Chapter 3
Regional Geologic and Site Reconnaissance Investigations

3-1. Background

Regional geologic and site reconnaissance investigations are made to develop the project regional geology and to scope early site investigations. The steps involved and the data needed to evaluate the regional geology of a site are provided in Figure 2-1. The initial phase of a geologic and site reconnaissance investigation is to collect existing geologic background data through coordination and cooperation from private, Federal, State, and local agencies. Geologic information collected should then be thoroughly reviewed and analyzed to determine its validity and identify deficiencies. Geologic data should also be analyzed to determine additional data requirements critical to long-term studies at specific sites, such as ground water and seismicity, that will require advance planning and early action. Upon completion of the initial phase, a geologic field reconnaissance should be conducted to examine important geologic features and potential problem areas identified during collection of background data. Field observations are used to supplement background data and identify the need to collect additional data.

a. Geologic model. Geologic background and field data that are determined to be valid should be used to construct a geologic model for each site. The model, which will require revisions as additional information is obtained, should indicate possible locations and types of geologic features that would control the selection of project features. Preliminary geologic, seismic, hydrologic, and economic studies should be used to indicate the most favorable sites before preliminary subsurface investigations are started. Proper coordination and timing of these studies, and incorporation into a GIS, can minimize costs and maximize confidence in the results.

b. Small projects. Many civil works projects are too small to afford a complete field reconnaissance study as outlined below. For smaller projects, emphasis should be placed on compilation and analysis of existing data, remote sensing imagery, and subsurface information derived from on-site drilling and construction excavations. A geologist or geotechnical engineer should be available to record critical geotechnical information that comes to light during investigations. An extensive photographic and video record taken by personnel with some background in geology or geotechnical engineering can serve as a reasonable proxy for onsite investigations.

Section I
Coordination and Information Collection

3-2. Interagency Coordination and Cooperation

Sources of background information available from other organizations can have a substantial influence on project economy, safety, and feasibility. During initial investigations, project geologists may be unfamiliar with both the regional and local geology. Limited funds must be allocated to many diverse areas of study (e.g., economics, real estate, environment, hydrology, and geology). For these reasons, contacts should be made with Federal, State, and local agencies to identify available sources of existing geologic information applicable to the project. A policy of formal coordination with the USGS has been established as outlined in the following text. In addition, informal coordination should be maintained with state geological surveys because critical geologic data and technical information are often available from these agencies. Other organizations listed below may also provide valuable information.

a. Coordination with USGS. The 27 October 1978 Memorandum of Understanding (MOU) with the USGS provided for exchange of information to assure that all geologic features are considered in project planning and design. The MOU outlines three main activities:

(1) The USGS provides the Corps of Engineers with existing information and results of research and investigations of regional and local geology, seismology, and hydrology relevant to site selection and design.

(2) The USGS advises the Corps of Engineers on geologic, seismologic, and hydrologic processes where knowledge is well developed and on specific features of site and regional problems.

(3) The Corps provides the USGS with geologic, seismologic, and hydrologic data developed from Corps studies.

The MOU requires that the USGS be notified in writing if planning studies are to be initiated at a new site or reinitiated at a dormant project. The notification should specify the location of interest and identify specific geologic, seismologic, and hydrologic considerations for which information is needed.

b. Other organizations. Contacts and visits to offices of the following organizations can produce valuable geotechnical information in the form of published maps and reports and unpublished data from current projects.

(1) Federal agencies.

(a) Department of Agriculture. - Forest Service - Natural Resource Conservation Service

(b) Department of Energy.

(c) Department of Interior. - Bureau of Indian Affairs - Bureau of Land Management

- Bureau of Reclamation - Fish and Wildlife Service - Geological Survey

- National Park Service - National Biological Service.

(d) Department of Transportation. - Federal Highway Administration regional and state division offices.

(e) Environmental Protection Agency regional offices.

(f) Nuclear Regulatory Commission.

(g) Tennessee Valley Authority.

(2) State agencies.

(a) Geological Surveys, Departments of Natural Resources, and Departments of Environmental Management.

(b) Highway departments.

(3) Municipal engineering and water service offices.

(4) State and private universities (geology and civil engineering departments).

(5) Private mining, oil, gas, sand, and gravel companies.

(6) Geotechnical engineering firms.

(7) Environmental assessment firms.

(8) Professional society publications.

3-3. Survey of Available Information

Information and data pertinent to the project can be obtained from a careful search through published and unpublished papers, reports, maps, records, and consultations with the USGS, state geologic and geotechnical agencies, and other Federal, state, and local agencies. This information must be evaluated to determine its validity for use throughout development of the project. Deficiencies and problems must be identified early so that studies for obtaining needed information can be planned to assure economy of time and money**.** Especially in the case of larger projects, data are most effectively compiled and analyzed in a GIS format. Table 3-1 summarizes the sources of topographic, geologic, and special maps and geologic reports. Most states regulate well installation and operation and maintain water well data bases that extend back many years. Wells may be municipal, industrial, domestic, or may have been drilled for exploration or production of natural gas. The information that is commonly available includes date of installation, screened interval, installer's name, depth, location, owner, and abandonment data. Lithologic logs may also be available and, in rare cases, production and water quality information.

Section II
Map Studies and Remote Sensing Methods

3-4. Map Studies

Various types of published maps, such as topographic, geologic, mineral resource, soils, and special miscellaneous maps, can be used to obtain geologic information and develop regional geology prior to field reconnaissance and exploration work. The types of available maps and their uses are described in Dodd, Fuller, and Clark (1989).

a. Project base map. Spatial components typically used to define a GIS referenced base map include: topographic maps, aerial photographs (digital orthophotos), monumentation/survey control maps, surface/subsurface geology maps, land use maps, bathymetry maps, and various forms of remotely sensed data. Project-specific planimetric maps, digital terrain models (DTMs), and digital elevation models (DEMs) are produced through photogrammetric methods and can be generated using a GIS. A DTM may be used to interpolate and plot a topographic contour map, generate two-dimensional (2-D) (contour) or three-dimensional (3-D) (perspective) views of the modeled surface, determine earthwork quantities, and produce cross sections along arbitrary alignments.

Table 3-1
Sources of Geologic Information

Agency	Type of Information	Description	Remarks
USGS	Topographic maps	U.S. 7.5-minute series 1:24,000 (supersedes 1:31,680). Puerto Rico 7.5-minute series1:20,000 (supersedes 1:30,000) Virgin Island 1:24,000 series. U.S. 15-minute series 1:62,500 (1:63,360 for Alaska) U.S. 1:100,000-scale series (quadrangle, county, or regional format) U.S. 1:50,000-scale county map series U.S. 1:250,000-scale series Digital elevation models are available for entire U.S. at 1:250,000, and for certain areas at 1:100,000 and 1:24,000 scales. Digital line graphs are available for some areas at 1:24,000, 1:65,000, 1:100,000 for: - Hydrography - Transportation - Boundaries - Hypsography	Orthophotoquad monocolor and color infrared maps also produced in 7.5- and 15-min series. New index of maps for each state began in 1976. Status of current mapping from USGS regional offices and in monthly USGS bulletin, "New publications of the U.S. Geological Survey." Topographic and geological information from the USGS can be accessed through the ESIC (1 800 USAMAPS)
USGS	Geology maps and reports	1:24,000 (1:20,000 Puerto Rico), 1:62,500, 1:100,000, and 1:250,000 quadrangle series includes surficial bedrock and standard (surface and bedrock) maps with major landslide areas shown on later editions 1:500,000 and 1:2,500,000	New index of geologic maps for each state began in 1976. List of geologic maps and reports for each state published periodically
USGS	Miscellaneous maps and reports	Landslide susceptibility rating, swelling soils, engineering geology, water resources, and ground water	Miscellaneous Investigation Series and Miscellaneous Field Studies Series, maps and reports, not well cataloged; many included as open file reports
USGS	Special maps	1:7,500,000 and 1:1,000,000: Limestone Resources, Solution Mining Subsidence, Quaternary Dating Applications, Lithologic Map of U.S., Quaternary Geologic Map of Chicago, Illinois, and Minneapolis, Minnesota, areas	
USGS	Hydrologic maps	Hydrologic Investigations Atlases with a principal map scale of 1:24,000; includes water availability, flood areas, surface drainage precipitation and climate, geology, availability of ground and surface water, water quality and use, and streamflow characteristics	Some maps show ground water contours and location of wells
USGS	Earthquake hazard	Seismic maps of each state (began in 1978 with Maine); field studies of fault zones; relocation of epicenters in eastern U.S.; hazards in the Mississippi Valley area; analyses of strong motion data; state-of-the-art workshops	Operates National Strong-Motion Network and National Earthquake Information Service publishes monthly listing of epicenters (worldwide). Information is available through ESIC (1 800 USAMAPS)

(Sheet 1 of 3)

Table 3-1 (Continued)

Agency	Type of Information	Description	Remarks
USGS	Mineral resources	Bedrock and surface geologic mapping; engineering geologic investigations; map of power generating plants of U.S. (location of build, under construction, planned, and type); 7.5-min quadrangle geologic maps and reports on surface effects of subsidence into underground mine openings of eastern Powder River Basin, Wyoming	
USGS	Bibliography	"Bibliography of North American Geology," (USGS 1973)	USGS Professional Paper
American Geological Institute	Bibliography	(American Geological Institute) print counterpart.	
		"Bibliography and Index of Geology" to "Geo Ref" digital index (USGS 1973)	1977 to present, 12 monthly issues plus yearly cumulative index
National Oceanic and Atmospheric Administration (NOAA)	Earthquake hazards	National Geophysical Center in Colorado contains extensive earthquake hazard information (303-497-6419)	
National Aeronautics and Space Administration (NASA)	Remote sensing data	Landsat, skylab imagery	
NOAA	Remote sensing data		
Earth Observation Sattelite (EOSAT)	Remote sensing data		
US Fish and Wildlife Service (FWS)	Wetlands	The National Wetlands Inventory maps at 1:24,000 for most of the contiguous U.S.	Available as maps or mylar overlays
USGS	Flood-prone area maps	1:24,000 series maps outlining floodplain areas not included in Corps of Engineers reports or protected by levees	Stage 2 of 1966 89th Congress House Document 465
USAEWES	Earthquake hazard	"State-of-the-Art for Assessing Earthquake Hazards in the United States," Miscellaneous Paper S-73-1 (Krinitzsky 1995)	Series of 29 reports, 1973 to present
Natural Resources Conservation Service (NRCS)	Soil survey reports	1:15,840 or 1:20,000 maps of soil information on photomosaic background for each county. Recent reports include engineering test data for soils mapped, depth to water and bedrock, soil profiles grain-size distribution, engineering interpretation, and special features. Recent aerial photo coverage of many areas. Soils maps at 1:7,500,000 and 1:250,000, 1:31,680, and 1:12,000 scale are available in digital format for some areas.	Reports since 1957 contain engineering uses of soils mapped, parent materials, geologic origin, climate, physiographic setting, and profiles

(Sheet 2 of 3)

Table 3-1 (Concluded)

Agency	Type of Information	Description	Remarks
State Geologic Agencies	Geologic maps and reports	State and county geologic maps; mineral resource maps; special maps such as for swelling soils; bulletins and monographs; well logs; water resources, ground water studies	List of maps and reports published annually, unpublished information by direct coordination with state geologist
Defense Mapping Agency (DMA)	Topographic maps	Standard scales of 1:12,500, 1:50,000, 1:250,000 and 1:1,000,000 foreign and worldwide coverage, including photomaps	Index of available maps from DMA
American Association of Petroleum Geologists	Geological highway map series	Scale approximately 1 in. equal 30 miles shows surface geology and includes generalized time and rock unit columns, physiographic map, tectonic map, geologic history summary, and sections	Published as 12 regional maps including Alaska and Hawaii
TVA	Topographic maps, geologic maps and reports	Standard 7.5-min TVA-USGS topographic maps, project pool maps, large-scale topographic maps of reservoirs, geologic maps, and reports in connection with construction projects	Coordinate with TVA for available specific information
U.S. Department of Interior, Bureau of Reclamation (USBR)	Geologic maps and reports	Maps and reports prepared during project planning and design studies	List of major current projects and project engineers can be obtained. Reports on completed projects by interlibrary loan or from USAEWES for many dams
Agricultural Stabilization and Conservation Services Aerial Photography Field Office (APFO)	Aerial photographs	The APFO offers aerial photographs across the U.S. Typically a series of photographs taken at different times, as available for a given site	Information is available at 801-975-3503
USGS Earth Resources Observation Systems (EROS) Center (EDC)	Aerial photographic coverage	The EDC houses the nation's largest collection of space and aircraft acquired imagery	Information is available at 605-594-6151 or 1 800 USAMAPS
Satellite Pour l' Observation de la Terre' (SPOT)	Remote sensing imagery	High-resolution multispectral imagery produced by France's SPOT satellite imager is available for purchase	Contact for SPOT images is at 800-275-7768

(Sheet 3 of 3)

(1) Geotechnical parameters resulting from surface and subsurface explorations can be georeferenced to a DTM resulting in a spatial data base capable of producing geologic cross sections and 2- and 3-D strata surface generation. Georeferencing spatial data requires that the information be precisely located. Global Positioning System (GPS) techniques offer a rapid and reliable way to accomplish this (EM 1110-1-1003). Even with a GPS however, surveyed monuments and benchmarks must be identified and used as control points in the survey. Benchmark and brass cap information is available through the National Geodetic Survey of NOAA for the entire United States guidance and criteria for monumentation installation and documentation on Corps projects is outlined in EM 1110-1-1002.

(2) A GIS can be used to streamline and enhance regional or site-specific geotechnical investigations by: (a) Verifying which information is currently available and what new data must be obtained or generated to fulfill requirements for the desired level of study; (b) Sorting and combining layers of information to evaluate the commonality of critical parameters and compatibility of proposed alternatives/sites; and (c) Assigning quantitative values and relational aspects of data combinations and classifications, e.g., computing the probability of correctly assigning a given liquifaction potential for a proposed foundation construction method at a given site location. In this respect, a geotechnically augmented GIS database can be used to quantify reliability and uncertainty for specific design applications and assumptions. Burrough (1986), ESRI (1992), Intergraph (1993), and Kilgore, Krolak, and Mistichelli (1993) provide further discussions of GIS uses and capabilities.

b. Topographic maps. Topographic maps provide information on landforms, drainage patterns, slopes, locations of prominent springs and wet areas, quarries, man-made cuts (for field observation of geology), mines, roads, urban areas, and cultivated areas. Requirements for topographic mapping and related spatial data are outlined in EM 1110-1-1005. If older topographic maps are available, especially in mining regions, abandoned shafts, filled surface pits, and other features can be located by comparison with later maps. Many topographic maps are available in digital format for computer analysis and manipulation. Image files of an entire 7-1/2 min (1:24,000) topographic map, for example, can be purchased. Digital elevation maps (DEM) provide a regular grid of elevation points that allow the user to reproduce the topography in a variety of display formats.

(1) Optimum use of topographic maps involves the examination of large- and small-scale maps. Certain features, such as large geologic structures, may be apparent on small-scale maps only. Conversely, the interpretation of active geomorphic processes will require accurate, large-scale maps with a small-contour interval. As a general rule, the interpretation of topographic maps should proceed from small-scale (large-area) maps through intermediate-scale maps to large-scale (small-area) maps as the geologic investigation proceeds from the general to the specific.

(2) Certain engineering geology information can be inferred from topographic maps by proper interpretation of landforms and drainage patterns. Topography tends to reflect the geologic structure, composition of the underlying rocks, and the geomorphic processes acting on them. The specific type of geomorphic processes and the length of time they have been acting on the particular geologic structure and rock type will control the degree to which these geologic features are evident on the topographic maps. Geologic features are not equally apparent on all topographic maps, and considerable skill and effort are required to arrive at accurate geologic interpretations. Analysis of aerial photographs in combination with large-scale topographic maps is an effective means to interpret the geology and geomorphology of a site. Information of geotechnical significance that may be obtained or inferred from aerial photographs and topographic maps includes physiography, general soil and rock types, rock structure, and geomorphic history.

c. Geologic maps. Surficial and "bedrock" geologic maps can be used to develop formation descriptions, formation contacts, gross structure, fault locations, and approximate depths to rock (U.S. Department of Interior 1977; Dodd, Fuller, and Clarke 1989). Maps of 1:250,000 scale or smaller are suitable for the development of regional geology because they can be used with remote sensing imagery of similar scale to refine regional geology and soils studies. Large-scale geologic maps (1:24,000) are available for some areas (Dodd, Fuller, and Clarke 1989). State geologic surveys, local universities, and geotechnical and environmental firms may be able to provide detailed geologic maps of an area. Large-scale geologic maps provide information such as local faults, orientations of joints, detailed lithologic descriptions, and details on depth to rock.

d. Mineral resource maps. Mineral resource maps produced by the USGS and state geological services are important sources of geologic information. For example, the USGS coal resources evaluation program includes preparation of geologic maps (7.5-min quadrangle areas) to delineate the quantity, quality, and extent of coal on Federal lands. The USGS and state geologic service maps provide information on oil and gas lease areas and metallic mineral resource areas. Mineral resource maps also include information on natural construction materials such as quarries and sand and gravel deposits. These maps can be used in estimating the effects of proposed projects on mineral resources (such as access for future recovery, or reduction in project costs by recovery during construction).

e. Hydrologic and hydrogeologic maps. Maps showing hydrologic and hydrogeologic information provide a valuable source of data on surface drainage, well locations, ground water quality, ground water level contours, seepage patterns, and aquifer locations and characteristics. The USGS (Dodd, Fuller, and Clarke 1989), state geologic surveys, local universities, and geotechnical and environmental firms may provide this information.

f. Seismic maps. Krinitzsky, Gould, and Edinger (1993) show the distribution of seismic source areas for the United States and potential magnitude of earthquakes associated with each zone. Maps showing the timing and location of >4.5 magnitude earthquakes in the United States for the period 1857-1989 have been published by Stover and Coffman (1993).

(1) The Applied Technology Council (1978) published a seismic coefficient map for the United States for both velocity-based and acceleration-based coefficients. Seismic coefficients are dimensionless units that are the ratio between the acceleration associated with a particular frequency of ground motion and the response in a structure with the acceleration of the ground (Krinitzsky 1995). For the same ground motion frequency, seismic coefficients systematically vary for different types of structures (e.g., dams, embankments, buildings). These coefficients include a judgmental factor, representing experience on the part of structural engineers.

(2) Spectral Acceleration (%g) Maps for various periods of ground motion are being generated to assess seismic hazard potential. The Building Seismic Safety Council will publish updated seismic hazard potential maps in 1997 that will be in the form of spectral values for periods of 0.3 and 1.0 sec (E. L. Krinitzsky, personal communication 1996).

g. Engineering geology maps. An engineering geology map for the conterminous United States has been published by Radbruch-Hall, Edwards, and Batson (1987). Regional engineering geology maps are also available. More detailed maps may be available from state geologic surveys. Dearman (1991) describes the principles of engineering geologic mapping.

3-5. Remote Sensing Methods

Conventional aerial photographs and various types of imagery can be used effectively for large-scale regional interpretation of geologic structure, analyses of regional lineaments, drainage patterns, rock types, soil characteristics, erosion features, and availability of construction materials (Rasher and Weaver 1990, Gupta 1991). Geologic hazards, such as faults, fracture patterns, subsidence, and sink holes or slump topography, can also be recognized from air photo and imagery interpretation, especially from stereoscopic examinations of photo pairs. Technology for viewing stereoscopic projections on the PC is available. Detailed topographic maps can be generated from aerial photography that have sufficient surveyed ground control points. Remote sensing images that are in digital format can be processed to enhance geologic features (Gupta 1991). Although it is normally of limited value to site-specific studies, satellite imagery generated by Landsat, Sky Lab, the Space Shuttle, and the French Satellite Pour l'Observation de la Terre (SPOT) satellites are useful for regional studies. Remote sensing methods listed below can be used to identify and evaluate topographic, bathymetric, and subsurface features:

a. Topographic/surface methods.

(1) Airborne photography (mounted on helicopter or conventional aircraft).

(2) Airborne spectral scanner (mounted on helicopter or conventional aircraft).

(3) Photogrammetry (for imagery processing or mapping of airborne/satellite spectral scanned data).

(4) Satellite spectral scanner (e.g., Landsat).

(5) Satellite synthetic aperture radar (SAR).

(6) Side-looking airborne radar (SLAR).

b. Topographic/subsurface methods.

(1) Ground Penetrating Radar (GPR).

(2) Seismic.

(3) Gravitometer.

(4) Magnetometer.

c. Bathymetric methods.

(1) Fathometer (vessel mounted).

(2) Side-scan sonar (vessel mounted or towed).

(3) Seismometer/subbottom profiler (bathymetry subsurface, vessel mounted, or towed).

(4) Magnetometer (vessel towed).

(5) Gravitometer (vessel towed).

(6) Remotely Opertated Vehicle (ROV) mounted video or acoustic sensor.

(7) SeaBat (multibeam echo sounder) technology.

Gupta (1991) provides more detailed discussions of remote sensing techniques and their application to geotechnical investigations. Additional information concerning remote sensing surveying of bathymetry can be obtained in EM 1110-2-1003. Additional information concerning photographic imaging and photogrammetric mapping can be obtained in EM 1110-1-1000.

Section III
Field Reconnaissance and Observations

3-6. Field Reconnaissance

After a complete review of available geotechnical data, a geologic field reconnaissance should be made to gather information that can be obtained without subsurface explorations or detailed study (Dearman 1991). It is desirable that the geological field reconnaissance be conducted as part of a multidisciplinary effort. The composition of a team would depend upon the type and size of the project, the project effect on the area in question, and on any special problems identified as a result of early office studies. The team should include engineering geologists, soils engineers, planning engineers, archeologists, and representatives of other disciplines as appropriate. Duties include: field checking existing maps, cursory surface mapping (aided by aerial photographs), examining nearby natural and man-made outcrops, and traversing local waterways that expose rock and soil.

3-7. Observations

Observations made during field reconnaissances can be divided into five categories:

a. Examination of geologic/hydrologic features and geologic hazards to confirm, correct, or extend those identified during early office studies, and the preparation of regional geologic maps.

b. Assessment of site accessibility, ground conditions, and right-of-entry problems that could affect field exploration work.

c. Identification of cultural features that could affect exploration work and site location, especially utilities.

d. Evaluation of the condition of existing structures and construction practices that would indicate problem soil and rock conditions.

e. Identification of areas that could be contaminated by HTRW.

(1) Observations of geologic features should include rock outcrops and soil exposures to verify or refine available geologic maps. The strike and dip of major joint sets and evidence of joint sheeting or steeply dipping beds that would affect the stability of natural or excavated slopes should be noted. Indications of slope instability such as scarps, toe bulges, leaning trees, etc. should also be recorded. Table 3-2 outlines special geologic features and conditions which should be considered. The location of

sources of construction materials, such as large stone, sand and gravel deposits, clay soils, and active or abandoned quarries, are also important. Observable hydrologic features include surface drainage flow, springs and seeps in relation to formation members, and marshy or thick vegetation areas indicating high ground water tables.

(2) The location of cultural features, such as power lines, pipelines, access routes, and ground conditions that could restrict the location of or access to borings, should be noted. Historical and archaeological sites that may impact site location or construction practices should be identified and noted for further cultural resource potential studies. Local construction practices and the condition of existing structures and roads should be observed and potential problems noted. The location of abandoned mine workings such as adits, benches, shafts, and tailings piles should be noted.

(3) Field observations have special value in planning subsequent investigations and design studies because adverse subsurface conditions often can be anticipated from surface evidence and the regional geology. Suitable alternatives for foundation or structure types may be suggested by comprehensive field observations.

(4) Field reconnaissance can identify the need for new mapping and new aerial photographic coverage. Such coverage should be coordinated with planners early in the study process to ensure sufficient and timely coverage.

(5) Any potential environmental hazard such as former landfills, surface impoundments, mining activity, industrial sites, signs of underground storage tanks, or distressed vegetation should be recorded and assessed for HTRW potential.

Section IV
Information Development

3-8. Summary

Compiled and properly interpreted regional geologic data, coupled with information obtained during field reconnaissances, will provide the information necessary to identify suitable sites and to determine the scope of site investigations. Specifically, regional geology and site reconnaissance studies should result in the following:

a. Regional geologic conditions identified and incorporated into a regional geologic map.

b. Preliminary assessment made of regional seismicity.

c. Tentative location of sources of construction materials.

d. Tentative models of geologic conditions at suitable sites.

e. Input for Environmental Impact Statement.

f. Identification and assessment of potential for HTRW at prospective sites.

Table 3-2
Special Geologic Features and Conditions Considered in Office Studies and Field Observations

Geologic Feature or Condition	Influence on Project	Office Studies	Field Observations	Questions to Answer
Landslides	Stability of natural and excavated slopes	Determine presence or age in project area or at construction sites Compute shear strength at failure. Do failure strengths decrease with age of slopes-- especially for clays and clay shales?	Estimate areal extent (length and width) and height of slope Estimate ground slope before and after slide (may correspond to residual angle of friction) Check highway and railway cuts and deep excavations, quarries, and steep slopes	Are landslides found offsite in geologic formations of same type that will be affected by project construction? What are probable previous and present ground water levels? Do trees slope in an unnatural direction?
Faults and faulting; past seismic activity	Of decisive importance in seismic evaluations; age of most recent fault movement may determine seismic design earthquake magnitude, may be indicative of high state of stress which could result in foundation heave or overstress in underground works	Determine existence of known faults and fault history from available information Examine existing boring logs for evidence of faulting from offset of strata	Verify presence at site, if possible, from surface evidence; check potential fault traces located from aerial imagery Make field check of structures, cellars, chimneys, roads, fences, pipelines, known faults, caves, inclination of trees, offset in fence lines	Are lineaments or possible fault traces apparent from regional aerial imagery?
Stress relief cracking and valley rebounding	Valley walls may have cracking parallel to valley. Valley floors may have horizontal cracking. In some clay shales, stress relief from valley erosion or glacial action may not be complete	Review pertinent geologic literature and reports for the valley area. Check existing piezometer data for abnormally low levels in valley sides and foundation; compare with normal ground water levels outside valley	Examine wells and piezometers in valleys to determine if levels are lower than normal ground water regime (indicates valley rebound not complete)	
Sinkholes; karst topography	Major effect on location of structures and feasibility of potential site (item 13)	Examine air photos for evidence of undrained depressions	Locate depressions in the field and measure size, depth, and slopes. Differences in elevation between center and edges may be almost negligible or many feet. From local residents, attempt to date appearance of sinkhole	Are potentially soluble rock formations present such as limestone, dolomite, or gypsum? Are undrained depressions present that cannot be explained by glaciation? Is surface topography rough and irregular without apparent cause?

(Sheet 1 of 4)

Table 3-2 (Continued)

Geologic Feature or Condition	Influence on Project	Office Studies	Field Observations	Questions to Answer
Anhydrites or gypsum layers	Anhydrites in foundations beneath major structures may hydrate and cause expansion, upward thrust and buckling Gypsum may cause settlement, subsidence, collapse or piping. Solution during life of structure may be damaging	Determine possible existence from available geologic information and delineate possible outcrop locations	Look for surface evidence of uplift; seek local information on existing structures Check area carefully for caves or other evidence of solution features	Are uplifts caused by possible hydrite expansion or “explosion”?
Caves	Extent may affect project feasibility or cost. Can provide evidence regarding faulting that may relate to seismic design. Can result from unrecorded mining activity in the area		Observe cave walls carefully for evidence of faults and of geologically recent faulting. Estimate age of any broken stalactites or stalagmites from column rings	Are any stalactites or stalagmites broken from apparent ground displacement or shaking?
Erosion resistance	Need for total or partial channel slope protection is determined	Locate contacts of potentially erosive strata along drainage channels	Note stability of channels and degree of erosion and stability of banks	Are channels stable or have they shifted frequently? Are banks stable or easily eroded? Is there extensive bank sliding?
Internal erosion	Stability of foundations and dam abutments affected. Gravelly sands or sands with deficiency of intermediate particle sizes may be unstable and develop piping when subject to seepage flow	Locate possible outcrop areas of sorted alluvial materials or terrace deposits	Examine seepage outcrop areas of slopes and riverbanks for piping	
Area subsidence	Area subsidence endangers long- term stability and performance of project	Locate areas of high ground water withdrawal, oil fields and subsurface solution mining of underground mining areas	Check project area for new wells or new mining activity	Are there any plans for new or increased recovery of subsurface water or mineral resources?
Collapsing soils	Need for removal of shallow foundation materials that would collapse upon wetting determined	Determine how deposits were formed during geologic time and any collapse problems in area	Examine surface deposits for voids along eroded channels, especially in steep valleys eroded in fine-grained sedimentary formations	Were materials deposited by mud flows?

(Sheet 2 of 4)

Table 3-2 (Continued)

Geologic Feature or Condition	Influence on Project	Office Studies	Field Observations	Questions to Answer
Locally lowered ground water	May cause minor to large local and area settlements and result in flooding near rivers or open water and differential settlement of structures	Determine if heavy pumping from wells has occurred in project area; contact city and state agencies and USGS	Obtain ground water levels in wells from owners and information on withdrawal rates and any planned increases. Observe condition of structures. Contact local water plant operators	
Abnormally low pore water pressures (lower than anticipated from ground water levels)	May indicate effective stresses are still increasing and may cause future slope instability in valley sites	Compare normal ground water levels with piezometric levels if data are available		Is the past reduction in vertical stresses a possible cause of low pore water pressure. Examples are deep glacial valleys and deep excavations like that for the Panama Canal, where pore pressures in clay shale were reduced by stress relief.
In situ shear strength from natural slopes	Provides early indication of stability of excavated slopes or abutment and natural slopes around reservoir area	Locate potential slide areas. Existing slope failures should be analyzed to determine minimum in situ shear strengths	Estimate slope angles and heights, especially at river bends where undercutting erosion occurs. Determine if flat slopes are associated with mature slide or slump topography or with erosion features	Are existing slopes consistently flat, indicating residual strengths have been developed?
Swelling soils and shales	Highly preconsolidated clays and clay shales may swell greatly in excavations or upon increase in moisture content	Determine potential problem and location of possible preconsolidated strata from available information	Examine roadways founded on geologic formations similar to those at site. Check condition of buildings and effects of rainfall and watering	Do seasonal ground water and rainfall or watering of shrubs or trees cause heave or settlement?
Varved clays	Pervious layers may cause more rapid settlement than anticipated. May appear to be unstable because of uncontrolled seepage through pervious layers between overconsolidated clay layers or may have weak clay layers. May be unstable in excavations unless well points are used to control ground water	Determine areas of possible varved clay deposits associated with prehistoric lakes. Determine settlement behavior of structures in the area	Check natural slopes and cuts for varved clays; check settlement behavior of structures	

(Sheet 3 of 4)

Table 3-2 (Concluded)

Geologic Feature or Condition	Influence on Project	Office Studies	Field Observations	Questions to Answer
Dispersive clays	A major factor in selecting soils for embankment dams and levees	Check with Soil Conservation Service and other agencies regarding behavior of existing small dams	Look for peculiar erosional features such as vertical or horizontal cavities in slopes or unusual erosion in cut slopes. Perform "crumb" test	
Riverbank and other liquefaction areas	Major effect on riverbank stability and on foundation stability in seismic areas	Locate potential areas of loose fine-grained alluvial or terrace sand; most likely along riverbanks where loose sands are present and erosion is occurring	Check riverbanks for scallop-shaped failure with narrow neck (may be visible during low water). If present, determine shape, depth, average slope, and slope of adjacent sections. Liquefaction in wooded areas may leave trees inclined at erratic angles. Look for evidence of sand boils in seismic areas	
Filled areas	Relatively recent filled areas would cause large settlements. Such fill areas may be overgrown and not detected from surface or even subsurface evidence	Check old topo maps if available for depressions or gullies not shown on more recent topo maps	Obtain local history of site from area residents	
Local overconsolidation from previous site usage	Local areas of a site may have been overconsolidated from past heavy loadings of lumber or material storage piles			Obtain local history from residents of area

(Sheet 4 of 4)

If an information system or electronic data base management capability already exists, serious consideration should be given at the beginning of a project to incorporate the geotechnical information into the system. Newly obtained/generated data should be incorporated into the information system data base for future project use. Data describing the site conditions encountered during construction should also be incorporated into the geotechnical data base. By electronically recording geotechnical information through the life cycle of a project, reliable diagnostic and forensic analysis can be conducted. Moreover, a GIS provides a powerful management tool for the postconstruction (operation and maintenance) phase of the project.