

1 Introduction to Landform Grading and Revegetation

A great number of picture books have been compiled to show people that nature is beautiful. But the type of beauty stressed in those books is, in my opinion, the superficial kind of beauty of form evaluated solely as ornament without consideration of function and purpose. Nature is never beautiful in this sense. If things in nature are beautiful, their beauty is not superficial but the resultant form of definite purpose. In the main nature is practical—much more so than man. Its forms are functional forms derived from necessity. And precisely because in the best sense of the word they are functional, these forms are beautiful.

Andreas Feininger, *The Anatomy of Nature* (1956)

1.1 FORM AND FUNCTION IN NATURE

Performance, efficiency, and functionality are generally regarded as important goals or aspects of engineering or physical design. These are goals that tend to have well understood metrics and criteria. What about the role of beauty, aesthetics, and visual impact in design? Are these merely secondary considerations of much less importance? How can they be factored into a cost-benefit analysis, a performance evaluation, or an energy-efficiency audit? Are they considerations that a design engineer or even an earthwork contractor should be concerned about?

It would be a mistake, however, to disregard these more abstract goals in design. Humans have displayed an ageless desire for beauty that transcends simple functionality, as evidenced by our arts, crafts, architecture, and by many of our engineering structures. Greek vases, the cathedral at Chartres in France, and the Golden Gate Bridge in California are all expressions of this impulse.

Perhaps there is greater congruence between beauty and functionality than at first meets the eye. Suppose we substitute for the word “beauty” the word “form,” which is an attribute or component of beauty. Form is much less subjective and more amenable to useful description. Form is also a critical component or aspect of the natural world. Form shows up everywhere in nature . . . in organic structures—whether flora or fauna. Form also shows up in nonorganic entities, ranging from mega structures, such as glaciated

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landscapes to fourth order, glaciated landforms—such as eskers, drumlins, and moraines.

Most people would agree that natural forms are attractive and beautiful. The question is why? In the absence of some supernatural force or directive, why should nature care about beauty? In fact, nature seems to be quite ruthless; forms that are not efficient and essential for survival tend to be discarded. Evolution works to optimize efficient design and functionality. We have a great deal to learn from nature in this regard.

The intimate connection between form and function in nature is discussed at length by Feininger (1956, 1976), who describes multiple examples from the natural world—both animate and inanimate. Superior natural forms exhibit certain intrinsic properties such as clarity of organization, economy of material, symmetry of shape, and perfection of execution among others. Feininger maintains that everything in nature is designed for a purpose and that nature achieves aesthetically pleasing designs in the process. In other words, beauty is intrinsic to the very purposefulness of design in the natural world.

The concept of form following function is clearly manifest in the case of geomorphic forms. Consider the evolution of streams and upland slopes. Streams are required to transport both water and sediment. Their equilibrium profiles tend toward concave shapes over time in order to achieve this purpose as efficiently as possible; that is, gradients are steeper in the headwater region and flatten out gradually toward the mouth. Their plan forms may be sinuous or braided, depending upon the gradient and flow (discharge) at any particular point.

Slopes, likewise, transport sediment and water; in so doing, they tend toward equilibrium profiles over time. The processes in this case are more complex. Terrestrial landscapes and landforms consisting of hills and upland slopes (including valley sides) are acted upon primarily by “diffusive” and “fluvial” processes, respectively. Diffusive processes include slope wash and creep. Fluvial processes, on the other hand, are characterized by pronounced incision and formation of channels—e.g., gullying and stream-channel erosion. These processes and the resulting landform shapes are discussed in greater detail in Chapters 4 and 5. The important point to observe in the case of either stream or slope development is the presence of curvilinear shapes, compound slope forms, and general absence of planar, unvarying slope gradients.

Finally, it is important to note that beauty as a design component can be considered a “value-added” type that can provide economic as well as aesthetic benefits. This value-added component may allow easier regulatory approval, higher market value, lower maintenance and repair costs, and greater client satisfaction. It should be no surprise, therefore, that this book is titled *Landforming*, which attempts to replicate stable, natural landforms and by association their inherent beauty.

1.2 HUMAN IMPACT ON LANDFORMS

Humans have modified the surface of the earth for centuries, extracting minerals, for agricultural purposes and for urban development. In the process of this alteration, artificial landforms have been created that often bear little resemblance to natural landforms and topography. Haigh (1978) claims that humans have become an important geomorphic agent and that a large percentage of the earth's landforms are man-made and artificial (anthropogenic).

This landform alteration, or reshaping process, has largely been conceived by what might be called the "linear perspective." This perspective tends to substitute natural landforms, which are characterized by complex shapes, with much simpler landforms, characterized by planar surfaces with single, unvarying gradients. The "linear perspective," and the grading practices that derive from it, are driven to some extent by economic factors and expediency. The long-term stability and environmental impact of such grading practices have generally not been taken into account.

The prevalence of the linear perspective in conventional grading practice is somewhat puzzling. Most people would probably agree that natural landforms are more interesting and pleasing to behold. And yet those in charge of promulgating and promoting modern grading designs have apparently not been troubled by the incongruence and dissonance between natural and most artificial landforms. Numerous geomorphic studies of natural landscapes (Hack and Goodlett, 1960; Howard, 1988; Roering et al., 1999) have shown, for example, that many soil-mantled hillslopes have compound, curvilinear shapes. Some of these hillsides are not only convex in profile but also in planform. Parsons (1988) recognized that slope units may be planar, concave, or convex in plan, just as they may be in profile. Accordingly, nine possible slope-unit shapes are required for completeness, as shown schematically in Figure 1.1. Where slopes transition into valley networks or convergent parts of the landscape, slope and channel profiles tend to become concave. Studies by Hancock et al. (2003), for example, have shown that soil-mantled, fluvial erosion-dominated catchments generally have convex upper-hillslope profiles with concave profiles developing further downslope, as shown in Figure 1.2.

As drainage areas increase in these channelized or incised portions of the landscape, slope gradients tend to decrease, thereby leading to concave slope profiles. Apparently, there has been a general failure to recognize the existence of these more complex slope forms and to realize that rectilinear profiles and planar slopes are seldom found in nature.

What is the long-term stability of artificial, planar-slope shapes versus more complex slope forms that include concave- and convex-slope profiles? This question is examined in some detail in Chapters 4 and 5. Even in land restoration and reclamation work, there has been a tendency to use artificial landforms with rigidly conceived slope forms and profiles.

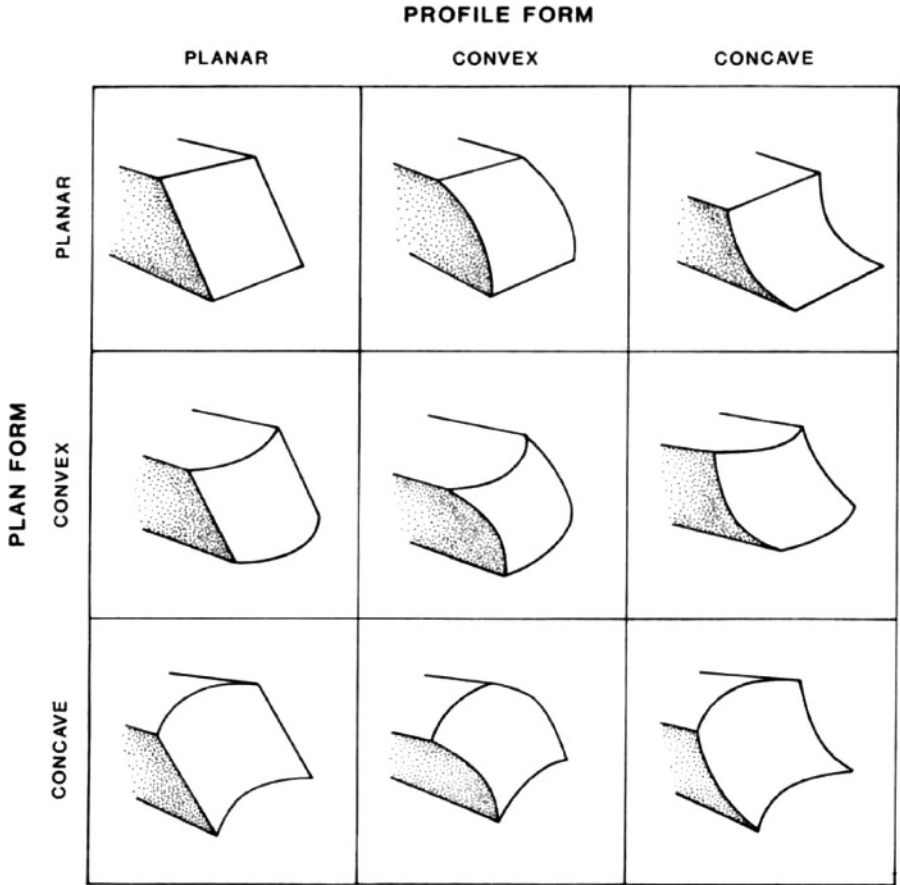


Figure 1.1 Nine basic shapes for hillslope units (after Parsons, 1988).

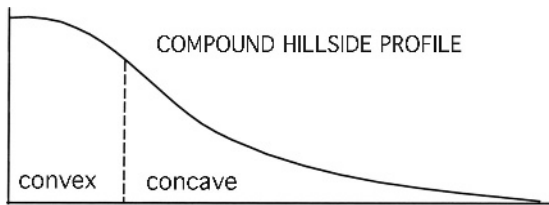


Figure 1.2 Idealized cross section of a natural hillslope in a soil-mantled landscape.

One could ask why it has not occurred more often to persons in charge of these restoration efforts to utilize at least some natural landform shapes? Why have not more owners and regulatory agencies considered the long-term environmental and aesthetical impact of such artificial reshaping and remolding of natural topography upon future generations? Landforming techniques described in this book provide a basis for adopting a new land restoration and reclamation paradigm.

1.3 HISTORICAL DEVELOPMENT

Earlier urban development generally occurred on mostly level land that was fairly easy to build upon. Over time, more towns and cities were built in areas with greater topographic relief. Development of towns and cities in hilly terrain was feasible, steepness of slopes notwithstanding, if located on dense and stable bedrock such as igneous or metamorphic rocks.

One way of avoiding incompatibility between a proposed land use and the underlying terrain is to adopt a landscape-planning approach that is based on ecological rather than purely economical considerations. This entails identifying suitable land uses based on topographic, geologic, hydrologic, pedologic, and botanic factors. One of the primary and most forceful exponents of this “design with nature” approach to landscape planning was Ian McHarg (1969), whose book had a seminal impact on the field of land planning and landscape architecture. Other exponents of the design-with-nature approach followed in his footsteps in an attempt to integrate land planning, land science (geology, geomorphology, and geography), and landscape design. The importance of slopes and topography in land-use planning has been emphasized by Marsh (2005). He noted that land uses have slope limitations and showed how slopes have been misused in modern land developments.

The impact of urban development in hilly terrain on the natural topography could normally be minimized if low densities were maintained, because building sites could be fitted into the existing terrain with minimum grading and access-road widths. Alignment and grades were flexible enough to adjust to natural conditions. Under these circumstances, geotechnical concerns, such as slope stability and bearing capacity, could be handled with small scale remediation as opposed to massive grading and earthwork. This resulted in urban development that fitted or blended into the landscape with minimal disturbance and earth movement as shown in Figure 1.3.

An entirely different situation is apt to occur when mining, landfilling operations, and intensive urbanization move into hilly terrain. Potential problems are compounded when the underlying bedrock is sedimentary and when major geotechnical instability problems have to be considered, such as faults, landslides, groundwater, compressible (or expansive) soils, buried boulders, and so forth. Under these circumstances, single-family, detached-housing lots, building pads for multiple, attached-family units, and pads for commercial,



Figure 1.3 Illustration of hillside development that blends or fits into the terrain without excessive topographic disturbance.

industrial, and institutional buildings generally require large-scale grading, landform alteration, and remedial treatments to create large, flat, and level building sites.

Such use also calls for a more extensive circulation system designed for wider roads to accommodate greater traffic volumes, larger horizontal and vertical radius street curves, and flatter grades for higher and safer speeds. Other infrastructure facilities have their own special location and site needs, that is, reservoirs, pump stations, waste-disposal landfills, water-treatment plants, gravity sewers, and so forth. When these land uses are combined with high relief and adverse geologic or soil conditions, the results often require extensive grading and reshaping of the natural topography with the objective of (1) creating level building pads and (2) mitigating or correcting geotechnical instability problems.

Over the years, stringent design standards have been established by regulatory agencies and the civil engineering profession to meet these objectives. The primary emphasis has been on meeting short-term stability requirements

and runoff control in grading designs. Geotechnical slope-stability analyses (Abramson et al., 2002) seldom if ever included time as an explicit variable. The result was a visual product of flat surfaces and rigid, linear, and angular slope forms with little resemblance to the original natural landscape. This also tended to result in a man-made environment with few redeeming aesthetic or visual qualities. The fundamentals of conventional grading practice are treated in greater detail in Chapter 6.

Landform grading concepts were developed to redress these deficiencies and to introduce aesthetic considerations into hillside development. Early work examined various elements of such projects to determine which would be best suited for possible rethinking and reconfiguration. These early efforts led to the realization that hillside grading transformed natural topographic elements (swales, ridge lines, and side slopes) into two basic components, namely, flat pad areas and slopes, as shown in Figure 1.4.

It also became apparent that the pad areas quickly became obscured by structures, roads, and other appurtenant development features. On the other hand, the slope component continued to stand out as a permanent visual element for better or worse, as illustrated in Figure 1.4.

Accordingly, initial studies focused on the slope element. This element was compared to equivalent natural slope forms to determine if Nature could provide some useful lessons and directions with regard to reintroducing the functional beauty of a natural hillside into mass-graded, man-made environments. These initial studies led to the discovery that the shape of the slope element had a significant influence on aesthetic appearance. Furthermore, slope shape



Figure 1.4 Transformation of natural hillside topography as a result of modern grading practices into two basic components, namely, flat pad areas and planar slopes.

and form also impacted the configuration of building pads above and below the slope and, ultimately, on road alignments and the configuration and placement of structures. Important characteristics and attributes of the slope element are considered in greater detail in Chapters 2, 4, and 5.

Follow-on work consisted of careful visual observations and photographic studies of natural hillside slopes throughout the world. Their morphology was measured on topographic maps to determine their size, shape, and exact proportions. The map studies provided additional information about scale and proportion. The finding that emerged from this study was the recognition that natural hillsides consisted basically of a series of universal slope “building blocks,” or components, which tended to repeat themselves regardless of the local soils and climatic conditions.

These hillside components consisted in their general form in a series and variety of concave, convex, and occasionally linear elements. Some occurred in relatively simple arrangements while others occurred in more complex arrays. All were ultimately the product or the result of erosional processes. Additional information and attributes about these slope forms and arrays are provided in Chapter 8.

Landform grading essentially attempts to: (1) respect the underlying, basic landforms by preserving or replicating them and their associated vegetative patterns and (2) re-create or mimic the important, stable natural hillsides with their rich variety of different slope elements and forms. When this conceptual approach is applied to hillside housing developments a very different topography and configuration of building pads, roads, and drainage ways emerges, as shown schematically in Figure 1.5. A photograph of an actual hillside development where landform grading was employed is shown in Figure 1.6.

Hillside grading fundamentals are discussed briefly in Chapter 6. The main characteristics and differences between landform and conventional grading practices are discussed and compared in Chapter 7. The use of *landforming* techniques to repair and rejuvenate man-made or damaged natural landscapes are discussed in this chapter as well. Natural slope elements and forms are identified and described in Chapter 8. Different approaches to grading a natural landform with distinct topographic features are presented herein as a prelude to the chapters that follow.

Aerial photos of natural landforms, as well as the different approaches to grading them, are presented in Figures 1.7–1.8. The underlying topography in the first case is characterized by an east-west trending, primary ridge line, from which a series of secondary ridges and valleys descend in a north-south trending direction. A conventional approach of cutting perpendicularly across the secondary features with little or no concern to preserving or replicating the original topography is illustrated in Figure 1.7. This approach ultimately results in a terraced, stair-stepped landscape that obliterates the features of the original terrain.

Figure 1.8 shows a similar approach, however, the underlying landform was a broad, round slope feature. The grading in this case created terraced

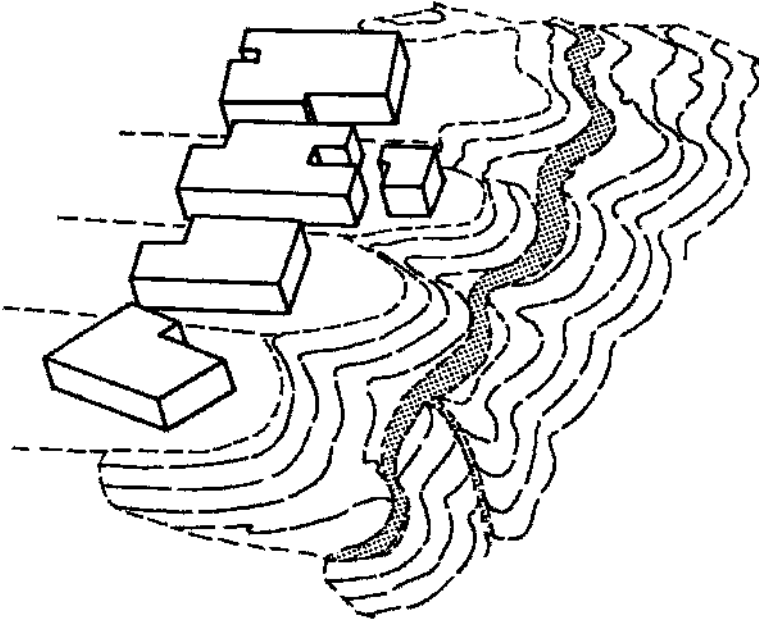


Figure 1.5 Schematic illustration of landform grading approach showing topography of slopes, configuration of building pads and position of drainages.



Figure 1.6 Photograph illustrating landform grading approach in a hillside development project in California.



Figure 1.7 Conventional grading that cuts across secondary ridges and valleys, resulting in a terraced, stair-stepped landscape that obliterates the original terrain features.

slopes and building pads but, nevertheless, replicated the underlying landform. This approach displays aspects of both conventional grading practice and landform grading. Once fully developed this grading approach still retains the character of the original, underlying terrain.

1.4 OBJECTIVES AND CHALLENGES

There are some fairly formidable challenges that stand in the way of more widespread adoption of landform grading practice. One of the main purposes of this book is educational, namely, to present in a single source and in a



Figure 1.8 Alternative grading approach on a broad, round slope feature. Grading created terraced slopes and building pads but nevertheless replicated the underlying landform.

concise form all the available information about *landforming* and its attributes. Another purpose is to make the case for *landforming* by demonstrating its advantages by comparing the relative stability of simple, planar slopes versus more complex slope shapes and by presenting case studies of actual projects.

The following are some of the challenges to more widespread adoption and implementation of landform grading practice:

1. Overcoming the inertia of the civil engineering profession both in the office design and field surveying departments that have relied on traditional grading designs and simple landforms.
2. Providing more direction, training, and control to the planning professions. These include land planners, landscape architects, and terrestrial ecologists.
3. Informing geotechnical engineers about the merits of using more complex slope shapes. Geotechnical engineers normally work with and analyze only the stability of planar slopes with linear profiles.
4. Overcoming the skepticism about and reluctance to approve new grading approaches on the part of regulatory agencies.

Landform Grading is applicable not only to hillside housing developments but also to land-reclamation and watershed-restoration work following mining

operations. In this case, the slope forms that are created are not simply cut slopes but artificial embankments, ridges, and depressions. The same principles still apply, namely, creating stable landforms that are visually compatible with the surrounding natural landscape and in harmony with regional vegetation patterns and surface hydrology.

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