CHAPTER 2

RECOGNITION OF PROBLEM AREAS

2-1. Site selection

The choice of the construction site is often limited. It is important to recognize the existence of swelling soils on potential sites and to understand the problems that can occur with these soils as early as possible. A surface examination of the potential site as discussed in paragraph 3-2 should be conducted and available soil data studied during the site selection.

a. Avoidance of potential problems. If practical, the foundation should be located on uniform soils subject to the least swelling or volume change. Discontinuities or significant lateral variations in the soil strata should be avoided. Swampy areas, backfilled ponds, and areas near trees and other heavy vegetation should be avoided, Special attention should be given to adequate compaction of filled areas, types of fill, and leveling of sloped sites (para 7-1).

(1) *Undeveloped sites.* Undeveloped sites generally have little or no subsurface soil information available and require subsurface exploration (para 3-3).

(a) Substantial differential heave may occur beneath structures constructed on previously undeveloped sites where trees and other heavy vegetation had been removed prior to construction, Soil moisture will tend to increase since loss of heavy vegetation reduces the transpiration of moisture. Construction of the foundation over the soil will tend to further increase soil moisture because of reduced evaporation of moisture from the ground surface.

(b) Swampy or ponded areas may contain greater quantities of plastic fine particles with a greater tendency to swell than other areas on the site.

(c) Future irrigation of landscaped areas and leakage from future sewer and other water utility lines following development of the site may substantially increase soil moisture and cause a water table to rise or to develop if one had not previously existed. Filled areas may also settle if not properly compacted.

(2) *Developed sites.* Subsurface exploration should be conducted if sufficient soil data from earlier borings are not available for the site selection and/or problems had occurred with previous structures. Some subsurface exploration is always necessary for site selection of any structure of economic significance, particularly multistory buildings and structures with special requirements of limited differential distortion.

(a) An advantage of construction on developed sites is the experience gained from previous construction and observation of successful or unsuccessful past performance. Local builders should be consulted to obtain their experience in areas near the site. Existing structures should be observed to provide hints of problem soil areas.

(b) The soil moisture may tend to be much closer to an equilibrium profile than that of an undeveloped site. Differential movement may not be a problem because previous irrigation, leaking underground water lines, and previous foundations on the site may have stabilized the soil moisture toward an equilibrium profile. Significant differential movement, however, is still possible if new construction leads to changes in soil moisture. For example, trees or shrubs planted too close to the structure or trees removed from the site, change in the previous irrigation pattern following construction, lack of adequate drainage from the structure, and improper maintenance of drainage provisions may lead to localized changes in soil moisture and differential heave. Edge movement of slab-on-grade foundations from seasonal changes in climate may continue to be a problem and should be minimized as discussed in chapter 7.

(3) *Sidehill or sloped sites.* Structures constructed on sites in which the topography relief is greater than 5 degrees (9 percent gradient) may sustain damage from downhill creep of expansive clay surface soil. Sidehill sites and sites requiring split-level construction can, therefore, be expected to complicate the design. See chapter 7 for details on minimization of foundation soil movement.

b. Soil surveys, Among the best methods available for qualitatively recognizing the extent of the swelling soil problem for the selected site is a careful examination of all available documented evidence on soil conditions near the vicinity of the site. Local geological records and publications and federal, state, and institutional surveys provide good sources of information on subsurface soil features. Hazard maps described in paragraph 2-2 document surveys available for estimating the extent of swelling soil problem areas.

2-2. Hazard maps

Hazard maps provide a useful first-order approximation of and guide to the distribution and relative expansiveness of problem soils. These maps should be used in conjunction with local experience and locally available soil surveys and boring data. The maps discussed in a and *b* below are generally consistent with each other and tend to delineate similar areas of moderately or highly expansive soil.

a. Waterways Experiment Station (WES) Map. This map, which was prepared for the Federal Highway Administration (FHWA), summarizes the areas of the United States, except Alaska and Hawaii, where swelling soil problems are likely to occur (fig. 2-1). The basis for classification depends primarily on the estimated volume change of argillaceous or clayey materials within the geologic unit, the presence of montmorillonite, the geologic age, and reported problems due to expansive materials. The stratigraphy and mineralogy are key elements in the classification.

(1) *Classification. The* soils are classified into categories of High, Medium, Low, and Nonexpansive as shown in figure 2-1. The distribution of expansive materials is categorized by the geologic unit on the basis of the degree of expansiveness that relates to the expected presence of montmorillonite and the frequency of occurrence that relates to the amount of clay or shale. The amount refers most significantly to the vertical thickness of the geologic unit, but the areal extent was also considered in the classification. The premises in table 2-1 guide the categorization of soils.

Table 2-1. Premises for Categorization of Soils by the WES Hazard Map

1. Any area underlain by argillaceous rocks, sediments, or soils will exhibit some degree of expansiveness.
2. The degree of expansiveness is a function of the amount of expandable clay minerals present.
3. Generally, the Mesozoic and Cenozoic rocks and sediments contain significantly more montmorillonite than the Paleozoic (or older) rocks. (Damage to structures founded on Permian (Upper Paleozoic) has also been observed.)
4. Areas underlain by rocks or sediments of mixed textural compositions (e.g., sandy shales or sandy clays) or shales or clays interbedded with other rock types or sediments are considered on the basis of geologic age and the amount of agrillaceous material present.
5. Generally, those areas lying north of the glacial boundary are nonexpansive due to glacial drift cover.
6. Soils derived from weathering of igneous and metamorphic rocks are generally nonexpansive.
7. Climate or other environmental aspects are not considered.
8. Argillaceous rocks or sediments originally composed of expandable clay minerals do not exhibit significant volume change when subjected to tectonic folding, deep burial, or metamorphism.
9. Volcanic areas consisting mainly of extruded basalts and kindred rocks may also contain tuffs and volcanic ash deposits that have devitrified and altered to montmorillonite.
10. Areas along the glaciated boundary may have such a thin cover of drift that the expansive character of the materials under the drift may predominate.

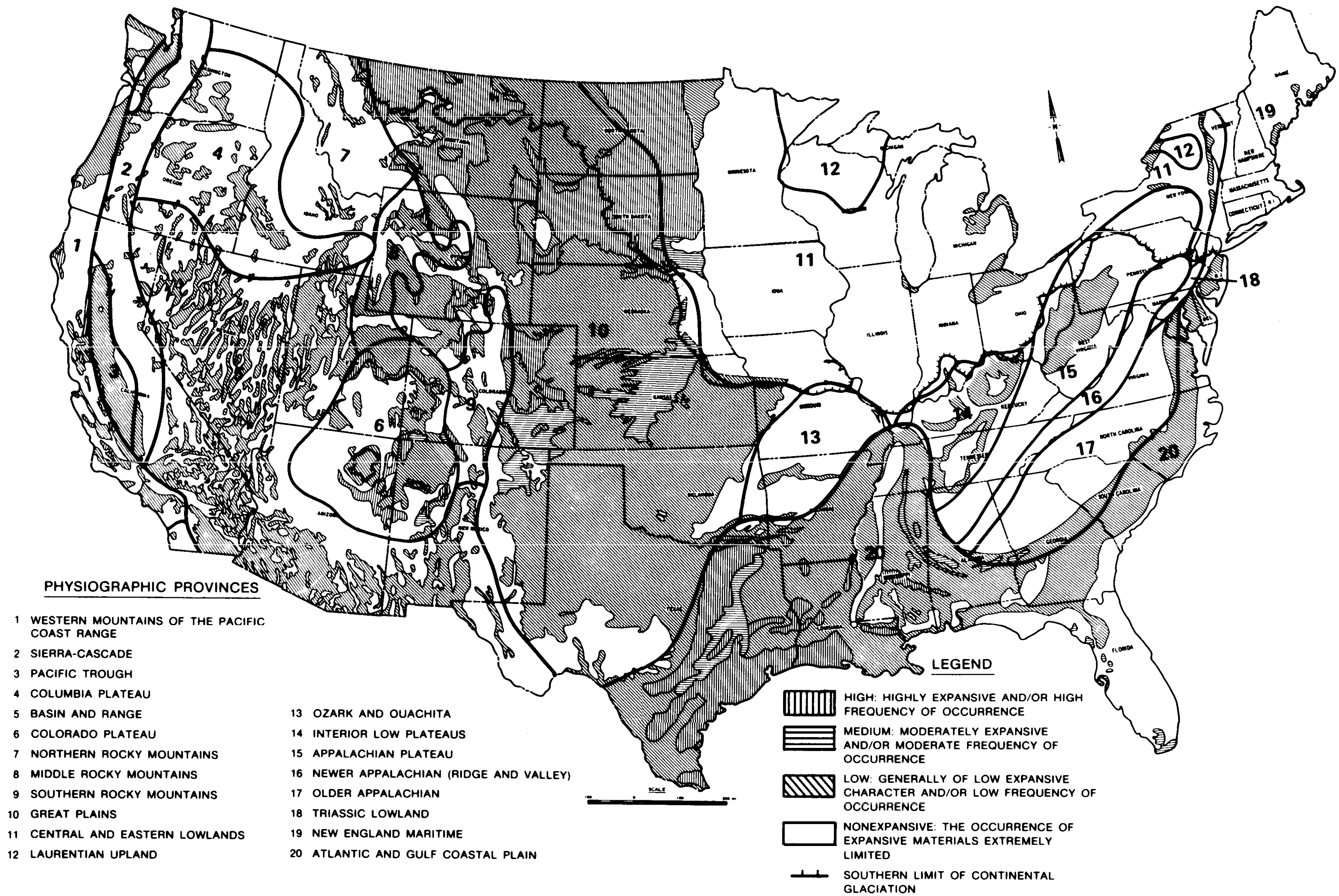
(2) *Physiographic provinces.* Table 2-2 summarizes the potentially expansive geologic units on the basis of the 20 first-order physiographic provinces. Figure 2-1 shows the locations of the physiographic provinces.

b. Other maps.

(1) *Area map of susceptible soil expansion problems.* A hazard map was developed by M, W. Witczak (Transportation Research Board, Report 132) on the basis of the occurrence and distribution of expansive soils and expansive geologic units, the pedologic analysis, and climatic data to delineate areas susceptible to expansion problems. Some geologic units for which engineering experiences were not available may have been omitted, and the significance of pedological soil on expansion was not shown on the map.

(2) *Assessment map of expansive soils within the United States. The* major categories for classification of the severity of the swelling soil problem presented by J. P. Krohn and J. E. Slosson (American Society of Civil Engineers, *Proceedings of the Fourth International Conference on Expansive Soils,* Volume 1 (see app. A) correspond to the following modified shrink-swell categories of the Soil Conservation Service (SCS) of the U. S. Department of Agriculture:

High:	Soils containing large amounts of montmorillonite and clay (COLE >6 percent)
Moderate:	Soils containing moderate amounts of clay with some montmorillonitic minerals (3 percent $\leqslant$ COLE $\leqslant 6$ percent)
Low:	Soils containing some clay with the clay consisting mostly of kaolinite and/or other low swelling clay minerals (COLE <3 percent).



U. S. Army Corps of Engineers

Figure 2-1. Occurrence and distribution of potentially expansive materials in the United States, 1977, with boundaries of physiographic provinces.

Table 2-2. Tabulation of Potentially Expansive Materials in the United States

Physiographic Province No.[a]	Physiographic Province Name	Predominant Geologic Unit	Geologic Age	Location of Unit	Map[b] Category	Remarks
1	Western Mountains of the Pacific Coast Range	Reefridge	Miocene	CA	1	The Tertiary section generally consists of interbedded sandstone, shale, chert, and volcanics
		Monterey	Miocene	CA	1	
		Rincon	Miocene	CA	1	
		Tembler	Miocene	CA	1	
		Umpqua	Paleocene-Eocene	OR	3	
		Puget Gp	Miocene	WA	3	Interbedded sandstones and shales with some coal seams
		Chico Fm	Cretaceous	CA	1	
2	Sierra Cascade	Cascade Gp	Pliocene	OR	4	Predominate material is volcanic
		Columbia Gp	Miocene	WA	4	Interbedded sandstones and shales may occur throughout, particularly in western foot hills
		Volcanics	Paleozoic to Cenozoic	NV	4	
		Volcanics	Paleozoic to Cenozoic	CA	4	
3	Pacific Trough	Troutdale	Pliocene	WA	3	Great Valley materials characterized by local areas of low-swell potential derived from bordering mountains. Some scattered deposits of bentonite
		Santa Clara	Pleistocene	CA	3	
		Riverbank	Pleistocene	CA	3	
4	Columbia Plateau	Volcanics	Cenozoic	WA, OR, ID, NV	4	Some scattered bentonites and tuffs
5	Basin and Range	Valley fill materials	Pleistocene	OR, CA, NV, UT, AZ, NM, TX	3	Playa deposits may exhibit limited swell potential. Some scattered bentonites and tuffs
		Volcanics	Tertiary	OR, CA, NV, UT, AZ, NM, TX		
6	Colorado Plateau	Greenriver	Eocene	CO, UT, NM	3	
		Wasatch	Eocene	CO, UT, NM	3	
		Kirkland shale	Upper Cretaceous	CO, UT, NM, AZ	2	Interbedded sandstones and shales
		Lewis shale	Upper Cretaceous	CO, UT, NM, AZ	2	
		Mancos	Upper Cretaceous	CO, UT, NM, AZ	1	
		Mowry	Upper Cretaceous	CO, UT, NM, AZ	1	
		Dakota	Jurassic-Cretaceous	CO, UT, NM, AZ	3	Interbedded sandstones and shales
		Chinle	Triassic	NM, AZ	1	

(Continued)

[a] Refer to map of physiographic provinces, Figure 2-1.
[b] Numerical map categories correspond as follows: 1 - high expansion, 2 - medium expansion, 3 - low expansion, and 4 - nonexpansive.

(Sheet 1 of 4)

Table 2-2. (Continued)

Physiographic Province No.	Physiographic Province Name	Predominant Geologic Unit	Geologic Age	Location of Unit	Map Category	Remarks
7	Northern Rocky Mountains	Montana Gp	Cretaceous	MT	1	Locally some sandstone and siltstone
		Colorado Gp	Cretaceous	MT	2	Locally some siltstone
		Morrison	Jurassic	MT	3	Shales, sandstones, and limestones
		Sawtooth	Jurassic	MT	3	
8	Middle Rocky Mountains	Windriver	Eocene	WY, MT	3	
		Fort Union	Eocene	WY, MT	3	
		Lance	Cretaceous	WY, MT	1	
		Montana Gp	Cretaceous	WY, MT	1	
		Colorado Gp	Cretaceous	WY, MT	2	
		Morrison	Jurassic-Cretaceous	WY, MT	3	
9	Southern Rocky Mountains	Metamorphic and granitic rocks	Precambrian	WY	4	Montana and Colorado Gps may be present locally with some Tertiary volcanic and minor amounts of Pennsylvania limestone (sandy or shaly).
		Metamorphic and granitic rocks	Precambrian	CO	4	
		Metamorphic and granitic rocks	Precambrian to Cenozoic	NM	4	
10	Great Plains	Fort Union	Paleocene	WY, MT	3	
		Thermopolis	Cretaceous	WY, MT	1	
		Montana Gp	Cretaceous	WY, MT, CO, NM	1	
		Colorado Gp	Cretaceous	WY, MT, CO, NM	2	
		Mowry	Cretaceous	WY, MT, CO, NM	1	
		Morrison	Jurassic-Cretaceous	WY, MT, CO, NM	3	
		Ogallala	Pliocene	WY, MT, CO, NM, SD, NE, KS, OK, TX	3	Generally nonexpansive but bentonite layers are locally present
		Wasatch	Eocene	MT, SD	3	
		Dockum	Triassic	CO, NM, TX	3	
		Permian Red Beds	Permian	KS, OK, TX	3	
		Virgillian Series	Pennsylvanian	NE, KS, OK, TX, MO	3	
		Missourian Series	Pennsylvanian	KS, OK, TX, MO	3	
		Desmonian Series	Pennsylvanian	KS, OK, TX, MO	3	
11	Central and Eastern Lowlands	Glacial lake deposits	Pleistocene	ND, SD, NM, IL, IN, OH, MI, NY, VT, MA, NE, IA, KS, MO, WI	3	Some Paleozoic shales locally present which may exhibit low swell

(Sheet 2 of 4)

Table 2-2. (Continued)

Physiographic Province No.	Name	Predominant Geologic Unit	Geologic Age	Location of Unit	Map Category	Remarks
12	Laurentian Uplands	Keweenawan	Precambrian	NY, WI, MI	4	Abundance of glacial material of varying thickness
		Huronian	Precambrian	NY, WI, MI	4	
		Laurentian	Precambrian	NY, WI, MI	4	
13	Ozark and Ouachita	Fayetteville	Mississippian	AR, OK, MO	3	May contain some montmorillonite in mixed layer form
		Chickasaw Creek	Mississippian	AR, OK, MO	3	
14	Interior Low Plains	Meramac Series	Mississippian	KY	3	
		Osage	Mississippian	KY, TN	3	
		Kinderhook	Mississippian	KY, TN	3	
		Chester Series	Mississippian	KY, IN	3	Interbedded shale, sandstone, and limestone
		Richmond	Upper Ordovician	KY, IN	3	
		Maysville	Upper Ordovician	KY, IN	3	
		Eden	Upper Ordovician	KY, IN	3	
15	Appalachian Plateau	Dunkard Gp	Pennsylvanian-Permian	WV, PA, OH	3	Interbedded shale, sandstone, limestone, and coal
16	Newer Appalachian	See Remarks	See Remarks	AL, GA, TN, NC, VA, WV, MD, PA	4	A complex of nonexpansive Precambrian and Lower Paleozoic metasedimentary and sedimentary rocks
17	Older Appalachian	See Remarks	Paleozoic	AL, GA, NC, SC, VA, MD	4	A complex of nonexpansive metamorphic and intrusive igneous rocks
18	Triassic Lowland	Newwark Gp	Triassic	PA, MD, VA	4	
19	New England Maritime	Glacio-marine deposits	Pleistocene	ME	3	Pleistocene marine deposits underlain by nonexpansive rocks. Local areas of clay could cause some swell potential
20	Atlantic and Gulf Coastal Plain	Talbot and Wicomico Gps	Pleistocene	NC, SC, GA, VA, MD, DE, NJ	4	Interbedded gravels, sands, silts, and clays
		Lumbee Gp	Upper Cretaceous	NC, SC	3	Sand with intermixed sandy shale
		Potomac Gp	Lower Cretaceous	DC	3	Sand with definite shale zones
		Arundel Fm	Lower Cretaceous	DC	1	
		Continental and marine coastal deposits	Pleistocene to Eocene	FL	4	Sands underlain by limestone, local deposits may show low swell potential

(Sheet 3 of 4)

Table 2-2. (Continued)

Physiographic Province No.	Physiographic Province Name	Predominant Geologic Unit	Geologic Age	Location of Unit	Map Category	Remarks
20	Atlantic and Gulf Coastal Plain (Cont'd)	Yazoo Clay	Eocene	MS, LA	1	A complex interfacing of gravel, sand, silt, and clay. Clays show varying swell potential
		Porters Creek Clay	Paleocene	MS, AI, GA	1-3	
		Selma Gp	Cretaceous	MS, AI, GA	2-3	
		Loess	Pleistocene	LA, MS, TN, KY	4	A mantle of uniform silt with essentially no swell potential
		Mississippi alluvium	Recent	LA, MS, AR, MO	3	Interbedded stringers and lenses of sands, silts, clays, marl, and chalk
		Beaumont-Prairie Terraces	Pleistocene	LA, MS, TX	1	
		Jackson, Claiborne, Midway	Paleocene-Oligocene	LA, MS	1-3	
		Navarre, Taylor, Austin	Upper Cretaceous	TX	1-2	
		Eagle Ford, Woodbine	Upper Cretaceous	TX	1-3	
		Washita	Lower Cretaceous	TX, OK	1-3	
		Fredricksburg	Lower Cretaceous	TX	3	
		Trinity	Lower Cretaceous	TX	4	

(Sheet 4 of 4)

These categories of classification use the coefficient of linear extensibility (COLE), which is a measure of the change in linear dimension from the dry to a moist state, and it is related to the cube root of the volume change. Premises guiding the categorization of the Krohn and Slosson map include: degree of expansion as a function of the amount of expandable clay; cover of nonexpansive glacial deposits; and low-rated areas with nonexpansive and small quantities of expansive soils. Environmental factors, such as climatic effects, vegetation, drainage, and effects of man, were not considered.

(3) *Soil Conservation Service county soil surveys. Survey* maps by SCS provide the most detailed surficial soil maps available, but not all of the United States is mapped. Soil surveys completed during the 1970's contain engineering test data, estimates of soil engineering properties, and interpretations of properties for each of the major soil series within the given county. The maps usually treat only the upper 30 to 60 inches of soil and, therefore, may not fully define the foundation soil problem.

(4) *U.S. and State Geological Survey maps. The* U.S. Geological Survey is currently preparing hazard maps that will include expansive soils.

c. Application of hazard maps. Hazard maps provide basic information indicative of the probable degree of expansiveness and/or frequency of occurrence of swelling soils. These data lead to initial estimates for the location and relative magnitude of the swelling problem to be expected from the foundation soils. The SCS count y survey maps prepared after 1970, if available, provide more detail on surface soils than do the other maps discussed in *b* above. The other maps used in conjunction with the SCS maps provide a better basis for election of the construction site.

(1) Recognition of the problem area at the construction site provides an aid for the planning of field exploration that will lead to the determination of the areal extent of the swelling soil formations and samples for the positive identification and evaluation of potential swell of the foundation soils and probable soil movements beneath the structure.

(2) Problem areas that rate highly or moderately expansive on any of the hazard maps should be explored to investigate the extent and nature of the swelling soils. Structures in even low-rated areas of potential swell may also be susceptible to damages from heaving soil depending on the ability of the structure to tolerate differential foundation movement. These low-rated areas can exhibit significant differential soil heave if construction leads to sufficiently large changes in soil moisture and uneven distribution of loads. Also, low-rated areas on hazard maps may include some highly swelling soil that had been neglected.

(3) Figure 2-1 indicates that most problems with swelling soils can be expected in the northern central, central, and southern states of the continental United States. The Aliamanu crater region of Fort Shafter, Hawaii, is another example of a problem area.