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Modeling, Physical and Virtual
In the early 1980s, the State of California commissioned the landscape architects Hargreaves Associates, the artist Douglas Hollis, and the architect Mark Mack, to transform an existing parking lot fronting San Francisco Bay into a landscape for public recreation. During the client interview, the design team of landscape architect, artist, and architect intentionally scrambled their presentation slides to integrate the work of the three distinct entities and to strengthen the perception that the team would be both interactive and collaborative.

Rather than relying on traditional graphic techniques that render collaborative design unwieldy, Douglas Hollis suggested the use of a sizable sandbox to study various developmental strategies. A 5’ x 7’ sandbox was constructed in the Hargreaves Associates office that supported rapid, if crude, collaborative work that resisted control by any one member of the design team. The result was an active and immediate relationship between thinking and making that allowed for significant revisions, rapidly proposed and implemented.

Using the sandbox, the time invested in the design studies could be minimized, yet the risk of disruption was high when compared to more stable model-building materials. Keeping the various schemes intact proved difficult as the sandbox occupied a table within a small design office. Despite these logistical problems, there were positive aspects to the medium. Sand as a modeling medium had the distinguishing characteristic of conforming to a natural angle of repose approximating that of an actual earthwork; this kept the sandbox study "honest" in terms of slope and footprint.

The various sand-generated alternatives were dutifully photographed for use in public and client presentations. The State of California project representatives intermittently attended meetings in the Hargreaves office and viewed the sand model in its various stages. The three-dimensional models were intended to help clients understand and embrace the innovative concepts proposed by the designers. To ensure that interested neighborhood constituencies also understood the ideas behind the park’s design, a more durable cork model was made, translating the smooth surfaces of sand into the more abstract wedding-cake terraces of contour models.

The translation from sand to cork unintentionally distanced the presentation of the idea from the original concept. Of course, both sand and cork models are abstractions of the landscape. Sand more closely represents a scaled-down miniaturization of continuous landscape surfaces, while cork models increase the degree of abstraction by eliminating surface continuity, replacing...
it with stacked strata. Each layer of cork rendered visible the otherwise invisible contour lines of the terrain. Of course, contours are themselves an abstract representation of grading used to describe three-dimensional topography in two dimensions by assigning intervals of elevation, typically in one-foot increments. This translation creates difficulties for many clients—and even design professionals—because these contours do not exist in the landscape.

The massive size and weight of the sandbox required that all design meetings take place either on site or in the office, ensuring that the collaborators would make all design decisions collectively, based on site revelations or modeling studies.\(^5\) The sandbox encouraged any individual to test ideas and to gather immediate feedback from the broader team, making the medium truly collaborative. Unlike sketching, where the drawing tends to be of small format, or even the 24” x 36” size of conventional drawings, the larger dimensions of the sandbox fostered broad gestures and experimentation.

The construction of the Candlestick Point Recreation Area began in 1986, but then abruptly stopped on the discovery of a rotted wood pier buried within the project site. The problematic decomposing wood was removed in due course, but the landscape grading had to be recalculated and adjusted to correspond to the reduction in available soil for on-site redistribution. The sandbox supported the study of the revised landform alternatives using the reduced amounts of soil available and the dimensional relationship between landforms.\(^6\)

As the sandbox was not portable, the various stages of the design were preserved only in photographs, and the resulting Polaroid prints became the prime two-dimensional records of the continued revisions. An additional drawback was the difficulty of translating the sand forms into drawing, despite the Polaroids. In this particular case, the sandbox designs were not overly complex and so translating the model forms to two-dimensional drawings was not unusually troublesome. The sandbox design studies were inherently low in complexity, exploring proximity relationships and scale comparisons for the various landforms although it did not effectively model the precise intersections of two or more landforms. The days of the sandbox were numbered.

**CLAY**

As a design and artistic medium, clay has been used for a broad spectrum of purposes from ceramics to modeling concept cars. The sculptor Isamu Noguchi once stated, "Any medium, after all, is new (or old) in time."\(^7\) Noguchi "worked with the malleability of the clay, exploiting the speed with which new shapes
can be fashioned and transformed, and freely drawing on the wet surfaces,”
reveling in the quick results of the medium. He worked with various clays,
though primarily for eventual firing for ceramic production.8

Noguchi worked with sand too, notably on his Sculpture to Be Seen from
Mars (1947).9 Many of Noguchi’s early landscape models were finalized in
white plaster, and some of these were later cast in bronze.10 However, the
smooth surfaces and neutral color of these same Noguchi models were
suggestive of working with a malleable material such as plasticine. Clay,
unlike plaster, can be rapidly altered and repeatedly re-worked, although
water-based clays dry out and crack if left unfired. Roma plastilina is an
alternative oil-based clay containing sulfur that remains permanently pliable.
Roma plastilina Grey-Green No. 2 is the most widely favored of the four
commonly available consistencies, leaning toward the softer end of the
hardness spectrum, and referred to generically as clay. While Roma plastilina
does remain pliable, it tends to harden slightly over time, thereby maintaining
the same heft and weight as the raw form. If not adequately protected, it
can accumulate dust that muddies the smooth surfaces and is not always easy
to remove. Clay took the place of sand in the landscape office, for use in
modeling organic topography, as it had found an earlier place in architecture
offices for exploring structural components and details.11

Given that practicing designers teach design studios and technology courses at
universities, clay periodically appears in various architecture and landscape
architecture design courses, particularly at Harvard University’s Graduate
School of Design.12 Clay is well suited for quick volumetric studies as well as
immersive fundamental skills workshops, as it allows for repeated adjustment
and editing by both student and instructor.13 In the first semester of a land-
scape curriculum in which students wrestle with a variety of overwhelming
concepts and techniques, the use of clay may appear as a return to a more
familiar, fundamental skill of making things learned as early as in elemen-
tary school.14

ISSUES AND METHODS
Clay modeling helps designers explore the two fundamental grading issues:
slope and intersection. Slope refers to the geometric vertical rise and hori-
zontal run of a given elevational difference between two points, and is used
to describe topography as a percentage, degree, or proportion. Slope can
also describe a section through a landscape, and is particularly easy to record
in a conventional orthographic view. Applying a consistent slope through-
out a three-dimensional landscape becomes more challenging as a designer
juggles scale and proximity of one or more volumes to each other, in addition to maintaining the parameters that define pure geometric volumes. An added level of complexity arises when depicting the overlap of two or more solid volumes, resulting in a Boolean union with a predictable intersection of their respective surfaces. For instance, conventional projection drawings can capture the intersection of a cone and a pyramid with a square base and four triangular sides—but the drawing does not yield a three-dimensional model nor lend itself to rapid adjustment. The intersection between these two volumes becomes infinitely variable as the two solids are rotated, scaled up or down, or positioned in different locations, leading the designer to seek a medium for testing multiple scenarios in a minimum period of time and with the least effort. The resultant volume can be understood only from the parameters that defined the two original solids: dimension, consistent slope, and uniformity of surfaces, in addition to the unique points of intersections.

The desired end result of designing a landscape is not a set of drawings, however, but a built landscape. Modeling the landscape in three dimensions identifies areas needing further adjustment. The apparent diversion from clay into geometric modeling leans heavily on designer-determined guidelines or rules for executing the work, recognizing that the three-dimensional model will be translated back into the drawings provided by the contractor for construction.
WORKSHOP

Harvard’s Graduate School of Design Clay Landform Workshop set three objectives: (1) the development of a basic landform vocabulary; (2) the use of landforms to define spaces; and (3) the acquisition of quick modeling skills to aid in the preparation of grading plans. The first objective helps students develop a vocabulary of fundamental landforms including constructed geometric volumes and those derived from natural processes. This vocabulary ranges from primitive cones and pyramids to glacial drumlins and Aeolian sand dunes. The elements of this vocabulary do not suggest that a cone, drumlin, or any other landform is preferable for student adoption, however, but rather that the range of diversified forms will expand the student’s ability to explore and describe simple volumes.

The studio’s second objective was to “exercise and build design muscles,” developing a familiarity with, and proficiency in, crafting three-dimensional volumes as the primary form and space generators of a designed landscape. This emphasis on the use of landforms to define space is distinctly landscape architecture-focused, as is the parallel use of vegetation.

The third objective develops the student’s ability to confidently conceive and rapidly configure landforms from which a two-dimensional grading plan evolves, as well as the opposite path: the visualization of three-dimensional surfaces and volumes from a grading plan. The overarching goal is to conceive a designed landscape that can be tested in model form, documented in drawings, and ultimately constructed. Notably, students entered the workshop prior to taking classes in which they would learn the technical conventions of contour grading and site sections.

The intent was to immerse students in the process of creating earthworks before considering the practical grading skills and conventions they did not yet understand. As such, the workshop offered valuable trial-and-error exposure to grading concepts, preparing students for the less forgiving technical aspects of shaping the land, and differentiating existing topography from designer-initiated grading. The fundamental message defined landforms as intentional and calculated constructions, configured according to “rules” determined by the designer rather than only a surprising coincidence of the tidy resolution of contours and ridges.
The workshop set a number of ground rules, including the stipulation that no slopes might exceed 2:1, although this proportion of horizontal to vertical exceeds the natural angle of repose for most materials. Other rules required that each subsequent shape intersect with one or more of the preceding shapes, that all intersections be sharp and uniform, and later, that subtractive operations resulted in the removal of clay from previously configured shapes.

The ability to describe individual land components allowed the larger composition to be understood as either a collection of recognizable additive and subtractive shapes, or as a complex composition of surfaces and intersections. This transformative topographic composition was no longer subject to facile verbal description, but still abided by a series of basic rules relative to slope and continuity of lines. Blurring intersections or blending the shapes into the base was discouraged for this exercise, because the identity of the shape rapidly diminishes when boundaries and intersections are intentionally smoothed out. The clarity of the study depended to a large degree on the student’s skill at modeling the medium. If the initial 12” x 12” base of clay was rough, and the subsequent shapes poorly formed, it became more difficult to model abstractly and to precisely resolve the contours of the surfaces. The emphasis on distinct forms and pronounced intersections between these surfaces runs counter to the prevailing attitude in landscape architecture to “soften” or blend grading into the existing conditions to make new interventions appear seamless or solely as background scenery. The workshop emphasized “hard-edged” landforms to force students to wrestle with the
challenges offered by geometric and intersecting surfaces as a means of developing the rigor to approach and solve later terrain problems.

In reality, sharp ridges and smooth surfaces are necessary to accentuate grading for landforms to be legible within the context of adjacent structures and densely vegetated surroundings. This attitude by no means reflects only a twentieth-century sensibility. The Hopewell Indians in Central Ohio constructed earthworks and effigy mounds as precise geometric shapes that remain powerfully distinct from the broader landscape to this day [11-3]. The crispness of these earth forms caught the eye of early settlers from the 1790s through the 1840s, encouraging their documentation prior to subsequent destruction by later agricultural development.¹⁹

The end goal of the workshop was not so much a good-looking model, but a constructed, scale-less landscape composition with dramatic contrasts between the existing ground plane and the student’s intervention. Over nearly a decade of the workshops, the students demonstrated that their mastery of solving complex geometries in abstract clay studies afforded greater understanding and facility in solving basic grading and drainage problems in subsequent design studio and technology coursework.

**MEDIUM**

Clay became the preferred physical modeling medium because it is responsive, plastic, forgiving, and easy to work with. The clay model can be tilted and rotated for an infinite number of viewpoints. On the other hand, clay demands a fair degree of attention to craft, especially when creating straight lines and smooth surfaces. Another downside of clay is a sticky residue that clings to the hands and equipment and its lingering smell.

Three-dimensional clay models are typically more accessible to a broader audience than three-dimensional computer models because their physicality makes them easier to understand through touch and sight. In contrast, the projected two-dimensional digital image of a landscape still leaves many viewers struggling to form a mental image of the design concept in the absence of richly detailed textures that provide crucial cues to depth and distance. Clay supports free inspection whereas digital models require con-
trolled vantage points. And while three-dimensional computer images offer infinitely variable station points and perspectives, revisions to digital models often take more time to execute than clay models. While clay has the immediacy and tactility lacking in digital models, the latter are more easily converted to various conventional drawings with multiple end uses, including those of presentation and construction. However, the development of fundamental clay-modeling skills accelerates the adoption of more abstract and structured mathematical concepts necessary for executing digital computer modeling.

TRANSLATION

Craft
The translation of a scale clay model to a constructed landscape relies on craft. Craft in this context refers to planar surfaces that appear neither bulging nor sunken, and uniform lines that neither sag nor jog erratically. Craft fosters the discipline to precisely and persuasively describe a proposed landform. As one example, Hargreaves Associates initially worked in clay to develop a basic concept for the annual Festival of Gardens at Chaumont-sur-Loire, France, snapping Polaroids to record ongoing design evolutions over a period of days [11-4]. A final clay concept was packaged, and shipped to France for approval. The presence of the clay model persuaded the competition administrator, in the designer’s absence, of the proposal’s clarity though it was unusually complex for a staff unfamiliar with constructing earthworks. Once approved, construction documentation commenced.
For this phase of the project, a model less than a square foot in area was the sole design tool. Translating the three-dimensional clay model into a set of two-dimensional construction drawings was a crucial step toward realization. Drawing on the principles described in the clay landform workshop, each shape was solved individually during the process of documenting the proposed terrain.

Using computer-aided design (CAD) software, each shape was described by defining ridges and contours prior to stitching the components together. Contour spacing for each volume was determined by setting a desired slope independent of existing adjacent topography and by offsetting, at an equal distance, all subsequent contours. The grading process integrated the contour lines of intersecting volumes resulting in a complex landform described by contours and the junctions of the ridges and valleys. This process resulted in a composition of three primitive landforms fused together, yet decipherable as independent volumes nonetheless [11-5]. A grading plan is not the ultimate goal. Models and construction drawings were the stepping-stones to a built landscape.

*Interpretation*

Transforming clay to drawings involves considerable interpretation due to the differing degrees of precision afforded by hand-crafted clay models and CAD-constructed drawings [11-6]. Considerable adjustment is necessary to complete the process for rendering in drawings what appears so clearly in
a clay model. In the 1990s, students photocopied small clay models to use as crude two-dimensional bases for their grading plans. Not surprisingly, this mode of representation was both messy and contentious for the institutions and for other students who used the same machine for other rightfully intended uses. More recently, digital photos of larger clay models have made the translation process much quicker, more precise, and significantly less messy.

A raster image can be inserted into a digital survey file to scale and adjust the forms to correspond with the prior vector data. The grading process focuses on assigning contours and uniform slopes to each volume defined in the raster image. Individual landforms are graded from the apex downward, then adjusted and integrated with the existing contours, and where multiple volumes intersect, adjustment is normally necessary. The resulting grading plan effectively integrates the once abstracted volumes into a scaled drawing that can be used for calculating projected soil volumes and surface areas for planting, irrigation, and drainage.

Scanning
More precise, though costly, translation tools are currently available. Three-dimensional laser digitizers can now record a "point cloud" of an object or model, capturing its outline and surfaces with literally millions of data points. These points are integrated into a three-dimensional digital file more accurately than either by point-by-point hand digitizing or by photographing and assigning contours after the fact. Today laser digitizers are beyond the financial means of most firms, however, although some schools have already purchased them and their use is increasing. Clay landform models are scaled representations of a larger landscape and, so, even in the case of a finely crafted model, there is an inherent lack of precision in translating a scale model up to a 1:1 constructed landscape. The interim step of drawing and adjusting contour lines remains a necessary step despite the overwhelming data-recording devices.

In the end, if clay models are used to explore a concept, why not bypass clay altogether and generate a three-dimensional digital model? Working with clay provides a more fundamental and exponentially faster entry point to studying volumetric landforms, free from the governing conventions of grading plans, and is far less daunting than a blank computer screen. Experience at Hargreaves Associates has shown that a three-dimensional digital model is more successful and useful for representing a design derived from a two-dimensional CAD file—and not the reverse.
Simplicity

Determining a consistent distance between contour lines in a two-dimensional construction drawing sets uniform slopes that can be staked and built in the field, whereas working with three-dimensional digital drawings at the outset requires the additional step of revising contour intervals to whole-integer dimensions [11-7]. Good construction drawings are simple drawings, readily understandable to the various trades that construct the landscape. Therefore, there is a preference for working with whole numbers rather than odd fractions, with reasonable tolerances of not less than one-hundredth of a foot.20

Allocating time and money to exploring a landscape in clay during the earliest stages of a project may seem to be a luxury. However, Hargreaves Associates has found that the resources are well spent on a three-dimensional kick-off to the design process, concurrently integrating the programmatic and circulation patterns into the studies of the volumetric landscape. Although this entails adjustment to the modeled landscape, the project is often better integrated by working simultaneously on all aspects of the design rather than solving the grading at a later time. This early focus on topography illuminates the relationships between program and circulation that might otherwise be overlooked, had the evaluation of topography been delayed.

In their work, Hargreaves Associates strives for a legibility of landforms by accentuating the contrast between the pre-existing ground plane and the reformed configuration [11-8]. This is achieved by crafting uniform surfaces