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Sand, Silt, Salt, Water: Entropy as a Lens for Design in Post-industrial Landscapes

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ABSTRACT *Entropy is a contemporary buzzword in landscape architecture used to describe a vast range of material, environmental, and social processes. Most uses of the word are loose appropriations of a very specific thermodynamic principle. This paper first explores some of the more common applications of entropy to describe post-industrial case study projects explored by Robert Smithson, Matthew Gandy, Gilles Clément, and John Beardsley. It then suggests that entropy is a lens for understanding particular challenges associated with designing in landscapes that bear the traces of past industrial occupation. It concludes by offering a design technique using physical models of salt crystallisation, sand dispersal, sedimentation, and water flow, for engaging with these themes as part of the design process. The paper suggests that viewing post-industrial sites through the lens of entropy raises productive design questions and that the indeterminacies of entropic processes are analogous to productive indeterminacies in the design process.*

KEY WORDS: Entropy, post-industrial landscapes, models, design research

1.0 A Jejune Experiment

1.1 Introduction

> Picture in your mind's eye a sandbox divided in half with black sand on one side and white sand on the other. We take a child and have him run hundreds of times clockwise in the box until the sand gets mixed and begins to turn grey; after that we have him run anti-clockwise, but the result will not be a restoration of the original division but a greater degree of greyness and an increase of entropy. (Smithson, 1967, p. 74)

So goes a 'jejune experiment' 'to prove entropy' by American land artist Robert Smithson in his essay 'A Tour of the Monuments of Passaic, New Jersey' (Smithson, 1967). Smithson's monuments are the artefacts of past, present, and hints of future industrialisation seen along a walking excursion through Passaic, a former industrial city turned into a New York suburb. Like many post-industrial cities, Smithson suggests, 'Passaic seems full of "holes" compared to New York City, which seems tightly packed and solid, and those holes in a sense are the monumental vacancies that define, without trying, the memory-traces of an abandoned set of futures' (Smithson, 1967, p. 72). Smithson's entropy experiment describes the temporal and material

dialogue in many post-industrial cities between past industrial artefacts and their current remains overtaken by nature as they are subsumed by vegetation, eroded by water, and worn by weather. His interest in entropy as a process and as a conceptual framework mirrors broader application of entropic processes to lateral disciplines ranging from economics to ecology in the 1960s. Entropy, and more specifically, *making entropy visible*, is one of the defining features of Smithson's work.

Entropy has re-emerged as a buzzword in landscape architecture in relation to designing in post-industrial contexts. In the 2012 article, 'Entropy by Design: Gilles Clément, Parc Henri Matisse and the Limits of Avant-garde Urbanism', cultural geographer Matthew Gandy explores the tension between the ecological ambitions and the cultural reception of Clément's Derborence Island, an inaccessible concrete wall containing undisturbed nature in Parc Henri Matisse in Lille, France. Gandy uses entropy as a metaphor for the exclusionary nature of the design and for a breakdown between scientific intent by designer and public reception. In 'A Word for Landscape Architecture,' art historian John Beardsley suggests 'entropy' is a narrative device that has the power to give increased agency to landscape architecture as a discipline. Using three post-industrial landscapes as precedents, Beardsley (2008) suggests that 'it is this tension—between order and disorder, between organization and entropy—that provides much of the narrative power of contemporary landscape architecture' (p. 196). A common thread in Smithson, Gandy, and Beardsley's writing is use of the term entropy to describe processes within a particular context: post-industrial landscapes that are untended, scarred, derelict, or degraded. Close reading reveals that entropy is a useful lens for highlighting particular design challenges of working in post-industrial landscapes. After exploring three such design themes revealed through the lens of entropy—indeterminacy, a new aesthetic, and dialectics—the paper concludes by introducing a design technique using physical models that engages with these themes early in the design process.

1.2 Defining Entropy

The First Law of Thermodynamics states that energy can neither be created nor destroyed; all energy that will ever exist already exists. While tidy and predictable, this law does not take into account that energetic processes have temporal directionality. The Second Law of Thermodynamics, the Law of Entropy, introduces 'time's arrow' to energetic processes. The Law of Entropy states that there is an energy penalty incurred in establishing equilibrium in a closed system; this penalty is often in the form of thermal energy or dissipated heat. The mid-nineteenth century discovery of this scientific law ushered in a new thermodynamic world view that differed from the mechanistic world view that preceded it. Luis Fernández-Galiano (2001) notes that this world-view initiated a fundamental paradigm shift in how space and time were conceived. He cites complexity theorist Edgar Morin as noting:

> …the universe inherited from Kepler, Galileo, Copernicus, Newton and Laplace was a cold, frozen universe of celestial spheres, perpetual movements, implacable order, measurement, balance. It is necessary to exchange it for a warm universe with a burning cloud, balls of fire, irreversible movements, order mixed with disorder, waste, imbalance. (p. 37)

In this new world view, cyclical time and orderly space are replaced by irreversible time and continually degrading space.

The 1960s marked a time of peak interest in applying understanding of entropic processes to lateral disciplines. Of particular significance were Rudolf Arnheim's application of entropy to art, Nicholas Georgescu-Roegen's to economics, Ilya Prirogine and Isabelle Stengers's to chemistry, Norbert Weiner and Claude Shannon's to information theory, and Howard and Eugene Odum's to ecology (Fernández-Galiano, 2001; Ponte, 2011). The Odums' application of cybernetics-based interpretations of entropy to ecology is perhaps most significant to landscape architecture (Lystra, 2014). Margot Lystra has explored how Ian McHarg applied the Odums' interpretation of entropy to his highly influential ecological theories of design; McHarg used entropy as a counterpoint to ideas about fitness, "posing it (entropy) as a threat to the healthy, balanced functioning of a living system" (2014, p.25). Application of entropy to landscape architecture reflects a circuitous interdisciplinary journey from thermodynamics, to information theory, to landscape ecology, and finally to design.

Entropy is a complex scientific law that has been so widely appropriated by non-scientific disciplines that its exact meaning has been dulled. Fernández-Galiano (2001) explores the many interpretations that the second law of thermodynamics has had on conceptions of space-making. He cautions that:

> …such generic use of the word…has given rise to the introduction of the concept of entropy in fields from economics to sociology, from psychology to art. However, the extended use of the concept has not been accompanied by a parallel deepening in its real sense; original rigor has gradually dispersed in a merely metaphorical use. (p. 59)

It is misleading to describe all visual manifestations of disorder, waste, imbalance, or chaos as entropic. Frank Lambert (2002) notes that 'over the years, popular authors have learned that scientists talked about entropy in terms of disorder, and thereby entropy has become a code word for the "scientific" interpretation of everything disorderly from drunken parties to dysfunctional personal relationships, and even to the decline of society' (p. 187). While processes associated with waste, imbalance, and disequilibrium are often entropic at molecular scales, they are not necessarily entropic at the human ('heat engine') scales associated with classical thermodynamics. One example of literal thermodynamic entropy in post-industrial projects is the spontaneous mixing of fluids due to temperature differentials. Oxidisation of iron resulting in rust and photosynthetic chemical reactions of plant growth are examples of entropy at a molecular level. Any clutter, waste, or visual disorder, however, is not entropy, at least not at the scale of observation of the viewer.

Given the scientific complexity and the circuitous disciplinary journey of 'entropy', it is not surprising that it is a term in which literal and metaphoric use are often unknowingly conflated. The intention of this paper is not to recentre literal thermodynamic entropy as a scientific principle to landscape design; this requires an unreasonable level of technical knowledge. Similarly, the intention is not to advocate for increasingly tenuous application and misapplications of the term that tightropes unknowingly between the literal and metaphoric. While entropy is a term whose

application often lacks clarity, that it is used to describe a range of conditions particular to post-industrial sites, suggests that it offers a productive lens for focusing on challenges associated with designing in this context. Therefore, my intention is to use Smithson, Gandy, and Beardsley's writing to reveal some common applications of entropy in post-industrial projects and then to explore what issues these uses offer for understanding challenges associated with designing in post-industrial landscapes.

1.3 Methodology

Methodologically, research operates in two related strands that adopt Christopher Frayling's distinction between research *into* design and research *through* design (Frayling, 1993/4). Research *into* design adopts the conventions of the humanities model of researching history, theory, and aesthetics. In this case, analysis of the ways in which Smithson, Gandy, Clément, and Beardsley use entropy to describe particular conditions within post-industrial contexts operate as research *into* design. Robert Smithson's work was selected because his writing on entropy in the 1970s provides a natural starting point for understanding how entropy figures into the temporal and material framing of early creative practice within degraded sites. Gandy and Beardsley's papers were selected because both authors explicitly and recently use entropy to describe processes taking place particularly within post-industrial contexts.

Research *through* design includes 'materials research', 'development work', and 'action research' (Frayling, 1993/4, p.5). The paper concludes by presenting a series of schematic physical models that operate as material research. The models—of sand, silt, salt, and water—explore the relationship between natural processes such as erosion, tidal ebbs and flows, and water evaporation and the relatively inert synthetic materials that contain and direct these processes. Videos of the models reveal 'entropic' processes at work and suggest a design process that raises parallel themes to those revealed through Smithson, Gandy, Clément, and Beardsley's writing. Just as text-based research explores *what* design themes are raised by viewing design in post-industrial contexts through the lens of entropy, research through design explores *how* designers might actively engage with these themes early in the design process.

2.0 Entropy as a Lens

2.1 Robert Smithson: Irreversible Time and Material Juxtaposition

For Robert Smithson, the land artist best known for Spiral Jetty, entropy was the 'matrix that holds together the whole diverse body of his work' (Flam, 1996, p. xix). His 1973 interview 'Entropy Made Visible' begins with a conventional description of entropy:

> Ok, we'll begin with entropy. That's a subject that has preoccupied me for some time. On the whole I would say entropy contradicts the usual notion of a

mechanistic world-view. In other words it's a condition that's irreversible, it's a condition that's moving towards a gradual equilibrium and it's suggested in many ways. (in Flam, 1996, p. 301)

Smithson elaborates on several examples of 'entropy made visible,' which generally include confrontations between the natural world and the manmade processes of industrialisation. Smithson's examples vacillate between the quotidian, such as Humpty Dumpty's fall and futile reconstruction, and the profound, such as the energy crisis in which the earth is understood as a closed system with finite resources that are being increasingly exhausted and accelerated through industrialisation (Smithson, 1973).

Smithson's art 'makes entropy visible' through temporal and synthetic/natural material juxtaposition. In 'Asphalt Rundown,' for example, a single dump truck releases asphalt down the eroded side of a steep hill. The asphalt coagulates across the hill's topographic contours. The pour is filmed and lasts just over a minute; the timeframe of the pour is juxtaposed against the temporalities of the weathering away of eroded soil as well as what Smithson refers to as the slow 'fluvial entropy' of geological processes. 'Asphalt Rundown' is the most well-known of Smithson's 'Pour' projects; others, using concrete and glue, reveal similar synthetic/natural material exchanges. Smithson used large-scale natural disasters and sites of industrial reclamation to illustrate similar disjuncted temporalities. He critiqued reclamation strategies that deny traces of their industrial past through wholesale erasure, suggesting these projects are 'an attempt to recover a frontier or a wilderness that no longer exists. Here we have to accept the entropic situation and more or less learn how to reincorporate these things that seem ugly' (Smithson, 1973, p. 307).

Post-industrial landscapes were frequent sites of Smithson's work, possibly because those sites where untended nature and obsolete industrial artefacts co-exist offer a visual counterpoint to the reclamation strategies of erasure he critiqued. In 'A Tour of the Monuments of Passaic,' Smithson used film and photography to capture this juxtaposition between industrial relics and natural processes, heightening natural/synthetic dialogues of weathering and change. His home state of New Jersey was a frequent site of investigation. Passaic, a city-turned-suburb close to Hoboken and Newark, across the Hudson River from New York City, has similar urban conditions to many post-industrial cities that show the traces of a more productive industrial past. These traces and the resultant spaces in-between are often particularly legible along historic infrastructural routes like rivers and rail lines. The route Smithson traverses and chronicles is littered with infrastructural relics, so-called 'monuments' that have been increasingly paved over, left unattended, and turned back to nature. The 'monuments' identified include a derelict walking bridge over the Passaic River, a pumping derrick, concrete highway abutments, and a parking lot covering a former rail line. Smithson's work aestheticizes maximum entropy in post-industrial contexts by revealing often radical disjunction in rates of material change over time. His work 'aspires to engage and reveal, even if they cannot contain, the whole of nature and the distant extremes of time' (Flam, 1996, p. xiv). Smithson applies particular features of entropy—temporal irreversibility and tendencies towards equilibrium—to non-thermodynamic processes, such as material flow or vegetative growth adjacent to industrial relics, reflecting an intermixing of the literal with metaphor.

2.2 Matthew Gandy and Gilles Clément: Social Breakdown

In 'Entropy by design: Gilles Clément, Parc Henri Matisse and the Limits to Avant-garde Urbanism', cultural geographer Matthew Gandy explores the social, political and ecological implications of Clément's Derborence Island, a patch of undisturbed nature bound by an eight-metre-high, inaccessible, raw concrete wall within Parc Henri Matisse in Lille, France. Parc Henri Matisse was commissioned as part of the Office for Metropolitan Architecture (OMA)-masterplanned 'Euralille' project in an attempt to rebrand the post-industrial city through large-scale development (2013). Clément's design creates an amorphous island of untended nature within a large tended public park. The effect of the contrast between contained 'wild' and maintained lawn is amplified by the exaggerated height of the intervention; below the vegetation lies a seven-meter-deep pile of rubble excavated during construction of an adjacent train station (Clément, 2006, p. 96).

      Derborence Island reflects Gilles Clément's interest in the ecology of 'fallow' urban spaces. In this project, it is tempting to frame entropy in ecological terms by describing the contrasting dynamics between tended and untended nature or the tendencies of ecological systems towards dynamic equilibrium. However, while much has been written about the relationship between ecology and entropy, there is little consensus as to a precise application of the term. Isabelle Vranken, Jacques Baudry, Marc Aubinet, Marjolein Visser, and Jan Bogaert (2014) conducted a literature review of how the term entropy was applied in over 50 landscape ecology papers, noting that the term was widely used to describe a loose range of temporal and pattern-finding ecological processes, and that there was no consensus in precise application of the term. They identified two strands of interpretation: a literal thermodynamic application, and one rooted in cybernetics and information theory. The team concluded that 'there is no confirmation that any thermodynamic interpretation of information theory is relevant. Information entropy is, therefore, merely a formal parallelism to thermodynamic entropy' (Vranken et al., 2004, p. 4).

      Instead, Gandy uses entropy as a social metaphor. He focuses more on the cultural implications of making the design physically and intellectually inaccessible, suggesting that the project is *socially* entropic. Because the island is conceptually opaque, physically inaccessible, and not signposted, Gandy suggests the project is socially disruptive. He uses entropy as a metaphor to describe the exclusionary nature of the design and the interpretive rift between scientific intent by designer and public reception. Gandy (2013) says 'there is an implicit didacticism and utilitarianism that runs through the discourse of landscape design, which presupposes the existence of a relationship between professional practice and public culture' (p. 11), and suggests that Clément's design breaks a social contract between the landscape architect and the public.

      Knowing whether to frame Clément's work in relation to ecological or social entropy varies depending on whether the focus of the analysis is on the garden, the gardener, or the public. Clément's writing about *planetary gardens* suggest an ecological reading of entropy because his gardening strategies are predicated on allowing naturally entropic processes to play out with little to no resistance through design intervention; he goes so far as to controversially advocate for the inclusion of non-native, persistent invasive species (Skinner, 2011). The gardener's role (and Clément would likely suggest the landscape architect should act as a gardener) is

simply to read this 'wilding' landscape of energy dispersal and to minimally intervene as necessary to act as its steward.

Clément's view of the general public is less adversarial than Gandy might suggest. For Clément, the public is not necessarily prioritised as the key stakeholder in a project. He suggests "the role of humans in the environment is to understand how it functions and to promote its continued functioning…man is just one species among the great diversity of species in nature" (Clément in Borasi, 2006, p. 90). Instead, the public's role is to be an active participant and observer of the natural taking place within the landscape. This may prove at times conceptually challenging, and is perhaps particularly so given the physical boundary around Derborence Island which prevents physical occupation. Ultimately for Clément, the public's role is as active observer and occasional participant in the larger logics of the garden's natural (and thermodynamic) progression; this is not an exclusionary view. Clément gardens tend towards entropy as the inevitable progression of natural processes, but his work is not culturally exclusive because it invites active occupation and engagement.

2.3 John Beardsley: A Value Shift

Beardsley suggests that 'it is this tension—between order and disorder, between organization and entropy—that provides much of the narrative power of contemporary landscape architecture' (2008, p. 196). In 'A Word for Landscape Architecture,' Beardsley explores the entropic narrative of three precedents: Herbert Dreiseitl's visible urban storm-water retention design for Renzo Piano's Daimler Chrysler Potsdamer Platz; the large-scale remediation of Landscape Park Duisburg Nord by Peter Latz and Partners; and the restoration of the pre-Aztec landscape of artificial garden islands in Parque Ecologico Xochilmilco in Mexico City by Mario Schjetnan. While Beardsley's description of entropy as 'disorder or randomness in a system' (p. 194) is an out-dated one, his writing is useful because he outlines some examples of entropy in conventional post-industrial project.

Beardsley's examples of entropy in post-industrial sites walk the tenuous tightrope between literal and metaphor described in section 1.3. In Parque Ecologico Xochilmilco, entropic processes include water pollution and eroding soils, which are juxtaposed against designed interventions such as walkways, walls, pergolas, and natural filtration systems that impose order by retaining, cleansing, filtering, and containing. As with Derborence Island, designated spaces are allowed to lie fallow or to succumb to inevitable processes caused by natural forces such as gravity, weathering, and other natural flows.

Beardsley's thesis reflects a value shift from understanding entropy historically as a threat to a contemporary understanding of it as an opportunity. Lystra (2014) notes that, according to Ian McHarg:

> …a system was inevitably entropic — but entropy was also a danger to the system's stability, and stability was associated with wellbeing. The individual—whether mathematician, scientist, or landscape architect —had a

> responsibility to facilitate order by constraining the entropic tendencies of the dynamic system. (Lystra, 2014, p. 75)

In the 1960s, entropy was seen as disruptive and destabilizing to ecological processes, which were seen as tending towards equilibrium. Entropy was understood as a threat to a desired sense of stability. Beardsley's re-framing of entropy as a productive narrative device suggests that it may play a much more productive and defining role in contemporary design practice; some of the broader design implications on this value-shift will be explored in the next section.

3.0 Focusing the Lens of Entropy

Smithson, Gandy, Clément, and Beardsley reveal some common appropriations of entropy in post-industrial contexts. Smithson applies literal thermodynamic ideas about temporal directionality and energy dispersal to non-thermodynamic conditions. While Gandy uses entropy as a metaphor for describing a social breakdown between designer and public in Gilles Clement's work, in fact Clement's work reveals a nuanced interpretation of how both designer and public might steward and respect, rather than resist, entropic landscape processes. Beardsley uses an out-dated understanding of entropy as disorder or chaos, focusing on visual patterns found in nature rather than on the energetic processes that govern these patterns, but reveals a clear value shift in use of the word. Rather than attempting to forge a clearer definition of entropy that retains fidelity to its scientific origins or that disambiguates literal from metaphoric application, this section explores a related question: what makes entropy such an appealing term for describing conditions within post-industrial contexts? How might we focus this lens of entropy to address particular concerns of designing in post-industrial contexts?

3.1 Indeterminacy

First, viewing sites through the lens of entropy raises questions about the agency and role of the designer. Entropic processes are spatially indeterminate, and they raise corresponding questions about design indeterminacy. This is not a new idea; Ignasi de Solà-Morales suggests in 'Terrain Vague' that design intervention in 'terrain vague' spaces should focus less on large-scale control and more on making the subtle tracings of forces and flows on the site legible (de Solà-Morales, 1995). More recently, Ian Hamilton Thompson (2013) suggests a number of designer classifications that define contemporary landscape architecture. Designing through the lens of entropy would certainly fall under the category of the 'Indeterminists', which is 'built on the notion that we should not attempt to determine all the outcomes of our design interventions' (p. 31). Hamilton-Thompson refers to James Corner's 'Terra Fluxus,' which suggests that landscape architects 'can set processes in motion but cannot, and indeed should not seek to control them in their entirety' (2013, p. 31).

> Smithson and Clément's work, in particular, reveal the indeterminacy of what

constitutes a project and of where authorship of that project starts and stops. Smithson's work suggests that entropic processes can be made visible through a carefully constructed photograph, as is the case in 'A Tour of the Monuments of Passaic,' or through the introduction of one material system to another, as in the case of 'Asphalt Rundown' and his other 'Pour' projects. For Smithson, a subtle alteration to the landscape, a walking tour or journey, or the simple application of a new material to an existing natural condition all constituted projects; these acupunctural approaches redefined conventions of art practice at the time. Similarly, Gandy (2013) suggests, 'central to Clément's vision is a redefinition of the role of designer as a 'guide' to steer innate processes of landscape change and reintegrate the natural and the artificial' (p. 15). Clément (2006) admits that he finds 'that which is unpredictable, that which we cannot completely anticipate 'very pleasing' (p. 91).

Spatial indeterminacy is an inevitable twin to authorial indeterminacy. 'Entropic' processes do not follow predictable geometries or patterns, and they often resist containment and the tight tolerances imposed by designers. In 'Entropy Made Visible,' Alison Sky describes a spatial blurring that results when multiple temporalities play out over time, noting that 'Ruins melt and merge into new structures, and you get this marvellous and energetic juxtaposition occurring—with accident a large part of the whole process' (1973, p. 304). This blurring of physical edges of the fallow in Clément's work is particularly legible in Derborence Island.

3.2 A New Aesthetic

When Smithson (1973) notes that 'we have to accept the entropic situation and more or less learn how to reincorporate these things that seem ugly' (in Flam, 1996, p. 307), he is suggesting that making entropy visible necessitates developing a new aesthetic, one that challenges conventional notions of natural beauty, the picturesque, and design formalism. Jack Flam (1996) notes that Smithson 'renounced traditional notions of beauty and of the picturesque—and the nostalgia and sentimentality often associated with those values' (p.xx). Smithson's entropy is revealed through natural disasters, scars of industrialisation, messy materials, and natural deformations, all of which challenge conventional notions of the picturesque in design. In Smithson's (1973) writing about Central Park, for example, he notes an interest in landscape 'deformation' and on refining understanding of often overlooked, messy processes and materials and processes such as mud, asphalt, and sedimentation (in Flam, 1996).

Giovanna Borasi (2006) notes 'Clément dissociates himself from historical models as well as aesthetic approaches' (p. 40). Gandy suggests that Derborence Island is socially disruptive, using entropy as a metaphor for the exclusionary nature of the design; he notes that the opacity of Clément's design breaks a social contract between the landscape architect and the public. Surely part of the breaking of this social contract is related to the fact that Clément's design—nature that is untended, unruly, and overgrown within a raw, unrefined concrete wall—does not align with public expectations of what a public park should look like. Just as Smithson challenges conventional notions of the picturesque in the natural world, Clément (2006) suggests a value reappraisal of untended or *fallow* space 'which is not worthless, but rather…. something positive, even a great asset… it is no longer a place abandoned to the rubbish and weeds, but becomes a sort of reservoir or

"biological time capsule" for the future' (p. 92).

When describing Derborence Island, Gandy (2013) refers to Yuriko Saito's notion of 'The Un-Scenic.' Saito (1998) suggests that:

> a revolution in the aesthetics of nature often takes place when people start appreciating the parts of nature formerly regarded as aesthetically negative… We are witnessing another revolution in this country which started a century ago. Its primary purpose is to overcome the pictorial appreciation of the natural environment, a legacy left by the picturesque aesthetics. (p. 101)

Saito explores the aesthetic value to 'those environments devoid of effective pictorial composition, excitement, or amusement,' (p. 101) focusing on aesthetics of natural disaster, dangerous species/events, unappealing conditions, and materials such as rot, dirt, and waste. While it is beyond the scope of this paper to explore the broader history of such aesthetic theory, and the term 'un-scenic' is suggested here as an offering for future speculation as a way of refining a vocabulary for designing within the waste/degraded conditions of the post-industrial site.

3.3 Dialectics

Intervening within the often vast territorial scales of scarred post-industrial urban landscapes raises questions about where industrial remains stop and nature begins; about how synthetic and natural materials are altered, worn and degraded; and about how these rates of change are amplified or resisted through design intervention. One consistent design theme in case study projects is that 'entropic' conditions are most legible in relation to extreme material and temporal juxtapositions. Interpretations of entropy varied in selected case study projects, but in all cases, entropy was amplified through contrasting timescales, often made legible through material contrast. The following contrasts are heightened in post-industrial contexts: weathering of synthetic relics of construction in relation to the weathering of natural materials and systems; the growth and maintenance of natural conditions that are well-tended against those that are un-tended; and the invisible chemical compositions of contaminated soils or water against those that are pristine.

The rhetorical power of the dialectic was a tool used by Smithson (1973), most notably in his writing about Central Park, which he described as 'the democratic dialectic between the sylvan and the industrial' (in Flam, 1996, p. 162). Smithson 'makes entropy visible' through deliberate material and temporal juxtaposition, which allows for the measure of one rate of change against the backdrop of another. Gandy (2013) also notes that the Parc Henri Matisse 'can be conceived as a "third object" produced dialectically from the antimony between the island of disordered nature at its core and the more closely controlled features that surround it' (p. 12). Deliberate contrasts are evident throughout Derborence Island: the tended horizontal lawn of Parc Henri Matisse is set against the extreme extruded island of untended nature in Derborence Island; a conventionally accessible public park is set against an isolated inaccessible fragment; and a dynamic of extreme control and maintenance is offset by one of lack of control. On a more conventional level, for Beardsley, entropy is

heightened simply through the dialectic between ordered design systems and disorderly natural processes.

4.0 Model Experiments: Sand, Silt, Salt, Water

Viewing post-industrial sites through the lens of entropy raises particular questions about design and spatial indeterminacy, about honing a new 'un-scenic' aesthetic, and about heightening material change over time through juxtaposition. If viewing sites through the lens of entropy offers a new contextual focus, what generative design technique(s) might facilitate exploration of this dialogue off-site as part of early design investigation? A return to Robert Smithson's introductory 'jejune experiment' to 'prove entropy' provides a point of departure for answering this question. Smithson's thought experiment uses a simple material palette—a sandbox divided between white and black sand—and applies a simple process—a child that mixes the sand by walking through both halves—to illustrate a basic principle: the irreversibility of natural processes, the directionality of time, and the tendency for the entropy of a system to increase over time. It is not difficult to translate this thought experiment to a basic experiment using physical models of material processes.

Four case study models offer a nascent working method that draws from the insights explored in the last section. In each model, synthetic materials act as a vessel, scaffold, or substrate upon which active processes, of air or water flow or of material weathering, take place. A dialogue between natural and synthetic materials and rates of change between inert and active processes plays out in each model. Video as a time-based medium captures these exchanges, reinforcing their temporal irreversibility. The designer's role in developing the model is to establish a backdrop upon which natural processes can take place; the exact nature of these processes and the inscriptions they leave, are only partially predictable. As such, the design process reflects the indeterminacies of the designer's role and the resultant inscriptions reflect a spatial distribution that defies conventional formal aesthetics.

In the first model, a basic wind tunnel approximates the distribution of an array of grey and white sand piles across a windswept landscape (Figure 1). As with more sophisticated wind tunnels, the basic wind tunnel operates as a vessel within which air movement is translated from turbulent to laminar flow, thus approximating wind flow along a vast unobstructed landscape. Six conical piles of sand, three white and three grey, are arranged upon the wind tunnel surface, reflecting an initial ordered condition that is then activated by air. The resultant dispersal mirrors Smithson's sandbox observation that the final landscape will 'not be a restoration of the original division but a greater degree of greyness and an increase of entropy' (Smithson, 1967, p. 74). The base of the wind tunnel provides a backdrop upon which air inscribes its only partially predictable course onto the sand piles. A split-screen video captures the gradual wearing away of the piles of sand in one screen and increased intermixing and dispersal of the sand in the other screen.
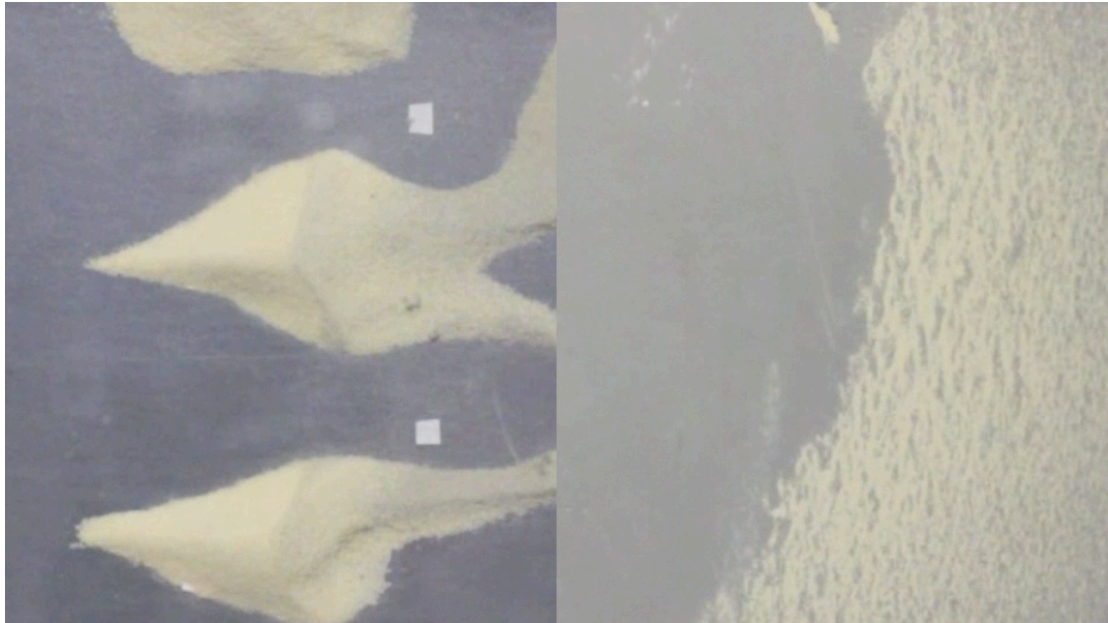
Figure 1. Sand: A basic wind tunnel distributes an orderly array of grey and white sand piles (left) across a windswept landscape (right). *Source*: video still by author.

The second model consists of an acrylic box into which thinned plaster containing suspended graphite particles is rocked (Figure 2). The model simulates particulate movement around a series of angled fins. The particulates act as traces, or material indices, of flow patterns. Video captures eddies and flows of particulate movement. The model approximates the intermixing that takes place when two fluids of differing densities or material compositions meet, particularly in tidal conditions or other fluid ebbs and flows. Examples of such conditions include material erosion along coastal edges where soil or other debris is swept into the sea or at the outlet of fresh or contaminated water to salt water where fluids of different densities intermix. The model includes interventions that allow the designer to alter flow rates and to see how changing the orientation of fins channels, directs, or catches the water's natural course. Altering the materiality of the fins, to steel (that would eventually rust) for example, would reveal further material rates of change.

In the third model, absorbent tapered 'towers' are placed in a tray of concentrated saltwater (Figure 3). As the saline solution evaporates and the towers absorb water, increasingly intricate salt crystals aggregate. The model replicates exchanges that take place in highly saline environments in which evaporation facilitates salt colonisation. Robert Smithson's earthwork sculpture 'Spiral Jetty' in the Great Salt Lake, Utah, can be read as a register both of water height and of salt growth as it has been increasingly encrusted with salt over time. Similar crystallisation takes place at finer levels within any saline evaporative environment and this process can be heightened or made more visible through materials that absorb and encourage salt growth. Similarly, some industrial or water desalination processes often have by-products of highly saline solution. The model suggests that design interventions might encourage crystalline growth in such contexts.
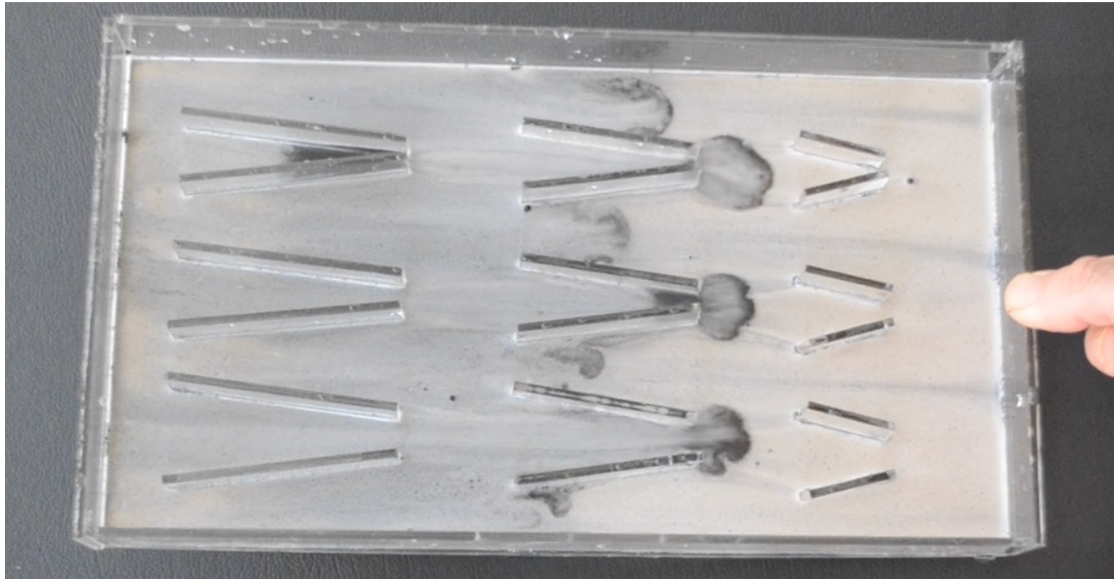
Figure 2. Silt: The sedimentation experiment simulates flow around physical obstructions and indicates eddies and flows of particulates over time. The particulates act as traces, or material indices, of these flow patterns. *Source*: video still by author.
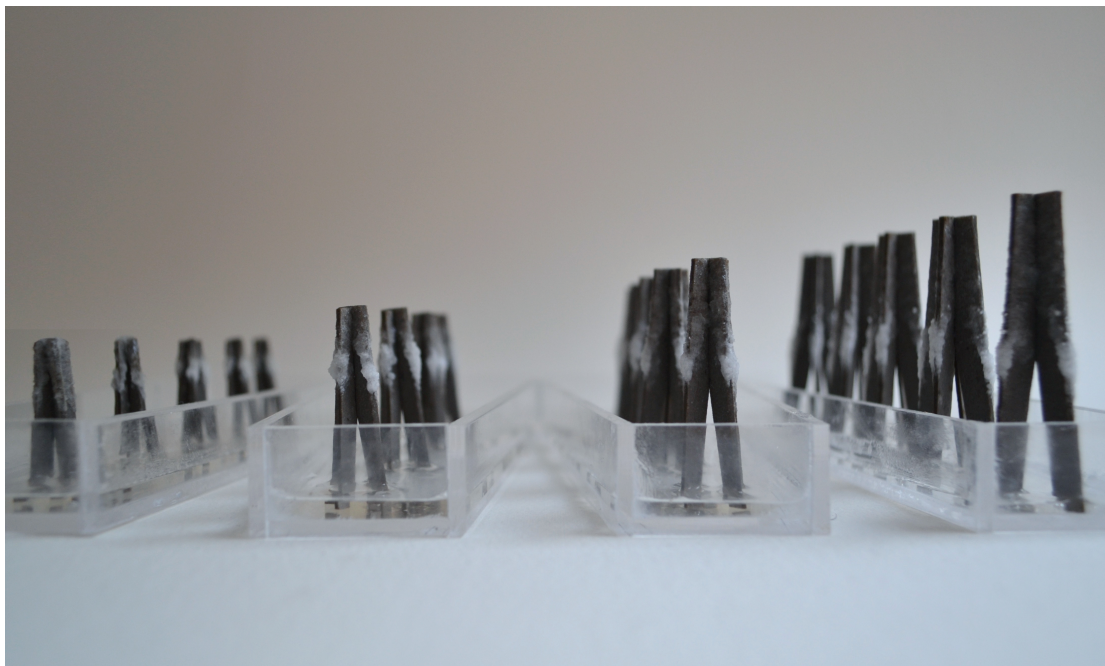

Figure 3. Salt: Tapered 'towers' in a tray of concentrated saltwater act as a substrate for salt crystal growth, offering insights for designing within saline environments where salt growth might be made visible as a natural process. *Source*: photo by author.

A final model operates more as a 'thick' drawing or 'thin' model (Figure 4). In this experiment, a hybrid model/drawing is completed on a substrate that is half dry and half wet, allowing for a dialogue between a fixed 'inert' substrate which receives ink undisturbed and the only partially predictable flow of ink within a thin wet surface that is shifted and raised. This artefact registers flow patterns, and the technique could expand to test how alterations or obstructions to the paper substrate, varying degrees of fluidity, or the nibs of different ink drawing implements affect these patterns. The

drawing/model offers insights to designing in a way that accommodates absorption, inclination, porosity, and configuration of ground conditions of varying moisture levels.

Figure 4. Water: A hybrid model/drawing is completed on a substrate that is half dry and half wet, allowing for a dialogue between a fixed 'inert' substrate which receives ink undisturbed, and the only partially predictable flow of ink within a thin wet surface that is raised and folded. *Source*: video still by author.

In all four experiments, one can imagine design variations for testing these material dispersal tendencies. In the sedimentation study, the location and size of acrylic fins, the configuration of the container and the speed and directionality of flow could be altered. In the salt crystal study, the size, configuration, and materiality of the tapered legs and the amount of saline bath could be altered and tested. The testing of variations allows for the kind of call and response required for imaginative design engagement. Each of these processes are not entirely predictable and often results in blurry, indeterminate, and only partially predictable results, but they allow for active design engagement with the messy, ill-defined problems of the only partially known familiar in design exploration (Cross, 2007).

Physical models have been relatively under-theorised in comparison to drawing in design discourse. This prioritisation traces back to the Victorian era when drawing was conducted within the clean, gentlemanly domain of the studio, whereas models were relegated to the messy material domain of the workshop (Starkey, 2005). It is the very messy materiality of models, however, that make them productive design tools for exploring entropic processes. The models evade conventional aesthetic descriptions because they introduce material processes—of erosion, sedimentation, and crystallisation—that are dispersed, shifting, and formally elusive. The models merge sensibilities from their dual disciplinary roots in design and environmental science, thus leading to a further indeterminacy of disciplinary roles. Rather than

being quantitative environmental models, however, they operate as qualitative tools that allow the designer to refine understanding of how designed interventions interact with the materials and timescales of natural processes.

Entropy is a complex thermodynamic principle whose lateral disciplinary use over time has dulled its meaning. Projects explored by Smithson, Gandy, Clément, and Beardsley reveal some of the more pervasive literal and metaphoric applications of entropy in post-industrial landscapes. Rather than honing a more precise definition of entropy, these readings suggest that entropy provides a lens for viewing conditions particular to post-industrial contexts. Active physical models refocus the lens of entropy as material registrars of energetic processes. The dialogue between messy and erratic natural processes and more static artefacts of construction are analogous to many material and temporal dialogues present in 'entropic' post-industrial landscape projects. The slippage between model and world, between energetic process and material registrar, and between designing with intention and designing through accident opens up productive interpretive possibilities for designing within the expanding post-industrial landscapes of contemporary shrinking cities.

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Figure Captions

Figure 1. Sand: A basic wind tunnel distributes an orderly array of grey and white sand piles (left) across a windswept landscape (right). *Source*: video still by author.

Figure 2. Silt: The sedimentation experiment simulates flow around physical obstructions and indicates eddies and flows of particulates over time. The particulates act as traces, or material indices, of these flow patterns. *Source*: video still by author.

Figure 3. Salt: Tapered 'towers' in a tray of concentrated saltwater act as a substrate for salt crystal growth, offering insights for designing within saline environments where salt growth might be made visible as a natural process. *Source*: photo by author.*Source*: photo by author.

Figure 4. Water: A hybrid model/drawing is completed on a substrate that is half dry and half wet, allowing for a dialogue between a fixed 'inert' substrate which receives ink undisturbed, and the only partially predictable flow of ink within a thin wet surface that is raised and folded. *Source*: video still by author.