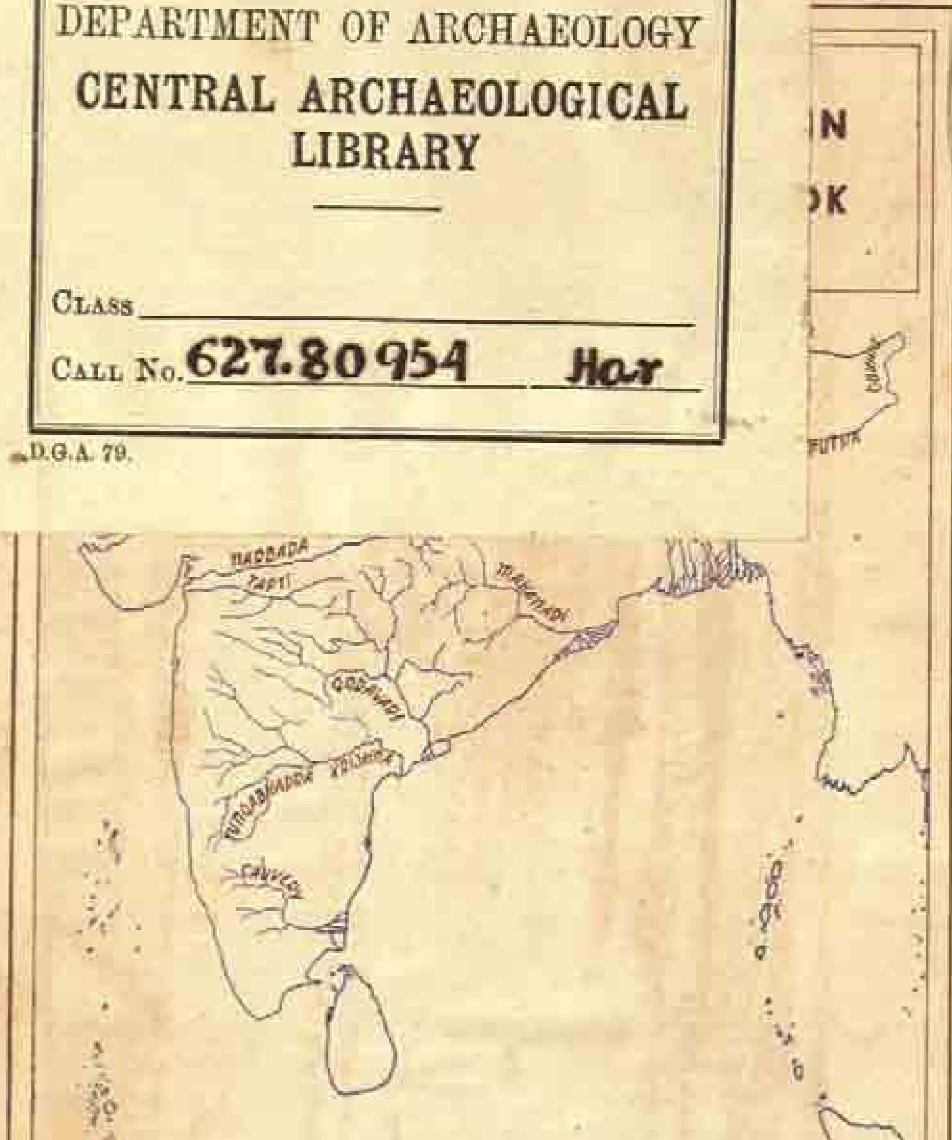
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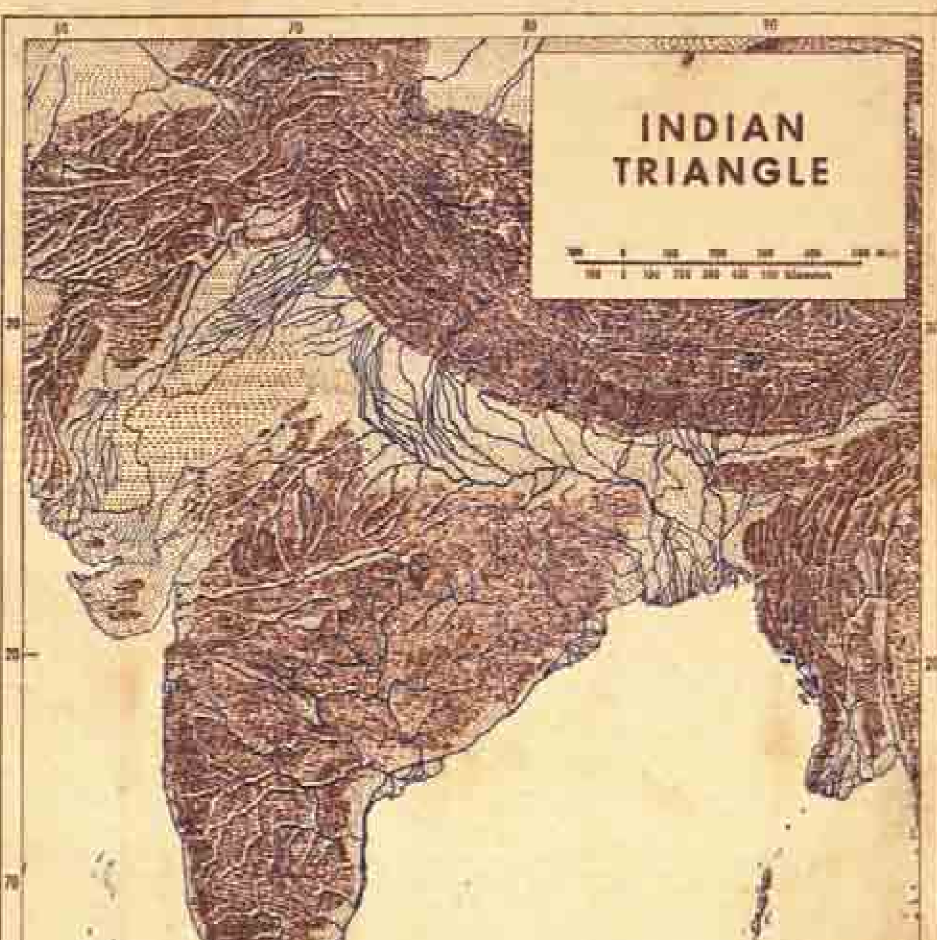
INDIAN
TRIANGLE

NEW INDIA'S RIVERS

NEW INDIA'S RIVERS

HENRY C. HART
Ph.D., Political Science Faculty,
University of Wisconsin

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6 & 7 CLIFFORD STREET, LONDON W. 1
AND AT
NEW YORK, TORONTO, CAPE TOWN AND MELBOURNE

First published 1956

PRINTED IN INDIA
BY S. C. GHOSE AT CALCUTTA PRESS PRIVATE
LIMITED, 1 WELLINGTON SQUARE, CALCUTTA.

TO
ALL WHO DIED
WITHOUT SEEING
THE NEW INDIA
THEY BUILT

free from Orient Longmans Bombay 4.6.58

PREFACE

This is not a travelogue, not a technical book of hydrology or engineering. It is a book about men at work on rivers: engineers, administrators, politicians, stonemasons, operators of earthmoving machines, labourers—men and women. In its physical dimensions their job, harnessing India's rivers, is one of the largest on earth. But consider its human dimensions. Can an engineer build a dam twice as high and twice as fast as he, or any of his men, has seen one built? Can legislators, representing citizens voting for the first time, select sound plans, and hold to them staunchly through ten years of minor and major crises? Tens of thousands of humble folk must be uprooted. Who among them will accept the discipline of the common good: the workmen at the dams, in their new trade unions? Those dispossessed from the reservoirs? And what of the millions of cultivators suddenly asked to use, and pay for, the irrigation canals?

When habits and institutions are stretched like this forthwith to the dimensions of a new order it is commonly called a revolution. Revolutions can be expected to energize themselves partly by the excitement of tearing down the old regime. But India is trying something new, even in revolutions: no destruction, no terror, no hatred of old rulers. Can the power of constructive leadership alone quicken the blood of a generation? Can men make out the future rising in the midst of the familiar? Can a revolution, in short, be *built?* That question is implicit in all of India's sweeping plans. Considered in this broad sense, the river valley developments ask that men lift their skills, their associations, their ideals out of old channels, while they are lifting the rivers out of theirs; the former is at once the necessary means and the highest end of the latter. Could it be so, India's rivers—Ganga, Jumna, Cauvery, Damodar, Mahanadi, Tungabhadra, Sutlej, Tapti, Koyna, Kosi, Godavari, Krishna—immemorially revered, would earn a fresh reverence from New India.

For me, I must acknowledge, this theme has a personal attraction. To the 'underdeveloped area' (the awkward term was not yet fashionable) in which I matured, a newly-harnessed river brought new life. That was the Tennessee River in America. As a minor administrative officer in the Tennessee Valley Authority, I shared the excitement. It was a bold experiment in government, hardly a revolution. For the most part, it worked.

In India, the experiment is writ large. Many rivers, big and small, are being dammed and used. Into that work goes something like one-fourth of a hard-pressed nation's savings, perhaps still more of her specialized talents. The success or failure will be writ large, too. The repercussions will spread far outside the Republic of India. Two-thirds of the human race have begun to think of their economies as underdeveloped. To some hundreds of millions of them, what India can do with her rivers will be an example.

With these questions in mind, though vaguely, I proposed in 1952 to come to India to study river valley developments. 'The time is not ripe for your investigations,' said several officials who knew India well. I could see how that might be. Why should any nation, straining to achieve something big and new, open the record in mid-course to appraisal by a foreigner. But once I reached India, the objection proved imaginary. To be sure, key facts about the Bhakra-Nangal project were reserved; India was engaged in difficult negotiations with Pakistan concerning the waters of the Sutlej as of other Indus tributaries. But at other projects, nothing I asked for was withheld.

The strongest single image I retain from two years in India is that of a busy—no, an overburdened—administrator pushing back the relentless press of papers on his desk, or of an engineer coming in after ten hours at the work site, to answer my questions. Those men gave their time; they gave their confidence, too. Their assistance toward a detached study (they could certainly not all agree to all its conclusions) would in any case deserve a scholar's respect. Its real worth is measured by their own dedication to the work they helped me to study with detachment.

Among all those engaged on the work to whom I feel this sort of gratitude, I want here to thank those whose help contributed most to this particular book.

For initial advice and permission to gather information: A. N. Khosla, Tarlok Singh, T. Sivasankar, Kanwar Sain, A. R. Khanna, M. Narasimhaiya, S. N. Mozumdar, Sudhir Sen.

On the Central Government, (besides those named): S. Ratnam, Yadava Mohan, M. Hyath, Allan Monkhouse, M. L. Sood, S. Venkataraman; *on Parliament*: Jaisukhlal Hathi, Bali Ram Bhagat, Hare Krushna Mahtab, Vithal Babu.

On the Cauvery projects: Mirza M. Ismail, K. R. Seshachar, George Chandy, H. Ananthachar, G. V. K. Rao (*all of Mysore*): and M. S. Sivaraman, P. S. Natarajan, E. V. Narayanan (*of Madras*).

On the Damodar Valley Corporation: P. P. Varma, B. C. Guha, A. N. Ganguli, K. S. V. Raman, Andrew M. Komora, Franklyn Rogers, P. K. Bhattacharya, A. L. Das, H. N. Ray, Sohan Lal, B. C. Mullick, M. N. Das, B. Parthasarathy, S. S. Pillai, A. N. Lahiri, A. N. Sinha, B. P. Neogy, K. Subramaniam, R. S. Mandal, N. K. Bhose, N. Gopalakrishnan, S. M. Banerjee (*of D.V.C.*); B. C. Roy, Sushil Kumar Dey, Asok Mittra (*of West Bengal*); Ramcharitrar Singh, S. V. Sohoni, T. P. Singh (*of Bihar*).

On Hirakud: M. S. Thirumale Iyengar, N. Dharmarajan, R. P. Verma, A. R. Chellani, K. Padmanabha Pillai, R. C. Hoon, S. C. Das, S. Raghavachari, N. K. Agrawal, S. P. Chugh, A. Shankaran, G. V. Anantha Ramiah, R. M. Singh

(*of the project*); N. K. Chaudhuri, R. N. Rath, B. Sivaraman, Juganath Misra, H. B. Mohanty, Banamali Patnaik (*of Orissa*).

On Tungabhadra: A. R. Venkataraman, K. R. Rajagopalan, S. Ramaiyer, G. Srirangachary, M. E. Hussain, M. Hanumantha Rao, D. Satyanarayana, S. K. Iyer, N. V. Khursale (*of both sides of the project*); N. Sanjeeva Reddi, B. Joogappa, K. Krishnaswami, I. Sambasiva Rao (*of Andhra*); Mehdi Nawaz Jung, K. V. Rao, Zahir Ahmed, Abdul Khader, Hassan Ali (*of Hyderabad*).

On Bhakra-Nangal: C. P. N. Singh, Choudri Lahri Singh, R. R. Handa, R. K. Gupta, H. L. Vadera, M. P. Mahesh, Ajit Singh Kalha, S. S. Kumar.

On Bombay projects: T. J. Mirchandani, M. L. Champhekar.

Shri P. S. Rau very kindly read several chapters of the manuscript to catch errors of fact; Shri S. Venkataraman read it all. I deeply appreciate that help. Shri K. K. Sinha and P. K. Menon opened to me the store of knowledge in the files of their *Indian Journal of Power and River Valley Development.*

Mrs. Earl G. Thompson typed the final manuscript impeccably.

This book testifies to the enterprise of the publishers, Orient Longmans, Calcutta, in bringing out a book on a subject hitherto touched on only in government documents and newspaper reports, and to the patience of the staff of that Company in dealing with an unbusinesslike author.

The maps became something of an adventure in themselves. Through the medium of simple black-and-white drawings, the cartographer had to make complex engineering plans intelligible to the layman. This Mr. Randall Sale of the University of Wisconsin Department of Geography did, putting aside his own work for several weeks. For this major contribution I thank him, and Professor Arthur Robinson, chairman of that department. One front endpaper is made from a map drawn by Dr. William L. Thomas for the book *Asia, East by*

South by J. E. Spencer. I am indebted to them, and to the publisher, John Wiley and Sons, New York, for permission to use the map. For the photographs I thank those whose names appear with the captions.

My opportunity to be in India during 1953-54 to make this study I owe to a grant from the Ford Foundation Board on Overseas Training and Research in New York. The auspices were ideal for a research worker. That grant directly followed a Fulbright lectureship in India in 1952-53. I feel deeply grateful to both foundations. A research grant from my own university in the summer of 1955 helped me finish the manuscript.

Projects are being finished and dedicated so often in these years that, in its discussion of physical works, this book may not long seem up-to-date. But all of us engaged in this effort to understand and evaluate a very dynamic subject, (especially, I should think, the reader) have a compensating advantage. Each year's progress will show us more clearly whether events bear out the conclusions about the abiding human values and problems of the river valley projects for which this book is, more than anything else, a search.

Madison, April 1956 Henry C. Hart

ACKNOWLEDGMENTS

Permissions to quote from the sources named are gratefully acknowledged to the following:

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Jonathan Cape Limited, London; Louis Fischer, *The Life of Mahatma Gandhi*, 1951.

John Day Company, New York and Signet Press, Calcutta; Jawaharlal Nehru, *The Discovery of India*, 3rd. ed., Calcutta 1947.

The Director General of Archaeology in India for the quotation on pp, 15-16 from Epigraphia Indica, vol. VIII p. 42 ff.

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The Indian Journal of Power and River Valley Development; extracts from articles by B. P. Saxena, 1952 and Prof. Innokenti Kandalov, 1953.

Sir M. Visvesvaraya; quotations from his published works, including *Memoirs of my Working Life*, Bangalore 1951.

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1

DESCENT OF THE GANGA

INDIA regards her rivers with a love and awe which are no recent growths. In this, as in other paths of Indian thought, history guides us but a little way toward the immemorial sources of her habits and her attitudes. Where history leaves off, the voices of the past call loud but indistinct, beguiling the unwary modern to discover in some ambiguous phrase of ancient lore the origin of what he likes in India today. All the voices of tradition declare the sacredness of rivers, but there is one voice more insistent and dramatic than the rest. It tells of the origin of Ganga, the holiest of holy streams.

There are few Indians living, and probably few dead, who have not heard this story. It was woven by India's Homer, Valmiki, into the epic *Ramayana*, the most familiar and the most attractive narrative of Indian culture. The painted carvings on the wooden temple car in an Andhra village, the folk play staged before glaring gasoline lanterns under Malabar palms, the recitation in cultured Bengali to a barge-load of visitors at the Banaras ghats, the chant of the mendicant repeated by the housewife to her untiring children, the temple sculpture of Thailand and the dances of Bali faithfully recording the lore exported by prehistoric Indian mariners: all tell the tale. Valmiki himself must have embroidered it upon his narrative of Rama's exploits only because it was an accustomed favourite of his generation.

Ganga was the daughter of the mountain god, Himalaya, a dweller in heaven as the collective consort of all the gods. The need to fetch her down arose when legendary king Sagara lost all his 60,000 sons, burned by the wrath of Vishnu. Their souls could only be released to heaven by Ganga's waters purifying their ashes where they lay in the nether world. For this pious rite Sagara's descendants sought to bring the river down; two generations failed. The king who succeeded was Bhagiratha. Brahma took pity on him for his harsh and patient penances, and gave him the secret of diverting the river from heaven. The archaic verses of Griffith's translation of the *Ramayana* tell the story as well as English can:

Ganga, whose waves in heaven flow
Is daughter of the Lord of Snow.
Win Siva that his aid be lent
To hold her in her mid descent,
For earth alone will never bear
Those torrents hurled from upper air.

Siva helped:

He held the river on his head,
And kept her wandering where
Dense as Himalaya's woods were spread
The tangles of his hair.

. . . .

On Siva's head descending first
A rest the torrents found;
Then down in all their might they burst
And roared along the ground.

. . . .

Where'er the great Bhagirath led,
There ever glorious Ganga fled,
The best of floods, the rivers' queen
Whose waters wash the wicked clean.

. . . .

The monarch reached the Ocean's side,
And still behind him Ganga hied.

. . . .

So leading through earth's nether caves
The river's purifying waves,
Over his kinsmen's dust the lord
His funeral libation poured.

Brahma rewarded the king's achievement with these words:

Ganga thine eldest child shall be,
Called from thy name Bhagirathi;
Named also — for her waters fell
From heaven, and flow through earth and hell—
Tripathaga, stream of the skies,
Because three paths she glorifies.

A story so popular, entwining geographic facts with the feats of gods and fabled kings has naturally intrigued modern interpreters. There is, of course, a Bhagirathi River. It is the declining upper course of the Hooghly, Calcutta's outlet to the sea. Most authorities agree it was, a few centuries ago, the principal mouth of the Ganga. Sir William Willcocks, a British irrigation engineer, some years ago advanced the thesis that the Descent of the Ganga was but the folk-record of the Ganga's finding this Bhagirathi mouth, just as it is known later to have turned back eastward in the normally erratic process of delta-building.[1] Sir William was prepared to believe that a prehistoric king may in fact have cut a pilot channel for the Bhagirathi, thus aiding nature in the diversion of a great river. It is a bold conjecture.

It would be much simpler to believe that this is a myth born of the awe of the dwellers of the Gangetic plain at the mysterious source of their great river in the fastnesses of the Himalayas. The two great rivers known to that civilisation, Indus and Ganga, are indeed unmatched in all the world for the contrasting environs of their upper and their lower course. He who climbs even by slow degrees from the sandy plains of Oudh through the foothills to the glaciers and snowy peaks of Badrinath or Gangotri returns wonder-struck that the vast sprawling Ganga of the simmering plains could be born among the snows and clouds and crests of the Himalayas.

But the verses of the *Ramayana* tell us much more about the mental climate of their age, if we hear them in the context of

[1] For notes numbered thus, see end of book.

a still more ancient time. Before *Ramayana*, the *Vedas* also praised the names of rivers. The first voices we can understand in this subcontinent, the voices of the Aryan followers of Indra, invoked the rivers in these words:

> *I call the Waters, Goddesses, wherein our cattle*
> *quench their thirst.*
> *Oblations to the streams be given . . .*[2]

The men who sang the hymns of the *Rigveda* swept across the Northwest with their cattle and their horse-drawn chariots. Rivers were obstacles to be overcome.

> *Bow lowly down; be easy to be traversed: stay, Rivers,*
> *with your floods below our axles.*[3]

So were the fortified cities upon the rivers' banks. To their invincible God, Indra, the Aryans sang:

> *Then didst thou set the obstructed rivers flowing*
> *and win the floods that were enthralled by Dasas.*[4]

Who were these 'Dasas'? The *Rigveda* tells us they were dark-skinned, they offered neither sacrifices nor hymns to the true God; they were merchants whose stores of gold and grain, whose hidden cattle, offered rich booty to the conqueror; they built great forts whose walls and towers, 'iron-faced' or paved, commanded the river routes. In the last few years, the archaeologists, however, have begun to tell us more. They have dug into ruins which they now believe must be in fact the citadels of the 'Dasas'. These city-forts disclose a culture that had somehow attained the same flowering—in art, engineering, and administration—as the contemporary civilizations along the banks of other great rivers: the Nile, the Tigris and the Euphrates. They were, the archaeologists conclude, such cities as we now call Harappa and Mohenjo-Daro. These cities existed upon those rivers, and until that date (about 1500 B.C.) which would fit them to be the victims of the Aryan conquest. By that time, too, they show evidences of decline that would have left them vulnerable to conquest. And in the buried streets and stairways of Mohenjo-Daro, the archaeologists came upon the sprawled skeletons, some pierced by weapons, which indicate massacre by an invading host. 'On circumstantial evidence such as this. . . ,' concludes Sir Mortimer Wheeler, 'Indra stands accused.'[5]

Verse after verse of the *Rigveda*, of which the translators have so far extracted only the most figurative meaning, would become intelligible if we assume that the warriors of Indra wrested the river routes from citadels which, dotted on their banks, commanded them.

> All the banks of rivers yielded to his manly might:
>
> *. . . to him who, as with thunder, demolished Sambara's hundred ancient castles.*[6]

Starting with the archaeologist's facts about the complex civilization of the Harappans, it would be quite plausible to read into a few otherwise cryptic passages of the *Rigvada* a story of tremendous drama and significance.

> *Thou settest free the rushing wave of waters, the flood's great swell encompassed and obstructed.*
> *Along steep slopes their course thou turnedst, Indra, directed downward, speeding to the ocean.*[7]
> *O Indra, him who lay at length staying thy copious waters, thou*
> *In his own footsteps* [or, says the translator, *In the waters at his feet*] *smotest down.*[8]
>
> . . .
>
> *There as he lies like a bank-bursting river, the waters taking courage flow above him.*
> *The Dragon lies beneath the feet of torrents which Vritra with his greatness had encompassed . . .*
> *Rolled in the midst of never-ceasing currents flowing without a rest forever onward,*
> *The waters bear off Vritra's nameless body: the foe of Indra sank to 'during darkness.*

Guarded by Ahi stood the thralls of Dasas, the waters
stayed like kine held by the robber.
But he, when he had smitten Vritra, opened the cave
wherein the floods had been imprisoned.[9]

And this simile, magnificent to one who has seen flood-softened embankments settle:

E'en now endures thine exploit of the Rivers, when,
Indra, for their floods thou clavest passage.
Like men who sit at meat the mountains settled . . .[10]

Did the Aryan besiegers, balked by the brick battlements of some river-bank citadel, take advantage of or engineer the breach of an earthen dike upstream, to undermine by flood walls otherwise impregnable?

Such questions the resounding verses raise, but answer not. What they utter is not history, but the prayers and faith of a people. Of the nature of that faith they tell us much:

Since then e'en Gods have been afraid of Indra:
he conquered all the floods which serve the Dasa.[11]

What had happened to the faith and hopes of the people by the time we hear their voices tell of rivers in *Ramayana?* They had migrated, it is clear, from the basin of the Indus to the basin of another mighty stream. Ganga is named but twice in the *Rigveda*, and never as a river occupied. *Ramayana's* people dwelt:

Within the spacious plain that lies
From where Himalaya's heights arise
To where proud Vindhya's rival chain
Looks down upon the subject plain.

This was a tract of continental size: large enough for a great nation, and too little compartmentalized by natural barriers to be safe for small ones. The route of empire for the Aryans now lay along, not athwart, the river system. Bhagiratha's feat would, indeed, have been a myth ideally suited to legitimatize the rule over the Gangetic plain of a dynasty whose path of conquest was the river's course.

There had been a change far more crucial than the change of place. The *Vedic* people were city-breakers. *Ramayana's* people were city-dwellers. It is not of etymological interest alone that the word civilization with all its sister words—civic, civil service, and even civil engineering—comes from the original Latin word for city-state. Indra's people, to whom rivers had been watering places for herds, obstacles to migration, or allies in the reduction of city-forts, had now settled down upon the banks of rivers.

On Sarju's bank of ample size
The happy realm of Kosal lies.
With fertile length of fair champaign
And flocks and herds and wealth of grain.
And famous in her old renown,
Ayodhya stands, the royal town . . .
Right glorious is her royal street
Where streams allay the dust and heat.

The great cities, the seats of empires, would now be river cities, gaining commerce by boat, dependent on water supply, facing the risk of floods.

Unawares, the former nomadic Aryans had now assumed a still greater risk. Drought, to their pastoral ancestors, meant migrating with the flocks to some still-green pastures. But drought to the city-dwellers and the rulers of kingdoms meant famine. (Famine intrudes, incidentally, into the romantic verses of *Ramayana.*) From this time on, through all the twenty-five or thirty centuries of Indian history, civilization would be a sporadic, but ever-recurring battle against famine. In this war, the rulers and leaders of India eventually found many allies, but the strongest and surest were the rivers. 'Self-ruling waters, ye bestowers of kingship,' ran the very enthronement ritual of ancient maharajas, 'Bestow kingship on. . . .'[12] And wherever he may be, in rivulet or tank however small, the pious Hindu recites at the time of bathing the words used by his ancestors for centuries:

> *May the waters of Ganga, Yamuna, Godavari, Sarasvati*
> *Narmada, Sindhu, Kaveri mingle in the waters here and now.*[18]

Sometime between the *Vedas* and the *Ramayana*, in short, the invaders and settlers of India had traded their nomadic freedom for civilization. They had now to live with their rivers, whether in fear or in gratitude, in awe or in adjustment. Whoever could bring the rivers down to earth was now for real as well as literary reasons a god, or a hero.

THE ANATOMY OF INDIA'S RIVERS

Rivers, like all else in India, pulsate to the annual beat of the monsoon. Residents of Europe and America, to whom rain and sun are daily possibilities, can scarcely conceive the suspense with which a tropical land awaits the one tremendous rainstorm of the year, or the fatefulness of abnormality in that single rain. India has the most exhilarating January in the world. But for the next five months, the country simmers in steadily rising heat. Madras, Calcutta and Bombay steam; Delhi parches under the sandblast off the western desert. If there is grass or foliage enough to colour the landscape, anywhere on the subcontinent, in April or May or the first week of June, that place is an oasis. Then the random breezes die, at great altitude a haze covers the sky, and upon tensely expectant people and dessicated plants, the monsoon breaks.

Weather men know that 'breaks' is the right word—there is nothing random or gradual about the way the monsoon comes—but even to them the suddenness is a riddle. For months the pressure in the wet atmosphere over the equatorial Indian Ocean has been building up. Where the Tropic of Cancer crosses the continent of Asia, air heated by a sun straight overhead has risen. A mild, but vast vacuum has accumulated. Now on some day between the 7th and 21st of June, the ocean winds rush inland from the south to fill the gap. If the monsoon is 'strong' the rivers and the rice bins will be full. Some years, it will be 'weak'. But all over India, from June to October, some rain will fall. Except for the Madras east coast, which catches some rain as the monsoon winds return down the Bay of Bengal in November, and Punjab, which in January gets a rain or two of the Atlantic (cyclonic) variety, it will be India's only rain for the year.

Pre-ordained in its season, pre-ordained in its direction, the monsoon is pre-ordained also in the paths of its winds across the land. Lines of coast and mountain tell how much rain one district will receive, and how little another. The Malabar rice farmer looks for six feet of rain on his paddy lands as anxiously as the Hyderabad farmer looks for 18 inches on his millet. From India nature has withheld the moderate risks, the risks of human scale, of the dates and the paths of storms. There is but one risk that absorbs them all—the risk of a weak monsoon.

This is the way the land lies for the approaching monsoon: Reaching a thousand miles into the Indian Ocean is the triangle of the Indian Peninsula. Above the low coastal margin on the east and west is the inner raised triangle of the Deccan Plateau. It is higher in the west than in the east and highest of all at its southern tip. Sloping down gently to the north, it finally ends in a jumble of hills reaching across the base of the Peninsula. Loosely speaking, they are called the Vindhyas. Beyond the Vindhyas, the great North Indian Plain stretches from sea to sea. For most of its length it is 150 to 200 miles wide. But it flares out at the extreme west and east of India into two north-south river basins — the Indus and the Brahmaputra. Between these funnel-like ends neither hill nor valley breaks the level surface. Nature has left a perfect wind tunnel from the Bay of Bengal to the Arabian Sea.

West, north and east this corridor is walled by mountains so high and so unbroken that rain-bearing winds, as well as human commerce, barely leak through. Up to the altitude of 17,000 feet, the height of the three Himalayan passes, India is hermetically sealed from the rest of Asia. The transit of the snowy heights is left for those chill jets of the upper atmosphere which, tearing the powdered snow off the crest of Everest, perpetually display its white plume.

The monsoon winds blowing from mid-June to mid-October are hoisted 3,000 feet almost vertically by the sharp western edge of the Deccan Plateau. From the refrigerated clouds the rain pours down upon the Ghats (or mountainous rim). The minimum precipitation is 75 inches; some Ghats stations record 350 inches of rain. Across the narrow strip of the Malabar Coast both rain and rivers pour abundantly. The Bedti, the Sharavati, the Netravati, the Chaliyar, the Pennani, the Periyar—these rivers have not far to go between the mountain and the sea. The magnificent waterfalls upon their upper courses reveal their energy.

Robbed of their moisture while crossing the Ghats, the monsoon winds blow on eastward without yielding much more rain. The Deccan Plateau needs more water than it gets. The rivers that rise upon it run briefly from June to October. Thereafter most of their beds are dry hollows of stone and sand. The Palar and Pennar and the rivers that lie in Hyderabad represent this fickle type. Upon the whole plateau there are only three rivers fed by the torrential rains of the Western Ghats. Rising within 50 miles of the Arabian Sea, they must follow the descent of the Deccan Plateau clear across the peninsula to empty their water into the Bay of Bengal. These rivers are the Cauvery, Krishna and Godavari. They never go dry. But since they are monsoon rivers, they run for six months at a mere hundredth of the monsoon volume.

The Deccan Plateau is built of the oldest rocks which still lie exposed upon the earth's surface. Time and the rivers have had their way with that ancient gneiss and granite. The rivers have long since eroded the valleys on gentle slopes toward river beds cut deep in rock. For men who would use the water on their fields, these facts are decisive. Year-round supplies of water must be stored eight months after the monsoon; canals can escape the deep-cut river beds only by raising the water a hundred feet or so. The Deccan rivers have their advantages, too. Except in their deltas they run in beds too deep for harmful floods, and though in the monsoon they bring down silt, it is the fine soil that fertilizes fields, not the coarse that clogs reservoirs.

The Vindhyan ranges receive more rain than the southern plateau (50 inches as compared to 20 or 30). Monsoon winds from the Bay of Bengal as well as the Arabian Sea converge upon them. And back to both seas run the rivers from these highlands. The Wardha and Wainganga flow south to join the Godavari. The Mahanadi (Great River) runs east through Orissa. Westward the Tapti and the Narmada run side by side to the Arabian Sea. The northern slopes of the whole Vindhyan chain feed tributaries of the Ganga: the Chambal, the Betwa and the Son.

The Himalayan rivers are a class unto themselves. Two of them rise behind the first snowy range. From the foot of Mount Kailas, the home of the Gods, the Sutlej runs west, joins the Indus and thus reaches the Arabian Sea. Beneath Mount Kailas, too, rises the Brahmaputra. It has three names in the three parts of the long course. As the Tsangpo it flows eastward through Tibet, under the name Dihang it cuts south through the walls of the Himalayas, and is called the Brahmaputra finally in the major valley of Assam. But rains come from the south, and the southern face of the Himalayas receives the heaviest downpours. From the high valleys southward run countless mountain torrents, joining into parallel rivers as they level out upon the North Indian Plain. At 13,000 feet near the glacier of Gangotri there is a cave of ice, and the trickle of the Himalayan snow melting from the ceiling of this cave is the traditional source of the Ganga. As it flows down the North Indian Plain it collects the water from the other Himalayan rivers: Jumna, Gogra, Sarda, Gandak and Kosi. These rivers flood in the monsoon, but they are filled also by the melting snow. The hot months of March, April and May which dry up the peninsular rivers, therefore swell the rivers of the Himalayas. Even at their lowest they are big streams, and taking the year around, they are among the mightiest in the world. Add the flow of the rivers Cauvery, Krishna and Godavari; the Indus is bigger than the three. To those three add the Mahanadi, Tapti and Narmada; the Brahmaputra carries more water than all six. Greater than all is the Ganga; its volume is to the Brahmaputra's as 4 : 3.

Geologically speaking, these big rivers have a big job to do. They are stripping off the tops of the Himalayas to fill up the North Indian Plain. The geologists tell us the Himalayas are as young as the Deccan is old. The same final wrinkling of the earth's crust which thrust the mountains five or six miles up also folded down the surface of the continent at their feet, perhaps to an equal depth. That is why no matter how deep men have drilled into the soil of the North Indian Plain, they have struck no solid rock, only the sands washed down through eons of geologic time from the summits of the Himalayas.

Flooding rivers, aided at the western end of the Plain by desert winds, laid the alluvium in terraces of almost perfect smoothness. And they left it inexhaustibly fertile. It would produce the richest crops in the world—if it had water enough. But the monsoon winds blowing from south-west to north-east must turn at right angles to enter the wind tunnel through which the Ganga flows. For some curious reason, the monsoon winds coming up from the Arabian Sea scarcely penetrate inland at all. It is a fortunate year when the lower valley of the Indus gets 5 inches of rain; 12 months may pass without a drop. The valley of the Ganga has to depend on rain out of the Bay of Bengal. Those winds which sweep up the Bay of Bengal drop 50 inches of rain as they first make the turn west. As they move up the Ganga, they yield less and less—one inch less for every 30 miles they travel — until Punjab has to get along with 15 inches. (Punjab has one compensation. It is the only part of India to which some of the Atlantic and Mediterranean winds leak through the Himalayan barrier. In January this north-west corner of India may get an inch or two of rain. It is just enough to make wheat growing possible.)

That is a detail. In the main the North Indian Plain gets less rain than it needs. Yet it combines the greatest supply of water for irrigation with the most level and inexhaustible soil in India. The water is not only from the Ganga and her tributaries, it is also standing beneath the surface of the soil itself. Before the foothills of the Himalayas, a swampy belt, 'Terai', like a huge wick perpetually soaks up the drainage from the mountains and leads it underground through the layers of alluvium which make up the entire Plain. There is water enough in this subterranean reservoir to dwarf the most grandiose storage works of men. But on the North Indian Plain, one of the world's best opportunities for irrigation is coupled with the risk of silt and flood. For the Himalayan rivers have not yet finished their geological task of eroding the surface of the mountain and depositing the spoil upon the plain below. The Kosi, busiest of them all, carries enough sand and gravel to fill up the largest reservoir man can build to harness it. Men who live within reach of such Himalayan rivers as the Kosi and the Gandak are living on a half-built land, and the price they pay for the richness of the alluvium is the tragic price of perennial floods. Taming the Himalayan rivers is indeed a job for Bhagiratha.

TEMPLES AND TANKS

'See how the husbandman waiteth,' sang the psalmist in a Mediterranean climate, 'and hath long patience till he receiveth the early and latter rains.' The Indian husbandman always had long patience. But for him (except in Punjab with its January showers, and the Madras coast, which gets some rain as the monsoon winds return south) there were no 'early and latter' rains. When the monsoon burst upon him in the month of June, he got his one annual chance. If he lost—if the rains did not sprout the millets, or bring the rice to its flowering in October — it would be fourteen months before he could harvest again. He would wander in search of work or charity, but in such years the chances were that someone in his family would die.

Since the people of India settled upon the land — since they gave up the life of herdsman or hunter — they have looked therefore to the skies with misgiving, and to the streams with hope.

That hope has always been expressed in two ways. One is the worship of rivers, which began in the hymns of the *Vedas* and was strengthened as the descendants of the *Vedic* people settled upon the banks of the Ganga and its tributaries, and then the rivers further south. That worship is one of the great national bonds of India. It brings the pilgrim from the Deccan along the mountain path to Badrinath and Gangotri. When, every twelve years, the planet Jupiter is in Aquarius and the sun is in Aries, it packs a million people on to the bathing ghats of Hardwar, Allahabad, Ujjain or Nasik for the Kumbh Mela. It brings the living and the dead to the ghats of Banaras. It has planted temples at the source of every great river, and places of ritual bathing and worship in every town along its banks. It puts a bottle of Ganga water in millions of homes throughout the country.

Mingled in unknown proportions with the worship of rivers were works to adapt them to human needs.[14] The beginnings of irrigation and flood protection in India are lost in prehistory. Nor can we gauge how much of the country they benefited at any time before the British period. The evidence of irrigation before the birth of Christ is contained almost exclusively in the words of books which were not written down at the time but carried, and perhaps supplemented, as oral teachings for many subsequent generations. The exception is the eye-witness account of Megasthenes, who shortly after the death of Alexander the Great, became ambassador in the court of 'Sandrakottus'. Several years ago this figure of Greek history books was firmly identified as Chandragupta Maurya, founder of the first empire of all northern India. 'There grows throughout India,' wrote Megasthenes, 'much millet, which is kept well watered by the profusion of river streams. . . the fact is almost all the plains in the country have a moisture which is alike genial, whether it is derived from the rivers, or from the rains of the summer season, which are wont to fall every year at a stated period with surprising regularity.' The operation of the canals called for the competent bureaucracy which was a feature of the Mauryan reign. Of district officers Megasthenes observed: 'Some superintend the rivers, measure the land as is done in Egypt and inspect sluices by which water is let out from the main canals into their branches, so that every one may have an equal supply of it.'[15]

In the peninsula of Kathiawar, not far from Junagadh, stands a rock bearing two Sanskrit inscriptions. The first dates from about A.D. 150.

> This lake Sudarsana [which means the equivalent of Belle View], from Girinagara, even so well joined in construction as to rival the spur of a mountain . . . without gaps and made of stone clay . . . and with well-provided conduits, drains and means to guard against foul matter . . .
> by the excessively swollen floods of the streams of Mount Urjayat, the dam. . (though proper precautions were taken the water [being] churned by a storm . . . of the most tremendous fury . . .) was thus laid open down to the bottom of the river.
> By a breach, four hundred cubits long, just as many broad [and] seventy-five cubits deep, all the water flowed out.

... the Mahakshatrapa Rudradaman, in order to increase his religious merit and fame ... by the expenditure of a vast amount of money from his own treasury and in not too long a time made the dam three times as strong in breadth and length.

The inscription opens a glimpse of an administrative system which could not only construct a reservoir some one hundred feet in depth upon the margins of the empire, but could maintain a provincial governor with the initiative and authority straightaway to repair the breach. Three hundred years later, probably in A.D. 456, the dam again burst. But that is not a discreditable life for such a work. And the governor for the Gupta king Skandagupta achieved repairs in a time of two months. His feat, too, is duly recorded by an inscription on the other side of Girnar Rock. There is no trace of the reservoir today. Clearly, however, it required a mastery of earth and masonry embankment, and experience in the design of medium-sized reservoirs wholly without peer at the time.

Between the present cities of Tanjore and Tiruchirappalli, the Cauvery River branches into its delta. Rice-growing in the delta was naturally as risky as it was profitable, for the same Cauvery floods which watered and fertilized the paddy might wash it away in an abnormal monsoon. Before recorded history, Tamil literature gives some basis for thinking that a king named Karikala I of Tanjore took the whole problem of the delta in hand. Dragooning thousands of labourers from Ceylon he constructed a system of embankments along the floodways and canals to carry the water safely to more distant fields. Many generations later the canals began to lose their effect because, according to the tendency of deltaic streams, a new outlet, the Coleroon, began taking the bulk of Cauvery floods northward.

At a time still before firm dates can be fixed, the Chola rulers of Tanjore undertook a work of almost unbelievable daring: to dam the Coleroon and thus redirect the river toward their southern canals. Their work is called in the palm-leaf texts the Kal Anai, or Grand Anicut. For 1080 feet across the river channel the Chola kings placed layer upon layer of rough granite blocks, 10 to 20 tons in weight. The joints were packed only with clay, but their very weight withstood the scouring action of the river. The top of the anicut was covered with a layer of cut stone set in lime mortar. Interestingly enough, at that remote date part of the crest was designed in the same smooth curve (engineers call it an 'ogee curve') which modern designers use for spillways. And the downstream toe of the anicut was prudently protected from undermining by a long apron of stone. In 1830, the first British engineers to tackle the problem of irrigation from the delta of a major river came upon that Grand Anicut in Tanjore. The Cauvery had deposited so much silt behind it that water now flowed unimpeded over it into the Coleroon. But its huge stones were sound, and the British, gaining permission to use additional granite from an ancient temple nearby, merely heightened the weir to turn low floods again into the Tanjore canals. Several more modifications have been made in the last 120 years. They still stand fast on a foundation perhaps a thousand years old.

The development of Indian rivers owes one more debt to the Grand Anicut. The British engineer who discovered its significance in 1830 happened to be Captain Arthur Cotton. It taught him what no living engineer or treatise then affirmed: that dams capable of withstanding the full force of a river at its mouth could be founded not on rock, but on pure sand. Captain, later General, Cotton risked his reputation and his career on that revolutionary demonstration. He built the Upper Anicut across the Coleroon by the same technique. And when he had proved that the feat of the Chola kings could be reproduced by engineering science, he got authority to dam the Godavari and the Krishna and the Mahanadi. Every one of those great barriers, resting safely on sand, is a monument to ancient engineering and modern ability to learn.

It was the Muslim conquerors of the North who first, so far as we know, took the water of the Himalayan rivers out of their banks for extensive irrigation.[16] To water palace, garden, or retreat was the prime motive; farmers benefited incidentally. Feroz Shah Tughlak, toward the end of the fourteenth century, built the first canal from the Jumna River. It was not to carry water to Delhi, past which the Jumna flows, but to the sultan's hunting preserve at Hissar, 100 miles west. The canal avoided high ground, which would have given it command of the fields en route. It was actually a series of trenches through the sand, connecting existing drainage ways. Its life, therefore, was short.

Two centuries later, Emperor Akbar ordered the restoration of the canal. In the words of his proclamation of 1568:

> Now I have given the darkar (district) of Hissar to the great, the fortunate, the obedient, the pearl of the sea of my kingdom... my son Sultan Muhammed Salim Bahadur (may God grant him long life and greatness) . . .
> For God has said, 'From water all things were made.' Therefore I ordain that this jungle in which subsistence is obtained with thirst, be converted into a place of comfort, free from all evil.

Akbar's officials succeeded magnificently in laying out a branch of the Jumna canal to his capital. For three centuries it led Jumna water to the fountains, gardens and barracks of his Red Fort, and to the bazaars of Delhi. But even Akbar's writ did not prevail upon the desert of Hissar. When British engineers, two and a half centuries later, turned water into the western branch of the canal, they found its alignment faulty, as Feroz Shah's had been. Passage had not been left for drainage to cross the canal in times of heavy rain. The British remedied Akbar's error in the last century; in this, the new Republic has completed the job by finally giving the drought-stricken farmers for miles around the old imperial hunting preserve a steady water supply.

Until the last century India had not, as far as we can tell, that complete adaptation of a major river to the needs of man which supported the flowering of ancient Egyptian and Sumerian civilizations. But those civilizations of the Nile and the Euphrates collapsed utterly and the Indian, however fragmented and reshaped by outsiders, remained. From the age of the Mauryan emperors right down to the present, India had (perhaps with China) the largest benefits of irrigation in the world.

Of these achievements, the most useful of all were the least conspicuous. In the Gangetic Plain, these were the small wells by which individual cultivators or *zamindars* tapped the groundwater and lifted it to the fields by the labour of men, bullocks or camels. In the Deccan and along the coastal rim, the corresponding local works were tanks—small reservoirs to collect a monsoon's rain and send an even supply to the fields. We do not know the numbers of these beneficent works before the British period. From Dr. Francis Buchanan, the physician sent throughout the South by the East India Company in 1800 to survey the welfare of the people, we have a report full of praise for the system of local tanks, and their generally good repair.[17] An actual count of the number of tanks in the Madras Presidency in 1876 showed 33,318. Each irrigated, on the average, 100 acres.

Maintenance of wells and tanks was certainly not always effective. But it was within the power of the larger landlords, or of the Brahmins of the temple to which a tank might be dedicated. In the South, by the custom called *kudimaramat*, peasants traditionally contributed labour to repair and remove silt from the tanks which benefited their lands. But main canals, flood-embankments, and especially reservoirs big enough to store the water of main rivers required more extensive and durable organization. Only strong kings could build them, and stable dynasties maintain them. Especially remarkable was the power of the Maurya and Gupta regimes to achieve great irrigation works even in remote corners of their empires. When strong kingdoms fell, the development of India's great rivers had to wait for the establishment of a large-scale, durable dominion.

Surveying civilization as a whole, the irrigation and flood control works built by Indians in the second century before Christ, and in perhaps the tenth and the sixteenth centuries *A.D.*, were unsurpassed by foreign contemporaries. They were unsurpassed, too, by later generations of Indians down to the nineteenth century. Through more than two thousand years, Old India's rivers witnessed remarkable works of genius, daring and stewardship, but remarkable failures to accumulate and improve upon the lessons learnt.

Each brilliant achievement was isolated, and not alone by the breaks in civic order. It was isolated (to apply the words of Jawaharlal Nehru) 'when thought lost its explosive and creative power and became a tame attendant upon an outworn, meaningless practice.'[18] There was not the restless curiosity concerning the causes of success or failure in engineering which would have permitted more and more accurate predictions of its results. There was not the scepticism to subject formulas deliberately to trial. We should not miss the central deficiency. It was not a lack of professional men, nor of specialists. We know from the old manuscripts that the builders of channels and tanks resorted customarily to the advice of Brahmins learned in 'the lore of waters' (*pathas sastra*). Nor was the deficiency essentially due to shutting out foreign ideas. Only in recent centuries had foreigners much to contribute to Indian irrigation; then they were imported. In the sixteenth century De Paes, a Portugese engineer, advised Krishnadeva Raya, ruler of the central Deccan. Not much later, Ali Mardan Khan applied his experience of Afghan irrigation in Akbar's service.

Superstitious awe can accompany rational control of nature —part way. De Paes himself carried away from Krishnadeva Raya's court a remarkable illustration. When the masonry of a dam on which he was advising unaccountably collapsed, the king sent for 60 condemned prisoners and had them beheaded on the spot. After that, the work progressed smoothly.

What Old India lacked, Prime Minister Nehru once expressed precisely: 'the refusal to accept anything without testing and trial, the capacity to change previous conclusions in the face of new evidence.'[18] It was what all the world lacked until Europe's Age of Enlightenment: *science*. In the nineteenth century a few men initially innocent of India's two millenia of irrigation experience, certainly not possessed of greater zeal for good works than her best emperors and kings, would nonetheless in a single generation surpass their greatest river works. The only thing utterly new in those men was the 'adventurous yet critical temper of science.' By them, in a way incomprehensible to the sages and the poets, Ganga was brought to earth anew.

2

TWO FORERUNNERS

THE MAN WHO TURNED THE GANGA

IN DECEMBER 1839, a young man travelled up the sacred Ganga past Garhmukteswar to the pilgrim ghats at Hardwar, where the clear mountain river breaks through the last foothills on to the plains.[1] He was equipped not with the bowl and staff of the *sanyasi*, but a theodolite on its tripod: the instrument for measuring levels and laying out angles. His task was clear. He had to find a way to get the water of the Ganga out of the hills at a level high enough to get on top of the 83-foot tableland beginning at Roorkee. If he could do that, he could lead it on to an almost limitless expanse of dry alluvium, four million acres.

The engineer, Captain Proby Cautley of the Bengal Engineers, had created the mission for himself. Three years earlier he had proposed a Ganges Canal, provided the water could be got up on to that ridge. We know of two other engineers who in 1839 thought the job possible; there were probably no more. The reason was simple. Between the gorge at Hardwar and the tableland at Roorkee, the Ganga receives four tributaries. Three are mountain torrents, foaming out of the foothills during the monsoon laden with boulders and gravel, dry the rest of the year. The fourth ran in a wide depression. If Cautley turned water out of the Ganga below the torrents, he knew the water would be too low to get on to the tableland. But if he began his canal higher up, he would have to get it across the torrents.

As far as scientific knowledge was concerned, Cautley walked alone into an unknown land. The lay of the land had never been mapped; the flow of the river was unmeasured.

Cautley took every one of his levels with his own theodolite. Before the snows began to melt in March, when the Ganga was at its lowest, he measured its discharge by a rough expedient, timing an object carried by its current through a known distance, then multiplying the speed of the river by the depth and width of its bed. He found he could count on 7,000 cusecs (cubic feet per second: each cusec equals a stream one foot wide and one foot deep, moving one foot per second). As he reconnoitred, he kept his eyes open for traces of building materials. There were no stones below the mountains, of course, but he found clay which could be burned into bricks. Within six months his survey was complete, and his report submitted.

Captain Cautley said the canal could be built. He found, at Ganesh Ghat just below the town of Hardwar, a place from which Ganga water could be led out. It was higher than the tableland at Roorkee. But it was also 18 miles away, and in between ran down the three mountain torrents. He had made up his mind that a canal could be built across them. He proposed doing it this way. Where it crossed the torrent, the lower bank of the canal would become a masonry spillway, at the end of which he would build a set of gates across the canal. Floods coming out of the mountains could flow freely into the canal and out the other side; the gates would keep them from going further along it. In other words, he would let the waters mingle. For the three-mile slough in front of Roorkee he proposed an aqueduct.

Once the water was at Roorkee, the whole strip of plain between the Ganga and the Jumna down to Allahabad lay beneath it, 400 miles long by about 40 miles wide. Irrigation would be limited only by the water supply. Cautley proposed, on this account, to divert virtually all the water the Ganga carried in dry weather: 6,750 cusecs. It was just three times the largest flow modern engineers had carried by artificial canal before.

What gave him the supreme confidence, upon his rough data and his quick reconnaissance, to be sure it could be done? Cautley had spent fourteen years improving the eastern Jumna Canal. It was, like every British canal up to that time, a restoration of an ancient Indian work. He had explored and pondered the projects of Feroz Shah and Ali Mardan Khan. To use the words of his own report: 'With so many examples before us, no great exertion of intellect was required to see that the system might be generalized.'

The Governor-General in Calcutta and the East India Company in London were equally confident. In the dreadful famine of 1837, the contrast between the prosperity of the Jumna Canal zones and the misery eastward along the Ganga was obvious. They quickly approved Captain Cautley's scheme. In 1841 he began, with two fellow officers, a detailed investigation of the canal route, and on 16 April 1842 excavation began. Then came one of those tests which seem designed to find out whether big and novel works are in the hands of men of proportionate courage and confidence. Two months after the work began, the erratic new Governor-General of India, Lord Ellenborough, issued an order to stop it. Captain Cautley, however, had received a second government order through military channels calling for continuation. Taking advantage of the slightly later date upon this second order, he kept his force at work, and wrote to the government asking for confirmation of what he had done. Three months later, vague confirmation came, in the form of a limit upon his spending of two lakhs per year! He borrowed two engineers from the Jumna Canal, of which he still had command, and kept doggedly at the work. The legitimate fears concerning the canal, that it would cause malaria and that it would injure navigation, he answered by laying out the channel so as to minimise stagnant water alongside and by incorporating a system of navigation locks in the main canal itself. It was not until five years later that a new Governor-General, Sir

Henry Hardinge, came to Hardwar, carefully considered the objections to the canal and ordered full speed ahead.

The engineers, feeling their way against unknown forces of nature, were frank to admit that the delay may have given time to correct some otherwise costly mistakes in design. The most striking was the crossing of the mountain torrents. By 1849, Cautley's scheme of letting their floods wash right through the canal had a tryout. When the season's floods were over, the canal and its completed regulating structures lay buried under 12 feet of sand. It was plain that the hill torrents carried too much debris to let into the canal. A junior engineer proposed, and Cautley quickly accepted, the only alternative: to lead them over it. This called for one bridge 200 feet wide, another 300, each strong enough to carry a rampaging young river, and fitted so accurately into the torrent's bed that it would neither be buried with the outwash of the mountains, nor undermined by the rapid current. In only two places had structures across similar torrents been tried out. One was at the upper end of the East Jumna Canal, the others were the canals in the Italian Piedmont; neither passed the torrent *over* the canal. Framing hydraulic theory as they went, the engineers nevertheless built successful overpasses.

At its nineteenth mile, the canal came to its severest obstacle. It was the three-mile-wide valley of the Solani River, just in front of the level upland at Roorkee. Captain Cautley's task was to carry the whole dry-weather Ganga over the valley, 36 feet up in the air. He laid out the solution in two steps. On both edges of the valley, he planned an earth embankment held in by a massively buttressed brick wall on both sides, the wall reaching up to form the canal banks. Across the Solani River, he designed an aqueduct of fifteen arches, each spanning 50 feet.

Consider the difficulty of the problem and the ingenuity with which Cautley and his team of young engineers tackled it. There were, of course, no contractors to build any part of the structure. The very word 'concrete' was, in the 1840's, not in use (the French had just tried out on a breakwater project in Morocco a kind of concrete to which they gave the name *béton*). But even if the canal builders had known of concrete, they had no cement to make it from. Even lime for mortar was not for sale; it had to be burnt from limestone—from boulders brought down by the hill torrents, or from lime nodules called *kankar* deposited in the alluvial soil. Building stone was out of the question, once the work got away from the hills. Could bricks be burnt in sufficient numbers and quality? Brickmaking was an old, old art in North India. But it took a new-fangled English moulding machine and a new pattern of laying the raw bricks in the kilns (invented after months of experiment by Cautley's sergeant) to manufacture more than 150 million bricks. As the canal crossed the lower country, clay was not always near at hand. Once the ruins of a century-old fortress supplied bricks for sluices and regulators.

Excavation of the main canal—110 miles of it were built in the initial project—was technically simple. But it was an enormous job of organization and control. Nomadic bands of labourers, whom Cautley called 'Oades', proved to be the best diggers. They moved the spoil to the embankments on donkeys.

It was the construction of the great aqueduct to carry the canal across the bed of the Solani torrent that called forth all of Cautley's genius for improvisation. The piers supporting the fifty-foot arches had to be founded on bottomless sand. Experimenting with a device he had never seen employed, Cautley had built on the site of each pier huge twenty-foot cubes of solid brickwork. They were built on the surface of the sand; they had to be sunk to their full depth. How? Simply by digging the sand out from under them through four vertical holes left in each cube. The labourers fastened long bamboos to their traditional digging hoes (*phowrahs*) to reach down through the blocks. By this simple method the prefabricated footings sank steadily into the sand, six inches a day. How were they kept sinking level? Simple again. Cautley had a plumb line at each corner of the blocks, and the workmen adjusted their digging among the four holes until the block stayed level. The masonry and the water of the Ganges Canal have pressed upon those ingenious foundations now for more than a century without discovering serious weakness.

A canal three times as big as its predecessors continued to teach its lessons after it was completed. Indeed, the turning in of the Ganga in April 1854, twelve years after work began, was by no means the end of the job. At one end of the Solani aqueduct an embankment gave way and had to be strengthened. Bridges had to be raised to attract navigation, but that aspect of the canal never had much use. When the canals ran full, they quickly showed that Captain Cautley had pitched their beds too steep (though the slope was only one foot per mile). The resulting erosion was checked by inserting a larger number of masonry step-downs. A permanent weir had to be built at Hardwar to turn the Ganga into the canal. Finally, in 1878, a great extension, equal in size to the original project, was opened in the lower half of the Ganga-Jumna tract. It carries irrigation all the way to Allahabad.

What were the results of Proby Cautley's project? Judged by commercial standards, it lost money for its first twenty years. Then in the 1873-4 season, the income from water rates exceeded the combined cost of operation and interest on the three-crore investment. By the end of the century, net income from the canal was yielding 10·3 per cent on the capital outlay. There was, of course, a larger return. At the century's end, the canal was irrigating just short of a million acres (978,000). It had saved more lives in each of four great famines: 1860-61 (the canal's first full season), 1868-69, 1877-78 and 1899. The pages of the district Gazetteers tell the story. In Saharanpur, for instance, the first district irrigated by the Ganges Canal, the 1837 famine, the one which provided the stimulus for the undertaking of the canal, was the last one to bring starvation throughout the district. By 1899, 'an almost total failure of the rains' hurt the district so little that 'no relief works were necessary.' In fact, 'the *zamindars* and cultivators who possessed the means of irrigation prospered greatly' from scarcity prices.

Building a 6,750 cusec canal to water a million acres is still a sizeable attainment. But a man's work must be measured from the point civilization had reached when he undertook it. Proby Cautley has unwittingly left us an accurate benchmark of the status of irrigation engineering in 1854. It is in the list of titles in the excellent professional library he collected for the canal staff. There were exactly three books on irrigation: one had been published in France, one in Italy, one in England. The Ganges Canal inaugurated a school of irrigation technique —literally as well as figuratively. For when the work accelerated in 1847, Governor Thomason and Baird Smith (along with Cautley, the pioneer of scientific irrigation in the north) saw that engineers would be needed in unprecedented numbers and of an unprecedented kind. Out of their early classes grew Thomason College, which opened its doors on the very banks of the Ganges Canal in 1854, the same year the canal opened. Grown now into Roorkee University, it has for a century trained the men who watered the North Indian Plain with the water that melts from Himalayan snows.

Proby Cautley was not the first man to do it. The search for the first leads a long way back, to Ali Mardan Khan and Feroz Shah and, it may be, to a school of unknown engineers who turned the waters of the Ravi or the Indus tributaries into Harappa or Mohenjo-Daro. But Proby Cautley has his own distinction. He left in India a foundation on which his successors could build works surpassing his own: scientific engineering.

THE MAN WHO STORED THE MONSOON[8]

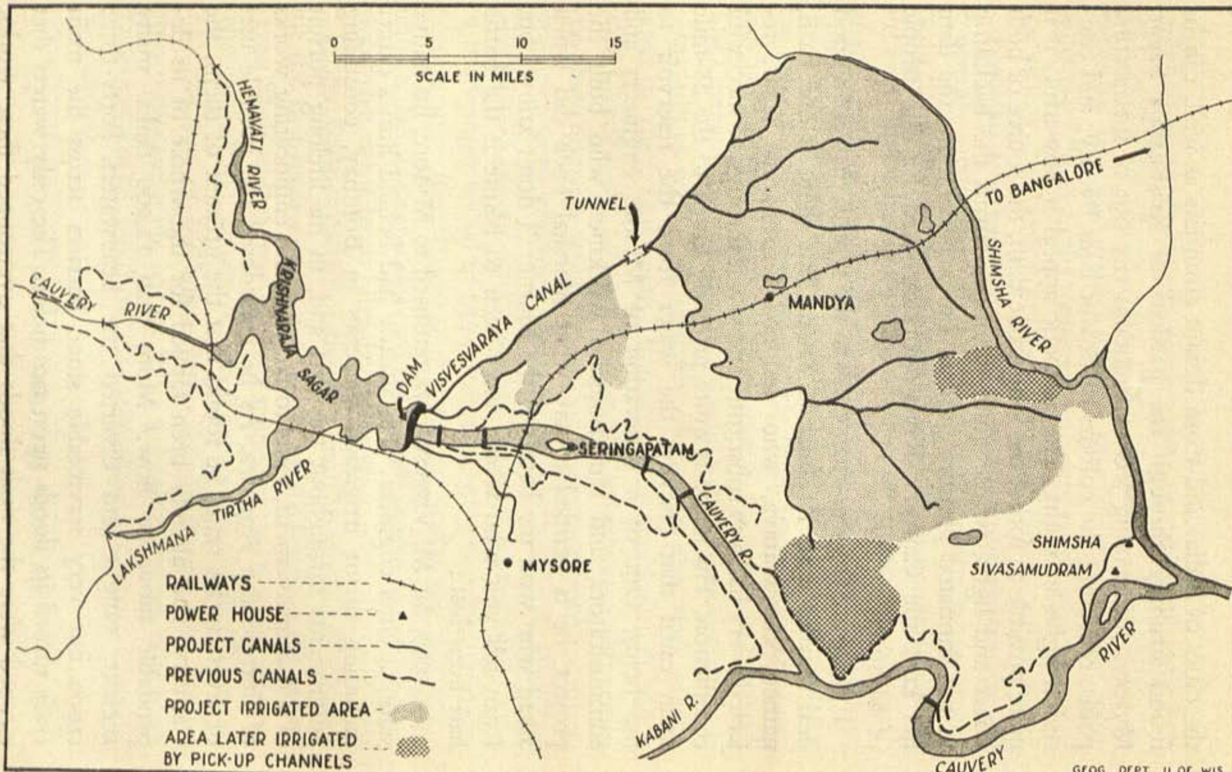
Any Sunday evening, carefree bands of tourists from all the cities of India, and from distant countries as well, can be found strolling through the gardens of Krishnaraja Sagar, Mysore. Intersecting jets of fountains rise out of intersecting pools, reflecting the colours of flower beds by day, and concealed lights at night. The aesthetic appeal is powerful; it is quite possible to forget the long stone dam, the source of both water and light, whose quiet silhouette forms the backdrop to the animated pleasure garden. For a generation, the dam has kept the Cauvery River working hard for the people of Mysore.

If there are any one-man dams in the world, they are a good deal smaller than Krishnaraja Sagar. But there is one man, named Visvesvaraya, who designed Krishnaraja Sagar, rejected every halfway substitute, and saw it through to successful completion. His name is quite properly given to the 28-mile main canal that conveys the water from the reservoir to the fields. Out of a generation of Mysore engineers and administrators, and ten thousand workmen who built the project, he is entitled to say what Marshal Foch did when asked who won the battle of the Marne: 'I don't know; but I can tell you who would have been to blame if the battle had been lost'.

In 1909, Sir M. Visvesvaraya returned to Mysore, his native state, as chief engineer.[3] He already had behind him a career including major irrigation successes in Bombay, consulting assignments throughout the East and, in his lifelong pursuit of self-improvement, visits to factories and engineering works of Europe and America. As he considered the possible uses of rivers in his state, he found that the greatest of them, the Cauvery, had already been tapped for the whole of its dependable monsoon flow.[4] More than 12,000 tanks, many ancient, caught and diverted the headwaters. Forty-three crude but very serviceable stone barriers across the main river turned its floods upon rice fields. The only waters that escaped were the peak floods that overtopped these works,

FIG. 1

MYSORE'S CAUVERY RIVER PROJECT



and the dry-weather flow which the crude anicuts could not lift to the level of the canals. All the old works were useless in a weak monsoon, when they were needed most. None of them supplied water for a second or third crop. Yet the Cauvery was at that time the most highly developed river in India, perhaps in the world.

Lower down, where the Cauvery left Mysore to enter the state of Madras, its great waterfall, Sivasamudram, had been harnessed to electric generators.[5] That was India's first hydro-electric installation except for a small Darjeeling plant: when it started in 1902 there were few anywhere in the world. Water at Sivasamudram, however, dwindled to a small stream of 100 cusecs in the dry months. Electricity from the plant served a gold mine at Kolar; by use of electric ventilating fans, the shafts had been driven a mile straight down through the quartz rock. The manager of the mining company came to the new chief engineer with a request for 5,000 horsepower of electric current more than he was then getting. He needed to electrify his hoisting apparatus—the high-speed lifts to draw men and ore out of the shafts. But power for this purpose must be infallible. Could Mysore supply his needs, whether or not the Cauvery received a good monsoon? If the state could not, he would erect his own steam generating station.

The ultimatum fitted nicely into the plans of the chief engineer. For years, there had been talk of a reservoir on the Cauvery at the site of Krishnaraja Sagar. But to regularize the flow of the Cauvery would take a big dam. In his first two years as chief engineer, Sir M. Visvesvaraya had designed the structure, 130 feet high and 8,600 feet (that is over a mile and a half) long. He sent the project now to the Maharaja of Mysore, with a proposal that two and a half crores be granted to build it. To put the scheme in perspective: what he asked for was as much money as the state had spent for all its irrigation projects over the last fifty years. Quite naturally the Maharaja hesitated. One day Sir M. Visvesvaraya let him know that his continuance as chief engineer depended upon the sanction of the project. 'Don't be hasty,' the ruler told him, 'I will do what you want.' The Maharaja's backing from that day onward was unstinted; his own name, Krishnaraja, was later given to the reservoir (in Sanskrit *sagar*).

A greater difficulty now arose.[8] The Cauvery runs out of Mysore into Madras, where from its delta more than a million acres of land receive irrigation. This was, in fact, the site of the ancient Grand Anicut to water the fertile district of Tanjore. Madras protested that the construction of Krishnaraja Sagar would threaten the delta's water supply. Mysore engineers disagreed, and they submitted the dispute to arbitration. The arbitrator, who was appointed by the Government of India, decided that the reservoir could be built to the full height of 124 feet and he provided rules for storage that would prevent injury to Madras irrigators. There was jubilation in Mysore when the decision was confirmed by the Government of India and announced. But Madras appealed to the British Government in London, and the Secretary of State there upset the award. Mysore was a small 'native state' for whose development Britain was not responsible; Madras was a great segment of British India. Mysore had now no choice but to try by concessions to win the voluntary agreement of Madras.

What Madras actually wanted was to continue getting enough water across the state line not only to supply her existing irrigation but to fill a future reservoir, twice as big as Krishnaraja Sagar, and to use it to extend irrigation to 300,000 new acres in Tanjore. Luckily, engineers of the two states finally satisfied themselves by careful daily gauging of the Cauvery that both reservoirs could be filled, except in the very worst years. In 1924, a decade after the arbitrator's award, Madras agreed that Mysore could build Krishnaraja Sagar. It could, however, only store water each day to the extent that the Cauvery's flow exceeded the requirements of existing

Madras canals in the Cauvery delta of Tanjore. In an average year, it meant that Mysore could hold back about a fifth of the flow to fill her reservoir: it is enough for Mysore's irrigation, except in very dry years like 1950 to 1952. The great cost of the dispute, a price which men pay everywhere for political boundaries across great interstate rivers, was a decade of wasted water, wasted crops and wasted electricity. The waste, would, in fact, have stretched over two decades not one, had it not been for the calculated risk of Sir M. Visvesvaraya.

He refused to put his project on the shelf when Madras objected. Instead he divided it into two stages, the first stage calling for a dam of only eighty feet. It was enough to meet the power requirements of the mines, and could not possibly deny Madras water she needed. If and when the dispute was settled, the dam could be raised according to his original design to 124 feet. This arrangement satisfied the Government of India. In 1911, therefore, as soon as the high water went down, Sir M. Visvesvaraya set his crews to work at the dam site, excavating the foundations. The foundations they laid that year were not for an 80-foot structure. They were thick enough *to support the full height of 124 feet.* The chief engineer had persuaded his government that some day the dispute with Madras was bound to be settled in favour of Mysore. Thirteen years later, he proved to be right. 'As we believed our claim was correct and just,' he once explained, 'we took the risk.'

He took another risk the next year. He signed a contract with the gold mining company to have enough water stored behind the dam on 1 July 1915 to keep the generators turning, drought or no drought. The manager of the mines, even with the contract in his hands, was as Sir M. Visvesvaraya recalls, 'sceptical'. He had to have dependable power by the deadline. How could a great river be dammed in four years? He was willing to give the Mysore engineers a chance; but he kept his plans for a private generating plant ready in case they failed.

Building a dam in four years in 1911 meant, of course, building it by hand. The engineers at the Cauvery site quickly recruited 10,000 labourers, most of them from outside Mysore. Children worked along with their mothers, and wives carried earth and stone that their husbands excavated. It was the pre-motor age. Stone came from the quarry three miles away by bullock cart and coolie-powered trolley. Skilled men cut the stones of which the dam was laid, and put them in place. This army of workers was directed wholly by government engineers and foremen. There were no contractors. The burden of supervision was unprecedented. But the engineers could count on the quality of the masonry built that way, and the workmen got honest pay.

Not long ago an American engineer who had supervised the construction of a number of concrete dams came to see the pioneer work at Krishnaraja Sagar. His eye fell upon the reddish mortar in which the stones were laid. 'What have you put into your cement?' he inquired. 'There is no cement at all in that mortar,' came the reply, 'It is *soorki*.' Intrigued, the engineer took out a piece of steel of known hardness from his pocket, and scratch-tested the joints. He was amazed to find the *soorki* as hard as cement. 'This mortar,' he commented, 'is something about which we can take lessons from you.'

Soorki, unknown to the West, made Krishnaraja Sagar possible. In those days, cement was an expensive rarity. But almost anywhere in India could be found limestone, clay, and fuel. That was all it took to make *soorki* mortar, and those ingredients were abundant within five miles of the dam site. *Kankar* was dug and burned in local kilns; the product was lumps of unslaked lime. The *soorki* was simply well-burnt brickbats, ground with one-fourth their quantity of the lime. Steam-powered mills, wheeling a stone roller in a circle over the moistened ingredients, did the grinding. It was application of power to the homely method by which the Indian housebuilder, using bullock power, grinds his mortar to this day. *Soorki* was cheap. The engineers verified by crushing daily samples in the laboratory that when it set it had ten times the strength the design of the dam required. But it sets slowly—a year to full strength, and a week to the strength required to hold up the structure. That was another fact which made the Visvesvaraya plan of storing water in four years a daring one.

The main challenge, however, came from the river itself. The dam had to be built where the Cauvery flows swiftly through its rocky bed. And before the stone could be laid, fifteen to thirty feet of unsound rock had to be pried and blasted away. To get the main dam across, the engineers shut the water out of the river bed, a section at a time, with temporary dikes or cofferdams. They would never have been able to withstand the Cauvery with the simple masonry cofferdams of those days, had they not been able to count on six months of low water each year. In those months they had to strip the foundation in a new section and cover it with masonry. Monsoon floods would pour over the new stonework without damage. In October the sand left by the floods would be cleaned off and the dam raised further. Sometimes there were some close races with the rising river. At two o'clock one afternoon in 1913, the superintending engineer was alarmed to find the river rising suddenly. Already it was within a foot of the top of the cofferdam protecting a section of masonry far too fresh to withstand the current. He summoned every man, woman and child on the project to raise the cofferdam wall an extra foot. At nightfall he had to send the women and children out of danger of the river. The flood was already up on the new level of the cofferdam and still rising. There was only one thing to do. He took the men who volunteered to work by lantern-light and cut through a second cofferdam at a place where the masonry was seasoned enough to stand the current. Thus released the Cauvery stopped its rise, and the crisis passed.

With all their efforts, however, the Mysore engineers found themselves at the beginning of their fourth working season in what one of them later called an 'almost desperate situation.' On 1 July they had to have not a foot less than fifty feet of water backed up to supply the Sivasamudram generators: otherwise they would forfeit their contract with the gold mines. But with eight months to go, their lowest block of masonry was only 8 feet above the riverbed! And in raising the dam 42 feet across its whole length, they had to install the intricate deep sluiceways and gates through which some of the 1915 floods would have to flow.

In that last hectic year, it was the zeal of the huge team Sir M. Visvesvaraya had drawn to the dam-site that saved the day. The senior engineers shared his own determination; they had tackled a job everyone said could not be done, and their self-respect was at stake. Their assistants were Mysoreans fresh from engineering college, and the physical energy and zeal of those youths seemed to grow with the obstacles. Thousands of ordinary workmen in that fourth year paid back to the job the loyalty created by three years of steady work at fair pay. A third of them undertook to work half a day overtime for extra pay, and thus the work went on, with a single shift, from seven o'clock in the morning until eleven at night.

The Cauvery floods came in 1915 on the 27th of June. It was a day of mingled pride and disappointment for the engineers. For the lowest stretch of the dam fell short of the required 50-foot height by just 24 inches, and the river, pouring through that gap, ended their hope of adding more masonry in time to store the floods. They might supply the electricity their contract called for *if* 1915-16 should not be a dry year. Then, in July, nature came to their rescue. For one week, the Cauvery subsided until the deep sluices alone could carry its flow. That week was enough for the dam builders. When the water came up again, it had an extra thirty inches of masonry in front of it. The engineers had protected their fresh stonework with a hastily improvised concrete facing so that it could stand the overflow. A small army of zealots had redeemed Sir M. Visvesvaraya's pledge.

This heroic effort was followed by a decade of doldrums. The dam was heightened only as fast as the power demands at Sivasamudram increased; the unsettled objection of Madras ruled out any major irrigation. When agreement was reached with Madras in 1924, the full reservoir 124 feet deep became possible, and with it Sir M. Visvesvaraya's original scheme for 120,000 acres of irrigation.

It was, for the twenties, a formidable scheme. True to form for a Deccan river, the Cauvery had carved out a V-shaped valley. There was not much level land in it, and that little already got flood irrigation from ancient anicuts. But beyond the immediate valley, north-east toward Bangalore was a great level tract dependent wholly upon scattered tanks for irrigation. It needed Cauvery water sorely, but between it and the unfinished reservoir lay 30 miles of hills, ending in a rocky ridge higher than the canal could ever be carried. The Visvesvaraya plan was to take a canal out of the reservoir at a height of 60 feet, and conduct it by tunnel through this ridge. The cost would be 2.8 crores, more than the cost of the dam itself. When the scheme was revived in 1924, the British officer who was serving as private secretary to the Maharaja advised against it. To him it seemed risky and extravagant. But the ruler for whom the reservoir is named took the advice of his prime minister, Sir Mirza Ismail, who believed in rapid economic development of Mysore. Again he gave the signal to go ahead.[7]

The canal was completed in 1931. Its tunnel through the obstructing ridge is one and three quarters miles long, at that time unequalled in India. The canal system was built not for 2.8 crores, but for just two crores. Depression prices made the saving possible, and the new irrigation was a powerful support to the economy of that central part of Mysore during the remainder of the economic slump. It has never come quite into full use; but it now irrigates 90,000 acres. On this land famines are forgotten, and the old crops of gram and ragi are replaced by rich paddy and sugar cane. The man whose far-sighted ventures made that oasis possible is fittingly remembered by the name Visvesvaraya Canal.

In so many of its aspects a pathfinder for Indian engineering, the Krishnaraja Sagar dam also left behind one warning. It is that floods may come which exceed all those of which engineers have records. The Cauvery produced such a flood in 1924. Down a valley which Sir M. Visvesvaraya had found carried but 240,000 cusecs, came 290,000. An 18-foot thick waterfall poured over the two lowest sections of the unfinished dam. Below one section, where the engineers were planning to erect their spillway gates, the flood in a single week carved a wholly new river channel out of earth and rock. Its marks still show on the tumbled strata below this flank of the dam. The masonry, however, held fast. Duly warned, the engineers discarded their old plans to handle a 250,000 cusec flood and built into the final dam, gates enough to pass 350,000 cusecs. Like Sir Proby Cautley, they had cause to be grateful that governmental difficulties delayed their original scheme until nature could reveal her vagaries. Modern engineers, who build too fast for second thoughts, are learning from just such lessons to collect data enough, or to have foresight enough, to design for the whims a river may exhibit once in a hundred or once in a thousand years.

To people in almost every country, as Julian Huxley pointed out, the initials 'T.V.A.' stand for the multiple use of a single river to meet all the needs of man.[8] To India itself, the popular appreciation of multiple-purpose schemes came via T.V.A. But India had a multiple-purpose project, begun 22 years before T.V.A. Krishnaraja Sagar was, it is true, but crudely co-ordinated with the other great reservoir on the Cauvery, Mettur. A state boundary got in the way of an integrated chain of dams which might have controlled the whole river. The operation of Krishnaraja Sagar independently had no place for the control of the rare floods which come down the river: such a flood occurred as lately as 1953. But Krishnaraja Sagar's design embodied, twenty years ahead of its general acceptance, the engineering principle of multiple-use: that once the rains have been stored, water let down evenly for irrigation can turn electric generators on the way. The economic principle was there too: that income from electricity, abundant and prompt, may help pay for irrigation which develops slowly and whose greater rewards (in the form of food produced and famines prevented) may not enter the state treasury directly. In the last two decades, it has become commonplace that electricity as 'paying partner' can make remunerative a combined scheme, which for irrigation alone would operate at a loss. Sir M. Visvesvaraya foresaw it in his original project report, dated 5 May 1911 :

> Once commenced, the scheme opens up a vista of possibilities of ever-increasing value to the State . . . The promise of extraordinary direct returns from power at commencement, and the opportunity it affords of building up a great irrigation project from the sale proceeds of power, form a combination of advantages rarely vouchsafed to such undertakings in any part of the world.

That promise has been fulfilled. Krishnaraja Sagar storage has permitted a five-fold increase in electric capacity at Sivasamudram. The combined project is returning between five and six per cent net income upon its combined cost, for all purposes, of ten crores.

Nowhere on earth was the multiple-purpose idea more desperately needed than on the Deccan Plateau. The Himalayan rivers, and the great rivers of the coastal deltas, flow abundantly throughout the irrigation season. The land around them, being built by the rivers themselves, is level and low. Irrigation is easy and immensely profitable. The Deccan waited twenty years after the harnessing of the deltaic Cauvery, Krishna and Godavari, and the Himalayan Jumna and Ganga. It waited on two keys to unlock its double barrier to irrigation—seasonal flow in deep-cut riverbeds. The first key had already been fashioned in 1879 at Khadakvasla Dam in Bombay out of the natural situation of the Deccan rivers themselves. The deep rocky beds would permit storage, once men had the skill and courage to build dams high enough. But the cost of getting canals out of the rocky valleys on to the level uplands could seldom be recaptured until the electric energy was harnessed at the rivers' steep falls. The Deccan was waiting, in short, for a man to store the monsoon, and make it pay.

Between 1946 and 1948, India effected her political revolution. It is so sharp a turn in the history and especially in the outlook of her people, that one quite properly refers to the subsequent nation as the New India. It is radically new, of course, in its boundaries. Such world-renowned works as the Sukkur Barrage and Canals go undescribed here because, though built in a province of British India, they belong since partition to Pakistan. The amalgamation of the princely states, too, has left its mark (usually a Gordian knot cut) on every river project we shall investigate. But there are other things new in the development of river resources since 1947: size, pace, boldness of design and erection, range of benefits, cognizance of needs, popular support. It is the business of the concluding chapter of this book to say just how new, to India and to the world, this development is.

But the turn in history was not a break. One fundamental reward of India's way of winning her freedom is that she left herself free to build on the past. Some part—in two cases almost all—of the planning for New India's river projects was done under the British regime. Planning is but a little, of course, of the tasks of building and using. Independence had its particular meaning to each of the four great river projects underway after 1947, and to the totality of important, though lesser, works. It is to their story that we now proceed.

It is worth noting in passing, however, that Krishnaraja Sagar itself exhibited a characteristic case of India's present, however new, nevertheless being penetrated by her past. It had long been known that Tippoo Sultan, the last Indian ruler of Mysore to withstand the British Empire, had attempted to dam the Cauvery. Workmen clearing the foundation for the modern dam uncovered a stone slab dated 1794. The inscription, which was in Persian, contains these sentences :

> In the name of God, the Compassionate, the Merciful . . . Hazrath Tippoo Sultan, the Shadow of God, the Lord Bestower of Gifts, laid the foundation of the . . . Dam across the river Cauvery to the West of the Capital. . . . The start is from me, but its completion rests with God.

3

BORDER DAM

BEHIND that section of the Eastern Ghats which is called the Velikonda Range is an artificial reservoir seven miles long and more than two miles wide.[1] It is retained by three earthen dams altogether three-quarters of a mile long filling the saddles between the encircling hills. Stone slabs pave the embankments for the safe overflow of floods. This great tank was completed in the year 1369. The careful superintendent who built it for Prince Bhaskara of the first Vijayanagar dynasty left a durable record of his durable work; the record is inscribed on two slabs standing before the ruined temple of the nearby village of Porumamilla. The inscriptions tell us that a thousand labourers worked two years upon the embankment, a hundred carts brought the stones to the revetment and sluiceways. They also perpetuate for us the lessons of technique and statecraft which had been learned by the river-controllers of six hundred years ago.

Twelve requisites are prescribed for successful reservoir construction. The first two are: 'A king endowed with righteousness, rich, happy, and desirous of the permanent wealth of fame,' and 'a Brahmana learned in the science of waters.' Future irrigators are also warned against six hazards: water seeping through the dam, saline soil, high ground in the middle of the reservoir, inadequate water, insufficient irrigable land, and one defect outside the field of engineering, 'situation at the boundary of two kingdoms.'

To the 'Rayas' or Vijayanagar rulers who built Porumamilla tank, and hundreds like it, that last warning must have condensed much bitter experience. With great tenacity, the Hindu Rayas held a frontier line against the invasions of Muslim sultans from Delhi and their Muslim feudatories on the Deccan itself.[2] For three centuries their final line of defence was the Tungabhadra River. With a keen strategic sense, the Rayas built their fortress-capital, Vijayanagar, on its granite-studded southern bank. But at last the insolence of one of the line united all the Muslim sultans against him. When in 1565 the sultans reduced the city of Vijayanagar to the picturesque ruin we find today, the great tanks and irrigation channels from the Tungabhadra finally paid the price of being situated on the frontier.

From 1565 to 1948 there was never a lasting sovereignty extending across the Tungabhadra. When the rising strength of the British in Madras encountered the dominion of the Nizam of Hyderabad in 1800, the Nizam ceded to the East India Company the territory south of the river. From that time on, the history of Tungabhadra Dam, which now stands seven miles upstream from Vijayanagar, was the history of painful but patient attempts to build a dam across the boundary of two kingdoms.

BORDERLAND

Long before these clashes of empire, nature made the Tungabhadra country a frontier. The river comes down from the Western Ghats in Mysore and Bombay. That 3,000–4,000 foot wall precipitates 100 to 300 inches of rain into its catchment every year. But the water that swells the river is lost to the clouds, and the valley of the Tungabhadra in the centre of the Indian Peninsula gets 19·4 inches of rain—in an average year. The trouble is, of course, that so far removed from its source in the Indian Ocean, the monsoon is rarely average. For a year or two, dry crops flourish—*jowar*, *ragi* or cotton. Then comes a year when they fail. Famine is never far off. Rayalaseema ('the country of the Rayas') and the Hyderabad district of Raichur across the river, are among those fickle lands which are not quite desert nor yet quite arable, but some years one and some the other. Men lose confidence in themselves in that environment, for the experience of one season is upset unaccountably by the conditions of the next. For centuries starvation repeatedly evacuated that land. Generation after generation, men who did not wish in some years to beg found homes elsewhere.[3]

It is true that the Rayas centred a populous urban civilization in that capricious zone. They did it partly by conscripting the inhabitants, but partly by leading seventeen indispensable canals through the rocky banks of the Tungabhadra River to the famine threatened fields. This was the final insurance policy behind their hundreds of widely scattered tanks. After 1565, when both tanks and channels lapsed into disrepair, the population dwindled; the cities died. It was not until three centuries later, in 1863, that a new canal was taken from the Tungabhadra.[4] It was Sir Arthur Cotton's Kurnool-Cuddapah Canal. Though he had succeeded brilliantly in irrigating the Krishna and Godavari deltas, his £1,000,000 Madras Irrigation Company failed from the start with this Kurnool-Cuddapah Canal. It, too, fell victim to the fickleness of climate, for the peasants took no water in wet years.

FORTY YEARS' CONTROVERSY

A large storage reservoir on the Tungabhadra, to feed canals through the famine-vulnerable Rayalaseema, was proposed by Madras to the Indian Irrigation Commission of 1901–03. After investigating other locations for a dam, Madras selected the present one, and prepared a detailed scheme. The Commission said Hyderabad, too, should get water from the reservoir; but the border proved to be a stumbling block.[5] Hyderabad was unwilling to become a partner in the enterprise, partly because she had a lesser canal scheme of her own to which Madras had refused consent. But if Madras built the dam, 54 square miles of land in Hyderabad would be flooded. It was one of the greatest feudatory estates in the Nizam's domain, that of Salar Jung, and the Nizam would accept as compensation for it only an equivalent territory.

For thirty-nine years, the weary dispute between two governments waxed and waned. They could not agree how much water each should draw from a common reservoir. Madras had a design for a dam to store up the floodwaters; Hyderabad did not. But Madras had decided, soon after her initial rebuff in 1905, to give priority to extending the great irrigation projects on the Cauvery and the Krishna. They were not so urgently needed as insurance against famine, but they promised to repay their investment with interest. The Tungabhadra scheme did not. In Hyderabad, a great engineer, Ahmed Ali, later called Nawab Ali Nawaz Jung, had by 1921 caught the vision of the value to his state of irrigation from a Tungabhadra reservoir. But though he negotiated with Madras representatives for the remainder of his career, his government never gave him authority to propose actual construction of the dam. Towards the end, Mysore entered her claim to use water from the two tributaries, the Tunga and the Bhadra, for irrigation and power. Remembering her difficulties with Madras upon the Cauvery, she insisted on a strict legal definition of her rights against Madras.

It was the zeal for post-war reconstruction, and the growing sense of nationality bred by the war, which finally made agreement possible. In 1930, Ali Nawaz Jung wrote out an allocation of water which representatives of both states signed. Irrigation water was to be divided equally. In addition Hyderabad could draw out of the common reservoir a certain flow to turn its hydro-electric turbines, and Madras could use the same water lower down the river in her existing canals. But the agreement aroused further controversy, for Madras insisted the water should pass through Hyderabad turbines uniformly throughout the year. Hyderabad at first agreed, then refused. In 1940, Ali Nawaz Jung got the chief engineers together at the dam-site. They came to some understandings—Hyderabad would design the dam, it would be built of *soorki* mortar if that were available, and the quarry and water supply would be common to both sides. But they could not agree who was to build. Madras wanted sole charge; Hyderabad would not agree. The meeting broke off.

Still, both states were determined that the project should go ahead. C. C. Dalal, a Hyderabad engineer, proceeded to design the dam. And Madras, under the vigorous leadership of C. Rajagopalachari and S. V. Ramamurthi assigned a team of engineers under M. S. Thirumale Iyengar to make quite independent designs for the dam, as well as for a complete canal system.[6] At last under the pressure of a Madras proposal for Government of India arbitration, the two states conferred in June 1944 and reached a firm agreement upon use of the Tungabhadra reservoir. Under this agreement, each side may draw out 65,000 million cubic feet for irrigation (one and a half times the content of Krishnaraja Sagar).[7] An unspecified amount of water may be used in addition for hydro-electricity, and passed on down the river. The following month, Madras and Mysore settled their immediate claims as well. Before the end of the year the joint scheme was sanctioned by the Government of India; on the last day of February 1945, Hyderabad and Madras governments inaugurated the project.

Yet for two years more, very little work was done. The border still came in the way. Unable to agree on a single chief engineer, or even on the constitution of a joint board to manage the whole work, the two states decided to build independently with their individual public works departments. If fundamental disagreements arose, the two chief engineers, agreeing on a third member, would comprise a board to settle them. In 1947, it was clear that this would not work. Each state thought the other was wasting money, half of which it would have to pay in the final reckoning. And there were fundamental discrepancies in their unreconciled designs for the dam itself. In October 1947, two months after the British government left India independent, they convened the board of arbitration, and the man they selected as the impartial chairman was Sir M. Visvesvaraya.

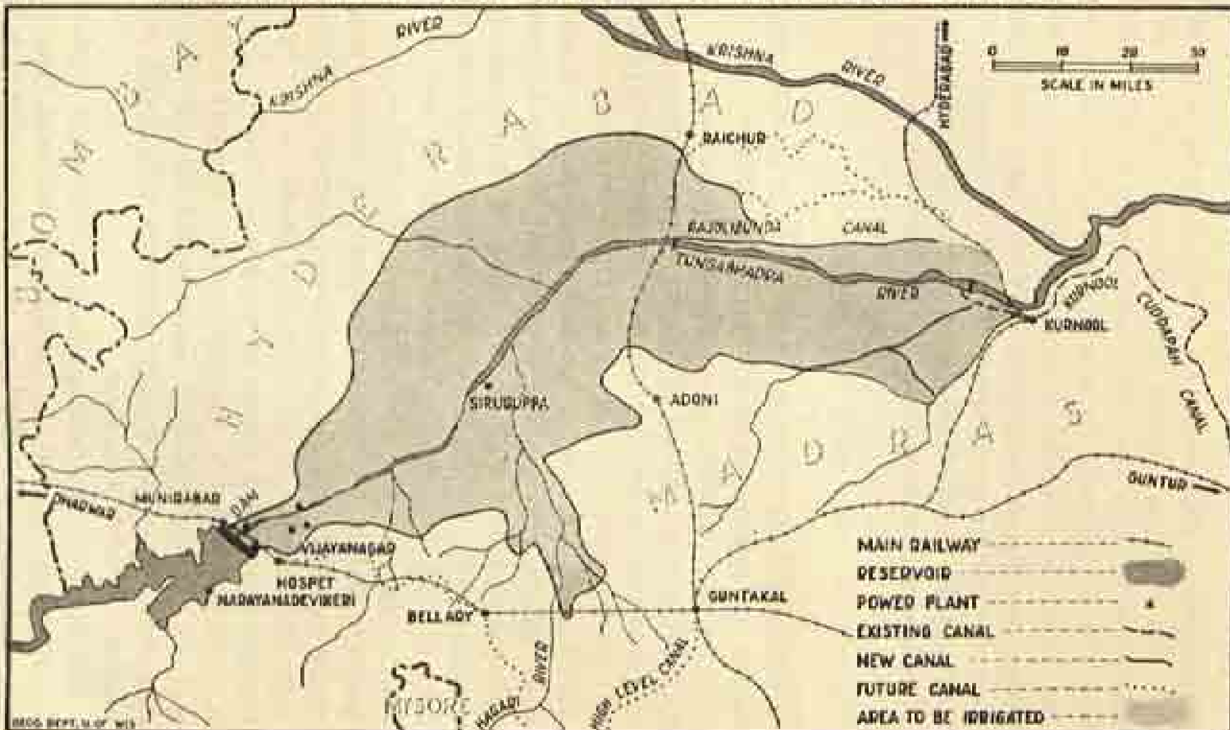
ONE DAM, TWO BUILDERS: [8]

Engineering is not an exact science. It is, in certain respects, subject to experiment, but where scientifically controlled trials are not possible, accumulated experience serves. Sir M. Visvesvaraya applied all his 62 years of experience to the questions on which competent engineers in Hyderabad and Madras stubbornly disagreed. Hyderabad wanted lime-*soorki* mortar, with which it had built a large reservoir at Nizamsagar. Madras insisted on standardized Portland cement, with which it had built Mettur Dam. Sir M. Visvesvaraya decided *soorki* was perfectly safe; six good-sized dams had been built of it without a failure. It would be used for the bulk of the dam; but where the water was to flow over the spillway, and in the masonry surrounding sluices, cement would be substituted. He compromised, likewise, a difference as to the thickness of the dam: it is thicker at the base as Hyderabad proposed, thinner at the top *à la* Madras. Scientific evidence settled a third difference — Madras's narrower spillway, over which flood water would flow twenty feet deep, was proved safe by experiments on scale models at the Madras Engineering College.

But it was on the basic question of division of work that the arbitrator showed the wisdom of Solomon. The two states had intended to divide up the total cost after each had

FIG. 2

TUNGABHADRA PROJECT: STATES AS THEY WERE UNTIL 1953



built half the dam. This engendered suspicion that the overhead charges — housing, water supply, engineering staff, medical attention, roads — were wasteful on the other side. Yet neither side wanted its own spending for these matters reviewed by the other. Sir M. Visvesvaraya's solution realistically limited the matters on which unanimity would be necessary. Instead of dividing the cost after building the dam, 'first divide the dam, and let each side bear the whole cost of its own half.' Then either side's extravagance would carry its own penalty; and economy its own reward.

Dividing the dam was not so easy as it sounds. Because there were two auxiliary dikes on the Hyderabad side, and because each foot of the main dam's length contains a different volume of masonry, half the dam's 6007 feet of length would not give half the work. But with a single design and estimate agreed to, a point could be found where the cost of the work to be done north of it and south of it would be exactly equal. The point was finally located, only in 1952, 3072 feet from the Madras end of the dam. Meanwhile, Madras had built 184 feet and 4 inches further north of that point; she recovered the cost of the excess work from Hyderabad.

Collaboration, without a single manager, had failed. With each side on its own, a healthy competition now developed. In the years when both the Madras and Hyderabad exchequers were sorely strained, particularly 1951-52, neither government could afford to slow down its rate of investment in Tungabhadra Dam. The other state would have got ahead. Hyderabad, especially hard pressed for revenue, actually starved its own canal work in order to keep the building of its half of the dam on schedule.

Sir M. Visvesvaraya was emphatic that without a single design, the great structure would be a 'patchwork', discrediting the engineering competence and the civic dignity of the participating states. A Hyderabad engineer was given the job of preparing common designs and specifications, and in 1948 they were ready. The two chief engineers still had troublesome differences to thrash out: at what level the sluiceways could draw water out of the reservoir; how thoroughly the foundation rock should be grouted (or sealed with liquid cement under pressure); how the water, rushing down the face of the dam from the spillway crest, should be stilled in the basin 98 feet below. But they never again failed to agree.

By 1950, engineers from the two states had confidence enough in one another to abandon the principle of independent halves and undertake genuine joint effort. The thirty-three huge steel spillway gates, and the steel spans for the bridge on top of the dam from which they would be opened and closed, are being fabricated and put in place by the mechanical engineering workshop on the Madras side. Hyderabad pays half the cost. And to get their share of the experience, Hyderabad deputed a few engineers to the Madras workshops.

CIVIL WAR[9]

Meanwhile, a time had come when the engineers building the construction camps and digging the foundations of the dam across the border had put down their transits and T-squares and taken up guns.

In 1948 the Nizam of Hyderabad had embarked on a suicidal course. He may have been encouraged in it by the 1947 Act of Parliament which, terminating British authority in India, left the princely states apparently free to choose India, Pakistan, or independence. The Nizam, whose state was situated in the heart of the Indian republic, and whose people were overwhelmingly attached to India, began recklessly arming to defend Hyderabad's independence. In addition to his regular troops, he ordered Civic Guards mobilized throughout the state. Internally, his state fell into a deadly cycle. When sporadic incidents of violence broke out, he allowed the arming of an irregular band called 'Razakars' on the excuse of suppressing it. The Razakars, thoroughly lawless, carried on border raids into Indian territory.

Hyderabad's head of construction for Tungabhadra Dam in 1948 was a brilliant London-trained engineer named Khwaja Azeemuddin. He was ordered, as chief engineer, to arm the Civic Guard. At the Tungabhadra workshops, he turned out a prototype rifle, and sent it north, along with machine tools from the dam, for mass-production. The Hyderabad arsenal was established in the historic Muslim fort of Golconda. For additional armament the Nizam and his government relied on a New Zealand soldier of fortune named Sydney Cotton who flew several cargoes of weapons from Karachi, over the Indian blockade. The project had a thoroughly romantic, albeit tragic, air. Golconda's rifle barrels, for instance, were made of ordinary steel tubing. But there was one bitterly practical consequence. Hyderabad funds for the dam (the Hyderabad officer who had charge of disbursing them estimated about Rs. 50,00,000) were spent on arming the Civic Guard and importing Pathan mercenaries.

At the south end of the dam, these preparations raised the prospect of a Razakar raid. Madras engineers sent their families home and organized themselves into a Home Guard detachment, 35 strong. It was not a formidable force: three-fourths were armed with shotguns. But they were determined to resist the Razakars if they came. For three days they waited, barricaded in the house of the superintending engineer (the strongest house in the construction colony) waiting for an attack that never came.

The combination of internal anarchy and border tension could not endure. 'We march,' Prime Minister Nehru declared. Before dawn on 13 September 1948 spearheads of the Indian Army moved into Hyderabad. Munirabad, the dam construction camp on the Hyderabad side of the river, was one objective of the first advance. It proved to be one of the most difficult.

The Hyderabad Civic Guard had taken control of the camp. Sadiq Ali Khan, executive engineer on the project, was the local Hyderabad commander. Strategically, the defenders had the better position. At the centre of Munirabad camp was a high hill, surrounded on the river side by a ready-made trench — the excavation of the main canal. By daylight on the 13th, the Indian forces occupied the railway bridge across the Tungabhadra and the Munirabad railway station. On to these positions, Hyderabad forces poured mortar and machine-gun fire. They counter-attacked the bridge without success. But, led in a reckless charge by a Hyderabad Army captain, they took the railway station. On the 15th, Sadiq Ali Khan personally rallied his men for a long counter-attack on the bridge. Driving forward in a Tungabhadra Dam jeep, this son-in-law of the great champion of interstate co-operation, Ali Nawaz Jung, was shot dead by a rifleman of the Indian forces. The counter-attack was beaten back. But the Hyderabad forces still held out at the dam-site. They were bombed that day by planes of the Royal Indian Air Force. That evening, Indian Army forces regained the Munirabad railway station.

On September 16th, 109 hours after the Indian Army entered his territory, the Nizam surrendered. About the same hour, a white flag appeared on the crest of Munirabad hill. Indian Army troops occupied the camp and the dam-site and pushed north to mop up Razakars who were still holding out in the hills. The shooting was over at the dam across the border. 'The hostiles suffered heavy casualties,' reported the Indian Army communique on the Tungabhadra action. But the Indian Army force lost, too (according to pension claims, 16 killed, 6 wounded).

Hostility did not, any more than the idea of independent Hyderabad, go very deep. Ordinary workmen on the Hyderabad side of the dam, mostly Hindus, did what work they could during the shooting. I asked the Muslim engineer in

Hyderabad who had administered the affairs of the Civic Guard how the brief war had affected personal relationships between the two teams of engineers on opposite sides of the river. 'For six weeks our meetings with the Madras engineers were a bit chilly,' he recalled, 'though we settled the engineering problems that needed agreement. After that, we began dropping into one another's quarters as before.' As for Khwaja Azeemuddin, dam and rifle builder, he was kept in house arrest for six months. Afterwards, he was permitted to move to Pakistan, where he became a chief engineer.

HOW IT WAS DONE

Tungabhadra Dam is the only dam in the world built from opposite banks of the river by two independent builders—two corps of workmen, two chief engineers, two governments. The Government of India was, of course, always available as a court of last resort; in 1948, it stepped in to suppress downright hostility by a small minority in one government. From that time forward, there was an overriding political loyalty that lessened the divisive power of the border more than ever before in 300 years. But the dam got built mainly on the strength of the sheer patience and tact of men who met one another as independent equals, but determined to get along. It was a triumph of self-restraint in which India can take a peculiar pride.

There was one other requirement for success under those almost impossible conditions. The engineers in charge had to have confidence in one another's technical ability. After the Hyderabad police action the confidence was there. And they had to be men decisive enough to settle differences when the crises of the construction job cried out for action. When Mr. Papaiah of Hyderabad, and Mr. Thirumale Iyengar of Madras made their monthly rounds of the work on the dam, no issue went unsettled. One of the engineers at Munirabad told me that Thirumale Iyengar was astonished to discover, when as chief engineer he first arrived at the dam-site, no road bridge connecting Munirabad with the Madras construction site. Hyderabad had built a bridge to an island halfway across the river; Madras had never completed the job. 'Nonsense!' exclaimed Thirumale Iyengar, 'The engineers on this dam can't go on meeting one another in boats.' The bridge was built.

It was after all, one dam across one river. Engineers empowered, and not afraid, to decide the common requirements as they arose, from sudden floods or foundation faults or breakdowns of equipment, could meet in midstream and get things done.

WATER FLOWS

On 1 July 1953, Tungabhadra Dam was opened with two ceremonies. On the Madras side, a simple rite was performed by the engineers before the assembled workmen and their families. But at Munirabad, on the Hyderabad side, there was a gala occasion. Ten thousand farmers watched, turning their multi-colored turbans, as the fifty-feet deep river foamed from the base of the dam and curved down the new canal. It was an auspicious hour, blessed alike by recitations from the Holy Qurān and invocations of the Hindu Lord Varuna, the God of Rain. A thousand *dhoties* and *saris* had been given to the poor, as befitted so historic an occasion, and sweets to the waiting children. Hyderabad's irrigation minister, Nawab Mehdi Nawaz Jung had been asked to open the gates. But he declined the honour. 'Let it be done,' he said, 'by the oldest farmer under the canals.' So it was 82-year-old Sankarappa, from the village Hosahalli, who pressed the switch of the electric hoist to raise the sluice gate. Some of the Deccan farmers, who like him had lived with famine, stared at the never-failing jet of water with stunned silence, but from other thousands came the involuntary cry of triumph: 'Jai!'

The two states had certainly created the greatest blessing to the precariously-watered Deccan since the fall of the Vijayanagar empire. Behind more than a mile of masonry, the first two weeks of the monsoon freshets had already delivered fifty feet of muddy water. Another month, and the great lake would fill: 2·6 million acre-feet, 113,000 million cubic feet of water (an acre-foot is enough water to cover an acre of land one foot deep). It is enough to water 9,00,000 acres: 4,50,000 in Hyderabad; 4,50,000 in Madras. In the driest monsoon man has yet recorded, the crops on those acres will get enough water from that lake to bring them to harvest.

In half a century of deliberation, administrators and engineers had worked out an intricate system for combining security against famine with the generation of electricity. Each side had its separate plans. In Hyderabad, half the land from the dam to the confluence of the Tungabhadra and the Krishna would get water; most of it for the lightly irrigated crops (cotton, *jowar*, *ragi*, pasture, and green manure), 137,000 acres for garden, paddy and sugar cane. No part of the hydro-electric plant had yet been built. But eventually the water would turn turbines—once at the foot of the dam, again where the irrigation canal drops 75 feet down rocky slopes on the way to the fields.

In Madras, the plan was even more complex. Half the Madras share of water would be reserved for a high canal yet to be built; a costly scheme, but one which would water 200,000 acres in the very centre of the Rayalaseema famine zone. Her remaining 250,000 acres of canal-benefited land, Madras had chosen to disperse here and there through three times that much dry acreage. This, too, was costly — it has required a main canal all the way from the dam-site to Kurnool, 225 miles—because the water must pass by two unirrigated acres to reach every acre it benefits. But that 'localization' scheme spreads oases of perennially irrigated farms through much more famine-vulnerable land than would normally be possible.

When the dam was opened, Madras was beginning her two generating stations; one at the foot of the dam, the other where the existing main canal drops seventy-five feet from the walls of the old Vijayanagar citadel. The 750 miles of transmission lines extend principally eastward to the towns of Adoni, Bellary and Kurnool, and to the pumps for the well-irrigation schemes of Cuddapah.

THE NEW BORDER

On 1 July 1953, it seemed that the border had been overcome at last and the common river put to the harmonious services of men on both banks. On 1 October 1953, Hyderabad found herself confronting two entirely novel partners on the south bank. The intricate system of canals and transmission lines on the southern side were cut jaggedly through by a new boundary. Mysore and the new state, Andhra, had divided the former Madras share of the project — along the line of language. But the canal had been designed upon the contours of the slopes, and the location of irrigable soils; the electric cables had been strung toward the most pressing demands. The new boundary cared neither for nature nor for economics, and the results left the engineers a little stunned.

Where it crosses the tributary Hagari River, the canal system might have been cut with surgical precision, and a quantity of water fixed to pass across the single aqueduct to the new state below. Language did not stop at rivers. The main canal now winds across the Hagari before it leaves Mysore; and after it has entered Andhra, feeds branches which re-enter Mysore. Distributary channels cross the arbitrary line of language without an engineering structure to measure or control the water.

A decision based on other considerations than the project had located the southern half of Tungabhadra headworks in the state of Mysore. The canal headgates were there, the spillway gates to store or release floods, both sets of turbines. But the use of water and power alike is mostly in Andhra; 55 per cent of the water, and 80 per cent of the presently-planned electricity. The gates of Tungabhadra Dam are destined to control, besides, the fortunes of cultivators lower down along the older canals fed from the Tungabhadra and Krishna Rivers. In their first season, those gates released water not needed in the Tungabhadra canals to irrigate a second crop of paddy on 100,000 to 150,000 acres of land in the Krishna delta, 300 miles away. The sluices in Mysore will let down the water for the old Kurnool-Cuddapah canal, which will demand more water as it is modernized and extended. The turbines also, will make a partially competing claim. Here is a situation fraught with more potential controversy than the construction of the common reservoir had been. Nor is the task simply one of finishing the project designed in 1948 and operating it. The high level canal through Mysore and Andhra is yet unbuilt; power generators must be installed when they are needed and ordered three years before. The new border, in short, bisects a job of building, running, and paying for canals and electric plant; but it also bisects an opportunity for development, choosing the best future expansions and promoting the full use of water and power.

North of the river, the unfinished canal system is also crossed by the same linguistic line which has divided Mysore and Andhra on the southern bank. The dismemberment of Hyderabad would make Tungabhadra again a two-state enterprise, with Mysore and Andhra replacing Hyderabad and Madras. But it would reopen the questions of relative shares, and extend the dependence of Andhra irrigators and power customers upon a headworks in Mysore.

Across the new border reaches the power of the Government of India. That is as it should be. It was the nation's funds, loaned to Madras and Hyderabad, that permitted the work to go ahead when state money was exhausted. An inter-state river is, as the Constitution provides, a proper concern of a national government. But the dispatch of water and electricity from the sluices and turbines of Tungabhadra project will determine the fate of long established state government concerns, not only of irrigation and electrification from the project itself, but of the irrigation from the Krishna delta and Kurnool-Cuddapah canals. Control of those inter-state interests will have to rest nearer than Delhi.[10]

Can the Government of India wield its basin-wide power, and wield it in a manner sufficiently decentralized to meet these needs? If it cannot, the controversy, the lost motion, and the second-best solutions which plague a project divided by a border will be Tungabhadra's lot again. But with courage and the willingness to think anew this need be no longer a border dam. The oceans and the Himalayas are the borders now.

4

FLOOD, FAMINE AND FORESIGHT

THE NIGHT OF 16 JULY[1]

ON THE evening of 14 July 1943, rain began to fall steadily at Asansol. On the next day, a real cloudburst began: in 24 hours ending on the 16th, 11 inches of water came down. As usual, the Damodar River, a flashy monsoon stream, rose quickly. By midnight on the 16th, it was carrying 350,000 cusecs of water past Burdwan, 70 miles below. This was not an exceptionally high flood; the most moderate, in fact, in the last three years. But this time the Damodar found a weak spot in the century-old embankment defending its northern bank. No one noticed, in the dark of night, the strange spring boiling out of the base of the dike. The muddy torrent spilled into a depression which had once been the bed of the Damodar and spread over the land. Every minute the leak grew.

It was the Air Raid Precautions Controller at Burdwan who first got the alarm. At daybreak, picking up the district magistrate and engineer, he drove his jeep south along the top of the embankment. Where a village named Amirpore had been, the three officers came to a sudden stop. In front of them a thousand feet of the embankment was missing. Through the breach two-thirds of the Damodar River flowed.

Three miles north runs the Grand Trunk Road, the first lap of the route from Calcutta to Delhi. Parallel, and just beyond, is the double-tracked main line of the East Indian Railway. Their culverts over a small drainage-way called the Gangur were never designed to pass the water of the Damodar; on the 18th of July both washed away.

By the middle of July in that part of Bengal paddy seedlings have been transplanted from the seedbeds into the fields. No light green rectangles of young rice showed that year in 50 square miles from Saktigarh to Kalna. Beneath a heavy layer of sand and mud and water, the seedlings died. The flat country under the breach is drained by four old channels of the Damodar—Gangur, Behula, Banka and Kana Nadi—meandering eastward to the Bhagirathi River. They had been filling up with weeds and silt for a century. The outlet they afforded was no match for the 200,000 cusecs pouring in from the Damodar. Twenty or thirty miles from the river, and for days after the break occurred, Damodar water crept quietly into the houses of villagers who had never seen the river in its normal course. Mud walls, when they had stood in water for a time, melted softly into thatch-topped lumps. The minister for Public Works made an estimate that in 70 villages, 18,000 houses were destroyed. Fortunately, because the water came up slowly, no one is known to have drowned.

The same issues of the Calcutta *Statesman* which briefly reported the Damodar Flood, gave major headlines to other news.

> 19 July: 'A B-25 flew from a base west of Calcutta to the Sweli bridge on the Yunnan border and dropped a load of bombs and returned to its base.'
>
> 27 July: 'MUSSOLINI RESIGNS'.

The war in Burma, however, was not going so well for the Allies. How much logistics suffered when for eleven weeks the Fourteenth Army was cut off from its headquarters and bases of supplies by the flood that severed the East Indian Railway, we do not yet know. What is clear is that, in the crucible of war, the Damodar emerged as an all-Indian problem.

Military transport was not the only strain upon the railways entering Bengal from the west in July 1943. Four months before it would harvest its first rice in November, Bengal had exhausted its food supply. Punjab wheat was available. The government was moving an average of 106 wagons of grain into Calcutta over the East Indian Railway every day when the line was cut. The only route now ran 300 miles around via the Khargpur detour; but it had already been overtaxed. There was no substitute for the main line.

Just a month after the news of the flood, the columns of the *Statesman* began a grisly accounting of its ultimate, indirect cost.

20 August: 'Calcutta ambulances on Wednesday removed from the streets another 129 cases of people suffering from starvation.'

26 August: 'From 15 August to 23 August the police corpse disposal squad removed 142 bodies from the streets.'

HALF-HARNESSED

A glance through the *District Gazetteer* suggests that neither flood nor famine is a novel visitation to Burdwan.

1787: 'flood covered everything but the bunds of tanks. Every house in Burdwan fell down'—Collector Kinloch.

1770: 'Famine killed one third of the people of Burdwan.'

But there is one theme in the old eyewitness accounts that makes strange reading now:

The delta of the Damodar, Ajay and Ganges 'on the British accession was found to be the richest tract in Bengal and the area of its oldest and most settled cultivation.'

1760: '. . . the enlarged, compact and fertile *zamindari* of Burdwan, which is like a garden in the wilderness.'

There is good evidence that in 1862 Burdwan began a period of decline in agriculture and prosperity—above all in morale—and the reasons are discoverable in the files of the Bengal Secretariat.

The late chief engineer of Bengal, C. Addams-Williams, traced the story back eighteen centuries.[2] A map drawn by Ptolemy in the second century A.D. shows Nadia or

Nabadwip as an island in the delta of the Ganga at the head of the Bay of Bengal. Nabadwip, indeed, means 'New Island.' In those days the Damodar, emerging from the Bihar hills, must have flowed straight east, falling into that enlongated Bay directly, as Orissa rivers do today. But the silt of the Ganga filled the Bay, and gradually raised the level of the southward-stretching delta. As late as 1757 the Damodar continued to flow east, now entering the Bhagirathi (Hooghly) channel of the Ganga delta well north of the present Calcutta. Sometime thereafter (tradition says in 1762) a sharp change took place. The Damodar found itself a lower outlet by turning sharply south midway between Burdwan and the Bhagirathi. It assumed its present dog-leg shape, entering the Bay far south of Calcutta. It is the characteristic story of delta-building: by the silt of its own floods the mouth of the river builds up the surrounding land and its own bed, until a new route offers a lower escape. To this day the lower reaches of the Damodar, beyond the elbow, are slowly working back toward the west.

As in any delta, the unused mouths continued to carry off the waters of the peak floods. The Banka, Gangur, Behula and the Kana Nadi had thus their annual cleansing, or as Bengal engineers say, 'flushing'. But the strengthened administration of the Burdwan Maharaja, and the demand of cultivators for the rich deltaic soil left behind by the old mouths of the Damodar, interfered. Ancient embankments below Burdwan were gradually reinforced. They held the usual freshets. But the high floods which topped them every decade or so did all the more damage; for houses and fields had encroached in the old floodways. Floods occurred so severely in 1840 (breaching the left embankment in 113 places) and 1848 (washing out a number of bridges on the Grand Trunk Road), that engineers debated whether to abandon the levees and let the river spend itself in its old channels.[3]

The issue was abruptly settled in 1852. 'Construction of the East Indian Railway,' said a memorandum of the railway's consulting engineer, 'makes abandonment of embankments in front of the rail line impossible.' That year inhabitants along the old bed of the Damodar begged in vain for an opening of the embankment so that they could receive Damodar water. The spill channels taking off from the left bank of the river were sealed by order of the Military Board. The following year a proposal by 'the natives, who offered to pay for it' to dig a canal from the Damodar where it now bends south to the Hooghly (not unlike the Eden Canal the government built a generation later) was also turned down, lest it carry sand into the Calcutta Port. From 1856 to 1860 the old *zamindars'* embankments along the left bank of the Damodar were realigned and reinforced. The route from Calcutta to Burdwan had to be made safe for the new railroad.

There followed at once an epidemic called Burdwan Fever. It was a virulent form of malaria, infecting a population hitherto unexposed to it. Dr. Charles A. Bentley, Director of Public Health in Bengal, who made a thorough investigation of the epidemic, estimated that between 1862 and 1874 it killed one third of the Burdwan population.[4] 'It is reported,' Dr. Bentley wrote in 1925, 'that in Burdwan prior to the epidemic seven-eighths of the land was under cultivation, whereas the latest returns show only 47 per cent of the cultivable area as being cropped.' Malaria came, Dr. Bentley concluded, when:

> This natural process of flood and flush was destroyed by the advent of the railways which required embankments for their tracks and a system of feeder roads to convey passengers and produce to their stations.

As to *why* the periodic flushing of the delta with Damodar water should have an antimalarial effect, Dr. Bentley could but guess. Flood water might drown grass and weeds; its higher temperature might be uncongenial to the larvae.

Twenty years later, Indian scientists, applying knowledge of malaria gained from the tropical battlefields of World War II, showed the soundness of Dr. Bentley's guess.[5] The malaria-carrying culprit of the Damodar delta is *Anopheles Philippinensis*, its habits what the layman would least expect. Swampy, waterlogged ground makes *A. Philippinensis* a poor home. High, dry tracts are its special habitat. The Bengal engineers of a century ago shut the annual floods out of the district on the Damodar's left bank. They made it safe for the railway—and unwittingly for the malaria mosquito.

So much a half-harnessed river cost on the left bank. The right bank is another story. The railway engineers knew well enough that they could never build levees along both banks of the Damodar high enough to hold its big floods. With realistic ruthlessness, they made a huge safety valve out of the country on the right bank. In 1855, the Government ordered that 20 miles of the locally-built embankments on the right bank opposite Burdwan be demolished. The Bengal engineers delayed a year to give warning to the villagers, then complied. The result was not surprising. In a moderate flood of 1856, according to a contemporary account:[6]

> the Town of Burdwan, the Railway, the Grand Trunk Road, are protected for the present; but on the other hand, the early and valuable rice crops, the staple produce of the district on the right bank, have been destroyed.

In 1891, the Lieutenant Governor decided to level all the remaining embankments on the right bank (ten miles were left) leaving only platforms 150 feet long 'on which the people and their cattle can take refuge in the event of high floods occurring.'[7] The right bank inhabitants remonstrated in vain. For a hundred years they have had two consolations for their periodic floods. Silt is enriching and slowly raising their countryside, so extreme floods cannot hurt them as they hurt the low left bank in 1943. And they have very little malaria.

There is one more unhappy footnote to the policy of half-harnessing the Damodar. Every year or two, beginning in 1856, the enlightened *zamindars* of the right bank villages, chiefly Ramapersad Roy and Joykissen Mookerji and their descendants, sought permission to divert the low flows of the Damodar to their fields for irrigation of winter (*rabi*) crops. This had become necessary since the right bank summer rice crops were perennially flooded out. The *zamindars* were ready to throw temporary sand weirs across the Damodar with their own men and money. But when answers came from the Secretariat in Calcutta it was usually too late to do the work.[8] (1858 was an exception; a fine crop was irrigated on 5,000—6,000 acres). Monsoon floods had already come.

NO FUNDS

A full century before the Damodar was dammed, an astonishingly prophetic engineer looked into the possibility of storing, instead of trying perennially to build defences against, Damodar floods. D. H. Dickens was followed in 1864 by Lt. Garnault who actually located storage sites; by Messrs. Schiller, Peterson and Goodenough who offered to pay for a waterway if the government would combine it with an irrigation and flood control scheme; by D. B. Horn in 1902, by C. Addams-Williams in 1914; and E. L. Glass in 1918-19. The prescience of these Bengal engineers was remarkable. While American engineers debated the feasibility of storage reservoirs, they were busy surveying them, insisting on them. 'There is only one possible way,' Mr. Horn wrote in 1902, 'controlling reservoirs.' They had the idea of multiple-use, too. But on the Damodar, reservoirs big enough to hold the biggest flood were too big to pay for out of the proceeds of irrigation and navigation. The government had no money to spend on flood control itself; it produced no revenue. The reaction of the Secretary of State in London to one multiple-purpose scheme revealed the cause of ninety years of frustration:[9]

> I cannot think, therefore, that the scheme under consideration could be proceeded with immediately without the risk of serious financial loss.

A grandson of *zamindar* Joykissen Mookerji commented:[10]

> The same unvaried note of despondency has been heard alike from the rulers and the ruled.

TACKLING THE PROBLEM

It would be hard to imagine a sharper break with the past than the government reaction to the 1943 flood. Mr. R. G. Casey, then Governor of Bengal, appointed an enquiry committee, and sent its report promptly to Delhi.[11] Though not an engineering plan, the report enlarged the previous views of the problem in two ways. First, it suggested that hydro-electricity help finance the scheme of storage. Second, it advocated bringing Bihar and the central government into the work. To the Viceroy, Casey proposed a survey 'by a really high level man or men from, say, the United States.'

In Delhi, Lord Wavell took an equally broad view of the case. 'The nearest parallel to the Damodar,' the flood enquiry commission had said, 'is in the Tennessee Valley, U.S.A.' Instructions were sent to the British Ambassador in Washington, Lord Halifax, to enlist a T.V.A. engineer not for fleeting consultation but for sustained planning. No doubt this was in spite of 'opposition of certain British interests';[12] Lord Wavell's move was not the normal strategy of empire. In any event, an engineer was brought from T.V.A., a man named Voorduin.

William L. Voorduin was an uncommon engineer. His work in the T. V. A. had given him scope to consider all the uses of a river. As one of the early specialists in engineering planning (the selection, as distinguished from the design of reservoirs) he had accustomed himself to decisions involving hydrology, and even economics. He had a tendency to fit apparently unrelated facts together. The War was in its grimmest phase when Mr. Voorduin joined the Central Technical Power Board in Delhi. But in six months the Board, greatly helped by the engineers of Bihar and Bengal, who exchanged data freely with the Board, had its plan ready.[13]

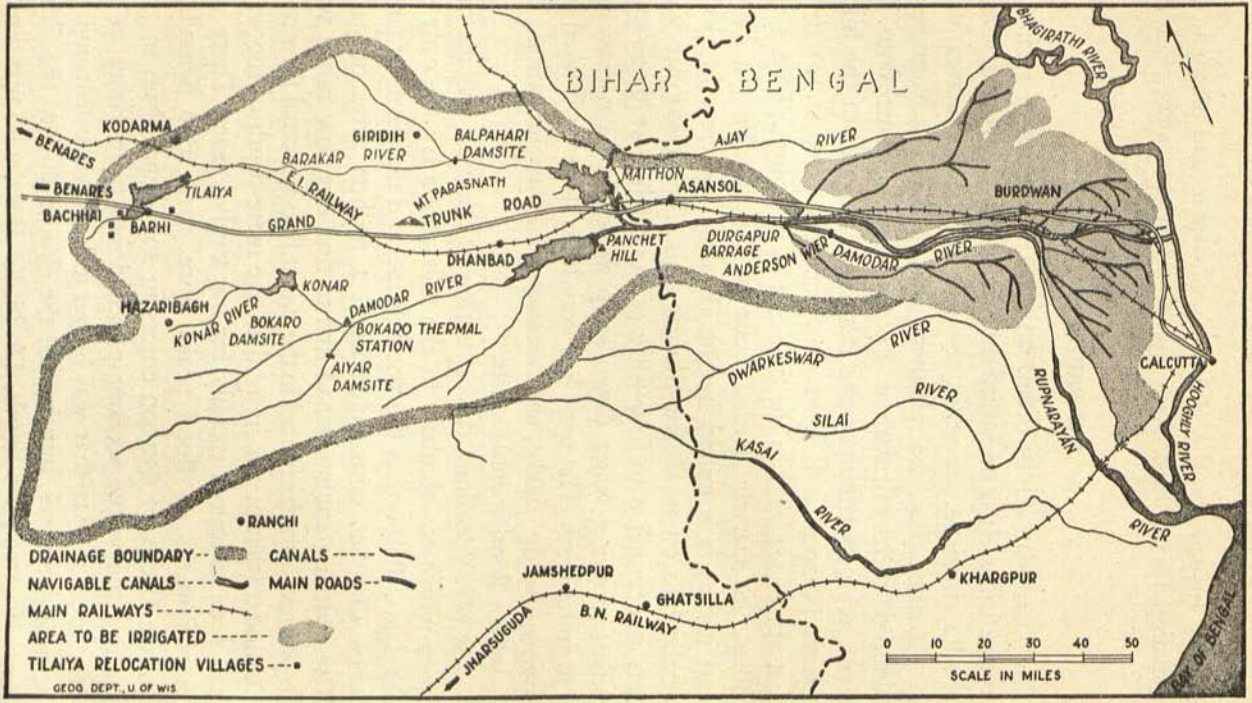
THE RAIN THAT FALLS

The Damodar River drains an area of moderate size, 8,500 square miles. It is one-third the size of the Cauvery or Tungabhadra drainage, one-fifth the size of the Tennessee Valley in America. For the planners that had one advantage—it reduced their calculations to manageable dimensions. The river, with its tributary the Barakar, comes from the hills of Chota Nagpur and flows down steeply from 2,000 to 500 feet above sea level in the first half of its course. That is all in Bihar, in sparsely settled country. At the Bengal border, and just as it is joined by the Barakar, the river breaks out of the hills on to its flat alluvial plain. The Damodar Valley acts as a funnel with four-fifths of the catchment (6,960 square miles), pouring water down steep slopes into a narrow neck 156 miles long. The neck has very little slope; it is lined with towns, paddy fields, and arteries of communication. That is where flood trouble starts.

For Mr. Voorduin, the beginning of the neck was the point from which to calculate. In the hills above lay the only sites for dams. Below was the flood threat, and the threat of famine when October rains failed upon a million acres of paddy. The planning engineers had first to find out how much water might run into the funnel in the worst flood. Actual flow on the Damodar (that means more than the mere depth of the water) had been measured steadily for but twelve years. There were measurements of flood peaks since 1911. But behind the known floods of 650,000 cusecs in 1913, and again in 1935, loomed the vague account passed down from father to son, of a flood in 1823 that was bigger still. Government engineers became detectives, hunting for the elusive clues to the dimensions of unrecorded floods. Dr. N. K. Bose, who was director

FIG. 3

THE DAMODAR VALLEY PLAN FOR THE FIRST PHASE



of the River Research Institute of Bengal, tracked down a record of an ancient temple, standing on an island, that had been inundated in 1823. It would have required a greater flow than any on record. But the temple was too far above the neck of the funnel to make it a reliable measure of the flood on the river lower down.

The planners turned therefore from the scant records of the river to the more complete records of the rains. They found an interesting thing. The cloudburst that caused the 1913 flood, though it delivered only 12 inches of rain over the Damodar catchment, actually averaged 20 inches elsewhere. Its centre happened to be a bit west of the funnel, otherwise the Damodar flood would have been much higher. On the other hand, there was no reason in meteorology why a storm could not pour its worst rains directly over the Damodar basin; precisely that had happened (fortunately with a smaller storm) in 1917. Mr. Voorduin now had to make a decision not of engineering but of policy. Should he plan against the worst flood known to *have* happened, or the worst that *could* happen? Men's records reached back but a short time; his plans must meet the test of a long future. He planned therefore against a 'design flood'—a flood bigger than any men had measured but which the clouds might any year deliver.[14] It would drop twenty inches of rain upon the seven thousand square mile funnel of which eighteen inches would run off the ground towards the neck. But the neck could pass half that amount without bursting its banks. The task was clear: to store in reservoirs the equivalent of the excess nine inches of water running off 7,000 square miles. That called for more reservoir space than Tungabhadra or Mettur or any other dam yet built in India.

The cost of flood storage on a stream which though not large was so obstreperous, had always blocked control plans. Mr. Voorduin knew he must, therefore, somehow make the storage pay by using it for irrigation and for power. An assured food supply and further industrialization were moreover second only to flood protection in their urgency. But though 'multiple-purpose use of stored floodwaters' was by that time a catchword, it was easier said than done. How could the reservoirs stand empty to catch the monsoon floods, yet somehow be full at the end of the monsoon to generate power and fill canals through seven months when no rain falls?

At this point, Mr. Voorduin found the monsoon had one saving grace. The great floods which might pour eighteen inches into the funnel have never occurred after 15 August. Floods may come also in October, but they are of moderate size. During the second half of the monsoon, therefore, it would be safe to let the reservoirs fill up four out of the nine inches of flood storage.

Now Mr. Voorduin came at his problem from the other end, irrigation and power supply. How much water could the Damodar be counted on to yield, even in a weak monsoon? How much storage space would it take to hold back that flow so that it could be doled out evenly through the dry months? The answer came, seven inches of catchment-wide run-off. Now, as we have just seen, four inches of the seven could be fitted into the flood space after 15 August; three inches would have to be added to the reservoir capacity calculated for flood storage.

Here we can see exactly what is saved by multiple-purpose planning. There would be reservoir space for nine inches of flood run-off—all that was needed, and for seven inches of irrigation and hydro-electric supply—all that could be counted on. In single purpose reservoirs that would take sixteen inches of storage. By multiple-use, both jobs could be done by building storage for twelve inches of run-off: saving 25 per cent. We see, too, what a completely harnessed river means. In the wettest year, no water overflows. In the driest, none runs waste to the sea.

The planners had now to locate sites for the reservoirs to hold this much water. For flood control, they ought to be as near as possible to the neck of the funnel, otherwise floods might come into the river below the dam. The engineers located the first two sites, therefore, where the Damodar and the Barakar break out of the hills, just before their confluence. They found another big reservoir site midway up each river, and the remainder of the storage where it was cheapest and easiest to build—four more smaller dams—a total of eight.

Would the project pay? In that form, Mr. Voorduin had to admit that it would not. Not enough saleable hydro-electricity could be got from the reservoirs. For though they could turn out 130,000 kilowatts of power in the monsoons, their dry-weather capacity would be but half that much. Most consumers require electricity all year round. For this problem, the Central Technical Power Board had a solution new to the Damodar, new to India. They would link with the hydro-electric generators equally powerful generators driven by steam from coal. In the dry months, the thermal station would run steadily, the water-wheels only when there was a peak demand. In the monsoon, the water-wheels would take up the full load, harnessing otherwise wasted floods and saving coal.

Mr. Voorduin was quite aware that a plan was not necessarily worth what it cost, merely because it was comprehensive. He could not yet be sure what the reservoirs would cost, for they had not yet been designed. But he put down a 'rough approximation': 55 crores for the entire system, based on the estimates that had been made for previous schemes and the 1945 rates for labour. He allocated this combined cost to flood control, to irrigation and to power, according to the cost of the reservoirs and other plant which would have been required to serve each purpose separately. He concluded that his plan would give insurance against floods for an annual premium of 54 lakhs. It would irrigate three quarters of a million acres for an annual cost of eight rupees an acre, and deliver power to switch-yards at three pies per kilowatt hour. A way had at last been found to make the Damodar, over the years, earn the cost of its own harness.

ESTABLISHED BY LAW

In six months of brilliant work the comprehensive engineering proposal was ready. But planning had just begun. It was not only that the engineers had yet to design their dams and other works and to estimate their costs. At best the engineers could deal with but two of the elements of an enduring plan. They could take account of the rain that falls and of the conformation of the valley and how they might fit together. As to the third element, the will of the valley's inhabitants, they could but proceed on economic assumptions. The judgment of what the people would in the long run (not merely under the shock of such a catastrophe as the flood) use and support and pay for, was in the highest sense a political question. For thirty months, planning of the Damodar properly fell into the hands of politicians.

There were men equal to the task. The man who in the political sense decided that the Damodar would be developed was the Minister of Labour in the pre-Independence cabinet, Dr. Ambedkar. The man who hammered out the details of the bill and championed it in Parliament was Shri N. V. Gadgil, the Minister of Works, Mines and Power in the new nation. But there were a dozen other men, some in the central secretariat, some in State governments, who made their contribution to a plan as bold politically as it was hydraulically.[13]

Mr. Voorduin and many other engineers had hoped that foundations would be dug for the first Damodar dams after the monsoon of 1946. In August, even while the representatives of Bihar, Bengal, and the Government of India had their first formal talk about the legislation of the Damodar project, Bengal staggered under a catastrophe not made by nature. The unrestrained slaughter that began in Calcutta on

'Direct Action Day' had its equally savage reaction in Bihar a few months later. With the energies of the Damodar Valley as of all India seized in a fit of separatism, Mr. Voorduin's heart sank and he went home uncertain that the Damodar would be harnessed.

Slowly, in quiet negotiation and in conference after conference, the vital political interests were discovered and somehow fitted together. The most difficult problem grew directly out of the engineering facts. Bengal would get the flood protection and most of the irrigation. It was not because any one willed it but because the floods came in the neck of the funnel and along it lay the miles of level alluvium needing irrigation. Bihar, equally unavoidably, would bear the hardships of farms and villages drowned beneath the reservoirs. It was only in her narrow valleys that reservoirs could be built. This was a clash of interests at least as serious, potentially, as that which for ten years stopped Krishnaraja Sagar half-built, and cost Tungabhadra Project forty years.

It was not solved by a single formula, but it certainly could never have been solved without the formula of which Shri Gadgil became the leading champion and to which all governments eventually agreed. It was to share the costs of development generally according to the incidence of the benefits and the ability to pay. The formula rested on a calculation which Mr. Voorduin had made and which had the confidence of all governments—the allocation of the common costs of the dams and reservoirs to the three purposes, irrigation, power and flood control. Irrigation investment was then divided among Bengal and Bihar exactly in proportion to the water they received for that purpose; Bengal, of course, would get at least nine-tenths of both water and cost. Flood control was the equal financial burden of Bengal and the Government of India, except that the Central contribution would not exceed seven crores. All three governments would equally share the power cost. Now, financially the scheme became as attractive to Bihar as, physically it was unattractive. She would get abundant electricity rendered cheaper not only by the economies of multiple-purpose reservoirs, but by Central assistance.

There was a second political problem. Most of the subjects of governmental action involved in the scheme (water supplies, irrigation, canals, embankments and water storage) fell within the provincial powers of the existing constitution. Electricity was a concurrent power of the centre and the provinces. Both Bengal and Bihar had adopted schemes under these powers which would have to make way for the Damodar Project. Bihar had its 'Grid' plan to electrify its mica mines and attract industry to the state. Bengal had its Damodar-Hooghly Flushing and Irrigation Scheme (enacted in 1939 but never built), to reach more than half the acreage proposed to be irrigated in the Voorduin plan. On the other hand, each province naturally had more confidence in the centre than in the other province (the Bihar Chief Minister was careful to explain to his legislature that this was a Central Government, not a Bengal, proposal). And only the centre had the funds to undertake the work.

To this situation, the political planners proposed a solution as radical as the comprehensive storage of the engineers. They called upon the two provinces to give up their own powers over the Damodar to the national Parliament. It would have been unthinkable, of course, had they not by months of frank consultation won the consent of the provincial governments to the bill whereby the Parliament would wield those powers. The bill contained the agreed arrangements for financial participation of the three governments. It set up the Damodar Valley Corporation. And it guaranteed to the provinces the right to retail distribution of electricity from the scheme and to control irrigation from Damodar waters within their boundaries. (In this respect the political planners cleanly divided the total job, ending the central responsibility at the canal headworks and the electric sub-stations, upon the same principle of fixed responsibilities that had permitted two governments to build Tungabhadra.)

Drawing the bill was one thing. Getting power transferred by the provincial legislatures was another. Bihar, which had the most to lose, was the test. Opponents got the enabling legislation referred to committee. The legislators knew there was bitter and sincere opposition to the measure from the people most directly affected; those whose homes would go beneath the waters of the reservoirs. It was the more tragic to uproot them because they belonged in many cases to forest tribes. 'There was rebellion brewing among the Santhals,' one M. P. later recalled.[16] But the courage and leadership of the Chief Minister and the Irrigation Minister were equal to the political risk. For the contention that this might be a good scheme but it would hurt Bihar, there was a shrewd answer :[17] 'If Bihar objects to D.V.C. because inundation hurts her and flood control benefits only Bengal, Nepal might apply the same tactic to Kosi.' The Chief Minister Shri Krishna Sinha, adjourning the first day's debate, talked with deep conviction:[18] '. . . it sickens my heart to find my friends objecting to it on the ground that it will be more to the interest of Bengal than to Bihar. . . India is geographically a whole, and to that belief we have sworn.'

The time of troubles which had disheartened the engineers had at last brought nationhood to India. Bihar debated the enabling resolution only forty days after Independence and on the crest of the upsurge of national loyalty passed it over-whelmingly. Once authorised by the transfer of provincial powers, the Damodar Valley Corporation bill encountered no serious difficulty in the national legislature. This was, in 1947 and 1948, the Constituent Assembly. Its members were keen for the national planning of which Damodar Valley Corporation was a peculiarly well worked out opportunity. They had been 'chafing under a sense of frustration' (Minister

N. V. Gadgil's phrase) in the national legislature since 1935. A Bihar member said: 'It is one thing to run a Government and another thing to protect it, but it is altogether a different thing to work for the real good of the people.' It was a peculiar satisfaction to draw up a durable peace with the forces of nature in one small corner of the country whose future seemed to stretch so far ahead.

The Damodar Valley Corporation Act was passed on 18 February 1948, and became law the next month.

TEST OF TIME

Seven years after the law was enacted and the Damodar Valley Corporation established, the working of the law had been subjected to the full scrutiny of parliamentary democracy. An Estimates Committee report criticized some important features of the Act itself.[19] An administrative Committee of Enquiry, headed by Shri P. S. Rau, found administrative mistakes but concluded that the plan, both as to its engineering and its statecraft, was thoroughly sound.[20]

The engineering plan of 1945 took shape in concrete, earth and steel with remarkable faithfulness to the drawings.[21] It is true that of Mr. Voorduin's eight reservoirs, four only are being built. They have 2·8 million acre feet of storage, not 4·7 as Mr. Voorduin planned. That means that though they can completely check a flood of the recorded 1917 or 1935 dimensions, they will spill the flood that might occur from a more catastrophic storm. The country from Burdwan to Calcutta still lies vulnerable in that sense. India decided, as the sorrows of other rivers came more to light, that every valley must bear some risk as long as others lacked the most primitive protection.

As I write these lines, in the summer of 1955, Tilaiya and Konar Dams have stood filled with water for two years. Maithon and Panchet Hill reservoirs will fill in 1956 and 1957:

all where Mr. Voorduin's plan fixed them a decade ago. Canals are cutting through a million acres of Bengal paddy fields (more than Mr. Voorduin planned) and the low barrage at Durgapur to feed them is nearly done. From it a boat canal will connect the Raniganj coalfield to Calcutta on something like the route of the prehistoric Damodar. For over two years D.V.C. has been operating at Bokaro the largest thermal power station in India, 150,000 kilowatts. From the generators run the transmission lines, farther already than Mr. Voorduin planned and soon to form a continuous grid from Patna to Calcutta to Jamshedpur. On the horizon are the new industries and the new crops which will give the valley a new economic birth.

Even more staunchly than the engineering plans, the political decisions of 1946–48 have stood the test of time. The Damodar Valley Corporation Act has not, as Shri N. V. Gadgil once hoped, served 'as a model for other schemes to come.' But it has weathered the severest storms that it is likely to encounter. The first of these grew out of the reluctance of a very large nation of limited capital, to carry through intensive development of one region while other areas have no river development at all. The second was the discovery, four or five years after the Damodar Valley Corporation was launched, that its cost would be between two and three times Mr. Voorduin's 'rough approximation'. The very consent of the participating governments had been given upon their cost calculations. Had the founders of the Damodar Valley Corporation not built upon solid foundations, in statecraft as well as engineering, the government of the Damodar scheme would certainly have had to be reconstituted as have other contemporary schemes throughout the world.

What are the secrets of the constitution of a river valley scheme which will endure? I believe it is a question which any alert citizen has a right to ask, and can answer by examining the history of the Damodar project.

FIRST.

The Damodar scheme was founded *by law*. That meant two things. Governments whose interests were at stake in the common plan (and who were themselves accountable to their own electorates) and the local communities and particular businesses who stood especially to suffer or to gain, formulated their claims in advance. The claims were deliberately and clearly matched with one another until all participants understood what was the best part they could have in the common undertaking. They have not, therefore, advanced their original impractical claims again. Moreover, in the legislative and parliamentary debates the public heard the arguments and glimpsed the goal, and the seeds of public responsibility for the completion of the undertaking were sown.

SECOND.

The founders of the Damodar scheme deliberately set about finding an administrative instrument that would exactly fit the job in hand. They found an analogy in the Tennessee Valley Authority, and they learned from the experience of T.V.A. all they could. But they made no blind copy. The Damodar Valley Corporation instead fits the peculiar conditions and history of its basin, just as the T.V.A. was tailored to a somewhat different region in America. Since the Damodar job was new, its planners organized anew. A new level of river control and use will be the result.

THIRD.

The physical plan was comprehensive. That is a much misused word. Comprehensiveness meant in the case of the Damodar, a plan to control the most, or the least water the river might bring, in ways that would do the most good. It was, like most plans, born of particular crises; flood and famine. Crises tend to be forgotten. But the plan has endured because it considered all the possibilities, in nature and in engineering, in their inter-relations. Selections had to be made from these possibilities. They were made with their relative costs known and in the full publicity of debate.

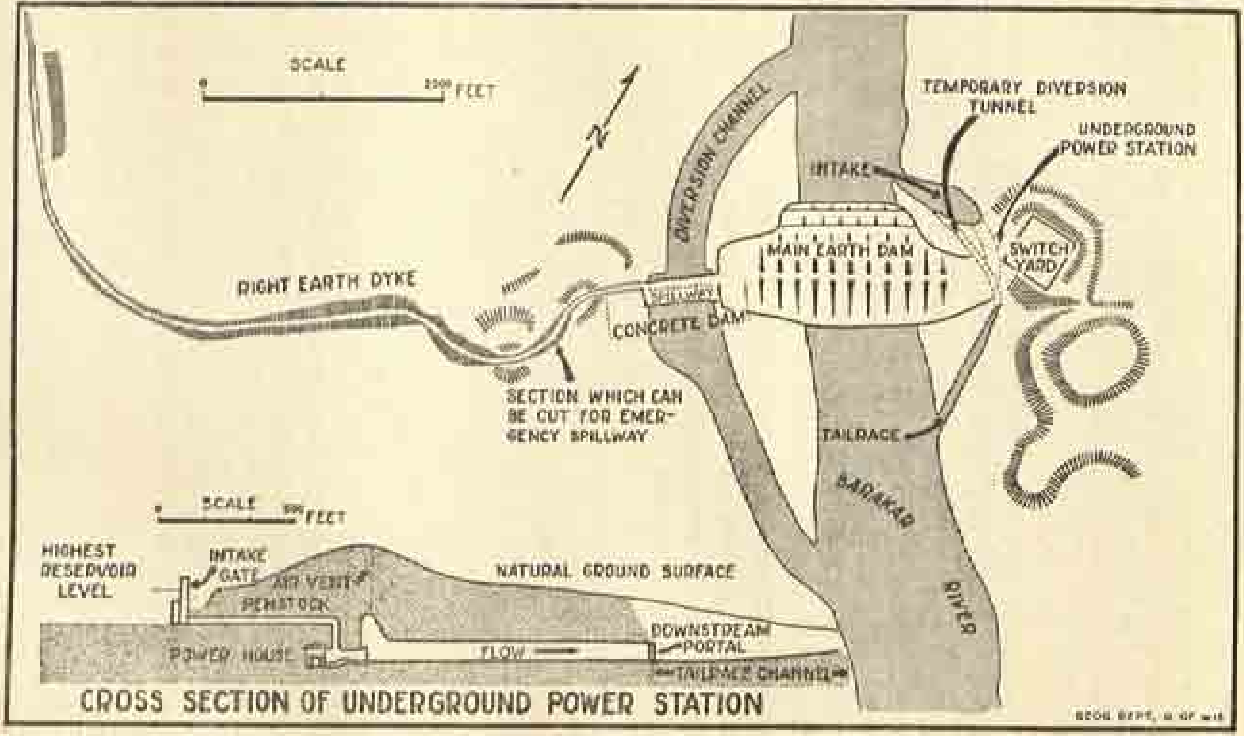
FOURTH.

The Damodar River was tackled, not upon engineering formulae alone, but for the good it might do the people it reached. The relation of the watershed to its eroding soil, the relation of the canals to the farms and of the power lines to the industries, have not always been worked out clearly in practice. But those relations were in the vision of the men who planned the dams and wrote the law. That was a new thing from which the country will not turn back.

Now and then every nation passes through a crisis which imperils its existence. It is fortunate if the very intensity of the crisis challenges her leaders to pause and look about, and plant some demonstration of the way future generations may live in the enjoyment of the permanent gifts of nature—of the water and the soil. Such was the challenge Roosevelt and Norris felt when they planted the T.V.A. in the years of America's worst depression. India went through deeper troubles when she got her D.V.C. But her leaders, too, found the energy and the imagination in those fiery months to design a fragment of the future.

FIG 4

PLAN OF MAITHON DAM OF THE D.V.C.



5

BETWEEN MONSOONS

On the morning of 8 June 1953, Mr. A. M. Komora, the chief engineer, took me to the edge of the freshly cut channel into which the D.V.C. was going to move the Barakar River. The channel was 350 feet wide; it had been cut through clay and boulders deep into the grey bedrock to river-bed level. Upstream, it stopped just short of the Barakar's waters. The monsoon when it came, would quickly raise the river enough to spill over the unexcavated end and rush down the artificial channel until it re-entered the natural riverbed, almost a mile downstream. Busy power shovels were digging at the stone walls and floor of the channel. Other machines hustled the spoil up the far side of the excavation and down into the former riverbed. They had already piled up a solid embankment, 2000 feet long and half as broad, completely blocking the Barakar. Every fresh load of earth or rock strengthened the main earthen section of Maithon Dam.

Beyond the still dry diversion channel, and the dammed river, ran yet a third channel. This one was out of sight, an 1100-foot tunnel. It matched on the far bank the route of the diversion trench on our side. Thirty-four feet wide and forty-two feet high, the tunnel could contain a modest three-story house. It was now carrying the entire dry-weather flow of the Barakar.

That panorama told at a glance how daring, and how crucial, was the season's target for Maithon Dam. In 1952, a contracting firm had driven the tunnel through the hills on the opposite bank in time to divert the low waters of the Barakar. This year, the D.V.C. had to do two things at once: to build up the earthen dam across the river-bed high enough and strong enough to block the biggest monsoon floods; and to get the diversion trench deep enough so that, with the tunnel's help, those floods could find their way safely around the flank of the earthen dam. In short, they were trying to move a good-sized river out of its bed and permanently to dam that bed, in eight months of a single working season. It was, indeed, a target beyond Old India's reach.

Shri M. N. Das, the project manager, came up as we stood talking. 'The morning paper says the monsoon has come up into the Bay of Bengal,' the chief engineer said quietly to him. 'Perhaps you had better start moving your machines out of the hole.'

'How far ahead will we know of a flood coming down the river?' asked the project engineer. He heard the answer, 'Twelve hours,' in silence.

Next day, when I called on Shri Das, I found out why he asked that question. He was in a confident mood, and he told me he could keep the excavation machinery digging away in the diversion channel until the very day the river came up. The chief engineer had agreed. 'But how do you know you will have time to get the equipment out of the way of a flood?' I asked, thinking of the low earth plug separating the river from its future channel and of the cumbersome pace of the drills and power shovels, scattered along the path of the coming flood. 'I know we can get everything out in eight hours,' said the project manager, 'because we did it last night.' He had stayed up all night with the third shift and staged a complete rehearsal of the emergency evacuation. He had lost a night-shift's production, but he had won all the working time until the monsoon broke. And at Maithon that season there was not an hour's work to spare.

Shri M. N. Das when I talked with him was 42 years old. He had done some government jobs before joining the Corporation (Kanpur Water Works, and some engineering for the old Rampur State). But like many of the D.V.C. engineers, he had also experienced the more flexible work methods of private contractors (he had been resident engineer for the firm building the Naini Tal water works and electric system). Even before the Corporation was chartered, he had been selected by Mr. Voorduin as executive engineer on D.V.C.'s smaller first dam, Tilaiya. And he had won the right to direct Maithon Dam by proving what he could do at Tilaiya.

Tilaiya was an adventure in itself. Though the reservoir had to fill in 1952, high-speed construction equipment had not been ordered. There was neither cableway nor trestle from which to pour concrete into the forms. Shri Das and the chief engineer hit upon an unheard-of solution. They perched the two cranes upon the highest blocks of concrete that had hardened, and from that vantage point, hoisted concrete to the others until they had been built above the level of the cranes. Then the travelling cranes 'walked' up ramps to the higher blocks, and when the last block had been poured, 'walked' off the dam on to the abutting ridge. Taking a risk, the D.V.C. team closed the last low gap in the concrete after the 1952 monsoon had set in. Week by week, the rising reservoir raced the freshly-placed concrete up to the spillway crest, but the builders stayed ahead.

D.V.C. had spent two painful years finding the men who could meet deadlines—and weeding out those who could not. D.V.C. paid that price for starting a job which there was no existing organization to take in hand. D.V.C's. reward was a resilient team of construction engineers, men who had shown they could master new methods. Shri Das took two of his Maithon executive engineers from his Tilaiya team, for example, and one each from the early D.V.C. projects at Bokaro and Konar. D.V.C. had others of the same quality: the Bengali revolutionist who studied dam design at California Institute of Technology and had never been known to overrun a target date, the quiet executive engineer from the United Provinces' Sarda hydro-electric project who watched over the contractor building Konar; the young executive engineer at

Durgapur Barrage who, when the contractors' tenders for that job were too high, offered to build it departmentally for less cost provided only he could pick out his own subordinates.

A team like this was building Maithon in half the time a multiple-purpose dam had been built in India—five years from breaking ground to generation of electricity. That speed meant machine work. Standing on the edge of the diversion trench, I got a panorama of the intricate planning which big machines exact in return for speed.

Along the edges of the channel were piles of rock drilled and blasted down by the preceding shift. Before them stood nine diesel-driven shovels. With each thrust of the bucket, they lifted two and a half cubic yards, well over 5,000 pounds. It took a shovel, skilfully operated, just fifty-one seconds to bite off, lift and empty that load.

Every four minutes, a rubber tired transport sidled up to the working shovels. Great rear-dumping lorries came to receive the loads of rock. Softer material was taken away in bottom dumpers. These unconventional-looking monsters had the wheels of a giant lorry, the engine of a powerful tractor and the body of a railroad coal wagon. Each held, in fact, fourteen cubic yards—five or six bites of the power shovel. Sagging slightly under each new shovelful it took a heaped-up load and moved instantly away in a burst of diesel explosions. Once up out of the hole it rolled on to the new dam at twenty-five miles an hour. A trip to the centre of the dam and back took six minutes. From the radiator of each transport flapped a signal flag. At a glance, its colour told the embankment supervisor what was in the load. A black and white flag meant stone from the floor of the cut; he signalled it to the upstream or downstream surface of the dam. Green meant gravelly material for the bulk of the fill. White marked impervious clay carefully placed in a core running the full length of the dam to make it watertight. As his machine spread over the assigned sector of the fill, the operator pulled a lever. The bottom of his earthmover opened and spread the contents in a wind-row beneath the rear wheels.

Behind a row of the 'bottom dumpers', power-driven scrapers moved along the wind-row, leaving an even layer of new material eight inches thick. Water tankers sprayed it just enough to make it pack hard. Samples of the earth or rock tested daily in the Maithon laboratory told the engineers just the proper mixture of materials and moisture to obtain the density in the embankment that the designs called for. Tamping was the work of a machine whose odd appearance is becoming familiar in India, a roller studded all over with heavy blunt spikes. After eight passes of this 'sheepsfoot roller' the soil, though perforated at the top, was more hard, dense and stable than it would be after years of natural settling.

The bird's-eye view of the fleets of high-speed machines, each doing in its turn a task on which the next depended, was a picture of effective organisation. It was like a switchyard of a great railway terminus, except that there could be, in that shifting mass of earth and rock, neither tracks nor time-tables. Each hurtling machine was directed into place by continuous brain work, and those brains had to be at the controls of the machines as well as at the desk of the construction engineers.

* * *

As I dug into the D.V.C. records, I learned that the most critical part of the planning of the machines began three years before. D.V.C. engineers who were old hands at mechanized dambuilding sat down with the designs of the dam and the profiles of the surface and subsurface structure of the earth at Maithon. They calculated first the number of standard two and a half yard shovels they would need to do the excavation. It was a complex calculation but the heart of it was this. Steadily employed, each machine could load 175 cubic yards of material an hour. They had 1,560,000 cubic yards of earth and rock to take out of the diversion channel. With a liberal allowance for breakdowns and delays, they calculated nine shovels could do it in one season. Each shovel would fill a transport in four minutes. If the spoil had to go to the near end of the dam, less than a quarter mile, the round trip would also take four minutes. Two dumpers could keep the shovel busy, one unloading while the other filled up. To move earth or rock to the far end of the dam, it would take four dumpers to keep the shovel busy. Similar calculations told the engineers how many sheepsfoot rollers they needed, how many scrapers, water tankers, tractors and bulldozers. There were many minor and auxiliary items, but the big standard machines made a list like this:

Number required	Machine	Capacity	Cost per machine, delivered, Rs.
9	Power Shovels	$2\frac{1}{2}$ cubic yards	3,70,000
19	Bottom Dumpers	14 cubic yards	1,60,000
8	Rear Dumpers	10 cubic yards	1,46,000
8	Rear Dumpers	15 cubic yards	1,80,000
8	Crawler Tractors	122 horse power	89,000
14	Crawler Tractors	175 horse power	1,05,000
4	Motor Grader		64,000
5	Sheepsfoot Roller		32,000

Seventy of the seventy-five machines in the partial list had to come from the United States. That meant six months to nine months before delivery. It meant, in short, that the engineers would be powerless to add another shovel or dumper during the construction season. The rains would be upon them before it could reach Maithon. Machines required foresight, but foresight could come only from experience.

Nor could men to drive the machines be called in when they were needed. D.V.C. was somewhat luckier in this respect than other Indian builders, for the nearby coal fields provided some men who had worked power shovels before: but not enough. In April 1952, therefore, D.V.C. opened a school for operators. There were no classes in the conventional sense. The 'school' was in fact an outlying portion of Maithon Dam, the earth dike over a mile long, closing a gap between two hills some distance from the main dam. The men learned first by riding with experienced D.V.C. operators and supervisors, then by taking the controls themselves. Greasers who had serviced the machines had their chance to learn to drive them. Outsiders were trained, too. One shovel operator who learned his skill that way, twenty-five year old Shri A. Ghosh, loaded 1365 cubic yards in a single shift.

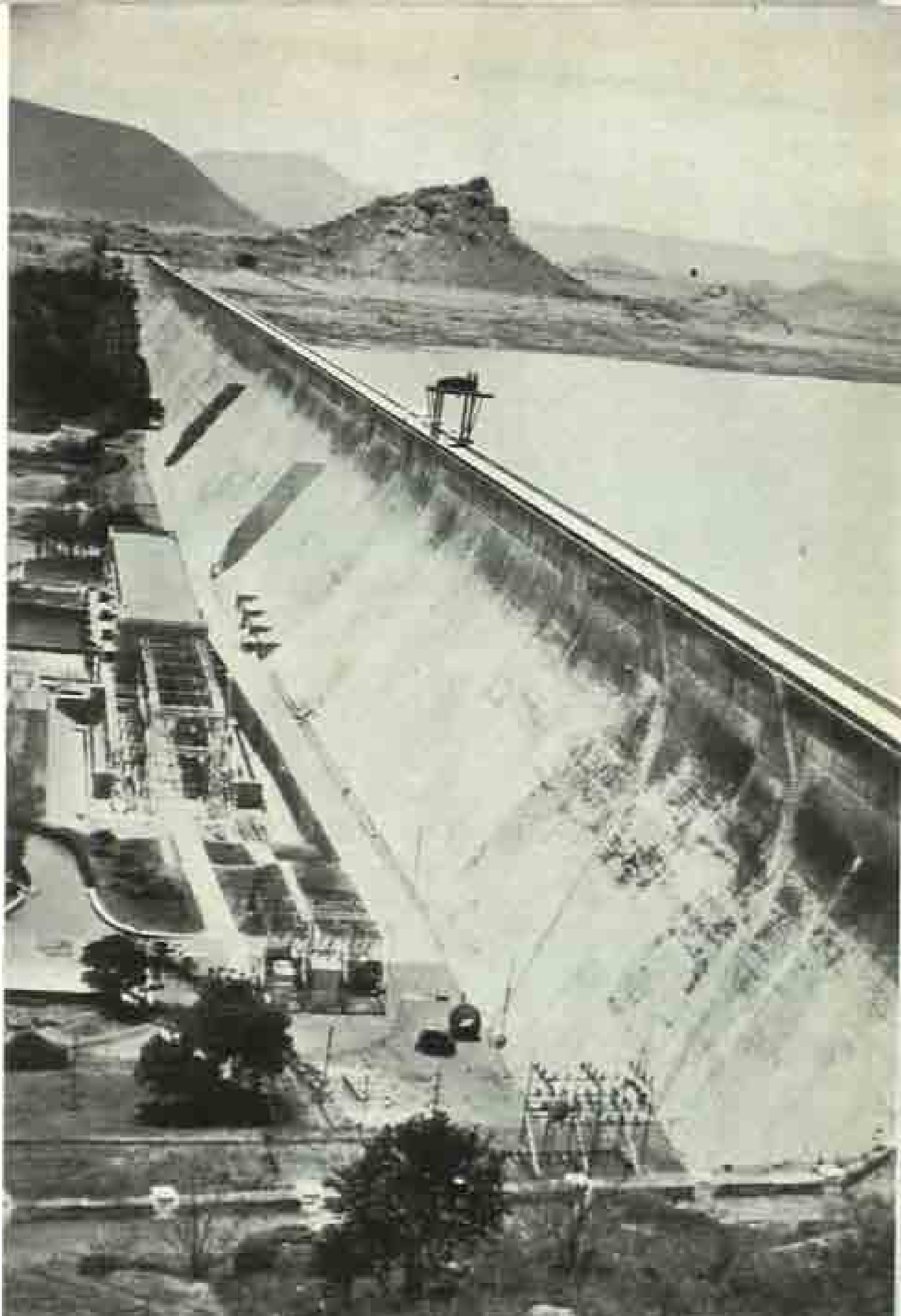
Intensive schooling, of course, was no substitute for the mature judgment of lifetime operators. The cost of inexperience was sometimes tragic. One operator disregarded rules to give a fellow workman a lift in his bottom dumper. Involuntarily he tripped the lever, the bottom opened and the rider fell beneath the wheels. An Industrial Revolution is never painless. Maithon, like other mechanized projects, went through it not in a century or a generation, but in a year.

When the rains came in 1952, the chief engineer knew his time for planning and preparation had been well spent. Was D.V.C. ready for the big push across the Barakar next season? Months before, one of the most seasoned consulting engineers in the world, the late Mr. L. F. Harza, had visited D.V.C. He was head of the firm which with the help of Indian engineers designed Maithon. 'If you do not have all the necessary construction equipment, the trained operating and supervising staff and the funds at site by October 1st,' he warned the Corporation, 'do not start the job on the diversion channel.' In June 1952, the chief engineer decided every one of those requirements would be met. He told some of his colleagues, engineers in Bihar and West Bengal and of the Central

Government of his schedule; D.V.C. was going to excavate 12,000 cubic yards of earth and rock a day next season and place them across the Barakar. His advisers were sceptical. 'Our people are not used to machines;' they said, 'they are not used to meeting deadlines.' Two years earlier, the chief engineer would have been shaken. Now he knew his team, from M. N. Das to the men at the levers of the shovels. 'We will move the river,' he decided, 'before the next monsoon.'

On 16 October 1952 the rains were over and the river went down. That day Shri M. N. Das set his machines to work. The work was not exactly what he had counted on: construction work never is. Maithon Dam like the old delta anicuts, is built on a foundation of sand, not rock. Solid rock is sixty feet down. But unlike the old anicuts, Maithon is 162 feet high. To keep the water under such pressure from forcing its way underneath the dam, the design called for an impenetrable curtain, reaching through the sand to the bedrock. It was to be of interlocked steel piling driven straight down to rock, all the way across the river. The heavy pile driving equipment was ordered to be delivered at Maithon in August. But in spite of D.V.C.'s urging, it had not come on time. The piling had to be driven along the centre of the dam before the earth could be packed in place. Shri Das and the chief engineer decided on an emergency solution that would save two months' delay. They would raise the upstream and the downstream edges of the dam, leaving the central core low until the steel curtain could be driven there. On 25 November the equipment arrived and they began the slow job of driving piling. Had they delayed their earth moving until then, it would have been too late.

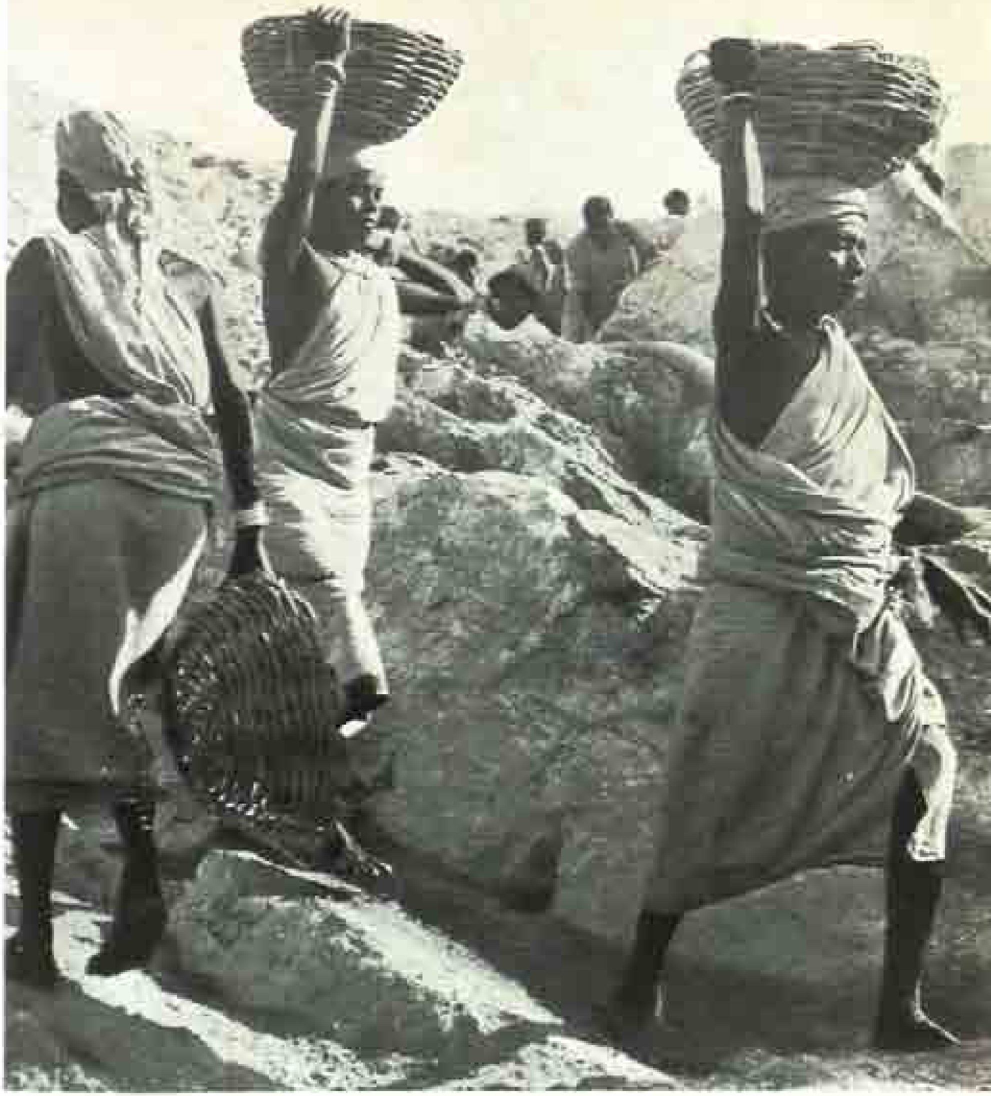
There were other unscheduled difficulties. Along the route of the diversion channel boulders were scattered on top of the ground. But beneath the surface, exploratory drill holes showed only dirt and clay, underlain by gradually firmer rock. The construction men believed the drill findings. But when



1. Mettur Dam in Madras, a product of British India. When completed in 1934 it was the world's largest masonry dam. Stored here, the Cauvery waters Tanjore the year round.

2A. Six bites of the power shovel fill the bottom dumper with material out of the Maithon diversion channel. It takes five minutes.

2B. Two minutes later the machine is half a mile away. Its bottom opens. Still rolling, it spreads 14 cubic yards of earth on Maithon Dam. That equals 378 headbaskets. *F. C. Rogers, Harza Engineering Co.*



3. Machines will pour the concrete at Maithon, but these women clean the foundation first. *F. C. Rogers, Harza Engineering Co.*

4 A. Indian artisans built Tungabhadra with hand tools and simple machines.

4 B. Workshop foreman Eswariah, translated the engineers' blueprints for high pressure sluicegates into the language of village blacksmiths.

the excavation got underway, the drills hit embedded boulders —hard and big. The boulders could not go into the new embankment, where they would prevent packing and rolling. They had to be sorted out, and that took time.

As the excavation got through the boulders down to soft rock, a worse difficulty began to dog the project. Shovels and tractors and dumpers, though serviced regularly night and morning, and checked up every Sunday when the work stopped, began to break down. The disease became an epidemic as the eight months drew to a close. D.V.C. had maintenance men trained to repair the machines. The trouble was that parts had broken in unexpected numbers, parts not to be had in India. On the dumpers, it was the intricate clutch and transmission parts that had to be ordered from England. On the shovels, the brakes and other parts that controlled the loading mechanism had to be replaced. Tractors waited for spare parts for tracks, transmission mechanisms, fuel injectors and pistons. Spares unavailable in India took six months to get. Some were ingeniously manufactured on the job; not all could be.

The interest on the money invested in a two and a half cubic yard shovel, at four per cent, comes to Rs. 96 per day. The machine costs that much, 'sick' or working. But every idle machine disrupted the intricate procession of other machines which had been planned to depend on its output. Dumpers could not work without shovels, nor graders and rollers without dumpers. But as the 1953 monsoon drew near, seven of the nine big shovels posted in the diversion channel were out of action. Taking the season as a whole, Maithon had its shovels and dumpers working only forty-five per cent of the time, drills fifty per cent.

* * *

'No doubt there were,' the chief engineer wrote me later, 'many sleepless days and nights.' Shri M. N. Das, who worked an average of fourteen and a half hours per day from January to June, spent one sleepless night, as we have seen, or 8 June rehearsing the evacuation of machinery to earn more time in the excavation. As it turned out, he earned two extra weeks. When the floods did come on 21 June 1953 his men pulled their drills and shovels safely out of the hole. A year before, the chief engineer had told his advisers D.V.C. could move 12,000 yards of earth and rock a day. He planned to place two million yards of material in the dam. On 21 June 1953 there were 1·6 million yards in the dam. For all its crippled machines, the project had moved 11,000 yards of material per day. Statistically, D.V.C. had fallen short of its target, just short. But strategically it had won. And on that day, the new Maithon Dam backed up the river and the muddy waters, lapping over the upper end of the diversion channel, rolled safely down through the mile of rock cut channel.

Suppose they had failed to complete the diversion when the monsoon broke. It is possible to picture the consequence. Certainly the unprotected earth in the dam, overtopped, would have washed away. The river might have escaped suddenly enough to have flooded the Damodar Valley below. Men who knew these risks had run them, for they believed in their organisation and their plans.

If this were an adventure story, it would end here. But it is an account of a nation developing her river, and some questions therefore remain. Could Maithon have been built by hand labour, even if it took more time, and thus made work for more people? Was there good reason for the haste? Would slower work have been cheaper?

Much to my surprise, I found that it was not the newer school of engineering that provided answers to these questions. It was nature. The Barakar River has done everything it could to bar conventional dam-building. It cut a narrow bed 60 feet down into the rock, and filled that hidden gorge with sand. To build a high dam of masonry would mean digging out that sand, and starting the masonry 60 feet underground to reach a secure foundation. The cost would have ruled out the site. On the other hand, the broad, even weight of an earthen dam could rest securely on the bed of sand, seepage of water beneath it being stopped by the inexpensive curtain of steel piling.

As I probed into the reasons for the Maithon construction programme, I had to turn from the builders to the designers. D.V.C. had decided three years before that the site called for the most versatile designers to be had, regardless of boundaries. They enlisted the Harza Engineering Company. I went to Mr. Franklyn C. Rogers who alone represents the company at Maithon—all the designs are drawn by Indian engineers—to learn why Maithon was built this way.

An earth dam at Maithon could only be safely built, he told me, if it closed off the river in a single season. That is because of another peculiarity of the Barakar. Unlike the Cauvery at Krishnaraja Sagar, or the Tungabhadra, it has no flood plain. There was no room between its steep banks for both floods and unfinished dam. (Unlike masonry, of course, earth dams cannot withstand water running over them). The only thing to do with the monsoon river during construction was to dig it a new channel around through the rocky hill and meanwhile to get the earth high enough to guarantee the river would not overflow there. Haste was not a matter of engineering preference; it was dictated by the only economically feasible design. In Mr. Roger's words:

> If single-season closure had been considered highly improbable, we should have resorted to a different basic design, probably a concrete or masonry dam extending for the full width of the river. The concrete or masonry dam would cost at least fifty per cent more than our present design.

I began to realise how ingeniously the Maithon design fits the site and the habits of Indian rivers. Every peculiar obstacle of nature has been converted, not into an advantage perhaps but into a facility for dam-building. The Barakar is like other monsoon rivers, two rivers alternating in the same bed. For eight months it is a small stream—the tunnel was designed for it then. When, in the monsoon, it becomes a mighty river, a huge open cut was waiting for it.

The Barakar's bed was sand and the flanking hills were rock —an arrangement the conventional designer would have thought perverse. So the dam was made of earth, and the hills of rock used to carry the tunnel and the diversion cut without hazard from the rushing water. But the arrangements for construction were made, besides, to serve the permanent uses of the reservoir. The left-bank tunnel has a permanent job as a tailrace carrying spent water away from the hydro-electric turbines. The turbines and generators themselves are being installed underground in a man-made cave cut from the solid rock above the present tunnel. It is a daring innovation, used not because it is daring but because it makes use of the natural rock in the hill to save building an expensive section of concrete between the reservoir and the turbines.

Likewise the diversion channel will become the permanent flood spillway of the finished dam. Rock blasted from its floor, properly crushed and mixed with cement, is going back in place as the concrete spillway section of the dam. Expensive concrete is kept to the bare minimum width to safely pass Barakar floods down into the diversion channel and thus away from the earth dam. The channel thus does double duty; quarry for earth and rock during construction, spillway upon completion. The multiple purpose idea makes its contribution to dam-building as well as reservoir use.

Could a dam like this have been built without the investment of money and foresight required by machines? Could it have given more employment to construction labourers? Again, it was not the preference of the engineers but the nature of the job that decided the question. Six thousand of the best coolies in India could, in one season, have dug the earth out of the diversion channel and pushed it on simple tramlines to the river-bed.

Hard rock would have called for an unknown number more. But when it came to packing the fresh earth and rock to a carefully designed solidity, human muscles are helpless. No engineer in India, or anywhere else, would try to build an earth dam 162 feet high, compacted by hand. Only the machines of the last twenty years—the bottom dumper, power scraper, sheepsfoot roller—and above all the soils laboratory, daily testing for solidity a sample of the new earth dam that the scientists can be sure represents *all* of the day's earthwork, have permitted high earth dams to be built in any country. Certainly, of the Maithon site, old India's engineers, working in stone or handplaced earth, would have had to say: 'This place is not fit for a dam to hold a million acre feet.' Mr. Rogers and his designers could draw the plans that fit the Barakar and its site best, because they knew Shri Das and his builders could build fast enough, with enough versatility in the use of materials, to execute them.

The cost of digging the diversion channel at Maithon and of placing the material in the embankment is about two rupees seven annas per cubic yard (Rs. 90 per 1000 cubic feet). That would be exorbitant for the earthwork of a canal where the material is moved a few hundred feet and dumped. It is not expensive for digging unselected material, for transporting it several thousand feet, and for consolidating it to rigidly controlled density. But machine work was not dictated at Maithon by an immediate saving in construction cost. It was dictated by the larger saving of storing water where it was needed by the only construction technique that could economically store it. Maithon is one of the sites—Hirakud, Bhakra and Nandikonda are others—where machines and men who can wield them have made dams feasible for the first time.

Maithon's economy is in the things the dam will do for the people. It is in the control of Damodar floods. For Maithon is the last place on the Barakar River where devastating floods could be caught and stored. There are higher sites where it would be easier to build. But they would let floods rise and sweep down on to the level Bengal plains from water that fell below them. Maithon will, in flood season, always have room in its million-acre-foot reservoir for one-third of the record flood that came down the lower river in 1917 and again in 1935. The other two-thirds will be caught by D.V.C.'s twin reservoir at Panchet Hill, seven miles away on the Damodar itself. Working the huge sluice and spillway gates of those two dams, D.V.C.'s water dispatcher will control the lower Damodar as readily as a housewife turns her water tap.

Maithon's economy is in its irrigation storage, too. For beneath the space left for floods its reservoir will annually provide water to irrigate 270,000 acres—to grow two crops a year even when the monsoon fails. And the water that flows down to the canals will flow through the turbines in the underground power house, turning 60,000 kilowatt generators. That electricity is worth 68 lakhs a year.

Maithon *could* be built because New India organized new skills and wielded them with a new courage. It *was* built to bring new safety and new wealth to people whom the old methods had consigned to a 'valley of sorrow'.

6

MEN AND MACHINES

DAM-BUILDING SILPIS

It was an old question that drew me out to the quarry two miles downstream from Tungabhadra Dam. I wanted to know whether, in a highly complicated job like dam-building, men are left in the world who can hold their own against machines.

Fifty-three year old Vellu Pillai, squatting in the shadeless quarry on a four inch slab of granite, ten inches wide and two feet long, gave me the first clue. In his left hand, which he protected from abrasion on the stone by a flap of inner tube, was a flat-tipped chunk of steel. Its end had been coarsely serrated in the forge nearby, and as Vellu Pillai's hammer drove it with casual swiftness against the face of the stone, it smoothed the irregular surface like a powerful file. Five o'clock ended the day's work for the stonecutters. In eight hours, Vellu Pillai had picked out a raw polygon of granite from the quarry, split off the surplus bulk, chipped the surfaces plane with successively finer chisels, and uniformly rounded one edge to match the sheet iron template at his side. His finished product attained the required accuracy, nowhere as much as a quarter of an inch larger or smaller than the pattern. He looked surprised when I inquired how many stones broke under his chisel. The answer was 'None.'

The stonecutter's history explained why this work was not difficult. In his Tanjore village forty years earlier, his father put the tools into his hands. Since then, Vellu Pillai had cut every variety of stone in South India. For ten prosperous years out of a life of dressing stones for well-linings and walls, he carved the ornaments and images of a Tanjore temple. There were a thousand stonecutters in the Tungabhadra quarry.

But there were hundreds more, under-employed, in each of the southern districts where stone was abundant and rice scarce, or where the public buildings of vanished kings had attracted earlier generations of artisans; Salem, Coimbatore, Tanjore, Ramnad. Here was a vast pool of skill.

Some of these men were more skilled than Vellu Pillai. One such artisan had been commissioned by the engineers to carve in granite a life-sized Pampatheswar, the manifestation of Siva identified with the river Tungabhadra or Pampa. There is a niche for this statue high on the downstream face of the dam. The sculptor, Shanmughachari, had executed the job without a flaw, following the prescriptions of the *Silpi Sastra*, a Sanskrit text of which lay in his home in Ramnad District. He readily explained to me the proportions of the male body laid down in that code: the head one-ninth of the total height, the throat one-thirty-sixth, the upper arm two-ninths. But Shanmughachari, the master artisan, balked at the creation of new forms. 'I will not undertake to give God a new shape,' was the way he put it.

When I asked Vellu Pillai where his finished stone would go, he could answer only, 'In the dam.' It was from a young design engineer that I got the answer to that question later that night. He showed me a drawing to scale of every stone cut for the faces of the dam, the spillway piers and the stilling-basin below. The round-edged stone I had seen dressed was destined for the coping of the spillway piers.

It was only a week later that I learned why, with simple techniques, so much could be accomplished at Tungabhadra Dam. I found seven miles away from the dam itself in a place now called Hampi—the ruins of the old imperial capital of Vijayanager. There was the evidence of the *Silpi's* craftsmanship four hundred, five hundred, six hundred years ago. The invaders from the north having found it too much trouble to demolish completely, there stood the same grey granite I had seen in the Tungabhadra quarry; fashioned into a triumphal procession in bas-relief, an overhead aqueduct to supply the queen's bath, temple *mandaps* innocent of the arch but sculptured as elegantly as the Gothic cathedrals of Europe. It had been four hundred years ago that the *Silpis* from throughout the South last gathered here to create work as daring, as advanced in their age, as Tungabhadra Dam was in this. (In that age they had, for that matter, put up sizeable dams paved with cut stone: it was on one of these, Krishnadeva Raya's celebrated Rayakeri tank, that the Portugese engineer De Paes had seen the prisoners executed to expedite the masonry.) The tools, the formulae, the lore of the craft had come down through the generations from Vijayanagar to Tungabhadra, unimpaired. But the inventiveness, the sense of design out of which the *Sastra* originated had slept four hundred years. Had it now awakened in a new profession among the design engineers? Men who would not cut stone to 'give God a new shape,' were cutting stone to impound a river a hundred feet deep. By the metal template at Vellu Pillai's hand invention gave old craftsmanship a new mission. The design itself was novel. But the teamwork of brain and hand was a renaissance.

THE DISCIPLINE OF MASONRY

I realized now, with the involuntary awe of one from the West who comes upon the clean lines and true curves of a structure laid by hand, why it could be done. I stayed at Tungabhadra to ask a more difficult question. Was this an efficient way to build?

Tungabhadra is a big dam. It blocks a valley one and one-eighth mile across to a depth averaging 110 feet. It is almost exactly the size of Mysore's pioneer Krishnaraja Sagar Dam — a bit higher, not quite so long. Unlike Maithon, which because it rests on sand is built of earth, Tungabhadra is solid masonry straight across the river-bed. (On the Hyderabad side, there are two small separate dikes closing gaps in the ridge. They are built mostly of earth.) The amount of masonry required for a dam this size is staggering. To the engineer, it is 32 million cubic feet—well over a million cubic yards. To the non-engineer, a million cubic feet is a hopelessly outsized scale. Imagine the masonry in Tungabhadra Dam being laid as a highway, 20 feet wide, 6 inches thick. It would extend from Lucknow to Calcutta, or from Bombay to Madras.

Now the masonry of Tungabhadra Dam was completed, from bedrock to parapet, in five years and some months. To keep up that pace meant laying 40,000 cubic feet a day, except when special difficulties intruded. The peak rate was about 50,000 units. Going back to our imaginary highway, that means a mile finished per day.

When masonry is rising at that pace, it has the look of rampant chaos. The future dam is a mile of uneven boulders, their surface deliberately left as rough as possible to anchor the next layer. Upon them squat 400 masons, each gradually extending the one-foot layer of new stone, perhaps eight to ten feet square, which is his day's work. In ragged file the stones arrive, carried just as they were to the walls and *mandaps* of Vijayanagar on the heads of women and the shoulders of men. From the womens' heads the masons' helpers unload the lighter stones they carry—stones weighing up to eighty pounds. After half-a-dozen of these, arrives a cyclopean chunk of granite to give weight and hence stability to the mass. One or a pair of these will weigh 300 to 400 pounds, a four-man load. The weight is slung in a light chain, draped with deceptive casualness from two stout bamboos.

There is skill even in porterage, a highly inefficient use of human bones and muscles. In that skill these four-man teams excel. Bred in the Telegu districts, they search India for heavy weights and premium wages (at Tungabhadra they got Rs. 2-8 per day). Teams of them arrived early at the damsite from Burma whence they had been driven by war. At one place where the masonry lay below the tram-track from the quarry, I was astonished to see building stones carried *down* by these Bezwada coolies. "Why not simply slide them down a chute?" I asked. 'We tried it,' said the engineer, pointing to a disused wooden trough. 'It cost us too much in breakage and the risk of injuries from falling stones. These men take the stones down as fast as we could collect them at the bottom of the slide the other way.'

Among the masons at each level of the dam move men in khaki, government overseers. Under their eyes the loose mortar and dirt of the previous day's masonry must be brushed clean before the new layer is deposited. Steel probe in hand, they check the mortar joints against cavities. The masons and the coolies supplying them are employees, not of the government, but of minor labour contractors. To ensure the quality of their work, government engineers not only inspect it but supply mortar of adequate 'richness'. The mortar, which reaches each mason along with his stone on the heads of female coolies, is mixed in engine-driven machines, twenty cubic feet at a time.

On top of a finished block of the dam, the seasoned construction engineer R. K. Gopalan, who had begun dam-building a quarter century before at Mettur, showed me a long round cylinder of mortar and granite. It had been cut from the heart of the seasoned random-rubble masonry by a diamond-pointed core drill. It weighed, he told me, a bit more than concrete, and almost as much as the native rock itself. To the engineers that density was the crucial point, for against the tipping pressure of a hundred feet of water against its upstream face, Tungabhadra like other straight gravity dams stood fast by its own weight alone.

The system of construction by which concrete is poured into prefabricated forms rigidly sited under the radii of crane-booms, creates an order at once apparent, for it is geometric. Behind the trackless paths of the coolies and the amorphous deltas of rubble beneath each mason's trowel, however, I began to detect a different kind of order. It was an order of habit and pace, but its relations were as sure as they were flexible. Undeterred by other builders, the mason and his helpers laid their hundred cubic feet a day of random rubble on to the heart of the dam. On the two vertical faces, the more skilled masons brought the cut stone up proportionately. Five coolies—more or less, according to the length and steepness of the bamboo ramps—supplied each man with stone.

Behind them the invisible suppiy lines moved on wheels. A narrow-gauge tram line brought the stones, dressed and rough, from the island quarry. The nearest bed of sharp clean sand lay twenty-four miles away upriver. It was collected, by headbaskets, into tram cars. Thence from the railhead four trainloads moved down the broad-gauge tracks each day to Tungabhadra. Cement came by rail from Hyderabad. Lime and brickbats for *soorki* were burned in improvised kilns at the foot of the dam. For the fine clay required in the manufacture of *soorki* the Madras engineers were indebted to the 16th century monarch Krishadevaraya. In all the sandy Deccan soil, only the bed of his great Rayakeri tank yielded the proper raw material.

Some of the operations by which Tungabhadra was built are far more ancient than recorded history. Lime mortar was introduced in India by the second century B.C. Stones were dressed and transported by identical techniques in the quarries of Asoka. But the building of the dam was neither entirely traditional nor entirely by hand. Modern core drills explored the foundation and prepared holes for grouting—high pressure pumping of mortar down into the fissured rock. Lorries and trains moved the raw materials through the longer distances. A dockyard crane on each side of the river lifted the greater weights such as bridge girders to the top of the dam. Piped water and electricity served the whole site. Everywhere small power-driven mixers were relied on for the production of mortar and concrete. Masonry was laid by hand, but the over-all method of construction was a prudent mixture of hand and machine work.

In the worst crisis of construction, machines proved indispensable. That was in the rainy season of 1951, when the masonry was first thrown entirely across the river and the high water funnelled through the temporary low blocks in the spillway left open for it. Unfortunately there was also another low notch in the dam, where passage of the river would have done tremendous damage. It was the section through which penstocks lead water to the powerhouse turbines on the southern side. These four steel pipes, eleven feet in diameter, had been delivered late by the manufacturer. As the masons rushed to embed them in stone, and to bring up this section of the dam to its scheduled height, the river also began to rise. A low semicircular dyke of earth was thrown up to keep the water out of this penstock section.

On 26 July news came of a downpour in the headwaters. It was like the warning of an enemy offensive to a besieged army. Every labourer was put to work piling earth on to the cofferdam. Their strength was about half enough. The earthmoving machines were drafted, their number reinforced from the nearest canal excavation and from the Hyderabad construction organization as well. Two power shovels, three dumptrucks, two earthmoving scrapers and two graders worked around the clock to double the height of the cofferdam before the flood crest arrived. Next day the river stood thirty-two feet deep against the emergency embankment. It would have been twelve feet over the top of the previous day's defences. But by now the embankment, though thinner than the engineers would have liked, was 40 feet high. For six weeks the engineers took turns standing an all-night guard lest the river breach their precarious defence. Meanwhile the masonry slowly rose around the penstocks, out of danger. Men and machines, neither enough by themselves, had together saved the penstock pipes and got the dam back on schedule.

The relatively simple machines, the traditional crafts and the familiar processes employed at Tungabhadra could readily be added to when the need arose. In the logistics of material supply, there was no dependence on complex mechanical links that might be broken by delays of imports or shortages of spare parts. Supplements could always be found. Halfway through, the engineers found the masonry lagging behind schedule. By now the foundation difficulties were overcome; costs were known. Hyderabad and Madras chief engineers enlisted large private contractors to take major sections of the masonry work. The contractors, doing a familiar job, could supply their own material and equipment. That way, the work was brought on schedule.

But the schedule that can be set for masonry projects has its limits. They applied to Tungabhadra as to Krishnaraja Sagar and all the other dams built by handplaced stone. A new layer of masonry cannot be laid until the one beneath has set. The unit of vertical progress is about one foot. But concrete goes into its forms in lifts five feet deep (at Bhakra, six feet). At Tungabhadra, 20,000 men could reach a daily peak output of 50,000 cubic feet; at Bhakra 2,000 men attain an output of 150,000 cubic feet. What is speed worth? It may, in some sites, mean closing off the river in a single season and thus avoiding exorbitant diversion costs. That was the situation of the earth dam at Maithon. It may be the only way of working through a narrow gorge, as at Bhakra, where materials must move continuously at high speed or get hopelessly delayed. And it may save money, by bringing returns on invested capital with a minimum sum at interest.

Aside from speed, there are some dams so high that they could be designed safely only with the uniform strength of concrete: Bhakra and Nandikonda are of this class. But where the dam is long and no more than two hundred feet high, the fundamental bottleneck of masonry construction can often be prudently accepted. In return, the Indian builder escapes a number of subsidiary bottlenecks that plague the engineer who relies on highly mechanized techniques.

'When you build a dam of concrete,' Shri M. S. Thirumale Iyengar, Tungabhadra chief engineer, put it with characteristic force, 'you reduce a mountain of rock to gravel, then cement the gravels together again. For high dams, you have to do it. For dams this size, why not handle the rock in bigger pieces and save the intervening steps?' The chief engineer revealed by his smile that he was not disposing of the question of technological efficiency by so simple a formula. But Tungabhadra demonstrated that there was a solid economic truth behind his words. Concrete required stone broken to six inch size to pass in utterly repetitive processes through huge machines. Masons, applying intelligence along with dexterity, could handle much larger units, placing each stone according to its shape. The question of masonry versus concrete (where the choice was permitted by moderate height and availability of stone) thus boiled down to a question of the labour and machines in the market. India had a wealth of men whose intelligence was geared to the application of muscles via hand tools to stone and mortar. She had painfully to train each operator and manager of automatic machines. Tungabhadra was built with the utmost reliance on the ability India had, and virtual independence of the ability India had not.

Already India needs a corps of dam builders competent in high speed construction. She will become independent of imported talent only if these men have carried the responsibility on smaller dams of placing concrete mechanically. Maithon, from that viewpoint, is a pilot plant of the Industrial Revolution in dam building. It is recruiting for the future. Tungabhadra needs no long range justification: it is a good job of work.

The unsentimental test of this economic logic is the cost of masonry as compared with concrete placed by machines. Truly comparable cost figures are not easy to get. Fortunately, both the Madras Public Works Department and the Damodar Valley Corporation have gone to some pains to analyze their costs of construction. They are themselves anxious to submit the economy of their building to comparison. Each hundred cubic feet of masonry laid at Tungabhadra actually cost, on the average, Rs. 128 or Rs. 132. Lime-soorki mortar permitted the cheaper rate. D.V.C. has at Maithon Dam the most completely rationalized, scientifically planned concrete-laying plant (until Bhakra) in India. But its product will cost Rs. 145 or 150 per unit. Bhakra, with its huge volume of production is another story; its estimated cost of Rs. 100 per 100 cubic feet is not available by any method on lesser dams. And remembering that both D.V.C.'s Maithon cost and Bhakra's cost are advance estimates, whereas Tungabhadra's figure is actually attained, it is certainly clear that, rupee for rupee, big automatic machines have not been able yet to do more work than men working with simple machines.

THE DISCIPLINE OF THE PHOWRAH

In America, a hundred years ago, muscle-power gave machine-power its last stiff competition in a task demanding crude strength alone. That was upon the laying of the railroads. Out of the contest has come a folk ballad, sung often to the rhythm of the sledge upon the spikes anchoring rail to sleeper. It recounts the stubborn attempt of John Henry, a giant among the railroad track-gangs, to race a power-driven machine (symbolized in the song as a 'steam drill') in the driving of spikes. John Henry, like the contemporary labourers of India, had followed his sweaty trade all his life, and he had already taught his infant son 'You're going to be a steel-driving man.' When the machine came on to the railroad, he offered to stake his future on a direct test of speed.

John Henry told his Captain
That a man is a natural man

And befor he'd let that steam-drill beat him down
He'd fall dead
He'd fall dead
With a hammer in his hand.

Rails are still spiked by hand in the United States, but in the song where this contest symbolized a larger issue, John Henry lost to the machine. 'He laid down his hammer and he died.'

No more in India than in America can workmen outdistance the machine in a sheer test of speed. But as to cost, the race is by no means over. India may be one of the last nations of which this is true; and it may surprise some economic theorists. But again and again, on the simplest of construction labour, human muscle still competes cost-wise with machines. The race has been clearest on the earthwork of canals, where men and women work alongside some of the most modern machinery in the world, doing exactly the same job.

Like John Henry, the earthmoving labourers have produced their own champions. I found them digging the 175th mile of the Tungabhadra main canal. On the red and black tableland of western Andhra, toddy palms as well as fantastic outcrops of granite boulders were scattered a mile or more apart. In the uneven bed of the canal, five hundred men, their tall bodies clad only in loincloths, were loosening the hard soil with *phowrahs* and pulling it into iron pans at their feet. Their women, pans lifted on their heads, climbed the zigzag steps carved into the slope of the canal bank and dumped the spoil outside. Not six feet beyond the rising heaps of excavated earth stretched their row of a hundred or so straw huts. There was not another dwelling nor road nor sign of human habitation as far as the eye could reach.

These were the famous Palamooris, whose villages lay 150 miles north in the Mahboobnagar district of Hyderabad. Their workday started at six when the sun rose, ended at six when it set. As the hot months came on, they worked through the moonlit nights and slept by day. Three times they halted work to eat, for thirty minutes each meal. Their rice was cooked not by wives for husbands, but by a few old women for the entire group. Men and women alike had deducted from their earnings one rupee a day for the cost of food. By as gruelling a day's work as free men do in the modern world, a man and his wife might thus earn above expenses two or three rupees, calculated upon the volume of earth they moved. Unfortunately, few Palamooris saved this much. Toddy took its share. These men and women constituted, in fact, an earthmoving collective under the control of the contractor who had brought them south across the river. This man was the *zamindar* of their native villages. Indebted to him for their railway fares to the job and in some instances for agricultural loans as well, they were tied firmly to their toil.

It was, however, a less simple motive that urged the Palamoori labourer to excavate at the rate of 120 cubic feet a day. Unrelenting digging was as much a social habit with him as the code of the *Silpi* to the stonecutters. The Palamoori's first attachment was to his fields; he worked outside only between harvest and ploughing. But in those four months, nothing could stop his moving of earth save the limit of physical endurance.

There was one exception. In 1952, three Palamooris on the canal died of cholera. As one man, the surviving thousand fled back to their native villages.

Reliance on great armies of men and women, like reliance on imported machines, produced its unexpected hazards for the canal. Thirumale Iyengar proposed originally to excavate it entirely by handwork, using a single power shovel. In the end, half the work had to be done mechanically. The reason will astonish those who think over-simply of mass unemployment in India: for two years the engineers sought in vain for labourers enough to dig the canal. Aside from the

Palamooris (1000 on the Madras side, 5000 on Hyderabad's canals) and some industrious labourers from the Godavari and Krishna deltas, nobody accepted the work. At last machines had to be ordered from abroad, not because they were more economical, but to finish the canals in time.

Some of the engineers attributed the labour shortage to the 'famine mentality' of the villagers in the canal area. 'For generations,' I was told, 'these people have tilled their fields if the rains were good, and done only famine relief jobs if the rains failed. They don't know what it is to work hard for wages.' It would, of course, be strange if centuries of capricious harvests had not driven the more enterprising peasants from this Rayalaseema tract.

Then why did not enough workers come from afar, as they did to Tungabhadra Dam itself? The answer was obvious. Long-term employment at the dam gave even common labourers a chance to erect stout huts; they had water taps, transportation, schools. Canal work, being transient, traditionally ruled out these amenities and canal wages were not raised enough to compensate for them.

Is there a lesson in that experience which applies beyond the famine-cursed Rayalaseema? Have labourers, especially unskilled men and women, come to demand a larger share of the nation's income; and are they thus shifting the economic advantage a bit toward mechanization? We need not speculate on this point. Here are the percentages by which wages have risen in India since 1939, compared to the rise in the cost of cement (since it is used for concrete) and equipment for mechanized dam and canal building:[1]

	Per cent of 1939 cost		
	1946	1950	1953
Wages of skilled labour	233	315	345
Wages of unskilled labour	268	355	413
Price of cement per ton	173	239	248
Construction equipment	135	293	373

The figures are not yet conclusive. But they suggest that a revolution, at once economic and social, has unobtrusively begun in India. Because men and women are putting a higher price on their services, a higher degree of mechanization is becoming feasible. Engineers from industrialized countries have had to learn in India that the revolution is far from complete: western ways of building are not necessarily economical here. Meanwhile, Indian engineers are learning that the revolution is underway: that by and large and little by little, the workers of New India will demand more income and that means using them at higher skills.

MECHANIZED EARTHMOVERS

On many of the new projects can be found today a variety of engineer unknown to India ten years ago — the mechanized earthmover. His hands are equally accustomed to the bulldozer's control bar and the slide rule, his eyes to grade stakes and blueprints, his mental processes to miles-per-hour as to cubic-feet. Most of these men are dam builders.

In Bombay, Shri G. G. Dhanak built an earthen dam somewhat bigger than Maithon's entirely by high-speed scrapers. On this Gangapur project he developed such interest in the efficient selection and management of machines that the Ministry of Irrigation and Power brought him to Delhi to be secretary of an all-India committee on construction machinery.[2]

Uttar Pradesh is dotting the valleys of the Vindhyan range with irrigation reservoirs for her southern districts. The sixth of these, 100-foot-high Rangawan Dam, was put into use in December 1953 exactly twelve months after its construction began. Chief engineer B. P. Saxena, who supervised the projects from their beginning in 1946, tells a typical story of the new sort of engineer:[3]

> When mechanical equipment arrived in Uttar Pradesh, trained personnel was not available. . . . So Shri G. L. Sharma, executive engineer, took the wheel himself. He became a capable operator-

mechanic in a short time, and then started training local men with great perseverance. He has now built up a solid force of 150 dependable operators and 50 mechanics.

To test the costs of hand and machine work, the U. P. engineers used them side by side on three dams. The labourers moved earth over shorter distances; even so, their work cost Rs. 65 to 80 per thousand cubic feet, compared to Rs. 26 to 33 for the machines.

High earth dams, as we have seen at Maithon, require mechanized construction for another reason. Earth placed by headbaskets cannot be depended on for the uniform density to assure watertightness. But in digging canals, as Tungabhadra showed, builders often have a choice of methods. D.V.C. has run on its canals a closely measured race between labour and machines, and the machines are in charge of a man who personifies much that is new in the new profession of earthmoving.

A short, quiet, 40-year-old engineer from Travancore, S. S. Pillai, manages D.V.C.'s general pool of earthmoving equipment. When Independence came, Shri Pillai was a resident civil engineer in the Ministry of Fuel and Power of England. He had gone there during the War to build marshalling yards and aerodromes. He stayed on in charge of five open-pit coal mines, using power excavators which were among the largest in the world. In 1947, Shri Pillai sent a letter to the Home Minister of India which went something like this: 'I left my native Travancore when it was a princely state. Now that my country is building big projects, I want to work for the Indian Republic. Can the Indian government put me to work?'

It took months, but his availability finally got to the notice of the infant Damodar Valley Corporation. At the end of 1948 he reported for duty at Hazaribagh in the hills of Bihar. His first machines were a second-hand Caterpillar tractor with a bulldozer blade, and two farm tractors with ploughs. His first task was the levelling and bunding of new fields for the peasants dislocated from Tilaiya reservoir. Shri Pillai's machines grew in size and number until his unit became, as it were, contractors for the D.V.C. canal and smaller dam-building operations. His unit is not involved in building major earth dams like Maithon. By 1953 it operated the largest force of earthmoving machines, not devoted to any particular dam, in India — sixty-three power driven units. Most of them had been working for three and a half years; time enough to test wear and repair, as well as initial performance.[4]

In 1953, Shri Pillai was asked to put his machines to work on a six-mile stretch of the main D.V.C. navigation and irrigation canal. Just below that stretch, four private contractors were at work moving earth in headbaskets. The wet clay along the Damodar River kept the machines out of action from June to October, while the labourers could work. Nevertheless, the cost of digging one thousand cubic feet of earth by machinery was Rs. 24. By hand it was Rs. 30. This was on the huge main canal — twenty feet deep, and one hundred and twenty feet wide at the bottom. The economy of using machines depended, D.V.C. found, strictly on the width of the canal to be dug and thus on the distance to which the dirt had to be removed. In the case of channels only forty feet wide, handwork could be done for Rs. 20 per thousand cubic feet, cheaper than machines. But the cost climbed to Rs. 30 as the bed width increased. For a canal of seventy feet or wider, machines saved money.

This contest of efficiency was with tractor-drawn earth-moving scrapers. But for canal excavation there was a cheaper and more reliable machine available. It is the dragline — a crane-like machine casting out a steel bucket suspended by cable from a long moving boom. As the heavy bucket is reeled back to the machine, its toothed open end scoops up the earth. Then a sweep of the boom swings the loaded bucket on to the pile of spoil, where the operator dumps it by remote control. Unlike the travelling scrapers, the drag-line can keep working in soft earth and mud. In 1953 the D.V.C. added two draglines to Shri Pillai's equipment and he put them to work on a sixty-foot-wide branch canal. They were small, as such machines go; each bucket held sixty-seven cubic feet. With two sweeps of the boom, its operator could move in one minute exactly as much earth as a Palamoori labourer moves in a day. After three months, although too early to be sure, it looked as though draglines might make handwork a luxury even on medium-width channels. The first half-mile of dragline excavation cost Rs. 18 per unit.

Even these costs, Shri Pillai believed, could be lowered. What he needed was a dragline with reach long enough to excavate the one hundred and twenty foot width of the D.V.C. main canal while travelling on the canal banks. In 1954 his opportunity came. One of India's two big draglines, machines with buckets holding 135 cubic feet (more than a whole day's headloads) arrived at the D.V.C. canal. Those two machines had been ordered originally for Tungabhadra canals. But they arrived so late that they were dispatched instead to Hirakud, whence one reached D.V.C. after completing its work on Hirakud main canal. Economy in the use of such a giant, costing five lakhs, calls for a steady succession, an orderly phasing of major construction projects which depend on foresighted legislation and administration. These are beyond the capacity of engineers. But properly managed, Shri Pillai is sure, scrapers and draglines can build India's main canals as well as larger embankments both faster and cheaper than head-baskets.

In 1954 the all-India engineers' seminar, meeting at Nangal on the Bhakra project, reached this recommendation:[5]

> Jobs requiring leads of less than about 500 feet and lifts of less than 30 feet need not be mechanised unless the progress schedules make it impossible to use only manual labour.

On cost considerations alone, human labour might not be given carrying distances as long as recommended here. But there are other proper considerations — considerations of the social cost of idle agricultural labour, for instance, in an area which is to benefit by a canal. In any event, even the mechanized earthmovers would agree that up to some point hand work is more efficient.

What should not be forgotten is the improvement in relative economy of operation that machines have shown in a mere decade. Their costs steadily decline under the enthusiastic management of some of India's most enterprising engineers. What of the costs of *phowrah* and headbasket? They inevitably rise with the rising claim upon standards of living. It seems evident that the scope for manual earthmoving will depend in the long run upon applying to it some of the ingenuity which has lately been invested in huge machines, so that even unskilled workers can earn more by producing more. With simple improvements of tools and conveyance — the wheelbarrow and bullock-drawn scraper are suggestive — India's earth workers need not go the way of John Henry.

Not machines *or* men; machines *for* men is the lesson of India's own canal and dam building experience. That is an attractive slogan. But in the Tungabhadra mechanical workshops it is also a very practical engineering method.

THE THICKNESS OF A STRING

A War-surplus hangar at the base of Tungabhadra Dam houses not only the project workshops, but India's first hydraulic gate factory.[8] When I walked in and met the mechanical engineer who directed both, Shri G. Srirangachary, and his assistant Shri Ahuja, they said at once, 'If you want to find out how we make things here, you must get acquainted with our shop foreman. He has the secret.'

There was no question about it: they had succeeded in manufacturing steel structures so large and intricate that India had always imported them before. They were making gates worth one crore of rupees for Tungabhadra alone.

Water pours through the base of Tungabhadra Dam into the irrigation canals via sluiceways six feet wide and twelve feet high. The sluices are closed by dropping into them, through eighty-three feet of water (if the reservoir is full) ten-ton steel gates. The pressure of the water against each gate equals one hundred and ninety tons; under that weight the gate must slide freely and close precisely. Shri Srirangachary's factory has already made the gates to do that job perfectly, complete with the electric hoists to operate them. Recently another dam in Madras received similar gates imported from Germany. They cost twenty per cent more than the Tungabhadra products.

On the day of my visit the gate factory was completing the trial erection in the shop of the first spillway gate. It dwarfed the earlier accomplishments. The dam's thirty-three spillway gates are twenty feet high by no less than sixty feet long — fifty tons of steel. I asked Shri Srirangachary how the intricate mass of steel could be moved to the crest of the dam for installation. We weld five-ton sections here,' he explained. 'When we have moved them piecemeal on to the dam, they have only to be riveted together through those holes you see prepared.' When I asked what margin of error was allowed in the final dimensions of the sixty-foot gate, he answered, 'A quarter inch.'

Shri Eswariah, the shop foreman, came up, a man six feet tall in a long khaki work coat. Americans would call his face Lincolnesque; its look of self-respect reflected not status but responsibility borne. Through the vast hangar, the four of us followed the route of the steel beams and plates from railway wagon to spillway gate. We watched electric saws cut the steel to length, hydraulic presses straighten them in a 50-ton squeeze. Shri Eswariah turned on the oxyacetylene torch of a 'profile cutter,' and cut out the curved shape of a corner brace from a stack of eight plates of three-eighth inch steel as easily as a tailor cuts his pattern. Every operation on the steel was, in fact, done to a pattern; prearranged, controlled. For welding, the ten or twenty-foot parts were lowered gently by pillar cranes into precisely set blocks or 'jigs' which would not permit misalignment. Every step had to be calculated beforehand in relation to every other; the right cranes to pick up the assemblage, the right capacity in each machine, the right speed of each operation to prevent delays in the next. The gates had, in a sense, been manufactured twice; once in the engineers' minds and on their drawing boards, only then in the factory.

When I expressed this thought to Shri Srirangachary he shook his head. 'You have left out the crucial step,' he said. We walked over to a miniature spillway gate, completely fabricated upon a one-sixteenth scale ('one anna to the rupee,' in the foreman's words). 'Here is the step you missed,' I was told. 'Eswariah made this model. That's why he can make the gates.'

'You asked about permissible tolerances. We'll ask him.' I could not follow the Tamil interchange, but it was clear that the foreman knew the strain each member had to bear, how precisely its dimensions must be controlled. It was his gate, too. One word interested me in Eswariah's explanation; he used it repeatedly in explaining the fitting of parts. It sounded like *nul*.

'You've hit upon the missing link,' Shri Srirangachary exclaimed when I asked what *nul* meant. 'That's the way Eswariah's spillway gate gets to the workmen who make it. To them, a *nul* still means what it always did to the village mechanic — the thickness of a string. To Eswariah it means one eighth inch, no more, no less. And that is what it means on the steel too, for the men measure their *nuls* with our calipers.'

I saw much else in the factory. There was a blacksmith who had spent a lifetime bending three-eighth-inch steel into bullock-cart tires over a cowdung fire. Now the mild steel he pulled from the forge was two and three-quarters inches thick, but he applied the hammer in his familiar way. At the end of two and a half days he had made the circular rim of a heavy gear-wheel to drive the sluice-gate hoists.

There was the X-ray machine, so powerful that it could penetrate two inches of steel, which inspected the crucial welds for internal flaws. It was the last severe check upon the strength of the thirty-five miles of welds in the spillway gates, a check so minute that every welder recorded on a card the number of inches he had welded with each electrode. The work had indeed been translated into the vocabulary of the traditional crafts, but not by compromising its engineering integrity.

But the profound lesson of the Tungabhadra workshop is the lesson of the *mul*. A nation which enters late into the technological race of mankind sets out to catch up by profiting from other nations' trial and error. But it finds their technology produced and communicated in a complex language of its own accessible only via the *lingua franca* of science. That walls it off completely from the skills of folk artisans. Both from his profession as a mechanical engineer and from his deputation to Detroit, Shri Srirangachary had mastered the concepts of the machine age. But he had come home determined to reformulate them into the concepts and the processes of Indian workmen. When, in a Madras highway equipment repair shop he discovered the sheer mechanical intelligence of Shri Eswariah, a man who could write no more than his name, he knew it could be done.

The mild steel itself was the common ground between engineer, foreman, and ex-village blacksmith. Its properties and potentialities they all knew in different contexts, and once they began communicating in *muls* it was as though the blind men groping at different parts of the elephant, had suddenly been restored to sight. The habitual patience and dexterity of the artisan made good the shortcomings of the available machines. The machines, in return, multiplied his strength and speed and accuracy so that he could make the things New India needs. It was not an English or American or German technology transplanted to India. It was not Indian handiwork fighting a lost cause against the machines. It was something utterly new under the sun, a technology of Indian artisans using machines in ways especially designed for them. The techniques were not always the latest, but the guiding idea was the essence of technological rationalization: skills and tools chosen to fit one another in the most economical combination.

A great river development project can be taken up as a way of bringing electricity, irrigation, and flood protection to the people as quickly and cheaply as possible. Or it may be taken up as a way of giving employment to labour. I doubt whether either approach alone can ultimately satisfy India. Tungabhadra Dam was built to deliver its benefits as economically as possible *through* enlisting the fullest measure of Indian abilities.

7

A RIVER TOO BIG

MAHANADI means 'Big River.' The name is not misplaced. In an average year seventy-four million acre feet of water run down it to the Bay of Bengal. Except for the Godavari, which is a little bigger, no other river south of the Ganga approaches this size. And it is across the Mahanadi alone of its greatest rivers, that India is building a mainstream dam. That dam, Hirakud, is proportionately big. It is, for instance, sixteen miles from end to end — which must certainly be the world's record length. In its first five years it appeared, indeed, too big for the organization that was trying to build it. What India learned at Hirakud in those five years can save a lot of wasted money and wasted water and wasted confidence, upon the projects that lie ahead.

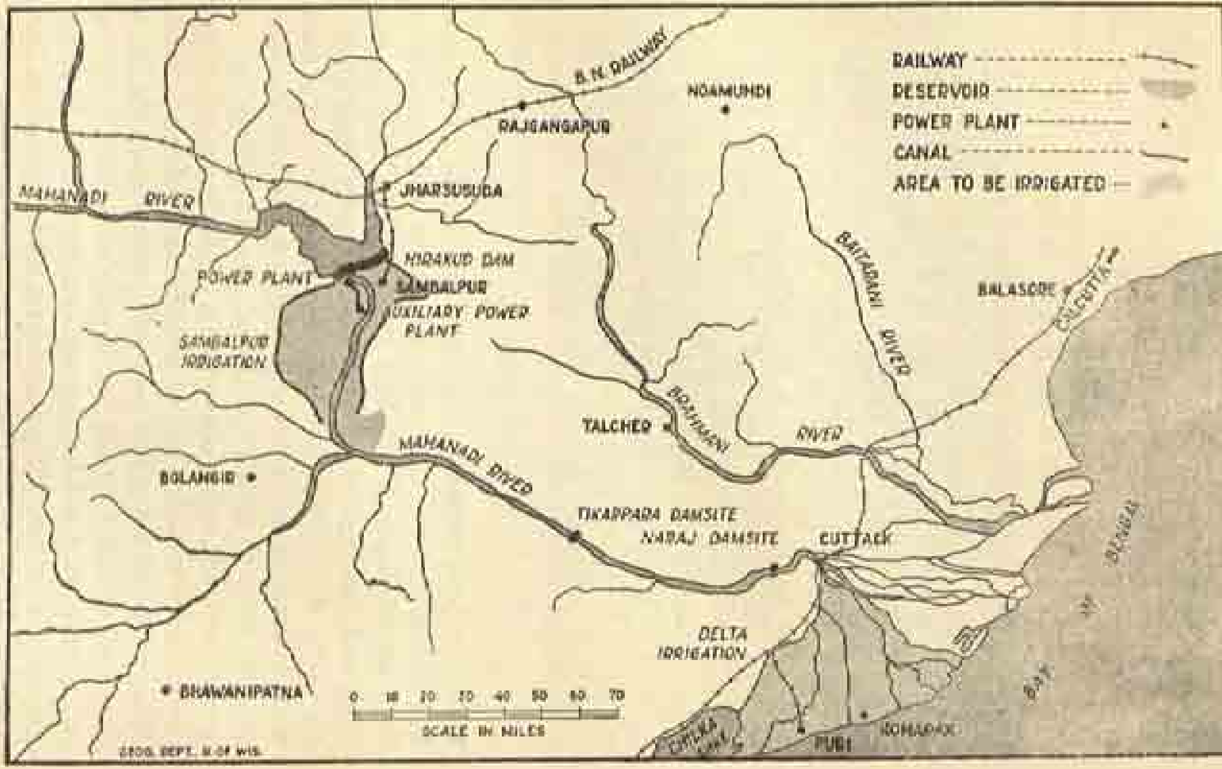
THE DECISION

Men have been wrestling with the Mahanadi for a long time. The first trouble with the river is that it now and again collects from the highlands of Madhya Pradesh and Orissa (sloping south and east from the Maikal Range) more water than it can carry. At Cuttack, which is the head of its coastal delta, the river branches out into dozens of almost-flat channels which meander lazily to the Bay of Bengal. But all of them put together can carry only three-quarters of the water that pours down the great rocky bed of the Mahanadi above Cuttack. When the floods get to that bottleneck, they convert the whole delta into a shallow muddy sea, deposit at random an inch or two of sterile sand or fertilizing silt upon the level fields, drown out roads, wells and villages and drain off lazily into the Bay.

Markat Kesari in the 8th century had the first success against

FIG. 5

HIRAKUD PROJECT AND THE MAHANADI VALLEY



the river.[1] He protected his citadel, now Cuttack, with a stone rampart against Mahanadi floods. The wall was raised with a two-foot coping in 1927—the job was done almost overnight when the citizens of Cuttack found the river lapping within inches of the crest—but it has never been overtopped. The fundamental reason was that Markat Kesari's floodwall, like a feudal castle in a disordered land, attempted only a tiny island of safety and left the rest of the delta to absorb the fury of the floods. When in the British period an attempt was made to extend his defences a few miles, the river in 1848 broke through. For the next hundred years the history of the Mahanadi was that of the Damodar. Gradually and incompletely, engineers realized that only upstream storage of the highest floods would bring the delta within human power to protect. But the cost of storage on so great a river was outside the government's horizons. Nothing was done.

Meanwhile, the years 1865 and 1866 showed that Orissa had two tragic water problems. The rice had still to flower in September 1865 when the rains ceased. The crop never matured. Next year, the rice on which famished villages were waiting was drowned out by flood. In Cuttack District alone, a million people died of starvation. Sir Arthur Cotton had come to the delta four years earlier. He had launched a combined scheme of irrigation and navigation canals, on the Krishna-Godavari pattern. As with the Kurnool-Cuddapah canal, he had to undertake works which were essentially safeguards against famine through a commercial corporation, because the government was not interested. And as in Rayalaseema, the venture failed in business terms. *After* the famine, the government took over and finished the canals. But with floods washing them out every few years, and with sixty inches of rain permitting a good autumn rice harvest *except when the monsoon failed*, irrigation was neither well administered nor well received. In recent years less than half the project's 400,000 acres have been receiving water.

In 1937 a Congress ministry took office in the new province of Orissa just as a high flood devastated the delta. Mahatma Gandhi, appalled at the suffering, appealed to Sir M. Visvesvaraya to see what could be done.[2] The great engineer's report was prophetic. Reservoirs alone, he said, could check floods and they held the answer to drought as well. Unfortunately, at the moment when there was the will to act, lesser engineers fell into controversy over the details of so bold a plan as damming the Mahanadi.

It took still another flood to bring forth a project for the big river. News of the 1944 flood reached the Orissa Congress leader, Hare Krushna Mahtab, in Ahmednagar jail. He knew also of the plans being discussed to harness floods on the nearby Damodar and his vision of what could be done with Orissa's greatest resource—and problem—came clearly into focus. From jail he sent a request to Dr. B. R. Ambedkar, the Government of India Minister who had charge of such matters, to take up the Mahanadi along with the Damodar. Again, the idea had Mahatma Gandhi's blessing. In November 1945 Dr. Ambedkar called a meeting in Cuttack to see what sort of harness might be put on the Mahanadi. The head of the Central Waterways, Irrigation and Navigation Commission, Shri A. N. Khosla, had already reconnoitred the river. He said that three damsites merited detailed investigation. One was at Naraj, where the river broke through the last range of hills above Cuttack. A second was Tikarpara, where the river could be backed up in a deep and narrow gorge by a high dam. The third was Hirakud, nine miles upstream from the town of Sambalpur. Of the three, Tikarpara promised the cheapest storage and the greatest head of water for hydro-electricity. But it was flatly rejected by the rulers of the tiny native states along the Mahanadi who attended the meeting. Its reservoir would have flooded the semi-feudal state of Athmallik, and drowned its capital. In 1945, that was a fatal obstacle. The meeting produced agreement that the Central Waterways, Irrigation and Navigation Commission would investigate all three sites, but thenceforth attention focussed on Hirakud for initial construction.

Hare Krushna Mahtab was released from jail in 1946. He found opposition gathering even to the Hirakud damsite. The landlord heads of the villages to be submerged by the reservoir —*gountias* they are called in Orissa—banded together to block the project. It was not only the taking of their reservoir lands that these short-sighted spokesmen of the Old India resented. It was the abundant employment and relatively high wages which dam construction would offer the cultivators, hitherto held as serfs to their lands for want of other work. Dimly, too, some of them realized that the coming of irrigation to Sambalpur District would end the dependence of cultivators upon their usurious loans in times of famine. The hold of the *gountias* upon rural Sambalpur had never been challenged. Shri Mahtab's campaign for Hirakud created a tempest within the Congress Party. The Party's Sambalpur leader resigned and joined the opposition. Mass meetings at which Shri Mahtab defended the dam were always turbulent and sometimes violent. But in 1947 he won the approval of the Orissa legislature to a resolution asking the Government of India to build Hirakud Project. The way was open for the engineers.

PLANNER AND PLAN

The personality of A. N. Khosla is indelibly imprinted on the Hirakud project. Twenty-eight years of his professional career he had spent upon the greatest irrigation works in the world, the barrages and canals of the Indus tributaries in undivided Punjab. As a designer he knew more than any man alive about how low dams or headworks could be built upon foundations of sand. Thus, in the North he had carried the lesson Sir Arthur Cotton learned from the Grand Anicut in the South to the stage of an applied science. But he was also a builder. At the confluence of the Chenab and the Jhelum the Emerson Barrage had been designed to be constructed in four years. Shri Khosla got it built in two.

Shri Khosla's contacts, like his reputation, were worldwide. From America he drew the conception of rivers controlled from headwaters to mouth by multiple-purpose reservoirs. Perhaps from America, too, he caught the vision of a single national agency in which would be concentrated the design and the building of the biggest river developments in his country. That agency would be the Central Waterways, Irrigation and Navigation Commission, CWINC, which he chaired. In any event the general consciousness after the War of the need to plan rivers as units and of the need to fit all the projects into one co-ordinated plan for the economic regeneration of India offered comprehensive responsibility to the man who would receive it. Shri Khosla did. CWINC had been asked by Orissa to survey the Mahanadi, and Shri Khosla was ready also to take in hand the construction of the huge dam. It would demonstrate what CWINC could do. He chose carefully the words with which he asked Prime Minister Nehru to lay the first mixerful of concrete in the foundation trench of Hirakud Dam:

> . . . you will be laying the foundation of the development of the entire Mahanadi Valley—nay more than that—you will be laying the foundation of the rapid and progressive development of the many other valleys in India for the conservation and utilisation of their water resources.

Shri Khosla's plan for the Mahanadi was ready in June 1947, thirteen months after his agency undertook detailed investigation.[3] It called for damming the river eventually at all three points in Orissa where dams were possible—Naraj, Tikarpara, and Hirakud. At each dam would be irrigation canals and hydro-electric plant. But Hirakud would be built first, and Hirakud would be a tremendous project. Of its sixteen mile dam, three miles would be across the riverbed; thirteen miles of dykes would be required to close the gap in the surrounding hills. For the site at Hirakud, in contrast to Tikarpara, unfortunately is no narrow gorge. The reservoir would hold six million acre feet: two Tungabhadras, or all the storage Mr. Voorduin planned on the Damodar plus Krishnaraja Sagar. Canals taking off from the reservoir would irrigate a million acres, six lakhs by gravity flow, and more than four lakhs from higher canals into which the water would be lifted by electric pumps. Generators at the dam itself, and at an auxiliary plant taking advantage of the further fall of the Mahanadi fourteen miles downstream from the dam, could ultimately produce 321,000 kilowatts of power. It was considerably more than the D.V.C.'s total hydro-electric capacity.

That was not all. Shri Khosla saw in the Mahanadi an answer to the crying need of underdeveloped Orissa: transportation. From Sambalpur to Cuttack is 206 miles by river. There is no railway, except the incredibly circuitous route of 532 miles going around the northern boundary of the state. Hirakud, in operation, would keep the Mahanadi flowing with 8,000 cusecs of water, even in the dry month of April. Shri Khosla proposed a navigable waterway the whole distance from Madhya Pradesh, above the Hirakud reservoir, 380 miles down to the Bay of Bengal. At the Bay end, there would be a great ocean port, designed to handle half Calcutta's pre-War commerce. True, the intervening rocks and rapids of the Mahanadi's bed would interpose an obstacle. They would be removed by blasting. All this meant that Hirakud would have to incorporate locks, for passing boats up to its reservoir. The channel connecting the auxiliary power plant to the main dam would form a link in the waterway; it would accordingly be equipped with locks at its upper and lower ends.[4]

Like Mr. Voorduin, Shri Khosla offered a cost figure for Hirakud before designs had been drawn. It was forty-eight crores.

THE CHARTER

A project so sweeping, upon a river of the Mahanadi's size, would have presented a real challenge to the most experienced public works department in India. But Orissa was a new state which had never built even modest canals and embankments. Shri Mahtab recognized his state's inability to build the dam. But when the Government of India hesitated at taking on the financial commitment of so long-termed a project, he had the courage of his convictions. 'Orissa asks for no gift from the Centre,' he told the ministers in Delhi. 'Give us a loan; we have faith that the power and irrigation returns will enable us to pay it back.' So it was arranged in an agreement entered between the two governments on the basis of which the Hirakud project was undertaken.[5] The agreement is however, vague at some vital points. What about the expense of flood protection? The Central Government did not undertake to make a grant for this purpose. But neither did Orissa clearly commit herself to pay back the flood storage cost unless, as was then hoped, the income from power and irrigation should suffice to cover it.

As to the construction of the project, there was some division of responsibility in the agreement. Construction 'will be under the CWINC and will have a Chief Engineer at its head with such other staff as the Government of India may from time to time sanction.' Designs would be drawn by a central designs organization of CWINC. Hirakud would be one of many projects with which this organization would have to deal. But land acquisition, resettlement of people displaced by the reservoir and canals and development of the use of electricity and water would be Orissa's responsibility. Co-ordination with the construction activities would be by a development board on which the chief minister of Orissa and the chairman of CWINC would sit.

Because Orissa, as the final owner of the project, had a vital interest in the economy of construction, there was also a board to allot work to contractors. Its four members were the chief minister of Orissa, the chairman of CWINC, Hirakud's chief engineer and financial adviser.

Diffusion, rather than clear location of authority and responsibility characterised the agreement. But there was an even more important point. The agreement was not law. It was not debated in the legislature of Orissa and the national Parliament, and it was not therefore a commitment of public opinion as to the lasting roles of the two governments, or the distribution of the cost burden among the various beneficiaries.

THE BRIDGE[6]

The whole length of the Mahanadi in Orissa is crossed by a single bridge—the one at Cuttack. One of the requirements of building a dam in the wilderness above Sambalpur was to secure an all-weather crossing to permit heavy equipment to be moved between the two ends of the dam and to link the right end with the railhead at Sambalpur. CWINC therefore proposed a bridge at Sambalpur. It had the advantage of serving the future requirements of the national railway expansion and of the planned national highway between Calcutta and Bombay. But to get it ready fast, CWINC undertook to build it rather than to leave it to the experienced railway or highway departments. The foundation was laid in November 1948. The order that came from Shri Khosla in Delhi was drastic: build it before the rains of 1949.

The job was to raise twenty-four piers from the rocky bed of the Mahanadi, to link them with concrete girders each one hundred feet long and to lay a concrete roadway on top. In the emergency of a single season schedule, the superintending engineer of the bridge hired an army of labour and paid them on the basis of a daily muster. Five hundred labourers, in one ase, were supposed to report each morning to a single foreman.

It was impossible to keep a foolproof check of attendance. In March and April 1949, when the weather was hottest and the pressure of work most intense, cholera broke out. The labourers quit. Desperate, the project engineers let a contract for the labour of placing the concrete to a Delhi contractor without competition or even submission of a tender. He was allowed the cost of transporting labour from Delhi and even Pathankot, and the rates of pay on which his contract was based were not the local rates of Rs. 1-4-0 to 1-8-0, but 2-8-0 or 2-12-0 per man per day. The extra cost to the project was Rs. 2,72,000.

The usual way to put up concrete bridge girders was via temporary centring supported from the riverbed. The superintending engineer felt there was not time. So he bought from the military authorities the Army's device for building bridges under combat conditions—Hamilton girders. These are heavy fabricated steel spans, shipped knocked-down. Bolted together, they have stiffness enough to be shoved out horizontally from the abutment across the waiting piers a hundred feet apart without support from below. The idea was ingenious; but nobody at Hirakud knew how to place Hamilton girders, nor how to pour the permanent concrete girders from them when once they were in place. After the steel spans had painfully been pushed across six spans, the idea began to seem impractical. By that time the Hamilton girder plan had cost Rs. 6,09,000.

An executive engineer engaged on the bridge had another bright idea. He had once used an overhead cableway, he said, from which to pour concrete spans. So a cableway was bought for Rs. 30,000. But he got it up no faster than the Hamilton girders, and when it was erected it proved too weak to do the job.

By the middle of 1949, it became evident enough that the Hirakud engineers had failed to meet an impossible target. They fell back, therefore, on the slower conventional means of bridge building, and built up timber supports from the bed of the river to support the concrete forms. By the high water of 1950, they finished this work, and in August the bridge was done.

Designs and estimates, meanwhile, got sanctioned only two months before the work was over. But the interesting sequel was that estimates approved in June 1950 were overrun more than fifty per cent by the work completed in August 1950. Some years later, an emiment outside engineer and accountant appointed to appraise the work on the Mahanadi bridge concluded that of the Rs. 68 lakhs the bridge cost, 13 lakhs were wasted by errors of judgment, bad management, inadequate control over expenditure, and leakage of government money. All the evils stemmed however, from one basic cause. The men in Delhi made demands beyond the abilities of the men they had stationed at Hirakud.

EQUIPMENT

To build Hirakud amounts of materials had to be placed which were unheard of in India: twenty-four million cubic yards of earth (six Maithons) plus one and a half million of masonry (one-third more than Tungabhadra). CWINC decided that such a huge job would have to be mechanized, but in 1948 mechanized dam building was new to India. Suddenly, a providential opportunity appeared to get the machines at bargain rates from military disposals. The government director of disposals, anxious to wind up his operations, offered vast quantities of military construction equipment at twenty per cent of its value, if it were taken before the end of 1949. After that it would be put up for auction to private purchasers. CWINC could not let the bargain pass. About five crores worth of material was bought in 1949 and dumped at Hirakud. The sheds to store it in were also bought from disposals and they did not arrive until after the stores, so the material lay piled in the open for many months.

It is impossible for one who has not seen it to picture the vast miscellany of material in the Hirakud stockpile. Bulldozers were there, and binoculars; short wave radios and landing mats. When the stock was finally taken, 60,000 separate items were found. But that was in 1952. For Hirakud's first four years, nobody knew for sure what stores were in that enormous dump.

The chief engineer tried belatedly to find out. He asked for a special stores division to inventory and book the material from disposals. Neither the Finance Ministry representative, nor his own ministry in Delhi, approved the extra staff. He could perhaps have hired accountants by some other arrangement, but he did not press the point. By 1953, with the dam half built, half of the 60,000 items had still to be priced. Here was an open invitation to waste the material in stock, or even to let it get out of government hands. Effective check on the cost of the dam became impossible.

On the right bank of the Mahanadi River stands a high steel octagon, supported above a complex structure of cement bins and endless belt conveyors. It is an automatic plant for weighing out the crushed rock, sand, and cement that makes concrete and mixing it with just the right proportion of water. Engineers call it a 'batching plant.' When it was installed, this one happened to be the largest in all Asia: it can mix 60,000 cubic feet (2,222 cubic yards) of concrete in two shifts. But this great machine, which cost twelve lakhs of rupees, can work only at half capacity. The trouble is that the stone-crusher which starts material moving up the endless belts to the batching plant can only crush stone for 20,000 cubic feet a day—one third the batching plant capacity. Hirakud engineers have supplemented that as best they can. By feeding on to the endless belt all the extra stone they can get from a battery of portable hand-fed crushers, they keep the batching plant running half the time, instead of one third. But that will not keep up the original schedule at the original estimated cost.

I tried to find out why the stone crusher has become such a serious bottleneck. The reason is simple. It is the wrong kind of crusher. Its steel jaws could break limestone without too rapid wear. Hirakud's granite eats them away so fast that the machine spends half its time under repair. Hirakud needs a rotary type of crusher. In Europe or America, one could be installed in a few months.* But importation of a new machine to India would take years. Some inexperienced engineer in the early days of planning Hirakud saved some dollars by ordering that inadequate crusher. It was a costly bargain.

What is true of the crusher is true of much of the heavy equipment ordered to build Hirakud. The great steel arms 'booms' on the cranes cannot drop the concrete buckets into all parts of the forms. Coolies pick up the contents of the buckets from beneath the cranes and carry it by headbasket to the outer edges of the dam and power house. The double handling costs money, and it needlessly disturbs the wet concrete. But the cranes got from disposals happened to have booms of seventy-five or eighty feet instead of one hundred-twenty and no tracks were designed to get them nearer the work.

In jute bags, cement costs Hirakud Rs. 4-8-0. Transported in bulk and pumped direct from goods wagons into the cement bins, it now costs 4-4-0; in 1952 the project authorities thought they could save much more, one rupee a bag, by buying in bulk. But such is the arithmetic of giant dams that even four annas a bag saves Rs. 12 lakhs over the entire job of concreting. Moreover, the machinery for handling cement in bulk was at the project; it was not in good enough repair to be dependable. In 1954, Hirakud still used bagged cement.

DESIGNS

Work got well underway at Hirakud in 1949. Two years later, in 1951, detailed designs were prepared. This is not necessarily wrong. Advance designs are desirable, but there are rivers upon which building dams concurrently with preparing designs, and thus saving a year or two in completing construction, may be more desirable still. But beginning Hirakud before designing it placed the full strain of planning upon the judgment and foresight of the men in charge. They were asked to begin without designs, a sort of dam they had never built before, and to do it by novel mechanized methods. That is why mistakes were made.

There was of course, another danger in delayed designs. It made it impossible to estimate the cost of a particular feature of the dam before it was begun. That precluded supervision upon the economy of construction by any one except the executive engineer doing the building.

Designs and estimates were held up for a number of reasons. CWINC contracted with an American firm, International Engineering Corporation, to design the dam. But the drawings supplied by that corporation were not detailed enough to work from. CWINC, undertaking the preparation of working drawings, had to recruit a new staff in a market where experienced designers and draftsmen were, if available at all, held on to by their own state public works departments. But the root cause of delay was the split in responsibility which made a chief engineer at Hirakud responsible for building to sound designs and estimates which he had no power to procure: for drawing the designs was the work of the CWINC in Delhi.

The best evidence that dual responsibility was at fault came in 1951. Shri Kanwar Sain was in that year made chief engineer, in addition to his work as head of designs for CWINC. By the end of the year, designs for the dam itself were ready.

CORRUPTION[7]

There was corruption during the first three years at Hirakud. Every newspaper reader knows one or two of the incidents. There was the executive engineer who bought from Punjab 14,000 deodar sleepers, and paid 25 per cent extra for them, though they were not of selected grade. The Inspector-General of Forests called it a 'sharp sale'. There was the superintending engineer who hired bullocks from Punjab to pull sheepsfoot rollers to pack down the earth of the right-hand dike at Hirakud. One of the suppliers happened to be a relative and some of the bullocks turned out on arrival at the project to be she-buffaloes capable of supplying milk to the establishment: they did not prove capable of pulling the rollers. Questioned about the transaction by the Public Accounts Committee of Parliament, the superintending engineer tried to cover up the deal.

These were the most fascinating cases of misconduct. There were others in which more government money was lost, though they were undramatic. Project petrol, for instance, found its way unpaid into the vehicles of contractors. Probably few officials of high rank at the project took part in the misuse of government money and stores. But the moral atmosphere at Hirakud was tainted.

GRANDIOSE COMMITMENTS

It was natural that a plan for one of India's least developed regions formulated in the year of Independence should be ambitious. The 1945 plan for the Damodar likewise turned out to be more than the nation proved able to undertake. At Hirakud, the difference was that work was done at once on some of the least considered and most questionable features of the project. There were good reasons at the time, but there was neither the foresight to see that the reasons might pass nor the deliberate facing of the political decision as to the scope of the project which stable plans require.

The 1947 plan called for a large canal leading from the main Hirakud Dam to a subsidiary dam one hundred and twenty feet high. The arrangement had two purposes; to generate additional electricity by dropping the water a second time below the main dam, and to permit navigation by carrying boats through locks in the main dam down the canal through a second set of locks 14 miles below. This would by-pass some of the Mahanadi's worst rapids. Work was rushed ahead on these features. One reason was that electricity from the subsidiary dam would involve a slightly lower investment; another, perhaps that the smaller project would train men for the greater. The canal and foundations for the subsidiary dam were dug. The bridge over the Mahanadi was followed by a second bridge, high enough for boats to pass below it, over the future navigation-power canal. Two hydro-electric turbines were ordered and delivered for the subsidiary power plant.

At this point, in December 1951, the Planning Commission considering that the country needed irrigation more urgently than electricity, suspended work on the whole subsidiary power scheme. Its two turbines were shifted to the main dam. But they were built to operate under a constant head of 77 feet of water: since the depth at the main dam varies up to 115 feet, they sacrifice some efficiency.

The navigable waterway clear across Orissa meanwhile dropped quietly from the picture. That fundamental change in policy (no more debated and legislated publicly than was the 1947 plan) opened the way, as we shall see, to a more realistic design for the subsidiary power plant.

REACTION

In 1951 malpractices began to come to light in the auditors' reports. In addition, the chief engineer proved unable to exact obedience from his engineering subordinates and CWINC would not back up his request to discipline them. The chief engineer was removed and Shri Kanwar Sain, who was already in charge of Hirakud designs as member for designs of the CWINC, took on the added, and thankless, duty of chief engineer.

In 1952 a subcommittee of the Public Accounts Committee made a searching investigation. They found trouble with the bridge, the bullocks and the sleepers. The indignation in Parliament, in the press, and in the minds of leaders of public opinion was instant and sharp. India is not one of those countries calloused to negligent or dishonest handling of public money by officers of her higher services. The executive engineer in charge of stores at Hirakud was dismissed. The superintending engineer responsible for the hire of bullocks was put under investigation for possible criminal action. From that time on, every Hirakud officer who may have been guilty of malfeasance could expect to be brought to book. By the end of 1953, not a trace of the old atmosphere of moral cynicism remained at the project.

The reaction reached deeper than the punishment of individual miscreants. It seemed to Parliament that all the trouble stemmed from the attempt to build the dam from Delhi. The Public Accounts Committee found a fundamental defect in Shri Khosla's triple role. He had the most important single voice in the Board which directed construction; he chaired the central engineering organization responsible for planning and designing Hirakud (along with other projects); finally, as additional secretary in the responsible central ministry, he had power in sanctioning and appointing men for these activities. Thus for Hirakud he was something of builder, designer and supervisor, yet all three roles had to share his time with the planning of other river valley projects, and with the international engineering organizations he helped lead 'Nothing could be more unsatisfactory,' concluded the Public Accounts Committee, 'than the combination of all these functions and imposition of them in one officer.' The government agreed, and made the Central Water and Power Commission, into which Shri Khosla's CWINC had been transformed, a body of technical consultants, and took away the chairman's administrative role. Shri Khosla, whose health broke under strain and criticism, retired. Hirakud had proved the undoing of a man of great personal ability who tried to do too much. The Mahanadi was too big, not for Shri Khosla, but for Shri Khosla part time and far away.

The government did not follow the Public Accounts Committee's second recommendation to appoint 'a high level all-round Administrator of the widest experience and ability in entire charge of the Project.' The concept that responsibility to build should be unified and fixed and the concept that it should be distributed, so that several officials could watch against misdeeds, remained unreconciled. On the latter theory, the government kept its faith in a Hirakud Control Board, bigger in membership and power than the old contract board. Orissa's chief minister remained chairman, but there were new members from Orissa (finance secretary and the commissioner or administrator of the northern division of the state), and from the Central Government (secretaries of finance and irrigation and power). But the government also took a step which insured, in practice, a powerful trend toward unified responsibility. In June 1953, Shri M. S. Thirumale Iyengar was brought north from Tungabhadra to become Hirakud's chief engineer.

As usual, the furore over waste and corruption at Hirakud came to a head while the physical work on the project was beginning to make real progress. Many sections of the dam had all along been under the direction of able and incorruptible engineers. To take only one example, there was Shri N. K. Agrawal, executive engineer in charge of the left spillway section. An honours graduate of Roorkee, he had post-graduate engineering at Columbia University and an apprenticeship in the U. P. Public Works Department. By the 1953 monsoon he had his block of the dam paved, with abutments built on both sides, to pass safely a high Mahanadi flood. The output of such sections was handicapped by poor equipment and by the deterioration in governmental confidence in the project generally. But under Kanwar Sain's direction in the working seasons 1951-2 and 1952-3 such men got the foundation exposed, and but for a nasty rift in the bedrock on the powerhouse side, got it covered with concrete. They filled in the valley traversed by the huge earth dam, and got half the left dikes done. It was unspectacular work, most of it buried underground. But it brought the sprawling project to a stage where the dynamism of a new chief engineer could make itself visible.

8

OPERATION HIRAKUD

AFTER Shri M. S. Thirumale Iyengar had been at Hirakud for a few months, the new order began to irritate some of the 'contractors'—men without previous construction experience who worked groups of coolies on the job, hired out their lorries, or supplied small quantities of local materials. In the good old days they had known how to divert government petrol into their vehicles, and to get petty contracts without being capable of the high-speed construction the project required. Those days were gone. Soon scrawled signs began to appear on the walls of Hirakud buildings: 'Go back, M.S.T.' Anonymous threats came to the new chief engineer by mail, the burden of which was that an outsider might not be personally safe in the wilds of Orissa. After the war of nerves had progressed a few weeks, one of the contractors called on the chief engineer, told him he had seen the 'unfortunate' signs, and hoped, in an unctuous manner, that the chief engineer was not concerned about them.

Shri Thirumale is not a tall man, but he has a formidable bulk about the shoulders, and at times like this, his eyes take on a fiery glint. 'I was finding Hirakud a bit dull until these threats began,' he told the contractor. 'Now it's getting interesting. I have made up my mind to stick.' The threats stopped coming after that visit.

BATTLE PLAN

After he took charge of Hirakud Project on 7 June 1953, Shri Thirumale Iyengar came to refer to his charge as 'Operation Hirakud.' It is certainly true that he mapped out a plan of campaign with as rigorous an assessment of the requirements of the situation, and of his forces' capabilities, as ever a field general did on the eve of an attack.

A dam is earth and rock, selected, moved, and packed or cemented into place. The plan for 'Operation Hirakud' started, therefore with what the military men call 'logistics'. Hirakud rock comes out of a hill of granite, Lakshmi Dungri. When he came to the project, Shri Thirumale Iyengar found 200 tons a day being quarried. The existing construction target called for 5,000 tons. The jackhammers, power shovels and other equipment required to reach this output were not on hand. Moving 5,000 tons of rock to the crushing and mixing plant would keep 300 railway wagons busy night and day; there were but 200 wagons for all the project's needs. Beyond that point, the defective crushing machinery and chronic breakdowns in the batching plants stood as further bottlenecks. The chief engineer set his sights realistically: 2,000 tons of rock a day for the next three working seasons. It was still tenfold the previous output.

But Shri Thirumale Iyengar was not content to limit construction to the capacity of the quarrying and crushing equipment. He gave rein to an independent operation—masonry construction. Using their own quarry, and making no demands on the crushing and batching machinery, the masonry crews could step up their operations enough to take over part of the dam that had been designed for concrete. It gave his plan of campaign flexibility, a deficiency in the mechanized sector dependent on equipment from overseas.

There was one other bottleneck, designs for the masonry works of the main irrigation canal: simple falls, bridges, and siphons. They were being drawn in Delhi, months after they were needed. Furthermore, designs made at Hirakud, adapted to the local materials discovered along the route of the canal, and demanding only the available types of labour or equipment, could save construction cost. At Delhi, the headquarters staff work had got too far from the field command; a canals design organization was opened at Hirakud itself.

Having drawn up his battle plan, the new chief engineer took a fresh look at the ultimate strategy of exploiting the Mahanadi. Below Hirakud Dam, the rapids of the river offered much potential hydro-electric energy. Shri Thirumale Iyengar, renouncing the grandiose plan of navigation, could propose a much more economical scheme for power. Instead of the costly auxiliary dam, he designed simple pressure pipes to lead the water down from the end of the power canal to the turbines at river level. The power canal already dug would not be wasted. But at less cost than the old plan, this scheme would provide 72,000 kilowatts of firm power instead of 57,000. It would be one of the cheapest power projects in India, and Orissa's booming new industries of paper, cement, ferro-manganese and aluminium, promised to require the power. It promised, in short, to give a new lease of life to the auxiliary power plant which for three years had been suspended.

ALLIES

In the popular notion, the general is a man who tries to arrogate power to himself. The new chief engineer, once his construction plan was drawn, quickly demonstrated how much he differed from the stereotype. For every operation on the dam that could be managed separately, he invited tenders from private contractors. He made one stipulation—those who bid must be experienced in doing big jobs fast; they must have their own qualified engineering organizations. What he wanted to do was to break through the bottleneck of managerial decisions in his own organization. The response to his invitations was heartening. Verma and Ranade, Bombay, undertook to operate the entire Lakshmi Dungri quarry, transport the stone, crush it, and deliver it to the bins in the batching plant. The arrangement, at a single stroke, added to the project organization a going concern of drillers, mechanics, welders, electricians, and above all, tested supervisors.

On the powerhouse section of the right end of the dam, where the bottleneck of the concreting equipment was being by-passed by building with stone masonry, another set of new contractors went to work. One of them, Shri Lal Chand Kalra, was a Sindhi colliery operator. He came to Hirakud with 40 Punjabi coolies and plenty of capacity to command. When I talked to him in 1953 he had a hundred masons and 400 labourers at work on the dam. More workmen were in his own quarry, supplying all his raw materials save mortar. The contractor on the adjoining sections was a leading firm from South India, Gannon and Dunkerly. They had been able to bring to Hirakud, intact, an organization assembled, complete from stonecutters to engineers, at Tungabhadra. Coimbatore and Salem stone workers were brought to Hirakud that way without expensive recruitment by the government.

I told the executive engineer directing the Gannon and Dunkerly masonry work that I thought the pace set by their workmen was a fast one. He was unimpressed. 'The chief engineer believes we can bring this section up twice this fast,' he remarked. 'What he wants on a job is action.'

The practice of giving full scope to able contractors was not an innovation at Hirakud. On the great six-mile dike, closing a valley to the right of the river through which the reservoir would otherwise escape, Kalinga Construction Company already had its own earthmoving machinery working full blast. Shri Thirumale Iyengar's new tactic was to carve out a number of such assignments, make it clear to all contractors that they must have engineering competence in order to qualify (irresponsible firms bidding low would not get the jobs and then forfeit their security after a year of failure) and then accept the low tender. On the main dam, the new tactic put top-notch contractors alongside construction divisions of the project itself. The competition was all to the good.

DISCIPLINE

The layman may imagine that what a new chief engineer does, when he comes to a job where indiscipline had become chronic, is to get rid of the old leadership and install his own. It is not so simple. It was not easy to determine, in the first place, how much of the laxity was in the atmosphere, how much was in the character of particular officers and supervisors. Good new men would not, under Hirakud conditions, be had in less than a year. Moreover, the disruption involved in replacements was a cost to be set off against the inertia of the old organization.

Shri Thirumale Iyengar kept most of the old executive and superintending engineers. To those who proved capable of taking on extra work, he gave it in abundance. They began working through two shifts as a reward for their ability and zeal. For the rest, it was a question of infusing new standards of performance into the daily habits of 10,000 men by the relentless drive of a few determined engineers.

First-line supervisors began to learn that if they could not get fast, waste-free work out of their crews, the chief engineer could. The test case was the earthmoving operation. Operators, many of them of little experience, had successfully defied past attempts to enforce reasonable care of the earthmoving equipment. The big tractors, bulldozers, dumpers and scrapers were the vital organs of the project: they cost a lakh or more apiece, and they could not be replaced at any price in time to finish the dam. Yet in May 1953, the log books showed that 40 per cent of the machines on an average day were completely out of action; another 24 per cent had to have repairs before completing their scheduled two shifts. All the difficulties experienced at Maithon contributed to the 'sickness', but in addition was this problem of neglectful driving. Within a month of the new chief engineer's arrival, he had his chance to break the habit. Word came to him that a bulldozer operator had driven his machine, blade upraised, into the rear of a parked earthmover. The blade slashed through the rear tires of the forward machine. Those giant tires cost Rs. 4,500 apiece. But the supervisor on the spot was afraid to punish this case of apparently wanton destruction. He believed the whole shift of equipment operators would quit work if he did. The chief engineer went straight to the work site. He climbed on to the frame of a machine and summoned the operators around him. He explained to them what one man's careless driving had cost the project. And he demanded to know whether any eyewitness of the incident saw any excuse for it. None did. Thereupon, he dismissed the guilty operator. There were fewer 'accidents' of that type from then on.

But the drive against slipshod maintenance and operation of the irreplaceable machines could never let up. One afternoon while I was at Hirakud, the chief engineer defied a temporary illness to station himself in the middle of the three-mile haul road along which clay is carried to the main earth dam in 14-cubic-yard dumpers. Waving down each machine he climbed aboard, made a quick check of the maintenance, and sent the driver on with a warning to tighten a few nuts here, or see to greasing there. One unfortunate operator came up at 35 miles an hour with oil dripping from the crankcase of his grader. Upkeep of his machine turned out to be so consistently and unpardonably negligent that it led to the dismissal of the field maintenance supervisor responsible.

Building Hirakud was not a matter of giving orders. It was following orders relentlessly to the ultimate executor, and seeing that they became action. In 1954, that relentless check-up began to improve output in the earthmoving section. By the end of March, when I visited the project, earth placed in the five and a half months of the current working season had exceeded the previous season's eight months' total.

Tightening up the Hirakud organization so that orders would be obeyed and deadlines met was not a popular process. Two facts created a bond between the commander and the men: he worked as hard as he insisted they do. And they gradually began to sense that it was not a chief engineer driving them: it was a construction schedule. A friend of mine from the Secretariat in Delhi, visiting the project, once asked Shri Thirumale Iyengar why he maintained an atmosphere of such unrelieved discipline in dealing with his subordinates. 'You will have the answer to your question,' came the reply, 'when the water flows in the Hirakud canals."

LEADING STRINGS[1]

In 1954, Hirakud hummed with activity. Everyone was about his business, confident that the others on whose work he depended would keep pace. But the targets ahead were difficult, and the unforeseen hazards which are the lot of dam construction schedules might make them impossible. There was one inexplicable handicap imposed on the dam builders Their work was made about 25 per cent harder than it need to have been by the leading strings in which they were kept by their own government.

Take the matter of purchasing. The chief engineer had normally to make his big purchases (over Rs. 40,000 for the whole order) through the Central Government's purchasing agency in Delhi. That took an average of six months. If a machine lay waiting for expensive spare parts, that delay would be insufferable. So in January, 1954, the chief engineer won from the Hirakud Control Board and the ministry a new power. He could buy even costly spares direct from the supplier, provided there was an emergency. But this still left him with two severe handicaps. The emergency purchase must be at the Central Government's standard rates. Equipment dealers would not take spares off their shelves without a premium—20 per cent if the item would take six months to import, 15 per cent if it would take three months, etc. The central purchasing agent would approve paying the premium, but only if it were the lowest available—that took several months to find out. It was a perfectly reasonable requirement in general. But idle machines at Hirakud cost a great deal more than the premium on spares. The chief engineer needed the right to substitute another reasonable rule, which would fit construction requirements. The project would pay the supplier the standard price on delivery. He could wait to be paid his premium until the central purchasing agent found out whether it was the lowest available price. But this was a power the chief engineer did not yet have.

Or take the matter of getting qualified construction engineers to direct divisions or subdivisions at the dam. There were two ways the chief engineer could do it. One was by requesting the ministry in Delhi to ask the Union Public Service Commission to hold an examination. The second was to ask the ministry to permit a temporary selection or promotion until the Public Service Commission supplied their nomination. The first is illustrated by the case of the safety engineer who had just reported for duty when I visited Hirakud in September 1953. The chief engineer asked the ministry for a safety engineer on the 23rd of October, 1952. The Union Public Service Commission advertised for applicants in December; they held interviews in June, 1953, and filled the post eleven months after the requisition. Most construction jobs cannot await appointment that long a time.

The chief engineer resorted, therefore, to the second alternative, temporary appointments. They are poor makeshifts, from every point of view. The very best men will not take them, and the chief engineer could not offer those who did take them any inducement to extraordinary effort, since he could not even assure them employment for the life of the project. Could not temporary appointees take the Public

Service Commission's examination and so get permanent status? They could, if they were patient, but from the viewpoint of construction ability, the examination is a lottery, for it leans heavily on academic qualifications and familiarity with the latest engineering formulae, rather than ways of keeping equipment moving. I made it a point to find out from actual cases, what had happened to these temporary appointees. The experience of three assistant executive engineers is typical. One to four months after they began temporary appointments, a request for permanent selection was sent to Delhi. It then took another seven to thirteen months for the Union Public Service Commission to advertise the vacancies. A year after the advertisement, in the best instance twenty-four and a half months after the temporary appointment, no selection had yet been made. All three engineers remained uncertain as to their status, and the project uncertain as to its officers.

What the chief engineer needed was not unreasonable. He did not need power to give men positions in any Central Government service. He merely needed to fill vacancies for the duration of Hirakud project. But it, too, was a power he did not have.

How one appraises these leading strings depends on one's perspective. Compared to the past chief engineers, Shri Thirumale Iyengar had much broadened powers. And the rules had their own logical justification from the point of view of the Central Government. But from the point of view of getting the dam built, they hurt. Shri Thirumale Iyengar had been able to save a good deal of the time and energy of his top engineers by letting out major jobs under contract. That saving was crucial to his schedule. But it was more than offset by the time and energy spent trying to adapt government procedures to fit the situation at the dam. And from the point of view of Hirakud, that was not only a heavy burden; it was, to use an auditor's phrase, an infructuous expenditure.

9
CODE VERSUS CORPORATION

INDIA is making a set of decisions during the 1950's which will have even more to do with the pace of her future river valley developments than the questions of which dams to build, whether to build of stone or concrete, or whether to use machines. These decisions all concern the question 'How shall river developments be governed?[1] The ordinary voter, whose reaction will ultimately decide these questions, is usually bored or bewildered by matters of legislation and administrative organization. He is used to hearing aphorisms of constitutional structure brought forward to settle the matter —'decentralization', 'Parliamentary control', 'unity of command', 'undivided responsibility', and the like. But there are enough of these 'principles' to defend all the ways in which river development is apt to be undertaken. Even wise men differ at every turn.

Luckily for her, India has a better way of choosing the governmental machinery best suited to this job. It is one of those rare things in government: something like a scientific experiment. For over five years, India has operated side by side the two most attractive devices for big-scale multiple-purpose river valley development. On the Damodar she has a corporation, chartered by special law, wielding an almost complete set of powers to build and manage its projects. Nearby, on the Mahanadi, is an organization within the regular government department, regulated, except as special dispensations are made, by the normal public works department code. Both are national agencies. They are about the same age. And though there is an essential contrast between the two rivers, the jobs these agencies tackled is so nearly the same that their success can be measured by a common yardstick. Here by sheer good fortune is an opportunity no other nation possesses: to put the alternatives side by side, and select those governmental arrangements for future rivers which have turned the resources of the Damodar or the Mahanadi to best account.

The remainder of this chapter draws just such a trial balance. The accounting cannot be final; the agencies are still at work on both rivers. Disinterested assessors from other backgrounds and professions, and informed critics engaged on these projects themselves, will wish to differ with some of the conclusions. But, like any attempt at experiment, this analysis consists of observations of fact, and of interpretations drawn from those facts to explain them, and predict what will happen in the future. In scientific spirit, the comparison below rigorously segregates the facts from the conclusions. Upon the facts, it should be possible to agree. Around the conclusions, debate will certainly be in order, but it need no longer be pitched up in the clouds of constitutional principles. It will be brought down to the earthy matters of units of electricity, acres of irrigation, and rupees of cost, in all of which the citizen can take an intelligent interest.

I. THE FACTS

DAMODAR	MAHANADI
1. THE VALLEY	
Area: 8,500 square miles	60,000 square miles; seven times as large
Flood threat: major—1 million cusecs peak	Very slightly larger—1·2 million cusecs
Water supply for irrigation and hydro-electricity: average flow 11,000 cusecs	Average flow nine times as great, 100,000 cusecs

DAMODAR	MAHANADI
Potential reservoir sites: small and limited, compared to the storage requirement for flood control and regularized flow	Three main river sites, one (Tikarpara) among the world's most attractive from an engineering standpoint, each of others capable of containing entire flood. Additional tributary sites
Mineral resources: abundant; partially being exploited	Abundant; almost wholly unexploited
Coal: available on the river	Same
State boundaries: divide Bihar in which storage must be located, from Bengal in which project is most needed	Orissa contains all parts of the basin under development. Before 1948, small princely states affected plans
State development experience: Bihar relatively inexperienced; Bengal experienced in small irrigation and flood embankments	Orissa, newly formed, inexperienced and financially weak
Problems of construction: supply easy due to nearness of Calcutta and to industrialization in area; labour unionized and somewhat higher paid	Site on railhead, but remote from supplies; labour not unionized, low paid

2. THE PLAN

Speed of formulation: six months	Thirteen months
Planning agency: Central Technical Power Board	Central Waterways Irrigation and Navigation Commission
Selection of reservoirs: all known sites compared as to cost and production of multiple-purpose benefits	Of three sites on main river, Hirakud selected because alternative site (Tikarpara) would flood land of princely states. Though objection altered in 1948, question not reopened

DAMODAR	MAHANADI
Allocation of cost to each multiple-purpose use: one method of allocation steadily applied	Changing theories of allocation
Selection of features: each part of the plan included because benefits exceeded costs	Navigation included in original plan without cost analysis
Intensity of development planned: 30 per cent of average flow to be stored; related soil conservation and thermal power plans	Storage only 10 per cent of Mahanadi average flow. Plans for industrialization not closely connected to river development

3. THE DECISION

Occasion for public consideration: 1943 flood and famine	Perennial flood problem; 1944 flood not catastrophic*
National interest: to protect main traffic artery and national defence	National interest general, not specific
Leadership in decision: strong at the national level	Strong initiative from the state
Inter-governmental disputes: clearly revealed and reconciled, as between Bihar and Bengal, between both and the Centre	No inter-state dispute. Differences between Orissa and Centre not clearly identified and settled in authorization of project
Inter-governmental transfer of power: clear and lasting	Temporary administrative arrangement for construction only
Legislative debate: in both state legislatures and Parliament prior to authorization	In Orissa legislature only, before authorization
Decision made in law	Decision made in administrative form

*A disastrous flood occurred in 1955

DAMODAR	MAHANADI
4. DURABILITY OF THE DECISION	
Original plan divided into two phases in 1949. Only first phase (2.8 out of 4.7 million acre feet of storage, not protection against worst possible flood) undertaken These changes made before work started Hydro-electric plant at Konar suspended, may now be reinstated	Work suspended 1951 on subsidiary dam and power plant. This may again be taken up. Navigation, in original plan, not taken up Lift irrigation from reservoir dropped. Delta irrigation and flood control proposed in 1953 for addition. This change in turn affects economics of ultimate development of Tikarpara and Naraj reservoirs These changes made after work had started
5. CONSTRUCTION	
The task: to build four storage dams in separate places, 124,000 kw. of hydro-electric installations at those dams, two low barrages, 456 miles of large irrigation canals, 375 miles of heavy duty transmission line, 9 major substations and a large steam-electric plant of 150,000 kw. capacity	To build a dam comprising at a single site as much work as all D.V.C. dams, 123,000 kw. of hydro-electric installations at the dam, plus possibly 72,000 kw. auxiliary, 531 miles of large canals (including delta irrigation), 340 miles of transmission line and four major substations
Cost: high at Konar and Tilaiya, where D.V.C. learned its lessons. Including Maithon, too, the costs will be about Rs. 182 per hundred cubic feet of concrete, Rs. 99 per thousand cubic feet of earth dam	Concrete expensive — due to poor initial equipment planning — about Rs. 193. But increased use of low-cost masonry brings Hirakud's cost of concrete plus masonry sections to about Rs. 177. Earthwork in the dam costs the same as in D.V.C. — Rs. 99. Hirakud's work is at one spot, but requires longer hauls

DAMODAR	MAHANADI
Start: 1949. Little progress for two years	Also 1949. Little progress for one year
In 5 years, by March 1954, D.V.C. had placed 38 per cent of all its concrete and 2/3 of its dam earthwork. It had done only 1/6 of the earthwork in its canal system	Hirakud had finished the same per cent of concrete and masonry together (38%). 1/2 of its larger quantity of earthwork in dam and dikes, 2/3 of its Sambalpur canal earthwork, but the same fraction of canals as D.V.C. (1/6) if delta work is considered
In addition, D.V.C. had built 3/4 of its transmission system and substations, and finished the 150,000 kw. thermal station	Hirakud was just beginning its electrical work

6. OPERATION

Organization established for power system and partial reservoir operation	No operation yet

7. SUPERVISION

Administration, including construction, operation, and proposal of plans, completely under the charge of a corporate board of three members. They are appointed by the Centre after consultation of the states. They serve full time, and have no other responsibilities	Until 1951-52: administration of construction was divided between a chief engineer, Hirakud, and CWINC at Delhi. The chief engineer was supervised, and relations between Orissa and the Centre worked out, by boards chaired by chief minister of Orissa and comprising representatives of both governments. Chairman of CWINC had a triple role as engineering supervisor of chief engineer, vice-chairman of supervisory board, and additional secretary of ministry in Delhi.

DAMODAR	MAHANADI
	After 1953: engineering administration concentrated in the hands of chief engineer, Hirakud, but subject to normal department rules. To make exceptions to these rules a Board of Control meets monthly, with chief minister, Orissa, as chairman and representatives of finance and irrigation and power ministries from Delhi among the members
Corporate board conducts its own merit selection procedure. It has been free of suspicion of favouritism	Chief engineer, Hirakud, always required to recruit under the departmental rules. But since Union Public Service Commission selections require about one year, many emergency appointments were resorted to. In the early years, this involved some favouritism. Now, it involves delay or loss of continuity of experience
Corporate board conducts its own purchasing under a qualified staff. It uses the Centre's purchasing machinery when time permits	Bound by departmental rules from the beginning, Hirakud nevertheless acquired vast quantities of stores on emergency basis in 1949-1951. Waste and possibly misappropriation resulted. Recently since dependence on Centre's purchasing machinery requires many months' waiting, chief engineer has been given some power to buy direct from suppliers

DAMODAR	MAHANADI
A financial adviser not responsible to corporate board checks every expenditure. He may report his objections to finance ministry in Delhi. He also prepares D.V.C.'s budget requests	Approximately the same arrangement. Hirakud financial adviser also had, pending sanctioning of over-all estimates for the project, power to approve detailed estimates before they were adopted for construction. This check did not prevent waste and some corruption up to 1951
Relations of the corporation to the states watched over by their representatives meeting with representatives of finance and irrigation and power ministries from Delhi. This committee is *advisory* to the governments and to D.V.C.	Inter-government relations worked out by board of control, which has power to make administrative decisions within sanctioned plans, and by a development board, which has power only to propose plans
Corporation budget submitted to state legislatures as well, but only Parliament has effective power over it	Same arrangement
Administratively, Centre has power to direct D.V.C. to follow central policy. Such directives must be formal and explicit	Centre has the same power over Hirakud. But it may be exercised in any manner
Parliament does not question corporate board directly. Minister of irrigation and power answers for D.V.C., but does not always possess full information, due to separateness of corporation	Parliament gets information about Hirakud from minister of irrigation and power
Finality of Centre's control demonstrated by reconstitution of corporate board in 1953-54	Centre's control always complete in theory; ineffectively exerted until 1951

DAMODAR	MAHANADI
8. COST AND BENEFITS	
Original (1945) 55 crores or 38 crores for first phase;	Original (1947) 48 crores;
1953 estimate (including Konar hydro-electric plant): 92 crores	1953 estimate: 71 crores for sanctioned project. Proposed addition: delta irrigation (15 crores), and a redesigned subsidiary power plant (8 crores) make a much more attractive economic arrangement. Total: 93 crores

9. VALUE UPON COMPLETION

DAMODAR			MAHANADI		
Flood Protection: not appraised			Flood Protection: not appraised		
Irrigation:			*Irrigation:*		
new acres	841,000		new acres (Sambalpur)	451,000	
			new acres (delta)	584,000	
improved acres	185,000		improved acres (delta)	406,000	
Total	1,026,000		Total	1,441,000	
Electricity: continuously available capacity, kilowatts	193,000		*Electricity:* continuously available capacity, kilowatts[8]	133,000	
Estimated returns in lakhs of rupees per year:			*Estimated returns in lakhs of rupees per year:*		
	Gross	*Net*		*Gross*	*Net*
Irrigation[9]	135·4	100·0	Irrigation	233·5	183·7
Power	584·2	412·9	Power	289·0	224·1
Total	719·6	512·9	Total	522·3	407·8

II. THE CONCLUSIONS

From these facts emerge two conclusions of crucial importance. The first is that two rivers, whose floods were twin threats to life and to production in their deltas, could be converted by the scientific techniques and large-scale government powers of New India into valuable servants to the people living in their valleys. It could be done as a paying investment, because the water was used for power and irrigation, too. Secondly, the smaller, less dependable river, the Damodar, with an average water flow one-ninth the Mahanadi's could be geared into a plan producing benefits worth as much as the Mahanadi's. The smaller river is more intensively developed, and coal resources are exploited along with water resources. But the cost of this intensive utilization is no higher, and the returns have commenced earlier. Here is unmistakable evidence of sounder planning and more effective management.

If she will extract the full lessons from this experiment, India can develop rivers beyond the reach of existing organizations and methods. If she will employ the best devices of government revealed by the comparative experience of the Damodar and the Mahanadi, she can extract the fullest measure of benefits which scientific engineering promises. To do so, she must enquire why D.V.C. extracts more from less, and why both D.V.C. and Hirakud have rectified some early mistakes. This means trying, in a hardheaded mood, to explain the differences in planning, chartering, building, operating, and supervising.

Planning. Of course, plans should be based on the fullest information about the river, the reservoir sites, and the economic needs of the valley. They should be well considered. They should be comprehensive. But these obvious truths do not take us very far. There was most incomplete data about the Damodar in 1945, and the Mahanadi in 1947. One plan was drawn up in six months, the other in thirteen. Yet the first, having been divided into stages, is going into effect substantially as it was drawn. The other has been altered, even after construction began, and the basic economic relation between upper and lower reservoirs in the ultimate development of the Mahanadi upset. The reason is partly that the Damodar, a medium-sized basin, came more nearly within the scope of our present ability to plan and decide.

There is a very important additional reason. The Damodar plan clearly assessed the cost and the benefit of each alternative reservoir, and of each use of the water controlled—irrigation, power, flood control, navigation. It proposed the schemes that best stood the test. In this sense it was perhaps less 'comprehensive', more realistic, than the Mahanadi plan, which included navigation and lift irrigation, without strict analysis of their cost, relative to the cost of other uses of the water, or other modes of transport and irrigation. That is why the Mahanadi plan was due for change.

There is a second explanation. Plans for big rivers, and those which involve several works not all to be undertaken at once, simply cannot foresee all the factors that will decide the final development. Some modification, some phasing, some extension or elimination of works is inevitable. What is needed is not a once-for-all commitment to build particular dams, canals and power stations, but delegation of responsibility to renew planning continually, so that the plan can change when there is any decisive change in the basic conditions of the valley, or any necessary revision of the always limited data about the river. The Damodar plan was no doubt saved, when the nation's budget became tight in 1951, by the fact that Mr. Voorduin's 1945 plan had been divided into stages in 1949, and thus brought within the country's resources to invest. It is expanding currently on the electricity side as new demand is met in Calcutta. The Mahanadi plan was too long frozen as a fixed list of works after the nation's priorities altered, and when at last the government decided in 1951 that there would not be money for the whole scheme at once, the subsidiary dam and power channel had to be suspended in the midst of construction. Planning on developments of this scope keeps on during construction and after. It must continue to be someone's specific job.

Decision. At the end of six years, Hirakud is undergoing essential modifications of plan (addition of delta irrigation and reinstatement in modified form of the auxiliary hydroelectric plant); it has been reconstituted with a control board; an important question has come up concerning the financial obligations respectively of the national and state governments regarding resettlement of displaced villagers; and more such questions lie ahead with regard to the cost of flood protection. In all such matters, decisions made in chartering the Damodar plan have proved durable. The reason is inescapable. Planners of the Mahanadi assumed that undertaking a great river development promising so much good to both Orissa and India, was simply an engineering and administrative matter, to be authorised by the Orissa legislature, but decided by administrative agreement.

But no governmental decision could be more fraught with intrinsically *political* questions: How much will the Central Government invest in one area of the country? Will the Central Government assume any of the cost, corresponding to the national interest in the development? Who will be responsible for building, and to what government and legislature will they be accountable? How will the cost of building reservoirs be shared among the cultivators, electricity consumers, and others who use them jointly? Neither engineering nor economics can finally answer these questions. In a democracy, representatives of the voters will in the last analysis decide them. But it makes a tremendous difference whether the questions are clearly and informatively put by the technical planners in proposing the scheme. In the case of D.V.C., they had to be faced, because the interests of two separate states obviously conflicted upon these points. They were faced on the basis of a technical plan measuring, as nearly as technical men can, the cost and value of alternative answers, The tentative agreement thus worked out was then vigorously and publicly debated in each of the representative legislatures concerned. Political questions got the authoritative political answer in a law.

Orissa and the Central Government have been fortunate that they have enjoyed, so far in the life of Hirakud Project, the control of the same political party. Even so, in the absence of a Hirakud law, dispute and ambiguity have appeared. This experience should warn us of the germs of future dissension absorbed into a major river development in which two or three governments are intimately involved if it is undertaken merely by administrative agreement—germs which will be incubated only when different parties control the different governments.

Parliament has become somewhat disillusioned with Hirakud and D.V.C. alike. One reason is Parliament's inability to get current and realistic cost estimates, compared with estimates of benefits and returns. It needs these facts in order to make effective use of its power to vote annual grants. Genuine, annually exercised, legislative power of the purse over these vast developments is equally necessary with a steadily-maintained long range technical plan. For the political decision, like the technical plan, must be periodically renewed, but not completely re-done, as new costs and new needs come to light.

Building. Building a dam, like commanding a military offensive, is an exercise in fitting parts into a whole. The dam-builder's elements—earth and rock, cement and steel, gates and turbines—are always less standard and less predictable than the person to whom these things are only words could ever realize. The means of assembly are machines of considerable intricacy—shovels, dumpers, batching plants, cranes—and men of a hundred skills and a thousand tempers. Everything never goes according to plan, though nothing will go without planning. No more than the general knows his enemy's strength until the battle is over does the dam builder know his foundation until he bares it, or the exact date of the high flood until it is lapping against his cofferdam. Co-ordination proceeds in either case upon the joint effort of a variety of staff specialists, but it ends in the decisions of a single general or project engineer. For no institution can supersede the unique capacity of a single human nervous system to perform this sort of running readjustment.

In the days of Cautley and Cotton, the engineer in charge of a project had the full powers of field command. He has them now—to build roads or tanks or school buildings. But because of the practice in the state or central public works department code, of defining an engineer's powers in terms of the number of rupees he can spend, not the project he is to build, this power does not normally come into the hands of the engineer in charge of big dams. There is a germ of justification for the limitation of his powers. For the man who builds a Hirakud, or even a Maithon, unlike Cautley or Cotton, must hire a variety of administrative and engineering officers, he must buy steel and cement that is in scarce supply, he must purchase overseas, he must decide for or against using major contractors instead of direct departmental labour. These are not wholly engineering decisions, and they raise policy questions.

There have been two solutions to the divergent requirements of unified field command and, on the other hand, sound recruitment and purchasing policies. One is to leave the dam building engineer restricted by the codes in general but count on escape clauses to meet emergency situations. That way, under a weak chief engineer at Hirakud, pemitted malpractices. But under a strong chief engineer, it is resulting in repeated demands on his part for more powers, which are usually granted, though piecemeal and not at once, by the ministries concerned. He devotes a good deal of his time and energy to winning exceptions to the code.

The other solution is that of D.V.C. The dam builder is held more steadily to fixed rules of hiring and buying than if he were under a general code, but the rules are made for the particular river development by the corporation itself. They are made for high-speed dam building, and not for roads, culverts, or school buildings. Moreover, there are personnel officers and selection committees to pick out the engineer's staff and decide on their rates of pay. There is a professionally-trained purchasing organization available to carry on the contacts with suppliers, and inspect equipment at their plants, while the engineer sticks to his job at the dam. But these personnel and purchasing organizations are just as anxious as he is to finish the dam on time and within the estimate, for they answer to a common corporate board of directors which will be judged by its success at just those points.

When they are put side by side, the records of Hirakud and D.V.C. in fact force one to a startling conclusion. The way to insure honest buying at the lowest rates, and the way to insure fair recruitment of the best personnel, is not by tying the chief engineer to the rules of the Union Public Service Commission, which he is compelled to waive by temporary appointments, or of the central purchasing organization, which force him, if he is in a hurry, to let out work to contract in order to get it done, or indeed of the PWD code itself, to which continual emergency exceptions must be made in building a big project, but to subject him to firm, but appropriate administrative policies, and to give him the best help of qualified purchasing, personnel, and other managerial organizations in carrying them out. But appropriate rules and helpful managerial services and controls seem to be possible only under the supervision of men directly responsible for getting the dam built—men who may lose their jobs if it does not get built on time and economically, as well as if it does not get built honestly. That is the position of the D.V.C.

board, and it is not the position of the Hirakud control board. And that is the principal way in which the D.V.C. chief engineer can work more effectively than the Hirakud chief engineer, even today.

There are other aspects of dam building to which, with minor variations, the same conclusion applies. There is an argument, for instance, for separating the design from the building of dams, and for pooling designs for several projects in a central organization, as CWINC tried to do. In the early years, though, Hirakud was hamstrung by centralized designing which never was ready in time. Central designing worked well for D.V.C., and for Hirakud, when both designing and building came under the charge of men who would be judged on their success in getting the dam built.

The question is not whether centralized services are used, but whether the decision to use them is left with an agency responsible for construction results.

Dam building though kept under single direction, must be fitted together with a host of other activities which are beyond the scope of civil engineering: buying of lands, resettlement of people from the reservoir, distribution and marketing of power, setting of rates and distribution of water for irrigation, control of malaria problems brought in by the reservoir and canals. D.V.C. organization permitted most, not all, of these things to be done by especially qualified men in D.V.C.'s employ, and, again, responsible to the same board of directors that controlled the engineers. Hirakud's dual arrangement is now working quite well in the case of activities loosely connected with dam building, such as resettlement or fixing of irrigation rates. It has not proved satisfactory in the case of purchasing and the employment of engineering personnel. The lesson is that in undertaking each such project, a fresh appraisal needs to be made of the non-engineering activities —how important they are, and how intimately connected to dam building. If they are important and intimately connected, the full-time head responsible for both engineering and non-engineering activities is the best solution yet tested.

Operation. Hirakud has not reached the operating stage, and the arrangements to be made for that stage are a question mark. D.V.C. is operating two reservoirs and its electrical system, and two points are already clear. The first is that controlling a multiple-purpose reservoir, still more a chain of such reservoirs, is a delicate business. On the opening and closing of the gates hinge the flood risk in the delta hundreds of miles below, the supply of water in the canals six months hence, and the money to be derived from the sale of electricity at the moment. These considerations are by no means equally visible and pressing. Flood hazards tend to be forgotten in the long intervals between catastrophes. So do the potential needs of cultivators during the decade or so they are becoming accustomed to irrigation. Power customers are insistent all the time, and they offer the most money per cusec of water released. Neither safety nor public confidence can be had from divided control—power penstocks operated by one department and flood gates or canal headgates by another. There are really two alternatives for operating such a reservoir. One is to have a corps of water despatchers responsible to a multiple-purpose agency like D.V.C. The other is to have rigid rules, negotiated and agreed to by the departments, or the different state governments, concerned with electricity, irrigation, flood control and perhaps navigation, with a single department or government responsible for operating the reservoir according to the rules. Either way is safe. Reliance upon rules, however, wastes some water which continual joint administration can safely utilize.

The second point is illustrated by D.V.C.'s agreement to supply electricity to Calcutta and to the Bihar grid at Gaya. This kind of periodic expansion is implicit in an electrical system serving an expanding economy. Indeed, it is one of the main reasons for undertaking river valley development.

Someone should remain, at the operating stage, charged with continual planning to foresee and meet such new demands upon the water and power system.

Supervision. A factual comparison of D.V.C. and Hirakud suggests a conclusion that does not fit in well with the cliches of constitutional structure. The 'autonomous corporation' was promptly pulled up by the supervising ministries when under pressure to get water stored, it signed a contract for the construction of Konar Dam which permitted the contractor to make many claims for extra payments. Though no question of fraud was involved, an administrative committee later conducted a searching enquiry. But at Hirakud, which was directly under ministry control, serious incidents of collusive buying and neglect of controls over materials and payrolls came to light only through the investigations of audit authorities. Actually, the 'autonomous corporation' proved more accountable.

The explanation to this seeming paradox is that where the nature of work involves on-the-spot decisions in any case, separate responsibility for building and for supervision yields more effective control than a mixture of the two in the same hands. Thus CWINC, and arm of the ministry in Delhi, had power to make important designs for Hirakud, and to approve its engineering estimates. But it was the chief engineer at Hirakud upon whom the real pressure fell to get them done in time. So when designs and estimates fell way behind, and loss of control over the cost side of the project followed, the ministry came to the conclusion that 'This ambiguity has made it impossible to pinpoint responsibility.' The ambiguity continues in the Hirakud board of control. There representatives of the irrigation and power and the finance ministries in Delhi help decide whether, for instance, a new division is required by the chief engineer to accomplish his task. Yet it was absentee decision of just such a point (when in 1949 the chief engineer asked for a stores division to inventory the five crores worth of miscellaneous equipment he had got from military disposals) that sowed the seed for waste at Hirakud. The ministry remains in no position to review such decisions in the light of their results, for it has previously taken its stand in the board of control.

The organizational defect will probably make itself felt no longer at Hirakud, where every person in power is on the alert against waste and corruption. It lies in wait for untried chief engineers, new ministers and new secretaries, perhaps in state governments, where deciding, and passing judgment on the propriety of decisions, are mixed in the same hands by a control board.

The record of D.V.C., and especially of Hirakud, demonstrates the indispensable function of unawed, relentless, Parliamentary scrutiny over work in which executive discretion is inescapable. Legislative scrutiny has been most effective where most direct. Parliament, or rather the members most interested, once got a much more revealing glimpse into the thinking of the D.V.C. board in an informal meeting with them face-to-face, arranged by a minister, than has been the rule. The Estimates and Public Accounts Committees have, in the circumstances, conducted surprisingly constructive enquiries into both agencies. But there is still too much suspicion of the agencies on the part of an ill-informed Parliament, and too much insulation of the building and operating authorities from legitimate Parliamentary curiosity and concern. It could be remedied, without transgression of the ideal of ministerial responsibility, in an annual hearing of the agency heads by a Parliamentary committee in preparation for the vote on demands for budget grants.[4]

The aspect of D.V.C. and Hirakud alike which has most defied effective ministerial and legislative supervision is certainly the financial aspect. There has yet been shown no way to get realistic estimates, nor to hold the builders to the estimates they made. But this is precisely the aspect, and it is the only aspect, where the hands of the dam-builders are effectively tied by strings running ultimately to the finance ministry in Delhi. This is an astonishing and revealing fact to anyone who will leave his sterotyped conclusions behind and examine the actual working of these projects. The present variety of financial adviser has proved surprisingly useless as an aid to the financial supervision of either project. At Hirakud, where he had an unprecedented check upon both estimating and spending, the most he could do in the familiar cases of the hire of bullocks and the purchase of sleepers was to keep records which, years later, put the Public Accounts Committee on the trail of the miscreants. Audit could have done as much, and without the unfortunate incidental effect of convincing the CWINC, and sometimes the responsible ministry, that there was a financial objection to almost every step needed to build the dam.[8]

Right down to the present, objections (or the even more characteristic reservations) by a financial adviser may be warnings of fraud, or breach of agency rules or the policy controlling the project. But they may, just as likely, reflect the view of the financial adviser, or of the finance ministry in Delhi, as to what the agency ought to do. Accounting control is not of much use for supervision when it gets mixed up with this sort of back-seat driving. At the same time, the men who have responsibility for building are denied genuine financial counsel. They sorely need at their right hand a person experienced in accounting and fiscal policies, and worthy of being listened to because he shares the mission, not only of being honest and obeying rules, but of giving the people the most river control and utilization for their money. That sort of responsible *advice* would equip them to submit project estimates and budget demands more accurate and informative than the present ones. If their motivation to do so were at the same time enlivened by more direct legislative scrutiny, and if the present audit reports were speeded up, ministers and legislators could begin to be certain they were getting their money's worth.

When the lessons of Hirakud and D.V.C. have been set down, two rather widespread beliefs are missing. The first is that some single pattern has emerged which can now be reproduced in each new river basin taken up for intensive development. The evidence has been, rather, to the contrary. The corporation worked better than the code and the control board. D.V.C. and Hirakud happen to be projects of about the same size, but one river is much smaller, one project required the collaboration of two states with the Central Government, one involved four dams, as against a single one. A governmental solution, to be appropriate, would have to be fitted to these differences. Still more would it have to be fitted to much larger or much smaller projects, to projects requiring little participation by the Central Government, to single-purpose schemes. What emerges from the experiment of Hirakud and D.V.C. is not a model, but a set of cautions and reassurances. The creative task will still await the founder of each future development—the task of fitting this considered experience with the conditions peculiar to his river and the needs of its valley's population in his time.

There is another thing this record does *not* show. It does not show that dam building by the Central Government is less efficient, or more efficient, than dam building by the states. It is true that the lesson of D.V.C. and Hirakud were learned at a price, a price greatly lightened in the case of D.V.C. because its founders had the sagacity and daring to profit by lessons of the T.V.A. That is not the price of national administration. It is the price of doing something big and new with a new organization. It would be foolish to pay that price again by setting up a new organization to do work which an existing state engineering organization could do, and which fell within the powers of the state. But it would be no less foolish to discard the ability which has now accumulated in the Central Government—engineering talent, successful methods of work, equipment and men to operate it, above all, knowledge of what kind of men are needed and what considerations deserve priority—*where the alternative is to build up an untried state organization.* This is to say nothing of the demonstration D.V.C. affords of the capacity of national powers, sensitively wielded, to overcome the handicap of state borders cutting apart an inter-state valley development.

India is in the singular position of having a fair comparison in progress between the corporation and the code. The experiment is coming to its conclusion before her governmental arteries have hardened, while she is still considering how to enact and execute her next great agenda of river valley developments. It is the sort of opportunity which nations generally leave unexploited, for patterns of government are set more often by inertia and accidents of political leadership than by a rational weighing of the evidence. But in this, as in so many other ways, India may turn out to be unique.

10

MAZDOORS

IT WAS the holiday of Sivaratri, and since the engineers would not be in their offices at Hirakud, I walked upriver to the site of the dam. The great concrete-making plant was shut down. But on the masonry abutment, connecting the earthen left flank to the concrete spillway, I was surprised to find a crowd of contractor's labourers busy. The usual procession of men and women bearing stones up the bamboo ramp was too colourful for any amateur photographer to resist. While I was preoccupied with my camera, I was puzzled to have a protesting male baby, about a year old, deposited at my feet. Three young women, waiting to take their next stone, had snatched him from the heap of warm sand where, with half a dozen of his fellows, he had lain waving arms and legs in unattended, and unconcerned, amusement. They tied up his legs with a scrap of *coir* string so he could not escape, and made it plain by signals that they wanted me to take his picture.

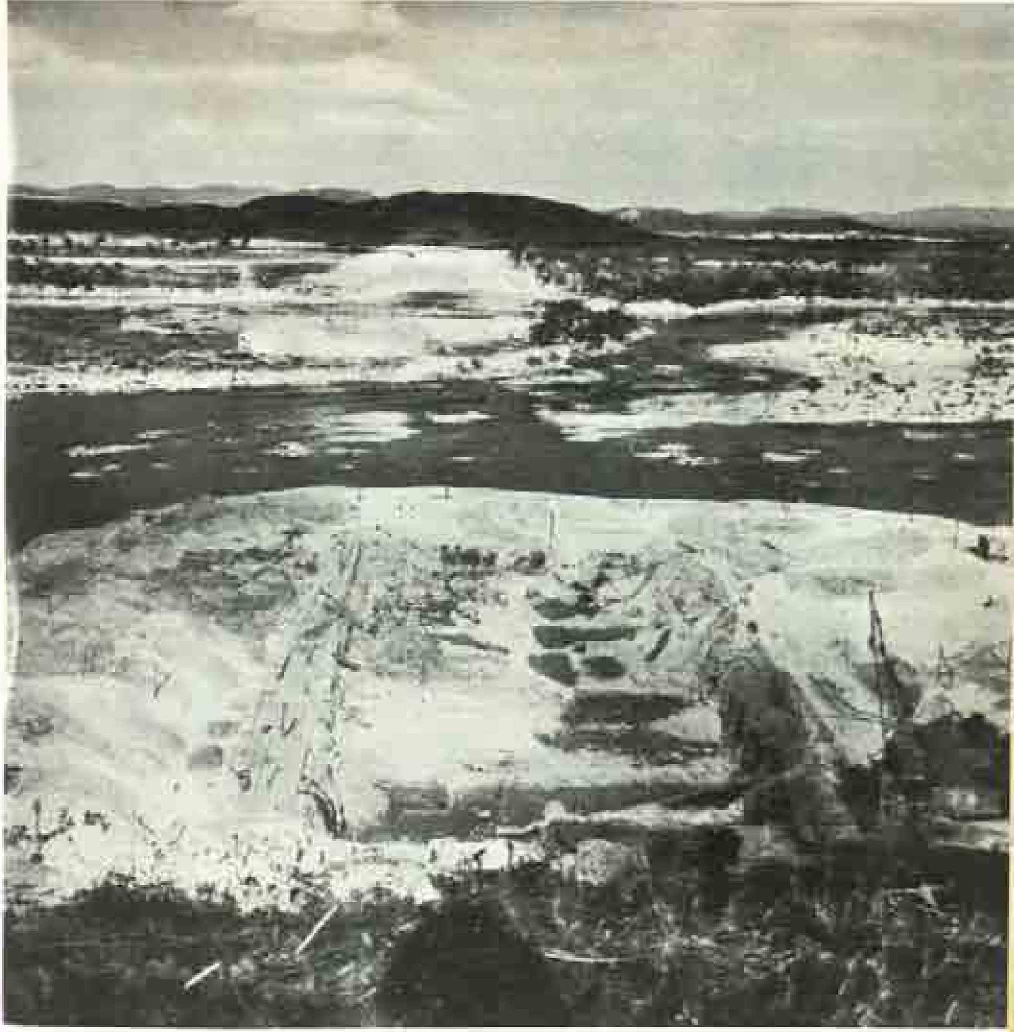
At this a fourth woman, quite evidently pregnant, ran up. Showing a mother's concern lest her baby be photographed bare of clothing, she rolled him into her sari, untied his feet, and restored him to the nursery in the sandpile. The merriment of the whole gang of men and women, who had stopped to watch, showed that the mother had been made the victim of a good joke. Ponamal, as I learned from the timekeeper standing by that the mother was called, recovered from her discomfiture as soon as she resumed her work. Squatting almost to the ground, she and the male labour opposite hoisted another 80-pound stone for one of the waiting line of men and women to carry off on shoulder or head. Each lift followed an animated appraisal of the prowess of the waiting bearer. Ponamal joined in the chatter.

It was passing strange to me that a woman engaged in what, during pregnancy must have been arduous toil, could appear so carefree. Hard work and long hours, had, however, their compensations. Ponamal had her small family of three together at the job, for her husband worked nearby unloading sand from lorries. The contractor paid them every Sunday: Rs. 1-8-0 a day to the woman, Rs. 1-12 to the man. Otherwise landless labourers in a village at the edge of the forest a dozen miles away, they had never got so much money before. Work was hard, but it had a human rhythm and human respites. Another woman took Ponamal's place when the contractor's man brought round the morning cup of free tea. And before I turned away from the *mazdoors* whose holiday work began at dawn, and would last until dusk, my eye was caught by dots of dazzling pink, waving up the bamboo ramp alongside the stones and pans of mortar. They were icicles of sweetened and coloured water, bought from the ubiquitous hawker for half an anna. Thirst for the gaudy refreshment was infectious. Ponamal found it possible to lift her stones with her right hand alone, while her left took care of the pink ice.

THE PETTY CONTRACTOR

Of the major dams undertaken since Independence, only two—D.V.C.'s Konar and Vaitarna in Bombay—have been wholly given over to contractors. The rest have been built 'departmentally' by government. But the truth is that even on these projects, direct employees of the government constitute a minority. Including both skilled and unskilled labourers, the figures were like this in 1952:

	Government Employees	Contractors' Employees	Total Force
D.V.C. (all projects)	10,000	15,000	25,000
Hirakud	10,000	17,000	27,000
Tungabhadra (Madras side)	13,000	22,000	35,000

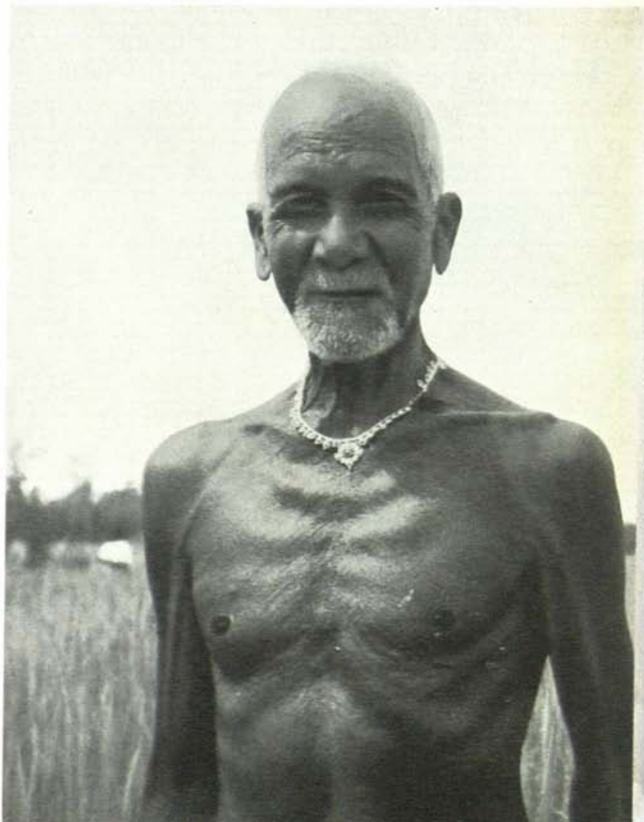


5. By 1952, the site of Hirakud Dam could be traced across the Mahanadi to the far dark hill. Earth dikes extended beyond that hill, and behind the camera. No eye could take in the whole project. *Chappelles, U. S. Int. Coop. Adm.*

6 A. Acres of war surplus machinery at Hirakud. The inventory took five years. *Chappelles, U.S. Int. Coop. Adm.*

6 B. Order and speed began to show in 1953. These lorries have just dumped earth fill on the main dam. *McPherson. U.S. Int. Coop. Adm.*

7A. D.V.C. built new houses of high standards for villagers flooded out by Tilaiya Dam. This family has closed in the model verandah with a mud wall.



7B. Shri Raghunath Pradhan, pioneer resettler from Hirakud Reservoir, in his new field of paddy. *Deputy Commissioner Relocation, Orissa.*

8A. Irrigation beyond reach of the rivers. Every piece of the wheel that raises water in the village Khajuraho, above, was made in the village. It waters five acres.

8B. A tubewell of the same depth, one of over 2,000 paid for partly by American 'Point Four'. A few annas worth of electricity waters 500 acres. *U. S. Int. Coop. Adm.*

Among the contractors themselves, a small minority had large organizations, employed some skilled labour, and paid their workers directly. D.V.C.'s contractors for Konar Dam or the Maithon tunnel were of this type. Ponamal worked for such a contractor at Hirakud. Except that they gave their workers more immediate amenities like Ponamal's free tea, or a bonus to dumper operators making the most trips with the least breakdowns, and less of the indirect amenities like housing, sanitation and medical care, such major contractors offered about the same conditions of work as government.

Very different were the petty contractors, employing the overwhelming majority of all contractors' labourers. They undertook the performance of unskilled labour only: breaking stones, moving earth, transporting material by head load. They brought to the project gangs of workers, men, women and children alike, who were in some way their personal dependents. The petty contractor might in fact be none other than the headman, landlord, or money-lender of the village. He might have advanced to 50 or 100 agricultural labourers the cost of their transport to the project; some might be long-standing debtors to him. By virtue of this debt he could keep them at work regardless of their inclinations, and exact from them effort more arduous than they would do for wages alone. Worse off in every economic respect, the labourers of these petty contractors retained certain social advantages. Families lived and worked together. The familiar food, traditional festivals, and customary associations remained intact. Except for the location of his work, in fact, the labourer scarcely knew he had left the agricultural village. He had no more attachment to the great canal system or dam to which another had committed his labour than he had to the land he customarily ploughed or harvested, but did not own.

In Europe and America, the system by which labour used to be engaged in gangs, their conditions of work wholly at the mercy of an agent who had some personal hold upon them, was known as the *padrone* system. Economic historians regard its replacement, something like a century ago, by the direct employment of workers at wages, as one of the milestones of the Industrial Revolution. In India, that system which dug the old Ganges Canal for Sir Proby Cautley, served as well to dig the canals of Tungabhadra and Hirakud. Engineers preferred it for unskilled operations because it took off their shoulders the time-consuming tasks of direct supervision. They had not, by the petty contract system, to recruit labour, measure individual production, see that output was maintained, handle hundreds of small wage payments, or end the services of the accumulated work force when the job was done. But that is not quite all the story. The fact is that under the complicated procedures of the ordinary public works code, engineers had not the time to manage direct payrolls. Only D.V.C., with more flexible routines, and more accounting help at the disposal of the field engineers, was equipped to dispense with the petty contractor as a general rule.

WAGES

Contractors paid more or less, according to whether the workers were their financial dependents, and the extra performance they might be able to exact. On the other hand, the wages of government employees on the dams and canals, in 1953, were something like the figures shown in the table on the next page.

Aside from the general difference among the projects (D.V.C. paid more than Hirakud, Hirakud more than Tungabhadra) whether these wages are high or low depends on your point of view. Perhaps the most objective standard of comparison is the average annual income of the whole Indian population. In 1950-51 it was calculated by the government as Rs. 265. But that is *per capita*. Since, according to the 1951 Census, there are two dependents for every wage earner, the average income *per earner* was three times as much—

	D.V.C.	Hirakud	Tungabhadra
Mazdoor (unskilled)	Rs.	Rs.	Rs.
men	1-8 to 2-0	40 per	1-2 to 1-8
women	1-2 to 1-4	month (1-10)	0-10-6
Helper (semiskilled)	2-0	50 per month (2-1)	1-8 to 2-4
Mason (skilled)	3-0 to 4-0		2-10 to 3-8
Dumper operator	175 to 225 per month	125 to 150 per month	80 to 110 per month
Power shovel operator	250 to 300 per month	165 to 205 per month	160 to 200 per month

Rs. 795. Before comparing the pay of dam or canal workers, we must remember that they get, customarily, in most of India, employment only during the non-monsoon months. For the working season, the male *mazdoor* at Hirakud got Rs. 320. That is 40 per cent of the national average earnings. Ponamal and her husband together got Rs. 650, assuming they worked steadily between monsoons—still below the national average though two worked in a family of three. But of course, these are the rates for the least skilled of workers. The national average is very close to the earnings of the masons and carpenters at D.V.C., or the fitters and dumper operators at Tungabhadra. Our very approximate conclusion is that skill for skill, the builders of river projects fare neither better nor worse than the population of the country as a whole.

Of course, construction wages were usually a tremendous improvement in the income of the particular persons who came to work. They would not otherwise have travelled long distances to the project. Many of the *mazdoors* were farm labourers having little or no land. Work on the dam gave them income in months when they would otherwise be quite unemployed.

For families living at the level of subsistence, it is not money that counts, but the amount of food that wages can purchase. In this respect, fluctuating prices since the War added tremendously to the insecurity of workers who left their agricultural villages to depend on money wages and purchased rice. Madras State kept accurate statistics on the cost of food and the cost of living in general at a village (Madhavaram) near the Tungabhadra main canal. In seven months from December 1947 to July 1948, the cost rose 30 per cent—meaning that the wages of canal-diggers fell that much in buying power. In the single month of March 1952, on the other hand, a wage unchanged in rupees gained 15 per cent in buying power. At Hirakud, where by 1952, *mazdoor's* wages consisted of Rs. 13 per month basic pay, plus Rs. 40 dearness allowance, money wages were cut to adjust to the fall in living costs. A *mazdoor* who in February 1952 got Rs. 53, got Rs. 40 in March. He could buy as much rice as he could the year before; but he never entirely reconciled himself to the adjustment.

The king of the manual workers at the projects is the operator of the walking dragline—the machine that was ordered for Tungabhadra, arrived in time for the big canals at Hirakud, and moved on to dig the irrigation-navigation canal in the Damodar Valley. At Hirakud, the best operator of that gargantuan machine used to earn Rs. 300 per month. Between that wage and the income of the *mazdoor* is a difference of six or eight to one. Even the normal dumper driver, who earns Rs. 140 at Hirakud or 200 at Maithon, gets about four times the pay of the *mazdoor*. The difference in wages between the skilled worker and the unskilled is twice what would be found in America; it is a good deal greater than the difference between the *mistry's* and *mazdoor's* wage on India's traditional masonry building operations. No doubt the output of the modern Indian machine operator more than justifies the contrast; but his comparative position needs to be remembered when we look for discontent on the river valley projects.

LIVING CONDITIONS

At six one evening, not long after I met Ponamal, I decided to take an unconducted tour of the worker's colonies at Hirakud. From the Spartan grey concrete office building of the engineers on the right bank I set off on foot. Taking the upriver road towards the dam, I quickly left behind the plain, spacious bungalows of the administrative officers, the fine new high school and hospital. After a stretch of abandoned fields, I came to a colony of mud-walled houses. Scientific engineering had worked its revolution, however, on the traditional building material of the poor. Mixed with a trace of bitumen, the mud stood perfectly square after a season's rains. Asbestos cement sheets made a tight roof. These were labour quarters: continuous rows of rooms 10 feet by 12 feet, with one family in each room. Unfortunately, as usually happens, higher classifications of workmen, short of housing, had occupied some of the quarters built for the *mazdoors*. The man I talked to was a helper in the mechanical workshop where the earthmoving machines were overhauled. For each row of quarters there was one water tap and a latrine. Since the water had been turned on in the main—it ran two hours in the evening and an hour and a half morning and noon—women waited their turn to fill their pots as they would in any other Indian town. Frugal as they appeared, these rent-free quarters were great prizes among Hirakud *mazdoors*. Many families elected to share the room allotted them with another household.

Kudaratha Bagh's habitation was a different matter. I came upon it across some abandoned fields from the government labour colony. It stood at the end of a row of leaf and bough shelters, none more than waist-high. Kudaratha Bagh's was made, not of leaves alone, but of odd bits of asbestos sheets and tin, perhaps a trifle less leaky. Two small children came out; they alone could stand inside. Their mother, emerging next, showed me the man of the house coming back through the dusk. He worked as a water carrier and servant to a quarrying contractor. I could get nothing else out of him about Hirakud. He pressed into my hands a much folded letter from the local revenue officer in a hilly district of Orissa, showing that he had applied for repossession of a tract of 26 acres, including five acres of rice land. It had once been property of his forefathers, but had fallen to disuse. It was the hope of establishing his claim to this land that animated him; Hirakud was a way-station. Kudaratha Bagh had no latrine, no light, no water nearer than the government colony half a mile back, or the river a mile away. From the project upon which he worked he got absolutely nothing but his pay. Yet he had no better place to go.

* * *

Night upon a major damsite is an impressive scene. A hundred feet up the cluster of floodlights dim moon and stars. Through the dust, the three-dimensioned motion of the crane-boom seems majestic and free compared to the workers receiving and placing the load of concrete it delivers. Far below on the foundation, they look like insects.

A mile further on is the earthfill dam. As far as the eye can reach it is raw earth, criss-crossed by a thousand tracks of cleats, treads and sheepsfoot rollers. A single *mazdoor* wets down the mass with a high-pressure hose. Through the jet of water lumbers the next tractor-scraper, dumping its 18 yards of clay. On that artificial ridge, vibrating under massive treads, any pedestrian feels that he is a rash interloper.

Yet, a hundred yards away, is the bazaar street of a labourers' village. The glare of floodlights and the noise of motors penetrates, without impression. There are the same crannies filled with sewing machines, the same *pan*-shops behind acetylene flares, the same knots of men at tea shops, that one would see in any small town at nightfall. Down the gullied street, the usual cows walk with placid dignity, the usual curs nose gregariously about. Men and women alike, a day's labour done, lie down on the smooth earth floor wrapped in a cotton cloth. Patiently, they endure all things. Has their patience an end?

* * *

Hirakud's camp is as big as the dam. I walked nine miles without traversing all the scattered colonies. But otherwise it differs little from the construction camp at any Indian project. All show the same contrast between the best quarters and the poorest. Tungabhadra had an unusually well laid out colony—even the thatched huts of the *mazdoors* were separated by lanes against fire. Durgapur Barrage of the D.V.C. is the only project I know of in India, or elsewhere, where every common labourer working for the government has been provided a weather-tight room. Even in D.V.C., contractors' labour shift for themselves—in a tragic fire at Tilaiya, 54 of their flimsy huts burned one afternoon; four babies died in the flames.

While I was at Hirakud, a UNESCO committee went round the labour colonies. 'Animals would not be given quarters like this in Europe,' one of the visitors exclaimed to his guide. For parts of Europe, that is true. But dam-building means assembling in a wilderness the population of a good-sized town—15,000 to 40,000 people. The buildings put up for them have but a few years of use; they must be paid for out of the irrigation rates and power revenues of the project. No country, under these considerations, houses its construction labourers at standards above the country's bare minimum. India's peculiarity is only that the thousands of unskilled workers required by hand labour construction give each project a dozen slums instead of one or two. It is one of the sobering facts of life that while a Caterpillar tractor, LeTourneau scraper, or Euclid dumper exact the same standards of fuel, maintenance and repair in India that they do in America or England, on pain of collapse, the *mazdoor* seems to have a capacity, not quite infinite, to absorb hardship and come back for another day's work.

HEALTH

Any man, woman or child who can get to a project hospital at any major Indian river development can get a doctor's attention. It matters not whether he be the employee of the government or a contractor, or for that matter, a cultivator from an adjoining village. This free, accessible medical care is the greatest single advantage that the *mazdoor* enjoys over the agricultural labourer. Families in the construction colonies make full use of the service. At Maithon in 1952-3, the average camp resident went to hospital or dispensary every other month; the same was true at Tungabhadra. The numbers of doctors and nurses available to take care of these cases were incredibly small—a doctor and two assistants at each project, plus a nurse and various attendants. There were 24 hospital beds at Maithon, 35 at Tungabhadra, 65 at Hirakud.

The only hope the medical officers had of keeping abreast of their cases was to prevent disease. Immunization and sanitation were the obvious answers. But vaccinating and inoculating thousands of families for the first time in their lives is less easy than it sounds. At Maithon, in a year when the camp population increased by 10,000, there were but 5,000 immunizations. Almost no one would take cholera inoculations—until an epidemic struck an adjoining town. The Tungabhadra doctor used a more timely incentive: no camp resident could get a ration card for rice until he had his 'shots'. Some epidemics penetrated the camps. At D.V.C.'s Konar Project, nine out of ten men in the initial crews got malaria. D.V.C. learned its lesson—the next year the disease was wiped out. Hirakud had a serious cholera epidemic in April 1952.

It was the *mazdoors* who suffered; almost half of them fled the project.

One sickness out of every six at the camps was intestinal. Contaminated water was one source. At Hirakud, the rocky banks of the Mahanadi made a popular latrine on the way down to a cooling bath in the standing pools immediately below. Contaminated food is even less amenable to control.

A baby was born almost every day at Hirakud and Tungabhadra. Delivery was invariably in the project hospital, and the mothers had pre-natal and post-natal care in their homes as well. Probably no population of similar income in India had healthier births. It was not a matter of medical attention alone. The project doctors confirmed the popular supposition that women had easier deliveries who, like Ponamal, worked vigorously right up to the onset of the pains of birth.

THE STRIKE

The strike at Hirakud in the last week of January 1954, moved towards its climax of violence and death with the remorseless certainty of a Greek tragedy. But that was not its only interest. The tense forces it momentarily bared were the forces generated unwittingly not only at Hirakud, but at all the great dams where thousands of men and women worked.

A year before the strike, the administering engineers at Hirakud saw trouble brewing. Men, particularly the equipment operators, had begun collectively to resist discipline for careless work. As an antidote, the management sponsored the Hirakud Workers Welfare Union. It was inaugurated in March 1953, with an assistant foreman of the mechanical division as secretary. He had contacts with the drivers of earthmoving machines, for he had been a field maintenance man. The project-sponsored union was registered with some 400 members. It got no enthusiastic response from the men.

Soon trouble came over an incredibly irrelevant argument.

The heavy equipment operators of the left side of the dam quarrelled with some contract workers over a woman. In the blazing heat of the afternoon shift, on the first of May, operators on the left side quit work. It was a Friday, and the following Sunday, defying a government ban on assemblies, the operators and other workers held a mass meeting. This was the debut of a rival union, certainly not sponsored by the Hirakud management, called the Hirakud Workers Union. Its affiliation was with the communist All-India Trade Union Congress; its president was also the organizer of the Orissa Peace Committee.

Both the management and the Hirakud Workers Union got what they were after in the May strike. Management dismissed eleven operators who defied orders to return to work; the rest of the workmen were on their jobs the following Monday. The organizers of the Hirakud Workers Union discovered the discontented workers and their natural leaders. They had, in the dismissals, cases they could build into martyrdom. They said, of course, that the men were fired for union activity.

Neither party, however, really dealt with the source of the work stoppage. On any great outdoor work built in a monsoon climate, the hot, pre-monsoon months are the tense season. At Hirakud the sun beat down so mercilessly on the crews that the levers controlling the scrapers and other machines got too hot to touch barehanded. It was in these months that the engineers, struggling to reach their season's targets and safeguard the unfinished works against high water, could least afford an interruption. But it was also in these hot months that two workers out of three at Hirakud, since their jobs would be suspended in any case as soon as the monsoon broke, began to feel indifferent to project discipline. With three to four months of unemployment awaiting them in any case, they had little to lose by striking. That was why, although Hirakud administrators had handled the union organizations with a little less sophistication than other projects, the stoppage of work in the hot months that they encountered had plagued D.V.C. projects as well. Only Tungabhadra, where few men did indispensable work like operating earthmoving machinery, and where work could go on with less interruption from the monsoon, escaped strikes.

Eight months later, the Union Minister of Labour visited Hirakud. Trying to attract his notice, some of the operators of the big scrapers deliberately kept their machines in low gear. It was evidence enough of the gulf between management and men. In those eight months, management had taken one step toward bridging the gulf. An experienced officer had been recruited to devote his full attention to labour relations. (He might have been on the job at the time of the strike in May, except that the government in Delhi rejected the candidate of the chief engineer and Control Board and substituted another.) But the Hirakud Workers Union had strengthened its position far more. It had the leadership of a real strategist.

The Workers Union leader was a native of Orissa who had chosen engineering as his career. At Patna University (Orissa then had no engineering college) he had failed the final engineering examination. His engineering career thwarted, he devoted his full energy to agitation. When he became general secretary of the Hirakud Workers Union, he knew exactly what he was about.

Having failed to ventilate their grievances to the Labour Minister, the scraper operators refused to take out their machines next day. They tried, unsuccessfully, to get the Mack dumper drivers to join the strike. At this point the project labour officer, learning of the trouble, first met the dissident operators and found out what they wanted. The demands were calculated to appeal to the maximum number of potential strikers: an immediate raise in pay for the operators, and restoration of the old monthly wage of Rs. 53 for *mazdoors*.

Up to this point, poor communications from the immediate supervisors to the top had kept any inkling of serious trouble from the ears of the chief engineer. The operators said their immediate supervisor had promised a pay rise, and that it had been vetoed by the executive engineer. However that might be, every earthmover was idle on Saturday, January 23, when the chief engineer got news of the trouble. He came immediately to the earthmoving section, called the striking operators together, and asked them to state their grievances. He accepted some of the wage demands, but the question of restoring the old *mazdoor* pay he could only promise to refer to the Control Board. The chief engineer had been patient and reasonable, and the men seemed mollified. Then one man got up and demanded: 'Will you put those concessions in writing?' To Shri Thirumale Iyengar, his own word was enough. The meeting failed.

Once more, a Sunday intervened as the strike was gathering momentum. The Hirakud Workers Union took advantage of the day of rest to call a general mass meeting. Now to the economic demands was added one that went to the heart of the question of discipline on the project. It was the demand for reinstatement of the eleven men dismissed in the course of the previous strike. It was a demand the management felt it could not accept.

Monday morning was the strike's critical hour. The chief engineer had, unfortunately, to be in Delhi. At the left bank colony, the superintending engineers were on hand to persuade the operators to load into the trucks for their ride out to the work site. Gradually the trucks filled. Just as their motors started, there was a voice from the crowd: 'Send your representatives, we'll talk it over.' The men climbed down and began picking out spokesmen. The superintending engineers agreed to meet employee spokesmen. But the Workers Union officers, playing for time, said they had to wait for their fellows coming over from across the river.

The delay gave the idle operators time to intercept workers on their way into the mechanical maintenance shops. A few joined the strike. The Workers Union leader arrived, but he was wary. He would not talk with the superintending engineers except upon their written request as representatives of the chief engineer. What the Union leader demanded, in other words, was recognition. But this was the very point that the engineers, considering the sponsorship of the union, were not ready to concede. One more attempt was made upon the Union leader. Among the top engineers of the project was a former professor from Patna, but to his erstwhile teacher of engineering, also, the Union leader was adamant.

The engineers now issued the same ultimatum which had brought the striking operators back to work eight months before: to fifteen men they said, 'Come to work, or lose your jobs.' But this time the union was well organized. It aroused the sympathy of others to the fifteen 'victims' and the strike spread. When the Union's loudspeaker trucks reached the project two days later, the workers generally were in the hands of the Union leader. All earthmoving and most concreting was at a standstill. The repair shops, too, were practically idle; mechanics who wanted to report for work were detained by the strikers.

For the engineers at Hirakud, the strike had now got out of control. They had to resort to the police power. Accordingly the beat of a drum was heard on Thursday noon in the Hirakud colonies, and the words of the traditional district magistrate's proclamation:

> Whereas information has reached me that there is apprehension of breach of peace in the. . . . area which is likely to cause obstruction to persons lawfully employed or danger to human life, health or safety or result in disturbance of the public tranquility . . . I, in exercise of my powers under section 144 Criminal Procedure Code do hereby promulgate this order banning all public meetings and processions, without permission, and shouting of slogans and moving out of persons carrying deadly weapons, including lathis . . .

Already, the achievements of the Workers Union leader were formidable. He had translated a wage demand peculiar to the operators into a project-wide demand. He had translated that into a demand for recognition of his union, and reinstatement of those who had disobeyed orders in its cause. Now all the issues of labour relations were submerged by a single issue of law and order, in which the traditions of the nation's struggle for freedom were all on the Workers Union side.

That night, in the tense calm of the ban, the district magistrate and the top engineers of the project sat down on the verandah of the guest house at Hirakud for a meeting with the Union leadership. The magistrate's presence had a healthy effect, for he told the union men flatly that they were making impossible demands, but that there was no reason why their economic demands should not be talked over with the chief engineer. It was agreed that the employees should nominate eight representatives to meet with the chief engineer next morning upon his return to Hirakud.

The morning session went better than could be expected. More housing for *mazdoors*, which had now been added to the demands, the chief engineer could agree to straight off. The workers' representatives seemed to accept the chief engineer's promise to do what he could for a wage increase before the Control Board. Even on the matter of recognizing the Hirakud Workers Union, a formula was found. The Union could put forward its claim again when its state registration had become final in March. Only the reinstatement of the dismissed workers was considered too vital to project discipline for the management to accept. The Union leader, however, had another card to play. How could the workers generally give their assent to the understandings of their representatives unless a public meeting could be called? The magistrate was firm. The terms could be discussed with the Union executive committee, not with employees *en masse*. It was agreed, and the strike seemed on the way to settlement.

But as the district magistrate drove back across the river from the meeting, he came upon a large gathering of striking workers. In the middle of it, talking to the men, was the Union leader who had just agreed to the ban on assemblies. The magistrate mounted the roof of his car and told the Union leaders on the spot that they had broken their agreement, as well as the proclamation against assemblies. Then he ordered his special detachment of armed police, who were stationed at the damsite, to disperse the meeting.

Excitement ran far too high for men calmly to go to their quarters. They no longer thought as workers—for almost a week work had been paralyzed—they were a mob. In sheer blind passion they headed toward the house to which the chief engineer had returned after his day of negotiations. It stood between the mob and the Mahanadi River, and in it Shri Thirumale Iyengar was alone. The district magistrate, on whose shoulders rested the responsibility for civil order, could do only one thing. He interposed his armed police before the mob at the gate of the chief engineer's compound. He had halted their advance; it was another thing to release their mounting tension. From the dark corners of adjoining buildings, bricks came hurtling at the police. Over and over the magistrate issued his ultimatum: 'Disperse or we charge.' The few who heard him reckoned not the future. At last he gave the order. The police swung their lathis down upon the packed heads. As those crowding upon the rear of the mob began to realize what had happened, the police fired into the air, and the mob broke.

That night the Hirakud hospital overflowed. Thirty-six workers were brought in with cracked heads. Two died the next day. Nine police and three watchmen came in wounded by bricks. Fury spent itself capriciously. During the night somebody set fire to a project jeep; and miles away at the canal construction camp, somebody else burned one of the engineers' offices. The leader of the Union was among the

50 arrested in the next two days. He was not among the 48 in the hospital.

On the Monday after the bloody Friday, men began going back to work. By Wednesday, the dam began to rise again, full speed.

CHANGING WORLDS

There were riddles in the Hirakud strike, and the strikes at D.V.C. and other projects, to make men of varied sympathies canvass their convictions anew, searching for solutions.

Has collective bargaining a place in dam and canal construction, where the life of the project gives little time for orderly relations to evolve? T.V.A. in America had made a great landmark in labour relations by beginning with a straightforward answer: 'Yes'. D.V.C., like Hirakud, had first said no, but in the end unions had to be dealt with in practice to keep the project at work. Yet at D.V.C., where management reconciled itself to negotiating with union representatives much earlier than at Hirakud, the union demands were, if anything, further from the scope of normal collective bargaining. As Bokaro thermal power plant drew to completion, for example, the union struck for employment of the surplus Bokaro labour at other D.V.C. projects, though those were already manned.

If a union chosen by the employees is recognized for negotiation, will employees gain enough confidence in management and understanding of its position so that agreements can be reached? Will it hold the workers it represents to the agreements it makes? The D.V.C. Employees Union (sponsored by the socialist Hind Mazdoor Sabha) was recognized in the utmost good faith at Maithon Dam. I asked the labour officer in D.V.C. whether early and sincere recognition of the union as representative of Maithon employees had fostered orderly collective bargaining. He could say only, 'At least it has done no harm.'

But underlying these questions of policy is a deeper riddle. Who was so deeply discontented at all these projects, and why? The answer is as clear and consistent as it is unorthodox. It was not the petty contractors' workers, living in hovels and paid at the caprice of a headman. It was not even *mazdoors* working at Rs. 1-8 per day, and waiting for years to be allotted a one-room tenement, who felt the real grievance, though organizers like the leader of the Hirakud Workers Union were clever enough to arouse their support in the end. It was the best paid among the workmen who struck first and most wholeheartedly—the drivers of the earthmoving machines, living rent-free in project houses, drawing a hundred to three hundred rupees per month. The statistics of the Hirakud strike support what the history has told us: 44 per cent of the unskilled workers struck, 67 per cent of the skilled. Time and again at D.V.C. it was the same story.

There is but one explanation that fits these facts. Pay and housing and other conditions of the job are the counters of labour relations on the big dams. They are not the motivating factors. The men who strike are the men best treated, materially, but most uprooted from the old allegiances—the allegiances of the father's occupation, the village and its headman, the protection and censures of family and associates. The men and women whose gaiety is most transparent, and whose discontentment can barely be aroused even under the blazing pressure of strike violence, are the Ponamals. Though they build something utterly unprecedented, they do it in the bosom of family, caste, and even village. They have been transplanted, not uprooted.

It is all an old paradox of the Industrial Revolution, and the communist strategists use it as efficiently in practice as they deny it basically in theory. When a semi-feudal agriculture gives way to a wage economy it is not misery that breeds unrest, but the changing of worlds. It is the men with the new skills, the least miserable, who become the most disaffected; they have both the most power to strike and the least anchorage to the old values and groups. The materialist motivation does not, after all, go deepest.

This changing of worlds, occupational and social, this willingness to work at a higher skill where higher wages beckon, to learn new tasks and go to new regions, holds the economic hope of the New India. But it also holds the unease. For the men who make the metamorphosis from the long millenia of hereditary tasks to the technological economy need something besides pay and housing to attract their loyalty. They need a sense of their place in the new economic world as real, personal, and immediate as the ties of family, land, and village. At the projects, as in other segments of the economy, the Industrial Revolution had got ahead of the cultural and social revolutions. No one had invented any ways of giving the new careers the warm flesh-and-blood significance of the old. Among the vanguards of the new order, the drivers of the machines, lords materially, but lonely psychically, the agitators found their tinder.

Not long ago Prime Minister Nehru paid a visit to the D.V.C. dam at Konar, then in the midst of construction. Interrupting the explanation of the structure being given by the project engineer, he walked over to a labourer transporting stones upon his shoulder. 'Why are you doing this work?' enquired the Prime Minister. '*Sahib bahadur,*' came the polite but matter-of-fact reply, 'that man tells me to take these stones over there. At the end of the week he gives me money. That is why I do it.' To the Prime Minister that was not purpose enough in life for a builder of the New India. He made that very plain to the member of the Damodar Valley Corporation who was at hand. Now and then, in a very different way, the *mazdoors* themselves have made it plain, too.

11

DESERTED VILLAGES

TOWN OF THE GOD NARAYAN

THE OFFICIAL opening of Tungabhadra Dam took place on 1 July 1953. On that day there were still some people nearby who hoped that the reservoir would not fill. They were the residents of Narayana Deva Keri (Town of the God Narayan). Though their town was twelve miles from the river, it was nevertheless on low land, and the reservoir was designed to engulf it as it filled.

For over two years, the engineers and civil administrators had been telling the townspeople that their houses and lands would be flooded. The warnings were not totally disregarded, for a strong movement grew among the people of Narayana Deva Keri to keep the water out, somehow. The citizens even tried to persuade the chief engineer to build a dike around their town; but it would have cost too much. The government men bought all the land and buildings. They laid out two new towns for the people of Narayana Deva Keri, one on the railway to satisfy merchants who liked that feature, one on the highway to suit another faction in Narayana Deva Keri. At each relocation site they laid out plots of land, dug wells, paved and drained the roadways: all free to the people relocating. The rains of 1952, cautioned the government officers, would bring the reservoir up into the old town. Still, few people moved.

Some did not wish to leave the temple. Its tall, richly sculptured *vimana* dominated the town. People came from afar to worship its God Narayan. A sentiment had already grown among the elders and the women that it would not be right to abandon the temple, when Narayana Deva Keri received a prophecy from a mendicant priest ('soothsayer', the civil administrator called him): 'The waters will never touch the God Narayan.' Some simple people took it as a statement of truth, compared to which the warnings of the engineers were insubstantial. To others, no doubt, it was an excuse for deferring the evil day of moving. Besides, there was the attractive illusion that the government might make a supplementary payment for houses and lands in its haste to evacuate the people. Thus it was that when the dam was commissioned, and the residents of all other villages had got out of the way, the people of Narayana Deva Keri stayed in their houses, watching the water edging over distant fields.

On the morning of 4 July the local administrator at Bellary received a frantic telegram. The people of Narayana Deva Keri begged to be delivered from their town; it was surrounded by water on three sides. The lorries working at Tungabhadra Dam, and private lorries as well, were ordered into service. Wealthier people in the town hired hundreds of bullock carts to move their belongings. Transport was free to the poor. But by the time the vehicles arrived, the last road into the town was under shallow water. Household belongings could still be carried to the waiting carts and lorries. But building materials from the abandoned houses had to be left behind and lost to the rising reservoir.

Wandering among the crumbling remains of Narayana Deva Keri after the reservoir waters had been drawn down, I got some appreciation of the attachment of many uncalculating folk to their native places. People in industrialized countries find their roots in the families of their own generation, in their relations to job and to country, in the contact the newspapers give them with the stream of great events. The roots of the Indian villager go deep, rather, in the family of his ancestors, his caste, and his hereditary occupation. All his ties have their manifestation in the village: in the quarter and meeting place and well reserved for his kind, in the hut or courtyard of his family, in the tools or fields of his ancestral work. On the whole geography of his character and career the immemorial village temple looks down. So I was reminded by the *vimana* of Narayana Deva Keri overlooking the jumbled heaps of mud and stone that once were houses clustered round about.

If occasionally a family or a village refuses to pull up roots so deep before the dams are built, it is not extraordinary. What is remarkable is the resignation with which thousands of families in hundreds of villages have moved. 'It is our fault we did not get out soon enough,' said a Harijan woman, who in her hasty flight from Narayana Deva Keri lost not only the poor timbers of her house, but her bundle of personal belongings, too. 'It is foolish to blame the government. They warned us in time.'[1]

THE MODEL VILLAGE OF BACHHAI

As in the case of Tungabhadra, so in the Damodar development there is no doubt that the suffering of the displaced people was for the good of the greater number. D.V.C.'s four reservoirs will flood out, for at least part of each year, 83,000 acres of land. In return, more than 1,000,000 acres will get irrigation, and most of them flood protection, too. In human terms, about 30,000 people had to move from reservoir land.[2] For every one of them, there are ten who will get electricity in their houses, towns, or work places; and thirty who will get water for two crops a year, forever free of drought.

But for the family or the village behind a D.V.C. dam, moving was no less cruel a prospect for all that. Some of the inhabitants of the Damodar reservoirs were Santhal tribesmen, with home ties even stronger than those of agricultural people. To such a one, gathering the fleshy petals of the *mahua* tree in April for the manufacture of the Santhal liquor, hunting small game with bow and arrow, or stealing half-grown saplings from the reserved forests to eke out a dwindling livelihood, each rock and tree of the familiar Chota Nagpur hills was a part of his being.

There is another reason why dislocation from reservoir lands carried a threat to the residents along the Damodar. It is a reason common to Indian projects everywhere; indeed it is the fundamental hazard of rural life. But in the case of the Damodar villages, we can find out, from the careful records of the D.V.C. relocation officers, the exact dimensions of the threat.[3]

For practical purposes, the people in the D.V.C. reservoirs were dependent on the land alone (96 per cent of the income earners were either cultivators or farm labourers). *Generation after generation the number of mouths to be fed increased, the land that fed them remained the same.*

What had happened was clear enough from the case of D.V.C.'s first reservoir, Tilaiya. It lies directly across the Grand Trunk Road where it runs through the Chota Nagpur hills. But neither the industry nor commerce which follows that road has involved its people in any way. Out of 2,850 men and women who made a living in Tilaiya reservoir area, only 111 had a non-agricultural occupation. One of the villages nearest the highway was Bachhai, inhabited by 54 families. Only two of them had a principal support other than farming. But between 1911 and 1951, when Tilaiya reservoir was built, the size of the average cultivator's holding in Bachhai shrank from 5⅛ acres to 1⅞ acres. That is forty years, almost two generations to the Indian cultivator. He had subdivided his lands twice among his heirs, who had no prospect of other livelihood. The average cultivator in Bachhai by 1951 had 17 or 18 separate fragments of land. Each averaged about 16 yards by 30—one-tenth acre.

Bachhai farmers did not submit to this fate without a struggle. Though they could not expand the boundaries of their village lands—on all sides they were surrounded by other villages—they could try to convert the steeper hill slopes to paddy or potato fields. This they did: in 40 years they added ten per cent to the *productivity* of the village area. But in *acres*, they lost as much as they gained, for the hillside cultivation often ended after some years in gullied, eroded soil unfit for cultivation. The net result was that two generations of toil added exactly two acres to Bachhai's crop area.

The outcome of the long struggle showed up in a simple statistic. In 1951, the yield of Bachhai's fields *per capita* was 76 per cent of what it had been in 1911. One villager put it quite clearly to a D.V.C. relocation officer : 'My grandfather's harvest was enough to feed his family three times a day. Mine is enough to feed us twice.'

That is why the building of Tilaiya Dam seemed such a catastrophe to the people of Bachhai. Along with 4,000 other displaced people, they would be thrown upon the shrinking, fragmented fields of the nearby villages, for like all rural folk, they would not move far from their traditional homes. A fair price for their old fields would not be enough to open an economic future to them. Somehow, they would have to get land. For this fundamental reason, Bihar insisted, and the Government of India agreed, that those displaced by D.V.C. dams should get land for land, and house for house. It was not a new departure. Mysore had made an arrangement like that for the people flooded out of Krishnaraja Sagar. But there was one thing new about the way it had to be done. There was no possibility in the D.V.C. reservoir margins to take some of the land of the big estates and divide it among the small cultivators. That had in effect already been done. There was only one way to meet the need : to build new farms out of land too rough to have been ploughed, even by the land-hungry cultivators of the hills.

The engineers who needed the old fields for their reservoir had, fortunately a new way of manufacturing replacements.[4] The same crawler tractors and earthmoving machines that built dams could terrace gullies, even light jungle overgrown with *sal* trees. In 1948, it was an operation new to India.

With Shri S. S. Pillai, the man in charge of D.V.C.'s mechanized earth reclaiming work, readers of this book have become acquainted in an earlier chapter. Bachhai's new fields were his training-grounds, and the work took longer than he planned. Nevertheless, in 1952 when Tilaiya reservoir filled with water, he had 4,500 acres of level, bunded cropland ready for the displaced farmers. D.V.C. gave them land for land. Since the new fields were above river level, whereas some of the old had been irrigated by ancient canals, Shri Pillai's scrapers equipped the new village site with an irrigation tank, capable of storing 100 acre feet of water. When it was all done, by D.V.C. Enquiry Committee's meticulous accounting, the purchase and reclamation of waste hillsides had provided first-class paddy land at a cost of Rs. 875 per acre.[5] In the existing villages, such land would have cost Rs. 900 to buy—had any been for sale. Only the new machines, and the new sciences of engineering and agriculture, could have done what Bachhai's sturdy cultivators had failed for 40 years to do—bring new land permanently under the plough.

Bachhai's farmers lost much in familiar surroundings; in one respect they clearly gained by the move. Their new fields were carefully allotted to equal their old in crop-producing capacity, but instead of being scattered in 15 or 20 tiny plots, consisted of three compact tracts—house site, upland, and paddy land. Generations of fragmentation were undone at a stroke. Whether the wasteful fragmentation would not set in again was up to the farmers themselves, and to D.V.C.'s wider efforts to make jobs for their surplus sons apart from the land.

The government had promised not only land for land, but house for house. D.V.C. set out to build villages acceptable to the people, without reproducing the unhygienic features of their old homes.[6] It turned out to be more difficult to do, at reasonable cost, than the city-dweller would imagine. For the old houses of Bachhai, though unprepossessing in appearance, were not cramped. The average family of five or six persons had three or four rooms. The rooms were mudwalled, but they were big—10 or twelve feet by 20. To find out what the villagers would accept, D.V.C. put up four trial houses, two large and two small, at the new Bachhai site. The reservoir families had plenty to say about what was wrong with them. Some of the criticisms D.V.C. accepted—an intermediate size of house, more loft space. Some, like elimination of all windows ('We don't want people looking in our rooms to locate our valuables so they can steal them by night.') seemed unhygienic.

Between the designers and the villagers, three house types were evolved, and 54 of them put up on the knoll which was to be the new Bachhai. The smallest had two rooms of 10×14 feet, plus small verandahs front and back. The largest had three rooms 10 by 20, and big verandahs. All had four main advantages over Bachhai's old houses. The mud-brick walls were sealed against the monsoon by a foundation and capping of burnt brick and an outside coating of cement plaster. The verandahs with their concrete benches gave adults a comfortable place to sit, and children a place to play, in light and air. There were shelves and niches to keep utensils off the floor. And every kitchen had its chimney to carry off the smoke of cooking.

Bachhai's 54 houses were laid out in a rectangle around a big village square. The smallest were on plots 50 by 100 feet and the biggest on 100-foot squares. Every house fronted on a drained, tree-bordered roadway. At one end of the village square was Bachhai's new 'basic school'; at the other, the community centre building. There were three wells, and the village was connected to the nearby Grand Trunk Road by a stone-surfaced road.

The appearance of the model town did not quieten the doubts among the villagers. Would the artificially-reclaimed fields grow paddy? Would the wells go dry? Were houses equipped with windows safe? One day in 1952, all the patient assurances of the D.V.C. relocation workers seemed in vain. The new village site lay directly south of the old. As at Narayana Deva Keri, a soothsayer put in his appearance, 'South is the domain of *Yama* (God of death),' he told the people, 'To move that way would be inauspicious.' The D.V.C. relocation workers however, sensed the changed reaction of the villagers. Presently another itinerant priest appeard. A southward move, he agreed, was imprudent, in the ordinary case. But there was no harm in moving south, *if the rivers themselves were moving that way.*

The real credit for leadng the people to their new village goes to the headman of Bachhai, Tokhan Mahto. He is an intelligent leader in the prime of life—the best farmer in the village, It was he who persuaded the sceptical villagers to plant a trial crop on the new terraces the year before the move. With proper fertilization, the harvests were as good as on the river bottom lands. It was he who arranged for the moving of the old village idol, or *murti*, to the shrine that D.V.C. built in new Bachhai. There was a grand festival, and a blessing by priests. When the water came up in Tilaiya reservoir in the monsoon of 1952, Tokhan Mahto led a procession of men, women, children, and laden bullock carts along the two-mile road to the model town.

The people (when I talked to them a year later) had their complaints. They wanted more wells, more temples. Some of the newfangled windows they had stopped up with bricks. But their crops were good. They had salvaged much from their old houses before the water engulfed them, including a season's fuel supply. They had a keen pride in the new basic school. Already, fruit trees were appearing around their new houses—some set out by D.V.C., but others by the citizens of Bachhai.

The new houses cost Rs. 3-8-0 per square foot of room and verandah area. The small, the medium and the large style cost Rs. 1900, 2900 and 4000 respectively. This was one-third more than it would have cost merely to pay the displaced families the value of their old houses. Some criticism of extravagance has, of course, resulted.[7] But the critics would have observed, had they surveyed the troublesome task of relocation as it has been carried on at other projects, that this is as modest a premium as it is possible to pay to quiet the conscience of a democratic state which must make some of its citizens suffer for the good of the rest. Bachhai, indeed, is a model of relocation, both satisfying to the people and elevating to their health and welfare, for any country in the world.

The real shortcoming at Tilaiya was, rather, that reservoir families refused to move into two of the four new villages that D.V.C. built for them. They took up almost all the new lands provided for them; but they would not follow the example of Bachhai and occupy the model houses. Perhaps the policy of 'house for house' allows too little free choice to the displaced family in a very personal matter such as living quarters. D.V.C. has, at later projects, asked families to choose in advance between cash compensation, or compensation in houses or lands to be provided by D.V.C. But at the same time that D.V.C. was being criticized for extravagance in building model villages, some political spokesmen were telling the unrelocated villagers in Tilaiya reservoir that D.V.C. could be pressed to pay them further in cash for their old houses if they refused to occupy the new.

Evacuating a reservoir site without needless hardship to its population is always difficult. Perhaps compensating them fairly without pauperizing them, and making new land available, is enough of an achievement to expect of the dam-building agency. If, however, the personal tragedy of relocation is to be converted into the birth of a new economic and community life, as it was at Bachhai, something more than good administration and good engineering is required. There has to be in addition what Tokhan Mahto provided his people—staunch leadership.

CLEARINGS IN THE FOREST[8]

Raghunath Pradhan was nursing a quarter-acre of vegetable garden through the hot months with water his sons dipped out of a muddy pond, and conveyed in a channel of hollowed logs. Leaning over the patch of tomatoes, brinjal, onions, greens and tobacco, a large tree grew out of the bund that formed the pond. In its branches was a crude platform, like a hunter's *machan*. 'One of us keeps watch there every night,' explained the farmer. 'Once an elephant came out of the jungle and trampled my vegetables. We are not going to let that happen again.' Whether the lone watcher in the tree could indeed frighten off an elephant by beating on brass pans, I do not know. But, except for an antique bow and arrows, and a thin-bladed axe, the uses of which had long since become ornamental, the settler in the jungle had no weapons at hand.

Shri Pradhan's erect body, clad only in a *dhoti*, had a luxuriantly wrinkled skin that confirmed his estimate of his age —'about eighty.' His extraordinary gold necklace confirmed his reputation as a man of wealth. He was the patriarch of a family of 30, including great-grandchildren. Yet when his 26 acres in the village of Jogini (only one of his holdings) was purchased to make way for Hirakud reservoir, he had without hesitation selected the most isolated of the government relocation sites, and there bought 40 acres for his new farm. Government authorities called the place 'Sangramal A'. When Shri Pradhan arrived there a year before it was no more than a brushy clearing in the Orissa jungle, watered by a pond built long ago as a water hole for wild game. There was not a house within five miles. Working with his three sons and a son-in-law, the old man planted five acres of paddy. Though the pond ran dry before irrigation was complete (government men promised to deepen the pond) Shri Pradhan harvested 45 maunds. The grain lay in his front room, safely stored in raised round bins of coiled rice straw rope. Hiring some extra labour, he and his sons had in five months completed a strong and spacious house, 45 feet by 20, walled with mud reinforced by a bamboo lattice, and tightly thatched with rice straw. The central room housed three pairs of bullocks. Five couples with their children lived and dined together in the other two large rooms. In the wilderness, the joint family came close to being a self-contained community.

The only thing that made Raghunath Pradhan restless was his craving for still more new land. He had gladly moved from Jogini because Sangramal A, surrounded by untenanted forest, seemed to offer unlimited scope for enterprise. Already he had applied for more than his 40 acres, and because the government did not want him to monopolize the rice land at Sangramal A, he was beginning to look for other lands in the vicinity.

Raghunath Pradhan, a true pioneer at 80, thrived in the wilderness. How many others, rooted in their villages along the Mahanadi, would willingly follow him? Commissioner Sivaraman, the resourceful civil servant who, in addition to his general charge of administering the government of northern Orissa, had the task of moving people out of the reservoir, gave a confident reply. 'We are fortunate with regard to the rural folk,' he remarked. 'If we have a fair proposition, and if we explain it to them patiently enough, sooner or later they will accept it.' Then he added : 'It may take two or three years. And all of us who speak for government have to be convinced.'

The Hirakud resettlement programme was, in fact, as much an exercise in persuasion, based on the economic self-interest of the cultivators, as D.V.C.'s had been an exercise in rural reconstruction.

At 'Sangramal B', another relocation site two miles from Raghunath Pradhan's, Pitambar Barik stood watching carefully while four hired labourers dug holes for the corner posts of his new house. He, too, was a first settler, but it was not a pioneering urge that made him the first of his village to relocate. It was a hardheaded assessment of the productive capacity of the old lands and the new. Jointly with two younger brothers and his father, he owned seven acres in the reservoir village of Mura. Four acres were paddy land. Of all the Mura farmers, Pitambar Barik had been the most sceptical of the government agent who told him, 'For the money you will get for your old farm, you can buy land just as good, and more of it, in a reclamation site.' Taking up the agent's offer, he had gone in the government lorry to examine every one of the fifteen sites which were being reclaimed for the displaced families. But his hardheadedness made him the most resolute to move, once he saw for himself that there was plenty of new land at Sangramal B each acre of which would give him as much paddy as an acre at Mura. On the day, therefore, that Shri Sivaraman's land acquisition officer appeared in Mura to pay owners the assessed value of the land, Pitambar Barik took the payment for his family property, Rs. 3,280, a few doors down the village street to where Shri Sivaraman's second agent, the resettlement officer, sat waiting. From the family's savings Pitambar Barik added Rs. 220, and put down Rs. 3,500 for a new government-reclaimed farm. Land in Sangramal B, as in all other sites for Hirakud relocation was sold at an average price of Rs. 213 an acre—Rs. 260 for irrigated paddy land, Rs. 125 for upland suitable for dry crops. At that rate Pitambar Barik knew he would get some fourteen acres to replace his seven, almost all the new land fit for paddy.

Unlike Raghunath Pradhan, this younger settler never would have moved by choice. Once convinced that moving was inevitable, however, he saw the advantages in moving early. As the first settler, he had his choice of all the house-plots in Sangramal B. He chose one at the upper end of the future village street. There was no shade—too hastily the government men had cleared all the trees—but Pitambar Barik's practical eye saw good drainage. Actually, building his house was a simple matter. Between the stout posts would go temporary screens of woven bamboo, later to become the reinforcement for the mud walls. A week's work would thatch the roof with paddy straw. His wife and father (Pitambar Barik was childless) would move to Sangramal B before the rains to help put in a paddy crop on the new land. Meanwhile his two brothers, ploughing with a second pair of bullocks, would continue to cultivate the old lands for two or three seasons until the completion of the dam forced them out. The double harvest was another incentive to early relocation.

While Pitambar Barik built his house, bulldozers levelled and roughly bunded the fields he and other settlers would in two months' time plant with paddy. The land had been located in the midst of Orissa's forest preserves. In having this rich land around the reservoir, the Hirakud authorities were more fortunate than D.V.C. Sale of the standing timber, most of it to the dam construction forces, paid the royalty charges of the forestry department. While heavy tractors rooted up the stumps, half a mile away through the timber power scrapers were raising an earthen dam across a small watercourse that would provide 150 acres in Sangramal B with irrigation water. The earth fill was rising rapidly. But it showed the mixed soils and irregular lines of an amateur job. Though engineers from the dam construction organization gave occasional advice, Shri Sivaraman's enthusiastic and otherwise able staff included not a single engineer.

The strength of D.V.C. resettlement was in its technical planning and construction, Hirakud's in its practical psychology. Shri Sivaraman's strategy was to do everything economically possible to make an exchange of lands visibly beneficial to the displaced cultivator, but to let him choose where to go. If he wanted to take the money the government paid him for house and lands in the reservoir village and waste it in a prolonged spree, there was nothing to stop him. If he bought new land with the proceeds of his old, it was he who picked it out and decided how much he would buy. How many of the displaced families would take the prudent course could only be known two or three years later, when the lands had all been acquired, and the rising waters forced a final choice upon the villagers. The reservoir will cover 108 villages. Two years before the water was to rise, the Orissa government had succeeded in buying the lands of about half of them (51 villages). In each of the 51, at least one landowner had used his payment to make a deposit toward the purchase of a new farm at a government relocation site. Shri Sivaraman was confident that this was enough of a lead to attract the rest of the cultivators to the new lands.

One thing was already clear. The more realistic strategy of the Hirakud resettlement had not avoided the government's having to spend more on relocation than it bargained for. Orissa first tried to get the land too cheap—at its 1947 value, on the grounds that any subsequent increase was due to the construction of the dam. In the end, not only were current values assessed, but the state government agreed to buy the land, and then to pay extra for trees, wells, and tanks.[9] The increase of several crores was added to the cost of the dam. Hirakud's cost for reclamation was estimated to be Rs. 213 per acre, less than half D.V.C.'s. But the actual cost of the 10,000 acres budgeted to be reclaimed through 1954 was the same as D.V.C's.[10]

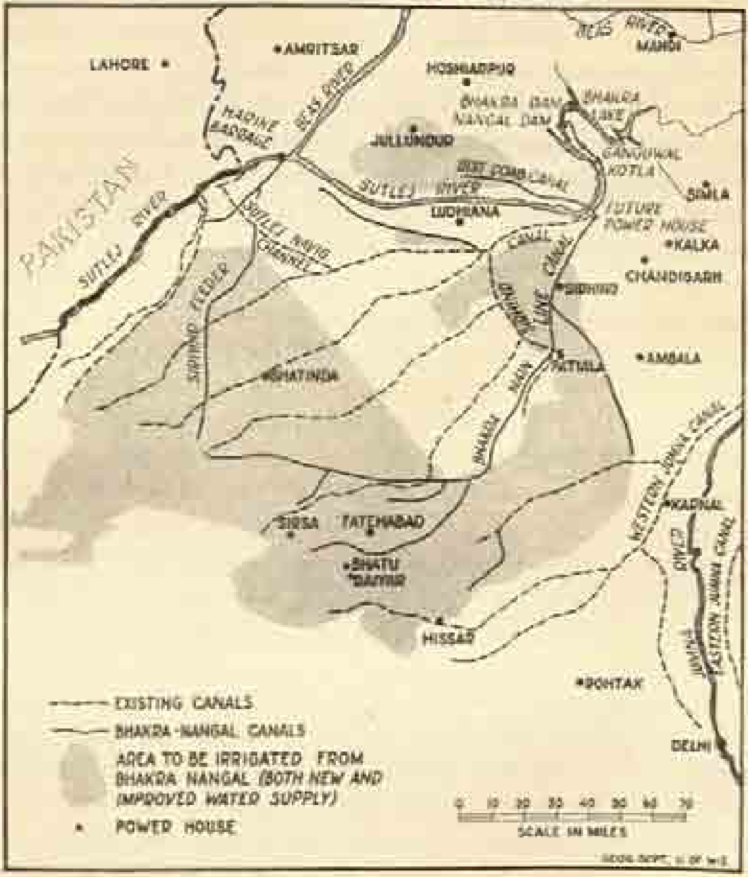
Certainly, letting a man build his own house in his own time, using his otherwise idle labour, is a net saving over the Bachhai plan. No doubt the Orissa strategy of voluntary selection of the relocation site by the cultivator would succeed in drawing him farther away from his native village to better lands than would be available within a mile or two.

Moving people from their homes and farms to make way for a dam that will confer distant benefits is one of the most painful duties of a humane government. The difficulties India has experienced are almost all inherent in the task. But there are lessons to be learned from the experience of both D.V.C. and Hirakud that will permit the builders of future dams to do it with more assurance.

Perhaps the most valuable of the lessons will turn out to be the willingness of the Indian villager to make way for a nation-building project, provided he is convinced that the sacrifice he is called upon to make is unavoidable. Pitambar Barik expressed the point in words that cannot be improved upon. After he had told his story I asked him whether the construction of the great dam at Hirakud seemed a good or a bad thing. 'For me it is bad,' he replied, and then, after a moment's hesitation: 'For the world (*dunya*) it is good.'

FIG. 6

BHAKRA-NANGAL PROJECT



12

COUNTRY IN COMMOTION

AT 11-45 on the morning of 8 July 1954, Prime Minister Nehru let the water of the Sutlej into Nangal canal. The river had been backed up behind the 26 steel gates of Nangal Dam, on the north end of which the Prime Minister stood. Across the river, the new headgates controlling the entrance to the canal rose noiselessly, lifted by the electric control at the Prime Minister's hand. The water leapt out toward 300,000 acres of dry farmland prepared for it in Punjab, PEPSU and Rajasthan. It had a long way to go. In its first forty miles, through Nangal canal, it would drop past two hydro-electric plants almost ready to harness its energy. Beyond waited 298 miles of Bhakra main canal and main branch, running west across the whole of Indian Punjab. Through five million acres ran the branching smaller channels; eventually 3·6 million acres would be irrigated. This year the first instalment of a potential million tons of grain and three-quarters of a million tons of cotton would grow under that sure watering, whatever rain might fall.

This much had been done. Eight miles upriver from Nangal the biggest work of all was only well started—Bhakra Dam. Five or six years hence, water would pour from its blue lake, 680 feet deep, 45 miles long, to fill Nangal canal in the dry months. As it shot forth, the water would turn the most powerful generators in India.

Before opening the gates, the Prime Minister talked in Hindi, then briefly in English.[1] He spoke extempore, as his custom is. There was an intensity of personal feeling in his words; he spoke as a participant in a great event. But exultation gave way repeatedly to reflection, to a search for historic meaning.

> I want to know from you what you think and feel... on this occasion, [he began] for in my heart and mind there is a strange exhilaration and excitement, for many kinds of pictures come before me. Many dreams we have dreamt, are today coming near and being materialized. There is perhaps some excitement in your heart, and some exhilaration. What are these?

The picture must have come to the minds of many who stood there (an enthusiastic correspondent reported 150,000 people) of the partition of Punjab which had been one heavy cost of independence. For some, there was a seven-year-old memory of exile, and an irrepressible image of the massacre of relatives and friends. For all, partition had brought the old threat of famine close. The line drawn between East and West Punjab in 1947 took no account of the world's most intricate network of canals. Twelve canals went to Pakistan, three to India, one was cut in two by the border. When the exodus of Muslims from East Punjab and Hindus and Sikhs from West Punjab had run its tragic course, half a million families of the latter groups found themselves transplanted in India—on the edges of a desert.

Bhakra-Nangal had been thought about in various forms for 40 years. Nangal Dam itself and the hydro-electric plants on its canals were taken up in a small way in 1946. But the great scheme for storing the Sutlej to irrigate four million acres and light up north-west India was too bold, too difficult, for those days. Bhakra reservoir would have inundated land of the little mountain state, Bilaspur. Bhakra canals would have cut across other arid, but proud, principalities. By 1948, the new Republic could see the job whole. A country suddenly challenged to replace a major source of its food supply took a new look at the engineering problems that had seemed insuperable, and began solving them.

> And so with the wound, the worries and the calamities came this new enthusiasm, new strength to take up this big work, and we took it up.

THE BIG UNIVERSITY

Then again I considered that it was a big university where we can work and while working learn, so that we may do bigger things.

Up and down the Sutlej, and its new artificial course, one could indeed identify the whole curriculum of engineering.[2]

Nangal, the finished diversion weir across the Sutlej, had lessons to teach the most advanced designers in any country of the world. It was the latest refinement of the technique demonstrated by Sir Arthur Cotton who got his lesson from the medieval Tanjore kings—the technique of founding low dams on sand alone. At Nangal, Punjab engineers no longer wasted stone or concrete anchoring their weir against unknown hydraulic forces. Men like A. N. Khosla and Kanwar Sain had identified and calculated those forces, learning from India's repeated successes in bulding structures like this, and writing texts for the engineers of other countries.

The refinement of design is evident in one part of Nangal Dam, even to the non-engineer. The Sutlej, fresh from the mountains, carries past Nangal not only water, but mud, sand, gravel, and 'shingle'—those boulders the size of a man's head which make a mountain torrent so beautiful to the layman, and so troublesome to the engineer. When he built the Ganges Canal, Captain Cautley never dreamed that a fixed dam could withstand such an onslaught of stone, so he arranged for his temporary weir to be replaced every year.

The Punjab engineers not only made Nangal Dam boulder-proof, they also installed in it an apparatus to separate the boulders, sand and gravel from the Sutlej water diverted into the irrigation canal. This 'shingle excluder', which embodies the lessons of many earlier Punjab canal headworks, takes advantage of a simple fact of nature—stone has twice the weight of an equal volume of water. At the left end of Nangal Dam, six subway passages permit the heavy stone rolling along the river-bed to pass harmlessly beneath the dam. The relatively lighter water, at that point, negotiates a sharp left turn and flows over the sill of Nangal canal, cleaned of its debris.

In other ways, too, Nangal canal made engineering history. It crosses 55 mountain torrents, as obstreperous as the four Captain Cautley negotiated. It has a concrete lining 92 feet wide, plus 28 feet up each sloping bank, throughout its 40 miles of length. On the way, it drops its water through two large powerhouses, already sending their electricity as far as Delhi. No stone was available for the powerhouse foundations; they 'float' safely on concrete rafts far underground in the wet gravel.

> A great work has been done. At least, one stage has been reached which has given us strength for other stages. . . . We may celebrate the completion of this work, but remember, that the most difficult work still remains to be done—the construction of the [Bhakra] Dam. . . The work bristles with difficulties and complications.

A university is a place not only for teaching but learning. The highest dam India had yet built was Mettur in the South, 214 feet. Bhakra will be 680 feet high.

Is it the biggest job of construction going on in the world today? Bigness, even in dams, has its various dimensions. Across the Volga at Kuibishev and at Stalingrad, Russia is building dams with more material in them; they will store more water. Across the Missouri, America is building two more very large dams. But though these dams are long, they are not high. And since they are made principally of earth, they make less complex demands of design and planning than Bhakra's concrete.

One dam that compares with Bhakra as an engineering problem is Hoover Dam, across the Colorado River in America, 726 feet high. But Indian engineers faced two difficulties unknown even at Hoover. Bhakra has to rest on rock seamed with clay. And it must withstand the pressure of a lake 680 feet deep by sheer weight alone. For various reasons, including possible earthquakes, it cannot be arched against the sides of the gorge like Hoover.

'When you double the height of a dam,' an engineer once remarked to me, 'you don't double the engineering difficulties. You multiply them by about ten.' It is possible, at Bhakra, to see why this is so.[3]

There is the problem of carrying the river safely past while foundations are being laid. Ordinarily there is room in the river-bed for the engineers to share it with the river; not so in Bhakra's narrow defile. Before they could begin on the dam, therefore, the engineers had to drive tunnels through the rock on both sides of the gorge, tunnels fifty feet in diameter and half a mile long. Prime Minister Nehru saw the water pouring through one of them before he went down to Nangal for the dedication.

There is the problem of piling up five million cubic yards of concrete (three Hirakuds, or four Tungabhadras) on to a foundation no longer than Tilaiya's, or Maithon's. Concrete has to be manufactured and put in place faster than India has ever done it; ten tons per minute through two eight-hour shifts. Even so, it will take three years. That schedule requires, among other things, two travelling cranes to deliver the buckets of concrete where they are needed. The cranes will be of a type and size never seen before in Asia. They will be of 'T' shape, with each arm reaching out 175 feet from the central track and capable of snatching an empty concrete bucket 200 feet up out of the foundation in 20 seconds.

But that is not all. When concrete is piled up that quickly in so huge a mass, the chemical reaction of the setting cement builds up heat faster than it can escape. The interior of the concrete would, the engineers calculated, get 40 degrees hotter than the temperature at which it was poured. When the cold depths of the lake rose against it, it would chill, shrink and crack. The remedy at Bhakra is to make the concrete, all five million yards of it, out of rock and water that have been artificially refrigerated to within eleven degrees of the freezing point. Chilling several million tons of rock right through the scorching heat of a Punjab summer is one of the novel tasks of the Bhakra engineers. In addition, they will have to embed in the concrete coils of pipe through which cold water can be pumped to carry off the further heat of cementation.

Up from the river-bed on both sides of the Sutlej, the rock rises so steeply that the engineers have used it for a blackboard; years ago they outlined the future shape of the dam with white lines on those steep walls. It is challenging to work beneath that picture of the goal, 680 feet up. But it is even more challenging to try to find, on the sheer rock of the gorge, room to marshal and process the huge quantities of material that will go into Bhakra Dam. Planners of Bhakra construction tackled the logistic problem this way. They drew up a ruthless set of priorities in which only the essential operations were to take place at or near the dam itself. The list is interesting. Concrete mixing and refrigeration, compression of air for the drills, distribution of acetylene and oxygen to the welders, assembly of the coils of cooling pipe, refuelling and quick repairing of Euclid dumpers, of lorries and drills, first-aid and drinking water for labourers, a tiny office for field direction —for these things level space has to be blasted out of or hung on to the sides of the canyon. Other facilities—warehouses and dumps for lumber, steel, fuel oil and grease, shops to assemble the large steel penstocks and other embedded parts, housing for the labourers, can be located on the gentler slopes below. Main stores, structural steel workshops and housing for engineers can find their places only on the first naturally level ground—at Nangal township, eight miles away.

The problem of planning Bhakra construction is essentially this. Before any of the millions of tons of ingredients arrive, and for the most part before they are ordered, someone must think how each item will be delivered, where it will be kept, how it will be put in place—all in time, and out of the way of other materials. Bhakra was a new type of engineering task for India. But it afforded neither time nor space for trial and error. India could have called in an experienced contracting firm from overseas. Some very wise engineers in Punjab and in Delhi thought that was the prudent course. But in the end, India took it, in the Prime Minister's words, as 'a big university where we can work and while working learn, so that we may do bigger things.'

Under S. D. Khungar, the seasoned and thoroughly competent general manager, were appointed the most able directors of design, construction, and inspection Punjab could find. Working alongside these men, India wanted someone who had built high concrete dams before. From the United States they got M. Harvey Slocum. He is among the three or four living men who know how to get muck out of a site like Bhakra's, and get steel and concrete in. But all his life he has been a construction boss, not a teacher. It was not as easy as it sounds, in any event, to learn while working, where someone must be responsible that mistakes are not made. Somehow, while tunnels were drilled, a railroad built, the gorge trimmed down, and the crucial plans for construction laid, the university functioned.

> Just before coming here I had gone to Bhakra where the Dam is being built and there I stood on the banks of Sutlej and saw the mountains to the right and left of it. Far away, at various spots, people were working . . . . From a distance they looked very small, and the mountain very mighty . . . . The thought came to me, that it is these men who have striven against the mountains and brought them under control.

Pandit Nehru had later on to dedicate a plaque to 60 men who had died drilling the tunnels. He may have had this in his mind when he said, 'Which place can be greater than this, Bhakra-Nangal where thousands and lakhs of men have worked, have shed their blood and sweat and laid down their lives as well?'

BUILDING THEIR OWN FUTURE

This work was a pledge that we feel we are building our own future in which we are partners in whatever capacity we work.

The Prime Minister could well have been speaking of the workers at Nangal and Bhakra and on the miles of main canals. They had done a good job, and it was gratifying that for six years they had worked without serious interruption. But there was a wider meaning, even more remarkable, in his statement.

A hundred and fifty miles away from Nangal, as the crow flies, the tail end of the canal system fans out into the western margin of Punjab, bordering on the Rajasthan desert. Those little tail channels—distributaries, the engineers called them—had been built not by P.W.D. employees, not by contractors and their men, but by the future irrigators themselves, organized village-by-village into labour co-operative societies. It was a new thing in India, an unorthodox thing for farmers anywhere, and it seemed to reach a long way into India's future.[4]

Punjab's labour co-operatives were, frankly, an experiment. 'Villages would rather work for the petty contractor, who loans them cash,' said some sceptics. 'Somebody will run off with the pay cheque,' others opined, 'and that will be the end of the co-operatives.' 'We would like to see them established,' pointed out some of the canal engineers, 'but we have to get the distributaries dug in time to open the system in 18 months. We don't have time for a social experiment.'

As the time grew short for completing the canals, three men in Punjab determined to give the co-operatives a trial. One was the minister of irrigation and power for the state, Choudhri Lahri Singh, who in September 1952 assembled all the top canal engineers to hear the proposal. Another was Pandit Ram Dhan, Punjab's grand old man of co-operative societies—one of those selfless civic workers who carry on the Gandhian tradition. The third was the superintending engineer in charge of canals in the western district of Hissar, Sardar Ajit Singh Kalha. He got up in response to Pandit Ram Dhan's plea and said, 'We will give the co-operative societies all the work they can do in Hissar, if you can get them organized.'

So the experiment was launched. The various government officials made sure that the likeliest villages received the idea, and that the engineers had work staked out ready for them to do. The representatives of the government co-operative department explained the plan to the peasants. So did Pandit Ram Dhan and several members of the legislature, invited by the minister. The message was simple. 'Enlist in a labour co-operative, elect your own officers. The government will pay your society exactly what it pays contractors for digging channels. But you can earn it all, instead of letting the contractor pocket two or four annas out of the rupee. And you will be digging your own canals.'

The response must have set some kind of high water mark for popular enthusiasm. In five months from December 1952, fifty-three societies began work. And in nine months, those societies, plus ten new ones, had moved over four million cubic yards (11 crores of cubic feet) of earth. That was twice as much as the D.V.C. machines moved (of course, under much more exacting conditions) in about the same time at Maithon Dam. To put it another way, in the year after they were launched, the co-operatives, with their labour strength of six to seven thousand, provided a fifth of all the manpower building Bhakra canals in Hissar district.

At the end of November that year, I asked Sardar Kalha to take me to see a few of the societies at work. We set off by jeep, and travelling on the level sand across country, came upon the cluster of mud-walled huts which is the village Daiyar. Not over 100 yards from the houses ran a channel labelled on the engineers' blueprints Dhabi Minor Distributary. It was no more than a double line of sandbanks, dwindling where the excavation was in progress to two rows of stakes on the sprouting fields of gram. But Sardar Kalha assured me that upon its seven-mile length would depend 12,000 acres of irrigated crops.

Seventy men and women worked in the ditch: the 57 members of the Daiyar labour co-operative plus some unenrolled relatives. When the society's neat account book was brought up from the village, I got the president to count the number of members of the Jat caste (there were 29) and the number of Harijans (18). The Harijans had their wives carrying head-baskets alongside them; the Jat women stayed indoors. There was no other distinction. High caste and outcaste members worked, voted, and drew their pay shoulder to shoulder.

Every member acknowledged in the proper square of the account book his receipt of each week's pay. There were 10 signatures and 47 thumb-prints. It was obvious that, though a young sub-inspector of co-operatives came every month to audit the books, the president and secretary held great power in dispensing money to their illiterate fellows. I was anxious to know whether the selection of officers had been really free or whether (as so often happens in any rural community) they were the wealthy or otherwise powerful farmers whose leadership nobody dared challenge. It was interesting that when the Daiyar co-operatives met at the beginning of the year to elect their officers, three candidates were put up for president. One withdrew. On a secret ballot, another was elected by 35 votes against 12. There was an element of genuine choice reflected by those figures, as well as wide interest in the outcome. (The people of Daiyar were tactful as well as democratic, and they proceeded to choose the unsuccessful presidential candidate secretary).

Had the co-operative way of building changed the men's conception of the huge irrigation scheme of which, in less than a year, they would become beneficiaries? No single visit could answer that question. 'Why should I not work for the co-operative,' one member answered me. 'Last year when I worked for a private contractor he paid me ten annas for a unit of earth. I get one rupee from the society.' But another digger made a comment that may be equally telling. When we remarked on the true slope he was giving the embankment, he pointed a long way ahead, along the rows of stakes. 'My fields are seven furlongs down. If the water leaks out here, my own ditch will go dry.'

There is one other chapter of the Hissar story that deserves telling. In 1953 the co-operative experiment succeeded; but the year before it seemed to have failed. Government organizers got the societies formed that year; the engineers gave them work. But instead of elected presidents and secretaries, they had 'group leaders' appointed for them by the local civil administrators. Instead of letting members save the contractor's profit, the government set out to save it, paying the co-operatives seventy-five per cent of the normal rate. Pay cheques were often delayed (the canal engineers were as usual shorthanded), but members could not wait for the week's pay when there was no contractor to give them an advance. The peasants lost heart. By May 1952, the co-operative work force was down to 500. It did no good, then, for the government to restore pay rates to the contractors' level.

Administrators had failed, late in 1952, when a politician took hold of the co-operative idea. Irrigation Minister Choudhri Lahri Singh, himself a Jat farmer, knew that if the villagers were to accept Bhakra as *their* project, the authorities themselves would have to treat it that way. One little change he made was characteristic. It caused as much reassurance among the diggers as it caused overtime work in the offices of sub-division engineers. He saw to it that every Tuesday, come what may, each society's cheque for the previous week's work would be waiting at the nearest engineer's office. The bigger changes were in the same spirit. The response to the labour co-operatives in 1953 was all the more cheering because a year before, any social reformer might have appraised western Hissar as an unpromising place to win the people's participation. Had not the villagers, though famine-stricken for three years in succession, just turned their backs on a scheme specially designed 'to help them help themselves?'

A NEW WAY OF LIFE

'When you tell a farmer to stop looking up to the sky to water his crops, and tell him to look down to the ditch,' a wise old principal of an agricultural college in one of America's semi-desert states once remarked, 'you are asking him to change his job as well as his philosophy.' It is quite true that irrigation upsets every habit of farming. The cultivator has to replace his crops with new ones; at the very least add a second crop of new varieties. Where shall he buy his seed? When shall he sow, how till, when reap? Where can he sell his new sugarcane, or cotton, or grain? He has got used to his soil dry. How will it behave wet? Will it pay to fertilize? If so, who will loan him money for fertilizer? Can he pay the water rates the government assesses? How shall he share the new costs and the new income with his landlord, or tenant? Will his fields get waterlogged? How much water does he need to put on to give the best crop? What if his neighbour, with whom he has not had to be friends before, takes more than his share from the common sluice?

India has been continually at the business of irrigated farming longer than any nation but Egypt; whereas Egypt has basically one irrigation source, one class of soils, one climate, India has learned to adjust to all of them, some time, somewhere. Taking the country as a whole, it would be roughly true to say, 'There is nothing new under the ditch.' Every one of the new irrigator's problems has been solved, either by the slow, shrewd accumulation of folk knowledge through the generations, or by the work of agricultural experimentation that has gone on in the various states. Here are some, from among many more, achievements from distant regions of India in answering the intricate questions irrigation poses.

Knowing the Soils. Before a single canal was located in Mysore's new Lakavalli irrigation project, soil scientists found out exactly which acres would take water best.[5] Moreover, they found out which fields were best suited to which crop rotations. That meant digging a test pit (one foot square and three feet deep) every 200 yards over the whole commanded area of a third of a million acres. It will be well worthwhile when it comes to repaying the cost of the project out of increased yields. It is now sure, for example, that sugarcane, the most profitable crop, can safely be grown on 62 per cent of the acreage, provided it is grown with paddy and lightly-irrigated crops like millet or gram in rotation.

Spreading the Protection. There is water enough for the present right bank canals at Tungabhadra to irrigate 250,000 acres. It would have been easy, and cheap, to reach that much land in a compact block not far below the dam. But all Rayalaseema needs protection against monsoon failures. In planning the project, therefore, the Madras government (since replaced on the right bank by Andhra and Mysore) scattered irrigation widely through 750,000 acres.[6] A team of one engineer, one agricultural expert, and one land revenue officer went systematically over the land under each canal outlet and selected the third of the total commanded acreage which would respond best to irrigation.

'You have given irrigation to the poorest *ryots* (cultivators) in the village,' I heard one hereditary village record-keeper exclaim to a member of the 'localization team'. To the villager, that in itself was revolutionary.

Having been localized, the irrigated third of the land was further divided into a smaller, well-drained sector that could stand very wet cultivation, like paddy, and a larger acreage of the heavy black soil which produces wonderful cotton, but has to be watered cautiously for fear of waterlogging. Where the two sectors met, the team located a sluice with two outlets. For 11 hours of the night, it would turn water on to the paddy land. During the 13 daylight hours, the same water would less heavily irrigate about three times as great an acreage of cotton, millet, or groundnuts. The canal system could run continuously full of water during the growing season, while the fields took turns. The localization teams did not, unfortunately, have the detailed maps of subsurface soil conditions which the planners of Lakavalli used. But they had another great advantage. Fifteen years before, Madras had set up an irrigation experiment station in the heart of the area to be irrigated by Tungabhadra.[7] By the time the land was chosen and the crop system fixed, therefore, the planners could be sure just how much water the sensitive black soil could stand year after year, and what crops would give the best returns with that much watering.

Every Field a Fertilizer Factory. Tanjore has been irrigated by the waters of the Cauvery at least for the thousand years since the Chola kings built the Grand Anicut. But with more and more control over the river, it has lately become possible to get water into the delta for a second and even a third crop each year. Going over the records of Tanjore's two modern agricultural experiment stations, the Madras director of agriculture, M. S. Sivaraman, discovered that the key to higher rice yields, with two or three crops on the same land, was to restore the fertility, especially the humus, taken from the soil by each harvest. Green manure seemed the only possible solution. But how was the hard-pressed

Tanjore *ryot* to get it? Even if he could get water to grow a green manure crop between paddy seasons, the unfenced village cattle would graze it off. Even if he could gather tree leaves, or make compost, how could he haul them through the mire of the paddy fields at ploughing time? While he was pondering the cultivator's genuine difficulties, Shri Sivaraman came upon two immigrant plants. Their Latin names are famous now throughout Tanjore—*Glyricidia* and *Sesbania*. The agricultural experts designate them as legumes, which means that while their leaves are growing green manure, their roots are harbouring bacteria which add nitrogen to the soil.

Their importance for Tanjore lies in their capacity for quick growth. There is only one bit of land the Tanjore *ryots* will spare from their paddy crop. That is the narrow raised *bunds* bordering their fields. *Glyricidia*, planted on the *bunds* when paddy is put in the fields, will have its branches up out of reach of the goats by the time of the paddy harvest. After that, all a farmer must do is strip off a season's growth of leaves—two tons from *Glyricidia* grown on the *bunds* in an acre of land—and plough them under. *Sesbania* grows even more green manure; it must be replanted each season.

Using green manure plants properly, the Tanjore *ryot* can grow a good second crop even without buying fertilizer. Within two years after the department of agriculture started popularizing the green manure trees, *Sesbania* lined the *bunds* of 100,000 acres in Tanjore. Shri Sivaraman's target for the next year (1954) now that the delta *ryots* had had a good look at the results, was 430,000 acres making their own green manure.

The World's Most Intricate Irrigation. Every problem which can assail an irrigation system has been met, and solved, in the 60-year history of Bombay's Nira Canals.[8] Here again we have heavy black soil, but far more vulnerable to water-logging than at Tungabhadra. The Deccan water supply is inherently short and uncertain. But a succession of engineers deeply interested in agriculture have helped the cultivators make this one of the highest-value crop areas in India. It began in 1902, when the 20-year old project was already partly ruined by waterlogging. The young executive engineer, M. Visvesvaraya, worked out a way—the 'block system'—to get sugarcane growers to rotate crops and rest the land.[9] The eminent Scots engineer who headed the all-India Irrigation Commission was so impressed by the practicality of the proposal that he had had it printed verbatim in the Commission's report. Twenty years later, C.C. Inglis, then head of one of the first irrigation research organizations in the world, began an effective programme to reclaim the fields under Nira Canals which had already been damaged by salt. Now the distribution of water is completely systematized to protect the soil, and at the same time to use just the amount stored in the reservoir. When the water supply from the monsoon has been calculated by the Bombay engineers, a programme is worked out for each irrigator showing just how many acres of each crop he can grow. Water is distributed in exactly the amount, and at the times, required for that crop.[10] It is an extremely intricate system gradually perfected by the engineers, the cultivators and the large sugar plantations.

There is no one best way to irrigate throughout the whole of India. Over the years, most of the provinces and states have shown that they possessed the technical knowledge to work out each of the adjustments necessary to fit an irrigation system to their own soils, markets, water supplies, and habits of cultivation. Cultivators who have mastered all the tricks of irrigation can be found among the Telegu-speaking people of the Krishna and Godavari deltas, the Sasvad Malis in Bombay, the colonists along the old Punjab canals.

Why then should the water from the new irrigation projects like Bengal's Mayurakshi, the Damodar, or the Tungabhadra, be going begging for two or three years already? Were these areas where irrigation methods were not known? I discovered this was not the difficulty. Canal irrigation has been practised near the Mayurakshi area, and within the D.V.C. irrigation area, for twenty years. Even second crop irrigation has been done on thousands of acres. Scattered through some parts of the Tungabhadra area are the object lessons of the old river channel irrigation systems and the state experiment station; a few villages have also the benefit of the practical experience of irrigators recently migrated from the Krishna delta. Moreover, the planners of the project, both on the Hyderabad and Andhra-Mysore sides have very comprehensive schemes worked out to develop irrigated agriculture. 'I must have written a hundred notes on how to get the canals into use,' one development commissioner told me. I read some of them —they were masterly. And in each of the villages I went to there was at least one cultivator who was already preparing his land for water.

Yet, though water was spilling over the dams, and even running in the main canals, it did not get into many of the fields. I was reminded of some of the newer irrigation projects in the great plains of America. The cost of these projects is very high per acre irrigated. Farmers can grow satisfactory crops with the natural rainfall in the area, most years, though they could grow better ones with irrigation. They know the government has already got the huge projects built, and feels great anxiety to have the water used. They are therefore waiting. Perhaps the government will lower the water rates. In India, too, it is a striking fact that the difficulties in getting water used have not come in those areas where the changes required by irrigation were the most drastic. In colonizing the early Punjab canals, whole villages had to be established on a barren desert. But the water was quickly put to good use. There the irrigators knew, as well as the government, that life depended on the canals.

Technical adjustments India could make, then, provided the psychological adjustments were accomplished. Each of the big new projects was expected to get lakhs of acres under irrigation in five or ten years. Their enormous storage reservoirs and long canals necessarily cost heavily — an average of 277 rupees per acre. The country expected lakhs of cultivators, who had never paid water rates or who had paid two to four rupees under old canals, quickly to assume a burden of the order of 10 rupees per acre, or for two crops, twenty-five, plus payments toward the capital cost. Who would pay for levelling fields, building new roads, manuring, buying new seeds and livestock — all expenses which the new cultivation required? The nation, which had invested of its development funds in irrigation projects, and postponed other works to give them priority, was naturally in a hurry. So were some cultivators, who knew the earning power of an irrigated farm. But most cultivators did not; understandably, they were content to wait.

The psychological gap could discredit the projects. For there was the possibility that should the government apply pressure to get the water used (by levying a compulsory water or capital tax, for instance) the cultivators might organize resistance. The transition to widespread irrigation which requires the joint effort of peasants and government agencies, would then be difficult indeed.

A farmer's change to irrigation requires him to change his vocation and his philosophy. But the change of a hundred villages to irrigation within a few years requires a social and economic revolution. India's engineering had certainly been revolutionized since Independence. But had her hundred-crore, million-acre projects come too big, and too fast, for her villages to accept? Or could her peasants move as fast as her planners and her dam-builders?

Bhakra, by three times the biggest irrigation project of them all, should be able to answer that question. Its success depended on five lakhs of cultivators, in villages like Daiyar. They would have to change their tillage in step with the progress of engineers who even now, could not be precisely sure when they would have water stored. And they would have to pay back their share of the cost of enormous structures a hundred miles away, which they would never see. Had Indian peasants enough imagination? Could they change at the pace of the bulldozer and the double cantilever crane? Were they, in short, ready for a rural revolution?

For Bhakra, at least, I am satisfied that I got the answer. The peasants of Punjab gave it when they assented to a special tax over and above the annual water rate, toward the extra cost of building the Bhakra Dam and canal system. They supported the enactment of a 'betterment levy', by which Punjab can take up to half of the new value which their land acquires by virtue of being irrigated, or irrigated better. The betterment levy had been enacted in other states, first of all, like so many irrigation institutions, under the sponsorship of Sir M. Visvesvaraya, for the Krishnaraja Sagar canals. But when the Punjab legislature passed it, the peasants' eyes were open, and their voices heard.

When the Punjab irrigation minister introduced the bill, he knew it looked like a painful exaction. He called the leaders of the opposition to his room and talked frankly. 'You can fight this bill in the Assembly,' he said, 'and no doubt get a few negative votes. But it will cost you the support of the cultivators. If you don't believe me, go back to your constituencies and ask them.' He gave them time, while the bill waited in committee. And when they returned to the legislature, they passed the betterment levy without opposition.

How had peasants, yet to receive water from the project, grasped the need to tax themselves for it? By accident, I had a chance to see for myself. The irrigation minister took me along on one of his political campaign trips on which the fairness of this very tax was at issue.

We got out of his government automobile at the sun-baked town of Fatehbad, and mounted a 'desert jeep' flying the Congress Party flag. The vehicle was actually an antique sedan stripped of such non-essentials as mudguards and muffler and mounted on oversize wheels. We rode it not only the better to clear sand drifts, but because Indian political ethics do not allow the use of a minister's official vehicle in a party campaign.

A seat in the Punjab legislature was at stake in a bye-election. The Congress Party candidate, though he was a respected local farmer who had held local government office, was an almost unlettered man who said not a word on his own behalf. Winning uncommitted votes was evidently the task of the minister. Three times in one evening, beginning at five o'clock and ending at midnight, Choudhri Lahri Singh addressed crowds of voters. One of the speeches was unscheduled. The 'jeep' as it crept between the mud walls of a village not laid out for motor traffic was so completely stalled by rows of men, women, boys and girls pressing in upon it from doorways and rooftops that the minister had no choice but to stop and address the populace. His speech, delivered by the glare of a petromax lantern in the crossroads of that lonely place, sounded very little like a vote-getting talk.

It began with history. 'Every conqueror of our country has marched past your village,' he said, 'Timur and Babar and the British. Why did their armies win? Is it that the men of this place will not fight?' At this sally, the local party chief, who stood with the minister behind the lantern, visibly puffed out the bandolier which crossed his chest. 'You know there was another reason. You always fell to quarrelling before the battle was won. Some village, some leader, some caste, some state had to go its own way. And the outsiders conquered India.'

'Then one came who taught us to unite. Together, we followed his lead, and together we drove the British out.'

'Now we are engaged in a second fight together. We are out to conquer poverty. Again, we will fail if each man, each village, each caste, the rich and the poor, go their own way. Again, we will win, if under the lead of Jawaharlal, you will carry on the fight as one.'

He shifted to the local facts of life. 'From where do you get the water which you drink, and your animals drink?' I learned later from the young *Sarpanch*, or village leader, that since their own tank was brackish they fetched it three miles from another village. 'You have a good harvest in your houses this year, and your *rabi* fields have sprouted. What will you do if the rains fail in the next monsoon, as they did during the last three years? You will be afraid no longer. From the next monsoon, the water will be flowing in your fields, and flowing in your village, from the canal. You have seen the channels dug, you have dug some of them yourselves, and so are they being dug from the River Sutlej. You have not seen the main canal, or the high dam which is being built, which will fill the canals in the *rabi* season. They are not finished. They will cost more than a hundred crores of rupees. From where will the money come? It can come from but one source—the cotton, maize, wheat and sugar-cane you will harvest from your irrigated fields. That is why the legislature has passed the betterment levy, and that is why you are willing to pay it. For unless these canals pay, there can be no dam, no new canals. Famine will return to Punjab.'

Finally came words that sounded like campaign talk. 'What do the other candidates say about the Bhakra project, and the tax that will pay for it? Do they oppose both? Do they praise the one and attack the other? Then you know they really would put an end to both. Or do they say they are for the irrigation and the tax? If so, will you vote for the party that had the courage to do these things, or the party that lacks the courage either to do them or oppose them?

The crowd gave no sign of its reaction. Once there was a great stir at the edges, where people were packed far into one of the alleys. It turned out to be only a string of camels making their awkward way through the campaign meeting. Out in the starlit desert, where the cart track we were following back to Fatehbad forked around a sand dune, I got a hint of the affection in which the people held Choudhri Lahri Singh, this man of their own who was now directing the best work that had ever reached them. A band of small boys had run four miles from the last village to meet the 'desert jeep' at that turning, and point the minister on his homeward way.

Punjab has some peculiar advantages in getting its irrigation into use. Among the refugees from Pakistan to the Bhakra area are some whose fathers were drawn from that same area to the canal colonies of Lyallpur and Montgomery. In the meantime they had become expert irrigators. Rainfall in Hissar district averages 13 inches, which makes irrigation a more obvious necessity, than even at Tungabhadra, with its 19 inches. Even so, there will be lags in some of the changes irrigation requires—in developing the 30 planned *mandis*, or markets, for instance, and in improving roads. But the crucial fact remains that the people will be working *with* the government in creating the new era. The psychological barrier is down.

It is as though the ancient communities through which Indian peasants built and maintained their tanks and small river channels had been expanded to encompass the biggest irrigation system in the world. And the physical bounty and reliability of modern engineering had been joined to the human solidarity of the old village republics. If so, it will be a brand new achievement in this world, an achievement of engineers, of peasants, and of politicians who gave them both the means, and the challenge, to work together.

We of our generation—many of us present here [Jawaharlal Nehru said at Nangal] belong to that generation which fought for the freedom of India.... We are children of that revolution of India.... A revolution does not mean the breaking of heads. A revolution means changing things in a big way... and that revolution is not over. We finished it in a way in the political sphere. We have to continue it in the social and economic sphere...

See what millions of our people are doing, whether they are working in the factories or in the fields or in these various constructive schemes and projects and community schemes and all that, because millions and millions are working there... this great country is in commotion.

There was a great roar of 'Bharat Mata Zindabad'; then 'Nehru Zindabad', when the huge crowd on the right bank of the Sutlej saw the distant gates go up, and the water shoot foaming into the canal. Precisely at that moment, the peasants on the left bank of the river, who saw the wall of water coming down Nangal canal toward them set off hundreds of home-made bombs. For 150 miles the boisterous celebration spread like a chain reaction along the great canal and the branches and distributaries to the edges of the Rajasthan Desert, long before the water got there.

13

EXPLORING THE ELECTRICAL AGE

WHEELS OF THE FUTURE

[One] began to feel the forty-foot dynamo as a moral force, much as the early Christians felt the Cross. The planet itself seemed less impressive, in its old-fashioned, deliberate, annual or daily revolution, than this huge wheel, revolving within arm's-length at some vertiginous speed, and barely murmuring—scarcely humming an audible warning to stand a hair's-breadth further for respect of power—while it would not wake the baby lying close against its frame. In the end, one began to pray to it; inherited instinct taught the natural expression of man before silent and infinite force.[1]

THUS reacted Henry Adams, an American gifted with a sense of history, to the steam-electric generating machine at the great Paris Exposition in the year 1900. Half a century later, the visitor to India's Bokaro thermal power station, though habituated perhaps to the marvels of a machine age, stands no less awestruck. For the three immaculate machines before him, encased in their green enamelled cylinders, produce a controlled energy beyond even Henry Adams' prophecies. One of them, humming at three thousand revolutions per minute, could supply Delhi's whole need for light and power. Another could drive all the trains connecting Poona and Bombay, or Burdwan and Calcutta—this last job, in fact, it will take on as soon as the East Indian Railway is electrified. Teamed together, the three turbo-generators could light eight lamps in every village in India—provided, of course, the greater miracle of interconnection were accomplished.

To the physicist, even Bokaro's conquest of the energy of burning coal is far from complete. Of all the theoretical power locked in a ton of coal, the newest, biggest, and most efficient thermal power station in the world captures only 38 per cent; Bokaro uses 36 per cent. But compared to the technology of Henry Adams' dynamo in 1900, or the steam locomotives still pulling trains today, which harness five per cent of the coal's heat, Bokaro stands for a new pitch of efficiency in the adaptation of nature to man's needs. Considered in another light, it stands for the chance open to a newcomer to the Industrial Revolution to by-pass some of the crudities of earlier industrial systems. The standard, for instance, by which the British Electricity Authority distinguishes its economical generating plants is only 26 per cent of theoretical thermal efficiency.

Bokaro, whose design was an application of higher mathematics to a half-century of electrical experience, and whose assembly required the skill of watchmakers operating on a twenty-ton scale, stands for an even more basic efficiency. Paradoxically, it was deliberately planned to burn the worst coal used by any major thermal power station in the country, coal with too little volatile matter to light up easily, and with a most undesirable proportion of inert stone. Every ton, in fact, produces 520 pounds of ashes. Those very liabilities commended the coal to the planners of the Damodar Valley electrical scheme. For India has a vast surplus of high-ash coal like that. But of the very highest grade of coal suitable for making coke, and producing iron and steel, her resources are seriously limited. Supposing all India's high-grade coking coal were burned only in the blast furnaces and steel mills, at the rate contemplated at the end of the Five-Year Plan, the supply would last only 360 years.[2] Hence the concern of the government to discover that in 1950 most of this vital coking coal that was mined in India was being used up in locomotives, electric plants, and even in the boilers operating the collieries themselves. For all these uses, the abundant high-ash coal would do. Yet, from a shortsighted business viewpoint, its use would be inefficient. For locomotives and city electric stations this was true because to burn poor coal they would have to haul 500 pounds of inert matter in every ton of coal. As for the great collieries of Jharia and Raniganj, which produce half the nation's coal, how could they afford to haul in less desirable fuel for their lifts and pumps when they were mining the best coal in India?

India faced a dilemma in which the economic interests of present coal users seemed to be pitted against the long-range interests of the nation to conserve her metallurgical coal supply. The dilemma was focussed in the Damodar Valley, where both the high-grade coal, and the largest coal users, were concentrated. The basic efficiency of the Damodar Valley electrical system lies in its resolution of that dilemma. The resolution was accomplished this way: poor coal is burned at the pithead, thus avoiding freight costs, and sent where it is needed —throughout the triangle Calcutta-Patna-Jamshedpur—in the form of high-voltage electricity. Transmission costs (less to begin with than hauling coal) are recouped by the higher plant efficiencies of a very large central power station. At the ends of the D.V.C. power lines, mines, mills and city electric utilities can thus buy electricity cheaper than they can generate it themselves from high-grade coal. The drain on the nation's resources for becoming a great industrial power will come to an end—painlessly.[3]

The conception of that high strategy was the work of men in the Central Technical Power Board ten years before Bokaro began production. But their plan could not have materialized without calling upon the most advanced designs, materials and techniques available to modern industry. India, therefore, got the equipment for the Bokaro plant principally from the General Electric Company, and retained an American contracting firm to take responsibility for its erection. So far is this arrangement from being unusual that in the United States itself factory erectors customarily install the equipment of such a plant; anyone who studies the intricacies of Bokaro's workings will see why.[4]

The planners had first to find a plentiful supply of high-ash coal, easy to mine, close to a river with enough cold water to cool the spent steam. They found the mine—the enormous fifty-foot Bermo seam—but it lies five miles from the Konar River. Over that distance, therefore, the coal is moved in the cheapest possible way, by an overhead cableway, to the Bokaro plant. Mining is done by power shovels, not picks. These economies are important to a plant that, running at full throttle, burns a ton of coal every 40 seconds.

Behind each of Bokaro's three generators stand two great boilers. Each is a steel tower six stories tall, enclosing a bundle of steel tubes. With the boiler burning, the tubes are enveloped in a flame of 2100 degrees Fahrenheit, a flame fed by superheated air and coal ground to flour. Water entering the tubes bursts instantly into steam; the steam is further heated as it courses through superheater tubes atop the boiler. It leaves the boilers for the turbines at 910° temperature, and the incredible pressure of 895 pounds per square inch. Steam approaching that heat and pressure had never been harnessed in India—even the Calcutta Electric Supply Corporation's post-War plant generated only 630 pounds of steam pressure.

There is efficiency in this enormous heat and pressure. There is also a terribly destructive power. Steel had to be hardened with chrome, molybdenum and titanium alloys to resist the corrosion of that steam in Bokaro's superheater pipes. Even so, the maze of piping is not foolproof. Once during the trial run of Bokaro's first turbine, for instance, a tiny leak developed in a joint of the main steam line. The superheated steam sliced through the steel of the joint like a welder's torch, and the boiler had quickly to be shut down. Engineers traced the trouble to an almost invisible flaw in the steel ring that sealed the joint; it had rusted before it was installed.

Henry Adams would have found his dynamo crude and clumsy beside a modern steam turbine. The steam jets are caught on blades no bigger than a table knife, each of high-alloy steel beautifully fitted into its place in the ring. Twenty-one times the Bokaro steam passes from one ring of spinning blades to the next. It is a smooth, swift progression, wholly free of reciprocating motion. That is why the fifty-foot shaft of the turbo-generator, spinning at the same speed as a small automobile engine, shows none of its vibration. D.V.C. engineers had no sleeping baby to demonstrate the point; they did set a tumbler of water on the main bearing.

Spent steam is, in a locomotive, wasted from the cylinders. Here it is kept enclosed and cooled again to water. Using the same water over and over saves purifying anew the enormous quantities of water required by the boilers; the vacuum caused by chilling the steam also helps drive the turbines. But the cooling or condensing operation takes an unbelievable quantity of cold river water. It takes, in fact, 165,000 gallons per minute —something like the municipal supply of Bombay or Calcutta. That is why Bokaro depends on D.V.C.'s comprehensive river plan by which Konar Dam, a bit higher up on the same river, was completed in the same year—1953-54. Even in drought seasons Konar's deep lake is ample to pass down to the Bokaro plant enough water to keep the great condensers cool.

The electric generators which ride the other end of each Bokaro turbine shaft are like the generators at India's water power plants, only turning much faster. There is one other important difference, something entirely novel in India. The sealed atmosphere in which these generators whirl is not air, but pure hydrogen. For a reason it would take a chemist to comprehend, hydrogen greatly reduces the loss of electrical current among the coils in the generator. There is a remarkable sequel. By increasing the pressure of the hydrogen, and thus its electrical insulating effect, each generator can be made to turn out more than its rated capacity of 50,000 kilowatts of electricity. It can, in fact, be stepped up to 57,000. This will be an enormous advantage to meet brief peak loads, when, on a dark and chilly winter evening, everybody turns on his lights while the electric trains and trams are still struggling with the evening rush. But like high-pressure steam, hydrogen cooling achieves its efficiency only by creating a potentially explosive hazard—a hazard kept in check only by seasoned designers and D.V.C.'s carefully trained crews.

Overlooking the generator floor is an air-conditioned room, brilliantly lighted, and cased in glass. Down its rear wall is a panel topped by meters which record, both on dials and on permanent charts, the amount of current sent out along the D.V.C. grid. The grid itself is diagrammed on the panels. Each line of the diagram is punctuated by a control handle, no bigger than the one that opens the door of an automobile, but capable of sending, or interrupting, 132,000 volts through the inch-thick aluminium cables that run east and south from Bokaro.

Bokaro-Sindri-Maithon is the initial trunk transmission line. The great government fertilizer plant at Sindri has a sizable surplus electrical generating capacity, 22,000 kilowatts, to contribute to the grid. Available even before Bokaro, that capacity served D.V.C.'s first customers. When the first hydro-electric generators at Maithon Dam start work, that transmission line will begin delivering the benefits of an integrated generating system, combining thermal and hydraulic energy. During the 15 monsoon weeks when the river is full, Maithon's 40,000 kilowatt generators will work steadily, harnessing water that would otherwise spill. Bokaro will not be idle; its job will be to meet the peak demands for power a few hours each day. During the remaining dry weeks of the year, Bokaro will be the work horse, with Maithon storing up its limited water supply to serve peak loads. Neither plant alone could be as reliable or economical as the two together. Nothing like the full hydro-electric capacity of a flashy, monsoon river could in fact have been made marketable except by supplementing it with thermal generation. When the other hydro-electric generators at Panchet Hill and Konar are tied in, too, D.V.C. will have a well-balanced generating system—150,000 kilowatts of steam capacity (172,000 with Sindri) and 120,000 kilowatts of hydro.

So far, most of the customers at the ends of the transmission lines are companies who had been generating their own electricity. They could get it cheaper, and more steadily, from D.V.C. The big consumers are the government locomotive factory at Chittaranjan, the Raniganj, Luchipur and Jharia coalfields (to which existing utility companies distribute D.V.C power), the Kumardhubi Engineering Works and the Indian Iron and Steel Company at Kulti. The Tata Iron and Steel Company was to draw 20,000 kilowatts southward over another high-tension circuit. From Jamshedpur it would extend east to the copper mines at Ghatsila and the railroad centre of Kharagpur.

In 1954, only one of Bokaro's three turbo-generators was busy; the other two awaited customers. The end of the wait, however, was in sight. Instead of building its own new steam-electric plant in 1956, the Calcutta Electric Supply Corporation signed an agreement to get its additional electricity from D.V.C. The size of this demand, 45,000 kilowatts, is enough to occupy the initial Maithon hydro-electric plant, or almost all of one Bokaro generator. In 1957, moreover, the Railway Board planned to use 30,000 kilowatts of D.V.C. power to electrify the trains running into Calcutta's Howrah station from Burdwan. The contracts with these customers assured that Bokaro thermal power station would fulfil its purpose of replacing wasteful use of high-grade coal with economical combustion of surplus grades. Meanwhile, D.V.C. had proved it could deliver an abundant, steady supply of electricity to its switchyards at a cost of about two-thirds of an anna per unit. With those switchyards spotted through 25,000 square miles of country rich in minerals and well served with transportation, D.V.C. was confident that there would be other new customers, too.

BOOM IN THE JUNGLE

Sitting in his solitary office on top of a knoll at the outskirts of the town of Sambalpur, Commissioner Sivaraman of the northern division of Orissa was wrestling with a novel problem. His jurisdiction, which had comprised little more than a vast jungle dotted by paddy fields, and a few small towns connected by bus lines, was turning into one of the fastest-growing industrial areas in India.

Just as Hare Krushna Mahtab foresaw, Hirakud Dam started the transformation. The government needed cement to build the dam, half a million tons of it. Dalmia interests agreed to put up a cement plant at Rajgangpur, 100 miles away, if the Hirakud project would supply it with electricity. Until the dam was finished, that was done by steam and diesel sets. Meanwhile, Orissa has its first heavy industry.

Then came the Indian Aluminium Company, a subsidiary of the Aluminium Company of Canada. Since it takes 10 to 12 kilowatt-hours of electricity to smelt a pound of aluminium, the company was looking for low-cost power. They found plenty of it at Hirakud, and planned to take 25,000 kilowatts continuously to make 10,000 tons of metal per year. They decided to build their smelter at the damsite itself, where transmission lines would be shortest, and a colony with all its facilities would be left over from dam construction. There were years between 1947 and 1952 when the businessmen had their doubts whether Hirakud power would ever materialize. But in 1953 and 1954, they were becoming increasingly definite, during their visits to the site, about construction plans. They asked whether, five years from 1957 when they intended to start production, they could draw double the promised 25,000 kilowatts.

The Orient Paper Mill near Jharsuguda had used up much of the rapidly transportable supplies of bamboo. It sought new sources of pulp—tall Sawai grass or timber. Processing would require 3,000 kilowatts of power, and now that Hirakud assured it, the company was going ahead.

Like the Damodar Valley just to the north, Orissa is rich in minerals, but hers are almost untouched. There are small railway collieries east of Hirakud at Talcher. They will be electrified, and their operations brought to a higher efficiency, by the high-voltage transmission line to Cuttack. Near the northern boundary of the state, too, the Tata Iron and Steel Company has long mined iron and managanese ores to feed its Jamshedpur blast furnaces. Cheap Hirakud power opens up a very attractive opportunity here. India has a large export market, second only to Russia's, for crude manganese ore. If the ore could be smelted within the country into ferro-manganese, India would capture a far higher value from her minerals. That requires electric furnaces. Tata's plans just such furnaces in northern Orissa, using 15,000 kilowatts of Hirakud power at first, 30,000 in full production.

'There is scope for the development of a steel industry based on the presence of necessary raw materials in Orissa and the neighbouring areas,' runs the vague, though hopeful, agreement which Shri Mahtab exacted from the Government of India at the time Hirakud project was sanctioned. In 1954 his successors in the state government won for Orissa the Government of India's first steel mill in hot competition with West Bengal and Madhya Pradesh. Though the mill may not consume huge quantities of electricity when it is in operation, for it will have its own source of energy, there is no doubt that the availability of Hirakud power along the railway which connects coal, iron ore, and limestone was a necessary factor in the decision to locate the great plant at Rourkela.

While Commissioner Sivaraman struggled with the problems of converting jungle and paddy fields into mills—the question of land acquisition, public services and labour supply—the government officials in Cuttack were trying to plan ahead for the longer-range requirements of an industrial revolution. Dr. H. B. Mohanty, the professor of physics who has become secretary of Orissa's unique department of river valley development, prudently began in 1949 to arrange scholarships for some 80 students a year to get technical training in the colleges of neighbouring states. Orissa had no technical college of its own. In 1954, it appeared that the gap would be filled. Joint contributions from Tata's and the state government assured the opening of Hirakud Polytechnic Institute. The state was taking care that the boom in basic industries ushered in by the promise of Hirakud power, would also bring a boom in career opportunities for Orissa youth. Orissa's iron ore and manganese were going to begin contributing their full value to their native state. The same would now be true of her ablest young men.

THE POWER-HUNGRY STATE

Madras has, within her present borders, neither coal mines nor rivers of the first magnitude. The state made fuller use, earlier, of her limited hydro-electric resources than any state except neighbouring Mysore. But her farmers and industrialists have developed, even faster, an appreciation of the need for power. Madras has natural resources, and the technical organization to fill the need. The state is one of the few areas on earth where every other ingredient of economic acceleration is present, but lack of electric generating capacity alone genuinely holds back development.

It was the dynamism of Sir C. P. Ramaswamy Aiyar, combined with a geographic accident, that started Madras in the business of extending the benefits of electricity widely to her populace.[5] Her cheap power sources are not, like Bengal's coal, or Bombay's waterfalls, near her big city. When in 1932 Madras opened the Pykara hydro-electric plant, using a vertical drop of more than half a mile (3,080 feet) in a picturesque stream near Ootacamund, it had to find its own market, quite unconnected with the existing demand in the capital city. Tea estates and the lighting of small towns used some of the Pykara power. Most of it went to the industrialization of Coimbatore. That dynamic city of textile mills, growing in the midst of the cotton fields which supply its raw materials, was by 1950 using a good deal more electricity than Madras city, twice its size.

Mettur Dam, the same size and shape as T.V.A.'s renowned Norris Dam, though it was built five years earlier, created another sort of opportunity for electrification. Its tremendous storage of Cauvery River water, two million acre feet, was devoted first to supplying Tanjore's old and new canals. Water could not be spared for turbines in the hot months. Madras, therefore, attracted to the damsite basic chemical industries which could, in return for very cheap electricity, afford to close down several months a year.

By the end of the War, high-voltage lines tied together Mettur and Pykara with Papanasam, a high-head generating station in the far south. The same basic grid connected the heavy demands and steam plants at Madras in the north and Madurai in the south. Seven thousand miles of low-voltage lines took power out to the smaller towns. Madras had a vigorous rural development programme underway.[9] One of its features was the electrification of a model group of villages, fifty or more, in each district of the state. In the beginning, the government found it took a great deal of propaganda to get farmers and village industries to adopt electric power. High post-War prices for rice helped change that attitude, and the electricity department had more applications for connecting pumps and rice mills than it could grant. In some areas, electrification met another obstacle. The limited companies (with two notable exceptions) and municipal undertakings which served the towns showed no interest in rural electrification. Their generating costs from small diesel or steam sets were high, and their profits lay in the densely populated towns. In 1949, therefore, the state passed the Electricity Supply Undertakings (Acquisition) Act, by which it could buy these urban systems and integrate them in a transmission net having rural coverage as well.

By 1952, Madras had 2,100 villages electrified: all the rest of India put together had about half that many. Underlying the enthusiasm was a solid economic advantage in the use of electric pumps for irrigation. A large landowner, or *mirasdar*, 50 miles east of Tanjore explained it to me. He had driven a percolation well, of six inch diameter, into the delta's subsoil water. On top of it he mounted a simple rotary pump driven by a seven horsepower electric motor. The flow of 20,000 gallons per hour easily irrigated 12 acres. With a capital outlay of only Rs. 2,500, and with electricity from the Madras grid at one anna per kilowatt-hour, the *mirasdar* estimated the actual cost of delivering water at only Rs. 50 per crop acre. This is perhaps too low; even so, he had a nice profit. He sold the water to his tenants at 75 rupees per acre. 'But look at the tenants' side of it,' he pointed out. 'If it were not for my pump, they would be lifting water by bullock power at Rs. 115 per acre.'

In 1952, Madras had 20,000 irrigation pumps connected to her electric grid. But 40,000 more farmers were waiting for connections. It had taken the state 2,000 years, probably more, to accumulate its 33,000 small irrigation tanks. A pump-set waters only a tenth as much land, on the average as a tank. Even so, 20,000 pumps in 20 years was an achievement to set alongside the classical era of village tank building.

Then, in 1952, the Madras grid received a heavy blow. For four years in succession the monsoon had been short; power had been rationed to the mills seven months a year. But the 1952 drought was disastrous. The small rivers feeding Pykara and Papanasam dried up, and there was no storage above to draw down. Mettur's reduced storage had to be spent on irrigation; by February 1953 water was only 27 feet deep behind the 214 foot dam. During the winter and the hot months of 1952-53, the state had to cut its city customers to a half, and finally a third of their normal consumption. The loss in industrial production was 3·7 million pounds of yarn, 3,000 tons of cement a month.[7] Coimbatore became a great camp of unemployed textile workers. The cities were 'browned out'. Existing irrigation pumps were not rationed, but new installations had to be deferred.

Power rationing ended with the abundant monsoon of 1953. That year and the next, Madras added 70,000 kilowatts of new waterwheel generators to the hard-pressed grid. Most of it was at Pykara, and just below, where Pykara tail-water is dropped another 1,300 feet into waterwheels at the bottom of the Moyar Gorge. Further in the future were plans to build a new high-head project near Pykara at Kundha, and to develop power from the Periyar River in the south. In 1955, Travancore-Cochin agreed to the use of her water for the latter scheme. Each project would give 75,000 kilowatts initially. But in the five years it would take to complete these big schemes, Madras would again have run out of power. And her grid would still be at the mercy of the monsoon.

The permanent solution must certainly include balancing hydro-electricity with thermal power. Having taken over the large city utilities of Madras and Madurai, the state added to them 44,000 kilowatts of steam generating capacity. But the grid's supply remained three-fourths hydro. That is why Madras pins so much hope on the investigation of the South Arcot lignite desposits. They are ideally located between Madras city and the hydro stations to the south-west. The supply of soft, wet 'brown coal' there is abundant. If it proves economical to burn, Madras hopes to build a thermal power station as big as Bokaro. It is one way she can be sure she will not soon run short of electricity again.

PRIVATE ENTERPRISE IN WATERPOWER

The largest producer of hydro-electricity, public or private, in India in 1955 was the Tata Hydro-Electric System in

Bombay. In 1915, when only Mysore was seriously engaged in harnessing her rivers for electricity, the first of the Tata plants began work. It turned out 40,000 kilowatts of power, thrice the Mysore capacity.[8] Since then two new plants have been built, and all three expanded. The hydro system had a 1954 capacity of 236,000 kilowatts. The plants all use the fall of very small rivers down the Western Ghats: their waterwheels receive water under heads of 1660 to 1740 feet, heads not so high as Pykara, but still very advantageous. The streams are abundant during monsoon downpours, but storage dams have had to be added to supply water during dry months. The Tata policy of expanding capacity and reducing rates has helped make Bombay industries the largest in India. During the war, however, expansion stopped perforce, and as in Madras, a power shortage developed. The Tata system drew upon the continuous production of the 40,000 kilowatt coal-burning plant erected by the G.I.P. Railway for the electrification of its Bombay-Poona lines. Working hours of the great textile mills and other industries were staggered, the city 'browned out', and still power ran short in the dry years between 1948 and 1952.

In 1955, a further great addition to Tata capacity was commissioned. At the site of India's huge new oil refineries on Trombay Island in Bombay harbour, the first half of a 100,000 kilowatt thermal plant was completed. Its design is even more advanced than Bokaro's—steam is raised to a pressure of 1200 pounds per square inch.

But the dynamic Tata system has shown also the limitations of a privately financed system. There has been almost no extension of electricity in Bombay outside the industrial cities, Bombay and Ahmedabad. The state government consequently took a hand. It began extending a medium-voltage transmission network to the unelectrified towns, with the ultimate plan of linking the major generating plants in a high-voltage grid, and running lines to villages as well.

Here again, the D.V.C. pattern will be repeated. The strengths of hydro-electric and thermal capacity are being tied together. The great dark spaces of the state are slowly lighting up as the transmission network links them to cheap, central power sources.

TRIPLE-DUTY WATER

Captain Cautley's Ganges Canal, however modernized and extended, left a lot of the alluvial plain at the foot of the Himalayas unirrigated. Twenty-five years ago, Sir William Stampe, a remarkable chief engineer in U.P., launched his campaign 'to make the rest of the province green.' His technique, which is still as good as ever, was to drive tube-wells into the vast reservoir of water underlying U.P.'s sands, and to lift the water to the surface by electric pumps. A U.P. tubewell is an entirely different matter from one in Madras: it irrigates 250 to 500 acres. Where would the power for heavy-duty pumps come from? U. P. had no cheap fuel. While it had tremendous water power reserves in the Himalayas, tapping them meant dams and tunnels and power plants too expensive for those days: these were projects on the scale of Bhakra. But the western part of the state had a modest, widespread power resource which could be exploited step-by-step at small cost. It was the chain of artificial waterfalls averaging only 10 feet in height, built into the Ganges Canal to accommodate the difference in height between Hardwar and Allahabad. The U. P. government combined the 13 falls into 7, and in the decade 1928 to 1937 installed water-wheels at each one. The 19,900 kilowatts of generating capacity were connected via the Ganga Grid. An equal amount of steam generating capacity was added in the next ten years to carry generation through the months of canal closure and to meet increased demands.

The power cost more than Madras' high head hydro-electricity, more even than D.V.C.'s new capacity. There was no bulk demand from industry to pay for the cost of the main transmission lines. U. P. tackled both problems by a bold innovation. The state constructed and managed its own system of tubewells, collecting the cost of pumped water from the cultivators as in a canal system. The state could run its pumps at hours when other loads were light, and so use otherwise idle generator capacity. It had not to wait so long as Madras for farmers to develop enthusiasm for electric pumping. By 1936 there were 800 U. P. state tubewells; by 1946, 1800; by 1951, 2300. That was the first phase. In the next five years 1951–6, U. P. planned to double her state tubewell system, and in 1953 she was progressing on schedule with over 400 wells sunk in the year.

The demand for power sprang up in central and eastern U. P., beyond reach of the Ganga Grid. The state turned to a newer canal, Sarda, along which a 60-foot fall could be obtained. It was a tough construction job. Foundations had to be secured on sand, far below subsoil water level, just as on Punjab's Nangal plants. But in 1955 the first of three 13,800 kilowatt generators in the Sarda power house began energizing tubewells and towns between Bareilly and Naini Tal. Eventually the electricity would go to Moradabad and Lucknow.

Still further east, in the least developed part of the state, U. P. is building small steam power plants to drive the irrigation pumps and develop a demand for power in small towns. In 1954, work was at last started on the great hydroelectric project which, five or six years hence, will take over the supply of electricity to this area as well as adjoining Bihar, Vindhya Pradesh and Madhya Pradesh. It will help this area catch up with the economic advance of central and western U. P. This is Rihand Dam—a 250-foot high structure on a tributary of the Son. Its capacity, 240,000 kilowatts, will be a good deal greater then all U. P.'s present plants, hydro and steam, public and private.

Sir William Stampe's way of harnessing the Ganga was less dramatic than Captain Cautley's. But in the end its possibilities are at least as great. U. P., like other parts of the Gangetic plain, has beneath its rich sands a reservoir of irrigation water greater than man will ever build. Himalayan rains and snow perennially renew it. It is a source of water to all those fields too high or too remote for canals to reach; it is also a vast cistern collecting the seepage from canal-irrigated fields, and rendering it up to be used again. The modern steel tubewell has answered the problem of a permanent duct through the sand. Electricity meets the problem of energy. A U.P. farmer driving one bullock up and down his inclined ramp all day can raise 150 ten-gallon buckets of water—enough for half an acre. A 12 horsepower electric motor, drawing Rs. 7/8 worth of current a day, can water 300–500 acres. Under her state-owned tubewells alone, U.P. has more than a million irrigated acres. Private well irrigation, of course, reaches many additional acres, just as electrification serves many uses besides irrigation pumping. But the key to U. P.'s current rapid development is the triple use of the water. Two of the uses are very old: surface canals, and irrigation by lifting water from the unfathomed basin underlying the state. But the third is new and very promising: to drop the water from the Himalayan and Vindhyan heights, and in the canals themselves, over waterwheels, and to convey this energy to the pumps in tracts poorly served by rivers. The three-pathed Ganga has come fully into the service of man.

A SAMPLE OF THE FUTURE

India has boldly set out, in 15-20 years, to quadruple her electric power capacity. That will bring her average yearly use of electricity to 43 kilowatt-hours for every man, woman and child. What will it mean to living standards, to employment, to lightening the burdens of house and work? The best way, by far, to find out what changes that degree of electrification will bring is to examine a working model of the future. It is the model provided by the state of Mysore, which though blessed with sources of power no more fortunate than most other states, and serving a predominantly rural area along with its metropolis, distributed 66 kilowatt-hours of electricity, on the average, for each of its inhabitants in 1952.[9] Any citizen of India can thus have a look at the level of electrical development which, in his lifetime, his country as a whole seems likely to attain.

The first gain Mysore foreshadows is that many more people, and communities, are destined to get the benefits of electricity. Every twelfth Mysore family (130,000 families in all) is a customer of electricity. Of all the states' villages, big and small, 650 (one in twenty-five) have electricity. Another way of putting it is that Mysore has brought to villages of 1,000 people the same access to electric connection that people in towns of 5,000 people enjoy generally throughout India.

Mysore at once impresses the alert visitor as a different state on this account. The loud chirp of the oil engine, which advertises the local flour mill in North India, is replaced here by a silent electric motor. The state has 192 cinemas; whether for good or ill, the screen's lively picture of other times and places and standards of living is accessible to most country people as well as urbanites.

There are other differences that even careful observers cannot fully assess. One is a surprising boom in agriculture in some of the least productive districts of the state. Electric irrigation pumps, being installed at the rate of a thousand per year throughout the state, provide even some city youths with a frontier of opportunity on the farm.

In the forests at the edge of the Western Ghats, electricity has permitted the steady growth of a totally new industrial town—Bhadravathi. Mysore is rich in iron ore, but like most other parts of India, lacks coal. Two big new electric furnaces at Bhadravathi are smelting pig iron without benefit of coke. In the last 25 years, other power-using industries have clustered around the iron mills: steel, rolling mills, cement, paper, creosote and other wood by-products. Plentiful power permitted the operation of one of India's first fertilizer plants near Mysore City, and had helped draw three big industries to Bangalore: Hindusthan Aircraft, Indian Telephone Industries, and the National Machine Tool plant. Electrification itself has, in turn, created a market for other new businesses which Mysore has been alert to introduce. The Kirloskar factory makes irrigation pumps, as well as machine tools; the government porcelain factory produces insulators for transmission lines; the REMCO factory makes radios and insulated wire; transformers and electric meters are made, under Japanese patents, at the Government Electric Factory.

Even more interesting, and unexpected, is the effect of electricity on small town and village industries.[10] Chennapatna, 40 miles from Bangalore, is a town of 18,000 people where a dozen years ago, half of the families were engaged in weaving silk saris on handlooms. The weavers' work had not changed in many generations. About 1940, electricity reached the town, but for three years the weavers remained uninterested. Then they saw the economic results of weaving on power looms. In the next five years, 448 looms were installed, each powered by a motor of less than one horsepower. The work remained in the homes. Recently, at the request of a U. N. agency which wished to make the experience available to other Asian countries, the Mysore government enquired into the reasons for the popularity of electric motors among the Chennapatna weavers. The table on p. 245 shows the essence of what they found.

Here, in a nutshell, is the lesson of the relation between electricity and employment. It lightens labour; thus extends the productive power of men. Will the increased output (in this instance threefold) be disposed of? Or will some weavers

	Handloom	*Powerloom*
Cost of loom complete	Rs. 400	Rs. 6,000
Total expenses per year (including labour, maintenance, depreciation and interest, and power)	Rs. 850	Rs. 1,576
Number of saris produced in one year	125	400
Cost of producing one sari, exclusive of raw materials	Rs. 6/8	Rs. 3/9

go idle? The answer to that question, too, is foreshadowed very broadly by the example of Chennapatna. At lower prices, more people *want* to buy saris and with the higher wages of more productive work, they *can*.

With its people using electricity at five times the all-India rate, has Mysore saturated the market? Has the pace of electrification slowed? Exactly the opposite is true. Electrification goes on, and at a steadily increasing rate of acceleration. Mysore was a world pioneer in hydro-electricity with its 4,500 kilowatt plant in 1902. Since then every ten years marked a 50 to 100 per cent increase in generating capacity — down to the last decade. Then between 1942 and 1952 Mysore's power capacity almost *tripled* from 62,000 kilowatts to 179,000. The quickening pace is evident wherever one turns. In the first twenty years of rural electrification, Mysore connected an average of 23 villages per year; now the rate is 70. Seven hundred and fifty new houses or businesses got electric lights every month between 1947 and 1950; from 1950 to 1954 it has been 1,000 a month.

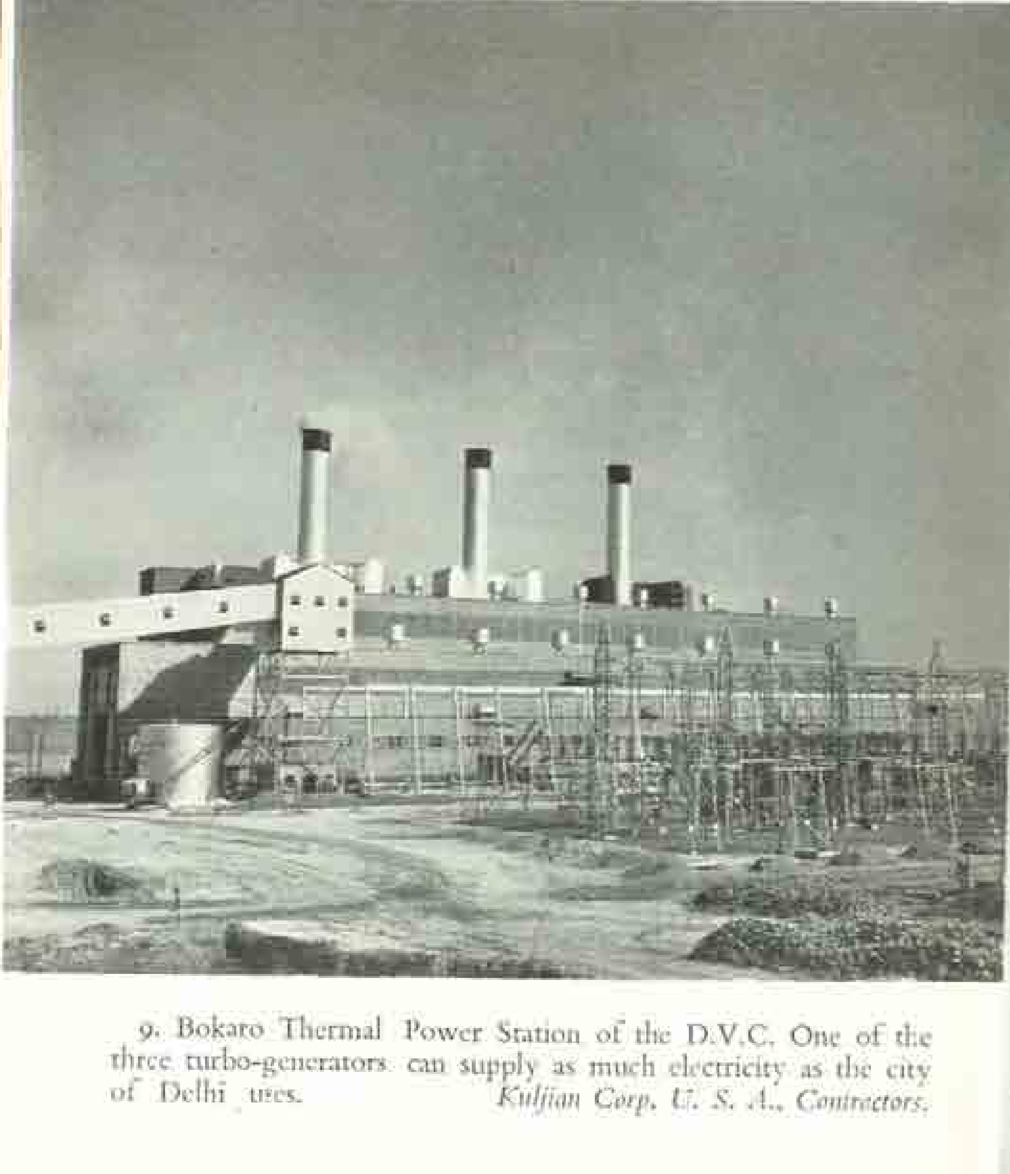
Mysore is not essentially different from the rest of India. Its electrification is just 20 years ahead. In 1932, its people were using only 15 units of current a year, the present India average. Since then Mysoreans have increased their demand to 66 kilowatt-hours. That is not much more than India proposes to do in the next 15 to 20 years. And we have very interesting evidence that India's future *rate* of electrification, too, may be like Mysore's present rate.[11] In ten years ending 1949, electricity consumption in 182 representative towns of Bombay, U. P., Madras and Punjab grew 12 to 23 per cent a year. In the same period, consumption in 27 Mysore towns and villages grew 21 to 32 per cent a year. Bigger towns always show a faster growth of demand, but in Mysore, villages of less than 1,000 people increased their use of electricity as rapidly as cities of 100,000 to 250,000 population elsewhere. Mysore's record shows that the ceiling is unlimited as to *per capita* use of electricity, and the horizons of extension into the countryside unlimited, too.

How had Mysore got ahead? Partly it was the sheer good fortune of a conscientious ruler and a wise prime minister—Maharani Vani Vilasa Sannidhana and Dewan K. Seshadri Iyer—who gave Mysore an early start in 1902, at a time when electricity was generally thought of as an experiment. Partly it was another providential blessing—waterfalls at Sivasamudram and Jog that could be cheaply harnessed. Most Indian states, however, are blessed either with coal or falling water.

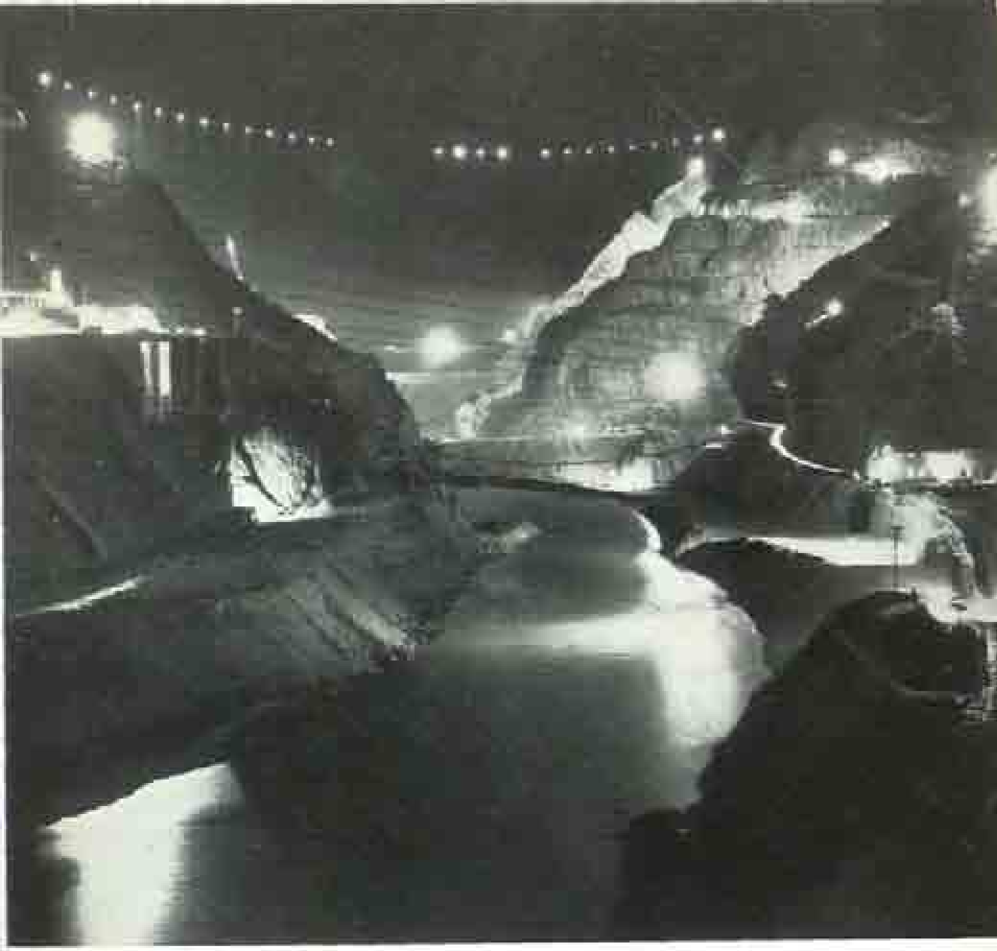
Mysore would never have got ahead, even so, without a steadily wise *policy*. It might be called the goal of abundant electricity for all. The idea was not adding generators to stave off a power shortage, it was deliberately promoting the use of electricity to stimulate production. The fact that Mysore's power came from water, so that after the initial installation each kilowatt-hour cost very little to produce, encouraged this idea of maximum use; hydro-electricity generally does. But beyond that, Mysore's government was willing to take well-calculated financial risks, trusting in the state's economic growth. Electric rates were kept low (they still average half an anna). Though the state was fortunate in having an initial income from electricity out of which to expand its plant, Dewan Sir Mirza Ismail took the crucial step of borrowing money to expand even faster than earnings allowed.[12] That saved Mysore from a power shortage during World War II. In its policy of abundance, finally, the state took advantage of the quick, certain, and high income from industries and big cities to help pay the cost of lighting up the villages. Sivasamudram would never have been possible without the sale of a large block of power to a private, profit-making gold mining company at Kolar. But Mysore made sure there was always additional power for the less profitable users in towns and small industries. The policy was not orthodox, financially. 'Rural electrification will bankrupt Mysore,' a finance minister once objected. 'You cannot tax all the people,' firmly replied Sir Mirza, 'to electrify the big cities.'

Mysore's other asset has been a succession of thoroughly competent electrical engineers. They have contributed to the electrification of all India. Shri N. N. Iyengar, now a consultant to Tata's, and formerly the chairman of the Central Electricity Commission, who bore most of the responsibility for planning D.V.C.'s power system, got his early experience in Mysore. The member for hydro-electricity of the Central Water and Power Commission in Delhi, Shri M. Hyath, was the long-time chief electrical engineer of Mysore. Why were Mysore's standards so high? Undoubtedly a number of reasons contributed: good engineering colleges coupled with a practice of sending young men to the great manufacturers of electrical equipment for practical training. But foremost was the opportunity Mysore offered for steadily doing newer, bigger jobs. There was a time, fifteen years ago, when almost every chief electrical engineer in India had some experience at the continuously growing Sivasamudram plant. Mysore's rural electrification engineers, too, broke new ground. They lowered the transmission lines three feet; this simple step to fit Indian conditions saved three per cent of distribution costs. They saved the whole cost of meters and meter reading by charging village families a flat eight annas per lamp. One of the finest rewards of an aggressively and imaginatively expanding service has been its attraction for the able and ambitious youth of the state.

Mysore does *not* demonstrate that electricity is an economic cure-all. Electricity plus accounting may, in Lenin's variously quoted phrase, equal communism. It does not suffice for the economic future India has determined upon. In spite of her vigorous electrification and the industrialization that accompanied it, Mysore's industrial employment continued in 1951, as in 1941, to absorb only 11 per cent of her population. To the extent that the population grew, therefore, overcrowding on the land worsened. Industrialization had to come still faster, or population growth be checked, if the state were to turn its back on poverty. That new challenge may be in all India's future, too.



9. Bokaro Thermal Power Station of the D.V.C. One of the three turbo-generators can supply as much electricity as the city of Delhi uses. *Kuljian Corp, U. S. A., Contractors.*

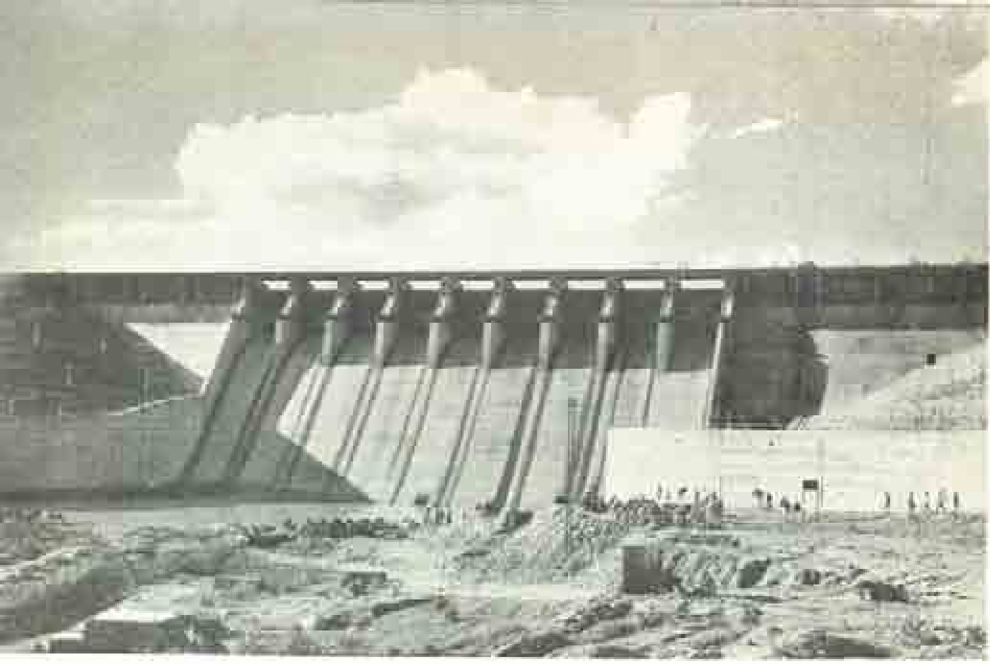


10 A. Day and night, Bhakra Dam rises in its Himalayan gorge, 680 feet high.

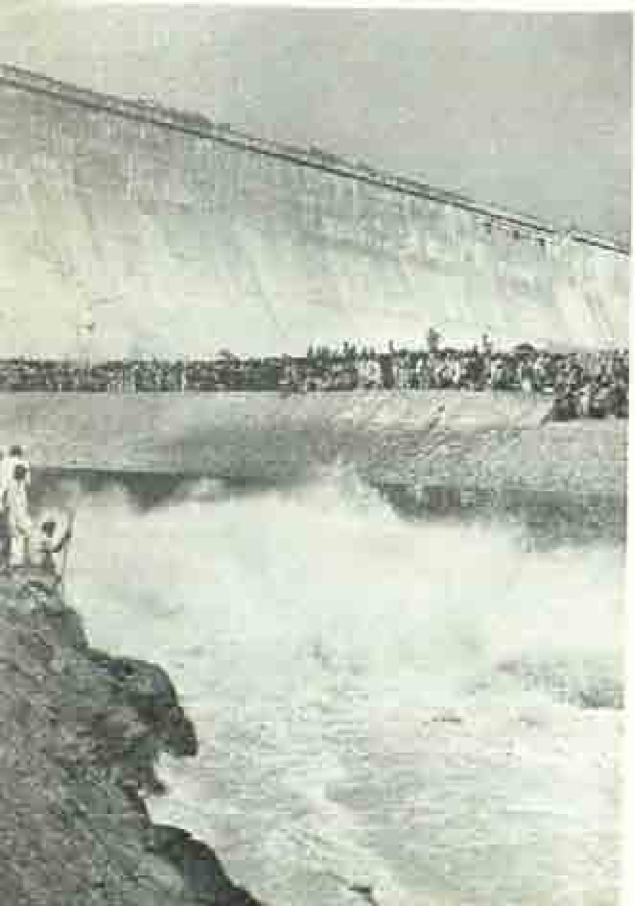
10 B. Throwing this switch, Prime Minister Nehru turns the water of the Sutlej into the new Bhakra-Nangal canals. *Press Information Bureau, India.*

11 A. Durgapur Barrage opened by the Vice-President, August 1955.

11 B. Orissa's plans should minimise the danger of floods such as this of August-September 1955. *Statesman, Calcutta.*



12 A. Konar Dam began to function in October 1955.



12 B. The pent-up waters of the River Mayurakshi roaring from the sluices after the opening of the Canada Dam at Massanjore. *Statesman, Calcutta.*

14

PERFORMANCE AND PLAN

BIG PROJECTS AND SMALL

THE PROJECTS of which we have seen the most in this book—Bhakra, the Damodar, Hirakud, Tungabhadra—are samples, only, of what India is doing with her rivers.[1] They are the giants. Each one will irrigate a million acres or more. Each will supply more power than any of India's pre-Independence plants. But other medium-sized projects, considered as a group, will do still more. North, east, south and west are new irrigation systems which will water two to five lakhs of acres apiece, and generate electricity as well: Sarda canal extension and the Sarda hydro-electric stations in U.P., Mayurakshi in West Bengal, Lakavalli in Mysore and Lower Bhavani in Madras, Kakrapar in Bombay, Kaddam (first element of the modern development of the Godavari) in Hyderabad. These are not plans or sanctions; they are already masonry and embankments. Some are finished. Besides these are the single-purpose irrigation projects built or being built since Independence: Harike Barrage in Punjab, U. P.'s series of irrigation dams in the Vindhyas (of which Rangawan is the sixth and largest to be completed), Rajolibunda anicut in Hyderabad, Malampuzha in Madras, Chalakudi and Peechi in Travancore-Cochin, Gangapur, Gataprabha and Mahi in Bombay. And there are the hydro-electric schemes, all finished or nearly so: Machkund on the border between Orissa and Andhra, Pykara, Moyar and Papanasam expansions in Madras, Sengulam in Travancore-Cochin, the powerful Jog station already supplying 120,00 kilowatts in Mysore, and the additions to the Tata system in Bombay.

Even these thirty dams, with all their connected canals and power plants and transmission lines, do not tell the story of New India's rivers. There are the small weirs, the large tanks, the flood irrigation channels, the extensions of old canal networks; the flood embankments; the navigation improvements; the new generators, transmission lines and switch-yards connected to existing hydro-electric installations. There is the interesting work of research upon the ways of rivers, and the testing of scale models of river projects, in India's twelve hydraulic research stations. Beyond the rivers, too, the work of irrigating and of generating power goes on. Tubewells and pumps lift water to the surface of the eastern deltas and the Gangetic plain; thermal stations bring power to the cities. The government has no prejudice for large projects or small, for comprehensive multiple-purpose schemes like D.V.C., or efficient single-purpose schemes like Jog or Machkund.

It is not for their quantity of work or benefits that Bhakra and the Damodar, Hirakud and Tungabhadra earn their place of prominence in this appraisal, as in the public eye. As we shall see, the whole programme of river development, including big and small schemes, is more noteworthy than these four giants, not only in its size, but also in its rate of growth. The big multiple-purpose projects stand out rather for their quality of newness. In terms of the country's economy, they assure a new kind of benefits — dependable through the worst monsoon, dynamic in the most backward region. In terms of the country's history, too, they stand for something India could not build, and did not will, before she became a nation.

PAST ACHIEVEMENTS

Let us recall, in large terms, what is old and what is new in India's use of her rivers. From Mohenjo-Daro to Akbar's sanction of the Jumna Canal stretched some four thousand years which we may call the *traditional era* of India's river projects. It is a great heritage. Though the desert kingdoms of Egypt irrigated more intensively, the Babylonians controlled the Tigris and Euphrates more systematically, though the Chinese dynasties built longer canals, India's wells, canals, reservoirs and embankments combined some features of each.[2] But the inscriptions of Girnar Rock above the forgotten Saurashtra reservoir, the Grand Anicut, and the old Jumna canals are monuments to a technical daring, and an administrative power which lacked the capacity to improve upon, or even to reproduce, themselves. Kingdoms and empires fell; the conception of great river works fell with them. In the episodes of disorder and darkness it was the thousands of plain little works — tanks, temporary diversion dams and channels — that survived. Without, firstly, continuous political order, and secondly, the scientific method, India at the end of four thousand years was able to do no more with her rivers than she had been at the start.

Then came the British Empire and the Royal Engineers. Beginning work a hundred and thirty years ago, they irrigated the great deltas and vast tracts of sand along the Ganga and the Indus, as far as the natural flows allowed. All India must have had, when they commenced work, between one and two million acres under permanent government canals. When they left, India had eighteen million acres. Tanks and wells had been inherited in a quantity unknown until the end of the 19th century. Between 1892, when complete records began to be kept, and 1947, the acreage irrigated from wells and tanks grew from 20 to 28 million.[3] All these figures are for the present territory of the Republic of India. It is a record of which the imperial power need not be ashamed, nor colonial India, either. The Royal Engineers, coming from a humid climate, received their first lessons in irrigation engineering out of India's traditional era. Scientific thinking, geared to an administrative system capable of mobilizing vast amounts of money and manpower for canal-building, enabled a few bright, bold tyros to outstrip the great emperors and craftsmen of India's past. But even in the colonial era the new profession of hydraulic engineering, the new pattern of administrative order, proved to be nobody's monopoly. It was an Indian engineer, employed by a 'native state', who built the first multiple-purpose reservoir — Krishnaraja Sagar.

Projecting an estimate of minor well and tank irrigation back to the 1820's, we can conclude that the 120 years of the colonial era at least tripled, and perhaps quadrupled the sum total of Indian irrigation. There were some kinds of irrigation, however, which were more planned and talked about than built in that period. Of the 18 million acres of government canal irrigation, 1·1 million acres were fed by storage reservoirs. The rest came from Himalayan streams, or lay mostly in great eastern deltas, where irrigation was relatively easy, but not always needed most desperately. All the government canal projects cut the toll of famines. But of the many projects planned primarily for famine protection, not earning capacity, less than a million acres were actually built. Incidentally, works outside 'British India', Nizam Sagar in Hyderabad and Krishnaraja Sagar in Mysore, accounted for one-third of the storage of water against poor monsoons, and for one-third of the famine-protective acreage.

Of hydro-electric capacity, the colonial period yielded half a million kilowatts. At the close of British rule, all the nation's rivers produced just a bit more electricity than the steam turbines of the Calcutta Electric Corporation alone. Half the hydro-electricity was in the Tata system, built by pioneering Indian capital to serve the ready market in another great metropolis. With one exception, the eleven sizable hydro-electric installations were of the inexpensive, simple design permitted where very high waterfalls provided a drop of hundreds of feet upon the waterwheels. The exception was Mettur Dam, in Madras. Along with Krishnaraja Sagar higher on the Cauvery River, Mettur showed the way toward large-scale storage, and the use of the stored water for irrigation as well as to create a head of water upon the turbines.

Financially, the river projects of the colonial era were successful. Taking all government canal systems built before 1940, Mr. R. A. Gopalaswami, in the *Census of India Report, 1951*, calculated a net surplus of revenue over operating and interest charges of more than Rs. 50 crores. The net revenue was, of course, far more handsome from the early than from the more recent projects: it was more than 11 per cent for projects built before 1891, 5 per cent for those built between 1891 and 1920, and a little over 3 per cent for those built between 1920 and 1940. These figures, coupled with what we know about the physical design of these projects, point to one conclusion: India's easy projects—river developments for which the demand was unquestioned, the ratio of cost to annual benefits low, and the engineering straightforward—were mostly built by the time of Independence.

As the colonial era came to its end, two more things were happening. The provinces, native states, and the Government of India alike took up the challenge to plan works on a generous scale for the post-War development of the country. Tungabhadra, D.V.C., Bhakra and many lesser projects were surveyed, and more or less completely designed during the years of the second World War. Present achievements would have been impossible without that pre-Independence preparation. But it is equally true that the last twenty years of the British Empire in India were years singularly sterile of actual building on a large scale. Of course, the lucrative projects had been finished, and years of economic depression were followed by years of war austerity. But even these reasons do not fully explain the loss of momentum which had been accumulating in river construction work through the early 1930's. As the future of the Empire in India fell into doubt, the government's zeal to embark on bold new works faltered. Indian political leaders themselves were preoccupied with the Independence struggle. The imperial government was no longer one to which they could urge their town or farm constituents to pay taxes or water rates to support new irrigation and power schemes.

THE NATION-BUILDING ERA

In each age there were the trail-blazers for the next. Just as the Chola kings taught Sir Arthur Cotton, so Sir M. Visvesvaraya and the British engineers taught and gave examples to the builders of the current projects. One can even trace to one or more of the older river works each of the distinguishing features of the *era of nation building* which began with Independence. But before their time, the new ideas could not dominate; they could not become the measure of public demand. What were the features which distinguish river development in the era which began with Independence?

1. *New Needs, New Benefits.* In practice, the standard test of the desirability of river developments in the colonial era was their ability to repay their cost, including interest and a fixed per cent of surplus revenue. It was in this exacting sense that they had, with the occasional exception of famine-protective works, to be 'productive'.

The perspective of the Republic broadened inevitably; river valleys came to be viewed as parts of—using the term literally—a *commonwealth*. Whatever damages rivers inflicted in flood or drought hurt the whole nation; while any service the rivers could render was of general benefit. On the procedural side, that means a new yardstick for the scrutiny of plans, a new definition of productivity. The aim is that all the true economic benefits be balanced against all the costs. Benefits of river improvement which reach beyond the ordinary means of reimbursement—water and power rates—are now repaid through taxes of more general coverage. The betterment levy is the prime example, though the income-tax, too, returns a share of any general benefits to the exchequer. The test of fiscal soundness is thus brought much nearer the facts of genuine economic worth.

The new definition of 'productivity' merely registers a deeper re-orientation, illustrated by the new importance of flood control. Only since Independence, in fact, has India planned major projects against floods. D.V.C., Hirakud and the new Kosi project share that purpose. Why was it not attended to before? Our review of the frustrating history of flood control plans for the Damodar and the Mahanadi yields the answer: because the Empire could not collect back the cost of flood protection. It was only in lives, crops and homes saved, in factory production and transport maintained uninterrupted, that flood control paid for itself. To the new government, those payments count; it has even conceived a way, through the betterment levy for flood-protected lands, to translate them partly into revenues.

In other ways, too, the conception of needs and benefits has expanded. Under-developed river valleys are considered for the potential demands for water and electricity which may be awakened in them. The 'nursery scheme' for electrification, and the 'village level worker' demonstrating irrigated farming typify the new era. Older projects aimed chiefly at satisfying demand; the new at promoting growth. Electrification of rural villages and industries is the pride of the new emphasis, just as electric service for great cities and industrial centres was of the old. However great the old regime's professions of interest in undeveloped provinces of India, it is only the nation-building era which has in fact begun developing their river resources regardless of their financial resources. The Republic appreciates its national stake in pushing forward the present river projects in Assam, Orissa, Madhya Bharat, Rajasthan, Andhra, and several Part C states. In the development of river resources, this nation-wide perspective of needs and resources has peculiar merit. For nature has not located all the fine hydro-electric sites or irrigable lands near the industrially advanced states which have the capital to exploit them.

The new projects, finally, are designed to be dependable even in the years when the rains and the rivers misbehave. That necessarily costs more than the old-style canals which, lacking adequate storage, ran dry when the monsoons failed, or the old-style embankments which, like those along the Damodar, were topped by the high floods. But a nation sensitive to the bitter human cost of extreme floods and droughts, and determined to develop the complex, interdependent economy which is most seriously disrupted by catastrophes can no longer afford to give hostages to the monsoon.

2. *New Engineering.* It is the multiple-purpose storage reservoir that has correctly come to symbolize the engineering of the era of nation building. Simpler engineering solutions still are, and should be, used for the majority of river problems; each river is distinctive in this respect. But it is storage for comprehensive use that is new. Bhakra, D.V.C., Hirakud and Tungabhadra all employ it; only Mettur and Krishnaraja Sagar did so before. The multiple-purpose reservoir is not much more than twenty-five years old anywhere in the world. But in India there are special reasons why it was not used much until recently, and why it is appropriate in so many cases today. Far more than most countries embarking on development programmes, India had already used up the simpler project sites. At the same time, she was confronted with rapidly expanding needs for water, electricity, and flood protection. It was a very happy coincidence by which the new engineering technique of multiple-purpose storage came to her rescue. For on her larger rivers and to meet her most intense needs, only controlled storage, made economic by the exploitation of its electrical as well as irrigation capabilities, offered a feasible solution. To India the larger reservoirs offer the great additional advantage of storing water through a weak monsoon, or harmlessly containing the most destructive of floods.

3. *New Management.* Bhakra Dam leaves any observer awe-stricken at the problems of design, and of construction generalship, presented by the very largest of the multiple-purpose reservoirs. The other current projects are less difficult. Yet to some degree they all demand the co-ordination of the labour of men and the assemblage of materials and equipment at a level of complexity new to India. The nation has a priceless asset in an established profession of river engineering; but never has the work of that profession changed so rapidly as it has since 1947. Not all the new demands are technical ones. Labour unrest, for example, poses a real threat to construction schedules today. In the old days, government could saddle on a host of petty contractors the responsibility, and the problems, arising from labour relations. Orderly, disciplined, but humane relations with thousands of workmen is now a vital part of building dams.

Good management is called for, too, off the construction site. Big reservoirs require the relocation of whole groups of villages. It is a high administrative challenge. Even higher is the challenge to keep two or three distant and quite unlike programmes advancing in step with one another; the construction of the engineering works, the agricultural development of the villages to receive irrigation, and the economic development of a market for large blocks of electricity.

In the large new projects, as we have seen, the same reservoir stores flood water and releases it later to the hydro-electric plant and to irrigation canals. In the enthusiasm for multiple-purpose schemes, few laymen have pondered the implications of this fact, though it presents important administrative and political decisions, as well as engineering ones. How is the common cost of the reservoir to be allocated among the flood control, irrigation and power programmes it serves? The answer, of course, affects the repayment obligation of each type of user. Moreover, which use of the common storage space is to have priority over alternative uses? After a serious drought there comes an understandable demand to keep the reservoir full in future monsoons, so that the canals do not go dry in the hot months. But the consequence may be that an uncommonly severe flood will overflow the reservoir, wreaking more havoc than the drought. Steadfastness of management is a special requirement of the multiple-purpose reservoirs, along with a clear-cut distinction of the hydraulic and economic facts from the political decisions which must be made about them.

4. *New Planning.* India's new river projects, like all else in her economy, show the results of over-all national planning. The river projects were themselves selected to contribute what the economy needs most. In the short run, that was food via irrigation; in the long run, power. We have seen, in the case of Hirakud, how other aspects of the project were deferred to bring the irrigation features to completion more quickly. The support given small irrigation schemes in the Five-Year Plan was calculated not only to distribute its benefits widely, but to yield the quickest increases in harvests.

The big multiple-purpose projects are creatures of national planning, too, in another sense. They made enormous demands upon the very resources of which India was running short: steel, cement, foreign exchange, spare parts for machinery, transport facilities, investment capital, top engineering talent. Immediately after Independence, there were not four but eight huge river projects beginning to compete for these already scarce items. The government, cutting the coat to fit the cloth, gave priority to the four that promised earliest yields of food production and electricity. It was an exceedingly difficult decision to withhold support from the other four schemes on which a great deal of planning had already been done by the states concerned—Rihand and the Jumna storage project in U.P., Koyna in Bombay, and Ramapadasagar then in Madras. Without such realistic planning, though, it is unlikely that any of the major river development projects could have been built rapidly enough to produce new crops or electricity by 1956.

That is only the negative aspect. To those projects which did receive priority in the Plan, support and supplies were made available which would have exceeded the engineers' fondest dreams in the colonial era. Obviously, that is true of budgetary allotments. But in addition, India's productive system was expanded at certain points to supply materials to the dam builders. Entire new cement mills were commissioned at Hirakud and at Bhakra, to supply concrete at the necessary rate.

Engineers, administrators and ministers who struggled to get work underway on each of the great projects we have examined rightfully insist that the Five-Year Plan, drafted only in 1951 and adopted in 1952, did not launch their projects. True enough. The Plan frankly incorporated major schemes already underway. The point is that those schemes could not have moved forward toward completion without the Plan's mobilization of resources. Beyond that, each of the major schemes owes its progress to the nation-building perspective. For, as we have seen, each reached across old state boundaries, each exceeded the financial capabilities of the individual states involved. National strength, national determination, overcame these stumbling blocks. If the projects are marshalling the nation's water resources to build India's economic future, it first took national planning to marshall the nation's economic resources to build the projects.

5. *New Scale, New Pace.* The clear, unmistakable manifestation of all these far-reaching changes is that India has, since 1947, developed her river resources on a scale, and at a pace, for which the old era offered no precedent. Consider these two comparisons of the old with the new. In the last half-century before Independence, new canals brought irrigation to 8·7 million acres; in the five years 1951–56, India's target was 8·5 million acres more. In 1897 a tiny plant at Darjeeling

produced India's first electricity. During the fifty years until Independence, an electrical capacity of 1·4 million kilowatts was installed; in the Five-Year Plan period, 1·1 million additional kilowatts of capacity were added.[4] Considering hydro-electricity specifically, the five years of the Plan should add 684,000 kilowatts to a capacity that was only 510,000 kilowatts in 1947. We come to an astounding conclusion: *India has set about building in five years as much irrigation and hydro-electric capacity as she acquired in the fifty years before Independence*. That is in terms of physical production. But the new projects must be far more elaborate, as we have seen, because the easier sites have been taken. Expressing the comparison in terms of uninflated costs (that is, allowing for the lower purchasing power of the rupee), *the Republic of India is investing more in irrigation and power in five years than was invested in British India as well as the States during the whole of the colonial era.*[5]

WILL THEY GET BUILT?

Time and again, in second-class compartments of Indian trains, my fellow passengers put substantially the same question to me. Learning that I had spent some time at the various construction sites, they invariably wanted to know: 'What about Hirakud and D.V.C. and Bhakra? What about the big Five-Year Plan schemes for irrigation and power? Will these projects get built?'

That persistent question prompted the writing of this book. I hope every chapter contains an element of the answer. But the simplest and least biased answer can be had now from the actual record of achievement upon the irrigation and power programmes established in the first Five-Year Plan. Any reader can make an up-to-date check for himself by consulting the latest progress report of the Planning Commission. In 1952, the Commission fixed not only final targets for 1956, but also targets for each year until then. These objectives have not been modified to allow for any of the untoward events, such as shortages of spare parts, which occurred since 1952; they constitute the acid test. Here is India's actual achievement compared to her original objectives for the five years of the Plan.[6]

	Target 1951–56	*Achievement* 1951–56
Acres irrigated by medium and large projects since 1951, in millions	8·5	7·0
Kilowatts of electrical capacity installed since 1951, in millions	1·1	1·1

In other words, 100 per cent of the power capacity scheduled to be built by 31 March 1956 has in fact been built, and 82 per cent of the irrigation. There is room here for improvement. To put it more realistically, there is a challenge here to solve all the problems we have discovered besetting the dam builders, so as to pull up to the mark. But to the more fundamental question, 'Will India get these projects built?' the answer is indisputable. She is doing it.

That is not the whole answer. Projects are not finished when the dams, canals, generators and even the transmission networks and distributary channels have been installed. Beyond the period of the Plan, and wholly outside the progress statistics reported above, lie most of the tasks of putting water and power to productive use. Secondly, it is the purpose of the Five-Year Plan not only to complete construction of the four great, and innumerable lesser, river works we have discussed, but also to begin work on new ones, including five of great size.

The initial Five-Year Plan is only one among many on India's road from hunger to abundance. We know little of the targets of the subsequent plans, but we do know what they will be, in general, for irrigation and power. On 13 October 1954, Shri Gulzarilal Nanda, Minister for Irrigation and Power, indicated to the ministers of state governments meeting in the Board of Co-ordination of River Valley Projects some long-range goals: 'Our aim is to make irrigation available for 40 per cent of the land and increase the available power from 1·7 million kilowatts to 8·7 through the projects in the first three Five-Year Plans.' These plans, in other words, are to double India's irrigation and multiply her electric power by five. Shri Nanda's cost forecast for the whole fifteen-year programme, Rs. 2000 crores, does not call for an annual rate of investment in irrigation and power construction very different from the rate attained in recent years, 1953-54 and 1954-55, roughly 150 crores per year. What of these further goals? Is India able to attain them?

THE TECHNICAL CHALLENGE

Up to this point, we have rigorously trained our attention on visible achievements. This is a book about earth and stone and steel, about water controlled and made serviceable, about the men who thus changed nature, and about the knowledge, character and habits of working together that gave them the ability to do it. But a book about New India's rivers would not be quite complete without examining what New India has by now set about doing in the future. What is necessary to remember is that the assessment of future capabilities in the next few paragraphs cannot be as certain as the assessment of accomplishments down to this point.

India's second round of big multiple-purpose river developments has been inaugurated in the first Plan with five projects: Chambal, Rihand, Koyna, Nandikonda and Kosi. As a whole, the five new giants correspond closely to the four now built or being built—in size, complexity, benefits, and costs. Considered individually and in detail, however, they promise some untried difficulties and potentialities. Now, as always, the easiest projects have been taken up first. What lies ahead is still in important respects, a pioneering job. To appreciate the coming technical challenge at its most difficult, consider the ultimate task of harnessing the Kosi.

KOSI

The world has at least one river more obstreperous than the Kosi—the Yellow River in China. But in India the Kosi is unique in two respects.[7] It visits North Bihar with India's most devastating floods. And it seems to have the power eventually to destroy any controls the engineers have been able to design for it. Today, in fact, the Kosi appears to be a rogue river.

It was up one of the river's ultimate tributaries, the Dudh Kosi, that Sir John Hunt led his party of British and Sherpas on their way to Everest. Another fork, the Arun, penetrates the backbone of the Himalayas to drain a great, high, north-sloping area of Tibet, so that all of Everest's glaciers, even those of its northern face, melt into the Kosi's catchment. At lower altitudes, and further to the south, the three major tributaries catch the heavy downpours of the monsoon, where it beats upon barren mountainsides of Nepal, from Kathmandu to Kanchenjunga. Goats have long since stripped the last plant from many of those slopes. Others through which the Sun Kosi has carved a bed, are merely loose debris piled up at the foot of the glaciers. Just short of the boundary between Nepal and India, the waters of the Sun Kosi, Arun and Tamur merge to cut through the last Himalayan ridge. Through this famous gorge of Barakshetra pours more water than leaves the Himalayas at any other point between the Indus and the Brahmaputra. But the water carries with it a river of sand and stone—the stuff ground down by the glaciers of Tibet and sluiced down by the rains of Nepal. In 1947-48, when engineers first measured the quantity of that sediment, they discovered that it amounted in a twelve months' period to 7,300 tons for every square mile of the Kosi's catchment. Considering the relative size of the catchments, that is rather more debris than comes down China's Yellow River, which up to that time had been regarded as the greatest silt-mover in the world.[8]

Southward from Barakshetra, the river falls steeply through the Terai belt, dropping five feet in every mile it progresses. Once across the border into India it levels off, the current slows down, and before it empties into the Ganga some distance east of Patna, it has left behind almost all of its sand and gravel. The Kosi has thus turned North Bihar into the dumping ground for a silt-moving operation whose scale makes human efforts to move earth by means of draglines, scrapers and headbaskets appear as the work of ants.

The Himalayan rivers, though they have not had long—as geologists measure time—to do the job, have generally finished their labour of stripping off the softer layers from the upward-folded ranges and depositing the burden at their feet to form the Gangetic plain. The Kosi alone, springing from the mightiest of the mountains, restrained behind the foothill range until it escapes at Barakshetra within 150 miles of its mouth, still attacks that geologic task with the fervour of youth. The face of North Bihar is a record of its work. As lately as two centuries ago, some geologists believe, it flowed east from Barakshetra to empty into not the Ganga but the Brahmaputra. Again and again since that time, its flood-borne silt raised the level of its bed until it broke out westward into a lower course. Measured sideways, east to west, it has now migrated 70 miles. Each successively abandoned bed is now a waterlogged trough, hospitable to *kans* grass and mosquitoes, and not much else. It last broke out of an old bed in 1937, following the disturbance of ground levels by the great Bihar earthquake of 1934. Since then, it has shifted 11 miles westward — averaging more than half a mile a year.

Viewed with academic detachment, this is a typical instance of delta building; we have observed its counterpart near the mouths of the Damodar, the Cauvery, the Krishna and the Godavari. Some of the sediment the river carries is extremely fertile; bumper rice crops grow in it, provided the fields are not covered with floodwater or coarse sand before the crop matures. But the Kosi differs from the other delta-building rivers in two ways. It is working faster, and consequently shifting its bed more capriciously, in direct proportion to the extraordinary load of silt it carries. Since it empties, secondly, not into the ocean but the Ganga, it may find its outlet running in flood just when the Kosi's own volume is greatest. The consequence is the most damaging, most frequent, and longest-lasting floods in India.

In its present form, obviously, the Kosi delta is not a hospitable place of human settlement. At least every other year, the villagers in Darbhanga, Bhagalpur and Purnea districts flee to raised platforms while the paddy fields they need to till lie beneath a tan sea. Drownings are few, for the floods surprise no one. Typhoid and dysentery, endemic in villages whose wells are flooded, kill many. Snakes, too, kill some of their fellow refugees on the isolated embankments. Starvation is, however, the real threat. Yet this unhappy delta holds a thousand people per square mile, as dense a population as one finds in rural India. One reason is the chance of very good crops in the seasons when the floods permit. The main reason is that the villages the Kosi has engulfed in its westward aggression have no place else to go. No doubt as the geologists tell us, after some thousands of years the Kosi will have levelled up its delta and completed its earthmoving job; its domain will then be fit for settled habitation. But the million people who live there quite naturally cry out that their government should make it safe for them now. No humane and democratic government could stop its ears to that cry.

The Central Water and Power Commission has an immediate plan for the Kosi, and Bihar has undertaken to execute it. It includes a barrage at Hanuman Nagar, on the plains below Barakshetra, with flood embankments lining both banks for miles downstream. From the barrage, irrigation canals will take water to a million and a half acres, 180,000 of them in Nepal. The barrage itself is being built on Nepal territory. As a result of negotiations completed in 1954, the two nations have agreed to facilitate the construction of the project.

In 1954-55, the 42 crore construction job was tackled in dead earnest by a diverse but very heartening alliance of forces. Aside from the large crews of hired labourers, there were at the height of construction in April, 10,000 members of the National Cadet Corps, 8,000 students working during their vacations, 450 *shramdan* workers, and 12,000 villagers working co-operatively under their *gram panchayats*. Their toil was raising the great western dike at good speed; work was not going so rapidly on the eastern side, which was not the Kosi's aggressive front.

Embanking the river wins time to work out a permanent answer to the river's challenge. As soon as the barrage and dikes are finished, which is estimated to take six years, the Kosi will commence filling them in with gravel and sand. It is the old, unsolved problem of a river heavy with coarse silt which builds up its bed until men can no longer raise dikes higher, and then breaks out into a lower channel. Can India dike the Kosi more permanently than China has been able to dike the Yellow River?

There was a more radical plan for the Kosi. It was announced in 1946 by the government's engineering adviser, Shri A. N. Khosla, and it was no little plan.[9] The proposal was to block Barakshetra gorge by a concrete dam 'possibly 750 feet high'. That structure, higher than Bhakra or any other dam yet built, would have to stand on rock subject to earthquake in an inaccessible part of Nepal. Most troublesome of all was the discovery after the plan had been announced that the Kosi's silt comes down so fast as to endanger the continued usefulness of even such a gigantic reservoir. The great dam at Barakshetra held bright promise — a million kilowatts of hydro-electric capacity, or much more than all India has in 1955, several million acres of irrigation, even navigation. But apart from its prodigious cost and the problem of utilizing so much power in an entirely rural area, storing the Kosi's outpouring of water mixed with coarse sediment is simply beyond economic solution by present engineering methods.

India is, meanwhile, doing what can be done. The dikes will give villagers a provisional security. The irrigation channels will help offset the famine threat in flood years to the extent that they water a second crop. But *harnessing* the Kosi is another matter. To many engineers that seems as remote as the summit of Everest did to mountaineers, before June 1953.

THE GOVERNMENTAL CHALLENGE

The Kosi is, in terms of the engineering obstacles to ultimate control, the most obdurate of the rivers tackled in the second round. The other four schemes just started in the first Plan are Rihand in the Vindhyas (U.P.), Koyna on the Western Ghats (Bombay), Chambal (Madhya Bharat and Rajasthan), and Nandikonda on the lower Krishna (Andhra and Hyderabad). Rihand and Koyna require relatively high concrete or masonry dams, structures on the scale of Mettur. But unlike Mettur, both will include extremely powerful hydro-electric plants, about 240,000 kilowatts each. Koyna, in addition, will utilize a spectacular 1,500 foot drop of water down the Western Ghats into an underground powerhouse. There will be three dams on the Chambal, of which Gandhi Sagar, the large storage reservoir, is already under construction by Madhya Bharat, Rajasthan having undertaken to build the Kotah barrage lower on the Chambal. The two states agreed to share the water for irrigation, and in 1955 a board of control, intergovernmental in its composition, was established to supervise the project. Nandikonda, in a magnificent site at the lower end of the gorge which the Krishna River cuts through the Eastern Ghats, will be a concrete dam approaching Bhakra's scale, and like Bhakra will make water available to some three and a half million acres.

Taking these four projects as a whole, plus the immediate plan for dealing with the Kosi, India has a big and challenging job ahead. Yet it is by no means so far beyond her proved capacities in 1955 as were the projects tackled on the morrow of Independence: Bhakra, D.V.C., Hirakud and Tungabhadra. The nation can confidently expect that Chambal will offer no problems of controlling an inter-state river by a chain of dams more difficult than D.V.C. has solved, that Nandikonda will come within the capabilities of the builders of Bhakra, and Rihand and Koyna within the proved abilities of those responsible for Bhakra, Mettur and Jog — provided one condition holds. That condition is that *the lessons learnt on earlier projects can be carried over to the construction, operation, and control of the new.*

India's ability to meet that organizational challenge will turn on an issue the importance of which goes almost unrecognized: whether the Central Government shall continue, concurrently with the states, to take up some river valley projects for construction. The lack of public debate of so vital an issue no doubt reflects the almost accidental way in which it arose.

Every one of the states of the Republic has a share—in terms of the quantities of work and benefits, the larger share — in river development. It is one of the great strengths of the working Constitution that federalism had a sturdy growth in the functions of irrigation, electrification and flood control. It is vital that state powers continue to be exercised. The carefully thought-out D.V.C. Act preserved them in the states.

Building small irrigation and electric-generating systems, distributing electricity and water even from large systems, and collecting the rates from such distribution, would be most awkward functions for a national government. The big new multiple-purpose schemes rely on the same constitutional powers, and are means to the same ends — irrigation, electrification and flood control — as these long-standing state functions. Yet, in all the ways we have noted as characteristic of the nation building era, they present a different organizational challenge.

In 1947-48, the new national government took up this challenge in Bihar and West Bengal, and in Orissa, and became a sort of contractor for the Bombay government in building the Kakrapar weir. This was the only solution at the time, though the national government was then as uninitiated in major river construction as most of the states. In the process of learning, the central agencies D.V.C. and Hirakud lost about two years' time, and made certain mistakes. These we have traced to the lack of men qualified to head construction, and to the partly related tendency to 'build from Delhi' — to keep centralized checks upon estimating, designing, hiring personnel, spending, or purchasing. The Government of India learned by these mistakes, and in the most public way.[10] Every error, and many an apparent error, was vociferously questioned in Parliament. This was natural since many of the critics came from constituencies remote from the projects, and to them present costs were more obvious than future benefits. When the criticism was fully reported in the press, popular scepticism of the Government of India as a builder grew just when the basis for that criticism was being removed.

The large projects under state construction went through parallel delays. In the case of Tungabhadra between 1945 and 1949 the fault was outside the state government, at least the government of Madras; and in the case of Bhakra it was partly due to the novel complexity of the task. In any event, state legislators who felt the benefits closer at hand, and who were aware that the national government was bearing part of the cost, were less critical of those delays. This was the last of a long train of circumstances, beginning with the incompletely integrated government of the East India Company when modern irrigation began in India, and including the devolution to the provinces alone of self rule in these functions under dyarchy,[11] which has produced the assumption that the actual construction of irrigation and power works invariably belongs to the states.

It is assumed or decided, therefore, that Bihar will build Kosi; U.P., Rihand; Bombay, Koyna; Madhya Bharat and Rajasthan, Chambal; Hyderabad and Andhra, Nandikonda. Yet the governments which had by 1955 already acquired substantial experience in building giant multiple-purpose projects were Mysore, Madras, Hyderabad, and Punjab, and the central government through the D.V.C. and Hirakud organizations. Hyderabad while it remained a state offered the only prospect of carrying forward experience directly to the new schemes.

One way in which experience can be brought to new works though they lie in new states is by the development in India of an industry of heavy construction contracting. That would require several business firms staffed and equipped to make tenders on entire dams, canal systems, or electric stations. The basis for such an industry was laid when D.V.C. gave over Konar Dam to a general contractor and Bombay municipality gave over Vaitarna Dam. Now the award of Rihand to a contractor by U.P. may give the large-scale contracting industry a further lease on life. If so, India will have an unappreciated national asset. Not only can seasoned engineering groups and key pieces of construction equipment thus pass from job to job, but harassed governments can be spared the pressure of day-to-day supervision. Government estimates, which have been none too exact, can have the check of independent competition.

But there are states, and they hold some of India's finest river development sites, which bring to the task of development neither the financial resources nor the governmental experience required to draw up the best projects and let contracts. It is in these very states, perhaps naturally, that one finds the same reluctance to make accurate plans, enlist top managers, engineers or contractors, and then give them full responsibility for executing the plans — which plagued the national government in its first approach. Moreover, certain of the valleys under development will always be interstate valleys. Even if competent contracting firms compete, can the states themselves take on the whole list of future projects?

A fair answer requires an appreciation of the varied, often pioneering activities the Government of India has initiated to effect an *indirect* transfer of experience from project to project and from state to state. Keystone of the machinery is the Planning Commission itself, which holds up standards of adequate planning and maintains procedures for selecting the best claimants for national support among competing plans. Political understanding of the projects is interchanged in meetings of the state irrigation and power ministers with the central minister, and in the latter's meetings with M.P.'s especially interested in project areas. The Irrigation and Power Ministry has also since 1954 conducted a remarkable series of seminars for the top engineers of the large projects, and appointed nation-wide committees to make recommendations on such general problems as the cost of a unit of earthwork, masonry or concrete, or the efficient operation and maintenance of construction machinery. These activities, for which Shri Nanda deserves primary credit, will insure as well as can be that previous lessons are not overlooked at new projects.

Information, though, is not enough to build dams, powerhouses and canals of the new complexity, or to operate multiple-purpose systems for irrigation and power. Had it been, the problem would have been solved immediately after

Independence by sending Indian engineers abroad and bringing foreign specialists to India to impart information. Even the long-discussed proposal to create an all-India service of irrigation and power engineers so that individual transfers from project to project might be easier would not suffice to avoid old delays and errors. For governments themselves must be experienced in the disposition of huge projects; while the actual ability to build the new projects at top efficiency can be carried forward at full value only by teams of key men — chief engineers, with the mechanical, electrical, civil and design engineers they rely on, plus managerial officers for running colonies, accounting, purchasing and handling personnel matters, and a few key superintendents. Ideally, with each team would go certain pieces of strategic equipment. Even such a team can master only some of the new techniques — large dams, for instance, *or* high-head hydro-electric plants. But once proved and put on an appropriate project, such a team can be counted on to build to an estimate. And unlike a contracting firm, it can be counted on also to be alert to the non-engineering problems and opportunities inherent in village relocation, colony management, labour relations, etc.

Can *every* state government prepare itself for planning, decisions and management on the scale required by the largest projects? Probably any but the smallest can. Can it do so without repeating the waste of time and perhaps of money which were required to prepare the Central Government and some of the states immediately after Independence? That is more doubtful. Can India afford a 'big university' like Bhakra in each state? Or can teams of engineers and equipment be passed from state government to state government as new projects succeed one another in different parts of India?

The alternative is not to make river projects, even major river projects, exclusively central. It is to keep both the Government of India and the stronger state governments — those already prepared and likely to have a succession of major projects — at work. This assumes, of course, that the Central Government will undertake construction through decentralized boards, administrators, or chief engineers. This lesson has largely been learned at D.V.C. and Hirakud. And where river development crosses state lines, involves several related multiple-purpose reservoirs, and is intended to stimulate general economic advancement, the semi-autonomous corporation has proved itself to be the most productive central instrument.

Three things are certain. The states can manage distribution of power and water and the construction of smaller projects better than the nation can. Secondly, no nation on earth can establish, or even maintain, some fifteen separate agencies, each possessing the highest competence to build whatever new type of river project may happen to fall within its territory. Thirdly, the Government of India now has, like several of the larger states, competent and dependable design and construction teams. The organizational challenge will extend to the utmost all of the governmental resources that are available. India can manage the building of the projects that lie ahead, but not with one hand tied behind her back.

THE POPULATION CHALLENGE

In 1953 the Government of India published a remarkable document: the *Report* of the 1951 Census, by the Census Commissioner, R. A. Gopalaswamy. Shri Gopalaswamy moved to his conclusions on the basis of a marshalling of facts so authoritative, and reasoning so rigorous, that his *Report* has to be the starting point for all later considerations of the problem he tackled. That was the relation between India's population and her food supply. Shri Gopalaswamy assumes India's numbers will be:

1951—36 crores
1961—41 „
1971—46 „
1981—52 „

He assumes that the whole of the irrigation of which construction has been started will be realized, that all the other measures of the Five-Year Plan to increase agricultural production will bring the expected results. He further assumes that India will achieve the lower limit of the long-range goal set for irrigation in the Plan—40 million new acres in 20 years. Along with that irrigation, he assumes, will come other measures such as reclamation of waste land, fertilization, better tillage, and improved crop varieties which will improve the nation's total yield twice as much as the irrigation alone.

The conclusion which follows is so arresting that it must be read from his own words:[12]

At the end of all this, our estimate of the increase of agricultural productivity is still only 240 lakhs of ANNUAL tons; of which one-sixth is to be secured by an increase of acreage under crop; one-third by increase of acreage under irrigation and one-half by all methods of increasing yield per acre other than irrigation. *This increase will fall short of our needs before 1971. It will be just about sufficient to overcome the present shortages and meet our growing needs until our number reaches 45 crores* — which will occur round about 1969. . . .

What follows — that starvation is our lot? *No.* It follows that we should make up our mind that we shall not go on increasing in number as we do.

The challenge that comes from Shri Gopalaswamy's analysis does not depend upon his ability to forecast the precise quantities either of population or food supplies. His warning holds so long as numbers go on increasing at not less than the present rate, compounded, whereas each addition to food production becomes, as we have observed in the case of irrigation itself, a more and more costly effort. There comes a limit.

Let us test out this point by making the most optimistic assumptions about the rate at which food production can be raised—assumptions which Shri Gopalaswamy rejected as being beyond what past accomplishments give us grounds to hope. Let us assume the actual *use* of irrigation doubles in 24 years from 1951; in other words that India can add 50 million acres by 1975, instead of 40 million by 1981 as Shri Gopalaswamy considered feasible. This amounts to saying that all the projects which Shri Gulzarilal Nanda called for inclusion in the first three Plans could be brought into full production by that year. Let us further assume, as Shri Gopalaswamy does, that the 10 million tons (one ton for each five acres of new irrigation) this would add to annual agricultural production is only one-third of the total improvement which might then be secured by cultivating waste land, and raising yields by fertilizing and other methods. We should have 30 million tons of new production in 1975. But by that time India would already number 48·4 crores, and require 30·8 million tons of extra food. In other words, a plan of development in irrigation and agriculture so optimistic as this would only put off the predicted day of reckoning *by six years*.

India could then face such a recurrence of the old cycle of population increases, cancelled by famines, as controlled her numbers down to the last generation. Or she could depend more and more on imported food, a course against which she turned decisively in 1951. Or she could, as Shri Gopalaswamy persuasively proposes, immediately determine upon a programme of birth control as extensive, and of the same order of priority as her present Community Projects programme.

But suppose this admitted 'near-miracle' cannot be realized either by 1969, or at best, by 1975. Or suppose Shri Gopalaswamy's conservative estimates of population growth are overrun by a sharp reduction of deaths, as might come, for instance out of the current national malaria control campaign. Suppose, as the Planning Commission itself assumed at one point in its long-term calculations, that the population should rise to 50 crores by 1975.[13] Then the shortfall of food production, even optimistically calculated, will already be 4·8 million tons—exactly what it was when India began planning to abolish it.

On any of these quite likely assumptions, India will be faced with an entirely new imperative. She will find even doubling her irrigation is not enough. At the end of a really heroic effort, she will face the need of an equally heroic fresh start. She will by that time have used up the sites which now seem feasible and economic. She will call on her engineers for the now impossible feats—feats of the order of difficulty of permanently harnessing the Kosi.

Here is the challenge to Indian planning. Even present plans, which seem to extend the nation to the limit, may prove too little. The conclusion would, however inescapable, seem theoretical and remote were it not reinforced by every other conclusion to which this chapter has led us. India's challenge is not merely to do the job she has set herself; *it is to prepare herself to do still more.*

15

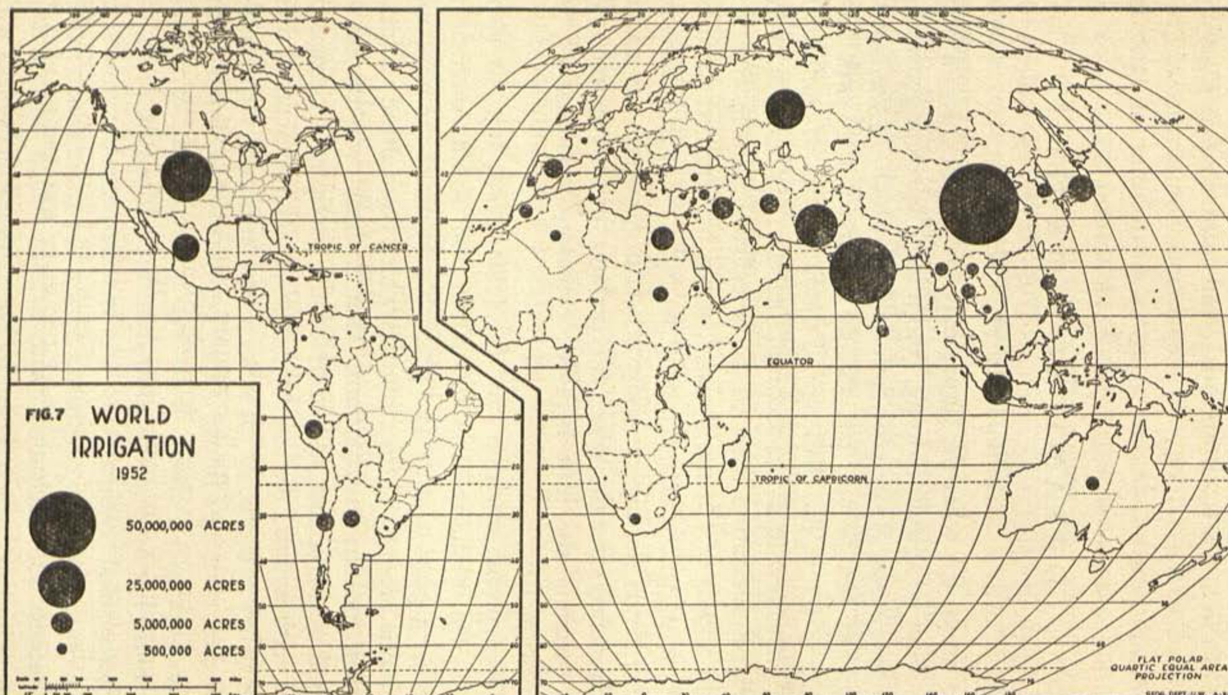
DREAMS NO LONGER

INDIA AND THE WORLD

So much for what the future may hold. But this is a book about what India *is* doing. And if India's present generation will take stock of the economic rebirth which, in the case of irrigation and power, has already occurred, they will have reason to accept the challenge of the future full of confidence. For what New India has accomplished by 1955 deserves, if any work of civilization deserves, to be called a miracle. She has, in the words of Chester Bowles, when he returned from his mission as American ambassador to India, 'Got in full swing on her rivers the biggest construction programme any nation has launched since the War.' It is perhaps the least appreciated, and certainly the least heralded economic conquest of the generation.

The supreme question, not for India alone, but for two-thirds of mankind in Asia and Africa and South America, is whether a poor country can peaceably overtake the headlong economic progress of the countries which have already achieved their industrial revolutions. That, I think, was the unexpressed question that still troubled the thoughtful citizens of India with whom I discussed the obvious achievements of their river valley projects. With what a new assurance they would view their country's future if they could realize a simple truth. In developing her rivers, India has attained a *rate of progress* that ranks her among the most dynamic nations on earth.

International comparisons are treacherous; the more so when one attempts to compare a nation like India which makes full reports and disclosures, with nations which do not. But let us, with this caution, begin by comparing India's plans with



SOURCES: U.N. Food and Agriculture Organization Yearbook, for U.S.S.R. source, see text.
Compiled by Roy Chung, Gurdev Gosal, Kenneth Korb, and Ikramur Rahman under supervision of Prof. C.W. Olmstead.

those of the U.S.S.R. In the 1953 Annual of the *Indian Journal of Power and River Valley Development*, a Soviet writer, Professor Innokenti Kandalov, gave us an account of Russian irrigation and power programmes. He wrote:

> The Directives concerning the Five-Year Plan of development of the U.S.S.R. for 1951-1955, adopted by the Nineteenth Congress of the Communist Party of the Soviet Union provide a 30-35 per cent increase in the irrigated area already in 1955 and an 80 per cent increase, respectively in electric power output, the latter primarily in hydro-power development.

Now we know that India planned in approximately the same five years to increase her irrigated area 38 per cent, and her electric capacity 52 per cent. For irrigation, we are given actual quantities. Russia's advance is from a small base: she planned to add some 5 million acres to her 16 million. India, of course, is adding 19 million to her 50 million. Russia did not reveal her electric plant capacity, but since she is reported to produce 20 times as much electric energy per year as India already, her more rapid rate of increase is noteworthy. But this is Russia's *fifth* Five-year Plan. It should not be too disheartening for India to realize that while her *first* Plan does not match the Russian rate of increase in electrical output, her *second* Five-Year Plan with its target of a 100 per cent increase will do so.[1]

We have fuller information, compiled by United Nations' statisticians, for the nations other than Russia and China.[2] They show that India, adding 11 per cent a year to her electric plant capacity in 1951 to 1954, expanded more rapidly in this respect than any large nation, including even the United States, Japan, and Canada. Small, booming Venezuela alone grew still faster. This is an electrical age, and many nations built generators very rapidly during and since the War. Yet India is gaining a larger share of the total world production of electricity. In 1938, she produced one kilowatt-hour for every 166 produced throughout the world. In 1951 her share was one in 164; in 1954, one in 160. India has far to go, but she is catching up.

As to irrigation, India's unprecedented growth is even more evident. No country with any substantial area already irrigated approached India's achieved expansion of five per cent per year, 1951-54. This is the more remarkable, considering the fact that India already has one-fourth of the world's irrigated acreage. India need no longer ask, in short, when she will attain the dynamism of the West, but only when the rest of her economy will catch the dynamism of her river valley projects. Unobtrusively, they have become the pacemakers for the world.

China remains. While this book was being written, it seemed quite hopeless to seek figures which might serve, even with reservations, to compare her status and progress with India's. But in September 1954 Premier Chou En-lai made a report to the First National People's Congress in which he announced actual quantities of production, including electric output. And in March 1955, the U.N. Economic Commission for Asia and the Far East published these, with much other data on mainland China's economy. The outlines of a fascinating picture begin to emerge.[3] It shows China reporting an annual increase of electric output twice India's (26 per cent in 1952-53 and 20 per cent in 1953-54). Her *per capita* electric output is, however, still slightly lower than India's (18·6 kilowatt-hours per year, compared to India's 19·6, in 1954). Much of China's dramatic growth has been by the restoration of war-damaged and looted plants, such as the great Fengmen hydro-electric station in which three 100,000 kilowatt generators were replaced in 1954. In a longer perspective, 1938 to 1954, China's output of electricity has increased 3·6 times, compared to India's increase of 3 times. Premier Chou En-lai announced the goal of adding 100 per cent to China's 1952 electric capacity in a somewhat indefinite period of five to ten years. Perhaps a roughly comparable Indian target is to increase electric capacity 131 per cent by completion of the projects *started* in the first Five-Year Plan.

China has added 10·1 million acres to her irrigated lands in the five years 1950 to 1954. India added slightly more (10·2 million acres) in the first four years of her Plan (1951–54). This by no means expresses the difference. For China has had vast tracts under canals for centuries; in 1938 the area was estimated at 107 million acres—almost half her cropland.[4] What she is doing now is chiefly repairing and rehabilitating damaged portions of that ancient system. The Economic Commission for Asia and the Far East reports the Kiangsu Irrigation scheme under construction to lead water between the Grand Canal and the east coast. It is planned for 4·4 million acres — about the commanded area of Bhakra-Nangal. The Chinese programme otherwise comprises some eight million ponds and ditches, a million wells, and 600,000 lifting devices driven by manual, animal or mechanical power. Clearly this is comparable to the types of irrigation rapidly expanded in India a century ago: small projects or great canals in the river deltas. China has barely tackled the technically difficult job of building storage reservoirs. Her large-scale irrigation depends on natural floods. By the same token, abnormal floods hang as a constant threat over those same areas, just as they did to the old canal tracts of the Damodar, Mahanadi, Cauvery, or Krishna deltas before the positive control of those rivers by the great modern reservoirs. China has only in Manchuria and in the Huai River scheme the forerunners of the multiple-purpose reservoirs India began with the commencement of Krishnaraja Sagar 45 years ago. In 1954, nature made that tragically clear. Dreadful floods covered 25 million acres of the Yangtze and Huai River tracts—a third of China's irrigated land. Sixty per cent of the dikes which had been strengthened in the great popular effort of the past five years had to be repaired again.

There is no country to which India need defer for the scope, the complexity, the sound planning, and the rich benefits of her river valley developments. To her coming generation, she can say: 'Here is the biggest, most constructive work in the world.

You need not patiently await it; your country is doing it now.' For some two lakhs of men and women who want to build dams and canals and power stations—to drive or to repair earthmoving machines, to perform or supervise construction labour, to control turbo-generators, these projects offer an immediate place in the next five years. The number to whom they offer the challenge of taking up irrigated farming, of putting electricity to work at pump-sets or in small industries, runs into millions. To all these, the nation can say, 'Your own enterprise and skill will be the limits of your advancement. Other nations inherited a frontier of open land. This nation has created its own frontier of opportunity in its river valleys. Here is the future in your midst. These things are dreams no longer.'

MONUMENTS TO WHAT?

In each vigorous age, a civilization erects its monuments. Some are, like the Pyramids of Giza or the Taj Mahal, dedicated to the power or the beauty of the dead. Some are forts, or triumphal arches to receive the parades of victorious armies. Many honour the mystery of God. Surviving for centuries after the last of the rites or ceremonies for which they were designed, monuments like these nevertheless tell us much of what we know of the civilizations of the past: the dominant purposes to which they devoted their wealth, their work and creative skill. The great works were, in fact, erected partly to teach these things to contemporary generations. To all who came and marvelled, they subtly pointed the way to greatness.

The greatest of the monuments of free India are on her rivers—the Sutlej and Damodar and Tungabhadra, the Mahanadi and Chambal and Tapti, and many more. To these places men and women come, in a pilgrimage growing season by season, to see for themselves the dams and canals and power stations. Each visitor, looking at the vast works, will draw conclusions of his own. The workman or woman may perhaps ponder the toil that raised the masonry or earth. The farmer or industrialist will think of the benefits of water or power. The ratepayer will think of his taxes, the engineer of problems solved or to be solved, the legislator of the needs of his own constituency. Only the archaeologist of the future, not privy to any of these thoughts, will dare give any simple answer to the question 'Monuments to what?'

Yet to all who make the pilgrimage, New India's river monuments have certain things to teach. One lesson is very old: here water is life. The Aryan singers of the Vedic hymns acquired their very names—India and Hindu—from the Indus, the first great river of their long migration. To all their successors, the rivers were connecting arteries between the life-giving waters of the monsoon, and the otherwise sunbaked fields. To the channels in the Harappan cities, the tanks and anicuts of southern villages and kings, the canals and embankments of the northern emperors, these twentieth-century works are a fitting climax. Here men who still chant the names of rivers, journey to their headwaters to meditate, and burn the dead upon their banks, may take a traditional pride. Eking out their poverty, they have raised upon their sacred rivers monuments of magnificent proportions. It is the flowering of a river-minded culture.

So, it may be, the pilgrim's imagination runs as he stands in the shadow of a great dam. There is in its very shape, broad based and tapering upward, the appearance of strength in repose. There is a certain kinship to the shape of other monuments that survive through centuries—citadels, *stupas* and temple towers.

But let the visitor climb to the crest to observe the reservoir to its blue-green depths, cool, unfailing and obedient. Is this the same river that held its dependents through the centuries as much in terror as in affection? Is this the devourer of cities, the deserter of crops? Or let him enter the quiet, almost empty room that houses the turbo-generators. The industrial revolution is here, not crude but refined. Nature is put to a use freshly conceived by men.

On India's rivers these are the monuments to a new mind—the universal mind of science. In India it is a century old. But applied to these sacred streams it can make visible and commonplace a lesson of revolutionary import. Man cannot create the forces of nature; neither have they created his fate for him patiently to bear. By knowing them he can use them to free himself from their worst visitations—want, disease and early death. Thus he can make more room for his spirit. He can do it in a measure which every year extends itself, and finds its limit only in his ability to identify truths of matter and experience with truths of thought. Ideas need not be useless to be true, is the lesson of these creations of science, nor unearthly to be universal, nor wholly inward to have their spiritual reward.

Through such works as these, what was the fate ordained by nature comes within the choice of man. But science may serve as well to destroy as to create. Purpose becomes the more important. And the purpose of the civilization which concentrates so much of its surplus upon these river works must suggest itself in the services to which they are put. Leaving the river, the visitor who ponders these things notices overhead the strands of aluminium conveying energy, perfectly controlled, to hundreds of mills and towns, thousands of pumps and villages. He travels the geometric banks of canals, engineered against failure or flood, past a thousand sluice-gates into ripening fields. Has the civilization which began at the river banks, and then turned to the rivers both to sustain and renounce life, now returned to them to remake life? Have the people, the millions, who petitioned and blessed their rulers for good works, begun enjoying—and creating—works too vast, and too intimately serviceable, to be the work of any sovereign, save themselves?

If so they alone, now, the people, can assert the ultimate purpose of which these great working monuments are both symbols and servants. All we can hear now are the words of the men who called the nation-building effort forth.

> If I could persuade myself that I could find God in a Himalayan cave I would proceed there immediately. But I know I cannot find him apart from humanity.... I recognize no God except that God that is to be found in the hearts of the dumb millions.[5]

That was Mahatma Gandhi, who lived to see the great river projects only begun. Some years later Jawaharlal Nehru, throwing open a dam and canal which brought a Himalayan river into the service of some millions of farmers and more millions of townspeople, said:[6]

> For me the temple or the *gurdwara* or the church or the mosque today are these places where human beings labour for the good of humanity, of other human beings.... Where can be a greater and holier place than this?

SOURCES AND NOTES

Chapter 1. DESCENT OF THE GANGA

1. *Lectures on the Ancient System of Irrigation in Bengal*, University of Calcutta, 1930. For a more careful interpretation confirming the eastward shift of the main outlet of the Ganga from the Bhagirathi several centuries ago, but not the artificial establishment of Bhagirathi earlier, *see* C. Addams-Williams, *Note on the Lectures of Sir William Willcocks*, Calcutta: Bengal Irrigation Department, 1931.
2. R. T. H. Griffith (trans.), *Hymns of the Rig Veda*, London, 1896-7, Book I, Hymn 23
3. *Rig Veda* II, 33
4. *Rig Veda* VIII, 85
5. R. E. M. (Sir Mortimer) Wheeler, *The Indus Civilization*, Supplementary Volume of *The Cambridge History of India*, Cambridge, 1953.
6. *Rig Veda* II, 13, 14
7. *Rig Veda* VI, 17
8. *Rig Veda* VIII, 6
9. *Rig Veda* I, 32
10. *Rig Veda* VI, 30
11. *Rig Veda* V, 30
12. E. G. Jayaswal, *Hindu Polity*, Calcutta, 1924, p. 207
13. For this Puranic verse, and its translation from Sanskrit, I am deeply indebted to Professor M. Yamunacharya of the University of Mysore.
14. Shri Satya Shrava has assembled the most interesting cases of prehistoric irrigation in a pamphlet published by the Central Board of Irrigation in 1951: *Irrigation in India Through Ages.* I owe much of the following paragraph to him. The reader of the pamphlet should discriminate as he has done between conjecture from the texts of the scriptures, and eye-witness accounts or inscriptions.
15. From McCrindle's *Ancient India as described by Megasthenes and Arrian.*
16. The following two paragraphs are based upon the Government of India's authoritative *Triennial Review of Irrigation in India, 1918-21.*
17. *Journey Through Mysore and Southern India*, 1807, quoted extensively in Romesh Chunder Dutt, *Economic History of India under Early British Rule*, London, 1901.
18. *The Discovery of India*, Calcutta, 3rd. ed. 1947, p. 181
19. Ibid. p. 433

Chapter 2. TWO FORERUNNERS

1. Leaving detailed and accurate records is implicit in scientific engineering, and both of the projects reported in this chapter are exemplary in this respect. Sir Proby Cautley's *Report on the Ganges Canal Works*, Vols. I-III, London, 1860, together

with the District Gazetteers to bring it up to date, provides the material in this section.

For a brief account of the whole of the British contribution to irrigation in India, the reader can secure from the British Council: Frederic Newhouse, M. G. Ionides, and Gerald Lacey, *Irrigation in Egypt and the Sudan, the Tigris and Euphrates Basin, India and Pakistan*, London, 1950. There is a fuller and highly interesting, though now dated account in D. G. Harris, *Irrigation in India*, India of Today Series, Vol. 3, London, 1923.

2. Through a series of mishaps, the Krishnaraja Sagar project has never been chronicled in the comprehensive way it deserves. Upon the design and construction phases, a series of professional papers in the *Proceedings* of the pioneering Mysore Engineers Association, beginning in 1911, supply accurate, detailed accounts. The most comprehensive is N. Sarabhoja, 'Note on the Krishnaraja Sagar Works', in the Association's *Silver Jubilee Souvenir Volume*, Bangalore, 1932. To fill in gaps, I consulted the state *Administrative Reports* from 1912-13.
3. *See* his *Memoirs of My Working Life*, Bangalore, 1951.
4. M. G. Rangaiya, 'Irrigation in Mysore State', *Silver Jubilee Souvenir Volume*, p. 106
5. C. M. Cariappa, 'Cauvery Falls Power Scheme', in the *Silver Jubilee Souvenir Volume.*
6. The source for the interstate dispute and settlement is Mysore Public Works Department, *Mysore Madras Arbitration: Enquiry into the Question of Storage of the Cauvery Waters within Mysore Territory*, Bangalore, 1914-24.
7. From Sir Mirza Ismail in an interview in 1954.
8. Julian Huxley, *TVA, Adventure in Planning*, Surrey, England, 1943.

Chapter 3. BORDER DAM

1. *Irrigation in India Through Ages*, pp. 15-16
2. R. Sewell, *A Forgotten Empire*, London, 1900, is the classic source on Vijayanagar.
3. Administrative surveys of the problem of developing the tracts being irrigated by Tungabhadra Project, on both sides of the river, refer to the people's 'famine mentality'.
4. For this and the following paragraph, *see* the *Report of the Indian Irrigation Commission*, 1901-1903, Vols. I, II.
5. Information on the dispute is from H. E. H. The Nizam's Government (Hyderabad), Public Works Department, *The Tungabhadra Project Correspondence*, Vol. I, 1898 to 1937; Vol. II, 1938 to 1945.
6. This report remains the best technical account of the project: Madras Public Works Department, *Tungabhadra Project Report*, Madras, 1942.
7. The agreement has been merged in a new agreement allocating the water of the entire Krishna

basin. Government of India Planning Commission, *Report of the Technical Committee for the Optimum Utilization of the Krishna and the Godavari Waters*, New Delhi, 1953, Appendixes B and C.

8. Basic source: *Report of the Board of Engineers Appointed by the Governments of Madras and Hyderabad for Settlement of Certain Disputed Points in the Design and Construction of the Dam*, October 1947. I have drawn some inferences as to the reasons for positions taken.

9. Detailed information on the 'police action' is hard to get. Current reports in the Madras *Hindu* are useful, though not for the Nizam's side. The Government of India's *White Paper on Hyderabad*, Sir Mirza Ismail's account in *My Public Life*, London, 1954, ch. 10 and V. P. Menon's *Integration of the Indian States*, Calcutta. 1956, Chs. XVII-XIX give the political setting. I am indebted to eyewitnesses on both sides for their recollections, but errors may have crept into this reconstruction.

10. Upon the creation of Andhra State, the Government of India set up a Tungabhadra Board, *Gazette of India, Extraordinary*, No. 121, 29 September 1953. Its members however, served part-time and ex-officio, and its powers were confined to the Mysore-Andhra portion south of the river. A chief engineer for the project was as far away as ever. In March 1955, the Tungabhadra Board was simplified and strengthened by a reorganization. Under a full-time chairman (the former Secretary of the Ministry of Works, Mines and Power in Delhi, Shri B. K. Gokhale), one member each represents Andhra, Hyderabad and Mysore, and one the central Finance Ministry. It has now a chief engineer.

Chapter 4. FLOOD, FAMINE AND FORESIGHT

1. The authoritative account of the flood is the *Report of the Damodar Flood Enquiry Committee*, Government of Bengal, 1944.

2. *Note on the Lectures of Sir William Willcocks*, Bengal Secretariat, 1931. Mr. Addams-Williams was answering the half-truths contained in the Willcocks' *Lectures on the Ancient System of Irrigation in Bengal*, University of Calcutta, 1930. In the latter the element of truth was that diking the Damodar brought malaria; the doubtful guess was that the old beds of the Damodar north and east of its present lower course were really ancient canals. Sir William even assumed the Chola kings applied here their Tanjore engineering! The latest word on this controversy is S. C. Majumdar, *Rivers of the Bengal Delta*, University of Calcutta, 1942.

3. The important reports and correspondence on all the pre-1943 schemes for the Damodar are in Bengal Public Works

Department, *Selections from the Minutes of the Bengal Secretariat on Damodar River Embankments*, 3 vols.

4. *Malaria and Agriculture In Bengal*, Bengal Secretariat, 1925, pp. 19-20
5. M. Jafar and M. O. T. Iyengar, 'The Incidence of Malaria in a Deltaic Area of Lower Bengal between the Damodar and the Hooghly Rivers', *Indian Journal of Malariology*, 1947, Vol. 1, pp. 441-67
6. *Selections*, Vol. I, p. 165
7. Ibid. Vol II, p. 124
8. Ibid. Vol. I, p. 166, Vol. III, p. 15
9. Ibid. Vol. II, p. 136
10. Ibid. Vol. III, p. 15
11. *See* note 1, this chapter
12. *Damodar Valley Corporation* (Rau) *Committee of Enquiry Report*, New Delhi, 1953.
13. Central Technical Power Board, *Preliminary Memorandum on the Unified Development of the Damodar River*, Calcutta, 1945. This is the basic source for the following section.
14. There has been some interesting controversy, partly on the *need* to design against a bigger recorded flood, partly on how big a Damodar flood *might* be. On both points, *see* N. K. Bose and S. K. Nag, 'Design Rain Storm for Damodar Catchment', a paper read at the Fourth Congress on 'Large Dams', New Delhi, 1951. The latest word on the second point bears Mr. Voorduin out remarkably well. S. K. Pramanik and K. N. Rao, in *Hydrometeorology of the Damodar Catchment, Memoirs of the India Meteorological Department*, 1953, Vol. 29, Part 6, calculate that the million cusec 'design flood' would be likely to occur once in something more than 800 years (between 816 and 851 years, to be precise).
15. Based on statements by participants in the *Constituent Assembly of India* (*Legislative*) *Debates*, upon passage of the D.V.C. bill.
16. *Constituent Assembly of India* (*Legislative*) *Debates*, 12 December 1947, p. 1842
17. *Bihar Legislative Assembly Debates*, 11 October 1947.
18. Ibid., 25 September 1947, p. 39
19. *Fifth Report of the Estimates Committee*, New Delhi, 1952, Section III.
20. *Damodar Valley Corporation* (Rau) *Committee of Enquiry Report*, New Delhi, 1953.
21. Extraordinarily full progress information is available in the Corporation's yearly *Budget Estimates*, and, some months later, in its *Annual Report*.

Chapter 5. BETWEEN MONSOONS

This chapter could not, obviously, have been written save for the facts supplied by the engineers at Maithon. They would not agree with quite all the conclusions. Another source has been useful for the difficult business of comparing efficiencies: Ministry of Irrigation and Power, *Engineers' Seminar at Nangal*, New Delhi, 1954. Vols. I-III.

Chapter 6. MEN AND MACHINES

1. Government of India, Ministry of Irrigation and Power, *Engineers' Seminar at Nangal*, New Delhi, 1954, Vol. I, p. 35. Reliable, fairly presented facts of this sort are among the things we owe to the Ministry's seminars.
2. I have not seen the report which was to be issued as Ministry of Irrigation and Power, *Report of the Construction Plant and Machinery Committee*, New Delhi, 1955.
3. 'Earthmoving Equipments: a Study', *Indian Journal of Power and River Valley Development*, 1952.
4. For a model of systematic, accurate cost records, *see* Damodar Valley Authority, Soil Conservation Department, *Review of Works of Mechanised Earth-Moving Circle from July 1949 to March 1953*, Hazaribagh, 1954.
5. *Engineers' Seminar at Nangal*, Vol. I, p. 19
6. A systematic account may be found in G. Srirangachary, 'Manufacture of Gates and Shutters at Tungabhadra', *Indian Journal of Power and River Valley Development*, 1954.

Chapter 7. A RIVER TOO BIG

1. For some items in this historical sketch, I am indebted to the Finance Minister of Orissa, Shri R. N. Rath, for others to Shri Hare Krushna Mahtab. The classic study of flood frequency and volume is P. C. Mahalanobis, *Rainstorms and River Floods in Orissa 1932*, rev. ed. 1941.
2. From Sir M. Visvesvaraya's *Memoirs of My Working Life; see also* Central Water-Power, Irrigation and Navigation Commission, *Quinquennial Report*, New Delhi, 1950, pp. 106–8
3. Central Waterways, Irrigation and Navigation Commission, *Mahanadi Valley Development—Hirakud Dam Project*, New Delhi, June 1947.
4. Central Waterways, Irrigation and Navigation Commission, *Report of the French Mission on Navigation of the Mahanadi.*
5. 'Financial Arrangement and Other Terms of Agreement between the Central Government and the Government of Orissa in Respect of Hirakud Dam', printed by the Government of Orissa, 1951.
6. Ministry of Irrigation and Power, *Mahanadi Bridge Committee Report*, New Delhi, 1953.
7. Public Accounts Committee, 1952–3, *Sixth Report, Hirakud Dam Project*, New Delhi, 1953. and Ministry of Irrigation and Power, 'Memorandum on the Recommendations of the Sixth Report...', New Delhi, 1953. For early reactions to the criticism from the project viewpoint, *see* R. P. Vashishth, 'Hirakud Dam, a Report of Progress', *Indian Journal of Power and River Valley Development*, March 1951.

Chapter 8. OPERATION HIRAKUD

1. Anyone familiar with the managerial affairs of river construction projects soon learns that engineers may become so involved in the contest with nature that they tend to regard *any* rules of administration imposed on them as onerous. This may be the case even when they are not making use of all the powers they actually possess. I am grateful to the ministry and the chief engineer for letting me get enough details of particular cases and the operation of specific rules to find out whether this was the situation at Hirakud. On the contrary, I found rules controlling Hirakud administration faithfully and skilfully administered, but still proving too restrictive. Only a fragment of the evidence for that conclusion can be presented here.

Chapter 9. CODE VERSUS CORPORATION

1. The Administrative Committee of Enquiry headed by Shri P. S. Rau concluded that 'the semi-autonomous corporation is the best method yet devised of executing multi-purpose projects efficiently and economically,' *Report*, p. 115. While it took some comparative evidence, its detailed study was of D.V.C. alone. This had already been concluded by A. D. Gorwala, *Report on Efficient Conduct of State Enterprise*, 1951. For one of the most effective arguments ever published for the D.V.C.-T.V.A. approach, *see* Dr. Sudhir Sen, 'We Need More River Valley Authorities in India', *Indian Journal of Power and River Valley Development*, 2nd. Annual Number, 1953. The *Fifth Report of the Estimates Committee*, 1951-52 recommends its own solution to the problem of controlling projects. *See also* 'Comments' on the report by D.V.C., mimeographed, 1952. The *Indian Journal of Power and River Valley Development*, in a 'Memorandum' submitted to the Rau Committee, published by the *Journal*, January 1953, defends D.V.C. autonomy. Paul H. Appleby thinks it should be limited, *Public Administration in India: Report of a Survey*, New Delhi, 1953.
2. Assuming 48,000 kilowatts (total initial capacity) from the subsidiary dam as 100 per cent firm power
3. A rough estimate in lieu of operating cost estimates.
4. *See* the debates on parliamentary control over government corporations generally, Lok Sabha, 10-12 December 1953.
5. The Comptroller and Auditor General commented on this point in a 'Memorandum' circulated by the Ministry of Irrigation and Power in 1954.

Chapter 10. MAZDOORS

Aside from personal observation, this chapter is drawn from reports of project labour welfare officers, from engineers who participated personally in negotiations, and from brief reports on strikes by ministers to their respective legislatures. My information from union leaders is thus second-hand.

Chapter 11. DESERTED VILLAGES

1. Despatch from Hospet of 11 July 1953, published in the *Hindu*, Madras.
2. *D. V. C. Enquiry Committee Report*, p. 26 (with estimate for Panchet Hill added).
3. These data appear in a valuable paper by the D.V.C. director of rehabilitation and development, Shri K. S. V. Raman, 'Studies in Land Use in the Damodar Valley: Fragmentation', presented at a symposium on soil conservation, December 1951 (mimeographed).
4. K. S. V. Raman, 'Land Reclamation in the Damodar Valley', *Indian Journal of Power and River Valley Development*, October 1952, pp. 23-28
5. This includes imputed depreciation and maintenance costs beyond the D.V.C.'S booked cost of Rs. 713 per acre. *D.V.C. Enquiry Committee Report*, pp. 26-8.
6. For data in this paragraph, plus maps and plans of the relocation village Bachhai and its houses, *see* D.V.C., *Improved Land Use in the Damodar Valley*, Calcutta, 1951.
7. In its *Fifth Report*, 1952, the Estimates Committee of Parliament considered D.V.C. relocation extravagant and recommended a special committee investigation. The Rau Committee, in Chapter 3 of its *Report*, examines all the grounds for the charge and finds most, though not all, the expense resulting from the human and political imperatives of an area lacking good empty land, p. 25. Interpellations on D.V.C. relocation costs may be found in the Parliamentary Debates, House of the People, 12 June and 24 July 1952; and 26 June 1953.
8. For material in this section I am indebted to Shri Juganath Misra, deputy commissioner, relocation, Government of Orissa, and to Shri Ramachandran and Shri Pujari, land reclamation and relocation officers, who showed me the sites described.
9. For the issues raised and decisions taken one must go to the minutes of the Hirakud Board of Control.
10. Costs and progress are shown in Government of Orissa, River Valley Development Department, *Hirakud Dam Project, Budget Estimate for the Year 1954-55*, Cuttack.

Chapter 12. COUNTRY IN COMMOTION

1. Quotations are from the English text of Prime Minister Nehru's speech, supplied by the Indian Information Service.
2. The whole engineering task is described in the *Indian Journal of Power and River Valley Development*, Bhakra-Nangal Number, November-December, 1953.
3. *See* S. D. Khungar's remarkable article, 'Planning the Bhakra Dam', in the publication just cited.
4. S. Ajit Singh Kalha, superintending engineer, Hissar, described and appraised the labour co-operatives in a comprehensive note to the Central Board of Irrigation, 1953 meeting, of which he kindly gave me a copy.
5. My source on Lakavalli irrigation plans is a note prepared by Shri K. Krishnaswami, special deputy collector for localization, and Shri I. Sambasiva Rao, special district agricultural officer, Tungabhadra Project, Bellary.
6. The planning reports on the development of irrigation at Tungabhadra ought to share with the Columbia Basin Joint Investigations in the U.S.A. the status of worldwide classics. For the Madras side, they begin with the unfavourable report on soils by R.W.Priestley. A scientific, though not intensive, survey resulted: P. V. Ramiah, *Soil Survey of the Tungabhadra Project Area*, Madras, 1937. The various interrelated problems of getting the water used were canvassed by T. N. S. Raghavan, *Report on Development of Irrigation and General Problems other than Labour*, Madras, 1947; and *Report on Cropping Scheme*, Madras, 1947. For the detailed planning of localization, there was an 'Integrated Survey Report' presenting agricultural, economic, and engineering data for the land under each distributary. More recent agricultural development plans may be followed in the papers of the Tungabhadra Project Development Board, Hyderabad, especially the meeting of 12-13 November 1951, and of the former Rayalaseema Development Board, Madras.
7. *A Popular Account of the Work done at the Agricultural Research Station, Siruguppa*, Madras, undated.
8. C. C. Inglis, *Development of Irrigation in the Deccan Canals*, Technical Paper, No. 49, Bombay Public Works Department, 1934.
9. C. C. Inglis, *Note on Irrigation on the Block System in the Deccan Canal Tracts*, Technical Paper, No. 16, Bombay Public Works Department, 1927.
10. *The Bombay Canal Rules, 1934*, Government of Bombay, 1951.

Chapter 13. EXPLORING THE ELECTRICAL AGE

1. Henry Adams, *The Education of Henry Adams*, Boston, 1927, p. 380. I owe the quotation to C. Herman Pritchett, *The Tennessee Valley Authority*, Chapel Hill, U.S.A., 1943.
2. Committee on the Conservation of Metallurgical Coal, 1949, cited by the Planning Commission, *The First Five-Year Plan*, New Delhi, 1953, pp. 385-8
3. Sudhir Sen, 'Why a Steam Power Station', *Indian Journal of Power and River Valley Development*, October 1952.
4. Technical facts may be found in an attractive inaugural pamphlet, *Bokaro Thermal Power Station*, published by D.V.C. 1953, or in the article by P. K. Bhattacharya, 'Bokaro Power Station', *Indian Journal of Power and River Valley Development*, October 1952.
5. George Kuriyan, *Hydro-Electric Power in India—A Geographical Analysis*, The Indian Geographical Society, Madras, 1948, pp. 28, 30
6. Shri G. Sundaram, chief engineer for electricity, Madras, has told this story many times. *See* his remarks in Government of India, Ministry of Works, Mines and Power, *Proceedings and Report: All-India Power Engineers' Conference*, New Delhi, 1950, pp. 47-8. *See also* the outstanding position of Madras revealed in P.V.S. Ayar, 'A Note on Some Aspects of Planning for Rural Electrification in India', in the same volume.
7. Statement of Shri D. P. Karmarkar, Council of States, 27 March 1953, as reported by P.T.I.
8. For history of electricity in India, *see* Central Water and Power Commission, *Planning for Power Development in India, a Handbook of Information*, 2nd. ed., New Delhi, 1951, pp. 6-16
9. Shri G. Chandy, Mysore Chief Electrical Engineer, supplied a note which has been very helpful in the preparation of this section.
10. From a study made for the U.N. Economic Commission for Asia and the Far East by the Mysore Electricity Department.
11. U.N. Economic Commission for Asia and the Far East, *Techniques for Estimating Future Power Demands*, Bangkok, 1952, pp. 16 ff.
12. From an interview with Sir Mirza Ismail, 1954.

Chapter 14. PERFORMANCE AND PLAN

1. For a complete list, statewise, of all the irrigation and power projects with estimates of cost and benefits, *see* Planning Commission, *Development Schemes in the First Five-Year Plan*, New Delhi, 1952.
2. Newhouse, *Irrigation in Egypt and the Sudan . . .*, cited above in note 1, Ch. 2.
3. Data supplied by the Central Water and Power Commission.
4. These figures are for public utilities alone, excluding generators

installed to serve particular industries. To arrive at the planned hydro-electric installation, I have added the capacities of hydro schemes listed in *Development Schemes in the First Five-Year Plan*.

5. Gulzarilal Nanda, 'A Paradise of Opportunity', commencement address at Roorkee University, 1953.
6. Targets: *The First Five-Year Plan*, p. 351. Achievements: Minister of Planning, Irrigation and Power replying to debate on demands for grants, Lok Sabha, 5 April 1955.
7. For a short account of the technical problems though not the present project; *see CWINC Quinquennial Report*, pp. 120-32.
8. U.N. Economic Commission for Asia and the Far East, *Flood Damage and Flood Control Activities in Asia and the Far East*, Flood Control Series, No. 1, Bangkok, 1950, p. 50
9. *CWINC Quinquennial Report*, pp. 122, 131-2
10. The *Rau Committee Report* is a remarkable instance of a government analyzing past errors without losing perspective.
11. Sir Percival Griffiths, *The British Impact on India*, London, 1952, p. 319
12. Quotations are from pp. 206 and 210, of the *Report, Census of India, 1951*, Vol. I, Part I-A. The 240 lakh tons refer not only to foodgrains, but to the yield of other crops as well, calculated in terms of food-grain equivalents. Italics in the *Report*.
13. *The First Five-Year Plan*, p. 23

Chapter 15. DREAMS NO LONGER

1. I have made this calculation from figures given by the Secretary of the Ministry of Irrigation and Power, Shri T. Sivasankar, in a radio broadcast, 11 May 1955.
2. Data on electric capacity from *U. N. Statistical Yearbook, 1953*; on irrigated areas from U.N. Food and Agriculture Organization, *Yearbook of Food and Agricultural Statistics, 1953*, Pt. 1, Rome, 1954. I have calculated India's share of world electrical output from the *U.N. Monthly Bulletin of Statistics*, April 1955. World figures exclude Russia and mainland China.
3. Information on China is from U.N. Economic Commission for Asia and the Far East, *Economic Survey of Asia and the Far East, 1954*, Bangkok, 1955.
4. In the famous Buck Report on Chinese agriculture. But the *F.A.O. Yearbook* carried a figure of 75,000,000 acres for 1952.
5. Quoted by Louis Fischer, *The Life of Mahatma Gandhi*, London, 1951, p. 330
6. Address at Nangal, 8 July 1954.

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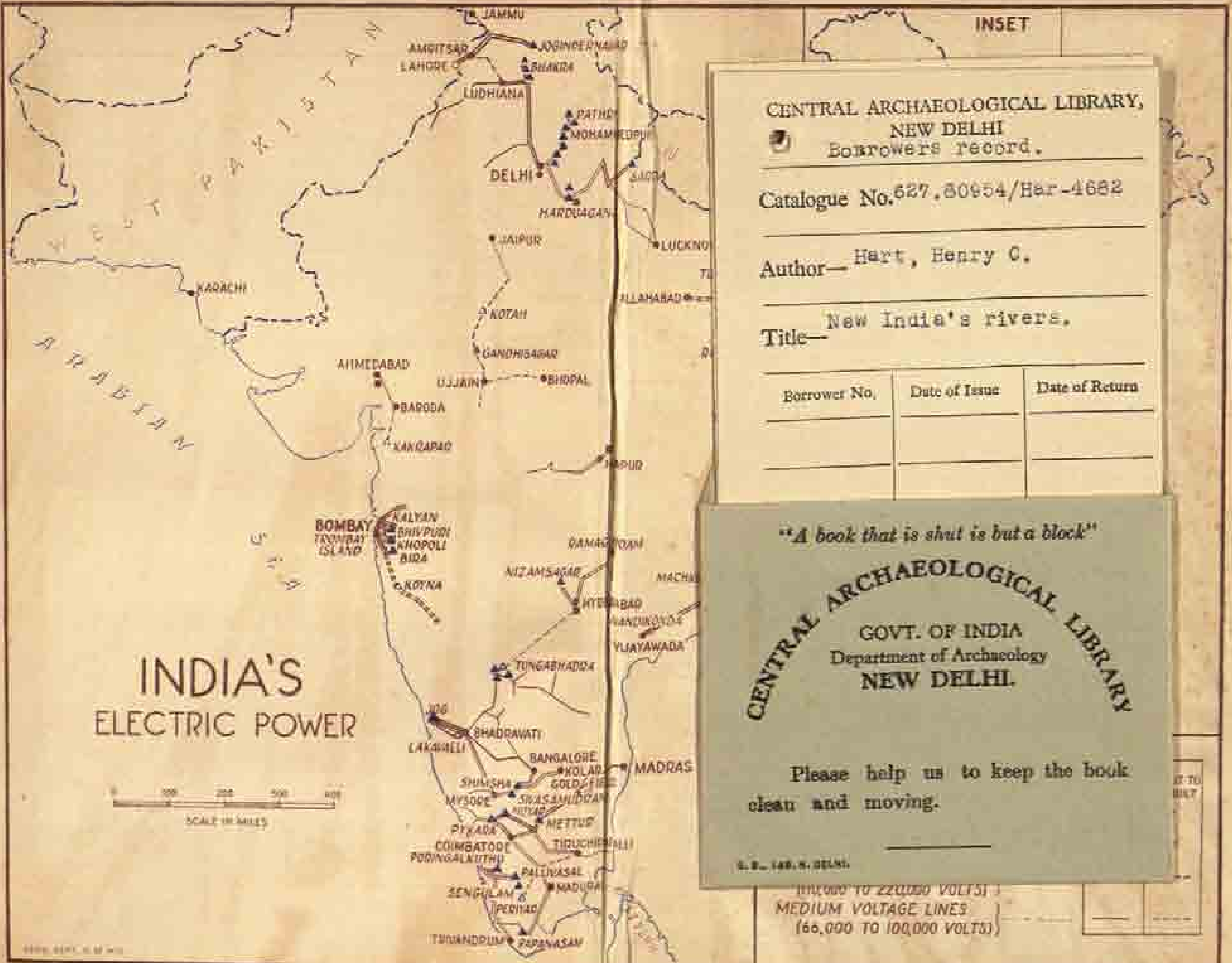
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