

CHAPTER 5. REQUIREMENTS FOR GEOLOGIC INVESTIGATIONS  
AND SAMPLING

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## CHAPTER 5. REQUIREMENTS FOR GEOLOGIC INVESTIGATIONS AND SAMPLING

Requirements for design and construction vary widely depending on such conditions as size and purpose of the structure, kinds of construction materials, site conditions, and economic and safety considerations. Geologic site investigations and soil mechanics tests are geared to requirements for design and construction. Hence the procedures and intensity of investigation and the kinds of samples taken vary from site to site. This chapter outlines the requirements for preliminary and detailed site investigations and sampling and also the minimum requirements for intensity of study and for sampling for soil mechanics tests.

### Intensity of Site Investigations

Before beginning specific site studies, the geologist should make a reconnaissance survey of the watershed or general area to become familiar with the general geologic situation. He should then make a preliminary geologic investigation of all structure sites to determine geologic conditions and characteristics of materials (both consolidated and unconsolidated) pertinent to design. This should be done regardless of purpose of the structure, source of funds, or contractor. Detailed subsurface exploration or the collection and testing of samples may not be necessary for small, no-hazard structures, such as farm ponds, drop structures, or chutes, to be built in areas of generally homogeneous materials. For these structures, the engineering characteristics of the material at the site need only to be recognized and evaluated on the basis of experience in the area.

### Geologic Reconnaissance

Before starting specific site studies, the geologist should become familiar with the general geologic conditions of the area. This can be done by reviewing available data, by examining topographic and geologic maps, and by making a reconnaissance survey. Data gathered during the reconnaissance are primarily descriptive and should include the items in the following list.

1. General geology of possible dam sites.
2. Geologic conditions that may affect channel stability and improvement.
3. Geologic conditions that may influence ground-water movement and recharge.
4. Ground-water conditions.
5. General character of streams and valleys, including steepness of grade and side slopes, bed material, and whether the stream is aggrading or degrading.
6. General availability of suitable construction materials.

### Preliminary Site Investigation

The geologist should make a preliminary or surface examination of every site where a structure is planned. This investigation should

include a thorough inspection of outcrops, cut banks, and other surface exposures and an examination of erosion conditions, landslides, seeps, springs, and other pertinent conditions in and adjacent to the watershed to obtain the basic information needed to evaluate the geologic conditions and the character of materials at the site.

The purpose of the preliminary investigation is to determine the geologic feasibility of the site and the extent of detailed subsurface investigation that will be required and to furnish the engineer with enough information to make sound cost estimates. At some sites, the preliminary investigation may furnish enough data on geologic conditions and engineering characteristics of materials for design purposes.

#### Detailed Site Investigation

A detailed site investigation is made to determine the geologic conditions and to provide the engineer with information for use in design and construction. Usually, detailed subsurface investigations require separate scheduling of equipment such as backhoes, dozers, power augers, and core drills.

Detailed subsurface investigations must be of sufficient intensity to determine all the conditions that may influence the design, construction, and functioning of the structure. The extent of geologic investigation required for a particular dam site depends on (1) complexity of site conditions, (2) size of the structure, (3) potential damage if there is structural failure, and (4) purpose of the structure.

Detailed exploration consists of two phases: (1) Determining and interpreting subsurface conditions and (2) taking samples for soil mechanics tests.

During phase 1, test holes must be put down and logged in the foundation, emergency spillway, and borrow areas. These test holes must be deep enough to insure penetration of all pertinent materials. The number and spacing of test holes must be adequate for correlation in both longitudinal and transverse directions and to the distance needed for complete interpretation of any condition that may influence the design of the structure. Geologic structural features, such as faults, folds, and joints, must be identified and located. Enough information must be obtained on unconsolidated deposits to classify them genetically and to determine their location, thickness, and extent. Test holes can be put down by drilling or by excavating open pits or trenches. Where drilling methods are used, the standard drop-penetration test (blow count) is to be made in cohesive foundation materials below the water table and in noncohesive materials where practical. This test provides a measure of the resistance of the material to penetration by the sampler and also furnishes samples of the material penetrated for identification, classification, and logging. The test is used to evaluate in-place density of the materials. Additional in-place field tests are to be made where needed.

In phase 2 of the detailed site investigation, the data gathered in phase 1 are analyzed on site and the behavior characteristics and engineering significance of the materials and conditions logged are evaluated. From this analysis and evaluation the geologist and engineer determine what materials are to be sampled and what laboratory analyses are needed. This determines the kind, number, and size of samples needed. The necessary samples are obtained by using appropriate sampling procedures. Any additional or special in-place field tests that are needed should be made.

#### Classification of Structure Sites for Geologic Investigation

Engineering Memorandum SCS-33 (Rev. 1960) establishes the following broad groups of structure sites to permit the association of minimum requirements for geologic investigations with maximum fill height of the proposed dam, construction materials, purpose of the structure, and the damage that might result from a sudden major breach of the earth-dam embankment (Engineering Memorandum SCS-27).

##### Group I Dam Sites

This group includes proposed sites for--

- a. All class (c) dams.
- b. All class (b) dams.
- c. All dams with maximum fill height of 35 feet or more not included in class (b) and class (c).
- d. All structures of the following types more than 20 feet high: Concrete or masonry arch or gravity dams, drop spillways, box-inlet drop spillways, and chutes.
- e. All dams with maximum fill height of more than 20 feet where the principal purpose is forming storage reservoirs for recreation, municipal water supply, or irrigation and where the product of the storage times the height of the dam is more than 3,000.

##### Group II Dam Sites

This group includes proposed sites for--

- a. All dams not included in class (c) or class (b) with maximum fill height of 25 to 35 feet.
- b. All structures of the following types with maximum height of 10 to 20 feet: Concrete or masonry arch or gravity dams, drop spillways, box-inlet drop spillways, and chutes.
- c. All dams less than 20 feet high where the principal purpose is creating storage reservoirs for recreation, municipal water supply, and irrigation and where the product of the storage times the height of the dam is between 1,000 and 3,000.

##### Group III Dam Sites

This group includes proposed sites for--

- a. All other types of dams not included in groups I and II.

Minimum Requirements for Geologic Investigations

The following criteria establish the minimum site investigations that will provide an acceptable basis for design and construction. The investigations needed above this minimum will vary somewhat based on the complexity of the site and the class of the structure.

Group I Dam Sites

All sites in this group must be investigated under the supervision of a qualified geologist. This applies to the preliminary investigation as well as the detailed and subsurface exploration. Subsurface exploration must be of sufficient intensity to:

1. Delineate and determine engineering characteristics, continuity, relative permeability and other pertinent characteristics of all materials to the specified depth beneath the entire base and abutment area, or area of influence, of the dam and outlet structure. The structural area of influence may be far into the abutments or may be the entire reservoir basin under some geologic conditions or structure purposes.
2. Determine the attitude, location, extent, and character of such geologic features as folds, faults, joints, solution cavities, unconformities, schistosity, slaty cleavage, and bedding. In some cases, angle holes may be necessary to help define these factors.
3. Delineate the incompressible rock surface where within the depth of influence.
4. Determine the extent and character of materials to be excavated for open spillways and the character and slope stability of the material in the spillway cut slopes.
5. Determine the depth, thickness, continuity, distribution, and engineering properties of the material proposed for use as fill.
6. Determine the depth to ground water and the extent and character of aquifers.
7. Verify the presence or absence of economic mineral deposits within the area of influence.

The depth to which the above information must be obtained will in no case be less than equivalent to the proposed height of fill unless hard, massive, unweathered or otherwise unaltered rock is encountered at a shallower depth. Extend borings far enough into rock to determine its character and condition and whether it is in place.

The minimum depth of borings in weak or compressible materials, where the influence of loading by the fill may be significant to depths greater than the height of the dam, will be determined in consultation with the responsible design engineer.

For all concrete dams, the depth of borings will be no less than 1.5 times the height of the controlled head of the dam.

All borings are to be sufficiently deep and closely spaced to establish reliable correlation of strata under the entire base of the structure. The number, depth and the spacing of holes needed depend on such geologic features as regularity, continuity, and attitude of strata and character of geologic structures.

Sufficient borings must be made along the centerline of drop inlets or other conduits to provide reliable correlation of all strata from the riser to the outlet and to a depth equal to the zone of influence of the structure. Where rock occurs within the zone of influence, the investigation must accurately delineate the rock surface below the centerline of the conduit. Normally, bore holes are placed at the riser, at the intersection of the centerlines of the dam and conduit, and at the outlet, with sufficient holes in between to furnish reliable correlation.

Where an excavated emergency spillway is planned, investigations must be of sufficient intensity to determine quantity and character of the materials to be excavated, limits of common and rock excavation, suitability of the excavated material for use in construction, and erodibility of the resulting spillway channel. Each boring for emergency-spillway investigations must extend to a depth of not less than 2 feet below the bottom of the proposed emergency spillway. A sufficient number of emergency-spillway holes must extend a minimum of 20 feet below the bottom to determine the erodibility of the bulk of the material in the spillway.

Enough borings must be made in the borrow areas to identify and establish the distribution and thickness of all materials to be used for fill. All borrow-area borings should extend at least 2 feet below the expected depth to which material is to be removed unless consolidated material that is not suitable for fill is found. Determine the depth to ground water at the time of boring for all borrow-area borings.

Hydraulic-pressure tests are to be made in rock foundations and abutments of proposed dams forming storage reservoirs. This test consists of a holding test of not more than 1 p.s.i. per foot of depth below ground surface, followed by a pumping test if the pressure drop in the holding test exceeds 10 p.s.i. per minute (chapter 2).

### Group II Dam Sites

A geologist is to make the preliminary site investigation and to determine what is needed in the way of a detailed site study.

The intensity of subsurface exploration and sampling needed for sites of the larger structures in group II is similar to that for group I sites. General experience in the area, present geologic information, and the preliminary geologic examination, however, may provide enough information so that a less intensive program of subsurface exploration and sampling will suffice for the sites of smaller structures in this group.

### Group III Dam Sites

The intensity of investigation needed for group III structure sites can usually be determined by persons holding positions to which job-approval authority for the class of structure under consideration has been delegated by State memorandum. In areas where there is little or no experience on which to base conclusions and in areas where geologic conditions are complex, a geologist should be consulted. A geologist is to investigate those structure sites in group III that require the technical approval of the head of the EWP Unit.

For very small structures, the economic feasibility of site studies must be considered. Weigh the cost of such studies against the cost of the structure and the possible adverse effects of structural or functional failure.

### Minimum Requirements for Sampling of Dam Sites

The intensity of sampling needed, like the intensity of site investigations, varies with design requirements. Thus the minimum sampling requirements can be coordinated with the various dam-site groups established to determine the intensity of geologic investigation needed.

### Group I Dam Sites

It is essential that adequate samples be obtained both for field examination and for testing and analysis by a soil mechanics laboratory. This usually means taking both undisturbed and disturbed samples of unconsolidated materials and in some places obtaining rock core samples.

For all sites in group I, representative samples for classification purposes should be taken of all types of materials in the borrow, foundation, relief-well, and spillway sections.

For all sites in groups Ia, Ib, and Ic, samples for compaction and shear tests should be taken from the borrow and emergency-spillway areas. For sites in groups Id and Ie, samples for compaction tests should be taken from the borrow and emergency-spillway areas if there is not enough information or experience in the area to definitely determine the behavior of materials.

For all sites in groups Ia, Ib, and Ic and for the sites of all dams more than 25 feet high in groups Id and Ie, undisturbed samples for shear tests should be taken from all strata of fine-grained soils of questionable stability in the foundation within a depth equivalent to one-half the height of the dam.

For all sites in groups Ia, Ib, and Ic, undisturbed samples for consolidation tests should be taken of all fine-grained materials of questionable stability within a depth equivalent to the maximum height of the dam. Where compressible materials extend to depths greater than the height of the dam, the depth from which such samples should be taken must be increased. For sites in groups Id and Ie, such samples are also to be taken of questionable materials of low shear strength, such as soft clays and soft silts, in the foundations of dams more than 25 feet high.

For sites in group I, samples for chemical analysis should be taken of all water supplies to be used for construction of the embankment or of concrete appurtenances if it is suspected that the water contains a high concentration of salts (particularly sulfates and alkalies) or of humic and other acids that have a deleterious effect on construction materials.

For all sites in group I, samples should be taken of all materials proposed for stabilization by soil cement or chemical methods.

For all sites in group I, samples should be taken of reservoir and abutment materials to determine reservoir-sealing requirements if storage (other than sediment-pool storage) is to be incorporated in the design and if moderate or serious leakage is suspected.

#### Group II Dam Sites

For all dam sites in group II, representative samples for classification purposes should be taken of all types of materials in the borrow, emergency-spillway, foundation, and relief-well sections.

For all sites in group IIa, samples for compaction tests should be taken from the borrow and emergency-spillway areas.

For all sites in group II, undisturbed samples for shear tests are required if questionable materials of low shear strength are encountered. Soft clays and silts that develop low shear resistance because of the nature of particles are included. Usually undisturbed samples are not required for shear tests of foundation materials of dams less than 25 feet high.

Samples for consolidation tests are required under the same conditions as those outlined for shear tests. If compressible materials are encountered, samples may be needed from depths greater than the equivalent height of the dam.

The sampling requirements for permeability tests, water analyses, soil-cement tests, and reservoir-sealing tests for dam sites in group II are the same as for dam sites in group I.

Group III Dam Sites

For dam sites in group III, samples for laboratory analysis are not usually necessary if adequate information and experience is available in the area on which to base conclusions. Where such information is not available or if highly questionable conditions are found, sampling may be necessary.