Ecological Design for Dynamic Systems: Landscape Architecture’s Conjunction with Complexity Theory

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ABSTRACT

Ecological design adequate to help resolve current social-environmental problems will have to engage organisms, ecosystems, and cities as far-from-equilibrium, open, self-organizing systems. Because these systems are inherently dynamic, with elements co-constituting one another, the goal of ecological design should not be a specific condition or end state. Rather, the entire network of processes, especially the positive feedback loops from which a given system’s self-organizing capacity emerges, needs to be maintained. Thus, the task of fully ecological design is to avoid interrupting or impairing a system’s ability to maintain or transform itself; or, as is increasingly necessary, enhancing or helping restore damaged ecosystem dynamics. Thankfully, landscape architecture and allied design disciplines and practices are developing greater capacity to facilitate dynamic adaptive processes—substantially contributing to a transition from a first to a second phase of ecological design that operationalizes the new paradigm of complexity theory. In order to continue the transformation we need to make explicit and integrate the fundamental dimensions of this shift and the implications for design. To present a clear description and analysis that also emphasizes the actual physical changes that make an ecological difference the essay uses examples concerning hydrologic flow regime and flooding.

Keywords: ecological design, complexity theory, dynamic systems, self-organization, adaptive processes, hydrologic flow regime, flooding.
INTRODUCTION

Ecological design adequate to help resolve current social-environmental problems will have to be able to engage organisms, ecosystems, and cities as the dynamic, far from equilibrium, open, self-organizing systems that they are. Thankfully, the capacity to facilitate the dynamic adaptive processes through which systems maintain or transform themselves is growing within landscape architecture and allied design disciplines and practices. This positive development is substantially due to their participation in the transition that is well underway from a first phase of ecological design to the second, in which the new paradigm of complexity theory will hold sway. In order to continue the transformation to a fully ecological design we next need to make fully explicit and integrate the fundamental dimensions of this change, and especially the unique contribution of landscape architecture. As a starting point, the current situation is clearly seen in a snapshot of three developments presented within the last year and (fourth) their background:

1. An increasing number of designs and projects achieve the necessary ecological goals (but are not fully theorized): for example, “The Resilient River”: Turenscape, Beijing, Team Leader and “Streamline,” Stoss Landscape Urbanism, Boston, Team Leader in the reprogramming of the Mississippi River waterfront (Landscape Architecture Magazine 2011, 36-44)

2. In treating best practices some recent works helpfully bridge conventional ecological and engineering ideas and new concepts such as resilience (but do not attempt or accomplish the needed deeper theorization within complexity): for example, Donald Watson and Michele Adams’ (2010).

3. Presentations are beginning to transfer ideas from resilience and urban ecology to urban design (but require more detailed empirical development and theory): for example, sessions on Refocusing Ecological Urban Design in Waterfront Projects at the Resilience, Innovation, and Sustainability Conference held in Phoenix in March, 2011 (Roderick, Wilson, Rottle, 2011).

4. A series of projects and reflections have situated design within the transition to non-equilibrium ecological theory and identified the importance of complexity thinking but have not gone on to elaborate the critical concepts or their full consequences: for example, Johnson and Hill’s Ecology and Design (2005).

As a next step in articulating second-phase ecological design, this essay examines the stages of understanding “resilience,” “adaptation,” “plasticity,” and related concepts, draws out their implications for practice and unfolds the underlying, more comprehensive complexity theory. Though our remarks in large part apply to environmental design in general, we will focus on landscape architecture, urban design, and civil engineering in order to present a clearer description and analysis and to appreciate the earlier stages of the transformation. We use examples that mainly deal with hydrologic flow regime and flooding to emphasize the actual physical changes that make an ecological difference.
For heuristic purposes we can distinguish first from second phase ecological design. This is not to imply a simplistic historical account, since indeed there are multiple iterations of systems theory as it has developed from the early work by Ludwig von Bertalanffy (1968), Oden (1953), and cybernetics by Watson and Adams. Yet, while many other systems approaches have been implemented in areas ranging from engineering to organization studies, there indeed was a notable shift in emphasis with the ecological design initiated by Ian McHarg and others in the 1970s and continuing today in the work of many landscape architects such as Anne Winston Spirn and Fritz Steiner. Additionally, there is substantial evidence that another distinctive pulse occurred with the work of Prigogine and others such that a disjunctive line of systems thinking emerged—a discontinuous bifurcation in the terms of complexity theory. From the perspective of the theory and practice situated along this new trajectory, and as documented by Science and Technology Studies (STS), a paradigm shift has occurred: already well-recognized in domains such as ecology, resource management, sustainability, and other social-natural sciences, we are only recently recognizing that it is operative in landscape architecture and (more broadly) in ecological design. Thus, the major point of this essay is not to focus on the historical evolution of the new paradigm, but, after acknowledging its importance in many areas of science and professional practice, to explicitly theorize it in relation to landscape architecture, ecological design, and engineering (and also to elaborate the implications for what is built). The focus, then, will be only on the two ecological approaches that have transformed design.

In the first phase of ecological design – which we could say roughly runs from Ian McHarg’s *Design with Nature* (1969) to the first few years of the new millennium – it became apparent that design could not remain only functional or aesthetic, but needed to be ecological. This ecological design strives to make ecology the basis for design or to integrate ecological principles into design. At the heart of prevailing ecological design discourse and theory is the conviction that designers need to minimize destructive impacts to the environment and cultivate ecologically sound forms in order to ensure long-term survival of all species (Van der Ryn and Cohen 1996, 18). As a result, there has been sustained attention to new modes of integrated design, to interdisciplinary cooperation with ecology and other life sciences, and to the goals of conservation, preservation, and finally restoration. A substantial advance has been made beyond the long-dominant mode of design of the modern era, which laboured under the old dualisms in which the designer was taken to be the creative, controlling subject and the environment to be mere raw material to be manipulated, all with the intention of satisfying anthropocentric values such as were identified with aesthetic, functional, or profitable-commoditized objects.

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1 Watson and Adams begin their chapter 12 by saying that “Design for resilience is an emerging paradigm for the design profession” (257) and go on to describe its basic characteristics and best practice responses the coverage is quite general. Critically, though in a positively pluralistic approach, they consider it only as a new strategy to be added to those already in use: “Strategies of resilient design of coastal communities meet all best practice standards of flood-resistant design and represent the next criteria. The first four [traditional] criteria represent a first line of defense and typically are required of property owners undertaking new or substantially improved construction projects.” (199). Here is a well-intended and pragmatic case of remaining within first-phase ecological design rather than moving to the second-phase — which requires internalizing the radical changes involved and helping work out the dramatic reformulation of previous understandings and practices that the shift to complexity theory’s non-equilibrium dynamics involves.

2 On the technicalities of paradigm shifts in general and the transition to non-linear complexity there is good coverage in the Science and Technology Studies (STS) literature, such as Stengers 1997; Taylor 2005; Latour 1987.
THE IMPACT OF COMPLEXITY THEORY

The accomplishment of the first phase of ecological design remains important, indeed needs to be incorporated and continued though transformed. To put it in the simplest way, the reasons for the unavoidable transition to the second phase of ecological design lie in the development and appreciation of complexity theory and the associated phenomena. The early work of Grégoire Nicolas and Ilya Prigogine already described how, for example, “our climatic system is a case of far from thermodynamic equilibrium” which displays and can be described in terms of “nonequilibrium, positive feedback loops, transition phenomena, and evolution” that characterize nonlinear dynamical complex behaviour among the many elements involved and that finally form the basis for emergent behaviour (1989, 36-40, 226-228). Over the next two decades other scientists successfully applied the view to describe processes of the open, self-organizing biosphere, including organisms’ development and evolution (Kaufman 2000, 21, 188-194).

Ecology and Design, an important collection of essays by leading figures in environmental design and planning edited by Bart Johnson and Kristina Hill, witnesses the point of transition between first- and second-phase ecological design, where the latter is recognized as the new region opened by the larger paradigm shift to complexity theory (2005, 1, 3, 6). Most of the essays operate on the older side: for instance, Anne Whiston Spirn elaborates first-phase ecological ideas as she explores the generative metaphor of the garden seed (2005, 29-49). On the other side, second-phase ecological design appears as some of the essays mention the new non-equilibrium theory of ecology, which is congruent with complexity thinking. However, these concepts are not developed there. For example, in their chapter (“Ecology’s new paradigm: what does it offer designers and planners?”), H. Ronald Pulliam and Bart Johnson (2005, 51-89) discuss a shift from an equilibrium point of view to a disequilibrium one where history matters, ecosystems as open systems as opposed to closed ones, and then-recent developments proceeding from the old view; yet they do not elaborate the dramatic implications of work by Prigogine or other natural scientists. More problematically, in other works even where there is talk about and acceptance of the new ecological paradigm, professional practices intending “sustainability” too often remain solidly entrenched in the old paradigm, whereas what is actually built (and how) needs to be substantially changed.

We are faced, then, with kind of questions nicely posed by Steven A. Moore as editor of the recent Pragmatic Sustainability: Theoretical and Practical Tools (2010): “The systems approach to ecological planning advocated by Steiner, as introduced by McHarg in the 1970s, has much in common with the ‘complexity theory’ proposed… If the ‘planning’ of complex adaptive systems requires constant and continual effort, what are the implications for the production of ‘city plans’?” (211). or, “the concept of CAS [Complex Adaptive Systems] suggests that we should engage in ‘dynamic process-oriented’ designs (likened to a recipe) rather than static outcome-oriented designs (likened to a blueprint). How will such a proposal influence the worlds of architecture and engineering in which blueprints drawn at a distance from the site and time of construction hope to control the outcome in every detail?” (64). This

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3 An important early argument to begin the shift is made by Stuart Cowan, who has a doctorate in complexity theory; still, though briefly considering turbulence and flooding, the landmark Ecological Design that he did with Sim van der Ryn (1996) focuses on the broad implications, biodiversity, and the bio-regional scale rather than specific designs and physical changes.
essay pursues the same questions more broadly cast — “What are the implications of complexity theory for a fully ecological design?”

DESIGN ALIGNS WITH COMPLEXITY

Given their innate, substantial pre-alignment to complexity theory’s fundamental features, it is puzzling that the design disciplines and professions, though employing the ideas here and there and generally recognizing that cities are ecosystems, have not been in the avant-garde delineating the new paradigm. When engaging in design activity, a designer/design team proceeds through iterations in which all the elements (e.g., design concept, functional objectives, designed physical forms) mutually modify one another: in each cycle all the major identifiable elements are included and brought into a coherent pattern, in the course of which further problems, inconsistencies, and alternative possibilities come forward. These “results” could not be anticipated or fully predicted. That is, the design process and the design work (the “final design” for the designers) in a project are both emergent phenomenon. Design work also is dramatically site- and case-specific such that each project is unique, not allowing the use of any universal formula or set of rules, thus already incorporating the critical variables of initial conditions, contingency, and history which are so prominent in complex self-organization and dissipative phenomena. Landscape design, especially, not only takes into account the existing site contexts (such as the hydrological, geological, historical, and cultural), but also considers plants’ and landforms’ inherent changes and interactions with other elements that occur during their life cycles. Such design always has worked with the open, dynamic interactive processes of growth and decline, of assembly and dissipation.

Design’s processes and trajectory can better be brought together with complexity theory’s resources if we make explicit the dimensions of the paradigm shift and the implications and opportunities it has for design (specifically for landscape architecture and urban design) and engineering that directly deal with dynamic, far-from-equilibrium environmental processes. Table 1 lays out the main differences among the views of modern design, first-phase ecological design, and second-phase ecological design. Note, however, this does not display a simplistic, divisive range: no more than anyone would propose that organic holism began with McHarg, it is neither as if no one used complexity theory before the second phase of ecological design, nor that the second phase no longer appreciates organic wholes. Rather the point is to identify alternative paradigms and to discuss the current change that is well underway but that nonetheless needs to be discussed and brought fully—pushed—to the next stage. Thus, not all the terms listed for second-phase ecological design are part of our present design vocabulary; one of our intentions is to begin to become fluent in their meanings and application.

4 The urban ecology literature consistently connects complexity and sustainability of the built environment but does not include design, especially as a matter of actual physical change. As to design, despite promising titles, even the best such as Alexiou, Johnson, and Zamenopoulos (2010) link design and complexity research but focus on systems analysis and modeling from a dominantly mathematical and engineering approach; the exception, Leonard Bachman’s essay, “Embracing complexity in building design,” that does conceptualize and historically locate aspects of complexity in relation to the built environment remains abstract, not treating actual physical changes. Even among the books within “sustainable design,” for the most part neither is substantial complexity content delivered nor are there explicit design outcomes. Positive exceptions include Yang (2006); Hensel, Menges, and Weinstock (2010).
Table 1. Comparison of Paradigms

**RESILIENCE AS A GOAL FOR ECOLOGICAL DESIGN**

The first phase of ecological design has been genuinely holistic, seeing healthy, un-impacted ecosystems or environments as important to support human systems. The underlying idea is that an organic whole, comprised of parts each of which individually and all together act as an integrated system, grow so as to fulfil their potential which finally is realized in a stable climax condition. This ideal image identifies the ecological well-being of a landscape with its aesthetic and functional maturity. Correspondingly, not only new designs, but projects aiming at preservation and conservation have a clear measure: the goal of design is to achieve or maintain such ideal “end states.” Even the notorious question of “what state” of an ecosystem should be intended in restoration is subsumed within the idea of a fixed “kind.” The goal would be to restore a mature stable tall grass prairie or an alpine lake district. But, ecological design based on such an image operates on the premise of an outdated ecological theory of equilibrium, ignoring the dynamic, open nature of environmental systems.

In contrast, complexity theory emphasizes that organisms and ecosystems (as well as cities) are open systems, far from equilibrium. The nature of these systems is inherently dynamic with contingent constituents mutually informing one another, thus indicating that the goal of ecological design should not be a specific condition or end state (such as their mature unity). Rather, the entire network of processes, especially the complex of feedback loops, is what needs to be maintained, as spelled out in theories of self-organization for the entire environment or particularly by autopoiesis for the living organisms. The minimal task of design in the second phase of ecological design, then, is to avoid interrupting or impairing a system’s ability to maintain itself. Given our current environmental problems ecological design increasingly has the even harder task of enhancing or helping restore the ecosystem dynamic.
Image 1. The continuous dynamism, rather than stability, that marks ecosystems is apparent in an old growth rain forest. Olympic Peninsula, Washington.

Image 2. Complex processes and cycles over time are played out in the meandering of rivers. River South Esk, Angus, Scotland.
Whereas the received modern view in the West (and by extension much of the planet) is that humans are the masters of nature and can do as we will (thus changing ecological regimes entirely, as attempted in the desert around Las Vegas and Dubai or in the drained and filled-in wetlands of Florida), the first phase of ecological design recognizes the importance of individual ecosystems. Here the design is intended to make built forms and human uses appropriate to and supportive of a specific sense of place and identity as desired by humans, based on images of what stable, mature ecosystems ideally should be. When the system in question deviates from the preferred steady state, this norm of maintaining a system as it “should be” prompts designers to restore the system to that condition as quickly as possible. Confusingly, in the engineering field (Wang and Blackmore 2009) and some ecological literature (Pimm 1984), the speed at which a system can return to its “normal” state is also discussed as an issue of system resilience. In his now-authoritative definitions sorting out conflicting usages, Holling identifies this older equilibrium-based viewpoint as “engineering resilience” to distinguish it from the newer “ecological resilience” that acknowledges changes and variances as an inherent part of the system dynamics (1996). We want to further clarify the categories by pointing out that because it operates within the same tradition of using linear thinking and the concept of uni-directional causality to understand what are taken to be closed, near-equilibrium phenomena that self-organize into steady states, first-phase ecological design actually shares the same means and goal as engineering. In this essay, then, first-phase ecological design and engineering resilience are treated as being the same, and are differentiated from second-phase design’s “ecological resilience” proper.

*Image 3. Attempts to master nature drive much of our built environment.*

Dubai.
In light of the appreciation of the non-linear and open character of dissipative flows described by complexity theory, exemplarily holistic and stable place identity as perceived in the first phase doesn’t actually exist, particularly when the ecosystems are viewed in a much larger timeframe. Because ecosystems are dynamic, they could not be maintained in a fixed condition nor perhaps even be recovered when lost. Since organisms and their environments are dynamically co-constitutive, the sense of place and the identity of an ecosystem would be a pattern that emerges over the course of historical process, shifting across stages in life trajectories and continuous transformations of communities of persons, non-human organisms, and non-living elements that together organize and maintain themselves as life-worlds (Umwelts) or bio-cultural regions (Mugerauer 2011).

As noted, second-phase thinking already is operative in many environmental disciplines and practices. A good example of the critique of first-phase approaches occurs in McDaniel and Lanham’s position on sustainable development:

The agents in these CAS [Complex Adaptive Systems] … are diverse, interact non-linearly, self-organize, contribute to the development of emergent properties, and co-evolve with their environments over time. Rather than striving for system balance, or equilibrium, complexity science informs us that systems can operate more effectively at points far from equilibrium. Campbell’s model of sustainable development, which emphasizes the achievement of balance, seems to imply that sustainability is the desired outcome of a single-level, closed system. However, [we] view the systems in which sustainable development is sought as open systems both affecting and being affected by their environment. (2010, 52)

Thus, while the second phase of ecological design does not at all reject the approach and goal of the first phase, which is to make our built environment more sustainable, it recognizes “the dynamic nature of the landscapes on which sustainability is typically sought” (McDaniel and Lanham 2010, 51), and thus, in the terms of this essay, that an ecological system is much more variable than hitherto appreciated and may in fact have multiple possible states. Individual system elements are surprisingly plastic and their interactions are complex. Therefore the same system can display different behaviours over time. Such a system would have a wide range of regime, within which its elements change, sometimes in long periodic cycles, sometimes unpredictably. A system may also reach a point at which it jumps across a threshold—without smooth linear change— to another regime altogether, where system elements and their internal interactions are altered, resulting in dramatically different sets of system behaviours. For example, depending on the long-term outcome and the interpretation, a lake's shift from clear to murky (a flip from an oligotrophic regime with low phosphorus, low algae, and rooted aquatic plants to an eutrophic regime with high phosphorus and high algae) might be an irreversible flip between two distinct trophic states or only a transition among two phases of a single state with a wide range, where slowly over a long cycle the system might self-organize to alternate between the phases.
Therefore, ecological resilience proper is the amount of perturbation that can be absorbed before the system shifts to another behaviour regime (granted that the empirical identification and theoretical definition of regime is not always as clear as when what had been a grass-dominated savannah becomes shrub- or tree-dominated, or a tropical forest becomes grassland). But, in light of complexity theory’s understanding of far-from-equilibrium, open phenomena, even when applying the idea of ecological resilience as the ability of a system to persist through external shocks, there is no a priori or abstract way to assert whether the goal for a particular system should be its persisting without moving into a different regime with new behaviours or (for multi-equilibrium systems) its crossing a threshold to another of its stable states (Holling 1973). Further, we need public debate and policy concerning when ecological design should strive to maintain or restore system resilience, so it could stabilize in a regime that is desirable for human beings or when we need to take into account scenarios where the system encounters an external shock inducing a irreversible regime shift such that humans need to adapt by accepting the changed condition.
In principle, then, there can be neither a single specific paradigmatic image of what second-phase ecological design should accomplish and look like, nor of what resilience would concretely entail. The issue is not one of some universalizable structure or appearance, much less “aesthetics” or style; rather, the issue concerns the resilience of each particular historically evolved system with which a design is dealing uniquely. This is not at all what we are used to perceiving or enacting. To reiterate, we traditionally have taken a given environment to be stable, and then have either attempted to keep it the same by controlling what seemed to disturb it – fire in a forest, flooding in a river valley – or by deliberately making the changes necessary to produce a different environment that we prefer – a fertile agricultural region out of California’s central valley, achieved by dams, canalized rivers, and irrigation systems. To recognize and accommodate the wide range of phenomena within a watershed as long-term complexity events and conclude that we should “let them be” is another matter. The variation and historical contingency of the flow of water, the rise and fall of rivers and tributaries, the shifting shoreline as banks are undercut, the varying course when the river migrates, and the changing pattern of floodplains in time and space, all would have to be incorporated into a design even when we are dealing with a small waterfront park or engaging in river restoration works.

ADAPTATION

The question is how we would actually design in the second ecological phase. Again, this is not to call for some totally unheard-of mode of design. It simply makes explicit the parameters brought forward by complexity theory and recognizes that the work generated out of design process is in fact not pre-formed, but emergent. By calling out and gathering together already successful approaches and projects and by adding more examples here to give “systematic” coverage of the major dimensions, we hope to articulate and encourage the needed but unpredictable design for complexity.

Many of the examples that follow are intended to indicate how we might translate the recent reemphasis on “adaptation” that has been occurring in climate change discussion to more fully accomplish the parallel shift from the dominant modern design approach through the first phase of ecological design to the second. In a most basic sense, ecological design is about how we adapt our practices and projects to the historical unfolding of organic-environment relationships. Whereas dominant views have contended that adaptation is a matter of either yielding to or conquering external deterministic forces, second-phase ecological design attempts to respond to our surroundings by finding strategies to resonate with and modulate the given situation which, in fact, is already constituted by multi-directional physical-biocultural interactions. In the scientific-technological era where the environment is taken as fixed and nature is separated from culture, according to neo-Darwinian ideas “adaptation” normally refers to the need to adapt to the unavoidable, fixed external environment, where failure to do so leads to death. Or, with the complementary tradition of attempting to dominate nature, in cases where we have the means we often use our technology to simply change the environment so it matches our habits and needs, at least temporarily – an approach which is the cause of much of today’s environmental crisis. In both modes, we take nature to be predictable, and then deal with environmental variance by either limiting change as much as possible or bending it to our will. This is “adaptation by control.”
In contrast, in first-phase ecological design, we adapt by trying to understand what the whole, healthy environment would be like and to identify disturbances needing mitigation so as to allow the system’s self-organizing processes to be restored. We correct either our behaviour or intrusive, harmful phenomena that block healthy growth and stability. Here, design resonates with natural ecology in the attempt to achieve well-being – “adaptation by cooperation.” The evidence that climate change will involve increasingly extreme events together with the shift toward a more eco-centric view that turns away from trying to exercise power in order to control the world has led to a renewed interest in developing strategies to maximize our adaptive capacity. The first steps have been to recover the heritage of successful work (White 1964) and to develop more sophisticated strategies for proactive adaptation rather than mitigation after the fact (Global Environmental Change 2008). But this entails a different understanding of adaptation since in processes already underway, and in fact never starting from scratch, the organisms of an ecosystem simultaneously respond to facets of their environment and also help shape their surrounding worlds, thus providing changed habitats for succeeding generations of their offspring and for the other organisms in the system (Mugerauer 2011). In processes of open development where organisms and their environments co-constitute each other, the task is not to investigate what we can do to maintain or recover a specific wholeness, but to actually enter into the unfolding dynamic processes to help bring forth a new set of interactions, that is, “adaptation by acceptance.” It accepts – even if not always embracing – the long-term, large-scale dynamic that is and will be operative, then adjusts the feedbacks “in process,” so that changed interactions of particular living and non-living elements simultaneously modify the character of the system. Hence the degree of adaptability of an element or system is the degree of ease with which it adjusts physically in response to changing conditions, including abrupt external disturbance and slow internal dynamics.

The differences between modern, first-phase, and second-phase ecological design are striking. Modern design non-ecologically and technologically attempts to control environments, for example, by armouring and canalizing rivers in order to direct and maintain water flow at levels desired for agricultural or commercial uses. First-phase ecological design holds that if changes are necessary to fulfil human demand, they should be done with less negative environmental impact: the required engineering, for example, should use “ecologically-friendly materials.” In contrast, second-phase ecological design considers an entirely different approach to such problems. The greatest difference of the second-phase ecological design would appear in adaptations that defer to the sovereignty of the overall dynamic, as the Dutch have in ceding dominance to the sea and the river by dramatically changing both their philosophy of human-environment relationships and their practices (Doevendans and Schram 2007). On a large scale this appears in the flood management approach of “room for the river”

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5 Though it is beyond our scope here, the requirement that ecological design adequately operate within, and even become a co-determining element of complex systems opens further challenges. The fundamental principle that all elements of an ecological system need to be engaged both in their heterogeneous particularity and in their tangled structural couplings not only requires considering the diversity of other-than-human life but, importantly, inclusionary social practices and collaboration among too-often-unconnected diverse professional and resident groups (Ernstson 2008). Here increased democratic participation in policy decisions and management practices aligns with the ethical obligation to provide at least adequate, if not equal, access to resources. In terms of our examples, by utilizing complexity theory to integrate the local or even neighborhood-scale with the watershed, we can develop ecological designs for industrial or post-industrial areas that are responsive to both distressed riverfront sites and populations (Kibel 2007).
It can be noted that there are precedents for second-phase design within our own heritage, as with the Hegemann and Peets, and then Olmsted Firm’s design for the city of Kohler, Wisconsin (1913), which allowed for the Sheboygan River’s annual spring flooding by designing Ravine Park so as to leave the flood plain alone yet, though landscaping, provide for its use as a grassy-banked amphitheatre in the summer and fall months.

**Image 6.** Armouring is a paradigmatic mode of attempting to control rivers with non-ecological technology. Taiwan.

**Image 7.** Second-phase ecological design has precedents within our heritage as with Ravine Park which left the flood plain alone. Kohler, Wisconsin, 1913.
Since the difference between first- and second-phase ecological design is not fundamentally one of appearance, but of mode of integrating into a system’s dynamics, the distinctive adaptations of the second-phase may not be fully apparent. Some of the latter are a matter of implementing short-term strategies that pick up and refine the approaches of first-phase ecology, but extend them by recognizing and accommodating extremes occurring within the range of one regime, as San Francisco has done by retrofitting skyscrapers with sophisticated, computer-controlled flexible foundations to change their structural coupling with seismic activities. Or, fixed elements may be used to modify the course of events as adaptations by second-phase ecological design (and differ from first-phase approaches) with the fuller understanding that new built environmental features modify the organic and non-living systems, initiating new feedback loops whose changes in turn impact the overall dynamic, continuing along in further cycles. The change from creosote pilings and bulkheads to concrete and steel along shorelines is an example: in Puget Sound “the replacement promotes the growth of polychaetes, mussels, and anemones, a diversity which in turn is important with regard to food web relationships with fish species,” the result of which further modulates the local ecosystem and thus the environmental cycles from then on (Wilson 2009, 83, 211, 299; Roderick, Wilson, Rottle 2011). In contrast, though devices such as the Thames Barrier, the Netherlands’ Oosterschelde Storm Surge Barrier, and Venice’s MOSE Tide Barrier do not close off the flow of water they nonetheless are instances of traditional engineering. While movable upwards, they are permanent underwater structures resting on the sea- (or river-) bed, whose size, materials, and placement will induce changes in morphology, current flow, chemistry, and ecology thus setting off fresh sub-cycles in the local environment. Yet complexity is not operationally incorporated: the diversity of interactive elements and their feedback loops are neither modelled in the engineering studies nor used to generate a norm in practice (Pirazzoli and Umgiesser 2006; Rinaldo et al. 2008).

Given that any ecological design requires engineering and construction in order to be actualized (as is well treated in work such as Watson and Adams’ Design for Flooding cited earlier), in the emerging second-phase a new relationship with a new kind of engineering is required. In fact, non-linear engineering already operates where thermal convection is a critical factor, for example in fluid dynamics (as in the circulation of the atmosphere and oceans) and where turbulence is a major concern (as in pipelines, or by extension in traffic flow), which is one reason this essay uses so many hydrological examples (Nicolis and Prigogine, 1989; Prigogine and Herman 1971). As noted, the change in engineering in relation to ecological design may not be visually apparent: the difference between second-phase and earlier approaches and built projects is not a matter of size, movability, or a particular material or form. Rather what matters is the way linear and non-linear thinking deal with far-from equilibrium, open ecological phenomena. The former brackets them off, while second-phase ecological design recognizes and responds to them – indeed in two primary modes, emphasizing complexity and ecology.

Design and engineering can focus on the complexity of environmental processes by accepting and engaging the operative dynamics. A well-known example (in relation to the striking change in the Netherlands’ world-view mentioned above) is the “amphibious houses” that would rise and fall with the water level in Maasbommel, an idea now further developed and at least imaginatively applied to entire cities (Watson and Adams 2010, 244-248). Another, less apparent case occurs in Köln where temporary baffles can be placed atop the walls along the bank of the Rhine in the event of flooding – a technique important not because of its movable
format, but, because it results from conscious attention to the overall complex hydrological, pollution, and hard built environmental systems’ feedback loops operative at both normal water levels and during flooding.

*Image 8.* Amphibious houses are one of the ways the Netherlands now accepts and responds to the dynamics of ecological complexity and climate change.

*Image 9.* Mobile wall spill barriers can be used to accommodate the complex environmental feedback loops operative at both normal water levels and during flooding. Köln, Germany
Or, in light of the acceptance of complexity, there can be a direct emphasis on ecology since design and engineering are in a better position to protect and even improve ecosystems. How such positive environmental changes are concretely built can be clearly seen in the changes made to the Isar River in Munich where the river is recently allowed to run more freely between the levees to create more complex habitat environments.

*Image 10.* Second-phase ecological design can restore the resilience of urban rivers as has been done with the Isar. Munich, Germany.

Similarly, as mentioned at the beginning of this essay, in projects treating the Mississippi River waterfront Turenscape’s “The Resilient River” proposes acting incrementally in four phases over 50 years, patiently relocating industry and creating wider green corridors; Stoss Landscape Urbanism’s “Streamline” approach, recognizing “that a river is actually a complex, braided landscape of ever changing channels,” would move first to reclaim the river, extending the “social or civic floodplain” through strategies involving new parkland, forested fingers, and newly located green industry (*Landscape Architecture Magazine*, 2011, 40, 44). Another example is the way urban water runoff is mitigated so as to deal with the full range of ecological functions in the watershed in Seattle, Washington.

*Image 11.* Bio-swales provide a way to protect, even improve, ecological function in urban watershed systems. Seattle, Washington.

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PLASTICITY

To consider the larger scale of the regional bio-cultural landscape (for example, a watershed), second-phase ecological designs are dealing with two sorts of challenges. First, can our built environment be designed in a way to maximize resilience that is to accommodate the environmental variance within a regime of the ecosystem or, where there are multiple possible states, can it operate across thresholds to entirely different regimes? Second, in terms of the human community, can it help us suffer less when an inevitable disruptive regime shift occurs; can it help an ecosystem move out of an undesirable regime where ecosystem services are degraded? Here the plasticity, operative not only generally in the ecosystems themselves, but in all the components and scales or even in multiple regimes, comes to the fore because it is one of the major factors that make adaptation possible in the first place. Just as biological growth, development, and evolution are possible because the same molecules can become different sorts of cells and the same sorts of cells can become different organs (Harold 2001; Gunderson 2003), ecological design depends on enacting flexible built elements — such as hydrological infrastructure — as well as policy and management practices that are able to respond differentially to the heterogeneous world.

Another way in which second-phase ecological design and new engineering are operating together is found where material science is exploring “the potential to extend design processes from the development and fabrication of a single static artefact or building to families of variant forms that can respond to varying conditions,” for instance in the “computational generation of responsive architectural ‘skins’ and for adaptive intelligent environmental systems for buildings” that are interactive with material and energy flows (Hensel 1997, 11, 19, 64, 69; Ball 1997). To continue our hydrological examples, since it is harder to change a major urban area already prone to flooding than it is to plan future settlements away from flood plains, flexible design could be used to retrofit existing buildings. For example, supporting elements could be treated as pilotis, the fixed ground floor walls replaced with raisable ones, and only easily portable furnishings utilized on that ground floor, so that as farmers once routinely did during spring floods, belongings and activities could be moved upward until the water recedes. Or, more innovatively, new materials might be developed that function just as well in multiple regimes, dry or flooded. Imagine a sponge-material stiff enough to function well as a wall when dry, but with the possible alternate state of absorbing and holding water.

Image 12. Plasticity for multiple ecological regimes can be accomplished through new design and engineering. A variable ground floor could be provided by building with pilotis and raisable walls.
Ecological design and new material science could allow a building to have alternate positive states. Consider a sponge-walled house that functions well when either dry or wet.

CONCLUSION

Scientific, political, and design developments all align in one trajectory. By fully engaging with complexity theory, no matter what the scale, the second phase of ecological design can better understand the open, dynamic systems that constitute our world and thus become capable of more appropriately and effectively participating in the organism-environment co-generation always underway – especially by designing and implementing actual physical changes that maximize the plasticity and adaptation critical to the emergence of resilience.

REFERENCES


