Chapter 11

Human-Altered and Human-Transported Soils

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Introduction

This chapter is a practical guide for soil scientists conducting or interpreting a soil survey that includes human-altered and human-transported (HAHT) soils and materials. HAHT soils include soils that were intentionally and substantially modified by humans for an intended purpose, commonly for terraced agriculture, building support, mining, transportation, and commerce. They do not include soils modified through standard agricultural practices (such as shallow plowing, liming, and fertilization) or farmed soils with unintended wind and water erosion. Evidence for HAHT soils includes manufactured items (e.g., artifacts) present in the profile, human-altered material (e.g., deeply excavated or plowed soil) or human-transported material (e.g., fill), and position on or above anthropogenic landforms (e.g., flood-control levees) and microfeatures (e.g., excavator scrape marks). Detailed criteria regarding the identification of anthropogenic (artificial) landforms, human-altered material, and human-transported material are in the *Keys to Soil Taxonomy* (Soil Survey Staff, 2014).

Using position on or above very specific anthropogenic landforms and features as a property of the soil for classification purposes is somewhat of a departure from past conventions for defining classes in Soil Taxonomy. However, landscape- and landform-related criteria have been used for the identification of Fluventic and Cumulic subgroups (i.e., slope) and for the plaggen epipedon (i.e., raised landforms). The use of specific kinds of anthropogenic landforms for HAHT soils is an extension of these precedents. Destructional and constructional anthropogenic (human-constructed) landforms and microfeatures (see chapter 2) have evident purpose and are undeniably linked to the soil itself. Linear straightening of waterways, drainage ditches, sanitary landfill mounds, and geometric shaped excavation features are all tied to extreme soil modification or compilation (fig. 11-1). Regardless of the characteristics of the soil, if a soil is on or above an anthropogenic landform or microfeature, it can definitely be associated with a human activity and assigned to a unique taxa. For example, it would be hard to deny that the soil on the large public landfills in figure 11-1 was transported by humans, whether manufactured items are found in the 2-meter profile or not. Historical records can provide additional supportive proof. The movement of soil by humans resets the soil-forming factor of time and commonly truncates or buries a more developed soil, thus strongly influencing soil properties. Soil development depends on all soil-forming processes, including those associated with the construction of the anthropogenic landform or microfeature.

Soils in urban areas are commonly human-transported (e.g., fill) or human-altered (e.g., truncated or mixed *in situ*) to significant depth. They generally exhibit a wide variety of conditions, and many are covered with impervious surfaces (e.g., buildings and pavements). The same situation occurs in suburban and low-density urban areas, but the proportion of less altered soils is higher and the proportion of buildings and pavements is lower. In many areas with HAHT soils, surface geomorphology and hydrology have been intensely altered. Other highly modified landscapes contain significant amounts of human-transported materials, such as steep farmland with closely spaced hillslope terraces (fig. 11-2) and areas of intense activity, such as mines, oilfields, and highway corridors. Spoils from land-leveling, filling, construction, mining, dredging, waste-disposal, and manufacturing operations become parent materials for new soils, which are commonly used to extend urban areas or airports into shallow water or to fill wetlands. Major areas of human-altered materials occur where agricultural areas have been deeply ripped to loosen impervious subsoil horizons, such as in the Central Basin of California. There is a need to identify, describe, and map HAHT soils because these soils have been modified enough from their original state that former soil maps do not provide the correct information or there is no information on them at all.

Background

Humans substantially modify or transform the physical, chemical, and biological properties and processes of the soil through anthropedogenesis (Richter and Yaalon, 2012). Because they can profoundly affect all five

Figure 11-1

Top image—This landfill complex (center-right) is a constructional anthropogenic landform that rises approximately 33 m higher than the surrounding lower coastal plain swamp near Virginia Beach, Virginia. The geometric shaped excavation pit (now a lake) is an associated destructional landform. Both landforms are out of context with surrounding soils and landforms. Bottom image—The anthropogenic landform can be confirmed with edaphic and documented evidence of methane-producing garbage and artifacts layered between a geotextile membrane and soil material. (Images by R. Facun and S. Early, courtesy of The Virginian-Pilot)

soil-forming factors (parent material, climate, organisms, time, and relief or topography), some authors (Dudal, 2005) have established a sixth factor, described as a "master variable capable of modifying or controlling the other five factors" (Amundson and Jenny, 1991). In particular, humans excavate deeply enough to remove most or all soil

Figure 11-2

Machu Picchu, Peru. HAHT soils can be identified not only by diagnostic features in the soil profile but also by their association with anthropogenic landforms, whether manufactured items are found in the profile or not. This ancient urban area has geometric hillslope terraces on cut-and-fill landforms (foreground and lower right) created by humans in mountainous terrain to allow grazing, farming, and house building on formerly steep slopes. It demonstrates intentional human modification and transportation of soil. (Photo by Pedro Szekely)

horizons, impart manufactured materials and debris (artifacts) that become included in soil parent materials (fig. 11-3), and transport and deposit extensive amounts of soil, rock, and sediment that become new parent materials.

Humans also level (cut and fill) large areas, destroying natural landforms and building anthropogenic landforms and microfeatures (e.g., drainage ditches) as described in chapter 2. Archaeological evidence shows that humans have been altering soils for at least 8,000 to 10,000 years. Soil alterations have been slight (surficial) and collateral to standard agricultural practices (e.g., erosion) or been intentional and profound (e.g., mountaintop mining and extensive landform alteration through terracing or oilfield activity). Extensively modified areas with integrated land management are called "anthroscapes" (Eswaran et al., 2005) (fig. 11-4).

Figure 11-3

Profile of the Laguardia soil series showing artifacts in multiple deposits of human-transported material. The buried building debris contains brick, concrete, wire, steel, and asphalt. (Photo by Richard Shaw)

Development of HAHT Soil Concepts in the U.S.

The effort to formally describe and classify HAHT soils began in 1988 with the formation of the International Committee for Anthropogenic Soils (ICOMANTH). This committee was commissioned by USDA's Soil Conservation Service to introduce differentiae and taxa for classification and survey of observed human-altered and human-transported soils (also called anthropogenic soils). The charge of the committee was to introduce HAHT soils into U.S. Soil Taxonomy, facilitate mapping of urban areas, introduce new terms and materials into USDA databases,

Figure 11-4

An ancient Roman urban anthroscape, which reminds us that humans have been purposely modifying and moving soil in urban areas for millennia (the Colosseum is at the back on the right). Modern urban anthroscapes often include a mosaic of water, parks, buildings, and pavements (roads and sidewalks). (Photo by Andreas Tille)

enable meaningful interpretations of unique materials and soils, and facilitate establishment and correlation of new soil series. Between 1995 and 2010, seven circular letters were distributed internationally for feedback on committee ideas. The International Field Tour of Anthropogenic Soils of Nevada and California in 1998; the 5th Soils of Urban, Industrial, Traffic and Mining Areas (SUITMA) tour held in New York City in 2009; and the 4th IUSS Conference for Soil Classification held in Lincoln, Nebraska, in 2012 were used to test proposals and solicit feedback from diverse groups. ICOMANTH proposals were reviewed, accepted, and published in the 11th and 12th editions of the *Keys to Soil Taxonomy* (Soil Survey Staff, 2010, 2014). Major outcomes were the identification of human-altered material, human-transported material, and manufactured items as differentiae at both the subgroup and family levels in Soil Taxonomy. In addition, standard terms and conventions for describing anthropogenic features (artifacts) in soil profiles, as well as additional horizon nomenclature for identifying horizons impacted by human activity, were adopted (see chapter 3).

Importance

The human impact on the global environment since the Industrial Revolution has been so profound that a new geological epoch—the "Anthropocene"—has been proposed (Crutzen and Steffen, 2003; Steffen et al., 2011). As the human population increases, so does the degree and amount of land alteration by humans. About 3 percent of world's land surface is classified as urban (CIESIN, 1995), and the percentage is increasing as more people move into cities, especially along coastlines, where 10 percent of the land is urban. As of 2011, approximately 82 percent of the U.S. population and 52 percent of the world's population lived in urban areas (United Nations, 2013). In many areas, humans grow food in or near heavily developed areas, in soils with undocumented or unpredictable properties. Human alteration of soil occurs worldwide. For example, humans are clearing land deep into South American jungles for agriculture and mining, thus driving settlement further north into previously undeveloped areas. Agriculture on modified soils occurs extensively on most continents. Rice is grown in human-irrigated and -flooded paddies (many of which are hillslope terraces) covering 153.7 million hectares (IRRI, 2010).

Little was previously known about the chemical and physical properties and behavior of profoundly altered soils. In the past, their classification was minimal because of high variability. For example, urban HAHT soils were commonly classified at higher taxa, such as Udorthents, and had almost no specific information in USDA databases to provide meaningful interpretations. In order to improve soil survey of HAHT soils, additional taxa were needed for their classification, new methods were needed for their analysis, and new terms were needed for describing their properties so that soil maps and proper interpretations for their use could be provided.

Resource Management Issues and HAHT Soils

Important uses of soil survey information in urban areas include restoration and revegetation efforts, hydrologic interpretations for stormwater management, urban agriculture, and resource inventory (e.g., to identify wetlands). Urban soil surveys are used to advocate for best use and management practices for open space areas.

Mined and drilled lands, farmlands, intensively used agricultural areas, and some urban areas contain contaminated HAHT soils. Now that over half of the world's population is in urban areas, soil-related health risks are increasingly important. Human health concerns occur from contact with or exposure to contaminated soils, many of which are HAHT soils. Soils may impact humans directly (e.g., dust inhalation or contact with bare feet) or indirectly (e.g., metal uptake by vegetables). Some highly contaminated soils are not safe for direct soil sampling except by trained and equipped specialists; less-contaminated soils are likely to be surveyed and mapped. Agricultural areas subject to heavy pesticide, herbicide, or fungicide application also have an adverse impact on soil water, surface water, and ground water. Developers, administrators, politicians, regulators, and planners need soil information in determining best management practices to protect water quality and public health. Potentially contaminated sites can be managed for human use. For example, some landfills and brownfields have been carefully constructed or reclaimed for use as parkland (Scheyer and Hipple, 2005; Craul, 1992, 1999).

Occurrence

HAHT soils occur on all continents, even Antarctica (fig. 11-5). They are common on intensively managed lands where humans have established civilizations, including some areas now underwater. New HAHT soils are being formed every day. In the future, HAHT soils may occur on other celestial bodies. There is no record on global distribution of HAHT soils besides maps using national classification systems or the World Reference Base for Soil Resources (IUSS, 2014). Although HAHT soils are global in extent, they are commonly unmapped, unrecognized, and underappreciated.

Identification

By definition, HAHT soils have profound and purposeful alteration or occur on landforms with purposeful construction or excavation. The alteration is of sufficient magnitude to result in the introduction of a new parent material (human-transported material) or a profound change in the previously existing parent material (human-altered material) (see chapter 2). HAHT soils do not include soils with incidental or unintentional surficial changes due to standard agricultural practices or the shallow incorporation of artifacts through plowing. For example, a soil that has higher pH, fertility, or base saturation due to standard practices does

Figure 11-5

McMurdo Station, Antarctica. Human alteration of landforms, relocation of soil for building of infrastructure, and alteration of soil profiles occur even in this remote location. (Photo by Alan Light)

not have long-term change, whereas a soil that was shaped into an agricultural conservation terrace is profoundly and intentionally altered for a long-term purpose. Some changes serve no useful purpose and can be judged as unintentional (e.g., cultivation can lead to wind or water erosion or salinization and discarded manufactured trash can end up in a plow layer).

Many classification systems, including the World Reference Base (IUSS, 2014) and Soil Taxonomy, recognize HAHT soils at the highest levels, as Anthosols and as Technosols and Anthosols, respectively. Soil Taxonomy presently recognizes HAHT soils with a combination of taxa at the subgroup and family levels. Features of these soils include:

- An anthropic or plaggen epipedon
- Material between 25 and 50 cm thick that meets all the requirements of a plaggen epipedon except thickness
- 50 cm or more of human-altered and human-transported material over the original soil material

- HAHT material comprising the entire soil above a root-limiting layer or a contact that is shallower than 50 cm

Soil properties and characteristics that are used for the identification of human-transported and human-altered material are given in chapter 3 of the *Keys to Soil Taxonomy* (Soil Survey Staff, 2014) and are summarized below.

Human-Transported Material

Human-transported material (HTM) is soil parent material (organic or mineral) that has been moved horizontally onto a pedon from a source area outside of that pedon by purposeful human activity. Since constructional anthropogenic landforms are built with transported material, HTM is associated with these landforms. Commonly, a lithologic discontinuity or a buried horizon can be observed just below HTM. It may be difficult to distinguish human-transported material and parent material from mass movement processes (e.g., landslides) without intensive onsite examination and analysis. Evidence of HTM includes:

- Detached pieces of diagnostic horizons (such as argillic, calcic, histic, or spodic horizons) which are derived from the excavated source material
- Presence of artifacts such as brick, asphalt, glass, metal, plastic, combustion by-products, mechanically abraded rocks, midden material, and scrape marks
- Irregular distributions of artifacts or contaminants either with depth in the profile or with proximity away from an anthropogenic landform, feature, or constructed object, such as a road or building
- Lithologic discontinuities at the contact between HTM and the underlying former surface
- An underlying manufactured layer, such as a geotextile liner or concrete
- Location of the material on a constructional anthropogenic landform or microfeature or within the boundary of a destructional anthropogenic landform or microfeature

Human-Altered Material

Human-altered material (HAM) is soil parent material (organic or mineral) that has undergone anthroturbation (mixing or disturbance by humans). It differs from HTM in that it generally has been altered in place and contains little or no evidence of being transported from another location. Examples include agricultural soils that have been deeply mixed (e.g., by deep ripping of a root-restrictive subsoil layer such as a duripan) and soils that have been mechanically compacted to impound water (as in a rice paddy with anthric saturation). The concept also includes soils that have been removed, stockpiled, and replaced during reclamation (as in some surface mining or urban development activities) and soil materials that remain exposed after excavation (such as those on the floor of a gravel pit).

Human-altered materials are commonly associated with destructional anthropogenic landforms. These landforms are in areas where soil material has been removed (pits, quarries, mined areas, etc.). In some cases, a destructional landform may be recognized by tracing a subsurface horizon (such as an argillic or spodic horizon) from adjacent non-human-altered soils laterally to the point where it disappears abruptly, which corresponds to the boundary of the destructional landform.

Destructional anthropogenic landforms are excavated but may later be filled or covered. Where the excavations have been partially or totally filled with the original soil material, the material is considered HAM. Where they have been filled with different soil material, the material is considered HTM.

Evidence of human-altered material includes:

- Material occurs in an area impacted by the agricultural practices of deep plowing to rip a root-restrictve layer or of intentional compaction to puddle water.
- Material occurs within an excavated area (destructional land-form) such as a pit or quarry.
- The soil profile has features such as reoriented pieces of diagnostic horizons; rock fragments that are mechanically abraded; scrape marks underlying soil material that was removed, stockpiled, and replaced on site; or purposely compacted layers formed during construction activities.

Manufactured Layers

A manufactured layer is an artificial, root-limiting layer below the soil surface. These layers can be identified by their presence in or on an anthropogenic landform or microfeature, ranging from landfills to concrete-lined ditches to ponds. The soil above is HAHT material. The layers are used in construction (e.g., roof of an underground building) or to impede water, gas, or roots (e.g., landfill liner). There is a contact with HTM at the top of the manufactured layer, typically made out of geotextile liners, asphalt, concrete, rubber, or plastic. Below the layer, there may be more HTM, a layer of human-altered material, natural soil material, or rock.

Description

HAHT materials are described using standard methodology and procedures as discussed in chapter 3. Many of the standard conventions are also used, but there are a few items unique to descriptions of human-transported and human-altered soil materials. These items are briefly summarized below. See chapter 3 for additional information.

Horizon Nomenclature Common to HAHT Soils

A caret symbol (^) is used as a prefix to the master horizon capital letter (e.g., ^A) for soil horizons or layers that formed in HTM. These materials are commonly at the current surface. In many archaeological sites, however, human-transported materials are buried by more recent materials or by naturally transported material.

A numerical prefix can be used in front of the caret symbol to indicate a discontinuity (e.g., ^A-2^C). The description of lithologic discontinuities is independent of the description of HAHT materials. It is not necessary to indicate a discontinuity at the contact between all HAHT material and the underlying material, but this can be done if the materials are significantly different and it helps in understanding the nature of the soil profile.

Horizons and layers of HAHT material containing artifacts are identified with both the caret as a prefix and the lowercase letter u as a suffix (e.g., ^Au). There is no minimum percentage volume of artifacts. Incidental trash (e.g., a windblown plastic grocery bag or discarded aluminum can) need not be described with a "u" unless indicative of purposeful deposition by humans.

Manufactured layers (i.e., liners) are identified with the master horizon capital letter M. There is a manufactured layer contact at the top. Recognized types of liners include geotextile liners, asphalt, concrete, rubber, and plastic. The caret symbol prefix is not used with "M." Intentionally compacted soil may act as a liner, but since it is not industrially manufactured, it is indicated with the lowercase letter d as a suffix. The layer may be further identified as densic material and having a densic contact if it meets those criteria (Soil Survey Staff, 2014).

Artifacts

Artifacts are materials created, modified, or transported from their source by humans, typically for a practical purpose in habitation, manufacturing, excavation, agriculture, or construction activities (Soil Survey Staff, 2014). Artifacts may be particulate (< 2 mm in diameter) or discrete (≥ 2 mm in diameter in smallest dimension). Particulate artifacts cannot be estimated by sight or feel in the field and are measured on an oven-dried weight basis. They are not typically described until after lab measurement. Examples of discrete artifacts include bitumen (asphalt), brick, concrete, metal, paper, plastic, rubber, and treated or shaped wood products (see fig. 11-3). *Persistent artifacts* remain in the soil relatively unchanged for a decade or more. *Nonpersistent artifacts* undergo rapid weathering or decay and remain intact in the soil for only a few months or a few years. After burial, artifact properties may change over time. Their presence and their weathering by-products can significantly affect the physical and chemical properties of the soil. Some artifacts are considered noxious, such as arsenic-treated wood products, discarded batteries, petroleum products, and medical waste. Others are considered relatively innocuous, such as untreated wood products, iron, bricks, cinder blocks, and paper products. Knowing the nature and properties of artifacts can be very important in understanding the soil and in developing appropriate plans and strategies for land management. Because of their importance, kinds of artifacts are evaluated when assigning HAHT soils to taxonomic families in Soil Taxonomy (Soil Survey Staff, 2014).

Artifacts are described separately from rock fragments or other features in the soil. Descriptions of artifacts generally include quantity, degree of cohesion, persistence, size, and safety classes. They may also include shape, kind, penetrability by roots, and roundness. Other attributes may be described if considered useful in understanding and interpreting the soil. In addition, for soils containing more than 15 percent, by volume, artifacts, texture classes are modified with the adjective "artifactual." The terms and classes used to describe artifacts are provided in chapter 3.

Survey Methods and Procedures

Assessing Survey Needs

At the onset of an urban soil survey, its potential uses and audience need to be evaluated and the survey objectives established, including the type of information needed. Typical users include the municipal parks department; city, State, and Federal agencies; schools, colleges, and universities; and community groups. Environmental professionals in the urban community may be less familiar with soil survey and its applications. An advisory committee can be assembled to help identify users' needs, provide operational guidance and assist with land access, review survey progress, publicize the survey, and disperse information.

Reference Materials

Examples of Previously Completed Urban Soil Surveys

To date, urban soil surveys in the U.S. recognizing HAHT materials have been completed in San Diego (USDA-SCS, 1973); Washington, D.C. (USDA-SCS, 1976a); St. Louis (USDA-SCS, 1982); Baltimore (USDA-NRCS, 1998); Chicago (Web Soil Survey, 2013); New York City (Web Soil Survey, 2014); and Los Angeles (Web Soil Survey, 2017) and have begun in Los Angeles and Detroit. Other surveys on the urban fringe include Montgomery County, Maryland (USDA-NRCS, 1995); Essex (USDA-NRCS, 2007b) and Hudson (Web Soil Survey, 2012) Counties in New Jersey; Plymouth County, Massachusetts (Web Soil Survey, 2010); and Fairfax County, Virginia (Web Soil Survey, 2011). Other soil surveys covered human-altered soils in the Central Valley of California (USDA-NRCS, 2003), mined lands in coalfields, and heavily terraced lands across the United States. These soil surveys can provide examples and ideas when planning new surveys in similar urban areas. Soil survey updates commonly need to remap tracts of more recently developed land. Even though some profoundly altered areas exceed the minimum size of a map unit, many are correlated to the original soil series, are correlated as miscellaneous land types, or occur in map units such as "Udorthents-Urban land complex" or "Area not mapped." There is a high demand for information about these areas. As the work to conduct soil surveys in urban areas progressed over the nearly 50 years represented by the above examples, the understanding of human-altered and human-transported soils improved and the way these soils are described, classified, and mapped also advanced greatly. Consulting examples of previously completed urban soil surveys, especially those that used the most recent advances in this area, is the first step in planning new urban soil survey projects.

Other Ancillary Resource Materials

Urban areas include a variety of land uses, e.g., inner city or urban cores, industrial and residential areas, cemeteries, parks, and other open spaces. Pouyat et al. (2010) refer to an "urban soil mosaic," where the natural landscape has been fragmented into parcels with distinctive disturbance and management regimes and, as a result, distinctive characteristic soil properties. Where HAHT materials occur to a significant extent, an understanding is needed of pre-development conditions and land use history throughout the area. Topographic maps, including older maps from libraries and agencies, can be used to locate natural landforms and significant anthropogenic alterations. Archival aerial photography can help in identifying land use changes. Older soil or surficial geology maps can help in determining the nature of pre-existing parent material (which can also serve as local fill) and/or substratum conditions and may help in initial delineation of the survey area. These maps can also indicate the location of formerly wet or stony areas or other "undesirable" areas buried under human-transported materials in highly altered landscapes. Records of transportation departments (municipal, State, and Federal), along with landfill and dredging records from various departments, may provide valuable information. Municipal boring logs (e.g., those of the Department of Design and Construction, NYC) can serve as valuable data points in documenting the nature and thickness of HTM. Records from onsite soil investigations can provide field notes or pedon descriptions. Information from adjacent areas, especially those with similar geologic and soil conditions, is also useful. Publications of news articles, scientific reports, theses and dissertations, and documents from city agencies and historical societies commonly contain valuable information on the age and origin of HTM. The thorough collection and review of existing information in the area before the first hole is dug will save time and effort in the long run.

Mapping Scale

The challenge of mapping soils in urban areas is that severe disturbance and fragmentation of the land create high spatial variability that is beyond the scope of standard survey methods. For example, HTM may change across an area no larger than one pedon, as when a truckload of material is moved in. In this case, there are no polypedons to constitute a soil map unit. Order 1 surveys (see chapter 4) can offer 0.2-hectare level of detail (close to lot-sized) but may be time- and cost-prohibitive if routine soil survey methods are used. Small yards in residential areas, narrow transportation corridors, and soils in small commercial zones, medians, and parking lots are typically better suited to onsite inspections. However, the larger open spaces (more than a hectare) generally exhibit more uniformity in soil conditions because they have been disturbed less, or, if they have been subject to alteration and filling, consist of similar materials filled at the same time. They are generally easier to survey than small residential parcels. In addition, there is generally more demand for soils information on the larger areas for management, restoration, and resource inventory purposes.

Mapping scales for initial soil surveys in urban areas in the U.S. have ranged from 1:24,000 for San Diego, St. Louis, and Los Angeles to 1:12,000 for Washington, D.C., Baltimore, Chicago, and New York City. The soil survey of South Latourette Park in New York State consisted of 130 hectares mapped at a scale of 1:6,000. It served as a pilot project for modern soil mapping in New York City (USDA-NRCS, 1997). A general, or reconnaissance, soil survey at a scale of 1:62,500 was also conducted in New York City (USDA-NRCS, 2005) to provide a general guide to soil patterns around the city and serve as the foundation for more detailed future surveys. Order 1, high-intensity surveys include the Gateway National Recreation Area (USDA-NRCS, 2006) at 1:4,800, a scale that was compatible with other natural and cultural resource mapping and assessment by the National Park Service, and the Bronx River Watershed (USDA-NRCS, 2007a) at 1:6,000, which emphasized hydrologic applications and stormwater management. The complexity of soil patterns, the high value of the land and its intensive use, and the number of taxpayers potentially affected by better land use and management decisions in urban areas all favor a larger mapping scale. The primary considerations when selecting a mapping scale, however, are the survey objectives, the users' needs, the size of the survey area, and the time requirements.

Designing Taxonomic and Mapping Units

Soils in HAHT materials present a formidable challenge to soil survey; spatial and vertical variability can be complex and unpredictable, and soil conditions commonly change with little variation in landscape or vegetation. The variability in HAHT soil properties needs to be examined, along with the consistency and extent of various soil types. Certain HAHT soil types or human-altered landforms may be associated with a particular surficial geology type, landscape position, or pre-existing soil map unit and so allow for some soil-landscape modeling. In addition, the objectives of the survey need to be kept in mind when establishing differentiating criteria for soil components because some soil properties will vary with land cover and land use. Although important properties and ratings, such as saturated hydraulic conductivity (K_{sat}), hydrologic soil group, content of soil organic matter, pH, and nutrient content, can vary widely across the entire urban landscape, the range in these properties is generally much narrower within a specific land use.

Characterization and classification of HAHT soils will vary according to mapping scale. It has evolved somewhat with successive urban and suburban mapping efforts. Earlier surveys used miscellaneous areas (e.g., "Made land," in the 1973 soil survey of San Diego Area by USDA-SCS) and the great group level, commonly Udorthents. The Washington D.C. survey (USDA-SCS, 1976a) mapped 11 phases of Udorthents. It had no ratings or interpretations for these phases, but some selected samples were listed in tables of physical and chemical properties. The Baltimore survey (USDA-NRCS, 1998) included six phases of Udorthents with some ratings. A minimum set of physical and chemical properties, approximating the series level of classification, is useful for many applications and suitable for most interpretations.

Defining Soil Series and Phases for HAHT Soils

The use of soil series for HAHT soils began in the 1970s. It has included strip-mining spoils in Haskell County, Oklahoma (USDA-SCS, 1975), dredge materials in Wagoner County, Oklahoma (USDA-SCS, 1976b), cut-and-fill soils in St. Louis (USDA-SCS, 1982), and deep-ripped, chemically altered soils in California's Central Valley (USDA-NRCS, 2003). For these HAHT soils, the user has a complete set of estimated properties, ratings, and interpretations. The survey of New York City's South Latourette Park (USDA-NRCS, 1997) featured five new series for HAHT soils, using artifact content in the > 2 mm fraction as one of the differentiating criteria. Soil Taxonomy uses amount and kinds of artifacts in the definitions of some family-level classes (Soil Survey Staff, 2014). Artifact content is also used by the World Reference Base for Soil Resources to define the Technosols reference soil group and the Technic and Hypertechnic (second-level) qualifiers (IUSS, 2014). The legend for the initial New York City survey (2014) included 29 HAHT soil series. Significant amounts of fill and waste materials serve as soil parent materials in this area. The Los Angeles survey included HAHT series; fill, landscaped, and graded phases at the great group, subgroup, and series levels; and some Urban land phases based on land use (i.e., commercial, residential, and industrial). This survey area extended beyond the city into areas of suburban and industrial land use, and human-altered landforms and landscapes were common.

Miscellaneous Areas

The miscellaneous area "Urban land" has long been used in soil survey as a map unit component. Because the definition of Urban land is somewhat ambiguous, the term has been used inconsistently. A miscellaneous area, by definition, is not soil. However, the Urban land component includes soil in some soil surveys. To avoid confusion, the New York City soil survey proposed a “Pavement and buildings” miscellaneous area because it was more descriptive. Ideally, such a miscellaneous area is restricted to actual impervious surfaces (e.g., an Urban land consociation would have 85 percent or more impervious surface). Delineating these areas and adding a substratum phase based on a surficial geology or predevelopment soil map, or adding a land use phase to the consociation, may provide additional information of value to the user (Efflend and Pouyat, 1997). The additional information would be especially important if the covered material was saturated or posed a risk of subsidence or a health hazard to humans (e.g., covered unregulated landfills).

Quantifying and describing the extent of impervious surfaces typically is done using geographic information system (GIS) tools or on aerial photographs or high-resolution satellite imagery. Other techniques use a dot grid. Impervious surfaces include sidewalks, rooftops, driveways, bridges, paved roads, and parking lots, excluding those known to be pervious (e.g., special materials, gravel, or packed soil).

Map Unit Design

Urban land is also frequently mapped in complex with HAHT soils and minimally altered soils. Several different complexes may be needed to reflect lot sizes and percent composition of Urban land. For example, in the initial soil survey of New York City, less than 10 percent Urban land in a map unit was considered an inclusion. In areas with 10 to 49 percent impervious surface, Urban land was named as a major component of a map unit complex, and in areas with 50 to 90 percent impervious surface, Urban land was named as the dominant component of the complex. Areas with over 90 percent Urban land were named as a map unit consociation, with the type of original surface identified (e.g., glacial till, outwash, tidal marsh) as a substratum phase. Other human-altered miscellaneous areas include Dumps, Oil-waste land, Pits, Quarries, Scoria land, and Slickens.

Classification

As discussed above, soil series can be defined for HAHT soils where the human-induced processes leading to their formation are relatively uniform over mappable areas (e.g., deep ripping, replacement of stockpiled soils after mining, placement of uniform fill material, and extensive subsoil compaction for flood irrigation). When surveying an area, new soil series should be developed for predictably recurring soils that have a significant amount or type of HAHT material, undergo deep alteration of hydrology (anthraquic saturation), or are deeply excavated. Existing series may need to be reclassified or areas resurveyed to recognize HAHT soils.

To properly classify HAHT soils, descriptions of HAHT soil profiles need to document the kind and amount of HAHT soil materials and the kind and amount of artifacts present and to recognize the presence of diagnostic horizons and features (such as an anthropic or plaggen epipedon, anthric saturation, and densic materials). Soil Taxonomy (Soil Survey Staff, 2014) recognizes various taxa for HAHT soils at the subgroup and family levels. These taxa are listed in tables 11-1 and 11-2 along with a brief statement about the concept for the taxa and its general occurrence. There will likely be additional taxa in the future.

Table 11-1

Soil Taxonomy Subgroups and HAHT Soil Concepts

Subgroup	General concept
Anthraquic	Soils have a currently or formerly ponded surface due to flood irrigation, commonly with puddled or compacted horizons that hold water near the surface. They commonly occur in rice paddies and aquaculture areas.
Anthrodensic	Soils have a constructed densic contact due to human activity. They commonly occur in reclaimed mined lands and building or transportation construction sites.
Anthropic	Soils have an anthropic epipedon. They occur in many areas associated with sustained human habitation or cultivation.
Plaggic	Soils have a plaggen epipedon (50 cm or more of plaggen material). They mostly occur in northern Europe. They may also be associated with some intensive organic farming operations.
Haploplaggic	Soils have 25 to 49 cm of plaggen materials. They mostly occur in northern Europe. They may also be associated with some intensive organic farming operations.
Anthroportic	Soils formed in parent material that was transported by humans (HTM). They occur worldwide.
Anthraltic	Soils formed in parent material that was altered in place by humans. They mainly occur in intensely cultivated areas and in areas of burials or trenching.

HAHT soils may be further identified at the family level by the presence of unusual materials anywhere in the upper 2 m that are not geologic in nature. The HAHT family classes explained in table 11-2 are inserted between particle-size class and mineralogy class for soils that qualify for HAHT subgroups, that have at least 50 cm of HAHT material on top, or for which the whole soil above a root-limiting layer or contact occurring at a depth shallower than 50 cm is HAHT materials.

Table 11-2

Soil Taxonomy Family Terms and HAHT Soil Concepts

Family term	General concept
Methanogenic	Soils produce ≥ 1.6 ppb methane or methyl mercaptan. They occur in landfills and waste-disposal sites. They do not include natural anaerobic environments.
Asphaltic	Soils have a layer ≥ 7.5 cm thick that contains ≥ 35% (by volume) asphalt (bitumen) ≥ 2 mm in diameter. They occur in fill areas with construction debris, on top of old impervious surfaces, in landfills, and near highway paving projects.
Concretic	Soils have a layer ≥ 7.5 cm thick that contains ≥ 35% (by volume) concrete ≥ 2 mm in diameter. They occur in fill areas with construction debris, on top of old impervious surfaces, in landfills, and near construction projects.
Gypsifactic	Soils have a layer ≥ 7.5 cm thick that contains ≥ 40% (by weight) synthetic gypsum products, commonly as drywall or flue gas desulfurization gypsum. They occur in fill areas with construction debris, in landfills, and near building projects.
Combustic	Soils have a layer ≥ 7.5 cm thick that contains ≥ 35% (by volume) coal combustion by-products ≥ 2 mm in diameter and too heavy to be volatile (e.g., bottom ash or coal slag). They occur in approved disposal areas, unregulated fill sites, city parks, and gravel-topped roads in urban areas.
Ashifactic	Soils have a layer ≥ 7.5 cm thick that contains ≥ 15% (by grain count in the 0.02 to 0.25 mm fraction) light-weight, coal combustion by-products that are volatile, such as fly ash. They typically occur in approved disposal sites, unregulated fill sites, and retention ponds near power plants.

Table 11-2.—continued	
Family term	**General concept**
Pyrocarbonic	Soils have a layer ≥ 7.5 cm thick that contains ≥ 5% (by grain count in the 0.02 to 0.25 mm fraction) light-weight products of pyrolysis, such as fuel coke or biochar. They typically occur in approved disposal sites, unregulated fill sites, and retention ponds and near power plants. They include terra preta soils.
Artifactic	Soils contain ≥ 35% discrete artifacts ≥ 2 mm that are both persistent and cohesive in a layer ≥ 50 cm thick. They typically occur in landfills, fill areas, and transportation corridors.
Pauciartifactic	Soils contain ≥ 15% (up to 35%) discrete artifacts ≥ 2 mm that are both persistent and cohesive in a layer ≥ 50 cm thick. They typically occur in landfills, fill areas, urban areas, construction sites, and transportation corridors.
Dredgic	Soils contain finely stratified (≤ 5 cm thick) layers of dredged or irrigated sediment in a layer ≥ 50 cm thick. They occur on anthropogenic landforms near a dredged source, in tailing ponds, and in agricultural fields flood-irrigated with diverted stream water.
Spolic	Soils contain ≥ 50 cm of HTM. They mainly occur on anthropogenic landforms, in clean fill areas, and in artificially landscaped areas.
Araric	Soils contain a layer ≥ 7.5 cm thick with ≥ 3% (by volume) mechanically detached and re-oriented pieces of diagnostic horizons or characteristics. They mainly occur in intensely managed agricultural fields, burial grounds, excavated borrow and mine pits, transportation corridors, and flood-irrigated rice and fish production areas.

Additional Soil Survey Information

More than easy-to-understand map unit descriptions and a special symbols legend are important in conveying soil survey information for urban and other highly modified areas. Block diagrams, soil profile and landscape photos, a glossary, explanation figures, and catena tables with drainage class by parent material can also be used. For example, the soil survey of South Latourette Park in New York City included a series of colorful cartoon-like soil profile drawings. Soil-system type block diagrams depicting water movement through the environment are particularly useful for stormwater management and hydrologic modeling.

Field Operations

The degree of parcelization of the landscape that is common in urban and suburban areas can create problems with survey site access. Establishment of good relations with parks department personnel; property managers in golf courses, cemeteries, and schools and colleges; and other environmental professionals is typically very beneficial. Utility companies and city engineering and parks departments should be contacted to find out if any soil excavations are planned in the survey area. Open gravesites in cemeteries can provide access to natural soil materials. Construction sites and street excavations provide opportunities to observe substratum characteristics.

The following points should be considered when surveying human-altered landscapes:

1. A preliminary examination of the original topography, landform, surficial materials, or soil types, as well as the land use history, should precede any site investigations.
2. Historical maps, records, and vintage photographs should be gathered and related to current mapping resources before and during mapping.
3. Familiarity with the parent material and soil properties in an area helps in determining whether a particular pedon is human-altered or -transported.
4. A characterization, classification, or delineation of the site beforehand is generally helpful. Depending upon the survey objectives and map unit design, these soil lines can reflect pre-existing natural landforms, human-altered landforms, current land use or land cover patterns, or some combination of these. The traverse across the initially delineated area will determine soil uniformity.
5. Highly contrasting soils should be differentiated if possible, with transecting to determine map unit composition.
6. Chemical properties of human-transported soils, particularly when enriched with artifacts, can be significantly different than those of soils in naturally occurring materials.
7. Predictions of soil-landscape associations eventually become evident. For example, certain vegetation types occur with

undisturbed soils and certain human-transported soils occur with certain parent materials or landscape positions.

8. Generally, the location of human-transported soils is somewhat logical. For example, areas with undesirable soil conditions are used for waste disposal. In disturbed areas, however, predictions need more verification than in undisturbed areas.
9. Conventional mapping protocol generally may be followed and modified when encountering anthropogenic landforms, unusual or abrupt changes in parent material, miscellaneous land types, or small areas of contrasting soil.
10. The location of buried utilities, such as gas lines, fiber optic cable, water pipes, etc., must be ascertained before digging.

Topography, Landforms, and Anthropogenic Features

Many constructional and destructional anthropogenic landforms and microfeatures are listed in the *Keys to Soil Taxonomy* (Soil Survey Staff, 2014). Additionally, the *Field Book for Describing and Sampling Soils* (Schoeneberger et al., 2012) provides a list of anthropogenic (earth-surface) features, ranging in size from entire landscapes to bioswales and road cuts. Anthropogenic landscapes, or anthroscapes, are human-modified with substantial and permanent alterations. Anthropogenic landforms are large enough to delineate at commonly used map scales (1:24,000 to 1:10,000). They can be grouped as constructional (e.g., fill) or destructional (e.g., excavated). Anthropogenic microfeatures are features that formed at the surface by purposeful human activity and are too small to delineate at commonly used map scales (1:24,000 to 1:10,000). Included with microfeatures are what archaeologists call "anthropogenic features," which do not occupy three-dimensional volume (e.g., scrape marks of machinery), and temporal forms too small to map at any scale (e.g., plowed ridges and furrows).

The British Geological Society has established a hierarchical classification system for mapping "artificial ground classes" (Rosenbaum et al., 2003). At the upper level of this classification, there are five genetic subdivisions: made ground, worked ground, infilled ground, disturbed ground, and landscaped ground. They are followed by a topographic/geographical category (e.g., embankment, waste heap) and finally a material or lithologic type (e.g., building rubble, rock waste). Consideration of these or similar classes may be helpful in understanding HAHT soils.

Equipment Needs

Because compacted soils, sharp objects, cobble- and stone-sized artifacts, and rock fragments are common in urban areas, digging equipment should include heavy-duty tools, such as a reinforced metal shovel and a large metal bar. Conventional soil survey equipment is also needed, along with recent maps and locational equipment, such as cell phones or GPS units. Soil quality (soil health) testing equipment is needed for special project areas and should include soil tests that relate to ecosystem functions and services. Portable field equipment for measuring pH, conductivity, total dissolved solids, bulk density, infiltration, saturated hydraulic conductivity, and heavy metals should be taken on survey trips.

Rapid and non-invasive geophysical methods have great potential for use in urban soil survey (see chapter 6). Ground-penetrating radar (GPR) can provide information on depth to or thickness of human-transported or contrasting materials, buried tanks or drums, etc. Electromagnetic induction (EMI) has been used to assess differences in soil water content, compaction, texture, lithology, mineralogy, pH, $CaCO_3$ content, soil organic carbon, and other soil properties. Magnetic susceptibility can be used to identify industrial dusts and certain types of artifacts (Howard and Orlicki, 2015) and as a proxy for trace metal levels in soil (Yang et al., 2012). Portable X-ray fluorescence (PXRF) spectrometers can determine trace metal contents in the field and assess spatial variability. Most of these methods require some initial investigation (to determine their suitability) and some calibration. However, when considering the time needed for hand digging pits in urban areas and the extent of lateral and vertical variability in some fill materials, they may be deemed practical. Chapter 6 has a more extensive discussion of non-invasive tools.

Safety Precautions in Urban Areas

In urban areas, hazardous materials (HazMat) training is advisable. Maps of known Superfund and brownfield sites should be taken to the field. *Superfund* is a U.S. Federal government program designed to fund the cleanup of sites contaminated with hazardous substances and pollutants. A brownfield is a property, the expansion, redevelopment, or reuse of which may be complicated by the presence or potential presence of a hazardous substance, pollutant, or contaminant (US-EPA, 2016). PXRF meters should be used in suspected brownfield areas, unregulated landfills, and hazardous waste areas for the safety of surveyors.

Heavy-duty gloves, hard-toed boots, and hardhats should also be used in some areas. Traffic cones should be used to prevent accidents while parking or pausing vehicles. Utility companies must be contacted before digging to prevent accidents. Surveyors should set known check-in times and have a plan in case of traffic delays or late arrival. Using prepaid bridge and tunnel passes saves time and money.

Surveyors should work in pairs; carry cell phones, walkie-talkies, and whistles; and wear uniforms with insignia or obvious lettering (e.g., New York City Soil Survey) and identification badges. Cars should have a magnetic car door logo or other markings clearly identifying their official purpose. In urban areas, it is important not to look vulnerable, e.g., surveyors should show evidence that they are connected to a protected and respected group and can summon help quickly. Surveyors should avoid areas with vagrants unless accompanied by authorities, avoid trespassing into high-security areas, and recognize dangerous parts of urban areas. Exposure to drug sales or manufacturing, marijuana gardens, gang violence, sexual attack, and racism and other discriminatory actions may pose a real threat in certain urban areas. Surveyors should not carry valuables, other than essential identification, in the field or in the vehicle. They should take proper precaution in dark areas and at night. Rabies and animals infected by rabies, insects, snakes, and dogs are abundant in urban areas, as are poisonous plants.

Pedon Descriptions

Most pedon properties are described according to conventional standards. Exceptions are defined earlier in this chapter. Two representative pedon descriptions of HAHT soils are provided below.

Laguardia Series

The Laguardia series consists of very deep, well drained soils. These soils formed in a thick mantle of construction debris intermingled with human-transported soil materials. They occur on modified landscapes in and near major urbanized areas of the Northeast. Slope ranges from 0 to 75 percent. Saturated hydraulic conductivity is low to moderately high. Mean annual temperature is about 13 degrees C, and mean annual precipitation is about 1196 mm.

Taxonomic Classification: Loamy-skeletal, artifactic, mixed, superactive, nonacid, mesic Anthropic Udorthents

^Au—0 to 20 cm; brown (10YR 4/3) artifactual coarse sandy loam, pale brown (10YR 6/3) dry; weak very fine subangular blocky structure; friable; few very fine and medium roots; 15 percent cobble-sized brick and concrete fragments, 5 percent cobble-sized asphalt fragments, 5 percent gravel-sized glass fragments, and 5 percent natural cobbles; neutral (pH 7.2); gradual wavy boundary.

^BCu—20 to 66 cm; brown (10YR 4/3) very artifactual coarse sandy loam; weak very fine subangular blocky structure; friable; few very fine roots; 25 percent cobble-sized brick and concrete fragments, 5 percent cobble-sized asphalt fragments, 5 percent cobble-sized metal fragments, 5 percent gravel-sized plastic fragments, and 5 percent natural cobbles; neutral (pH 7.2); gradual wavy boundary.

^Cu—66 to 200 cm; brown (10YR 4/3) very artifactual coarse sandy loam; massive with compaction-related plate-like divisions; very friable; few very fine roots; 25 percent cobble-sized brick and concrete fragments, 10 percent cobble-sized asphalt fragments, 5 percent cobble-sized metal fragments, 5 percent gravel-sized glass fragments, 5 percent gravel-sized plastic fragments, and 7 percent natural cobbles; neutral (pH 7.2).

Ladyliberty Series (fig. 11-6)

The Ladyliberty series consists of very deep, moderately well drained soils with moderately low to moderately high saturated hydraulic conductivity. These soils formed in a thick mantle of human-transported material consisting of coal slag, dredged materials, and/or any geologic deposits ranging from till, outwash, alluvium, or coastal plain sediments (typically from a local source). They occur on anthropogenic landforms in and near major urbanized areas of the Northeast. Slope ranges from 0 to 8 percent. Mean annual temperature is about 13 degrees C, and mean annual precipitation is about 1196 millimeters.

Taxonomic Classification: Sandy-skeletal, combustic, mixed, mesic Anthropic Udorthents

^Au—0 to 5 centimeters; very dark grayish brown (10YR 3/2) fine sandy loam; weak medium granular structure; very friable; many very fine to coarse roots throughout; 10 percent gravel-sized coal slag fragments; strongly acid (pH 5.2); clear wavy boundary. (5 to 27 centimeters thick)

^ABu—5 to 16 cm; dark yellowish brown (10YR 3/4) artifactual loam; moderate medium subangular blocky and moderate fine granular structure; friable; common fine roots around fragments; 15 percent coarse subangular gravel-sized coal slag and 2 percent gravel-sized fine wire, bed springs, and glass; strongly acid (pH 5.2); abrupt smooth boundary.

2^Cu1—16 to 39 cm; black (7.5YR 2.5/1) very artifactual loamy sand; massive; loose; few fine roots within cracks; 25 percent gravel-sized subangular coal slag and brick, 20 percent gravel-sized wood, and 2 percent gravel-sized wire; slightly acid (pH 6.2); abrupt smooth boundary.

2^Cu2—39 to 65 cm; strong brown (7.5YR 4/6) extremely artifactual loamy sand; massive; firm; 70 percent gravel-sized subangular coal slag; slightly acid (pH 6.4); abrupt smooth boundary.

3^C1—65 to 96 cm; dark yellowish brown (10YR 4/4) gravelly sand; massive or single grain; loose; 20 percent well rounded fine gravel and 2 percent shell fragments; neutral (pH 6.8); abrupt smooth boundary.

3^C2—96 to 167 cm; dark brown (10YR 3/3) sand; massive or single grain; loose to firm; 2 percent well rounded fine gravel; slightly alkaline (pH 7.8); abrupt smooth boundary.

3^Cg1—167 to 185 cm; very dark gray (10YR 3/1) sand; single grain; loose; 2 percent well rounded fine gravel; slightly alkaline (pH 7.8); abrupt smooth boundary.

4Cg2—185 to 200 cm; very dark gray (N 3/) silt loam; massive; firm; strongly alkaline (pH 8.6).

Figure 11-6

A profile of the Ladyliberty soil series (similar to the one described in the text). Multiple deposits of human-transported materials overlie a naturally deposited gleyed substratum at a depth of 120 cm. The upper 16 cm consists of transported topsoil over transported coal slag with artifacts. Beneath the coal slag, at a depth of 55 cm, is a dredged spoil deposit. (Photo by Richard Shaw)

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