ENTERED

TECHNICAL &
PROFESSIONAL
TRAINING

GROUND-WATER MONITORING AND SAMPLING TECHNOLOGY:

Design, Installation, Development, of Ground-Water Monitoring Wells

COURSE NOTES

35809

TECHNICAL &
PROFESSIONAL
TRAINING

GROUND-WATER MONITORING AND SAMPLING TECHNOLOGY:

Design, Installation, Development, and Sampling of Ground-Water Monitoring Wells

Instructors

David M. Nielsen, Nielsen Ground-Water Science, Inc., Galena, OH
David B. Kaminski, QED Environmental Systems, Inc. Pleasant Hill, CA
Gillian L. Nielsen, Nielsen Ground-Water Science, Inc., Galena, OH

(C) 1995 by American Society for Testing and Materials. This document is not an ASTM standard, standards adjunct, manual, or proposal. It has neither been peer reviewed nor approved by the ASTM consensus system. It is not intended to recommend any particular course of action to any individuals or organizations. It is intended solely for the information of the attendees of the ASTM Technical & Professional Training course at which it is distributed. It is not to be reproduced or distributed or quoted, in whole or in part, by any means without the express written approval of the President of ASTM.

TABLE OF CONTENTS

	Pages
Course Introduction.....	1 - 4
Ground Water Monitoring Well Design & Construction.....	1-1 - 1-112
Ground Water Monitoring Well Development Methods.....	2-1 - 2-28
Field Equipment Decontamination Methods.....	3-1 - 3-12
Purging and Sampling of Ground Water Monitoring Wells.....	4-1 - 4-48
Ground-Water Sample Collection Procedures.....	5-1 - 5-12
Sample Pretreatment Methods and Procedures.....	6-1 - 6-16
Sample Handling, Shipment, & Documentation Procedures.....	7-1 - 7-14

Committee D-18 ON SOIL AND ROCK

Fundamentals of Ground-Water Monitoring & Sampling Technology

COURSE INTRODUCTION

- Your Instructors
- What is ASTM?
- Activities of Subcommittee D-18.21 on Ground Water & Vadose Zone Investigations
- ASTM Standards Covered in this Course

Instructor:

David M. Nielsen
Nielsen Ground-Water Science, Inc.
4686 State Route 605 South
Galena, OH 43021-9652

© 1995, Nielsen Ground-Water Science, Inc.
Galena, Ohio. All Rights Reserved.
These materials are copyright-protected under the laws of the United States and are the exclusive property of Nielsen Ground-Water Science, Inc. Any unauthorized duplication will result in prosecution.

ASTM STANDARDS COVERED IN THIS COURSE

Section 1: Monitoring Well Design and Construction

D5092 Standard Practice for Design and Installation of Ground-Water Monitoring Wells in Aquifers

D1785 Standard Specification for Poly (Vinyl Chloride)(PVC) Plastic Pipe, Schedules 40, 80, and 120

F480 Standard Specification for Thermoplastic Well Casing Pipe and Couplings Made in Standard Dimension Ratios (SDR), Schedule 40 and 80

D1586 Standard Method for Penetration Test and Split-Barrel Sampling of Soils

ASTM STANDARDS COVERED IN THIS COURSE

Section 1: Monitoring Well Design and Construction

C136 Standard Method for Sieve Analysis of Fine and Coarse Aggregates

D4380 Standard Test Method for Density of Bentonitic Slurries

C150 Standard Specification for Portland Cement

D5521 Standard Guide for Development of Ground-Water Monitoring Wells in Granular Aquifers

ASTM STANDARDS COVERED IN THIS COURSE

Section 2: Field Equipment Decontamination

D5088 Standard Practice for Decontamination of Field Equipment Used at Nonradioactive Waste Sites

ASTM STANDARDS COVERED IN THIS COURSE

Section 3: Ground-Water Purging and Sampling Devices

(Draft) Standard Guide to the Selection of Purging and Sampling Devices for Ground-Water Monitoring Wells

(Draft) Standard Guide for Purging Ground-Water Monitoring Wells

D4448 Standard Guide for Sampling Ground-Water Monitoring Wells

D4750 Standard Test Method for Determining Subsurface Liquid Levels in a Borehole or Monitoring Well

ASTM STANDARDS COVERED IN THIS COURSE

Section 4: Ground-Water Sample Collection & Handling

(Draft) Standard Guide for Planning a Ground-Water Sampling Event

(Draft) Standard Guide to the Collection and Handling of Ground-Water Samples

(Draft) Standard Guide for Filtering Ground-Water Samples

(Draft) Standard Guide for Documenting a Ground-Water Sampling Event

Committee D-18 ON SOIL AND ROCK

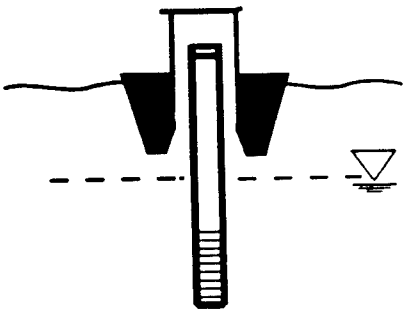
Fundamentals of Ground-Water Monitoring & Sampling Technology

GROUND WATER MONITORING WELL DESIGN & CONSTRUCTION

- Standard D-5092
- Role of Site Characterization
- Objectives of Monitoring Wells
- Sources of Chemical Interference
- Selection of Well Casing & Screen Materials
- Types & Designs of Well Screens
- Design & Installation of Filter Packs
- Selection & Installation of Annular Seal Materials
- Surface Protection
- Alternative Well Completions
- Preparation for Long-Term Monitoring

Instructor:

David M. Nielsen
Nielsen Ground-Water Science, Inc.
4686 State Route 605 South
Galena, OH 43021-9652



© 1995, Nielsen Ground-Water Science, Inc.
Galena, Ohio. All Rights Reserved.

These materials are copyright-protected under the laws of the United States and are the exclusive property of Nielsen Ground-Water Science, Inc. Any unauthorized duplication will result in prosecution.

ASTM STANDARD D-5092
STANDARD PRACTICE FOR DESIGN AND INSTALLATION OF GROUND-WATER MONITORING WELLS IN AQUIFERS

Purpose: To Promote Reliable and Durable Well Construction and Acquisition of Representative Ground-Water Data

- *Not* a Rigid Standard or Specification For One Well Design To Apply To All Sites and Conditions
- A Set of Flexible Guidelines, Including Design Parameters For Individual Well Construction Components, That Allow For Variable Site-Specific Conditions and Regulatory Requirements

ASTM STANDARD D-5092
STANDARD PRACTICE FOR DESIGN AND INSTALLATION OF GROUND-WATER MONITORING WELLS IN AQUIFERS

Promotes Thorough Site Characterization and the Use of Conceptual Models as Tools to Develop an Understanding of Site-Specific Conditions

Why?

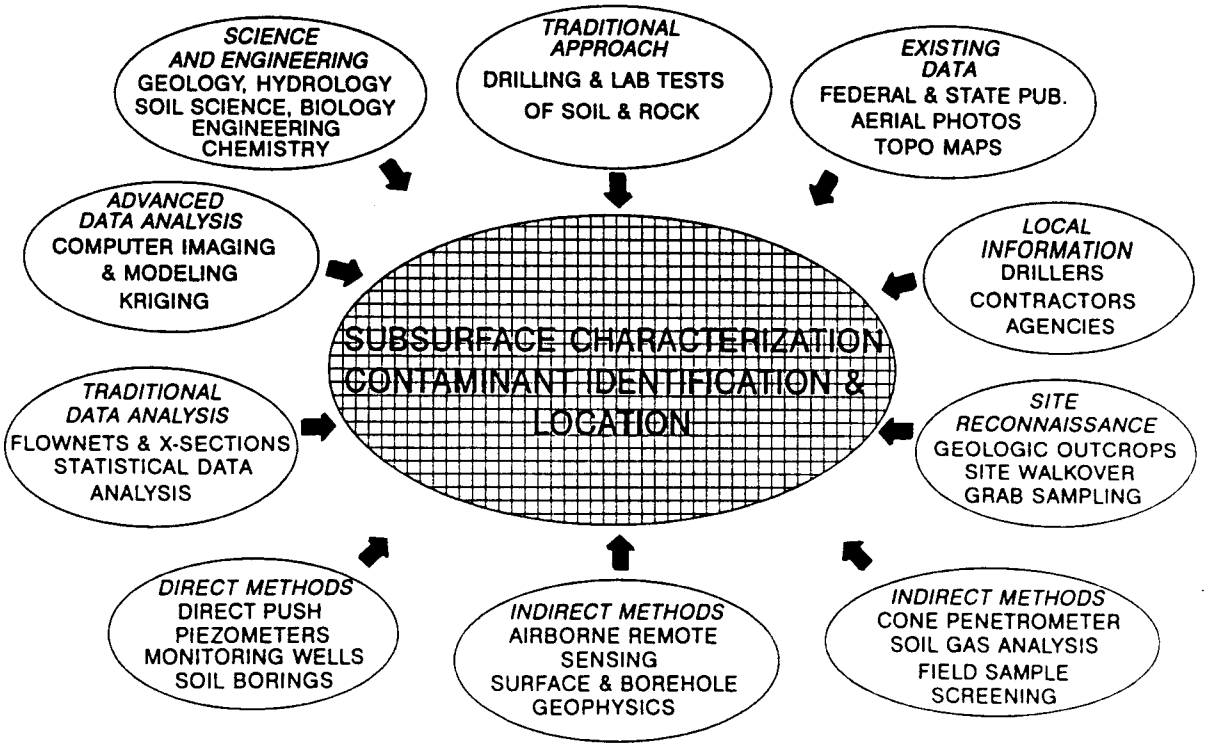
- Because Site-Specific Geologic, Hydrologic and Chemical Data Are *Required* to Ensure Proper Well Design and Installation

ASTM STANDARD D-5092
STANDARD PRACTICE FOR DESIGN AND INSTALLATION OF GROUND-WATER MONITORING WELLS IN AQUIFERS

What is Site Characterization?

- A Stepwise Procedure Combining Various Data-Gathering Methods to Assist in Identifying Target Monitoring Zones and Optimizing the Positions of Wells and Well Screens to Suit Site-Specific Conditions
- Uses Office-Based Methods (Background Information Review, Aerial Photo Analysis), Field Reconnaissance, and Field Investigation Methods (Geophysics, Cone Penetrometers, Direct-Push Sampling, Soil Borings, Field Sample Screening, Piezometers, Observation Wells) to Develop Necessary Data

TOOLS APPLIED TO SITE INVESTIGATIONS



TYPES OF SITE EVALUATIONS

- Characterization
  - Data Collected to Establish Environmental (Ambient and/or Contaminant-Related) Conditions at a Site or in a Specific Medium Over Space (3-Dimensionally) at a Single Point in Time

- Monitoring
  - Data Collected to Study Changes in Environmental Conditions at a Site or in a Specific Medium Over Time, Usually at Fixed Locations (Monitoring Stations, Monitoring Wells, Effluent Discharge Points)

ESTABLISHING OBJECTIVES OF THE INVESTIGATION

- Important in Ensuring Wise Use of Resources
  - Helps Avoid Wasting Time and Money Gathering Unnecessary Data
  - Ensures That All Required Data Are Collected

COMMON OBJECTIVES OF SITE CHARACTERIZATION

- Determine Ambient Environmental Conditions at a Site
- Determine If, and to What Degree, a Site Has Been Adversely Affected by a Contaminant Release
- Define Site-Specific Controls on Contaminant Movement (Soil/Geology Types and Characteristics, Hydrology, Anthropogenic Influences)
- Establish Contaminant Type(s), Characteristics and Sources

COMMON OBJECTIVES OF SITE CHARACTERIZATION

- Define Contaminant Distribution, Transport Patterns and Rates
- Identify Potential Receptors -- Types, Locations, Probable Impacts
- Determine the Need for Additional Work at the Site (Monitoring, Risk Assessment or Remediation)
- Prioritize Sites for Further Action

Objectives Commonly Progress as More Information Becomes Available, Usually Requiring a Phased Approach

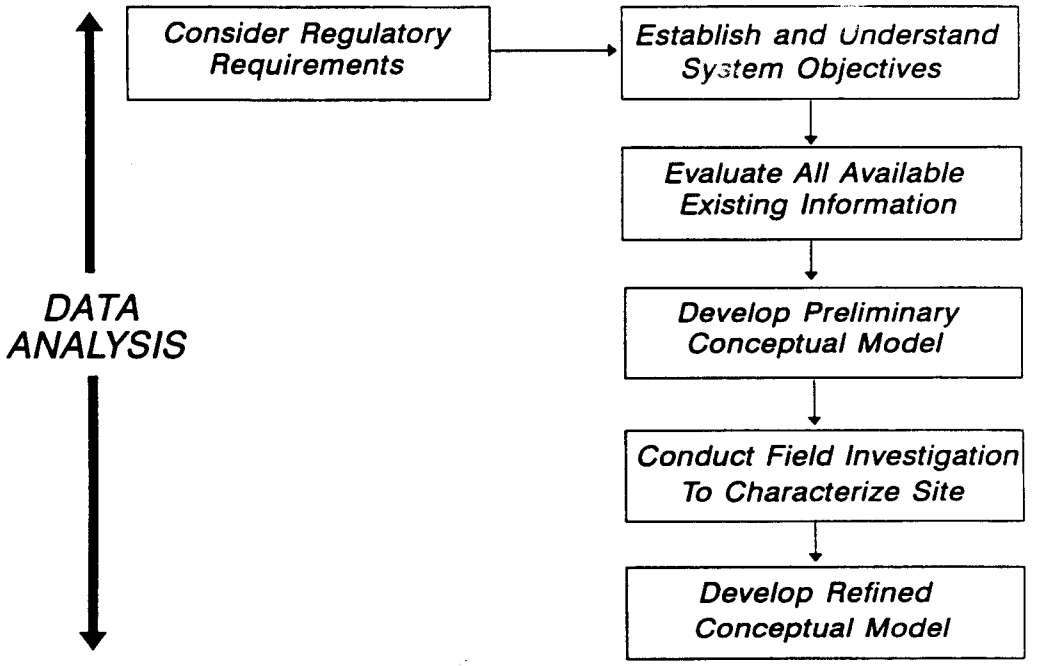
COMMON OBJECTIVES OF MONITORING

- Establish Baseline Environmental Conditions (Water Levels, Water Chemistry, Soil Chemistry, etc.)
- Detect Variations in Environmental Conditions (Natural--Seasonal, Tidal, etc. -- and Man-Induced)
- Provide a Summary of Average or Extreme Conditions
- Demonstrate Compliance with Environmental Regulations
- Assess the Adequacy of Controls on Contaminant Releases

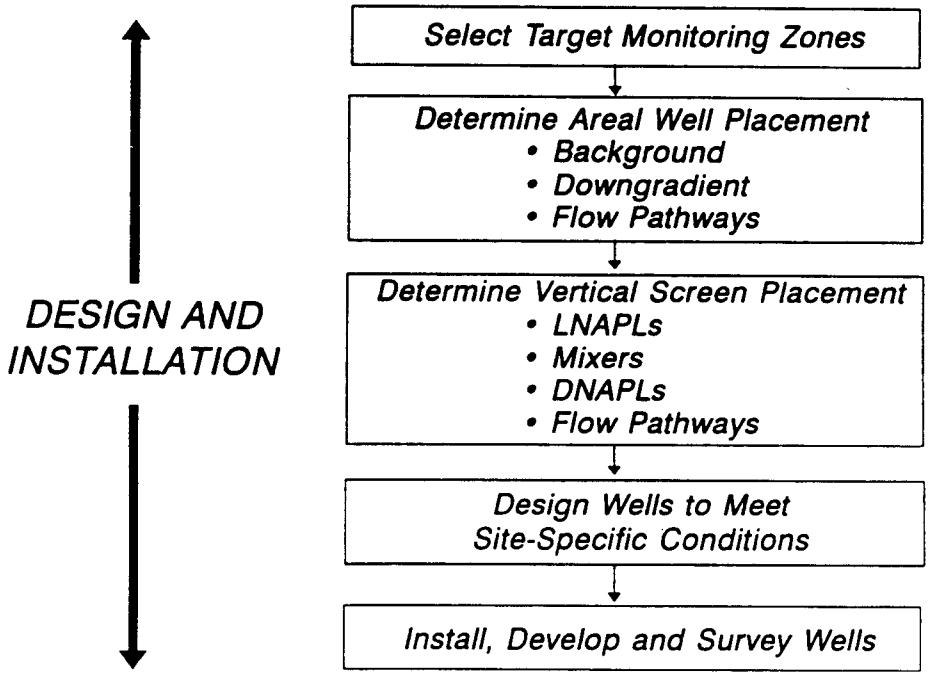
COMMON OBJECTIVES OF MONITORING

- Detect the Presence of Contaminants
- Determine the Source(s) of Specific Contaminants
- Assess the Extent of Contamination, the Concentrations of Contaminants and the Rate and Direction of Contaminant Movement
- Detect Long-Term Trends in Contaminant Distribution
- Determine the Effectiveness of Remedial Actions

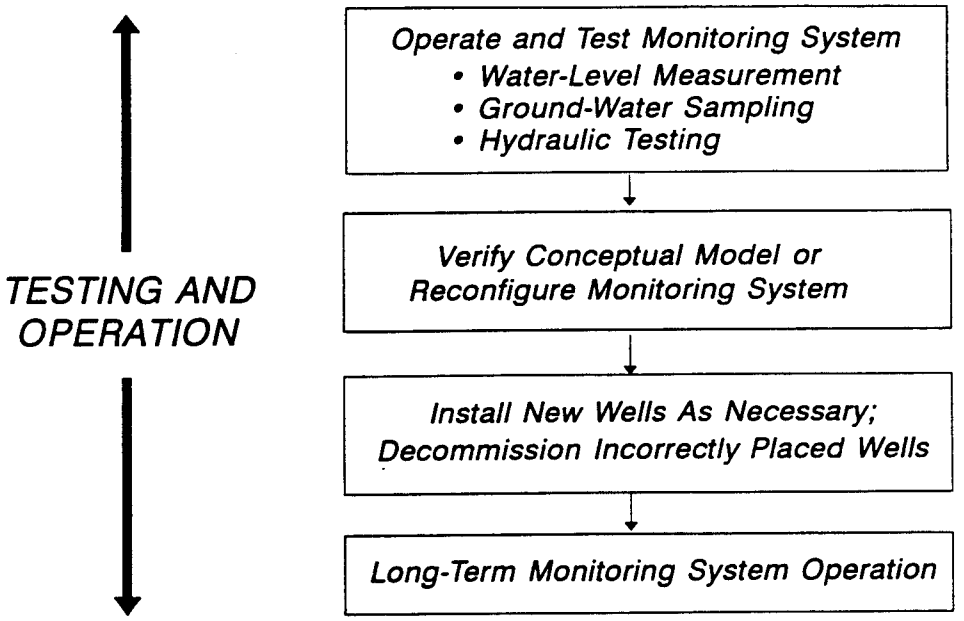
GROUND-WATER MONITORING SYSTEM FLOW DIAGRAM



GROUND-WATER MONITORING SYSTEM FLOW DIAGRAM



GROUND-WATER MONITORING SYSTEM FLOW DIAGRAM



GROUND-WATER MONITORING SYSTEM DESIGN

- Because of the Inherent Uncertainty, Complexity and Heterogeneity of the Subsurface, It is Very Difficult, If Not Impossible, to Properly Design a Cost-Effective Ground-Water Monitoring System Without Extensive Prior Knowledge of the Site, Including:

  - Geologic and Hydrogeologic Conditions
  - Nature and Characteristics of Contaminants
  - Presence of Preferential Migration Pathways
  - Impact of Man's Activities

This Requires a Phased Approach to Site Investigation -- It Cannot Be Done Properly in One Step

DATA NEEDS AND USES FOR PROPER MONITORING WELL DESIGN AND INSTALLATION

Data Needed	Data Uses
Site Hydrogeology	
Geologic Material (Sediment vs. Bedrock; Boulders, Caving Zones, Large Voids)	Define Ground-Water Regime; Preferred Drilling Method; Well Completion Type; Need For Special Completion
Preferential Ground-Water Flow Pathways	Define Target Monitoring Zone(s)
Target Monitoring Zones (Position, Depth, Thickness)	Define Well Placement; Screen Placement and Length; Well Depth

DATA NEEDS AND USES FOR PROPER MONITORING WELL DESIGN AND INSTALLATION

Data Needed	Data Uses
Site Hydrogeology	
Grain Size of Material in Target Monitoring Zone	Defines Screen Slot Size; Filter Pack Grain Size; Type of Development Method
Position and Degree of Fluctuation of Water Table	Defines Screen Placement For LNAPL Monitoring Wells
Depth of Frost Penetration	Defines Depth of Surface Seal

DATA NEEDS AND USES FOR PROPER MONITORING WELL DESIGN AND INSTALLATION

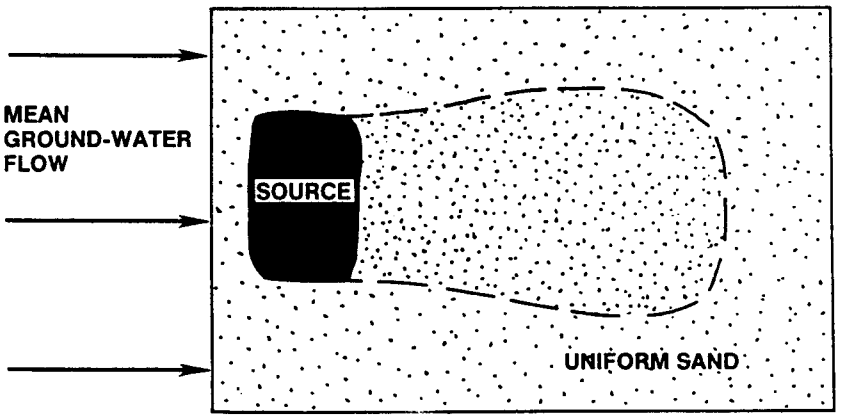
Data Needed	Data Uses
Site Hydrogeochemistry	
Ambient Ground-Water Chemistry (Esp. pH, O2, CO2, TDS, Cl, H2S)	Define Well Construction Materials (Casing, Screen, Annular Seal)
Contaminant Types and Concentrations (Esp. NAPLs)	Define Well Construction Materials; Screen Placement and Length
Microbiology (Esp. Iron Bacteria)	Define Well Construction Materials; Need For Special Well Maintenance

< 3,000 ppm Cl^-

interfers w/ bentonite

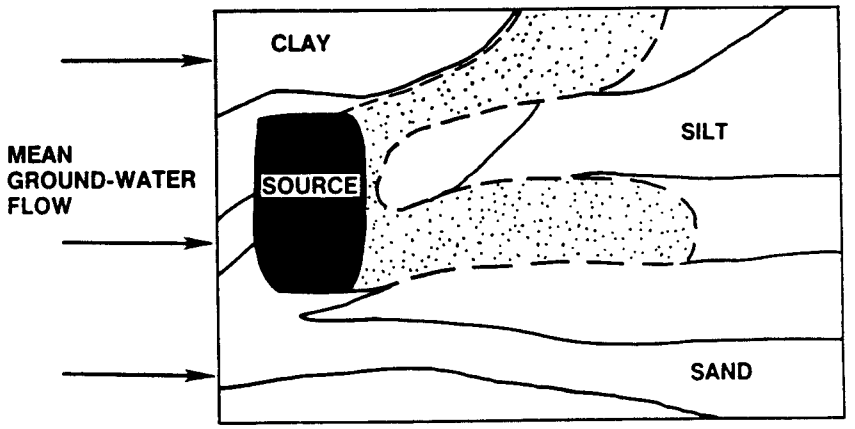
CONTAMINANT MIGRATION IN GRANULAR MATERIALS (PLAN VIEW)

- ISOTROPIC, HOMOGENEOUS



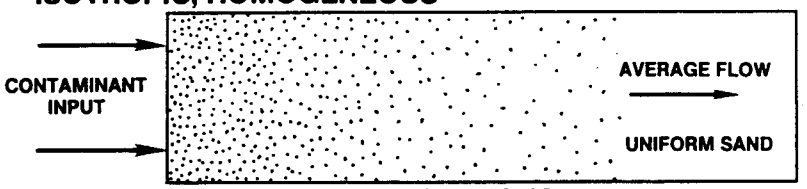
CONTAMINANT MIGRATION IN GRANULAR MATERIALS (PLAN VIEW)

- ANISOTROPIC, NON-HOMOGENEOUS

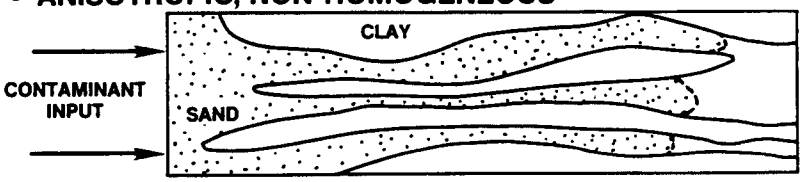


CONTAMINANT MIGRATION IN GRANULAR MATERIALS (CROSS-SECTIONAL VIEW)

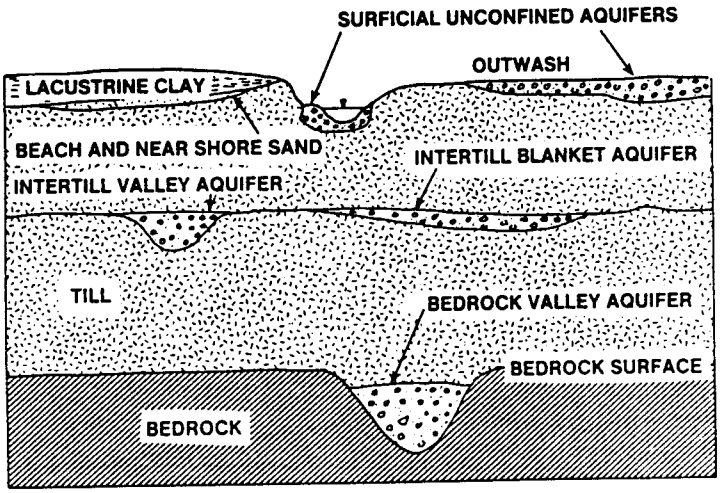
- ISOTROPIC, HOMOGENEOUS

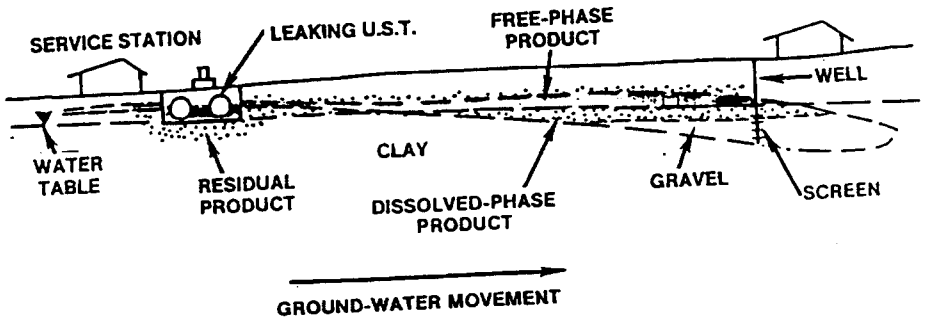


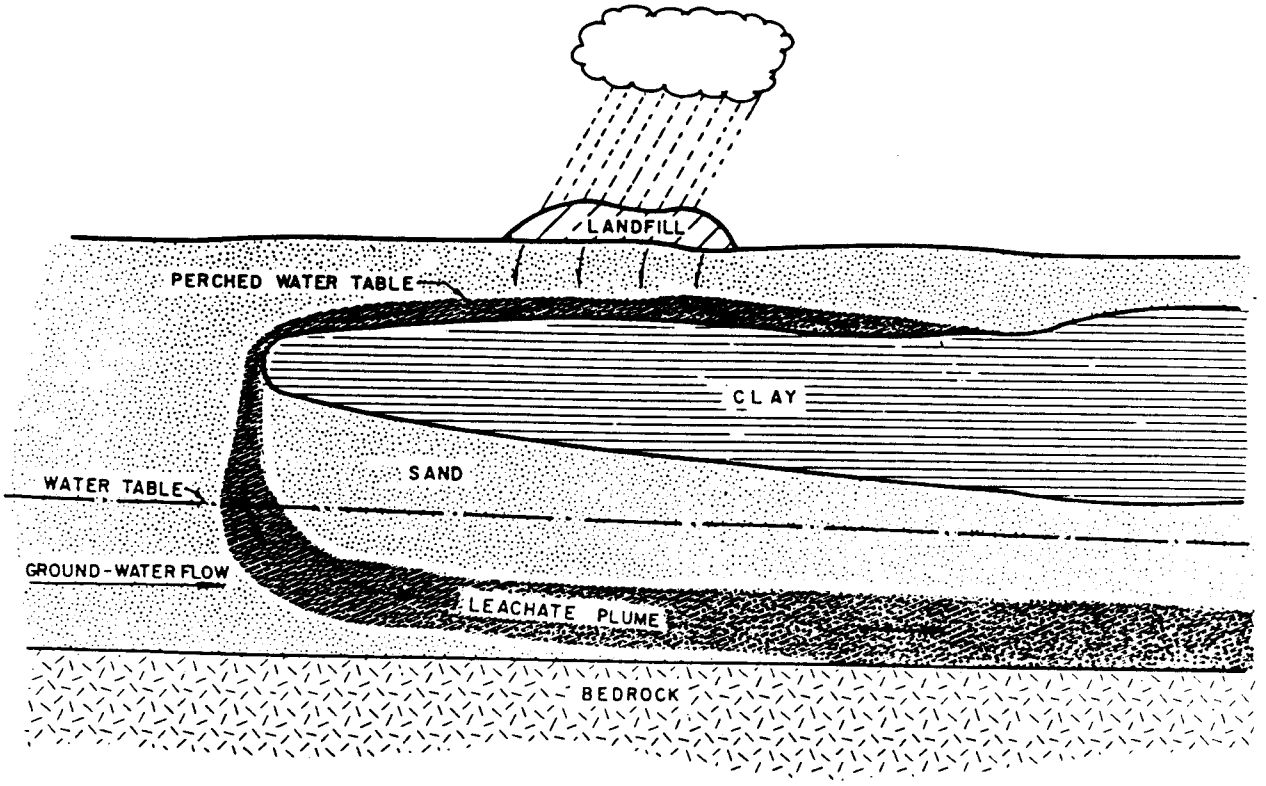
- ANISOTROPIC, NON-HOMOGENEOUS



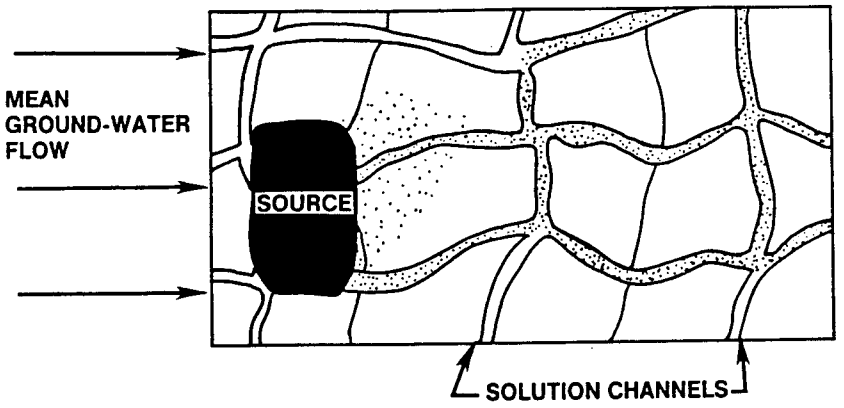
SCHEMATIC DIAGRAM OF AQUIFER OCCURRENCE IN A GLACIATED REGION

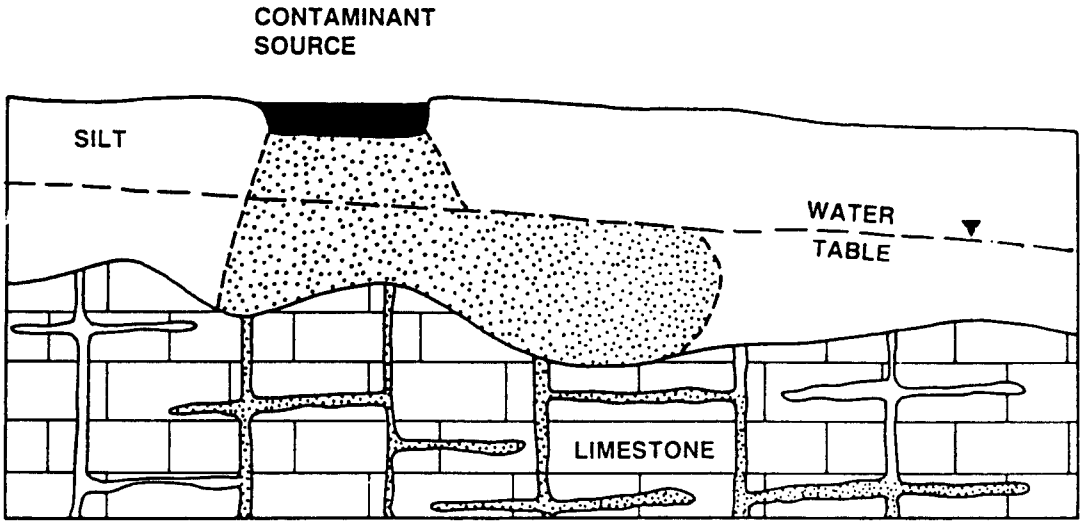



SERVICE STATION
LEAKING U.S.T.
FREE-PHASE PRODUCT
WELL
WATER TABLE
RESIDUAL PRODUCT
CLAY
DISSOLVED-PHASE PRODUCT
GRAVEL
SCREEN
GROUND-WATER MOVEMENT

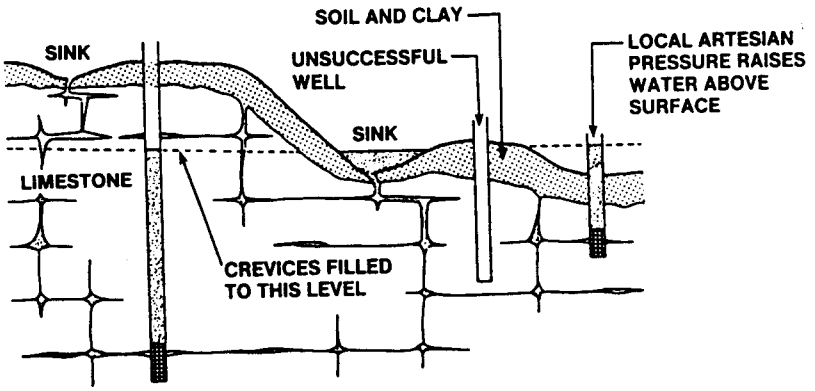

LANDFILL
PERCHED WATER TABLE
CLAY
SAND
WATER TABLE
GROUND-WATER FLOW
LEACHATE PLUME
BEDROCK

CONTAMINANT MIGRATION IN SOLUTION-CHANNELLED MATERIALS (PLAN VIEW)

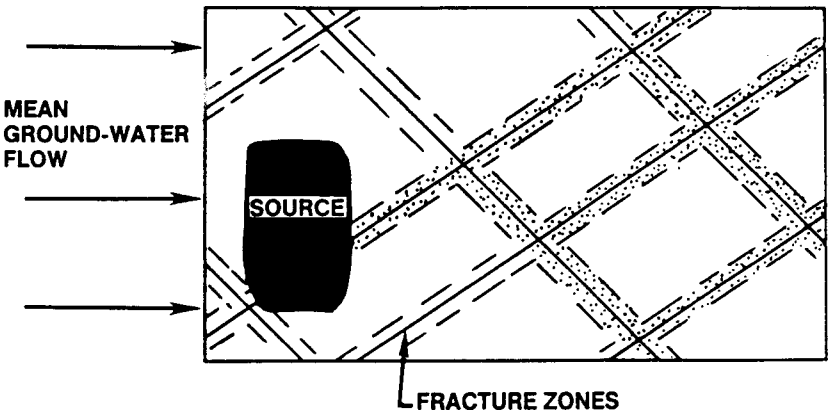


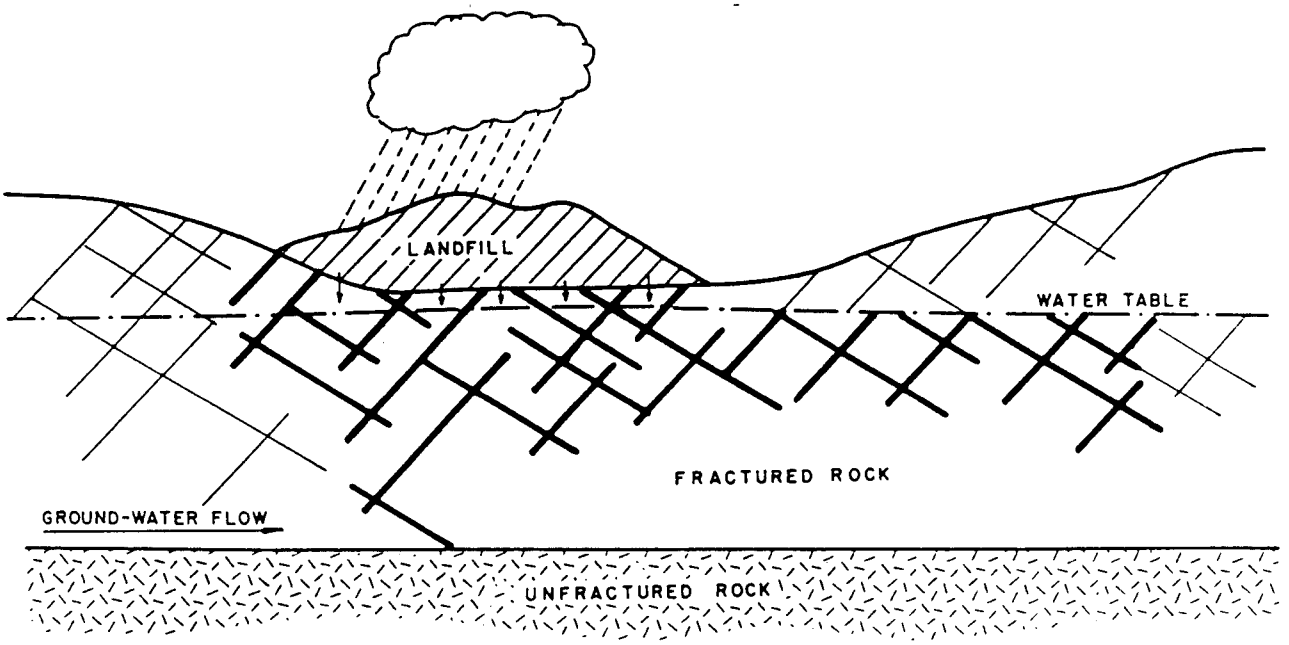


SCHEMATIC ILLUSTRATION OF THE OCCURRENCE OF GROUND WATER IN CARBONATE ROCK. SECONDARY PERMEABILITY OCCURS ALONG ENLARGED FRACTURES AND BEDDING PLANE OPENINGS.

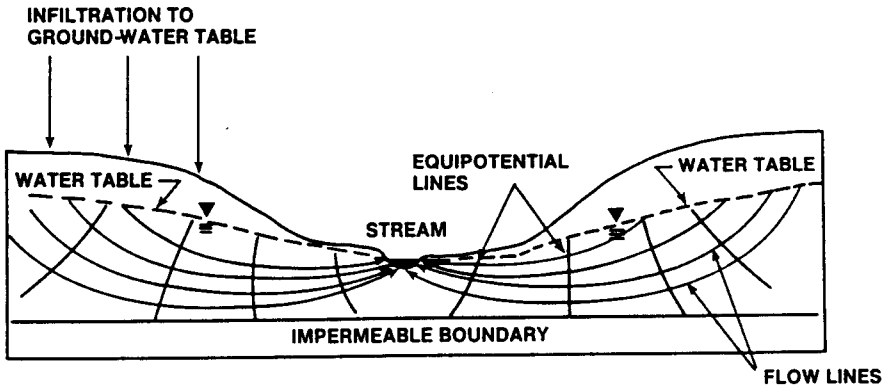


CONTAMINANT MIGRATION IN FRACTURED MATERIALS (PLAN VIEW)

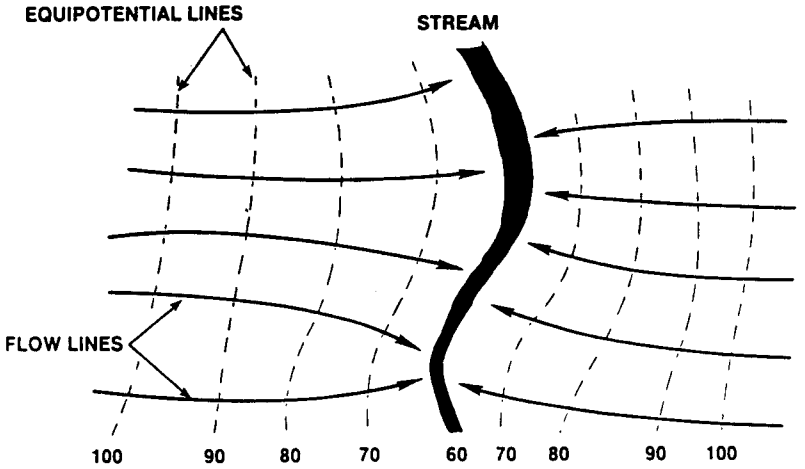


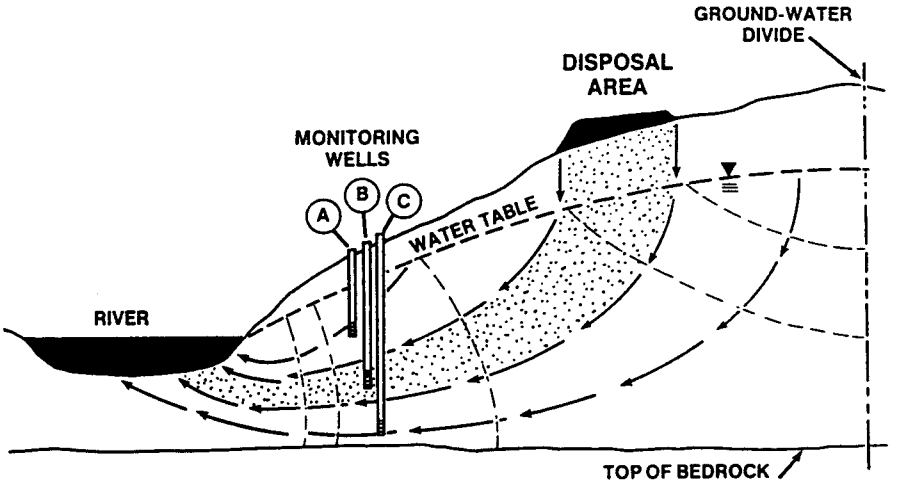


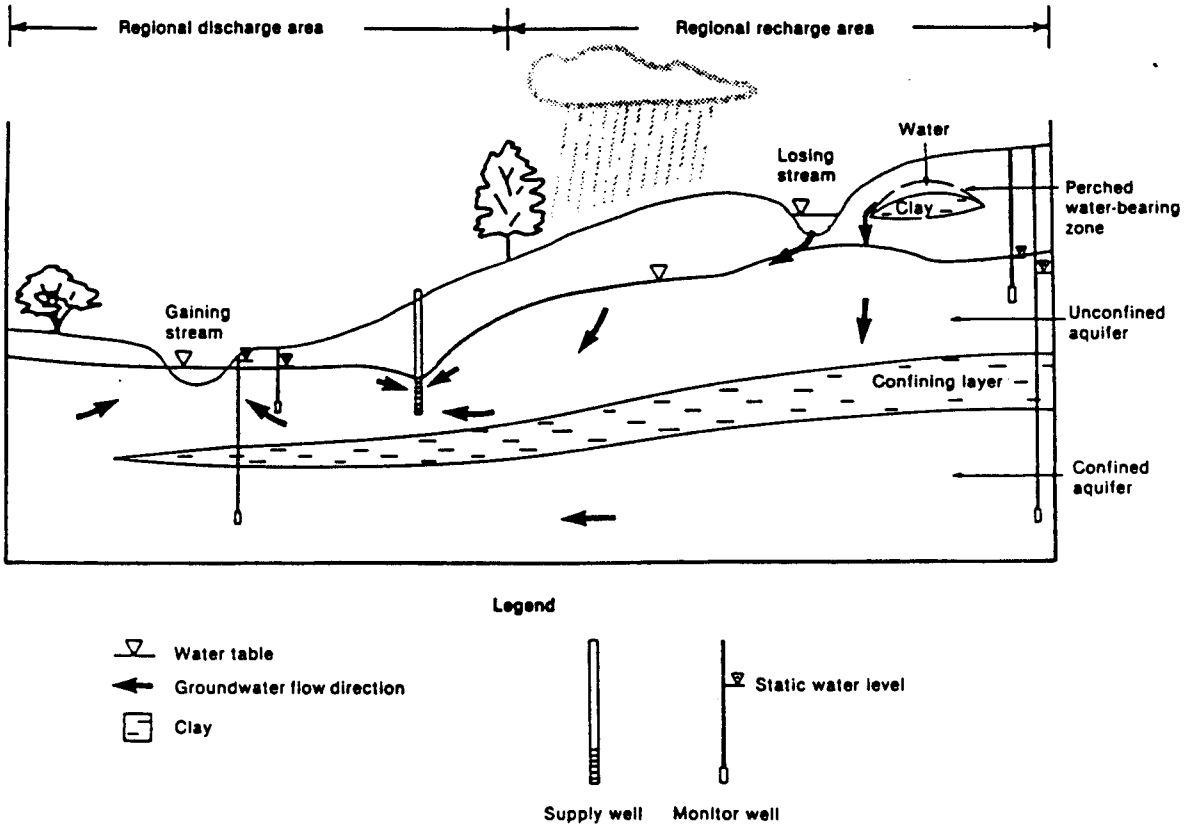
CROSS SECTION THROUGH A STREAM VALLEY SHOWING FLOW LINES IN THE GROUND-WATER SYSTEM.



LOOKING DOWN ON THE STREAM VALLEY FROM ABOVE WITH THE WATER TABLE EXPOSED. EQUIPOTENTIAL LINES REPRESENT POINTS OF EQUAL GROUND WATER ELEVATION.



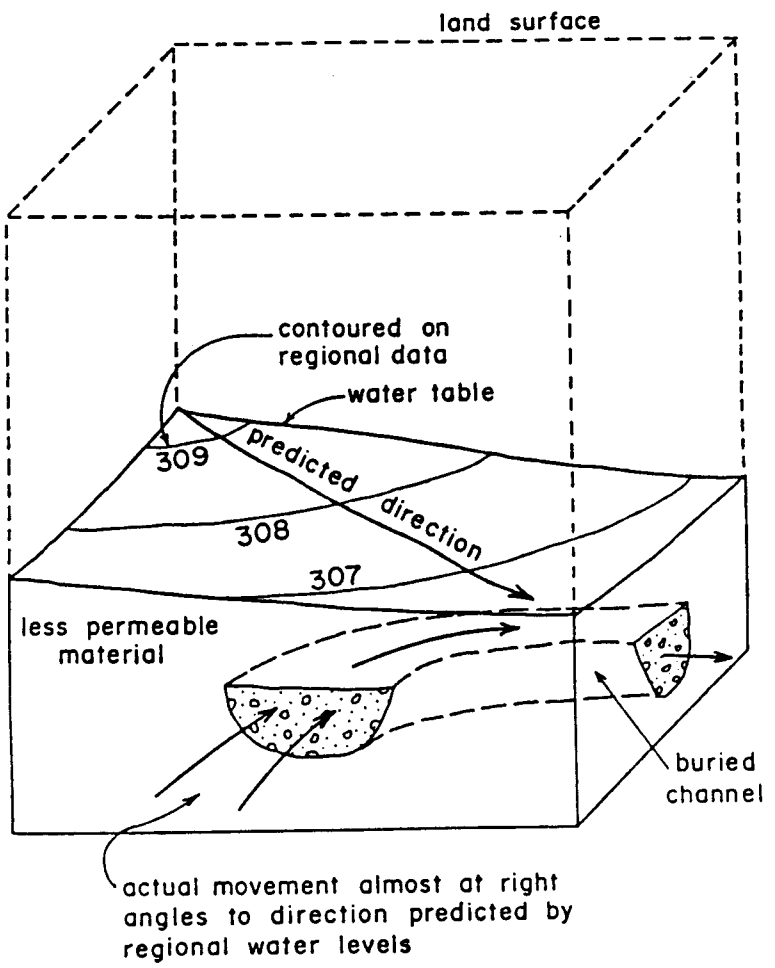




Circulation of Groundwater From Regional Recharge Area to Regional Discharge Area

GENERAL OBSERVATIONS REGARDING GROUND-WATER FLOW

1) Ground Water Always Flows From Areas of High Hydraulic Head to Areas of Lower Hydraulic Head
2) Ground Water Generally Flows Away From Topographic Highs and Toward Topographic Lows
3) The Water Table in an Unconfined Aquifer Has the Same General Shape as the Surface Topography
4) Ground-Water Recharge Zones are Generally on Topographic Highs, While Ground-Water Discharge Zones are In Topographic Lows
5) A Sloping Water Table (or Potentiometric) Surface Indicates that Ground Water is Flowing
6) In the Absence of Ground-Water Flow, the Water Table Will Be Flat



GROUND WATER MONITORING NETWORK DESIGN
TYPES OF CONTAMINANTS

- **Floaters -**

  less dense (lower specific gravity) than water, mostly immiscible/insoluble; phase-separated into free product, dissolved phase, vapor phase

- **Mixers -**

  nearly the same density (specific gravity) as water, mostly miscible/soluble

- **Sinkers -**

  more dense (higher specific gravity) than water, mostly immiscible/insoluble; phase separated into free product, dissolved phase

INORGANIC CONSTITUENTS

- Heavy Metals, Radionuclides, Salts
  - All Soluble to Some Degree in Water, Depending Upon Water Chemistry (pH, Redox Conditions, Dissolved Constituents)
  - Do Not Volatilize at Ambient Temperatures (except Mercury)
  - May Sorb Strongly Onto Soils, Especially Clays (Except Salts)

PHYSICAL PROPERTIES OF SELECTED ORGANIC CHEMICALS

CHEMICAL	DENSITY (gm/cm^3)	SOLUBILITY (mg/l @ 25°C)	VAPOR PRESSURE (mm Hg @ 25°C)	HENRY'S LAW CONSTANT ($atm \cdot m^3/mole$)
Hexachloroethane	2.209	50	0.5	2.18×10^{-3}
Ethylene Dibromide	2.175	4310	17.4	8.03×10^{-4}
Pentachlorophenol	1.978	20	1.7×10^{-5}	3.4×10^{-6}
Lindane	1.870		6.7×10^{-5}	3.25×10^{-6}
Tetrachloroethylene	1.623	150	18.6	2.3×10^{-2}
Carbon Tetrachloride	1.594	785	99	2.58×10^{-2}
Chloroform	1.483	8220	240	3.8×10^{-3}
Arochlor 1254 (PCB)	1.475	0.012	7.7×10^{-5}	2.76×10^{-3}

PHYSICAL PROPERTIES OF SELECTED ORGANIC CHEMICALS

CHEMICAL	DENSITY (gm/cm^3)	SOLUBILITY (mg/l @ 25°C)	VAPOR PRESSURE (mm Hg @ 25°C)	HENRY'S LAW CONSTANT ($atm \cdot m^3/mole$)
Trichloroethylene	1.462	1100	77	1.16×10^{-2}
p-Dichlorobenzene	1.458	79	1.2	3.1×10^{-3}
1,1,2 - Trichloroethane	1.443	4420	20	9.0×10^{-4}
Methylene Chloride	1.327	20000	438	2.52×10^{-3}
1,1,1 - Trichloroethane	1.339	720	127	4.2×10^{-3}
trans - 1,2 - Dichloroethylene	1.257	6300	315	5.3×10^{-3}
1,2-Dichloroethane	1.255	8690	84	1.46×10^{-3}

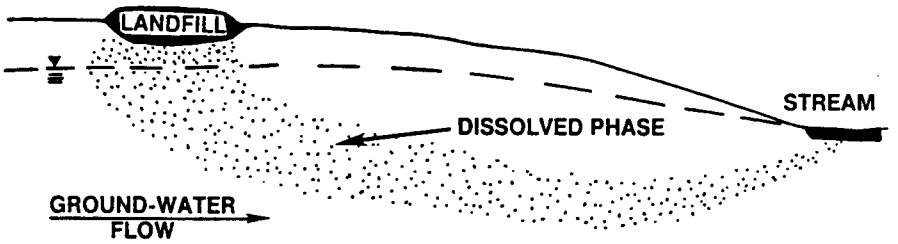
PHYSICAL PROPERTIES OF SELECTED ORGANIC CHEMICALS

CHEMICAL	DENSITY (gm/cm^3)	SOLUBILITY (mg/l @ 25°C)	VAPOR PRESSURE (mm Hg @ 25°C)	HENRY'S LAW CONSTANT ($atm \cdot m^3/mole$)
1,1-Dichloroethylene	1.204	400	599	1.5×10^{-2}
1,1-Dichloroethane	1.174	5500	183	5.4×10^{-3}
Chlorobenzene	1.106	500	7	4.5×10^{-3}
Phenol	1.072	93000	0.35	2.7×10^{-7}
Acetylacetone	0.975	21000	325	
Cyclohexanone	0.948	7540	136	
Vinyl Chloride	0.912	60	2660	5.6×10^{-2}

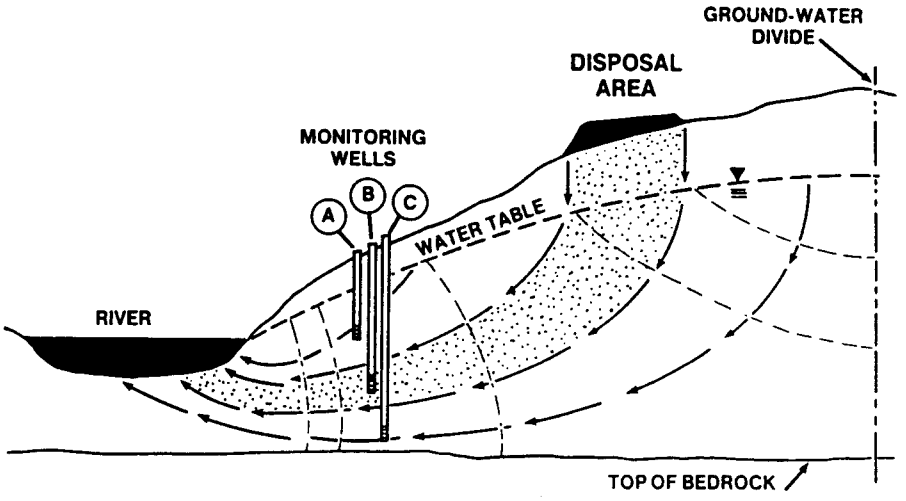
PHYSICAL PROPERTIES OF SELECTED ORGANIC CHEMICALS

CHEMICAL	DENSITY (gm/cm^3)	SOLUBILITY (mg/l @ 25°C)	VAPOR PRESSURE (mm Hg @ 25°C)	HENRY'S LAW CONSTANT ($atm \cdot m^3/mole$)
Benzene	0.879	1780	76	4.6×10^{-3}
Ethylbenzene	0.867	206	8	5.3×10^{-3}
Toluene	0.867	515	28.4	6.68×10^{-3}
Xylene	0.866	180	6.5	2.67×10^{-3}
Methyl Ethyl Ketone	0.805	270000	100	3.0×10^{-5}
Methanol	0.796	Miscible	92	
Acetone	0.792	Miscible	270	3.97×10^{-5}
Methyl Tert-Butyl Ether	0.741	48000	245	

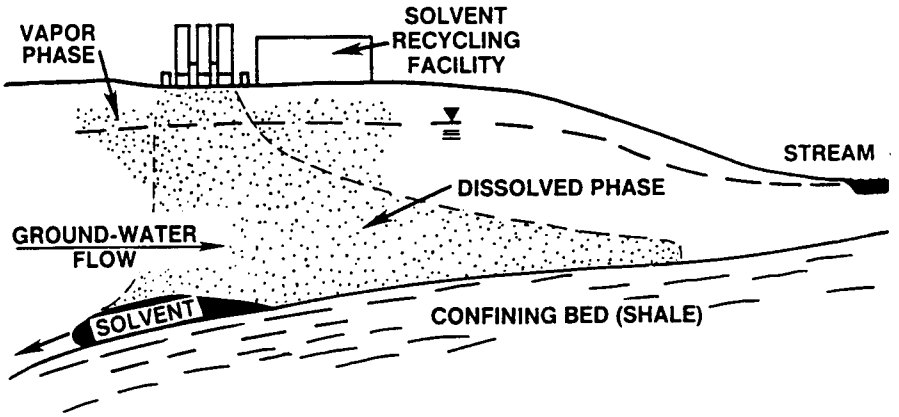
MIXERS - NEARLY THE SAME DENSITY AS WATER; MOSTLY MISCIBLE/SOLUBLE IN WATER; MAY BE STRONGLY SORBED BY SOILS

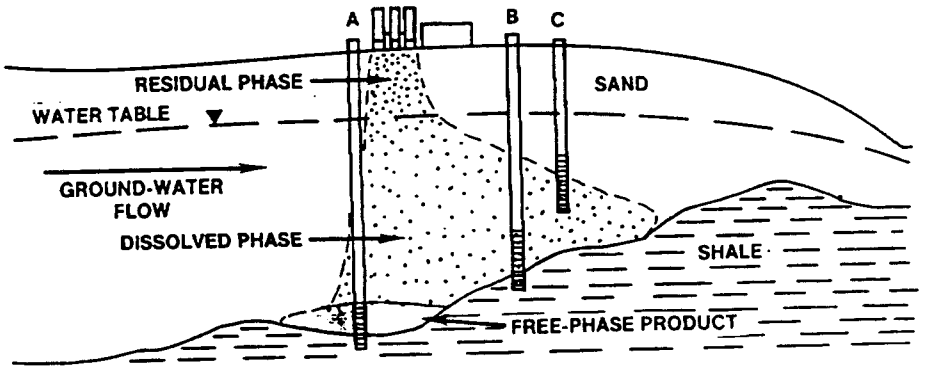


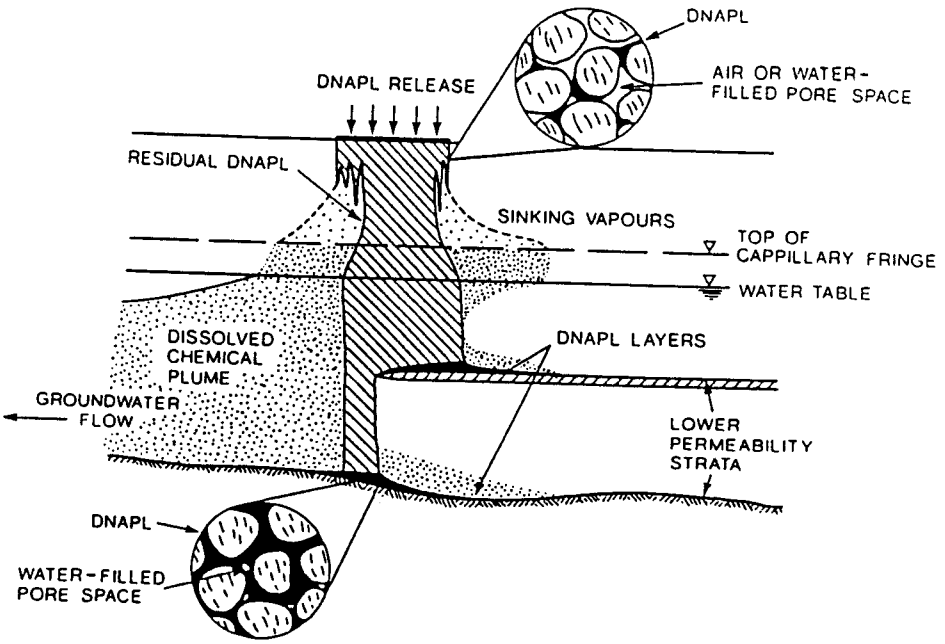
"Mixers"

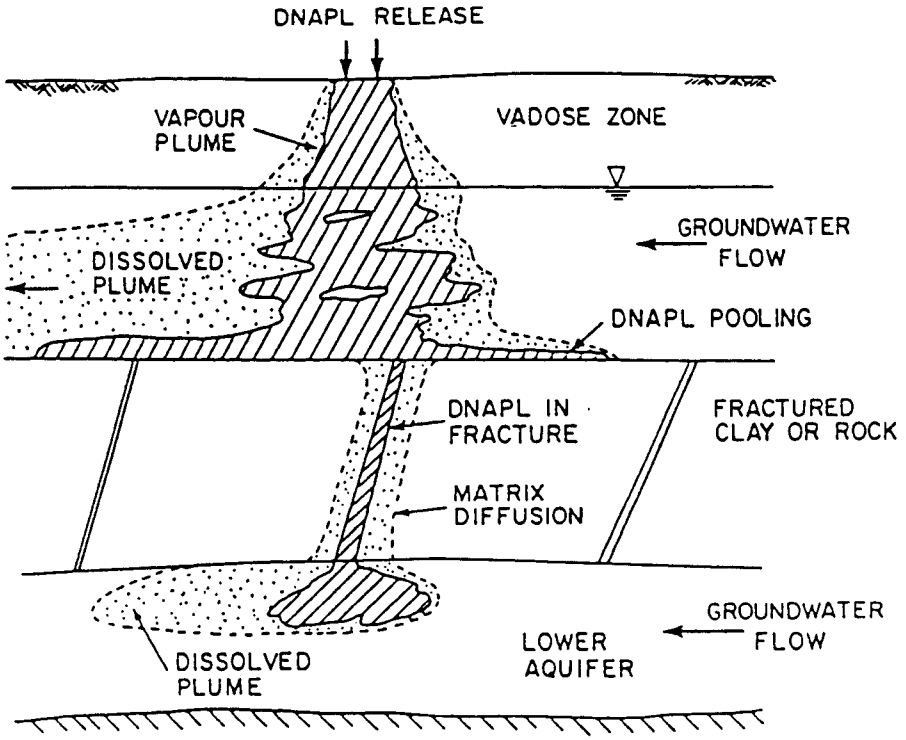


SINKERS - MORE DENSE THAN WATER; MOSTLY IMMISCIBLE/ INSOLUBLE IN WATER; PHASE-SEPARATED INTO FREE PRODUCT, DISSOLVED PHASE, VAPOR PHASE; MAY BE STRONGLY SORBED BY SOILS

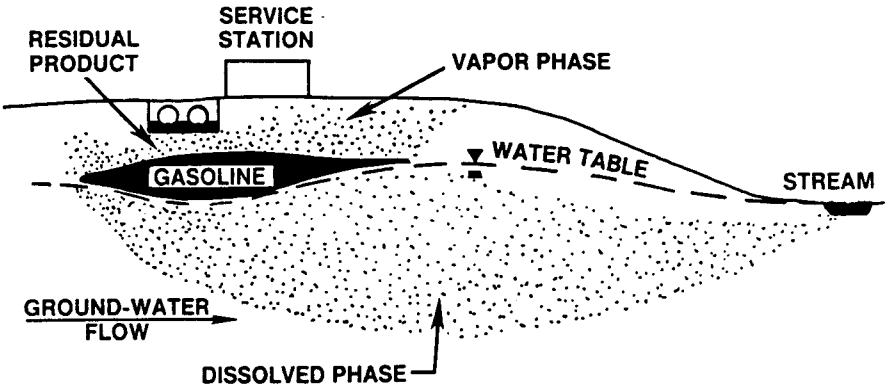


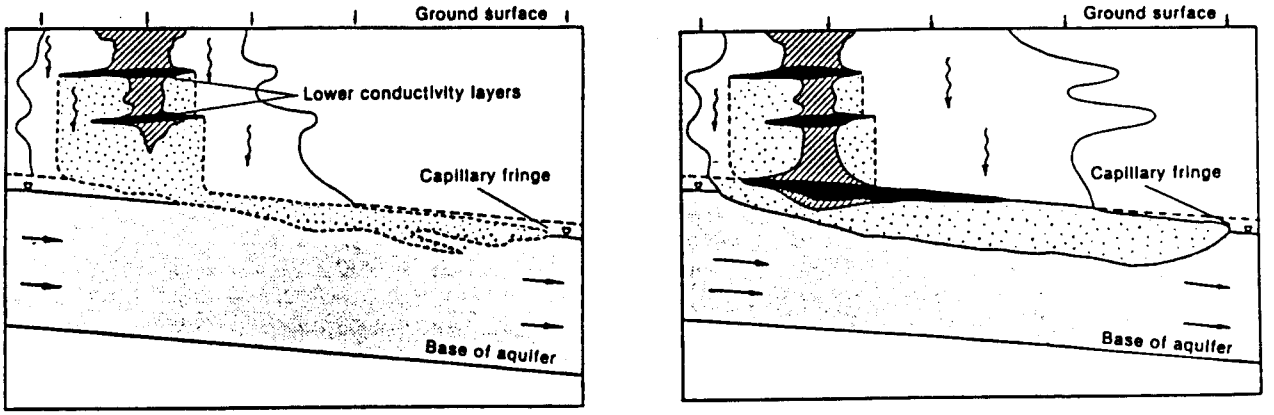



DNAPL
AIR OR WATER-
FILLED PORE SPACE
DNAPL RELEASE
RESIDUAL DNAPL
SINKING VAPOURS
TOP OF
CAPPILLARY FRINGE
WATER TABLE
DISSOLVED
CHEMICAL
PLUME
DNAPL LAYERS
GROUNDWATER
FLOW
LOWER
PERMEABILITY
STRATA
DNAPL
WATER-FILLED
PORE SPACE


DNAPL RELEASE
VAPOUR
PLUME
VADOSE ZONE
GROUNDWATER
FLOW
DISSOLVED
PLUME
DNAPL POOLING
DNAPL IN
FRACTURE
FRACTURED
CLAY OR ROCK
MATRIX
DIFFUSION
GROUNDWATER
FLOW
LOWER
AQUIFER
DISSOLVED
PLUME

FLOATERS - LESS DENSE THAN WATER; MOSTLY IMMISCIBLE/ INSOLUBLE IN WATER; PHASE-SEPARATED INTO FREE PRODUCT, DISSOLVED PHASE, VAPOR PHASE; STRONGLY SORBED BY SOILS





a. Releases In Which the Liquid Hydrocarbons Do Not Make Direct Contact With the Regional Groundwater Zone

b. Releases Characterized by Free Liquid Hydrocarbons Reaching the Regional Groundwater Zone

Legend

Hydrocarbon Phases

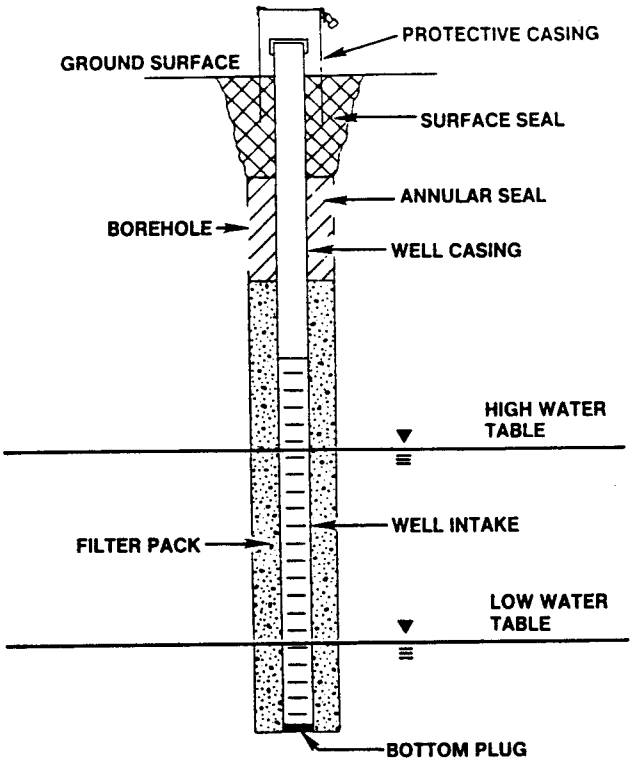
- Vapor phase
- Free liquid phase
- Residual liquid phase
- Dissolved phase in vadose zone
- Dissolved phase in groundwater
- Uncontaminated groundwater

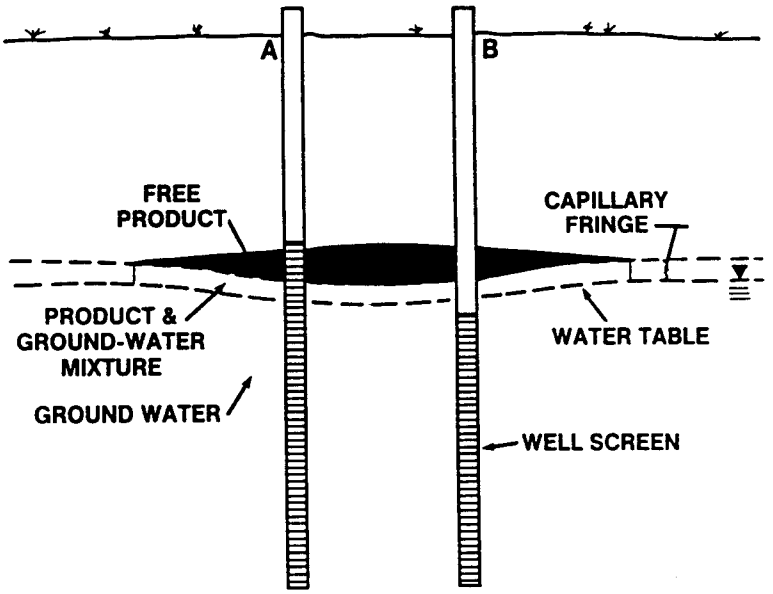
Generalized Water Flow

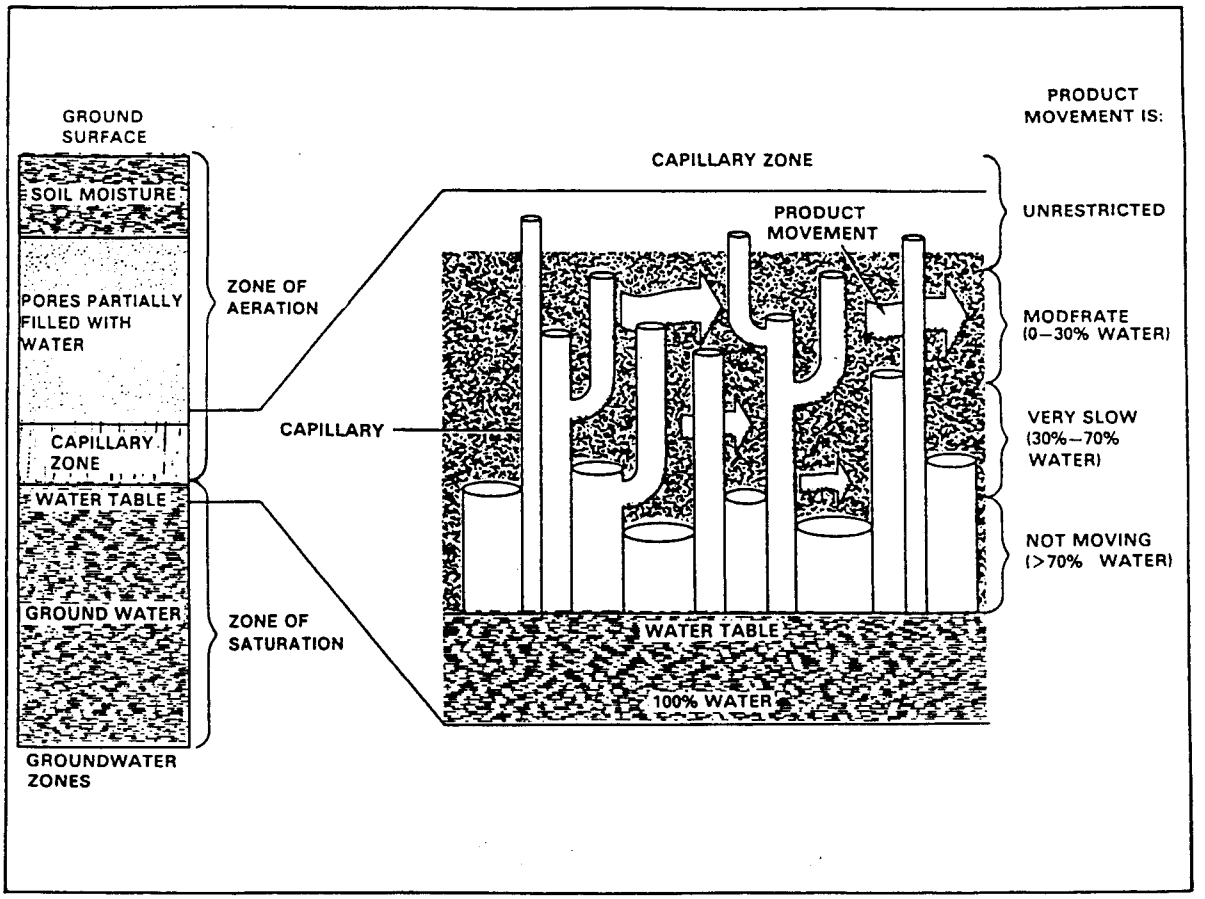
- Infiltration at land surface
- Unsaturated flow
- Groundwater flow

Distribution of Hydrocarbons From a Small Release (a) and a Large Release (b)

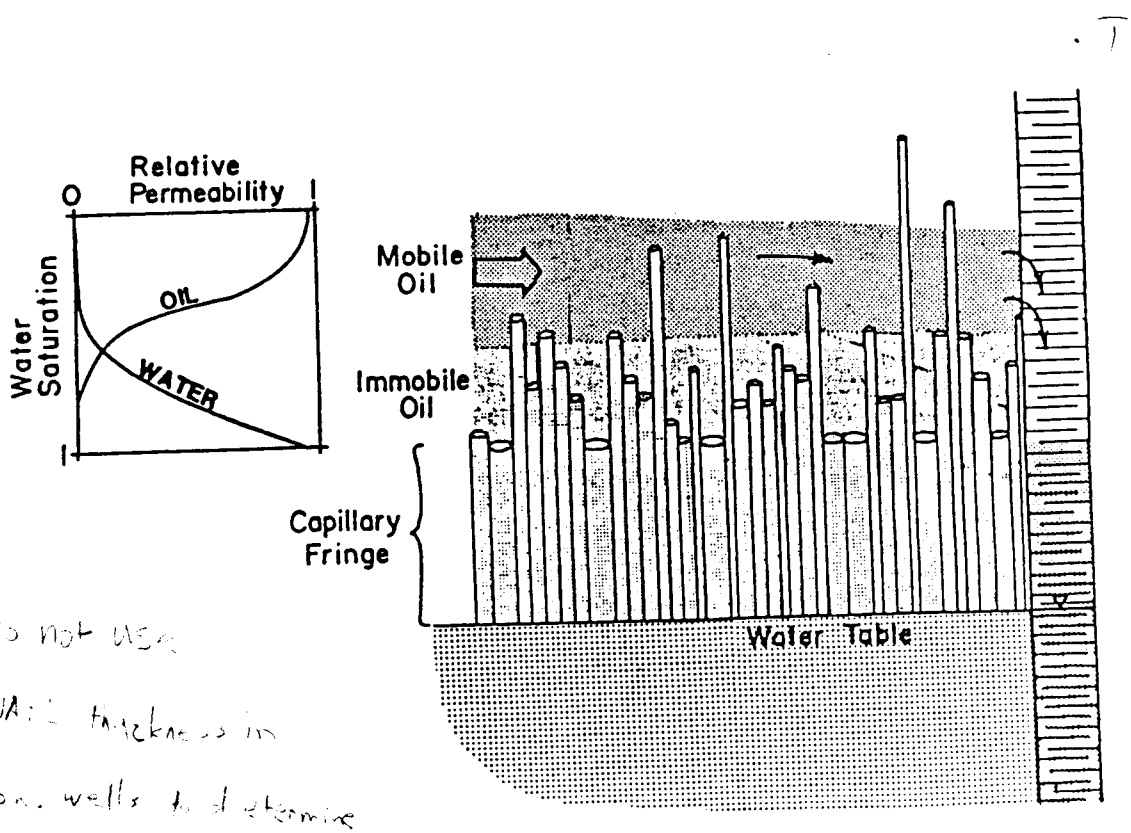
MONITORING WELL CONSTRUCTION FOR "FLOATERS"



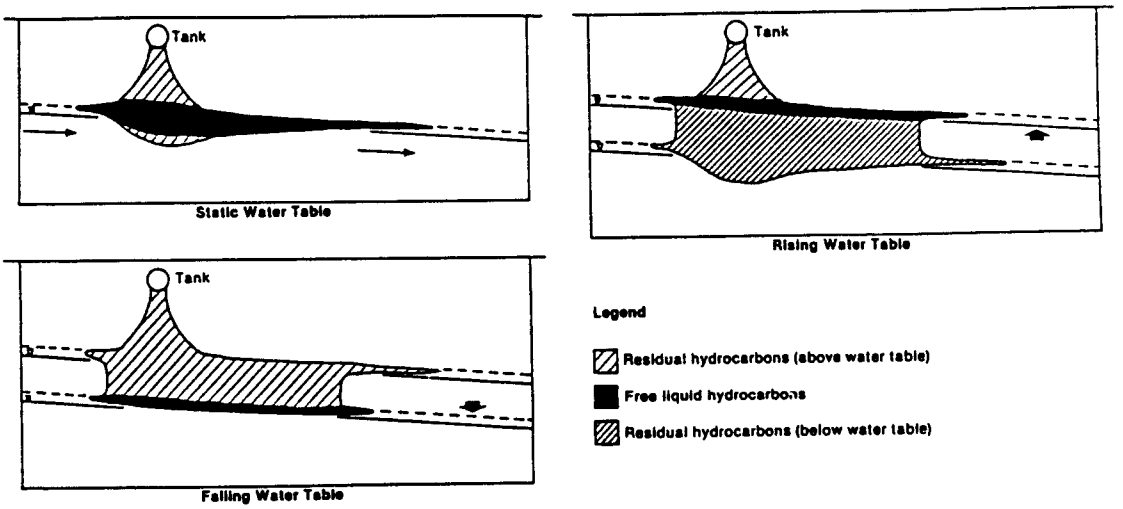




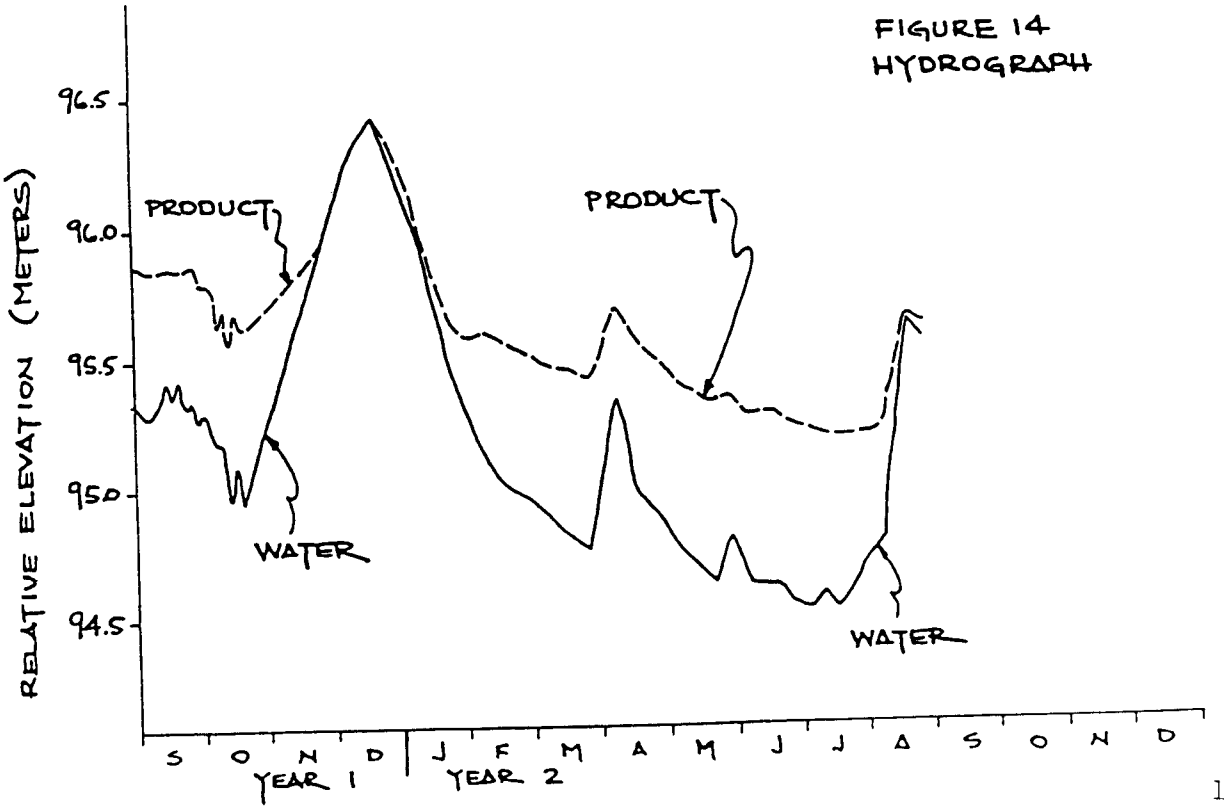
Diagramatic Illustration of Water Rising in Capillaries of Varying Diameters and the Restricting Effect on Product Movement Through the Zone



Do not use LNAPL thickness in monitoring wells to determine mass volume



Spreading of Hydrocarbons as a Result of Water Table Fluctuations



SITE INVESTIGATION AND CHARACTERIZATION STEP-BY-STEP PROCESS

STEP 1 – Preliminary Site Characterization (Background Information Review & Site Reconnaissance)

STEP 2 – Develop Preliminary Conceptual Model

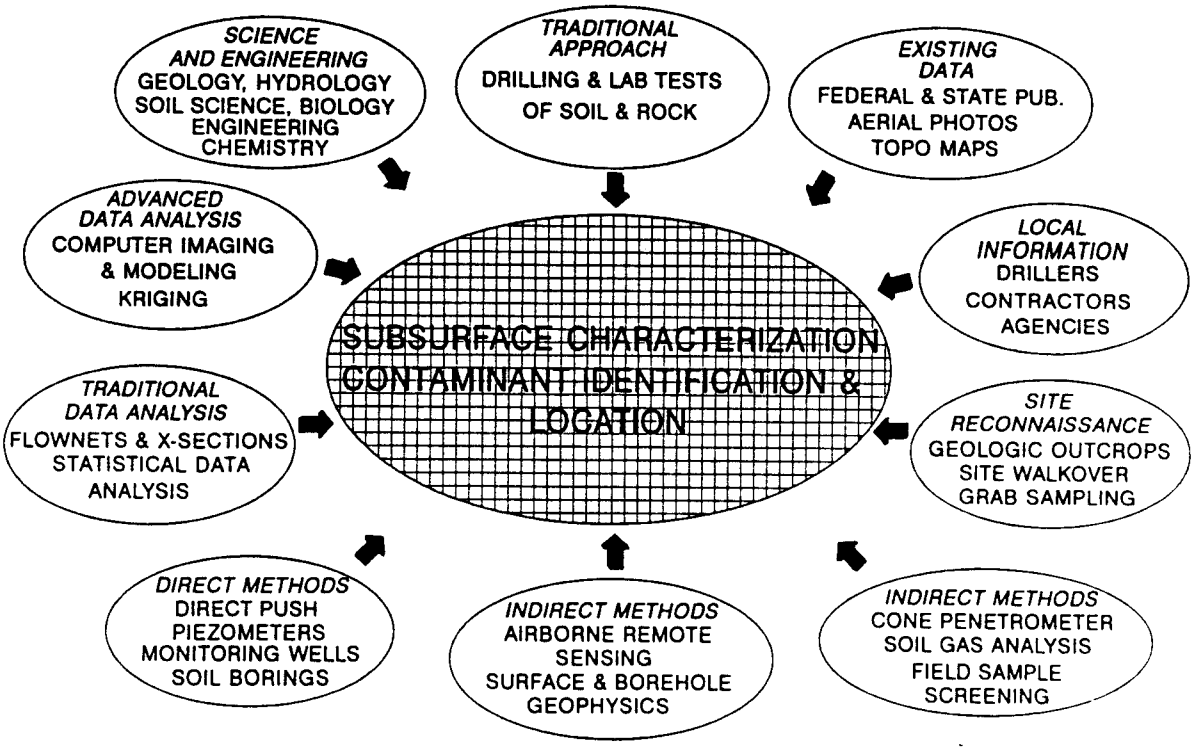
STEP 3 – Detailed Site Characterization (Field Investigation)

STEP 4 – Develop Refined Conceptual Model

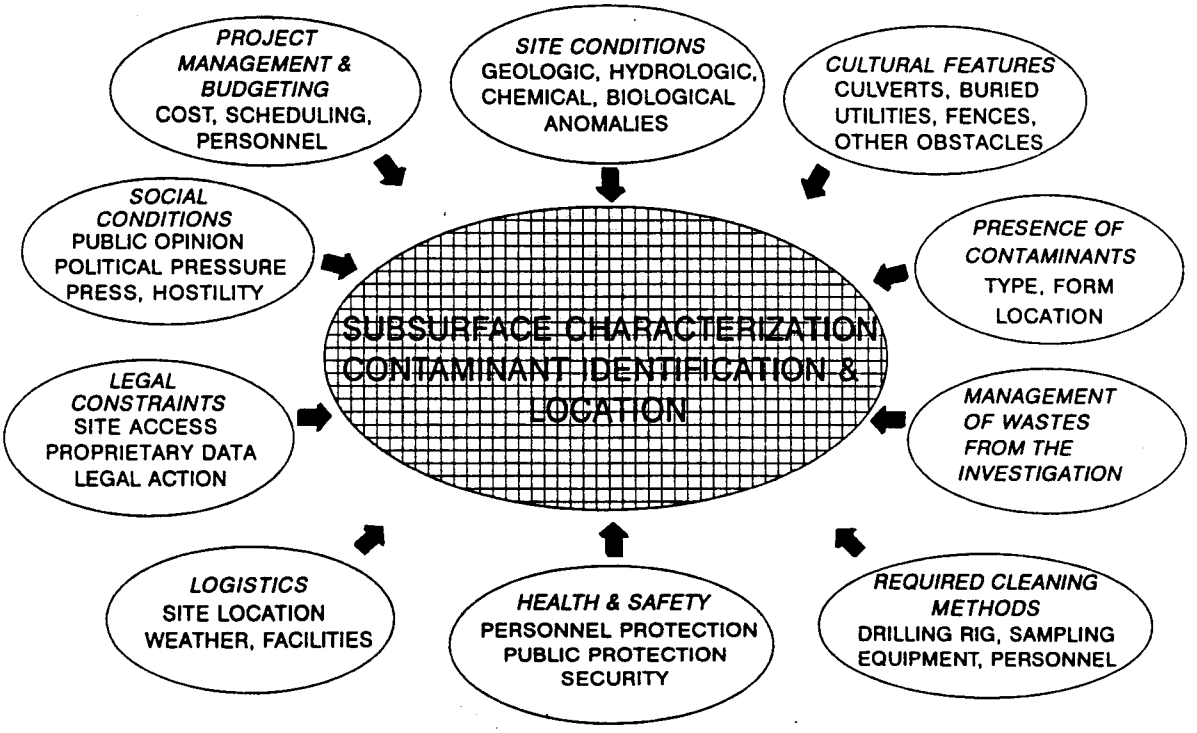
STEP 5 – Select Optimum Locations for Long-Term Monitoring Points and/or Select Appropriate Options for Site Remediation

~10% of $ on Lit. Search

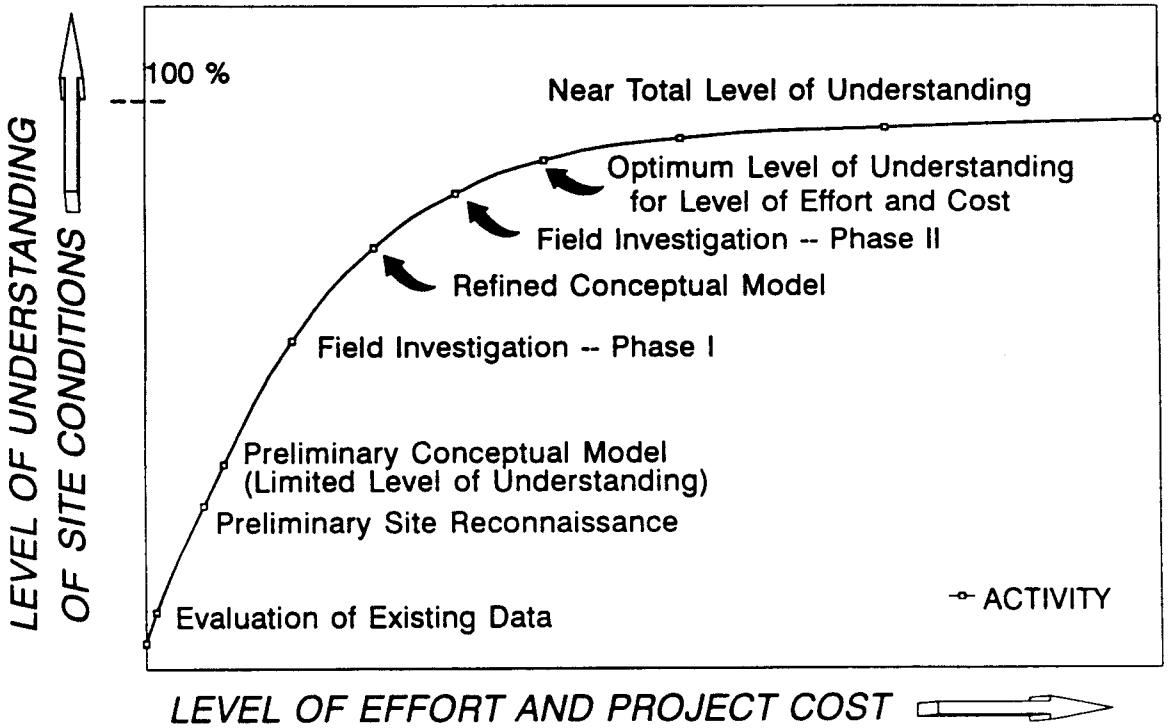
TOOLS APPLIED TO SITE INVESTIGATIONS

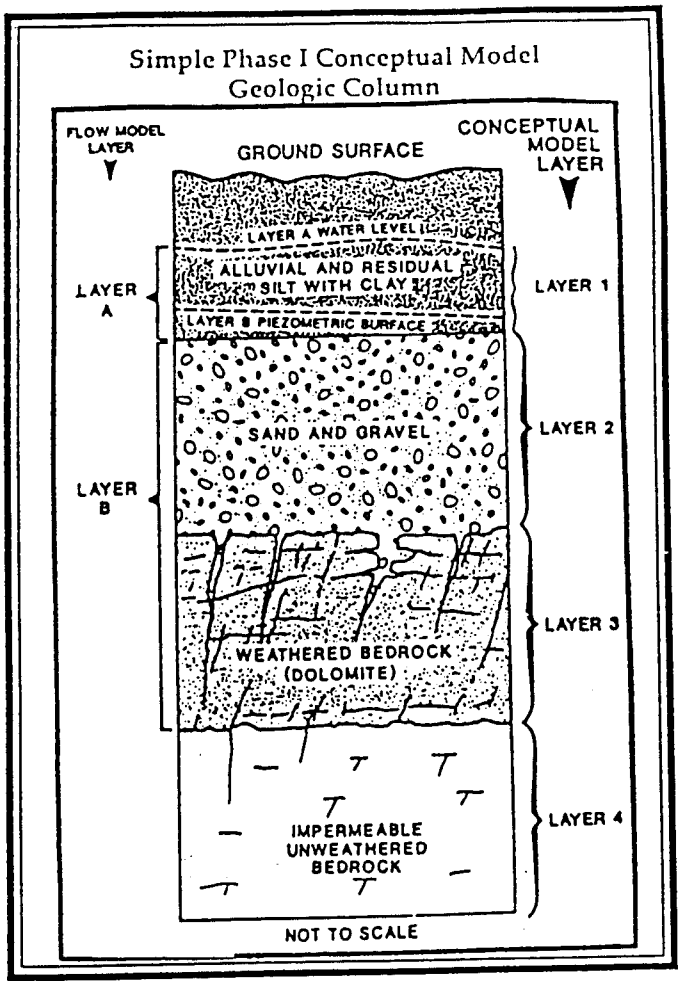


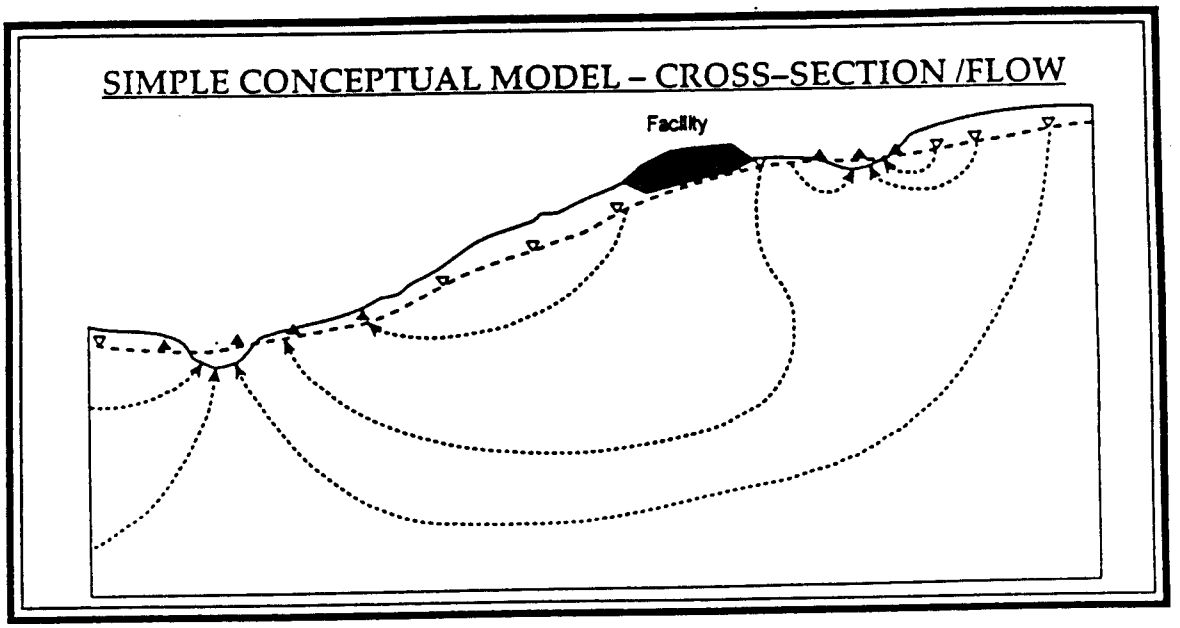
FACTORS AFFECTING SITE INVESTIGATIONS



SITE INVESTIGATION PROGRAM




Simple Phase I Conceptual Model
Geologic Column
FLOW MODEL LAYER
GROUND SURFACE
CONCEPTUAL MODEL LAYER
LAYER A WATER LEVEL
ALLUVIAL AND RESIDUAL SILT WITH CLAY
LAYER B PIEZOMETRIC SURFACE
SAND AND GRAVEL
WEATHERED BEDROCK (DOLOMITE)
IMPERMEABLE UNWEATHERED BEDROCK
LAYER A
LAYER B
LAYER 1
LAYER 2
LAYER 3
LAYER 4
NOT TO SCALE


SIMPLE CONCEPTUAL MODEL – CROSS-SECTION /FLOW
Facility

Initial Description of Site Geology

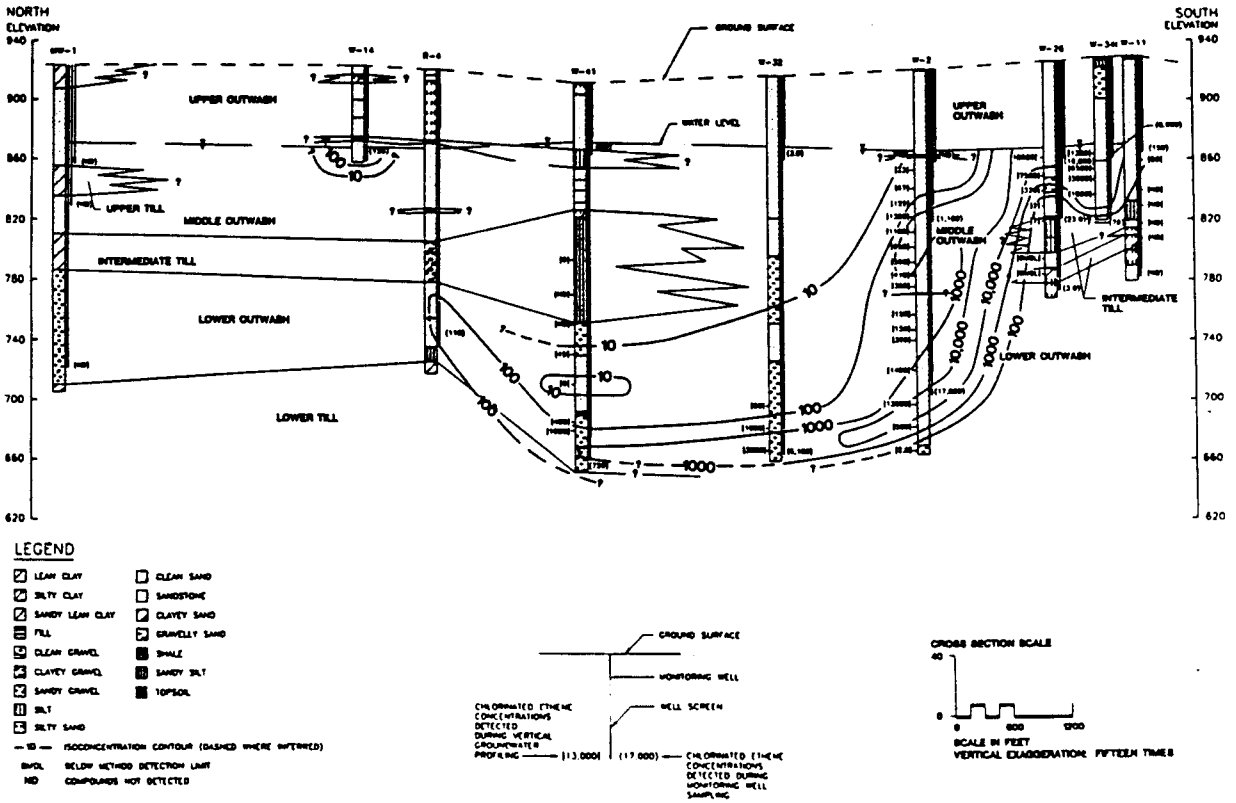
(Preliminary Conceptual Model Based on Existing Published Information)

"A Clay-Rich Glacial Till Which is Remarkably Consistent Throughout Its Areal and Vertical Extent"

Revised Description of Site Geology

(Refined Conceptual Model Based on Data Analysis From Soil Borings and a Geophysical Investigation)

"An Extremely Complex Hydrogeologic System Consisting of a Surficial Unit of Clay-Rich Till Containing Significant Channels of High Hydraulic Conductivity Material Underlain by Fractured Granite"

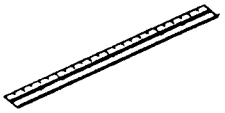


Site B - Cross-section through the central axis of the contaminant plume.

SPECIFIC PURPOSES OF MONITORING WELLS

- To Collect Representative Ground-Water Samples From the Target Monitoring Zone for Chemical Analysis, Accurate to The Limits of Detection For Many Parameters (Especially Organic Compounds and Heavy Metals)
- To Collect Accurate Ground-Water Level Data
- To Collect Accurate and Representative Hydraulic Parameter Data (Especially Hydraulic Conductivity Data From Slug/Bail Tests or Pumping Tests)

PUTTING LOW-LEVEL CONCENTRATIONS INTO PERSPECTIVE "THE NUMBERS GAME"

	I PART PER MILLION	I PART PER BILLION	I PART PER TRILLION
	1¢ /$10,000	1¢ /$10,000,000	1¢ /$10,000,000,000
	1 Minute In 2 Years	1 Second In 32 Years	1 Second In 320 Centuries
	1 Inch In 16 Miles	1 Inch In 16,000 Miles	1 Inch In 16,000,000 Miles

CHEMICAL INTERFERENCE SOURCES IN GROUND-WATER MONITORING PROGRAMS

- Drilling Operations
- Well Construction Materials
- Well Installation Operations
- Well Development
- Ground-Water Sampling Operations

POTENTIAL SOURCES OF CHEMICAL INTERFERENCE IN MONITORING WELL INSTALLATION

- Drilling-Related Sources

  - Drilling Fluids (Water, Bentonite, Additives, Compressor Oil)
  - Lubricants (Hydrocarbon/Heavy Metal-Based Compounds)
  - Hydraulic Fluid, Transmission Fluid, Fuel
  - Contaminated Drilling/Sampling Equipment
  - Antifreeze in Water Lines (During Cold Weather Downtime)
  - Drilling/Sampling Tools Lost Downhole

MINIMIZING DRILLING - RELATED CHEMICAL INTERFERENCE

- THOROUGHLY CLEAN DRILLING RIG, FLUID CIRCULATION SYSTEM AND ACCESSORY EQUIPMENT PRIOR TO ENTERING SITE AND BETWEEN WELLS
- FILL RIG WITH FUEL AND OTHER FLUIDS PRIOR TO ENTERING SITE
- MINIMIZE OR ELIMINATE USE OF DRILLING FLUIDS AND ADDITIVES
- ANALYZE QUALITY OF ANY WATER ADDED TO THE BOREHOLE

MINIMIZING DRILLING - RELATED CHEMICAL INTERFERENCE

- CHECK ALL HYDRAULIC PUMPS, SEALS, LINES AND FITTINGS FOR LEAKS PRIOR TO ENTERING SITE
- USE ONLY "NON-CONTAMINATING" LUBRICANTS ON THE RIG AND ON THE DRILL STRING AND SOIL SAMPLING EQUIPMENT
- KEEP ALL ACCESSORY DRILLING EQUIPMENT OFF OF THE GROUND SURFACE
- INSTALL SURFACE CASING BELOW DEPTH OF SOIL CONTAMINATION
- COLLECT AND STORE DRILL CUTTINGS AWAY FROM BOREHOLE
- FLUSH AND DRAIN WATER LINES IN LIEU OF USING ANTIFREEZE

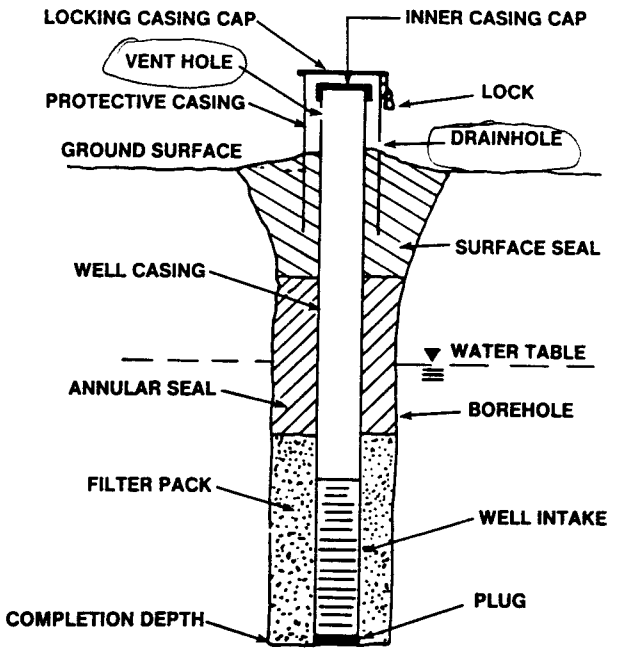
POTENTIAL SOURCES OF CHEMICAL INTERFERENCE IN MONITORING WELL INSTALLATION

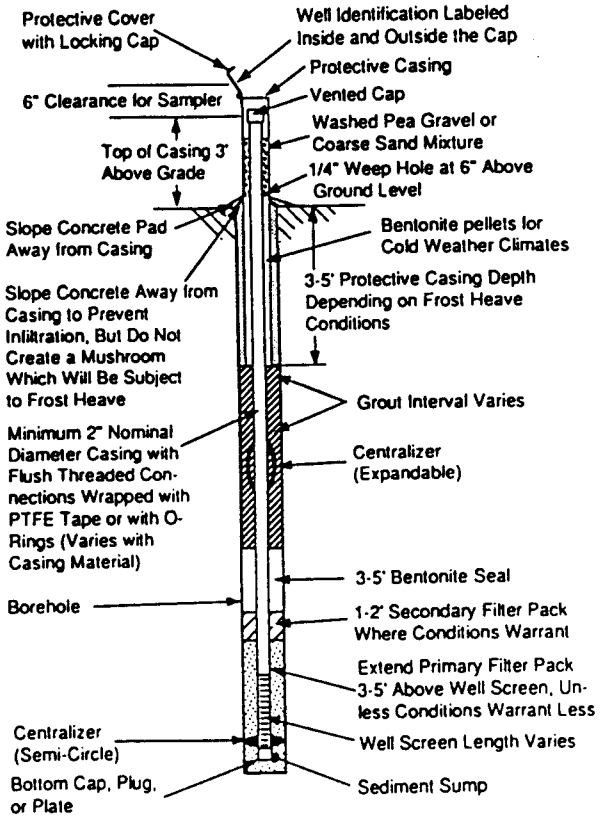
- Well-Construction Materials
  - Well Casing and Screen (Plastic, Steel, PTFE, FRE)
    - Sorption/Desorption; Leaching
    - Corrosion/Degradation
    - Manufacturing Residues
    - Storage and Handling Residues
  - Casing Coupling Procedures
    - Solvent Welding
    - Heat/Resistance Welding

POTENTIAL SOURCES OF CHEMICAL INTERFERENCE IN MONITORING WELL INSTALLATION

- Well-Construction Materials
  - Filter Pack Materials and Placement
    - Sand/Gravel
    - Installation Method
  - Annular Seal Materials and Placement
    - Bentonite
    - Neat Cement
    - Installation Method
    - Proximity to Top of Well Screen

TYPICAL DESIGN COMPONENTS OF A GROUND WATER MONITORING WELL





Not to Scale

Typical monitoring well design components.

COMMON MONITORING WELL DESIGN FLAWS

- Use of Inappropriate Well Casing or Screen Materials to Meet Site-Specific Requirements
- Use of Non-Standard Well Intake (Screen) or Improper Screen Slot Sizing Practices
- Improper Placement and/or Length of Well Screen

COMMON MONITORING WELL DESIGN FLAWS

- Improper Selection of Filter Pack Grain-Size and Materials and/or Improper Placement of Filter Pack Materials
- Improper Selection and/or Placement of Annular Seal Materials
- Inadequate Surface Protection Measures
- Improper or Inadequate Well Development

COMMON MONITORING WELL DESIGN FLAWS

- **USE OF INAPPROPRIATE WELL CASING OR SCREEN MATERIALS TO MEET SITE-SPECIFIC REQUIREMENTS**

  RESULTS:

  - **SAMPLE CHEMICAL ALTERATION (THROUGH SORPTION OR LEACHING)**
  - **DEGRADATION OF WELL CASING OR SCREEN MATERIALS**
  - **PHYSICAL FAILURE OF THE WELL**

FACTORS INFLUENCING CASING MATERIAL SELECTION

SITE-SPECIFIC FACTORS	LOGISTICAL FACTORS
• Geologic Environment	• Well Drilling Method Used
• Geochemical Environment	• Ease of Handling
• Anticipated Well Depths	• Ease of Cleaning
• Types/Concentrations of Contaminants	• Cost of Materials & Shipping

Tensile strength

Remember -- Each Site is Unique, Requiring That Materials Be Selected Based on the Conditions at That Site

REQUIREMENTS OF WELL CASING/SCREEN MATERIAL

- Must Be Strong Enough to Withstand Stresses Imposed on it During Installation and Development
- Must Not Alter Concentrations of Contaminants
- Should Be Easy to Handle and Clean
- Must Not Degrade in the Environment in Which it is Emplaced (Natural and Man-Induced)
- Should Be Cost Effective

METALLIC MATERIALS

- Carbon Steel
- Low-Carbon Steel
- Galvanized Steel
- Stainless Steel (304 & 316)

FIBERGLASS MATERIALS

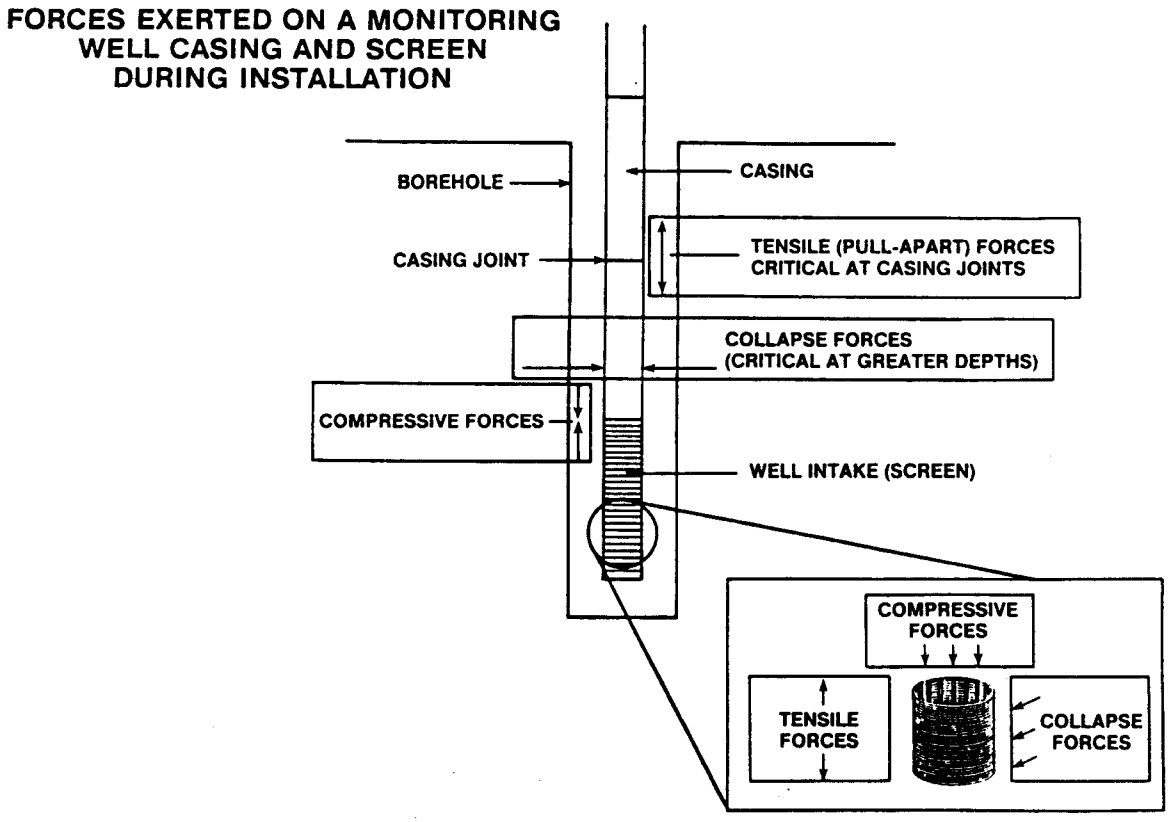
- Fiberglass-Reinforced Plastic (FRP)
- Fiberglass-Reinforced Epoxy (FRE)

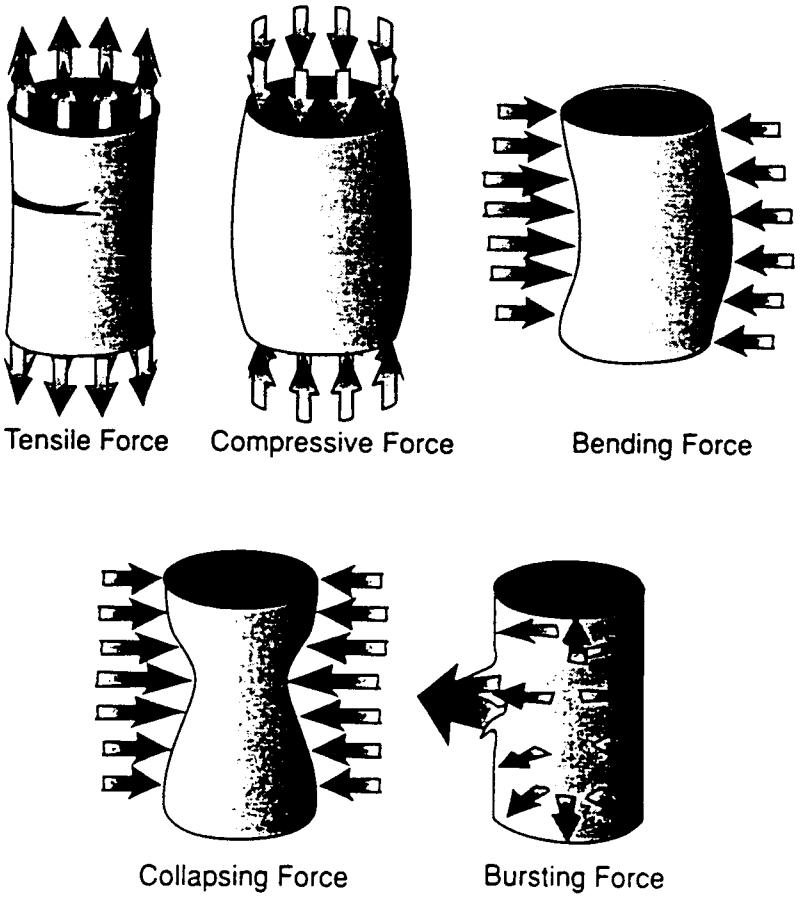
PLASTIC MATERIALS

- Polyvinylchloride (PVC)
- Acrylonitrile-Butadiene-Styrene (ABS)
- Polypropylene
- Polyethylene

FLUOROPOLYMER MATERIALS

- Polytetrafluoroethylene (PTFE)
- Tetrafluoroethylene (TFE)
- Fluorinated Ethylene Propylene (FEP)
- Polyvinylidene Fluoride (PVDF)





Forces acting on well casing.

COMPARATIVE STRENGTHS OF WELL CASING MATERIALS

one pipe manf.

Material*	Casing Tensile Strength (lbs) 2" Nominal	Casing Tensile Strength (lbs) 4" Nominal	Casing Collapse Strength (psi) 2" Nominal	Casing Collapse Strength (psi) 4" Nominal
PVC	7,500	22,200	307	158
PVC Joints+	1,800	6,050	---	---
Stainless Steel	37,760	92,000	896	315
Stainless Steel Joint+	15,900	81,750	---	---
PFTE	No Data	No Data	No Data	No Data
PTFE Joints+	540	1,890	---	---

*Steel casing materials are Schedule 5, plastic casing materials are Schedule 40.

+Joints are all threaded flush joints.

WEIGHT PER UNIT LENGTH AND SPECIFIC GRAVITY OF WELL CASING MATERIALS (2" NOMINAL)

Material	Weight by Schedule #lb./ft. 5	10	40	80	Specific Gravity
PVC	----	----	0.65	0.91	1.37
Stainless Steel	1.62	2.06	3.08	5.07	N/A
PTFE	----	----	1.21	1.90	2.20

ASTM STANDARD D 1785
STANDARD SPECIFICATION FOR POLY (VINYL CHLORIDE) (PVC) PLASTIC PIPE, SCHEDULES 40, 80 AND 120

Purpose

To ensure that PVC plastic pipe made in Schedule 40, 80 and 120 sizes meets minimum requirements for materials, workmanship, dimensions, sustained pressure, burst pressure, flattening and extrusion quality. Also included are criteria for classifying and a system of nomenclature for PVC pipe and methods for marking pipe.

either or

ASTM STANDARD F 480
STANDARD SPECIFICATION FOR THERMOPLASTIC WELL CASING PIPE AND COUPLINGS MADE IN STANDARD DIMENSION RATIOS (SDR) SCHEDULES 40 AND 80

Purpose

To ensure that thermoplastic pipe and couplings used for well casing (Acrylonitrile-Butadiene-Styrene [ABS], Polyvinylchloride [PVC] and Styrene Rubber [SR]) meet minimum requirements for materials, workmanship, dimensions, stiffness, crush and impact resistance, thread design and joint strength. Also included are test methods for each of these parameters, and methods for marking pipe.

ASTM STANDARD F 480
STANDARD SPECIFICATION FOR THERMOPLASTIC WELL CASING PIPE AND COUPLINGS MADE IN STANDARD DIMENSION RATIOS (SDR) SCHEDULES 40 AND 80

Materials

PVC must meet or exceed requirements of ASTM Specification D 1784 or NSF Standard 14 for pipe used for potable water applications (well casing or potable water rated).

NSF Std. 14

use NSF
WC well casing
or
PW potable water

not
↳ DWW

ADVANTAGES AND LIMITATIONS OF PLASTIC (PVC) WELL CASING/SCREEN MATERIALS

Advantages

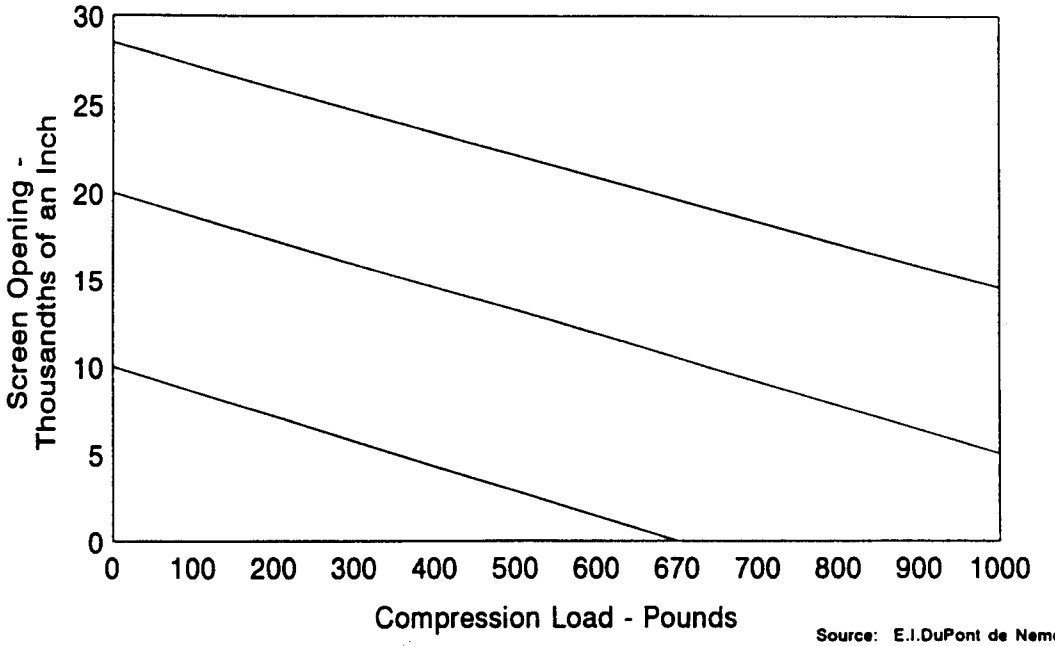
- Can Be Used in a Wide Range of Natural Geochemical and Contaminant Conditions
- High Strength and Low Weight Per Unit Length
- Readily Available
- High Open Area Screens Available
- Very Low Purchase Price

Limitations

- May Degrade in High Concentrations of Certain Organic Solvents (Esp. Ketones, Amines Chlorinated Alkenes, Aldehydes and Alkanes)
- May Fail if Subjected to High Differential Pressures (i.e. During Surging)
- May Fail if Subjected to High Temepratures (i.e. During Grouting with Neat Cement)
- Unsuitable for Driven Wells

~25% of saturation

RESULTS OF SHORT-TERM STATIC COMPRESSION TESTS ON PTFE SCREEN



Source: E.I.DuPont de Nemours Co.

ADVANTAGES AND LIMITATIONS OF PTFE WELL CASING/SCREEN MATERIALS

Advantages

- Can Be Used in a Wide Range of Natural Geochemical and Contaminant Conditions
- Can Be Used in a Wide Range of Temperatures

Limitations

- May Absorb/Desorb Organic Constituents From/Into Solution
- Only Slotted Casing Available for Screens
- Deformation Due to Compression May Close Screen Slots
- Extreme Flexibility May Result in Non-Plumb Well
- Non-Stick Nature May Cause Annular Seal Failure
- Moderate Weight and Low Strength Per Unit Length
- Unsuitable for Driven Wells
- Very High Purchase Price

INDICATORS OF CORROSIVE CONDITIONS

- Low pH - Acid Conditions (pH < 7)
- High Dissolved Oxygen Content - > 2 ppm
- Presence of Hydrogen Sulfide - > 1 ppm
- High Total Dissolved Solids - > 1000 ppm
- High Chloride Ion Content - > 500 ppm
- High Dissolved CO_2 Content - > 50 ppm

Combinations of These Conditions
Enhance Corrosive Effects

Should be beveled
on inside
at joint

COMPOSITION OF STAINLESS STEEL WELL CASING/SCREEN MATERIALS

CHEMICAL COMPONENT	SS 304	SS 316
CARBON	0.08	0.08
MANGANESE	2.00	2.00
PHOSPHOROUS	0.04	0.045
SULFUR	0.03	0.03
SILICON	0.75	1.00
CROMIUM	18.0 - 20.0	16.0 - 18.0
NICKEL	8.0 - 11.0	10.0 - 14.0
MOLYBDENUM	—	2.0 - 3.0
IRON	REMAINDER	REMAINDER

ADVANTAGES AND LIMITATIONS OF STAINLESS STEEL WELL CASING/SCREEN MATERIALS

Advantages

- Can Be Used in a Wide Range of Natural Geochemical and Contaminant Conditions
- High Strength in Wide Range of Temperatures
- Readily Available
- High Open Area Screens Available
- Moderate Purchase Price
- Suitable for Driven Wells

Limitations

- May Corrode in Some Geochemical Conditions (pH <4.5; TDS >2000 ppm)
- May Contribute Metal Ions (Fe, Cr, Ni, Mn) to Ground-Water Samples
- High Weight per Unit Length

ADVANTAGES AND LIMITATIONS OF FIBERGLASS (FRE) WELL CASING/SCREEN MATERIALS

Advantages

- Can Be Used in a Wide Range of Natural Geochemical and Contaminant Conditions
- Moderate Weight and High Strength Per Unit Length
- Moderate Purchase Price

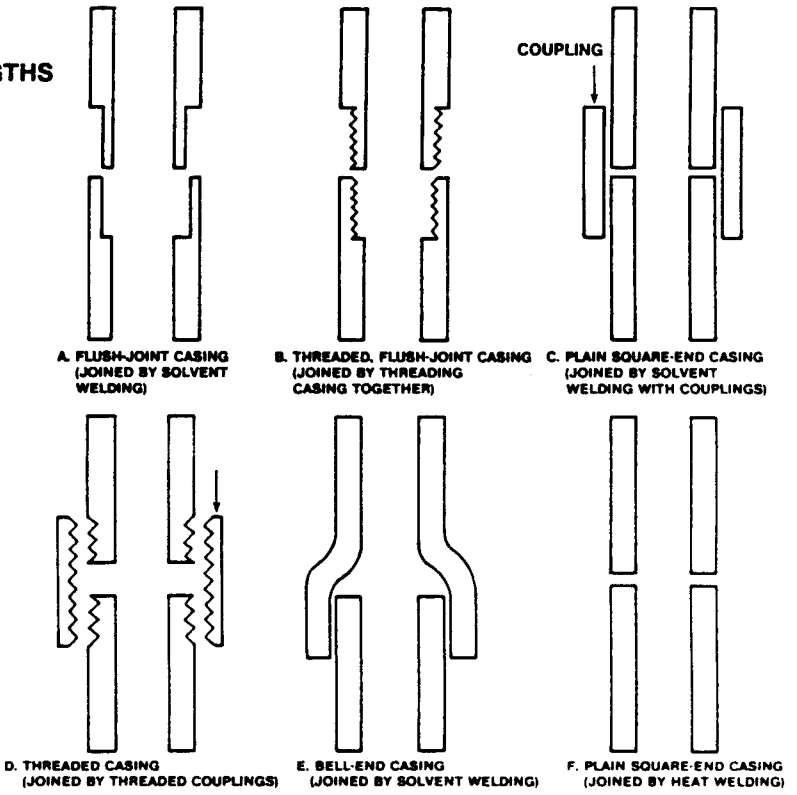
Disadvantages

- May Degrade in High Concentrations of Certain Organic Solvents (Esp. Amines), Certain Acids (Chromic, Acrylic, Nitric, Phosphoric, Sulfuric) and H_2O_2
- Unsuitable for Driven Wells
- Not Widely Available
- May Fail If Subjected to High Temperatures (i.e. During Grouting with Neat Cement)

SELECTING WELL CASING MATERIALS THE WRONG WAY

"Desirability" of Casing Materials	"Desirability" of Automobiles
PTFE	Ferrari Testarossa
Stainless Steel 316	Mercedes 500 SL
Stainless Steel 304	Toyota Land Cruiser
PVC	Honda Civic
Other Materials	Yugo

TYPES OF JOINTS TYPICALLY USED BETWEEN CASING LENGTHS

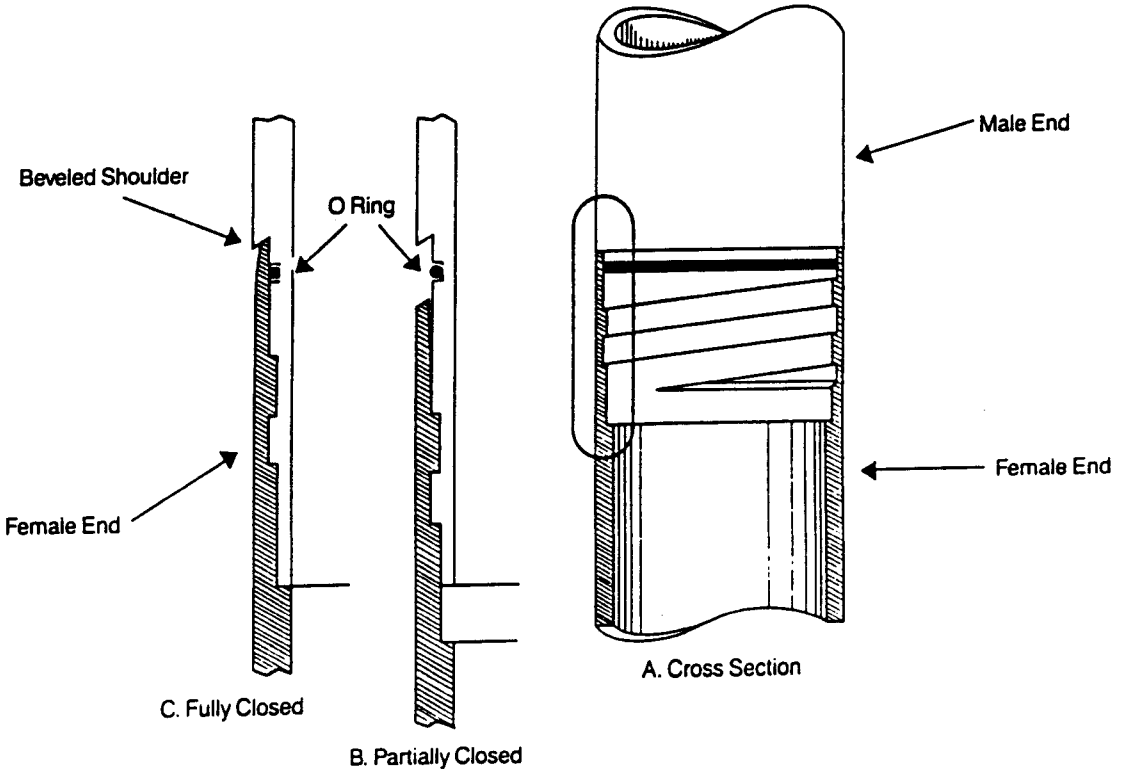


COMMON CONSTITUENTS OF PVC SOLVENT CEMENT

- Tetrahydrofuran (THF)
- Methyl Ethyl Ketone (MEK)
- Methyl Isobutyl Ketone (MIBK)
- Cyclohexanone
- Dimethylformamide

2 threads/inch

ASTM F480 Flush Joint Thread



FACTORS THAT AFFECT SELECTION OF CASING DIAMETER

- Use of Downhole Equipment (Well Development Tools, Borehole Geophysical Tools, Purging & Sampling Devices, Water Level Measurement Devices, Pumps for Pumping Tests)
- Volume of Water Required to Purge Well (Affects Sampling Time and Costs, Logistics of Handling Purged Water)
- Rate of Recovery of Well After Purging (Critical in Low Hydraulic Conductivity Formations)

↑size ↑time for recovery

- Type of Drilling Method Preferred (i.e. Accounting for Diameter Limitations of the Specific Method)
- Ease of Well Devleopment (Availability of Preferred Development Method for Specific Well Diameters)
- Unit (Per Foot) Costs of Casing Materials & Drilling

Outside Diameter, Wall Thickness, and Inside Diameter of Well Casing.

Casing Size (Nominal)	Outside Diameter (Standard)	Wall Thickness				Inside Diameter			
		Sch 5	Sch 10	Sch 40	Sch 80	Sch 5	Sch 10	Sch 40	Sch 80
2 in	2.375	0.065	0.109	0.154	0.218	2.245	2.157	2.067	1.939
3 in	3.500	0.083	0.120	0.216	0.300	3.334	3.260	3.068	2.900
4 in	4.500	0.083	0.120	0.237	0.337	4.334	4.260	4.026	3.826
5 in	5.563	0.109	0.134	0.258	0.375	5.345	5.295	5.047	4.813
6 in	6.625	0.109	0.134	0.280	0.432	6.407	6.357	6.065	5.761

COMPARATIVE COSTS OF WELL CASING AND SCREEN MATERIALS

Material±	Casing Cost (per ft.)* 2" Nominal	Casing Cost (per ft.)* 4" Nominal	Screen Cost (per ft.)* 2" Nominal	Screen Cost (per ft.)* 4" Nominal
Galvanized Steel	$2.00	$3.75	---	---
PVC	$2.30	$4.80	$13.00	$21.00
Stainless Steel (304)	$8.50	$18.00	$25.00	$40.00
Stainless Steel (316)	$12.50	$25.00	$35.00	$56.00
PTFE	$25.50	$78.50	$33.00	$91.00

*Costs are average costs from several suppliers in 1987 dollars.

± Steel casing materials are Schedule 5; plastic casing materials are Schedule 40; PVC and SS screens are continuous-slot wire-wound; PTFE screens are slotted casing, with maximum open area.

COMMON MONITORING WELL DESIGN FLAWS

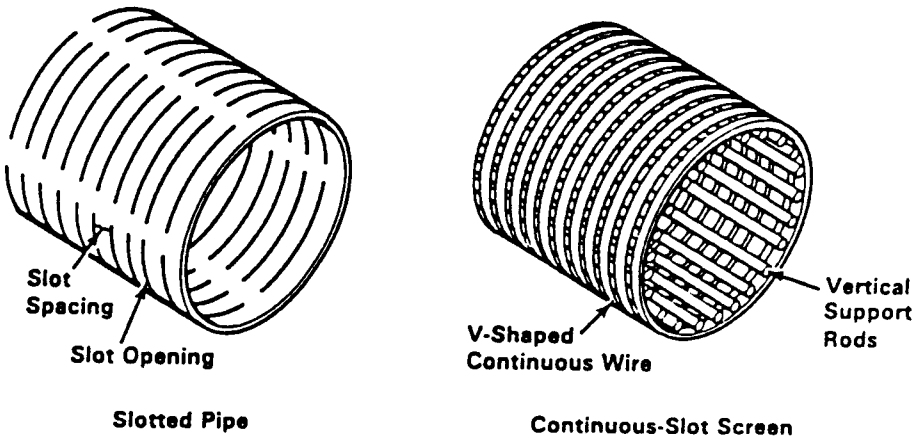
- **Use of Non-Standard Well Intake or Improper Well Intake Slot Sizing Practices**

  Results:

  - Sedimentation of the Well
  - Acquisition of Turbid, Sediment-Laden Samples
  - Plugging of the Well Intake
  - Inability to Properly Develop the Well

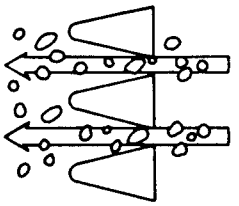
DESIGN FACTORS FOR MONITORING WELL SCREENS

- SHOULD BE CONSTRUCTED OF MATERIAL THAT IS INERT TO NATURAL GEOCHEMICAL AND CONTAMINANT CONDITIONS
- OPEN AREA SHOULD BE MAXIMIZED TO ALLOW RAPID SAMPLE RECOVERY, EFFECTIVE WELL DEVELOPMENT, AND PROPER CONDUCT AND ANALYSIS OF SLUG OR BAIL TESTS
- SLOT OPENINGS SHOULD BE NON-PLUGGING IN DESIGN
- SLOT OPENINGS MUST BE SIZED TO ALLOW THE SCREEN TO RETAIN THE FILTER PACK OR FORMATION MATERIAL WHILE STILL PERMITTING EFFICIENT WELL DEVELOPMENT

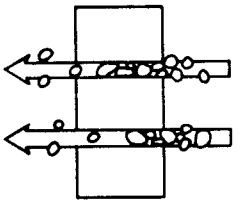


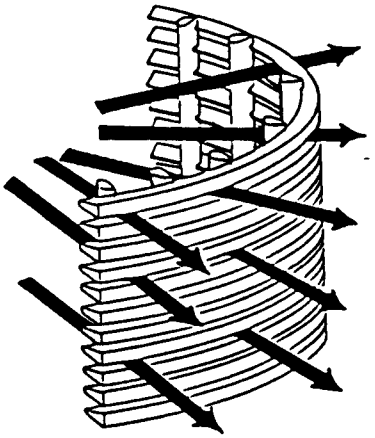
Two Primary Types of Monitoring Well Screen

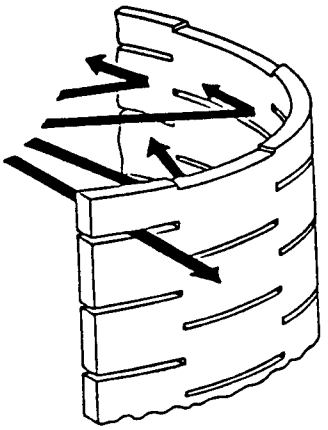
SLOT OPENINGS ARE V-SHAPED IN CONTINUOUS-SLOT SCREENS. THE SLOTS ARE NON-CLOGGING BECAUSE THEY WIDEN INWARDLY. PARTICLES PASSING THROUGH THE NARROW OUTSIDE OPENING CAN ENTER THE SCREEN.



ELONGATED OR SLIGHTLY OVERSIZED PARTICLES CAN CLOG STRAIGHT-CUT OPENINGS.







COMPARISON OF SCREEN OPEN AREA (%) FOR CONTINUOUS-SLOT SCREENS AND SLOTTED CASING

Manufacturer data

SCREEN DIAMETER (INCHES)	*CONTINUOUS SLOT**		*SLOTTED CASING***	
	10 SLOT	20 SLOT	10 SLOT	20 SLOT
2	7.6	14.4	2.9-5.1	5.5-9.4
4	6.8	12.7	2.4-4.3	4.6-7.8
6	5.3	10.0	2.0-3.6	3.9-6.6

* Data are for PVC - In Stainless Steel, Open Area Will Be Twice as Much

** Because Slotting is Performed in Many Different Ways, A Range From Low to High is Given

ASTM STANDARD D 1586
STANDARD METHOD FOR PENETRATION TEST AND SPLIT-BARREL SAMPLING OF SOILS

Apparatus

Drilling Equipment

Any drilling equipment that provides a clean open hole before insertion of the sampler and ensures the test is performed on undisturbed soil

Sampling Rods

Flush-joint steel drill rods used to connect the split-barrel sampler to the drive-weight assembly ("A"-rod or "N" rod)

ASTM STANDARD D 1586
STANDARD METHOD FOR PENETRATION TEST AND SPLIT-BARREL SAMPLING OF SOILS

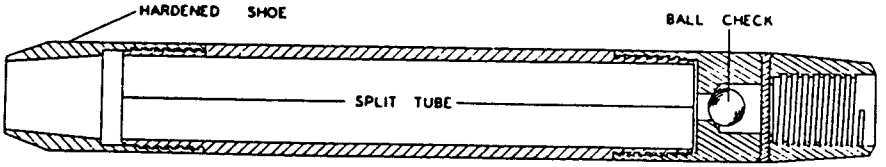
Apparatus

Split Barrel Sampler

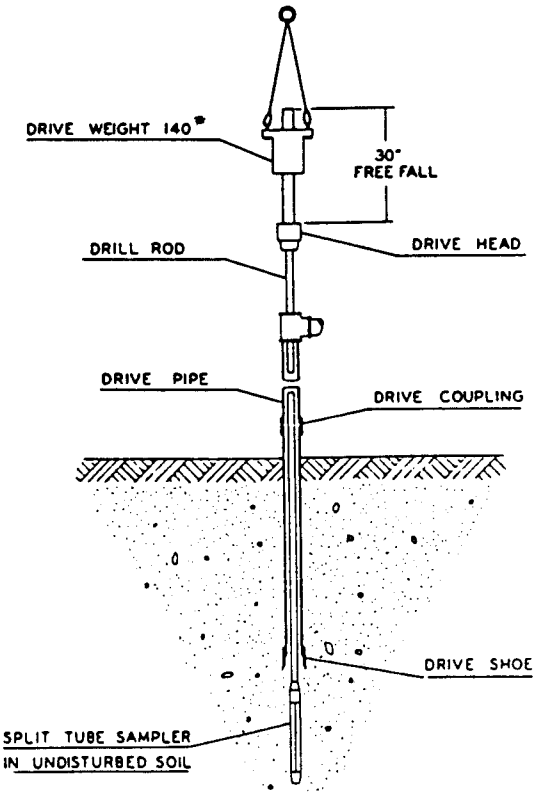
Standard 2.0" O.D., 1.5" I.D.; 18.0" to 30.0" long barrel with hardened steel drive shoe and vented drive head

Drive-Weight Assembly

140 lb. hammer with hammer fall guide and anvil which conveys driving force to sampling rods connected to hammer drop system (rope-cathead, semi-automatic or automatic systems may be used)



Standard split tube sampler



Driving sample

ASTM STANDARD D 1586
STANDARD METHOD FOR PENETRATION TEST AND SPLIT-BARREL SAMPLING OF SOILS

Procedure

- Attach split-barrel sampler to sampling rods and lower into the clean, open borehole
- Position the hammer above and attach the anvil to the top of the sampling rods
- Rest the assembly on the bottom of the boring and apply a setting blow
- Mark drill rods in successive 6-inch increments so advance of sampler can be observed

ASTM STANDARD D 1586
STANDARD METHOD FOR PENETRATION TEST AND SPLIT-BARREL SAMPLING OF SOILS

Procedure

- Raise hammer 30 inches above anvil and allow it to drop unimpeded to strike the anvil
- Drive sampler with blows from the hammer and count blows for each 6-inch increment
  - first 6-inches is "seating drive"; sum of blows in second and third 6 inches of penetration is termed the "standard penetration resistance" or the "N-value"
- Retrieve the sampler, open it, record percent recovery and sample length
  - describe the sample as required, place into suitable containers, and label containers

STANDARD PENETRATION TEST RELATIVE DENSITY CORRELATION (for Cohesionless Materials)

# of Blows Per 12 " Drive (N)	Relative Density	Presumed Bearing Strength (T/ft ^{2})
0 - 4	Very Loose	< 1
5 - 10	Loose	1 - 3
11 - 30	Medium	3 - 5
31 - 50	Dense	5 - 7
> 50	Very Dense	7 - 12
	[Sound Bedrock]	[100]

STANDARD PENETRATION TEST CONSISTENCY CORRELATION (for Cohesive Materials)

# of Blows Per 12 " Drive (N)	Consistency	Presumed Bearing Strength (T/ft ^{2})
< 2	Very Soft	< 1
2 - 4	Soft	1 - 1 1/2
5 - 8	Firm	1 1/2 - 3
9 - 15	Stiff	3 - 4
16 - 30	Very Stiff	4 - 5
> 30	Hard	5 - 6

ASTM STANDARD C 136
STANDARD METHOD FOR SIEVE ANALYSIS OF FINE AND COARSE AGGREGATES

Summary

A weighed sample of dry granular material is separated through a series of sieves of progressively smaller openings for determination of particle size distribution.

ASTM STANDARD C 136
STANDARD METHOD FOR SIEVE ANALYSIS OF FINE AND COARSE AGGREGATES

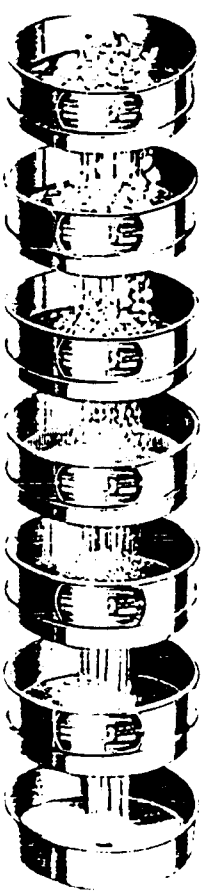
Apparatus

- Balance or Scale - readable and accurate to 0.5 g or 0.1% of the test load (for coarse granular material)
- Sieves - must conform to Specification E11 (Specification for Wire-Cloth Sieves for Testing Purposes)
- Mechanical Sieve Shaker (optional) - must impart vertical or combined lateral and vertical motion to the sieves
- Oven - capable of maintaining a temperature of 110°C (230°C)

ASTM STANDARD C 136
STANDARD METHOD FOR SIEVE ANALYSIS OF FINE AND COARSE AGGREGATES

Procedure

- Dry the sample to constant weight; record total sample weight
- Use sieves suitable to provide required information; nest the sieves in order of decreasing size of opening from top to bottom
- Place the sample on the top sieve; agitate the sieves by hand or by mechanical apparatus for a period sufficient to ensure compete sieving
- Disassemble the sieves; determine the weight of each size increment by weighing on a scale or balance; record weight of sample on each sieve
- Calculate percentages passing, total percentages retained, or percentages in various size fractions to the nearest 0.1% on the basis of the total weight of the initial dry sample



Sand and Gravel

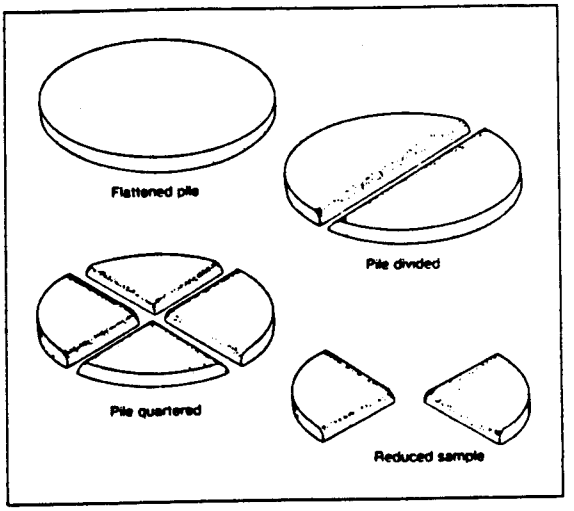
in	mm	Mesh No.
0.131	3.33	6
0.093	2.36	8
0.065	1.65	10
0.046	1.17	14
0.033	0.84	20
0.023	0.58	28
0.016	0.41	35
0.012	0.30	48
Bottom pan		

Coarse Sand

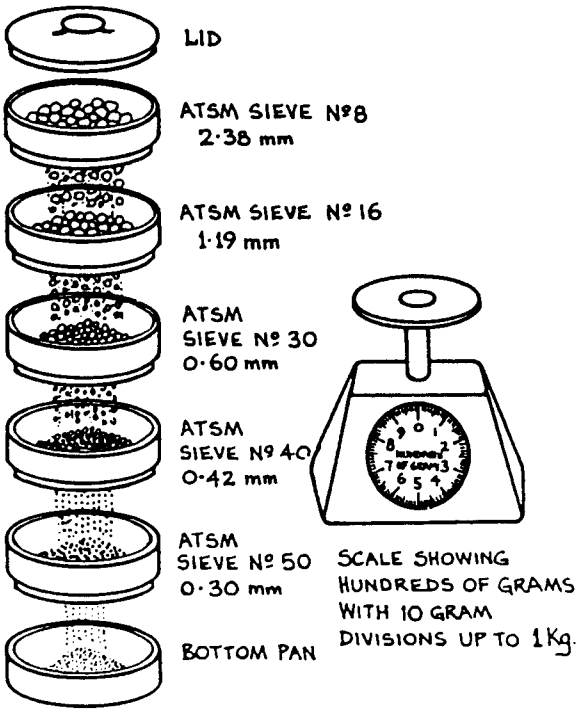
0.046	1.17	14
0.033	0.84	20
0.023	0.58	28
0.016	0.41	35
0.012	0.30	48
0.008	0.20	65
Bottom pan		

Fine Sand

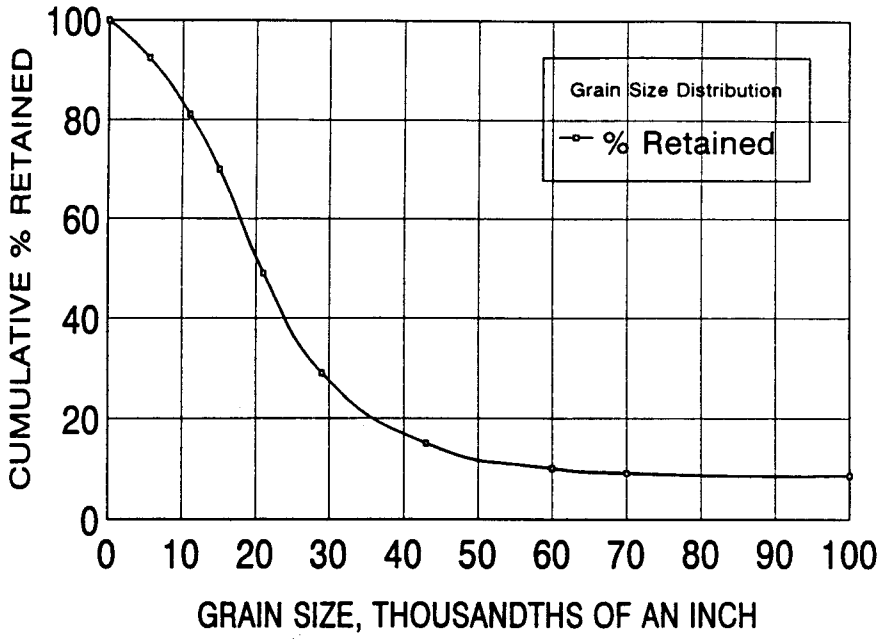
0.023	0.58	28
0.016	0.41	35
0.012	0.30	48
0.008	0.20	65
0.006	0.15	100
Bottom pan		



The quartering method can be used to obtain a representative fraction from a large sample so that the sieves will not be overloaded.



PLOT OF GRAIN SIZE VERSUS CUMULATIVE PERCENTAGE OF SAMPLE RETAINED ON SIEVE



SIZING WELL SCREEN SLOTS FOR MONITORING WELLS

- Naturally Developed Wells

Step 1) Obtain Samples Representative of Formation Materials

Step 2) Perform Formation Grain-Size (Sieve) Analysis

Step 3) Select Slot Size That Retains > 70% of Formation Materials

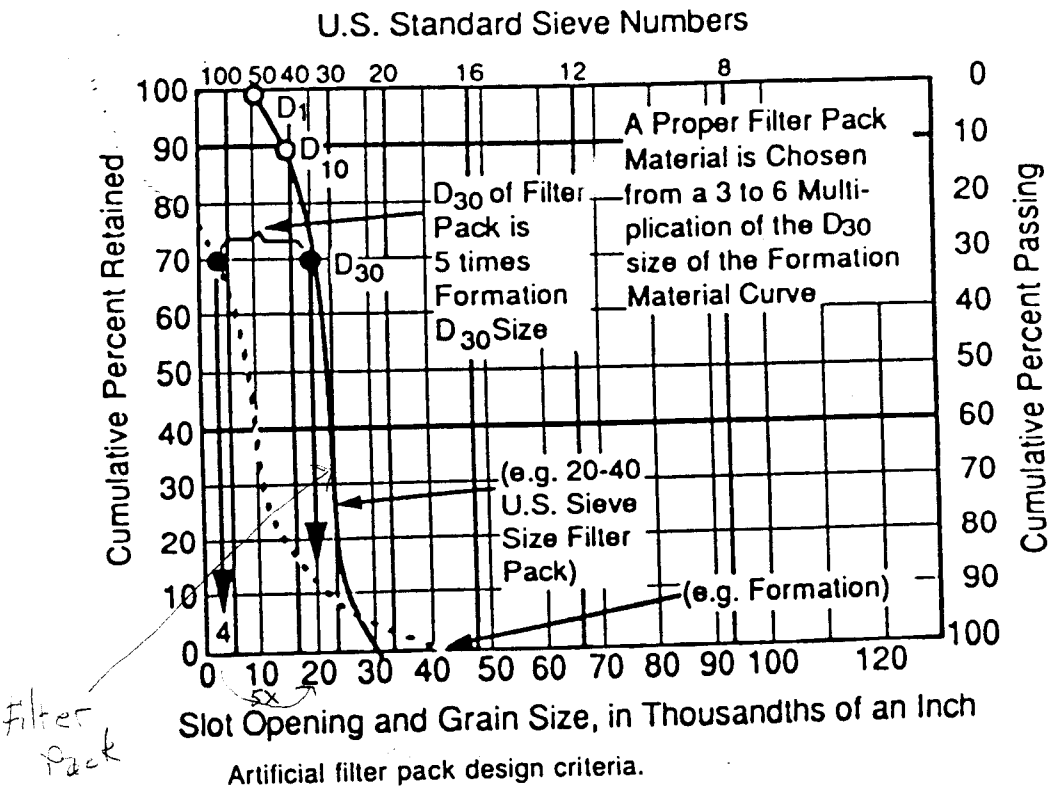
SIZING WELL SCREEN SLOTS FOR MONITORING WELLS

- Filter Packed Wells

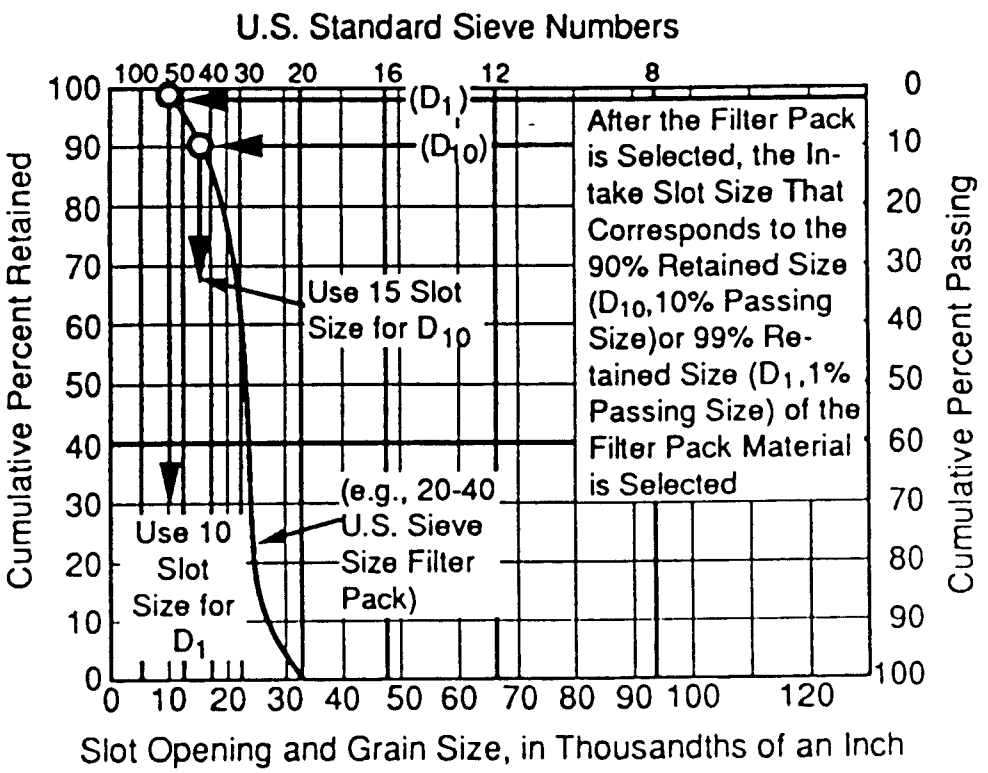
Steps 1) and 2) - Same as For Naturally Developed Wells

Step 3) Select Filter Medium (Sand) Based on 70% Retained Formation Grain Size Multiplied By:
- 3 if Formation is Fine and Uniform, or
- 6 if Formation is Coarse and Non-Uniform (Uniformity Coefficient of Filter Medium Should be Less Than 2.5)

Step 4) Select a Slot Size That Retains 95 - 100% of Filter Pack Materials



Artificial filter pack design criteria.



Selecting well intake slot size based on filter pack grain size.

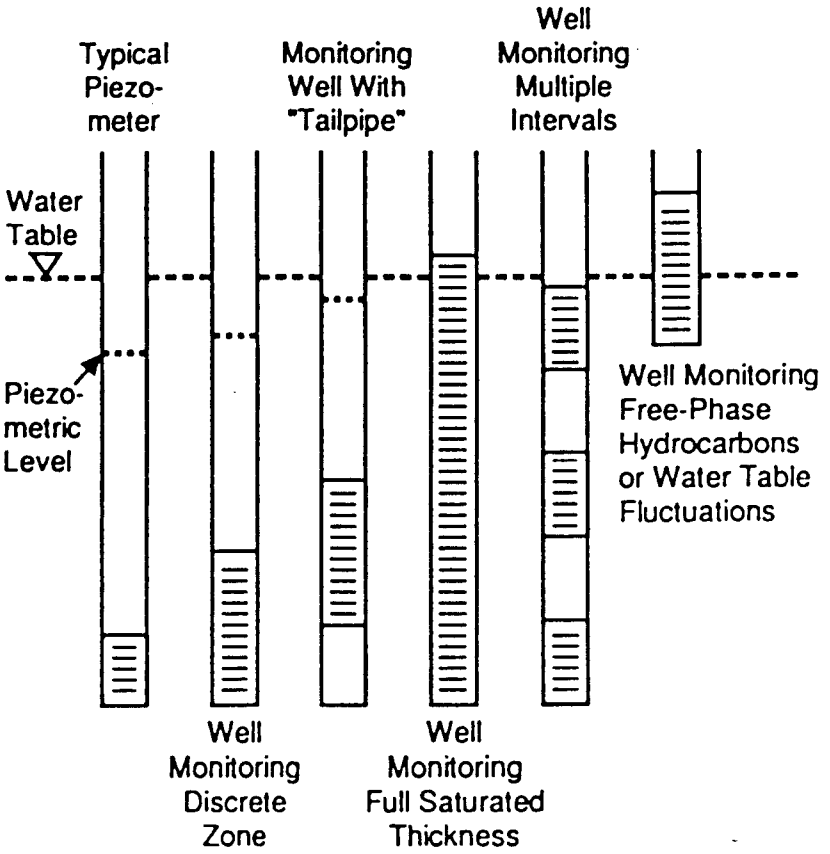
Size of Screen Slot, in. (mm)	Recommended Filter Pack Grain Size (U.S. Sieve Size Range)
0.006 (0.15)	50 - 100
0.010 (0.25)	20 - 40
0.020 (0.50)	12 - 20
0.030 (0.75)	12 - 20
0.040 (1.0)	8 - 12
0.060 (1.5)	6 - 9
0.080 (2.0)	4 - 8

COMMON MONITORING WELL DESIGN FLAWS

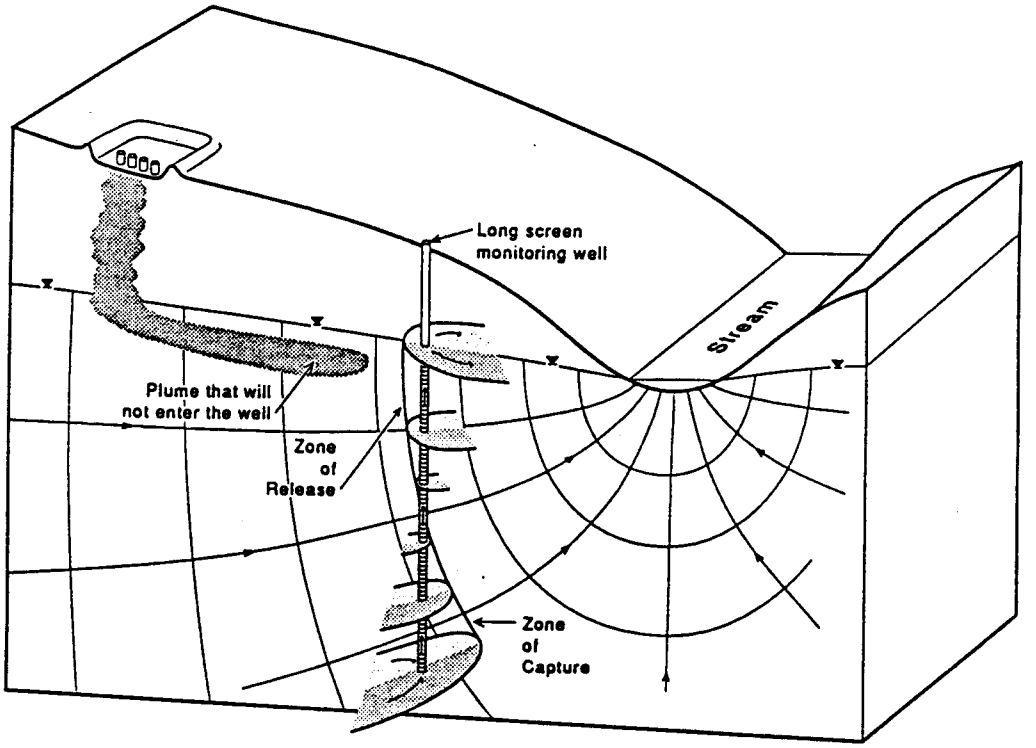
- **IMPROPER PLACEMENT/OR LENGTH OF WELL INTAKE**

  RESULTS:

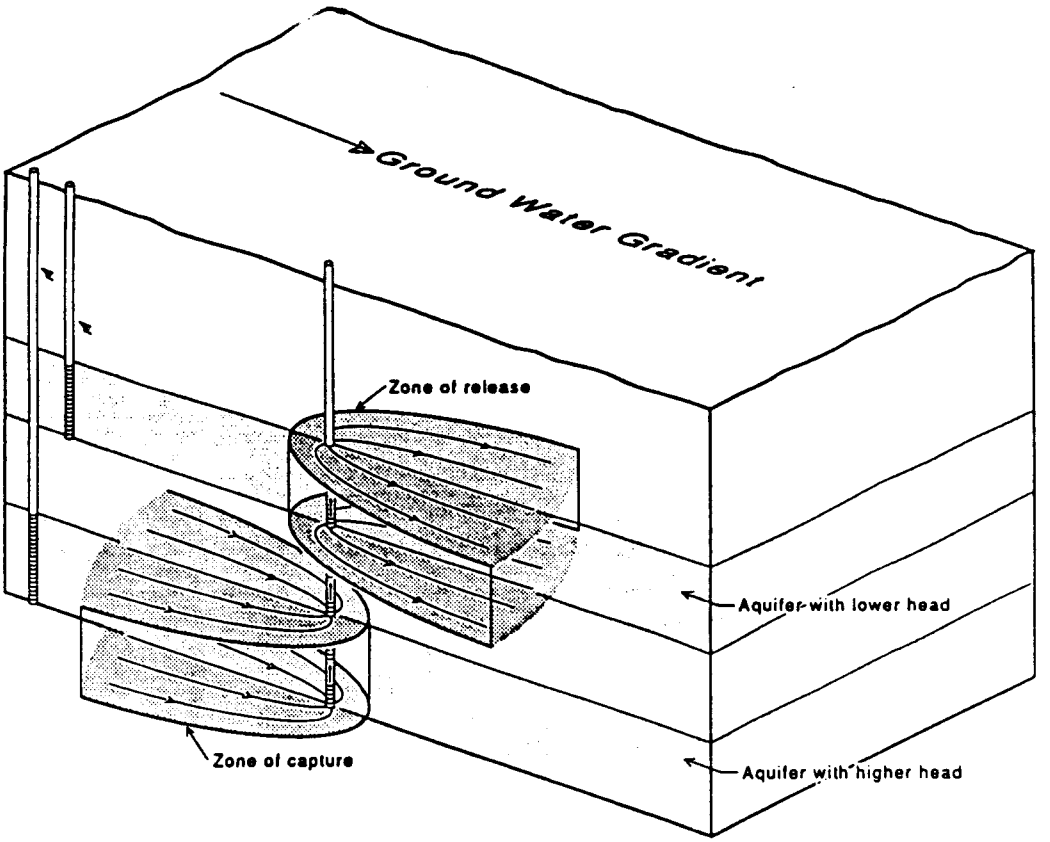
  - **ACQUISITION OF NON-DISCRETE WATER LEVEL OR WATER QUALITY DATA**



Screen length variability in monitoring wells.



Flow Through a Long Screen Monitoring Well In a Thick, Unconfined Aquifer



Capture of Ground Water In Zone With Higher Head and Release to Zone of Lower Head by Vertical Flow Through a Long Screen Monitoring Well

COMMON MONITORING WELL INSTALLATION ERRORS

Casing/Screen

- Poor Assembly of Joints (Cross-Threading, Using PTFE Tape Where Not Needed, Over Tightening, Using Solvent Cement, Omitting O-Rings)
- Failure to Center Casing/Screen String in the Borehole
- Failure to Use Clean Gloves When Handling/Assembling Casing/Screen String
- Use of Casing with Different Wall Thicknesses or Thread Patterns

COMMON MONITORING WELL INSTALLATION ERRORS

Casing/Screen

- Allowing Casing/Screen String to Land Heavily on the Bottom of the Borehole (Resulting in Broken Joints, Fractured Casing, Screen Failure)
- Failure to Install Bottom Plug [Properly]
- Failure to Clean or Use Pre-Cleaned Casing/Screen Materials
- Failure to Keep Track of Installation Details (Casing/Screen Type, Dimensions, Measurements)

COMMON MONITORING WELL DESIGN FLAWS

- IMPROPER SELECTION OF FILTER PACK GRAIN SIZE AND MATERIALS AND/OR IMPROPER PLACEMENT OF FILTER PACK MATERIALS

  RESULTS:

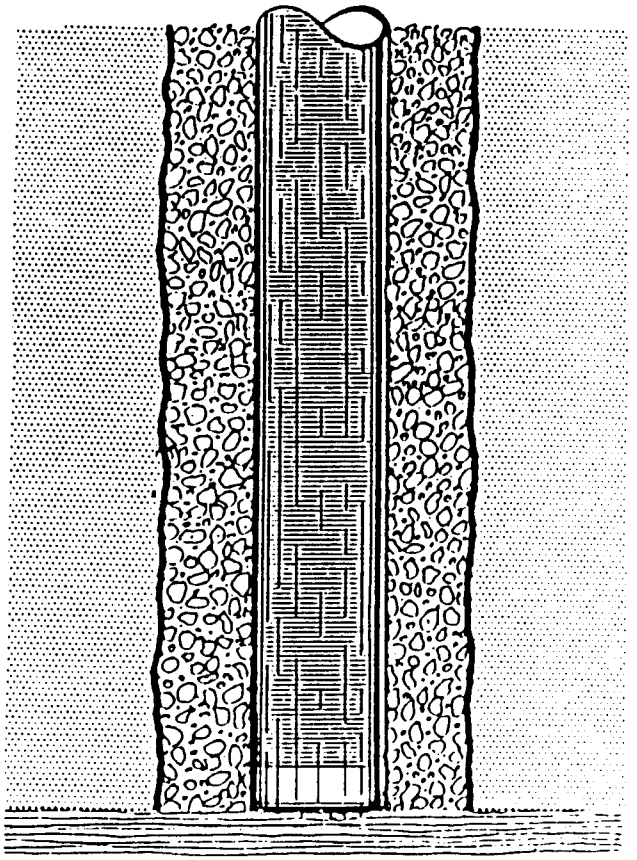
  - SEDIMENTATION OF THE WELL
  - PLUGGING OF THE WELL SCREEN OR FILTER PACK
  - SAMPLE CHEMICAL ALTERATION
  - FAILURE OF THE WELL

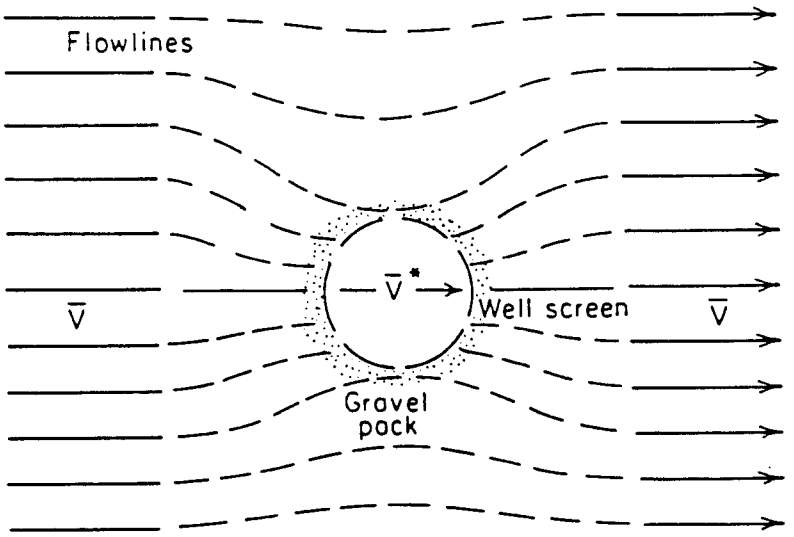
FILTER PACK

A FILTER PACK CONSISTS OF A CLEAN, WELL - ROUNDED SILICEOUS SAND OF SELECTED GRAIN SIZE AND GRADATION THAT IS INSTALLED IN THE ANNULAR SPACE BETWEEN THE WELL INTAKE AND THE WALL OF THE BOREHOLE. THE FILTER PACK HAS A CONSIDERABLY HIGHER PERMEABILITY THAN THE FORMATION, THUS INCREASING THE EFFECTIVE DIAMETER OF THE WELL.

FUNCTIONS OF A FILTER PACK

- Increase Effective Diameter of the Well
- Allow Water to Flow Readily into the Well
- Hold Fine Formation Material Out of the Well





Distortion of flow pattern caused by the presence of the well screen and sand or gravel pack.

WHEN TO USE AN ARTIFICIAL FILTER PACK

- When Formation Materials are Highly Variable
  - When Formation is Highly Stratified
- When Formation is a Uniform Fine Sand or Finer Grained Material (i.e. Predominantly Silt or Clay)
- When Formation is Poorly Cemented Sandstone
- When Formation is Highly Fractured or Solution Channeled Rock

ARTIFICIAL FILTER PACK DIMENSIONS

Length:
Pack Should Extend From the Bottom of the Well Screen to at Least 3 to 5 Feet Above the Top of the Well Screen to Account for Settlement During Development and to Provide a Buffer Between Well Screen and Annular Seal

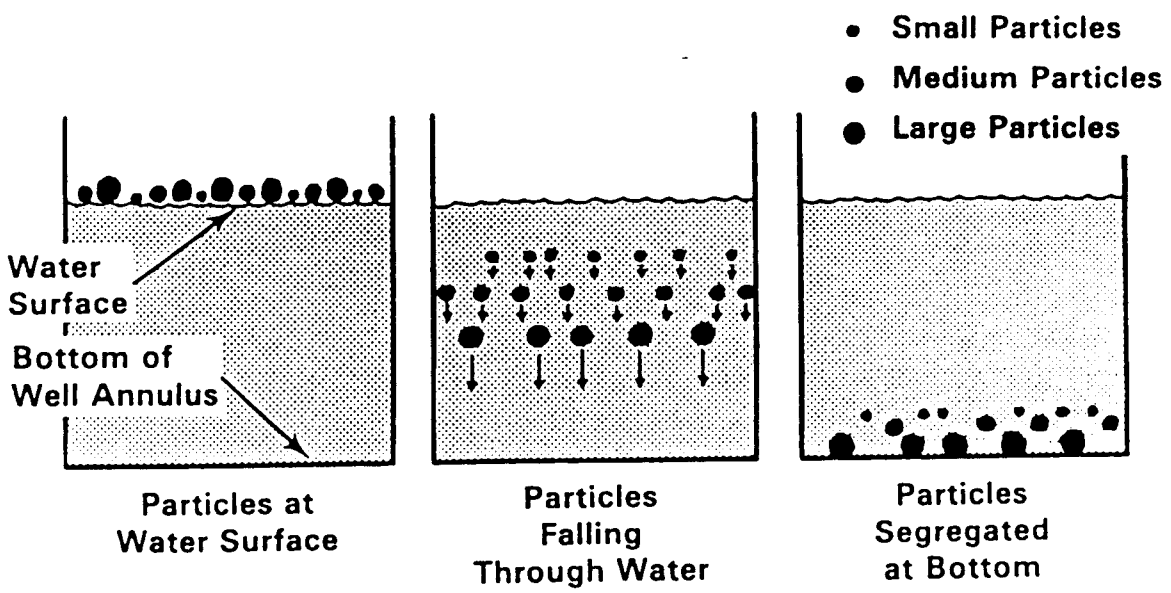
Thickness:
Pack Should Be Thick Enough to Surround the Well Screen Completely But Thin Enough to Minimize Resistance Caused by the Filter Pack to the Flow of Water into the Well During Development. Thicker Isn't Necessarily Better; 2 - 3 Inches is Usually Sufficient

ARTIFICIAL FILTER PACK MATERIALS

- Should Be as Chemically Inert and Non-Reactive as Possible
  - Clean Quartz Sand Preferred (Less Than 5% Nonsiliceous Material)
- Individual Grains Should Be Well-Rounded
- Should Be Washed, Dried and Packaged to Minimize Potential for Contamination

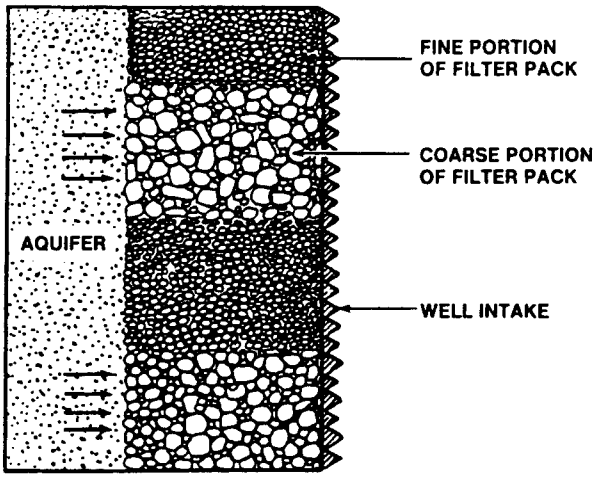
DESIRABLE FILTER PACK CHARACTERISTICS

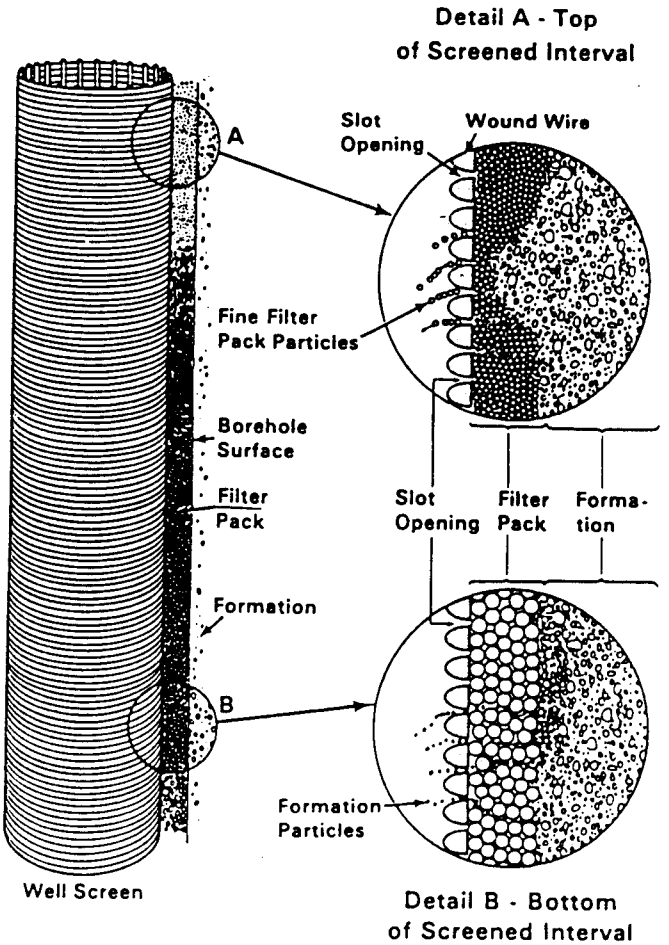
Characteristic	Advantages
Clean	Minimal Losses During Development Less Development Time
Well Rounded	Higher Porosity and K Higher Yield; Reduced Drawdown More Effective Development
> 95% Quartz	No Loss of Volume Through Dissolution No Chemical Alteration of Samples



Segregation of particles by size and relative fall velocities.

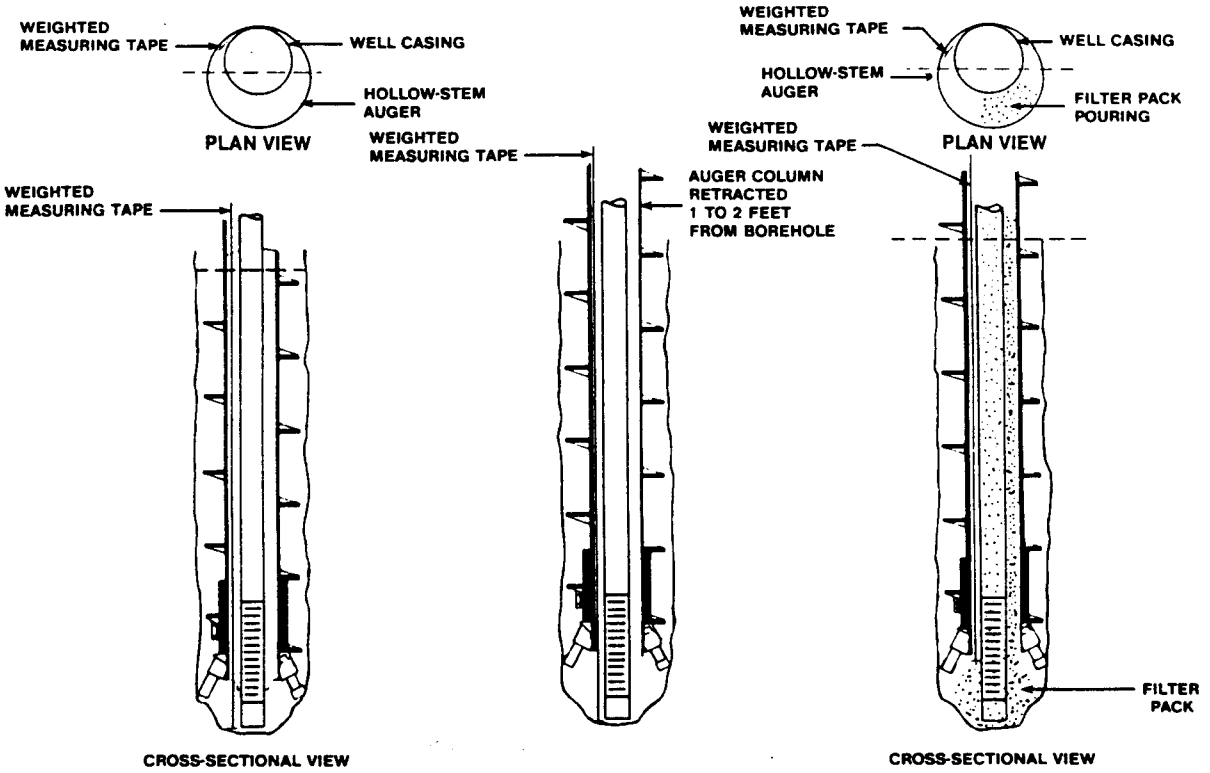
SEGREGATION OF ARTIFICIAL FILTER PACK MATERIALS CAUSED BY GRAVITY EMPLACEMENT.





Impact of particle segregation of a nonuniform filter pack.

FREE-FALL METHOD OF FILTER PACK EMPLACEMENT WITH A HOLLOW-STEM AUGER.



A. PLACEMENT OF WEIGHTED MEASURING TAPE

B. AUGER COLUMN RETRACTED

C. FILTER PACK FREE-FALLS THROUGH WORKING SPACE BETWEEN CASING AND AUGER

MAXIMUM WORKING SPACE AVAILABLE BETWEEN VARIOUS DIAMETERS OF THREADED, FLUSH-JOINT CASING AND HOLLOW-STEM AUGERS

NOMINAL DIAMETER OF CASING*	OUTSIDE DIAMETER OF CASING*	WORKING SPACE FOR VARIOUS INSIDE-DIAMETER HOLLOW-STEM AUGERS*				
		3.25	3.75	4.25	6.25	8.25
2	2.375	0.875	1.375	1.875	3.875	5.815
3	3.500	--	0.250	0.750	2.750	4.750
4	4.500	--	--	--	1.750	3.750
5	5.563	--	--	--	0.687	2.687
6	6.625	--	--	--	--	1.625

* All casing diameter and working space measurements reported in inches.

TREMIE-PIPE EMPLACEMENT OF ARTIFICIAL FILTER PACK MATERIALS

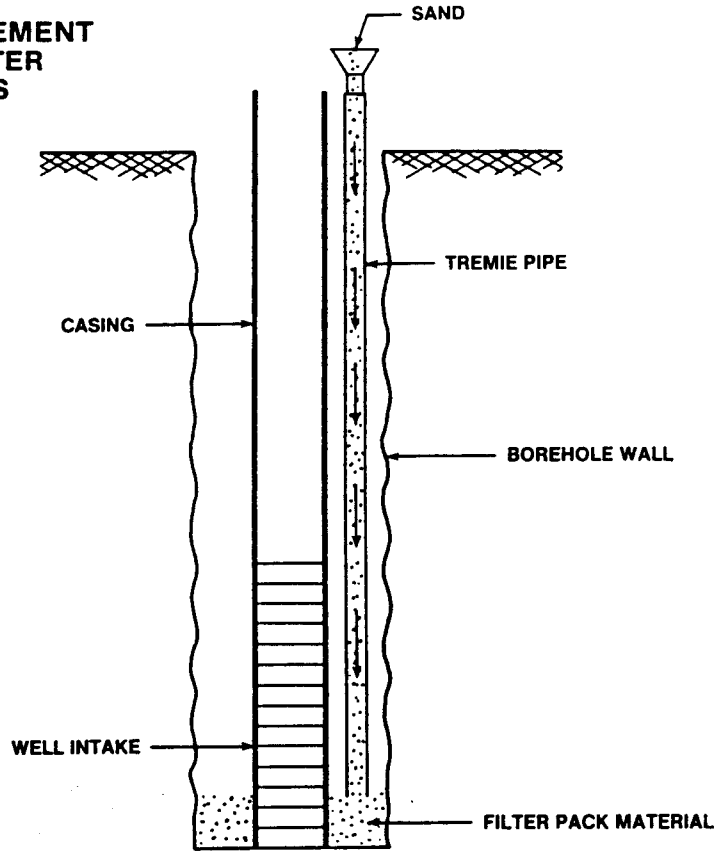
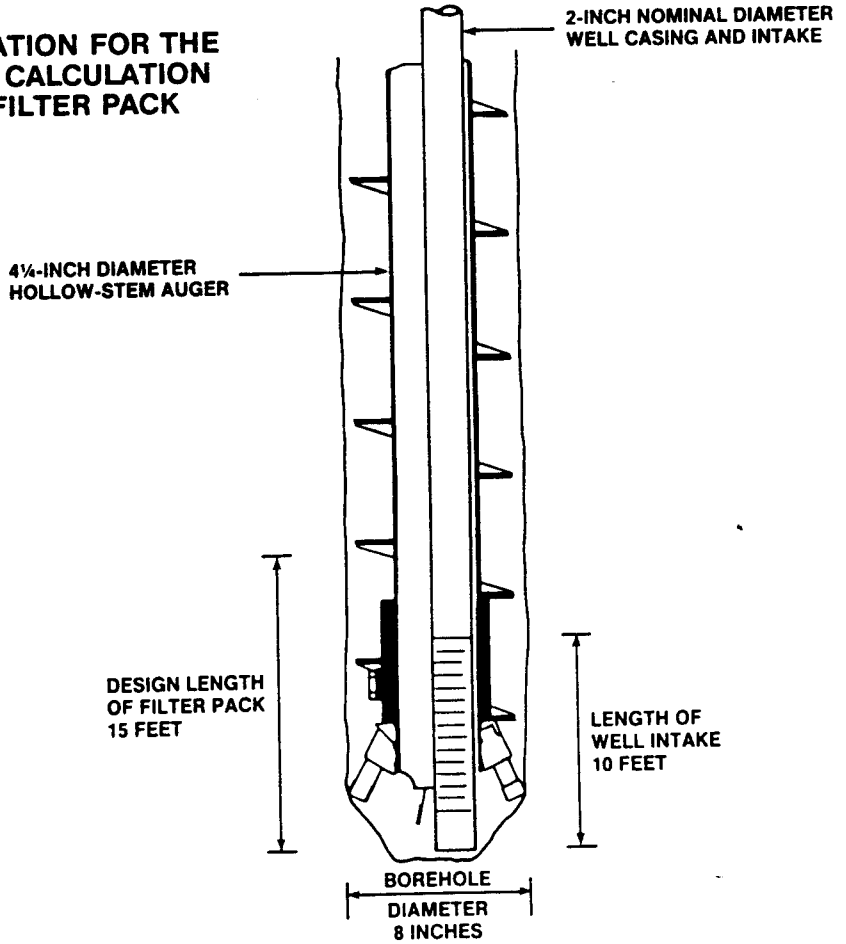


ILLUSTRATION FOR THE SAMPLE CALCULATION OF A FILTER PACK



DIAMETER OF CASING OR HOLE INCHES	*CUBIC FEET PER FOOT OF DEPTH*	*CUBIC METERS PER METER OF DEPTH ($X\ 10^3$)*
1	0.0055	0.509
1 1/2	0.0123	1.142
2	0.0218	2.024
2 1/2	0.0341	3.167
3	0.0491	4.558
3 1/2	0.0668	6.209
4	0.0873	8.110
4 1/2	0.1104	10.26
5	0.1364	12.67
5 1/2	0.1650	15.33
6	0.1963	18.24
7	0.2673	24.84
8	0.3491	32.43
9	0.4418	41.04
10	0.5454	50.67
11	0.6600	61.31
12	0.7854	72.96
14	1.069	99.35

CALCULATING FILTER PACK/ANNULAR SEAL VOLUME

EXAMPLE

70' Well, 2" nom. casing (2 1/2" O.D.), 8" borehole
10' Screen, 60' Casing (to surface)
15' Filter Pack, 5' Bentonite Seal, 50' Grout Seal

Filter Pack Volume = $L_{fp}\ (V_b) - [L_{fp}\ (V_c)]$

$15 \times (0.3491) - [15.\ (0.0341)]$

$5.24\ ft.^3 - 0.51\ ft.^3 = 4.73\ ft.^3$

Annular Seal Volume = $L_{as}\ (v_b) - [L_{as}\ (V_c)]$

$60 \times (0.3491) - [60\ (0.0341)]$

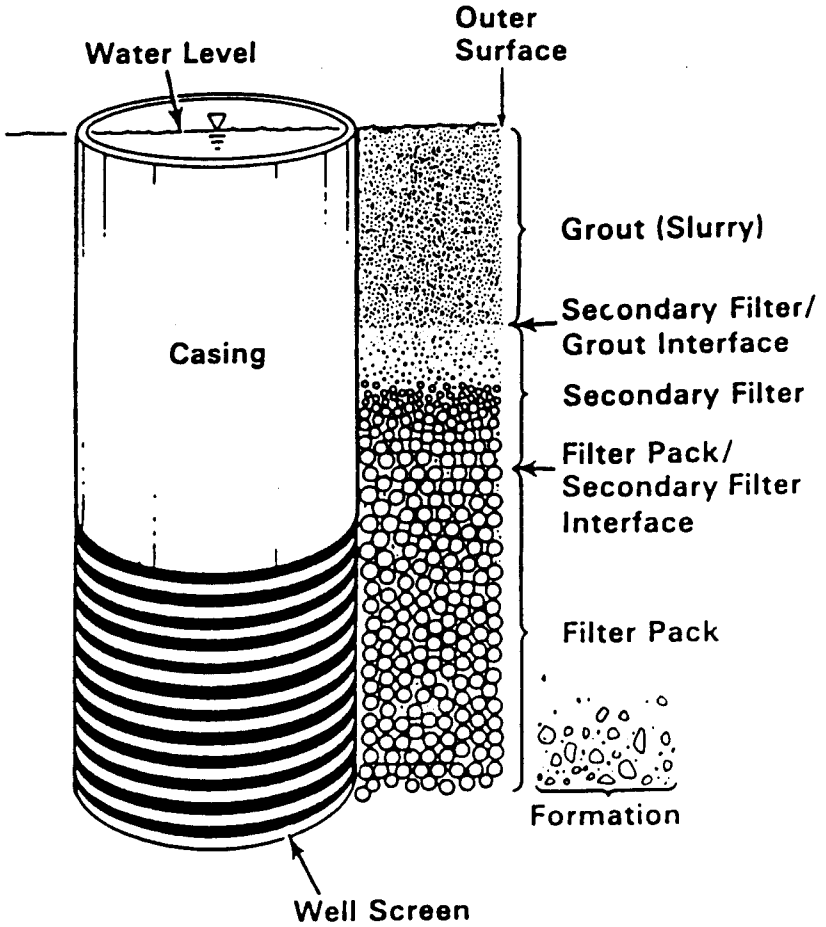
$20.95\ ft.^3 - 2.05\ ft.^3 = 18.90\ ft.^3$

Bentonite Seal = 10% of Annular Seal; Grout Seal = 90% of Annular Seal.

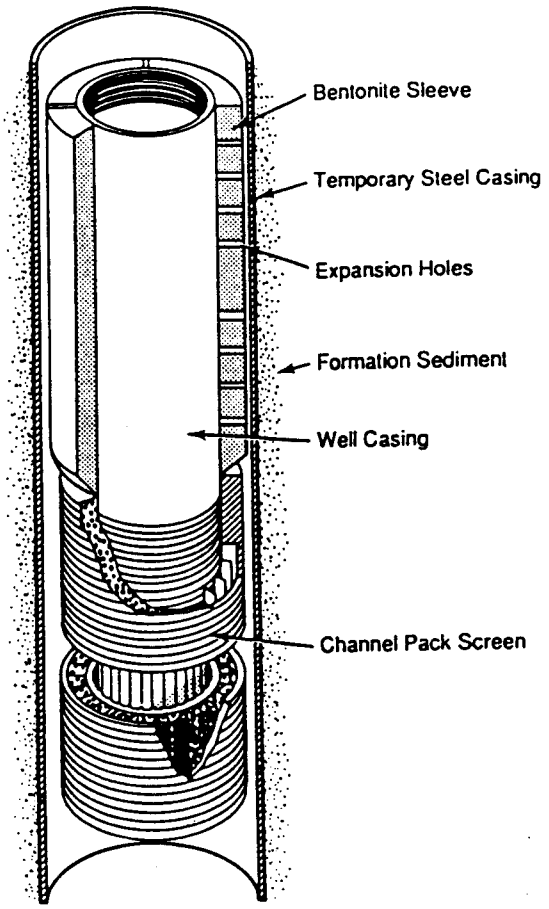
ISOLATING SCREEN AND FILTER PACK FROM GROUTS

- Extend Filter Pack to 3 - 5 Feet Above Top of Screen
- Pre-Develop Well to Stabilize Filter Pack Material
- Install Fine-Grained, Graded Sand Above Filter Pack (2 to 3 Feet)
- Install Bentonite Pellets/Chips Above Filter Pack (2 to 3 Feet) and Allow Bentonite to Hydrate Adequately (Only Feasible in the Saturated Zone)

must allow hydration prior to grout at least 24 hr.



Particle distribution of a secondary filter placed through water.



Dual well screen/filter pack (channel-pack) arrangement.

COMMON MONITORING WELL INSTALLATION ERRORS

Filter Pack

- Attempting to Pour Filter Pack Material Into Place In Open Borehole (Results in Segregation, Incorporation of Sloughed Formation Material, Bridging)
- Failure to Recognize and Correct Bridging (Especially Inside Augers)
- Attempting to Use Tremie Pipe Inside Auger with Inadequate Working Space

COMMON MONITORING WELL INSTALLATION ERRORS

Filter Pack

- Failure to Bring Filter Pack to 3 - 5 Feet Above Top of Screen, and to Stabilize Material Prior to Installation of Annular Seal Materials
- Failure to Keep Track of Well Installation Details (Top of Filter Pack in Relation to Top of Screen, Filter Pack Volume)

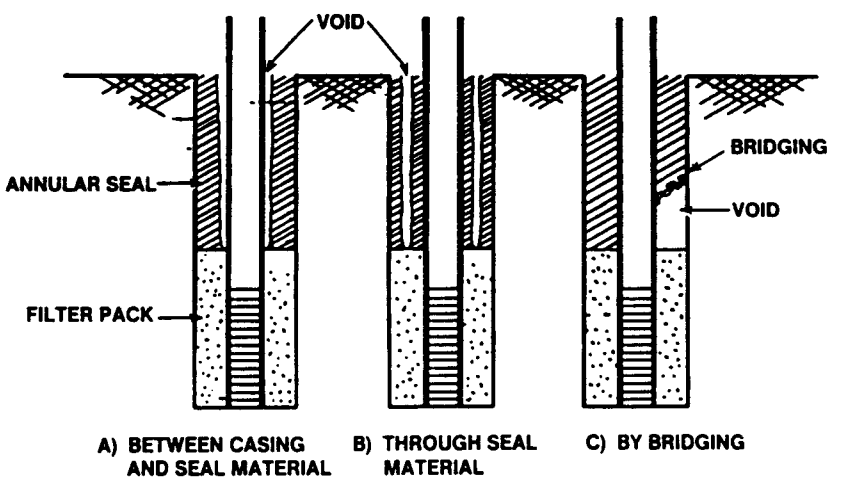
COMMON MONITORING WELL DESIGN FLAWS

- Improper selection and/or placement of annular seal materials

Results:

- sample chemical alteration
- plugging of the filter pack or well intake
- cross-contamination from inadequately sealed - off geologic units
- acquisition of non-representative water water level data

POTENTIAL PATHWAYS FOR FLUID MOVEMENT IN THE CASING-BOREHOLE ANNULUS.



FUNCTIONS OF AN ANNULAR SEAL

- Prohibit Vertical Migration of Water or Contaminants in the Annular Space (Cross-Contamination)
- Seal Off Discrete Sampling Zones, Hydraulically and Chemically
- Provide Protection Against Infiltration of Surface Water and Potential Contaminants from the Ground Surface
- Increase the Life of the Casing by Protecting it Against Exterior Corrosion or Chemical Degradation
- Provide an Element of Structural Integrity

ANNULAR SEAL MATERIALS

Bentonite

- Dry - Pellets, Chips, Granules
  (Must Be Hydrated to Function as a Seal)
- Grout - Powdered Bentonite and Water

Neat Cement

- Grout - Portland Cement and Water;
  May Contain Shrinkage - Compensating Additives, Setting -Time Accelerators, or Other Additives

BENTONITE -

A hydrous aluminum silicate comprised principally of montmorillonite clay; expands 10-15 times its dry volume when hydrated because of incorporation of water molecules into the clay lattice; in-place hydraulic conductivity typically 10^{-7} to 10^{-9} cm/sec; forms seals by expanding against casing and formation

BENTONITE SLURRY -

Mix of dry bentonite power with fresh water in a ratio of about 14 to 15 pounds of bentonite to 7 gallons of water (yields 1 cubic foot of slurry). Remains workable/pumpable for about 1/2 hour (depending upon whether additives are required).

PHYSICAL PROPERTIES OF BENTONITE SLURRIES

	GROUT	DRILLING FLUID
Montmorillonite Content	85 - 90%	85 - 90%
Solids Content	2~~0~~8 - 30%	3 - 6%
Weight	9.5 - 10.1 lbs/gal	8.7 - 9.2 lbs/gal

ASTM STANDARD D 4380
STANDARD TEST METHOD FOR DENSITY OF BENTONITIC SLURRIES

Summary

The weight of a fixed volume of bentonite slurry is measured in a mud balance by moving a rider counterweight along a graduated scale. The density of the slurry is then read directly off the graduated scale after the instrument is balanced.

ASTM STANDARD D 4380
STANDARD TEST METHOD FOR DENSITY OF BENTONITIC SLURRIES

Apparatus

Mud Balance

A mud cup attached to one end of a beam which is balanced on the other end by a fixed counterweight and a rider free to move along a graduated scale. A level bubble may be mounted on the beam.

Calibration

The instrument should be calibrated frequently with fresh water, which should give a reading of 1.00 g/cm^3 at 20°C. If it does not, adjust the balancing screw or the weight at the end of the graduated arm as required.

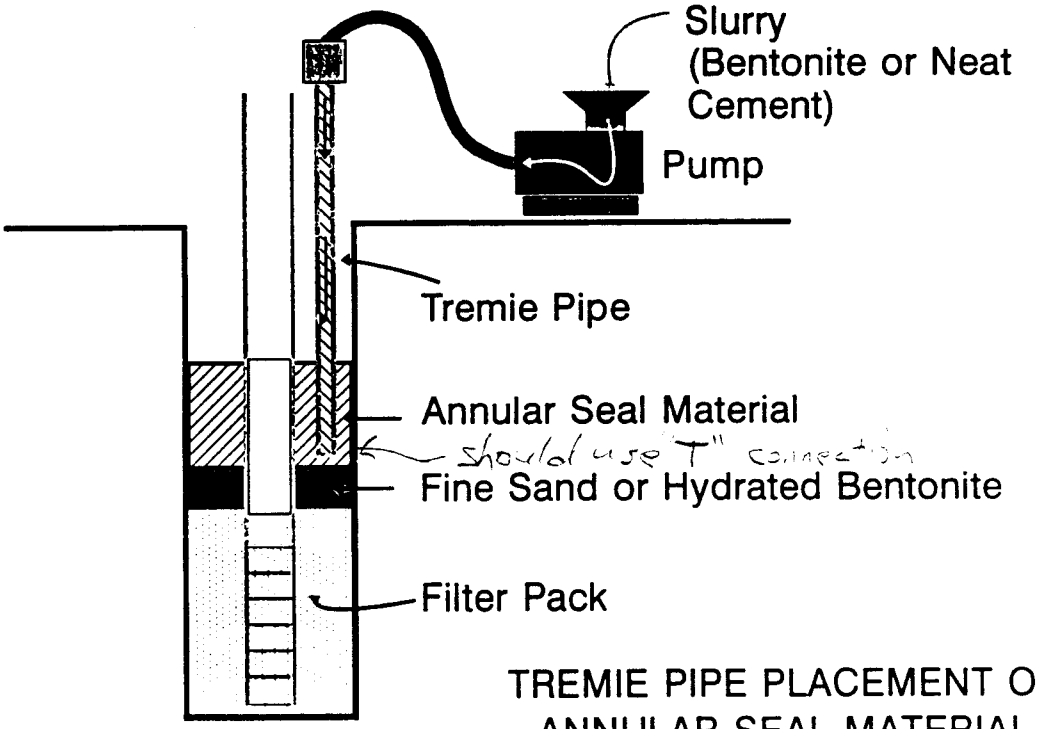
ASTM STANDARD D 4380
STANDARD TEST METHOD FOR DENSITY OF BENTONITIC SLURRIES

Procedure

- Set up the mud balance so it is level
- Fill the clean, dry cup with the slurry to be tested, place the cap on the cup and firmly seat it. Make sure some slurry is expelled through the hole hole in the cap to free trapped air or gas.
- Wash or wipe the excess slurry from the outside of the cup
- Place the beam on the support and balance it using the rider
- Read the density at the side of the rider toward the knife edge; record density to the nearest 0.01g/cm^3
- Clean and dry the mud balance for next use

WEIGHTS OF SLURRIES USED IN MONITORING WELL CONSTRUCTION

Slurry Type & Composition	Weight (lbs/gal)
DRILLING FLUID 10 gal. water/5 lbs. bentonite	8.7
HIGH SOLIDS BENTONITE GROUT 14 gal. water/50 lbs. bentonite	10.1
do not use → NEAT CEMENT/BENTONITE GROUT 8.5 gal. water/5% bentonite/94lb. sack of cement	13.8
NEAT CEMENT GROUT 6.0 gal. water/94 lb. sack of cement	15.0
CONCRETE GROUT 6.0 gal. water/94 lb. sack of cement/equal vol. sand	17.5



TREMIE PIPE PLACEMENT OF ANNULAR SEAL MATERIAL

LIMITATIONS TO THE USE OF BENTONITE AS AN ANNULAR SEAL MATERIAL

- Unhydrated Bentonite Should Not Be Used in the Vadose Zone

- Bentonite May Not Swell Adequately Where Water Quality is Unsuitable
  - High Total Dissolved Solids or Chloride Content
  - High Concentrations of Organic Solvents or Organic Acids
  - Separate-Phase Petroleum Hydrocarbons

NEAT CEMENT GROUT -

Usually a mixture of Portland Cement (ASTM C-150) and 5 to 6 gallons of clean water per bag (94 pounds or 1 cubic foot) of cement. This mix yields a 14 pound/gallon slurry with a mixed volume of about 1.5 cubic feet and a set volume of about 1.2 cubic feet; volumetric shrinkage is about 17%.

↑pH, Al

ASTM STANDARD C 150
STANDARD SPECIFICATION FOR PORTLAND CEMENT

Definitions:

Portland Cement
A general purpose cement produced by pulverizing hydraulic calcium silicates, and usually containing calcium sulfate

Air-Entraining Cement
Portland cement with an air-entraining addition, which is used in cold weather applications to prevent cracking of the cement during curing

ASTM STANDARD C 150
STANDARD SPECIFICATION FOR PORTLAND CEMENT

ASTM Cement Types

Type I - For General Use
Type IA - Air-Entraining Cement for General Use
Type II - For Use When Moderate Sulfate Resistance or Moderate Heat of Hydration is Desired
Type IIA - Air-Entraining Cement with Same Properties as Type II
Type III - For Use When High Early Strength is Desired
Type IIIA - Air-Entraining Cement with Same Properties as Type III
Type IV - For Use When Low Heat of Hydration is Desired
Type V - For Use When High Sulfate Resistance is Desired

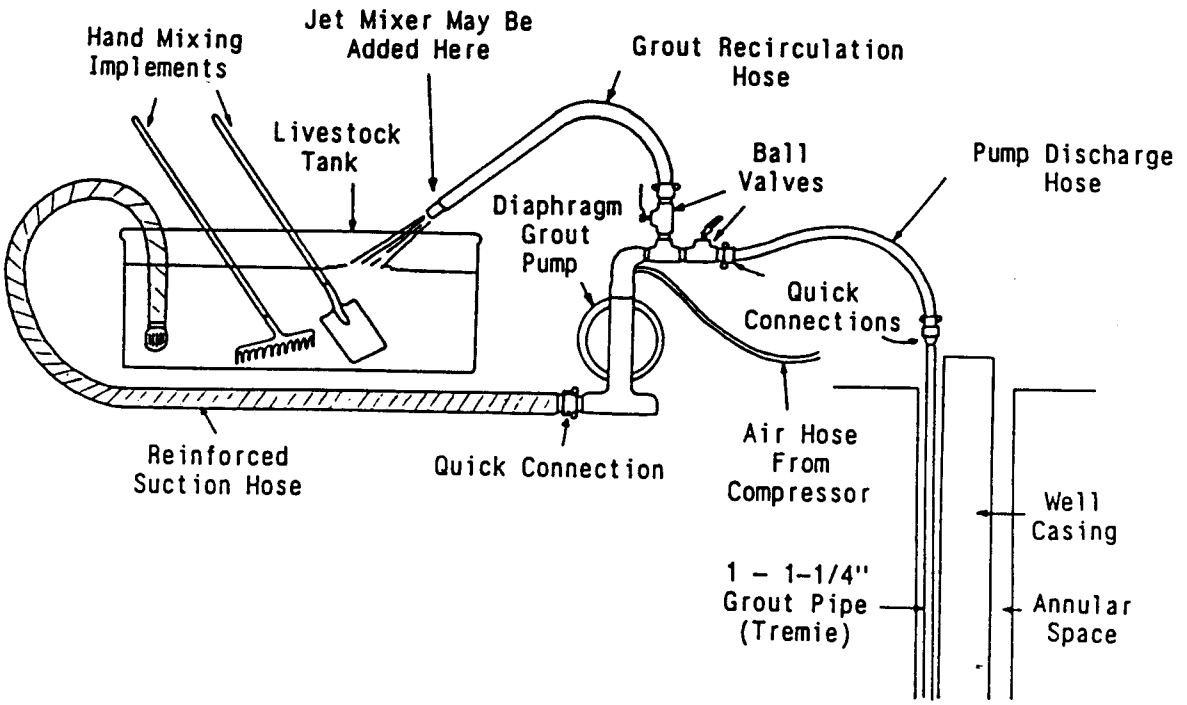
NEAT CEMENT ADDITIVES AND THEIR FUNCTIONS

- **Bentonite -- Added at approximately 3% to 8% by volume**
  - **-- Improves workability, reduces slurry weight and density, reduces shrinkage, lowers cost**
- **Calcium Chloride -- Added at approximately 1% to 3% by volume**
  - **-- Provides accelerated setting time, higher early strength (useful in cold climates)**
- **Gypsum -- Added at approximately 3% to 6% by volume**
  - **-- Accelerates setting time, increases strength, expands on setting**

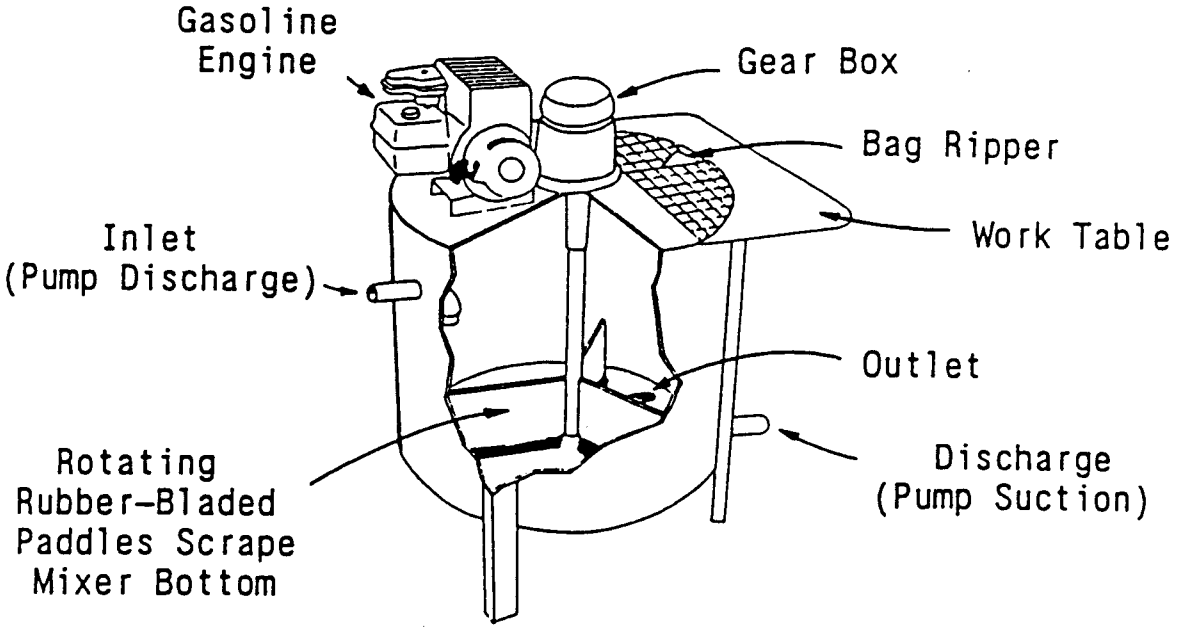
usually used

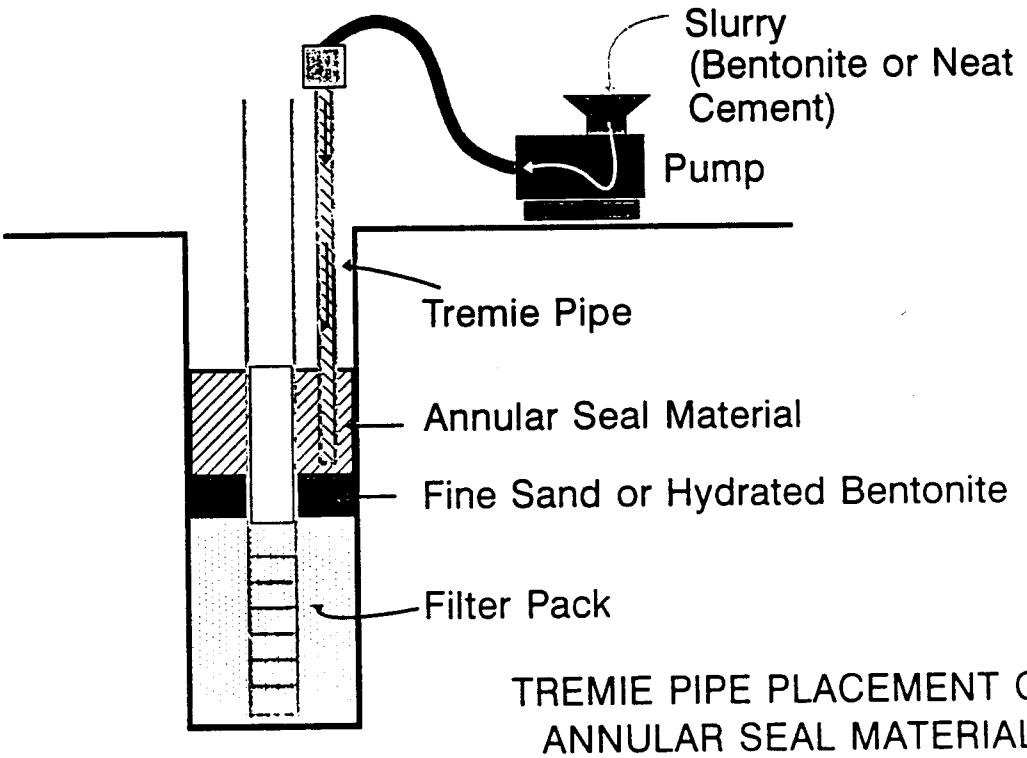
- **Aluminum Powder -- Added at approximately 1% by volume**
  - **-- Produces stronger, quick-setting cement that expands on setting**

RECIRCULATION/HAND MIXING PROCEDURE



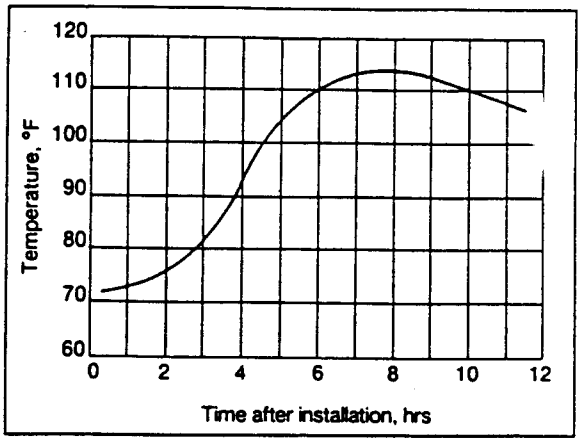
TYPICAL PADDLE MIXER





TREMIE PIPE PLACEMENT OF ANNULAR SEAL MATERIAL

can go ↑ ≈ Al powder



Heat is produced when cement is hydrated. The amount of heat released depends on the volume of cement used to grout the casing, the ambient temperature of the formation, and the pressure in the borehole. This graph shows the temperature change over time at a depth of 550 ft (168 m) where the formation temperature was 65° F (18.3°C), the mixing water temperature was 74° F (23.3°C), and the slurry weighed 15.4 lb/gal (1,850 kg/m³).

LIMITATIONS TO THE USE OF NEAT CEMENT AS AN ANNULAR SEAL MATERIAL

- Cement Should Not Be Placed Directly On Top of The Filter Pack
- Excessive Heat of Hydration (Caused By Setting Time Accelerators or Washouts in the Borehole) May Cause Failure of Plastic Casing Materials
- Cement May Not Form An Adequate Seal Where Water Quality is Unsuitable
  - Low pH or High Sulfate Content

OPTIMUM HYDRATION/SET TIMES AND HYDRAULIC CONDUCTIVITIES FOR ANNULAR SEAL MATERIALS

Bentonite Pellets	Bentonite Slurry	Neat Cement Grout
@ 90 hrs.	@ 48-72 hrs.	@ 48-72 hrs.
$K = 1x10^{-6}$ cm/sec	$K = 1x10^{-7}$ cm/sec	$K = 1x10^{-7}$ cm/sec
@ 20 hrs.		
$K = 2x10^{-4}$ cm/sec		

CHEMICAL INTEGRITY PROBLEMS - ANNULAR SEALS

Bentonite:

Sets up with High Cation Exchange Capacity and Moderately High pH (Between 8.5 and 10.5); May Contain Organic Polymer Additives

Neat Cement:

Sets up with High pH (Between 10 and 12), High Specific Conductance and High Alkalinity; May Contain Various Additives

COMMON MONITORING WELL INSTALLATION ERRORS

Annular Seal

- Use of Drill Cuttings to Fill Annular Space
- Placement of Grout Directly on Top of Filter Pack
- Failure to Allow Dry Bentonite (Pellets, Chips, Granules) Adequate Time to Hydrate Prior to Grout Placement

COMMON MONITORING WELL INSTALLATION ERRORS

Annular Seal

- Failure to Formulate or Mix Grouts Properly (Bentonite or Neat Cement; Additives in Neat Cement)
- Attempting to Pour Grout Through Water Column
- Failure to Detect and Correct Bridging (Especially Inside Augers)

COMMON MONITORING WELL INSTALLATION ERRORS

Annular Seal

- Use of Bentonite Pellets or Chips in the Unsaturated Zone
- Failure to Recognize Washouts or Zones of Fluid Loss To the Formation
- "Jetting" Grout into Filter Pack or Secondary Pack
- Placement of Too Much Grout in the Annular Space at Once
- Attempting to Overextend Mixing/Pumping Time of Neat Cement
- Not Allowing Grout to Set Properly Prior to Well Development

MINIMIZING WELL CONSTRUCTION - RELATED CHEMICAL INTERFERENCE

- **Select casing/screen, filter pack and annular seal materials based on site - specific conditions**
- **Use flush - joint threaded casing/screen; avoid solvent or heat welding**
- **Thoroughly clean all casing/screen and filter pack materials prior to installation**
- **Maintain clean storage and handling practices for all materials**
- **Use water of known quality to mix slurries**
- **Place annular seal well above (i.e. >3 ft.) top of well intake**
- **Allow annular seal to set up prior to well development**
- **Retain samples of all well construction materials for possible analysis**

COMMON MONITORING WELL DESIGN FLAWS

- INADEQUATE SURFACE PROTECTIVE MEASURES

  RESULTS:

  - SURFACE WATER ENTERING THE BOREHOLE (WITH SUBSEQUENT SAMPLE CHEMICAL ALTERATION)
  - DAMAGE TO OR DESTRUCTION OF THE WELL BY VEHICULAR TRAFFIC
  - DAMAGE TO THE WELL BY FROST HEAVING

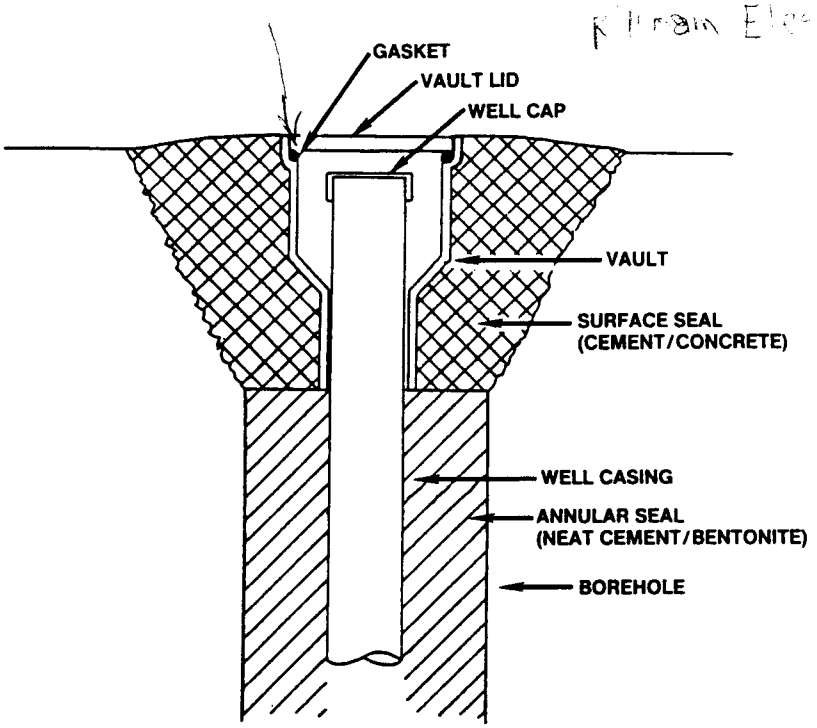
SURFACE PROTECTIVE MEASURES

- PROTECTION FROM SURFACE WATER ENTRY
  - CEMENT/CONCRETE FOOTERS
- PROTECTION FROM PHYSICAL DAMAGE AND VANDALISM
  - SURFACE PROTECTIVE CASING
  - BUMPER GUARDS
  - LOCKING CASING CAPS

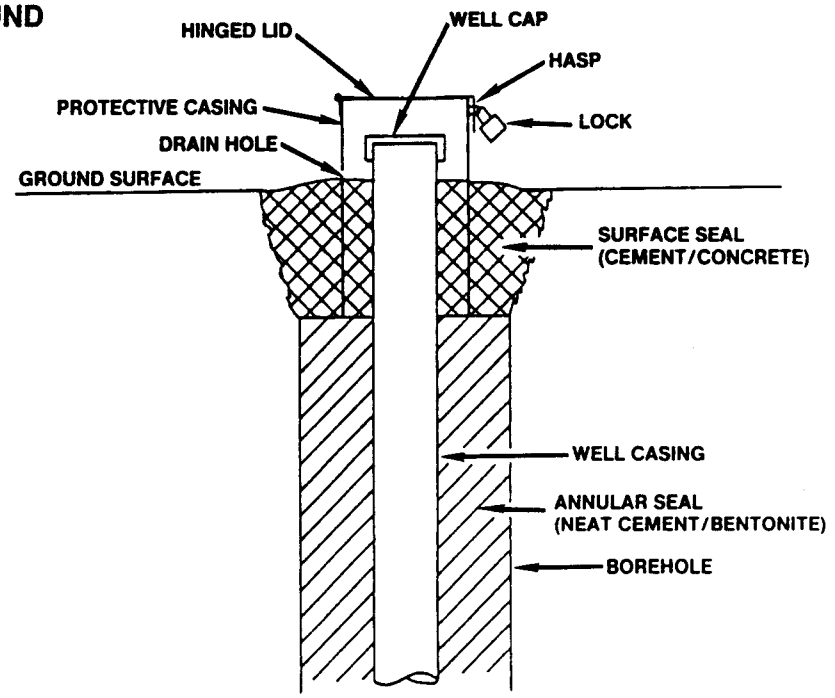
Derrick Drill → (Hydro tight)

Drain Electrolyte

TYPICAL FLUSH-TO-GROUND-SURFACE MONITORING WELL COMPLETION



TYPICAL ABOVE-GROUND MONITORING WELL COMPLETION



COMMON MONITORING WELL INSTALLATION ERRORS

Surface Protection

- Using Protective Casing with Too Small an Inside Diameter to Allow Access to Well
- Failure to Provide Drainageway for Water Between Protective Casing and Well Casing
- Failure to Install Vent Hole (Above-Grade Completions)
- Failure to Install Water Tight Completion (Below-Grade Completions)
- Failure to Extend Surface Seal to Below Depth of Frost Penetration

COMMON MONITORING WELL INSTALLATION ERRORS

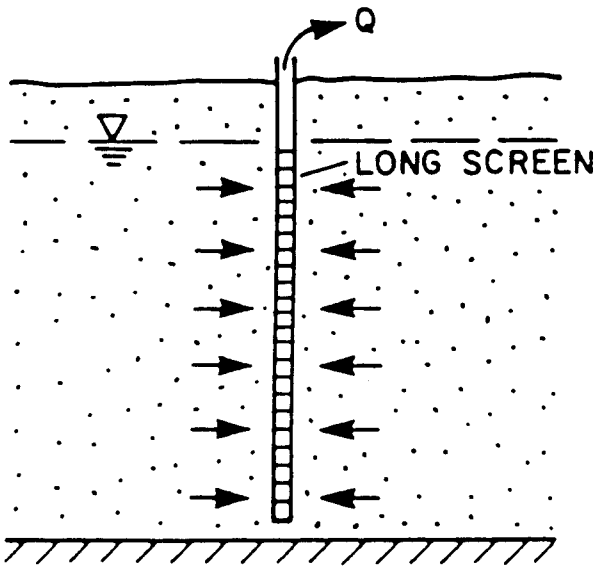
Surface Protection

- Failure to Mark Permanent Identification on Well Enclosure
- Using Easily Corrodible Materials in Corrosive Environments
- Failure to Measure for Adequate Clearance for Cap at Top of Well
- Failure to Provide Bumper Guards in Areas of High Traffic (Above-Grade Completions)
- Failure to Use Traffic Rated Enclosure in Areas of High Traffic (Below-Grade Completions)

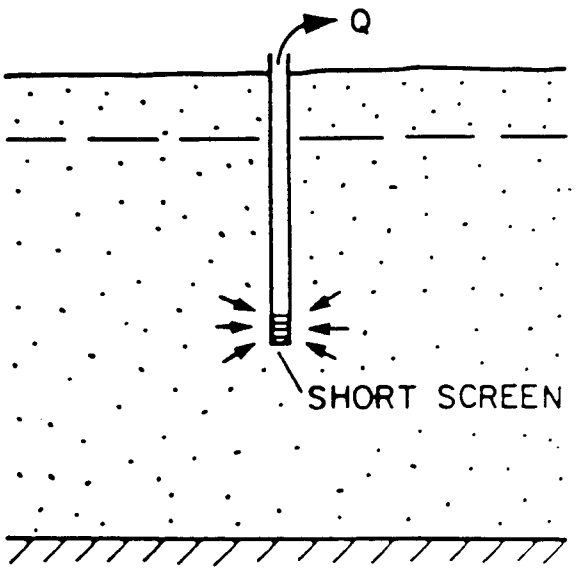
ALTERNATE MONITORING WELL COMPLETIONS

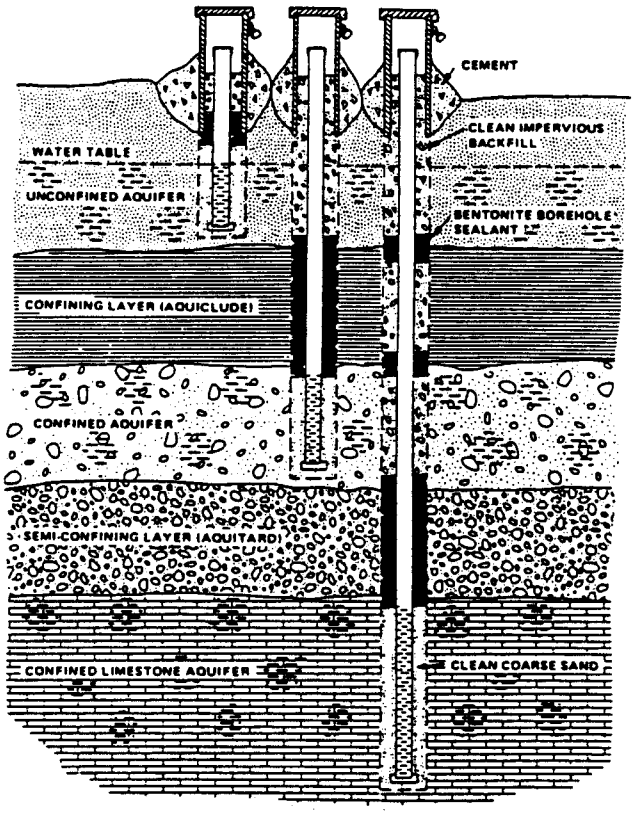
- Single-Casing, Short-Screen Wells
- Single-Casing, Long-Screen Wells
- Multiple-Casing (Telescoping) Wells
- Nested Wells (Multiple Wells in a Single Borehole)
- Multiple-Screen Wells
- Multi-Level Monitoring Systems
- Open-Hole (Bedrock) Completions

DEPTH INTEGRATED

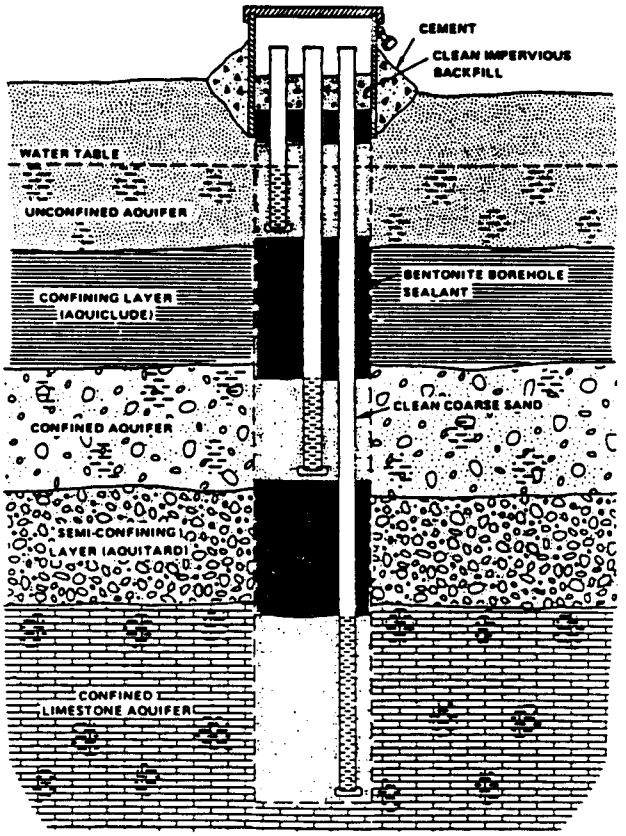


DEPTH SPECIFIC



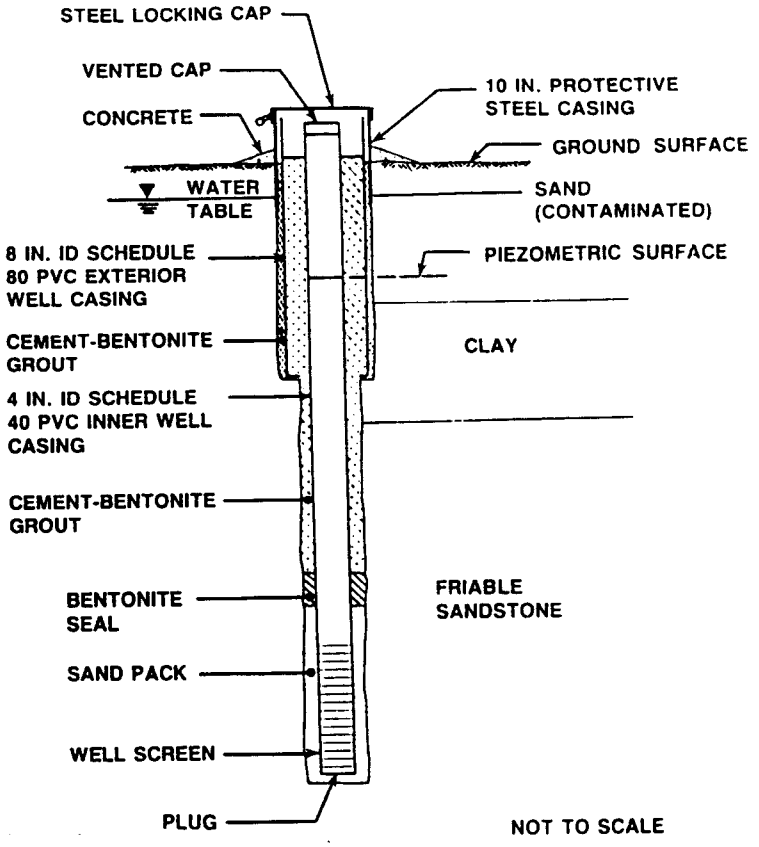


Multilevel Sampling Wells Installed In Individual, Small Diameter Boreholes for Groundwater Quality In Three Distinct Aquifers



Multilevel Sampling Wells Installed In a Single, Large Diameter Borehole for Monitoring Groundwater Quality In Three Distinct Aquifers

DOUBLE-CASED WELL CONSTRUCTION DIAGRAM



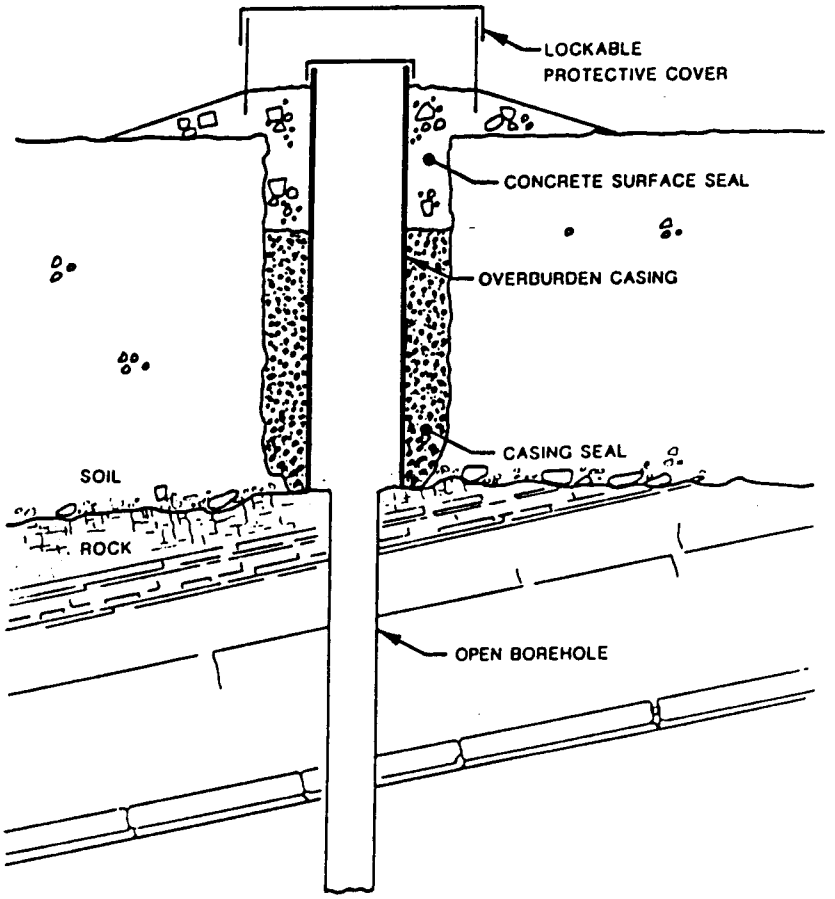
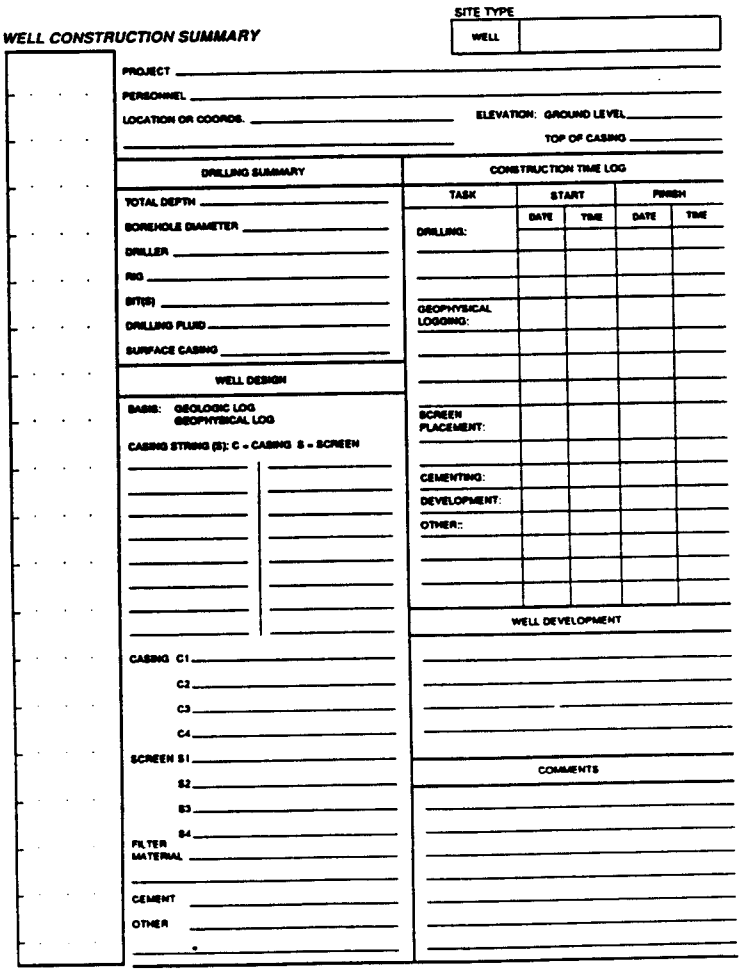


Diagram of an open-hole ground-water monitoring well in rock.

PREPARATION FOR LONG-TERM MONITORING

- Documentation of Borehole and Well Construction Details
- Clear, Permanent Identification of Wells
- Surveying of Wells to a Common Datum (Preferably N.G.V.D.)
  - Elevations of Measuring Points (±0.01 ft.)
  - Locations of Wells
- Provisions for Well Maintenance/Redevelopment/ Rehabilitation



WELL CONSTRUCTION SUMMARY

SITE TYPE: WELL

PROJECT

PERSONNEL

LOCATION OR COORDS.

ELEVATION: GROUND LEVEL

TOP OF CASING

DRILLING SUMMARY

TOTAL DEPTH

BOREHOLE DIAMETER

DRILLER

RIG

BIT(S)

DRILLING FLUID

SURFACE CASING

WELL DESIGN

BASIS: GEOLOGIC LOG
GEOPHYSICAL LOG

CASING STRING (S): C = CASING S = SCREEN

CASING C1
C2
C3
C4

SCREEN S1
S2
S3
S4

FILTER MATERIAL

CEMENT

OTHER

CONSTRUCTION TIME LOG

TASK	START DATE	START TIME	FINISH DATE	FINISH TIME
DRILLING:				
GEOPHYSICAL LOGGING:				
SCREEN PLACEMENT:				
CEMENTING:				
DEVELOPMENT:				
OTHER::				

WELL DEVELOPMENT

COMMENTS

GROUND-WATER MONITORING SYSTEM DESIGN

References

Sara, M.N., 1993, Standard Handbook for Solid and Hazardous Waste Facility Assessment (Chapters 9 and 10, Monitoring System Design; Assessment Monitoring Design), Lewis Publishers, Ann Arbor, MI

Sara, M.N., 1991, Ground-Water Monitoring System Design, in Practical Handbook of Ground-Water Monitoring, D.M. Nielsen, Editor, Lewis Publishers, Ann Arbor, MI, pp. 17 - 68

U.S. EPA, 1980, Procedures Manual for Ground-Water Monitoring at Solid Waste Disposal Facilities, SW611, U.S. EPA, Washington, D.C., 269 pp.

U.S. EPA, 1986, RCRA Ground-Water Monitoring Technical Enforcement Guidance Document, OSWER-9950.1, U.S. EPA, Washington, D.C., 208 pp.

Pfannkuch, H.O., and Labno, B.A., 1976, Design and Optimization of Ground-Water Monitoring Networks for Pollution Studies, Ground Water, Vol. 14, No. 6, pp. 455 - 462

Pfannkuch, H.O., 1982, Problems of Monitoring Network Design to Detect Unanticipated Contamination, Ground Water Monitoring Review, Vol. 2 No.1, pp. 67 - 76

Benson, R.C., and Pasley, D.C. Jr., 1984, Ground-Water Monitoring: A Practical Approach for Major Utilities, in Proceedings, Fourth National Symposium on Aquifer Restoration and Ground-Water Monitoring, National Water Well Association, Worthington, OH, pp. 270 - 278

Cherry, J.A., 1992, Ground-Water Monitoring: Some Current Deficiencies and Alternative Approaches, Chapter 13 in Hazardous Waste Site Investigations: Toward Better Decisions, R.B. Gammage and B.A. Berver, Editors, Lewis Publishers, Ann Arbor, MI, pp. 119 - 134

Benson, R.C., Thomas, C.M., and Yuhr, L., 1985, An Approach to Long-Term Ground Water Monitoring, in Proceedings, Sixth National Conference on Management of Uncontrolled Hazardous Waste Sites, Hazardous Materials Control Research Institute, Silver Spring, MD, pp. 112 - 115

Nacht, S.J., 1983, Ground-Water Monitoring System Considerations, Ground Water Monitoring Review, Vol. 3, No. 2, pp. 33 - 39

technical references disk

U.S. EPA, 1983, Ground-Water Monitoring Guidance for Owners and Operators of Interim Status Facilities, SW-963, U.S. EPA, Washington, D.C.

Perazzo, J.A., Dorrier, R.C., and Mack, J.P., 1984, Long-Term Confidence in Ground-Water Monitoring Systems, Ground Water Monitoring Review, Vol. 4 No. 4, pp. 119 - 123

technical references disk

ENVIRONMENTAL DRILLING TECHNOLOGY

References

Davis, H.E., Jehn, J.L., and Smith, S., 1991, Monitoring Well Drilling, Soil Sampling, Rock Coring and Borehole Logging, in Practical Handbook of Ground-Water Monitoring, D.M. Nielsen, Editor, Lewis Publishers, Ann Arbor, MI, pp. 195 - 237

ADITCL, 1992, Australian Drilling Manual (Chapter 11 - Drilling Applications, Section III - Environmental Applications), Australian Drilling Industry Training Committee, Ltd., New South Wales, Australia, pp. 473 - 490

Driscoll, F.G., 1986, Ground Water and Wells, (Chapter 10 - Well Drilling Methods) Johnson Division, St. Paul, MN, pp. 268 - 339

Campbell, M.D. and Lehr, J.H., 1973, Water Well Technology, McGraw-Hill Book Company, New York, NY, 681 pp.

USDI, 1981, Ground Water Manual (Chapter 16 - Water Well Drilling), John Wiley and Sons, New York, NY, pp. 385 - 396

Roscoe Moss Company, 1990, Handbook of Ground-Water Development (Chapter 7 - Drilling Systems), John Wiley and Sons, New York, NY, pp. 131 - 154

U.S. EPA, 1981, Procedures Manual for Ground-Water Monitoring at Solid Waste Disposal Facilities, SW611, U.S. EPA, Washington, D.C., pp. 132 - 146

Todd, D.K., 1980, Ground Water Hydrology (Chapter 5 - Water Wells), John Wiley and Sons, New York, NY, pp. 164 - 217

Aller, L., Bennett, T.W., Hackett, G., Petty, R.J., Nielsen, D.M., Lehr, J.H., Sedoris, H., and Denne, J.E., 1991, Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells (Section 4 - Description and Selection of Drilling Methods), EPA/600/4-89/034, U.S. EPA, Washington, D.C., pp. 35 - 71

Barcelona, M.J., Gibb, J.P., Helfrich, J.A. and Garske, E.E., 1985, Practical Guide for Ground-Water Sampling, ISWS Contract Report 374, Illinois State Water Survey, Champaign, IL, pp. 25 - 29

technical references disk

Gillham, R.W., Robin, M.J.L., Barker, J.F., and Cherry, J.A., 1983, Ground Water Monitoring and Sample Bias, API Publication 4367, American Petroleum Institute, Washington, D.C.

U.S. EPA, 1987, Handbook on Ground Water, EPA/625/6-87/016, U.S. EPA, Washington, D.C., pp. 95 - 98

Stollar, R.L., 1990, Ground Water Monitoring (Chapter 6 in Subsurface Migration of Hazardous Wastes), Van Nostrand Reinhold, New York, NY, pp. 174 - 187

Keely, J.F., and Boateng, K., 1987, Monitoring Well Installation, Purging and Sampling Techniques, Part I: Conceptualizations and Part II: Case Histories, in Proceedings, National Water Well Association Focus Conference on Northwestern Ground-Water Issues, National Ground-Water Association, Dublin, OH, pp. 443 - 499

Smith, S.A., 1990, Monitor Well Drilling and Testing in Urban Environments, in Ground-Water and Vadose Zone Monitoring, D.M. Nielsen and A.I. Johnson, Editors, ASTM Special Technical Publication 1953, American Society for Testing and Materials, Philadelphia, PA , pp. 55 - 63

Dustman, J., Davis, R. and Oothoudt, T., 1992, Soil, Bedrock and Ground Water Sampling Using Rotasonic Drilling Techniques, in Proceedings, Sixth National Outdoor Action Conference, National Ground Water Association, Dublin, OH, pp. 179 - 186

Davis, R., and Oothoudt, T., 1993, The Use of Rotasonic Drilling in Environmental Investigations, manuscript submitted for publication in Ground Water Monitoring Review

Godsey, K.D., 1993, The (Sonic) Wave of the Future, Water Well Journal, Vol. 47, No. 5, pp. 86 - 90

Hix, G.L., 1991, Casing Advancement Methods for Drilling Monitoring Wells, Water Well Journal, Vol. 45, No. 5, pp. 60- 64

Strauss, M.F., Story, S.L., and Mehlhorn, N.E., 1989, Application of Dual-Wall Reverse Circulation Drilling in Ground-Water Exploration and Monitoring, Ground Water Monitoring Review, Vol. 9, No. 2, pp. 63 - 71

Riddle, J. and Johnson, R.J., 1991, Dual-Tube, Reverse Circulation Drilling for Effective Exploration of Ground-Water Conditions, in Proceedings, Fifth National Outdoor Action Conference, National Ground-Water Association, Dublin, OH, pp. 787 - 797

technical references disk

Holsten, D.B., and Morgan, J., 1989, The Dual-Tube Air Percussion Drilling Method for Installation of Ground Water Monitoring Wells, in Proceedings, Third National Outdoor Action Conference, National Ground Water Association, Dublin, OH, pp. 1 - 14

Murphy, J., 1991, Application of ODEX Drilling Method in a Variably Fractured Volcanic/Igneous Environment, in Proceedings, Fifth National Outdoor Action Conference, National Ground Water Association, Dublin, OH, pp. 799 - 914

Baker, J.A., Holdredge, T.J., Buck, D.J., and Hubbard, E.J., 1987, Use of ODEX Drilling System for Monitoring Well Installation in Aquifer Containing Glacial Boulders, in Proceedings, First National Outdoor Action Conference, National Ground Water Association, Dublin, OH, pp. 363 - 372

Woessner, W.W., 1988, Drill-Through Casing Driver Drilling Method for Construction of Monitoring Wells in Coarse, Unconsolidated Sediments, Ground Water Monitoring Review, Vol. 8, No. 1, pp. 69 - 72

Perry, C.A., and Hart, R.J., 1985, Installation of Observation Wells on Hazardous Waste Sites in Kansas Using a Hollow-Stem Auger, Ground Water Monitoring Review, Vol. 5, No. 4, pp. 70 - 73

technical references disk

GROUND-WATER MONITORING WELL DESIGN AND CONSTRUCTION

References

Nielsen, D.M. and Schalla, R., 1991, Design and Installation of Ground-Water Monitoring Wells, in Practical Handbook of Ground-Water Monitoring, D.M. Nielsen, Editor, Lewis Publishers, Ann Arbor, MI, 717 pp.

Aller, L., Bennett, T.W., Hackett, G., Petty, R.J., Nielsen, D.M., Lehr, J.H., Sedoris, H. and Denne, J.E., 1991, Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells, EPA/600/4-89/034, U.S. EPA, Washington, D.C., 221 pp.

Nielsen, D.M. and Sara, M.N. (Editors), 1992, Current Practices in Ground-Water and Vadose Zone Investigations, ASTM Special Technical Publication 1118, American Society for Testing and Materials, Philadelphia, PA, 431 pp.

Nielsen, D.M., and Johnson, A.I. (Editors), 1990, Ground Water and Vadose Zone Monitoring, ASTM Special Technical Publication 1053, American Society for Testing and Materials, Philadelphia, PA, 313 pp.

Collins, A.G., and Johnson, A.I. (Editors), 1988, Ground-Water Contamination: Field Methods, ASTM Special Technical Publication 963, American Society for Testing and Materials, Philadelphia, PA, 491 pp.

Fetter, C.W., 1993, Contaminant Hydrogeology (Chapter 8 - Ground Water and Soil Monitoring), MacMillan Publishing Company, New York, NY, pp. 338 - 391

Palmer, C.M., 1992, Principles of Contaminant Hydrogeology (Chapter 3 - Ground-Water Monitoring Well Installation), Lewis Publishers, Ann Arbor, MI, pp. 51 - 67

Stollar, R.L., 1990, Ground Water Monitoring, Chapter 6 in Subsurface Migration of Hazardous Wastes, Van Nostrand Reinhold, New York, NY, pp. 169 - 266

Driscoll, F.G., 1986, Ground Water and Wells (Chapter 21 - Ground Water Monitoring Technology), Johnson Division, St. Paul, MN, pp. 702 - 733

U.S. EPA, 1991, Handbook on Ground Water, Volume II: Methodology, EPA/625/6-90/0166, U.S. EPA, Washington, D.C., 141 pp.

technical references disk

ASTM, 1990, Standard Practice for Design and Installation of Ground-Water Monitoring Wells in Aquifers, ASTM Standard D 5092-90, American Society for Testing and Materials, Philadelphia, PA, 12 pp.

Glotfelty, M.F., 1993, Monitoring Well Design Considerations, Water Well Journal, Vol. 47 No. 5, pp. 63 - 66

Narkunas, J., 1985, How to Construct the Monitoring Well, Ground Water Age, Vol. 19, No. 8, pp. 28 - 35

Wehrmann, H.A., 1983, Monitoring Well Design and Construction, Ground Water Age, Vol. 17, No. 5, pp. 35 - 38

Gates, W.C.B., 1989, Protection of Ground-Water Monitoring Wells Against Frost Heave, Bulletin of the Association of Engineering Geologists, Vol. 26 No. 2, pp. 241 - 251

White, A.E., 1990, Design/Installation of Deep Ground Water Monitoring Wells in an Arid Region, in Proceedings, Petroleum Hydrocarbons and Organic Chemicals in Ground Water, National Ground-Water Association, Dublin, OH, pp. 101 - 109

Nielsen, D.M., 1993, Ground-Water Monitoring Well Design and Installation: Doing it Right the First Time is the Key to a Cost-Effective Monitoring Program, Environmental Protection, Vol.4 No. 7

Henne, M.S., and Meinert, W.W., 1986, Quality Control Considerations in the Selection of Well Design, Drilling Procedures, and Well Construction Materials, in ASTM Special Technical Publication 925, American Society for Testing and Materials, Philadelphia, PA, pp. 3 - 20

Collins, M., Rohrman, W.R., and Drake, K.D., 1991, Monitoring Well Design and Sampling Techniques at NAPL Sites, in Proceedings, Fourth National Outdoor Action Conference, National Ground-Water Association, Dublin, OH, pp. 209 - 218

Gear, B.B., and Connelly, J.P., 1985, Guidelines for Monitoring Well Installation, in Proceedings, The Fifth National Symposium on Aquifer Restoration and Ground-Water Monitoring, National Ground-Water Association, Dublin, OH, pp. 83 - 115

technical references disk

Nielsen, D.M., 1987, Common Problems Associated with the Design and Installation of Ground-Water Monitoring Wells, in Proceedings of the National Conference on Hazardous Wastes and Hazardous Materials, Hazardous Materials Control Research Institute, Silver Spring, MD, pp. 178 - 184

technical references disk

Committee D-18 ON SOIL AND ROCK

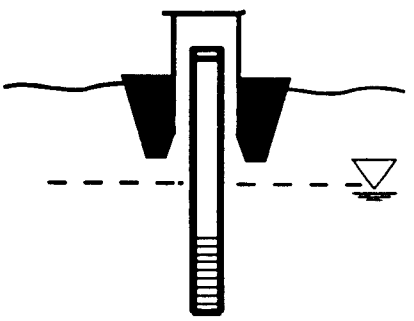
Fundamentals of Ground-Water Monitoring & Sampling Technology

GROUND WATER MONITORING WELL DEVELOPMENT METHODS

- Standard D-5521
- Objectives and Uses of Well Development Methods
- Advantages and Limitations of Various Methods
  - Mechanical Surging
  - Pumping & Backwashing
  - Hydraulic Jetting
  - Air-Lift Pumping

Instructor:

David M. Nielsen
Nielsen Ground-Water Science, Inc.
4686 State Route 605 South
Galena, OH 43021-9652



© 1995, Nielsen Ground-Water Science, Inc.
Galena, Ohio. All Rights Reserved.

These materials are copyright-protected under the laws of the United States and are the exclusive property of Nielsen Ground-Water Science, Inc. Any unauthorized duplication will result in prosecution.

ASTM STANDARD D-5521
STANDARD GUIDE FOR DEVELOPMENT OF GROUND-WATER MONITORING WELLS IN GRANULAR AQUIFERS

Purpose: To Establish Procedures for Well Development That Will Minimally Impact Ground Water Sample Integrity and Result in Wells That Yield Relatively Sediment-Free Samples From Granular Aquifer Materials

- Focuses on Physical, Not Chemical Development Methods and on Screened Wells, Not Open Boreholes
- Establishes Qualitative, Not Quantitative Criteria for Determining When Development is Complete

COMMON MONITORING WELL DESIGN FLAWS

- IMPROPER OR INADEQUATE WELL DEVELOPMENT

  RESULTS:

  - ACQUISITION OF TURBID, SEDIMENT - LADEN SAMPLES
  - GROUT CONTAMINATION OF THE FILTER PACK (WITH SUBSEQUENT SAMPLE CHEMICAL ALTERATION)
  - REDUCED WELL YIELD

TWO STAGES OF WELL DEVELOPMENT

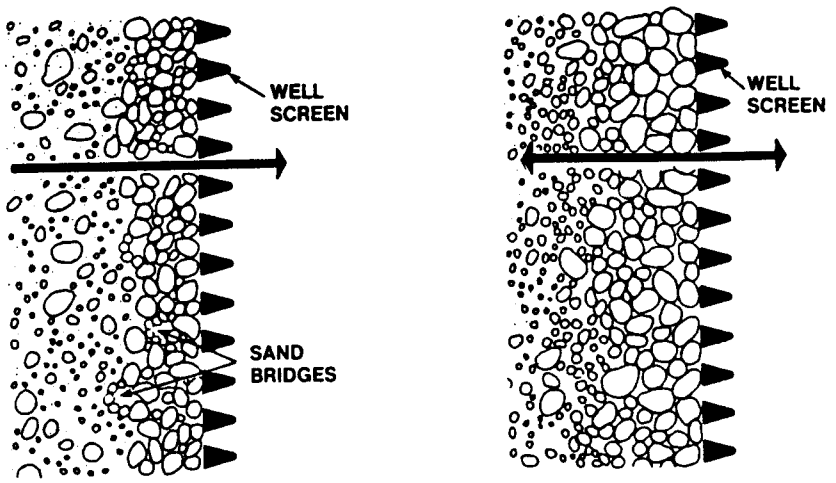
- Predevelopment
  - Steps Followed During Well Construction to Minimize Formation Damage (i.e. Drilling Fluid Control, Removal of Filter Cake)
- Development
  - Procedures Performed After Well Installation (i.e. Mechanical Surging, Hydraulic Jetting)

WELL DEVELOPMENT

- Application of Sufficient Energy to Agitate the Water Column and Create Flow Reversals in the Well, Filter Pack and Formation to Draw Fines into the Well

- Pumping to Draw Drilling Fluid and Fines Out of the Borehole and Adjacent Formation Into and Out of the Well

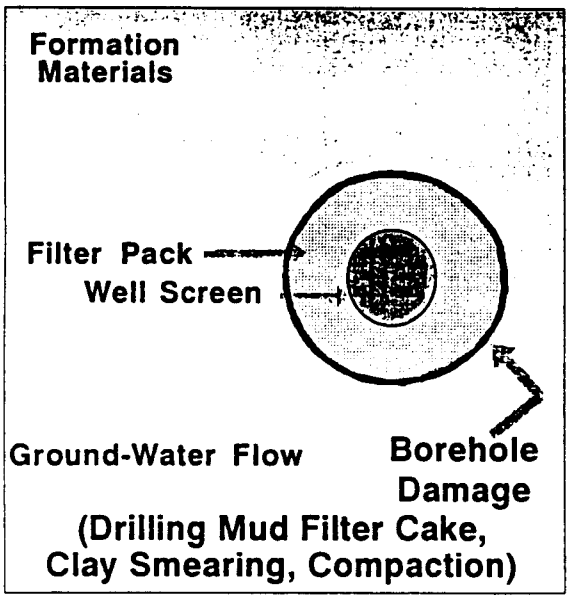
EFFECTIVE DEVELOPMENT ACTION REQUIRES MOVEMENT OF WATER IN BOTH DIRECTIONS THROUGH SCREEN OPENINGS. REVERSING FLOW HELPS BREAK DOWN BRIDGING OF PARTICLES. MOVEMENT IN ONLY ONE DIRECTION, AS WHEN PUMPING FROM THE WELL, DOES NOT PRODUCE THE PROPER DEVELOPMENT EFFECT.



PURPOSES OF WELL DEVELOPMENT

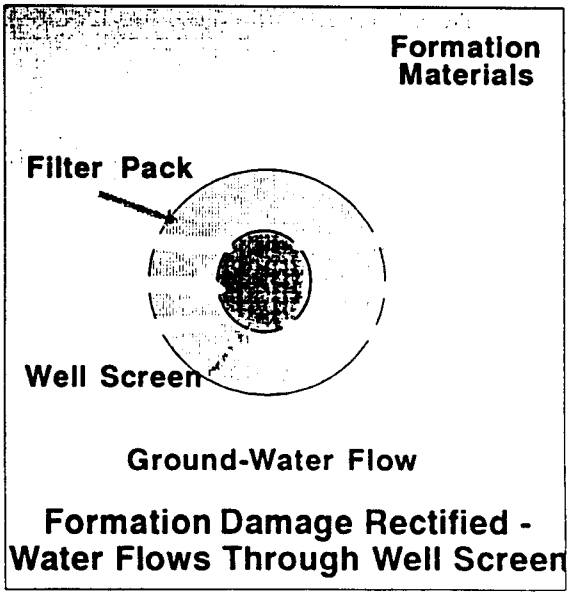
- Rectify Drilling Damage
  - Clogging, Smearing or Compaction of Formation Materials at Borehole Wall
  - Localized Reductions in Formation Hydraulic Conductivity
- Remove Fines (Clay, Silt, Fine Sand) from Formation Adjacent to Borehole
  - Increase Formation Hydraulic Conductivity
  - Eliminate Turbidity in Future Samples
  - Minimize Potential for Clogging and Damaging Pumping Equipment

IMPROPER OR INCOMPLETE WELL DEVELOPMENT



(Drilling Mud Filter Cake, Clay Smearing, Compaction)

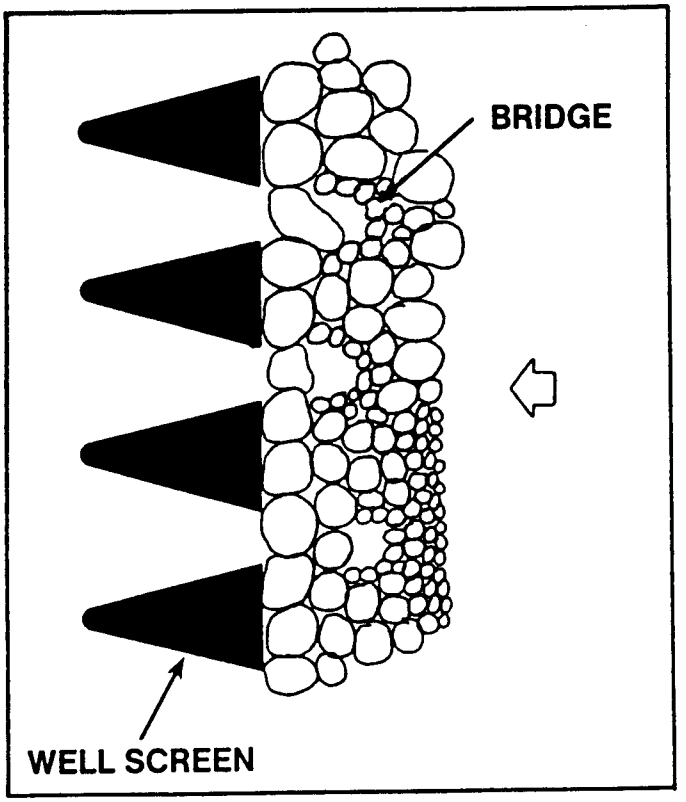
PROPERLY DEVELOPED WELL



Formation Damage Rectified - Water Flows Through Well Screen

PURPOSES OF WELL DEVELOPMENT (cont.)

- Stabilize Filter Pack Material Adjacent to Well Screen
- Retrieve Lost Drilling Fluid From Formation
- Optimize Well Efficiency and Hydraulic Communication Between Well and Adjacent Formation
  - Maximize Value of Formation Test Data and Representativeness of Ground-Water Samples



FACTORS AFFECTING SELECTION OF A WELL DEVELOPMENT METHOD

- Well Construction
  - Type and Diameter of Casing and Screen
  - Type of Casing Joints
  - Screen Length and Slot Size
- Character and Hydraulic Conductivity of Formation Material
- Drilling and Well Installation Method Used
- Depth to Water and Height of Water Column in the Well
- Type of Suspected or Known Contaminant(s)

FACTORS AFFECTING SELECTION OF A WELL DEVELOPMENT METHOD (cont.)

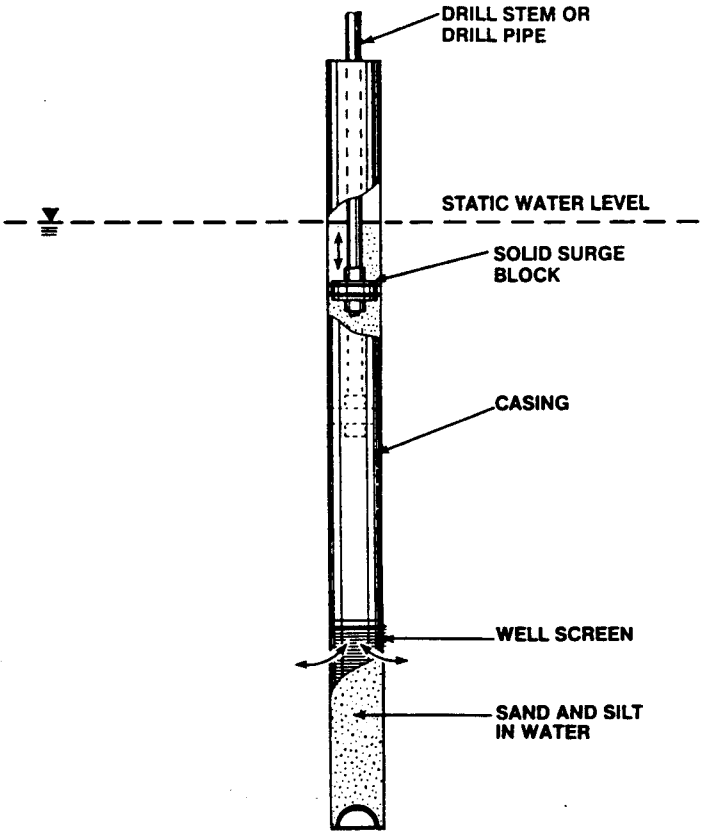
- Necessity for Containment and/or Treatment of Removed Water and Sediment
- Site Accessibility
- Type and Portability of Equipment (i.e. Need for a Rig)
- Desirability of Introducing Foreign Fluids Into the Well
  - Air, Water, Acids, Dispersing Agents
- Time Available for Development
- Cost

METHODS AVAILABLE FOR WELL DEVELOPMENT

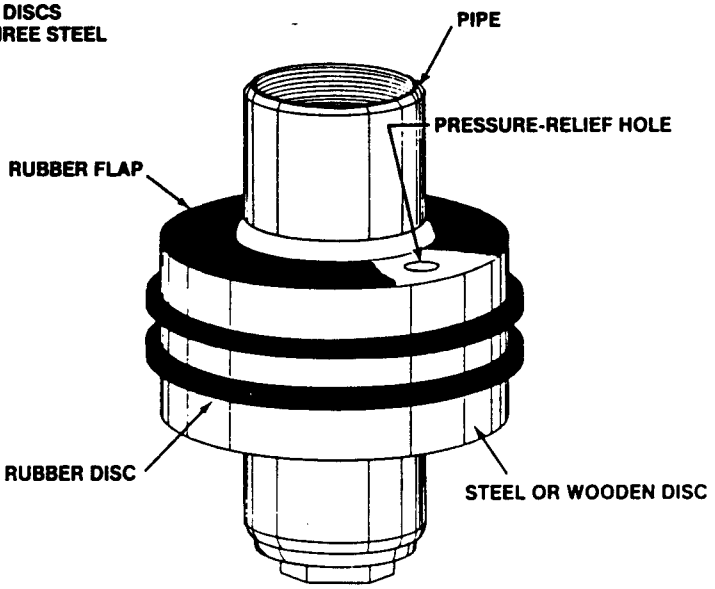
- Mechanical Surging and Pumping/Bailing (Swabbing)
- Pumping and Backwashing (Rawhiding)
- Hydraulic Jetting
- Air-Lift Pumping and Surging
- Combinations of Any of the Above

SURGING AND PUMPING/BAILING

- Agitating the Water Column in the Well with the Up-and-Down Motion of a Plunger-Like Device, Then Removing the Sediment Brought into the Well by Pumping or Bailing

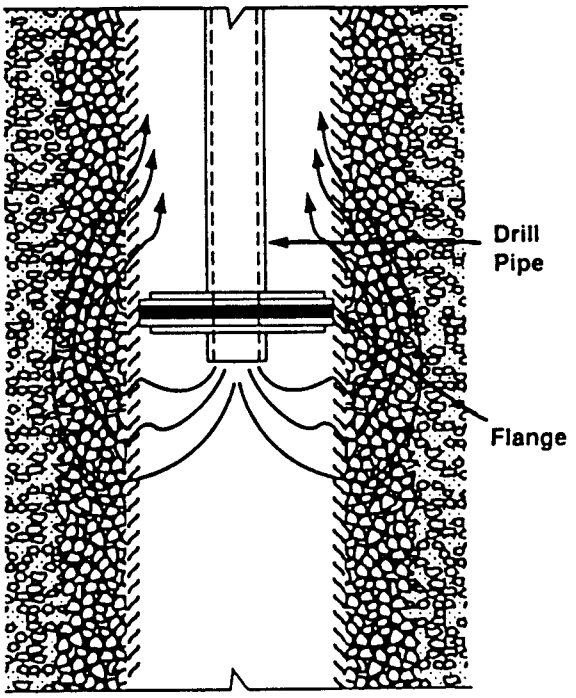


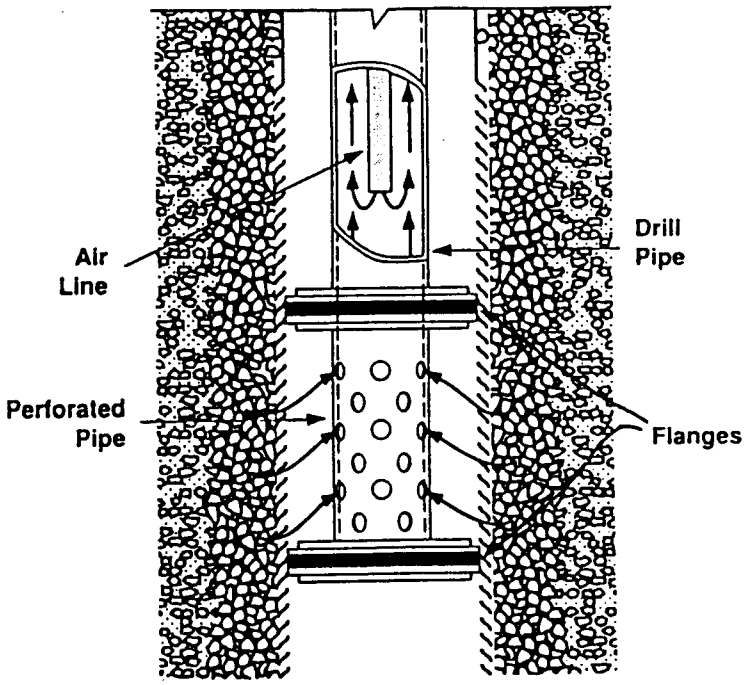
TYPICAL SURGE BLOCK CONSISTING OF TWO LEATHER OR RUBBER DISCS SANDWICHED BETWEEN THREE STEEL OR WOODEN DISCS

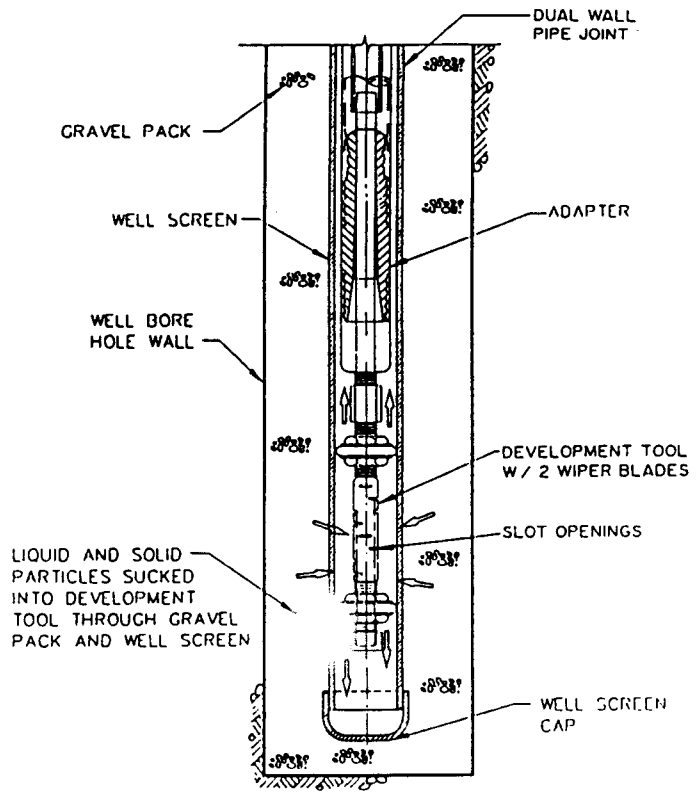


MECHANICAL SURGING AND PUMPING/BAILING

- *Procedure*
  - Lower Surge Block to Top of Screen
  - Lower and Raise Surge Block 2 to 4 Feet per Stroke
    - Downstroke Forces Water Into Filter Pack and Formation, Breaking Bridges
    - Upstroke Pulls Water & Fines Into the Well
  - Work Down to Bottom of Screen in 2 to 4 Foot Intervals
  - Pump/Bail Sediment Periodically to Avoid Sandlocking Surge Block & Damaging Screen
  - Note Amount of Sediment Removed Over Time
  - Continue Until Discharge Clears







DOUBLE WIPER DEVELOPMENT TOOL W/ ADAPTER
CONNECTING LAST JOINT OF PIPE
TO DEVELOPMENT TOOL

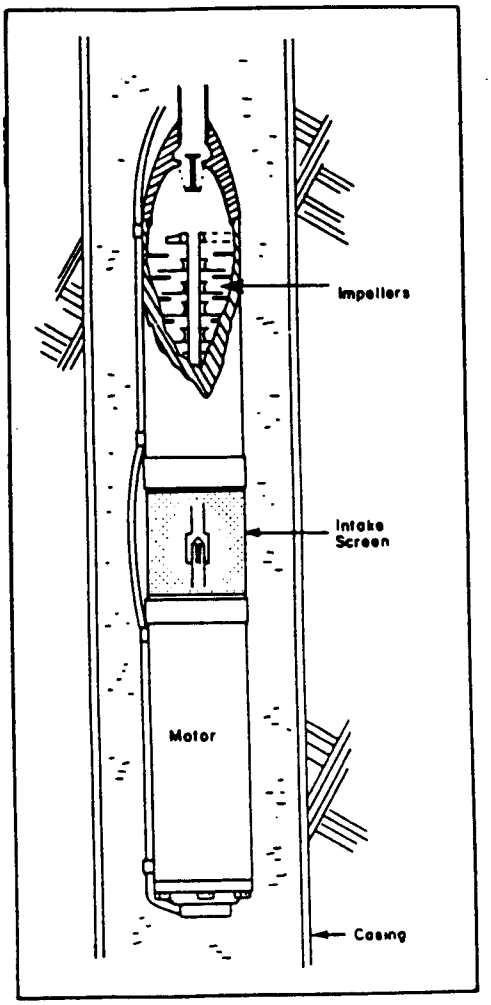
MECHANICAL SURGING AND PUMPING/BAILING

- *Advantages*
  - Effective on Entire Screened Interval
  - Very Well Adapted to Cable Tool Installations
  - Uses Simple, Highly Portable Equipment
  - Does Not Require Introduction of Foreign Fluids

- *Disadvantages*
  - Excessive Pressures During Surging Can Damage Well Screen or Casing
  - Not Well Suited to Wells With Non-Flush Casing Joints

PUMPING AND BACKWASHING

- Pumping the Well at a Rate Higher than the Estimated Yield for a Brief Period, Then Shutting off the Pump to "Slug" the Well



PUMPING AND BACKWASHING

- *Equipment Required*
  - Submersible Pump Without Check Valve
  - Drop Pipe/Discharge Line
  - Electrical Power Source
  - May or May Not Require a Rig
- *Procedure*
  - Lower Pump to Just Above Screen
  - Pump at High Rate for Short Time
  - Shut Off Pump to Allow Water in Discharge Pipe to Drop Back Into the Well
  - Repeat Until Sediment Accumulates in Well
  - Remove Sediment Periodically
  - Continue Until Discharge Clears

PRIMARY LIMITATIONS TO THE USE OF VARIOUS PUMPS FOR WELL DEVELOPMENT

- Centrifugal Pumps
  - Only Effective if Depth of Well is < 25 Feet (Due to Limit of Suction Lift)
- Submersible Pumps
  - Impellers Sensitive to Excessive Sediment (Pump Can Sand-lock or Impellers Can Erode)
- Inertial Pumps
  - Excessive Sediment May Clog Foot Valve
- Gas-Drive Pumps
  - Excessive Sediment May Damage Check Valves
- Air-Lift Pumps
  - Require at Least 30% Submergence of Air Line
  - Oil Entrained in Compressed Air May Contaminate Well

PUMPING AND BACKWASHING

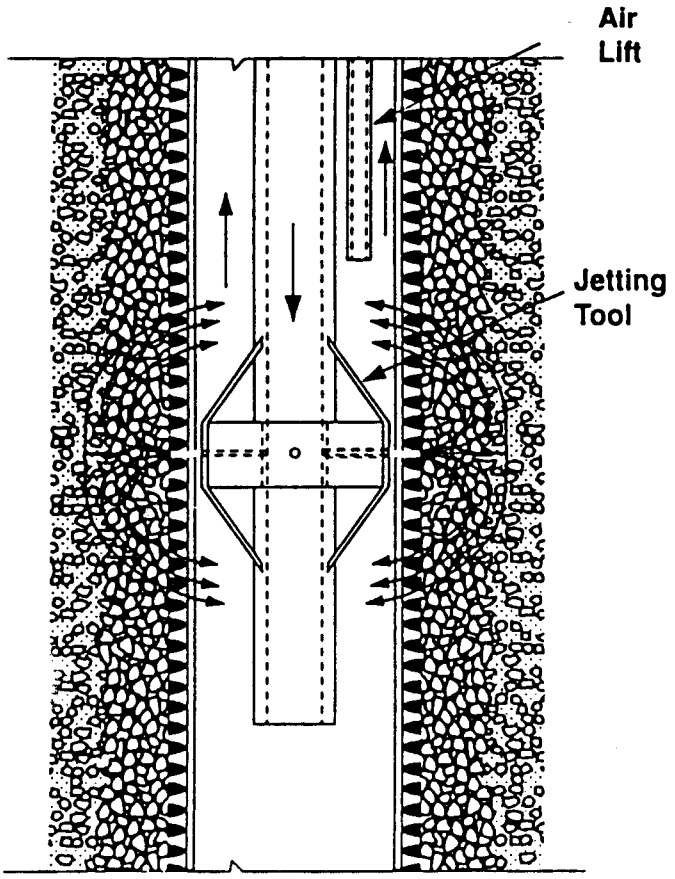
- *Advantages*
  - Does Not Require Introduction of Foreign Fluids
  - Well Suited to All Types of Well Construction
  - Uses Simple, Readily Available Equipment
  - Generally No Potential for Damaging Well Screen
- *Disadvantages*
  - Preferentially Develops High-K Zones and/or at Top of Screen
  - Generally Used Only in Wells > 4" Diameter
  - Requires Heavy, Bulky Equipment

DRAWBACKS OF "PASSIVE" WELL DEVELOPMENT (i.e. Pumping Only)

- Does Not Sufficiently Agitate Filter Pack or Formation Material to Break Bridges or Stabilize Material
- Does Not Effectively Remove Formation Fines
- Future Agitation of the Water Column (During Formation Testing or Sampling) May Release Considerable Turbidity

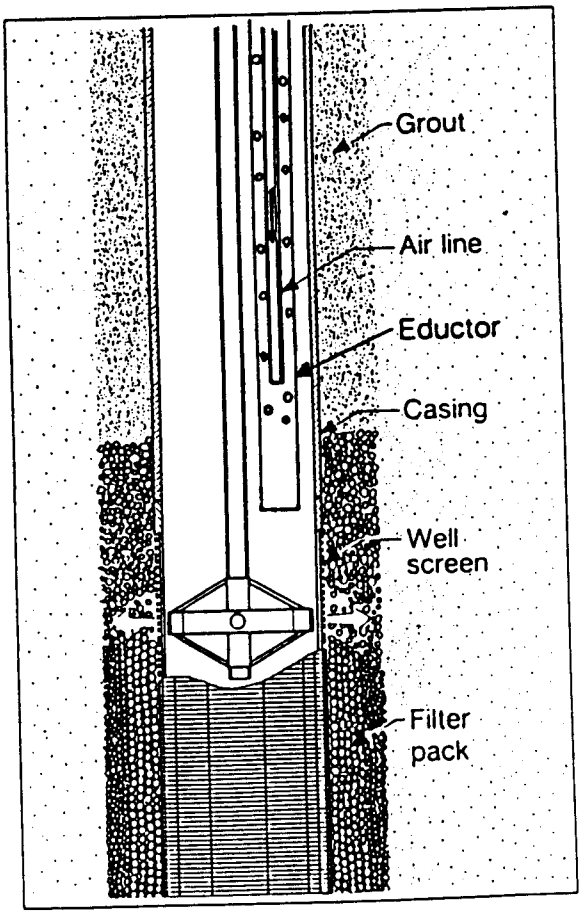
HYDRAULIC JETTING

- Forcing a High-Velocity Stream of Water Into the Filter Pack and Formation to Rearrange Grains and Flush Out Fines



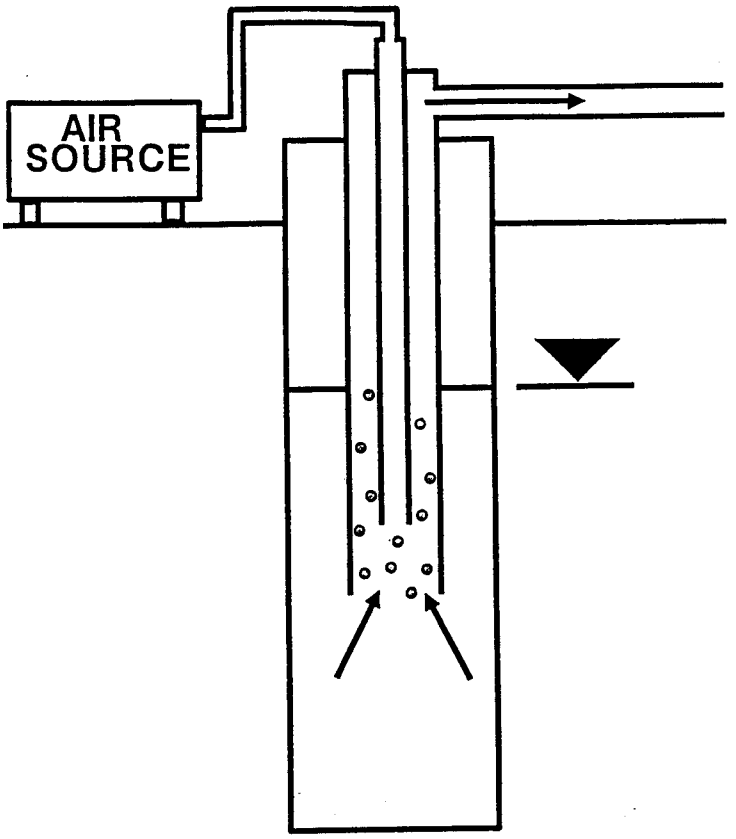
HYDRAULIC JETTING

- *Procedure*
  - Lower Jetting Tool to Top of Screen
  - Slowly Rotate Jetting Tool While Allowing to Fall, Then Pull Upward in 2 to 4 Foot Strokes
  - Initiate Water Flow (Nozzle Velocity > 100 ft/sec Optimum)
  - Work Down to Bottom of Screen in 2 to 4 Foot Intervals
  - Remove Sediment Periodically
  - Continue Jetting Until Discharge Clears

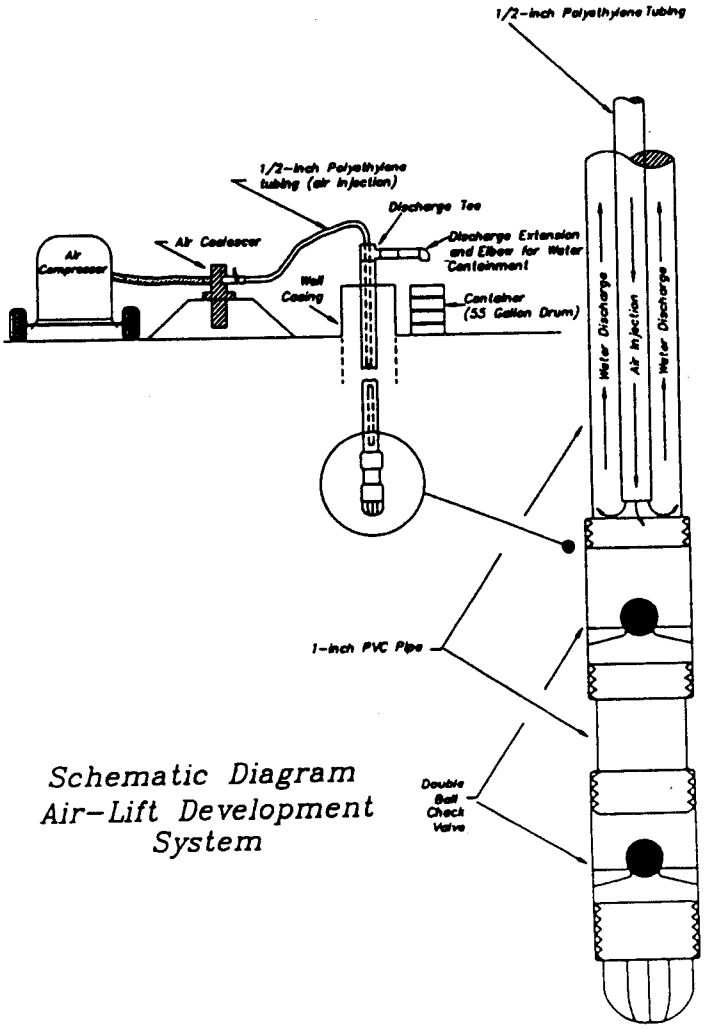


HYDRAULIC JETTING

- *Advantages*
  - Effective on Entire Screened Interval
  - Excellent Method for Open Hole Completions
  - Well Suited to All Types of Well Construction
- *Disadvantages*
  - May Damage PVC or Other Plastic Screens
  - Adds Water to the Well and Formation
  - Requires Water Source and Heavy, Bulky Equipment



AIR LIFT PUMP



Schematic Diagram Air-Lift Development System

AIR-LIFT PUMPING AND SURGING

- *Procedure*
  - Install Eductor Pipe To Just Above Well Screen and Air Line in Eductor Pipe, With Bottom of Air Line 2 - 3 Feet Above Bottom of Eductor
  - Air Line Must Be Submerged so at Least 30% is Below Anticipated Level of Drawdown; 60% Submergence Produces Optimum Results
  - Apply Adequate Air Pressure and Volume to Lift Water Column (Min. psi required = length of air line - static water level/2.31; Volume required is typically 50 to 100 cfm)

AIR-LIFT PUMPING AND SURGING

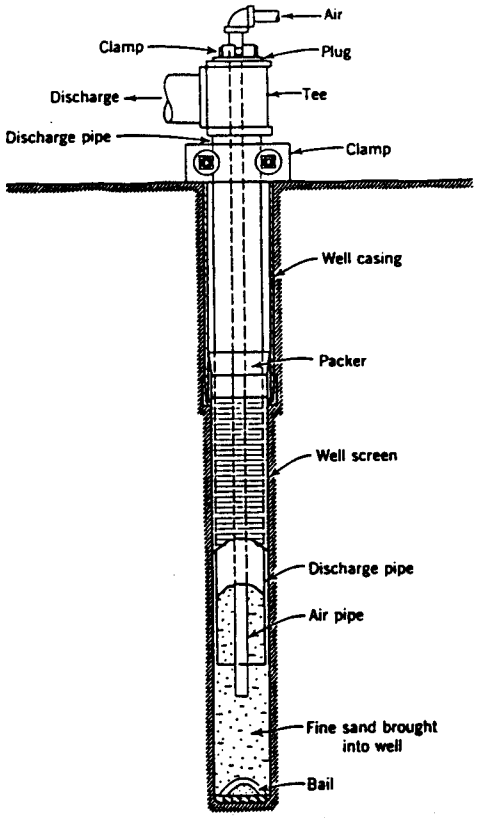
- *Procedure (continued)*
  - Shut Off Air Supply (Water Column Falls, Causing Surging)
  - Restart Pumping Process
  - Continue Pumping and Surging Until Sediment Accumulates in Well
  - Lower Air Lift Pump to Bottom of Screen to Remove Sediment
  - Repeat Until Discharge Clears

AIR-LIFT PUMPING AND SURGING
Caveats

- Intake of Air Compressor Should Be Located Away From Sources of Air Contamination (i.e. Exhaust)
- Air Should Be Filtered to Remove Compressor Oil
- Well Itself Should Not Be Used as Eductor Pipe
- Air Line Should Not Be Allowed to Extend Below Eductor Pipe
- Air Line and Eductor Pipe Should Be Cleaned Between Uses

AIR-LIFT PUMPING AND SURGING

- *Advantages*
  - Uses Simple, Readily Available Equipment
  - Well Suited to All Types of Well Construction
  - Generally No Potential for Damaging Well Screen
- *Disadvantages*
  - Preferentially Develops High-K Zones and/or Zone at Top of Screen
  - Requires Heavy, Bulky Equipment
  - Introduces Foreign Fluid (Air) Into the Well



Should not be used c̄ mon. well

DRAWBACKS OF DEVELOPING WITH AIR

- Air May Be Entrained in Filter Pack and/or Formation, Lowering Hydraulic Conductivity and Affecting Water Quality

- Compressor Oil May Be Entrained in Air Stream, Contaminating Water With Which it Comes in Contact

WHEN TO DEVELOP

- After Casing, Screen and Filter Pack (If Required) Are Installed, and Before Installation of Annular Seal

or

- As Soon as Practical After the Well is Installed and Annular Seal Materials Have Set/Cured (48 - 72 Hours)

Order of Development Should be the Same as the Order of Well Installation (Least Contaminated to Most Contaminated)

HOW LONG TO DEVELOP

- Until Visibly Clear Water is Discharged From the Well
- Until Indicator Parameters (pH, SC, T) are Stable
- Until the Volume of Fluid Discharged is Some Multiplier of the Volume of Fluid Lost to the Formation During Drilling or Added to the Well During Development

LIMITATIONS OF WELL DEVELOPMENT

- Should Not Be Applied to Wells in Fine-Grained Formations
  - Attempts to Develop May Significantly Increase Turbidity
  - Development Will Not Improve Hydraulic Conductivity of Formation or Hydraulic Efficiency of Well
  - Adds Cost With No Accompanying Benefit
- Should Not Be Applied to Wells With Free Product
- Not Effective in Wells in Which Screens Straddle Water Table (Unsaturated Portion of Screen)

MONITORING WELL DEVELOPMENT

References

ASTM, 1993, Standard Guide for Development of Ground-Water Monitoring Wells in Granular Aquifers, Draft ASTM Standard, American Society for Testing and Materials, Philadelphia, PA

Hix, G.L., 1993, Monitoring Well Development: Tools and Techniques, Water Well Journal, Vol. 47, No. 6, pp. 52 - 57

Craig, M., 1991, Developing Monitoring Wells, Ground Water Age, Vol. 25, No. 10, pp. 30 - 32

Izraeli, R., Yeskis, D., Collins, M., Davies, K., and Zavaka, B., 1992, Monitoring Well Development Guidelines for Superfund Project Managers, U.S. EPA, OSWER, Ground Water Forum, April 1992, 4 pp.

Kraemer, C.A., Shultz, J.A. and Ashley, J.W., 1991, Monitoring Well Post-Installation Considerations, in Practical Handbook of Ground-Water Monitoring, D.M. Nielsen, Editor, Lewis Publishers, Ann Arbor, MI, pp. 333 - 365

Aller, L., Bennett, T.W., Hackett, G., Petty, R.J., Nielsen, D.M., Lehr, J.H., Sedoris, H. and Denne, J.E., 1991, Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells (Section 7 - Monitoring Well Development), EPA/600/4-89/034, U.S. EPA, Washington, D.C., pp. 115 - 124

Dricoll, F.G., 1986, Ground Water and Wells (Chapter 15, Development of Water Wells) Johnson Division, St. Paul, MN, pp. 497 - 533

Roscoe Moss Company, 1990, Handbook of Ground-Water Development (Chapter 14 - Well Development), John Wiley and Sons, New York, NY, pp. 263 - 275

Barcelona, M.J., Gibb, J.P., Helfrich, J.A. and Garske, E.E., 1985, Practical Guide for Ground-Water Sampling, ISWS Contract Report 374, Illinois State Water Survey, Champaign, IL, pp. 37 - 41

Todd, D.K., 1980, Ground-Water Hydrology (Chapter 5 - Water Wells), John Wiley and Sons, New York, NY, pp. 194 - 199

technical references disk

Stollar, R.L., 1990, Ground Water Monitoring, Chapter 6 in Subsurface Migration of Hazardous Wastes, Van Nostrand Reinhold, New York, NY, pp. 210 - 215

NCASI, 1981, Ground Water Quality Monitoring Well Construction and Placement, NCASI Technical Bulletin 342, National Council on Air and Stream Improvement, New York, NY, pp. 26 - 29

USDI, 1981, Ground Water Manual (Chapter 17 - Water Well Development), John Wiley and Sons, New York, NY, pp. 397 - 415

Johnson Division, 1975, Principles and Practical Methods of Developing Water Wells, Bulletin 1033 (Revised), Johnson Division, St. Paul, MN, 24 pp.

List, E.J., 1989, Analysis of Development Methods for Gravel Envelope Wells, Roscoe Moss, Co., Los Angeles, CA, 16 pp.

Kill, D.L., 1990, Monitoring Well Development -- Why and How, in Ground Water and Vadose Zone Monitoring, ASTM Special Technical Publication 1053, D.M. Nielsen and A.I. Johnson, Editors, American Society for Testing and Materials, Philadelphia, PA, pp. 82 - 90

Paul, D.G., Palmer, C.D., and Cherkauer, D.S., 1988, The Effects of Construction, Installation and Development on the Turbidity of Water in Monitoring Wells in Fine-Grained Glacial Till, Ground Water Monitoring Review, Vol.8, No. 2, pp. 73 - 82

Nuckols, T.E., 1990, Development of Small-Diameter Wells, in Proceedings, Fourth National Outdoor Action Conference, National Ground Water Association, Dublin, OH pp. 193 - 207

Dougherty, P.J., and Paczkowski, M.T., 1988, A Technique to Minimize Contaminated Fluid Produced During Well Development, in Proceedings, Fourth National Outdoor Action Conference, National Ground Water Association, Dublin, OH, pp. 303 - 317

Hall, S.H., and Luttrell, S.P., 1990, Geochemical Criteria for Developing and Purging Ground-Water Monitoring Wells, in Proceedings, Fourth National Outdoor Action Conference, National Ground Water Association, Dublin, OH, pp. 333 - 371

technical references disk

Howard, W.O., Danahy, T.V. and Ianniello, M. 1988, An Air-Lift Development System for Deep Wells, in Proceedings, Focus Conference on Eastern Ground-Water Issues, National Ground Water Association, Dublin, OH, pp. 559 - 564

technical references disk

Committee D-18 ON SOIL AND ROCK

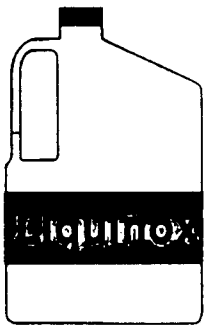
Fundamentals of Ground-Water Monitoring & Sampling Technology

FIELD EQUIPMENT DECONTAMINATION METHODS

- Objectives of Equipment Decontamination
- Decontamination of Non-Sample Contacting Equipment
- Decontamination of Sample-Contacting Equipment
- QA/QC Considerations

Instructor:

Gillian L. Nielsen
Nielsen Ground-Water Science, Inc.
4686 State Route 605 South
Galena, OH 43021-9652



© 1995, Nielsen Ground-Water Science, Inc.
Galena, Ohio. All Rights Reserved.

These materials are copyright-protected under the laws of the United States and are the exclusive property of Nielsen Ground-Water Science, Inc. Any unauthorized duplication will result in prosecution.

ASTM D 5088 - 90

STANDARD PRACTICE FOR

DECONTAMINATION OF FIELD EQUIPMENT

USED AT NONRADIOACTIVE WASTE SITES

ASTM STANDARD PRACTICE D5088
OBJECTIVES OF DECONTAMINATION PROCEDURES

- Minimize Spread of Contaminants Within a Study Area and From Site to Site
- Reduce Potential for Worker Exposure to Contaminants
- Improve Data Quality and Reliability

SCOPE OF ASTM STANDARD PRACTICE D5088 FOR DECONTAMINATION OF FIELD EQUIPMENT USED AT NONRADIOACTIVE WASTE SITES

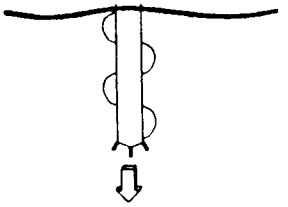
- Decontamination of Field Equipment Used in Sampling:
  - Soil
  - Soil Gas
  - Sludges
  - Surface Water
  - Ground Water

  Where Samples Are to Undergo Both Physical and Chemical Analysis
- Applies to Sites Where Organic and Inorganic Wastes Are A Concern But <u>Excludes</u> Radioactive and Mixed Waste Sites

ASTM STANDARD PRACTICE D5088 CATEGORIES OF DECONTAMINATION PROCEDURES

Procedures for Sample-Contacting Equipment

Procedures for Nonsample-Contacting Equipment



ASTM STANDARD PRACTICE D5088
SITE-SPECIFIC DECONTAMINATION PROTOCOL

Information to Include:

- Site Location and Description
- Statement of Sampling Program Objective(s)
  - Desired Level of Precision and Accuracy
- Summary of Available Information on Site Including:
  - Soil Types
  - Hydrogeology
  - Anticipated Chemistry of Materials to be Sampled
- List of Sampling Equipment and Materials Needed for Decontamination

ASTM STANDARD PRACTICE D5088
SITE-SPECIFIC DECONTAMINATION PROTOCOL

Information to Include:

- Detailed Procedures for Decontamination of Each Piece or Type of Equipment to Be Used
- Detailed Procedures for Rinse Fluids Containment and Disposal
- Summary of QA/QC Procedures and QA/QC Samples To Be Collected to Document Decontamination Completeness Including Specific Types of Chemical Analysis and Detection Limits
- Outline of Equipment Decontamination Verification Report

ASTM STANDARD PRACTICE D5088 DECONTAMINATION PROCEDURES FOR NONSAMPLE-CONTACTING EQUIPMENT

General Procedures:

Step 1: Clean with Portable Power Washer or Steam Cleaning Machine

or

Hand Wash with Brush Using Detergent Solution

Step 2: Rinse with Control Water

DI H_2O cleaner than Distilled.

TYPICAL CLEANING PROTCOLS HEAVY EQUIPMENT

What:

Drilling Rigs, Backhoes and Support Vehicles; Augers, Drill Rod, Drill Bits, Tools

When:

- Clean Prior to Coming On Site (or Before Drilling First Borehole)
- Clean Between Boreholes

How:

- High-Pressure Hot Water Wash
- Scrub With Soapy Water (Non-Phosphate or Lab-Grade Detergent)
- High-Pressure Hot Water Wash/Rinse
- Air Dry

ASTM STANDARD PRACTICE D5088 DECONTAMINATION PROCEDURES FOR SAMPLE-CONTACTING EQUIPMENT

General Procedures:

Step 1: Wash with Detergent Solution

Step 2: Control Water Rinse

Step 3: Rinse with Desorbing Agents

Step 4: Deionized Water Rinses

Should not
Alconox (wht. powder) (has PO_4)

use
→ Liquinox (liquid) or Detergent 2
(made by Alconox)

TYPICAL CHEMICAL DESORBING AGENTS

Inorganic Desorbing Agents: (Acid Rinses)

10% Nitric Acid
10% Hydrochloric Acid
(1 % Solutions Should Be Applied to Low - Carbon Steel)

Solution Made from Reagent Grade Nitric or Hydrochloric Acid and Deionized Water

Organic Desorbing Agents: (Solvent Rinses)

Isopropanol
Acetone
Hexane
Methanol

PROBLEMS WITH USING SOLVENTS AND ACIDS FOR CLEANING

- Special Handling Considerations for Concentrated Solutions of Acids and Solvents (Storage, Shipping, Use)
- Exposure of Personnel to Hazardous Materials (i.e. Toxic Materials with Low Flash Points or Low pH)
- Generation of Hazardous Waste (And Associated Costs for Analysis and Disposal)
- Degradation of Plastic and Rubber Parts in Equipment (Solvents)
- Corrosion and Pitting of Metal Parts in Equipment (Acids)
- Cost

TYPICAL CLEANING PROTOCOLS GROUND-WATER SAMPLING EQUIPMENT

When:

- Clean Prior to Use (Lab, Office or Field) (Some Protocols Require Lab Autoclaving)

- Clean Between Wells (Bailer and Line or Pump and Discharge Tubing)

How:

- Wash with Soapy Water (Lab-Grade Detergent)
- Acid Rinse and/or Solvent Rinse
- Rinse with Distilled or Deionized Water
- Air Dry

SPECIAL CONSIDERATIONS FOR PUMPING EQUIPMENT

- Thoroughly Clean and Rinse Internal Pumping Mechanism and Interior of Discharge Tubing by Pumping Solutions Through the System
- Allow All Water From Final Rinse to Completely Drain From Pump/Tubing Before Reuse

"EPA"
Use SS cable coated & teflon

ASTM STANDARD PRACTICE D5088 DECONTAMINATION PROCEDURES FOR SAMPLE-CONTACTING EQUIPMENT

Rigorous Protocol:

Step 1: Detergent Solution Wash Using Brush Made of Inert Materials to Remove Any Particles or Surface Film

For Equipment That Cannot Be Adequately Cleaned (e.g. Tubing), Circulate Decontamination Solutions Through Equipment

Step 2: Control Water Rinse

Step 3: Inorganic Desorbing Agent Rinse (Delete If Inorganics Not Being Analyzed)

Step 4: Control Water Rinse

ASTM STANDARD PRACTICE D5088 DECONTAMINATION PROCEDURES FOR SAMPLE-CONTACTING EQUIPMENT

Rigorous Protocol:

Step 5: Organic Desorbing Agent Rinse (Delete If Organics Not Being Analyzed)

Step 6: Deionized Water Rinse

Step 7: Allow Equipment to Air Dry Prior to Next Use

Step 8: Wrap Equipment with Inert Material (Aluminum Foil or Plastic Wrap) for Transport To Prevent Contact with Potentially Contaminated Material

ASTM STANDARD PRACTICE D5088 QA/QC ELEMENTS OF DECONTAMINATION PROCEDURES

Objective:
To Document the Effectiveness of Decontamination Methods

Procedure:
Collect a Rinse or Wipe Sample

1. Before Initial Equipment Decontamination to Establish A Baseline Level of Contaminants On or In The Equipment Being Cleaned
2. After Equipment Decontamination Following Its Use

When:
Collect Rinse or Wipe Samples After Every 10 Cleanings

ASTM STANDARD PRACTICE D5088
EQUIPMENT DECONTAMINATION REPORT

Post-Decontamination Activity Reports Should Include:

- Site Location, Date, Time and Weather
- Sample Location Where Equipment Was Used
- Location Where Decontamination Was Performed
- Names of Individuals Performing Decontamination
- Decontamination Procedures
- Source of Materials (Solutions) Used
- Handling of Rinse Fluids and Accumulated Solids (If Any)
- QA/QC Sampling Performed and Analytical Results

EQUIPMENT DECONTAMINATION

Nielsen, G.L., 1991, Decontamination Program Design for Ground-Water Quality Investigations; Chapter 15 in Practical Handbook of Ground Water Monitoring, D.M. Nielsen, Editor, Lewis Publishers, Chelsea, MI, pp. 625 - 636.

Moberly, R.L., 1985, Equipment Decontamination; Ground Water Age, April 1985, pp. 36 - 39.

Mickam, J.T., Bellandi, R., and Tifft, E.C., Jr., 1989, Equipment Decontamination Procedures for Ground Water and Vadose Zone Monitoring Programs: Status and Prospects; Ground Water Monitoring and Remediation, Vol. 9, No. 2, pp. 100 - 121.

Matteoli, R.J., and Noonan, J.M., 1987, Decontamination of Rubber Hose and Teflon Tubing for Ground Water Sampling; in Proceedings, First National Outdoor Action Conference, National Ground water Association,. Dublin, OH, pp. 159 - 183.

NJDEP, 1988, Field Sampling Procedures Manual; NJDEP Hazardous Waste Program, Trenton, NJ, pp. 16 - 31.

Brice, D.A., and Kelley, M.E., 1991, Evaluation of EPA Region 4 SOPs for Decontamination of Field Equipment When Sampling for Volatile Organic Compounds; in Proceedings, Fifth National Outdoor Action Conference, National Ground Water Association, Dublin, OH, pp. 601 - 608.

Fetter, C.W., and Griffin, R.A., 1988, Field Verification of Non Contaminating Methodology for Installation of Monitoring Wells and Collection of Ground-Water Samples; in Proceedings, Second National Outdoor Action Conference, National Ground Water Association, Dublin, OH, pp. 437 - 444.

Fink, M.J., and Boyajlan, R.T., 1989, Decontamination Procedure for Ground Water Sampling Equipment; in Proceedings, Third National Outdoor Action Conference, National Ground Water Association, Dublin, OH, pp. 305 - 311.

PURGING AND SAMPLING OF GROUND-WATER MONITORING WELLS

- Error/Bias from Purging and Sampling
- Water Level Measurement Methods and Devices
- Purging Methods and Procedures
- Overview of Purging and Sampling Devices
- Sampling System Design Considerations
- Reference Publications
- Figures and Diagrams

David B. Kaminski
QED Environmental Systems, Inc.
3333 Vincent Road, Suite 219
Pleasant Hill CA 94523
1-800-366-7610
FAX (510) 930-7646

Copyright 1995, David B. Kaminski, Clayton , California. All Rights Reserved.

Bias/Error in Ground-Water Samples - The Purging Process

- Equipment effects on water chemistry
  - Pressure, temperature changes
  - Aeration/oxidation, agitation, stripping
  - Material leaching, sorption/desorption
- Purge volume removed
- Purge rate
- Location of purging device in the well
- Use of portable equipment
  - insertion & removal of pumps, bailers
  - decontamination procedures

Bias/Error in Ground-Water Samples - The Sampling Process

- Equipment effects on sample chemistry
- Sampling flow rate
- Location of sampling device in the well
- Use of portable equipment
- Transfer of sample to containers
- Filtration method and procedure
- Preservation
- Transportation

Ground-Water Sampling Equipment

- Water level measurement devices
  - portable or dedicated
  - measure water level, thickness of layers
- Purging devices
  - pumps and bailers
  - packers for purge volume reduction
- Sampling devices
  - may be same device as purging device, or may be a separate device

Water Level Measurement

- First step of the purging & sampling procedure, after well head screening

- Data is used to:
  - determine volume of stored water for purging
  - create potentiometric surface maps to determine gradients
  - determine aquifer properties (pump tests)

- Accuracy required is typically 0.01 feet

Electronic Tapes (Dipmeters)

- Most commonly-used device
- Accuracy based on operator technique - can be as good as 0.01 feet
- Graduated tape marked in feet/10ths/100ths (meters/centimeters/millimeters if metric)
- Flat tape with stainless steel wire is best
- Some designs are submersible for cleaning

Repair & silicon

Interface Probes

- Can measure water level and layer thickness
- Variety of operating principles used to detect layers (float, light/prism, conductance)
- All detect LNAPLs, some detect DNAPLs
- Different signals for water level and LNAPL or DNAPL level
- Accuracy similar to electronic tapes, and based on operator technique
- Grounding cable for safety is preferred
- Some designs are UL or FM Approved

Steel Tape/Engineer's Tape

- Can be chalked or "seasoned" (oxidized)
- Tape is lowered until it enters water column then measurement is recorded; total length - wetted length = depth to water
- Accuracy can be 0.01 feet, based on operator proficiency
- Commonly used for water supply wells and survey wells; not common for water quality monitoring (contamination from chalk)
- Displacement of water by weighted end could affect accuracy of readings
- Can be used with hydrocarbon detection paste ("cut paste") for LNAPLs

Fiberglass Tapes

- Typically self-made; some commercially available
- Can be weighted or "popper" type
- Popper (inverted cup) makes a sound when it contacts water; can be heard at well head
- Accuracy can be 0.01 feet, based on operator proficiency
- Tapes tend to cling to plastic casing if wet
- Can be used with hydrocarbon detection paste ("cut paste") for LNAPLs

Acoustic Sounders (SONAR)

- Commercially available, but not widely used
- Transmits sound waves to waters surface, then calculates depth based on reflection
- Accuracy typically 0.1 feet or less; not adequate for most monitoring programs
- Accuracy affected by:
  - temperature of air in well
  - dedicated equipment in well
  - noise in well from running pumps

Bubbler Tube Devices

- Can be Bourdon-tube gauge (Magnahelic) or transducer type with digital readout
- Small-diameter tubing and weight (probe) extends below water surface
- Probe depth is referenced to water level at installation
- Air pressure is applied to the tubing; the pressure required to push a bubble out of the end is measured, then converted to a distance to determine depth
- Accuracy typically 0.02 feet for Bourdon-tube gauge, 0.01 feet for transducer type
- Accuracy and precision not affected by operator technique
- Tubing/probe usually dedicated to well; not practical for portable use
- Low cost-per-well to dedicate; no cleaning required; easy to use

Down-Hole Transducers

- Typically used for pump tests and long-term water level measurement
- Transducer with cable is set below water surface; depth is referenced to water level at installation
- Pressure on transducer is converted to distance to calculate depth to water
- Accuracy of 0.01 feet or better, depending on range of transducer
- Accuracy and precision not affected by operator technique
- High cost of transducer/cable discourages dedicating for most programs

Sounding the Well Depth

- Bottom-sounding data is used to:
  - determine purge volume if depth is unknown
  - identify problems with silt accumulation in the well screen
- Typically measured with weighted tapes
- Should be measured after sampling or at least one day before sampling to avoid disturbance to well, increased turbidity
- Difficult when dedicated sampling equipment is present; dedicated bottom sounders can alleviate this problem

Why are wells purged?

The purpose of purging a well prior to sampling is to remove "stagnant" water from the well that may be physically, chemically or biologically altered due to contact with air in the well, the well casing and screen, and the filter pack material, to obtain samples that are *representative* of formation water.

How much should you purge?

- Early research and regulatory guidance recommends:
  - 3-5 times the volume of water in the well (may include filter pack volume) for most wells
  - For low-yield wells, evacuate the well and sample upon sufficient recovery
    - » sample within 3 hours of purging recommended
    - » sample as soon as sufficient sample volume exists

Problems Purging Low-Yield Wells

- May not recover sufficiently to produce sample volume required
- Recovery time may be excessive, affecting sample chemistry
- Purging below top of screen may cause:
  - jetting or cascading in well screen, resulting in a loss of VOCs and dissolved gasses
  - oxidation of dissolved metals
  - trapped air in the well screen and filter pack
  - increased sample turbidity

Purge Volume Based on Indicator Parameter Stabilization

- Measuring indicator parameters while purging to determine purge volume
- Purging completed when parameters have changed and stabilized, indicating formation water in sampling zone
- Stabilization defined as a designated change in measured values over a selected period of time, number of readings or volume of water
  - ± 10% over three consecutive readings
  - ±10% over X gallons or liters
  - ±10% over X minutes
  - ± designated units over readings, volume or time

Indicator Parameters for Purging

- Indicator parameters include:
  - pH
  - temperature (T)
  - conductivity (C) SC (Temp compensated)
  - dissolved oxygen (DO)
  - turbidity
- DO and C most reliable indicators
  - pH stabilizes quickly
  - T is easily affected by sunlight, air temperature
  - turbidity not an indicator of water quality, but should be measured when sampling for metals

GW Mon & Rem. Robert Paul ↓ low flow sampling

Flow Rates for Purging

- Traditionally high for efficient purging
- Should not exceed pumping rates used for well development
- Should not cause excessive drawdown of water in well and surrounding formation
- High purging rates can affect samples
  - increased turbidity can elevate analyte concentrations
  - drawdown can cause jetting, cascading, stripping, mixing of zones within aquifer

QED Purge Saver
In-flow measurement cells

Flow Rates for Sampling

- Traditionally low to preserve sample chemistry
- Should be high enough to fill bottles efficiently, low enough to minimize agitation or aeration of samples
- Regulatory guidance suggests 100 ml/min. for VOCs, slightly higher for other samples

Low-flow/low-volume Purging (Micro-Purging)

- Based on the theory that ground-water flow through the well screen or open borehole is sufficient to maintain an exchange with formation water
- Reduces or eliminates purging prior to sampling
- Purge volume based on parameter stabilization (micro-purging) or a multiple of the sampling system volume (passive sampling)
- Requires that the screen zone be sampled without disturbing the water column
  - no insertion or removal of equipment (bailers, portable pumps)
  - no continuous drawdown of water column (purge rate < recovery rate)

Advantages of Low-flow purging

- Reduces purging time and labor; cuts purge volume up to 95%
- Reduces cost of purge water treatment/disposal if contained
- Can eliminate need to filter due to greatly reduced turbidity levels
- Can sample specific zones, rather than an average of the entire well screen
- Reduces chance of sample aeration, agitation, and mixing
- Sampling equipment is simpler, less expensive than high-flow systems

Packers may be used
for low-flow [illegible]

Requirement of Low-flow Purging

- Sampling equipment must be dedicated, or placed hours/days prior to use
- Bailers won't work - disturbs water column during use
- Flow rate must be low enough to pump without continuous drawdown, and not significantly increase colloidal density/turbidity - less than 0.25 gpm (1 liter/minute) recommended
- Indicator parameters should be monitored for stabilization (micro-purging), or low-flow data compared to conventional purging data (passive sampling)

Effects of Devices on Sample Chemistry

- Pressure changes
  - caused by moving water from in-situ pressure to atmospheric pressure
  - pressure changes from device (higher or lower) can cause stripping, degassing
- Temperature changes
  - caused by moving water from in-situ temperature to surface ambient temperature
  - additional heat from device can accelerate stripping, degassing, reactions
- Aeration/Oxidation
  - caused by an air/water interface in the device, or insertion/removal during use
  - can cause stripping of VOCs, increase or decrease dissolved gases, change pH

Effects of Devices on Sample Chemistry

- Agitation
  - caused by moving parts, valves or ports, insertion to or removal from the well
  - can increase turbidity, stripping of VOCs, increase or decrease dissolved gases
- Cavitation
  - occurs when speed of rotating impeller exceeds flow of water into the device
  - can cause stripping of VOCs, increase or decrease dissolved gases, change pH
  - can also result in damage to the impellers and pump motor

Effects of Materials on Sample Chemistry

- Adsorption/absorption of analytes from sample
- Desorption of sorbed analytes into subsequent samples
- Leaching of matrix components into samples
  - plasticizers and fillers from plastics (e.g. pthalates from flexible PVC)
  - dissolution of metals from alloys (e.g. chromium from stainless steel)
- Contamination of samples from manufacturing residues
  - extrusion agents, inks, waxes and adhesives from plastics
  - machining oils and anti-rust coatings from metals

Others Materials Considerations for Devices

- Should be able to withstand effects of cleaning agents and cleaning processes (such as steam cleaning) if equipment is portable

- Should be able to withstand long-term exposure to water chemistry without degradation if equipment is dedicated to the well

Ranking of Flexible Materials

- Flexible materials - used for tubing, hoses, bladders and seals
  - Fluoropolymers ("Teflon") - PTFE, TFE, FEP, PFA
  - Polypropylene (PP)
  - Polyethylene (PE)
  - Polyvinylidene Fluoride ("Viton") (PVDF) 'O' for rings
  - Flexible Polyvinylchloride ("Tygon", vinyl) (PVC II)
  - Silicone rubber
  - Synthetic rubbers - Buna-N, Neoprene, EPDM

Ranking of Rigid Materials

- Rigid materials - used for pump bodies, check valves, bailers
  - Stainless steel - Type 316, 304
  - Polytetrafluoroethylene (PTFE)
  - Polyvinyl Chloride (PVC I)
  - Polypropylene (PP)
  - Polyethylene (PE)
  - Low-carbon steel, carbon steel

Criteria for Selecting Sampling Devices

- Sampling accuracy & precision
- Materials of construction
- Lift capability
- Flow rate range and adjustability
- Reliability and ease of repair in field
- Purchase price and operating costs

Categories of Purging and Sampling Devices

- Grab samplers (Bailers, thief, syringe)
- Suction lift pumps (peristaltic, centrifugal)
- Air lift pumps
  - mixes water with air; constant discharge
  - not acceptable for purging or sampling
- Air/Gas displacement pumps
- Electric submersible pumps (centrifugal)
- Positive displacement pumps
  - Piston pumps - pneumatic and mechanical
  - Bladder pumps

Grab Sampling Devices

- Includes bailers of all types, and various designs of thief samplers such as syringes, Kemmerer samplers, Bacon bombs, etc.

- Grab samplers are lowered to the desired sampling depth, opened and/or closed in some cases, and retrieved for sample removal or transport to lab

Grab Samplers - Advantages

- Can provide accurate samples under controlled conditions
- Can be constructed of desirable materials (SS, PTFE, PVC, PE)
- Unlimited depth capability
- Can be made to fit any well diameter
- Simple to use (may not be *easy* to use)
- Reliable, repairable in the field
- Low initial cost, except some thief samplers

Grab Samplers - Limitations

- Accuracy and precision highly subject to operator influence
- Labor intensive, especially in deep/large wells
- Increases turbidity, aeration, agitation & mixing
- Can't isolate from surface environment, handling
- Leakage/sample loss in silty/sandy conditions
- Can't be used for low-volume purging & sampling
- Suspension cord/cable difficult to clean

Grab Samplers - Typical Costs

- Bailers - wide range of prices
  - Disposables range from $4-5 for PE non-weighted
  - Teflon & specialty bailers can run to $300 or more

- Thief samplers - range $200 to $3,000

Suction Lift Pumps

- Types include peristaltic (tubing) pumps, surface centrifugal pumps, diaphragm and vacuum pumps
- All operate by creating a pressure below atmospheric in the intake line, allowing atmospheric pressure on the well to push water up the intake line to the surface

Suction Lift Pumps - Advantages

- Intake line can be made of desirable materials
- High flow capability - up to 60 gpm (230 lpm)
- Some designs have adjustable flow rate
- Intake line can fit any well diameter
- Reliable, except in extremely silty conditions
- Operating costs typically low

Suction Lift Pumps - Limitations

- Accuracy is questionable for gas-sensitive parameters and VOCs
- Lift limited to 30 feet (9 meters); typically 15-18 feet (5-6 meters)
- Centrifugal designs require priming, could contaminate samples
- Flexible tubing used for peristaltics may affect sample chemistry
- Field repair may be difficult or impossible

Suction Lift Pumps - Costs

- Range from $500 to $3,000 for pump, tubing/hose/piping
- Power sources can be an additional $500 to $2,000 for generator or air compressor

Air Displacement Pumps

- Also known as gas-displacement, gas-drive or air-drive pumps
- Consist of a pump chamber, inlet and discharge check valves, and connecting tubing or hoses for air supply and discharge
- Pump chamber fills by submergence, opening inlet check valve; air pressure applied to chamber closes inlet valve and displaces water from the chamber past the discharge check valve to the surface. Air is vented to the surface to repeat the cycles.

Oil less Compressor Exhaust Filter

Air Displacement Pumps - Advantages

- Can provide accurate samples for some parameters
- Can be constructed of desirable materials
- Lift suitable for most wells; about 250 feet (75 meters) maximum
- Flow rates range 0.1 to 15 gpm (0.4 - 38 lpm)
- Flow rate can be varied on most designs
- Reliable, even in silty/sandy conditions; easy to repair in field
- Available to fit 1-inch (25 mm) wells and larger

Air Displacement Pumps - Limitations

- Accuracy is questionable for gas-sensitive parameters and VOCs; some improvement if inert drive gas (nitrogen) is used
- Flow rate & efficiency drop with depth; requires increased air pressure (two-stage compressor, air cylinder) for deeper applications
- Operating costs may be high if inert drive gas is used

Air Displacement Pumps - Costs

- Pumps range from $200 to $2,500, depending on materials and external-control or integral-control design
- Tubing or hose can range from $1.50 to $15.00 per foot, depending on materials
- Controls range $300 to $1,500 for external-control designs
- Power supplies range from $200 to $2,000 for air tanks and compressors

Electric Submersible Pumps

- Variations include centrifugal designs using rotating impellers (most common) and positive displacement designs, such as gear pumps and progressing cavity pumps; all designs have an electric motor below the pumping mechanism
- The pumping mechanism creates a slight suction, then pressurizes it either through centrifugal force or positive displacement
- Virtually all designs use the pumped water to cool the electric motor

"Stage" impeller

↑ depth ↑ stages

Electric Submersible Pumps - Advantages

- Can provide accurate samples, depending on design and flow rate; centrifugals may be questionable for gas-sensitive parameters
- High lift capability
  - up to 300 feet (92 meters) for 2-inch designs
  - up to 2,000 feet (600 meters) for 4-inch designs
- High flow rates, up to 60 gpm (230 lpm)
- Variable-speed flow control for purging and sampling
- Continuous flow simplifies bottle filling and in-line filtration

conventional 3,600 RPM

"small" variable speed up to 23,000 RPM

Electric Submersible Pumps - Limitations

- Heat could affect samples, reliability, and motor life
- Safety concerns with high-voltage electricity
- Metallic construction could affect sample chemistry
- Some designs could contaminate samples (oil in motor, plastics)
- High flow rates could increase turbidity, cause zone mixing
- Generators can be heavy, difficult to operate
- Sand can damage seals, cause impeller wear, cause motor failure
- Repair in field can be difficult or impossible

Electric Submersible Pumps - Costs

- 2-inch designs
  - Pumps range $600 to $900
  - Controls range $1,200 to $2,000
  - Tubing/hose/piping ranges $1.00 to $10.00 per foot
  - Motor cable (wire) ranges $3.00 - 5.00 per foot
- 4-Inch designs
  - Pumps range $300 to $2,000, depending on flow rate & lift capacity
  - Controls range from $150 to $1,500
  - Tubing/hose/piping ranges $1.00 to $10.00 per foot
  - Motor cable (wire) ranges $0.50 - 5.00 per foot
- Generators range $500 to $3,000

Piston Pumps

- Can be mechanically or pneumatically driven
- Single-acting designs pump in one direction of piston movement
- Dual-acting designs pump in both directions of piston movement
- Piston and seal arrangement reciprocates within a chamber, creating suction to fill the chamber and pressure to discharge the water from the chamber.

Piston Pumps - Advantages

- Can provide accurate samples for most parameters
- High lift capacity; 600 feet (185 meters) maximum
- Flow rates range 0.1 to 5.0 gpm (0.4 to 19 lpm)
- Variable flow control for some designs
- Available to fit 2-inch wells and larger
- Mechanical designs can be repaired in the field
- Can be manually operated without power source

Piston Pumps - Limitations

- Sampling accuracy and precision dependent on piston speed
- Flow rates may be too low for deep wells or large purge volumes
- Metallic construction could affect sample chemistry
- Piston seals and valves prone to failure in silty/sandy conditions
- Top packing seals (mechanical designs) often leak
- Pneumatic designs difficult or impossible to repair in field; complicated design often requires return to manufacturer for repairs

Piston Pumps - Costs

- Mechanical Piston Pumps
  - Package of pump, drive rod, discharge pipe, top seal assembly ranges $2,000-8,000, depending on depth and materials selected
  - Air motor and compressor ranges $1,500 - 2,500
- Pneumatic Piston Pumps
  - Package of pump, hoses, hose reel and controls runs $3,500 - 6,000
  - Dedicated systems range $2,000 - 6,000
  - Compressors range $500 to $2,000

Bladder Pumps

- Also known as gas-operated squeeze pumps, Middleburg pumps
- Can be inflation-type or squeeze-type bladder design
- Consists of a pump chamber with a flexible bladder (usually PTFE or FEP), inlet and discharge check valves, and air and discharge tubing
- Bladder fills by submergence, then air pressure is applied to squeeze or inflate bladder, closing the inlet check valve and displacing water past the discharge check valve to the surface. Air is vented to the surface to repeat the cycles.

Bladder Pumps - Advantages

- Highest degree of accuracy and precision under widest range of field conditions; not subject to operator influence
- Can be constructed of desirable materials, plastic and metallic
- High lift capacity, up to 1,000 feet (300 meters) maximum
- Flow rate adjustable for purging and sampling
- Available to fit 1.5-inch (38 mm) wells and larger
- Simple design is reliable, easy to repair in field

Bladder Pumps - Limitations

- Flow rates may be too low for deep wells or large purge volumes
- Sand could damage bladder if inlet screen is not used
- Some designs difficult to clean if used portably
- Operating costs can be high if air cylinders are used

Bladder Pumps - Costs

- Pumps range $350 to $800, depending on materials
- Tubing ranges $1.50 to $15.00 per foot
- Controls range $1,000 to $2,000
- Compressors range $500 to $2,000
- Typical dedicated systems (pump, screen, tubing and well cap) run about $600 to $800 per well
- Typical portable systems (pump, screen, tubing, hose reel and controls) cost $2,500 to $3,500

Sampling System Design - Well Data

- Casing & screen or borehole diameter - both I.D. and O.D.
  - I.D. determines maximum O.D. of equipment you can use
  - O.D. needed for some well cap designs (dedicated systems)
  - If design tolerances are close, or I.D. is unknown, use a "dummy pipe" attached to a strong rope or cable to check I.D. from top to bottom of well and screen
- Total casing & screen length, or total depth of well (if uncased at bottom)
  - Used to calculate stored water volume, if using fixed-volume purge method
  - Determines maximum lift capacity needed for some pumping devices

Sampling System Design - Well Data (cont.)

- Screen length, and length of casing to screen
  - Used to determine pump placement, and packer placement (if used)
  - Screen length used to calculate purge volume with packer (fixed-vol. purge)
  - Can also identify "tail pipe" below screen if total casing & screen length is longer
- Depth to water (from top of casing or borehole)
  - Used to calculate stored water volume, if using fixed-volume purge method
  - Used to calculate total lift/total dynamic head for some pumping devices
  - Used to determine pump placement, depending on yield/recovery & analytes

Sampling System Design - Well Data (cont.)

- Specific yield or well recovery rate data
  - Used to determine pump placement (pumping water level)
  - Used to determine maximum flow rate required for fixed-volume purging
  - Used to determine maximum flow rate for low-volume purging/sampling
  - Used to calculate purge times for fixed-volume purging
- Surface completion type - above grade, or at/below grade
  - Identifies need for well protection and well cap/seal
  - Identifies type of well cap/seal required for dedicated systems

Sampling System Design - Pump Placement

- Based on knowledge of:
  - well construction detail
  - static water level
  - well hydraulic performance
- Also affected by:
  - analytes of interest, and stratification of contaminants
  - any zones of preferential flow within the well screen zone
  - minimum submergence and flow required for proper pump operation

Pump Placement for Portable Systems

- Single device used for purging and sampling:
  - locate pump in casing above well screen/open borehole to purge
  - purge at or below recovery rate of well with minimum drawdown
  - lower device below purging point to sample, or to specific zone within screen if desired

Pump Placement for Portable Systems (cont.)

- Separate devices used for purging and sampling:
  - if possible, place sampling device below purge pump before purging
  - locate purge pump in casing above well screen/open borehole
  - purge at or below recovery rate of well with minimum drawdown
  - operate sampling pump before removing all equipment, or withdraw purge pump and bailer if installed together
  - if purge pump must be removed before sampling device is installed, continue to operate purge pump during withdrawal, if possible

Pump Placement for Dedicated Systems

- Single device used for purging and sampling:
  - if recovery rate exceeds pumping rate, locate device at or above top of screen
  - if evacuating well and sampling on recovery, locate device near bottom of well
  - for low-volume purging/sampling, locate device within screen zone identified
- Separate devices for purging and sampling:
  - if recovery rate exceeds pumping rate, locate purge pump in casing above screen, and sampling device within well screen
  - if evacuating well, locate purge pump at bottom of well and sampling pump just above purge pump, or next to purge pump if well diameter permits

Sampling System Design - Other Considerations

- Analytes of interest - affects materials, device selection, sampling point
- Purge volume requirements - affects device selection, flow rate used
- Program duration - affects selection of portable or dedicated system
- Sampling frequency - affects selection of portable or dedicated system
- Limitations of site conditions, terrain, weather - affects logistics, selection of equipment , safety considerations
- Purge water containment requirements - use of purge-reduction devices (packers) or methods (low-flow purging & sampling)

Portable Sampling Systems

- Lower equipment cost (purchase/rent/lease)
- Higher operating costs (operation/maintenance)
  - assembly/disassembly at each well
  - cleaning labor (average 1 labor-hour/well)
  - cleaning supplies (buckets, brushes, detergent & water)
  - reagents (isopropanol, methanol, hexane, acid wash)
  - cleaning blank sample analysis
- Potential for cross-contamination of samples & wells
- Greater exposure of operator to contaminants & cleaning agents

Dedicated Sampling Systems

- Higher equipment cost (purchase/lease)
- Lower operating costs (operation/maintenance)
  - no assembly/disassembly at each well
  - no cleaning labor
  - no cleaning supplies or reagents
  - no cleaning blank samples
  - labor typically 30% - 50% lower overall
- Eliminates cross-contamination form sampling equipment
- Reduces potential for operator exposure to contaminants

Portable Vs. Dedicated - Cost Considerations

- Portable systems are more economical for short-term programs, while dedicated systems cost less over time due to lower operating costs
- Break-even (payback) period for dedicated systems:
  - typically 6 - 8 sampling events (18 - 24 months of quarterly sampling) for conventional fixed-volume purging
  - can drop to 3 - 4 sampling events (9 - 12 months) for low-flow purging/sampling applications, since equipment costs and purge time are typically reduced
- Total cost of dedicated system is typically no more than 3% - 5% of total monitoring program costs
- Dedicated cost savings is not strictly dependent on the number of wells!

Small 12v generators

Suggested References

Ballestero, Thomas P., F.R. Fiedler, and N.E. Kinner, 1994. An Investigation of the Relationship Between Actual and Apparent Gasoline Thickness in a Uniform Sand Aquifer. Ground Water. Vol. 32, No. 5, pp. 708-718.

Barcelona, Michael J., H.A. Wehrmann, and M.D. Varljen, 1994. "Reproducible Well-Purging Procedures and VOC Stabilization Criteria for Ground-Water Sampling." Ground Water. Vol. 32, No. 1, pp. 12-22.

Barcelona, M.J., Gibb, J.P., Miller, R.A., "A Guide to the Selection of Materials for Monitoring Well Construction and Ground Water Sampling", Illinois State Water Survey, CR-327, 1983.

Barcelona, M.J., Gibb, J.P., Helfrich, J.A., Garske, E.E., "Practical Guide for Ground-Water Sampling", Illinois State Water Survey CR-374, 1985.

Barcelona, M.J. and Helfrich, J.A., "Well Construction and Purging Effects on Ground-Water Samples", Environmental Science and Technology, Vol.20, No. 11, 1986, pp.1179-1184.

Barcelona, M.J., Helfrich, J.A., Garske, E.E., Gibb, J.P., "A Laboratory Evaluation of Ground Water Sampling Mechanisms", Ground Water Monitoring Review, Spring 1984, pp. 32-41.

Barcelona, M.J., Helfrich, J.A., Garske, E.E., "Sample Tubing Effects on Ground Water Samples", Analytical Chemistry, 57 (2), pp. 460-464.

Giddings, Todd, 1983. "Bore-Volume Purging to Improve Monitoring Well Performance: An Often-Mandated Myth." Proceedings of the NWWA Third National Symposium on Aquifer Restoration and Ground-Water Monitoring, Columbus, Ohio. May, 1893, pp. 253-256.

"Ground Water Monitoring and Sample Bias", American Petroleum Institute Publication 4367, June 1983.

Heidlauf, David T. and Bartlett, Timothy R., 1993. Effects of Monitoring Well Purge and Sample techniques on the Concentration of Metal Analytes in Unfiltered Groundwater Samples." Proceedings of the NGWA Outdoor Action Conference, Las Vegas, NV, May 1993, pp. 437-450.

Holm, T.R., George, G.K., and Barcelona, M.J., "Oxygen Transfer Through Flexible Tubing and Its Effects on Ground-Water Sample Results," Ground Water Monitoring Review, Summer 1988, pp. 83-89.

Houghton, R.L., and Berger, M.E., "Effects of Well-Casing Composition and Sampling Method on Apparent Quality of Ground Water", Proceedings, Fourth National Symposium and Exposition on Aquifer Restoration and Ground Water Monitoring, NWWA, Columbus, OH, May 23-25, 1984.

Kearl, Peter M., N.E. Korte, M. Stites and J. Baker, 1994. "Field Comparison of Micropurging vs. Traditional Ground Water Sampling." Ground Water Monitoring and Remediation. Vol. 14, No. 4, pp.183-190.

Kearl, P.M., N.E. Korte and T.A. Cronk, "Suggested Modifications to Ground Water Sampling Procedures Based on Observations from the Colloidal Borescope", Ground Water Monitoring Review, Spring 1992, pp.155-161.

Lovejoy, S., Isaacson, K.A. and Eisenberg, D.M., "Cost-Effectiveness of Dedicated Sampling Systems for Groundwater Monitoring", Proceedings of the Hazmacon '89 Conference, ABAG, Santa Clara, CA, April 18-20, 1989.

Nielsen, D.M. and Yeates, G.L., "A Comparison of Sampling Mechanisms Available for Small-Diameter Ground Water Monitoring Wells", Ground Water Monitoring Review, Vol.5, No.2, 1985, pp.83-99.

Pohlmann, K.F., and Hess, J.W., "Generalized Ground Water Sampling Device Matrix", Ground Water Monitoring Review, Vol.8, No.4, 1988, pp.82-84.

Pohlmann, K.F., Blegen, R.P., and Hess, J.W., "Field Comparison of Ground-Water Sampling Devices for Hazardous Waste Sites: An Evaluation Using Volatile Organic Compounds", U.S. EPA Publication # EPA/600/4-90/028, May 1991.

Powell, Robert M. and Robert W. Puls, 1993. "Passive sampling of groundwater monitoring wells without purging: multilevel well chemistry and tracer disappearance." Journal of Contaminant Hydrology. No.12, 1993, pp.51-77.

Puls, Robert W., D.A. Clark, B. Bledsoe, R.M. Powell, and C.J. Paul, 1992. "Metals in Ground Water: Sampling Artifacts and Reproducibility." Hazardous Waste and Hazardous Materials. Vol. 9, No.2, pp. 149-162.

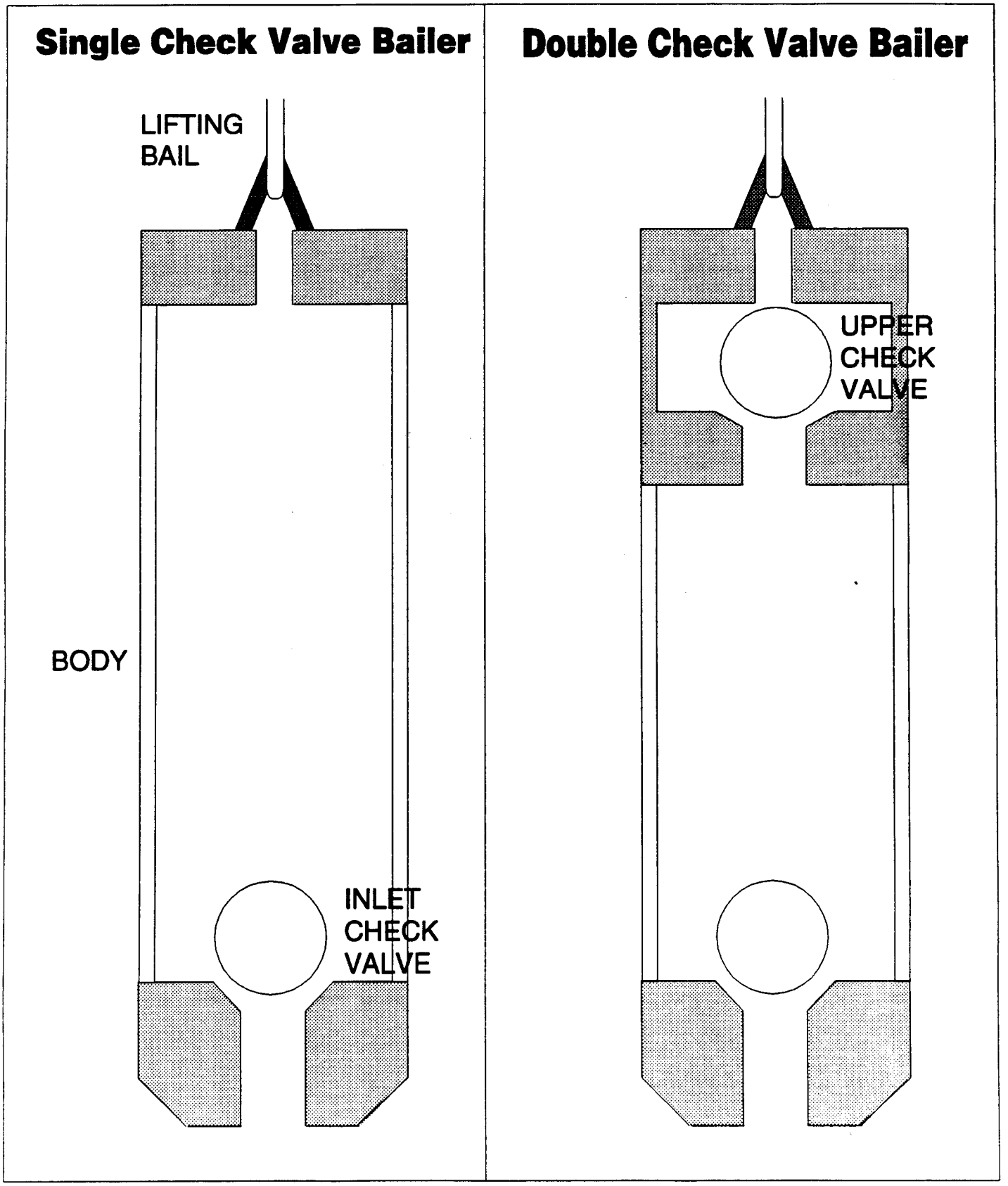
MP Puls, R.W. and M.J. Barcelona, "Ground Water Sampling for Metals Analysis", EPA Superfund Ground Water Issue, U.S. EPA Publication #EPA/540/4-89/001, March 1989.

MP Robin, M.J.L. and Gillham, R.W., "Field Evaluation of Well Purging Procedures", Ground Water Monitoring Review, Fall 1987, pp. 85-93.

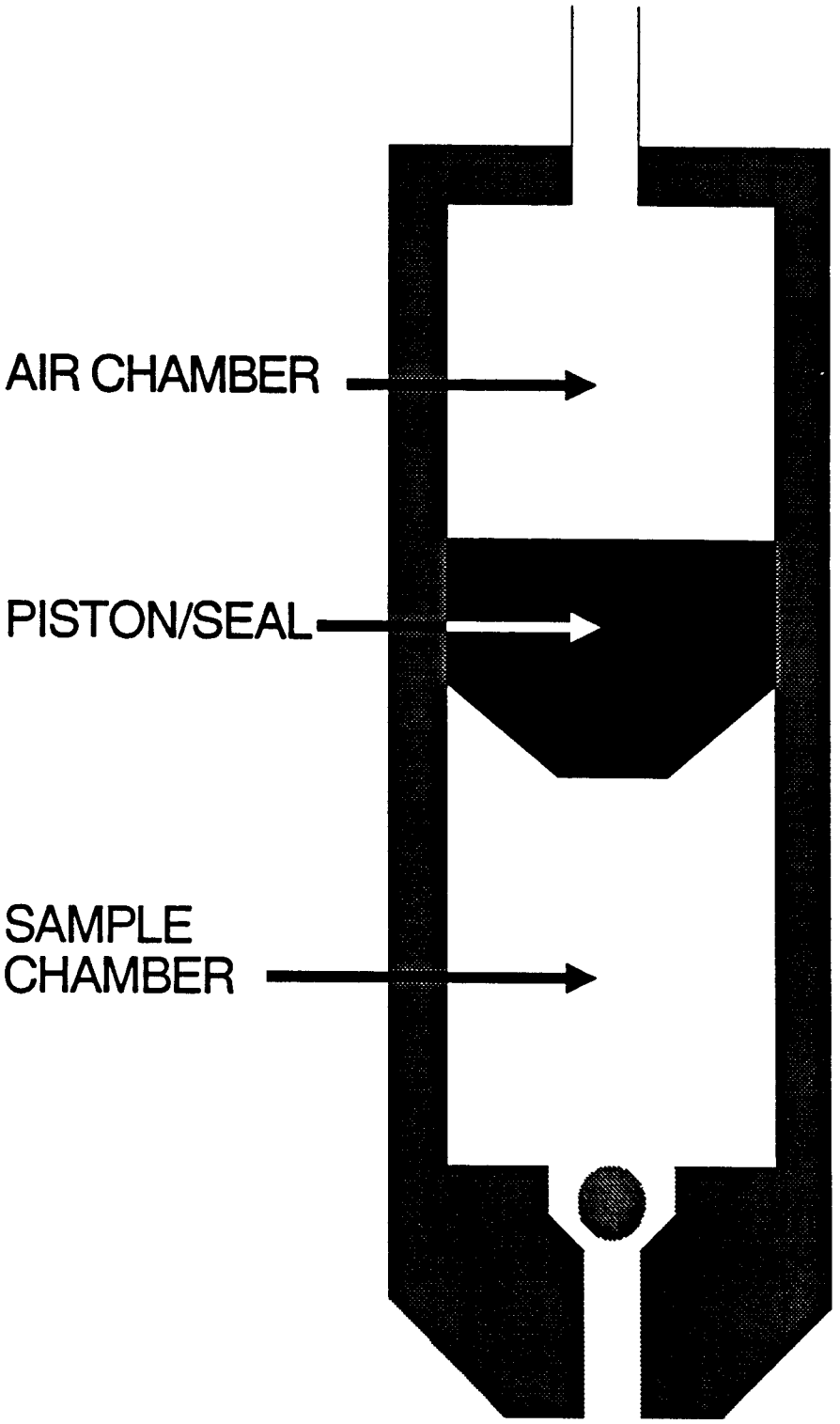
Yeskis, D., Chiu, K., Meyers, S., Weiss, J., Bloom, T., "A Field Study of Various Sampling Devices and Their Effects on Volatile Organic Contaminants", Proceedings of the Second National Outdoor Action Conference, NWWA, Las Vegas, NV, May 23-26, 1988.

Example Of Single And Dual Check-Valve Bailers

(Cross Section)

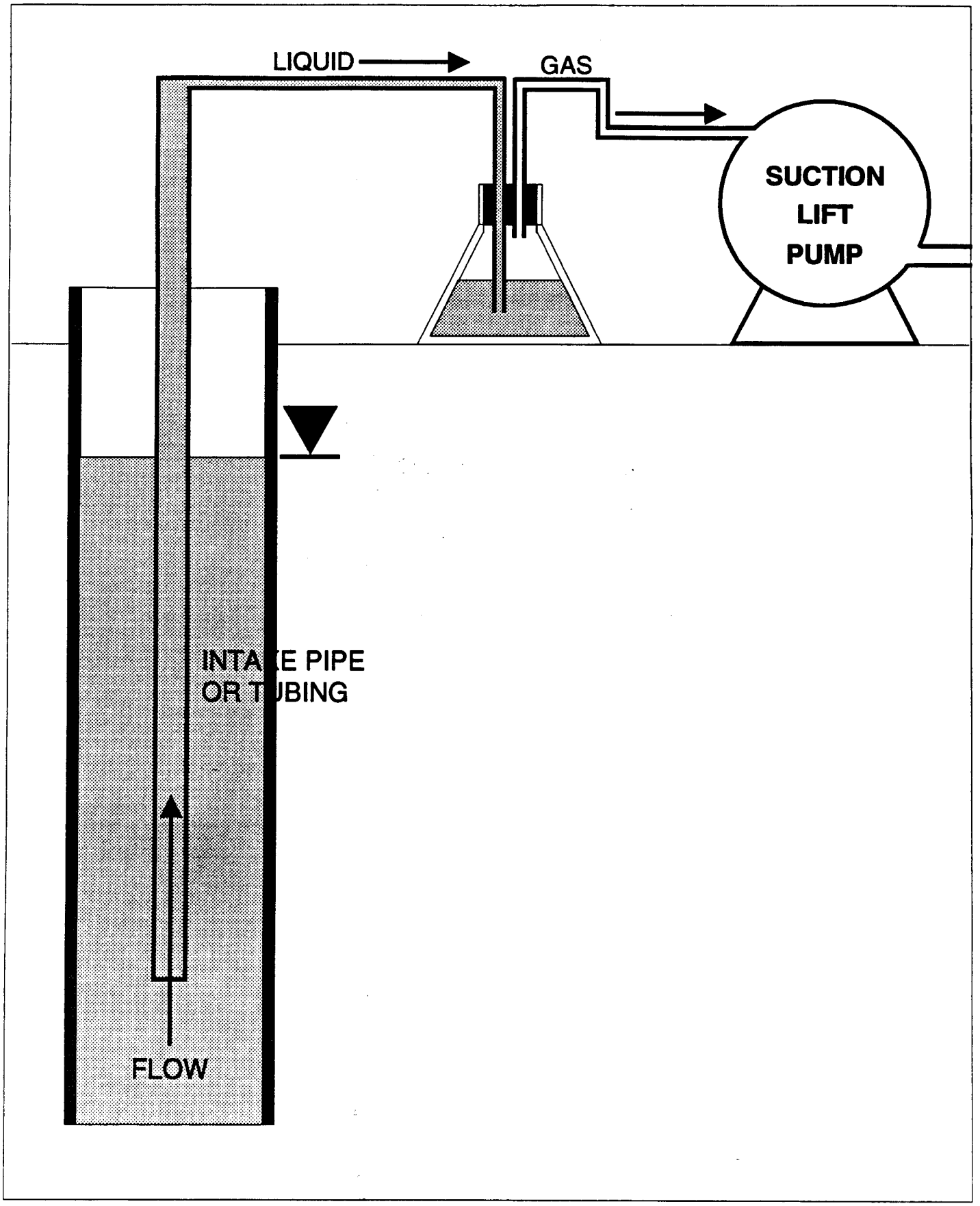


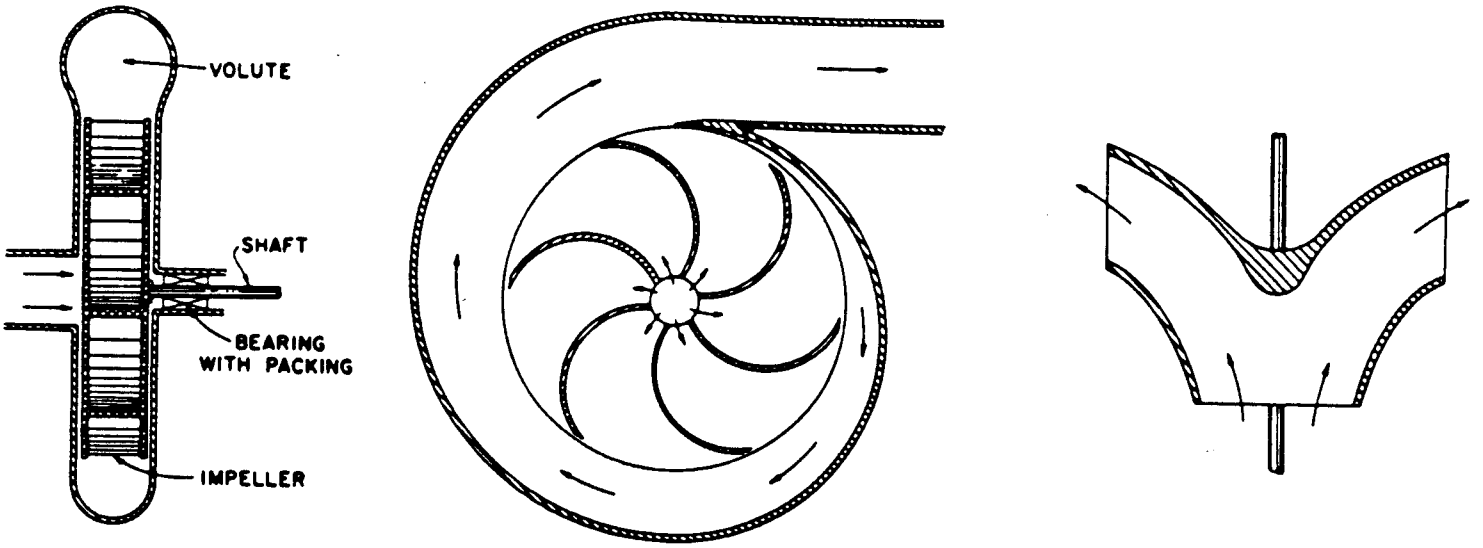
SYRINGE BAILER (THIEF SAMPLER)



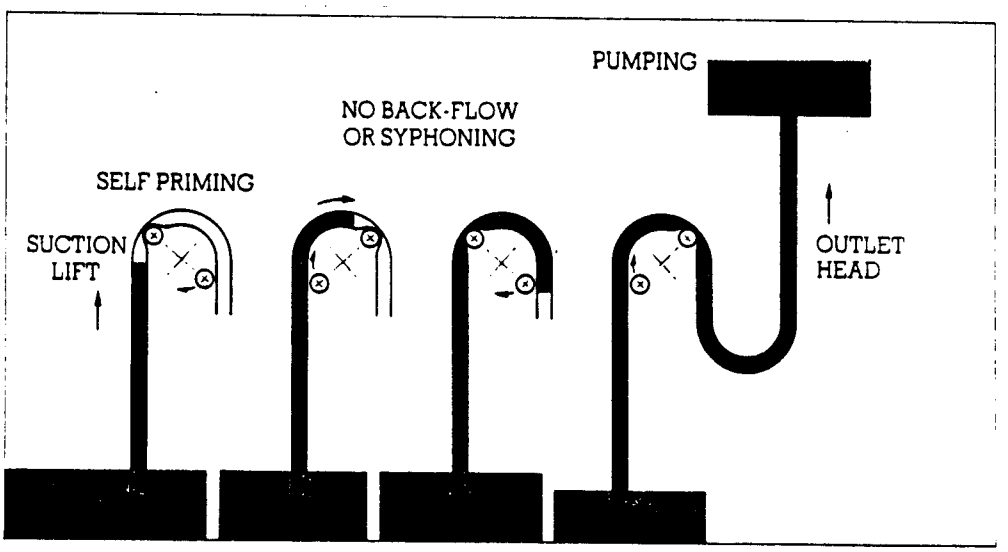
Example Of A Suction Lift Pump

(Schematic Drawing)

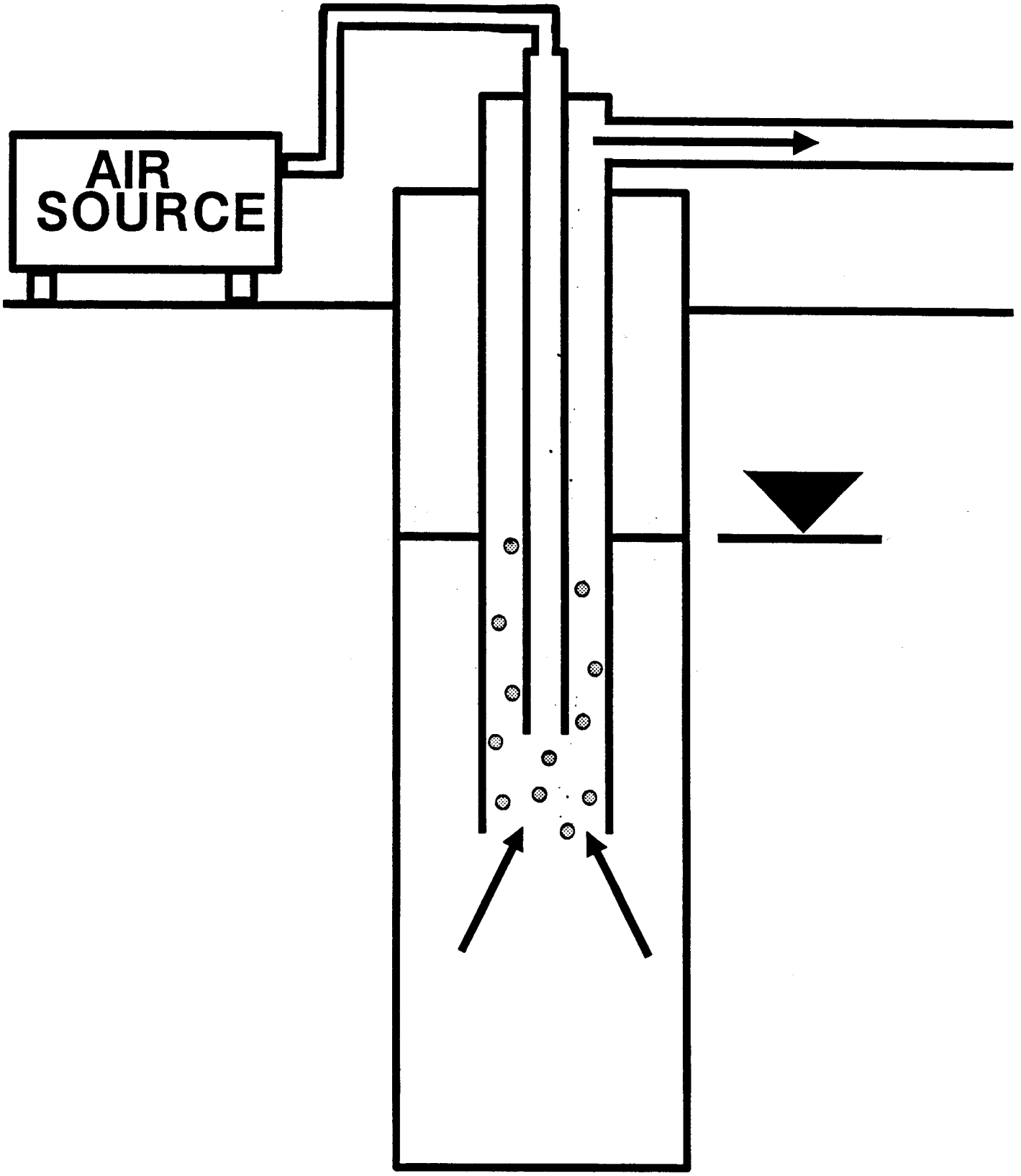




Schematic of impeller and volute of centrifugal pump (side and front views, left and center), and of mixed-flow impeller (right).



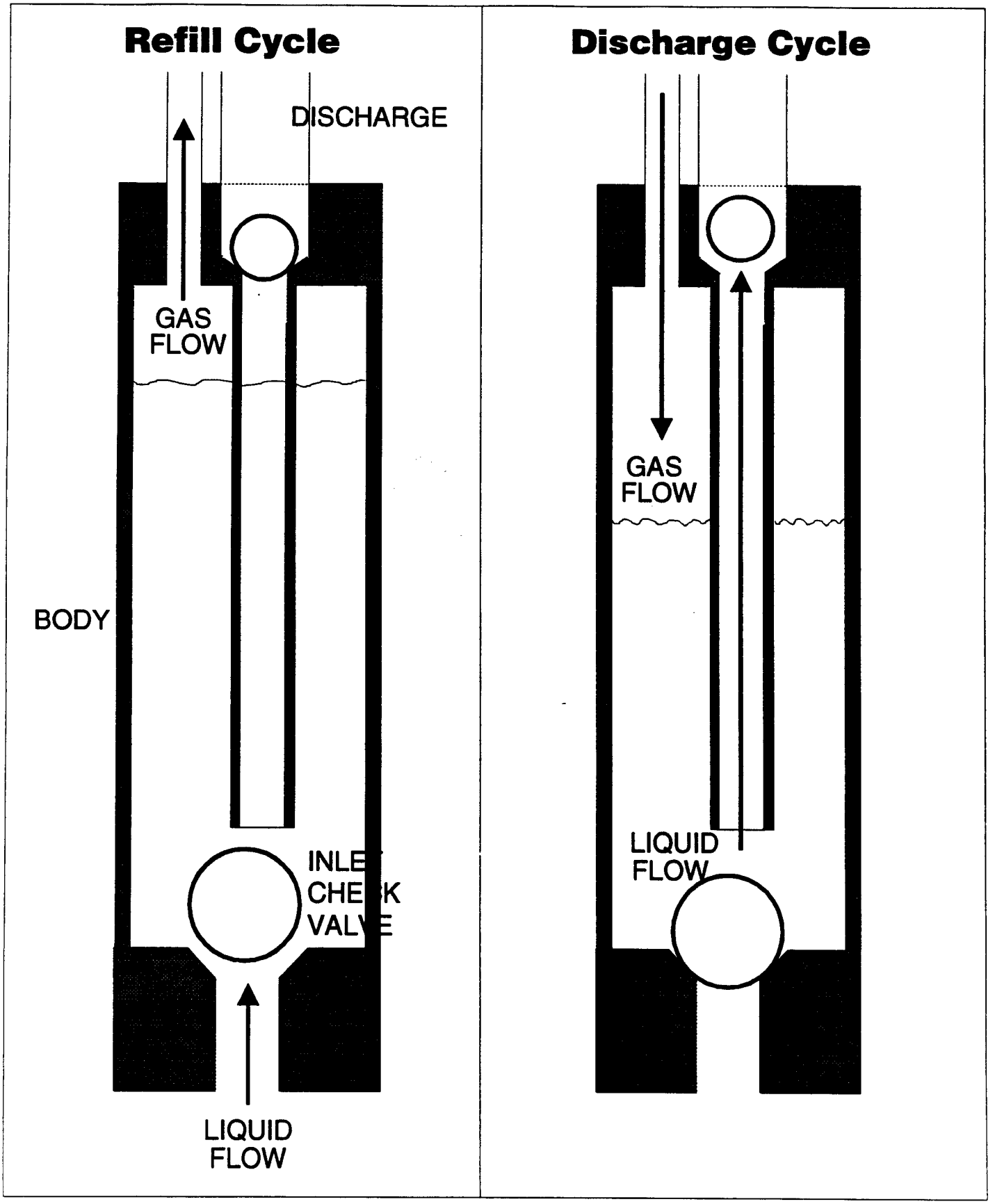
Peristaltic Pump



AIR LIFT PUMP

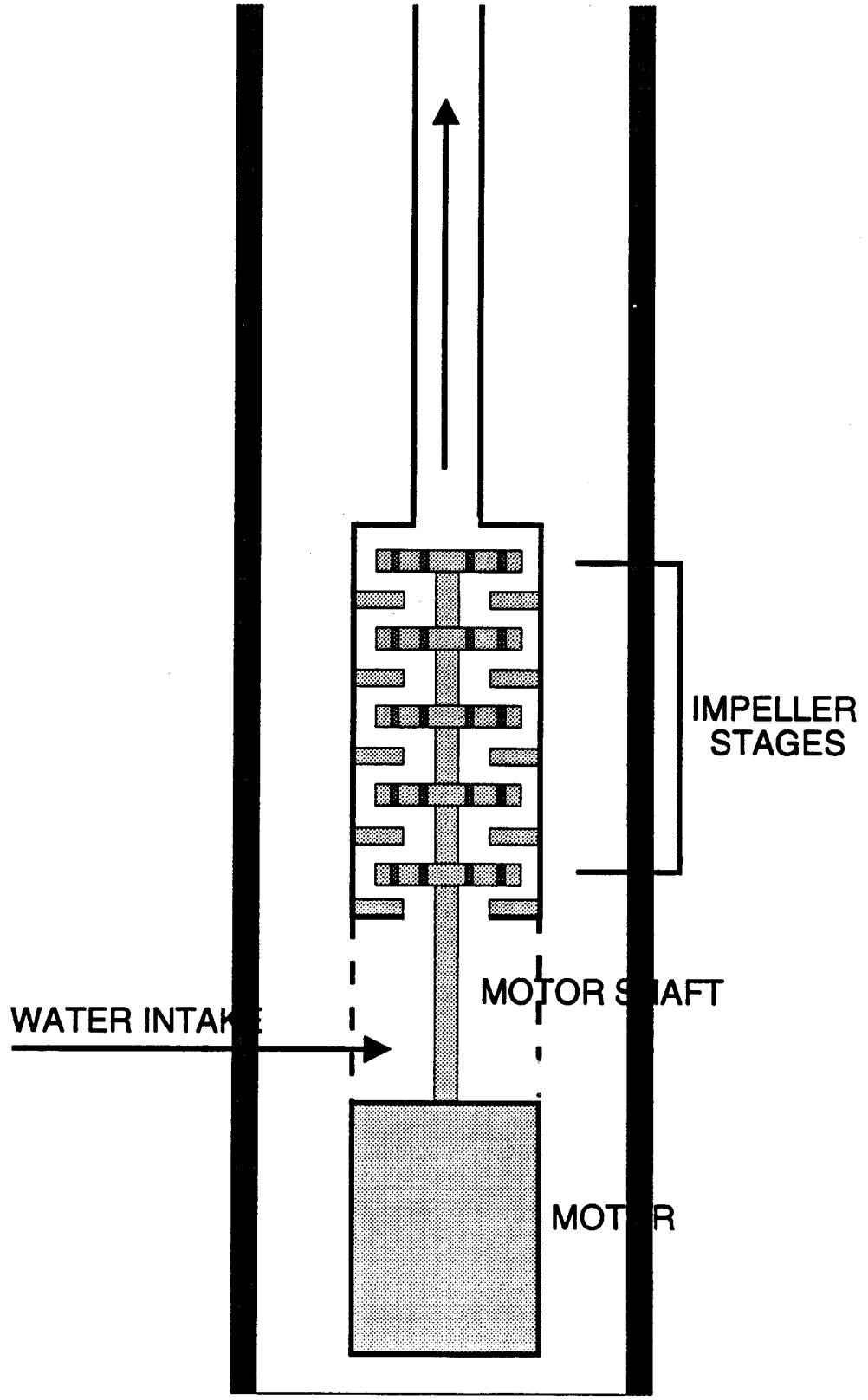
Example Of Air Displacement Pump

(Schematic Drawing)



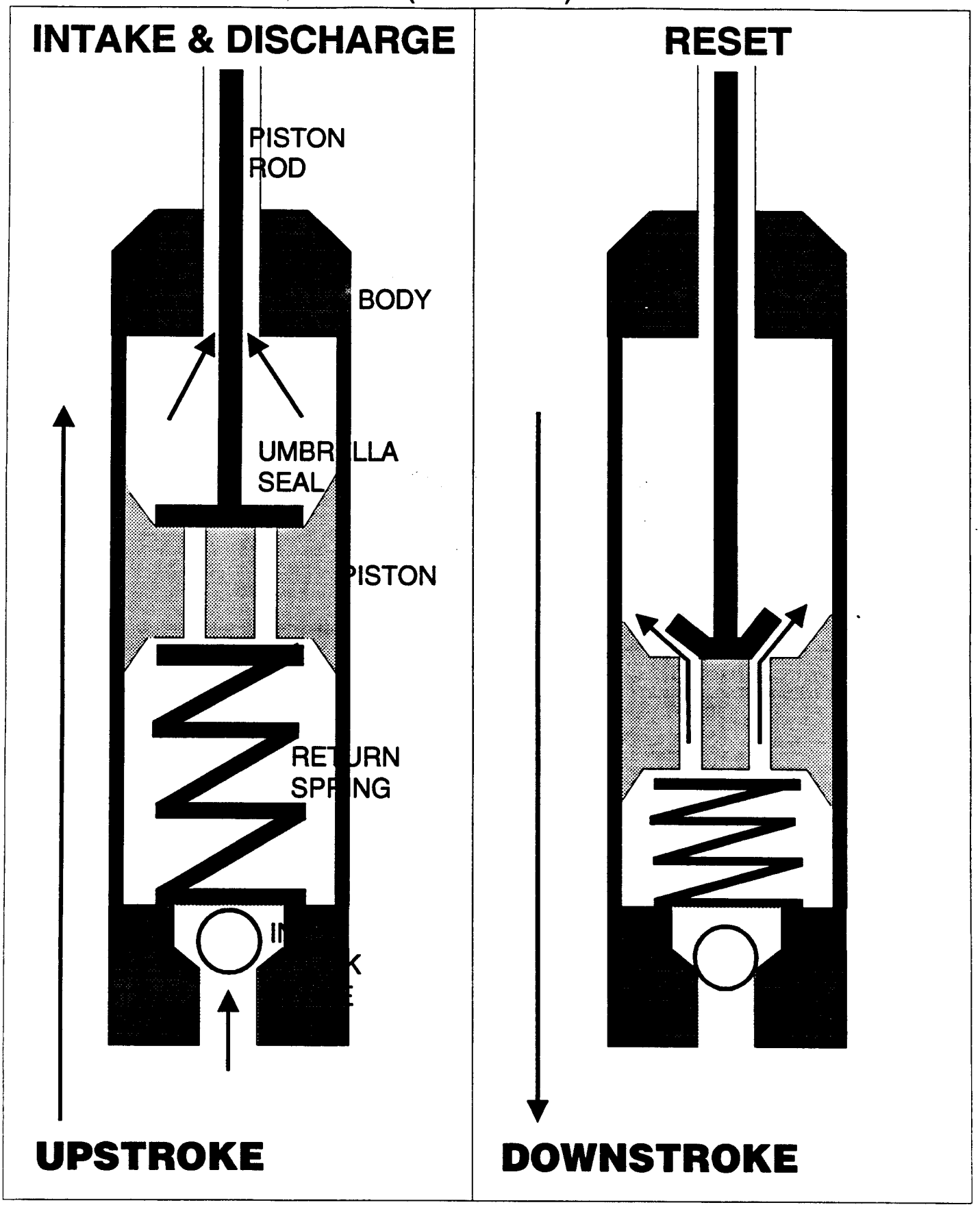
Example Of Electric Submersible Pump

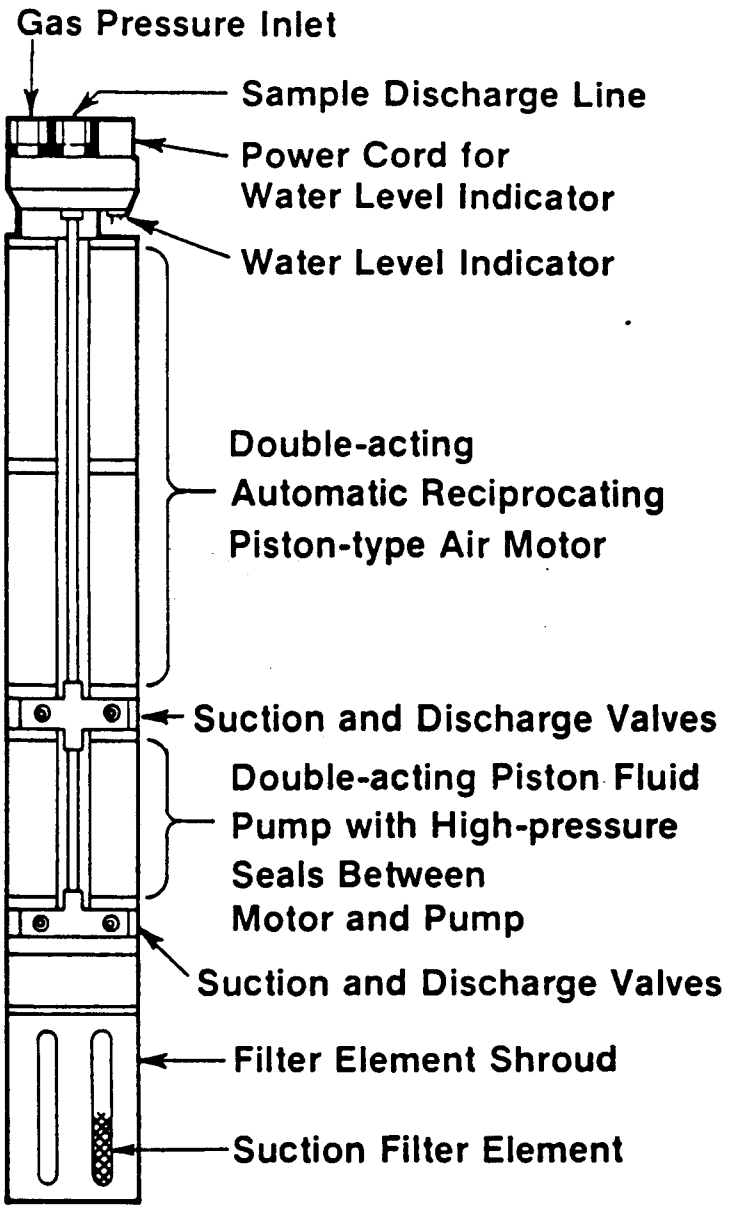
(Centrifugal Type-Schematic Drawing)



Example Of Mechanical Piston Pump

(Cross Section)

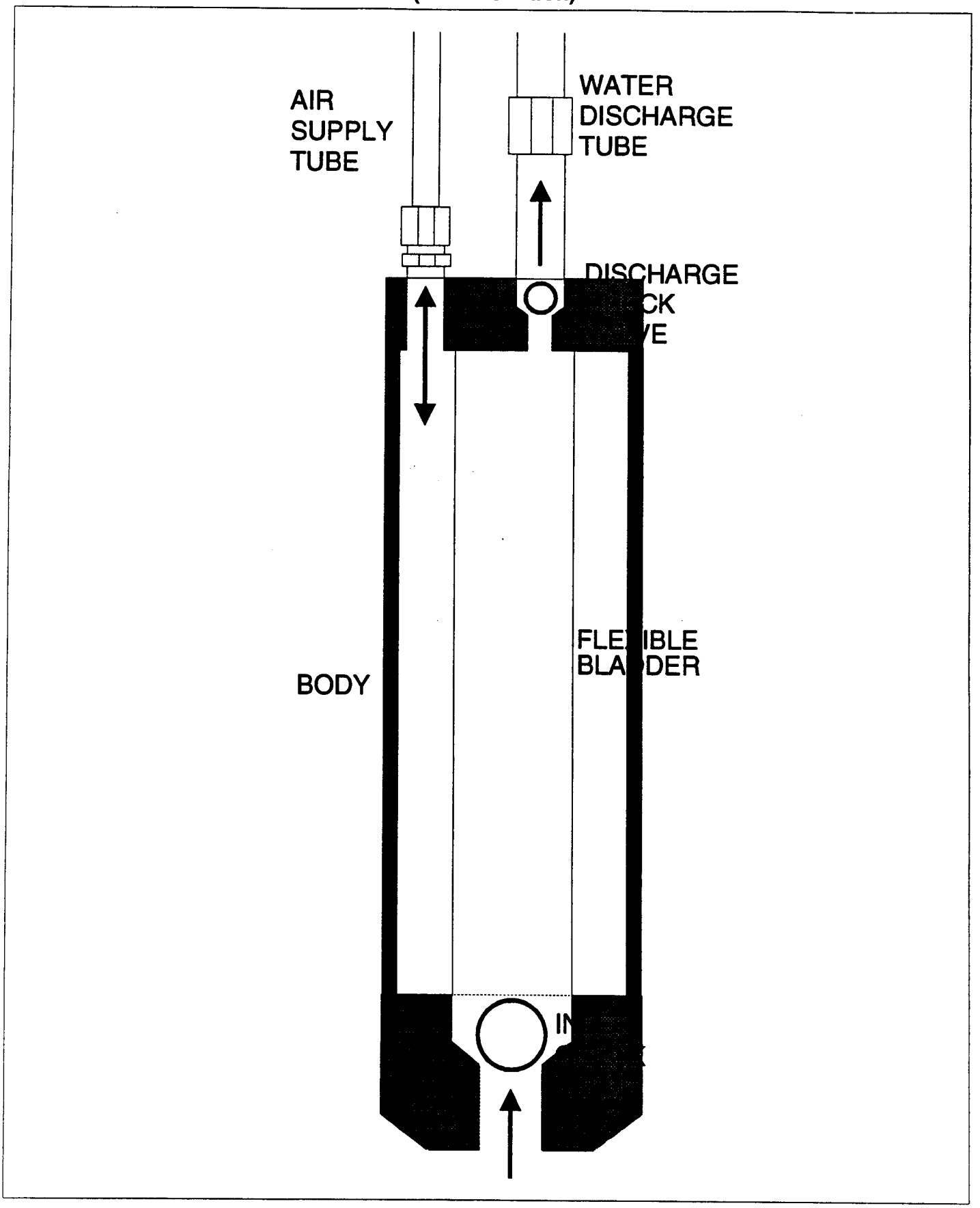




Pneumatic Dual-Acting Piston Pump

Example Of Bladder Pump

(Cross Section)



Committee D-18 ON SOIL AND ROCK

Fundamentals of Ground-Water Monitoring & Sampling Technology

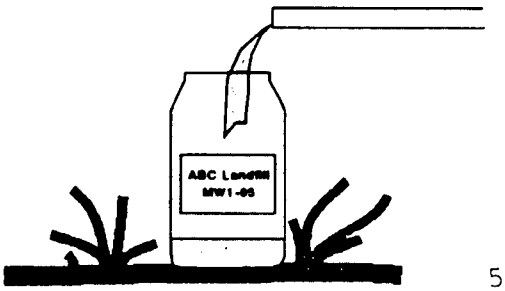
GROUND-WATER SAMPLE COLLECTION PROCEDURES

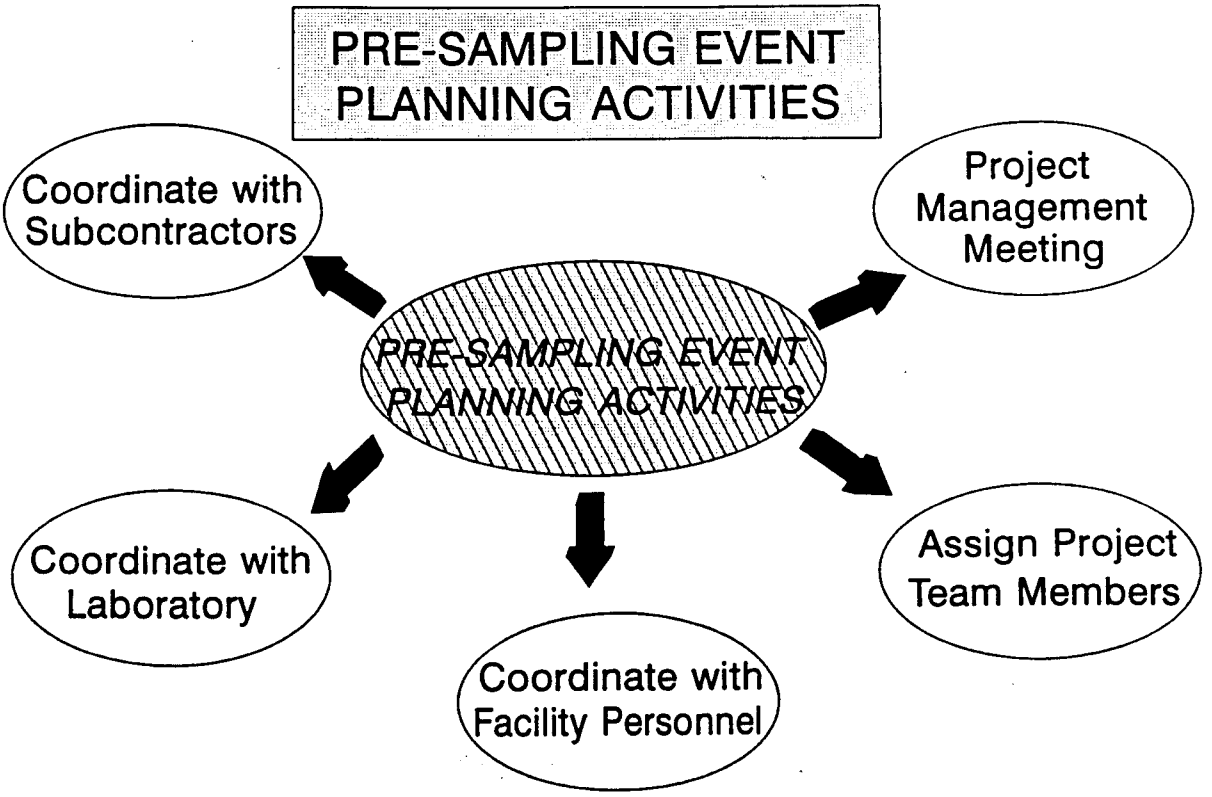
- Planning a Ground-Water Sampling Event
- The Importance of Good Housekeeping
- Selection of Sample Bottles
- Determining the Order of Sample Bottle Filling
- Parameter-Specific Sample Collection Procedures

Instructor:

Gillian L. Nielsen
Nielsen Ground-Water Science, Inc.
4686 State Route 605 South
Galena, OH 43021-9652

© 1995, Nielsen Ground-Water Science, Inc.
Galena, Ohio. All Rights Reserved.
These materials are copyright-protected under the laws of the United States and are the exclusive property of Nielsen Ground-Water Science, Inc. Any unauthorized duplication will result in prosecution.





Inefficient Planning Can Result In:

SHORTAGES = DELAYS

Personnel
Equipment
Supplies

Under Utilization of Resources
Cost Overruns

Unhappy Clients or Supervisors ⟷ *Project Losses*

WHY ARE GOOD HOUSEKEEPING PRACTICES SO CRITICAL IN GROUND-WATER SAMPLING?

- Prevent Accidents Resulting in Personnel Injury and Damage to Equipment
- Prevent Introducing Surface Contaminants into the Monitoring Well Being Sampled or Sample Being Collected
- Prevent Cross-Contamination of Samples
- Prevent Errors in Sample Bottle Labeling
- Minimize Potential of Personnel Exposure to Contaminants
- Ensure Safe Operation of Equipment

PRACTICAL PROBLEM AND DISCUSSION NOTES HOUSEKEEPING CONSIDERATIONS IN GROUND-WATER SAMPLING

Slide 1

cross-contamination

Vitons

one glove

finger regulator

sample technique

Cooler on Ground

IV, Cooler

plastic bag

do not use

use 6 mil plastic sheeting

Slide 2

No Gloves

Cooler on Ground

No Cooler

caps off

Slide 3

No Gloves

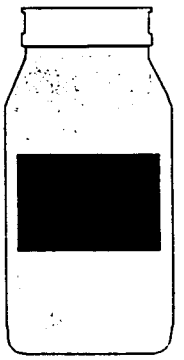
No Cooler

Transfer container

PRACTICAL PROBLEM AND DISCUSSION NOTES HOUSEKEEPING CONSIDERATIONS IN GROUND-WATER SAMPLING

DECISIONS TO BE MADE WHEN SELECTING SAMPLE BOTTLES

- Source of Bottles
  - Lab Performing Sample Analysis
  - Bottle Manufacturers
  - Commercial Suppliers of Bottles for Environmental Sampling Applications
- "Pre-Cleaned" vs. "You-Clean" Bottles
- Parameter(s) to be Analyzed
- Sample Volume Required
- Bottle Design and Shape
- "Pre-Preserved" vs. "You-Preserve" Bottles



U.S. EPA SPECIFICATIONS FOR SAMPLE BOTTLE CLEANING AND PREPARATION

Glassware and plasticware are cleaned using one of four procedures:

CLEANING PROCEDURE A

1. Bottles, liners and caps are washed in laboratory-grade, nonphosphate detergent.
2. Rinsed 3 times with distilled water.
3. Rinsed with 1:1 nitric acid.
4. Rinsed 3 times with ASTM Type 1 organic-free water.
5. Oven-dried for 1 hour.
6. Rinsed with hexane.
7. Oven-dried for 1 hour.

CLEANING PROCEDURE B

1. Vials, septa and caps are washed in laboratory-grade, nonphosphate detergent.
2. Rinsed 3 times with distilled water.
3. Rinsed 3 times with ASTM Type 1 organic-free water.
4. Oven-dried for 1 hour.

CLEANING PROCEDURE C

1. Bottles, liners and caps are washed in laboratory-grade, nonphosphate detergent.
2. Rinsed 3 times with distilled water.
3. Rinsed with 1:1 nitric acid.
4. Rinsed 3 times with ASTM Type 1 organic-free water.
5. Air-dried.

CLEANING PROCEDURE D

1. Containers are rinsed 3 times with deionized water.
2. Filled with deionized water and soaked for 48 hours.
3. Emptied and air-dried.

Glassware and plasticware are prepared in one of three ways:

LEVEL 1

Glassware and plasticware receive full EPA quality assurance treatment. Containers are cleaned according to EPA recommended wash procedures and undergo strict quality control analysis. Additional sampling custody seals for bottle closures are included in each case. Each case of containers is then custody sealed - chain of custody is intact right from the start. Each container is lot number labeled for traceability to the enclosed certificate of analysis.

LEVEL 2

Containers receive the same EPA washing treatment as Level 1 containers and are packed with a wash certificate and bottle labels in custody sealed cases.

LEVEL 3

Containers do not receive an EPA washing treatment and are ready for your own cleaning procedure. Containers are assembled and meet EPA recommended guidelines for sample container material component specifications.

Certificate of Analysis

Bottle Type & QA Level: B Level 1

Description : 40 mL. Clear Vial

Lot No.: B2055010 Date: 2-27-92

VOLATILES QUALITY CONTROL ANALYSIS

This is to certify that this lot was tested and found to comply with Eagle-Picher Environmental Services specifications for this product.

Compound Analyzed	Quantity Found (ng/bottle)
Chloromethane	<40.
Bromomethane	<40.
Vinyl Chloride	<40.
Chloroethane	<40.
Methylene chloride	<80.
Acetone	<200.
Carbon disulfide	<40.
1,1-Dichloroethene	<40.
1,1-Dichloroethane	<40.
cis-1,2-Dichloroethene	<40.
Chloroform	<40.
1,2-Dibromo-3-chloropropane	<40.
1,2-Dichloroethane	<40.
trans-1,2-Dichloroethene	<40.
2-Butanone	<200.
1,1,1-Trichloroethane	<40.
Carbon tetrachloride	<40.
Bromodichloromethane	<40.
1,2-Dichloropropane	<40.
cis-1,3-Dichloropropene	<40.
Trichloroethene	<40.
Dibromochloromethane	<40.
1,1,2-Trichloroethane	<40.
Benzene	<40.
1,2-Dichlorobenzene	<40.
1,3-Dichlorobenzene	<40.
1,4-Dichlorobenzene	<40.
trans-1,3-Dichloropropene	<40.
Bromoform	<40.
Bromochloromethane	<40.
4-Methyl-2-pentanone	<200.
2-Hexanone	<200.
Tetrachloroethene	<40.
Toluene	<40.
1,1,2,2-Tetrachloroethane	<40.
Chlorobenzene	<40.
Ethylbenzene	<40.
Styrene	<40.
Xylenes (total)	<40.

NOTE: ppb = $\frac{\text{Quantity (in nanograms)}}{\text{Container volume (in mL)}}$

Approved: Jul Shepherd

Date : 2-27-92

EAGLE PICHER

ENVIRONMENTAL SERVICES

36 B. J. TUNNELL BLVD. EAST • MIAMI, OKLAHOMA 74354-3300 • (800) 331-7425

RELATIVE SENSITIVITY OF TYPICAL GROUND WATER QUALITY CONSTITUENTS

Type of Constituent	Example
Volatile Organic Compounds	Chloroform
Organometallics	Diethylzinc
Dissolved Gases	Dissolved Oxygen
Well Purging Parameters	pH
Trace Inorganic Metals	Iron
Reduced Species	Nitrate
Major Cations and Anions	Sodium

Decreasing Sensitivity

U.S. EPA GUIDELINES ON ORDER OF SAMPLE COLLECTION

1. Volatile Organic Compounds (VOCs)
2. Total Organic Carbon (TOC)
3. Total Organic Halogen (TOX)
4. Samples Requiring Field Filtration
5. Samples for Field Parameter Measurement
6. Large-Volume Samples for Extractable Organic Compounds
7. Samples for Total Metals
8. Samples for Nutrient Anion Determinations

Source: EPA/625/6-90/016b 07/1991

PROJECT-SPECIFIC CONSIDERATIONS FOR DETERMINING THE ORDER OF SAMPLE COLLECTION

Any of the Following Criteria Could Dictate Which Samples Should Be Collected First:

- Political Sensitivity of Parameters
- Potential for Impact on Sample Chemistry Associated With:
  - Temperature Changes
  - Exposure to Air
  - Partial Pressure Changes
  - Contact with Well Construction Materials
- Sample Holding Times Sample fill until lab extract or analyze
- Samples Requiring Large Volumes
- Samples Requiring Filtration
- Samples Collected for Field Parameter Measurement

GROUND WATER SAMPLING

Nielsen, D.M. and Yeates, G.L., 1985, A Comparison of Sampling Mechanisms Available for Small-Diameter Ground Water Monitoring Wells; Ground Water Monitoring Review, Vol. 5, No. 2, pp. 83 - 99.

Herzog, B., Pennino, J., and Nielsen, G.L., 1991, Ground-Water Sampling; Chapter 11 in Practical Handbook of Ground-Water Monitoring, D.M. Nielsen, Editor, Lewis Publishers, Chelsea, MI, pp. 449 - 499.

Gibb, J.P., and Barcelona, M.J., 1984, Sampling for Organic Contaminants in Ground Water; AWWA Journal, May 1984, pp. 48 - 51.

Stolzenburg, T. and Nichols, D.G., 1984, Preserving the Chemical Integrity of a Ground Water Sample; in Proceedings, Fifth National Symposium on Aquifer Restoration and Ground Water Monitoring, National Ground Water Association, Dublin, OH, pp. 221 - 225.

Burger, R.M., 1988, Design and Implementation of a Successful Field Quality Control Program for Ground Water Sampling Events; in Proceedings, Second National Outdoor Action Conference on Aquifer Restoration and Ground Water Monitoring; National Ground Water Association, Dublin, OH, pp. 525 - 536.

Smith, J.S., Steele, D.P., Malley, M.J., and Bryant, M.A., 1988, Ground Water Sampling; Chapter 17 in Principles of Environmental Sampling, Lawrence H. Keith, Editor, American Chemical Society, Washington, DC, pp. 257 - 260.

Kent, R.T., and Payne, K.E., 1988, Sampling Ground Water Monitoring Wells: Special Quality Assurance and Quality Control Considerations; Chapter 15 in Principles of Environmental Sampling, Lawrence H. Keith, Editor, American Chemical Society, Washington, DC, pp. - .

Lietman, P.L., Gerhart, J.M. and Wetzel, K.L., 1989, Comparison of Methods for Sampling Dissolved Nitrogen in a Fractured Carbonate Rock Aquifer; Ground Water Monitoring Review, Vol. 9, No. 1, pp. 197 - 202.

Rankow, J.F., 1988, Minimization of Volatilization Losses During Sampling and Analysis of Volatile Organic Compounds in Water; in Significance and Treatment of Volatile Organic Compounds in Water Supplies, Lewis Publishers, Chelsea, MI, pp. 73 - 86.

Holm, T.R., George, G.K., and Barcelona, M.J., 1988, Oxygen Transfer Through Flexible Tubing and Its Effects on Ground Water Sampling Results; Ground Water Monitoring Review, Vol. 8, No. 3, pp. 83 - 89.

Wilson, L.C., and Rouse, J.V., 1983, Variations in Water Quality During Initial Pumping of Monitoring Wells; Ground Water Monitoring Review, Vol. 3, No. 1, pp. 103 - 109.

Keith, S.J., Wilson, L.G., Fitch, H.R., and Esposito, D.M., 1983, Sources of Spatial-Temporal Variability in Ground-Water Quality Data and Methods of Control; Ground Water Monitoring Review, Vol. 3, No. 2, pp. 21 - 32.

Rajagopal, R., 1986, The Effect of Sampling Frequency on Ground Water Quality Characterization; Ground Water Monitoring Review, Vol. 6, No. 4, pp. 65 - 73.

Gibs, J., Imbrigiotta, T.E., and Turner, K., 1990, Bibliography on Sampling Ground Water for Organic Compounds; US Geological Survey Open File Report # 90-564, U.S.G.S., Trenton, NJ, 22 pp.

Committee D-18 ON SOIL AND ROCK

Fundamentals of Ground-Water Monitoring & Sampling Technology

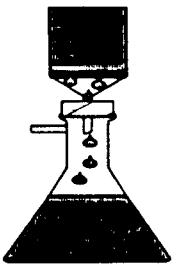
SAMPLE PRETREATMENT METHODS AND PROCEDURES

- Objectives of Sample Pretreatment
- Filtration of Ground-Water Samples
- Physical & Chemical Preservation of Ground-Water Samples

Draft std

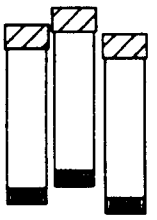
Instructor:

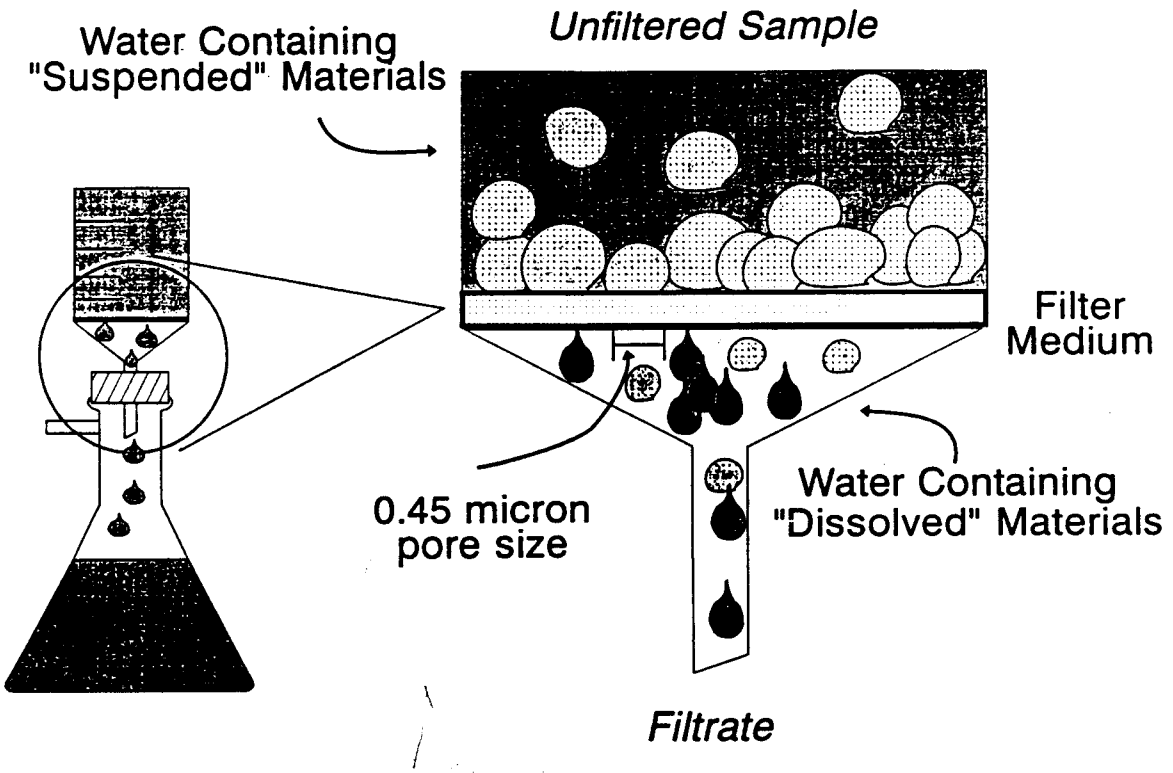
Gillian L. Nielsen
Nielsen Ground-Water Science, Inc.
4686 State Route 605 South
Galena, OH 43021-9652

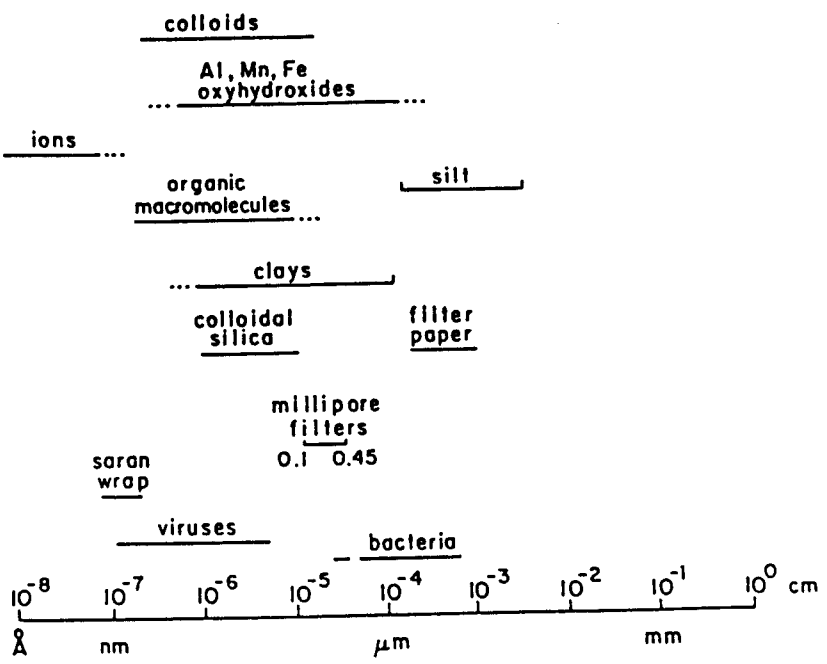


© 1995, Nielsen Ground-Water Science, Inc. Galena, Ohio. All Rights Reserved.

These materials are copyright-protected under the laws of the United States and are the exclusive property of Nielsen Ground-Water Science, Inc. Any unauthorized duplication will result in prosecution.





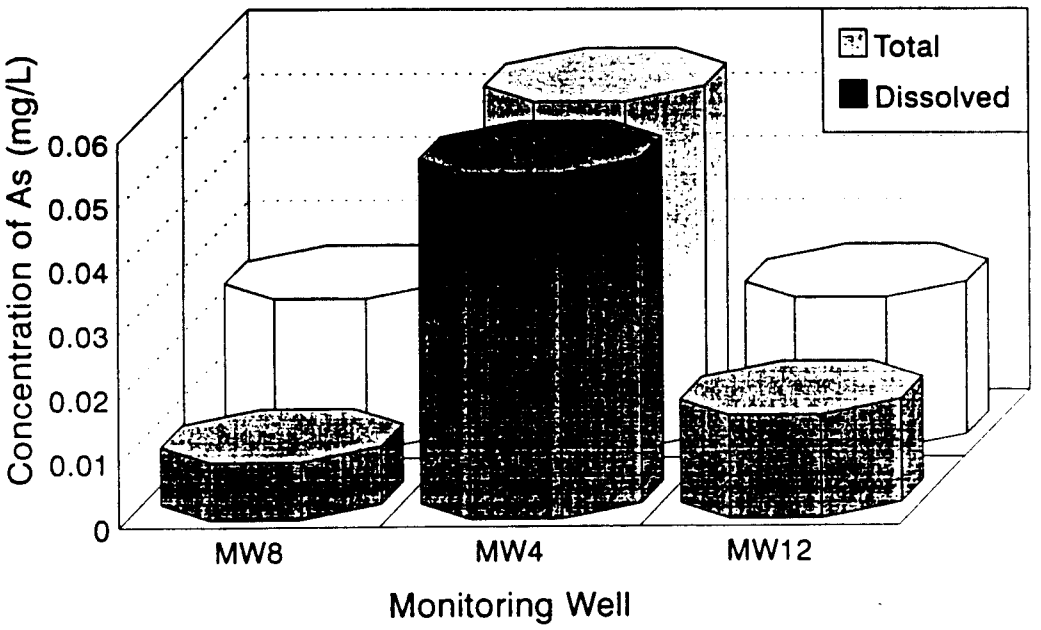


Particle size ranges of some common constituents of groundwater in relation to filter sizes

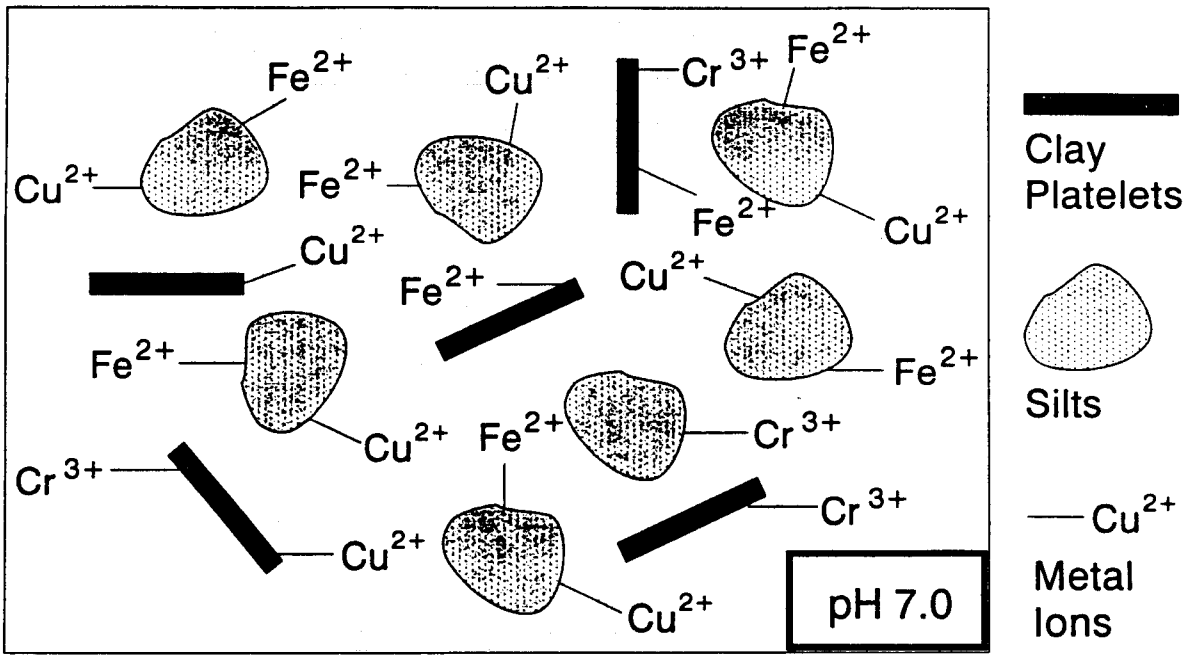
REASONS TO FILTER SAMPLES

- To Remove Sediments from Samples that Can Cause Interference During Sample Analysis
- To Minimize "Bounce" in Databases that Can Occur in Long-Term Monitoring Programs when Samples are Collected from Silty Sources
- To Determine Concentrations of Compounds That are Truly Dissolved
- To Permit Determining What Portion of "Total" Analyses are Directly the Result of Leaching of Compounds from Sediment in Samples that Can Occur As a Result of Sample Preservation

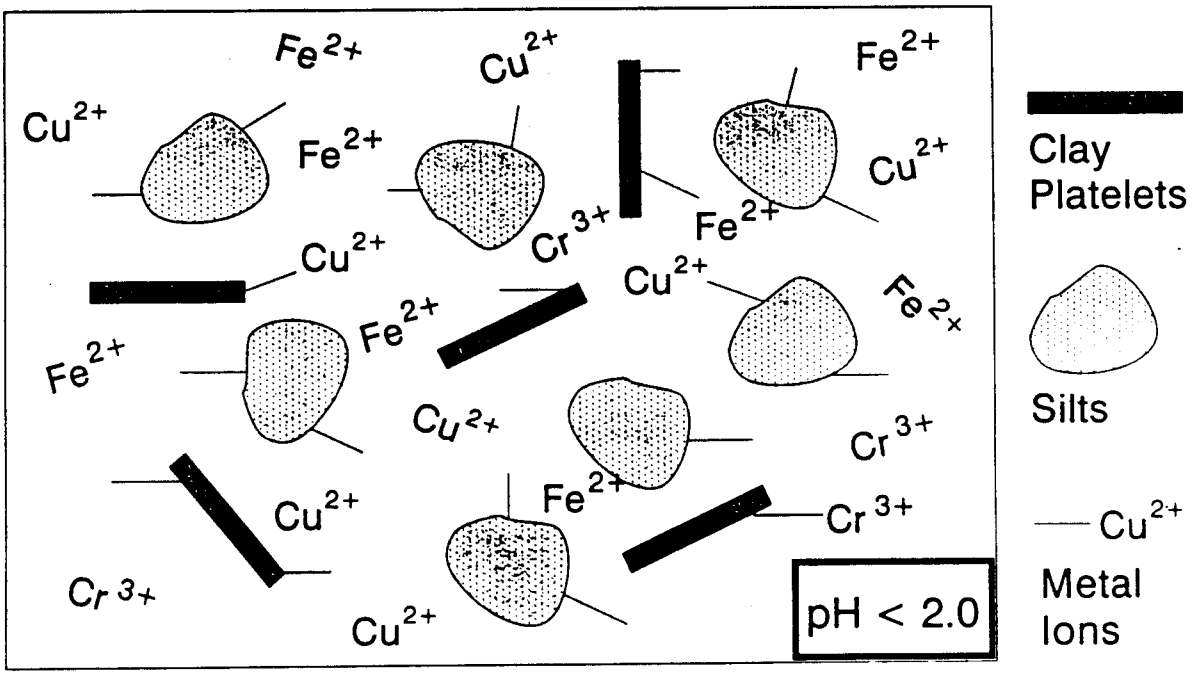
Total vs. Dissolved Arsenic in Ground-Water Samples



Adsorption of Metals
Prior to Sample Preservation



Desorption of Metals
Resulting from Sample Preservation



REASONS NOT TO FILTER SAMPLES

- To Allow Determination of "Total" Concentrations of Individual Constituents in a Sample
- To Prevent Physical and/or Chemical Alteration of the Sample Caused During Sample Transfer and Filtration (i.e. Aeration, Oxidation, and Resultant Precipitation of Metals; Removal of Gases Due to Partial Pressure Changes and Resultant Changes in pH)
- To Prevent Removal of Suspended (i.e. Colloidal) Particles from the Sample That May Be In Transit in a Ground-Water System (Particles That May Be Transporting Adsorbed Contaminants Via Facilitated Transport)
- To Prevent Introduction of Contaminants From the Filter Medium or Transfer Vessels Into the Sample
- To Avoid Lengthening the Sampling Process
- To Provide Comparability of Analytical Data with Data From Water Supply Wells

MATERIALS USED IN FILTER CONSTRUCTION

Disk Filters:

- Cellulose Nitrate
- Glass Microfiber
- PTFE
- Polycarbonate
- Cellulose Acetate
- Nylon (Hydrophilic)

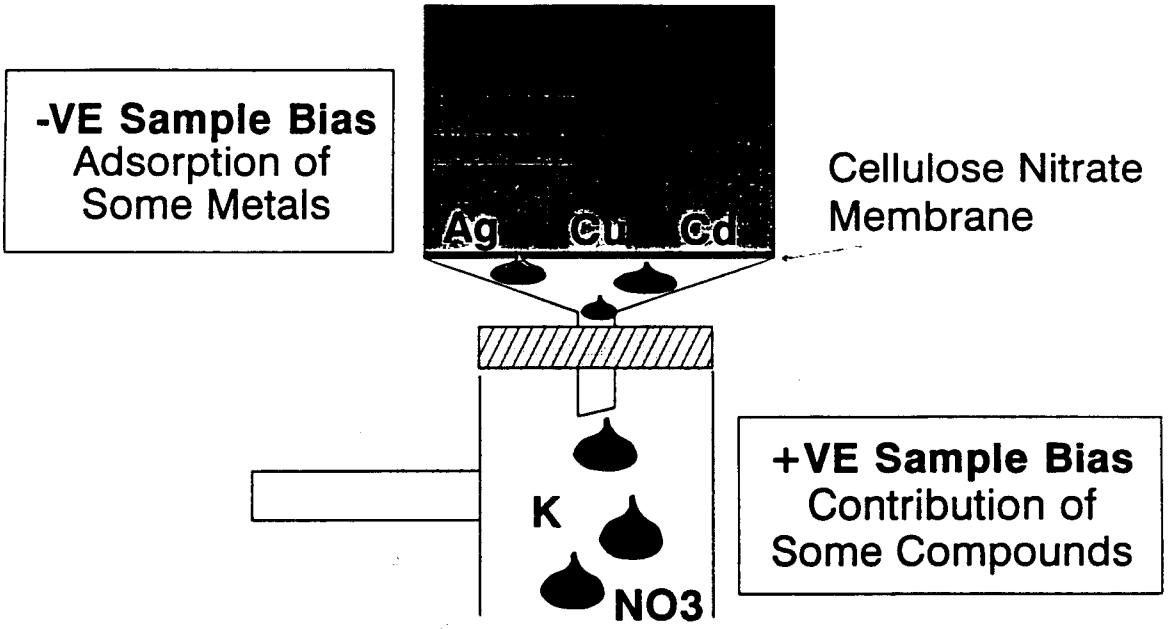
Filter Bags:

- Polyethersulfone (Supor)

Cartridge/Capsule Filters:

- Versapor (Acrylic Copolymer)
- PTFE
- Polycarbonate
- Nylon
- Polysulfone
- Cellulose Nitrate
- Cellulose Acetate
- Supor (Hydrophilic Polyether Sulfone Membrane)
- Thermopor (Polyether-Reinforced Polysulfone)

CELLULOSE NITRATE FILTRATION MEDIA
An Example of Potential Impact on Sample Chemistry



U.S. EPA RECOMMENDATIONS FOR GROUND-WATER SAMPLE FILTRATION

Samples That MAY Be Filtered

- Alkalinity
- Trace Metals
- Sensitive Inorganics
- Major Anions and Cations

Samples That Should NOT Be Filtered

- Volatile Organics
- TOX
- Dissolved Gases
- TOC
- Organic Compounds (Unless Specifically Required)

Source:
EPA/625/6-90/016b
07/1991

SAMPLE FILTRATION EQUIPMENT OPTIONS

- In-Situ Filtration Disks
- Vacuum Filtration
- Pressure Filtration
- Syringe Filters
- In-Line Cartridge Filters
  - With Bailers
  - With Transfer Vessels
  - With Pump Discharge Hoses

PREFILTRATION - PROS AND CONS

PROs

- Speeds Filtration of Sediment-Laden Samples
- Reduces Costs by Using Fewer Filter Papers

CONs

- Increases Potential for Changing Sample Chemistry Through:
  - Increased Contact Time with Air
  - Aeration of Samples
- Increases Equipment Requirements
- Increases Amount of Equipment that Must Be Cleaned Between Every Sample

FACTORS TO CONSIDER WHEN SELECTING SAMPLE FILTRATION EQUIPMENT

- Disposable vs. Common Equipment
- Volume of Sample to Be Filtered
- Potential for Changing Sample Chemistry By:
  - Changes in Partial Pressure
  - Contact Time with Ambient Air
  - Aeration of Samples During Filtration
- Ease of Use and Reliability in Field
- Compatibility of Materials with Sample
- Costs Associated with Initial Purchase, Supplies, Filtration Time, Cleaning Time and Down Time for Repairs and Maintenance
- Ability to Effectively Clean
- Ability to Use Filter Pore Size of 0.45μ

Preconditioning the filters

Wet membranes

3 or filter capacity volumes

↑

1 mm or 5 mm

SAMPLE PRESERVATION

Objective:
To Minimize Physical and/or Chemical Changes that May Occur in An Environmental Sample from the Moment of Collection to Sample Analysis

Potential Physical Change Mechanisms:
- Volatilization
- Adsorption and Absorption
- Diffusion
- Precipitation

Potential Chemical Change Mechanisms:
- Air Oxidation
- Photochemical Changes
- Microbiological Degradation

TYPES OF SAMPLE PRESERVATION

Physical Preservation
- Amber Glass Containers
- Aluminum Foil Layered Gas Bags
- Hard-Shelled Sample Shuttles and Coolers
- Wooded Core Boxes
- Double Packaging of Samples

Chemical Preservation
- Addition of Acids or Bases to Control pH
- Temperature Control
- Freezing

PRESERVATION TECHNIQUES TO MINIMIZE PHYSICAL SAMPLE CHANGES

Volatilization

- Collect Samples with Zero Headspace
  - Required for: Volatile Organics
    Total Organic Carbon
    Total Organic Halides

Adsorption and Absorption

- Proper Selection of Sample Containers on a Parameter-Specific Basis e.g. Plastic Bottles for Metals (Metals Irreversibly Adsorb onto Glass)
- Preserve Samples Immediately After Collection to Minimize Potential for:
  - Sample to Absorb Atmospheric Gases Which Initiate Air Oxidation (e.g. Sulfide Oxidizes to form Sulfate)

PRESERVATION TECHNIQUES TO MINIMIZE PHYSICAL SAMPLE CHANGES

Diffusion

- Use Appropriate Sample Containers (Usually Glass) with Teflon Liners Inside Caps (Organic Molecules such as Plasticizers and Phthalate Esters can Diffuse Through Walls of Plastic Sample Bottles and Caps)

Precipitation

- Adjust pH of Sample Immediately After Collection to Keep in Solution Ions that Have a Tendency to form Salts that Precipitate Out of Solution as a Result of Contact with Air and Changes in Temperature
  (Metal Oxides and Hydroxides Result from Reactions of Metal Ions with Oxygen)

ALTERNATIVES FOR CHEMICAL PRESERVATION OF AQUEOUS SAMPLES

Field Titration of Preservatives

Advantages

- Good Control Over pH Adjustment Process
- Assurance of Quality Chemical Solutions

Limitations

- Exposure of Sampling Team Members to Chemical Hazards
- Increased Sample Handling Time Often Results
- Can Be More Expensive
- Can Be Awkward to Do in the Field
- Must Have Quality Control Documentation to Show Source of Stock Solutions and How Dilutions Prepared

ALTERNATIVES FOR CHEMICAL PRESERVATION OF AQUEOUS SAMPLES

Preservatives Provided in Vials or Ampules

Advantages

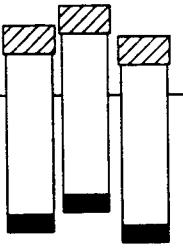
- Convenient
- Minimize Hazards Associated with Handling Concentrated and Large Volumes of Chemical Preservatives
- Available in a Variety of Volumes and Preservative Types

Limitations

- Fixed Volumes
- Must Be Purchased From a Reliable Supplier
- Glass Ampules Can Be Difficult to Open
- Empty Vials or Ampules Must Be Properly Disposed

ALTERNATIVES FOR CHEMICAL PRESERVATION OF AQUEOUS SAMPLES

Prepreserved Sample Bottles

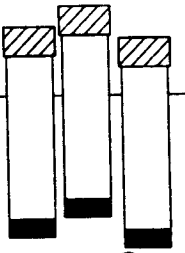


Advantages

- Convenient
- Reduces the Potential for Error in Using Incorrect Preservatives
- Minimizes Risks Associated with Handling Concentrated Preservative Solutions

ALTERNATIVES FOR CHEMICAL PRESERVATION OF AQUEOUS SAMPLES

Prepreserved Sample Bottles



Limitations

- Fixed Volume of Preservative
- Difficult to Obtain Additional Preservative from Same Supply (Manufacturer, Lot# etc.)
- Chemical Interactions Can Occur Between Bottle and Preservative Over Time
- Some Preservative May Form Vapors if Stored at Warm Temperatures Resulting in Exposure of Personnel
- Easy to Loose Preservative Through Overfilling of Sample Bottle or Knocking the Bottle Over

PRESERVATION TECHNIQUES TO MINIMIZE CHEMICAL SAMPLE CHANGES

Photochemical Changes

- Protect Samples From Exposure to Sunlight to Prevent Light-Catalyzed Reactions By Using:
  - Amber Glass Bottles
  - Aluminum-Layered Gas Sample Bags
  - Foil-Wrapped Samples
  - Dark Sample Shipment Containers

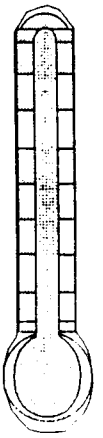
  e.g. Polychlorinated Biphenyls (PCBs)
  Polynuclear Aromatic Hydrocarbons

Microbial Degradation

- Adjust pH (Raise or Lower), Lower Temperature or Add Toxic Chemicals (e.g. Mercuric Chloride or Pentachlorophenol) to Sample to Inhibit Bacterial Activitity that Can Degrade Organic Compounds

OPTIONS FOR CONTROLLING SAMPLE TEMERATURE

- On-Site Refrigeration
- Refrigerating Coolers
- Dry Ice
- Natural Ice - Cubes, Blocks, Crushed
- "Blue Ice" Packs



Objective: To Cool Samples to 4.0°C From Time of Collection to Sample Receipt at Lab

SAMPLE FILTRATION

Puls, R.W., and Barcelona, M.J., 1988, Filtration of Ground-Water Samples for Metals Analysis; Hazardous Wastes and Hazardous Materials, Vol. 6, No. 4, pp. 385 - 393.

Puls, R.W., and Powell, R.M., 1992, Acquisition of Representative Ground Water Quality Samples for Metals; Ground Water Monitoring Review, Vol. 12 No. 3, pp. 167 - 176.

Burger, R.M., 1986, Positive Aspects of Sample Filtration; in Proceedings, Sixth National Symposium on Aquifer Restoration and Ground-Water Monitoring, National Ground Water Association, Dublin, OH, pp. 301 - 314.

Puls, R.W., and Eychaner, J.H., 1990, Sampling of Ground Water for Inorganics - Pumping Rate, Filtration and Oxidation Effects; in Proceedings, Fourth National Outdoor Action Conference, National Ground Water Association, Dublin, OH, pp. 313 - 327.

Kearl, P.M., Korte, N.E., and Cronk, T.A., 1992, Suggested Modifications to Ground-Water Sampling Procedures Based on Observations from the Colloidal Borescope; Ground Water Monitoring Review, Vol. 12 No. 2, pp. 155 - 160.

Patzke, J.A., 1989, Recommended Preparation Procedures for Ground-Water Samples Prior to Analysis for Inorganic Constituents; in Proceedings, Third National Outdoor Action Conference, National Ground Water Association, Dublin, OH, pp. 431 - 445.

Stolzenburg, T.R., and Nichols, D.G., 1986, Effects of Filtration Method and Sampling Devices on Inorganic Chemistry of Sampled Well Water; in Procedures, Sixth National Symposium on Aquifer Restoration and Ground-Water Monitoring, National Ground Water Association, Dublin, OH, pp. 216 - 234.

Stolzenburg, T.R., 1986, Ground Water Sampling Equipment and the Effects of Filtration on Ground Water Quality; in Subsurface Monitoring Technology Notebook, University of Wisconsin, Madison, WI, 14 pp.

Karfiatis, G.P., and Rapaioannou, C., 1986, Attenuation of Major Chemicals by Filters Used in Ground-Water Sampling Systems; in Proceedings, Third Eastern Regional Ground Water Conference, National Ground Water Association, Dublin, OH, pp. 494 - 502.

Perugini, F., and Jarke, FD.H., 1986, Techniques and Quality Control in Ground Water Sampling; in Proceedings, Sixth Annual Waste Testing and Quality Assurance Symposium, USEPA, Washington, DC. 15 pp.

Committee D-18 ON SOIL AND ROCK

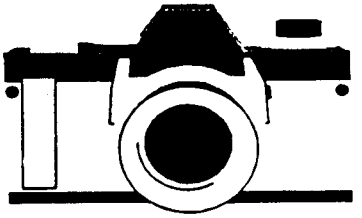
Fundamentals of Ground-Water Monitoring & Sampling Technology

SAMPLE HANDLING, SHIPMENT & DOCUMENTATION PROCEDURES

- Sample Preparation for Shipment
- Sample Shipment Issues
- Sample Security Systems
- Procedures for Documenting a Ground-Water Sampling Event

Instructor:

Gillian L. Nielsen
Nielsen Ground-Water Science, Inc.
4686 State Route 605 South
Galena, OH 43021-9652



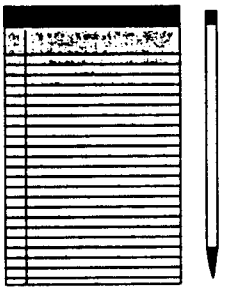
© 1995, Nielsen Ground-Water Science, Inc.
Galena, Ohio. All Rights Reserved.

These materials are copyright-protected under the laws of the United States and are the exclusive property of Nielsen Ground-Water Science, Inc. Any unauthorized duplication will result in prosecution.

SAMPLING EVENT DOCUMENTATION OPTIONS

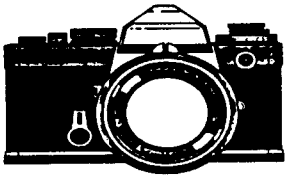
Written Records

- Dedicated Site Field Book
- Sample Bottle Labels
- Chain-of-Custody Forms
- Courier Manifest Forms
- Field Memos and Technical Reports



Audio-Visual Records

- 35 mm Slides
- Still Photographs
- Video Tape
- Tape Recorder



shipping

DOT 49 CFR

IATA

International Air Transportation Assoc.

HMTA (Haz. Mat Trans Act)

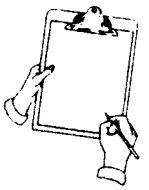
Docket HM181

PCS System

SPECIAL CONSIDERATIONS ASSOCIATED WITH DOCUMENTATION PROCEDURES

Written Records

- Only Site-Dedicated, Hard-Covered, Bound Notebooks Should Be Used for Recording All Field Observations and Measurements
- All Entries Should Be Made in Black, Indelible Ink
- In Instances of High Scrutiny of Data, GLPs Should Be Followed When Correcting Entries into the Field Book which Include:
  - Single Line Correction
  - Initialization and Coding of Change



COMMON FIELD DATA ERROR CODES

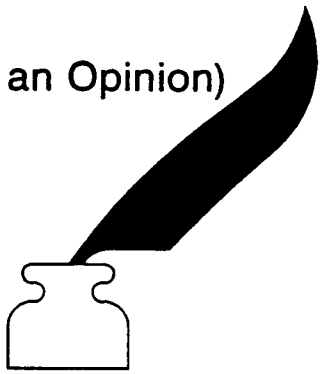
Error Codes Are Used to Explain Common Mistakes and Are Written Above or Close to the Mistake
Commonly Used Error Codes Include:

- RE Recording Error
- CE Calculation Error
- TE Transcription Error
- SE Spelling Error
- CL Changed for Clarity
- DC Original Sample Description Changed After Further Evaluation
- WO Write Over
- NI Not Initialled and Dated at Time of Entry
- OB Not Recorded at the Time of Initial Observation

Note: Error Code Should Be Circled When Recorded

When Recording Information in The Field Notebook, Make Sure Entries Are:

- Accurate
- Factual and Unbiased (Never Record an Opinion)
- Detailed but Concise
- Neat and Legible
- Understandable
- Written So Others Can "Reconstruct" What Occurred Later
- Written in Black Indelible Ink



INFORMATION TO RECORD DURING A GROUND-WATER SAMPLING EVENT

Beginning of the Day:

Weather

Time Arrived On-Site

People On-Site:
- Sampling Team Members
- Client Representatives
- Subcontractors
- Visitors/Guests
- Uninvited Intruders

Unusual Site Conditions

Statement of the Day's Objectives

Instrumentation Calibration Details

During Field Work (e.g. Monitoring Well Sampling)

Start Time

Observations on the Structural Integrity of the Well

Field Measurements for:
- Ambient Air Levels of Total VOCs
- Wellhead VOC Levels
- Water-Levels
- Well Depths

Well Volume Calculations

Discussion of Well Purging Strategy Used

Equipment Used for Purging

Comment on Hydraulic Performance of the Well During Purging

Description of Purge Water Appearance

Description of Purge Water Management

Actual Volumes of Water Removed During Purging

INFORMATION TO RECORD DURING A GROUND-WATER SAMPLING EVENT

- Description of Sampling Device Used, Operation and Setup Procedures
- Equipment and Procedures Used to Measure Specified Water Quality Parameters
- Results of Field Parameter Measurements
- List of Sample Bottles Filled And:
  - Order of Filling
  - Number & Types of Bottles
  - Sample Volumes per Parameter
  - Parameters to Be Analyzed
  - List Which Bottles Were Not Filled and Indicate Why
- Sample Description
- Sample and Shuttle Security Seal Numbers
- Chain-of-Custody Numbers
- Note Any Changes in Weather During Sampling
- Note Any Unusual Events or Activities During Sampling

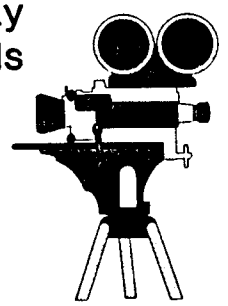
Following Field Work

- Method of Sample Shipment
- Time of Sample Delivery/Pick-Up
- Time All field Activities Were Completed
- List of People On-Site
- Weather Conditions
- Time Finally Left Site at End of the Day

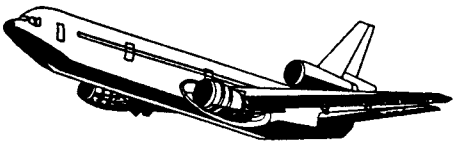
SPECIAL CONSIDERATIONS ASSOCIATED WITH SAMPLING EVENT DOCUMENTATION

Audio-Visual Records

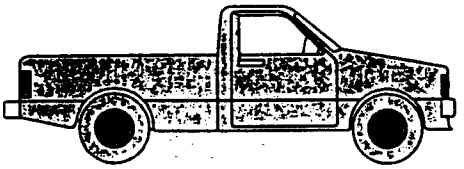
- May Be Necessary to Obtain Client Permission to Record Field Events
- Must Advise People Involved that Events are Being Recorded on Audio or Visual Tape
- In Cases Under Litigation, Courts May Restrict Use of Audio-Visual Materials (e.g. May Only Accept Photographs Taken with Self-Developing Film)



SAMPLE SHIPMENT CONSIDERATIONS



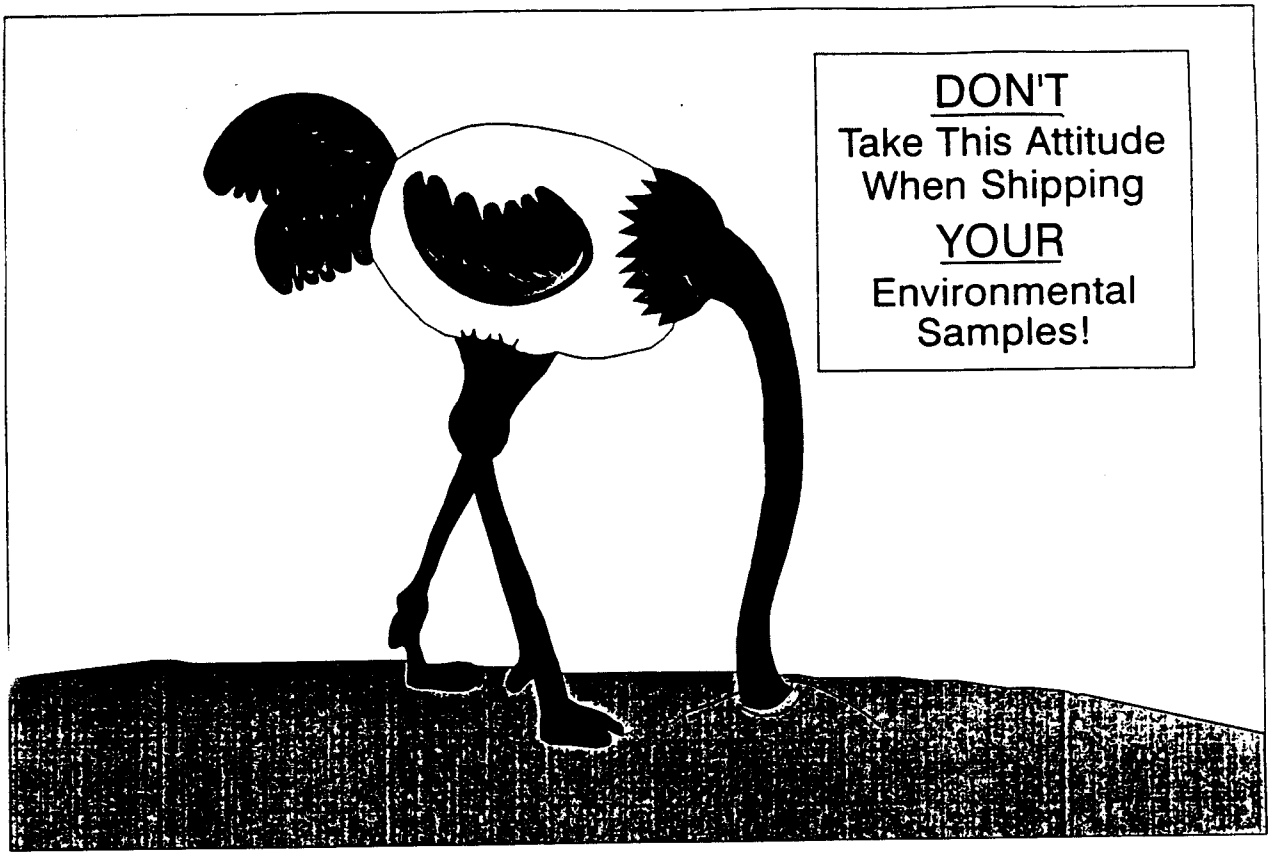
- Parameter-Specific Holding Times
- Availability of Pick-Up and Drop-Off Locations
- Compliance with Applicable Shipping Regulations (e.g. HMTA, RCRA) That Regulate Sample Labeling and Packaging
- Compatibility with Shipping Containers
- Cost



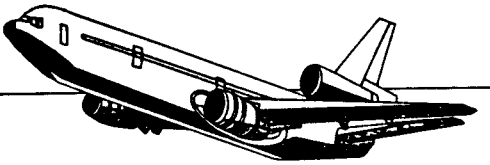
TYPICAL SAMPLE HOLDING TIMES

PARAMETER	HOLDING TIME
Volatile Organic Compounds	14 Days
Nitrogen, Nitrate	48 Hours
Metals	6 Months
Organochlorine Pesticides & PCBs	7/40*Days
Bacteria	6 Hours
Temperature	0-Field Measurement

NOTE: 7/40 Indicates Samples Must Be Extracted within 7 Days of Collection and Analyzed within 40 Days of Sample Extraction



Before You Ship .....



Do You Know the Following:

1. Hazard Characteristic(s) of the Sample(s) to Be Shipped
2. Correct Shipping Name and UN Number
3. Total Volume of Sample(s) to be Shipped
4. Packaging and Labeling Requirements That Comply with DOT and FAA Regulations
5. Limitations on Sample Volume and Weight Per Shipment

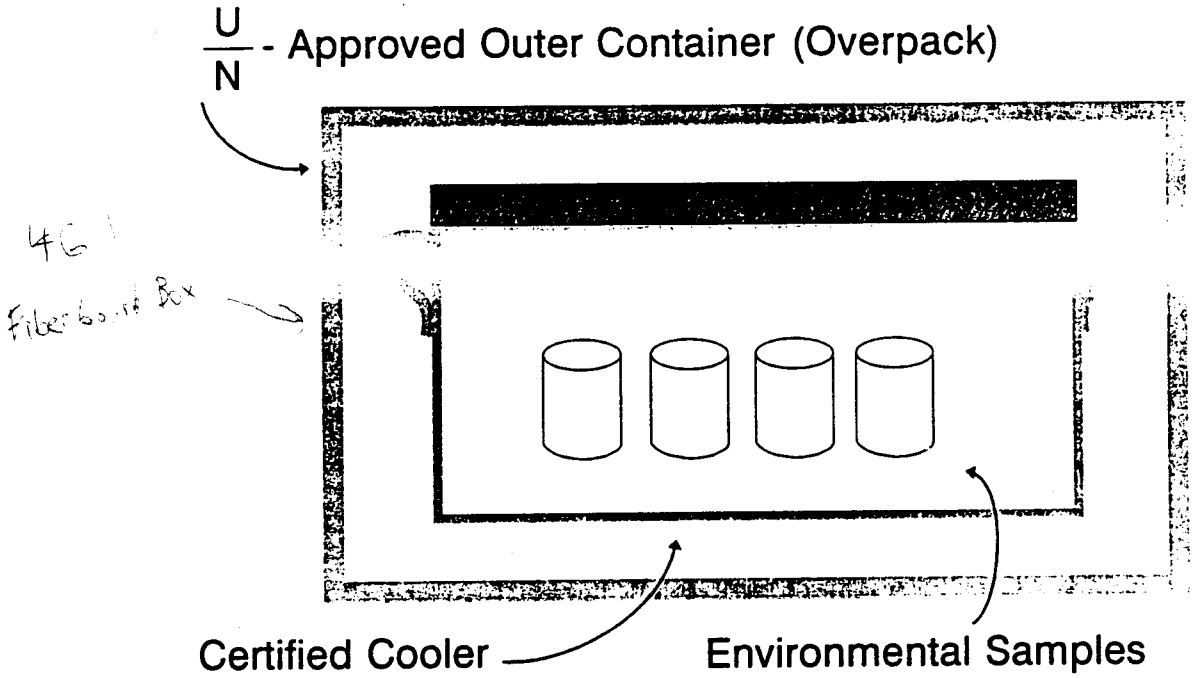
HOW TO DETERMINE THE POTENTIAL HAZARD CHARACTERISTICS OF FIRST-ROUND LAB SAMPLES

1. Literature Search - Historical and Current Records
2. Interviews with Site Personnel
3. External Appearance of Containment Systems
4. External Appearance of Material to be Sampled
5. Ambient Air Monitoring
6. Field Sample Screening
7. Field Laboratory Analysis

Who to Call If You Are Unsure

1. Local DOT Office
2. Local FAA Office
3. Local EPA Office or State Regulatory Agency Office
4. Commercial Carrier or Courier
5. Laboratory Performing the Sample Analyses
6. Your In-House Project Manager

SHIPPING SAMPLES IN COOLERS

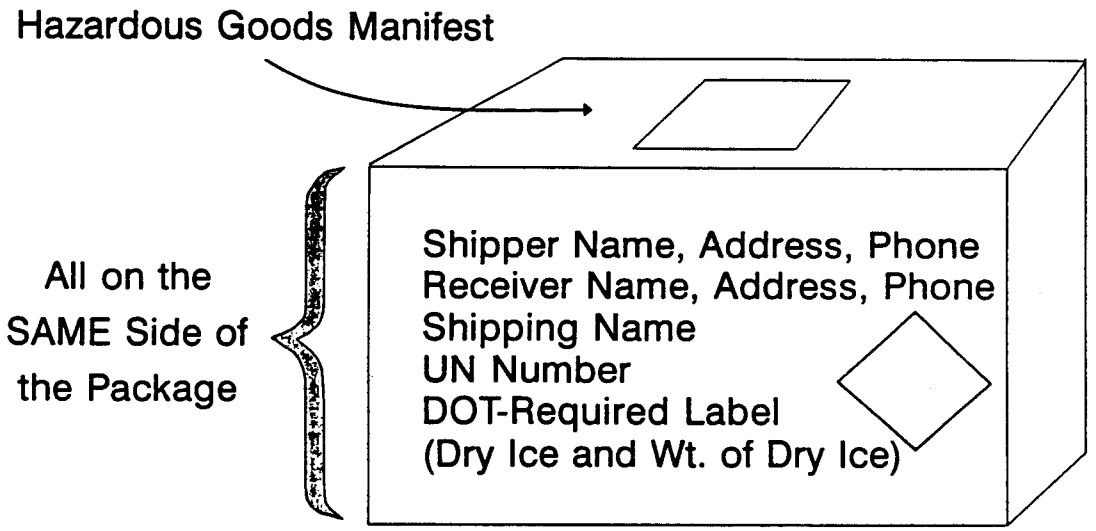


OPTIONS AVAILABLE FOR INTERNAL PACKAGING MATERIALS

- Vermiculite
- Foam Packing Blocks
- Bottle Wraps (Bubble Pack, Plastic Netting Sleeves)
- Styrofoam Packing Peanuts
- Sawdust
- Secondary Containers (Cans, Boxes, ZipLock Bags)

AVOID:
- Eco Pellets
- Pop Corn

PROPER LABELING OF SHIPMENTS



intern'l. symbol for "This Side Up"

SAMPLE SHIPMENT CONSIDERATIONS

- Selection of Shipment Method (Considering Time and Method of Travel)
  - Hand-Delivery by Sampling Team
  - Over-Night Courier Services
  - Ground-Delivery Couriers
  - Public Transportation Systems (e.g. Buses, Airlines)
  - Regular Mail
- Package Handling Practices
- Availability of Sample Manifesting
- DOT Restrictions on Samples Being Shipped

SAMPLE SECURITY PROGRAM OBJECTIVES

- Provide a Tracking System for All Samples
- Prevent Sample Tampering Between Collection and Receipt by the Laboratory
- Document Chain of Possession for All Samples
- Minimize Loss of Samples Due to Mishandling or Vandalism

In General, the More Sensitive the Program, the Greater the Control That Must Be Maintained on Sample Security

THE FUNDAMENTAL QUESTION OF SAMPLE SECURITY PROGRAMS ...

How is "Possession" of Samples Defined?

Possession Can Be Defined in <u>One</u> of the Following Ways:

- Physical Contact
- Visual Contact
- Within a Set Distance (e.g. 100 feet)
- Within the Sampling Team's Support Vehicle
- On-Site

AVAILABLE SAMPLE SECURITY MECHANISMS

Paper Trail Methods

- Chain-of-Custody Forms
- Courier Company Computerized Manifesting Systems
- Bar-Code Sample Tracking Systems
- Sample Bottle Labels
- Field Notes

Sample Tamper-Proofing Systems

- Security Seals on Sample Bottles
- Temporary Plastic Locking Seals on Shippers
- Coded, Plastic Locking Shipping Seals
- Padlocked Shippers
- Secure, On-Site Storage Lockers
- Locked, On-Site Refrigerators
- Posted Guards

CHAIN OF CUSTODY RECORD

PROJECT NO.	PROJECT NAME															
SAMPLERS (Signature)							NO. OF CONTAINERS								REMARKS	
STA. NO.	DATE	TIME	COMP.	GRAB	STATION LOCATION											

Relinquished by: (Signature)	Date/Time	Received by: (Signature)	Relinquished by: (Signature)	Date/Time	Received by: (Signature)
Relinquished by: (Signature)	Date/Time	Received by: (Signature)	Relinquished by: (Signature)	Date/Time	Received by: (Signature)
Relinquished by: (Signature)	Date/Time	Received for lab. by: (Signature)	Date/Time	Remarks	