Environmental Site Assessment: Site Characterization Methodologies

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Soil investigations for urban planning, development and environmental remediation have become standard practice in recent years for professional engineers, environmental scientists, and other related professionals. The need for environmental site assessments and detailed site characterization of contaminated sites and of other civil and environmental project sites has led to the development of numerous types of site characterization methodologies. Soil investigations for urban sites frequently involve complex characterization of atypical soil/geological/groundwater conditions due to man-altered subsurface conditions.

The purpose of this chapter is to present the range of site characterization methodologies that are being used in professional practice in the USA. There is no other combined reference source for all of these methods. The scope of this chapter includes published manuals, standards, and methods used in professional practice.

ENVIRONMENTAL SITE ASSESSMENTS

Planning and Audits

Environmental Site Assessments (ESAs) involve the scientific examination or survey of environmental data. The ESAs include soil surveys and soil investigations, as well as a wide range of other types of environmental data. The National Cooperative Soil Survey program of the U.S. Natural Resources Conservation Service (NRCS, previously SCS) and geologic surveys of the U.S. Geologic Survey are early examples of environmental assessments. In recent times the National Environmental Policy Act of 1969 started a process of environmental assessment reports and environmental impact statements for federal projects. As a result of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (also known as Superfund), ESAs and environmental audits became common practice for private commercial and industrial properties. Today it is virtually impossible to obtain a commercial bank, real estate or construction loan in the USA without preparing an environmental site assessment.

The ESA is the most commonly used generic professional term to refer to what is now an extremely wide range of scientific environmental investigations. This chapter is intended to outline the various types of ESAs that are in professional practice by soil scientists, geologists and geotechnical engineers. This body of professional practice represents modern urban soil survey techniques and methodologies in their broadest sense. The breadth of urban and environmental professional practice has led to considerable specialization; however, soil science is common to all types of environmental assessments.

Comprehensive Environmental Response, Compensation, and Liability Act Background

In 1980 Congress created CERCLA (Comprehensive Environmental Response, Compensation, and Liability Act; or the Superfund), 42 U.S.C. S 96G1, et. seq., to provide a comprehensive program for the cleanup of inactive hazardous waste sites. The potentially responsible parties, if they can be identified, can be held liable for cleanup costs of abandoned or inactive sites. The current property owner also can be held liable unless a so-called “innocent landowner defense” created by the U.S. Congress in the 1986 Superfund amendments applies. Defense is available to purchasers of contaminated property if the purchaser acquired the property after the hazardous waste disposal and if it can be proven that: (i) at the time the purchaser did not know and had no reason to know that any hazardous substance was disposed on the property, (ii) the owner is a governmental entity that acquired the property by any involuntary transfer or acquisition or through exercise of eminent domain authority or condemnation, or (iii) the owner acquired the facility by inheritance or bequest.

The purchaser is required to prove that he or she has satisfied one of these requirements and has exercised due care and has taken adequate precautions. At the time of acquisition all appropriate inquiry consistent with good commercial or customary practice is required in order to minimize liability. These federal requirements have led to extensive application of ESAs to essentially all commercial real estate transactions. Banks and lending institutions have broadened the scope of ESAs to include all types of environmental investigations that might identify potentially contingent liabilities associated with the property or facilities.

Real Estate Transactions

The American Society for Testing and Materials has promulgated “Phase I Environmental Site Assessment Process” (ASTM, 1998). The Transaction Screen Process has become the standard of practice for preliminary decision-making by most banks and lending institutions to determine if a Phase I Environmental Site Assessment is needed. The Phase I Environmental Site Assessment Process has become the standard, of practice for environmental consultants in preparation of the on-site environmental investigation report for a real estate transaction. The ESA Process provides detailed guidance including governmental records reviews, site reconnaissance. Interviews, and report preparation.

Corporate Compliance Assurance

The ESAs are becoming widely used by business and industries to achieve three objectives: (i) comply with existing laws and regulations, (ii) manage present and failure risks, and (iii) remediate existing sites where contamination has occurred as a result of past or present company activities (Duff, 1994). An ESA is a survey of existing properties and facilities of a company intended to take into account the business' ability to meet its legal environmental obligations in the most cost-effective manner possible (Holzer & Meyer, 1994). As such, most ESAs for corporate compliance assurance plans are completed by environmental scientists as confidential documents under the auspices of the corporate attorneys. This process has led to substantial implementation of voluntary remediation projects.

Facility Planning

Both governmental and corporate entities implement a range of ESAs in conjunction with facility planning studies prior to construction of new facilities. The ESAs are commonly used for industrial development program and site selection (Findley, 1982). Environmental assessments (EAs) and environmental impact statements (EISs) are commonly used for governmental facility planning efforts. Numerous environmental impact assessment methodologies have been developed to systematically rate and compare alternatives (Jain et al., 1993). Most methodologies are geographically based and utilize published information from soil, geologic, and topographic surveys. Agencies frequently implement ESAs to obtain site-specific data prior to the EIS process to provide more accurate baseline data.

Soil scientists, geologists, and geotechnical engineers have developed specialized site assessment methodologies to address the unique needs of various types of urban projects. The USDA's soil survey and Department of Interior's (DOI's) geologic survey programs provide an extremely useful source of information for an entire metropolitan area. More specialized ESA methodologies have been developed to deal with the need for more accurate site-specific data for various types of engineering projects.

SOIL SURVEYS FOR URBAN AREAS

The USDA soil survey program was originally developed for agricultural purposes (SCS, 1951) but has been modified to better address the needs of urban areas (SCS, 1975a), A system of urban soil complexes was developed to more accurately reflect the urban landscape. More accurate urban soil mapping and classification techniques have been developed (Stein, 1978; Kays, 1981; Short, 1983; Stein et al., 1974; Bockheim, 1974; Short et al., 1986a, b). Stein (1978), Fanning (unpublished data), Patterson (unpublished data), Short (1983) and Foss's (unpublished data) work on the Mall in Washington, DC, and Bockheim's (1974) work in Philadelphia, Pennsylvania, formed the basis for actual classification of urban soils. These new classification procedures are distinctly different from the concept of mapping urban complexes used by the National Cooperative Soil Survey. The soil survey approach was thought to be more of an urban soil/land use map rather than a true soil map. The new procedures were used to map Central Park in New York City (Warner, 1982). Kays (1981) illustrated that even this intensive level of soil survey can frequently be inadequate for site-specific project engineering. Kays proposed a complete intensive site characterization approach for soil engineering projects.

Soil survey laboratory methods (SCS, 1967) have been appropriate for soil sampling in urban areas. In some cases traditional field and laboratory procedures do not deal with the complexity of urban sites. Intensive site characterization procedures go beyond the traditional soil survey methods. For example, ground-penetrating radar (Truman, 1991; Kovas, 1991; Shih & Myhre, 1994; Lord & Koerner, 1987; Douglas et al, 1992; Chow, 1989) has begun to be useful for sites with complex substrata, buried structures and complex hydrology. See “Case Study” of this chapter for an example of complex soil characterization of an engineering site. Urban engineering projects frequently are faced with a high degree of site complexity. Therefore, complete site soil, geologic, and groundwater characterization often is required. This site characterization approach has been further developed for specialized purposes such as hazardous waste site investigations, hydrocarbon contaminated site investigations, and other types of site investigations.

SITE CHARACTERIZATION METHODS

Hazardous Waste Site Investigations

Hazardous waste laws are contained in two major pieces of legislation: the Resource Conservation and Recovery Act of 1976 (RCRA) and the CERCLA (1980). The EPA has developed a Remedial Investigation Feasibility Study (RI/FS) process to conduct CERCLA studies of hazardous waste sites. The work involves four basic steps: (i) preliminary site assessment, (ii) scoping of the RI/FS, (iii) remedial investigation (RI), which involves site characterization and treatability investigations, and (iv) feasibility study (FS) that involves development, screening, and detailed analysis of alternatives. The site characterization process of the RI (Step 3) involves field investigations and use of soil, geologic, hydrogeologic, surface waters, meteorologic, and ecological methodologies (EPA, 1987a, 1988b, 1989a). The purposes of the site characterization process are to: (i) identify the contaminants, (ii) assess exposure, (iii) assess toxicity, and (iv) characterize risk of the hazardous waste site.

The RCRA site investigation methods are contained in the RCRA Facility Investigation (RFI) Guidance, Volumes 1 to 4 (EFA, 1989c, d, e, f). Volume II (“Soil, Ground Water and Subsurface Gas Releases”) outlines site characterization including field sampling and monitoring methods (also see EPA, 19S9b, h; 1993b; Ford & Turina, 1985; Ford et al., 1983; Plumb, 1984). “RCRA Ground Water Monitoring” *(EPA, 1*993d) provides methodologies for characterization of site hydrogeology, monitoring wells, sampling, and analysis (also see Aller, 1990; Barth et al., 1989; EPA, 198la, 1984a, c, d. 1989g; Lesage & Jackson, 1992), sludges (EPA, 1988c), analysis unsaturated zone (Nofziger et al., 1994); analysis of sediments (EPA; 1993c; Schumacher, 1993), RI/FS under CERCLA (EPA, 1988b, c; EPA, 1985a) Table 3-1 lists EPA manuals addressing site characterization. Soil

Table 3-1. List of selected EPA site characterization and design manuals.

Publication title	Publication number	Ground water	Hazardous waste	Land application	Land-fills	Underground storage tanks	Waste-water
1. *Manual for Groundwater/Subsurface Investigations for Hazardous Waste Systems* (EPA, 1981a)	EPA 300/9-81-002	X	X				
2. *Assessment of Current Information on Overland Flow Treatment* (EPA, 1980a)	EPA 430/9-80-002			X			X
3. *Slow Rate Land Treatment: A Recycle Technology* (EPA, 1980d)	EPA 430/9-80-011a			X			X
4. *Rapid Infiltration Land Treatment: A Recycle Technology* (EPA, 1980c)	EPA 430/9-80-011b			X			X
5. *RCRA Ground Water Monitoring: Draft Technical Guidance* (EPA, 1993d)	EPA 530/R-93-001	X	X		X		
6. *Interim Final RCRA Facility Investigations (RFI) Guidance. Development on an RFI Work Plan and General Considerations for RCRA Facility Investigations,* Vol. 1 (EPA, 1989c)	EPA 530/SW-89-031		X				
7. *Interim Final RCRA Facility Investigation (RFI) Guidance. Soil, Ground Water and Subsurface Gas Releases*, Vol. 2 (EPA, 1989d)	EPA 530/SW-89-031	X	X	X	X	X	
8. *Interim Final RCRA Facility Investigation (RFI) Guidance, Air and Surface Water Resources*, Vol. 3 (EPA, 1989e)	EPA 530/SW-89-031		X				
9. *Interim Final RCRA Facility Investigations (RFI) Guidance, Case Study Examples,* Vol. 4 (EPA, 1989f)	EPA 530/SW-89-031			X			
10. *Cleanup of Releases from Petroleum USTs; Selected Technologies* (EPA, 1988a)	EPA 530/UST-88-001	X				X	
11. *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA, 1988b)	EPA 540/G-89-004	X	X				
12. *Technology Screening Guide for Treatment of CERCLA Soils and Sludges* (EPA, 1988c)	EPA 540/2-88/004		X	X	X		X
13. *Compendium of Superfund Field Operations Methods* (EPA, 1987a)	EPA 540/P-87-001	X	X			X	
14. *Guidance on Feasibility Studies Under CERCLA* (EPA, 1985a)	EPA 540/2-84-003a		X				
15. *Review of In-Place Treatment for Contaminated Surface Soils* (EPA, 1984c)	EPA 540/2-84-003a		X	X			
16. *Soil Screening Guidance* (EPA, 1996)	EPA 540/R-94-101		X	X	X		

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Table 3-1. Continued.

Publication title	Publication number	Ground water	Hazardous waste	Land application	Land-fills	Underground storage tanks	Waste-water
17. *Technical Background Document For Soil Screening Guidance* (EPA, 1995)	EPA 540/R-95-128		X	X	X		
18. *Evaluation of Unsaturated/Vadose Zone Models for Superfund Sites* (EPA, 1993c)	EPA 600/R-93-184	X	X			X	
19. *Assessment and Remediation of Contaminated Sediments (ARCS) Program: Quality Assurance Program* (EPA, 1993a)	EPA 600/R-93-242		X				
20. *Reclamation and Redevelopment of Contaminated Land: European Case Studies*, Vol. 2 (EPA, 1992b)	EPA 600/R-92-031	X	X		X	X	
21. *A Study to Determine the Feasibility of Using a Ground-Penetrating Radar for More Effective Remediation of Subsurface Contamination* (EPA, 1992a)	EPA 600/R-92-089		X			X	
22. *An Assessment of Soil-Gas Measurement Technologies* (EPA, 1991)	EPA 600/8-91-050					X	
23. *Assessment UST Corrective Action Technologies: Site Assessment and Selection of Unsaturated Zone Treatment Technologies* (EPA, 1990)	EPA 600/2-90-011	X				X	
24. *Handbook of Suggested Practices for the Design and Installation of Ground Water Monitoring Wells* (EPA, 1989g)	EPA 600/4-89-034	X	X	X	X	X	X
25. *Soil Sampling Quality Assurance Users Guide*, 2nd ed. (EPA, 1989h)	EPA 600/S8-89-046	X	X			X	
26. *Characterization of Hazardous Waste Site—A Methods Manual, Available Sampling Methods*, Vol. 2 (EPA, 1989b)	EPA 600/4-89-075		X				
27. *Nondestructive Testing Techniques to Detect Contained Subsurface Hazardous Waste* (EPA, 1987c)	EPA 600/2-86-066		X			X	
28. *Reclamation and Redevelopment of Contaminated Land: U.S. Case Studies*, Vol. 1 (EPA, 1986b)	EPA 600/2-86-066	X	X	X	X		
29. *Land Disposal, Remedial Action, Incineration and Treatment of Hazardous Waste* (EPA, 1986a)	EPA 600/4-86-022		X	X			
30. *Characterization of Hazardous Waste Sites—A Methods Manual, Available Analytical Methods*, Vol. 3 (EPA, 1984a)	EPA 600/4-84-038		X				

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Table 3-1. List of selected EPA site characterization and design manuals.

Publication title	Publication number	Ground water	Hazardous waste	Land application	Land-fills	Underground storage tanks	Waste-water
31. *Soil Sampling Quality Assurance User's Guide* (EPA, 1984c)	EPA 600/S4-84-043		X	X	X	X	
32. *Characterization of Hazardous Waste Sites—A Methods Manual, Site Investigations;* Vol. 1 (EPA, 1984a)	EPA 600/4-84-075	X	X				
33. *Characterization of Hazardous Waste Sites—A Methods Manual, Available Sampling Methods*, Vol. 2 (EPA, 1984a)	EPA 600/4-83-040	X	X		X	X	
34. *Handbook for Sampling and Sample Preservation of Water and Wastewater* (EPA, 1982)	EPA 600/4-82-029	X	X	X	X	X	X
35. *Design and Construction of Covers for Solid Waste Landfills* (EPA, 1979)	EPA 600/2-79-16					X	
36. *Management of Small Waste Flows* (EPA, 1978)	EPA 600/2-78-173			X			X
37. *DNAPL Site Evaluation* (EPA, 1993b)	EPA 600/R-93-022	X	X				
38. *Underground Storage Tank Corrective Action Technologies* (EPA, 1987d)	EPA 625/16-87-015	X				X	
39. *Handbook—Remedial Action at Waste Disposal Sites*, rev. (EPA, 1985b)	EPA 625/6-85-006		X				
40. *Process Design Manual for Land Treatment of Municipal Wastewater* (EPA, 1981b)	EPA 625/1-81-013			X			X
41. *Design Manual for On-site Wastewater Treatment and Disposal Systems* (EPA, 1980b)	EPA 625/1-80-012			X			X
42. *Process Design Manual for Sludge Treatment and Disposal* (EPA, 1974)	EPA 625/1-74-006			X			X
43. *Sanitary Landfill Design and Operation* (EPA, 1972)	EPA SW-65ts, 1972				X		

screening methods have become more standardized in the evaluation and cleanup of contaminated soils (EPA, 1995, 1996).

Recent innovations have led to use of a variety of geophysical methods for hazardous waste site characterizations. Nonintrusive geophysical methods are being used because they do not require deep penetration, are frequently less expensive, and avoid aggravation of subsurface contamination. Geophysical methods include seismic refraction, seismic reflection, electric resitivity, electromagnetic conductivity, magnetic flux and ground penetrating radar (Benson, 1988; EPA, 1992a; Glore & Dobecki, 1992; Douglas et al., 1992; Lord & Koerner, 1987). Remote sensing techniques have been developed for hazardous waste site detection and evaluation (Colten, 1988; EPA, 1981a; Lee, 1991).

Hydrocarbon Contamination Site Investigations

Specialized ESA methodologies have been developed to conduct detailed site characterization of soil, geology and groundwater for hydrocarbon-contaminated sites. These methodologies are widely used to conduct ESAs for leaking underground storage tanks. The American Petroleum Institute has developed several manuals for site investigations (API, 1984, 199la, b; Kane, 1987). Detailed site characterization includes geology (subsurface lithology investigations from borings, excavations and sampling), soils in the vadose (unsaturated) zone (subsurface investigations of water movement and areal extent of soil contamination), site hydrology (areal extent of plume of groundwater contamination) (Bryden et al., 1986; Byrnes, 1990; Cole, 1994; Elrick, 1989; Manchon, 1993; Villaume, 1985) and soil gas investigations (EPA, 1991; Rector, 1991; Pedersen & Curtis, 1991; Tillmann et al., 1989a, b). Methodologies for characterizations of hydrocarbon contaminants have been established (EPA, 1987c, 1988a, 1990; Parn et al., 1991). Numerous technologies for hazardous waste treatment are dependent upon in situ soil methods (EPA, 1984c, 1985a, 1986a,c, 1987b,d).

Soil vapor extraction methodologies (Kostecki & Calabrese, 1991; Shelby, 1991) and soil microbiological (Piotrowski, 1991) procedures have been developed to provide approaches to soil remediation of contaminants. The ASTM 4700 and 5126 procedures have been developed especially for soil sampling and analysis in the vadose zone.

Wetland Site Investigations

Wetland delineations and site investigations for wetland restoration are commonly used in most ESAs. Field methodologies for jurisdictional wetland delineations rely on assessments of hydrophilic vegetation, hydric soil and hydrology (U.S. Army Corps of Eng., 1987; SCS, 1987; EPA, 1989b; Hurt et al., 1998) for Section 404 permitting under the Clean Water Act (undated). The habitat evaluation procedures (HEP) are used to evaluate the wetland functions (U.S. Army Corps Eng., 1985). The *SCS National Engineering Field Handbook* (SCS, 1992) is used for site investigation for planning and design of wetland restoration, enhancement and creation projects. Procedures for soil and hydrologic engineering of sites are provided. Airborne wetland detection and mapping is being developed to improve the accuracy of large-scale mapping (Lee, 1991).

Landscape Restoration Site Investigations

Landscape restoration of urban parks, historical landmarks and urban open spaces is done to overcome deterioration of these urban, spaces. Many important urban spaces like Central Park in New York City and the Washington Mall in Washington, DC, date to the last century. Problems due to soil compaction, antiquated subsurface and surface drainage systems, and stressed trees and plants are important issues in the restoration process. The basic procedures for urban and soil investigation have been developed by (Kays, 1981; Kays & Patterson, 1981). The U.S. Forest Service (USFS) Urban Forest Soils Manual was the first comprehensive attempt to describe these basic procedures. Kays developed a site characterization methodology for such urban landscape and engineering projects.

Derelict Lands Site Investigations

Urban areas are plagued with numerous types of derelict and abandoned sites. These sites consist of waste building materials, waste metals, scrap yards, solid waste disposal sites, and mining sites. Many of these sites involve abandoned industrial facilities. Other sites involve organic, chemical, and mining waste disposal.

Scientists in the United Kingdom have developed procedures to identify, survey and assess abandoned sites (Bridges, 1987; Bridges, 1991; Davies, 1991; Soc. Chem. Indust., 1980). The survey and assessment procedures involve topographic, geologic, soil, chemical, and ecological survey methods (EPA, 1992b). Great Britain's national survey of derelict lands was intended to establish a data base to promote reuse of waste materials and reclamation of the sites. Contaminated soils have become a significant problem in urban areas. Site assessment methodologies to survey contaminated soils have become an international effort by industrialized nations (Assink & Van Den Brink, 1986; British Stand Inst., 1981). Airborne site assessment methodologies are being used to locate and inventory abandoned sites.

In the USA, RCRA and CERCLA regulations have focused efforts on hazardous waste sites (EPA, 1986b) while abandoned nonhazardous waste sites have received only limited federal attention (Colten, 1988; Greenburg, 1984; Kingsbury & Ray, 1986; Kingsbury & Bingham, 1992).

Transportation Facility Site Investigations

The U.S. Department of Transportation, Federal Highway Administration (FHWA) and the National Highway Institute (NHI) have developed a methodology for environmental impact statements and, highway corridor siting and selection (FHWA, 1993). The *Project Development and Environmental Documentation* manual establishes project planning, environmental assessment, and NEPA documentation procedures (1969).

Specific procedures for wetland assessment of highway corridors and permitting have been established (FHWA, 1988). Corridor and site assessment methodologies for functional wetland assessment are important in corridor siting and selection (FHWA, 1983a, b). The NHI has established assessment procedures for a number of soil and environmental factors.

Engineering Site Investigation

Geotechnical investigations have been conducted historically to: (i) assess suitability of a site, (ii) provide adequate design data, (iii) determine potential for failure prior to design, (iv) determine reasons for failure of remedial action, and (v) determine availability and suitability of soil material for construction purposes (Brink, 1982). Geotechnical investigations and soil engineering tests predate most other types of ESAs. The American Society for Testing and Materials (ASTM) has established a series of standard procedures that are used in professional practice (Table 3-2).

Specialized site characterization procedures have been established for various types of construction projects such as highways, building and structure foundation design, dams and hydrographic design, and damage control for earthquakes (ASTM, Table 3-2; Sherard et al., 1963; Tomlinson, 1963).

Sanitary Landfill Site Investigations

Site characterization is important in site selection and design of sanitary landfills (EPA, 1972). Methodologies for site characterization involve the geologic and hydrogeologic aspects (Brunner, 1972), hydrologic evaluation (EPA, 1984b, e) and soil characterization for landfill capping (EPA, 1979; Lutton et al, 1979; Lutton, 1982). Modern site characterization for lined sanitary landfill is becoming similar to RCRA standards for hazardous waste disposal assessments. The ASTM procedures in Table 3-2 provide standards for site characterization of soils, geology, and groundwater applicable to landfill sites and for gas sampling applicable to post-landfill closure.

Land Application Of Wastewater Site Investigations

The ESA for land application of wastewater generally follows soil science procedures and methods. Methodologies involve investigation of various possible land limiting soil factors including hydraulic loading, N loading, P loading, organic loading, salt loading and heavy metal loading of the site (Carlile & Phillips, 1976; Overcash & Pal, 1979). The EPA established the *Process Design Manual for Land Treatment of Municipal Wastewater* (EPA, 1981b), which serves as the basic approach for site investigations of municipal spray irrigation wastewater systems. Site investigations for various types of land applications of wastewater involve overland flow (EPA, 1980a), slow rate spray irrigation (EPA, 1980d), and rapid rate irrigation (EPA, 1980c). The EPA also established the manual for site investigation of municipal sludge application (EPA, 1974, 1988c) and for site investigations of small on-site wastewater treatment and disposal systems (EPA, 1978, 1980b).

Table 3-2, List of selected American Society for Testing and Materials Standards† for environmental sites characterization.

ASTM designation‡	Title of standard
D 420-93	Standard guide to site characterization for engineering, design, and construction purposes (ASTM, 1999a)
D 653-90	Terminology relating to soil, rock, and contained fluids (ASTM, 1999b)
D 1194-94	Standard test method for bearing capacity of soil for static load and spread footings (ASTM, 1999c)
D 1195-93	Standard test method for repetitive static plate load tests of soils and flexible pavement components, for use in evaluation and design of airport and. highway pavements (ASTM, 1999d)
D 1196-93	Standard test method for nonrepetitive static plate load tests of soils and flexible pavement components, for use in evaluation and design of airport and highway pavements (ASTM, 1999e)
D 1356-98	Standard terminology relating to atmospheric sampling and analysis (ASTM, 1998b)
D 1357-95	Standard practice for planning the sampling of the ambient atmosphere (ASTM, 1998c)
D 1452-80	Standard practice for soil investigation and sampling by auger borings (ASTM, 1999f)
D 1586-84	Standard test method for penetration test and split-barrel sampling soils (ASTM, 1999g)
D 15S7-83	Standard practice for thin-walled geotechnical sampling of soils (ASTM, 1999h)
D 1914-95	Standard practice for conversion units and factors relating to atmospheric analysis (ASTM, 1998d)
D 2113-83	Standard practice for diamond core drilling for site investigation (ASTM, 1999i)
D 2487-93	Standard practice classification of soils for engineering purposes (Unified Soil Classification System) (ASTM, 1999j)
D 2488-93	Standard practice for description and identification of soils (visual-manual procedure) (ASTM, 1999k)
D 2573-72	Standard test method for field vane shear test in cohesive soil (ASTM, 1999l)
D 2652-94	Standard definitions of terms relating to activated carbon (ASTM, 1993e)
D 3017-88	Standard test method for water content of soil and rock in place by nuclear methods (shallow depth) (ASTM, 1999m)
D 3213-91	Standard practices for handling, storing, and preparing soft undisturbed marine soil (ASTM, 1999n)
D 3249-90	Standard practice for general ambient air analyzer procedures (ASTM, 1998f)
D 3282-93	Standard classification of soils and. soil-aggregate mixtures for highway construction purposes (ASTM, 1999o)
D 3385-94	Standard test method for infiltration rate of soils in field using double-ring infiltrometer (ASTM, 1999p)
D 3404-91	Standard guide to measuring matric potential in the vadose zone using tensiometers (ASTM, 1999q)
D 3441 -98	Standard test method for mechanical cone penetration tests of soil (ASTM, 1999r)
D 3550-84	Standard practice for ring-lined barrel sampling of soils (ASTM, 1999s)
D 3614-97	Standard guide for laboratories engaged in sampling and analysis of atmospheres and emissions (ASTM, 1998g)
D 3686-95	Standard practice for sampling atmospheres to collect organic compound vapors (activated charcoal tube adsorption method) (ASTM, 1998h)
D 3687-95	Standard practice for analysis of organic compound vapors collected by the activated charcoal tube adsorption method (ASTM, 1998i)
D 4050-96	Standard test method (field procedure) for withdrawal and injection well tests for determining hydraulic properties of aquifer systems (ASTM, 1999t)
D 4083-89/94	Standard practice for description of frozen soils (visual-manual procedure) (ASTM, 1999u)

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Table 3-2, Continued

ASTM designation‡	Title of standard
D 4106-96	Standard test method for analytical procedure for determining transmissivity and storativity of non-leaky confined aquifers by the non-equilibrium method (ASTM, 1999v)
D 4220-95	Standard practice for preserving and transporting soil samples (ASTM, 1999w)
D 4394-84	Standard test method, for determining the in situ modulus of deformation of rock mass using the rigid plate loading method (ASTM, 1999x)
D 4395-84	Standard test method for determining the in situ modulus of deformation of rock mass using the flexible plate loading method (ASTM, 1999y)
D 4403-84	Standard practice for extensometers used in rock (ASTM, 1999z)
D 4428-91	Standard test methods for crosshole seismic testing (ASTM, 1999aa)
D 4429-93	Standard test method for CBR (California bearing ratio) of soils in place (ASTM, 1999bb)
D 4448-85	Standard guide for sampling groundwater monitoring wells (ASTM, 1998j)
D 4452-85	Standard, test methods for x-ray radiography of soil samples (ASTM, 1999cc)
D 4490-96	Standard practice for measuring the concentration of toxic gases or vapors using detector tubes (ASTM, 1998k)
D 4506-90	Standard test method for determining the in situ modulus of deformation, of rock mass using a radial jacking Test (ASTM, 1999dd)
D 4544-86	Standard practice for estimating peat deposit thickness (ASTM, 1999ee)
D 4553-90	Standard test method for determining the in situ creep characteristics of rock (ASTM, 1999ff)
D 4554-90	Standard test method for in situ determination of direct shear strength of rock discontinuities (ASTM, 1999gg)
D 4555-90	Standard test method for determining deformability and strength of weak rock by an in situ uniaxial compressive test (ASTM, l999hh)
D 4597-97	Standard practice for sampling workplace atmospheres to collect organic gases or vapors with activated charcoal diffusional samplers (ASTM, 1998l)
D 4622-86	Standard test method for rock mass monitoring using inclinometers (ASTM, 1999ii)
D 4623-86	Test method for determination of in situ stress in rock mass by overcoring method-USBM borehole deformation gage (ASTM, 1999jj)
D 4630-86	Standard test method for determining transmissivity and storativity of low permeability rocks by in situ measurements using the constant head injection test (ASTM, 1999kk)
D 4631-86	Standard test method for determining transmissivity and storativity of low permeability rocks by in situ measurements using the pressure pulse technique (ASTM, 1999ll)
D 4645-87/92	Standard test method for determination of the in situ stress in rock using the hydraulic fracturing method (ASTM, 1999mm)
D 4696-92	Standard guide for pore-liquid sampling from the vadose zone (ASTM, 1999nn)
D 4700-91	Standard guide for soil sampling from the vadose zone (ASTM, 1999oo)
D 4719-87	Standard test method for pressure meter testing in soils (ASTM, 1999pp)
D 4729-87	Standard test method for in situ stress and modulus of deformation using the flat-jack method (ASTM, 1999qq)
D 4750-87	Standard test method for determining subsurface liquid levels in a borehole or monitoring well (observation well) (ASTM, 1999rr)
D 4879-89	Standard guide for geotechnical mapping of large underground openings in rock (ASTM, 1999ss)
D 4971-89	Standard test method, for determining the in situ modulus of deformation of rock using the diametrically loaded 76-mm (3-in.) borehole jack (ASTM, 1999tt)
D 5079-90	Standard practices for preserving and transporting rock core samples (ASTM, 1999uu)
D 50SS-90	Standard practice for decontamination of field equipment used at non-radioactive waste sites (ASTM, 1999vv)

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Table 3-2, Continued.

ASTM designation‡	Title of standard
D 5092-90	Standard practice for design and installation of ground water monitoring wells in aquifers (ASTM, 1999ww)
D 5093-90	Standard test method for field measurement of infiltration rate using a doubling infiltrometer with a scaled-inner ring (ASTM, 1999xx)\
D 5126-90	Standard guide for comparison of field methods for determining hydraulic conductivity in the vadose zone (ASTM, 1999yy)
D 5195-91	Test method for density of soil and rock in-place at depths below the surface by nuclear methods (ASTM, 1999zz)
D 5254-94	Standard practice for minimum set of data elements to identify a groundwater site (ASTM, 1999aaa)
D 5514-92	Standard guide for soil gas monitoring in the vadose zone (ASTM, 1999bbb)
D 5408-93	Standard guide for set of data elements to describe a groundwater site; part one — additional identification descriptors (ASTM, 1999ccc)
D 5409-93	Standard guide for set of date elements to describe a groundwater site; part two — physical descriptors (ASTM, 1999ddd)
D 5410-93	Standard guide for set of date elements to describe a groundwater site; part three— usage descriptors (ASTM, 1999eee)
D 5434-97	Standard guide for field logging of subsurface explorations of soil and rock (ASTM, 1999fff)
D 5472-93	Standard test methods for determining specific capacity and estimating transmissivity at the control well (ASTM, 1999ggg)
D 5490-93	Standard guide for comparing groundwater flow model simulations to site-specific information (ASTM, 1999hhh)
E 1527-97	Standard practice for environmental site assessments: Phase I environmental site assessment process (ASTM, 1998a)
El 528-96	Standard practice for environmental site assessments: Transaction screen process (ASTM, 1998m)

† American Society for Testing and Materials, Philadelphia, PA.
‡ ASTM designation number and original year approved / current year approved.

The basic site investigation methodologies apply soil science methodologies in Klute (1986), Page et al. (1982), and SCS (1967, 1975b). Field investigation methodologies included soil profile descriptions, saturated hydraulic conductivity testing, unsaturated hydraulic conductivity testing. Infiltration testing, piezometer analysis, cation exchange capacity, and phosphorus adsorption methods (Elrick et al., 1989; EPA, 1981a, b; Kays & Patterson, 1981). Standard methodologies for wastewater chemical analysis have been developed by EPA (EPA, 1982).

CASE STUDY

Project: Great Lawn and Belvedere Lake Restoration
Location: Central Park, New York City
Owners: Central Park Conservancy. Inc., and New York City Department of Parks and Recreation
Landscape Architects: Central Park Conservancy. Inc., and New York City Department of Parks and Recreation
Engineers: Barrett Kays & Associates, P.A., Raleigh, NC Soil and, Environmental Scientists: Barrett Kays & Associates, P.A., Raleigh, NC

Background

The Central Park Conservancy. Inc., was founded in 1980 to assist in the restoration, maintenance, and operation of the largest and most used urban park in the USA. The park had seriously deteriorated over years of abuse and neglect. The Central Park Conservancy. Inc., started a long-term process to rebuild and restore the 340-m (840-acre) park.

In 1984 a group of urban soil scientists met to assist in evaluation of the soil problems for the Great Lawn restoration project. The Great Lawn is one of the largest open lawn areas in the park and is located behind the Metropolitan Museum of Art. The site comprises approximately 10 m (25 acres). During the initial site meeting the soil scientists (Drs. Fhillip Craul, Barrett Kays, and Richard Pouyat) discovered that the Great Lawn soils consisted of a thin veneer capping a debris landfill of approximately 10 m (25 acres) that Had been filled after the turn of the century. The debris landfill filled in the abandoned Croton Reservoir that was originally constructed in 1842. In the 1930s the landfill was capped, Belvedere Lake was constructed in the south end below Belvedere Castle, and the Great Lawn landscape was created. Today, the Great Lawn is heavily used for softball, football and other recreational purposes as well as for large outdoor concerts. More than 17 million visitors use the site each year.

With this heavy use, the Great Lawn has deteriorated significantly. The Lawn is heavily eroded, compacted, and has little or no grass cover. Runoff from the lawn discharges into Belvedere Lake that has become so polluted it has ceased to function as an attractive ecological setting.

In 1994 a major capital improvement project was begun by the Central Park Conservancy. Inc. A site characterization study was conducted prior to beginning the engineering and landscape design of the restoration project. The purpose of the site characterization study was to: (i) determine the physical and chemical nature of the soil above the landfill, (ii) determine the water table depths and gradients across the landfill, (iii) determine the drainage characteristics of the major soil horizons, (iv) determine the toxicity of sediments and waters in Belvedere Lake, and prepare an ecological evaluation of Belvedere Lake.

The basic findings of the site characterization study were:

1. The subsurface portions of the 1842 Croton Reservoir walls were intact and controlled groundwater flow. A middle wall in the reservoir was found that caused the water table elevation to drop approximately 3 m (10 ft). The upper reservoir water surface was found to be level and was saturated to the top of the middle wall; subsurface water was flowing over the top of the middle wall to escape the upper reservoir. The lower reservoir had been breached on the southeast side in the 1930s. The water surface in the lower reservoir had a gradient towards the outlet. The water surface elevation of Belvedere Lake was approximately 1 m (4 ft) above the groundwater elevation outside of the lake.
2. The depth across the landfill exceeded 9 m (28 ft). The landfill consisted primarily of rock, brick, plaster and concrete. There were limited amounts of wood, metal and other debris.

3. The soils capping the landfill averaged less than 0.5m (2 ft) in depth. The soils were highly compacted and the surface was eroded.
4. The sediments in Belvedere Lake had eroded from the Great Lawn. The sediments were found to have significant concentrations of Pb, Cu, Hg, and Zn.
5. Soil laboratory analysis included hydraulic conductivity and soil moisture retention data for the cap over the landfill and for a new proposed topsoil cap. A computer simulation model was used to evaluate rainfall, irrigation, soil / water movement and drainage through the site. The data was used to design the restoration improvements.

The restoration plans basically consisted of the following functional features: (i) deep drainage lines and water control structures to control the groundwater levels in the landfill; (ii) shallow drainage lines over the existing landfill soil cap; (iii) addition of sandy topsoil cover over the shallow drainage lines to provide a compaction-resistant lawn surface; (iv) addition of an irrigation system for the Great Lawn and to control flow into Belvedere Lake; and (v) dredging of Belvedere Lake, construction of various aquatic environments, and construction of water control inlet and outlet structures for the lake.

The design of the restoration improvements was specialized to correct all the problems identified in the site characterization process. Without the use of a detailed site characterization of the soils, groundwater, and lake, the restoration effort would contain fatal flaws. The proper use of site characterization and design can produce excellent technical solutions to complex urban soil problems.

The restoration construction project cost $18.4 million dollars and was completed in 1997. It is thought to be the largest single landscape restoration project for an urban park. The project is part of an overall $77 million dollar restoration program in Central Park.

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