

APPENDIX A

ABBREVIATIONS AND ACRONYMS COMMONLY USED IN BUREAU OF RECLAMATION ENGINEERING GEOLOGY

AGC	automatic gain control
AN	ammonium nitrate
A-S	anti-spoofing
ASCE	American Society of Civil Engineers
ASTM	American Society for Testing Materials
ATF	Bureau of Alcohol, Tobacco, and Firearms
AVIRIS	Airborne Visible and Infrared Imaging Spectrometer
BIPS	Borehole Image Processing System
bpf	blow per foot
bpm	blow per minute
BPSK	bi-phase shift keyed
BPT	Becker Penetration Test
C/A	coarse/acquisition
CDP	common depth point
CFR	Code of Federal Regulations
cm	centimeter
cm ²	centimeter squared
CME	Central Mine Equipment
cm/sec	centimeter per second
CPE	Circular Probable Error
CPT	Cone Penetration Test
CPTU	piezometric cones or piezocones
CRR	cyclic resistance ratio
DGPS	differential GPS

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DoD	U.S. Department of Defense
DOP	dilution of precision
DOT	Department of Transportation
DS13	<i>U.S. Bureau of Reclamation Design Standard No. 13 for Embankment Dams</i>
EBW	exploding bridge wire
EHE	expected horizontal error
EM	electromagnetic
EPE	expected position error
ERi	drill rod energy ratio
ETE	expected time error
EVE	expected vertical error
FoM	Figure of Merit
F_r	friction ratio
f_s	sleeve resistance
ft	feet
ft/sec	feet per second
ft ³ /min	cubic feet per minute
ft ³ /sec	cubic feet per second
gal/min	gallons per minute
GDOP	geometric dilution of precision
g/cm ³	grams per cubic centimeter
GPR	ground penetrating radar
GPS	Global Positioning System
HDOP	horizontal dilution of precision
HSA	hollow-stem auger
ICE	International Construction Equipment
ID	inside diameter
IME	Institute of Makers of Explosives
in	inch

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in/sec	inch per second
JPL	Jet Propulsion Laboratory
kg	kilogram
kg/cm ² /m	kilograms per square centimeter per meter
kg/L	kilogram per liter
kg/m ³	kilogram per cubic meter
kHz	kilohertz
km	kilometer
kPa	kilopascal
L	liter
lb/ft ³	pounds per cubic foot
lb/in ²	pounds per square inch
lb/gal	pounds per gallon
lb/yd ³	pounds per cubic yard
LEDC	low-energy detonating cord
L/min	liter per minute
L/min/m	liter per minute per meter
lu	Lugeon
LVL	low-velocity layer
m	meter
m ²	square meters
MHz	megahertz
mL	milliliter
mm	millimeter
mm/sec	millimeters per second
m/sec	meters per second
m ³ /sec	cubic meters per second
ms	millisecond
MSHA	Mine Safety and Health Administration

FIELD MANUAL

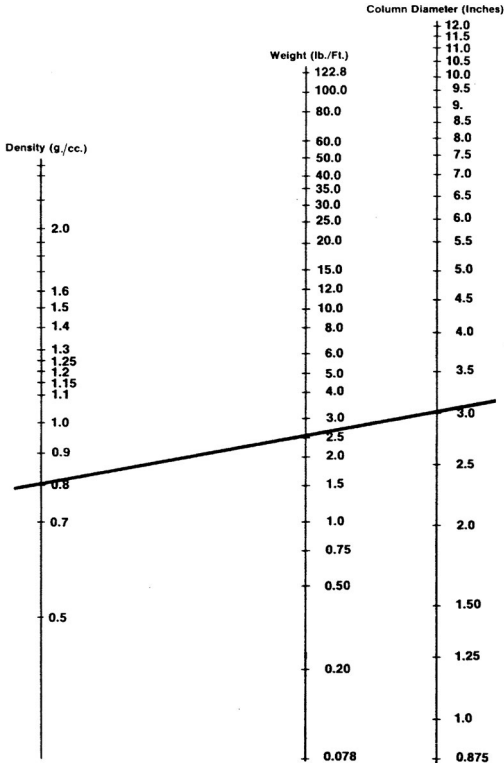
MSS	multispectral scanner
NAD27	1927 North American Datum
NAD83	1983 North American Datum
NASA	National Aeronautics and Space Administration
NAV	navigation
NAVSTAR	Navigation Satellite Time and Ranging
NFPA	National Fire Protection Association
NG	nitroglycerin
NIST	National Institute of Standards and Technology
NTU	nephelometric turbidity unit
OD	outside diameter
O&M	operation and maintenance
OSHA	Occupational Safety and Health Administration
OSM	Office of Surface Mining
P	compressional wave
PDA	pile-driving analyzer
PDOP	position dilution of precision
PETN	pentaerythritoltetranitrate
PMT	photomultiplier tube
PPS	Precise Positioning Service
PRN	pseudo-random noise
psi	pounds per square inch
psi/ft	pounds per square inch per foot
PVC	polyvinyl chloride
PVT	position, velocity, and time data
q_c	tip resistance
RMS	root mean square

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rps	revolutions per second
S	shear wave
SA	selective availability
SEP	spherical error probable
SLAR	side-looking airborne radar
SP	self-potential, spontaneous potential
SPS	Standard Positioning Service
SPT	Standard Penetration Test
SSS	side scan sonar
SSSG	surface saturated dry specific gravity
TDOP	time dilution of precision
TFOM	Time Figure of Merit
TM	thematic mapper
TNT	trinitrotoluene
ton/ft ²	ton per square foot
UE	user equipment
USERE	User Equivalent Range Error
URA	User Range Accuracy
USGS	U.S. Geological Survey
VDOP	vertical position dilution of precision
WAGE	Wide Area GPS Enhancement
° C	degrees Centigrade
° F	degrees Fahrenheit
3D	three-dimensional
2D	two-dimensional

APPENDIX B

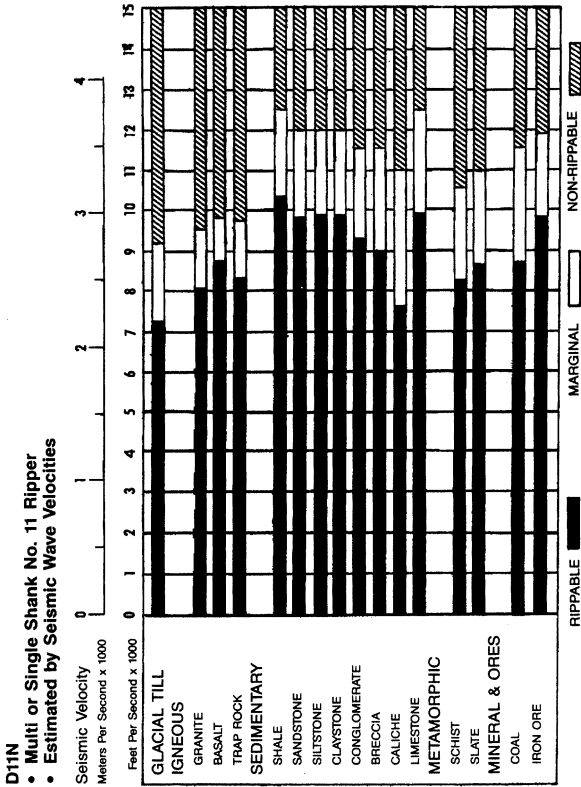
NOMOGRAPH RELATING THE DENSITY OF AN EXPLOSIVE IN G/CC, THE DIAMETER OF THE EXPLOSIVE IN INCHES, AND THE POUNDS OF EXPLOSIVE PER LINEAL FOOT



"Column Diameter" equals hole diameter for poured and pumped blasting products. (For cartridge products, estimate the explosives column average diameter, based upon cartridge diameter and amount of tamping or slump.) For example: a line drawn through the 0.8 gm/cc point (for ANFO) and the 3-inch column diameter point intersects the "weight" line at about 2.5 lb/ft.

APPENDIX C

CHART SHOWING RIPABILITY VERSUS SEISMIC VELOCITY FOR A D11N BULLDOZER



APPENDIX D

CHARTS SHOWING WEIGHT OF MATERIALS REQUIRED FOR TYPICAL LABORATORY TESTS

Weight of material required for aggregate soundness test

Designation No.	Nominal description of test	Maximum particle size	Minimum particle size	Practical field sample ¹	Recommended minimum test sample ¹	Required minimum test specimen	Comments
USBR 4088 ASTM C 88-83 (modified)	Soundness using NaSO ₄	No. 30 (600 μm)	No. 50 (300 μm)	1.2 lb, 520 g*	0.3 lb, 130 g*	100 g*	*If present in the source material in amounts of 5 percent or more ** For each fraction, with a 1-inch (25-mm) spread in sieve size.
		No. 16 (1.18 mm)	No. 30 (600 μm)	1.2 lb, 520 g*	0.3 lb, 130 g*	100 g*	
		No. 8 (2.36 mm)	No. 16 (1.18 mm)	1.2 lb, 520 g*	0.3 lb, 130 g*	100 g*	
		No. 4 (4.75 mm)	No. 8 (2.36 mm)	1.2 lb, 520 g*	0.3 lb, 130 g*	100 g*	
		3/8 in (9.5 mm)	No. 4 (4.75 mm)	1.2 lb, 520 g*	Same as test specimen	100 g*	
		3/4 in (19 mm)	3/8 in (9.5 mm)	5 lb, 2 kg*		500 g*	
		1 1/2 in (37.5 mm)	3/4 in (19 mm)	18 lb, 8 kg*		5 lb, 2 kg*	
		2 1/2 in (63 mm)	1 1/2 in (37.5 mm)	44 lb, 20 kg*		11 lb, 5 kg*	
Larger sizes			**	15.4 lb, 7 kg*, **			

¹ To permit quartering, the field sample should be >four times the required weight of the test sample. The test sample is sized to yield the required number of prepared test specimens.

Weight of material required for aggregate durability test

Designation No.	Nominal description of test	Maximum particle size	Minimum particle size	Practical field sample ¹	Recommended minimum test sample ¹	Required minimum test specimen	Comments
USBR 4131 ASTM C 131-81 (modified)	Resistance to degradation of small-size coarse aggregate	No. 4 (4.75 mm)	No. 8 (2.36 mm)	50 lb, 23 kg	Same as test specimen	11.02 lb, 5,004 g	
		¼ in (6.3 mm)	No. 4 (4.75 mm)	22 lb, 10 kg		5.51 lb, 2,502 g	
		⅜ in (9.5 mm)	¼ in (6.3 mm)	22 lb, 10 kg		5.51 lb, 2,502 g	
		½ in (12.5 mm)	⅜ in (9.5 mm)	22 lb, 10 kg		5.51 lb, 2,502 g	
		¾ in (19 mm)	½ in (12.5 mm)	22 lb, 10 kg		5.51 lb, 2,502 g	
		1 in (25 mm)	¾ in (19 mm)	11 lb, 5 kg		2.76 lb, 1,253 g	
		1½ in (37.5 mm)	1 in (25 mm)	11 lb, 5 kg		2.76 lb, 1,253 g	
USBR 4535 ASTM C 535-81 (modified)	Resistance to degradation of large-size coarse aggregate	1 in (25 mm)	¾ in (19 mm)	50 lb, 23 kg	Same as test specimen	11.02 lb, 5,004 g	
		1½ in (37.5 mm)	1 in (25 mm)	50 lb, 23 kg		11.02 lb, 5,004 g	
		2 in (50 mm)	1½ in (37.5 mm)	50 lb, 23 kg		11.02 lb, 5,004 g	
		2½ in (63 mm)	2 in (50 mm)	22 lb, 10 kg		5.51 lb, 2,502 g	
		3 in (75 mm)	2½ in (63 mm)	22 lb, 10 kg		5.51 lb, 2,502 g	

¹ To permit quartering, the field sample should be ≥ 4 times the required weight of the test sample. The test sample is sized to yield the required number of prepared test specimens.

Weight of material required for individual soil tests - sheet 1 of 7
(footnotes are at the end of the table)

Designation No.	Nominal description of test	Maximum particle size ^{1,2,3}	Practical field sample ⁴		Recommended minimum test sample ⁴		Required minimum test specimen	Comments
			English	Metric	English	Metric		
USBR 5300 ASTM D 2216	Moisture content	No. 40 (425 µm)	0.1 lb	40 g	Same as test specimen		10 g	
		No. 4	2 lb	800 g			200 g	
USBR 5305 ASTM D 4959		3/8 in	9 lb	4 kg			2.2 lb, 1 kg	
USBR 5310 ASTM D 4944		3/4 in	18 lb	8 kg			4.4 lb, 2 kg	
		1 1/2 in	26 lb	12 kg			6.6 lb, 3 kg	
USBR 5315 ASTM D 4643		3 in	26 lb	12 kg			6.6 lb, 3 kg*	*Or more to obtain a representative sample
USBR 5320 Method A ASTM D 854	Specific gravity minus No. 4	No. 4	5 lb	2.3 kg	1.1 lb	500 g	100 g oven dried	

Weight of material required for individual soil tests - sheet 2 of 7
(footnotes at end of table)

Designation No.	Nominal description of test	Maximum particle size ^{1,2,3}	Practical field sample ⁴		Recommended minimum test sample ⁴		Required minimum test specimen	Comments
			English	Metric	English	Metric		
USBR 5320 Method B or C ASTM C 127	Specific gravity and absorption plus No. 4	3/8 in	20 lb**	9.1 kg**	Same as test specimen	4.4 lb, 2 kg**	**Required weight of plus No. 4 particles, air dried	
		3/4 in	30 lb**	14 kg**		6.6 lb, 3 kg**		
		1 1/2 in	50 lb**	23 kg**		11 lb, 5 kg**		
		3 in	200 lb**	91 kg**		40 lb, 18 kg**		
USBR 5330 or USBR 5335 ASTM D 2487	Gradation: minus No. 4	No. 4	5 lb	2.3 kg	1.1 lb	500 g	100 g oven dried	
USBR 5325 ASTM D 2487	Gradation: gravel sizes	3/8 in	5 lb*	2.3 kg*	If not air dried, need test specimen weight plus amount equivalent to weight of moisture content		200 g*, **	*10 lb recommended for large mechanical sieve shakers **Air dried
		3/4 in	15 lb	6.8 kg			2.4 lb, 1.1 kg*, **	
		1 1/2 in	100 lb	45 kg			20 lb, 9.1 kg**	
		3 in	200 lb ⁴ n/a	91 kg			150 lb, 68 kg**	

Weight of material required for individual soil tests - sheet 3 of 7
(footnotes at end of table)

Designation No.	Nominal description of test	Maximum particle size ^{1,2,3}	Practical field sample ⁴		Recommended minimum test sample ⁴		Required minimum test specimen	Comments
			English	Metric	English	Metric		
USBR 5350 ASTM D 4318	LL - 1 point	No. 4	5 lb*	2 kg*	1.1 lb*, **	500 g*, **	100 g**	*Or more, as required, to have 120 g of air-dried soil (150 g if shrinkage limit is included) **Air dried
USBR 5355 ASTM (none)	LL - 3 point						100 g**	
USBR 5360 ASTM D 4318	Plastic limit						20 g**	Two 8-g wet-weight specimens
USBR 5365 ASTM D 427	Shrinkage limit						30 g**	

Weight of material required for individual soil tests - sheet 4 of 7
(footnotes at end of table)

Designation No.	Nominal description of test	Maximum particle size ^{1,2,3}	Practical field sample ⁴		Recommended minimum test sample ⁴		Required minimum test specimen	Comments
			English	Metric	English	Metric		
USBR 5400 ASTM (none)	Dispersivity (crumb, pinhole, double hydrometer)	No. 4	5 lb	2.3 kg	1.1 lb	500 g	500 g	
USBR 5405 ASTM D 4647								
USBR 5410 ASTM D 4221								
USBR 5525 and/or USBR 5530 ASTM D 4564	Minimum and/or maximum index unit weight (wet or dry maximum)	No. 4, 3/8 or 1/2 in	100 lb	45 kg	25 lb	12 kg	25 lb, 12 kg	
		1 1/2 or 3 in	150 lb	68kg	75 lb	34 kg	75 lb, 34 kg	
	(Wet and dry maximum)	No. 4, 3/8 or 1/2 in	100 lb	45 kg	50 lb	23 kg	50 lb, 23 kg	
		1 1/2 or 3 in	200 lb	91 kg	150 lb	68 kg	150 lb, 68 kg	

Weight of material required for individual soil tests - sheet 5 of 7
(footnotes at end of table)

Designation No.	Nominal description of test	Maximum particle size ^{1,2,3}	Practical field sample ⁴		Recommended minimum test sample ⁴		Required minimum test specimen	Comments
			English	Metric	English	Metric		
USBR 5500 ASTM D 2937	Laboratory compaction: minus No. 4	No. 4	200 lb	91 kg	50 lb**	23 kg**	50 lb, 23 kg**	**Air dried
USBR 5515 ASTM (none)	Laboratory compaction: gravelly soils (one specimen) 3 specimens	3 in	350 lb*	159 kg*	350 lb*	159 kg*	225 lb, 102 kg	*Or more as needed to have at least 50 lb of minus No. 4 and at least 50 lb of plus No. 4
			900 lb	409 kg	900 lb	409 kg	900 lb, 409 kg	
USBR 5600 ASTM D 2434	Permeability minus No. 4	No. 4	50 lb	23 kg	15 lb	7 kg	15 lb, 7 kg	
	Permeability gravelly soils	3 in	350 lb*	159 kg*	350 lb*	159 kg*	225 lb, 102 kg	

Weight of material required for individual soil tests - sheet 6 of 7
(footnotes at end of table)

Designation No.	Nominal description of test	Maximum particle size ^{1,2,3}	Practical field sample ⁴		Recommended minimum test sample ⁴		Required minimum test specimen	Comments
			English	Metric	English	Metric		
USBR 5700 ASTM D 2435	One-dimensional consolidation,	No. 4	15 lb	7 kg	3 lb	1.4 kg	1.5 lb, 0.7 kg	
USBR 5705 ASTM D 3877	Expansion or							
USBR 5715 ASTM D 3877	Uplift							

Weight of material required for individual soil tests - sheet 7 of 7

Designation No.	Nominal description of test	Maximum particle size ^{1,2,3}	Practical field sample ⁴		Recommended minimum test sample ⁴		Required minimum test specimen	Comments
			English	Metric	English	Metric		
USBR 5740 ASTM D 2850	Triaxial K ₀ (usually performed in conjunction with other triaxial tests)	No. 4	20 lb	9.1 kg	4 lb	1.8 kg	2 lb, 0.9 kg	One 2-in-dia specimen
		¾ in	100 lb	45 kg	50 lb	23 kg	45 lb, 20 kg	One 6-in-dia specimen
		1½ in	200 lb	91 kg	170 lb	77 kg	150 lb, 68 kg	One 9-in-dia specimen
USBR 5745 ASTM D 2850	UU	No. 4	65 lb	30 kg	16 lb	7.3 kg	8 lb, 3.6 kg	Four 2-in-dia specimens
USBR 5740 ASTM D 2850	CU or	¾ in	200 lb	91 kg	200 lb	91 kg	180 lb, 82 kg	Four 6-in-dia specimens
		1½ in	700 lb	318 kg	700 lb	318 kg	600 lb, 273 kg	Four 9-in dia specimens
USBR 5755 ASTM (none)	CD	1½ in	700 lb	318 kg	700 lb	318 kg	600 lb, 273 kg	Four 9-in dia specimens

¹ Maximum particle size present in original sample.

² No. 4 fraction means either maximum particle in original sample was No. 4 or smaller or a representative portion of the minus No. 4 fraction of the original sample is required.

³ Metric equivalents are: No. 4 sieve - 4.75 mm, ¾ inch - 9.5 mm, ¾ inch - 19.0 mm, 1½ inch - 37.5 mm, 3 inch - 75 mm and 5 inch - 125 mm.

⁴ To permit quartering, the field sample should be >4 times the required weight of the test sample. The test sample is sized to yield the required number of prepared test specimens.

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Weight of material required for combinations of soil tests -
sheet 1 of 1

Test combinations ¹	Maximum particle size ^{2,3}	Minimum sample required	
		English	Metric
Laboratory classification (gradation, Atterberg limits)	No. 4	50 lb	23 kg
	3/8 in		
	3/4 in		
	1 1/2 in	100 lb	46 kg
	3 in	200 lb	91 kg
Physical properties - Cohesive soil (gradation, Atterberg limits, specific gravity, laboratory compaction)	No. 4	50 lb	23 kg
	3/8 in	100 lb ⁴	46 kg ⁴
	3/4 in		
	1 1/2 in		
	3 in	200 lb ⁴	91kg ⁴
Physical properties - Cohesionless soil (gradation, Atterberg limits, specific gravity, maximum and minimum index unit weight)	No. 4	100 lb	46 kg
	3/8 in		
	3/4 in	200 lb	91 kg
	1 1/2 in		
	3 in		
Soil-cement (for 3 cement contents)	1 1/2 in	2,000 lb	908 kg

¹ Assumes field sample will be used for more than one test. If sample is divided to provide separate test samples, add up values for individual soil tests.

² Maximum particle size present in original sample.

³ Metric equivalents are: No. 4 sieve - 4.75 mm, 3/8 inch - 9.5 mm, 3/4 inch - 19.0 mm, 1 1/2 inches - 37.5 mm, 3 inches - 75 mm, and 5 inch - 125 mm.

⁴ Or more, as needed to have 50 lb of minus No. 4.

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In place density test requirements - test apparatus and minimum excavation

Cohesive materials		
Maximum particle size (in)	Minimum required volume (ft ³)	Apparatus and template opening
¾	0.25	8-in sand cone
1½	0.5	12-in sand cone
3	1	20-in sand cone or 24-in-square frame
5	2	30-in square frame
8	8	4-ft-diameter ring
12	27	6-ft-diameter ring
18	90	9-ft-diameter ring
>18	Determine on a case-by-case basis	
Cohesionless materials		
¾	0.25	20-in sand cone
1½	0.5	24-in-square frame
3	1	33-in-square frame
5	2	40-in-diameter ring
8	8	62-in-diameter ring
>8	Determine on a case-by-case basis	

APPENDIX D

Weight of material required for slope protection tests

Reclamation designation No.	Minimum required sample		Comments
	English	Metric	
6025 Design Standard No. 13	600 lb	275 kg	The minimum dimension of individual rock fragments selected should be at least 0.5 feet (15 cm). If source material quality is variable, the sample should include rock fragments representing the quality range of the source material.

APPENDIX E

USEFUL CONVERSION FACTORS METRIC AND ENGLISH UNITS (INCH-POUND)

To convert units in column 1 to units in column 4, multiply column 1 by the factor in column 2.

To convert units in column 4 to units in column 1, multiply column 4 by the factor in column 3.

Column 1	Column 2	Column 3	Column 4
Length			
inch (in)	2.540×10^{-1}	3.937×10^{-2}	millimeter (mm)
hundredths of feet	3.048×10^2	3.281×10^{-3}	millimeter (mm)
foot (ft)	3.048×10^{-1}	3.281	meter (m)
mile (mi)	1.6093	6.2137×10^{-1}	kilometer (km)
Area			
square inch (in ²)	6.4516×10^{-4}	1.550×10^{-3}	square meter (m ²)
square foot (ft ²)	9.2903×10^{-2}	1.0764×10^1	square meter (m ²)
acre	4.0469×10^{-1}	2.4711	hectare
square mile (mi ²)	0.386×10^{-2}	259.0	hectares
Volume			
cubic inch (in ³)	1.6387×10^{-2}	6.102×10^{-2}	cubic centimeter (cm ³)
cubic feet (ft ³)	2.8317×10^{-2}	3.5315×10^1	cubic meter (m ³)
cubic yard (yd ³)	7.6455×10^1	1.3079	cubic meter (m ³)
cubic feet (ft ³)	7.4805	1.3368×10^1	gallon (gal)
gallon (gal)	3.7854	2.6417×10^{-1}	liter (L)
acre-feet (acre-ft)	1.2335×10^6	8.1071×10^{-4}	cubic meter (m ³)
Flow			
gallon per minute (gal/min)	6.309×10^{-2}	1.5850×10^1	liter per second (L/s)
cubic foot per second (ft ³ /s)	4.4883×10^2	2.228×10^{-3}	gallons per minute (gal/min)
	1.9835	5.0417×10^{-1}	acre-feet per day (acre-ft/d)
cubic foot per second (ft ³ /s)	7.2398×10^2	1.3813×10^{-3}	acre-feet per year (acre-ft/yr)
	2.8317×10^{-2}	3.531×10^1	cubic meters per second (m ³ /s)
	8.93×10^5	1.119×10^{-6}	cubic meters per year (m ³ /yr)
Permeability			
<i>k</i> , feet/year	9.651×10^{-7}	1.035×10^6	<i>k</i> , centimeter per second (cm/sec)
Density			
pound-mass per cubic foot (lb/ft ³)	1.6018×10^1	6.2429×10^{-2}	kilogram per cubic meter (kg/m ³)
Unit Weight			
pound force per cubic foot (lb/ft ³)	0.157	6.366	kilonewton per cubic meter (kN/m ³)
Pressure			
pounds per square inch (psi)	7.03×10^{-2}	1.4223×10^1	kilogram per square centimeter (kg/cm ²)
	6.8948	0.145	kiloPascal (kPa)
Force			
ton	8.89644	1.12405×10^1	kilonewton (kN)
pound-force	4.4482×10^{-3}	224.8096	kilonewton (kN)
Temperature			
	$^{\circ}\text{C} = 5/9 (^{\circ}\text{F} - 32 ^{\circ})$		$^{\circ}\text{F} = (9/5 ^{\circ}\text{C}) + 32 ^{\circ}$
Grouting			
Metric bag cement per meter	3.0	0.33	U.S. bag cement per foot
Water:cement ratio by volume	0.7	1.4	water:cement ratio by weight
pounds per square inch per foot	0.2296	4.3554	kilogram per square centimeter per meter (kg/cm ² /m)
<i>k</i> , feet/year	0.1	10	Lugeon