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An Introduction to Field Explorations for Foundations

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1. INVESTIGATIONAL PROGRAMS. Field investigations can be divided into two major phases, a surface examination and a subsurface exploration:

Surface Examination	Subsurface Exploration
Documentary evidence	Preliminary
Field reconnaissance	Detailed
Local experience	

1.1 DOCUMENTARY EVIDENCE. The logical and necessary first step of any field investigation is the compilation of all pertinent information on geological and soil conditions at and in the vicinity of the site or sites under consideration, including previous excavations, material storage, and buildings. Use table 1 as a guide to sources and types of documentation.

1.2 FIELD RECONNAISSANCE. A thorough visual examination of the site and the surrounding area by the foundation engineer is essential. This activity may be combined with a survey of local experience. The field reconnaissance should include an examination of the following items as appropriate:

1.2.1 EXISTING CUTS (EITHER NATURAL OR MANMADE). Railway and highway cuts, pipeline trenches, and walls of river or stream valleys may reveal stratigraphy and offer opportunities to obtain general samples for basic tests, such as Atterberg limits and grain-size analysis for classification.

Types	Sources	Descriptions
Topographic, soil, drift (overburden) and bedrock maps	Local, state, federal and university geologic and agricultural organizations	These maps provide information on lay of land, faulting (tectonic), and material types
Surface and subsurface mining data, present and past	U.S. Bureau of Mines and state mining groups	Such data help locate subsurface shafts and surface pits. The presence of cavities in the foundation must be known. Current and even old workings may represent material sources for construction. In addition, surface pits near site may provide opportunity to observe stratification of foundation and allow taking of disturbed samples
Aerial photographs, continental U.S.	U.S. Government Printing Office	Aerial photos offer a valuable means of establishing some insight into the nature of foundation soils (2) and also expedite familiarization with the lay of the land
Aerial photographs, county and state areas	U. S. Soil Conservation Service, local or district office	
Local experience	Technical journals and technical reports; professional societies, universities, and state agencies	May include considerable boring data, test data, and descriptions of problems in construction
Boring logs, water well records, and construction records	State building commission, city hall, county courthouse, private concerns	Some of these types of information can usually be obtained for existing public buildings and facilities. Private firms may cooperate in providing limited data
Hydrological and tidal data	State agencies, river boards, U.S. Coast and Geodetic Survey, National Weather Service	

Table 1

Types and sources of documentary evidence

1.2.2 EVIDENCE OF IN SITU SOIL PERFORMANCE. A study of landslide scars contributes greatly to the design of excavation slopes; it may indicate need for bracing or suggest slope maintenance problems because of groundwater seepage. Evidence of general or localized subsidence suggests compressible subsoils, subsurface cavities, or ongoing sink-hole formations as in areas of limestone formations or abandoned mine cave-ins. Fault scarps or continuous cracks suggest bedrock movements or mass soil movements.

1.2.3 EXISTING STRUCTURES. Careful observation of damage to existing structures, such as cracks in buildings (or poor roof alignment), misaligned power lines, pavement conditions, corrosion on pipelines, or exposed metal and/or wood at water lines, may suggest foundation problems to be encountered or avoided.

1.2.4 GROUNDWATER. The extent of construction dewatering may be anticipated from factors such as the general water level in streams, spring lines, marshy ground, and variations in vegetal growth. The effects of lowering the water table during dewatering on surrounding structures, as well as potential environmental effects, should be appraised in a preliminary manner. Drainage problems likely to be encountered as a result of topography, confined working space, or increased runoff onto adjacent property should be noted.

1.2.5 AVAILABILITY OF CONSTRUCTION MATERIALS. The availability of local construction material and water is a major economic factor in foundation type and design. Possible borrow areas, quarries and commercial material sources, and availability of water should be noted.

1.2.6 SITE ACCESS. Access to the site for drilling and construction equipment should be appraised, including the effects of climate during the construction season.

1.2.7 FIELD INVESTIGATION RECORDS. Considering the value and possible complexity of a field investigation, a well-kept set of notes is a necessity. A camera should be used to supplement notes and to enable a better recall and/or information transfer to design personnel.

1.3 LOCAL EXPERIENCE. Special attention should be given to the knowledge of inhabitants of the area. Farmers are generally well informed about seasonal changes in soil conditions, groundwater, and stream flood frequencies. Owners of adjacent properties may be able to locate filled areas where old ponds, lakes, or wells have been filled, or where foundation of demolished structures are buried.

1.4 PRELIMINARY SUBSURFACE EXPLORATION. The purpose of preliminary subsurface explorations is to obtain approximate soil profiles and representative samples from principal strata or to determine bedrock or stratigraphic profiles by indirect methods. Auger or splitspoon borings are commonly used for obtaining representatives samples. Geophysical methods together with one to several borings are often used in preliminary exploration of sites for large projects, as they are rapid and relatively cheap. Procedures for geophysical exploration are described in standard textbooks on geotechnical engineering. Borings are necessary to establish and verify correlations with geophysical data. Preliminary reconnaissance explorations furnish data for planning detailed and special exploration of sites for large and important projects. The preliminary exploration may be sufficient for some construction purposes, such as excavation or borrow materials. It may be adequate also for foundation design of small warehouses, residential buildings, and retaining walls located in localities where soil properties have been reasonably well established as summarized in empirical rules of the local building code.

1.5 DETAILED SUBSURFACE EXPLORATIONS. For important construction, complex subsurface conditions, and cases where preliminary subsurface explorations provide insufficient data for design, more detailed investigations are necessary. The purpose is to obtain detailed geologic profiles, undisturbed samples and cores for laboratory testing, or larger and fairly continuous representative samples of possible construction materials. Test pits and trenches can be used to depths of 15 to 25 feet by using front-end loaders or backhoes at a cost that may compare favorably with other methods, such as auger borings. Test pits allow visual inspection of foundation soils; also, high-quality undisturbed block samples may be obtained. Continuous (2 1/2 - to 5-foot intervals) sampling by means of opendrive, piston, or core-boring samplers is used for deeper explorations. Penetration, sounding or in situ tests, such as vane shear, or pressure meter tests may be conducted depending on sampling difficulty or desired information.

2. SOIL BORING PROGRAM.

2.1 LOCATION AND SPACING. Borings spaced in a rigid pattern often do not disclose unfavorable subsurface conditions; therefore, boring locations should be selected to define geological units and subsurface nonconformities. Borings may have to be spaced at 40 feet or less when erratic subsurface conditions are encountered, in order to delineate lenses, boulders, bedrock irregularities, etc. When localized building foundation areas are explored, initial borings should be located near building corners, but locations should allow some final shifting on the site. The number of borings should never be less than three and preferably five-one at each corner and one at the center, unless subsurface conditions are known to be uniform and the foundation area is small. These preliminary borings must be supplemented by intermediate borings as required by the extent of the area, location of critical loaded areas, subsurface conditions, and local practice.

2.2 DEPTH OF EXPLORATION. The required depth of exploration may be only 5 to 10 feet below grade for residential construction and lightly loaded warehouses and office buildings, provided highly compressible soils are known to not occur at greater depths. For important or heavily loaded foundations, borings must extend into strata of adequate bearing capacity and should penetrate all soft or loose deposits even if over-lain by strata of stiff or dense soils. The borings should be of sufficient depth to establish if groundwater will affect construction, cause uplift, or decrease bearing capacity. When pumping quantities must be estimated, at least two borings should extend to a depth that will define the aquifer depth and thickness. Borings may generally be stopped when rock is encountered or after a penetration of 5 to 20 feet into strata of exceptional stiffness. To assure that boulders are not mistaken for bedrock, rock coring for 5 to 10 feet is required. When an important structure is to be founded on rock, core boring should penetrate the rock sufficiently to determine its quality and character and the depth and thickness of the weathered zone. Rock coring is expensive and slow, and the minimum size standard core diameter should be used that will provide good cores. NX or larger core sizes may be required in some rock strata. Core barrels can remove cores in standard 5-, 10-, and 20-foot lengths (actual core may be much fractured, however). Detailed exploration should be carried to a depth that encompasses all soil strata likely to be significantly affected by structure loading. If the structure is not founded on piles, the significant depth is about 1 1/2 to 2 times the width of the loaded area. An estimate of the required depth can be made using the stress influence charts in the technical literature to find the depth such that:

$$\Delta q \leq 0.1 q_0 \qquad \text{(eq 1)}$$

where Δq represents an increase in strata stress and q_0 is the foundation contact pressure. Note that in the case of a pile foundation, stresses are produced in the ground to an appreciable depth below the tips of the piles. Procedures to obtain Dq apply as for other foundations. This depth criterion may not be adequate for complex and variable subsurface conditions.

2.3 PLUGGING BORINGS. All borings should be carefully plugged with non-contaminating material if:

2.3.1 Artesian water is present or will be when the excavation is made.

2.3.2 Necessary to avoid pollution of the aquifer from surface infiltration, leaching, etc.

2.3.3 Necessary to preserve a perched water table (avoid bottom drainage through borehole).

2.3.4 Area is adjacent to stream or river where flood stage may create artesian pressure through the borehole.

2.4 SAMPLE REQUIREMENTS. Table 2 may be used as a guide for required sizes of undisturbed samples, and table 3 for general samples. The sampling program may depend on drilling equipment available and laboratory facilities where tests will be performed.

Test	Minimum Sample Diameter, inches
Unit weight	3.0
Permeability	3.0
Consolidation	5.0
Triaxial compression [a]	5.0
Unconfined compression	3.0
Direct shear	5.0

[a] Triaxial test specimens are prepared by cutting a short section of 5-in.-diam sample axially into four quadrants and trimming each quadrant to the proper size. Three quadrants provide for three tests representing the same depth; the fourth quadrant is preserved for a check test.

Table 2

Recommended undisturbed sample diameters

Test	Minimum Sample Required, Dry Weight (pounds) [a]
Water content	5.0
Atterberg limits	2.0
Shrinkage limits	5.0
Specific gravity	2.0
Grain-size analysis	5.0
Standard compaction	30.0
Permeability	2.0
Direct shear	2.0
4-inch diameter consolidation	2.0
1.4 inch diameter triaxial (4 points)	2.0
2.8 inch diameter triaxial (4 points)	8.0
6-, 12- or 15-inch diameter triaxial (4 points)	Discuss with laboratory
Vibrated density	Discuss with laboratory

[a] Fine grained (all minus No. 4 sieve). For material containing plus No. 4 sieve sizes, the sampling requirements should be discussed with the laboratory. In the final analysis, it is the responsibility of the engineer requesting the tests to ensure that adequate size samples are obtained. Close coordination with the testing laboratories is essential.

Table 3

Recommended minimum quantity of material for general sample laboratory testing

2.4.1 UNDISTURBED SAMPLES. Any method of taking and removing a sample results in a stress change, possible pore water change, and some structure alteration because of displacement effects of the sampler. Careful attention to details and use of proper equipment can reduce disturbance to a tolerable amount. Sample disturbance is related to the area ratio A_r, defined as follows:

$$A_r = [(D_0^2 – d_1^2)/D_1^2] \times 100\% \qquad \text{(eq 2)}$$

where:

D_0 = outside diameter of sampler tube

D_1 = internal diameter of the cutting shoe through which the sample passes (commonly the cutting edge is swedged to a lesser diameter than the inside tube wall thickness to reduce friction)

The area ratio should be less than 10 percent for undisturbed sampling. Undisturbed samples are commonly taken by thin-wall seamless steel tubing from 2 to 3 inches in diameter and lengths from 2 to 4 feet. Undisturbed samples for shear, triaxial, and consolidation testing are commonly 3 inches in diameter, but 5-inch-diameter samples are much preferred. An indication of sample quality is the recovery ratio, L_r , defined as follows:

L_r = Length of recovered sample/ Length sample tube pushed (eq 3)

A value for $L_r < 1$ indicates that the sample was compressed or lost during recovery, and $L_r > 1$ indicates that the sample expanded during recovery or the excess soil was forced into the sampler.

2.4.2 REPRESENTATIVE SAMPLES. Samples can be obtained by means of auger or drive-sampling methods. Thick-wall, solid, or split-barrel drive samplers can be used for all but gravelly soils. Samples taken with a drive sampler should be not less than 2 inches, and preferably 3 inches or more in diameter. Where loose sands or soft silts are encountered, a special sampler with a flap valve or a plunger is usually required to hold the material in the barrel. A bailer can be used to obtain sands and gravel samples from below the water table. Split-spoon samples should be used to obtain representative samples in all cases where piles are to be driven or the density of cohesionless materials must be estimated.

3. FIELD MEASUREMENTS OF RELATIVE DENSITY AND CONSISTENCY.

3.1 STANDARD PENETRATION TEST (SPT). This test is of practical importance as it provides a rough approximation of the relative density or consistency of foundation soils and should always be made when piles are to be driven. The split spoon is usually driven a total of 18 inches; the penetration resistance is based on the last 12 inches-the first 6 inches being to seat the sampler in undisturbed soil at the bottom of the boring. "Refusal" is usually taken at a blow count of 50 per 6 inches. (Commercial firms will usually charge an increased price per foot of boring when the blow count (N-value) ranges from greater than 50 to 60 blows per foot of penetration due both to reduced daily footage of drilling and wear of equipment.) An approximate correlation of results with density for cohesionless soils is shown in figure 1, and with Φ in figure 4-2; but Φ values above 35 degrees should not be used for design on the basis of these correlations. There is no unique relationship between N-values and relative density (DR) that is valid for all sands. The SPT data should be correlated with tests on undisturbed samples on large projects.

3.2 CONE PENETRATION TESTS . In this test, a coneshaped penetrometer is pushed into the soil at a slow constant rate; the pressure required to advance the cone is termed the penetration resistance. The Dutch cone is the most popular. The penetration resistance had been correlated with relative density of sands and undrained shear strength of clays.

3.3 VANE TESTS. The in situ shear strength of soft to medium clays can be measured by pushing a small four-blade vane, attached to the end of a rod, into the soil and measuring the maximum torque necessary to start rotation (shearing of a cylinder of soil of approximately the dimensions of the vane blades). The undrained shear strength, s_u, is computed from this, T, as follows:

$$T = s_u \Phi [(d^2h/2) + (d^3/4)] \qquad \text{(eq 4)}$$

where:

d = diameter of vanes

h = height of vane

φ = 2/3 for uniform end-shear (usual assumption) distribution

= 3/5 for parabolic end-shear distribution

= 1/2 for triangular end-shear distribution

The vane shear is best adapted to normally consolidated, sensitive clays having an undrained shear strength of less than 500 pounds per square foot. The device is not suitable for use in soils containing sand layers, many pebbles, or fibrous organic material. Vane tests should be correlated with unconfined compression tests before they are used extensively in any area. Strength values measured using field vane shear tests should be corrected for the effects of anisotropy and strain rate using Bjerrum's correction factor, λ, shown in figure 3. This value represents an average and should be multiplied by 0.8 to obtain a lower limit. The correction is based upon field failures.

(Refer to American Society of Civil Engineers . "Task Committee for Foundation Design Manual of the Committee on Shallow Foundations " Journal, Soil Mechanics and Foundations Division, No. SM6. 1972.)

Figure 1

Relative density of sand from the standard penetration test

3.4 BOREHOLE PRESSUREMETER TEST. A pressuremeter can be used to obtain the in situ shear modulus and/or K_0. Several versions of the device exist including self-boring equipment, which tends to avoid the loss of K_o conditions caused by soil relaxation when a hole is pre-drilled and then the device is inserted. The method is subject to wide interpretation and should not normally be employed in conventional investigations.

4. BORING LOGS. The results of the boring program shall be shown in terms of graphic logs of boring. The logs of borings shall be prepared in accordance with governmental standards. A typical log of boring is shown in figure 4.

5. GROUNDWATER OBSERVATIONS. In many types of construction it is necessary to know the position of the groundwater level, its seasonal variations, how it is affected by tides, adjacent rivers or canals, or the water pressures in pervious strata at various depths. Possible future changes in groundwater conditions, such as those resulting from irrigation or reservoir construction, should be anticipated.

5.1 BOREHOLES. With many fine-grained soils it may be necessary to wait for long time periods before water table equilibrium is reached in boreholes. Observations made in a borehole during or shortly after drilling may be misleading. Even with pervious soil, a water level reading should be taken 24 hours or more after drilling is stopped.

(Refer to J. H. Schmertmann, “The Measurement of In Situ Shear Strength, " Proceedings, Conference on In Situ Measurement of Soil Properties. Raleigh. N. C., Vol 2, 1975, pp 57-180. American Society of Civil Engineers. Reston, VA)

Figure 2

Rough correlation between effective friction angle, standard blow count, and effective overburden pressure

Water level readings obtained in drill holes should be shown on the boring log with the date of the reading and the date when the drill hole was made.

5.2 PIEZOMETERS. Piezometers provide an accurate means for determining the groundwater level over a period of time. In pervious strata, a temporary piezometer may consist of a section of riser pipe, the open bottom end of which is placed in a bag (filter) of coarse sand or gravel. The annular space between the piezometer riser pipe and the drill hole immediately above the stratum in which the water level is to be determined should be sealed off with well-tamped clay or cement, or chemical grout. In granular soils where a more permanent system is desired, a 2-foot section of well-point screen can be attached to the bottom of the pipe. A well-point screen should be selected that will prevent entrance of foundation materials into the screen, or else a suitable filter material should be used. For all piezometers, seal the top several feet below ground surface around the riser pipe to prevent infiltration of surface water. In granular soils, the riser pipe is normally about 1 1/4-inches inside diameter and generally made of plastic. In cohesive soils, a Casagrande-type piezometer (fig 5) is recommended. The water level in the piezometer is determined by means of a plumb line or sounding device. If the piezometric level is above ground surface, a manometer or a Bourdon gage can be connected to the riser pipe to greatly decrease the time for equilibrium to be achieved. If rapidly changing pore water pressures in clay are to be determined, use closed system piezometers.

(Refer to L Bjerrum, "Embankment on Soft Ground, " Proceedings, Conference on Performance of Earth and Earth-Supported Structures. Purdue University. Lafayette, Ind., Vol 2, 1975. Reprinted by permission of the American Society of Civil Engineers, Reston, VA.)

Figure 3

Correction factor for vane strength

5.3 FIELD PUMPING TESTS. Where accurate knowledge of the permeability of the foundation soils is necessary, field pumping tests offer the most reliable means. A rough estimate of the average permeability of the material around the bottom of a cased drill hole may be obtained by lowering or raising the water level in the casing and observing the rise and fall of the water level as a function of time with respect to the stabilized piezometric water level. A field pumping test is best performed by pumping from a well in which a constant flow is maintained until the drawdown has stabilized, and when groundwater levels are measured at several remote borings or piezometers. It is desirable that well screens fully penetrate the strata for which the permeability is to be measured. Formulas for computing the overall permeability of a pervious stratum exhibiting gravity or artesian flow are shown in figure 5. The formula for the special case of a fully penetrating well and artesian aquifer is given as an example in figure 6.

6. IN SITU LOAD TESTS. Load tests are commonly made on test piles to confirm design capacity and may occasionally be used to determine bearing capacity and settlement characteristics. In general, specialized equipment and procedures are required to perform load tests and considerable judgment and expertise must be employed to interpret results. Plate load tests are occasionally used for bearing capacity determinations.

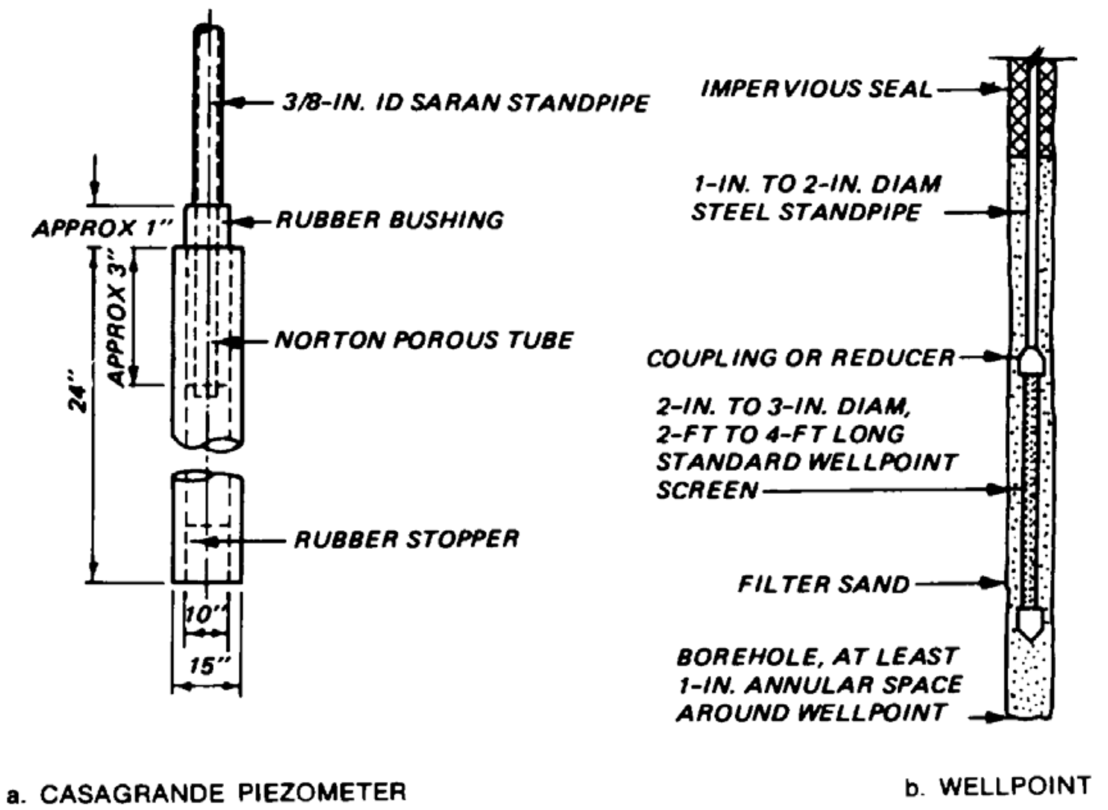
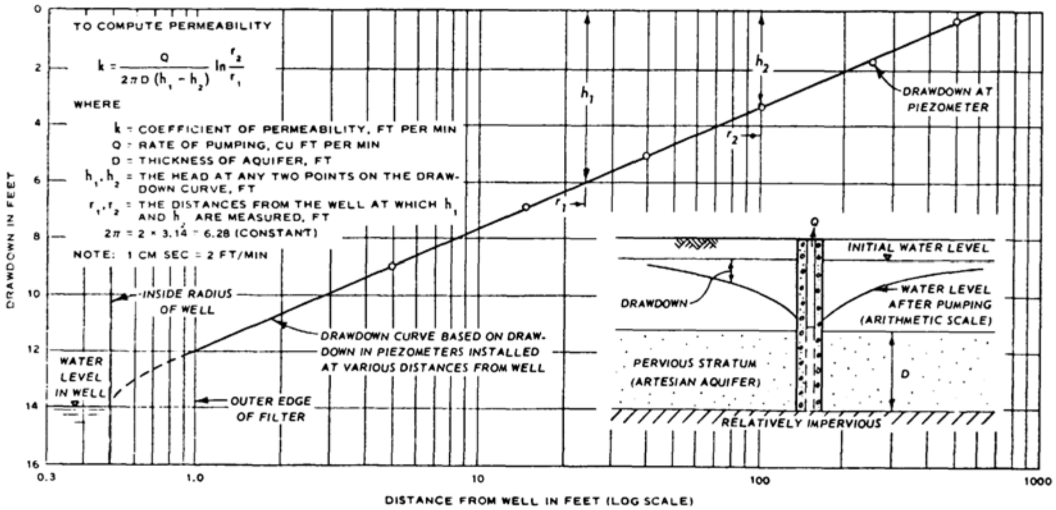


Figure 5

Typical details of Casagrande piezometer and piezometer using well screen

7. GEOPHYSICAL EXPLORATION. Geophysical methods of subsurface exploration are well suited for large sites due to the increasing cost of borings. Table 4 summarizes those geophysical methods most appropriate for site exploration. These methods are useful for interpolation between borings. Geophysical data must be used in conjunction with borings and interpreted by qualified experienced personnel, or misleading information is almost certain to result. The two most applicable geophysical methods for exploring foundations currently in use are seismic refraction and electrical resistivity. Information secured by seismic refraction is primarily depth to bedrock and delineation of interfaces between zones of differing velocities. An electrical resistivity survey is superior in differentiating between sand and clays. Both methods require distinct differences in properties of foundation strata materials to be effective. The resistivity method requires a high-resistivity contrast between materials being located. The seismic method requires that the contrast in wave transmission velocities be high and that any underlying stratum transmit waves at a higher velocity (more dense) than the overlying stratum. Some difficulties arise in the use of the seismic method if the surface terrain and/or layer interfaces are steeply sloping or irregular instead of relatively horizontal and smooth.



NOTE. WELL SHOULD BE PUMPED AT A CONSTANT RATE OF FLOW UNTIL THE RATE OF DRAWDOWN IN WELL AND PIEZOMETERS IS ESSENTIALLY CONSTANT. DRAWDOWN AT EQUILIBRIUM VERSUS DISTANCE FROM WELL PLOTS AS A STRAIGHTLINE ON SEMI-LOGARITHMIC PLOT.

Figure 6

Determination of permeability from field pumping test on a fully penetrating well in an artesian aquifer

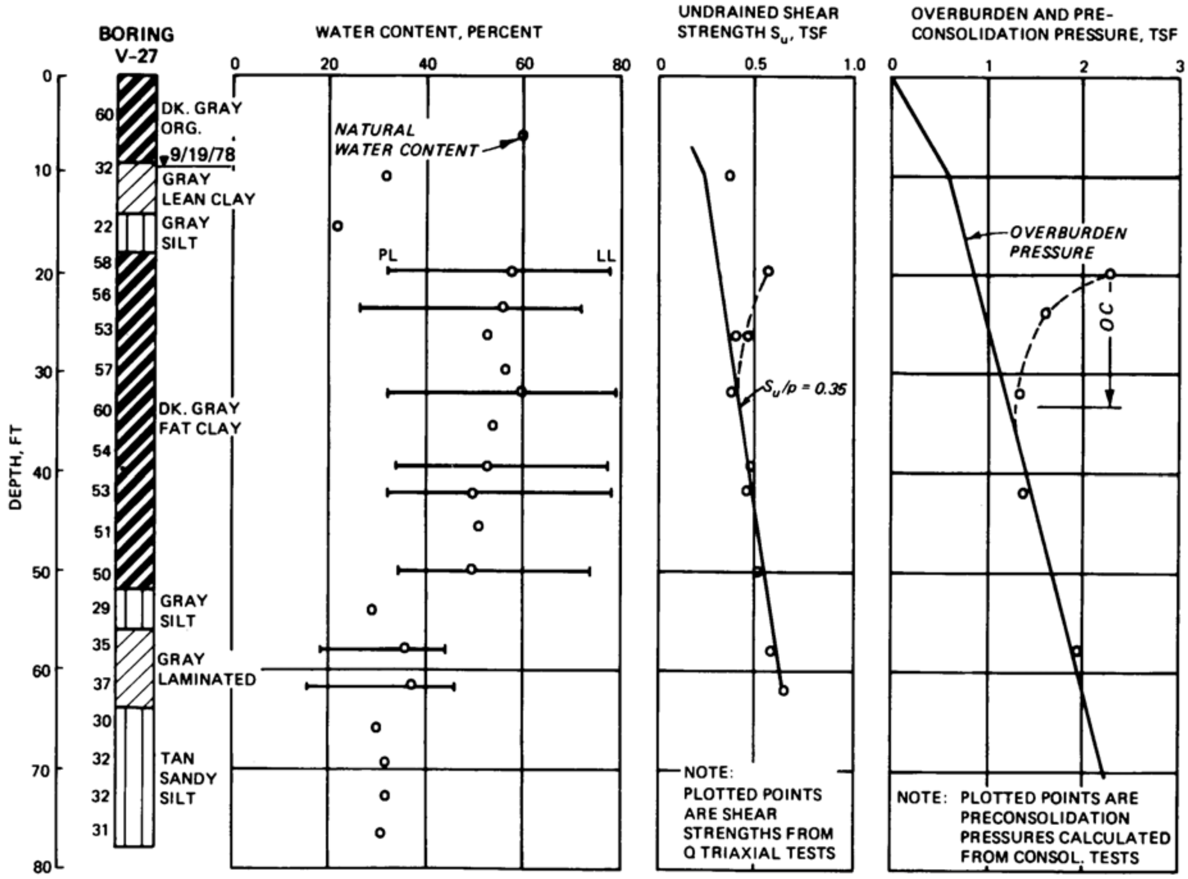


Figure 4

Typical log of boring

Name of method	Procedure or principle utilized	Applicability
Seismic methods		
Refraction	Based on time required for seismic waves to travel from source of blast to point on ground surface, as measured by geophones spaced at intervals on a line at the surface. Refraction of seismic waves at the interface between different strata gives a pattern of arrival times versus distance at a line of geophones.	Utilized to determine depth to rock or other lower stratum substantially different in wave velocity than the overlying material. Used only where wave velocity in successive layers becomes greater with depth. Used to determine rock type, rock and soil stratification, depth of weathered zone, etc.
Continuous vibration	The travel time of transverse or shear waves generated by a mechanical vibrator consisting of a pair of eccentrically weighted disks is recorded by seismic detectors placed at specific distances from the vibrator.	Velocity of wave travel end natural period of vibration gives some indication of soil type. Travel time plotted as a function of distance indicates depths or thicknesses of surface strata. Useful in determining dynamic modulus of subgrade reaction and obtaining information on the natural period of vibration for design of foundations of vibrating structures.
Electrical methods		
Resistivity	Based on the difference in electrical conductivity or resistivity of strata. Resistivity of subsoils at various depths is determined by measuring the potential drop and current flowing between two current and two potential electrodes from a battery source. Resistivity is correlated to material type.	Used to determine horizontal extent and depth of subsurface strata. Principal applications for investigating foundations of dams and other large structures, particularly in exploring granular river channel deposits or bedrock surfaces, sources of construction material, potential infiltration and seepage zones, and in cavity detection.
Drop in potential	Based on the determination of the ratio of potential drops between three potential electrodes as a function of the current imposed on two current electrodes.	Similar to resistivity methods but gives sharper indication of vertical or steeply inclined boundaries and more accurate depth determinations. More susceptible than resistivity method to surface interference and minor irregularities in surface soils.
Acoustic method		
	The time of travel of sound waves reflected from the mud line beneath a body of water and a lower rock surface is computed by predetermining the velocity of sound in the various media.	Currently used in shallow underwater exploration to determine position of mud line and depth to hard stratum underlying mud. Method has been used in water depths greater than 100 feet with penetrations of 850 feet to bedrock. Excellent display of subsurface stratification. Used most efficiently in water depths up to 50 feet with penetrations of additional 350 feet to bedrock.

Table 4

Surface Geophysical Methods

8. BOREHOLE SURVEYING.

8.1 Downhole surveying devices can be used in providing quantitative engineering parameters, such as porosity, density, water content, and moduli. Once a boring has been made, the cost of using these tools in the borehole is relatively modest. Different devices currently in use are summarized in table 5.

8.2 These devices can allow cost savings to be made in the exploration program without lessening the quality of the information obtained.

Device	Measurement obtained	Primary use
Electric logging		
Spontaneous potential (SP)	Natural voltages between fluids in materials of dissimilar lithology	Differentiating between sands and clays
Single-point resistivity	Resistance of rock adjacent to hole	With SP log provides good indication of subsurface stratification
Multiple-point resistivity	Resistivity of formations	Determination of mud infiltration and effective porosity
Radiation logging		
Gamma	Natural gamma radiation of materials	Identification of clay seams, location of radioactive tracers, and with SP and resistivity logs provides information on relative porosity
Neutron	Hydrogen atom concentration	Determination of moisture content and porosity below zone of saturation porosity
Gamma-gamma	Gamma radiation absorption	Correlates with bulk density and useful to determine porosity if grain specific gravity is known
Sonic logging		
Acousity velocity	Travel time of primary and shear wave site logs determine velocities	With caliper and density logs determine dynamic elastic and shear moduli of in situ rock
Acousitc imagery	Reflected acoustic energy	Locate fractures and voids and strike and dip of joints, faults, bedding planes, etc.
Fluid logging		
Temperature	Temperature gradient in borehole	Determine geothermal gradient and definition of aquifers
Fluid resistivity	Electrical resistance of borehole fluids	With temperature data the determination of dissolved solids—locate zones of water loss or gain
Trace ejector	Controlled ejection of trace elements	Groundwater flow patterns
Fluid sampler	Borehole or formation fluid from predetermined depths	Uncontaminated samples for water quality studies

Table 5

Borehole surveying devices

Visual logging		
Borescope	Visual image of the sidewalls of borehole to depths of 100 ft or less--a periscopic instrument	Cheap, rapid examination of borehole walls
Borehole camera	Photograph of a 360 degree sweep of the borehole wall taken approximately at right angles to the wall. Exposures timed so that slight overlap of each photograph is obtained	Examination of borehole conditions, bedding,joints, etc.
Downhole camera	Photograph of the sidewalls of the borehole taken from the bottom be of the camera. Several feet of hole below device taken with each exposure	Cheap, rapid examination of borehole walls
Borehole television	Image of the sidewalls of the borehole displayed at the time of exposure on a surface monitor	Examination of borehole conditions, bedding,joints, etc.
Miscellaneous logging		
Caliper	Borehole size	Washouts, fractures, etc., needed for interpretation of other logs
Borehole surveyor	Downhole directional survey	Precise location and attitude of features recorded on other logging tools

Table 5 (continued)

Borehole surveying devices