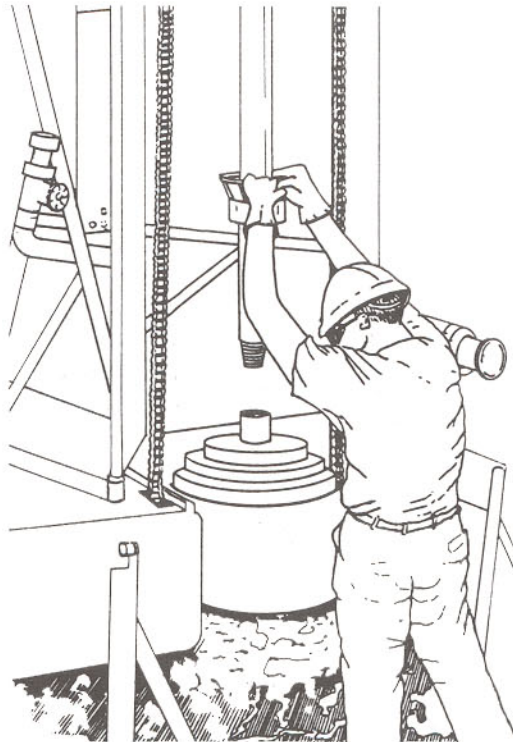


Army, Navy, Air Force

Multiservice Procedures for Well-Drilling Operations



**FM 5-484
NAVFAC P-1065
AFMAN 32-1072**

**Headquarters,
Department of the Army
Department of the Navy
Department of the Air Force**

**DISTRIBUTION RESTRICTION: Approved for public release; distribution
is unlimited.**

FOREWORD

This publication may be used by the US Army, US Navy, and US Air Force during training, exercises, and contingency operations.

FREDERICK M. FRANKS, JR
General, USA
Commanding General
United States Army Training
and Doctrine Command

RICHARD M. DEMPSEY
Captain, CEC, USN
Deputy Commander
Military Readiness (SEABEES)

MERRILL A. MCPEAK
General, USAF
Chief of Staff

**Field Manual
No. 5-484**

***FM 5-484
NAVFAC P-1065
AFMAN 32-1072**

**Navy Facilities Engineering
Command Pamphlet
No. 1065**

**HEADQUARTERS
DEPARTMENT OF THE ARMY
DEPARTMENT OF THE NAVY
DEPARTMENT OF THE AIR FORCE
Washington, DC, 8 March 1994**

**Air Force Manual
No. 32-1072**

MULTISERVICE PROCEDURES FOR WELL-DRILLING OPERATIONS

Contents

	Page
List of Figures and Tables	xv
Preface	xix

PART ONE. BASICS

Chapter 1. Introduction

1-1. Field Water Supply	1-1
1-2. Water Detection	1-1
Responsibilities	1-1
Procedures	1-1
Equipment	1-2

**DISTRIBUTION RESTRICTION: Approved for public release;
distribution is unlimited.**

***This publication supersedes FM 5-166, 30 June 1975**

	Page
1-3. Well Drilling	1-2
Forward Deployed Forces in a Developed TO	1-2
Permanent or Semipermanent Fixed Installation Forces in a Developed TO	1-2
Combat Zone (Corps Level and Below)	1-2
Communications Zone (EAC)	1-3
1-4. Well-Drilling Teams	1-3
Army	1-3
Navy	1-3
Air Force	1-3

Chapter 2. Groundwater

2-1. Fundamentals	2-1
2-2. Hydrologic Cycle	2-1
Recharge and Discharge	2-1
Water Storage	2-1
2-3. Groundwater Occurrence	2-1
2-4. Geological Setting	2-3
Unconsolidated Deposits (Soil)	2-3
Consolidated Deposits (Rock)	2-5
2-5. Groundwater Hydraulics	2-5
Porosity	2-5
Permeability	2-5
Specific Yield and Retention	2-8
Transmissivity	2-9
Yield and Drawdown	2-9
Hydraulic Gradient	2-9
Aquifer Tests	2-11
2-6. Aquifers	2-11
Unconfined	2-11
Confined	2-11
Perched	2-11
Catchment	2-12
Material	2-13

	Page
2-7. Groundwater Exploration	2-14
Reservoir Indicators	2-16
Boundary Indicators	2-26
Surface Indicators	2-29
2-8. Desert Environments	2-33
2-9. Water Quality	2-35
Aquifer Contamination	2-35
Saltwater Intrusion	2-36
Groundwater Contamination	2-37

Chapter 3. Field Operations

3-1. Team Concept	3-1
Commander	3-1
Driller	3-1
Helper	3-1
3-2. Team Planning, Coordination, and Preparation	3-1
3-3. Deploying Teams	3-3
3-4. Site Preparation	3-3
3-5. Equipment	3-4
600-Foot WDS	3-4
CF-15-S Drilling System	3-8
3-6. Transportation	3-10
600-Foot WDS	3-10
CF-15-S Drilling System	3-12
3-7. Drill-Rig Setup	3-13
3-8. Drilling Fluid	3-15
3-9. Well-Drilling Operations	3-15
Starting the Operation	3-16
Finishing the Operation	3-16
3-10. Sampling and Logging	3-17
3-11. Casing and Well Screen	3-18

	Page
Surface Casing	3-18
Screening	3-20
Filtering and Backfilling	3-20
3-12. Well Development	3-20
3-13. Sanitary Seals	3-20
3-14. Pumping Tests	3-21

Chapter 4. Pumps

4-1. Fundamentals	4-1
Pump Types	4-1
Selection Criteria	4-1
4-2. Shallow-Well Pumps	4-1
Pitcher Pump	4-3
Rotary Pump	4-3
Centrifugal Pump	4-4
Self-Priming Pump	4-5
4-3. Deep-Well Pumps	4-6
Submersible Pump	4-6
Turbine Pump	4-7
Helical-Rotor Pump	4-7
Jet Pump	4-9
4-4. Air-Lift Pumps	4-10
Principle	4-10
Installation Design	4-11

PART TWO. WELL DRILLING

Chapter 5. Well-Drilling Methods

5-1. Mud Rotary Drilling	5-1
Rotary Rigs	5-1
Drill Bits	5-3
Rotary Operation	5-5
Variables	5-5

	Page
Drilling Fluids	5-8
Rotary Drilling Problems	5-22
5-2. Air Rotary Drilling	5-24
Air Supply	5-24
Foamers	5-26
5-3. Percussion Drilling	5-27
Equipment	5-28
Power	5-29
Procedure	5-29
Adjusting to Variables	5-31
5-4. Reverse Circulation	5-32
Advantages and Disadvantages	5-32
Rig Configuration	5-33
5-5. Drilling Information	5-34
Driller's Log	5-34
Soil Sampling	5-34

Chapter 6. Well-Installation Procedures

6-1. Setting Casing	6-1
6-2. Selecting Casing	6-1
6-3. Installing Casing	6-3
Open-Hole Method	6-3
Single-String Method	6-3
Wash-In Method (Jetted Wells)	6-3
Driven Method (Driven Wells)	6-3
Uncased-Interval Method	6-3
6-4. Grouting and Sealing Casing	6-3
Dump-Bailer Method	6-4
Inside-Tremie Method	6-4
Outside-Tremie Method	6-5
6-5. Selecting Screens	6-6
Types	6-7
Lengths	6-8

	Page
Diameters	6-9
Slot Sizes	6-9
6-6. Installing Screen	6-10
Single-String Method	6-10
Pull-Back Method	6-11
Open-Hole Method	6-11
Washdown Method	6-12
Bail-Down Method	6-13
6-7. Placing Gravel	6-15
Open-Hole Placement	6-15
Tremie Placement	6-16
Bail-Down Placement	6-16
Double-Casing Placement	6-16
6-8. Using Alternative Methods	6-16
Formation Stabilizer	6-16
Unscreened Well	6-19

Chapter 7. Well-Completion Procedures

7-1. Well Development	7-1
Jetting Method	7-1
Pump-Surge Method	7-2
Gravity-Outflow Method	7-2
Pressure-Pumping Method	7-2
Surge-Block Method	7-2
Compressed-Air Methods	7-3
7-2. Dispersion Treatment	7-7
7-3. Rock Development	7-7
7-4. Well Protection and Treatment	7-8
External Preparations	7-8
Sealing Casing	7-8
Disinfection	7-8
Cathodic Protection	7-9
Well Head and Collar	7-9
7-5. Well-Completion Report	7-10

Chapter 8. Well-Performance Testing Procedures

8-1. Testing Pumps	8-1
Permanent Wells	8-1
Temporary Wells	8-2
Methods	8-2
8-2. Measuring Water Level	8-4
Electric-Line Method	8-4
Tape Method	8-4
Air-Line Method	8-4
8-3. Measuring Discharge Rate	8-5
Measured-Container Method	8-5
Flow-Meter Method	8-5
Circular-Orifice Method	8-5
Open-Pipe Method	8-6

PART THREE. SPECIAL CONSIDERATIONS

Chapter 9. Alternative Well Construction

9-1. Fundamentals	9-1
9-2. Jetted Wells	9-1
Equipment	9-1
Methods	9-3
9-3. Driven-Point Wells	9-6
Equipment	9-6
Procedures	9-10
Well Completion	9-13
9-4. Cable-Tool Method	9-15
General	9-15
Equipment and Procedure	9-15
9-5. Augered Wells	9-15
Equipment	9-16
Procedures	9-16
Well Completion	9-16

Chapter 10. Arctic Well Construction

10-1.	Considerations	10-1
	Arctic Water Supply	10-1
	Discontinuous Permafrost	10-2
	Thick, Continuous Permafrost	10-2
10-2.	Well Drilling	10-2
	Drilling Equipment	10-2
	Rotary Drilling	10-2
	Jet-Drive Drilling	10-3
	Drilling Fluids	10-3
	Air Rotary Drilling	10-4
	Well Installation and Completion	10-4

Chapter 11. Auxiliary Activities

11-1.	Exploratory Drilling	11-1
	Geological Exploration	11-1
	Logging Techniques	11-1
	Drilling Action	11-2
11-2.	Sampling Soil and Rock	11-2
	Rotary Cuttings	11-2
	Depth Determination	11-2
	Undisturbed Soil Samples	11-3
	Rock Core Samples	11-4
11-3.	Installing Monitoring Wells	11-5
	Safety	11-5
	Requirements	11-5
	Installation	11-5
11-4.	Supporting Construction and Demolition	11-5

Appendix A. Water Detection Response Team

A-1. Concept	A-1
A-2. Organization	A-1
A-3. Deployment	A-1
A-4. Operational Concept and WRDB	A-2
A-5. Water Resources Overlays	A-3
Existing Water-Supply Overlay	A-3
Surface-Water Overlay	A-3
Groundwater Overlay	A-3
Overlay Symbols	A-3
A-6. Potential Drilling Areas	A-4

Appendix B. Navy Well Drilling

B-1. General	B-1
B-2. Equipment	B-1
The ITWD	B-2
Air Compressor	B-2
Well-Completion Kit	B-2

Appendix C. Air Force Well Drilling

C-1. General	C-1
RH-1	C-1
RH-2	C-1
RH-3	C-1
C-2. Organization and Scope	C-1
Capabilities	C-1
Requirements	C-2
Team Composition	C-2
Publications and Documentation	C-3
Equipment	C-3

Appendix D. Electrical Logging System

D-1. Logging Unit	D-1
Well Probe	D-1
Resistivity Instrument	D-1
Power Supply	D-2
Logging Cable	D-2
Cable Reel and Reel Case	D-2
Extender Cable-Reel Assembly	D-3
Surface Lines	D-3
D-2. Types of Logging	D-3
With the Normal Arrangement	D-3
With the Lateral Arrangement	D-4
D-3. Mud Probe (on Units Modified for Mud Logging)	D-5
Calibrating	D-5
Setting up the Equipment	D-5
D-4. Troubleshooting Procedures	D-6
Checking Batteries	D-6
Using a Voltmeter	D-7
Calibrating the DR-74 Mud Logger (with a Known Salt Solution)	D-7
D-5. Maintenance	D-8
Of Resisitivity Measurement	D-8
Of Cable and Reel Case	D-8
D-6. Interpretation of Electrical Logs	D-8
Preparation of the Log	D-8
Significance of 0.25-Foot Spacing	D-8
Significance of 2.5-Foot Spacing	D-8
Significance of the Lateral Log	D-9
Interpretation of Resistivity Values	D-9
Selection of Formation Contacts	D-9
Correlation of Electrical Logs	D-9
Effect of Metal on the Resistivity Log	D-10
SP Curve	D-10

Appendix E. Bit Maintenance

E-1. Maintenance	E-1
E-2. Failure	E-2
E-3. Reconditioning	E-6
E-4. Rule of Thumb	E-6
Glossary	Glossary-1
References	References-1
Index	Index-1

List of Figures and Tables

FIGURES

	Page
Figure 2-1. <i>Hydrologic cycle</i>	2-2
Figure 2-2. <i>Water flow from recharge to discharge areas</i>	2-2
Figure 2-3. <i>Mississippi River Basin</i>	2-3
Figure 2-4. <i>Hydrographic basin</i>	2-4
Figure 2-5. <i>Primary and secondary openings</i>	2-6
Figure 2-6. <i>Hydraulic conductivity</i>	2-6
Figure 2-7. <i>Hydraulic conductivity of rocks and soil</i>	2-7
Figure 2-8. <i>Specific retention</i>	2-8
Figure 2-9. <i>Difference between hydraulic conductivity and transmissivity</i>	2-9
Figure 2-10. <i>Drawdown</i>	2-10
Figure 2-11. <i>Hydraulic gradient</i>	2-10
Figure 2-12. <i>Unconfined aquifer</i>	2-12
Figure 2-13. <i>Flowing artesian well</i>	2-12
Figure 2-14. <i>Perched water table</i>	2-13
Figure 2-15. <i>Catchment</i>	2-13
Figure 2-16. <i>Karst topography carbonate aquifer</i>	2-14
Figure 2-17. <i>Water flow through lava</i>	2-15
Figure 2-18. <i>Alluvial valley</i>	2-18
Figure 2-19. <i>Water in a coastal terrace</i>	2-19
Figure 2-20. <i>Alluvial fan</i>	2-20
Figure 2-21. <i>Alluvial basin</i>	2-20
Figure 2-22. <i>Glaciated region</i>	2-21
Figure 2-23. <i>Hydrogeologic strat column of the Great Basin</i>	2-21
Figure 2-24. <i>Structure map of western Iran</i>	2-22
Figure 2-25. <i>Faults and springs</i>	2-23
Figure 2-26. <i>Effects of consolidation on porosity and permeability</i>	2-24

	Page
Figure 2-27. <i>Stream drainage patterns</i>	2-26
Figure 2-28. <i>Hydrographic basin with recharge areas</i>	2-27
Figure 2-29. <i>Mounding</i>	2-27
Figure 2-30. <i>Hydrographic basin with discharge areas</i>	2-28
Figure 2-31. <i>Groundwater flow from recharge to discharge areas</i>	2-28
Figure 2-32. <i>Types of springs</i>	2-29
Figure 2-33. <i>Playas and salt-encrustation deposits</i>	2-31
Figure 2-34. <i>Pivot irrigation patterns</i>	2-33
Figure 2-35. <i>Geologic features in an intermontaine valley</i>	2-34
Figure 2-36. <i>Desert mount and plain terrain</i>	2-34
Figure 2-37. <i>Oasis</i>	2-35
Figure 2-38. <i>Qanat system</i>	2-35
Figure 2-39. <i>Permeable sands surrounded by salt water</i>	2-36
Figure 2-40. <i>Pumping effects in salt water</i>	2-37
Figure 2-41. <i>Saltwater encroachment</i>	2-37
Figure 2-42. <i>Groundwater pollution</i>	2-38
Figure 3-1. <i>600-foot well-drilling machine</i>	3-6
Figure 3-2. <i>Support vehicle</i>	3-7
Figure 3-3. <i>600-foot well-completion kit</i>	3-8
Figure 3-4. <i>Hose on well-completion kit</i>	3-9
Figure 3-5. <i>Steel mud pit</i>	3-9
Figure 3-6. <i>CF-15-S drilling machine</i>	3-10
Figure 3-7. <i>Well-completion kit</i>	3-11
Figure 3-8. <i>Casing for 600-foot WDS</i>	3-12
Figure 3-9. <i>Loading support truck on aircraft</i>	3-12
Figure 3-10. <i>Preparing the CF-15-S for loading</i>	3-13
Figure 3-11. <i>Raising a drilling-rig mast</i>	3-14
Figure 3-12. <i>Draw works and mast loads</i>	3-14

	Page
Figure 3-13. Mud hopper	3-15
Figure 3-14. Drill bits	3-15
Figure 3-15. Making up the kelly to the threads	3-17
Figure 3-16. Placing the hoisting plug on the drill steel	3-17
Figure 3-17. Taking samples	3-18
Figure 3-18. Connecting an elevator to casing	3-19
Figure 3-19. Setting slips	3-19
Figure 3-20. Casing in a spider bowl	3-19
Figure 4-1. Pitcher pump	4-3
Figure 4-2. Rotary pump	4-3
Figure 4-3. Centrifugal pump	4-4
Figure 4-4. Self-priming pump	4-6
Figure 4-5. Submersible pump	4-7
Figure 4-6. Turbine pump	4-8
Figure 4-7. Helical-rotor pump	4-9
Figure 4-8. Jet pump	4-9
Figure 4-9. Air-lift principle	4-10
Figure 4-10. Air pipe in an eductor pipe	4-11
Figure 4-11. Submergence percentage	4-12
Figure 5-1. Mud pump	5-3
Figure 5-2. Guide for bit selection	5-4
Figure 5-3. Plumbing the kelly	5-5
Figure 5-4. Hole diameter	5-8
Figure 5-5. Stabilizer	5-8
Figure 5-6. Marsh funnel	5-14
Figure 5-7. Nomograph for determining hydrostatic head produced by drilling fluids	5-15
Figure 5-8. Mud-pit layout with pit capacities and dimensions	5-19
Figure 5-9. Mud pit prepared on-site	5-20

	Page
Figure 5-10. Portable mud pit	5-20
Figure 5-11. Rectangular weir with end contractions	5-21
Figure 5-12. Triangular notch weir with end contractions	5-22
Figure 5-13. Fishing tools	5-24
Figure 5-14. Nomogram to calculate up-hole velocity	5-26
Figure 5-15. Foam from the well	5-27
Figure 5-16. Down-hole bit	5-28
Figure 5-17. Reverse circulation rotary drilling	5-33
Figure 5-18. Well driller's log	5-35
Figure 5-19. Piping and casing log	5-37
Figure 6-1. Plastic casing	6-1
Figure 6-2. Inside-tremie grouting method	6-5
Figure 6-3. Outside-tremie grouting method	6-6
Figure 6-4. Continuous-slot screens	6-7
Figure 6-5. PVC screens	6-7
Figure 6-6. Screen-hook installation method	6-10
Figure 6-7. Single-string assembly	6-11
Figure 6-8. Closed bail plug	6-13
Figure 6-9. Screen fittings for washdown installation	6-13
Figure 6-10. Assembled bail-down shoe	6-14
Figure 6-11. Shoe with a guide pipe	6-14
Figure 6-12. Bail-down placement	6-17
Figure 6-13. Double-casing, gravel-pack placement	6-18
Figure 7-1. Jetting tool on bottom of drill string	7-1
Figure 7-2. Surge block	7-3
Figure 7-3. Placing the drop pipe and air line in the well	7-5
Figure 7-4. Arranging equipment to build up air pressure	7-6
Figure 7-5. Sacrificial anode	7-9

Thank You for previewing this eBook

You can read the full version of this eBook in different formats:

- HTML (Free /Available to everyone)
- PDF / TXT (Available to V.I.P. members. Free Standard members can access up to 5 PDF/TXT eBooks per month each month)
- Epub & Mobipocket (Exclusive to V.I.P. members)

To download this full book, simply select the format you desire below

