

Water-Well Design and Construction

Richard L. Harlan

*Dames&Moore and Department of Geology and Geological Engineering,
Colorado School of Mines, Golden, CO 80401, U.S.A.*

Kenneth E. Kolm

*Department of Geology and Geological Engineering, Colorado
School of Mines, Golden, CO 80401, U.S.A.*

Edwin D. Gutentag

U.S. Geological Survey, Water Resources Division, Lakewood, CO 80215, U.S.A.



ELSEVIER

Amsterdam — Oxford — New York — Tokyo



TABLE OF CONTENTS

Chapter 1	INTRODUCTION.....	1
1.	PURPOSE AND SCOPE.....	1
2.	HYDROLOGIC CYCLE.....	2
3.	GROUND-WATER OCCURRENCE.....	6
4.	DEFINITIONS.....	8
5.	SELECTED REFERENCES.....	11
Chapter 2	SUBSURFACE EVALUATION.....	13
1.	PRELIMINARY CONSIDERATIONS.....	13
1.1.	<u>General Approach</u>	13
1.2.	<u>Legal/regulatory considerations</u>	16
2.	DRILLING AND CORING.....	17
2.1.	<u>Types of wells</u>	17
2.2.	<u>Drilling methods</u>	25
2.2.1.	<u>Cable tool/percussion/churn drill</u>	26
2.2.2.	<u>Rotary drills</u>	30
2.2.3.	<u>Reverse-rotary drills</u>	33
2.2.4.	<u>Air-rotary drills</u>	36
2.2.5.	<u>Hydraulic-percussion methods</u>	37
2.2.6.	<u>Jetting methods</u>	38
2.2.7.	<u>Auger methods</u>	40
2.2.8.	<u>Driven wells</u>	40
2.3.	<u>Drilling fluids</u>	40
3.	SITE OBSERVATIONS.....	43
3.1.	<u>Formation sampling</u>	43
3.1.1.	<u>Holes drilled by cable tool</u>	43
3.1.2.	<u>Holes drilled by rotary methods</u>	43
3.1.3.	<u>Holes drilled by auger methods</u>	44
3.2.	<u>Logging protocol (Unified Soil Classification System)</u>	44
3.3.	<u>Analysis of borehole cuttings</u>	46
4.	GEOPHYSICS.....	46
4.1.	<u>Remote-sensing techniques</u>	46
4.2.	<u>Surface methods</u>	46

4.3.	<u>Borehole measurements</u>	47
5.	SELECTED REFERENCES.....	52
Chapter 3	WELL HYDRAULICS.....	55
1.	CONCEPT OF HEAD.....	55
2.	DARCY'S LAW.....	58
3.	AQUIFER PROPERTIES.....	59
4.	RADIAL-FLOW EQUATIONS.....	67
4.1.	<u>Equilibrium (steady-state) equations--Thiem Equations</u>	69
4.2.	<u>Non-equilibrium equations</u>	72
4.3.	<u>Modified non-equilibrium equations</u>	75
4.4.	<u>Radius of influence</u>	78
5.	SELECTED REFERENCES.....	80
Chapter 4	PRINCIPLES OF WELL DESIGN.....	83
1.	PURPOSE OF PROPER WELL DESIGN.....	83
2.	WATER-QUALITY CONSIDERATIONS.....	85
3.	MATERIALS SELECTION: CASING AND SCREEN.....	89
4.	DIMENSIONAL CONSIDERATIONS.....	90
4.1.	<u>Well diameter (casing and screen)</u>	90
4.2.	<u>Well depth</u>	94
4.3.	<u>Well-screen length</u>	95
4.3.1.	<u>Homogeneous confined (artesian) aquifer</u>	95
4.3.2.	<u>Heterogeneous confined (artesian) aquifer</u>	96
4.3.3.	<u>Homogeneous unconfined (water-table) aquifer</u>	97
4.3.4.	<u>Heterogeneous unconfined (water-table) aquifer</u>	97
5.	WELL SCREENS.....	99
5.1.	<u>Screen slot size</u>	99
5.2.	<u>Screen diameter</u>	106
5.3.	<u>Well-screen transmitting capacity</u>	106

6.	GRAVEL AND FILTER PACKS.....	107
6.1.	<u>Design principles</u>	108
6.2.	<u>Gravel-pack materials</u>	110
6.3.	<u>Thickness of gravel pack</u>	111
6.4.	<u>Formation stabilizer</u>	111
7.	SELECTED REFERENCES.....	113
Chapter 5 WELL CONSTRUCTION, DEVELOPMENT, AND MAINTENANCE...		115
1.	WELL CONSTRUCTION.....	115
1.1.	<u>Installation and removal of screens</u>	115
1.2.	<u>Placement of gravel (filter) packs</u>	123
1.3.	<u>Grouting</u>	123
2.	WELL DEVELOPMENT, REHABILITATION AND MAINTENANCE.....	124
2.1.	<u>Well development</u>	124
2.2.	<u>Well maintenance and rehabilitation</u>	127
2.3.	<u>Well failure</u>	128
3.	WATER-SUPPLY SYSTEMS.....	129
3.1.	<u>System design</u>	129
3.2.	<u>Motor and pump selection</u>	129
3.3.	<u>Disinfection</u>	133
3.4.	<u>Treatment considerations</u>	134
4.	WELL CLOSURE AND ABANDONMENT.....	134
5.	SELECTED REFERENCES.....	137
Chapter 6 AQUIFER EVALUATION.....		139
1.	AQUIFER (PUMPING) TEST DESIGN.....	139
1.1.	<u>General</u>	139
1.2.	<u>Site selection</u>	142
1.3.	<u>Production-well design and construction</u>	142
1.3.1.	<u>Well diameter, depth, and screen length</u>	142
1.3.2.	<u>Number, spacing, and depth of observation wells and piezometers</u>	143

1.4.	<u>Aquifer-test measurements</u>	149
1.4.1.	<u>Measurement of pumping rate</u>	149
1.4.2.	<u>Water-level measurements</u>	150
2.	PROCEDURES FOR CONDUCTING AQUIFER TESTS IN SINGLE WELLS.....	154
2.1.	<u>Specific capacity</u>	154
2.2.	<u>Step-drawdown tests</u>	154
2.3.	<u>Well-efficiency tests</u>	154
2.4.	<u>Relation of specific capacity to transmissivity</u>	157
2.5.	<u>Slug and bail tests</u>	158
3.	PACKER TESTS.....	159
4.	LABORATORY TESTS.....	165
5.	SELECTED REFERENCES.....	166
Chapter 7	SPECIAL APPLICATIONS.....	171
1.	GROUND-WATER MONITORING.....	171
1.1.	<u>Monitoring-well design</u>	171
1.2.	<u>Water-quality sampling and analysis</u>	172
2.	DEWATERING AND DEPRESSURIZATION.....	173
2.1.	<u>Conventional dewatering wells</u>	174
2.2.	<u>Sand drains</u>	174
2.3.	<u>Well-point systems</u>	174
2.3.1.	<u>Materials</u>	177
2.3.2.	<u>Well spacing</u>	177
2.3.3.	<u>Screen length</u>	177
2.3.4.	<u>Installation of well points</u>	178
2.3.5.	<u>Development</u>	178
2.4.	<u>Electro osmosis</u>	178
3.	INFILTRATION GALLERIES/HORIZONTAL COLLECTORS.....	179
4.	SELECTED REFERENCES.....	185
Chapter 8	GLOSSARY.....	187
	INDEX.....	200