Hydrotecture

by

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ABSTRACT

Architecture has long been fated to work against nature in order to create shelter. This paradigm presents an obstacle for those who wish to work in harmony with nature, and has created our present condition of irresponsibility with regard to architecture. This, and the fact that freshwater scarcity has raised the ecological stakes in the built environment, means that we must address the need for the reallocation of the planet's resources in an architecturally responsible manner. Hydrotecture attempts to address the problem of the anti-nature paradigm shift and the scarcity of fresh water resources by conceiving the built environment through the lens of a new philosophy of design, one which is both completely in tune with the surrounding ecosystem and with the contemporary needs of its inhabitants within what is, after all, a manufactured space. This philosophy of architecture, far from being removed from the concerns of art, instead outlines responsive environmental parameters wherein creativity can be deepened, extended and justified.

HYDROTECTURE

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INTRODUCTION

Hydrotecture

Increasingly, during this century, the traditional means of accessing fresh water from sources such as ground water, rain, and surface water have become inadequate in many areas of the planet because of growing population and the improper, or inefficient, use of this invaluable resource. In certain areas the availability of drinkable water is abundant, but many communities have managed to disturb the hydrological cycle through deforestation, pollution, misuse and overuse. One particularly disturbing consequence today is that 3900 children die every day around the world simply because they lack access to clean water and adequate sanitation. Our planet is and will continue to be confronted with this serious issue if we do not change our means of consuming and supplying potable water. As drastic as it sounds, drinking water is the very source of life, since without it we will die. Although, this fact is deemed relevant only to the lesser developed nations around the globe, the impact of the scarcity of water is alarming. As an example, In the Detroit area alone, forty thousand homes are cut off from their water supply every year simply because its citizens cannot afford to pay their water bills. Politics also play a large role in the availability of potable water. In Detroit, this problem could be quickly regulated but the poorer sections of society do not have political influence. Another example of this is in Bolivia, where the government's decision to privatize the water supply obliged many inhabitants to go without water and continually search for alternative means to access water, most of which, were violent and unethical. It should be noted that it took nine months of a labourer's salary in Bolivia to pay for the costs involved in tapping into the privatized water system.¹ After a serious revolt in 2005, the water privatization program was halted, although in many other areas around the world, privatization of the water supply continues

1 A World Without Water Dir Brian Woods TrueVision, 2006 DVD

to occur. On a global scale, as the demand for water rises on account of external pressures, it is becoming increasingly difficult to provide enough water for drinking, not to mention the immense quantities needed to supply agriculture and industry. In California, the current water supply can barely supply existing farming needs, and increasing demands are already causing distress. As farms begin to disappear in California, food will have to be produced elsewhere, entailing extensive transportation back to the areas contributing to ever increasing environmental damage. Economics are also responsible for the scarcity of water in certain regions. The exponential growth in China's population and economy over the past several decades has come at a tremendous cost to the country's ecosystem. The nation's water resources are over allocated, inefficiently used, and grossly polluted by human and industrial wastes, to the point where vast stretches of riverbed are irredeemably polluted, or unusable, and lakes have become cesspools of waste. Groundwater aquifers are over-pumped and unsustainably consumed, innumerable species of aquatic life have been driven to extinction, and the direct adverse impacts on both human and ecological health are widespread and growing. Of the twenty most seriously polluted cities in the world, sixteen are in China. Three hundred million people lack access to safe drinking water in this country.² The issue has particular pertinence here.

Another factor that has intensified the problem is the unrestricted free-trade of water and this is responsible for the continuing harmful effects on human health. The potential profits at stake in controlling the water trade have attracted investment from several large corporations, such as General Electric, Procter and Gamble, and the Dow Chemical Company³. Future prospects do not look good and we are likely to witness extreme water wars in the near future. We will accordingly

² Gleick, Peter H. The World's Water 2006 - 2007 the Biennial Report on Freshwater Resources Washington DC Island, 2006 Print pg 79

³ Fong, Bryan "Water Purification Investment Opportunities " Valueline 25 Aug 2010 Web 15 Mar 2011

<[http //http //www.valueline.com/Stocks/Commentaries/Water_Purification_Investment_Opportunities.aspx](http://http://www.valueline.com/Stocks/Commentaries/Water_Purification_Investment_Opportunities.aspx)>

be at the mercy of these companies, just as we are in our present situation with the oil trade. This topic will be discussed in greater detail in the following chapters.

So where do we go from here? Current solutions to this issue include large scale industrial technologies, which most countries cannot afford to install, and they entail hefty maintenance costs thereafter. While these high-tech innovations produce drinkable water, they merely extend the problem by being devastatingly pollutant, and they involve computerized systems dependant on fabricated energy. For this reason, the following investigation will tentatively examine low-tech alternative solutions to harvest and produce fresh water in an environmentally friendly manner while yet being realistic and affordable. The incorporation of this issue within architecture will help to initiate a truly sustainable philosophy of building design. Hydrotecture is proposed as a design philosophy with a more ecologically holistic outlook on architecture, and one that can offer quantifiable benefits to address the current water situation. With one third of the global population lacking access to safe water, and this percentage scheduled to reach fifty percent by 2025, this is more than sufficient reason for further research. We simply must take action before it is too late.

Simply conceived, our most vital needs are for air, water, food and shelter. The intention of this investigation is to identify the interstices or overlapping domains where shelter can begin to be a provider of water, which, in turn, can produce food. This correlation of needs and desires also presents a critique on the development of current architectural practices. Today's designers are focused on creating masterpieces, albeit without meeting their fundamental objectives or responsibilities towards humanity. The meretricious race for the front page design magazines must be countered by the kind of thoughtful and creative responses that the more responsible exponents of our profession bring to a world in crisis. However, the current fashion in the business of conceiving conceptual buildings is

continually fed by the circus of architectural competitions. Sensitively elaborated “green” buildings should not be praised for their trendy subservience to environmentally sensitive add-ons: the idea of serving environmental needs and human needs must be more reciprocally conceived, and then concurrently executed within the design of a building. The form should respond to the meteorological conditions of a given place. If the idea of beauty is only amenable to subjective interpretations, architecture’s real and demonstrable advantages can be extracted from the beauty of its practical designs and benefits. Aesthetics should be derived from responsible architectural ideas, competently executed. Believing that quantifiable benefits can be at once beautiful and fully responsive to environmental concerns is the result of a healthy and happy planet and, not least, the precondition of a sustainable future.

Water Concerns

Chapter 1

First and foremost, humans need water. All agricultural and manufacturing activities depend on this essential resource, and humans have always controlled its supply from the origins of civilization up to the present day. Beginning with the Romans, who explored the theory of gravity to bring water to their cities, culminating in the high-tech pump stations still in operation today, the water distribution system is an important feature of our built environments. Much of our technical ingenuity in the allocation of water derives from the mechanical and engineering devices so instrumental to the organization of society, and most evidently manifest during the industrial era. Although these engineered innovations have revolutionized our water systems, they can also be held accountable for problems such as chronic pollution, and even, climate change. Our ecological safeguards are at the mercy of the cash fundamentals and the ideologies of capitalism. Moving forward, with the exponential growth of the global population and the increasing consumption of goods, the planet continues to be plagued by constant pollution and overuse, thereby diminishing the accessibility of fresh water.

We are presently consuming fresh water faster than the hydrological cycle can replenish the supply, which disrupts the natural process of a renewable resource. To compound the problem, we are ruining some sources of water by contamination. Peter H. Gleick, author of *The World's Water, 2008-2009: The Biennial Report on Freshwater Resources*, states that we are not able to sustain our present consumption of water. This has resulted in a decrease in the availability of a supposedly "renewable" resource. Therefore, as the planet's population continues to grow and the availability of fresh water continues to decrease, the problem is simply amplifying. Based on estimates provided by the United Nations and the U.S. Bureau of the Census International Data Group, the growth of the world's

population between 2000 and 2020 will be about 1.5 billion people. This will bring the total inhabitants of the planet to 7.5 billion. If this prediction unfolds, and the world's water issues are not addressed, the number of people without access to safe drinking water will rise to 1.3 billion people. This estimation of people without potable water is even optimistic, as the world's population growth is centralized in third world regions that already have serious issues with water supply.⁴Gleick goes on to stipulate that the number of people dying from preventable water-related illnesses such as diarrhoea will increase from the present 2.1 million to roughly 2.6 million by 2020. Given the current political and financial commitments in place to resolve the issue, Gleick does not believe that this prediction will be avoided. He rounds off his argument by ironically stating that the world's expenditure for bottled water is approximately 100 billion dollars annually.⁵ What makes this fact even more shocking is that the United Nations has declared that it would require an additional 30 billion dollars a year to its present budget to be able to provide the entire global population with safe drinking water.⁶ That's less than one third of what the bottled water industry generates yearly. Nonetheless, if economics could be given a holistic interpretation, as in Socrates' definition, a solution to our water problems would be more forthcoming. In the text *Oeconomicus* by Xenophon, Socrates discusses the meaning of wealth, defining it as entailing the well-being of all parties involved.⁷This is a global issue, and as it grows in amplitude, everyone will be affected.

4 Gleick, Peter H , and Heather Cooley *The World's Water, 2008-2009 the Biennial Report on Freshwater Resources* Washington, DC Island, 2009 Print P 12-13

5 Gleick, Peter H , and Heather Cooley *The World's Water, 2008-2009 the Biennial Report on Freshwater Resources* Washington, DC Island, 2009 Print P 12-13

6 FLOW *For the Love of Water* Dir Irena Salina Steven Starr Productions, 2008 Online

7 Xenophon, and Robin Waterfield *Conversations of Socrates* London Penguin, 1990 Print

The Impact of Humankind on the Hydrological Cycle

In areas of the planet where there are sufficient amounts to waste, water is obviously taken for granted. For this reason, humans play a large part in the disruption of the natural cycle of water and the life that derives from it. By building dams and intricate irrigation infrastructures, the natural course of rivers is altered. This displacement of the natural flow has been one of the leading causes of deforestation, which inevitably occasions torrential run-offs, and these can cause flooding and endanger animal species. Over-pumping ground water can also cause subterranean soil to leach naturally occurring contaminants, or allow sea water to enter into the water table.⁸

The Dangers of Depleting Groundwater

Ground water consists of 30.8% of all freshwater sources present on the planet. In comparison only 0.3% is found in rivers and lakes, making it logical to begin using groundwater sources. One issue to be addressed here is that people are not aware of the macro dimensions, or the scale, of such activities. Secondly, they exercise no choice in using this water, as in most cases, it is the only available source. It is consequently exceedingly difficult to control the amount of water being drained from below the surface. Nonetheless, groundwater is integral to the hydrological cycle. These aquifers are ancient reservoirs that have been accumulated over millions of years. Experts argue that the rate we are consuming this water is much faster than the rate that nature can recharge it. The more we remove, the more we affect the hydrological cycle, and consequently, as the ecosystem is offset, the natural ability to produce clean water is reduced.⁹ Some

⁸ Bowers, Noah "Drinking the Air " Thesis Pratt Institute, 2006 Print P 7

⁹ Bowers, Noah "Drinking the Air " Thesis Pratt Institute, 2006 Print P 8

theories also allude to suggestions that certain land masses, such as Mexico City, Mexico, are sinking due to the increase in groundwater depletion.¹⁰

Figure 1 - Diagram indicating effects on population caused by water scarcity
(Illustration courtesy of IUCN et al. 1996)

¹⁰ Blue Gold World Water Wars Dir Sam Bozzo Perf Jim Olson, Tony Clarke, Maude Barlow PBS Video (US), 2008 DVD

Colors of Gold: Comparing Oil and Fresh Water

Chapter 2

PEAK OIL: When you plot the production of an aggregate of oil fields over time you get roughly a bell curve

Figure 2 - Hubbert Curve analysis (Illustration courtesy of www.drmillslmu.com)

Among the theories purported to account for oil consumption and its availability is the concept of “peak oil,” which originated in the 1950s with the work of geologist M. King Hubbert and his colleagues, who suggested that the rate of oil production would likely be characterized by several phases following a bell-shaped curve. Thus, the discovery of an oil source would lead to an increased rate of exploitation, which would rapidly increase as demand rose. As production becomes more efficient, costs fall. Also, as oil is consumed more, the resource becomes increasingly scarce, and costs increase. Finally, increasing scarcity leads to a decline in the rate of production at a rate more rapid than new supplies can be found to

satisfy the manufactured need. The last phase in the cycle would typically be accompanied by a renewed search for alternatives to oil.¹¹

This analysis of oil depends on several factors, but for the purposes of this study, the key factor of transportability will be highlighted in comparing it with the availability of water. One problem with water is that as a result of the tremendously uneven distribution of sources around the planet, caused both naturally and by human influence, it is less quantifiable. Oil is transported around the world because it has a high economic value compared to the costs involved in transporting it. As a result, oil is shared globally, and as resources are depleted in certain regions, these shortages can be overcome by moving oil from one point of production to another. In contrast, water is expensive to move large distances and requires more of the liquid per day per person. Since it is not financially viable to demand a price for water that people cannot pay, and that businesses cannot profit from, water is not extensively transported. As a result, there is no single global stock of water, which makes regional constraints a legitimate and serious concern.¹² Because the cost and impracticality of moving large amounts of water is so prohibitively high, once an area has exhausted all readily available and renewable water sources, people will begin to tap into non-renewable resources such as slow-recharge aquifers (aka groundwater). Currently, since the natural groundwater sources are being depleted, we have begun to build large desalination plants, which further entail pollution. These water production factories indirectly cause more problems than they solve. But there is large amounts of money to be made, which in turn allows these large corporations to step in and begin manufacturing water, once again at the expense of the environment. This is definitely not a sustainable manner of managing water allocation. The significance of the comparison between oil and water is that oil is not a renewable resource, and yet alternatives do exist to provide other sources of

11 Gleick, Peter H. The World's Water 2006 - 2007 the Biennial Report on Freshwater Resources Washington DC: Island, 2006. Print. pg 7

12 Gleick, Peter H. The World's Water 2006 - 2007 the Biennial Report on Freshwater Resources Washington DC: Island, 2006. Print. pg 8

energy, whereas water does not enjoy such alternatives, which will result in the end of cheap and easy access to water once all renewable resources have been completely utilized. This would leave communities at the mercy of large corporations, who would be forced to pay high costs for potable water. The above comparison with the oil industry indicates that the water industry will be likewise amenable to the logic of capitalist exploitation of resources.

Continuing this investigation of oil, this time in relation to the built environment, it is undeniable that oil has revolutionized architecture over the last century. When we analyse all the efforts and energy involved in accessing, refining and transporting this liquid, seen in conjunction with its environmental drawbacks, a disturbing picture emerges. Despite all the negative consequences related to the use of oil, its beneficial by-products have demonstrably altered our built environment. Almost every single manmade object surrounding us today has some link with the exploitation of this extracted liquid. From industrial fabrication, to the transportation of goods, our dependence on this depleting resource has rendered the value of this liquid extremely high. We cannot suddenly cease using oil just as we cannot stop using water. Planet earth without oil would cease to provide our customary amenities. In 2010, France was marked by political protest, leaving several cities with low amounts of fuel. The protestors had blocked access to refineries around the country in response to several governmental decisions, including an increase in the retirement age. The lower supply caused chaos and considerable disruptions in daily activities, as all internal public transportation systems were affected, drastic limitations on fuel consumption were imposed, and the main airports servicing the country cancelled the majority of their flights.¹³ Now

13 "France Riots Petrol Rationing Introduced as Holidaymakers Braced for Chaos | Mail Online " Home | Mail Online Web 12 Feb 2011
<<http://www.dailymail.co.uk/news/article-1322846/France-riots-Petrol-rationing-introduced-holidaymakers-braced-chaos.html>>

imagine the same shortages occurring with water. Imagine opening a tap and nothing comes out. How will people react?

Figure 3- More than a quarter of the country's 12,500 petrol stations were dry and some of them had started limiting fill-ups to 30 litres for cars and 150 litres for trucks. Meanwhile riot police used tear gas and batons to end blockades at oil refineries. (Picture courtesy of www.dailymail.co.uk)

Judgement aside, oil has allowed us to produce unquestionable and very practical innovations, without which, our world would be unrecognizable. It has produced abundant labour world-wide and sustained economies in the pursuit of trade, thus bringing them additional resources: it heats our houses, runs our factories, and provides us with services. Nonetheless, we have finally realized that we must identify alternative ways to continue using technologies originally designed to use oil, but with less destructive environmental consequences. In this respect, we have learned that we must begin to understand and envisage natural resources through a different lens; one that takes account of the future of our planet and considers the well-being of all of its inhabitants. . The same must be done for fresh water. When comparing these two resources, the same factors are at play, and consequently we are forced into finding alternatives to providing water.

Characteristic	Oil	Water
Quantity of resource	Finite	Literally finite, but practically unlimited at a cost
Renewable or non-renewable	Non-renewable resource	Renewable overall, but with locally non-renewable stocks
Flow	Only as withdrawals from fixed stocks	Water cycle renews natural flows
Transportability	Long distance transport is economically viable.	Long distance transport is not economically viable.
Consumptive versus non-consumptive use	Almost all use of petroleum is consumptive, converting high quality fuel into lower quality heat.	Some uses of water are consumptive, but many are not. Overall, water is not "consumed" from the hydrologic cycle.
Substitutability	The energy provided by the combustion of oil can be provided by a wide range of alternatives.	Water has no substitute for a wide range of functions and purposes
Prospects	Limited availability; substitution inevitable by a backstop renewable source	Locally limited but globally unlimited after backstop source (e.g., desalination of oceans) is economically and environmentally developed.

Figure 4- Table comparing oil and water. (Table courtesy of The World's Water: 2006 - 2007: the Biennial Report on Freshwater Resources.)

It can be said that the achievements accomplished in the 20th century with regard to energy and oil must now be re-envisaged in regard to fresh water during the 21st century. The depletion of available resources obliges a renewed focus on innovative ways to obtain potable water. Looking forward, local techniques demanding less transportation, and fully implementing the wealth of the imagination, will be intrinsic to any new system attempting to resolve these issues. Or, as Buckminster Fuller once wrote, "The best way to predict the future is to design it."

Water Conflict

Chapter 3

Figure 5-The low water level of the San Luis Reservoir served as the backdrop for a rally of farmers on April 17, 2009 marking the end of their four-day march through the Central Valley from Mendota to bring attention to the California water crisis and environmental problems in the Sacramento-San Joaquin Delta. The third year of drought is expected to bring more job losses and rising food prices. (Picture courtesy of DAVID McNEW/Getty Images)

The water industry is placed 3rd in global money makers after oil and electricity.¹⁴ This poses a problem because the attributed monetary worth of water is not equal to its actual value as a resource. The irony of this discrepancy in price and value has existed for a long time and continues to be a key factor in conflicts related to water. Water is not a commodity, it is a necessity. Like air, it is a given that we humans require this resource, and will do anything to acquire it. The world is not prompted to transport this resource between borders as it is located unevenly in different areas around the globe. One outcome of these impending confrontations is undoubtedly war over fresh water supplies. Since water is locally limited, controlling and determining the accessibility of this resource can, and will, bequeath power.

14 FLOW: For the Love of Water. Dir. Irena Salina. Steven Starr Productions, 2008. Online.

The power struggle over water has existed for a long time. During the renaissance in Florence, two of history's greatest thinkers, Leonardo Da Vinci and Niccolo Machiavelli, planned to divert the Arno River away from Pisa in the event of war. This scheme meant depriving the local inhabitants of fresh water. Da Vinci, as the engineer of the project, had made many sketches of the river and the new diverted course.¹⁵⁻¹⁶ Although the plan was never implemented, the very idea demonstrates the relationship between water and power at a much earlier stage in our history. During the last century, there were innumerable wars over water in the Middle East and Africa.¹⁷ Wherever there is scarcity and the opportunity to control this priceless resource, war takes on an altogether different meaning. Water's worth is as incommensurable as its power is limitless.

**Figure 6-ca. 1504 Manuscript, ink and pigment on paper. Leonardo da Vinci's technical ingenuity is evident in this map, describing his plans to regulate the flow of the Arno River in Florence.
(Illustration courtesy of Walters Art Museum and Queen Elizabeth II)**

15 SparkNotes Editors 'SparkNote on Leonardo da Vinci' SparkNotes.com SparkNotes LLC 2005 Web 15 Nov 2010

16 Masters, Roger D. Fortune Is a River: Leonardo Da Vinci and Niccolo Machiavelli's Magnificent Dream to Change the Course of Florentine History. New York: Free, 1998. Print.

17 Wolf, A. T. 1997. "Water wars" and water reality: conflict and cooperation along international waterways. NATO Advanced Research Workshop on Environmental Change, Adaptation, and Human Security. Budapest, Hungary. October 9-12, 1997.

Over the previous 10 years, the objective of controlling the water supply has become more and more apparent. At the turn of the millennium the renewed discussion about water wars prompted the United Nations Secretary-General Kofi Annan to state that rivalries over water could harbour “the seeds of violent conflict”.¹⁸ In 2000, civil unrest exploded over the use and allocation of water in northern China’s largest natural lake, the Baiyangdian Lake. In July of that year, several people were killed in riots after government officials cut off the water supply. That same year in August, another six people were killed in the southern province of Guangdong. Officials had blown up a water channel to prevent a neighbouring country from diverting water to build a new power station.¹⁹ In 2001, the water flow to 100 000 people in Kumanovo, Macedonia, was disconnected for 12 days during conflicts between ethnic Albanians and Macedonian forces.²⁰ In 2002, during the invasion of Iraq by U.S. troops, numerous water systems and major dams were destroyed. The military intent was to reduce the supply of water to Baghdad.²¹ In 2004, about 250 people were killed in fights over water wells in Ethiopia. Limited water sources provoked what villagers called “the war of the wells.”²² These examples illustrate the fact that wars involving fresh water are an indication of the actual value of the resource and the affiliated power involved in controlling its accessibility. In 2005, a major water dispute caused outbreaks of violence throughout the year in Kenya. The battles between the Kikuyu and Massai tribes were responsible for 90 deaths. Massai herdsman had accused a Kikuyu government official of diverting a river to irrigate his farm, which consequently reduced the availability of water downstream. The war displaced more than 2000

18 "Better World Quotes - Water " The BetterWorld Project - BetterWorld net N p , n d Web 02 Nov 2010 <<http://www.betterworld.net/quotes/water/quotes.htm>>

19 "CNN com - Nature - Major Chinese Lake Disappearing in Water Crisis - December 20, 2000 " CNN com - Breaking News, U S , World, Weather, Entertainment & Video News N p , 20 Dec 2000 Web 15 Nov 2010 <<http://archives.cnn.com/2000/NATURE/12/20/china.lake.reut/>>

20 Agence France Press (AFP) 2001 "Macedonian troops fight for water supply as president moots amnesty " AFP, June 8, 2001

21 UNICEF 2003 "Iraq cleaning up neglected, damaged water system, clearing away garbage " News Note Press Release, May 27 http://www.unicef.org/media/media_6998.html

22 BBC 2004a "'Dozens dead' in Somalia clashes " BBC News World Edition online <http://news.bbc.co.uk/2/hi/africa/4073063.stm>

people who left in search of new water sources.²³ In 2006, the continuing disagreements between Israel and Lebanon caused the Hezbollah activist group to launch rockets, which damaged a wastewater treatment plant in Israel. In response, Israeli attacks destroyed water tanks, pipes, pumping stations and other water system facilities along the Litani River in southern Lebanon.²⁴ In 2008, the usual cycle of conflict and terror over fresh water was repeated in Pakistan. During a government operation against the Taliban, the terrorist group threatened to explode the Warsak Dam, which provides the main water supply for the area of Peshawar. The threat was never realized, although it definitely slowed down the military offensive.²⁵ These acts of contention are not always violent and are sometimes even bureaucratic. Thus, over a land dispute in 2009, China attempted to block a \$2.9 billion loan to India from the Asian Development Bank intended to help resolve water issues in India. The basis of China's opposition was that India's state of Arunachal Pradesh occupied a historical jurisdiction of Tibet.²⁶ Thus, a nation with its own formidable problems of pollution and water scarcity is indifferent to the fate of another with similar issues.

Considering these present conflicts, and future predictions of scarcity and drought, conflicts over water will occur in perpetuity. As the traditional means of acquiring water are beginning to diminish, new methods of accessing ground water are beginning to appear. Derived from innovations in the oil industry, drilling techniques are making it easier to reach large ground aquifers, which were not originally accessible as viable sources of water. One problem with these excavations is that the water below the surface is not divided in the same way our countries are, meaning that some aquifers span a subterranean region extending over several

23 Ryu, A 2005 "Water rights dispute sparks ethnic clashes in Kenya's Rift Valley " Voice of America, <http://www.voanews.com/english/archive/2005-03/2005-03-21-voa28.cfm>

24 Murphy, K 2006 "Old feud over Lebanese river takes new turn Israel's airstrikes on canals renew enduring suspicions that it covets water from the Litani " August 10, 2006 <http://articles.latimes.com/2006/aug/10/world/fg-litani10>

25 Perlez, J and P Z Shah 2008 "Confronting the Taliban at home, Pakistan finds itself at war " The New York Times, October 3, 2008, p 1

26 Edward Wong, 2009, "Tibetan area a tinderbox for China India tensions " New York Times, 4/9/2009

different states. Now what happens once one country begins to pump more water than another country? Battles over water rights will surely be inevitable. Is the proprietor the one who pumps it? Or is ownership governed by how much of the aquifer is actually below the surface of the country's territory? And how can this be determined? What happens if a given country sells its water rights to private companies who then exploit this water source for economic gain while yet other countries work on a public water distribution system? The answers to these questions surely entail some form of conflict. Thus, future water wars will likely be endless if the allocation of this scarce resource is not clearly defined.

Form

Chapter 4

What if our sense of form was a direct response to the environment surrounding the building, as well as to the needs of the people within it?

When I asked a 5 year old to draw a house, he produced the typical box shape with a triangle resting upon it. Basically, the typical form of these houses results from the desire to repel water from our buildings. Integrally, located within this system, is an entire network of strategies to keep the water away from the building, afterwards connected to a public drainage system, and beyond this, to a large body of water. Along this trail, much of the

Figure 7 - House drawn by a 5-year old child

water is lost while the water retained is usually polluted. After the water has been funnelled to a river or a lake, an equal effort is required to get the water treated and cycled back into the system. The way we manage water is neither efficient nor responsive in our present predicament. We must also keep in mind that water travels large distances within these underground macro-infrastructure systems.

The initial intention of architecture was to provide safety and shelter from the hostile and threatening aspects of nature, but this does not mean that we have been given permission to destroy it. Instead, we can choreograph a relationship with nature both to gain benefits from it and to enclose space to protect us from meteorological extremities.

Figure 8-The fort has a 5 kilometre long canal that was used to collect rainwater from the hills for storage inside the fort. There are three underground tanks to store this water. (Picture courtesy of Mridula Dwivedi / www.gonomad.com)

The Jaipur Fort in the cold Mahad desert area of India lies in a valley that funnels rainwater. The building was designed to harness this natural phenomena and collect water as it flows down the mountainside. The system was conceived 400 years ago, and collects approximately 27 million litres of water each wet season.²⁷ The significance of a built structure extends in its capacity to respond to human needs, and this simultaneously utilitarian and artistic function – the blending of purpose and form – is what allows us to appreciate the essential qualities of a building.

Hydrotecture encapsulates this idea of creating places which give back to the inhabitants of the space. Why should water depend upon such a complex system to take it from one place to another? Nonetheless, it is clear that nature's processes work in amazing ways to allow renewable resources to transport and replenish themselves. Harnessing water rather than attempting to repel it would offer

²⁷ Mishra Anupam The Ancient Ingenuity of Water Harvesting Speech TED Talks India Nov 2009 www.ted.com TEDIndia2009 Dec 2009 Web Oct 2010

quantifiable benefits in addressing both our physical needs and our environmental concerns. This vision of a sustainable world involves much less work than might be imagined. Practicing our understanding of nature's elements to transport water can obviate the necessity for intricate infrastructures. A sure grasp of the hydrological cycle combined with an effort to regulate our consumption can slowly lead to a world where the number of deaths caused by poor water accessibility can be substantially reduced. Built forms have the ability to do this, it just requires a slight tuning of the way we envision the future.

Water and Architecture

Chapter 5

For a long time now, we have taken for granted our approach to the processing and consumption of water, and instead conceive it mostly as a means of meeting our physical necessities, and sometimes as a means of emotional stimulation. In whatever context it is used, inventive approaches to controlling its flow continue to be of paramount importance. As discussed earlier in Chapter 3, the economic power implicit in the distribution of water has always been an important factor in the prosperity of a region. Likewise, building infrastructures to fulfill this task has been a prime motivating factor in the development of constructive innovations. This said, we know that the integration of water in architecture is not new; it is probably as old as architecture itself, and if we look deeper into its history, water is seen to be closely associated with the origins of dwelling. It is, without a doubt, the earliest material to be used in the repertoire of architecture. Even before any type of constructed entity had been built, water would necessarily determine the location of people's settlements. Access to this resource was the essential factor determining where people would decide to break the ground to build the very first forms of architecture. Written history has pinpointed the significance of water in design and still gives an explanation as to the position and distribution of cities throughout our planet today.

People need food and water to survive. Therefore, the earliest human beings continuously searched for both. Since water is the producer of life, food was usually conveniently located near bodies of fresh water. All animals and plants need this resource to nourish their growth, and it must accordingly be easy to replenish. In this respect, the first known habitations can be traced back to Mesopotamian civilizations. In investigating the rationale of people in the past, it is clear that they

understood the necessity for water in fixed dwelling places. This was the first time humankind had channelled its energies towards addressing the needs of the community as a whole.²⁸ Interestingly, Mesopotamia translates as “the country between two rivers” and this piece of land was located between the Tigris and Euphrates rivers in modern day Iraq.²⁹ As civilization advanced, this area began to be developed architecturally. At that time, the main elements of building were mud bricks, which were principally composed of clay and water. The logical placement for fixed dwellings would be near bodies of fresh water, thereby making the task of obtaining the necessary resources for living and building as easy to access as possible. This understanding served humankind during several thousands of years until people learned how to build infrastructures to move water to other desired locations. The Romans, in particular, are well known for their innovative aqueducts, which were used to transport water with the aid of gravity.

Figure 9 - Pont-aud-Gard, Roman Aqueduct (Picture courtesy of www.library.thinkquest.org)

They used arcade type constructions to move water from reliable natural sources to dry city centers in order to provide water for drinking, bathing, and the

²⁸ "Ancient Mesopotamia This History, Our History Life in Mesopotamia " Ancient Mesopotamia This History, Our History Web 18 Dec 2010
<[http://mesopotamia.lib.uchicago.edu/mesopotamialife/article.php?theme=First Cities](http://mesopotamia.lib.uchicago.edu/mesopotamialife/article.php?theme=First%20Cities)>

²⁹ "mesopotamia " Online Etymology Dictionary Douglas Harper, Historian 06 Feb 2011 <[Dictionary.com](http://dictionary.reference.com/browse/mesopotamia)
<http://dictionary.reference.com/browse/mesopotamia>>

basic industrial purposes of the people. The aqueducts fed fountains distributed around the city where civilians would gather from time to time to collect water for their individual needs. These aqueducts also supplied bath houses where people could publicly perform their ablutions since many of the establishments located throughout the cities did not have access to running water. The amount of labour and materials involved in building these massive man-made canals was unbelievable, but ultimately necessary to ensure the affluence and expansion of the empire. The ongoing link between the control of water and the dispensation of power should be duly noted.

With the modernization of these techniques, architecture has begun to incorporate the movement of water within the design of its buildings. The traditional methods used to control the flow of water have given rise to fountains and pools, which commonly symbolize the power of an establishment. An outstanding example of this is the Taj Mahal. This mausoleum was devoted to the third wife of Emperor Shah Jahan who died during the birth of their 14th child. The building's site is complemented by a long pool of water, accentuating its wonder and magnitude. The fountain and pool at the entrance of the walkway to the building provide a softening experience that alters the visitor's mood during the approach to the building. The endlessness of the landscape offered by the reflections playing on the body of the water has the power to convey a lived experience, subtly attuned to the symbolic dimensions of water, and evoking the idea of infinity and revitalization. Another outstanding example of the use of water in this context exists in the more recent architectural form of the Salk Institute. Louis Kahn divided this symmetrical site by a thin strip of water running towards the open sky of the valley in La Jolla, California. The experience of being in the courtyard is dynamically softened by the stream of water lighting up the hard stone surfaces of the complex.

Figure 10 - Entrance walkway to the Taj Mahal (Picture courtesy of www.serpholicmedia.com)

Figure 11 - Courtyard of the Salk Institute (Picture courtesy of Robert Mcdermott/Picasa)

The reflective, luminous, and indeed wondrous qualities of water can imbue architecture with an stream of subconscious emotion. Although effective at providing an inspiring or visionary enhancement to the aura of these buildings, some contemporary designs, by offering exaggerated and pompous versions of these ideal qualities, have lost the ample power and scope of these original designs, and instead, serve to display the meretricious, even banal, quality of their associations of water and architecture. For instance, in a world where thirst is endemic, the Bellagio Hotel in Las Vegas presents an enormous water show in the middle of the desert. The nine-acre man-made lake displays a synchronized tornado of water jets for the mesmerisation and delight of wealthy tourists. Looking ahead to the future of architecture, the incorporation of both humanistic and environmentally responsible approaches to the integration of water and architecture are extremely important. Minimal precipitation and low humidity levels made the task of building such a fountain in Nevada an illogical and yet daunting venture, but architects and designers persist in ignoring the delicate ecology of the planet, opting instead for visual riffs and fantasies, as ingenious as they are sterile.

Figure 12 - Bellagio Hotel in Las Vegas, Nevada (Picture courtesy of www.casinodir.org)

Eventually, there will be no alternative but to think responsibly about consuming water. There is a fine line between the use and abuse of materials in architecture. Its presence as a powerfully symbolic medium should ideally reference the nature of the resource and highlight its relative abundance or scarcity. When designs function in defiance of natural and environmental forces, almost pitting themselves against the environment to move water to distant spaces for selfish reasons, this merely belies the beauty of the symbolic connotations that water can inspire in architecture. Water-sensitive forms of architecture will undoubtedly inform the landscape in the immediate present and future. In the following chapter some key examples of water sensitive designs will be explored with regard to their positive qualities offered in an ecologically vulnerable planet.

Examples of Modern Water Sensitive Design

Chapter 6

Several architects and designers have begun to envisage a material world which can respond creatively to the scarcity of water. From small devices to purify water to buildings which harvest and collect it, the drive to resolve the issues related to providing accessible water sources to all is beginning to present itself as an influential factor within design. Whether these inspirations are guided by choice or by forceful constraints in the situation, conception and design of buildings, many innovative processes are in operation, albeit at different scales of intensity, throughout our planet. This chapter will investigate several examples for their approach to the philosophy of architecture and gauge their ability to provide reliable sources of fresh water.

Figure 13 - Procedure involved in operating the Watercone® (Pictures courtesy of www.thewatercone.com)

Starting with the simplest device, the Watercone® is a very primitive water-producing invention, which was designed to distil saltwater to produce potable water. Depending on environmental conditions, the mechanism can produce approximately 1.5 litres per 24 hours. A large majority of the world's population lives in coastal areas, many of which endure poor accessibility to freshwater, making this apparatus fairly viable. It also works well in times of crisis after natural disasters

when the infrastructures for obtaining water have been disrupted. The process of operation is very simple and low tech, and it does not demand manufactured energy or a complex system of moving parts. It is easily understood in minutes and efficient to use in lesser developed nations where the majority of users do not have any kind of educational background. It was designed to be stackable, making it easily transportable. Nonetheless, the main feature that makes this a useful item is that the cost of producing one litre of water is much less than the cost of water in most coastal areas, especially those that have poor or unreliable sources of freshwater. The cost of one litre of bottled water in most developing nations is around 0.50\$, while the Watercone® produces the same amount for about 0.02\$ to 0.05\$ over its lifetime.³⁰

Figure 14 - Lifesaver 4000® bottle description (Picture courtesy of www.lifesaversystems.com)

Another noteworthy device is the Lifesaver 4000®, which is a micro-filter capable of purifying almost any type of contaminated water. In many areas where freshwater sources are available, the water is completely polluted by chemicals or parasites that are extremely harmful for human consumption. This portable filtering bottle pushes the contaminated water through a filter which has holes even smaller than any harmful

³⁰ Watercone Solar Still Mage Water Management Web 10 Nov 2010 <<http://www.thewatercone.com>>

bacteria, consequently leaving only clean water for drinking. The smallest bacterium is approximately 200 nanometres and the most minuscule virus is 25 nanometres. Therefore, the device was designed with perforations in the filter no larger than 15 nanometres. Although completely effective at producing safe water, the device cannot remove salt particles or coloring substances. The developer, Michael Pritchard, conceived the idea in response to the hardships faced in obtaining potable drinking water after the 2004Tsunami in southern Asia and the 2005 hurricane Katrina in New Orleans.³¹

In respect to larger fixed structures, fog collectors provide a very efficient means of extracting water from humid air. Fog is quite a rare phenomenon, which occurs when the relative humidity is around 100%, making this device completely site specific. Maximum relative humidity means that the air is completely saturated with water vapour and can no longer hold any more. As the temperature gets cooler, air shrinks, causing the amount of permissible water

Figure 15 - Fog collector in Tinjure, Nepal (Picture courtesy of Mingma Sherpa, Pradeep Regmi, Frances Fierst, and Bill Brabender / Flickr)

vapour in the air to decrease. At this point, water droplets begin to precipitate from the surrounding air. To collect this water, all that is required is a surface for the water droplets to collect upon. A typical fog collector is made up of two layers of a mesh type fabric erected in midair. This construction is usually oriented towards the prevailing winds, and as the moisture-laden air passes through the mesh, the friction produced within the two layers extracts the water from the air. The water

³¹ Pritchard, Michael "Michael Pritchard's Water Filter Turns Filthy Water Drinkable" Lecture TEDglobal2009 20 Oct 2010 Wwww.ted.com Aug 2009 Web July 2009 <http://www.ted.com/talks/lang/eng/michael_pritchard_invents_a_water_filter.html>

then collects on the mesh and eventually runs down the fabric to an offshoot gutter, before finally accumulating for use in a storage bin. Since the liquid water is derived from its gaseous form, the water is fairly clean, requiring minimal treatment to make it potable. These types of structures can produce up to 10 litres of freshwater per square meter in one day, of course, all depending on the climatic conditions.³²

Figure 16 - Section of "capture the rain" skyscraper
(Illustration courtesy of www.archdaily.com)

In respect to buildings a great example would be the competition submission for a rain collecting skyscraper by H3AR architects in a 2010. The “capture the rain” proposal is a vertical building form intended to harvest precipitation for the daily needs of the occupants living within it. The design of the building’s roof and external shell incorporates a system of gutters, each of which funnels water to a storage location, where the water is purified by a hydro botanic treatment method.

32 Bowers, Noah "Drinking the Air" Thesis Pratt Institute, 2006 Print P 42-43

Figure 17 - Close-up detail displaying skin's gutter system (Illustration courtesy of www.archdaily.com)

The design of the exterior skin is based on the surface of a leaf, where the ripples in the texture guide the water to the receptive part of the plant. In the same way, the building's design works at moving the water to the desired location for purification before distributing it throughout. Obviously, this attribute affects the overall appearance of the building: it nonetheless satisfies an alternative aesthetic beyond the primacy of visual appeal.

The majority of projects focusing on water integration are relatively new or still at an early stage of development. Several students from France targeted these issues in their proposal for a skyscraper competition in 2010. The team, known as *Design Crew for Architecture* (DCA), formulated a protocol for creating a building type structure that would be able to produce sweet water, and consequently named the project "Fresh Water Factory." Their intention was to re-define the idea of the skyscraper to address present global concerns. Typically, the skyscraper has urban connotations, as its conception was in response to overcrowded city centers. Looking into potentially radical applications of building types, the team projected design for use in the countryside in Almeria, Spain.

Figure 18 - View of “fresh water factory” proposal
(Illustration courtesy of www.designboom.com)

Figure 19 & 20 - Explanation of the functioning of “fresh water factory”
(Illustration courtesy of www.designboom.com)

Distinct from most skyscraper sites, this region is responsible for the cultivation and supply of fruits and vegetables for the whole of Europe. The sun shines 2965 hours per annum making it one of the world’s brightest places. Its climate also allows for year-round agriculture, and 90% of the land is covered by greenhouses. The

students collectively composed a tower intended at helping supply the required clean water for intensive farming. The proposal featured a tower made of several circular tanks filled with brackish water. These tanks were to be sheltered within spherical greenhouses. The salt water was to be brought up the tower by tidal powered pumps. Each tank harbouring the saline water would be planted with mangroves, and these plants require brackish water to grow. Throughout their cycle of growth, their leaves perspire freshwater. The freshwater expelled on the leaves evaporates with the intense heat from the sun. At nightfall, as the temperature decreases the moisture in the sphere condenses along the surface of the spherical plastic skin of each greenhouse. In accordance with gravity, the harvested water collects in the base of the sphere and is then directed to a collection basin. Due to the high altitude of the skyscraper, the freshwater produced is distributed to the surrounding fields by gravitational flow. The total surface of the tower is one hectare, which is expected to produce enough water per day to cultivate one hectare of tomato fields.³³ This proposal begins to look at architecture as more than the sum of dead materials. Indeed, it re-identifies the nature of the skyscraper as a versatile form of building, and as yet another means for addressing global issues, including water scarcity in agricultural areas.

33 "DCA Freshwater Factory " Designboom Web 12 Dec 2010 <<http://www.designboom.com/weblog/cat/9/view/9405/dca-freshwater-factory.html>>

Figure 21 - Entrance canopies at Queen Alia International Airport in Amman, Jordan
(Illustration courtesy of www.fosterandpartners.com)

Another example of a project intended at raising awareness is Norman Foster's current design for the expansion of the Queen Alia International Airport in Amman, Jordan. The work commenced in 2005 and the expansion should be operational by 2012. The design explores a vision of what the twenty-first century airport might be while offering a holistic approach towards an ecologically sensitive architecture. Evoking an attributive sense of place and providing an enhanced gateway to the country, the design of the expansion is characterized by a series of canopies placed at the entrance to the airport.³⁴ These distinctively shaped structures were inspired by the organic form of natural palm trees. The roof canopies also act as thermal storage units to aid in temperature control within the building, and to counteract the drastic differences in heat between day and night in the desert region. The form of the canopies works to collect rainwater and night-time condensation for multiple uses within the building.³⁵

³⁴ Foster Partners Web 15 Dec 2011 <<http://www.fosterandpartners.com/Projects/1346/Default.aspx>>

³⁵ Queen Alia International Airport By Foster Partners Has Banks Of PV Panels Ecofriend Ecofriend Green Living Web 05 Jan 2011
<<http://www.ecofriend.org/entry/queen-alia-international-airport-by-foster-partners-has-banks-of-pv-panels/>>

Finally, one particular project has truly embraced the extraordinary capabilities of nature in extracting water from air. The Hawaii Gateway Energy Center in Nelha, Kailua-Kona, was designed to condense water from humid air by using seawater to cool the air. In contrast to typical efforts to reflect heat away from roofs, this building's curved copper roof is designed to serve as a heat collector. The sun heats air in a plenum under the roof, inducing stack-effect ventilation. The hot air rises out of a set of thermal chimneys, siphoning fresh air into the building at a rate of 12 to 15 air changes per hour through an under-floor plenum. This air enters the building through a small exterior structure that houses coils that contain 45°F (7°C) seawater pumped from 3,000 feet below the ocean's surface. The coils cool and dehumidify the air, and the water that condenses on the coils drips into a collection system and is used to flush toilets and irrigate plants.³⁶

Figure 22 - Diagram of Hawaii Gateway Energy Center system operation
(Illustration courtesy of www.greensource.construction.com)

³⁶ Roberts, Tristan. "Case Study: Hawaii Gateway Energy Center - GreenSource Magazine." Green Building, LEED Projects and Sustainable Design -- Commercial Green Buildings, Building Performance and Green Homes -- Sustainable Materials and Green Building Products -- GreenSource Magazine. Web. 25 Mar. 2011. <http://greensource.construction.com/projects/0707_HGEC.asp>.

Figure 23 - Typical cross-section of Hawaii Gateway Energy Center
(Illustration courtesy of www.greensource.construction.com)

Collectively, all fields of design should make use of the scarcity of water as a motivating principle for decision-making. This new trend in the sustainable development of our built world presents an innovative chapter in understanding and evaluating architecture. Some of today's visually stimulating ideas are subjective and opportunistic, uniquely the product of a specific set of configurations as they evolve through time, and are then interpreted by an individual or group at a specific time or place. Eventually they are surpassed by other more important aspects or contrary thinking. Hence, this references the evolution of styles. Nonetheless, this new 'anti-style' design approach can be instilled with a timeless aesthetic, as the outcome is derived from overtly declared utilitarian principles, and this is especially the case when the architects are resourceful and their thinking is grounded in actually deliverable results. Architects play an important role in shaping the future, and this task should be consciously integrated with all the related philosophies of design. There are priorities that must be addressed, as we all know that we need water to survive.

An Architectural Application

Chapter 7

Although this is a global problem, there are particular areas that suffer greatly from the present conditions of scarcity. For example, the Caribbean has been faced with water issues over a long period of time. Most small islands do not have many fresh water resources, and transporting water to these islands is not economically feasible in most cases. The majority of places in this region have minimal infrastructures for providing inhabitants with reliable sources of water. Many cities have built makeshift constructions, which provide minimum allocations of the resource, and yet the water is still not always available or safe to drink. Within the group, Haiti is one country that has been greatly hindered by this problem of impoverishment. Based on the *Human Development Index*, Haiti is the poorest country in the Americas, while having the highest fertility rate in the Western Hemisphere.³⁷ In 2005, 46% of the population did not have access to an improved water source, while a still greater 70% did not have access to improved sanitation facilities.³⁸ Keeping in mind the future strains on the water system, incurred by the rapidly increasing population, the country presently enjoys approximately 1 314 cubic meters of available freshwater resources per capita while its close neighbours Jamaica and the Dominican Republic have at 3500 and 2110 cubic meters, respectively.³⁹

37 International Human Development Indicators - UNDP Web 20 Jan 2011 <<http://hdrstats.undp.org/en/countries/profiles/HTI.html>>

38 "Haiti Stats | Haiti Works Incorporated - Haiti Works Incorporated Is a Not-for-profit Organization Formed for the Purpose of Identifying Needs and Opportunities That Will Assist Cities and Towns in Haiti with Rebuilding Haiti and the Haitian Economy " World Bank Web 14 Jan 2011 <<http://haiti-works.org/stats-haiti.php>>

39 "Renewable Internal Freshwater Resources per Capita (cubic Meters) | Data | Table " Data | The World Bank Web 14 Jan 2011 <<http://data.worldbank.org/indicator/ER.H2O.INTR.PC>>

Figure 24 - Map of the Caribbean region (Map courtesy of www.geology.com)

To compound the crisis, the 2010 earthquake, which destroyed a large part of the capital city of Haiti, has set the country back decades in economic growth. A large part of the infrastructure in Port-au-Prince was completely demolished. The disaster rendered the amount of people with access to clean water very low. The tragedy has also created poor conditions of sanitation and this has facilitated the spread of disease. Over the last year (2010), sudden outbreaks of cholera have seriously increased water related deaths. Moving forward, any conception of new architecture in the country must address the water shortage. Only then, can there be tangible benefits for the physical, social and political health of the nation.

While, most islands depend on tourism as a source of income, Haiti has failed to establish as such, and consequently is the poorest country within the group. Now, after one of history's largest natural disasters, the country is looking for new ways to re-instate an adequate condition of living. Seeing that most of the surrounding countries have focused on tourism to boost the internal economy, it is

only logical for Haiti to focus on promoting its beaches and its tourist culture. The political chaos over the last decades has not aided in enhancing or promoting the natural scenery, or in celebrating the intriguing local traditions of Haiti. The architectural proposals of this thesis will attempt to respond to the issue by providing a preliminary design for the new airport complex in Port-au-Prince. Its design philosophy will be based on the principle of providing water to a thirsty country while looking deeper to address context – ecologically and environmentally speaking – to provide long-term solutions during Haiti’s redevelopment.

Tourism based locations of the globe have a particular, often inverse, relationship with the prosperity of other nations. The development of the airplane in the US and Europe changed the nature of tourism and expanded the concept of travel. Borderless tourism has been the catalyst for the economies of most of the small under-developed countries over the last century. One very influential character in the aviation business in the early part of the 20th century had a unique vision to expand the industry. Juan Trippe was the founder of Pan American Airways, one of the most prominent airlines of the mid-twentieth century. He pioneered the idea of travel to the Caribbean islands for wealthy socialites from the US during the booming 1920’s. This worked out perfectly, as the American travelers bought into the idea of visiting beautiful countries, with their legal supplies of alcohol and tropical weather conditions. In turn, the Caribbean governments generated new sources of external income. The relationship between the US and a majority of the islands grew into notable alliances that were profitable for both parties. These new places of interest introduced a wave of economic speculation within the Caribbean. Between 1921 and 1927, US investments in the region multiplied forty-fold. Trippe believed that his airline entrepreneurship was bringing a benevolent form of capitalism to these less-fortunate nations.⁴⁰ Some 80 years

40 Gordon Alastair *Naked Airport: a Cultural History of the World’s Most Revolutionary Structure* New York: H. Holt, 2004. Print. P. 38-39

later, the majority of these Caribbean countries are much better off politically and economically than they would have been without the tourism which originated from Trippe's vision.

Figure 25 - A brochure for Pan American Airways, which began regular flights to the Caribbean in 1928 and offered an escape from U.S. prohibition laws: "Fly to Havana and you can bathe in Bacardi Rum two hours from now," cried PAA agents on the streets of Miami.⁴¹ (Illustration courtesy of Naked Airport: a Cultural History of the World's Most Revolutionary Structure / Gordon, Alastair.)

In today's age of air travel, airports are usually the main gateway to most of the Gulf islands. During the 2010 earthquake, the Toussaint Louverture International Airport in Port-au-Prince was severely damaged. After lengthy repairs, the airport has reopened but has never truly brought an influx of tourism as do most of the other Caribbean airports. A new design for an airport complex can help to establish an important infrastructure by means of which the population can entertain a prominent future for tourism. By targeting the situation of water scarcity in this design promotes an image of hope for the revitalization of the community, and can give optimism for a fresh and forward-looking identity to Haiti. The scope and significance of an international airport has the ability to bring economic prosperity

⁴¹ Gordon Alastair Naked Airport a Cultural History of the World's Most Revolutionary Structure New York H Holt 2004 Print P 37

and development to a vulnerable society. There are not many large-scale projects in Haiti so that each step in the redevelopment of the island presents an important prospect of development to the population. Even though a tourist complex cannot be considered as a direct response to the present chaotic situation, it nonetheless presents a long-term prospect for change within the country.

Over the past year, many countries have been physically and economically involved in helping Haiti to re-establish itself. This borderless support has been useful for the long-term redevelopment of the country. This situation has opened possibilities for relationships with first world countries and in turn, can promote tourism and trade once the country has been rebuilt. Not only would a radical and innovative design approach promote Haiti before the rest of the world, it would also affect local Haitians through the acquisition of fresh water and the principles behind its relationship with the built environment. With this proposal for a new environmentally sustainable complex, the population could hope to translate these beneficial ideals into other smaller scale projects around the city and hopefully initiate a movement for the creation of a healthy and environmentally conscious city.

Rationally, the country's urgent problems cannot be resolved by a new airport or through increased tourism, but the building can act as more than a waiting room for travellers, and can even provide a communication gateway between Haiti and to the rest of the world. Even, in the very early stages of the development of the airport program, the buildings were not solely used for housing passengers. The approach outlined below of conceiving a program specific building as serving more than its primary function entails a considered response to the economic strain involved in funding airports in the past. Besides obvious travellers' amenities, such as shops and restaurants, airports have a tendency to include other

features in order to stimulate the use of the complex and to raise capital to finance the building. In 1926, Washington's Hoover Field airport added a public swimming pool that was twice as big as the terminal itself and even more profitable.⁴² In Camden, New Jersey, a dog-racing track was built around the airport grounds.⁴³ Another intriguing multi-faceted project combining flying and leisure was a proposal for an airport in Enterprise, Alabama. The plan involved having three runways cut through a nine-hole golf course. There was a long drive across runway #2, while the seventh hole called for a tricky approach shot across runway #3. It also featured a dancing terrace overlooking a swimming pool, and a hangar that doubled as a community theatre and a basketball court.⁴⁴ One promoter was recorded as saying that, "by including recreational items in the airport [...] the town will derive an income from the property sufficient to solve the ever-present problem of upkeep, as well as to attract the general public, and in this way it becomes a self-liquidating community asset."⁴⁵ Even if these multi-functional projects do not directly relate to the emergency situation in Haiti, they justify the contextual arrangement of the program. Haiti's present challenge to fund such a project is similar to the issues that once faced, and even still confront, smaller US cities. Taking into account the self-financing logic behind these earlier proposals, Haiti can still have an airport with multiple auxiliary functions that can yet change dynamically in relation to the country's economic and social progress. For example, the present situation calls for urgent medical help and temporary housing for the people of Haiti. If the project can act as a shelter and hospital in the early stages of its construction, it can also help in resolving current issues and maintain a steady pace of growth. Then, as the situation ameliorates, the complex, built in several stages, will begin to change function, step by step, always keeping in tune with the country's other needs. Divided into discrete sections, the complex would have certain wings to be used for

42 Gordon, Alastair *Naked Airport: a Cultural History of the World's Most Revolutionary Structure* New York: H. Holt, 2004. Print p 28

43 Gordon, Alastair *Naked Airport: a Cultural History of the World's Most Revolutionary Structure* New York: H. Holt, 2004. Print p 28

44 Gordon, Alastair *Naked Airport: a Cultural History of the World's Most Revolutionary Structure* New York: H. Holt, 2004. Print p 28

45 "An Airport and Recreation Center Combined " *The Architectural Record* March 1934. Print

different purposes. As these critical needs begin to subside, the influx of tourists into the country will begin to increase, and the complex itself can begin to cater to the escalating demand for tourism.

One key justification for this form of architecture can be derived from a response to the present condition of the country with the idea of helping to provide a long-term resolution to the crisis. Architecture cannot be designed as if it were a static entity or it will not stand the test of time. Public buildings must be polyvalent, and responsive to change. Despite the best of motives and intentions, the life of the complex will undoubtedly shape itself. Architects cannot tell the future, but what we do know, is that times will inevitably change, and airport buildings must be able to absorb these transformations in society. The process of revitalizing society in Haiti will no doubt take time, and more than an airport is needed to solve them. Therefore, this program offers a tentative vision of the future designed to alter over time, and to eventually offer a tourist hub. In so doing, the building will create a sense of optimism and vitality for the people of Haiti.

Proposed Project

Chapter 8

See annexe A for related images of building proposal

Figure 26 - Aerial view of airport proposal

Scope

Geographic location and ecological context play an integral role in developing a form of architecture that can harness the environment's natural energy. The compelling combination of environmental science and architecture allows the conception of a hybrid structure used both for dwelling and for providing freshwater amenities.

Figure 27 - Image demonstrating the processes of the hydrological cycle
(Illustration courtesy of www.buffer.forestry.iastate.edu)

The natural occurrences investigated in the conception of this prototypical design are found within the hydrological cycle. It is readily understood that the salt water of the oceans creates most of the rain that falls to earth as fresh drinkable

water. Through evaporation, water particles rise as vapour leaving the heavy ocean salt behind. The moisture in the air accumulates as clouds, and the wind pushes the clouds inland. Eventually the air reaches a saturation point and the humidity falls back to earth as rain or snow, thus replenishing lakes, rivers and groundwater sources.⁴⁶

Most of the planet's freshwater sources are regenerated in this way by the hydrological cycle. Taking into account the present condition of all the available sources provided by nature, the world's population has been scrambling to find new methods to provide drinkable water, none of which are as efficient or effective as those obtained by harnessing the hydrological cycle for communal purposes. New techniques of desalination, such as reverse osmosis, are incredibly polluting and require massive amounts of fabricated energy, not to mention the hazardous by-products of the process, which pose yet other disastrous environmental problems. Another expensive method of converting seawater, electrolysis, separates salt water into its component oxygen and hydrogen parts and then recombines them into pure water. This technique is not energy efficient and it is also extremely expensive, making it impractical in respect to the lesser developed and poorer nations who are the most affected by issues of water scarcity. Other sources like groundwater are being over accessed in these affected regions. These large amounts of water located below the surface of the planet have accumulated as aquifers over thousands of years. Now, we are pumping the water to the surface for use at an exponential rate, thus prohibiting nature from regenerating itself in order to stabilize the availability of the resource in the area. This water also requires extensive purification efforts since it can be contaminated with animal waste or random earth minerals, which may be harmful for human consumption.

46 "Making Fresh Water from Salt Water Blue Water, Green Practices " Suite101.com Online Magazine and Writers' Network Web 12 Jan 2011
<<http://www.suite101.com/content/making-fresh-water-from-salt-water a218953>>

By incorporating this design strategy into the actual formulation of an airport plan, the intention is to conceive a method of building that can generate the same amount of water that would be required to operate. In this way, the building is not dependant on the existence or quality of the infrastructures surrounding it and it begins to propose a new level of sustainability. Learning from the elements of the hydrological cycle, the building will use its shape to direct humid wind into a designated area. Then using the difference in temperature between the wind itself and cold ocean water, the building's surface will encourage the moisture in the humid air to condense. The clean water produced will then be collected, purified and distributed for use within the building.

Collecting rainwater is second feature of the prototypical design that is integrated into the proposed project in order to truly optimize the building's availability as a resource and to satisfy the requirements of the occupants in such a large complex. Through the design of its funnel type roof, the airport captures a significant amount of rain water. Again, the water collected is purified and delivered to the various parts of the building.

Conceiving architecture with these types of attributes can offer stepping stones to the ongoing formulation of a new way of thinking about building design and its capabilities, beyond just providing shelter. Given the new responsibilities of architecture within society and towards the rest of the planet, it is only natural that architecture should take a new path beyond its traditional context in order to counteract the immense damage the world's population is presently causing through pollution, and the overuse and misuse of natural resources, most of which is closely associated with our poorly conceived built environments.

Site

The site of the airport is located on the north-western quarter of Port-au-Prince. On an island surrounded by open ocean, it can anticipate taking advantage of the humid winds coming inland and the temperature variations in the ocean waters. The site is bordered by mountain ranges to both the South and North which help funnel a streamline of winds through the city. The wind course in Port-Au-Prince mainly runs on an east-west axis and is bi-directional but definitely stronger coming from the easterly prevailing winds.

Figure 28 - Port-au-Prince wind rose depicting average annual wind speed and direction; (2000-2009) 10 year summary (Illustration courtesy of www.ncdc.noaa.gov/oa/haiti/haiti)

Figure 29 - Wind rose data; 2007 to 2010 average wind direction by month
(Illustrations courtesy of www.windalert.com)

Figure 30 - Map of Port-au-Prince displaying proposed location for project
(Original map courtesy of Sertit)

Although the majority of winds clearly come from the east, a substantial amount of humid air strikes the site from the coastline to the west.

Form

As outlined above, the project demonstrates the form of a building designed to exploit nature in order to collect freshwater from humid air. Inspired by the hydrological cycle and realizing its potential in combination with man-made structures, it thereby creates an environmentally based conception of architectural form. It ties the placement of the building to the ecology of the place to determine how a building performs. Nature can thus influence the formal design buildings.

Figure 31 - Diagram demonstrating the form and consequent movement of the winds intercepting with the building.

Since an airport is usually a large complex, it provides an opportunity to fruitfully take advantage of these occurrences, and thereby can obtain substantially beneficial results. Using the form of the building itself to funnel large amounts of humid air into a designated zone is one of the potential benefits that form and scale can offer. As the air blows inwards from the ocean, it is relatively high in moisture content. Likewise, as the winds collide with the large structure of the airport, the exterior surfaces can direct the humid wind to a specifically designated area. Following the path provided by the building's form, this high pressured

accumulation of moist air then enters a chamber where the humidity is condensed by coming into contact with a cold surface.

Condensation Chamber

Since Port-Au-Prince is located along a shoreline, the cold condensing surface is provided by ocean water, and the depths of the ocean. Being located close to the shoreline, the site offers a short distance of travel for the cold ocean water, which helps to maintain the temperatures provided by the depth of water.

Figure 32 - Map of Caribbean region displaying depths of the ocean
(Map courtesy of Encyclopædia Britannica 2010)

Within the ocean depths there is a certain level where the temperature changes drastically between the upper and lower layers. This transition zone is called the thermocline. Between 300 meters and 750 meters below the surface, the temperature of the salt water undergoes a significant change, which holds true for most of the oceans of the planet.

Figure 33 - Graph demonstrating changes in temperature in relation to depth of ocean water (Graph courtesy of www.windows2universe.org)

Air can contain various levels of humidity; the amount of moisture is dependent on the temperature of the air. As air gets warmer it expands and is able to hold more moisture. As it cools, the air shrinks and thereby minimizes the amount of water vapour it can hold. Eventually it reaches its maximum saturation point, and consequently produces condensation.

Figure 34 - Table showing the effects of cooling air in relation to moisture content
(Table courtesy of www.physicalgeography.net)

As with a cold beverage taken outdoors on a hot humid day, condensation occurs on the surface of cold objects. The air surrounding the beverage is warm, expansive and full of moisture. As it comes into contact with a cold surface, the air naturally tries to equalize the disparate temperatures.

Figure 35 - Image displaying condensation on the surface of a cold beverage container (Illustration courtesy of www.extension.purdue.edu)

In so doing, energy is exchanged; the air decreases temperature, and the drink increases in temperature in order to level out the varying supplies of energy. The air then gets cooler and this diminishes the amount of moisture it can hold. If the temperature difference is substantial enough it can cool the air to the point where it can no longer hold the moisture contained within it. This is known as the dew point of air.

Figure 36 - Chart of relationship between air temperature, relative humidity and dew point
(Graph courtesy of Easchiff 2008)

In harnessing the cold temperature of ocean water, this provides a cold surface for the humid and moist air to come into contact with. The same phenomenon occurs when condensation forms. Based on the relative humidity of air, and the temperature at that given point, the amount of moisture in the air and its dew point can be calculated.

Wind

The amount of moisture in the air depends on the particular volume of air. For example, there is 0.005 kg of moisture per 1 kg of dry air. The more air passing through the system, the greater the extraction of moisture would be. Therefore, as the volume of air coming into contact with the cold surface becomes greater, this dictates the amount of water that can be extracted. Therefore wind speed plays a particular role in the efficiency of the system.

System

In Port-Au-Prince, the ecological framework of the area provides the critical necessities for the system to be effective. Below are the average meteorological conditions:

Figure 37 - Several charts of average climatic conditions in Port-au-Prince, Haiti
(Graphs courtesy of www.climatetemp.info)

In the following example, the middle of June will be considered for calculations. In June, the average temperature in Port-Au-Prince is approximately 30°C with a relative humidity of about 65%. Formulating this information on a psychrometric chart will give an indication of the temperature difference required to achieve 100% relative humidity (dew point).

Figure 38 - Psychrometric chart showing moisture content at 30°C and 65% relative humidity
(Original graph courtesy of www.carrier.ca)

Based on the inputs available, the chart shows that in air that is 30°C with 65% relative humidity there is 0.021 kg of moisture (water vapour) per kg of dry air. The amount of moisture in the air is important in order to determine the temperature at which this same air would be completely saturated with moisture (dew point). When the air temperature is cooled, the amount of moisture (0.021kg / kg of dry air) does not change. As the temperature decreases, the percentage of moisture within the air increases since the air's density also decreases. At a given moment,

the saturation point is attained, and the amount of air is as small as it can be while still retaining the original moisture within it. When this barrier is surpassed, the moisture begins to condense into its liquid state. Going back to the chart, this indicates that at 23°C the same air that contains 0.021kg of moisture per kg of dry air will be at 100% relative humidity. From this moment on, as the temperature of the air is cooled beyond 23°C, the moisture within the air will consequently condense.

Figure 39 - Psychrometric chart showing moisture content at 23°C and 100% relative humidity
(Original graph courtesy of www.carrier.ca)

As discussed above, the deep ocean water will provide the required temperature difference. If ocean water is pumped from 750 meters below the surface, its temperature would be approximately 8°C. Using heavily insulated piping, low friction methods, and a vacuum type circulation technique, the water is assumed to reach the building at 10°C. The water can be propelled by a wave powered pump in order to leave the least possible footprint. The 10°C water is then channelled

through a systematic network of pipes in order to cool a portion of the building's surface and to reach the area intended at aiding condensation. To determine how much water would be produced per kg of air passing through the system, the maximum amount of moisture that the air can hold at 12°C must be calculated. A tolerance of 2°C is assumed for the difference between the pipe's temperature and that temperature being transferred to the air.

Figure 40 - Psychrometric chart showing moisture content at 12°C and 100% relative humidity
(Original graph courtesy of www.carrier.ca)

Using the psychrometric chart once again, this indicates that at 12°C and 100% relative humidity, the maximum amount of moisture that the air can hold is 0.011 kg / kg of dry air. Taking into account the difference in the maximum amounts of moisture content between the initial air and the cooled air gives the amount of moisture extracted per kg of air passing through the system. Therefore, if there is 0.021 kg / kg of dry air at 23°C and there is 0.011 kg / kg of dry air at 12°C, it can be deducted that there is the potential to extract 0.010 kg of moisture per kg of air

passing through the system. Given that the density of water is 1 kg / litre, each kg of air passing through the system can produce 0.010 litres of water.⁴⁷ To produce one litre of water, this would require 100 kg of air under these specific conditions. It is important to understand that the speed of the wind and the form of the building are the key factors in determining the rate at which air can enter the system, and this in turn can influence the amount of water which can be condensed from air during a given interval of time. The exact amount of condensation produced cannot be calculated as meteorological conditions often vary, but the intention of this explanation was to demonstrate the parameters pertaining to a system of this nature and to reconfirm the functionality of the theory.

HYDROTECTURE

PROTOTYPE WALL PANEL SYSTEM

Figure 41 – Description of condensation chamber function

⁴⁷ Hicks, Tyler Gregory, S. David. Hicks, and Joseph Leto. Standard Handbook of Engineering Calculations. New York: McGraw-Hill, 1995. Print.

Figure 42 - Rendering of condensation chamber; exterior skin of building

Rainwater Collection

Collecting rain can also be used to determine the form of this building. As already stated, the roof of the complex forms a large funnel. As with many other projects, both ancient and modern, the area occupied by the building can readily collect the rain that falls to the earth's surface as freshwater. The roof for this project is deliberately oriented around the center of the airport; likewise, the revolving structure of the roof slopes inward towards the center to collect rainwater. Port-au-Prince has a substantial amount of rainfall per year, and so the natural incentive to collect this water is strong, and readily justifiable.

The following chart displays the average rainfall in Port-au-Prince in millimetres:

Average Annual Rainfall ⁴⁸ - (mm)					
JAN	FEB	MAR	APR	MAY	JUN
33	58	86	160	231	102
JUL	AUG	SEPT	OCT	NOV	DEC
74	145	175	170	86	33

Total: 1353 mm

Figure 43- Average annual rainfall in Port-au-Prince, Haiti

The roof of the proposed building is a circular form with a diameter of approximately 305 meters. The area of the roof is:

Diameter = 305 meters

Radius = 152.5 meters

Area of a circle = πr^2

= $\pi (152.5m)^2$

= 73 025 m²

Once the amount of rainfall and the area of the roof are known, the amount of water collected can be calculated. Using the formula below, the amount of precipitation per specific area can be easily determined.⁴⁹

Rainwater Collected = 1 L / m² / mm of precipitation

= 1 L / 73 025 m² / 1353 mm of precipitation

= 1 L / 73 025 m² / 1353 mm of precipitation

= 98 802 825 L

48 "Port-Au-Prince Haiti Climate, Temperature, Average Weather History, Rainfall/ Precipitation, Sunshine " World Weather and Climate Graphs, Average Climate Charts, Guide to Precipitation, Temperatures, Best, Friendly, Holiday Climate Web 10 Jan 2011 <<http://www.climateinfo/haiti/>>

49 "Calculating Rainfall " Paul Robert Myers Web 20 Nov 2010 <<http://pmyers.pcug.org.au/Freeware/rainfall0.html>>

The collection efficiency of a roof is based on factors such as evaporation loss from prevailing winds, tree cover, and type of roofing. Using the standard assumption that 85% of rainwater can be actually collected⁵⁰, the potential amount of water collected would be:

$$\begin{aligned}\text{Actual Rainwater Collected} &= \text{Total potential amount of water that can be collected} \times 85\% \\ &= 98\,802\,825 \text{ L} \times 85\% \\ &= 83\,982\,401 \text{ L}\end{aligned}$$

Given the significant results obtained in collecting rainwater, the design of the complex has certain feasibility. The opportunity to collect water from rain is not utilized enough, and yet the results to be obtained from such an ecologically innovative airport design indicate the enormous potential of architectural design to contribute to practical resolutions for providing drinkable water.

Ventilation / Interior Climate

The manner in which the roof is structured above the building permits the warm air from within the space to rise and be evacuated. The openings (thermal chimneys) around the perimeter of the structure allow a natural stack-effect cooling system to regulate the climate within the space.

Figure 44 - Section diagram displaying flow of air within proposed building

⁵⁰ "The Rainwater Connection - How Much Water Can I Collect?" Rainwater Connection Web 10 Apr 2011
<http://www.rainwaterconnection.com/rainwater_harvesting/how_much.htm>

The roof of the proposed structure is coupled with an array of panels which move in accordance to the amount of sunlight. The surface of the panels reflects the sunlight away from the building and decrease the amount of heat gain. Each panel is designed to fit into one another so during times of reduced natural light, the panel's surface area on roof can be decreased and allow more sunlight in.

Figure 45 – Multiple roof panel configurations depending on the amount of sunlight at a given time

Figure 46 - Left: Rendering of roof panels in deployed configuration (reduced natural light)
Right: Rendering of roof panels in closed configuration (increased natural light)

Discussion

Responding to nature's recurrent phenomena, such as wind, moisture and rain, can offer quantifiable benefits in accommodating the crucial need for water. As discussed earlier, the intention of the design is to conceive a building that can support itself in terms of freshwater usage, and any additional amounts can be used to alleviate additional water shortages within Haiti.

For the purposes of comparison, Haiti's neighbour, the Dominican Republic, was analysed to ascertain airport passenger volumes and to gauge the potential for tourism within the area. The Dominican Republic is one of the most visited islands of the Caribbean, allowing it to enjoy a relatively strong economy. In 2010, the Dominican Republic received about 4 million tourists throughout its various international airports. The country's capital, Santo Domingo, harbours the Las Americas International Airport, which handles approximately 650 000 passengers per year.⁵¹ Taking this enormous potential into account in the prototypical design of Port-au Prince's airport, the building must be able to provide enough water for at least 650 000 passengers per year to render the concept functional. Based on a set of analysed statistics, it is safe to assume that each passenger would require an average of 60 litres of water for direct and indirect uses such as food preparation, cleaning, and any other practical functions required for the operation of the airport. Just taking into account the water collected from the rain harvest:

Amount of people serviced with water collected from rainfall collection = Total L / 60L

= 83 982 401 L / 60 L

= 1 399 707 people

51 "News November 2010 - Punta Cana Live" - News and Information from the Press of Punta Cana in Dominican Republic " Punta Cana Live" - News, Videos and Information from Punta Cana in Dominican Republic Web 15 Feb 2011 <<http://us.punta-cana-live.com/punta-cana/news/year-2010/november-2010.html>>

Seeing that the amount of water collected would serve approximately 1.4 million passengers, it renders the proposal reasonable. Not taking into account the water extracted from the air, this clearly shows that a building can produce much more water than is required for its operation. For design proposal in question, it demonstrates the return that this type of building can offer to the residents of Port-au-Prince by providing a reliable water source.

Conclusion

Chapter 9

For the purposes of this research, the type of creative inquiry about existing and potential methods for preserving and providing water conducted above has been labelled Hydrotecture. Semantically and etymologically related to the word architecture, Hydrotecture is defined both by the elements that link it to water and by the art of making or designing things. These created spaces must be reflective of the most pertinent issues relating to the society in question and the ecology of the place.

That said, the lack of a developed tourism infrastructure plays an integral part in Haiti's problems. Without a stable economy, future access to reliable water sources is not at all likely. This is why it is so necessary to draw on all of the aforementioned aspects of economy and environment to address the problems of linking architectural design to its potentiality. Undoubtedly, this will open up a new chapter in the field, and newly devised parameters of building design will be brought into play. The economic, social, political and ecological contexts relevant to the project will expand the horizons and creative potential of architecture. Nature is the master of all designers, and associating the possible benefits of built structures to this innovative system of occurring phenomena will promote novel modes of collective thinking about architecture, the environment and society.

Since water is both collected and extracted from air over time, the occupants of the space will readily understand that this resource is not infinitely renewable. By witnessing the periodic accumulation of water, the renewability of the resource will be referenced on a day-to-day basis, and thus provide a practical timeframe. The experience of the space elicits a moment of reflection, intended to encourage a respect for water and its usage, and thereby pointing to an understanding of its ecological role. It poses pertinent questions as to the world's future, both at the

micro and macro levels, and stands as a reminder that our dependence on water is inescapable, and as such, is of prime importance.

Looking to the future of drinkable water, a water-responsive form of architecture can aid in resolving drought, dearth and deprivation of this essential resource throughout the planet by promoting the construction of built environments intended to produce and harvest natural potable water. Just as architecture is responsible for providing basic needs for shelter and protection, it can also fulfill alternative functions while yet renewing and fulfilling those initial intentions. By cross referencing Haiti's situation with the proposal of a water-producing airport, it is hoped that this will create at least one opportunity for the resurgence of a desperate nation, as well as giving a renewed impulse to the distressed situation of architecture as a field of creative analysis. Finally, it should always be remembered that if we are without water then there will be no art or architecture worth practicing, and this is Hydrotecture's final vindication.

Annexe A

Figure 47 - First floor Schematic Plan

Figure 48 - First Floor Spatial Arrangement

Figure 49 - Second floor Schematic Plan

Figure 50 - Second Floor Spatial Arrangement

Figure 51 - Ground level view of approach to building

Figure 52 - View of passenger arrival ramp

Figure 53 - View of interior entrance area; public space

Figure 54 - View of interior central court; water collection basin

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