2/26/96	1817	6.73	1090	10.2	2.5	3.65	-55	13	Purged dry with dedicated pump
MW-5	2/26/96	1515	6.65	1030	11.6	1.5	0.01	250	4	Purged dry with dedicated pump
MW-7a[1]	2/28/96	1149	7.31	1270	13.6	3.6	1.05	30	28	Purged dry with dedicated pump
MW-7b[1]	2/28/96	1149	7.45	1280	13.2	3.8	0.64	40	14	Purged dry with dedicated pump
MW-10	2/27/96	1815	7.00	1390	10.9	5.3	0.36	215	34	Purged dry with dedicated pump

Note: [1] MW-7A investigative sample, MW-7B duplicate sample collected at MW-7

Table F-8 Surface Water Field Parameter and Discharge Measurements

Station Identification	Sample Date	Sample Time	pH	Conductivity (µS/cm)	Temperature (°C)	Dissolved O_2 (mg/L)	Fe^{2+} (mg/L)	Eh (mV)	Turbidity (NTU)	Discharge (gpm)
SMI-EBG-5	2/23/96	1110	7.82	3040	12.8	8.4	0	NA	1	0
SMI-WBG-1	2/23/96	1150	8.00	3070	13.0	0	0.31	245	8	0
SMI-SBG-1	2/23/96	1235	8.24	2980	14.0	8.2	1.12	230	0	>0, <1
SMI-BG-11	2/23/96	1305	8.27	3020	11.2	8.3	0.57	220	1	0.412
SMI-ZH-1	2/23/96	1640	8.12	2570	9.4	9.3	0.31	245	2	0
SMI-ZH-2	2/23/96	1714	7.78	2600	8.7	9.6	0.16	245	1	0
SMI-FS-1	2/24/96	0930	7.21	565	9.8	1.6	0	255	1	<1
SMI-HSN-1	2/24/96	1120	4.83	850	7.9	3.5	41.1	135	131	0
SMI-HSN-2	2/24/96	1046	6.36	550	7.4	5.7	0.09	160	2	0
SMI-PS-1	2/24/96	1408	7.16	580	12.8	5.9	0	125	1	0.58
SMI-GAP-1	2/24/96	1530	8.09	550	8.8	9.6	0.09	145	33	<1
SMI-GRP-1	2/24/96	1625	7.00	470	8.5	7.5	0	185	1	<0.5
SMI-TAIL-1A	2/24/96	1713	5.87	000	9.3	7.7	0	190	0	NA
SMI-TAIL-1B	2/24/96	1740	7.09	3090	7.7	7.3	0.29	230	0	0
SMI-TPS-1	2/25/96	1000	7.56	3360	12.7	6.2	0.23	250	1	<5
SMI-TPS-2	2/25/96	1050	7.03	3400	13.3	2.3	0.14	285	0	<5
SMI-TPS-3	2/25/96	1125	7.56	3410	10.2	8.2	0.22	250	1	10
SMI-MDD-1	2/25/96	1335	7.45	3940	10.0	4.5	0.07	250	1	<1
SMI-MDD-2	2/25/96	1315	7.31	3680	12.5	9.0	0.26	245	1	
SMI-ESDN-1	2/27/96	1755	6.81	4220	5.0	10.5	0	185	37	0

Table F-9 Analytical Parameters, Methods, and Detection Limits

Analyte	EPA Method	Detection Limit (mg/L)
Alkalinity, Total	310.1	5
Aluminum, Dissolved	200.7	0.05
Aluminum, Total	200.7	0.05
Antimony, Dissolved	200.7	0.05
Antimony, Total	200.7	0.05
Arsenic, Dissolved	200.7	0.05
Arsenic, Total	200.7	0.05
Bicarbonate (as HCO_3^-)	310.1	5
Boron, Dissolved	200.7	0.1
Boron, Total	200.7	0.1
Cadmium, Dissolved	200.7	0.005
Cadmium, Total	200.7	0.005
Calcium, Dissolved	200.7	0.1
Calcium, Total	200.7	0.1
Carbonate (as CO_3^-)	310.1	5
Chloride	325.2	1
Chromium, Dissolved	200.7	0.005
Chromium, Total	200.7	0.005
Cobalt, Dissolved	200.7	0.005
Cobalt, Total	200.7	0.005
Copper, Dissolved	200.7	0.005
Copper, Total	200.7	0.005
Cyanide, Total	335.2/335.3	0.005
Fluoride	340.2	0.5
Hydroxide (as OH^-)	310.1	5
Iron, Dissolved	200.7	0.01
Iron, Total	200.7	0.01
Lead, Dissolved	200.7	0.05
Lead, Total	200.7	0.05
Magnesium, Dissolved	200.7	0.05
Magnesium, Total	200.7	0.05

Table F-9 Analytical Parameters, Methods, and Detection Limits (continued)

Analyte	EPA Method	Detection Limit (mg/L)
Manganese, Dissolved	200.7	0.005
Mercury, Dissolved	245.1	0.0001
Mercury, Total	245.1	0.0001
Molybdenum, Dissolved	200.7	0.005
Molybdenum, Total	200.7	0.005
Nickel, Dissolved	200.7	0.02
Nickel, Total	200.7	0.02
Nitrate + Nitrite	353.2	0.05
Potassium, Dissolved	200.7	0.5
Potassium, Total	200.7	0.5
Selenium, Dissolved	200.7	0.05
Selenium, Total	200.7	0.05
Silicon, Dissolved	200.7	0.5
Silicon, Total	200.7	0.5
Sodium, Dissolved	200.7	0.1
Sodium, Total	200.7	0.1
Sulfate (as SO_4)	375.4	10
TDS (at 180° C)	160.1	5
Vanadium, Dissolved	200.7	0.005
Vanadium, Total	200.7	0.005
Zinc, Dissolved	200.7	0.005
Zinc, Total	200.7	0.005
pH	150.1	0.1 units

Table F-10 Sample Preservation and Holding Times

Analyte	Holding Time (days)	Preservation Method
Alkalinity, Total	14	Cool to 4° C
Aluminum, Dissolved	180	Filtered, HNO_3 to pH <2, cool to 4°C
Aluminum, Total	180	HNO_3 to pH <2, cool to 4°C
Antimony, Dissolved	180	Filtered, HNO_3 to pH <2, cool to 4°C
Antimony, Total	180	HNO_3 to pH <2, cool to 4°C
Arsenic, Dissolved	180	Filtered, HNO_3 to pH <2, cool to 4°C
Arsenic, Total	180	HNO_3 to pH <2, cool to 4°C
Bicarbonate (as HCO_3^-)	14	Cool to 4° C
Boron, Dissolved	180	Filtered, HNO_3 to pH <2, cool to 4°C
Boron, Total	180	HNO_3 to pH <2, cool to 4°C
Cadmium, Dissolved	180	Filtered, HNO_3 to pH <2, cool to 4°C
Cadmium, Total	180	HNO_3 to pH <2, cool to 4°C
Calcium, Dissolved	180	Filtered, HNO_3 to pH <2, cool to 4°C
Calcium, Total	180	HNO_3 to pH <2, cool to 4°C
Carbonate (as CO_3^-)	14	Cool to 4° C
Chloride	28	Cool to 4° C
Chromium, Dissolved	180	Filtered, HNO_3 to pH <2, cool to 4°C
Chromium, Total	180	HNO_3 to pH <2, cool to 4°C
Cobalt, Dissolved	180	Filtered, HNO_3 to pH <2, cool to 4°C
Cobalt, Total	180	HNO_3 to pH <2, cool to 4°C
Copper, Dissolved	180	Filtered, HNO_3 to pH <2, cool to 4°C
Copper, Total	180	HNO_3 to pH <2, cool to 4°C
Cyanide, Total	14	NaOH to pH >12, cool to 4°C
Fluoride	28	Cool to 4° C
Hydroxide (as OH^-)	14	Cool to 4° C
Iron, Dissolved	180	Filtered, HNO_3 to pH <2, cool to 4°C
Iron, Total	180	HNO_3 to pH <2, cool to 4°C
Lead, Dissolved	180	Filtered, HNO_3 to pH <2, cool to 4°C
Lead, Total	180	HNO_3 to pH <2, cool to 4°C
Magnesium, Dissolved	180	Filtered, HNO_3 to pH <2, cool to 4°C

Table F-10 Sample Preservation and Holding Times (continued)

Analyte	Holding Time (days)	Preservation Method
Magnesium, Total	180	HNO_3 to pH <2, cool to 4°C
Manganese, Total	180	HNO_3 to pH <2, cool to 4°C
Mercury, Dissolved	28	Filtered, HNO_3 to pH <2, cool to 4°C
Mercury, Total	28	HNO_3 to pH <2, cool to 4°C
Molybdenum, Dissolved	180	Filtered, HNO_3 to pH <2, cool to 4°C
Molybdenum, Total	180	HNO_3 to pH <2, cool to 4°C
Nickel, Dissolved	180	Filtered, HNO_3 to pH <2, cool to 4°C
Nickel, Total	180	HNO_3 to pH <2, cool to 4°C
Nitrate + Nitrite	28	H_2SO_4 to pH <2, cool to 4°C
Potassium, Dissolved	180	Filtered, HNO_3 to pH <2, cool to 4°C
Potassium, Total	180	HNO_3 to pH <2, cool to 4°C
Selenium, Dissolved	180	Filtered, HNO_3 to pH <2, cool to 4°C
Selenium, Total	180	HNO_3 to pH <2, cool to 4°C
Silicon, Dissolved	180	Filtered, HNO_3 to pH <2, cool to 4°C
Silicon, Total	180	HNO_3 to pH <2, cool to 4°C
Sodium, Dissolved	180	Filtered, HNO_3 to pH <2, cool to 4°C
Sodium, Total	180	HNO_3 to pH <2, cool to 4°C
Sulfate (as SO_4)	28	Cool to 4° C
TDS (at 180° C)	7	Cool to 4° C
Vanadium, Dissolved	180	Filtered, HNO_3 to pH <2, cool to 4°C
Vanadium, Total	180	HNO_3 to pH <2, cool to 4°C
Zinc, Dissolved	180	Filtered, HNO_3 to pH <2, cool to 4°C
Zinc, Total	180	HNO_3 to pH <2, cool to 4°C
pH	immediate	Cool to 4° C

Table F-11 Field Quality Assurance/Quality Control Sample Summary

Sample Identification	Sample Date	Sample Time	Comments
SMI-TAIL-01A	2/24/96	1713	Rinsate collected at tailings pond from decontaminated sample bucket with deionized water supplied by Accu-Labs
SMI-MW-7B	2/28/96	1149	Duplicate sample collected at MW-7
MW-19-02-960611	6/11/96	1235	Duplicate sample collected at MW-19
MW-19-03-960611	6/11/96	1305	Field blank collected at MW-19 with distilled water
MW-19-04-960611	6/11/96	1130	Rinsate sample collected at MW-19 from Redi-Flo2 with distilled water

Table F-12 Field Duplicate Data

Analyte	SMI-MW-7A	SMI-MW-7B	RPD	MW-19-01-960611	MW-19-02-960611	RPD
Alkalinity, Total	22	290	172	180	270	40
Aluminum, Dissolved	<0.050	<0.050	UDL	<0.10	<0.10	UDL
Aluminum, Total	0.90	0.46	65	<0.10	<0.10	UDL
Antimony, Dissolved	<0.05	<0.05	UDL	<0.05	<0.05	UDL
Antimony, Total	<0.05	<0.05	UDL	<0.05	<0.05	UDL
Arsenic, Dissolved	<0.05	<0.05	UDL	0.003	0.003	0
Arsenic, Total	<0.05	<0.05	UDL	<0.005	<0.005	UDL
Bicarbonate (as HCO_3^-)	27	350	171	220	330	40
Boron, Dissolved	<0.1	<0.1	UDL	<0.1	<0.1	UDL
Boron, Total	<0.1	<0.1	UDL	<0.1	<0.1	UDL
Cadmium, Dissolved	<0.005	<0.005	UDL	<0.005	<0.005	UDL
Cadmium, Total	<0.005	<0.005	UDL	<0.005	<0.005	UDL
Calcium, Dissolved	220	220	0	450	350	25
Calcium, Total	210	220	4.6	420	420	0
Carbonate (as CO_3^-)	<5	<5	UDL	<5	<5	UDL
Chloride	190	11	178	340	23	175
Chromium, Dissolved	<0.005	<0.005	UDL	<0.005	<0.005	UDL
Chromium, Total	0.006	0.005	18	<0.005	<0.005	UDL
Cobalt, Dissolved	<0.005	<0.005	UDL	<0.005	<0.005	UDL
Cobalt, Total	<0.005	<0.005	UDL	<0.005	<0.005	UDL
Copper, Dissolved	<0.005	<0.005	UDL	0.042	0.029	37
Copper, Total	0.12	0.061	65	0.038	0.039	2.6
Cyanide, Total	<0.005	<0.005	UDL	<0.005	<0.005	UDL
Fluoride	<0.5	<0.5	UDL	<0.5	1.5	UDL
Hydroxide (as OH^-)	<5	<5	UDL	<5	<5	UDL
Iron, Dissolved	0.63	0.44	35	<0.01	<0.01	UDL
Iron, Total	2.0	1.2	50	<0.01	<0.01	UDL
Lead, Dissolved	<0.05	<0.05	UDL	<0.005	<0.005	UDL
Lead, Total	<0.05	<0.05	UDL	<0.005	<0.005	UDL
Magnesium, Dissolved	34	34	0	110	88	22
Magnesium, Total	33	33	0	100	100	0
Manganese, Dissolved	0.81	0.81	0	0.31	0.24	25
Manganese, Total	0.80	0.80	0	0.28	0.28	0

Table F-12 Field Duplicate Data (continued)

Analyte	SMI-MW-7A	SMI-MW-7B	RPD	MW-19-01-960611	MW-19-02-960611	RPD
Mercury, Total	<0.0001	<0.0001	UDL	<0.0001	<0.0001	UDL
Molybdenum, Dissolved	0.38	0.38	0	0.080	0.067	18
Molybdenum, Total	0.38	0.38	0	0.080	0.085	6.1
Nickel, Dissolved	0.02	0.02	0	<0.01	0.01	UDL
Nickel, Total	0.03	0.02	40	0.01	<0.01	UDL
Nitrate + Nitrite	6.7	<0.05	UDL	NA	NA	NA
Potassium, Dissolved	3.1	3.2	3.2	7.8	5.7	31
Potassium, Total	3.5	3.1	12	6.8	6.8	0
Selenium, Dissolved	<0.05	<0.05	UDL	<0.010	<0.010	UDL
Selenium, Total	<0.05	<0.05	UDL	<0.050	<0.050	UDL
Silicon, Dissolved	15	15	0	13	10	26
Silicon, Total	16	15	6.4	12	12	0
Sodium, Dissolved	38	38	0	76	58	27
Sodium, Total	37	37	0	67	68	1.5
Sulfate (as SO_4)	1600	420	117	1100	3000	93
TDS (at 180°C)	2600	940	94	2500	4500	57
Vanadium, Dissolved	<0.005	0.005	UDL	0.006	0.005	18
Vanadium, Total	0.005	<0.005	UDL	0.005	0.005	0
Zinc, Dissolved	0.007	<0.005	UDL	0.32	0.26	21
Zinc, Total	0.087	0.049	56	0.28	0.28	0
pH	7.2	7.1	1.4	6.3	6.2	1.6

Note: UDL Under Detection Limit

APPENDIX F

GROUND AND SURFACE WATER DATA REPORT FOR SAMPLING EVENTS IN FEBRUARY AND JUNE 1996

Prepared for:
Cobre Mining Company, Inc.
c/o Chino Mines
No.14 Chino Boulevard
Hurley, New Mexico 88043

Prepared by:
Shepherd Miller, Inc.
3801 Automation Way, Suite 100
Fort Collins, Colorado 80525

December 1999

SHEPHERD MILLER
INCORPORATED

APPENDIX F

GROUND AND SURFACE WATER DATA REPORT FOR SAMPLING EVENTS IN FEBRUARY AND JUNE 1996

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1.0 INTRODUCTION

This report presents construction, development, and sampling data from new monitoring wells as well as ground and surface water data collected at other wells and stations by Shepherd Miller, Inc. (SMI) at the Cobre Mining Company, Inc. (Cobre) Continental Mine located in Hanover, New Mexico.

1.1 Project Description

Cobre proposes to expand its existing Continental Mine operations onto lands administered by the Mimbres Resource Area of the Bureau of Land Management (BLM). Expansion activities would be conducted under a proposed amendment to the currently approved 1993 Plan of Operations. BLM determined that preparation of an environmental assessment (EA) and an environmental impact statement (EIS) would be necessary before the expansion could be approved. Thus, Cobre contracted with SMI to collect data required to support the hydrologic sections of these documents.

1.1.1 Mining Copper Ore

The area included within the existing Continental Mine operations has produced commercial amounts of copper since 1858. Currently, Cobre is engaged in mining ore using both underground and open pit mining methods. The primary production metal recovered is copper, and by-products include zinc, silver, gold, and magnetite.

1.1.1.1 Underground

Existing underground operations are located immediately beneath the office area, the north portion of the tailings impoundment, and the northwest section of the Continental Pit. Underground workings are located approximately 750 to 1,400 feet below ground surface (BGS) and include an underground crushing facility, underground shops, and associated maintenance facilities. Copper ore is obtained by drilling and blasting selected ore blocks using the room and pillar method of mining.

1.1.1.2 Open Pit

Ore is currently mined from the Continental Pit at an approximate rate of 10,000 tons per day using conventional drilling, blasting, excavation, and hauling methods to move ore and waste from the active mining area.

1.1.2 Processing

On-site processing includes ore crushing, flotation/separation, tailings disposal, and waste rock disposal.

1.1.2.1 Ore Crushing

Ore collected underground is initially crushed in the underground jaw crusher prior to hoisting to the surface. Ore collected from the open pit is initially crushed in the primary jaw crusher located near the pit or is hauled directly to the Pioneer Crusher, located near the No. 1 Mill. After the ore is crushed, it is delivered to either the No. 1 or No. 2 Mill for grinding in autogenous grinding circuits.

1.1.2.2 Flotation/Separation

Finely ground ore is then processed through the first stage (rougher) flotation, which consists of passing the ore through a series of tanks. Each tank is equipped with a mechanism that agitates the ore slurry and induces air into the ore pulp. Reagents are added to the pulp to cause the copper-bearing mineral particles to adhere to bubbles created by the induced air and frothing agents. The copper-bearing bubbles rise to the top of the cell and are skimmed off. The resulting copper concentrate is dewatered in a settling facility and transported off-site to the Hurley, Hildago, or San Manuel smelters. No smelting or refining is currently conducted at the Continental Mine site.

1.1.2.3 Tailings Disposal

Following the flotation process, the remaining slurry, which consists primarily of non-valuable gangue minerals, pyrite, magnetite, miscellaneous unfloated minerals, and water, is pumped to the tailings impoundment. The tailings solids settle out in the impoundment and the decant water that remains on the surface is recycled back to the mills for re-use in the flotation process.

1.1.2.4 Waste Rock Disposal

Two waste rock disposal facilities are currently in use at the Continental Mine - the South Waste Rock Disposal Facility and the West Waste Rock Disposal Facility.

1.2 Ground and Surface Water Sample Locations

The baseline data collection effort included both ground and surface water sample collection. SMI has conducted two sample collection events at the site; one in February 1996 and one in June 1996. In February, 29 samples were collected and analyzed. These 29 samples included nine ground water samples from eight wells (one duplicate sample) and 20 surface water samples from 19 locations (one rinsate sample). In June, six samples, including a duplicate, rinsate, and field blank samples, were collected from three new monitoring wells (MW-19, MW-20 and MW-21). Both ground and surface water station locations are presented in Figure F-1. Table F-1 presents monitoring well survey data, and Table F-2 presents surface water station locations.

1.3 Standard Operating Procedures

In order to provide guidance and standardize procedures, Standard Operating Procedures (SOPs) have been prepared. Table F-3 lists the SOPs used during this project. Attachment F.1 presents hard copies of these SOPs.

2.0 MONITORING WELL DRILLING AND CONSTRUCTION

The general borehole drilling and monitoring well construction and development for the new monitoring wells (MW-19, MW-20, and MW-21) as discussed in this section, were performed according to SOP #3, Ground Water Monitoring Well Installation, and SOP #4, Monitoring Well Development.

2.1 Borehole Drilling and Sampling

Boreholes were drilled using air rotary drilling, air/water mist circulation drilling methods, and down-the-hole hammers and tricone bits.

2.1.1 Drilling Procedures

Before drilling each borehole, all downhole equipment was decontaminated following the procedures specified in Section 8.1. Bestolife GGT/Silicone thread compound and pure vegetable oil were the only lubricants used during drilling.

Steel surface conductor casing was installed and cemented in place with Type I-II Portland Cement.

2.1.2 Borehole Sampling

Drill cuttings were continuously observed and grab samples were retained in plastic chip trays. Cuttings samples were described following procedures specified in SOP #10, Visual Description and Classification of Unconsolidated Samples Obtained During Drilling, and SOP # 11, Visual Description and Classification of Bedrock Samples Obtained During Drilling. Borehole logs for MW-19, MW-20, and MW-21 are presented in Attachment F.2.

2.2 Monitoring Well Construction

Table F-4 presents monitoring well construction data for the three new wells installed by SMI in June 1996 and the eight existing monitoring wells. Monitoring well construction diagrams for the new monitoring wells are presented in Attachment F.2.

2.2.1 Well Construction Materials

Monitoring wells MW-19, MW-20, and MW-21 were constructed from Johnson Wheelabrator Schedule 40, 2-inch- or 4-inch-diameter flush threaded polyvinyl chloride (PVC) pipe and 0.020-inch slotted PVC well screen. Threaded PVC end caps and stainless steel centralizers were attached to the well screen. The filter pack consisted of 10-20 Colorado Silica Sand. Pel-Plug #30, 1/4-inch coated bentonite pellets and Pure Gold Medium bentonite chips were used to backfill and seal the annulus. A steel protective casing with a lockable cap and cement pad was used to complete the wells at ground surface.

2.2.2 Well Construction Methods

The PVC pipe was removed from the factory boxes and plastic sleeves and installed in the completed borehole. A threaded PVC cap was attached to the bottom of the PVC slotted screen, and stainless steel centralizers were attached at the top and bottom of the screened interval before installation in the borehole. The PVC pipe was carefully lowered into the borehole to the design depth and supported at the surface throughout well construction. The filter pack was installed through and measured with a 1¼-inch PVC tremmie pipe. Bentonite pellets and bentonite chips were installed directly down the annulus and were hydrated with potable water. A cement-bentonite grout was installed from the top of the bentonite to the ground surface. Protective steel casing with a lockable cap and cement pad were installed. Cement was installed in the annulus to above the level of the cement pad, and a weep hole was drilled in the protective casing above the cement to allow drainage to occur. The wells were constructed according to

SOP #3, Ground Water Monitoring Well Installation, and well construction data were recorded in the field log book.

2.2.3 Well Development Methods

Monitoring wells were developed by surging, back flushing, and overpumping, as specified in SOP #4, Monitoring Well Development. Development data were recorded in either the field log book or on a Monitoring Well Development Data Sheet (see SOP #4, Attachment F.1), as appropriate.

2.2.4 MW-19 Drilling, Construction, and Development Summary

To construct MW-19, a 10-inch nominal diameter borehole was drilled to 12.8 feet below ground surface (BGS), and 12.6 feet of 8-inch inside diameter (ID) 1/8-inch thick wall steel conductor casing was cemented in-place. An 8-inch borehole was then advanced to 28.0 feet BGS. Bedrock was encountered at 25 feet BGS. Water was first observed during drilling when a drill rod was added at 25 feet BGS.

Monitoring well MW-19 was constructed from Schedule 40, 4-inch PVC pipe. Due to the shallow depth of MW-19, a tremmie pipe was not used for filter pack installation. The bentonite seal was constructed from bentonite pellets; chip bentonite was not used due to the shallow depth of MW-19.

Monitoring well MW-19 was developed by repeated surging and backwashing, followed by overpumping. A 3.5-inch PVC bailer and nylon rope were used to surge the well. A Redi-Flo2 pump without a check valve was then used to backwash and pump the well. Surging and backwashing were repeated three times until sand production ceased. The well was then overpumped until field parameters stabilized. The maximum continuous pumping rate the well was able to sustain was 1.25 gallons per minute (GPM).

2.2.5 MW-20 Construction Summary

To construct MW-20, a 12-inch nominal diameter borehole was drilled to 12.0 feet BGS, and 12.0 feet of 8-inch ID 1/8-inch-thick wall steel conductor casing was cemented in-place. A 6⅞ – inch borehole was then advanced to 125.0 feet BGS. Bedrock was encountered at 1 foot BGS. At 65 feet BGS, moist cuttings were observed, but no water was produced. At 125 feet BGS, small amounts of water (i.e., 2 to 3 gallons) were produced after 40 minutes. A water level of 58.2 feet BGS was measured the next morning. The moist zone at 65 feet BGS and a possible fracture at 85 feet BGS were the only indications during drilling of possible sources of free water.

Monitoring well MW-20 was constructed from Schedule 40, 2-inch PVC pipe. A filter pack was installed through a tremmie pipe with about 40 gallons of potable water to facilitate sand placement. The bentonite seal was constructed from bentonite pellets and medium chip bentonite.

Monitoring well MW-20 was developed by repeated surging and backwashing, followed by overpumping. A 5-foot-long, 1.85-inch PVC bailer and new nylon rope were used to surge the well. A Redi-Flo2 pump without a check valve was then used to pump and backwash the well until it was dry. Surging and backwashing were repeated four times until a total of about 100 gallons had been purged. MW-20 did not sustain a steady pumping rate and could be easily dewatered with a Redi-Flo2 pump.

2.2.6 MW-21 Construction Summary

To construct MW-21, a 12-inch nominal diameter borehole was drilled to 10.0 feet BGS, and 10.0 feet of 8-inch ID 1/8-inch-thick wall steel conductor casing was cemented in-place. A 6⅞ – inch borehole was then advanced to 90.0 feet BGS. Bedrock was encountered at 41.0 feet BGS. At 63 feet BGS, moist cuttings were produced, and observable water was produced at 65 feet BGS. Beyond 65 feet BGS, water injection was required for drilling, so minor water-producing zones could not be detected. At 84 feet BGS, a fracture or soft spot was observed by the driller. No significant amounts of water were produced at the total depth of 90 feet BGS. The moist cuttings and water at approximately 63 feet BGS and a possible fracture at 84 feet BGS were the only indications during drilling of possible sources of free water. MW-21 was constructed immediately following drilling; therefore, a stabilized open borehole water level was not available.

Monitoring well MW-21 was constructed from Schedule 40, 2-inch PVC pipe. Filter pack was installed dry through a tremmie pipe. The bentonite seal was constructed from bentonite pellets and medium chip bentonite.

Monitoring well MW-21 was developed by repeated surging and evacuation with a bailer. A 3-foot-long, 1.85-inch stainless steel bailer and nylon rope were used to surge and purge the well seven times to produce 13.5 gallons of water. MW-21 did not sustain a steady pumping rate and could be easily dewatered with a bailer.

3.0 GROUND WATER SAMPLE COLLECTION

Ground water samples were collected from a total of 11 wells during the February and June 1996 sample collection events.

3.1 Ground Water Sample Collection Procedures

Ground water sample collection procedures are presented in SOP #5, Ground Water Sample Collection. These procedures included water level measurement, purge volume calculations, and field parameter measurements.

3.1.1 Water Level Measurement

Ground water levels in the monitoring wells were measured following procedures specified in SOP #2, Monitoring Well Water Level Measurement. Water level data are presented in Table F-5.

3.1.2 Purge Volume Calculations

Purge volumes were calculated as specified in SOP #5, Ground Water Sample Collection, for each well. All wells except MW-19 were purged dry and sampled when there was sufficient recovery. More than five saturated borehole volumes were purged from MW-19 before samples were collected.

3.1.3 Field Parameter Measurement

Field parameters for ground water samples were measured according to SOP #9, Field Parameter Instrument Calibration and Measurement. Field parameter measurements of the ground water samples are presented in Tables F-6 and F-7. Concentrations of dissolved oxygen, iron, and Eh were not measured during the June sampling event because geochemical evaluation of the samples was not planned.

3.2 MW-19 Sample Collection

MW-19 was purged and sampled with a Redi-Flo2 pump. The pump was installed at the bottom of the well, and the well was initially purged at a high rate to dewater the well. The pumping rate was then reduced to 1.25 GPM, and the well was pumped continuously until field parameters stabilized. The pumping rate was further reduced to produce a non-turbulent flow, and pumping continued until an additional 3 gallons of water were purged. Sample bottles were filled directly from the pump discharge. A disposable 0.45-micron filter was attached directly to the pump discharge for sample filtration.

3.3 MW-20 Sample Collection

MW-20 was purged dry at 3:30 p.m. on June 10, 1996 with a Redi-Flo2 pump with check valve installed. A 5-foot-long, 1.85-inch PVC bailer and new nylon rope were then used to purge the water remaining in the well. The well was sampled with the same bailer at 2:15 p.m. on June 11, 1996. Bailed sample water was composited into a 2.5-gallon plastic bucket and then poured into the sample bottles. Sample filtration was accomplished with a hand-powered peristaltic pump, Tygon® tubing, and a disposable 0.45-micron filter.

3.4 MW-21 Sample Collection

MW-21 was purged dry with a 1.85-inch stainless steel bailer and new nylon rope at 7:30 a.m. on June 11, 1996. The well was sampled with the same bailer on the same day at 3:00 p.m. Bailed sample water was composited into a 2.5-gallon plastic bucket and then poured into the sample bottles. Sample filtration was accomplished with a hand-powered peristaltic pump, Tygon® tubing, and a disposable 0.45-micron filter.

3.5 Existing Monitoring Wells

During the February sampling event, monitoring wells MW-1, MW-1A, MW-2, MW-3, MW-4, MW-5, MW-7, and MW-10 were sampled. Each well, with the exception of

MW-1A, was purged dry with dedicated submersible pumps, allowed to recover, and then were sampled. MW-1A was pumped at its maximum sustainable flow rate with the dedicated submersible pump until three pore volumes had been removed and field parameters stabilized. For all wells, the samples were pumped into a 1-gallon container from which sample bottles were filled. Sample filtration was accomplished with a 12-volt peristaltic pump, Tygon® tubing and a disposable 0.45-micron filter.

3.6 Ground Water Levels

Since monitoring wells MW-19, MW-20, and MW-21 have been installed, four water level measurements have been taken. Figure F-2 shows the water level elevations over time for these three wells. The water levels are stable at elevations of approximately 6,728, 6,668 and 6,728 feet in monitoring wells MW-19, MW-20, and MW-21, respectively.

4.0 MINI-PIEZOMETER AND ASSOCIATED BOREHOLE (MW-22)

To investigate the ground water gradient, a borehole was drilled into the bedrock, and a mini-piezometer was installed in the alluvium. Borehole MW-22 was drilled to 85 feet BGS. After an overnight break, a trickle of water that quickly dried up was observed at 45 feet BGS, although there was no indication of water during drilling. Water injection started at 45 feet BGS and continued to total depth. During this interval, no water production was observed. The estimated static water level of 29.8 ft. BGS was measured on June 12, 1996.

The hand-driven mini-piezometer is 10.45 feet long with 5.45 feet of 0.020-inch slotted stainless steel screen and 5.0 feet of galvanized riser pipe. The mini-piezometer was driven to 8.05 feet BGS with a stick-up of 2.40 feet. Details of the mini-piezometer installation and use are given in SOP #8, Mini-Piezometer Installation, Water Level Measurement, and Sampling. A water level was not measured in this mini-piezometer.

5.0 PNEUMATIC PIEZOMETERS

Three pneumatic piezometers (PP-01, PP-02, and PP-05) were installed around the perimeter of Hanover Mountain in November 1996. However, only one measurement was taken at PP-05 (November 23, 1996) because of a malfunction of the downhole hardware. Figure F-1 shows the locations of the piezometers.

Each piezometer was installed in an open borehole drilled to a desired depth. A small diameter PVC casing was installed with tubing, and the pneumatic pressure transducers were attached with tape to the outside. The open borehole was backfilled with a cement-bentonite (2 percent by weight) grout, totally encasing the entire assembly. The pneumatic piezometer installation and methods of measurement are discussed more completely in SOP # 12, Pneumatic Piezometer Installation and Measurement.

Hydraulic conductivities were estimated at each pneumatic transducer. A hydraulic conductivity was estimated for each location by taking the geometric mean of the hydraulic conductivities at each transducer. The estimated hydraulic conductivities are given below:

PP-01	$K = 1.0 \times 10^{-5}$ cm/s
PP-02	$K = 7.1 \times 10^{-7}$ cm/s
PP-05	$K = 1.6 \times 10^{-5}$ cm/s.

6.0 SURFACE WATER SAMPLE COLLECTION

6.1 Field Parameters and Discharge Measurement

Field parameters and discharge (where applicable) were measured at the time of surface water sample collection. Field parameters were measured following procedures presented in SOP #9, Field Parameter Instrument Calibration and Measurement. Surface water discharge was measured according to SOP #6, Surface Water Sample Collection and Discharge Measurement. Surface water discharge was measured with a cutthroat flume at SMI-BG-11, and a bucket and stopwatch were used to measure discharge at SMI-PS-1. All other discharges were estimated due to low discharge rates and/or dispersed flow. Table F-8 presents surface water field parameters and discharge measurements.

6.2 Surface Water Sample Collection Procedures

Surface water samples were collected according to SOP #6, Surface Water Sample Collection and Discharge Measurement. Samples were collected by compositing grab samples in a 1-gallon plastic container. Sample bottles were then filled from the container.

7.0 ANALYTICAL METHODOLOGY

All samples were analyzed by Accu-Labs Research Inc., which is located in Golden, Colorado.

7.1 Analytical Parameters, Methods, and Detection Limits

Analytical parameters, methods, and detection limits are summarized in Table F-9. Nitrate plus nitrite was eliminated from the parameter list for the June 1996 sampling event because all previous nitrate plus nitrite concentrations complied with New Mexico drinking water standards.

7.2 Sample Preservation and Holding Times

Sample preservation and holding times are presented in Table F-10.

7.3 Analytical Results

Analytical results for the February 1996 surface water sampling event are presented in Attachment F.3. Analytical results for the February 1996 ground water sampling event are presented in Attachment F.4. Analytical results for the June 1996 sampling event are presented in Attachment F.5.

8.0 QUALITY ASSURANCE/QUALITY CONTROL

Quality assurance/quality control (QA/QC) procedures include: decontamination, sample documentation (handling, packaging, and chain of custody procedures), and field parameter instrument calibration and measurement. Both field and laboratory QA/QC samples were analyzed to evaluate the reliability and potential bias of the investigative samples. QA/QC samples included field duplicates, field blanks, rinsate samples, laboratory matrix spikes, and laboratory replicate samples. Table F-11 summarizes the field QA/QC samples that were collected.

8.1 Decontamination

In order to minimize sample bias and prevent cross contamination, all equipment and materials that contacted samples were decontaminated before their initial use and between use at each sample site. New equipment, such as disposable filters that were certified to be clean by the manufacturer, were not decontaminated. Sampling equipment were decontaminated following procedures presented in SOP #1, Equipment Decontamination. These procedures are summarized below.

- Gross contamination was removed from equipment at the sampling or construction site.
- Equipment that water would not damage was sprayed with a Liquinox/potable water solution contained within a garden sprayer and then scrubbed with a bristle brush or similar utensil if necessary.
- The equipment was triple rinsed with potable water using a second garden sprayer to remove the Liquinox solution.
- The equipment was then triple rinsed with deionized water from a garden sprayer or laboratory wash bottles and allowed to air dry (if possible).

Downhole drilling equipment was steam-cleaned with Liquinox and potable water followed by a potable water rinse.

8.2 Sample Documentation, Handling, Packaging, and Chain of Custody

Sample documentation, handling, packaging, and chain of custody procedures are specified in SOP #7, Sample Documentation, Preservation, Handling, Packaging, and Chain of Custody. Sample custody was documented throughout sample collection and laboratory analysis. Chain of custody records are presented in Attachment F.6.

8.3 Field Parameter Instrument Calibration and Measurement

Field parameter instrument calibration and measurement procedures are presented in SOP #9, Field Parameter Instrument Calibration and Measurement. The pH, conductivity, and turbidity meters were calibrated daily before use and checked throughout the day as necessary to verify accuracy. Calibration data were recorded either in a field log book or on field data sheets, as appropriate.

8.4 Field Quality Assurance/Quality Control Samples

Field QA/QC samples are used to identify potential sources of sample contamination and evaluate potential error introduced by sample collection and handling. All field QA/QC samples collected in June 1996 were labeled with QA/QC identification numbers (i.e., "02" for duplicate samples, "03" for field blanks, "04" for rinsate samples, and "MS" for matrix spike samples) and then sent to the laboratory with the primary samples for analysis. The one exception is SMI-MW-7B which was a duplicate but was not identified with a "02". Field QA/QC sample collection procedures are specified in SOP #5, Ground Water Sample Collection, and SOP #6, Surface Water Sample Collection and Discharge Measurement. Table F-11 summarizes the field QA/QC samples, and QA/QC analytical data is presented in Attachment F.6.

8.4.1 Duplicate Sample

To check for the natural sample variance and consistency of field techniques and laboratory analyses, duplicate samples were collected side-by-side with primary samples.

Primary sample bottles were filled first, and the duplicate sample bottles for the same analysis were filled next until all necessary sample bottles had been filled. New filter and tubing were used to collect the duplicate samples. Duplicate samples were handled in the same manner as primary samples.

The analytical results and duplicate relative percent difference (RPD) for the field samples are presented in Table F-12. The RPD is defined as:

$$\text{RPD} = \left[\frac{(sample - duplicate)}{\left(\dfrac{sample + duplicate}{2} \right)} \right] \text{X } 100$$

The RPDs for most analytes were typically 30 percent or less, indicating acceptable agreement between the two analyses. Alkalinity, bicarbonate (as HCO_3^-), chloride, sulfate, and total dissolved solids (TDS) RPDs exceeded 30 percent in both sets of primary-duplicate samples. The RPD for the set of primary-duplicate samples for MW-7 exceeded 30 percent for total aluminum, total copper, total and dissolved iron, total nickel, and total zinc. The RPD for the set of primary-duplicate samples for MW-19 exceeded 30 percent for dissolved copper and dissolved potassium. Out of 220 analyses, only 18 RPDs exceeded the 30 percent RPD standard. The low number of exceedances indicate that the precision of the analyses is generally acceptable.

8.4.2 Field Blank Sample

Field blank samples are used to assess the potential sample bias due to field conditions, such as airborne dust. A field blank was collected by filling sample containers in the field with distilled water from the same source that was used for decontamination. One field blank sample (MW-19-03-960611) was collected during the June sampling event.

The results for the field blank sample show that very few analytes were detected. Only TDS, total calcium, total magnesium, and total sodium exceeded their analytical detection limits. These results are not indicative of significant field contamination.

8.4.3 Equipment Rinsate Sample

Equipment rinsate samples are collected to check if decontamination procedures are effective. During ground water sampling of the three new wells (June 1996), a rinsate sample was collected from the Redi-Flo2 submersible pump in MW-19 by transferring the final distilled water rinse that was pumped through the discharge hose to sample bottles. The rinsate sample was assigned the QA/QC sample identification number “04”. A rinsate sample was not collected when sampling the existing wells because dedicated pumps are installed in those wells, and no equipment was decontaminated during sample collection. During surface water sample collection for the February 1996 sampling event, a rinsate sample was collected from the decontaminated bucket used to collect and composite the surface water sample.

For the surface water rinsate sample, TDS, boron, and total sodium were the only parameters that exceeded their detection limits. For the ground water rinsate sample, total and dissolved calcium, total and dissolved sodium, total cobalt, total and dissolved copper, total iron, total and dissolved zinc, alkalinity, and bicarbonate were the only parameters that exceeded the detection limit or the associated field blank result. Of these parameters, only total and dissolved copper, total and dissolved zinc, and total and dissolved calcium concentrations are noticeably higher than their detection limits. These results are not indicative of significant field contamination.

8.5 Laboratory Quality Assurance/Quality Control

Laboratory QA/QC samples included matrix spike (MS) samples, laboratory replicate samples, and calibration verification. The laboratory QA/QC sample data are summarized on the QA/QC Data Sheets presented in Attachment F.6.

8.5.1 Matrix Spike Sample

MS samples are laboratory QA/QC samples used to evaluate potential matrix effects on sample analyses for all inorganic parameters. For the sampling events, matrix spike samples were split from an existing sample by the laboratory. Spikes of known concentration were added to the matrix spike sample and the percent recovery was calculated. The percent recovery was between 70 and 125 percent for all parameters.

8.5.2 Laboratory Replicate Sample

For the sampling events, laboratory replicate samples were split from the primary sample in the laboratory and analyzed as part of the laboratory's QA/QC program. The RPDs for all parameters of the two laboratory replicate samples did not exceed 10 percent.

8.5.3 Calibration Verification

The laboratory analyzes a sample of known concentration as a calibration verification as part of the laboratory QA/QC program. For both sampling events, the percent recovery for the calibration verification fell within 90 to 110 percent for all parameters.