Synthetic Ecological Frameworks

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Responsive technologies play a pivotal role in the evolving relationship between constructed environments and responsive ecological systems. Current models of machine/human interaction are slowly evolving to encompass more complex methods of simulated intelligence and nuanced response. The research presented attempts to formulate approaches to abiotic and biotic responses that directly interface with ecological and infrastructural systems across a variety of scales. This research posits a framework for understanding ecological interfaces and examines a series of pragmatic and speculative projects that support this line of inquiry.

Several technologies are converging to drastically change the landscape of responsive technologies including autonomous robotics, distributed intelligence, biotic/abiotic interfaces, and ubiquitous sensing networks. As a composite, these technologies fundamentally alter our ability to imagine constructed systems in highly nuanced relationships between environmental and ecological processes. These new relationships require an expanded view of networked and object-oriented relationships between designed devices, ecological entities, and regional influences.

OVERVIEW

Designed devices comprise a vast array of systems that potentially interact with ecologies and site phenomena. This may be large-scale infrastructure such as spillways, levees, or even power distribution networks or micro-scale systems embedded within the environment. Ecological entities are the biological systems that compose the relationships to fabricate ecologies. Plant and animal species can be considered with similar interaction principles and feedback loops as the designed devices. Regional influences refer to climatic phenomena, watersheds, or even migratory fauna that exist across multiple ecosystems. These three definitions are purposely broad to establish strata of interaction mediums necessary to engage ecological systems.

Considering each of these interaction mediums proposes a complexity of changing interaction models that go beyond typical responsive

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technologies. This shift calls for an expanded view that asks for ecological system abstraction, filtering, and embedded intelligence that drives feedback loops of sensing, processing, and visualizing. Considering Pask's Conversation Theory and construction of knowledge there is an evolved notion that systems, biotic and abiotic will construct internal knowledge models that are supported by networked interactions through specific data points. The composite of ecological systems, responsive technologies, and phenomena interacting as a field of reliant feedback loops asks designers to engage interaction beyond moments.

TECHNOLOGIES

Concurrent advancements in robotics, artificial intelligence, neurology, and genetics create a set of methodologies focusing responsive systems into nuanced ecological expressions. As each of the technologies advances, the interface between biotic and abiotic systems blurs, and the constructed world unconsciously becomes a hybrid interface of ever-evolving complexity. This complexity is intensified through both micro- and micro-scale layers that expand the scope and ubiquity of technological interfaces.

The evolving autonomy of computing systems is reaching critical stages in which it is necessary to consider their intentions. Many new systems are coming online that have specific decision-making abilities and go beyond remote controlled or unmanned devices. This form of artificial intelligence allows systems to analyze the context and to make decisions that are based on a vast array of information being processed in real time. Most systems are currently in the theater of warfare but one can imagine the implications of aerial or terrestrial robots that manage ecological processes, sensing localized conditions within a framework of regional data to make nuanced adjustments to biologic properties of ecologies. As expressed by a "Darpa" official in Peter Singer's *Wired for War*, "the human is becoming the weakest link in defense systems." These autonomous devices provide specific abilities for management or curating of ecologies outside of monolithic infrastructural relationships or controlled systems.

The concept of autonomy is also coupled with methodologies to develop shared or cooperative intelligence. The networking of devices and the formation of shared tasks and common goals are vital to the formation of devices that are able to make large impacts through nuanced adjustments of localized properties. Typical implementations of shared intelligence focus on the completion of singular tasks reporting back to a manager that assigns the next task in the queue, similar to batch render services. Newer models embed intelligence into the devices allowing for greater autonomy but requiring each device to be contextually aware of its environment and conspirators. This methodology puts the devices into a pattern of evolving priorities that determines its cooperative abilities.

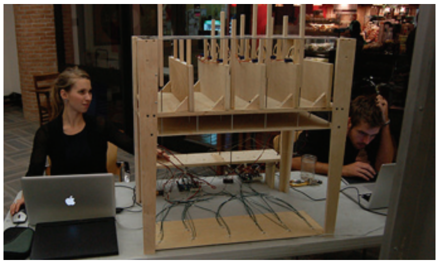
The earth we walk on, the soil, geology, and strata are difficult entities to punctuate and delineate in an orthodox manner to begin sensing and detecting phenomena both above and below surfaces. While in its infancy, several methods of embedding sensing networks directly within the strata are

Figure 1: Thresholds Exhibit, prototype highlighting interaction between visualization of isolines and light quality.

currently in place. This is typically accomplished with geotextiles that are wired to sense movement or other properties within the strata or on the surface above. "It is a computational fabric that structurally strengthens and physically monitors the landscapes it is buried within." It is possible to imagine that these embedded systems will be used to sense hydrology, seismic conditions, and soil compositions creating a real-time view of the ground underfoot.

The genetic modification and engineering of plants and microbes proposes an expanded set of possibilities for the integration of biotic and abiotic systems. The typical uses for genetic modifications include the engineering of pest-resistant plant varieties or drought-tolerant species for commercial purposes. Similarly these same techniques are used to modify aesthetic qualities through traditional hybridizing or more complex genetic alterations. It can be assumed that these technologies could be expanded to further capitalize on a variety of implementation concepts.

Beyond genetic alterations, advancements in neural interfaces and electro-vegetal systems are nascent areas that provide promise for synthetic ecologies. In most cases these technologies are at early stages of development but the direct interfaces between abiotic (electrical) and biotic (nervous system) provides models for cyborg ecologies.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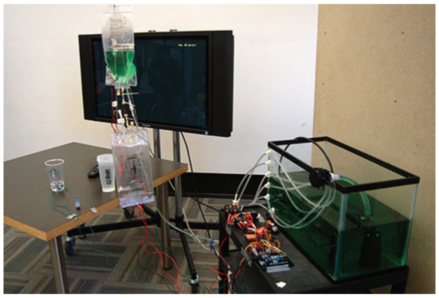
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DESIGN METHODOLOGIES

The complexity of ecological systems often dwarfs powerful methods of modeling and simulation requiring the digestion of systems in manageable chunks or low-fidelity composites. Current methods of understanding these systems punctuate complexity and typically filter away necessary relationships.

The investigation of responsive technologies that interface biotic and abiotic ecologies requires multiple approaches. The Louisiana State University Terrain Interaction and Kinetics lab focuses on creating physical prototypes and speculative proposals as two methods of addressing larger ecological applications. These explorations occur through funded internal projects and interdisciplinary design studios cultivating research in responsive technologies and synthetic ecologies.

The first explores typical sensory feedback loops through the creation of prototypes that address specific environmental phenomena. An example of one of these prototypes is the Threshold project, which explores the representation of light through the generation of isolines in relation to contrast. Isolines are used to represent the contrast of light through the processing of a camera feed or series of images. The real-time isoline generation provides a real-time view of light, rendering the volatility, transition, and relationships of light within a space.

These prototypes are typical experiments that highlight the possibilities between the sensing of phenomena and the response or actuation of systems. While very valuable to the understanding of the technologies at hand and how they affect interaction they are no different than many of the other

Figure 2: Sensing systems linking remote data systems with surface transformations.

Figure 3: Device prototype exploring water clarity and algae sequestration.

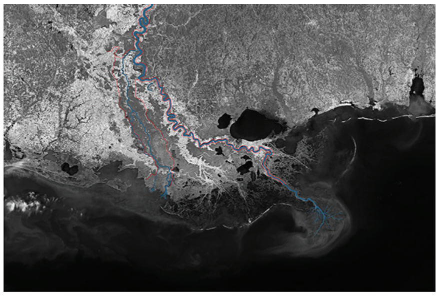

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Figure 4: Atchafalaya Basin

experiments that many architects and landscape architects are accomplishing within this area of the profession.

SPECULATIONS

The lab also examines the evolution of device prototypes as the catalyst for new landscape types, architectural interventions, management methods, and resource utilization protocols. In the fall of 2011 these topics were addressed within an interdisciplinary studio of architects and landscape architects that examined the potential of responsive technologies in regional landscapes. The studio focused on the articulation of a large-scale ecological process and abstract interventions that may alter, curate, or elevate the biotic systems. Students were then asked to isolate a single process and develop a series of digital and physical prototypes that would intervene within this system. The prototypes were then used to speculate on how they would affect the larger ecological systems.

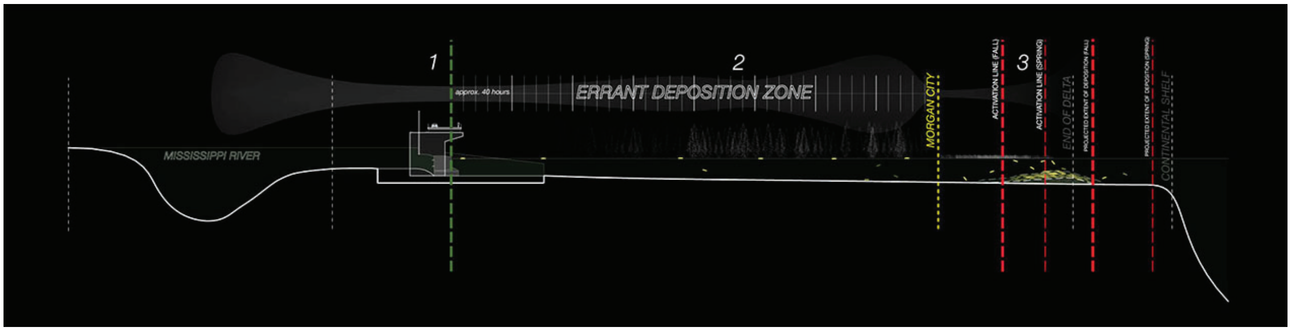
The projects were sighted within Atchafalaya Basin, in southern Louisiana, where it is possible to speculate on the interface between abiotic systems that are designed to alter specific movements in larger ecological processes. The Atchafalaya Basin is made up of the Atchafalaya River, wetlands, and wildlife, as well as a vast network of urban nodes and infrastructure that primarily serve agricultural and industrial services, including various petrochemical companies.s

POD MOD

The first project, Pod Mod, explores a system of sediment conveyance that borrows concepts from aerial drones and shared intelligence to imagine a system that allows for the flocking of congealed sedimentation. Due to an excess of sediment and nutrients, areas of the Atchafalaya River Basin are experiencing a significant increase in land mass while the rest of the Louisiana coast is in decline. While there is a surplus of built-up sediment and land within the basin due to flow of the river, dredging, and weather patterns, most of the sediment is lost to the Gulf of Mexico. To respond to this condition, the new concept creates an infrastructure at the Old River Control Structure that would harness the existing sediment load and convey it downriver. This conveyance system creates a greater concentration of deposited sediment, which would expedite the natural land-building process. In addition to providing a more concentrated sediment load, the conveyed sediment and its final resting point is identified, creating a sensor network that allows for a mapping of deposition patterns.

The conveyance system is comprised of two units, the first is an extrusion module that will be integrated into the existing Old River Control Low Sill Structure, and the second is a pod that is released from the extrusion module after a predetermined amount of sediment is captured. The pods float the sediment further down river allowing it to reach the salt/fresh water line where sediment and land building are most beneficial.

Once the pod reaches higher concentrations of saltwater, the metal clamp undergoes the process of galvanic corrosion, causing the clamp to



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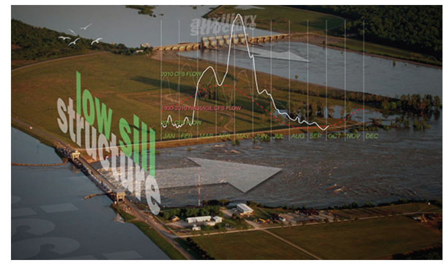
deteriorate and deflate the pod, which results in it falling to the river floor. This deposition zone near the saltwater line at the mouth of the Atchafalaya River begins to build concentrations of new land, developing an aggregated and stabilized network of land building. The pods will begin to create a framework of support for the channels as they deposit, as the network concentrates deposition, reducing the amount of sediment that is lost to the Gulf of Mexico. The pods will biodegrade in approximately four weeks while the RF sensor remains, and will be tracked by Coast Guard and Wild Life and Fishery boats, creating a real-time network of sediment deposition.

As the process builds land south of Morgan City at the Wax Lake and Atchafalaya Deltas the result will create an expanding spatial framework for new habitat and a stabilized terrain for surge protection. The process will also reduce the amount of dredging needed by floating past the problem areas in the river, which will increase the amount of sediment deposition in the Atchafalaya Bay. It will also create a real-time mapping of the sediment deposition, which helps identify areas of the greatest accretion, and also where the deposition process is being impeded so the system may be adjusted to achieve the most efficient results.



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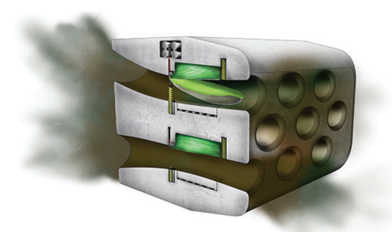

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VEG

The second project, Vacuolar Effluvia Genesis, inserts itself in the cycles of hypoxia currently present in the Atchafalaya Basin. Vacuolar Effluvia Genesis (VEG) is defined as the sequestration of a waste product or harmful substance in order to create a productive byproduct. This concept is used to capture or sequester biological processes that have negative effects to elements of the environment and to use the byproducts for productive purposes. Everyday 2.16 million pounds of nitrate-based fertilizer enters the Atchafalaya Basin before continuing downstream to the Gulf of Mexico. After entering the basin these anthropogenic nutrients lead to an overabundance of algae blooms, leading to a condition of hyper-eutrophication. Eutrophication is the natural oscillation in aerobic microbial decomposition and dissolved oxygen in aquatic ecosystems. As the massive amount algae dies and descends into the water column the algae is consumed by the microbes causing a spike in decomposition, lowering the amount of dissolved oxygen and resulting in a condition known as hypoxia.

VEG attempts to define the asymptote between the microbial decomposition and dissolved oxygen curves to maintain ecosystem health. The project

Figure 5: Conveyance Section

Figure 6: Low Sill Structure

Figure 7: Pod Module and Deployment

Figure 8: Pods Flocking

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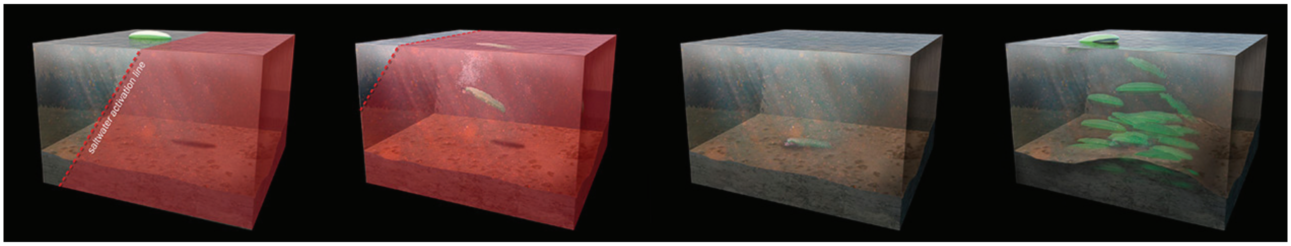

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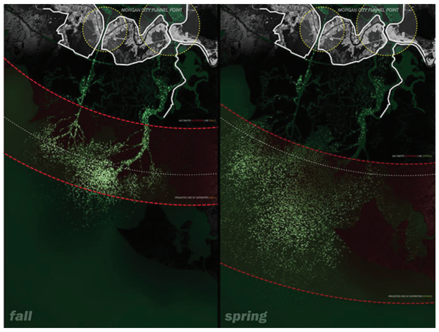

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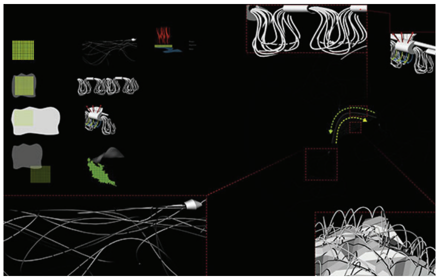


Figure 9: Pod Settlement

Figure 10: Delta Building

Figure 11 : Device Illustration

attempts to insert itself within this ecological process to develop multiple positive effects. This intervention is made possible by sequestering the process of microbial decomposition of algae into a synthetic abiotic structure. The composite of multiple units allows for a scalar response. Upon deployment to an area of potential hypoxia the units will initiate sequestration at the threshold of five ppm (parts per million) dissolved oxygen.

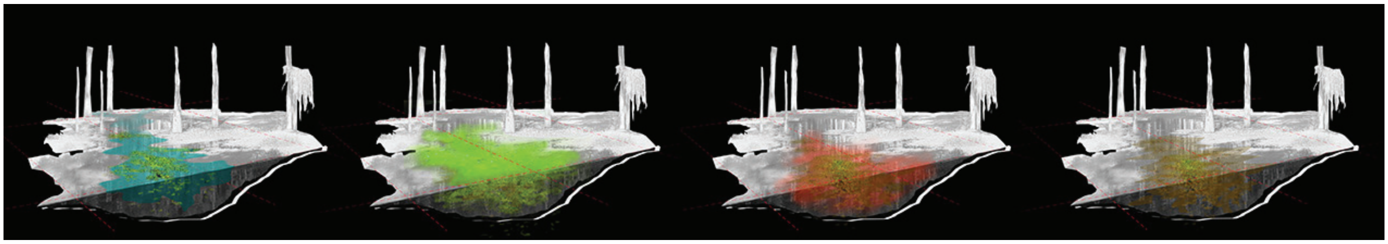
Utilizing an articulated network of tubing dispersed below the sequestration system and throughout the water column the unit will collect algae-laden water. The collection process will fill the system, starting the decomposition process. At the end of the decomposition cycle, which averages approximately 14 days, the process has three by-products: biogas, mineral matter, and water. The system is flushed back into the ecosystem except for the biogas, which is collected in a series of pockets. As the gas is collected the structure rises into a full dome supported by the gas within each pocket, creating a collectible structure and visual indicator of biogas production and environmental health. Each unit would conceivably produce between 500 and 600 liters of biogas per 1,000 liters of algae-saturated water and can be taken to biogas refineries for conversion into butanol.

LAND BUILDING

The third proposal examines land management, taking into account the positive and negative effects of these processes throughout the year. Managing land building in the Atchafalaya Basin redefines its relationship to ecological processes, and focuses on a nuanced approach to use biomass generated from algae and water hyacinth as a terrestrial substrate.

The project provides an articulated series of methods that adapt to the indeterminacy of ecological systems. The typical solution to regional infrastructure and land building has been to construct massive pieces of infrastructure that can interface at the scale of continental systems. This requires siting, building, and maintaining static systems when in reality, land is part of a living, fluctuating ecological system, and must be managed as such.

Using sensed real-time data of ecological processes to drive land-building locations and patterns develops a responsive methodology, capable of functioning at a micro scale and reacting to macro-system changes. In this project, sensors located throughout the basin provide real-time nutrient inputs and quantify where land-building substrate (algae and hyacinth) is available throughout the basin. By specifically locating where this biomass substrate is available and in what quantities, an average location of these points shows where land building could most efficiently occur.



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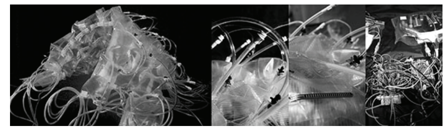
The sensed real-time data is investigated within this project at a number of scales and time periods. Within the Atchafalaya Basin, ecological systems fluctuate based on inputs from millions of influences. Within the scope of this project, it was necessary to understand some specific factors that relate to the growth and management of the major ecological systems. In order to provide a composite of real-time ecological data, a sensing network of three different scales is employed to sense the macro scale, an intermediate level, and a micro scale. These scales each imply a different temporal range of sensing. The sensing of this data at a variety of scales and times provides a composite model of the ecological system, and is interpolated to provide a vision of relationships between entities.

> The data that this sensing model provides is dynamic and fluctuates according to normal yearly trends as well as unseasonal and unexpected events and systems. Expected yearly trends may include the seasonal flooding of the basin in the spring of each year, because of the snow melt. Unseasonal or unexpected events may be storms, ecological pestilence, or industrial accidents.
>
> In addition to the macro cycles on which these different data-inputs fluctuate, the sensing model is also able to sense and identify micro changes in real time. Within each of these data criteria, minor fluctuations due to daily or even hourly micro-adjustments have an effect on the macro system. The real-time data-sensing model is able to pick up on these changes and provides a tool with which to aide programming and design.
> —Devon Boutte MLA 2012, Martin Moser BLA 2012

The real time model of the basin is accompanied by a series of evolving rules that govern the land-building process. This feedback loop of real-time sensing, land building, programming, and critique provides a nuanced evolution that can be tuned to specific observed or sensed changes in the ecological system. The goals and rules of the land-building strategy will be in flux without the need for a "best solution" but instead it will search for optimal conditions of ecosystem fitness, resiliency, or robustness.

The land building occurs as a series of typologies and rules that reflect the context of the current land-building operation. Three land typologies in the Atchafalaya basin—edge, open water, and fragmented—are identified and reflected in the land-building process. Embedded rules within each typology guide the creation of land in reaction to more specific real-time data at a site scale.



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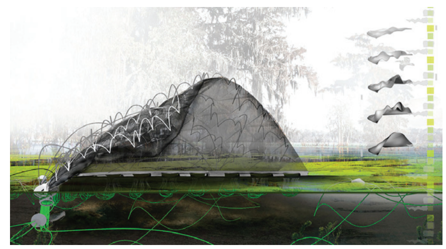

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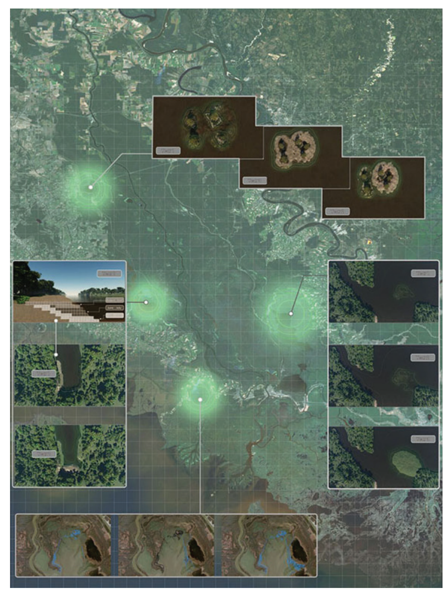

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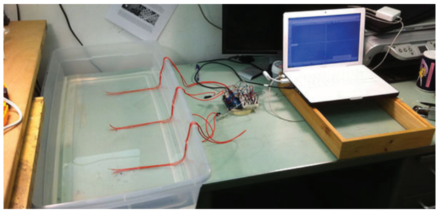
Figure 12: Hypoxia Diagrams

Figure 13: Device Prototype

Figure 14: Illustration of Collection Device in Environment

Figure 15: Basin Sensing and Response Procedures

16 

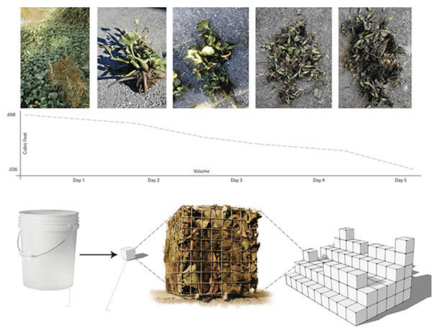
17 

Figure 16: Sensing Field

Figure 17: Hyacinth Compression Module

> The factors for determining the rules at the local scale may include more specific spacing, connecting, height, and proximity characteristics than the typological rules. The process for determining some of these rules involved utilizing scaled sensing models of the basin to provide a means of physical study of real-time data inputs. Additionally, incorporating City Engine software into this investigation may provide another tool for effective parametric modeling to aid in the adaptation of land building rules. Ultimately, all of these typologies and rules come together in a loop for ecological fitness and efficient land building, driven by the programming sequence of rules and typologies, and supplemented by feedback from the real-time sensing data that updates in response to changing site conditions.
> —Devon Boutte MLA 2012, Martin Moser BLA 2012

This methodology of land building posits a new infrastructure of emergent adjustments within ecological systems. This nuanced approach exemplifies the repurposing of current detrimental attributes for the greater fitness of the system.

CONCLUSION

The projects presented frame three approaches: autonomous sediment transport, micro-scale ecological interventions, and rule-based ecological constructions. Each method highlights a facet of how architects and landscape architects must begin to address the integration of technologies and ecological systems. While many issues are still laid bare, the projects frame a viewpoint that technology does not need to be redemptive but can be a proactive agent in the environment.

The emerging composite of computing autonomy and biological interfaces provides a speculative platform to imagine integration between biotic and abiotic systems. Our current models of interaction must evolve to frame ecological models of feedback and response, focusing on embedded intelligence and integrated feedback. The examination of the presented research and projects, in both built and speculative projects, leaves an understanding that new models of interaction are developing to create nuanced interactions between complex systems. It is at this juncture that we are able to imagine how responsive devices are emergent actors in landscapes and architectures at many different scales. These scales provide divergent methodologies for the application of ecological cultivation and nuanced, emergent infrastructural interventions. ◆

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