PEAK SAND:

On the Limits of Resource Extraction Urbanisms in the Straits of Singapore

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Singapore's vulnerability as a nation without a hinterland to supply it with vital natural resources becomes evident in the case of land reclamation. This precarious relationship is exacerbated by the following conditions: (a) sand is a limited natural resource; (b) this resource is without substitutes; (c) the nation's population is increasing exponentially; (d) sand dredging, the process of resource-extraction itself, is a self-accelerating cycle; and (e) overuse of sand is increasingly hitting its technological, environmental, and geopolitical limits. Yet, having appropriated strategies for urban expansion that come with natural limitations, this island nation suffers from a latent need to reclaim land from the foreshore for various types of development projects along its coastline.

Due to the spatial complexity of the issue and the range of spatial disciplines involved, gaining an overview of land reclamation in Singapore against the backdrop of impending peak sand is essential to ensuring Singapore's global competitiveness and regional scope for urban expansion. "Peak sand" is being hypothetically discussed in this essay as the point in time when the maximum rate of regional sand extraction is reached, after which the rate of reclamation is expected to enter terminal decline. While the human population has been increasing exponentially, the unlimited availability of sand as a resource is an illusion. At the same time, dredging—the process of resource extraction itself—is a self-accelerating process that could be understood as a "dredge cycle"; every year, billions of tons of earth are moved both by erosion caused by humans as well as by humans in response to erosion. Thus, the rate at which earth is being moved is increasing exponentially (Hooke 2000).

Singapore has reclaimed land from the sea since the mid-1960s and was able to expand its sovereign territory by nearly a quarter in half a century as a result. When reclamation works began, the depth of Singapore's shore was about five meters. That has sunk to about twenty meters, requiring four times as much sand and therefore four times more money to fill every square meter. The more sand is being dredged, the more the landscape is being destabilized. The quicker the area gets refilled, the more one needs to dredge. Without regularly scheduled maintenance dredging, the development and operation of ports, harbors, and offshore facilities situated in Singapore's waterways would shoal to critical depths, resulting in a significant loss of ship and barge payload capabilities and consequently a substantial reduction in territorial economic benefits at a series of scales in extreme conditions. Counteractively, as dredging companies on the lookout for quality sand are pushed further from the shore due to the limited and nonrenewable nature of the resource, their radius of action is spatially limited in turn by technical, environmental, economic, as

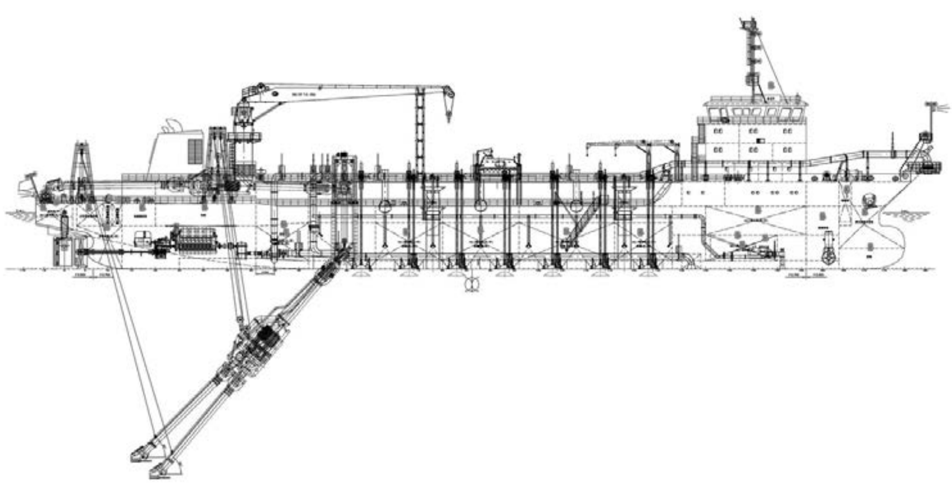

FIGURE 1. *Trailing Suction Hopper Dredger Model 2012 (8000 m3), Wazaf Trading and Shipbuilding Services*

well as legal concerns. As for how much more land the nation island can reclaim, we must ask, which technical, environmental, and geopolitical constraints and implications have to be considered? In regards to the spatial disciplines involved or excluded from the discourse, how can we possibly speculate on the architect's role in shedding light on possible solutions, leveraging extreme conditions as architectural opportunities for invention?

In Risk Society's Cosmopolitan Moment, Beck suggests that being at risk is the human condition at the beginning of the twenty-first century. He argues that, while risk produces inequality and destabilization, it can be the catalyst for the construction of new institutions. In the case of natural disasters, urgent architectural interventions and inventive modes of construction are often required. But can we think about a different kind of architecture that is not only a direct consequence of crisis—a humanitarian response, a basic shelter—but a more stable, flexible, and long-term "project" that could anticipate, even incorporate, such extreme conditions (Beck 2009)?

Too little attention is paid to the architect in relation to large-scale and long-term natural events. The architect is an active member of an actor-network. His diverse dependency on other parties in this network of actors, knowledge, and processes is presently of interest in academic research and professional discourse. Miessen's (2010) The Nightmare of Participation encourages the role of what he calls the "crossbench practitioner," an "uninterested outsider" and "uncalled participator" who is not limited by existing protocols, similar to the notion of an independent politician dissociated from a specific party. New urban practices are emerging at the intersection of ecology, geography, and politics, and it is presently common practice for architects and engineers to collaborate on diverse technical challenges. But while the discipline of engineering is based on the logic of calculated risk by definition, architecture seems to have no means of understanding and anticipating the broader and long-term impact of its actions. The impact of architecture, and more generally the human impact on the environment and landscape, is already so large that its consequences and byproducts have to be considered as a precondition for any new design project. However, a retroactive examination is usually not part of the design.

A STRATEGY *for* URBAN EXPANSION

Singapore's geography in relation to the sea has changed tremendously over the past century. Due to its strategic location, Singapore has been a center for trade and commerce, transportation, and other activities in the region since the establishment of a British colonial trading post in 1819. The result was a rapid growth of population in a country with a relatively small land area. Due to the resulting high population density and a rising demand for land as the population increases, the policy of urban planning in Singapore has historically been based on reclamation and maximized use of land. Thus large-scale land reclamation has been undertaken in different areas of the island state since the late nineteenth century. Nowadays, Singapore is virtually flat. But this has not always been the case, as Singapore's territorial expansion came at the expense of its own hills. While initially soil obtained from leveling the inland hills was used, sea sand obtained from dredging the surrounding seabed has become the main source of fill material for reclamation in recent years.

Earlier reclamation projects in Singapore were mostly confined to the southern tip of the main island. Fill materials were excavated from the hills in Bedok, Siglap, Tampines, and Jurong and used for filling swamp areas. Works included reclamation for the construction of commercial and residential projects. With the establishment of self-rule in 1959 and Singapore's independence in 1965, massive reclamation was initiated in order to cater to rapid development across various industries and businesses. Necessary amendments were made to the Land Acquisition and Foreshore Ordinances in 1964 in order to ensure that reclamation works could be executed without much hindrance. Initial works included reclamation for the construction of basic hard infrastructure such as airports, seaports, and roads.

Recent foreshore reclamation works were mainly carried out by three statutory boards of the government of Singapore. Other than the reclamation of the off-shore islands of Pulau Bukum, Pulau Bukum Kechil, Pulau Ular, and Pulau Ayer Chawan by two private oil companies, seashore reclamation was undertaken by the Housing and Development Board (HDB), the Jurong Town Corporation (JTC), as well as the Port of Singapore Authority (PSA). Reclamation works executed by the HDB were mainly for housing, commercial, and recreational purposes. Since the 1960s, the HDB had reclaimed the entire southeastern coastline of the main island, from Changi Airport at the east to the city center at the south. Being executed in major phases, these works were in tune with public housing development schemes, during which inland hills were leveled for the building of new towns. Further, reclamation works executed by the JTC were mainly for industrial development at numerous off-shore islands, while PSA carried out works for various purposes, including catering to recreational needs. Unlike JTC and HDB, fill for the reclamation works executed by the PSA was mostly dredged from the seabed (Kao, Wong, and Chin 1998).

A LIMITED RESOURCE

Besides being used as primary land reclamation fill material, sand is also used for making glass and concrete, filling roads as well as renourishing beaches. The demand for sand is ubiquitous throughout industries and businesses on a global scale. Essentially a nonrenewable resource, sand is a rare commodity on land (vs. off shore), and is without substitutes. It has become a crucial mineral for the expansion of society—literally being the foundation of the building and real estate industries. Due to its physicality and main constituent, quartz, sand has a number of desirable properties for use as foundation for surface construction and civil engineering. It does not expand or contract with changing moisture content and, unlike soil or clay, it resists high loads without sliding or compacting. Each application has its own requirements with respect to the quality of sand; glass is made chiefly from high-quality, clean, sharp sand. Formed at high temperatures, glass as a clear and inert substance is extremely resistant to wear, tear, and aging. About a third of concrete consists of sand. During the production of concrete, sand must also be strong and clean, like the aggregate rock, for the cement crystals to attach to. Inclusions of mud, silt, clay, and organic matter affect concrete strength considerably.

Sea sand, having been washed over and over again by every wave pounding on the beach, consists mainly of extremely hard quartz. Containing over ten percent of moisture by weight, sea sand needs to be washed to remove its salt. In popular places, where the cost can be justified economically by tourism, it has become common practice worldwide to perpetually renourish ailing beaches with new sea sand. On the one hand, by being less prone to being moved by wind than fine sand, coarse sea sand will not blow into built-up areas. Also, by being larger, coarse sand stays on top of the original sand.

THE LIMITS *of* GROWTH

There is a constant need to maintain the sea lines and provide new and larger ports for the bigger ships to anchor in the Straits of Singapore's limited sea space, to assure the region's competitiveness on a global scale. Journals in engineering research and practice concerned with dredging, sediment transport, and tidal wave action that affect the stabilization of shorelines, waterways, and harbors increasingly speculate on the future of dredging with respect to possible technological improvements or changes (Jordaan, Malan, and Bell 2009). Technology presently only allows reclamation of land from waters up to fifteen meters in depth. In the past, works used to be carried out from depths of five to ten meters. Today, however, reclamation works have to venture into deeper waters, incurring much higher costs. When dredging, sand is pumped up from the sea floor with suction pipes and then discharged into a storage compartment known as the "hopper." After filling up its storage compartment, the dredger sails to the disposal site where it unloads its cargo. It does so either by opening the doors or valves in the hopper bottom, using a pipeline running from the ship to the site, or using a bow jet in a technique known as "rainbowing." What follows is the reclamation process itself. When filling land, piles are first forced into the seabed to ensure the land will not collapse when put to use later on. After sand walls are built to keep sea water out, sand stored at the sea is sucked up, filling the enclosed area before it is compressed. Then granite walls are built to prevent soil erosion by waves. It takes one to five years until the land is ready for use.

Unlike sand taken from the bottom of the ocean, desert sand is not materially and structurally suitable for making artificial islands. Thus, dredging companies primarily operate near shore where known quantities of quality sand are to be found. However, as noted earlier, such sand only exists in very limited supply. It also belongs to the beach and dune system, with which it relates dynamically through forces that create and pull down beaches and dunes: tides, waves, wind, and sun on the one hand, and gravity and rain on the other. Wind, weather, and gravity have a decisive influence on the shape of beaches and dunes, causing their profiles to change on a daily basis and from season to season. Taking sand out of this equation can have a profound effect on the balance of this system and its entire profile. Changes are perceived sooner where sand moves more quickly (near shore, beaches), but changes may not manifest themselves for decades where sand moves more slowly (off shore, in deep waters).

An environmental priority is to prevent damage caused to the balance of the beach and dune system. In order to prevent beach erosion, dredging companies are advised to focus on areas with the least slope (off shore). Unfortunately, the cleanest and therefore most valuable sand is found in areas where the slope is steepest (near shore). Off-shore deep sand is being polluted by mud from unnaturally high soil erosion while off-shore rear dunes have been planted in the course of a century or polluted by humans and trapped sediments. In the context of these considerations, staying seaward of the 25- to 60-meter-deep contour of the coastline can be a potential compromise in establishing a safety zone around the coast in order to avoid interference with the natural beach and dune system.

The question remains whether sand removed from near shore would eventually be naturally replaced by off-shore sand and how soon. As the slope there is the steepest, sand removed from near-shore depth will most likely be replaced by beach sand to restore the balance. It may, however, take decades for deep storm waves to move sand from deeper near-shore depth towards the beach. The falling sea levels in previous ice ages made the shoreline move back out to sea, leaving Holocene sand behind. Thus, the question arises: what would happen once the Holocene sand on the sea bottom has been used up? Would the underlying Pleistocene sand change its properties once it is stirred around? To date, scientific knowledge about this process of sand being moved massively and over large territories is almost entirely lacking.

ENVIRONMENTAL CONSEQUENCES

Under climatic change, determinants of human health are forecast to worsen. Cities concentrate populations that are particularly vulnerable to the effects of climate change. Severe weather events like intense precipitation, cyclonic storms, or storm surge associated with climatic change in both developed and developing countries, combined with the many stresses on urban areas, can jeopardize infrastructure, resulting in economic damage and extreme health hazard to city residents. The increasing relevance of large-scale critical natural events to planning and design necessitates a redefinition of the architect's role as the co-creator of our environment.

Dredging companies are unable to reclaim too far out into the eastern side of Singapore because the reclaimed land would be constructed too far out into the open sea. It would be subjected to the destructive forces of waves and natural disasters. In fact, the main island is so sheltered from natural disasters that there is a common misconception that such events will not affect the island. But once sand is secured, it has to be protected from impending external influences such as tsunamis, typhoons, earthquakes, and a rising sea level. During periods of elevated sea levels, the variations between high and low tide are accentuated, putting Singapore's strategic reserves of sand at risk, as many of them lie adjacent to the coast.

In 1974 Singapore received a preview of just what devastation sea level rise could cause, when a rare astronomical event caused the tides to rise to more than double the usual level. Areas along the Singapore River were inundated, as were parts of the airport and a coastal public park built on reclaimed land. Documentation of tsunamis, typhoons, and earthquakes, which may have occurred centuries ago, is lacking, as Singapore's history does not go back long enough. Due to liquefaction, sand in reclaimed land slides like liquid when saturated with water, and buildings on reclaimed land may shake two to three times more than those on nonreclaimed land during earthquakes. The island nation stands on extensive soft marine clays and sands. In light of the experience in Mexico City, which was devastated by an earthquake in 1985 because it was built on the bed of an old lake, should not studies be put in place to realistically assess the plausible size of natural disasters and the detailed response of structures in Singapore?

GEOPOLITICAL CONSEQUENCES

Thus far, research conducted on sand dredging and land reclamation has mostly remained in the realms of logistics, planning, and engineering. Singapore's experimental policies in urban expansion, however, are perhaps a kind of extreme case study in how nations not only utilize natural resources but literally build themselves from the ground up (and down) as political acts of landscape architecture. When one departs from Singapore by boat, a series of environmentally disturbing sceneries of geopolitical significance can be witnessed—from artificial islands and booming construction sites to strategic sand reserve depots, dying beaches, and erased islands throughout the Straits of Singapore.

Land reclamation requires a large amount of sand that is not available from within Singapore. As a consequence, reclamation contractors import sea sand from neighboring countries. But in response to excessive digging into the ground of neighboring offshore seabeds, which strongly damage the environment, several adjacent regions have banned the export of sand to Singapore. This has in turn resulted in a continuous geopolitical friction throughout the region. Over the last couple of years, Vietnam and Malaysia have followed Indonesia's historical lead in banning sand exports. These bans, however, have not stopped the flow of sand from these countries. An illegal trade has flourished. Supply lines are not public information, as the Singaporean government does not disclose them. According to a recent study on sand trafficking throughout the region, the Construction and Building Authority says it is not public information where its sand comes from, while the National Development Ministry says the nation's infrastructure development company buys it from a diverse range of approved sources. By today, Singapore's insatiable demand for sand has been blamed not only for the disappearance of large tracts of mangrove forests and beaches along coastlines, but for the disappearance of whole islands in the Malaysian and Indonesian archipelagos (Global Witness 2010).

A mismatch between Singapore's reliance on questionably sourced sand and its position as a leader for sustainable development and environmentally sound urban planning is evident. But differences between Singapore and its neighbors are nothing new. Singapore—part of the region, but apart from it—has a history of disputes with its neighbors over land reclamation, water, satellite concessions, corporate takeovers, and military flight patterns, just to name a few. In fact, such disputes are as old as the nation itself. Its founding prime minister, Lee Kuan Yew, stated in his memoirs that his goal was to leapfrog the region as the Israel had done. After the island nation's independence from Malaysia in 1965, its leaders took advantage of Singapore's historic role as a trading post to lure investment and manufacturing, catapulting it to the ranks of the world's most affluent nations within two decades. According to officials in the region, Singapore is presently seen in two ways: On the one hand, it is a role model for development. On the other hand, it is seen as an arrogant economic giant prepared to use its financial muscle to undermine neighboring countries. If Singapore and its neighbors cannot agree to share basic resources like sand and water, then the stated goal of the ten member countries of the Association of South East Asian Nations—the establishment of a single market by 2015—remains in the realm of the illusionary.

POLICY PRECEDENTS

Without attracting much attention from its neighbors for centuries, Singapore has been reclaiming land since its early colonial days. However, if Singapore keeps employing land reclamation to increase its land size in relation to its neighboring countries, the political boundaries of Malaysia and Indonesia could be threatened. Singapore is one of the few nations in the world where the land mass of the country is constantly growing. And with this, its exclusive economic zone also increases. Thus, ironically, Singapore's resource-extraction-based urbanism leads to further securing of natural resources. In the long run, beyond environmental implications, this creates a problem on a geopolitical scale.

In 2002, the government of Malaysia claimed that reclamation works impinged on its territorial waters and caused environmental harm to the marine environment of the Straits of Johor. In regards to the land reclamation works in Pulau Tekong and Tuas View Extension, Singapore's neighbor applied to the International Tribunal for the Law of the Sea for provisional measures. Malaysia invoked the provisions of the 1982 UN Convention on the Law of the Sea and referred the dispute to arbitration, under Annex VII of the Convention. In 2003, Indonesia began to voice its displeasure with Singapore's land reclamation works. Marine ecosystems and habitats have been damaged irreparably by the uncontrolled sand extraction, which has also led to the disappearance of a number of small islets in the Riau Archipelago. Nipah Island is presently almost fully submerged. If the island sinks completely, the international boundary between Indonesia and Singapore will change, to Singapore's advantage. The two nations have an existing agreement on marine territory. But they have not yet settled their coastal baselines and exclusive economic zones (Koh and Lin 2006).

As a boundary line that determines where a nation's maritime sovereignty and jurisdiction begins and ends, a baseline is a legal construct. In fact, baselines determine all areas of maritime jurisdiction. They create a demarcation between areas where a nation has no rights and those where a nation does enjoy rights. The Anglo-Norwegian Fisheries Case in international law provided the first guidelines for drawing "straight" coastal baselines: In 1951, the United Kingdom and Norway contested access to fisheries off the Norwegian coast. Norway had attempted to claim ocean areas through some creative cartography. By drawing coastal baselines from points along its rugged coastline, Norway asserted that the enclosed areas between the deep fjords were exclusive Norwegian fisheries. Tracing a parallel or tangent line to a curve as a method of drawing political boundaries, the United Kingdom argued that coastal baselines should follow the outline of a coast. Eventually, the International Court of Justice ruled in favor of Norway's method of drawing straight baselines. According to Article 5 of the 1982 UN Convention on the Law of the Sea, a "normal" baseline is drawn at the low-water line, as stated in official charts. Essentially, it is an "outline" of a nation's coast. However, in some situations, it is either impractical or uneconomical to draw a normal baseline. In such cases, straight baselines are used in lieu of normal baselines.

In 2004, the Okinotorishima Atoll in the Philippine Sea was designated as a "series of rocks" by China. As China is worried that the U.S. Navy might use the surrounding ocean to ferry warships and supplies to Taiwan, there is no dispute over the ownership of the atoll between the governments of China and Japan. Instead, in this case the dispute is about the designation of the atoll—whether it is a "series of rocks" or a series of islands: If they are islands, the Okinotorishima Atoll grants Japan exclusive economic zone rights over an area of ocean about the size of California. According to the UN Convention on the Law of the Sea, an island is a "naturally formed area of land, surrounded by water, which is above water at high tide." Rocks which cannot sustain "human habitation or economic life" of their own shall have no exclusive economic zone. In an ongoing project to preserve the rocks and encourage new coral growth, Japan has erected concrete walls around the atoll. Slits in the walls ensure that the "naturally formed" land remains "surrounded by water," while a solar-powered unmanned lighthouse, installed in 2007, provides "economic life." Ironically, a concrete barrier is not natural, while a reef grown from transplanted coral in the shelter of artificial structures is.

Again, as we live in an era when the natural island nations are at risk of becoming ghost states and artificial islands tend to be inhabited as briefly as possible, such case studies stress the importance of a retroactive examination of large-scale design processes. What will become of your island when the legal and cultural environment that sustains it inevitably changes? The extremely formalized system of specific maritime zones provides a potential framework for planners who are creating programs involving off-shore resources. Knowledge of these zones, and how these zones are created, would ensure that today's regional and international planners are well informed and able to use this legal framework to their advantage.

CALLING *for an* ATLAS

During the present circumstances under which land is reclaimed in Singapore, peak sand seems inevitable. For the purpose of providing economic and national security during a crisis, some countries have strategic reserves of oil, rice, wheat, or other resources. Rising and diminishing in response to economic demands and international geopolitics, the island nation of Singapore stockpiles emergency inventories of imported sand. Singapore is aware of its challenges. However, adequate documentation and visualization of when and at what scale a crisis is going to happen are presently lacking. The limiting constraints as to how much more land the country can reclaim are bound to numerous factors in the realm of practices invisible to the public domain. In order to visualize and fully understand the complex spatial constraints and implications of land reclamation as a strategy for urban expansion across disciplines, it is essential to trace the invisible cartography of sand dredging. Thus, experts, who presently do not have a common language to sufficiently understand each other, could be brought to the table. By calling for an atlas of resource-extraction urbanisms in the Straits of Singapore, which would potentially compensate for the present information asymmetry among the parties involved, the architect can play a key role in this process.

In Architecture's Geographic Turns David Gissen (2008) describes an emerging group of geographically inclined architects who are adapting theories and concepts from geography, together with the discipline's representational tools. He describes a fascination with mapping that has been triggered by easily accessible phenomena like Google Earth and various forms of geographic information systems. Instead of plans and volumetric representations of spaces, architectural intent is communicated in the form of cartographical representations mapping transformations and flows in time and space. Rather then being strictly engaged with the architectural object emphasizing the specific experience of individuals within a building, "geo-architects" emphasize environmental flows of atmospheric material through a territory or at the scale of a person in order to develop proposals in the form of adaptable systems and flexible or hybrid infrastructures.

These systemic approaches to territorial situations point to architecture's capacity for arranging and structuring knowledge, to its power of deliberately turning information on and off. The architect's scope goes beyond the traditional notion of building. If the impacts of environmental disasters were addressed from a more entrepreneurial perspective, an advantage could be created out of an obvious disadvantage: An architect is, even though he knows about building, in reality in almost every domain a layman. In the case of a private house, he is to some extent a specialist, but when an architect gets commissioned to design an airport or a hospital, there is far more that he does not know than what he does know. The architect brings together disciplines and curates knowledge and information, speculating on the possibility of compromise in a sustainable and operative way, and to possibly softening the impact of environmental crises. This allows a kind of synthesis that specialists can no longer create.

The product of the map as a mental construct is an abstraction, a reduction of information. The architect as an expert generalist is a curator of information, turning information on and off. By reducing information, the architect is only telling part of the story as he is holding things back. Thus, when drawing a map, in order to be able to understand the bigger picture, we have to mess with history, hold information back to the extent of almost constructing a lie, an alternate reality. But when rethinking and applying the agency of the architect to mapping, the architect cannot be reduced to a negotiator between disciplines. While a negotiator arranges things among entities but doesn't gain anything from it, the architect brings multiple disciplines to synthesis. What, then, is the role of the architect in this contemporary panorama (Pauer 2012)?

FROM ANTICIPATION *to* SITUATIONS *of* CHANGE

Being a spatial issue at heart, it has been shown that land reclamation's radius of action is spatially limited in turn by technical, environmental, economic, as well as legal concerns. The increasing relevance of large-scale critical natural events to planning and design necessitates a redefinition of the architect's role as the co-creator of our environment. Beyond his ability to solve site and project-specific challenges, the skill and mind-set of the geo-architect, reinterpreted as an expert generalist bringing multiple disciplines to synthesis, could be of particular use in the production of a resource-extraction atlas at the particular site of Singapore.

At the core of this call for an atlas of an invisible cartography of sand dredging lies the understanding of subsurface urbanization in all its facets as a growing part of overall urbanization. This investigation of the limits of resource-extraction urbanisms in the Straits of Singapore is framed by the need to develop a methodological toolbox of the architect on an atmospheric and territorial scale. This toolbox would help the urban discourse identify new landscapes, networks, and urban models in the wake of destabilized economic, social, and environmental conditions. Thus, the field of urban studies could potentially understand the convergence of scales and timeline of events in nature, politics, and economics, and the performance of the discipline of architecture in this context.

Historically tracing earth moving per capita at a global scale, our ability and motivation to intentionally modify the landscape by moving earth in construction and mining activities have increased dramatically. Around 7000 B.C., the hunter-gatherer way of life gave way to farming and village life. Around 3000 B.C., the desire for minerals led to expanded mining, and metal tools facilitated earth-moving activities. After digging sticks and antlers had given way to wooden plows, iron spades and steam shovels around 1800, steam power and the Industrial Revolution led to a need for coal and at the same time provided machinery for mining coal and other earth-moving endeavors. The early 1900s' internal combustion engine eventually led to the enormous excavators of today. Erosion from agricultural fields also increased steadily as hunter-gatherer cultures were replaced by agrarian societies. This constitutes an unintended additional human impact on the landscape (Hooke 2000).

The twenty-first century has been characterized by unparalleled urban transformations, but the extent to which urbanization is happening underground is much larger than is generally assumed. Decentralizing urban growth is limiting the spatial capacity to accommodate the simultaneous demand for the construction and management of large-scale infrastructural projects. Current shifts in energy policies will continue to foster the exploration and development of subsurface territories for years to come. And the need for ecologically and economically sustainable resource management in the context of a growing awareness for conservation and protection of our natural and man-made environment often leaves no alternative but to construct new mobility and energy infrastructures below surface. On the input side, the production of both concrete and metals requires huge amounts of soil, gravel, and sand to be excavated, moved, and refined. On the output side, extractions from construction sites as well as mineral wastes from demolitions of buildings entail billions of tons of mineral waste (Dittrich et al. 2012).

Never before in history has humankind extracted, transported, shifted, processed, and reproduced more soil and minerals. Paradoxically, while minerals presently represent the largest material stream on earth, urban discourse has tended to focus its attention on visible urbanization processes, whereas invisible subsurface infrastructure is often ignored or taken for granted.

To the extent of being treated as two different and separate disciplinary entities in the field, the visible realm belongs to the architect, landscape architect, and urban planner while the invisible realm belongs to the civil engineer. However, this distinction does not correspond to the reality of urbanization processes. Simultaneously engaging the surface and subsurface, visible urbanization both requires and entails subsurface urbanization, and vice versa.

It is fascinating to think of the architect as a geomorphic agent and to consider his ambition on a territorial level, and even more so, the limits of this approach. In the case of land reclamation as a strategy for urban expansion, how has failure historically influenced representation and design methodology? Is "geo-architecture" a way to structure knowledge we have about what will happen, speculating on the possibility of compromise in a sustainable and operative way and possibly softening the impact of environmental crises? Thus, we would be moving from anticipation of situations to change, from theoretical speculation to an actual design approach. Can we think of infrastructure that would anticipate the technical, environmental, and geopolitical constraints we have to face? Can we design peak sand?

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