The mapping and spatial analysis by the Greater Angkor Project has revealed key insights into the urban planning of Angkor. The urban elements and the infrastructure network of Angkor stretch throughout its greater territory.

Scott Hawken

Angkor: Sprawling Forms of a Medieval Metropolis

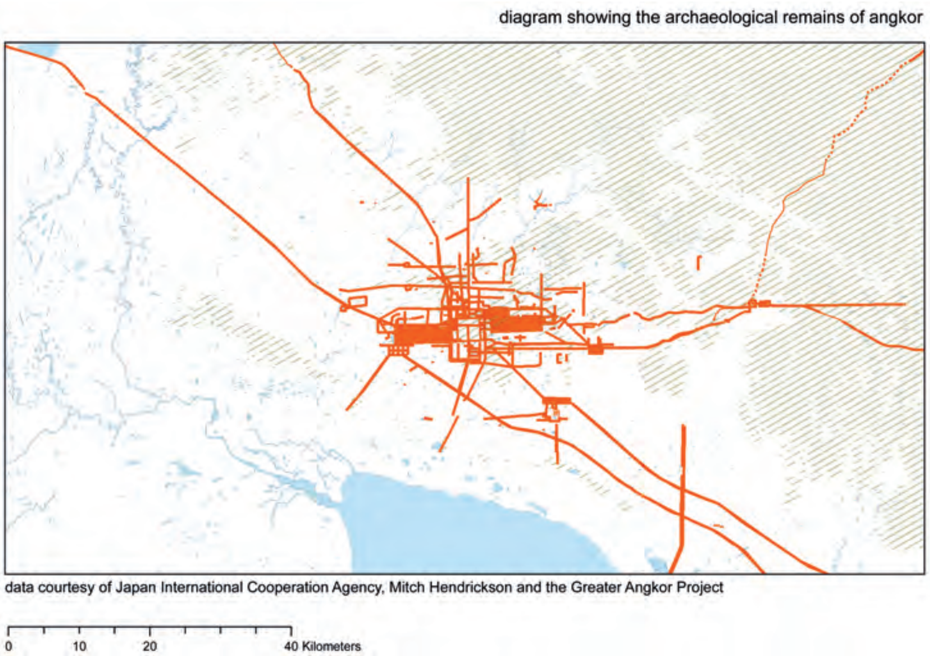
A collaboration between Australian, French and Cambodian scholars is revealing the sprawling form of a ruined medieval metropolis through remote sensing technology, excavations and new theories. A clearer understanding of Angkor's form and function may help contemporary planners and architects see the issues facing low-density cities of today and tomorrow.

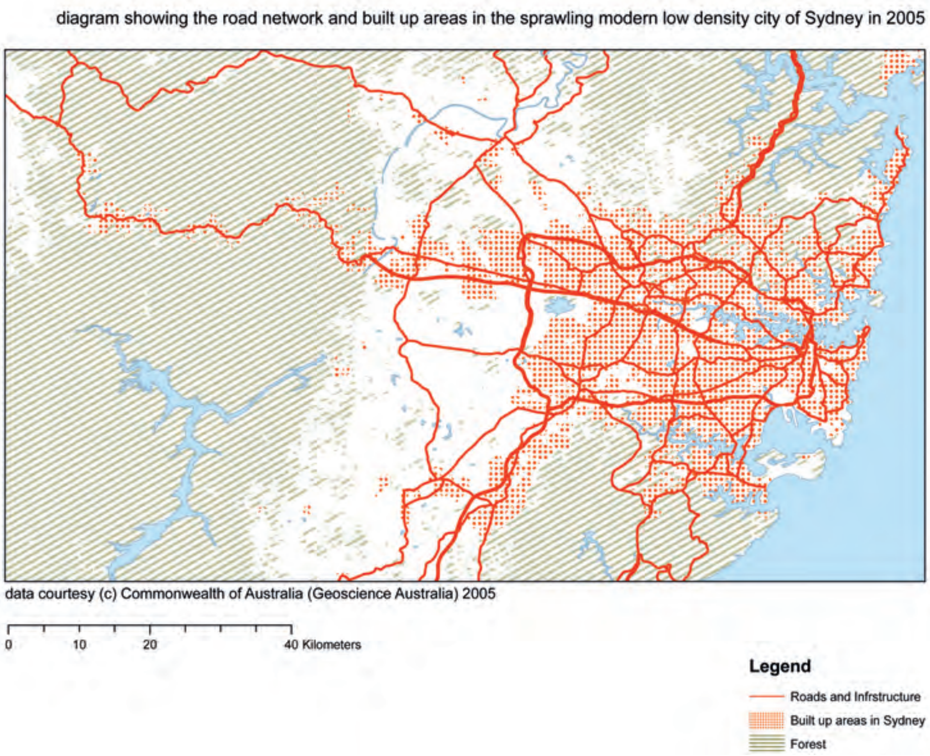
From January to May, tourists descending into the small, rapidly developing town of Siem Reap, Cambodia, look out of their passenger jet windows and see hundreds of glittering ponds set into the dusty dry floodplain of the Tonle Sap lake. During the monsoon the parched landscape below them is transformed into a network of geometric wetlands. The villages and towns become palm-fringed islands in a vivid green expanse of ricefields. The landscape of greater Angkor is full of vibrant communities living amongst the ruins of a medieval hydraulic system. Khmer villagers grow lotus in the ancient ponds; cultivate peppers and aubergines on old temple sites; and subdivide the medieval moats, canals and reservoirs into productive ricefields.

Seasonal variation in hydrology, driven by the monsoon rains, had a profound influence on the medieval civilisation of Angkor, which created a magnificent city in this area between the 9th and 15th centuries AD. From recent archaeological work by an international collaboration called the Greater Angkor Project, we know that this city had a network of canals, embankments, ponds and reservoirs that stretched across an incredible 1,000 square

The waters of the Angkorian reservoir known as the West Baray are still used for irrigation today. The original purpose of the structure was both symbolic and functional.

Even by today's standards Angkor was large: its greater territory and infrastructure was spread over 1,000 square kilometers (below). The built up area of Sydney comprises 1,500 square kilometers (bottom).





kilometers. Designed to manage the monsoon's yearly deluge, the hydraulic network integrated suburbs, ceremonial centres and villages into one low-density, sprawling city.

Wandering through today's shady villages and along the overgrown ridges of old hydraulic works, it is difficult to discern that this was once a metropolis. The problem lies, perhaps, in what we conventionally think of as "urban." Angkor's low-density form differed dramatically from what we might immediately call a city.

Sprawl and low-density cities

The study of Angkor's urban form is pertinent to contemporary urban planning because today's major cities are increasingly low-density. Morphological studies using streets, block patterns and other common analyses are insufficient in understanding low-density cities. Conventional methods for describing cities using an easily definable boundary have become irrelevant. Sprawling, multi-centred, porous and fragmented, contemporary cities are a veritable patchwork of architecture, agriculture, open spaces, obsolete precincts, industry and forests – all networked through a web of transportation infrastructure. Xaveer de Geyter has convincingly illustrated this in his book *After Sprawl: Research for the Contemporary City.* While De Geyter looks at European urban forms, low-density cities are a worldwide phenomenon. Jean Gottman's 1961 investigation of the Eastern Seaboard Megalopolis of the United States reveals a different spatial patterning than T.G. McGee's revelation of the Desakota city of Jakarta, yet they are both low-density cities that require a different scale of spatial investigation and a new order of operational understanding. Although both of these works are now more than 40 years old, the debate on sustainable urban form is still locked in an opposition between the compact city and the low-density city.

In a recent article titled *Causes of Sprawl – a portrait from space,* Marcy Burchfield and a remote sensing research team writes that “we have some understanding of what determines urban growth and the decentralization of economic activity within cities … however, we know almost nothing about the extent to which development is scattered or compact, how this varies across space or what determines that variation.” We need to think more carefully about what a city is – both spatially and operationally – before we cling to one model in pursuit of sustainability.

This value-laden debate on contemporary low-density cities has an interesting counterpart in the archaeological discussions regarding the cities of past civilisations. While there is a wealth of information on the ecological settings of ancient and medieval cities, there is a lack of comparative research on the sustainability of medieval and ancient low-density city forms. One reason for this is that while the low-density city is accepted as a maligned but ubiquitous aspect of modern life, in archaeology there is a resistance to accepting low-density cities as “urban.” A medieval or ancient city is not truly a city, the thinking goes, if it does not have a city wall. Instantly, this narrow viewpoint precludes low-density cities from contributing to a structured debate on the long-term sustainability of cities overall.

For the last one hundred years such thinking has generally been the case at Angkor, which has urban elements far beyond the walled city of Angkor Thom that sits at its centre. The urban elements and infrastructure network of Angkor stretches throughout its greater territory, generating the sufficient interactions needed to make urban functions viable, integrating the temple administrative and religious centres, and, more than likely, facilitating regular commuting between dispersed urban centres for religious festivals. The hundreds of village landscapes form a much larger corporate entity that cannot be comprehended at the local village level. Angkor needs to be understood at the regional level: at the scale of the metropolis.

The study of Angkor

In the 1860s the French explorer Henri Mouhot stumbled upon the ruins of Angkor. He found a city consumed by the jungle, and a wealthy Buddhist monastery still practicing at Angkor Wat, the supreme achievement of Khmer architecture. Even in ruins the temples astonish. In fact, this is part of their allure. Many of the temples remain enveloped in the humid grip of the forest much as they were when the French were seduced by the image of a once sophisticated civilisation swamped by tropical vegetation. Mouhot’s rich renderings and imaginative descriptions inspired a century of impressive scholarship that effected the dynastic reconstruction of Angkor. We now know, from inscriptions in Sanskrit and Khmer left behind in the temples, the names of the rulers, the years they reigned and the monuments that were dedicated by them.

Prasat Bantey Samre is a significant temple far from the centre of Angkor. While there is no inscription that details its foundation date, it was most likely built during the first half of the 12th century during the rule of Suryavarman II.

While the central temples were investigated and integrated into a chronological understanding relatively quickly through the work of the French scholars that made up the École Française d'Extrême-Orient (EFEO), it has taken more than a century to piece together a comprehensive map of the greater "hydraulic" city. Despite pioneering work in remote sensing and archaeological settlement studies by the EFEO, the sheer size of the city and a relentless focus on the temples limited a more accurate understanding of Angkor's spatial form and the implications this may have for how the city once functioned.

Today, the Greater Angkor Project Team is using a combination of remote sensing, aerial reconnaissance, traditional ground surveys and a range of scientific analysis to understand the settlement pattern of Angkor. These diverse approaches are integrated into a geographic information system. This acquisition of perhaps the most extensive library of remote sensed imagery for the region has helped fuel the recent breakthroughs in the study of the city.

The mapping has been limited to a suite of landscape elements that the archaeologists and architects believe, date from the Angkorian period. The elements include rectangular ponds called trapeang, embankments, roads, canals, reservoirs and temple sites and their moats. These elements leave a distinctive spatial signature in remote sensed imagery and have been repeatedly verified through ground surveys. Frequently it is the association between these elements in the landscape that reveals their Angkorian heritage. For example, a temple is often situated on a square mound with a shallow moat and aligned on a strict east-west axis with a trapeang. Other less durable elements such as ricefields have also been found to be Angkorian due to their alignments with temple/moat/trapeang complexes. Together these elements formed a sacred geography that was at once functional and symbolic. The eroded remains of these landscape elements and their associated ceramic scatters and smashed sculptures are all that remain of much of the metropolis. The majority of the everyday architecture, erected in rainforest timbers and palm fronds, has disappeared almost without leaving a trace. Major temples, built in more durable laterite, brick and sandstone, have endured the tropical climate much more successfully.

The structures of typical Angkorian temple complexes can still be seen in the landscape. They comprise of the temple, moats and ponds. Some roads derive from medieval routes.

The mapping and subsequent spatial analysis by Christophe Pottier, Damian Evans and the Greater Angkor Project has revealed key insights into the urban planning of Angkor. The most surprising of these insights is that the hydraulic superstructure seems to have been superimposed upon the landscape with a complete disregard for the previous pattern of land utilisation and cultivation patterns. The severe linear geometries of the embankments and canals cut across the landscape showing little correlation with the underlying, seemingly random distribution of ponds, temple sites and habitation mounds. Embankments, roads and canals were integrated to form multifunctional structures. Soil from the excavation of canals was used for the construction of embankments, which doubled as roads. These

The south embankment of the ancient reservoir known as the East Baray stretches off into the distance. The reservoir is now dry and subdivided with ricefields.

embankments, stretching across the landscape, trapped water behind them and directed it along the contours rather than letting it run its natural course. Embankments in association with immense reservoirs collected large quantities of water for various possible purposes, including flood protection, drainage and irrigation.

Complicated hydrological system

The network is intricate and, considering its size, surprisingly fragile. The very flatness of the floodplain upon which Angkor was constructed calls for a high degree of precision. A forty kilometers cross section of Angkor shows a 0.1 percent gradient. In such an environment siltation and erosion caused problems within the rigid rectilinear geometries used by the Angkorian engineers in the layout of their structures.

In a paper titled, *Redefining Angkor: Structure and environment in the largest, low density urban complex of the pre-industrial world,* Roland Fletcher and his collaborators make the observation that each component of the network relied on the correct functioning of each upstream component of the network. A failure in one part of the network had the potential to cause a failure in the entire system: a "cascade effect." As a result, many sections of the network became obsolete or were altered during the lifespan of the city. Each of the large reservoirs (called barays) identifiable today were built after earlier constructions became dysfunctional. This evidence of continued adjustment of the infrastructure to adapt to changing hydrological conditions is perhaps the most interesting insight gained from the mapping. It reflects a hidden narrative concerning the ecology of the city.

The intricacy of the hydraulic system is perhaps indicative of the dynamic relationship between the hydrology, ricefields and forests of Angkor. As Angkor grew, an increasing population may have stimulated the expansion of the

Khmer villagers subdivided the medieval structures into productive ricefields. The fields have abstracted a shallow water course into a geometric mosaic near Phnom Veak.

city, the construction of more ricefields and further demands on forest resources. An inevitable consequence of forest clearance would have been damage to the watershed. Once the hydrology was altered, the culture of forest clearance, expansion of ricefields and infrastructure construction may have become engaged in a desperate development cycle. As the matrix of ricefields expanded and the damage to the watershed became more severe, any attempt to secure further water resources through infrastructure projects would have been locked into a futile exercise of decreasing returns.

Furthermore, such a development cycle would most likely have escalated erosion, sending more sediment downstream to impact the operation of the hydraulic network. A deeper understanding of the dynamic interaction between the forests, ricefields, hydrology and infrastructure will help us understand the changing ecology of Angkor and offer further evidence on the phenomenon of ecological decline.

Sustainability and urban form

Approaches to studying the landscape ecology of Angkor to date have focused on spatial analysis of the mapped archaeological elements and on "catchments" (in which measurement of processes is limited to the area of land drained by a particular river). Other applicable tools include patch dynamics modelling which attempts to understand landscape processes through an analysis of the spatial heterogeneity of landscapes. Land use change analysis is also possible by incorporating remote sensing, palynological and archaeological data. All of the above approaches operate within a geographic information system software environment.

The mapping of 3,000 square kilometers of the broader Angkor region has led to critical breakthroughs in understanding that cities of the past can be sprawling and fragmented in the same way that modern cities are. While there are other precedents – the Mayan civilization of Central America also constructed sprawling cities – nothing comes close to Angkor in size and scale. Comparative research by Michael Coe and Damian Evans suggests that Angkor is around ten times the size of a major Mayan city such as Tikal. Even by today's standards Angkor was large: compare Angkor's 1,000 square kilometer spread of infrastructure with Sydney's 1,500 square kilometers of built up space.

Following the 15th century AD Angkor saw a drastic reduction in population, the complexity of its urban institutions and utilised land area. There are various reasons for this decline, including shifts in trade routes and invasions from Thailand. However, critical amongst the reasons for Angkor's decline in prosperity is its urban form and operation.

Angkor lasted more than 1000 years as a low-density city. This suggests the need for a closer investigation to test the longevity of such forms. A study of a medieval city may offer more than just the story of the rise and fall of an empire. It may give us a better understanding of the contemporary challenges of sustainable urban form and space.

Agriculture and population

The agricultural basis for Angkor is important as one of the few ways of calculating population. While we know from inscriptions that Ta Prohm temple commanded an entourage of 79,365 people, few other figures exist to help with population estimates. Potential quantities of rice cultivated within Angkor have been used as a rough guide to calculate the city's population in the past. Estimates by Bernard-Philippe Groslier, who popularized the hydraulic city theory, put the population during the Angkor era at one million, with around four hundred thousand in the central "hydraulic city." Since then, estimates produced by Eileen Lustig of the Greater Angkor Project suggest a more conservative figure of between 300,000 and 750,000.

However, the agricultural basis of Angkor is largely still speculative. Reports from a Chinese envoy in the 13th century cite multiple crops per year. This is still true today with different rice maturing at different times of the year due to varied hydrological conditions and the species used. There is also still some dispute concerning the degree to which irrigation was used at Angkor. Current thinking suggests that hydraulic infrastructure and water reserves were used to alleviate poor rainfall during sub-standard monsoons rather than intensify cropping cycles. Scholars are also unsure of the extent of agricultural cultivation during Angkor's peak. The antiquity and extent of medieval rice fields has not been fully scrutinised.

The ideas, theories and data discussed in this article have been developed within the collaborative environment of the Greater Angkor Project.