

# *Supplying the City: The Role of Reservoirs in an Indian Urban Landscape*



KATHLEEN D. MORRISON

IN NONINDUSTRIAL SOCIETIES, urban landscapes are necessarily also agricultural landscapes. With few exceptions, cities must develop and maintain food production zones to support their often substantial nonagricultural populations. Although archaeologists have been well aware of the issue of urban provisioning, we generally have not placed much emphasis on the diversity and complexity of productive organization required to maintain a city, looking instead for more general “types” of cities and of agricultural systems (e.g., Fox 1977; Marcus 1983; Wheatley 1971). In fact, the generation of such types may be complicated by the existence of a considerable degree of diversity and flexibility in urban agricultural arrangements. The agricultural landscape surrounding the city of Vijayanagara, in southern India, highlights some of the diversity in productive facilities and their organization that may exist in even a single area over a relatively short period of time. Such variability has important implications for understanding the nature and course of change in productive organization, because processes of change are likely to be multivariate and the actual paths of change circumstantially flexible.

Vijayanagara agricultural facilities and strategies were diverse both in form and in scale, with areas of production ranging from vast networks of canal irrigation to small rain-fed plots. South Indian agriculture has often been divided into three different types (discussed below), each associated with specific forms of agricultural facilities (Morrison 1992). One form of agricultural facility, the reservoir or “tank,” crosscuts these categories of type and scale, and thus brings out the potential variability in facilities of a single morphological type. Although the need to classify morphological variation in the archaeological record of features and facilities is very real, typological variation in facilities may not be sufficient to characterize organization of production. Instead, we must consider also the ecological and organizational contexts of each facility.

## RESERVOIRS

The use of reservoirs as facilities for water collection and storage is common in areas in which there are rainfall shortages relative to crop requirements, and par-

Kathleen D. Morrison is an assistant professor in the Department of Anthropology, University of Hawai'i, Mānoa, Honolulu, Hawai'i.

*Asian Perspectives*, Vol. 32, no. 2, © 1993 by University of Hawai'i Press. All rights reserved.

ticularly where marked temporal inequities in rainfall exist. Reservoirs have been (and still are) employed throughout the world wherever water "harvesting" and storage are important for agricultural production and/or domestic consumption. A great deal of morphological and functional variability is subsumed within the single term of reservoir, although the overall goal of water collection and storage remains consistent. Features that have been labeled as reservoirs range from Mesoamerican *chultuns* (MacAnany 1990), plastered subsurface pits that might also be termed cisterns, to wells, to large artificial lakes. Descriptions of archaeologically known reservoirs are found in Scarborough (1991), with more specific treatments in sources such as Crown (1987) and Vivian (1974) for the North American Southwest; Stargardt (1983) for Southeast Asia; MacAnany (1990), Matheny (1978), and Woodbury and Neely (1972) for Mesoamerica; and Butzer (1976) for Egypt. However, what unifies these examples is only the common need for and function of water storage and collection and the label of reservoir. Reservoirs are not necessarily associated only with urban settings or complex societies, nor are they always constructed on a monumental scale, even in the case of Vijayanagara.

#### RESERVOIRS IN SOUTH ASIA

A large number of water storage facilities, from the plastered baths of the elite to vast artificial lakes held back behind dams, are termed "tanks" in South Asian studies. However, I here reserve the use of the term reservoir for just one category of "tank," an artificial lake or pond created by the construction of a dam and fed by either runoff or some other source of water. Reservoirs have had a long history in South Asia, extending back as far as the Iron Age or "Megalithic" period (c. 1000 B.C. to c. 300 B.C.) in South and Central India (Sankalia 1962:103), when they were located near graves and settlements. These earliest reservoirs are dated only by association with nearby archaeological sites, a problematic practice in this long-occupied region. However, reservoirs were clearly present by the time of the earliest historic sources in India and played important roles in the structure of agricultural production in the early states and empires of India and Sri Lanka (e.g., Breckenridge 1985; Brohier 1935; Gunawardana 1978; Ludden 1985; Mahalingam 1951; Nilakanta Sastri 1966; Seneviratna 1989; Venkayya 1906; see also Leach 1971). In part, that role varied with the ecological context of the settlement. In the dry zone of Sri Lanka, for example, reservoirs fed both by canals and by runoff were vital to the support of intensive agriculture and thus to the existence of such early cities as Anuradhapura and Polonnaruva (Seneviratna 1989). In more well-watered portions of South India, reservoirs were often found at the terminus of a canal (Ludden 1985), and the storage capabilities of the reservoir enabled temporal fluctuations in river flow to be minimized, reducing the risks of production.

Sharma and Sharma (1990:20) categorized South Asian reservoirs into three types: (1) *system reservoirs*, which receive water from a river or canal and thus are not primarily dependent upon runoff and may not even have a significant catchment area; (2) *nonsystem reservoirs*, or "isolated" reservoirs dependent solely on runoff from their own catchment; and (3) *grouped reservoirs*, which consist of series of interconnected reservoirs receiving water from those upstream (although these may also obtain a significant supply from individual catchments). In part, the geographic distribution of these different types is linked to ecological conditions,

since system reservoirs require an appropriate water source, and nonsystem and grouped reservoirs are more common in drier regions. However, reservoir type is also a reflection of the intensity of land use, so that system reservoirs are found throughout parts of the state of Tamil Nadu where there exists a long history of intensive cultivation and construction of large-scale agricultural facilities such as canals (cf. Ludden 1985). Intensification of areas previously more extensively farmed also may have led to a process of infilling in valleys suitable for the support of long chains of reservoirs (grouped reservoirs). Finally, the logistic considerations of reservoir construction, maintenance, and water allotment varied with both the type and size of the reservoir and created a dynamic of their own, so that the social context of construction, operation, and maintenance must be considered in any attempt to trace out the role of reservoirs in the development of South Asian agriculture. Thus, variability in this class of agricultural facility may be considered along a number of different axes, including environment, the history of land use in a specific area, and the social-political context of the construction, operation, and maintenance of reservoirs.

#### VIJAYANAGARA

The Vijayanagara empire (Fig. 1) was a late pre-Colonial territorial polity that controlled much of southern India between the fourteenth and sixteenth centuries A.D. Ruled over by four successive dynasties of kings, the Vijayanagara empire transformed itself from a small regional kingdom to the major political and military power in southern India within the space of about 200 years. The degree of economic control exerted by Vijayanagara rulers over their vast territory appears to have been rather variable, with some forms of production managed much more closely than others (Morrison and Sinopoli 1992). Power was exerted militarily (Nilakanta Sastri 1966) and ritually (Stein 1980, 1989) in a fairly direct way, and political control was facilitated through a network of lesser kings and chiefs (Appadurai 1978). The historian Burton Stein has gone so far as to suggest that the Vijayanagara empire was, like Geertz's "theatre state" of Bali (1980), a ritually integrated polity, a "segmentary state" (Stein 1980) in which higher-level political structure merely reduplicated the (basic) local units of political authority. This conception has been subject to considerable criticism (Champakalakshmi 1981; Inden 1990; Palat 1987), and it may be most accurate to say that the degree and nature of authority exercised by Vijayanagara rulers varied with the scale (Stein 1989) and arena of control.

Agricultural produce was essential for the support of the capital city of Vijayanagara and indeed of towns and villages throughout the empire. With the exception of the coastal regions (Alaev 1982; Subrahmanyam 1990), the disposition of agricultural produce appears to have been predominantly local in scale. On the west coast, spice-producing regions such as Malabar and coastal trading entrepôts such as Goa ran grain deficits that were met by shipping rice and other foodstuffs from more productive regions such as Kanara in small boats along inland waterways (Fig. 1). Elsewhere, however, the transportation of goods was carried by trains of bullocks or by human porters, because long-distance roads could not support wheeled traffic. Within more localized regions, however, roads passable to bullock carts did exist (e.g., Sinopoli and Morrison 1992), and food production for urban markets constituted an important part of regional agricultural production

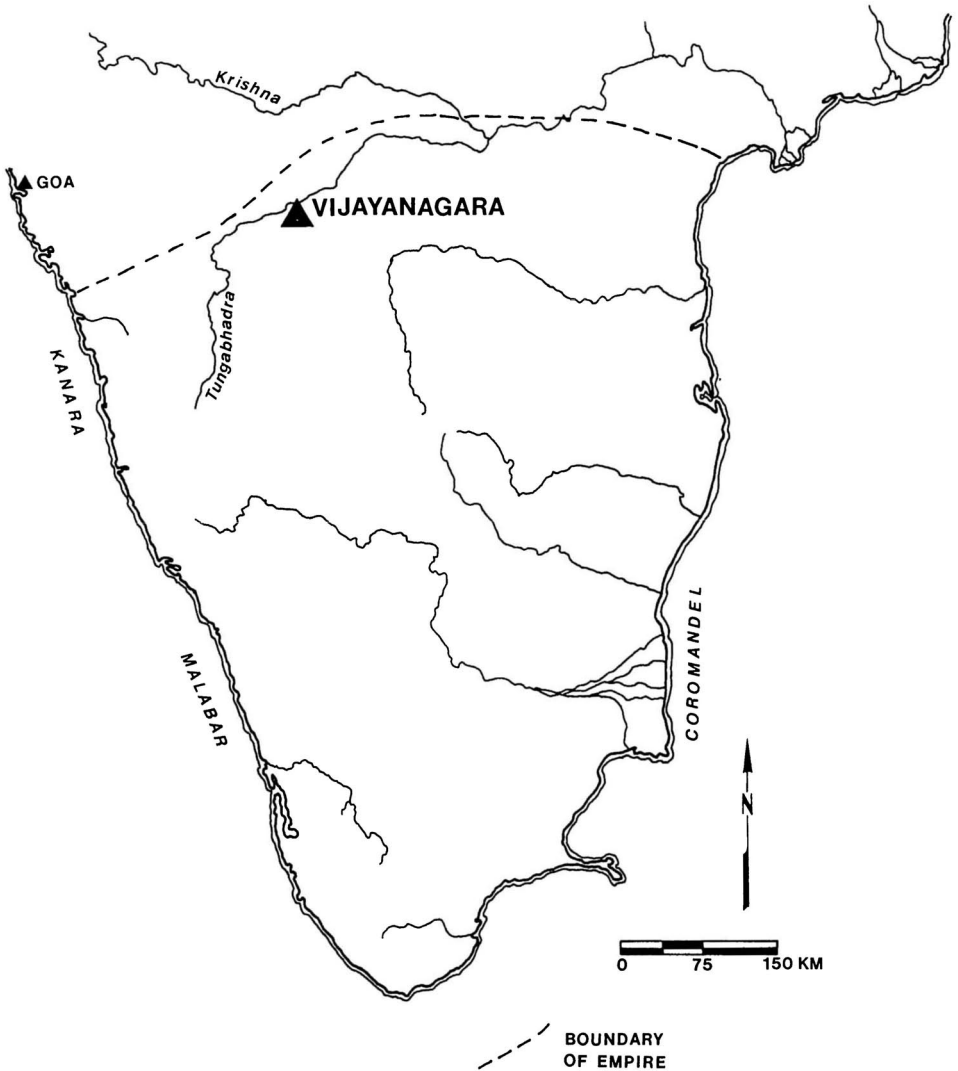


Fig. 1. Southern India, indicating the approximate extent of the Vijayanagara empire.

(Morrison 1992). Agricultural strategies within these localized zones of intensive agricultural production around cities and towns of the Vijayanagara period depended on a broad repertoire of facilities and cropping regimes, including reservoirs. One such zone is that surrounding the capital city of the empire, the “city of victory,” or Vijayanagara.

The capital city of Vijayanagara was located at the northern frontier of the empire, along the edge of the Raichur *doab* (land between two rivers), a fertile tract of dry land that passed in and out of Vijayanagara control. Situated on the south shore of the Tungabhadra, one of the two rivers bounding the Raichur *doab*, the city of Vijayanagara lay just south of the volcanic Deccan Plateau, on the smaller Karnatak Plateau. This region is characterized as semiarid, receiving an average

annual rainfall of less than 500 mm (Johnson 1969). However, this figure is misleading, because rainfall in this region is highly variable, with a variability of between 25 and 30 percent (Spate 1954:58). Within a single year, the distribution of rain is also highly seasonal, with most rain falling during the southwest monsoon. Within this period, there is an overall bimodal pattern of precipitation. Rainfall exhibits a minor peak in early summer, around June, followed by a larger peak in late September or early October. However, even these patterns may vary, so that in any given year the expected rains may fail to come altogether. Thus, it is not difficult to see why the Vijayanagara region falls within what has been called (Kanitkar 1960:1) the "scarcity tract."

In contrast to the rich alluvial deltas with their intensive agriculture that had supported many earlier South Indian capitals, the Vijayanagara region contains only the very limited alluvial soils of the Tungabhadra River. Outside this narrow alluvial strip the landscape is dominated by granitic outcrops with poor soil development. Because frost is not a consideration, soil and water constitute the primary limiting factors in agricultural production. The city of Vijayanagara was one of the largest cities of its day—population estimates range from about 100,000 to 300,000 inhabitants—and the surface archaeological remains of the walled city cover more than 26 km<sup>2</sup>. The urban center or core (Fritz et al. 1985) of the city contains a localized area of monumental, elite architecture enclosed within a series of high masonry walls. Outside of this zone are the traces of a dense urban population, including domestic structures and debris, temples, roads, and markets. North of the walled urban core and adjacent to the Tungabhadra River is a zone containing several large temple complexes, some domestic debris, and areas of intensive irrigated agriculture, termed by Fritz et al. (1984) the "sacred center." These urban features are situated within a rural landscape containing numerous villages and hamlets and characterized by a diverse repertoire of agricultural strategies (Morrison 1992).

#### VIJAYANAGARA AGRICULTURE

The Vijayanagara region supported a complex and internally differentiated agricultural economy, incorporating different types of crops, agricultural facilities, and scales of production. In general, one may classify agricultural regimes in the area according to the permanency of their water supply. Three major categories of crops and cropping regimes are usually identified: wet, dry, and wet-cum-dry. Each of these categories is associated with a particular array of cultigens and of agricultural facilities. There also exist relationships between these categories and the scale of production, the degree of investment and control exercised by non-cultivators, and the labor organization of the cultivators.

Wet cultivation is supported by a permanent, and in this area, artificial water supply. Wet crops are often multicropped, with sometimes as many as three crops a year. Agricultural facilities include canals, canal-fed reservoirs, aqueducts, and, in the case of orchards and gardens, wells. Wet crops include rice, sugarcane, vegetables, and tree crops. Wet agriculture in the Vijayanagara period was marked by a high degree of investment by institutions such as temples and by elite groups of various types (Breckenridge 1985; Mahalingam 1951; Nilakanta Sastri 1966; Stein 1980, 1989). This investment is discussed below.

Dry cultivation is supported only by rainfall and, as such, is limited to the monsoon and immediate postmonsoon season. Agricultural facilities include terraces, gravel-mulched fields, and check-dams. Dry crops include cotton, sorghum, various millets, and oilseeds. With the exception of cotton, an important cash crop, we have no indication of significant institutional involvement in dry agriculture that is reflected in the historical record. Sorghum and millets, both generally grown as dry crops, have been the staple food of the majority of the population in the Vijayanagara region for at least the last several hundred years.

Wet-cum-dry cultivation is a distinctive category, supported by semipermanent or seasonal water sources. The term wet-cum-dry is derived from a Tamil term meaning "dry crops on wet land" (Ludden 1985). Because of the high degree of long-term temporal variability in rainfall, wet-cum-dry plots may be farmed once a year, twice a year, or not at all, depending on the availability of water. Agricultural facilities include reservoirs and wells. Various crops may be grown under wet-cum-dry regimes; sorghum, millets and cotton are the most dependable, though vegetables and even rice may sometimes be grown.

However, the three-fold categorization of South Indian agriculture provides a fairly limited basis for understanding the complexity of the Vijayanagara agricultural landscape, and it can be seen that a single class of agricultural facility, the reservoir, may crosscut these three categories. Reservoirs constitute a morphologically and functionally distinctive category of archaeological feature, and yet different reservoirs may have supported entirely different crops, may have been constructed and maintained by entirely different mechanisms of investment and control, and may vary in scale by orders of magnitude. In the following sections, I will briefly consider the form and operation of Vijayanagara reservoirs, their integration with other facilities, and some of the ways in which their construction and maintenance were financed.

#### FORM AND OPERATION

Reservoirs consist of a water-holding basin and a dam or embankment. The basin is generally situated in a natural hollow or erosion channel; it may also be excavated. Water depths are generally shallow, rarely reaching more than about 10 m. Because of the extensive water-spread and relatively shallow depths, reservoirs are also marked by high evaporation rates (Sharma and Sharma 1990:20) and a high degree of overall water loss. Figure 2 illustrates a hypothetical reservoir in cross-section, showing all of the named elements. Water is retained by an earthen

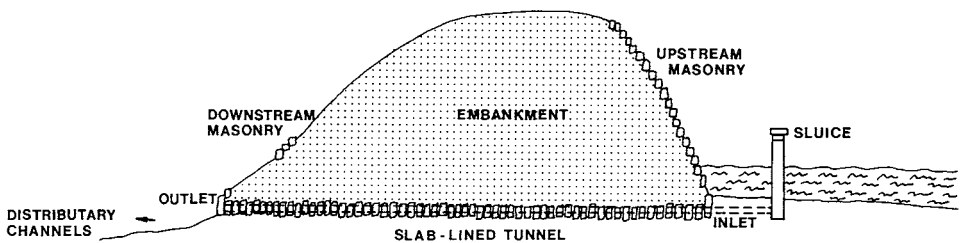


Fig. 2. Cross section of a reservoir, indicating features noted in text.

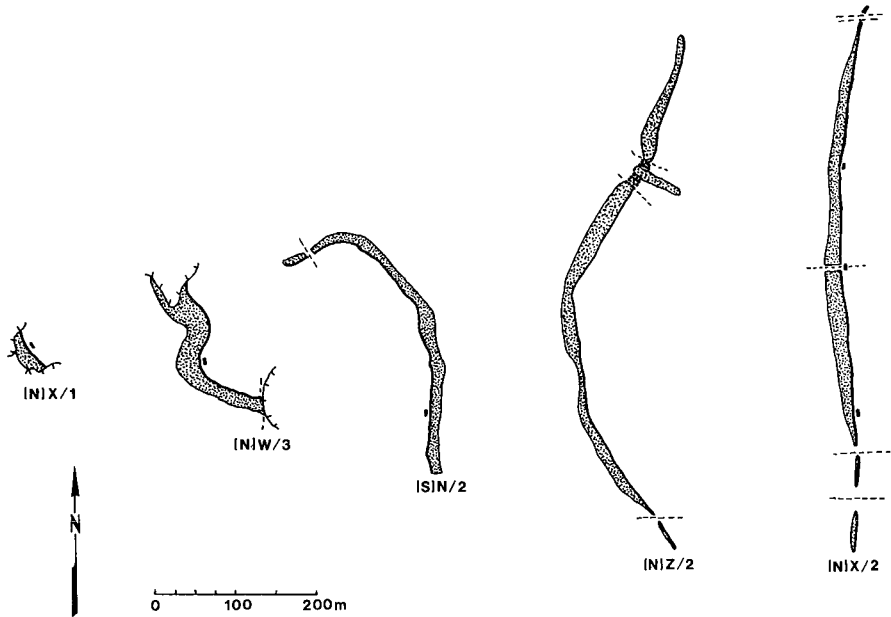


Fig. 3. Plan view of five reservoir embankments from the Daroji Valley.

embankment, usually containing a fine-grained stratigraphy caused by the accumulation of a great many small loads of soil and gravel.

Embankments located and described on survey in the Vijayanagara region (Morrison and Sinopoli in press; Sinopoli and Morrison 1991) varied from 2 m to more than 3 km long; the highest was 28 m high (Fig. 3). Thus, there exists a great range in reservoir size from the truly monumental to the very modest. However, reservoir size is not associated with spatial proximity to the city, since hydrological and geological considerations strongly constrained reservoir placement. Embankments use to good advantage the rocky hills of the region, often damming up valleys between ridges or capturing the runoff from a high granitic outcrop. Most earthen embankments are faced with stepped masonry on the upstream side and occasionally on both sides. Small reservoirs may have no masonry or a few rows of roughly coursed boulders; large reservoirs may have 15 or more courses of cut stone blocks. In many instances, projecting steps and staircases are built into the upstream masonry face. Forty-three reservoirs were located in an intensively surveyed area of c. 50 km<sup>2</sup>, and hundreds more dot the landscape around the city, attesting to their strategic importance.

It is the water source or sources that serve to differentiate Vijayanagara reservoirs. Permanently full reservoirs can support wet crops year-round. There are very few permanent reservoirs in the region around the city, and only one of these is still in use. This reservoir, the Kamalapuram kere (*kere* is the local, Kannada term for reservoir), is one of the oldest known reservoirs associated with Vijayanagara and has an embankment approximately 2 km long. It is supplied with water by a river-fed canal, as well as by seasonal runoff, and still supports continuous cultivation of such water-intensive crops as sugarcane, rice, coconuts, and bananas.

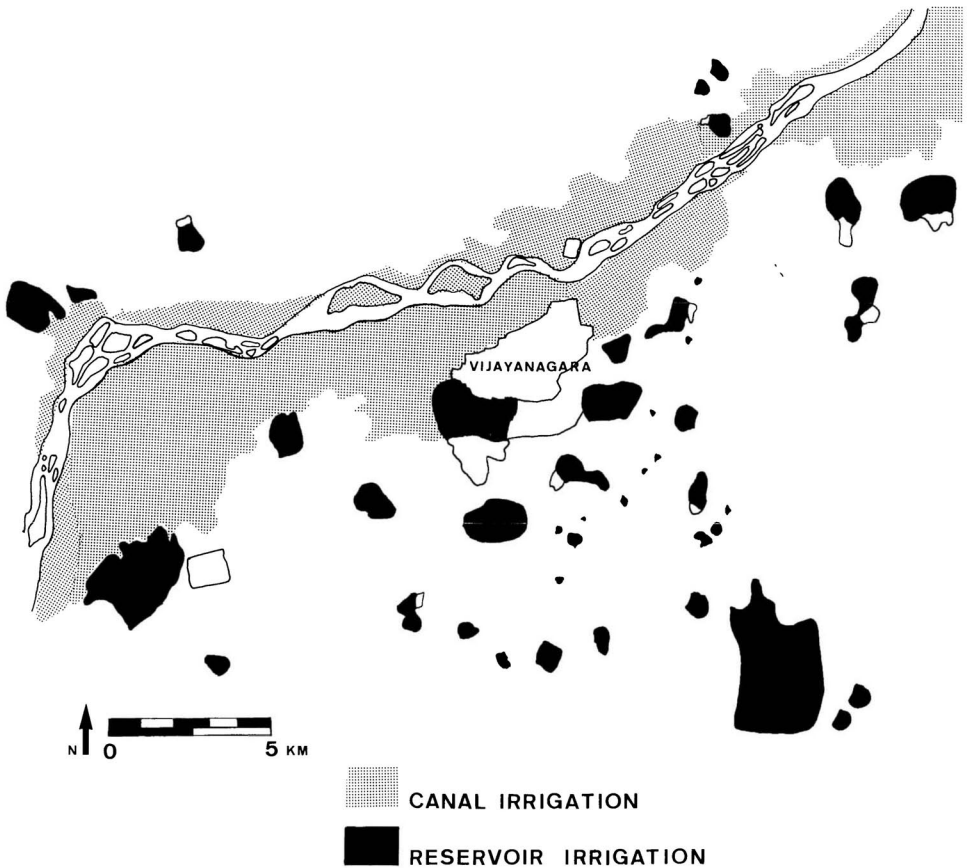


Fig. 4. The city of Vijayanagara and its surrounding agricultural landscape, with zones of irrigation.

Although the narrow strip of land along the Tungabhadra River supported a zone of intensive irrigated agriculture watered by a complex network of canals (Fig. 4), the Kamalapuram kere and a second, unnamed reservoir north of the river appear to have been the only canal-fed reservoirs in the region around the city. This pattern contrasts rather sharply with that found farther south in areas with a longer history of perennially irrigated land. Figure 4 also illustrates some of the variation in scale of reservoirs, with the black area representing an estimate of the area watered by each reservoir. The very smallest reservoirs are too small to be visible at this scale.

The great majority of Vijayanagara reservoirs are filled by seasonal runoff and fall in the wet-cum-dry category. Such reservoirs usually contain water only during the monsoon and for a few months afterward, though some retain small permanent pools. Runoff-fed reservoirs vary greatly in size and in water-holding capacity, depending on the size and nature of their catchments. The Daroji kere, for example, is the largest reservoir in the entire district, but is supplied entirely by runoff. The Daroji kere is also the lowest reservoir in a chain of grouped reser-



voirs. Wet-cum-dry cultivation below runoff-fed reservoirs allowed for quite flexible production strategies. In favorable settings and in wetter years, wet crops such as rice could be grown after the monsoon and dry crops in the winter season. More often, however, wet-cum-dry cultivation allowed for the more secure production of dry crops such as millets.

Some runoff-fed reservoirs belong in the category of dry cultivation, because they never collect any surface water. In all respects these small reservoirs, or embankments (Morrison 1991), operate like terraces or check-dams, but their morphology is similar to that of larger reservoirs. Although little or no water ever collects on the surface, the facility serves to check the flow of surface and subsurface water, and both slows and spreads the flow of water and soil down the slope. Such facilities can be distinguished from reservoirs, however, by local soil conditions (cultivation is carried out in the bed of the facility rather than below it) and sometimes also by structural features.

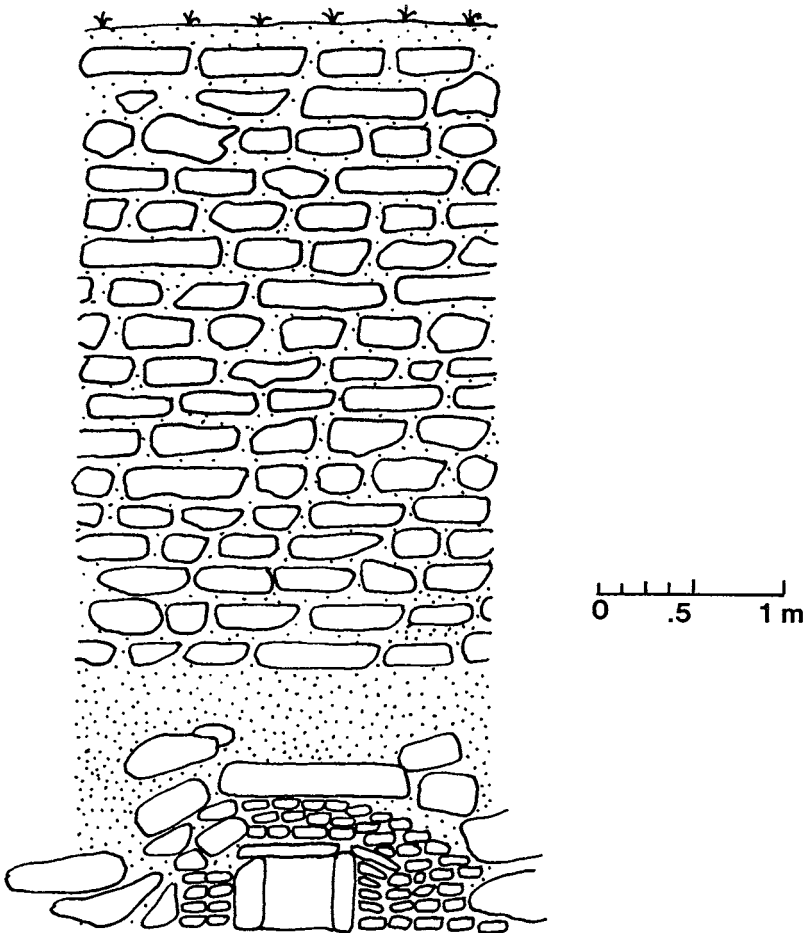


Fig. 5. Exposed tunnel inlet, west elevation, reservoir X/3, Daroji Valley.

Permanent and seasonal reservoirs evince great variability in water collection, but methods of water distribution are essentially similar. Water is released from the reservoirs to the fields below by means of tunnels that are constructed under the embankment. The tunnels are generally rectangular or square in cross section and are lined with stone slabs on all sides (Fig. 5). The slabs are often encased in a brick-and-plaster sheath. On the upstream side of the embankment, the tunnel inlet is usually under water, and the flow of water is regulated by sluices.

Vijayanagara sluices (Fig. 6; Pl. I) are highly distinctive, and serve as one of the best indicators of chronology and degree of elaboration of a reservoir. A typical sluice consists of two stone uprights joined by two or three crosspieces. The tunnel opening is located between the uprights (under water), and all the crosspieces are perforated by a round hole above the tunnel opening. The tunnel can be blocked by lowering a wooden plug attached to a bar or rope into the tunnel opening. The end of the bar or rope may be secured to one of the crosspieces, depending on the level of the water. The upper crosspiece or lintel commonly consists of a three-part molding sequence, similar to those seen in formal architecture of the period (Fritz et al. 1985). Sculptures of deities are also common, and in one case a sluice from a moderately sized, runoff-fed reservoir contains sculptures of the sort termed "donor portraits" in temple architecture. Both the Daroji kere and one other large reservoir in the Daroji system of grouped reservoirs contain huge double sluices, as do some reservoirs from later time periods.

Water can also be released from the reservoir by spillways, or waste weirs (Fig. 7). These "overflow sluices" may consist of very closely fitted stone aprons and low walls or, more commonly, appear to be a jumble of boulders and cobbles. The rocky landscape, the sparse vegetation, and the seasonality of precipitation virtually ensure that the velocity of runoff in the rainy season can be sufficient to breach even the largest reservoir. Spillways allow the excess water to flow out of the reservoir with minimum impact on the embankment. Some very small reservoirs do not have tunnels, but only spillways, and could have been used for only a very limited period of time each year.

On the downstream side of the embankment, water may flow out of the tunnel directly into the fields, or it may flow into a small basin. These basins were made either of stone or of brick and plaster and contain outlets for water to flow into earthen ditches to the fields.

#### INTEGRATION WITH OTHER FACILITIES

Vijayanagara reservoirs did not operate in isolation. Many of them were linked in a physical way with other agricultural facilities, such as the integration of a river-fed canal and reservoir in the case of the Kamalapuram kere. One of the most dramatic examples of interlinked facilities is that of the multiple-reservoir systems (grouped systems). In such systems, reservoirs are arranged along the length of a valley or sloping plain so that the irrigation channels below one reservoir flow into and help supply the reservoir or reservoirs downstream. There are several of these integrated systems in the area around Vijayanagara; one in the Daroji Valley contains at least 15 reservoirs. The Daroji system is located in a long valley, surrounded by hills on three sides, that opens into a wide plain. The valley slopes gently down to the east, so that reservoirs are situated to collect runoff from the

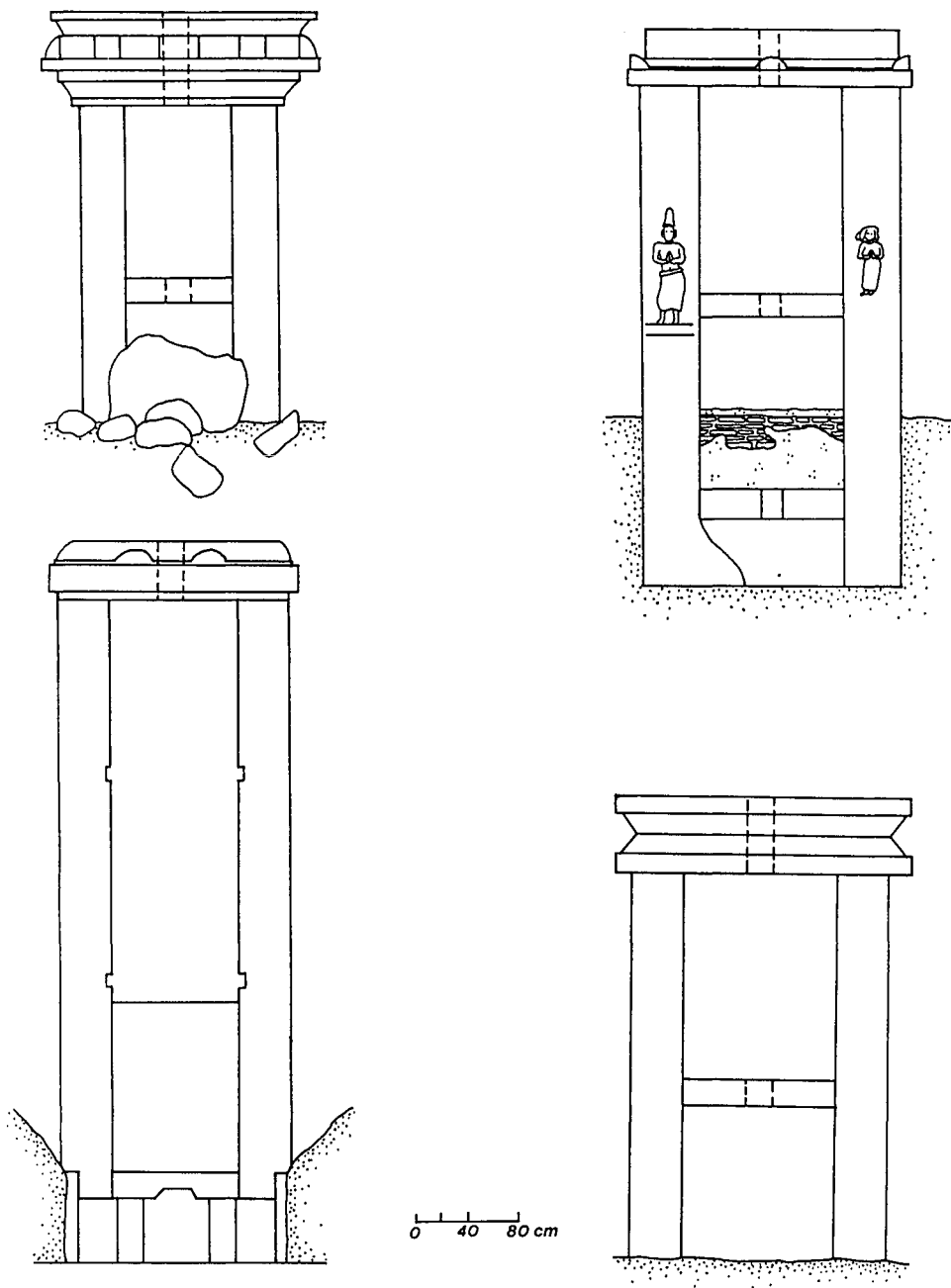
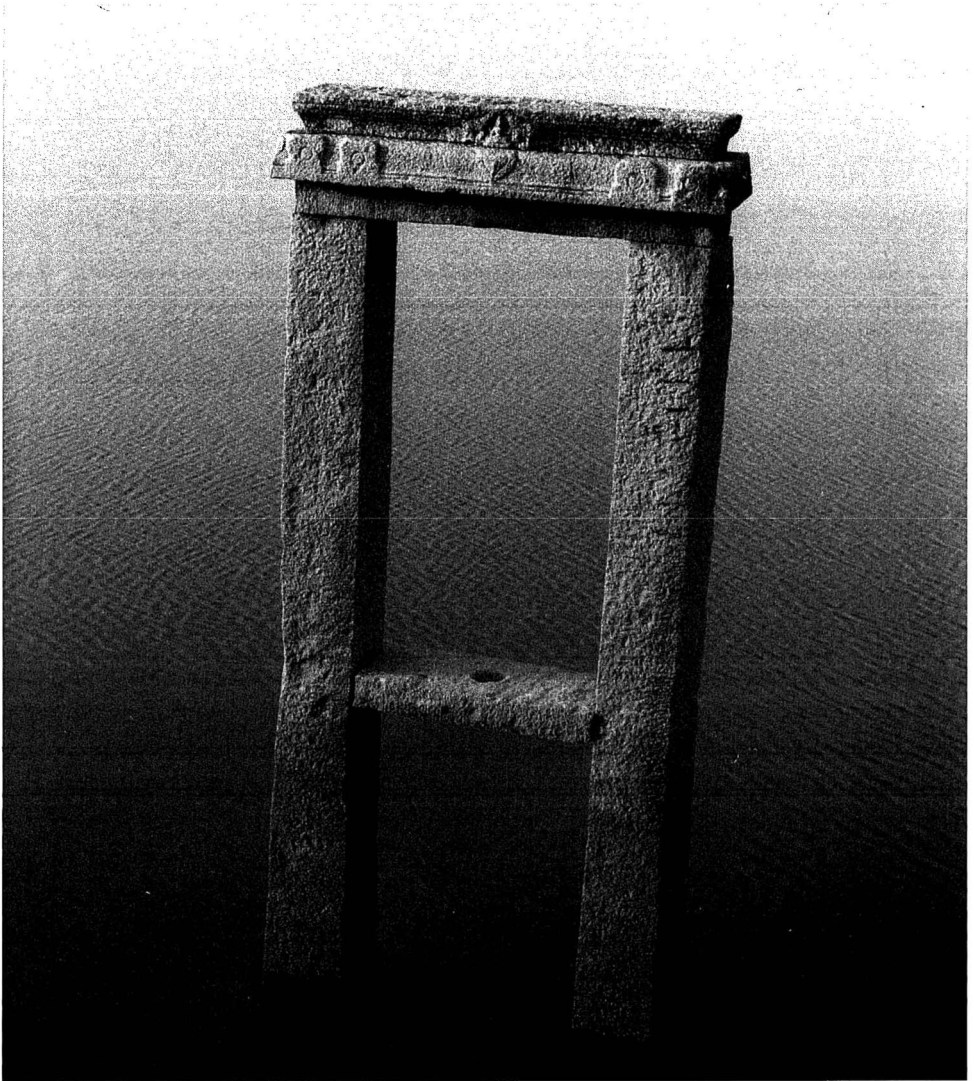


Fig. 6. Four Vijayanagara-period sluice gates. Note donor portraits on upper right sluice gate, VMS-4.



Pl. I. VMS-190, sluice with upper moldings and central carving of the goddess Lakshmi flanked by elephants.

west, south, and north. Although the exact proportions are difficult to estimate, it is clear that at its maximal extent, over half of the land in this funnel-shaped, c. 15-km-long valley (1–5 km wide) was once devoted either to reservoir beds or to fields watered by reservoirs. Almost all of the reservoirs in this system have been breached and are out of use; even so, it is still possible to trace some of the channels connecting different reservoirs. The lowest reservoir in this system is the Daroji kere, which today is permanently full of water. Its huge double sluices date to the late or immediately post-Vijayanagara period (sixteenth to seventeenth centuries A.D.), however, and suggest that the pre-Colonial capacity of this reservoir must also have been very great.

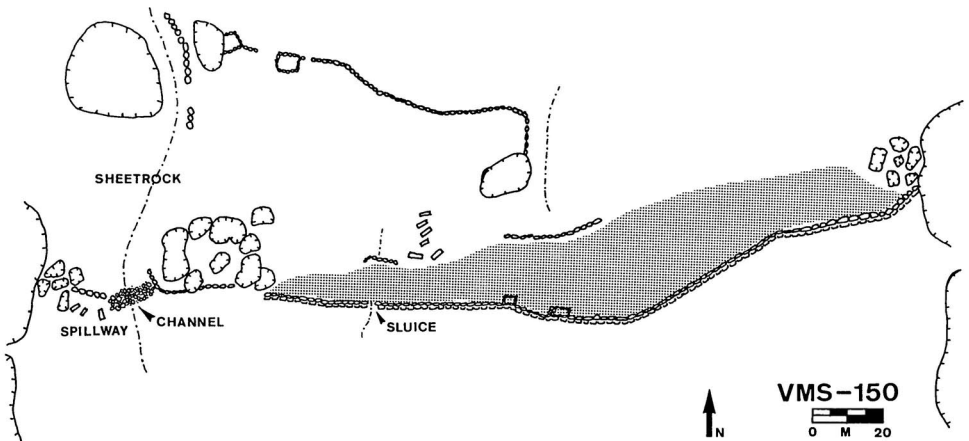


Fig. 7. Plan of reservoir VMS-150, which contains both a sluice and a spillway.

Reservoirs are also often associated with wells. Reservoirs raise the level of the water table in their immediate vicinity, and associated wells may contain water even when the reservoir itself is dry. Wells may also have been important for supplying water to reservoir-side villages and to livestock.

In the driest upland areas, reservoirs sometimes occur in linked systems with agricultural terraces, presumably to take advantage of the greater volume of runoff down more precipitous slopes to store water. The reservoir is usually located at the head of the system, in areas where the low, simple terraces built by Vijayanagara agriculturalists would not have been stable. Figure 8 illustrates one reservoir-terrace system located south of the city. This reservoir is seriously breached, so its sluice arrangements are not clear, but it is evident that the water released from the reservoir flowed down a cultivated slope defined by terrace walls to a large flat area below. Terraces are also often found within the watershed of runoff-fed reservoirs, and their role in preventing soil erosion into the reservoir may have been quite significant (see Morrison 1992). In fact, a very large reservoir lies just downstream of the reservoir-terrace system illustrated in Figure 8. The interrelation of facilities in the Vijayanagara region makes it clear just how difficult it is to understand the spatial structure of past agriculture without taking into account entire landscapes and a range of facilities.

#### INVESTMENT AND CONTROL

Although the construction of large canals was undertaken almost exclusively by kings, the financing of reservoir construction and, to a certain extent, maintenance was a matter of more general participation (Morrison 1992). South Indian temples in this period were major landholders and employers, and the operation of a large temple complex was almost like that of a small city. Kings and queens, members of elite households, groups of merchants or craft producers, and individual investors made grants of land or money to a temple (Appadurai 1978; Breckenridge 1985; Dirks 1987; Mahalingam 1951; Stein 1980). The temple then invested these grants in the construction of irrigation works, especially reservoirs. In some cases,

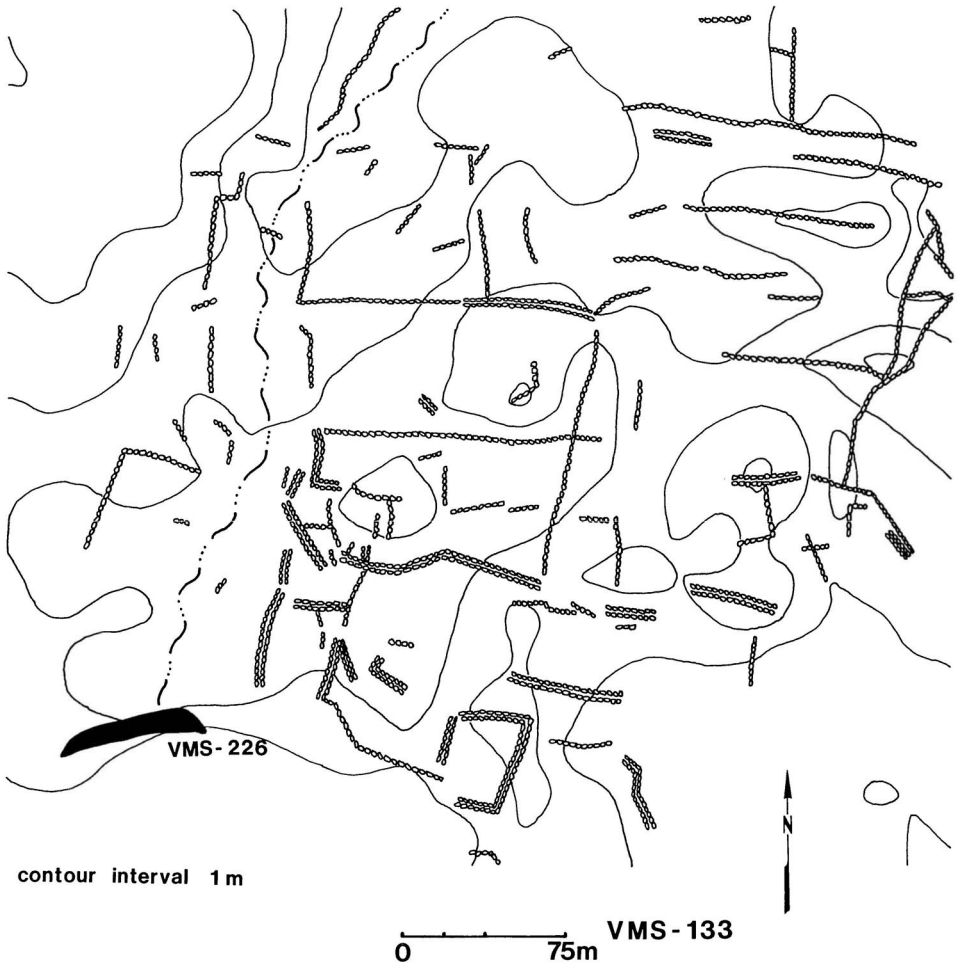


Fig. 8. Plan of reservoir VMS-226 and associated terrace system, VMS-133.

the temple directly controlled the land under the reservoir, but often it did not, and even where temples owned land outright they tended to lease the plots to tenant farmers (Stein 1980). The investment in irrigation meant improved or more reliable crop yields from the land watered by the reservoir, or made an extension of cultivation possible. The investor, in this case the temple, was entitled to a share of the increase in production (*kattu-kodage* rights [Stein 1982]). This produce was offered to the god of the temple and returned by him or her as *prasad*, or sacred food. The original donors were entitled to a share of the *prasad*, which had a definite economic as well as spiritual value and could be consumed or sold to pilgrims. Donors thus received not only religious merit for their gifts, but also economic return. In this way, small donations or investments were pooled to finance irrigation works requiring large capital outlays, and even very-large-scale agricultural facilities could be constructed without either centralized initiative or control.

The significance of this system of investment and of rights in produce is that not only were the rights and obligations of cultivators and investors shared, but so also were the risks. For the investor, the mechanism of temple investment meant that he or she could have small-scale rights in produce from a number of different areas simultaneously (Breckenridge 1985), an important strategy in this agriculturally uncertain region. Furthermore, rights in temple foodstuffs were spread out over a season or more of temple festivals so that the annual variability in the availability and cost of produce could be partially offset. Clearly, the rewards of temple investment were experienced by only a segment of the population, but large-scale public meals provided by temples on ritual occasions may have had somewhat more widespread impact.

Agricultural investment and temple donation were also very important as a political and social strategy. For the cultivator, outside capital made more productive agriculture possible; and although it increased the number of demands on their harvest, the cultivators' share also apparently increased. The construction of a new reservoir would have been significant for agriculturalists not only because it might allow more secure production or the production of more desirable crops, but also because villages were generally situated near reservoirs. Proximity to farmland was one issue, but villages also required secure water sources for people and livestock, and the raised water table created by a reservoir made wells more viable. Temple donations were also arenas for political legitimation, competition, and alliance building. Local political leaders in the provinces were able to forge horizontal material and political ties to temples in their areas and thus subvert efforts at centralization (Appadurai 1978).

What we know about investment in reservoir construction and maintenance is primarily derived from the stone and copper inscriptions of the period, most of which are associated with temples, although many are also built into agricultural features (Morrison 1992). Such information is available only for the larger reservoirs; the thousands of smaller ones are ignored in the historical record. Like reservoirs, temples also vary in size from tiny village shrines to city-sized complexes—perhaps smaller temples were involved in smaller-scale agricultural facilities. Or, it may be that individual households or other groups were responsible for the construction and maintenance of the small reservoirs. Given the absence of nonelite excavated contexts for the Vijayanagara period and the silence of the historical record on nonelite investment, it is clear that a great deal remains to be learned about the range of participation in agricultural activities.

#### IMPLICATIONS FOR URBAN PRODUCTION

The role that reservoirs, especially runoff-fed reservoirs, played in the provisioning of the city of Vijayanagara was critical. In the initial period of agricultural intensification associated with the rapid growth of the city during the early fourteenth century (Morrison 1992), the Kamalapuram kere and several river-fed canals provided a fairly secure source of water for farming, with some canals displacing earlier reservoirs. However, runoff-fed reservoirs were also present at this time in the dry upland zones beyond the reach of canals. During a later period of major agricultural, political, and probably demographic expansion in the sixteenth century, the course of agricultural intensification as reconstructed from archaeological,

historical, and botanical evidence (Morrison 1992) appears to have been complex, consisting of both geographic expansion and intensification in complementary strategies of wet, wet-cum-dry, and possibly also dry agriculture. Reservoirs were a key component in that process of intensification, with the extension of wet-cum-dry cultivation, in particular, both expanding the area of cultivable land and allowing for more secure production in those areas. Much, if not all, of the Daroji Valley system, for example, seems to date to this sixteenth-century period of agricultural change.

I have described a few aspects of the form and operation of Vijayanagara reservoirs to illustrate the diversity of one urban agricultural landscape. Vijayanagara agriculture incorporated multiple components, which have usually been categorized using the terminology of wet, dry, and wet-cum-dry cultivation. Reservoirs were part of all three of these forms of cultivation, working in concert with canals to provide perennial water sources, tapping runoff to provide seasonal water sources, or integrated with terraces in zones of dry cultivation. Within each category, however, reservoirs varied greatly in scale, elaboration, and probably also in their mode of finance. In spite of their morphological similarity and integrity as an archaeological "site type," South Indian reservoirs played diverse roles in the agricultural organization of the region. These roles can be differentiated, in part, by looking beyond the typological assignment of the facility and examining morphological variation in the reservoirs themselves. A fuller appreciation of actual production dynamics requires, however, a consideration of context—geomorphology, hydrology, settlement, and the historical development of the landscape. To understand the structure of and changes in agricultural production, we must begin to move beyond the simple dual classification of agricultural facilities and regimes as either intensive or extensive, as irrigated or dry, and begin to look for and to attempt to understand some of the complexity and diversity of productive strategies in urban agricultural landscapes.

#### ACKNOWLEDGMENTS

Thanks are given to the Government of India and the Archaeological Survey of India for giving research permissions and to the American Institute of Indian Studies for facilitating all phases of the research. Local support and collaboration were provided by the Directorate of Archaeology and Museums, Karnataka, and by Deccan College. Financial support for the Vijayanagara Metropolitan Survey was awarded by the American Institute of Indian Studies, the National Geographic Society (Grant 4186-89), The Wenner-Gren Foundation for Anthropological Research (Grant 5044), and the Smithsonian Institution Foreign Currency program (Grant FR00627500). As always, special thanks to Vijayanagara project members and to Mark Lycett and Michael Graves for their comments on the manuscript.

#### REFERENCES

- ALAEV, L.  
1982 Nonagricultural production: South India, in *The Cambridge Economic History of India*, Vol. 1: c. 1200–c. 1750: 315–324, ed. T. Raychaudhuri and I. Habib. New Delhi: Orient Longman.
- APPADURAI, A.  
1978 Kings, sects, and temples in South India, 1350–1800 A.D., in *South Indian Temples: An Analytical Reconsideration*: 47–73, ed. B. Stein. New Delhi: Vikas.



- BRECKENRIDGE, C.  
1985 Social storage and the extension of agriculture in South India 1350 to 1750, in *Vijayanagara: City and Empire*: 41–72, ed. A. L. Dallapiccola. Wiesbaden: Franz Steiner Verlag.
- BROHIER, R. L.  
1935 *Ancient Irrigation Works in Ceylon*, parts I–III. Columbo: Columbo Government Press.
- BUTZER, K. W.  
1976 *Early Hydraulic Civilization in Egypt: A Study in Cultural Ecology*. Chicago: University of Chicago Press.
- CHAMPAKALAKSHMI, R.  
1981 Peasant state and society in medieval South India: A review article. *The Indian Economic and Social History Review* 18:411–426.
- CROWN, P. L.  
1987 Water storage in the prehistoric Southwest. *Kiva* 52:209–228.
- DIRKS, N. B.  
1987 *The Hollow Crown: Ethnohistory of an Indian Kingdom*. Cambridge: Cambridge University Press.
- FOX, R.  
1977 *Urban Anthropology*. Englewood Cliffs: Prentice Hall.
- FRITZ, J. M., G. MICHELL, and M. S. NAGARAJA RAO  
1984 *Where Kings and Gods Meet: The Royal Centre at Vijayanagara*. Tucson: University of Arizona Press.
- GEERTZ, C.  
1980 *Negara: The Theatre State in Nineteenth Century Bali*. Princeton: Princeton University Press.
- GUNAWARDANA, R. A. L. H.  
1978 *Robe and Plough: Monasticism and Economic Interest in Early Medieval Sri Lanka*. Monograph of the Association for Asian Studies 35. Tucson: University of Arizona Press.
- INDEN, R.  
1990 *Imagining India*. Oxford: Basil Blackwell.
- JOHNSON, B. L. C.  
1969 *South Asia*. London: Heineman.
- KANITKAR, N. V.  
1960 *Dry Farming in India*, 2nd ed. New Delhi: Indian Council of Agricultural Research.
- LEACH, E. R.  
1971 *Pul Eliya, a Village in Ceylon: A Study in Land Tenure and Kinship*. Cambridge: Cambridge University Press.
- LUDDEN, D.  
1985 *Peasant History in South India*. Princeton: Princeton University Press.
- MACANANY, P. A.  
1990 Water storage in the Puuc Region of the northern Maya: A key to population estimates and agricultural variability, in *Precolumbian Population History in the Maya Lowlands*: 263–284, ed. T. P. Culbert and D. Rice. Albuquerque: University of New Mexico Press.
- MAHALINGAM, T. V.  
1951 *Economic Life in the Vijayanagar Empire*. Madras: University of Madras Press.
- MARCUS, J.  
1983 On the nature of the Mesoamerican city, in *Prehistoric Settlement Patterns: Essays in Honor of Gordon R. Willey*: 195–242, ed. E. Z. Vogt and R. M. Leventhal. Albuquerque: University of New Mexico Press.
- MATHENY, R. T.  
1978 Northern Maya lowland water control systems, in *Prehispanic Maya Agriculture*: 185–210, ed. P. D. Harrison and B. L. Turner II. Albuquerque: University of New Mexico Press.
- MORRISON, K. D.  
1991 Small-scale agricultural features: Three Vijayanagara embankments, in *Vijayanagara: Progress of Research 1987–88*: 81–84, ed. D. V. Devaraj and C. S. Patil. Mysore: Directorate of Archaeology and Museums.

- 1992 Transforming the Agricultural Landscape: Intensification of Production at Vijayanagara, India. Ph.D. diss., University of California at Berkeley.
- MORRISON, K. D., and C. M. SINOPOLI  
 1992 Economic diversity and integration in a precolonial Indian empire. *World Archaeology* 23:335–352.
- in press Archaeological survey in the Vijayanagara Metropolitan Region: 1990, in *Vijayanagara: Progress of Research 1990–91*, ed. D. V. Devaraj and C. S. Patil. Mysore: Directorate of Archaeology and Museums.
- NILAKANTA SASTRI, K. A.  
 1966 *A History of South India*, 3rd ed. London: Oxford University Press.
- PALAT, R.  
 1987 The Vijayanagara empire: Re-integration of the agrarian order of medieval South India, in *Early State Dynamics: 170–186*, ed. H. J. M. Claessen and P. van der Velde. Leiden: E. J. Brill.
- SANKALIA, H. D.  
 1962 *Indian Archaeology Today*. Bombay: Asia Publishing House.
- SCARBOROUGH, V. L.  
 1991 Water management adaptations in non-industrial complex societies, in *Archaeological Method and Theory*, Vol. 3: 101–154, ed. M. B. Schiffer. Tucson: University of Arizona Press.
- SENEVIRATNA, A.  
 1989 *The Springs of Sinhala Civilization (An Illustrated Survey of the Ancient Irrigation System of Sri Lanka)*. New Delhi: Navrang.
- SHARMA, R. K., and T. K. SHARMA  
 1990 *Textbook of Irrigation Engineering*, Vol. I: *Irrigation and Drainage*. New Delhi: Oxford and IBH.
- SINOPOLI, C. M., and K. D. MORRISON  
 1991 The Vijayanagara Metropolitan survey: The 1988 season, in *Vijayanagara: Progress of Research 1987–88*: 55–69, ed. D. V. Devaraj and C. S. Patil. Mysore: Directorate of Archaeology and Museums.
- 1992 Archaeological survey at Vijayanagara. *Research and Exploration* 8:237–239.
- SPATE, O. H. K.  
 1954 *India and Pakistan: A General and Regional Geography*. London: Methuen.
- STARGARDT, J.  
 1983 *Satingpra: The Environmental and Economic Archaeology of South Thailand*. Studies in S.E. Asian Archaeology 1, ISEAS. Oxford: British Archaeological Reports International Series 158.
- STEIN, B.  
 1980 *Peasant State and Society in Medieval South India*. New Delhi: Oxford University Press.
- 1982 South India: Some general considerations of the region and its early history, in *The Cambridge Economic History of India*, Vol. 1: *c. 1200–c. 1750*: 14–42, ed. T. Rayachaudhuri and I. Habib. New Delhi: Orient Longman.
- 1989 *Vijayanagara*, The New Cambridge History of India, Vol. 1, part 2. Cambridge: Cambridge University Press.
- SUBRAHMANYAM, S.  
 1990 *The Political Economy of Commerce: Southern India, 1500–1650*. Cambridge: Cambridge University Press.
- VENKAYYA, V.  
 1906 *Irrigation in South India in Ancient Times*, Archaeological Survey of India Annual Report for 1903–1904. Calcutta.
- VIVIAN, R. G.  
 1974 Conservation and diversion: Water-control systems in the Anasazi Southwest, in *Irrigation's Impact on Society*: 95–112, ed. T. E. Downing and M. Gibson, Anthropological Papers of the University of Arizona, 25. Tucson: University of Arizona Press.

WHEATLEY, P.

1971 *The Pivot of the Four Quarters: A Preliminary Enquiry into the Origins and Character of the Ancient Chinese City*. Chicago: Aldine.

WOODBURY, R. B., and J. A. NEELY

1972 Water control systems of the Tehuacan Valley, in *Chronology and Irrigation: Prehistory of the Tehuacan Valley*, Vol. 4: 81–153, ed. F. Johnson. Austin: University of Texas Press.

#### ABSTRACT

A class of agricultural facility, the reservoir or “tank,” has played an important role in the development of South Indian urban centers. The form and operation, patterns of integration with other facilities, and modes of investment in reservoirs are discussed in the context of the pre-Colonial city of Vijayanagara (c. A.D. 1300–1600). In spite of their general morphological similarities, reservoirs played diverse roles in the organization of Vijayanagara agricultural production and in its pattern of change through time. **KEYWORDS:** Irrigation, South Asia, urbanism, agriculture.