B. Jack Hanly

Architectures of Oil: Earthworks and Petrochemicals in Saudi Arabia c. 1973

Environmental History, History of Technology, Ecology, Oil, The Architects Collaborative

/Abstract

This paper examines the development of the Saudi cities of Jubail and Yanbu in the aftermath of the 1973 OPEC embargo. Developed as a means of shifting away from pure resource extraction and towards value-added technology sectors, the Saudi government aspired to build up the cities as petrochemical production hubs and investment "growth-poles." The paper considers the ways in which architecture, landscape, and environment became tools of petro-capital valorization. More specifically, it looks at how the master planning efforts of the construction conglomerate Bechtel and the late modern architectural firm TAC looked towards the quality and composition of the earth as their object of management, study, and design. Such a terrestrial vision of an extractive enterprise would seem to be paradoxical, but the paper ultimately shows how an emergent discourse of ecological systems thinking legitimated the diffusion of energy and chemicals. This program, therefore, depended upon a kind of interdisciplinary convergence between architects, engineers, oilmen, scientists, and officials, who collectively manipulated these "natural" resources as the preliminary activity of Jubail and Yanbu's urban administration. These efforts exhibited a scalar flexibility – from the micrological to the territorial – that show the labile modalities of extractive activity, as well as a planning regime that adjusted itself to the vagaries of oil's global political economy. The demand to both protect the environment from and cultivate it with the cities' attendant petrochemical infrastructure demonstrated a melding of technology and nature otherwise overlooked in histories of oil and architecture.

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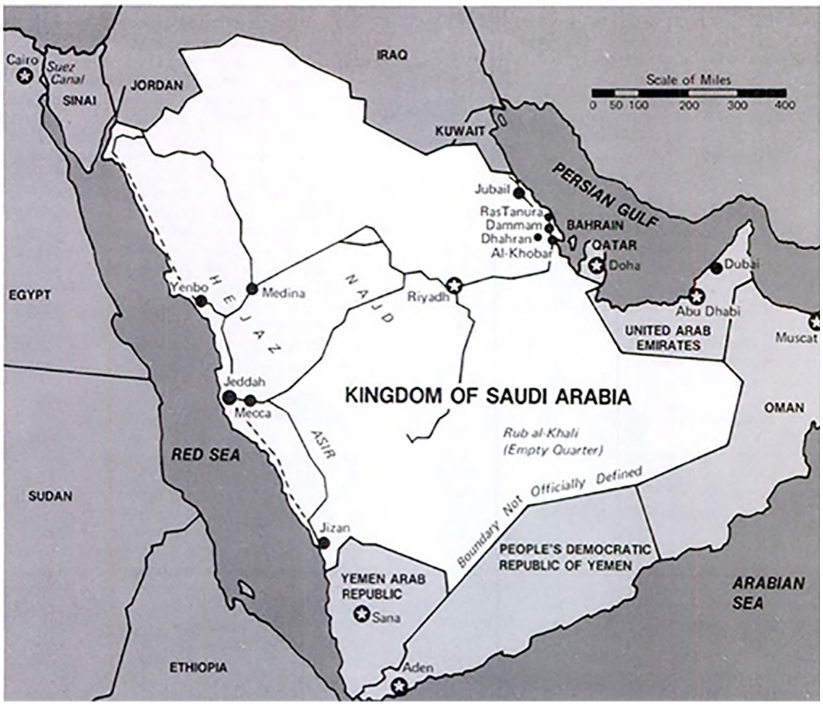
Rising from the desert on opposite ends of Saudi Arabia in the 1970s, the cities of Jubail and Yanbu were logical, if elaborate, correlates to the country's resource boom in the aftermath of the OPEC embargo. Flushed with petrodollars and eager to claim their seat among the global industrialized North, Saudi Arabia embarked on a massive and concentrated urbanization scheme across these two "growth poles." The scale of the development of the twin cities, which emerged essentially *ex nihilo* from the sand, invited comparisons to the pyramids at Giza as the largest single engineering project of its time. Excavated earth material alone reached some four hundred million cubic meters: enough soil to encircle the globe with a thirty-foot-wide embankment.[1] Bechtel, a multinational construction company, tasked by the Saudi government with building Jubail, undertook the complex feat with characteristic brawn, while Parsons Corporation, a defense and infrastructure firm, developed the smaller Yanbu. A pipeline would connect the two cities and carry oil from the fields of the Eastern Province on the Persian Gulf to the terminals and processing facilities on the Red Sea.[2]



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At the heart of the formation of these cities was a desire to transform Saudi Arabia's inchoate industrialization by pivoting the country's economy away from a total reliance on crude oil exports. Petrochemicals offered a promising and potentially lucrative alternative to a sheer crude export economy. Rather than send crude oil to other countries, where it would be turned into costlier products such as gasoline and plastics, the Saudis sought to build their own petrochemical infrastructure. In addition, Jubail would have been home to a steel manufacturing plant, reducing the need for imported construction goods and further diversifying Saudi Arabia's industrial base. It was here that the country's aforementioned *Gas Conservation Program* found productive application, powering the cities themselves and serving as feedstock for fertilizers and other products. Jubail and Yanbu attempted to resolve a number of problematics in Saudi Arabia's drive toward modernization through comprehensive city-making.[3] **[Fig.1]**

Fig. 1

Map of Saudi Arabia showing Jubail on the Persian Gulf and Yenbo [sic] on the Red Sea. Connecting the two cities would be a gas pipeline.

Source: "Housing and urban development in Saudi Arabia," U.S. Department of Hous-ing and Urban Development (Washington: U.S. GPO, 1977), 3.

1 "Foundations: The New Cities," *Saudi Aramco World*, Vol. 33, No. 6 (Nov./Dec. 1982): 30-40.

2 Andrea Pampanini, *Cities from the Arabian Desert: The Building of Jubail and Yanbu in Saudi Arabia* (Westport, CT: Praeger Publishers, 1997).

3 The relationships between natural resource extraction and urbanism are just beginning to be explored. See, for example: Eve Blau, *Baku: Oil and Urbanism* (Zurich: Park Books, 2018); Felipe Correa, *Beyond the City: Resource Extraction Urbanism in South America* (Austin: University of Texas Press, 2016); Carola Hein, "Oil Spaces: The Global Petroleumscape in the Rotterdam/The Hague Area," *Journal of Urban History*, Vol. 44, No. 5 (2018): 887-929; Pierre Belanger, *Extraction Empire: Undermining the Systems, States, and Scales of Canada's Global Resource Empire*, 2017-1217 (Cambridge: MIT Press, 2018).

One problematic was the environment or, rather, the problematic was how to approach the existing landscape in the development's path. Should the Saudis treat the landscape as a tabula rasa for infrastructural outgrowths, or as a jewel of the desert to be preserved for cultural and ecological posterity? While the former would seem to be the reflexive choice for a petroleum-fueled project of such monumental proportions, we have already seen how American projects of similar motivation were confusing this paradigm. To trace this shift in priorities, this paper examines the co-production of the environment and petrochemical infrastructure at Jubail and Yanbu through an analysis of planning documents, promotional literature, and architectural design, broadly construed. The primary characters in this narrative are the Bechtel Group (engineering and organization), The Architects Collaborative (architecture and planning), and the Saudi Arabia Basic Industries Corporation (SABIC) – the interdependent vehicles of the multinational construction conglomerate, late-modern architectural office, and international joint-venture partnership. I find that each assumed a redirected gaze in the aftermath of the 1973 OPEC embargo: each looked to the qualities and composition of the earth as their object of management, study, and design.

I contend that this gaze exhibited a scalar flexibility in line with the totality of its enterprise, extending from the level of the soil to the global political economy of oil. More than being a mere disguise against possible environmentalist objectors or an outwardly projecting image of responsible planning, I argue that the management of a series of natural objects – earth, plants, and agriculture – became a practical stand-in for the management of the city and its petrochemical infrastructure, in what can be called a kind of geophysical techno-politics. Gabrielle Hecht defines techno-politics as a "strategic practice of designing or using technology to enact political goals" within an expanded geography of Cold War expertise.[4] In this and other contemporaneous planning projects, ecological administration became a proximate technique of fossil fuel resource management and, ultimately, posited a seamless exchange between the chemical and the natural. The administration of this newfound ecological vision fell to a particular kind of business model, whose decentralized structure accorded the development with a level of programmatic flexibility, which the physical planning of the cities mirrored in turn. If architecture firms had, at this time, begun to see their work in terms of energy information and its circulation, Jubail and Yanbu were built through the gathering of environmental data and their structure predetermined by oil. The paper thereby examines the travelling theories of ecological systems thinking that shuttled between practices of architecture, energy, and development, demonstrating how a global vision of petroleum extensibility was undergirded not only by the scale and strategies of the territorial, but by that of the terrestrial.

4 Gabrielle Hecht, "Introduction," in *Entangled Geographies: Empire and Technopolitics in the Global Cold War (Cambridge*: MIT Press, 2011), 3.

From Large Technological Systems to Envirotechnical Systems, and Back Again

Jubail and Yanbu, if viewed only as petrochemical company towns, would, at first blush, appear to be prime examples of what Thomas P. Hughes identified as "large technological systems". As an assemblage of physical plants, organizational structures, *human* operators, legal regimes, and material resources, the Saudi Arabian state constructed the cities as a control system consisting of hardware and software, in line with national goals and cultural exigencies. The two cities advanced according to a "pattern of evolution" defined by five-year development plans that transferred existing technology and adapted it to the context of a developing economy. Builders, architects, and planners developed the cities with specific "technological styles" oriented toward geographic and social particularities. The case of Jubail and Yanbu, however, diverges from Hughes's model in an important respect. Hughes sees the large technological system as aspiring to "a closed system that does not feel the environment... [where] managers could resort to bureaucracy, routinization, and deskilling to eliminate uncertainty," and the environment and system could each exert a one-way influence on the other.[5]

Contrary to this model, Jubail and Yanbu are significant for the ways in which the Saudi state, through its Royal Planning Commission and parastatal petroleum corporations, enlisted the environment as a material and discursive partner in the construction of petrochemical infrastructure. Rather than simply becoming objects of total control, the landscapes of Jubail and Yanbu became part of what Sara Pritchard has called "an envirotechnical system", which planners sought to simultaneously augment with, and protect from, attendant petrochemical systems. If geophysical techno-politics is the method to this story, then the envirotechnical system is its primary consequence. In her 2011 book *Confluence: The Nature of Technology and the Remaking of the Rhone*, Pritchard calls for attention to technology as nature, nature as technology, and the administrative envirotechnical regimes of both.[6] That is, the industry of the two cities, reliant on the transformation of a natural material, became a kind of nature which, in turn, reshaped the environment into a technical artifact, suffused with petrochemicals and yet projecting a pristine state. Elsewhere, Pritchard has spoken of an effort to "naturalize industrialization" in historical scholarship, not to frame it as a teleological horizon, but to see the ways the nature-culture divide falls away when we realize that technology is embedded within and dependent upon the natural world.[7]

5 Thomas P. Hughes, "The Evolution of Large Technological Systems," in *The Social Construction of Technological Systems*, ed. W. E. Bijker, T. P. Hughes, and T. J. Pinch (Cambridge: MIT Press, 1987), 53.

6 Sara B. Pritchard, *Confluence: The Nature of Technology and the Remaking of the Rhone* (Cambridge: Harvard University Press, 2011), 21-24.

7 Sara B. Pritchard, "The Nature of Industrialization," in *The Illusory Boundary: Environment and Technology in History, ed. Stephen H. Cutliff and Martin Reuss* (Charlottesville: University of Virginia Press, 2010), 69-100.

While envirotechnical systems are a useful optic for thinking through these developments, from a historical perspective, Jubail and Yanbu exhibited the influence of ecological systems thinking on both architectural and extractive activities – a scientific and cultural paradigm that emerged in the post-war and flourished in the 1960s, the so-called "development decade," and in the 1970s, the decade of ecology. Without undertaking an exhaustive account of ecological systems thinking, it is worth briefly noting the work of one of its figureheads, Howard T. Odum, on the question of energetics. Odum applied to natural systems the dynamic circular models of self-correcting causal mechanisms, which the science of cybernetics used to describe man-machine interactions. Cybernetics, which was originally born out of wartime demands, soon spiralled out of the industrial research laboratory and into a range of social and professional spheres. Its ability to render visible the spontaneous interactions of systems offered a compelling tool in the management of unpredictable change.[8] For Odum's part, analytical tools with which to understand flows and exchanges of energy, resources, and human activity, understood discursively and visually in the language of a circuit board.[9]

Bechtel and the Ecological "Gigaproject"

In order to understand how these cities came into being, it is important to return to the origin story of Warren Bechtel, founder of the Bechtel Group, which would go on to mastermind the two Saudi industrial cities and serve as Jubail's Master Services Contractor (MSC). Bechtel travelled from state to state doing foreman work for the westward railroads, ultimately landing in Oakland with his family in 1904. By this time, the young family man had mastered the use of a powerful excavating machine, the steam shovel, which many other crewmen were loath to take up. Bechtel eventually struck out on his own and secured rail-laying and road-building contracts, which he managed with sophisticated machinery not yet in widespread use. Sensing a coming boom due to the spread of the automobile and road networks, Bechtel turned his sights to oil and gas, envisioning a vast system of refineries and pipelines connecting the country's fossil fuel companies. It proved to be a fortuitous outlook: Bechtel partnered with Standard Oil to build more than one thousand miles of pipeline by the end of the 1920s.[10]

Bechtel's first Middle East projects came in 1943, when American oil firms sought to boost their wartime refinery output in the small country of Bahrain.

8 See Paul Edwards, *The Closed World: Computers and the Politics of Discourse in Cold War America* (Cambridge: MIT Press, 1996); Jennifer Light, *From Warfare to Welfare: Defense Intellectuals and Urban Problems in Cold War America* (Baltimore: Johns Hopkins University Press, 2003).

9 Representative texts include *Environment, Power, and Society* (New York: Wiley-Interscience, 1971); and the textbook *Systems Ecology: An Introduction* (New York: Wiley, 1983). Odum's tendency toward social engineering through ecosystem engineering is discussed in Peter J. Taylor, "Technocratic Optimism, H. T. Odum, and the Partial Transformation of Ecological Metaphor after World War II," *Journal of the History of Biology*, Vol. 21, No. 2 (Summer, 1988): 213-244.

10 Sally Denton, *The Profiteers: Bechtel and the Men Who Built the World* (New York: Simon and Schuster, 2016), 26.

Bechtel helped build the facility and long-distance pipelines, deepwater oil berths, highways, airports, and railroads soon followed. According to the company literature, these early efforts were insistent on the long-range development of Saudi workforces, training nationals to operate and run the tools of the trade. By 1944, the Arab American Oil Company (Aramco) had hired Bechtel for work at its Ras Tanura refinery and administrative town in Dhahran, an idyllic suburban-style enclave complete with air-conditioned interiors, detached single-family homes, and bowling alleys. Bechtel engineered and built a spectrum of technical objects for the petroleum industry in the Middle East, from pipe-fittings and transmission lines to office buildings and power plants. In 1947, it began its most complex project: the Trans-Arabian Pipeline (Tapline), a gas-gathering system bringing oil overland from the Persian Gulf to Western Europe. The Tapline cost some $230 million and pumped oil at about three hundred and twenty thousand barrels a day.[11] All of these large-scale landscape transformations were crucial precedents for Bechtel's later work in Saudi Arabia, but they manifested none of the granular engineerings through earthworks, environmental monitoring, and landscaping of the later projects.

In 1973, Bechtel enlisted the help of former US ambassador to Saudi Arabia Parker "Pete" T. Hart to conduct preliminary studies for an industrial complex on the country's eastern coast. Hart had opened the first American consulate in Dhahran in the 1950s and served in various official roles throughout the Middle East over the decades. With Hart's insider perspective and the company's formidable experience in the area, Bechtel was well situated to capture what they projected to be tens of billions of dollars in contracts. The complex's early outlines listed everything from telecommunications to agricultural and human resources development, with the availability of oil and gas for feedstock and its undeveloped deepwater port as prime factors for the location. Correspondence between Bechtel consultants and executives, however, reveals an emphasis beyond the site's potential or the firm's technical and engineering capabilities. The firm stressed its innovative "systems approach" – design-build in excess of pure planning – and suggestions for training colleges drawn from studies done by the Arthur D. Little and SRI.[12] The company also spoke to the need for a coupling of environments and infrastructure at the new complex. In a letter from the third generation Bechtel president

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Fig. 2

Aerial view of Jubail residential sectors, beyond which lies a tangle of petrochemical infra-structure.

Source: https://www.bechtel.com/projects/jubail-industrial-city/

11 Richard Finnie, *Bechtel in Arab Lands: A Fifteenth Year Review of Engineering and Construction Projects* (San Francisco: Bechtel Corporation, 1958). On Aramco's racialized workforce policies in Dhahran and their intersection with the built environment, see Robert Vitalis, *America's Kingdom: Mythmaking on the Saudi Oil Frontier* (New York: Verso, 2009).

12 Various documents from Parker T. Hart Papers, #9026, Box 12, Folder 2, American Heritage Center.

Steve D. Bechtel Jr. to King Faisal, outlining the company's goals for such an undertaking, should it be approved, the businessman explained how a greater knowledge of the country's resources would contribute to the necessary infrastructural improvements:

> We are keenly aware, as I am sure is Your Majesty, of the need for *long-term advanced study* to make the *best use of natural assets* of terrain, groundwater, sea access, and human resources; and to *rationalize them with intended or expected developments* in electric power, industry, agriculture and water, transportation, communications, education, housing, public health and environmental safeguards.[13]

The letter reveals how a production of environmental knowledge through long-range resource forecasting structured the megaprojects at Jubail and Yanbu. Bechtel studied the country's "natural assets" and calculated their equivalent engineering projects. This knowledge could then be "rationalized," or co-produced with the desired national development plans, drawing what might otherwise be antagonistic forces into harmonious accord. Bechtel's letter constituted the first prong of the development's geophysical techno-politics, in which information concerning the region's surface and subsurface materials led to environmental control, subsequently designed in accordance with a predetermined set of political goals. [Fig. 2]

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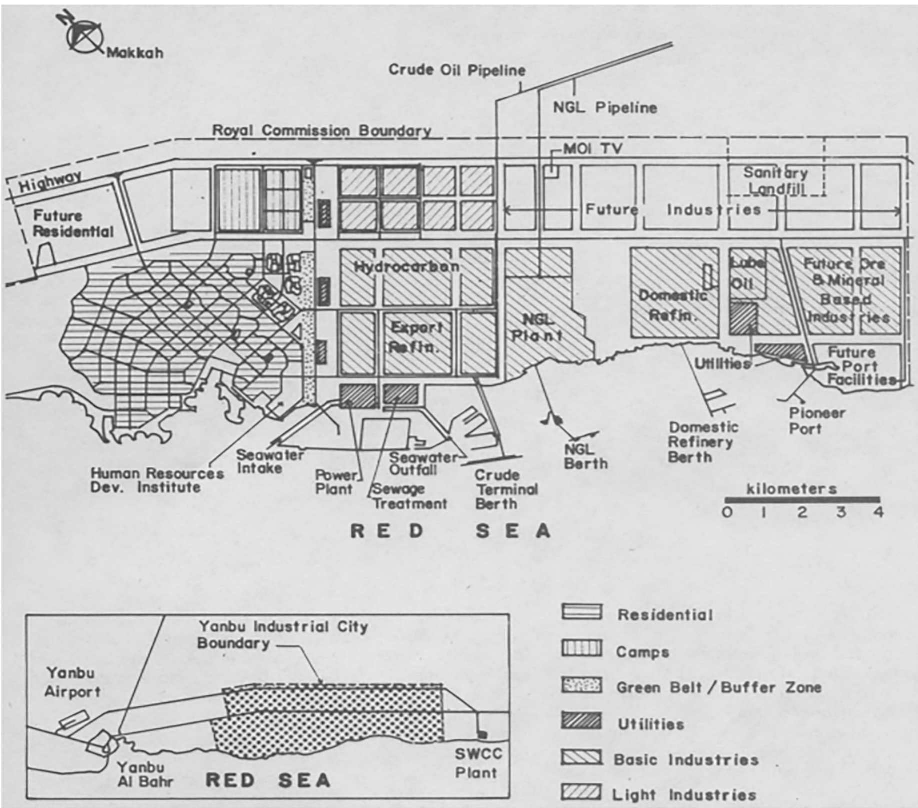

13 Letter from Steve D. Bechtel to King Faisal, 5 May 1973. Parker T. Hart Papers, #9026, Box 12, Folder 2, American Heritage Center. Italics of the author.

Early news reports recognized that Jubail and Yanbu constituted a new kind of urban development in that they coupled macro-scale engineering – what Bechtel executives called their first "gigaproject" –with environmental protection and a totalized systems dynamics approach. In a 1982 opinion piece, MIT professor and program coordinator for the Macro-Engineering Research Group Frank P. Davidson drew attention to the humanistic potential of a rediscovered capacity for grand projects. Davidson noted that this emerging field of study was helping to resolve the leftover resistance to "bigness" by social critics: large projects were here to stay, he suggested, and systems dynamics offered economic and environmental benefits in a single package. The transdisciplinary actors contributing to this field included psychiatrists, financiers, lawyers, and architect-planners, whose cooperative organization created new, holistic knowledge. Urbanization schemes like Jubail heralded a new wave of environmentally-oriented engineering within "an institutional, as well as conceptual, mechanism for launching public-benefit programs."[14] However, to accomplish such feats the world would need a new kind of professional: the engineer-manager, capable of

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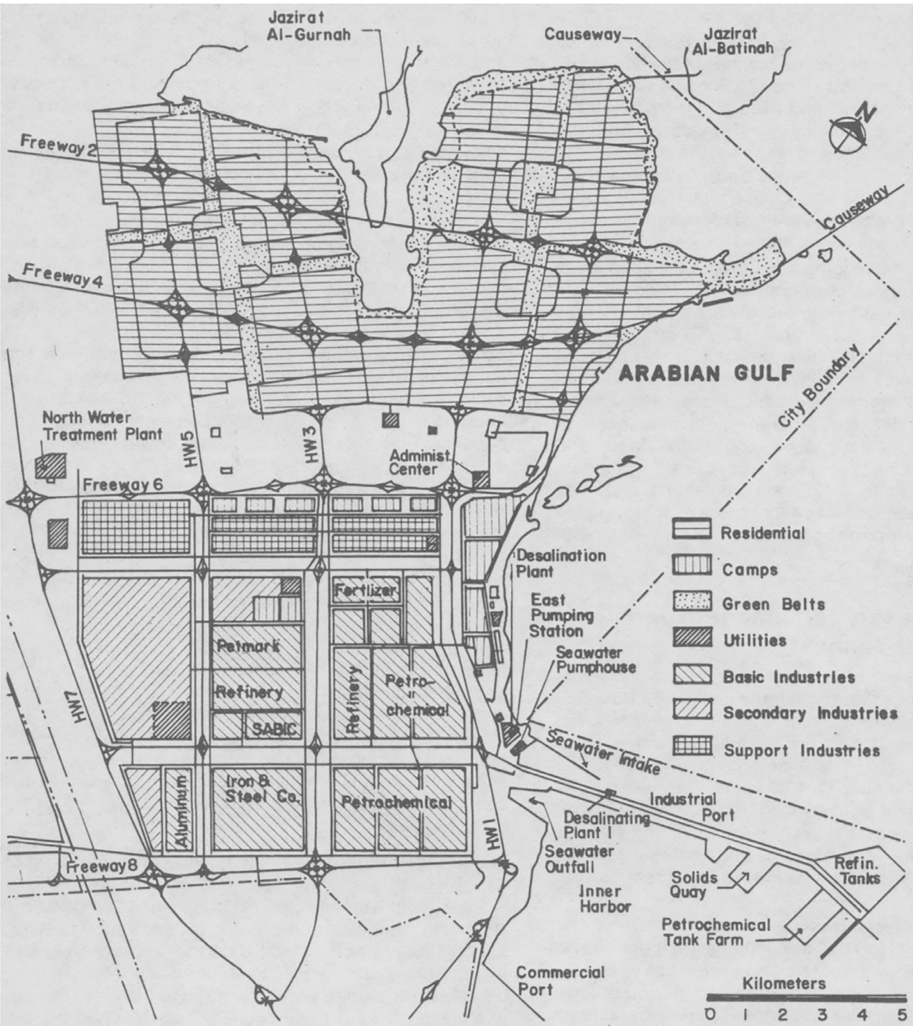

Fig. 3 a, b

The master plans of both Jubial and Yanbu show residential and social infrastructures tightly coupled with petrochemical and industrial manufacturing.. Source: Mahmoud A. Abdel-Latif and Wolfgang G. Roeseler, "Settling the Desert with Advanced Industrial Technology: Two Recent Saudi Arabian Settlement Projects," Ekistics, Vol. 52, No. 311 (March/April 1985): 163-175.

14 Frank P. Davidson, "Macroengineering: Mammoth Projects Need Love, Too," Christian Science Monitor, December 17, 1980. See also Frank P. Davidson, *Macro-engineering and the Infrastructure of Tomorrow* (Boulder, CO: American Association for the Advancement of Science by Westview Press, 1978).

leading the transition from declarations of values to their materialization in concrete and steel. Importantly, these leaders had begun to incorporate the needs of natural systems into their models of practice.[15] [Fig. 3]

The Architects Collaborative and Vegetal Expertise

If Bechtel was mustering the expertise of many different disciplines to extend the viability of its business model, so too was architecture. Though, where Bechtel was softening its imperious stance to engage both the ecosystem itself and the inhabitants of its outposts through training programs, architects were taking a different tack. By the 1970s, late modern architectural offices had achieved a global footprint completing complex projects with the efficiency and leanness of bureaucratic organization. Firms such as Skidmore Owings Merrill (SOM); Caudill Rowlett Scott (CRS); William Pereira and Associates; and The Architects Collaborative (TAC) pioneered a collaborative approach to architecture that prized flexible design methods culled from decentralized and specialized divisions.

In addition to furnishing the built works for a burgeoning post-war landscape of industrial research and production, firms began to adopt isomorphic organizational, operational, and strategic dispositions to those of their clients, aspiring to the global, integrated status of the multinational construction or energy conglomerate.[16] In doing so, they aspired to transform the landscape into a technical undertaking, applying the same professional apparatus of individual units operating under central command to the design of the "built environment" as that of a single building. In doing so, architecture modeled cybernetics' signature methods of interdisciplinary convergence in pursuit of universal applicability, and of the indiscriminate amalgam of the organic and the artificial.

The Architects Collaborative (TAC) was formed in 1945 out of a group of friends at the Yale School of Architecture. TAC's original members worked at corporate firms before joining together and seeking out an established leader to lend credibility to the young architects. The leader they found, Walter Gropius, was one of the founding members of the Bauhaus in Weimar, Germany, in 1919.[17] TAC grew from this small partnership into one of the largest US architectural firms in the 1970s, progressing from individual houses to universities and ultimately entire cities. TAC was therefore in a position to synthesize the vast scope of planning objectives at Jubail and Yanbu. This scope included the

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15 These models of practice that co-produce nature and technology persist. As Mark Jarzombek has pointed out, "nature around us is an illusion constructed in tight alliance with the world of pipes, ducts, and valves." See "ARUPtocracy and the Myth of a Sustainable Future," *Thresholds* 38 (2011): 64-65.

16 On TAC, see Michael Kubo, "Architecture Incorporated: Authorship, Anonymity, and Collaboration in Postwar Modernism" (PhD diss., Massachusetts Institute of Technology, 2018). On DMJM/AECOM, see Aaron Cayer "Shaping an Urban Practice: AECOM and the Rise of Multinational Architecture Conglomerates," *Journal of Architectural Education*, Vol. 73, No. 2 (October 2019): 178-192. For an overview of these shifts, see Paolo Tombesi, "The Carriage in the Needle: Building Design and Flexible Specialization Systems," *Journal of Architectural Education*, Vol. 52, No. 3 (Feb. 1999): 134-142.

17 Walter Gropius, *The Architects Collaborative, 1945-1965* (New York: Architectural Book Pub. Co., 1966).

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design of the cities' substrate through earthworks, soil, and plantings – the individuated components of the envirotechnical system.

In documents outlining the general requirements and technical specifications for the landscaping and earthworks at Yanbu, TAC established protocols for building the city's greenery into its industrial fabric. As stated in other promotional materials and paperwork by the architects and the planning commission, earthworks, that is, the large-scale excavation, transportation, and treatment of soil, was the prerequisite operation for all subsequent efforts of city-making. Earthworks prepared this ground as fleets of earthmoving trucks, the descendants of Bechtel's steam shovel, rearranged the unstable desert soil.[18] Jubail's low-lying coastal plain required massive preparation. Excavated soil was used to create a foundation two and a half meters above water level to guard against flooding and the hazards of the sea. Though these mega-engineering activities were outside its purview, TAC documents nevertheless paid a great deal of attention to the geophysical qualities of what was being moved. While a component of earthworks certainly encompassed a subtractive clearance, another was additive: planting, which effloresced after the clearing. These

dual activities, removal and replacement, constituted the earthworks category in general. [19] [Fig. 4]

Soil and planting, environment and object, were each subject to quality assurance measures to ensure their execution was in accord with TAC's specifications. Addressing contractors overseeing construction workers, the document advises deferment to authorized representatives for the ultimate directive in regard to soil suitability. When suitability was unclear, managers would provide

18 For a history of the bulldozer's material and discursive instrumentality in postwar urban planning and architectural production, see Francesca R. Ammon, *Bulldozer: Demolition and Clearance of the Postwar Landscape* (New Haven: Yale University Press, 2016).

19 Kevin Lynch, writing in a 1962 reference guide, stipulated that the "new ground must have a pleasing visual form" that maintained an equitable balance between *cut* and *fill* material. See Kevin Lynch, "Earthworks and Utilities," in *Site Planning* (Cambridge: MIT Press, 1962), 161.

Fig. 4
Earthmoving trucks rearrange tons of the desert substrate, preparing the ground for the new cities. Source: The Royal Commission for Jubail and Yanbu, Madinat Al-Jubail Al-Sinaiyah: Mokhtat Al-Mantikah Al-Sakaniyah (Riyadh: the Royal Commission, 1978).

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samples to architectural or technical personnel, who would then conduct soil tests and provide these results to construction managers. They could then reference previously established maxima and minima quality to determine appropriate action. Contractors were responsible for the sound interpretation of data results and for achieving the required "Field Quality Control."[20] A chain of oversight governed the handling of earth materials, just as it did in the realization of a physical building program, preparing the ground in accordance with suitable quanta. TAC's master-planning of the city ballooned outward from there but, first, the soil had to be prepared.

TAC's directives for contractors tasked with these responsibilities stipulated that they remain attentive to the geological conditions of the site, an inverted gaze to the typical figural attention of builders.[21] This may have been more practical than ontological. The delicate enterprise of building a city over a maze of pipelines, the presence of which justified the project's existence but required precautions to be diligently avoided. Building around existing utilities and avoiding explosive materials required continual examination of the substrate. Reading

20 Yanbu A3 R-4 Landscaping Section 02220: Earthworks, The Architects Collaborative (TAC), Microfilm Archive, Reel 595, Box 19, MIT Museum.

21 Yanbu A3 R-4 Landscaping Section 02220: Earthworks, The Architects Collaborative (TAC), Microfilm Archive, Reel 595, Box 19, MIT Museum.

Fig. 5

Landscaping laced the cities with greenery, which flourished due to desalination plants and petrochemicals. Source: The Royal Commission for Jubail and Yanbu, 10 Years of Accom-plishments (Riyadh: the Royal Commission, 1986).

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like a set of install instructions for large-scale landscaping, TAC's administrative documents speak to the orchestrated collisions of infrastructure and environment that characterized petrochemical city-making in Saudi Arabia. For all their talk of soil and planting, however, these documents merely set the stage for the beneficiaries of such tending: utilities in the form of pipelines, and housing structures serviced by *cul-de-sacs* of villas. Sectional drawings of roadways from Yanbu depict the concrete surface hemmed in on both sides, with parenthetical flourishes, above and below ground, of pipe and plant.[22] Such evidence shows that, in addition to the overt infrastructure of the petroleum industry, the roads, pipelines, and refineries that define the extractive imaginary, there is another, less visible component – that of dirt and plant matter. [Fig. 5]

Indeed, the Royal Commission and TAC planted upward of a million trees and shrubs at Jubail and Yanbu; yet, the degree to which administrators mandated oversight of individual plants is striking. Special planning divisions were responsible for tending to the plants at nurseries and higher officials had to authorize them suitable for collection, after which they would be acclimatized in special environments. It was again up to contractors, under the direction of "horticulturally qualified foremen," to determine the health of their charges. Plants were to be "typical of their species or variety; well-branched and densely foliated when in leaf; and free of dust, dirt and any chemical sprays and liquids which would have a deleterious effect on the plants' appearance and health."[23] Raised in glass vitrines and expelled into the desert environment, the aesthetic of the plants mirrored that of the city: precisely ordered, maintained according to scientific ideal types, and free from contamination. Despite this aspiration toward chemical

Fig. 6
Agricultural Experiment Station prepares plantings for eventual desert habitation. Source: Kathleen Kelly and R.T. Schnadelbach, Landscaping the Saudi Arabian Desert (Philadelphia, PA: The Delancey Press, 1976), 74.

22 Landscaping architectural bid construction, TAC Tube #12: Yanbu Industrial City, MIT Museum.

23 Yanbu A3 R-4 Landscaping Section 02220: Earthworks, The Architects Collaborative (TAC), Microfilm Archive, Reel 595, Box 19, MIT Museum.

purity, the growth environment itself operated as an instrument of petrochemical circulation.

Monitoring, Maintenance, and Containment

While TAC's geophysical manipulations laid the foundations for the envirotechnical system through design, another set of technics was necessary to maintain this precarious co-existence past its initial stages. In incremental five-year reports, the state's planning agency published glossy compendia of its activities at Jubail and Yanbu. These featured images of construction efforts, statistics on petrochemical production, and evocations of burgeoning social life. Organized into a progressive timeline of events, the publications exhibit shifting foci of the city-making projects in their various iterations. The array of infrastructural improvements, including an industrial port, telecommunications links, airports and housing, hold equal pride of place to the environmental planning efforts. Here, however, attention surrounds not so much the rearrangement of soil or the installment of plants, but the continuous monitoring of these elements to protect them from petrochemical contamination.[24] Saudi Arabia strove to sidestep the mistakes made by other countries in ignoring the environmental conditions of large-scale engineering systems. Part of this stemmed from a desire to construct the technical system into a global model of best practices, to incorporate the most up-to-date technology, and thereby attest to the development's sophistication. [Fig. 6]

This technology was both infrastructural and organizational: a network of testing laboratories, air and water monitoring stations, and computer models populated the landscape, from which human technicians collected data for interpretation.[25] Officials could then use this data to determine whether the system operated outside a targeted set of boundaries. It specified maximum allowable effluent and emissions, consistent pollution levels, and ideal air quality, while, in the case of emergency, computer models predicted the movement of toxic plumes. Simple spatial arrangements contributed to this cause. Residential communities were sited to take advantage of prevailing winds, with ample buffer room from production facilities. Archaeological sites were identified to be bypassed by development. The soil was treated with chemical stabilizers to prevent drifting sand from disrupting infrastructure.[26] Thus, the environmental program was attuned to both the qualities of space, from its material composition

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24 Historians of technology have recently shown an interest in the social construction of environmental monitoring systems and their politics of implementation. See: Etienne Benson, *Wired Wilderness: Technologies of Tracking and the Making of Modern Wildlife* (Baltimore: Johns Hopkins University Press, 2010); Deborah Coen, *The Earthquake Observers: Disaster Science from Lisbon to Richter* (Chicago: University of Chicago Press, 2012); Jennifer Gabrys, *Program Earth: Environmental Sensing Technology and the Making of a Computational Planet* (Minneapolis: University of Minnesota Press, 2016).

25 Architectural historians have recently turned their attention to forms of the "field station" typology. See Edward Eigen, "The Place of Distribution: Episodes in the Architecture of Place," in *Architecture and the Sciences: Exchanging Metaphors,* ed. Antoine Picone and Alessandra Ponte (New York: Princeton Architectural Press, 2003), 52-79.

26 The Royal Commission for Jubail and Yanbu, *10 Years of Accomplishments* (Riyadh: the Royal Commission, 1986).

to its formal presence in the landscape. Improvement and experiment, the twin pillars of Jubail and Yanbu's environmental program, were thus set in motion.

Overseeing these human technicians was the Royal Commission's Environmental Control Department (ECD), established in the same year, 1975, as the directorate's founding. This unit would contribute to the country's goal of building the cities into models of environmentally-sensitive manufacturing centers, and kept regional offices at both Jubail and Yanbu. The ECD also outlined regulations, health codes, and permitting standards. Environmental Impact Assessments (EIA), drawn from international standards, constrained initial designs submitted by Bechtel and TAC. Such policies steered the assemblage of infrastructures toward not only petrochemical production, which was the development's *raison d'être*, but to the production of its environment. Waste processing facilities, like a compost plant for non-hazardous and biodegradable materials, produced compost for the aforementioned horticulture activities, while stabilization and land-filling techniques furnished buildable ground out of the industrial detritus.[27]

Each one of these environmental-regulatory technologies demonstrates how Jubail and Yanbu enrolled the landscape in their project of petrochemical city-making. They also show how this landscape had to be simultaneously protected from inordinate strain and refigured into a technical object for this system to work. Promotional literature toggles between a view of the landscape as having previously been inhospitable and desolate, and a newly-lush setting, made possible by earthworks, infrastructures, and monitoring. In other words, the landscape could only be thought through the lens of the envirotechnical system. An example: despite its harsh characteristics, the Royal Commission notes that a number of desert-resistant flora and fauna existed at the sites before construction began, including camels, foxes, snakes, and a variety of migratory and endemic bird species.

Far from destroying these populations, the cities brought them forth: the landscape program provided habitat for newly flourishing birds, which expatriate Royal Commission employees documented in a dedicated publication.[28] Coastal waters featured coral reefs and offshore islands, while halophyte vegetation grew in low-lying marshes. These elements restricted certain areas of development while allowing for others. The deepwater port structures and navigational channels utilized conserved mangroves and reefs as natural infrastructural protection against storm surges, where protected areas formed a working landscape for industrial activity.[29] Touting its balanced development through ecological landscapes, the Royal Commission constructed an image of the envirotechnical system par excellence: the city as pristine, untouched natural

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27 Waseem Akhtar, "Protection of Environment and Public Health in Jubail and Yanbu: The Royal Commission Efforts," *Arab News* (June 5, 2009).

28 Peter Baldwin and Brian Meadows, *Birds of Madinat Yanbu Al-Sinaiyal* (Riyadh: the Royal Commission, 1990).

29 The Royal Commission for Jubail and Yanbu, *15 Years of Accomplishments* (Riyadh: the Royal Commission, 1991).

habitat, thriving with the help of technologies and regulations implemented as a socio-political state program.

In 1988, to recognize these accomplishments, the United Nations awarded the Royal Commission of Jubail and Yanbu its International Sasakawa Environment Prize for the organization's "successful bringing together of industry and government, and for excellent planning and implementation of environmentally sound management plans."[30] Established in 1982, under the United Nations Environment Program (UNEP), the award was devised to fill a considerable gap in the kinds of projects lauded by global institutions. The Nobel Prize, officials noted, had no provisions for environmental or ecological studies and advancements; the Sasakawa Environment Prize would therefore be of a "distinctional parity."[31]

The prize, underwritten by the Nippon Foundation, highlighted sterling examples of what was coming to be termed "sustainable development" in second and third world countries. Further documentation is conspicuously absent from the UN archives—oddly, 1988 was the prize's only missing entry in the records of Secretary-General Javier Pérez de Cuéllar. However, it's possible to speculate on the genealogy of "sustainable development" as a guiding set of principles for both spatial and petrochemical management.[32] If a contemporary understanding of this term emphasizes the containment of urban territory, so as to lessen its sprawling ecological impact, the Royal Commission's ECD instead supervised the selective containment of petrochemicals from accidental incursion. The symmetry of these practices, from urban strategy to environmental control, demonstrates the transposable nature, conflicting mandates, and scalar flexibility of institutionalized environmental expertise.[33]

Productive Dispersal and Petrochemical Dispersion

As late-modern industrial hubs, however, Jubail and Yanbu are more likely the results of opposite forces. Although planned and managed by a centralized monarchy, the development of the cities stands at a juncture of production models, in the marked shift from the centralized postwar factory to its decentralized and distributed successor.[34] The increasing international location of industrial development – the spatial dislocation of capital from core to periphery – is usually attributed to the strategic decisions of multinational corporations in pursuit of comparative advantage. In the case of petrochemicals, however, a

30 "International Environment Sasakawa Prize for 1988 Awarded to World Commission on Environment & Development and Royal Commission for Jubail & Yanbu of Saudi Arabia," *Environmental Conservation*, Vol. 15, No. 3 (1988): 273.

31 "International Environment Sasakawa Prize for 1988," 273.

32 Summary of AG-019 Secretary-General Javier Pérez de Cuéllar (1982-1991), S-1051-006 – S-1051-0038.

33 This symmetry can be seen in another spatial-to-biophysical register: from Cold War containment strategy to the containment of nuclear fallout.

34 For an analysis of this shift in the context of scientific research and artistic production, see: Peter Galison and Caroline Jones, "Factory, Laboratory, Studio: Dispersing Sites of Production," in *The Architecture of Science*, ed. Peter Galison and Emily Thompson (Cambridge: MIT Press, 1999), 497-540.

7

combination of market dynamics and state intervention led to the industry's dispersal into developing countries, characterized less by relocation than differential growth. The watershed of this change was 1973-1974, as production capacity plateaued in Western Europe and in the US, but net global output continued to rise. Engineering contractors such as Bechtel were important conduits for the transfer of technology, but the technology was at this point widely available, granting its recipients the bargaining power for the self-led development of petrochemical infrastructure.[35]

Administrators found that although they had the capital to purchase this technology, the country did not have sufficient manpower to absorb it. In other words, Saudi Arabia benefited from the worldwide dispersal of petrochemical manufacturing, but still could not meet the knowledge requirements demanded of its citizens. As one anonymous Bechtel executive put it, "the bottleneck is labor, from the top management level on down to the bricklayer."[36] In the rush towards development, Saudi Arabia had perhaps underestimated the difficulty in molding a rural, agrarian society into an urban, industrialized one. The construction executive's allusion to both petroleum expertise and the labor building the city makes clear the interdependencies of oil and architecture: without the directors managing resource logistics, there would be no reason for physical buildings; and without the architecture of administration, there would be no means of managing these flows.

To this end, the Royal Commission established a Human Resources Development Institute in both Jubail and Yanbu in order to keep pace with

35 Keith Chapman, "Agents of Change in the Internationalization of the Petrochemical Industry," *Geoforum*, Vol. 23, No. 1 (1992): 13-27.

36 Youssef M. Ibrahim, "Development Rush in Mideast Slowed by Hunt for Skills," *New York Times*, Feburary 20, 1978.

Fig. 7

Technicians collecting samples from air monitoring equipment. Source: The Royal Com-mis-sion for Jubail and Yanbu, 15 Years of Accomplishments (Riyadh: The Royal Commis-sion, 1991).

8 |

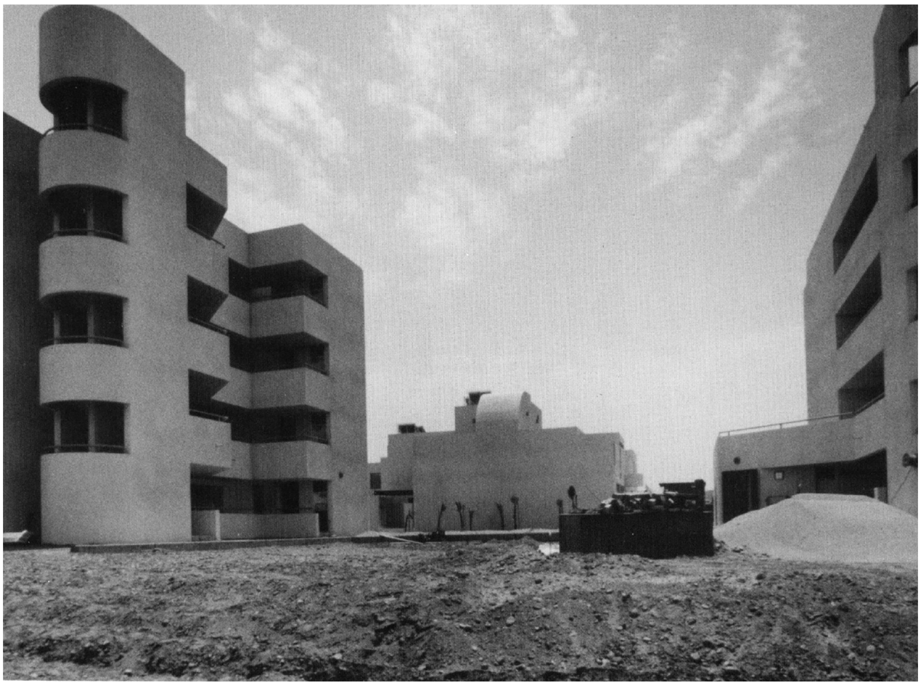
the goals of successive five-year plans. The intent was much the same as the country's bet on a home-grown petrochemicals industry: rather than shower American experts with lucrative contracts, Saudi Arabia would seek to build up its own class of technocrat managers.[37] The institute began as a skills training center established by the Royal Commission in 1978. With the construction of a new campus and administrative headquarters in 1982, it upgraded to an institute, and finally a full-fledged engineering and business college, the Jubail Industrial College, in 1989.[38] The centrality of this institute to the Royal Commission's overall goals demonstrates the degree to which human or knowledge resources were coeval to the more traditionally understood resources of oil. In aerial views of the institute's Jubail plan, a series of interconnected octagonal structures are linked by radial wings. An administrative structure serves as the entryway to the campus, while on either side training centers and student housing continue the octagonal motifs. Beyond this a central courtyard overhung by a tent-like skrim provided a meeting place for faculty and students, shrouding the institute's charges from the harsh desert sun. [Fig. 7] As one of the architectural centerpieces of Jubail, the Huma Resources Development Institute cultivated the future technicians of the city and the country at large's worldwide petrochemical diffusion.

It was not only high-modernist industrial sectors that were transformed by the new epistemological and material basis of oil, but traditional agricultural practices as the country sought to build up its agricultural sectors by utilizing the array of petrochemicals it was now producing. The fertilizer industry was a key component in achieving this goal, without which the country would be hard-pressed to inspire its soil to abundance. Fertilizer production facilities were state-owned and joint-venture enterprises under the broader SABIC organization, a consortium composed of individual companies in partnership with multinational firms; these utilized industrial feedstock like methane gas. As primary

37 Don A. Schanche, "'Instant' Cities Sprout in the Desert as Saudis Act to Ease Oil Dependence," *Los Angeles Times*, February 17, 1981.

38 This college is still in operation today: http://www.jic.edu.sa/en/about/Pages/default.aspx. Accessed June 8, 2021.

Fig. 8
Human Resources Development Institute at Jubail shows the octagonal administrative center in foreground, student housing at right, and training wings at left. Source: The Royal Commission for Jubail and Yanbu, 15 Years of Accomplishments (Riyadh: the Royal Commission, 1991).



9

industries that took natural gas byproducts to produce chemicals for domestic or international use, these companies synthesized a new material basis of environmental growth.[39]

These companies initiated Saudi Arabia's own "green revolution" and created a "green desert" in the place of an unproductive one. Where such developments in other countries signaled the intervention of global institutions such as the Ford Foundation and the World Bank, and are said to have disrupted traditional farming practices in the name of multinational profiteering, this was a charge led by Saudi Arabia itself.[40] Furthermore, the newly verdant landscape did not follow from chemical innovations alone: it required the combined tools of architectural construction, petrochemical infrastructure, and communication channels between industrial colleges and state-led industrial consortiums.

Crude Translations and Contingent Planning

The worldwide diffusion of petrochemicals and the political economy of oil that governed its trajectories, in turn, structured the physical layout of the two cities, ebbing and flowing in tandem with the vagaries of this unpredictable market. Officials had to ensure that planning frameworks took into account such unknowable resource futures. In other words, they should be infinitely extensible

Fig. 9
CRS residential housing in Yanbu demonstrates human-scaled regionally inspired form. In their repetitive plan-form and accretive morphologies, housing formed the crux of the flexible city making by which Jubail and Yanbu would develop. Source: Charles E. Lawrence, Saudi Search (Houston, TX: CRSS Research Division): 11-13.

39 Robert Crane, *Planning the Future of Saudi Arabia: A Model for Achieving National Priorities* (New York: Praeger Publishers, 1978).

40 SABIC's first chairman, Ghazi Abdul Rahman Al Gosaibi, was part of a new generation of technocrats in the 1970s who resisted the authoritarian and traditionalist monarchy. Gosaibi was known fondly as Saudi Arabia's "godfather of renovation." See Henry H. Albers, *Saudi Arabia: Technocrats in a Traditional Society* (Bern: Peter Lang Publishing, 1989).

and yet remain contingent in nature.[41] Residential sectors of the industrial cities can be seen as a barometer for this contingent planning in both its sectoral arrangement coupled with development plans and their ultimate occupancy. Though comprehensive in scope, the plans formed a flexible conceptual framework for both the physical layout and social infrastructures of the projected city. In addition to landscaping and soil, therefore, these housing communities would constitute the ideal growth patterns for the city in strategic phased dimensions, allowing officials to test and refine specific designs through its earliest development. [42] [Fig. 8]

Plans for the cities allowed for such contingent arrangement by virtue of their open district framework, nucleated into individual urban areas and linked by highways and green corridors. Comprehensive development could thereby proceed in a cohesive fashion, but in a phased manner that would not overextend the country's resources. Saudi planning officials emphasized flexibility as the key to this mode of planning in both spatial requirements and programming: flexible arrangements allowed for this reassessment to occur, which in turn affected the rate and order of change at ground level. These updated decisions were to incorporate the forecasting of future resources on the one hand, and the translation of plan components into locational distribution on the other.[43] This translation entailed a number of simultaneous processes: the "translation" of crude oil into value-added petrochemicals; the exchange of products for currency on the world market; the allocation of capital to plan components; and the reorientation of components in relation to available resources. Extensible districting through residential sectors was both the precondition for contingency planning, as well as the object of the plan's periodic stock-taking.

As a project manager for Bechtel in Jubail in the 1970s, architect Gordon Linden helped direct these modifications. After completing his bachelor of arts in architecture at Berkeley in 1968, Linden joined the Peace Corps and served in Venezuela, working on a number of municipal projects there. Upon returning to the US and completing a master of urban planning at the University of Southern California, Linden was hired by Bechtel to go back to Venezuela, where he worked on the planning of cities around oil refineries in the states of Anzoátegui and Monagas. This experience of building social infrastructures alongside oil infrastructures in a nation contending with vast resource wealth led directly to his work for Bechtel, when his friend Michael Cobb asked him to go to Saudi Arabia in his stead. Linden was tasked with updating the conceptual iteration of the master plan, which was almost at its second five-year phase, around 1978.[44]

41 For a discussion on the "pattern" of development as a flexible model attuned to the contingencies of cultural and economic circumstance, see: Arindam Dutta, *The Bureaucracy of Beauty: Design in the Age of Its Global Reproducibility* (London: Routledge, 2004). See also: M. Ijlal Muzaffar, "Fuzzy Images: The Problem of Third World Development and the New Ethics of Open-Ended Planning at the MIT-Harvard Join Center for Urban Studies," in *A Second Modernism: MIT, Architecture, and the "Techno-Social" Moment*, ed. Arindam Dutta (Cambridge: MIT Press, 2013), 310-341.

42 *Madinat Al-Jubail Al-Sinaiyah: Mokhtat Al-Mantikah Al-Sakaniyah* (Riyadh: the Royal Commission, 1978), 8.

43 *Madinati Al-Jubail Al-Sinaiyah 1403 H. Master Plan Update* (Riyadh: Royal Commission, 1983), 21.

44 Gordon Linden, in an interview with the author, conducted by phone on March 20, 2018.

Part and parcel of these five-year planning phases were interdisciplinary studies undertaken by firms contracted under Bechtel's directive, including but not limited to environmental, sociological, demographic, and future estimates. These statistical operations used space planning techniques for the projected populations of plant workers and combined these with the desired social institutions such as schools and hospitals. Linden stated:

> The hierarchy of industry has attached to it a logic of employment, housing, family status, etc. It all trickles down to demand for community facilities. It changes all the time because of technology and industry change. What was done twenty years ago for steel or plastics isn't done anymore, so that changes the whole structure of what you need. As far as infrastructure, that's one of the gambles of the master plan is that you establish some threshold for the services—power, telecom, water—and then you invest in a phasing. That allows you to say we're going to build two hundred units over here, a school over here, a park. If there's no take-up on the units, then you defer for another five years. [45]

Linden's conceptual equivalence between architectural production and petrochemical production reveals the co-construction of these two fields at Jubail and Yanbu, where the global political economy of oil regulated the spatial program of city-making. This is where petroleum as both process and form takes shape and where its materiality inflects the life-worlds of its administrators. Circulation of petrochemicals acquired an identifiable figure as it advanced across the envirotechnical system laid out by planners, architects, engineers, and officials.

Conclusion

As we have seen, the geophysical administration of transformed earth-matter served as the analogical precursor to the management of the city, its petrochemical infrastructure, and its populations. Technopolitics came to be imbricated with the materiality of the landscape, producing a hybrid formation, the envirotechnical system, that projected an incongruous image of wildlife and extraction pleasantly coexisting cheek-by-jowl. For the planners of Saudi Arabia's grand new cities, an ecologically infused system thinking naturalized the diffusion of petrochemicals and charted a path for achieving system stability. Architects aided in this administration of the extractive environment through their attention to chemical and energetic synthesis across tabula rasa landscapes, which became yet another self-correcting causal mechanism in the accumulation of petro-capital. In Saudi Arabia, oil came to be regarded as the principal force for the construction of society, at a time when Western countries saw energy scarcity as a threat to dearly held ways of life. The growing role of energy "information" and computer data helped direct these efforts, as immaterial "resources" signaled ways of transcending apparent limits to growth. The architecture of

45 Gordon Linden, in an interview with the author, conducted by phone on March 20, 2018.

oil in Saudi Arabia, therefore, includes the immense master plans of Jubail and Yanbu, the laboratories and infrastructures within them, as well as the landscapes manipulated and reshaped in their name.

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