
Charles W. Howe
THE EFFECTS OF WATER RESOURCE DEVELOPMENT ON ECONOMIC GROWTH:
THE CONDITIONS FOR SUCCESS

CHARLES W. HOWE*

In the post-war period, the Western World has pursued the issue of water development in the Third World in an often naive manner by trying to transplant technologies, successful in the West, into the social systems of these countries. Any hope for the success of such technological transplants rests upon an impressive array of necessary conditions: (a) that water is, in some sense, the real bottleneck to growth; (b) that capital is available for the water system under development and for related, complementary uses; (c) that institutions capable of managing the technology exist; (d) that the technology fits the social structure and values or that the latter will change to accommodate the technology. Such conditions have existed in relatively few cases. This paper investigates necessary and/or sufficient conditions for successful growth initiation by water projects by dealing both with the conceptual framework and empirical evidence of a case study nature.

WATER RESOURCES AS A BOTTLENECK TO GROWTH

Four conditions, alone or in combination, can cause water to be a bottleneck to the growth process: (a) when water inputs into important production processes are fixed in relation to output; (b) when water supplies are fixed or only capable of slow and/or costly expansion; (c) when supplies are rigidly allocated among uses over time; (d) when water is a controlling factor in human health and productivity.

In the simplest bottleneck, water is a fixed production coefficient of the sort expressed in an input-output model, that is, nothing can be substituted for water nor can increases in efficiency be found to permit production to proceed with less water. Naturally, if such fixed proportion production technologies exist and are confronted with a fixed or increasing cost water supply, production possibilities are limited. The importance of this bottleneck should not be exaggerated however, for in nearly every production process other inputs can be substituted for water. Examples from agriculture would include substitution of labor for water through more frequent and

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better controlled applications, substitution of capital for water by lining canals or using sprinklers, or changing cropping patterns to less water-intensive crops.

A serious bottleneck of an institutional nature is rigid allocation of water among uses. Rigid allocation is especially serious when raw water supplies are fixed or show high marginal development costs, since economic growth typically changes the relative importance of different types of economic activity. The usual shift is a reduction in the relative importance of agriculture, forestry, mining, and fisheries (primary industries) and an increase in the relative importance of manufacturing and transportation (secondary industry), and services (tertiary industry). An inability to reallocate water to the emerging higher-valued uses then forces either costly new source development or precludes further growth.¹

Finally, water can affect basic human well-being and the productivity of labor through impacts on health and the expenditure of human energy to gather water. Scarcity of water and lack of collection and distribution systems can lead to extraordinary consumption of time and energy in gathering daily water needs.² It is less clear under what conditions an improvement in potable water supply will lead to a significant improvement in health.

From a quantity point of view, there is little doubt that increases of supply up to, say, 50 liters per day per capita will improve health and well-being through direct consumption, bathing, and food preparation. From the quality viewpoint, a supply free from pathogens and parasites will be a great help, provided: (a) the supply is reliable; (b) the people continuously use the new supply without returning to traditional contaminated sources; and (c) other sources of exposure to the same contaminants don’t simultaneously exist, i.e., contact with irrigation or laundry water.

A SKETCH OF DIRECT GROWTH IMPACTS OF WATER

When water is a bottleneck to the continued growth of economic activity, the provision of either more water, better controlled water, or better quality water constitutes a necessary condition for economic growth. There is no guarantee, however, that such a provision will be sufficient to initiate further growth. It will be useful here to attempt to relate water to different types of economic activity in

greater detail, in terms of the likelihood that it is a bottleneck to continued growth. Our estimates of these qualitative relationships are exhibited in Table 1. This table is an intuitive summary of a large literature on the water use technologies and location decisions of various industries and human activities.3

TABLE 1

The Direct Importance of Water Services to the Support of Primary, Secondary, and Tertiary Economic Activities and Population

<table>
<thead>
<tr>
<th></th>
<th>Agriculture, Forestry, Fisheries, Mining</th>
<th>Manufacturing and Transportation</th>
<th>Services*</th>
<th>Population</th>
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<tr>
<td></td>
<td>macro</td>
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<td>irrigation/drainage</td>
<td>X</td>
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<td>navigation</td>
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<tr>
<td>hydro electric powers</td>
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<tr>
<td>waste disposal</td>
<td>X</td>
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</tr>
<tr>
<td>water quality</td>
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<tr>
<td>municipal supply</td>
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<td></td>
</tr>
<tr>
<td>flood control</td>
<td>X</td>
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</tbody>
</table>

*Including recreation.

A reliable and well controlled water supply is important to irrigated agriculture. To some extent, this stems from a fixed requirement between plant growth and water. This relationship weakens, however, as we move our attention from the plant root zone to the farm headgate.5 Agriculture is a heavy consumptive user of water, so where irrigation is required there is no doubt that either a physical limit on water or rigid allocation of water to a fixed set of uses can prevent further expansion of agriculture and its adaptation to changing commodity values.

Drainage is mentioned along with irrigation since adequate


4. The “macro” category in the table refers to whether or not the availability of a particular service will, with high probability, affect the basic economic viability of an activity and its choices of major regional location, e.g., in the southwestern United States, Mississippi Valley, or Gulf Coast region. The “micro” category refers to whether or not the particular service will, with high probability, affect the intraregional location decision of the activity, e.g., in the flood plain or out, within a particular metropolitan area or not.

5. Experimental work in the United States and Israel in cotton and wheat shows that reductions in water application below quantities dictated by rules of thumb frequently improve the value of the product if not its quantity.
drainage of the root zone is required for viable long term agriculture. Many of the problems commonly perceived as water shortage are in fact the result of poor drainage caused either by inappropriate soil types, lack of natural or man made drainage, or poor leaching practices. For example, a recent study concluded that it is not water which is preventing agricultural self-sufficiency of the Middle East but the poor practices followed regarding erosion, overgrazing, and especially drainage.\(^6\)

Navigation, especially inland transport which relies upon or competes with river control for other purposes, typically has many substitutes. With modern technology providing substitute technologies, inland navigation is usually not considered vital to any economic activity. However, it can provide very low cost transport for bulky commodities where natural conditions permit navigation without serious interference with other water services including electricity generation, irrigation, and water quality management.

Waste disposal is a valuable service provided by rivers, lakes, bays, and estuaries. The water environment has an assimilative capacity for various types of wastes which can beneficially be utilized; this is not a fixed quantity since it depends upon the other uses of water. The chemical, food processing, and paper industries historically have been heavy producers of pollution, thus their location decisions have been heavily influenced by adequacy of intake water and availability of adequate receiving waters for waste discharge. Technology has greatly reduced the waste loads of these industries, altering siting considerations. The reduction was induced, in part, by higher water quality standards and recognition that many "wastes" have value when recovered. Nonetheless, it remains true that costs of industrial waste reduction increase sharply as the percentage reduction becomes high. Thus, the assimilative capacity of water bodies remains a valuable resource.

Agriculture has been recognized in recent years as an important source of pollution. In some irrigated areas, nitrate pollution of groundwater supplies has made the groundwater unusable for human consumption. Nutrients contained in runoff from fields and particularly feed lots have accelerated eutrophication of streams and lakes. Restrictions are increasingly being placed on agricultural waste loads, thus affecting location decisions.

The other side of the coin is water quality. Degradation of water quality can adversely affect various water uses, especially fisheries,

recreation, and general esthetic values. Economical water quality management thus becomes a matter of finding the appropriate trade-offs between waste treatment, waste disposal, and these other valuable water services.

The provision of central municipal supplies can be important to manufacturing, services, and the capability of supporting population. Heavy water using industries often find it worthwhile to develop their own water supplies, but when the size of the plant is not large or when the development of water supply requires large scale projects to be economical, the availability of sufficient water from municipal systems can determine the feasibility of a particular industrial location.

The availability of municipal supplies at reasonable costs certainly can determine the population carrying capacity of a region. While the quantities of water needed for human existence are small, as living standards rise the amount desired for sanitation, bathing, laundry, and garden uses increases. High water costs can, therefore, impair the attractiveness of a region.

At the micro level, the provision of water and sewerage can be used to shape patterns of urban growth. When costs of private water supply development and sewage disposal are high, homes and businesses will be built only where these services are provided by a central agency. Some regional planners have recommended that water and sewerage services be used as an important growth control tool. The need for such tools depends, of course, on the type of economic system. In the United States, recent court decisions have ruled that such uses of water services are illegal.

The difficulties of technology transfer to developing countries have nowhere been better illustrated than in village water supply programs. The World Health Organization and various national aid agencies have traditionally required high technical and sanitary standards for village supply systems to which they have contributed. As a result, overly capital-intensive technologies, which cannot be properly operated in a remote village setting, have failed to develop reliable supplies and, through the capital constraints, have deprived other villages of water supply improvements.7

Finally, flooding is a major problem in some regions. The presence of topographic variation and the feasibility of local flood control measures make it unlikely that the macro location of agriculture, industry, and services will be strongly affected. However, micro loca-

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tion decisions and the composition of agriculture are strongly af-
fected by flood risk. Field crops are grown in the flood plain, but a
reduction of flood risk frequently leads to more valuable crops, fruits
as an example, being grown there. It remains true, however, that
human reaction to flood risk contains a great deal of irrationality so
that public programs of information are called for.

CASE STUDY SUMMARIES

This section gives brief sketches of water development projects
which can be broadly classified as successful or unsuccessful in terms
of their own productivity or in terms of desirable secondary effects.
The few cases presented are meant to illustrate some of the situations
presented in Table 1. For each case, one or more tentative conclu-
sions will be presented. The cases themselves are drawn from coun-
tries at all stages of economic development.8

Irrigation Projects

A. The Mwea Irrigation Settlement—Kenya9

This is a highly successful rice irrigation scheme, located about 60
miles northeast of Nairobi at an altitude of 3800 feet and just south
of the equator. Annual rainfall varies from 23 to 64 inches per year.
Soils consist of freely draining red lateritic clay loams and impervious
black cotton clays, underlain by murram and volcanic tuff. Only the
black cotton soils are now being irrigated. A small pilot plot was
started in 1951 and the decision to construct the main scheme was
precipitated in 1954 partly by a desire to settle detainees during the
"Mau Mau" emergency.

The settlement has a potential of about 13,000 irrigated acres
which has been developed since 1954 in stages of 2000 to 3000
acres. Emphasis has been given to bringing each stage up to full
production potential before initiating further expansion. In addition
to irrigated rice, tenants grow about 800 acres of cotton and sub-
sistence crops. Most tenants come from nearby Kirinyaga District
from closely knit Kikuyu society. Approximately 30,000 persons
occupy the 32 settlement villages which were built to house the
tenants. The only requirement for admission is landlessness and the
only requirement for remaining is satisfactory performance. Only

8. See also C. Howe, The Effect of Water Resource Development on Economic Growth
9. The basic source of the information on Mwea is J. J. Veen who was, in January 1972,
resident Manager of the Mwea Project for the National Irrigation Board. Personal visits over
the period 1964-1972 provided additional insights.
110 tenants were evicted during 1961-70, a small number relative to the 2600 current tenants.

No tenants had any previous experience in rice growing. Each tenant has a basic plot of four acres, one-eighth acre of which is permanent nursery, all rice being transplanted. The land is cultivated mechanically by tractors provided by the Scheme. Transplanting, weeding, reaping, threshing, and winnowing are carried out by the tenants, often supplemented by hired labor. The Scheme collects the bagged paddy, dries it, and mills it.

Tenants are charged a water rate of about $28 per acre to cover maintenance of structures and works. Mechanical cultivation, spraying teams, fertilizer, seed, and bags are available and charged against the value of the tenant’s crop which is sold only to the Scheme, with the exception of small quantities retained for home use. Housing loans are provided for repayment over 5 years, and the Scheme has successfully controlled malaria and bilharzia.

Mwea clearly has been highly successful. The success can be attributed in part to the following features of the project: (a) development of previously unoccupied land; (b) recruitment from tribally related peoples; (c) strict discipline over inputs, cultivation, pest control, timing of irrigation and harvest; (d) excellent water control because of centralized, well engineered land leveling and building of bunds, canals, drains, etc.; (e) (in recent years) protection of the domestic market for rice.

B. The Rio Fuerte River Basin Commission: Mexico\(^1\)

The progress of irrigated agriculture in Northwestern Mexico constitutes what is probably the greatest achievement in Mexican agriculture since 1945. The Fuerte Commission was established in 1951 along the same lines as the other Mexican Commissions, charged with integrated basin development. The river, at 4.5 million acre feet annually, is the largest in the Northwest. However, it is one of the most variable, draining an area of about 12,000 square miles. The Commission has confined itself to irrigation development and flood control in the lower parts of the basin in contrast to the widely varied activities of the other Commissions.

The originally irrigated lands were expropriated from the United Sugar Company in 1938 when the land was turned over to small holder collectives, ejidal lands. The Commission has expanded the irrigated acreage to 230,000 hectares, about half of which is ejidal

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land and half privately owned. The Miguel Hidalgo Dam provides water and power, and the area around the chief town of Los Mochis has attracted cotton ginneries and other processing and service industries. A railroad to the area from the north has promoted the export of winter vegetables to the United States. These valuable but risky export crops are grown by the larger private land owners because of the risk averting behavior of the small farmers.

A major reason for the success of this program is that the Rio Fuerte Commission took the initiative to provide a package of needed inputs: water, water delivery systems, land leveling, roads, and marketing facilities. If any national ministry failed to perform its tasks, the Commission was able to do the work itself. This high degree of coordination among inputs has been a major contributing factor.

C. The Impact of Irrigation on Regional Growth: Sonora, Mexico

Crosson has studied the relationship between the growth of agriculture and that of urban activities in the Yaqui and Mayo Valleys and Ciudad Obregon, Sonora, Mexico. In his theoretical formulation of the relationship, Crosson isolates four effects of expanded irrigation: a productivity effect which, by making new technologies possible, increases the potential productivity of local resources; an input-output effect of generating more varied and extensive demands for agricultural inputs; an income effect as recipients of increased income demand more consumer goods and services; a potential processing effect or forward-linkage which may attract firms to the area to process the primary products of agriculture. He points out that these effects will not develop fully unless the right resources are free to flow into the area. For mixed economies, this reemphasizes the importance of the responsiveness of private investment to public investment undertakings.

By 1950, most opportunities for expansion of private irrigation had been exhausted. Two very large public irrigation districts were formed in the Yaqui and Mayo Rivers and came into operation in 1951. A third district was established in 1953 to control the use of groundwater around Hermosillo. These districts increased irrigated land to 544,000 hectares by 1960. Agricultural technology continued to advance rapidly, with heavy technical service inputs from the United States and extensive public investments in rail, highway,
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and port facilities. The introduction of high-yield varieties of maize and wheat played an important role. Furthermore, farm price, credit, and foreign trade policies were used to reinforce the favorable climate. The completeness of the package of public, private, and policy inputs was unusual and resulted in rapid expansion of agriculture and directly related enterprises.

Howe and Oyarzabal, in a private report to the World Bank relating to the same region, noted the frequency with which strong risk-averting behavior is observed in the Rio Mayo District of Mexico, a factor which water planning must take into account. Farmers in the District have an option of growing one cotton crop per year or a two crop soya-wheat rotation. The average profit over time per hectare of cotton is 6000 pesos, while the average for soya-wheat is 4000 pesos. Many of the farmers choose the latter because of the risk which arises with cotton’s long maturation period which sometimes carries the harvest over into the rainy season with possible loss of part of the crop. Thus, both the farmers and society give up a very substantial value to avoid the volatility of private incomes from cotton.

D. Water Management in a Rapidly Changing Region: Central Arizona, U.S.A.

Kelso, Martin, and Mack have carefully studied the extent to which water constrains the continued growth of the economy of the State of Arizona. That State has been one of the most rapidly growing ones in the U.S., with government, finance, insurance, public utilities, wholesale and retail trade, and services leading the growth. Farms and mining have fallen from 28.4% of personal income in 1929 to 6.7% in 1970, although the absolute volumes have risen slightly. All surface water supplies available to the State are over committed with the exception of one million acre-feet of Colorado River water which is being developed through joint federal-state projects. Underground water is being used at a rate far in excess of recharge and water tables have fallen as much as 125 feet from pre-World War II levels.

The analysis was carried out using a sophisticated set of alternative economic projections, input-output models, and linear programming representations of the agricultural sector. The major findings of the study are: (a) water is an economically scarce commodity but not so physically scarce as to threaten the State’s economy; (b) much of the scarce water supply is, through water law and location, locked into uses of very low marginal value in terms of incomes directly and

12. Kelso, Martin & Mack, Note 1, supra.
indirectly generated; (c) curtailment of these low-valued uses would have very modest negative effects on the state's economy; (d) the reallocation of existing water supplies from such uses to the emerging higher valued uses would release the growth of the Arizona economy from all restraints by water well into the next century. This provides an excellent example of the importance of reallocation of water over time in water short regions.

Drainage

E. The Middle East

Clawson, Landsberg, and Alexander have studied the factors constraining agricultural output in Egypt, Lebanon, Jordan, Syria, Iraq, and Saudi Arabia. They concluded that the potential of the agricultural resources of the region is such as to permit these countries in one generation to escape the circle of rural poverty. Major parts of the region, the Nile Valley, the Mesopotamian Plain, and the hill country, were all garden spots historically. Much of the area is now decayed from soil erosion, overgrazing, poor drainage, and incredible accumulations of soluble salts. Yields are a meagre 10 bushels per acre in alternate years in much of the area. Areas of similar climate and soil characteristics in other parts of the world have yields many times higher. Livestock, too, is very unproductive due to disease and overgrazing.

Clawson points to two popularly held opinions about the area: (1) that the agricultural productivity of the area has been forever lost or, in Egypt, has reached its limits; (2) that water is the factor which is missing and which could restore the productivity of the area and expand its boundaries. Clawson and his colleagues find both to be myths. They estimate that, with appropriate farm technology and freed from institutional rigidities, in 20 to 30 years agricultural outputs could be doubled in Egypt, increased tenfold in Iraq, and expanded significantly in the other parts of the region, Israel excepted.

They found that water alone is not the key to this expansion, but that a package of inputs and programs must be supplied. Among the inputs are appropriate soils; they found soil more scarce than water. Drainage is basic, especially for Iraq and Egypt. Programs of laying drains and flushing out the soils are critical; disposal of the resulting brines and maintenance of the drains pose problems. In Egypt, they found that yields could be increased 50% and that shifting from

13. Id. at 26-27.
ditches to underground drains would free enough land surface to pay for the drainage program over time.

Overall, they found that drainage, land leveling, moisture conservation on rainfed lands, crop rotation, fertilizer, improved crop varieties, and weed control are more important factors than water. Water appears not to be the bottleneck to agricultural production. Increased water supply is neither necessary nor sufficient for further agricultural growth in this particular setting.

River Navigation

F. The Arkansas River, U.S.A.

The McClellan-Kerr Arkansas River Navigation System is one of the largest public water system developments in the United States. The navigation features of the project have cost $1.2 billion and involve a canalized passage 10 miles up the White River from the Mississippi, 9 miles through a canal to the Arkansas River, 280 miles of channel up the Arkansas to Muskogee, Oklahoma, and 50 miles up the Verdigris River to the outskirts of Tulsa, including many locks and dams. Belzung and Sonstegaard have studied the impact of this huge navigation investment on the region through which it passes. They point out that benefits of the project in this mixed-economy case depend entirely on private sector responses in providing transport facilities, ports, and the establishment of new types of waterway-using activities. The authors of that study conclude:

At this point, there does not appear to be any indication that the Region is on the threshold of a substantial surge of development; but the Waterway provides a significant improvement in the Region’s transportation system which may, in the future, be the focal point of economic expansion in the Arkansas-Verdigris Region.

Three score (60) or more new—or relatively new—facilities have been constructed in and around the port areas; but the point to be emphasized here is that these new developments are mostly changes in location of existing plants, they are relatively small by most standards, and very few of the new plants are really water transportation oriented. ... Unquestionably, there is reason at this time for some degree of pessimism for the long run...

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16. Id. at 1, 38 (emphasis added).
Hydro-Electric Generation

G. The Owen Falls Hydro-Electric Project: Uganda

The Owen Falls Dam is a single purpose hydro-electric project built across the Nile at Jinja, just a few miles from Lake Victoria which acts as the dam’s reservoir. Currently installed capacity is 150 MW. Interestingly, the idea of the dam was initiated by Churchill after an African journey in 1905, but the years through World War II saw practically no capital expenditures except for the railroad extension in Uganda from Kenya.

When the decision to build the dam was made in 1947, it was thought that an enhanced supply of electricity would be a sufficient condition to bring rapid industrial development. The press spoke of Jinja’s becoming “the Detroit of Central Africa,” and the postwar Worthington Plan noted that “experience with electricity in other parts of the world has nearly always shown that the most optimistic estimates of consumption have been greatly exceeded soon after the provision of a reliable and cheap supply.”

Electricity demand grew, but not nearly as rapidly as expected, and new customers were not of the types nor in the locations expected. Industry in Jinja and Kampala never materialized, while small scattered consumers predominated. The settlement pattern in Uganda caused problems because of the absence of nucleated villages, and an extensive distribution network had to be built.

Other steps to encourage industrial development were not included in the 1947 Development Plan, and several years passed before the Uganda Development Corporation was set up to co-sponsor projects with private firms. The efforts of the Corporation were not very successful, and it wasn’t until 1956 that the first major industrial customer—a textile mill—came on line. A copper smelter was established in Jinja in 1957 and remains the largest single customer.

A further step to promote industrial development was the creation of an industrial estate in Jinja. Rail sidings, access roads, offices, shops, and flats were provided. At the height of the construction phase, the labor force reached 2500 Africans, 200 Europeans, and 123 Asians, and future prosperity was assumed to be assured. Once construction of the dam and industrial estate were completed in 1954, however, the labor force fell rapidly, the buildings were left

empty or leased for storage rather than manufacturing, and the roads deteriorated.

The small industries which did comprise the bulk of Uganda’s growth were not power oriented and were widely dispersed, partly because the Electricity Board’s uniform tariff provided no incentive to locate in groups or near the source of supply. When consumption failed to grow as expected, the Electricity Board entered into a 50 year supply agreement with Kenya on terms extremely favorable to Kenya.

It is clear from this experience that hydro-electric power is not a sufficient condition for inducing industrial development.

H. The Grijalva River Basin Commission: Mexico

In 1951, a Commission for the integrated development of the Grijalva and Usamacinta River Basins in southeastern Mexico was created. The combined runoffs of the rivers of the basin constitute nearly a third of Mexico’s total runoff. The Commission started planning and road building in 1953, deciding to build the very large Malpaso Dam. Work started in 1958. The main activities have been to promote extensive resettlement from the central highlands as part of an overall government attack on the increasing concentration of population around Mexico City and other urban centers. The colonization schemes aim at settling 1000 families per year at a cost of about $7500 per family but are experiencing difficulties in transplanting people from highland areas to tropical Gulf Coast.

Overall, 15 years of heavy expenditure have had limited effects both on the region and on the national objective of decentralizing economic activity and population. Aluminum and petro-chemical industries have been established along the coast, attracted by ocean transport and cheap power, but no labor intensive industry has been established and little in-migration has been induced. Barkin and King19 conclude that there has been a great deal of waste of resources from an economic viewpoint.

I. Hydro-Electric Power and Industrial Location: Canada

Schramm has studied the effects of low-cost hydro-power on industrial location in British Columbia.20 He states:

Past experience shows that the availability of low-cost hydro power can significantly affect the locational decisions of power intensive

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industries. In the United States, the developments of the Tennessee Valley Authority in the southeast and the Bonneville Power Administration in the northwest have led to large-scale settlements of such industries in areas which, with the exception of low-cost energy, generally offered neither suitable local raw material sources nor nearby markets. . . . The almost exclusive raison d'être for Canada's and Norway's large, export oriented electro-metallurgical and chemical industries are favorable hydro power sources in close vicinity to tidewater locations.

Again, as in the preceding case, we observe the importance of power and ocean transport together.

Multiple Purpose Projects

J. The Lake Volta Project: Ghana

In the late 1940's, Britain sought a source of aluminum within the sterling area. Gold Coast, with bauxite and excellent sites for hydro-electric and port development, seemed a good candidate. The development would entail a major dam, the lake of which would cover 3275 square miles or 1/30 of the surface of the country; the largest new port in Africa; an alumina factory and aluminum smelter; a major new township; extensive infrastructure; and the resettlement of approximately 80,000 persons.

In 1952, a Preparatory Commission was set up for very careful planning of the project, with heavy emphasis on the human factor. The guiding principles of the Commission were (a) to prevent any in-migration to the areas to be inundated; (b) that all displaced persons should be made as well off as they were before; and (c) that resettlement should be accomplished through self-help after compensation for properties lost.

The Commission's planning work was completed in 1955, but financing negotiations stalled, partly because of political complications surrounding independence. The momentum of coordinated planning was lost. In 1961 when construction finally began, engineering work proceeded splendidly, being completed in three and one quarter years instead of the planned four and one half, at a cost saving of $40 million.

The resettlement program, however, was never fully pulled together and had to undertake a crash program to handle 80,000 people. Sights were raised and self-help forgotten; houses and villages

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22. The world was nervous about big products at that time because of the disastrous results of the groundnut scheme in Tanganyika.
were to be planned and modern; agriculture was to be cooperative, intensive, and mechanized; and intensive animal culture was to be introduced.

In spite of the rush, quite amazing feats had been accomplished by the end of 1964: 2000 miles of lake boundary had been marked; a rough social survey of 80,000 persons had been carried out; 14,000 acres of land had been cleared; 52 settlement sites had been negotiated; 500 miles of laterite road had been placed; 11,000 core houses had been built; and 10,000 families had been peacefully evacuated.

Equally impressive problems were created: resettlement sites had been poorly selected and were resisted by traditional occupants of the areas after the more liberal military government assumed power; housing styles were not liked by many people; water supplies were notoriously bad; the agricultural program fell far behind schedule, so that land was not available for most of the people; mechanization proved impossible because of lack of upkeep and trained personnel; the concept of cooperative agriculture was foreign, and when the mechanical cooperatives started to charge farmers for their services, most farmers opted out; and the livestock programs ran into terrible disease problems.

The total resettlement costs through 1971 totaled a very approximate $40 million. The following observations can be made: (a) The welfare approach to resettlement which replaced the self-help approach diverted resources into housing and infrastructure which could have been provided by the people themselves at much lower cost. The emphasis should have been on provision of more directly productive assets. "Economic success makes welfare possible, not the other way round." (b) Too much new development and economic change were attempted under the strain of relocation. (c) Under the enthusiasm for broad economic and social change, objective economic and social analyses of agriculture and infrastructure were not undertaken. Partly as a result, totally non-viable sub-schemes were undertaken. (d) Subsequent events have shown that the human, ecological, and physical dynamics of a large project are partly unpredictable, suggesting that resources must be provided for continuing monitoring and research on the project after it is in place.

K. The Mexican Integrated River Basin Experience: A Summary

In summing up the river basin experience of Mexico, it can be said that the attempts at integrated basin development in the isolated tropical basins of Papaloapan and Grijalvas have largely been failures,
while the more specialized development efforts in the arid areas of Tepalcatepec-Balsas and Fuerte have been moderately to highly successful when judged from the multiple-objective viewpoint of Mexico's development policy.

An interesting aspect of the integrated river basin development strategy is that it has centered solely on the development of the natural resources of each basin. Government has not provided incentives for other types of enterprise to locate there. As a result, few new activities other than those processing the agricultural outputs have settled in the basins. Private sector resources have not been attracted to the areas. When private response is low, the returns to public investment in terms of national objectives are greatly reduced.

CONCLUSIONS

The foregoing conceptual and empirical materials certainly have not led to a final understanding of the water-economic growth relationship. However, some observations have kept reappearing in different settings, giving some confidence that they could be used as guides to future policy formulation. These observations may be summarized:

1. The relative importance of the various services provided by water will change as economic growth takes place. This changing role of water is clearly shown in Kelso's study of Arizona and implies that economic growth can be accommodated, often in large part, by a reallocation of existing water supplies. The other side of this coin is that institutional arrangements (water laws, lack of clear jurisdiction over water, absence of markets for the sale of rights to water) can stifle economic growth if they lock water into uses which are of diminishing value to the economy.

2. Water development has its greatest impact in the earlier stages of regional economic growth because of the importance of agriculture in the industry mix. Often later growth can then be accommodated through reallocation to new higher valued uses. The Mexican river basin experience also suggests that more specialized agricultural development efforts are more likely to be successful growth initiators than attempts at integrated basin development.

3. The provision of a whole package of the requisite complementary inputs, while rarely observed in practice, can result in high productivity and growth effects. Irrigation is clearly a necessary but not sufficient condition for the initiation of growth of arid and semi-arid zone agriculture.

4. In mixed economies, private sector investment response to
public water project investment is a critical factor in determining total social returns. Most of the Mexican river basin developments failed to generate self sustaining growth because of a failure to attract any but the most basic processing industries.

5. The availability of lower cost hydro-electric power is a strong attraction to the power intensive metallurgical and chemical industries, especially in combination with tidewater location. While undeveloped hydro-electric sites are increasingly scarce and remote, this advantage is likely to increase in the future. Past examples of successful development include Ghana, Canada, Norway, and the Papaloapan and Balsas Basins in Mexico, the Columbia, Ohio, and Tennessee River Basins in the United States.

6. In more advanced economies, water development is likely to affect the micro-location decisions of nonagricultural economic activities but not the macro-location decisions. This is partly due to the small proportion of total production costs usually represented by water.

7. Even the best predictions of a large water project’s impacts on the economy and society contain sufficient uncertainty about ensuing events that provision of resources for continued monitoring and *ex post* assessment is warranted.