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Indirect Economic Impacts of Dams

Case Studies from India, Egypt and Brazil

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6 Bhakra Multipurpose Dam System, India

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Introduction and Overview

The Bhakra dam system in the northern part of India has contributed significantly to increases in irrigated area and the output of agricultural commodities and electricity over the last 40 years. These increases have inevitably generated downstream growth in many other sectors both in the regional economy as well as in other parts of the country. This chapter focuses on the indirect economic impacts of the Bhakra dam system and the subset of social impacts linked with changes in household expenditure, income, and its distribution. It considers as direct all economic impacts descending from the construction of the dam, the water stored and other services provided by the structure, and changes in flow regimes—regardless of whether these impacts were initially planned. Indirect and induced impacts are those that stem from the linkages between the direct consequences of the dam project with the rest of the economy. Among them are impacts due to changes in output and input use in sectors other than those affected directly by the dam, or changes in relative prices, employment and factor wages. The indirect and induced impacts have been estimated in terms of a multiplier value. As already discussed, multipliers are summary measures expressed as a ratio of the total effects (direct and indirect) of a dam project to its direct effects.

Apart from estimating multipliers, the models used in the study explicitly consider income distribution by disaggregating households into various income categories. The impact of the dam system is explicitly considered on the changes in income levels of landless workers, agricultural labour, self-employed farm households and urban households.

The material presented in this Chapter is organised as follows. We first present some salient features of the Bhakra dam system and its major outputs and impacts. This is followed by the approach and methodology used for the multiplier analysis. The estimates of multiplier values for the project multiplier are discussed next followed by a brief discussion of the multiplier effects of the Bhakra dam outside the project region. The social and environmental aspects of the Bhakra dam are presented next followed by the conclusions on the multiplier effects of the dam.

The Bhakra Dam System

The Bhakra Nangal Project, located in North-West India, is a multipurpose river valley project encompassing the three eastern flowing rivers—Sutlej, Beas and Ravi—as well as the Yamuna. The project is a splendid example not only of Integrated Water Resources Management (IWRM), as the project was planned not only on a basin level but also included inter-basin transfer of water from surplus basins to deficit basins. It is also a splendid example of inter-State cooperation between the states of Punjab, Haryana, Rajasthan and Jammu & Kashmir on sharing of water. The Bhakra Nangal Project thus, is inseparably interwoven with this grand integrated project of water management, known earlier as Bhakra-Beas-Rajasthan project, which was subsequently called the Master Plan for harnessing the waters of the Sutlej, Beas and Ravi. The Master Plan, envisaged as under;

1. The three rivers will be developed as an integrated unit and in addition will be integrated with the Yamuna river in so far as the Narwana branch of the Bhakra main line canal allows Sutlej waters to be used in the Western Yamuna canal areas.
2. Storage dam at Bhakra on the Sutlej to meet the needs of erstwhile Punjab via diversion at Nangal, Ropar and Harike with a small portion going to Rajasthan.
3. In order to fill the Bhakra reservoir in view of the heavy demands upon it from erstwhile Punjab and Rajasthan, Beas water will be diverted into the Sutlej via a high level canal and two tunnels between the Beas and Pandoh and the Bhakra reservoir (Beas-Sutlej link).

4. The remainder of the Beas water will continue to flow into the Pong reservoir to be released as required at Harike. Thus, the main burden of the Rajasthan canal component would be covered by Pong reservoir in Beas.
5. Harike also benefited from the Ravi-Beas link canal built in 1952-1954 from Madhopur headworks to Chakki tributary of the Beas. Ultimately the dam would be built upstream of Madhopur on the Ravi.

The process of integrated development has been carried out in a phased manner from 1954. As part of this process the Bhakra dam was the first to be built, which was completed in 1963. The Pong dam was completed in 1974 and the Beas-Sutlej link was completed in 1977. With the completion of the Ranjit Sagar dam recently the integrated master plan has been completed (See Figures 6.1 and 6.2).

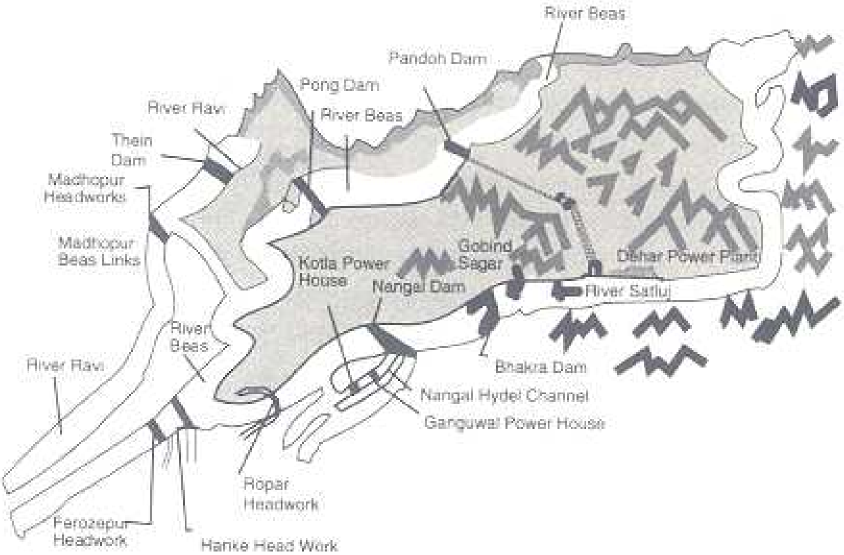
Bhakra Dam was described by the first Prime Minister of India Jawahar Lal Nehru as the "temple of resurgent India." The construction of the Bhakra dam system, resulted in a very significant increase in the gross irrigated area, output of agricultural commodities and generation of hydro-electricity. In addition to these direct economic impacts, the Bhakra system induced several indirect economic impacts. These direct and indirect economic impacts transformed the economy of the Punjab-Haryana region resulting in a significant reduction in the incidence of poverty in this part of the country. Higher output and consequently a higher level of marketable surplus of foodgrains in the Punjab-Haryana region made it possible to provide these foodgrains to the urban poor at affordable prices even in far away regions of the country. Increased demand for labour in agricultural and non-agricultural activities provided jobs and substantially higher incomes to migrant workers from such far off places as Bihar and Uttar Pradesh. The remittances by these migrant workers to their families back home helped contribute to the development of poorer regions of the country.

The Bhakra dam, completed in 1963, is a 225.55-meter (740 feet) high straight concrete dam. The lake created by the dam is 162.48 square km in area with a gross storage of 9340 million cum. The Nangal Dam, situated about 13 kms downstream of the Bhakra dam, is 29 metres (95 feet) high and comprises 26 bays of 9.14 metres (30 feet)

Figure 6.1

The Master Plan for Development of Water Resources

A. Satluj Beas Ravi Development Master Plan



each. It is designed to pass a flood of 10000 cumecs (350000 cusecs). The dam diverts the water of the river Sutlej into the Nangal Hydel Channel and Anandpur Sahib Hydel Channel for power generation and irrigation purposes. The Nangal pond acts as a balancing reservoir to smoothen out the diurnal variation in releases from the Bhakra Power Plants. The Nangal barrage provides the headwork for the 414 cumecs Nangal hydel channel with hydro stations at two falls at Ganguwal and Kotla with a combined installed capacity of 154 MW. The Bhakra main canal (360 cumecs) takes off from the Ropar headwork, 60 kms from Nangal Dam to irrigate large tracts and firm up supplies to some older systems. The Beas Project I comprises a diversion dam at Pandoh, several hydel channels, tunnels, control works, a balancing reservoir and Dehar power plant while the Beas Project unit II comprises the Pong dam, tunnels, spillways and Pong power plant. The salient features of the Bhakra dam system are given in Table 6.1.

The Bhakra dam and its various components were constructed at different stages over a number of years. At prices prevailing in the early

B. River Sutlej, Beas, Ravi and Connected Main Canals

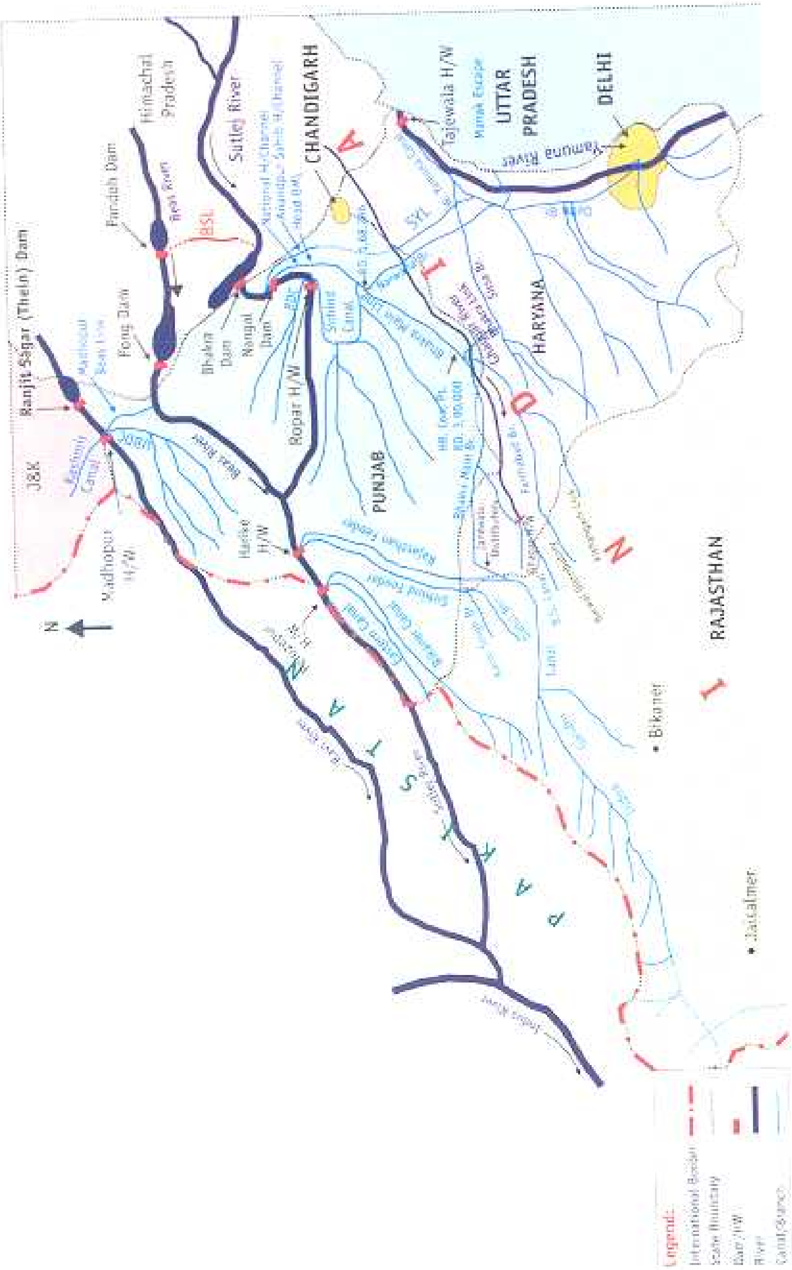
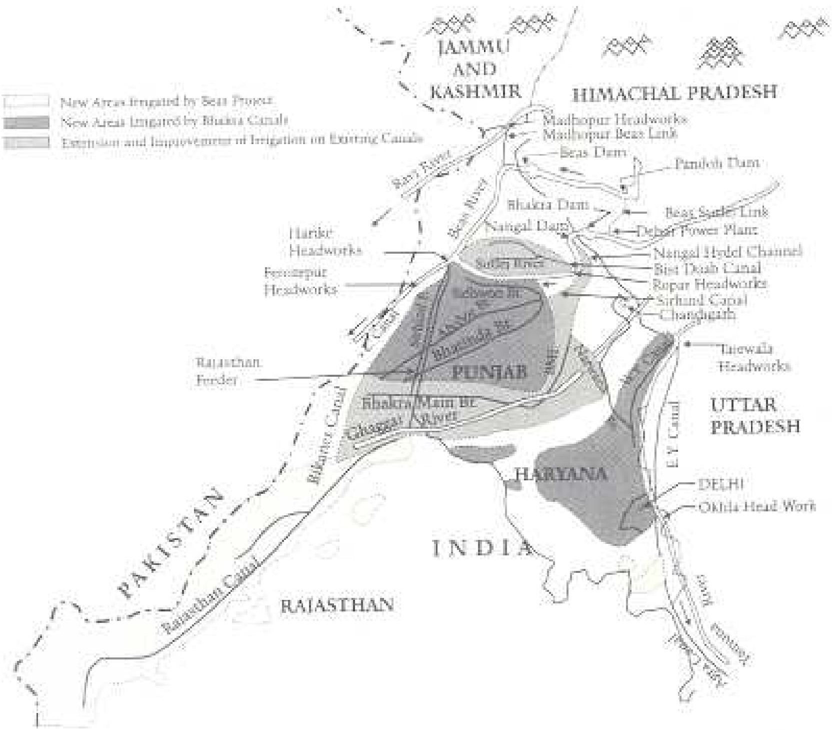


Figure 6.2

The Bhakra-Beas System



1950s, the estimated cost of the Bhakra and Nangal dams with canal systems was Rs. 2426 million (Table 6.2). At the time of its construction in 1967-68, the Bhakra right bank power house cost Rs. 983 million. The upgradation of the turbines in 1980-81 to add 150 MW capacity involved an additional expenditure of Rs. 100 million. A sum of Rs. 4492 million was spent on the construction of the Beas-Sutlej link project in 1976-77 while the construction of the Pong Dam cost another Rs. 3259 million. This totals to not more than about Rs. 11260 million at prices prevailing in those years when these investments were made (Table 6.2).[1] The capital cost of the entire Bhakra system at current prices (2001-02) is estimated at Rs. 123,478 million or US$ 2,680 million.

1 These are sum of undiscounted costs at the then prevailing prices.

Table 6.1

Bhakra-Nangal-Beas Project: Salient Features

	Bhakra Dam	*Nangal Dam*	*Beas Unit I-Pandoh Dam-DeharPower Plant*	*Beas Unit II*
Type of Dam	Concrete straight gravity		Earth cum Rockfill	Earth Core Gravel Shell
Height above Deepest Foundation	225.55 metres		76.2 metres	132.59 metres
Height above River Bed	167.64 metres	29 metres	61 metres	
Length at Top	518.16 metres	304.8 metres	255 metres	
Width at Top	9.14 metres		12.19 metres	
Catchment Area of Reservoir	56980 square Kms			12560 square metres
Area of Reservoir	162.48 square Kms			
Live Storage Capacity	6911 million cum		18.56 million cum	7290 million cum
Gross Storage Capacity	9340 million cum		41.00 million cum	8570 million cum
Number of Power Houses/ Units	2	2	6	6
Capacity of Power Plants	1325 MW (5×180+5×157)	154 MW (4×24+2×29)	990 MW (6×165)	396 MW (6×66)

Table 6.2

Capital Costs of the Bhakra System Components at Current Prices and 2001-02 Prices (Rs. Millions)

	Original Cost (Rs Million)	*Year of Investment*	*In 1993-94 at 1993-94 Prices*	*In 2001-02 at Current Prices*
Bhakra and Nangal Dams	2426	1957-58	33671	55751
Power House	983	1967-68	7404	12259
Upgradation of power house	100	1980-81	308	510
Beas-Sutlej Link	4492	1976-77	19236	31850
Pong Dam	3259	1976-77	13956	23108
Total	11260		74575	123478

Source: Bhakra Beas Management Board and Author's Calculations.

Keeping in view the complex system of water management, sharing and transfers within the system, of which Bhakra-Nangal project is the most important component, it will not be prudent to confine the benefits flowing from the Bhakra-Nangal project to the boundaries as defined in the original project reports and documents when this project was planned. Since the Bhakra-Nangal is the core around which all the activities described above have been carried out in phases, we have therefore interchangeably used the Bhakra system and the Bhakra-Nangal project to reflect some of these inter-linkages. Hence, the estimates of irrigated area in different states and the output of electricity reflect the benefits from all the components of the larger Bhakra-Nangal-Beas system termed here as the Bhakra system. These figures will be different from those given in the official documents that refer mainly to the Bhakra dam.

The Major Outputs of the Bhakra Dam System

The major outputs of the Bhakra dam system, *inter alia*, have been:

(i) Increased availability of water for irrigation resulting in higher agricultural output

(ii) Availability of water for industry, household enterprises and for households and livestock

(iii) Generation of hydro power, and

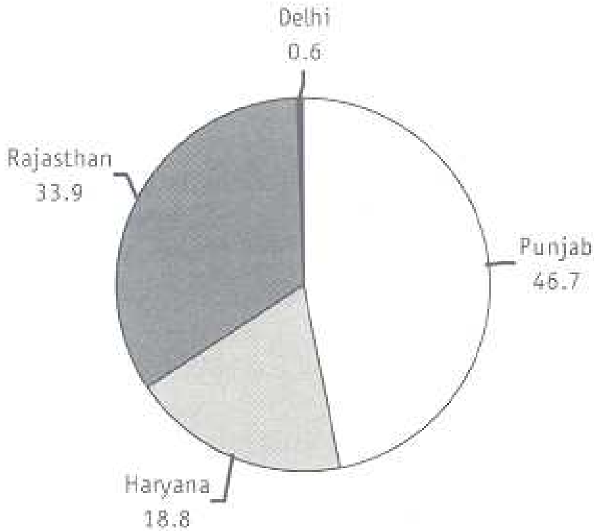
(iv) Moderation of floods reducing flood damage significantly.

The construction of the Bhakra system has made available huge amounts of water for meeting irrigation requirements of the region. The command area of the system—covers the three States—Punjab, Haryana and Rajasthan. Delhi also gets a small share of 1 per cent of the system water for meeting partially its drinking water requirements (Figure 6.3). (Gopalakrishnan, 2000).

A number of studies have been undertaken in the past to estimate the direct economic impacts of the Bhakra dam. In his pioneering study on the cost benefit analysis of a water investment project, Raj (1960) attempted to break down costs and returns of the project into certain categories and evaluated these according to selected criteria so as to determine the social economic value of the project as distinguished from its private economic value. According to the author, "the decision to

Figure 6.3

Shares of Different States in Water from the Bhakra System



Source: Prepared by authors from Gopalakrishna (2000).

locate a fertiliser plant at Nangal appears to have been, by itself, a correct one. The production of nitrogenous fertilisers is not only dependent on the availability of cheap power but it is vital to the economy of this region; in fact, it would make possible more effective utilisation of the irrigation facilities provided by the project" (Raj, 1960: 129).

Chopra (1972) presents results on the regional distributive effects of the irrigation component of the Bhakra dam using Social Cost Benefit approach. An evaluation of the investment in irrigation has been undertaken under alternative assumptions regarding investment costs and a number of alternative values of the parameters such as the shadow price of labour, the shadow price of foreign exchange and the premium on funds devoted to investment. The results show that regional incomes have increased to a far greater extent than aggregative incomes. The empirical analysis also shows that in the case of aggregative effect, the elements that are relatively more significant are the foreign exchange component of costs and the shadow price of foreign exchange. Interdependence between sensitivity with respect to different parameters highlights the need for determining them as part of the planning process. According to Verghese (1994), the Bhakra-Beas complex project "has been an outstanding success. It has built India and has long paid for itself many times over." The Bhakra-Beas projects have brought agricultural stability to Punjab and Haryana. "In the bad drought year of 1987, when many parts of the country reeled under distress, farm production in northwest India was unaffected. Thanks to that, India could face and overcome the crisis. Employment and income have risen appreciably and Punjab has attracted migrant labour for sowing and harvesting from as far as Bihar and Orissa" (Verghese, 1994: 39-40)

Additional Irrigation and Agricultural Output

The Bhakra system irrigation command is spread over several districts of the States of Punjab, Haryana and Rajasthan. Almost 86 per cent of the geographical area in the command area in Punjab and Haryana is under cultivation. More than 73 per cent of the gross cropped area in the region is devoted to the cultivation of food grains.

The availability of irrigation and consequent shifts in the cropping pattern have been accompanied by adoption of yield increasing technological innovations. Almost 96 per cent of the area under wheat and 86 per cent of the area under paddy-rice is sown with HYV seeds. The methods of cultivation have also undergone significant changes over the years. Large-scale mechanisation of such farm operations as land preparation, sowing (for wheat), irrigation, harvesting and threshing have made the region agriculturally the most advanced region in the country. Most of the area under rice and wheat is now harvested mechanically using combine harvesters.

The availability of irrigation water through this dam-canal network in addition has helped in increased recharge of groundwater. The water that is lost as seepage in canal irrigation system is available as surface return flow or groundwater recharge. Irrigation by groundwater on a very large area in this region, with an average rainfall of about 60 cm only, has largely been made possible through recharging of the groundwater by seepage through canals. It has been estimated that the natural recharge to groundwater in Punjab can sustain hardly half the existing number of private tubewells in the State. In other words, the availability of canal network has enhanced groundwater availability by a factor of two (Dhawan, 1993).

Adoption of the complementary yield enhancing technological innovations consequent upon availability of assured water supply has led to a very significant jump in crop yields. The yields of rice and wheat in the region are higher than yields obtainable in any other region of the country and compare favourably with the yield levels obtaining in some of the advanced countries of the world.

The availability of year round irrigation water through the dam-canal network (Figure 6.4) and groundwater pumping has helped in bringing large tracts of cultivated area under irrigation. Additional gross irrigated area has been of the order of 7.1 million hectares over a period of 40 years (Table 6.3). The total foodgrain production in the Bhakra command area during the year 1996-97 was of the order of 27 million tonnes, an additional output of 25.2 million tonnes compared to the food output in the mid 1950s.

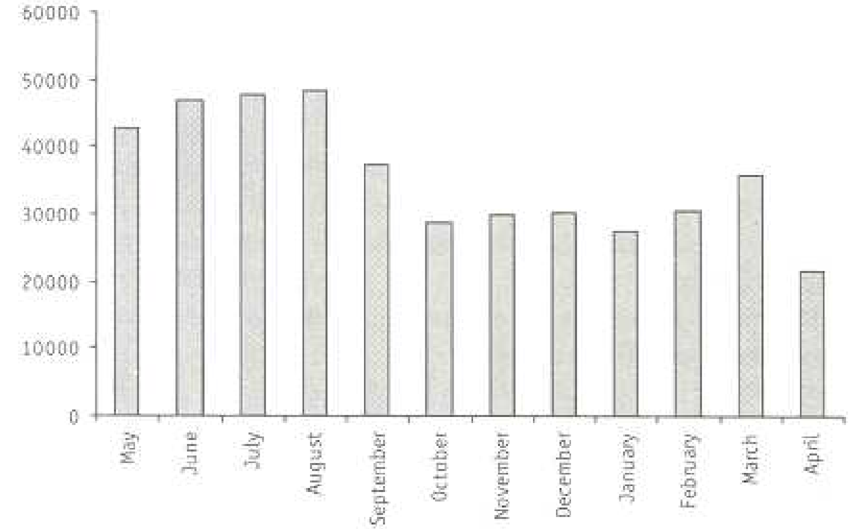
It may be emphasised that in a low-rainfall (less than 600 mm per year) area such as the Bhakra command, adequate and timely irrigation is an essential input without which the high-yielding variety seeds cannot be used. Further, the level of use of chemical fertilisers also critically depends on the availability of reliable irrigation water. It is in this context that irrigation from the Bhakra dam and from groundwater pumping in the area has been a 'leading input' without which it would not have been possible to attain such high crop yields in rice, wheat and cotton as have been obtained in Punjab and Haryana.

Impact on Food Security of India

The availability of huge surpluses of foodgrains from the region has significantly reduced the dependence of the country on imports of foodgrains for meeting the foodgrain requirement of the population, insulated the country to a large extent against droughts, made Indian agriculture more sustainable, contributed to the food security of the country and has helped in reducing wide fluctuations in the prices of foodgrains.

Figure 6.4

Water Releases from Bhakra During Different Months, 1998-99 (cumec days)



Source: Based on data from *www.bbmb.gov.in*

Table 6.3

Irrigated Area and Production of Foodgrains in Bhakra Dam System in Punjab and Haryana: 1955-56 and 1996-97

	1955-56 Without Project	*1996-97 With Project*	*Per cent Increase/Change (1996-97 over 1955-56)*
Gross Cropped Area (Million Ha)	7.0	11.2	60
Net Irrigated Area	3.0	5.6	87
Gross Irrigated Area	3.2	10.3	222
Production of Rice and Wheat (Million Tonnes)	1.8	27.0	1400
Fertiliser Consumption (Mn Nutrient Tonnes)	Neg	1.5	

Source: Statistical Abstracts of Punjab and Haryana, Various years

Increase in surface irrigation from the Bhakra dam and resulting groundwater pumping have led to significant increases in foodgrain production. By 1980, the production of foodgrains in both states had reached around 18 million tonnes or 19 per cent of the total all-India production. As much as 55 per cent of the total increase in foodgrain production in the country over two decades (1980 over 1961) came from the Bhakra dam command. As a result of such a high increase in domestic production, the net imports of foodgrains declined substantially from 10.3 million tonnes in 1966 to almost zero in 1972. Even though the imports declined, the net availability of foodgrains continued to increase. Further, even though the population increased from 442 to 666 million during the period 1961 to 1979 the net availability of foodgrains per capita did not go down substantially and remained around 470 grams per day.

Foodgrains for Distribution to the Urban Poor in India

The huge production of foodgrains in the region created vast quantities of marketed surplus of these grains. The procurement agencies of the Central government every year purchases enormous amounts of this marketed surplus of foodgrains for maintaining the national buffer stock of foodgrains and running the Public Distribution System (PDS) of the country through a distribution network of hundreds of ration shops spread all over the country. During the year 2001-02 the States of Punjab and Haryana contributed 17 million tonnes of wheat out of a total of 21 million tonnes procured by these agencies from all over the country. Similarly, during the year 2000-01 out of a total procurement of 19 million tonnes of rice from the entire country, Punjab contributed 7 million tonnes while Haryana contributed another 6 million tonnes.

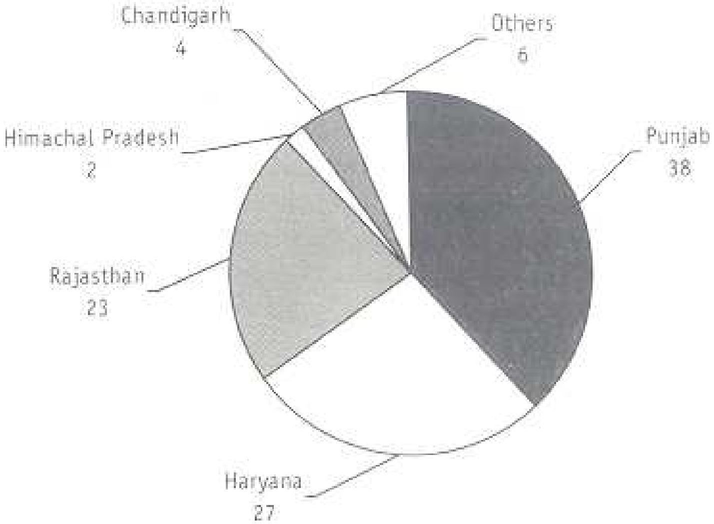
Impact on Hydropower Availability

The hydro power stations installed in the Bhakra system have a combined generating capacity of 2880 MW that currently generate about 14000 million Units (kWh) of electricity in a year. It has set up transmission lines running in to 3738 ckt kilometres. The power generated, benefits seven states/union territories. Of the total of 13796 million units of electricity transmitted during 1998-99, about 38 per cent was utilised by Punjab, 27 per cent by Haryana and 23 per cent by Rajasthan (Figure 6.5). The generation of hydropower has enabled the region to more than achieve the desired hydro-thermal mix of 40:60. As of March 1996, Punjab had an installed power generating capacity of 3509 MW of which about 51 per cent was hydel power, mainly from the Bhakra system. In Haryana, of the total installed generation capacity of 1762 MW, hydro constitutes about 50 per cent. In comparison at the all-India level the share of hydropower in the total electricity generating capacity was only 25 per cent.

Bhakra-Beas Management Board (BBMB) supplies about 50 per cent of the total hydropower in the Northern region besides meeting the peak demand of about 2500 MW of the Northern Grid. The availability of hydropower has helped BBMB generate huge revenue. The 14110 million units of hydropower generated in 1998-99 evaluated at a conservative price of Rs. 2 per unit is worth Rs. 28,220 million (Table 6.4). The operational cost of power generation and transmission work out to less than Rs. 0.10, perhaps the cheapest in the world (Gopalakrishnan, 2000).

Figure 6.5

Share of Different States in Electricity Generated in the Bhakra System



Source: Based on data from *www.bbmb.gov.in* and Author's Calculations

Table 6.4

Total Generation and Value of Electricity from the Bhakra System

Year	Total Generation (Million Units)	Value @Rs. 2 per Unit (Rs. in Million)
1994-95	12223	24446
1995-96	12086	24172
1996-97	12085	24170
1997-98	10607	21214
1998-99	14110	28220

Source: Based on data from www.bbmb.gov.in and Author's Calculations.

Rural Electrification

As a result of availability of power from the dam, 100 per cent electrification was achieved in Punjab and Haryana by the year 1976. Most of the towns and villages in Western Rajasthan have also been electrified. In comparison, at the all-India level average rural electrification was around 40 per cent. In other states, the percentage of villages electrified ranged from 28 per cent in Bihar, 32 per cent in Uttar Pradesh and 52 per cent in Gujarat. Thus, the Bhakra system provided electricity to all the villages and towns in the early seventies resulting in significant improvements in education, health, and quality of life. Village electrification also helped in the development of rural industries and agro-based industries in these areas resulting in all-round prosperity and poverty reduction.

The overall power consumption per 1000 population as also per square kilometres of area amongst all States in the country (except the highly urbanised Delhi) is the highest in Punjab. The electricity consumption (for utilities) per 1000 population during 1996-97 was 776 kWh while consumption per square kilometre area was 347,619 kWh. The corresponding figures for all-India average during the year were 297 kWh and 85,240 kWh respectively.

Installation of Tubewells

The increased availability of power enabled farmers to install private shallow tubewells for groundwater withdrawals. This has already been discussed above. These tubewells during the year consumed about 8700 million kWh of electricity. The proportion of electricity consumption for irrigation pumping to total electricity consumed in the region worked out to about 40 per cent.

Impact on Reduction in Poverty in Punjab and Haryana

The availability of irrigation water and electricity for households, agriculture and industry and the consequent growth in rural and urban areas that followed has helped in very significantly bringing down poverty in the two states of Punjab and Haryana. As already mentioned the benefits of this economic development in the region have been shared both by rural as well as urban areas. As a result this growth scenario has led to a steep decline in poverty in the rural areas of both the States—this despite the fact that a very large number of labourers from poor regions of the country having migrated to this region. The poverty in the two States is much lower in comparison to both all-India figures as also in comparison to other major States of the country. In rural areas, as shown in Table 6.5, the percentage of people below the poverty line during 1999-2000 was only 6.35 per cent in the Punjab and 8.27 per cent in Haryana as compared with 27 per cent in India. In urban areas, the per cent of people below the poverty line was only 5.7 in Punjab and 10 per cent in Haryana compared to 23.6 in the country as a whole. The Bhakra dam has played a very significant role in the last about 40 years in bringing about significant reductions in poverty in the states of Punjab and Haryana. It is expected that the remaining command area under the Bhakra system also experienced similar poverty reduction impacts.

Table 6.5

Poverty Ratios: Per cent of People Below Poverty Line in Punjab, Haryana and All-India

State	*Rural*		*Urban*		*Rural+Urban*	
	1973-74	*1999-2000*	*1973-74*	*1999-2000*	*1973-74*	*1999-2000*
Punjab	28.21	6.35	27.96	5.75	28.15	6.16
Haryana	34.23	8.27	40.18	10.00	35.36	8.74
All-India	56.44	27.09	49.01	23.62	54.88	26.10

Source: Economic Survey, 2001-02.

Flood Control Benefits of the Bhakra System

One of the most reliable structural methods to physically control floods is to store the excess water in major dams. The Bhakra and Pong dams were not planned as flood control reservoirs though these were expected to provide a cushion against floods. However, the Bhakra and Beas dams have helped in the moderation of floods by absorbing peak flood inflows as would be clear from the data in Table 6.6.

Table 6. 6

Impact on Moderation of Floods

Year	*Bhakra Dam*		*Beas Dam*	
	Peak Flood Inflow (Cumecs)	*Max Released (Cumecs)*	*Peak Flood Inflow (Cumecs)*	*Max Released (Cumecs)*
1978	10719	3887	—	—
1988	9004	4209	10692	7972
1992	6625	1542	6587	2741
1994	6364	1695	8931	1406
1995	8977	1658	9623	5633
1998	5244	1330	4270	—

Source: Gopalakrishna (2000)

The Bhakra dam has solved the problem of recurring floods in the Sutlej River, where a large extent of the wide bed of the Sutlej below the Bhakra dam is now utilised for intensive agriculture. (Gopalakrishnan, 2000).

Benefits from Integrated Management of Hydropower, Surface Irrigation and Groundwater Use

Benefits from the integrated management of hydro power and irrigation have been analysed in a few studies on the Bhakra system and the integrated operation of the Beas-Sutlej system (Minhas *et al.*, 1972; Rao and Ramaseshan, 1985; Rao and Ramaseshan, 1985a). In the Bhakra system, (the then) planned levels of power generation vary widely between 766 MW from December through April to 1697 MW in September. Conjunctive utilisation models have been developed for integrated management of surface and groundwater irrigation. A linear programming model of the system was developed (Rao and Ramaseshan, 1985a) that attempted to maximise the level of firm power and satisfied irrigation demands in each of the sub periods. The power required to lift groundwater was over and above the firm power that was to be supplied. This integrated framework led to a better understanding of the interaction between the irrigation and firm power objectives. The results show[2] that conjunctive utilisation can increase firm power by at least 36 MW (over and above a firm power of 797 MW). The results also indicate, contrary to the then practice, groundwater use occurs generally between May and November and not from December to April. The firm power level reached in a dry year is 200 MW (i.e. 20 per cent) less than that reached in a dependable year. The levels of irrigation and power planned for a dependable year from the reservoirs of the Beas-Sutlej system can be attained even in a dry year by conjunctive utilisation of surface and groundwater.

Multiplier Effects of the Bhakra Dam System in the Punjab State

As discussed above, the Bhakra dam system has benefited not only the states of Punjab, Haryana, Rajasthan, Himachal Pradesh and Delhi but also the entire country. For the estimation of the multiplier effects of the dam for the present study, we will however confine to the direct and indirect benefits of the dam system in only a part of the benefited area *viz.* the state of Punjab, the biggest beneficiary of the dam system. Further, the analysis captures the main effects of the dam system in a typical year during its lifetime *viz.* 1979-1980, approximately 20 years after the construction of the Bhakra dam was completed. By 1979-80 the benefits from the other components of the Bhakra system were also available in the Punjab state. The choice of geographical area *viz.* Punjab state and the choice of the year 1979-80 for the present analysis has in large part been dictated by the availability of an Input-Output (I-O) table (for constructing the Social Accounting Matrix) for the state of Punjab (Bhalla *et al.*, 1990) and not for the entire Bhakra system. In India I-O tables at the state level are available only for a few states and that too for only one or two points in time. It is however, expected that similar

2 It is likely that the Bhakra-Beas Management Board is operating the system so as to optimise the power and irrigation output.

indirect economic impacts are also available in other areas in Haryana and Rajasthan that have benefited from the Bhakra dam system.

For the last four decades or so, the Bhakra dam system has played an important role in the provisioning of irrigation and electricity to the Punjab state. During the period between 1955-1956 to 1979-80, the availability of net irrigated area has increased by almost 55 per cent while the gross area irrigated has increased by 125 per cent (Table 6.7). During the year 1979-80, the Bhakra system command produced about 3 million tonnes of rice and 7.4 million tonnes of wheat besides a host of other crops including sugarcane, cotton etc. (Table 6.8 and Figure 6.6).

The Approach and Methodology

Major outputs of the Bhakra multi-purpose dam system, like any other large multipurpose dam, and reservoir project include: hydropower, irrigated agriculture, water supply, fishing, flood control, drought prevention and value of recreational activities/tourism revenues. In

Table 6.7

Estimated Irrigated Area in the Bhakra System Command in Punjab: 1955-56 and 1979-80 ('000 Ha)

	1955-56	1979-80
Net Irrigated Area (NIA)		
- By Canals	1340	1478
- By Wells, TW and Other Sources	852	1913
Total NIA	2192	3391
Total Gross Irrigated Area (GIA)	2426	5448

Source: *Statistical Abstract of Punjab*, Various Issues

Table 6.8

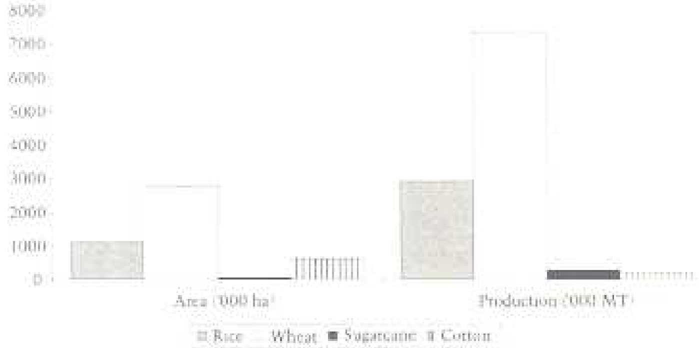
Area and Production of Important Crops in the Bhakra System Command: 1979-80

Crop	*Area (000 ha)*	*Production ('000 MT)*
Rice	1110	2923
Wheat	2787	7362
Sugarcane	59	294
Cotton	626	2045

Source: *Statistical Abstract of Punjab and Haryana*, Various Issues

Figure 6.6

Area and Production of Important Crops in Bhakra System Command: 1979-80



Source: Table 6.8.

addition, there are non-irrigation benefits of irrigation canals in terms of water for households, livestock, household enterprises, animals and birds, among others. The negative direct impacts of the dam project include, inter-alia, social, economic, and cultural costs of resettlement; value of lost ecosystem/historical/cultural heritage sites; opportunity cost of lost output from inundated area and reduction in fish output upstream. For the purpose of this paper, direct costs and benefits are all those that descend from the construction of the dam, as well as economic benefits accruing to all beneficiaries of the water stored and other services provided by the structure and the economic impacts—positive or negative—to all populations, species and ecosystems affected either by the construction or by the changed regime of the river.

Indirect and induced impacts are those that stem from the linkages between the economic, environmental, social or other direct consequences of a dam project with the rest of the economy, as well as the non-economic impacts descending from such linkages. Among them are impacts due to changes in output and input use in sectors other than those affected directly by the dam, or changes in relative prices, employment and factor wages.

Major outputs of the dam have significant inter-industry linkages and result in an increase in the demand for output of other sectors of the economy. Hydropower produced from a multipurpose dam provides electricity for households in urban and rural areas and for the increased output of industrial products (e.g., fertilisers, chemicals, machinery etc.). Changes in the output of these industrial commodities require inputs from other sectors such as steel, energy, and chemicals, among others. Similarly, water released from a multipurpose dam provides irrigation for the increased output of agricultural commodities. Changes in the output of these commodities require inputs from other sectors such as energy, seeds, fertilisers, etc. Further, increased output of some agricultural commodities encourages setting up of food processing and other industrial units. Thus, both the increased output of electricity and irrigation from a dam result in significant backward linkages (i.e., demand for higher input supplies) and forward linkages (i.e., providing inputs for further processing).

Increased outputs of industrial and agricultural commodities generate additional wages and incomes for households. Higher incomes result in higher consumption of goods and services that, in turn, encourages the production of various agricultural and industrial commodities. Further, changes in output generated by the project may affect prices of direct project outputs, inputs, substitutes, complements and factors of production. Changes in wages and prices have both income and substitution effects on expenditure and saving decisions of different owners of factors, which further impacts the demand for outputs both within the region and throughout the economy. Induced impacts reflect the feedbacks associated with these income and expenditure effects, and also include any impacts of changes in government revenues and expenditures that result from the project.

Major outputs from a dam thus generate both inter-industry linkage impacts and consumption-induced impacts on the regional/national economy. The level of indirect impacts of a dam on regional output and value-added will depend on the strength of linkages among various sectors of the economy. Multiplier analysis is one of the approaches for quantifying the magnitude of inter-industry linkages and consumption-induced effects, relative to purely direct impacts.

Multipliers are summary measures that reflect the total effects of a project in relation to its direct effects. A multiplier of 1.90, for instance shows that for every one dollar of value-added generated directly by the project at maturity, another 90 cents were generated in the form of indirect or downstream effects. Thus, a multiplier is a ratio of the total effects (direct and indirect) of a dam project to its direct effects.

Estimation of multipliers requires careful analysis of the direct effects of a dam. This involves the quantification and valuation of major outputs of the dam and the assessment of the share of direct effects that is attributable to the dam project. Valuation of outputs/benefits from a water project is quite a complex matter, particularly in the case of multi purpose dams.

As already discussed, the multiplier analysis reported in this chapter is confined to the state of Punjab, a major beneficiary of the Bhakra dam system, and the analysis has been done for a year (1979-80) for which adequate data were available from a detailed study (Bhalla *et al.*, 1990). The study employs a SAM-based multiplier model to estimate project multipliers using a Social Accounting Matrix for Punjab.[3] The model has been used to compute the values of relevant variables in the 'With Project' situation with their counterparts in the hypothetical case that the project had not been undertaken. This set of variables comprises all the elements of a SAM for the region in each situation, assuming fixed prices. In measuring the impact of the project, an attempt is made to assess the situation in the region (the Punjab state) for the hypothetical case of 1979-80 in the absence of the project. This has been done by assuming that all autonomous changes would have taken place except the effects of changes due to major outputs of the project, namely irrigation and hydro-electricity. This hypothetical case in the absence of the project[4] is termed as 'Without Project' scenario for 1979-80.

3. The approach and the methodology used in estimating the multiplier effects of the Bhakra dam are similar to those adopted in studies on the Muda dam in Malaysia (Bell, Hazell and Slade, 1982) and indirect effects of the green revolution in south India (Hazell and Ramaswamy, 1991).

4. Unlike in the pioneering study of the Muda dam (Bell *et al.*, 1982), it was not possible to prepare a SAM for the pre-project situation because not even input-output tables were available during 1952-53 when most of the additional irrigation was not available from the Bhakra dam.

As shown in Table 6.9, for estimating a project multiplier value for the Bhakra dam, for the numerator, we need to estimate the regional value-added (for Punjab state) under 'With Project' situation as well as the regional value-added under 'Without Project' situation. For the denominator, we need to estimate the value-added from the sectors that are directly affected by the major outputs of the dam (namely agricultural output, hydro electricity, water supply etc.).

Table 6.9

Values of Variables Required for the Estimation of a Project Multiplier of the Bhakra Dam Project, India

Definition of Project Multiplier	Regional value-added with project	-	Regional value-added without project
	Value-added of agriculture and electricity with project	-	Value-added of agriculture and electricity without project

Regional value-added under 'With Project' situation has been estimated by using the SAM-based multiplier model. The model has been used to estimate the SAM coefficients for each household category and for each production sector. These SAM coefficients have then been used to estimate the regional value-added under 'Without Project' situation by fixing the outputs of sectors directly affected by major outputs of the dam, namely irrigation and hydropower. Value-added of sectors directly affected by the project have also been estimated from the SAM model. The agricultural sectors directly affected by the project for which the outputs have been fixed are: wheat, rice, sugarcane, cotton, gram and other agriculture. The values of agricultural output and electricity sectors under the 'Without Project' situation have been estimated under a variety of assumptions regarding availability of canal irrigation, groundwater pumping and hydro power and the technology choices affecting area and yield of major crops. The details of the assumptions made in estimating the outputs of these agricultural sectors and electricity under a 'Without Project' situation have been described in the following sections. The multiplier values for the Bhakra dam, under different scenarios, have been estimated by using the values of regional value-added under 'Without Project' situation and comparing these with the regional value-added under 'With Project' situation.

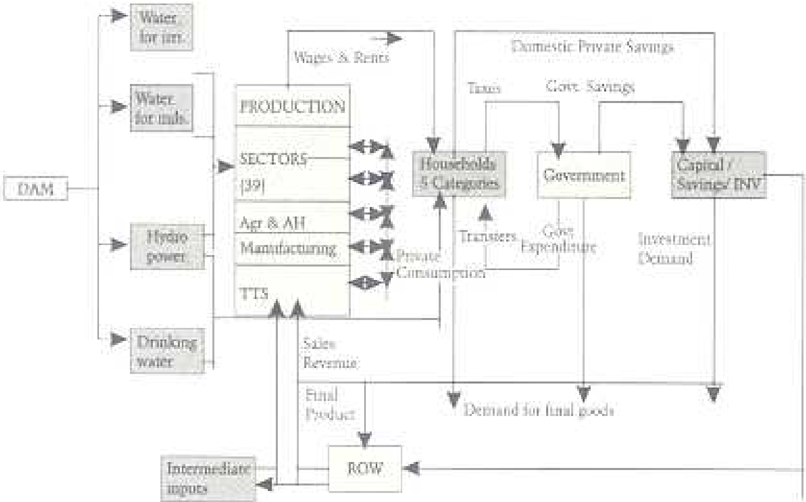
A Social Accounting Matrix (SAM) for the Punjab

This study uses an estimated social accounting matrix (SAM) to provide a detailed quantitative description of the Punjab economy in 1979-80, almost 20 years after the construction of the Bhakra dam was completed. The SAM framework provides a consistent, comprehensive, and detailed picture of the transactions in the economy (Figure 6.7). Production activities, government and households are considered and the pattern in which incomes are distributed takes its place alongside the sources of its generation. The SAM also provides a basis for the construction of a model of the regional economy that is used to estimate the direct and indirect effects of the Bhakra dam. The data source for estimating the full[5] SAM is a detailed study of the Punjab economy reported in Bhalla *et al.* (1990).

The key features of the regional economy[6] of the Punjab are analysed with the help of an aggregated SAM in Table 6.10. In this SAM,

Figure 6.7

SAM Interactions and Circular Flow of Income



5 The full SAM of the Punjab economy is available with the authors.

6 Figures used in the SAM are marginally different from those in the data sources in Bhalla *et al.* (1990) due to balancing of figures in the SAM.

Table 6.10

Aggregated SAM for Bhakra 1979-80 (Million Rs.)

	Self-Empl.	Agri. Lab.	Non. Ag. Lab.	Other-Rural	HHU	Agri.	Manf.	TTS	BIS	PS	Capital	Govt.	ROW	Total
Self-Empl.	0	0	0	0	0	9562	2870	179	214	221	0	0	-540	12505
Agri. Lab.	0	0	0	0	0	5010	0	0	0	0	0	0	-1006	4005
Non. Ag. Lb	0	0	0	0	0	1389	373	38	30	28	0	0	-732	1125
Other-Rural	0	0	0	0	0	3035	2498	216	194	191	0	0	2279	8413
HHU	0	0	0	0	0	1000	3092	8217	438	3584	0	0	0	16331
Agri.	3656	1390	393	2323	2048	2239	4800	0	0	202	235	25	12737	30048
Manf.	3833	1407	424	2422	3482	3609	13397	837	12	1327	9275	181	-3245	36961
TTS	1560	560	162	1115	1000	573	4055	1431	34	773	324	79	2175	13841
BIS	55	20	6	39	48	98	380	319	83	48	0	0	29	1123
PS	472	169	49	337	691	0	0	971	18	347	0	0	4266	7320
CapitaL	2296	235	26	1405	7939	749	1354	593	34	333	0	20	0	14985
Govt.	473	165	48	666	677	232	467	414	4	246	627	0	-3636	385
ROW	160	59	17	104	445	2552	3674	627	61	22	4524	79	330	12655
Total	12505	4005	1125	8413	16331	30048	36961	13841	1123	7320	14985	385	12655	0

39 production sectors have been aggregated to five categories. In 1979-1980, the gross value of output in the Punjab was Indian Rupees[7] (Rs.) 89.3 billion and the value-added was Rs. 42.4 billion (47.5 per cent of the gross value of output). Agriculture accounted for 33.7 per cent of the total value of output while manufacturing accounted for another 41.4 per cent of the output. Shares of value-added in the total value-added were: Agriculture and animal husbandry 47.2 per cent; Manufacturing 20.8 per cent and construction and services 32 per cent. The net transactions with the rest of the world (ROW) were Rs. 12.66 billion. The capital accounts were of the order of Rs. 14.99 billion.

A SAM-based Multiplier Model of the Punjab Economy

A SAM-based multiplier model has been used to provide a quantitative analysis of the direct and indirect impacts of increased agricultural production and electricity output available from the Bhakra dam. The model is calibrated for the year 1979-80 for Punjab using the Social Accounting Matrix (SAM) described in the previous section.

Since the SAM is a double-entry accounting system, we can use either the row or column accounts for its presentation. The rows provide the statement of receipts for each account, whereas the columns provide the statement of expenditure. For example, the row for the k th type household represents the receipts of household k, i.e.

Total income of household k = Value-added received by household k from the production sectors + Income transfers from abroad to the household.

The corresponding column for the household provides the details of the expenditures of the household, i.e.

Total expenditure = Expenditure on domestic goods + Savings + Taxes + Expenditure on imported goods.

Table 6.11 shows the interactions among different accounts in the SAM. These interrelationships are explained in more detail in the following equations:

7 The current (December 2002) conversion rate is Rs. 48.4 for a US$. The exchange rate during 1979-80 was approximately Rs 10 to a US dollar. In this report we have used Indian Rupees (Rs.) for value figures using 1979-80 prices.

Table 6.11

A SAM-based Multiplier Model of the Punjab Regional Economy

Expenditures / *Receipts*	*Households (HHs) k=1,...,5*	*Production Sectors i=1,2,...39*	*Capital Account*	*Government*	*Rest of the World*	*TOTAL*
Households k=1,...,5	0	$\sum_i w_{ki} X_i$	0	0	R_k	Y_k
Production Sectors i=1,2,...39	$\sum_k c_{ik} Y_k$	$\sum_j a_{ij} X_j$	I_i	G_i	E_i	X_i
Capital Account	S_k	S_i	0	S_g	S_R	F
Government	$\sum_k t_k Y_k$	$\sum_i t_i X_i$	0	0	R_g	G
Rest of the World	M_k	M_i	0	M_g	0	M
TOTAL	Y_k	X_i	F	G	M	

In the SAM-based multiplier model there are 39 production sectors including the agricultural sectors, manufacturing, electricity, gas and water supply, trade and transport services etc. (see Table 6.16 for a listing of these sectors). There are 5 types of households namely, self-employed rural households (HRSE), rural households employed as agricultural labour (HRAG), rural non-agricultural labour households (HRNA), other rural households (HRO) and urban households (HHU). The notation used in the following is as follows:

The subscript k = 1,2,...5 denotes the type of households, while i, j denote the production sectors.

Y_k = total income of households of type k

X_i = value of gross output of sector i

w_{ki} = coefficient (ratio) of value-added received by household type k to output of sector i

R_k = income transfers from abroad to households of type k

C_{ik} = proportion of income household k that is spent on the purchases of sector i's output

a_{ij} = input-output coefficient for production sectors

I_i = investment demand of sector i 's output

G_i = government purchases of sector i 's output

E_i = exports of sector i 's output
G = total tax revenues
t_k = tax rate for households of type k
t_i = tax rate for production sector i
R_k = income received from 'rest of the world' by the government
F = total savings in the regional economy
S_h = total household savings
S_i = savings/investment by production sectors
S_g = government savings
S_n = exogenous inflow of capital
M = total value of regional imports
M_k = expenditure on imported goods by household of type k
M_i = value of imported intermediates purchased by sector i
M_g = imports by the government

As in a Leontief system, we assume that all the structural relations (both behavioural and technological) are linear or at least that they can be approximated to linear functions. More specifically, some of these assumptions are stated below.

The model's coefficients were estimated from the SAM entries for 1979-80 for 39 production sectors based on data from Bhalla *et al.* (1990). A description of the various rows of the SAM-based multiplier model is presented in the equations given below.

Households:

$$Y_k = \sum_i w_{ki} X_i + R_k \quad \text{for } k = 1,2,...5.\ i = 1,2,...39$$

[Total income of households of type k] = [Total factor payments received from all production sectors] + [income transfers from abroad to households of type k]

Production Sectors:

$$X_i = \sum_k C_{ik} Y_k + \sum_j a_{ij} X_j + J_i + G_i + E_i$$

[Gross Output of production sector i] = [Sum of all households' demands for output of sector i] + [Intermediate demand by sector j for output of sector i] + [investment demand] + [Government purchases of sector i 's output] + [Exports of sector i]

Government Receipts:

$$G = \sum_k t_k Y_k + \sum_i t_i X_i + R_g$$

[Total tax revenues] = [Taxes paid by all households] + [Taxes paid by all sectors] + [Income received from rest of the world by the government]

Capital Account Receipts:

$$F = \sum_k S_k + \sum_i S_i + S_g + S_R$$

[Total Savings] = [Total household savings] + [Savings/Investment by production sectors]+[Govt savings]+ [exogenous inflow of capital]

Rest of the World Account:

$$M = \sum_k M_k + \sum_i M_i + M_g$$

[Total Imports] = [expenditure on imported goods by all households] + [value of imported intermediates purchased by production sectors] + [imports by the government]

Regional Value-Added:

$$\sum_k \sum_i w_{ki} X_i$$

Regional value-added is the sum of incomes received by all households from all production activities.

In this SAM-based multiplier model of the Punjab regional economy, regional value-added (RVA) has been taken as the objective function[8] to be maximised under the two situations: 'With Project' and 'Without Project'.

Simulations under 'With Project' Situation

As mentioned above, the SAM-based multiplier model described above has been used to compute the values of relevant variables in the 'With Project' situation with their counterparts in the hypothetical case that the project had not been undertaken ('Without Project'). This set of variables comprises all the elements of a SAM for the region in each

8 We have used GAMS (General Algebraic Model System) to obtain optimum solutions.

situation, assuming fixed prices. The optimum solution under 'With Project' situation gives an estimate of the regional value-added alongwith household incomes, sectoral gross outputs or export levels, savings and investments and government expenditure for the year 1979-80.

Simulations under 'Without Project' Situation

The regional value-added (RVA) under 'Without Project' situation has been obtained by using the SAM-based multiplier model by fixing output levels of agricultural commodities and electricity under the hypothetical situation of 1979-80 in the Punjab state in the absence of the Bhakra dam system.

Most of the inter-sectoral interactions in Punjab are driven by output increases in the agricultural sector. Agriculture in turn is driven very strongly by the availability of irrigation water. It is therefore, important to explicitly account for this important driving force of inter-sectoral linkages. To assess therefore, how the non-availability of irrigation water and hydropower in the 'Without Project' situation would have affected the inter-sectoral linkages and the production of different sectors in SAM, it is important to estimate how the agricultural production would have been affected in the event of non-availability of irrigation water and hydropower (a part of which is used for pumping groundwater for irrigating crops).

Irrigation and Agricultural Output under 'Without Project' Scenarios

The major effects of the Bhakra dam system have been in terms of increasing area under irrigation and the output of electricity. Had the dam not been built, it would have affected the availability of irrigation and hydropower. Thus, for the hypothetical case of 'Without Project' scenario, the following assumptions are made with respect to the availability of irrigation and the irrigated area.

Irrigation Under 'Without Project' Scenario in Punjab

The availability of Bhakra waters has helped in several ways in contributing to the increased irrigation availability in Punjab. It has led to changes both in terms of quantity of irrigation water available as well as quality (as measured in terms of reliability of irrigation water at the required time) of irrigation water available. It has helped in extending surface irrigation water availability to hitherto unirrigated areas, in tremendously increasing water availability in the existing canal network and, through seepage of canal waters to the groundwater, in making available huge amounts of groundwater for exploitation through tubewells.[9]

Thus, while it may not be correct to attribute the entire changes on the irrigation scene, presented above, to the building of the Bhakra dam, it is however correct to infer that the irrigation scene in the absence of the project would have been much different than that presented above. In the hypothetical situation of the Bhakra dam not having been built, the likely irrigation scenario in Punjab could be visualised as consisting of the canal network that existed in the pre project period continuing to carry low volumes of irrigation water, though maybe somewhat at a higher level than that in the pre project year, and a reduced level of groundwater availability due to the absence of recharge of groundwater from the canal waters. In the absence of data available on actual amounts of water flowing through the canal system, and to avoid any undue prejudices against the 'without project' scenario, we assume that the volume of water carried in large parts of the canal system would be sufficient to grow all crops including high yielding varieties of crops, except that of Paddy due to its high water requirement. The available water is however, assumed to be sufficient to grow local varieties of paddy due to their low irrigation water requirement. We also assume that of the total canal irrigated area available in 1979-80 in the 'without project' scenario, the water availability in 25 per cent of the cultivated area would be adequate to grow even high yielding varieties of paddy also.

9. The role of seeped in waters in improving recharge is often not so well recognised in the case of canal irrigation. A canal system is inherently rather leaky, more so when it is unlined. According to some of the available estimates, the natural groundwater recharge in Punjab could sustain half the existing number of tubewells in Punjab. In other words, the investment in canal works has enhanced groundwater availability in Punjab by a factor of two. Therefore, half the crop output originating from tubewell-irrigated lands in the Punjab State is from groundwater that is of canal origin (Dhawan, 1993). In another study on Punjab, Dhawan (1989) concludes, "These exercises should convince a discerning reader that we are justified to adopt a range estimate of 50 to 70 per cent for the share of canal seepage in total groundwater."

Irrigation from Check Dams

Given the flat topography of the land in most of the command area of the Bhakra dam system, it is assumed that no substantial irrigation could be obtained from investing in small check dams. In any event, the area that could have been potentially irrigated by small dams in the region would have been a very small part of the total area irrigated by large canals from the Bhakra dam system. Hence, we have not made any estimates for the area that could have been irrigated from the small/check dams under the 'Without Project' situation.

Thus, in the likely scenario of the Bhakra dam system having not been built, we envisage the irrigation scenario in Punjab would have been as follows, depending upon the assumptions made:

Assumption I: It is assumed that the water available in the canal irrigated area is sufficient to grow all crops, except HYV of paddy. However, in 25 per cent of this area, it is assumed that the available water is sufficient to grow HYV of paddy as well. The groundwater irrigated area has been assumed to be 50 per cent of the groundwater irrigated area in the 'With Project' situation and that the entire groundwater irrigated area is suitable for cultivation of all crops, including HYV of paddy.

Assumption II: It is assumed that the water available in the canal irrigated area is sufficient to grow all crops, except HYV of paddy. However, in 25 per cent of this area, it is assumed that the available water is sufficient to grow HYV of paddy as well. The existing groundwater[10] area in the pre-project period will become suitable for HYV of paddy and other crops but there would have been no new additions to area under groundwater irrigation.

The estimated figures suggest that had the Bhakra dam system not been built, the Net Irrigated Area (NIA) would have been between 43

10. It is assumed that, in the absence of water releases from the dam, the groundwater recharge would have been lower due to low volume of water available in the canal system. However, the existing wells would have converted into the tubewells and would have drawn more water than they were drawing before the project. But it is assumed that no new area under groundwater would have come. This restrictive assumption has been made to see the impact of low irrigation availability on direct and indirect impacts.

and 54 per cent lower in 1979-80 than that actually prevailing in 1979-80 (Table 6.12).

Table 6.12

Irrigated Area in Punjab under Alternative Assumptions (Thousand Hectares)

	Actual 1950-51	*Actual 1979-80*	*Without Bhakra 1979-80*	
			Assumption I	*Assumption II*
1. Canal Irrigated Area				
(a) Adequate Water for Growing HYV Paddy	–	1496	241	241
(b) Inadequate Water for HYV Paddy	922		681	681
2. Groundwater Irrigated Area	764	2062	1106	764
3. NIA (Net Irrigated Area)	1686	3558	2028	1686
4. GIA (Gross Irrigated Area)	2278	5708	3245	2698

Note 1. For calculating GIA we have used the same irrigation intensity that prevailed actually in 1979-80 viz., 1.60, though this may somewhat cause an upward bias.

2. While calculating the "without" Bhakra scenario figures we have applied percentage reductions to only Bhakra served area of Punjab.

Agricultural Production under 'Without Project' Scenario

To assess the implication of reduced availability of irrigation water on the agricultural sector, in the hypothetical situation that the Bhakra dam system had not been constructed ('Without Project'), a formal model of the agriculture sector has been developed. In particular, we developed a Linear Programming (LP) model of the agricultural sector, which solves for equilibrium values of the area allocation to different crops for a defined objective function. The model is validated for the year 1979-80. The model simulates the steady state equilibrium as it should have been during that year and may therefore, deviate from the values actually prevailing in the study region. Subsequently the model has been used to analyse the direct effects of the Bhakra project by solving the model for different hypothetical 'Without Project' situations as discussed above.

To simulate the regional agricultural economy in the absence of the Bhakra dam, apart from reduced availability of irrigation water as discussed above, it was also necessary to make some plausible assumptions about some of the underlying variables. It is assumed that identical input-output relations hold under both 'with' and 'without' project situations. It has also been assumed that farmers would have access to the same level of agricultural technology (HYV and mechanisation) and would have used the same input levels such as that of fertiliser and seeds on irrigated farms in the region in the absence of the Bhakra dam as in the presence of the dam. It is also assumed that it was reasonable to foresee the autonomous changes in population, incomes, prices and investments in the absence of the project. Further, we assume that prices of inputs and outputs, subsidies, markets, infrastructure (except that of irrigation), government policies etc. were identical in both situations. Hence, the difference in values of relevant variables derived from the two situations would provide an estimate of the 'pure' impact of the Bhakra dam system. Some of the relevant variables used for this impact evaluation are: increased area under irrigation under rice, wheat, cotton and other crops and the increases in output of these crops as a result thereof.

The production and value of output of some of the major crops, at 1979-80 prices for 'With Project' and 'Without Project' situations, are given in Tables 6.13 and 6.14. It may be noted that Tables 6.13 and 6.14 show the predicted differences between what would have been the situation in the region 'with' and 'without' the Bhakra dam system. In the case of animal husbandry, the value of output under 'Without Project' situation has been estimated to reflect the area available for fodder crops.

The results obtained from solution of the model under different situations suggest that if the Bhakra project had not been undertaken, the production of rice would have been about one half of what was being produced in 1979-80 with Bhakra. Similarly the production of wheat would have been between 54 and 65 per cent of the currently produced quantity of wheat (See Figures 6.8 and 6.9). The total value of these four major crops would have been between 52 and 61 per cent of the value currently obtainable.

Table 6.13

Impact of Alternative Irrigation Availability Scenarios on Production of Some of the Important Crops ('000 Metric Tonnes)

Crop	LP with 1979-80 Prevailing Conditions	LP with Groundwater at 50 per cent of use in 1979-80	LP without additional Groundwater use
Rice	3437 (100)	1717 (50)	1636 (48)
Wheat	8190 (100)	5354 (65)	4438 (54)
Cotton	259 (100)	157 (61)	125 (48)
Sugarcane*	477 (100)	471 (99)	285 (60)

Note: *Production of sugarcane is in terms of Gur.

Figures in parentheses are index numbers.

Table 6.14

Value of Output of Major Crops under Alternative Scenarios (Mn Rs. at 1979-80 Prices)

Crop	LP with 1979-1980 Prevailing Conditions	LP with Groundwater at 50 Per cent of use in 1979-80 (Assumption I)	LP without additional Groundwater use (Assumption II)
Rice	6187	3091	2945
Wheat	10647	6960	5769
Cotton	2072	1256	1000
Sugarcane	859	848	513
Total of Four Crops	19765 (100)	12155 (61)	10227 (52)

Electricity Output Under 'Without Project' Scenario

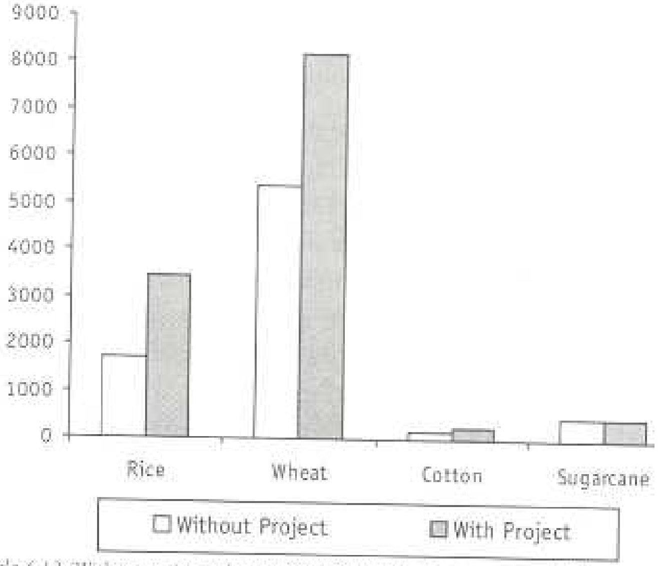
Apart from the reduced availability of irrigation water under the 'without' project scenario, the availability of electricity would have also been affected. We make the following two assumptions about the availability of thermal power in the absence of availability of hydro power from the Bhakra dam system:

Assumption I: No additional thermal power available to replace hydropower available from Bhakra.

Assumption II: Additional thermal power will be available to replace 50 per cent of hydropower available from Bhakra.

Figure 6.8

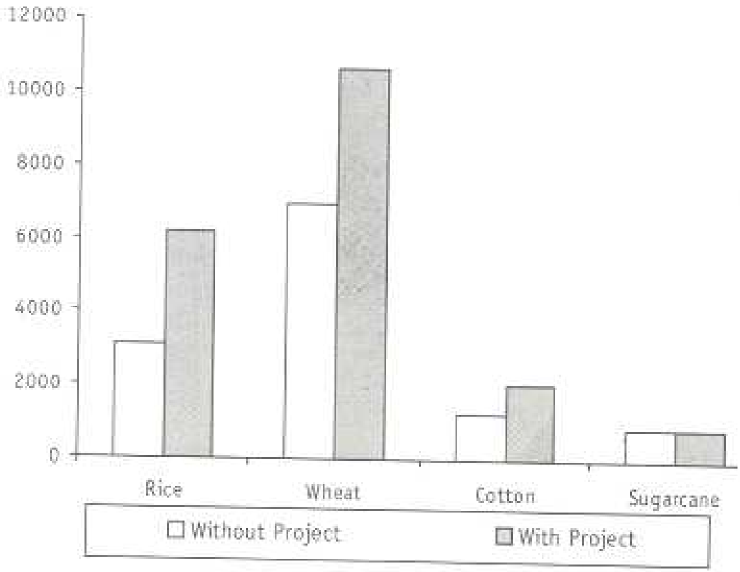
Production of Different Crops With and Without Bhakra Dam—Thousand Tonnes/yr



Source: Table 6.13 (Without project refers to Groundwater at 50 per cent availability)

Figure 6.9

Value of Output With and Without Bhakra Dam—Rupees Million/YR



Source: Table 6.14 (Without project refers to Groundwater at 50 per cent availability)

The electricity scenario in the two cases would thus have been as follows:

Assumption I: The installed capacity of electricity in Punjab in 1979-80 was 1536 MW of which 1416 MW was from the Bhakra dam system. In the year 1979-80 total electricity generated in Punjab was 6235 million kWh (mkWh) of which 6033 mkWh was from the Bhakra system.

According to the available data, estimated value of output of electricity, gas and water supply sector in 1979-80 was Indian Rupees[11] (Rs.) 1647 million (Bhalla *et al.*, 1990). Assuming that 90 per cent of this was due to electricity, this gives an estimated value of Rs. 1484 million from electricity for an estimated generation of 6235 million kWh or Rs. 0.24 per kWh. Using this estimate of the unit price of electricity, the estimated value of electricity from Bhakra in Punjab comes to Rs. 1442 million. Thus, in the hypothetical case under which the Bhakra dam system had not been constructed, the value of electricity output in the Punjab would have been Rs. 50 million (Rs. 1484 million minus Rs. 1434 million). Hence, the output value of electricity, gas and water sector in 1979-80 under 'Without Project' situation is estimated at Rs. 213 million.

Assumption II: The value of output from the electricity and gas sectors is taken at 50 per cent of the value of output under 'With Project' situation. Hence, the output value of electricity, gas and water sector in 1979-80 under 'Without Project' situation is estimated at Rs. 823 million.

The above two alternative assumptions have been used to derive simulation results on the impact of non-availability of hydro power from the Bhakra dam system using the SAM model.

Results of Multiplier Analysis

The gross output levels and value-added for Punjab during 1979-80 under different assumptions of irrigation availability and electricity availability in the 'Without Project' situation have been estimated using the SAM model. We present in Table 6.15 results for one such

11. The current (December 2002) conversion rate is Rs 48.4 for a US $. The exchange rate during 1979-80 was approximately Rs 10 to a US dollar. In this report we have used Indian Rupees (Rs) for value figures using 1979-80 prices.

combination of alternative scenarios comprising Assumption I for groundwater and Assumption II for electricity as discussed above. The results are presented for a sectoral aggregation of the 39 sectors. This Table also presents gross output and value-added, respectively, for each aggregated sector as estimated in the SAM for 1979-80 representing the 'With Project' situation. The detailed sector wise gross value of output and value-added for each of the 39 sectors under the 'With Project' situation are presented in Table 6.16.

Under defined combinations of assumptions about the availability of irrigation and electricity under the 'Without Project' situation, the aggregate gross output in the region under the 'With Project' situation is larger by Indian Rupees 20 to 24 billion (30 to 34 per cent) than it would have been had the project not been constructed.

Table 6.15

Estimated Gross Value of Output and Value-Added in Simulation Exercises using the SAM Model for Punjab: 1979-80 (Millions of Indian Rupees)

	Gross Value of Output			*Value Added*		
Sectoral Aggregation	*Without Project*	*With Project*	*Per cent Change*	*Without Project*	*With Project*	*Per cent Change*
Agriculture	15137	22072	46	9870	14398	46
Animal Husbandry	5583	7976	43	3919	5598	43
Agro Processing	3734	5566	49	473	727	54
Manufacturing	17790	21884	23	3866	4767	23
Electricity, Gas and Water	824	1647	100	473	946	100
Construction and Services	27501	30148	9.6	14277	15943	12
Total	70568	89294	26.5	32878	42379	29

Notes: * Figures do not add up to totals due to rounding.

1. In simulations under 'Without Project' scenarios, value of output was fixed for the following sectors: wheat, rice, cotton, animal husbandry and electricity, gas & water (See text).

Assumption: Assuming that under 'without project' situation, groundwater use will be at 50 per cent of the use in 1979-80 (under 'with project' situation) (Assumption I of irrigation availability scenario) and additional thermal power equal to 50 per cent of hydro output (Assumption II of electricity scenario) will be available.

Table 6.16

Value-Added and Gross Output of 39 Production Sectors in the SAM for Punjab (Millions of Indian Rupees) for 1979-80

	Value Added	*Gross Output*	*Value-Added Per Unit of Gross Output*	*Per cent of Regional Value-Added*
Wheat	5421	9735	55.7	12.8
Rice	3574	5189	68.9	8.4
Cotton	1573	2196	71.6	3.7
Sugarcane	650	813	79.9	1.5
Gram and Pulses	365	479	76.2	0.9
Oilseeds	367	454	80.8	0.9
Other Agr. and Forestry	2448	3207	76.3	5.8
Animal Husbandry	5598	7976	70.2	13.2
Dairy Products and Confectionary	155	669	23.1	0.4
Grain Mill Products	157	1874	8.4	0.4
Bakery Products	53	156	34	0.1
Sugar	34	195	17.5	0.1
Other Food Industries	140	512	27.4	0.3
Edible Oil	140	1876	7.5	0.3
Breweries and Beverages	47	285	16.6	0.1
Ginning and Textiles	1251	6932	18.1	3.0
Sawmills and Wooden goods	234	601	38.9	0.6
Paper, Printing and Publishing	51	144	35.3	0.1
Rubber and Leather Products	233	890	26.2	0.6
Basic Chemicals and Fertilisers	271	1055	25.7	0.6
Drugs and Pharma-ceuticals	7	39	17.1	0.0
Other Chemicals	36	233	15.4	0.1
Glass and Mineral Products	561	1488	37.7	1.3
Basic Metal Industries	392	4328	9.1	0.9
Metal Products	280	1377	20.3	0.7
Machinery except Electrical	241	1119	21.5	0.6
Electrical Machinery	112	536	21.0	0.3
Railroad Equipment	28	65	43.3	0.1
Motor Vehicles, Manufacture and Repair	399	1073	37.2	0.9
Bicycles and Parts	412	1313	31.4	1.0

contd...

contd...

	Value Added	*Gross Output*	*Value-Added Per Unit of Gross Output*	*Per cent of Regional Value-Added*
Scientific and Surgical Instruments	25	86	28.8	0.1
Sports and Athletic Goods	102	412	24.7	0.2
Miscellaneous Industries	133	193	68.9	0.3
Electricity, Gas and Water Supply	946	1647	57.4	2.2
Construction	2393	7863	30.4	5.6
Trade, Transport and Storage	8649	13841	62.5	20.4
Other Services	3494	6511	53.7	8.2
Banking and Insurance	877	1123	78.0	2.1
Real Estate and Owner of Dwellings	530	810	65.5	1.3
TOTAL	42379	89294		

As expected, the project had its biggest impact on the output of agricultural commodities, specially the output of wheat, paddy, cotton and oilseeds. The output of agricultural commodities is larger by Rs. 7 to 9 billion (46 to 66 per cent) under the 'With Project' situation than it would have been had the project not been undertaken. The output of electricity is estimated (for 1979-80) to be higher by 6033 million kWh or Rupees 1442 million.

Table 6.17 presents the results of the estimates of value-added multipliers based on the methodology and assumptions described above. Two estimates of multipliers have been reported based on the assumptions regarding the impact of seepage from canals on the availability of groundwater irrigation and the availability of electricity. These are:

Scenario I: Assuming that under the 'without project' situation, groundwater use will be at 50 per cent of the use in 1979-80 (Assumption I of irrigation under 'Without Project' situation) and additional thermal power equal to 50 per cent of hydro output will be available (Assumption II of electricity under 'Without Project' situation).

Scenario II: Assuming that under 'without project' situation, groundwater use will be at 50 per cent of the use in 1979-80 (Assumption I of irrigation under 'Without Project' situation) and no

Table 6.17

Estimated Values for Multiplier Effects of the Bhakra Dam Project, India

Definition of Multiplier	$\frac{\text{Direct Effects} + \text{Indirect Effects}}{\text{(Direct Effects)}}$
Value (Millions of Indian Rupees (Rs.) Scenario I	$\frac{\text{Regional Value Added (With Project)} - \text{Regional Value Added ('Without Project')}}{\text{Value Added of Ag.\& Elec. ('With Project')} - \text{Value Added of Ag.\& Elec. ('Without Project)}}$ $\frac{42379 - 32878}{15343 - 10343} = 1.90$
Value (Millions of Indian Rupees (Rs.) Scenario II	$\frac{\text{Regional Value Added (With Project)} - \text{Regional Value Added ('Without Project')}}{\text{Value Added of Ag. \& Elec. ('With Project')} - \text{Value Added of Ag. \& Elec. ('Without Project)}}$ $\frac{42379 - 30729}{15343 - 8807} = 1.78$

Notes: Scenario I: Assuming that under without project situation, groundwater use will be at 50 per cent of the use in 1979-80 (under with project situation) and additional thermal power equal to 50 percent of hydro output will be available.

Scenario II: Assuming that under without project situation, groundwater use will be at 50 per cent of the use in 1979-80 (under with project situation) and No additional power available from thermal sources.

Source: See text and tables.

additional thermal power is available in the absence of hydropower from Bhakra system (Assumption I of electricity under 'Without Project' situation).

Under Scenario I, the results show that the regional value-added under 'With Project' scenario at Rs. 42.38 billion is larger than the regional value-added under 'Without Project' scenario by Rs. 9.5 billion. Compared with this, the value-added from agriculture and electricity sectors at Rs. 15.34 billion is larger than the corresponding value-added under the 'Without Project' scenario by Rs. 5 billion. Thus, in the aggregate, the project induced an increase of Rs. 9.5 billion in regional value-added. Of this, Rs. 5 billion is due to an increase in the outputs of agricultural commodities and the additional generation of hydroelectricity from the Bhakra dam.

This gives a multiplier value[12] of 1.90 i.e. Rs. 9.5 billion/Rs. 5 billion. Thus, for every rupee (100 paise) of additional value-added

12. Here we are using the multiplier value for the project as a whole as defined in Bell *et al.* (1982). An alternative estimate of multiplier, as used in regional science literature, would be higher at 2.78 when total effects *vis-a-vis* direct effects are considered under the 'With Project' situation.

directly by the project in agricultural and electricity sectors, another Re 0.90 (90 paise) were generated in the form of downstream or indirect effects.

Under Scenario II, the results show that when electricity availability is lower than in estimate I (under the scenario of 'Without Project'), the regional value-added under 'With Project' scenario at Rs. 42.38 billion is larger than the regional value-added under 'Without Project' scenario by Rs. 11.65 billion. Compared with this, the value-added from agriculture and electricity sectors at Rs. 15.34 billion is larger than the corresponding value-added under 'Without Project' scenario by Rs. 6.53 billion. This gives a multiplier value of 1.78 i.e. Rs. 11.65 billion/ Rs. 6.53 billion. Thus, for every rupee of additional value-added directly by the project in agricultural and electricity sectors, another Re 0.78 were generated in the form of downstream or indirect effects.

Thus, the simulation results based on a SAM model show that the Bhakra dam project generated significant indirect or downstream effects in Punjab state. The multiplier values range between 1.78 to 1.90 depending on the assumptions regarding the impact of canals on groundwater availability. For every rupee (100 paise) generated directly, another 78 to 90 paise were generated in the region as downstream or indirect effects. These multipliers include the effects of inter-industry linkages as well as consumption-induced effects.

Multiplier Effects Outside the Region

In addition to the direct and indirect effects realised in the directly impacted region falling in the Bhakra system command, the dam has directly and indirectly also impacted regions and people in area located far-off from the project region. The increased economic activity in the directly impacted region has provided employment opportunities to thousands of migrant labours from some of the poorest regions of the country such as from the states of Bihar and Uttar Pradesh. The remittances from these migrant labours back to their families in their native villages in turn has impacted the economy of these villages. The huge foodgrain surplus production from the project region is procured by Government agencies for distribution at relatively low prices through 'fair price shops' to urban consumers all over the country. These procured foodgrains have also been used for giving wages 'in kind' to labours employed under food-for-work programmes etc. carried out in different parts of the country.

We briefly discuss some of these impacts.

Multiplier Effects of Remittances by Migratory Labourers in Villages Outside Punjab

The shifts in the cropping pattern and attendant changes in crop production brought about by the availability of irrigation water in the region created huge employment opportunities in agriculture and related sectors. The employment opportunities available on a continuing basis for hired labour every year lures thousands of labour from far-off poor regions of the country—Bihar, Uttar Pradesh etc, where wage rates are low and unemployment is very high, to migrate to this region in search of employment and better wages. While some of these labours have settled down permanently in the region itself, others migrate every year. In a study carried out recently by the Punjab Agricultural University it has been estimated that during the lean period of agricultural operations the number of migrant labour employed in Punjab was 387 thousand and this number increased to about 774 thousand in the peak period (Sidhu *et al.*, 1997). About 93 per cent of the migrants belonged to the poor states of Bihar and Uttar Pradesh while about 5 per cent also came from Nepal. It has further been estimated that the number of migrant labour have increased by about 35.31 per cent in 1995-1996 as compared to 1983-84. In terms of the proportion of migrant labour to local labour the proportion of migrant to local labour increased from 7.60 per cent in 1978-79 to 11 per cent in 1995-96. In other words, Punjab agriculture meets almost one-tenth of its total labour requirement by migrant workers.

The wage rates, which these migrant labourers get in their native villages, are much lower than what they get in Punjab. Thus, for example, about 46 per cent of migrant labour were getting less than Rs. 300 per month for being employed on a permanent basis in their native villages while in the Punjab they were getting almost 200 per cent higher wages.

It has been estimated that total earnings of the entire migrant labour force in crop production in Punjab during 1995-96 was Rs. 5344 million (US$ 114 million) out of which they remitted Rs. 3548 million (US$ 75 million or 66 per cent) back to their native places while the remaining Rs. 1796 (US$ 39 million) were spent by them in Punjab itself. About 18 per cent of the migrant labour utilised their savings for creation of assets in their native places.

The remittance of such huge amounts of money to relatively far-flung poor regions from where this labour often comes has helped improve the living conditions of people living there and has created its own further downstream effects. About 96 per cent of the migrant labours reported that they utilised these savings for purchasing consumer durables such as televisions, radios, bicycles, sewings machines etc. About 18 per cent also utilised their savings from Punjab on the repair and construction of their houses in their native village. A small percentage of labourers also used these savings to either lease land for increasing their operational holdings or for buying a new piece of agricultural land. In addition, part of the savings were of course used for improving daily consumption.

Apart from earning cash, these migrant labourers have acquired new skills in crop cultivation and operation of farm machinery during their stay in the Punjab. This has offered a great scope for transformation of the agricultural economies of their native villages but these labourers have not been able to use their acquired skills in their native villages due to a number of factors such as the non-availability of irrigation, inadequate credit etc. Nevertheless migration has helped them improve their skills

Multiplier Effects of Surplus Foodgrains used in 'Food for Work' Programmes

During the year 2001-02 the States of Punjab and Haryana contributed 17 million tonnes of wheat out of a total of 20.63 million tonnes procured by the State foodgrain procurement agencies from all over the country. Similarly during the year 2000-01 out of a total procurement of 19.10 million tonnes of rice from the entire country, Punjab contributed 6.93 million tonnes.

The Bhakra irrigated region provides the bulk of the foodgrains required by the Central Government for running the food distribution system in the country. While part of the procured foodgrains are utilised for running the Public Distribution System (PDS) of the country, a part of the procured foodgrains are provided to the States during emergencies created by natural calamities such as floods, droughts etc. These allocations in part are used by the States to create gainful employment opportunities under various employment generation programmes such as for creation of infrastructure etc. in which part of the wage payments are made using these foodgrains. For example during 1997 the central Government allocated 1303 thousand tonnes of rice and 705 thousand tonnes of wheat for various employment creation programmes in the States.

Multiplier Effects of Water Supply to Rural and Urban Areas

As mentioned earlier, the Bhakra system has provided adequate drinking water supply to many towns and cities in the states of Punjab, Haryana and Rajasthan. Even Delhi gets a part of its water supply from the Bhakra system.[13] In the absence of this water supply, the growth of industry and services in these towns and cities would have been adversely affected. However, due to the non-availability of any studies on the subject, it has not been possible to make any estimates of direct or indirect (and multiplier benefits) from the availability of water supply that is critical for generating urban incomes and employment.

Income Distribution Impacts of the Bhakra Dam System

The availability of irrigation water, and the consequent growth in rural and urban areas that followed, has helped in a very significant way in bringing down poverty in the two states of Punjab and Haryana. As already mentioned the benefits of this economic development in the region have been shared both by rural as well as urban areas. The income distribution effects of the Bhakra dam have been analysed using

13. Total water supply to Delhi from Bhakra in 1999 was 2803 cumec days out of a total of 428182 cumec days. However, the water supply from Bhakra meets a substantial part of the industrial demand for water supply.

the SAM-based multiplier model for the Punjab economy described above.

The income distribution effects of the Bhakra dam have been analysed in three ways:

(i) By comparing the shares of agricultural labour and other households in aggregate incomes under 'With' and 'Without Project' in the Punjab state.

(ii) By comparing the differences in aggregate income levels of various household categories under two scenarios of 'Without Project' and 'With Project'.

(iii) By assessing direct and indirect components of income differences under 'With' and 'Without Project'.

Shares of Agricultural Labour and Other Households in Aggregate Incomes under 'With' and 'Without Project'

The total population of 12.7 million in the Punjab has been divided into urban households (0.7 million) and four categories of rural households, namely, households self-employed in agriculture[14], agricultural labour households, non-agricultural labour households and other households. Of the total 12 million rural population, 46 per cent or 5.5 million were self-employed in agriculture while 23 per cent or 2.7 million were agricultural labour households. Non-agriculture labour households constituted about 6 per cent and other rural households constituted about 25 per cent of total rural households.

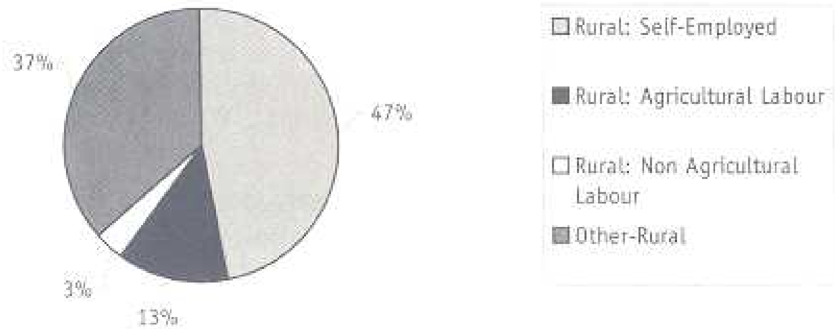
The SAM-based multiplier models have been used to assess the income effects of additional irrigation and hydropower provided by the Bhakra dam. This has been done for each of the above defined household categories.

Figures 6.10 and 6.11 depict results of the shares of different category of households in the aggregate rural income under 'with' and

14. Those households which earn 50 per cent or more of their total income from self-employment in agricultural occupation during the last 365 days are treated as self-employed in agriculture. Those households which earned 50 per cent or more of their total income during the last 365 days from wage paid manual labour in agriculture are treated as agricultural labour households.

Figure 6.10

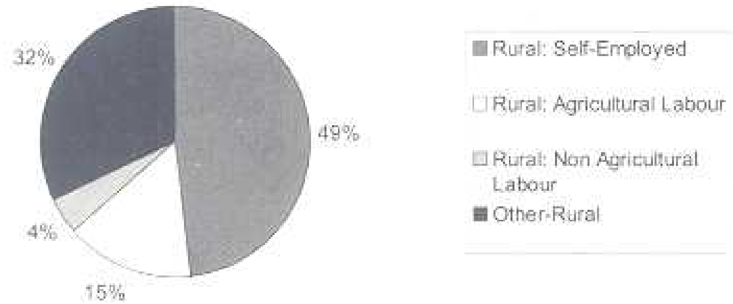
Income Shares: Without Project



Source: Author's calculations and based on model's results.

Figure 6.11

Income Shares: With Project



Source: Author's calculations and based on model's results.

'without project' situations. For example, for the self-employed rural households, the share of their income in aggregate rural income levels is 46.8 per cent under the 'without project' situations compared with 48 per cent under the 'with project situation'. The share of agricultural labour households at 15.4 per cent of the total under 'with project' situation is higher than 12.9 per cent under 'without project' situation. However, when a comparison is made between shares of aggregate rural and urban incomes in the total, the results show that the share of rural households is higher (61.5 per cent) under the 'with project' situation when compared with that (57.4 per cent) under the 'without project' situation. The share of urban households is 42.6 per cent and 38.5 per cent in the aggregate income under the 'without project' and 'with project' situations respectively.

Differences in Aggregate Income Levels of Various Household Categories under 'Without Project' and 'With Project'

The SAM-based multiplier models have been used to assess differences in household incomes under the 'with' and 'without project' situations.

Table 6.18 and Figures 6.12 and 6.13 show that all households have higher income levels under 'With Project' situation than under 'Without

Table 6.18

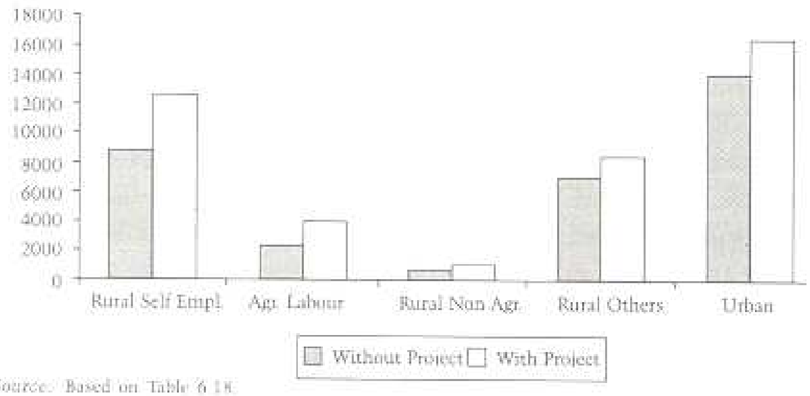
Differences in Incomes of Agricultural Labour and Other Rural Households: With and Without Bhakra Dam (Rupees Million)

Category Of Households	*With Project*	*Without Project*	*Difference*	*Percent Difference*
Self employed Rural Households	12505	8825	3680	41.7
Agriculture labor	4005	2425	1580	65.2
Rural Non Agriculture	1125	627	498	79.5
Rural-Others	8413	6988	1425	20.4
Urban Households	16331	14014	2317	16.5
TOTAL	42379	32878	9501	28.9

Source: Simulations using the SAM model for the Punjab 1979-80 described in the text (See text).

Figure 6.12

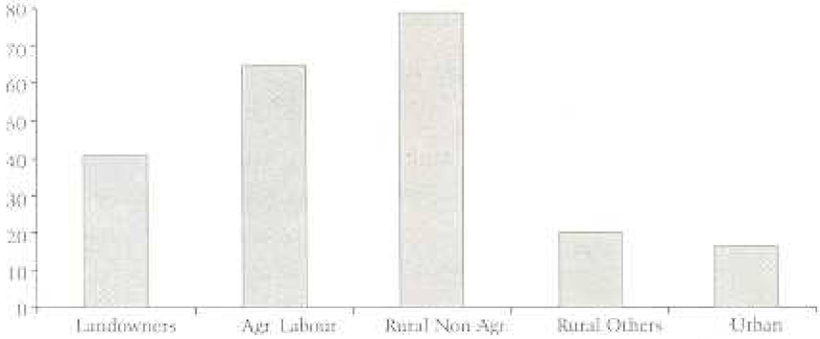
Income of Different Types of Households With and Without Project (Rs. Million)



Source: Based on Table 6.18.

Figure 6.13

Percentage Change in Income of Different Types of Households With and Without Bhakra Dam



Source: Based on Table 6.18.

Project' situation. For example, for self-employed rural households, the difference in income levels (under 'with' and 'without project' situations) is estimated to be Rs. 3680 million. Their income under 'with project' situation is 42 per cent higher over the income level under 'without project' situation (Rs. 8825 million).

In the case of agricultural labour households, the difference in income is Rs. 1580 million, which shows that their income under 'with project' situation is 65 per cent higher than the income level of Rs. 2425 million under 'without project' situation.

However, in the case of urban households, the difference in income levels under the two situations is relatively low, only 16.5 per cent. The level of income of urban households under 'without project' situation is Rs. 14014 million compared with Rs. 16331 million under the 'with project' situation. The results show that the gain for rural households from the dam is relatively higher than the average difference of 29 per cent between aggregate incomes under 'with' and 'without project' situations. Further, the investment in the Bhakra dam has provided income gains to agricultural labour households that are higher than those for the average households.

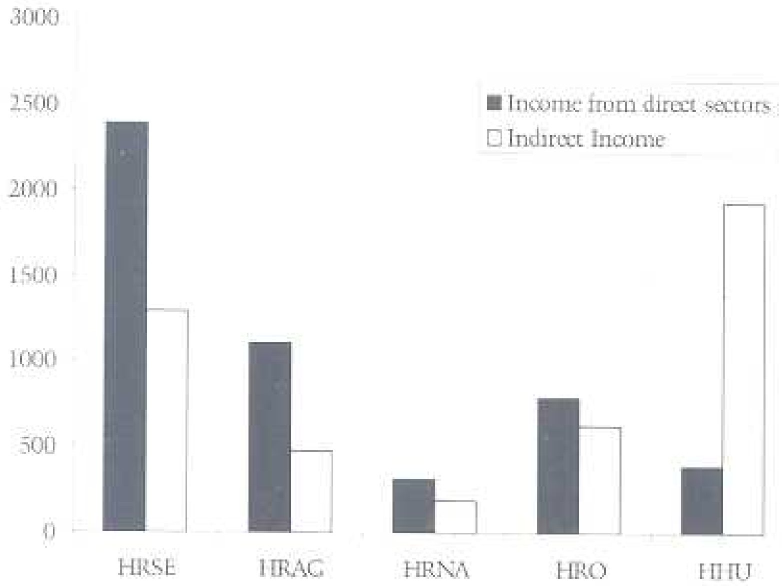
Direct and Indirect Components of Income Differences under 'With' and 'Without Project'

The SAM-based multiplier models have also been used to estimate direct and indirect income effects of additional irrigation and hydropower provided by the Bhakra dam. This has been done for each of the five defined household categories. The SAM coefficients for each household and each production sector have been used to estimate the value-added received by each household category from each sector. These SAM coefficients have been used to estimate the component of a household's income that is due to value-added from sectors affected directly by the outputs of the dam, namely irrigation and hydropower. Similarly, SAM coefficients for remaining production sectors have been used to estimate the component of income that is due to value-added from sectors affected indirectly by the outputs of the dam. This type of analysis is based on the usual assumptions for this type of fixed-price SAM-based multiplier models, namely that the value-added per unit of output remains the same for each sector and the adjustments take place through changes in quantity. The procedure used to estimate the share of direct and indirect components in household incomes is as follows. First, the SAM coefficients have been used to estimate values of a new SAM for the 'Without Project' situation by fixing the outputs of sectors directly affected by the dam (agricultural sectors and electricity). Then the difference between the values of outputs and household incomes in the two SAMs is used to estimate the differences in incomes under the 'with project' and 'without project' situations. The difference in household incomes is further divided into two components—one from direct sectors and the other from indirect sectors. To calculate the component from direct sectors we look at the row of each household in the matrix of income differences and sum up the incomes the household received from sectors directly affected by the project namely—wheat, rice, sugarcane, cotton, gram, other agriculture and electricity. To calculate the component from the indirect sectors we added the incomes received from the remaining production sectors out of the total of 39 production sectors used in the SAM.

The resulting estimates show, as predicted, that a major part of the income of rural households comes from the output of sectors directly

Figure 6.14

Income Gains to Households from Sectors Affected Directly and Indirectly by the Dam



Source: Author's Calculations

affected by the dam. Figure 6.14 presents the results of the disaggregation of the differences in household incomes under the 'with' and 'without project' situations into sectors affected directly by the dam and those indirectly affected. For example, for the self-employed rural households, the difference in income levels (under 'with' and 'without project' situations) is estimated to be Rs. 3680 million. About two-thirds of this difference (or Rs. 2391 million) is due to higher output and value-added in sectors that are directly affected by the dam, namely agricultural crops and electric power. The rest, about one-third, of the difference in income (or Rs. 1288 million) is attributable to changes in value of output and value-added of sectors that are affected indirectly (through inter-industry linkages and consumption-induced effects). In the case of agricultural labour households, as much as 70 per cent of the difference in income is due to changes in output/value-added of sectors that are directly affected by the dam. However, in the case of urban households, the situation is completely reversed. As much as 83 per cent (or Rs. 1925 million) of the difference (under 'with' and 'without project' situations) is accounted for by changes in outputs of sectors that are indirectly affected by the dam, namely agro-processing, manufacturing of textiles etc.

Social and Environmental Effects

Displacement of People and their Rehabilitation

Construction of big dams have almost always led to the submergence of large areas and displacement of people and the studied Bhakra dam is no exception. The figures about the number of actual people displaced by different dams vary very substantially according to the source of information.

The Bhakra reservoir submerged 17,800 hectares of land, affecting 371 villages with a population of about 36,000 people or about 7,200 families. Bilaspur town with a population of 4000 was also submerged. Of the 7,206 affected families, 5,027 were given cash compensation under the Land Acquisition Act and resettled elsewhere on their own. A Bhakra Rehabilitation Committee was appointed to examine the future of the remaining 2,179 families. Since these farmers expressed a desire for resettlement in the Bhakra command, the committee located suitable lands in compact blocks in Hissar and Sirsa districts in Punjab (now Haryana) and 13,200 acres were accordingly acquired in 30 villages. As the amount due in compensation exceeded the value of the land acquired, the displaced persons were compensated partly in land and partly in cash.

Landless tenants were declared eligible to be given an area equivalent to their submerged tenancy, subject to a maximum of 5 acres. Other artisans and labourers from the affected villages were offered a half acre homestead plot free of cost. Those choosing to remain in Himachal Pradesh were granted free fishing licenses in Gobindsagar for three years (Verghese, 1994).

The Pong Dam displaced 16,000 families (about one hundred thousand people). An attempt was made to rehabilitate about half of them in the faraway deserts of Rajasthan in the command area of the project. Each family was given 16 acres of land (the highest so far under any rehabilitation scheme in the country). In spite of this, unable to adjust to the new climatic conditions, water, people and language, most of the displaced people sold their lands and returned to their native place.

In a recent press statement, quoting government sources, it was reported that there are still 784 oustees of Bhakra dam who still remain to be rehabilitated.

Health Impacts

The availability of dependable source of drinking water for millions both in the project region as also in the neighbourhood is likely to translate into better health of people. With the Indira Gandhi canal, the percentage of the reported relative incidence of waterborne diseases to all diseases dropped considerably over a 12-year period in areas that received continuous irrigation facilities (Goel, 2000). In addition, the improvement in economic conditions of a majority of population within the irrigation command helps investment in improved sanitation and also makes the people more health conscious resulting in the reduced incidence of diseases.

Environmental Impacts

The construction of dams, apart from causing economic impacts, also causes a number of social and environmental impacts, some of which are beneficial for the environment while others have negative impacts.

Sedimentation of Reservoirs

The sedimentation of reservoirs as a result of soil erosion in the catchment areas of these reservoirs has been much faster than that assumed at the time of planning of these reservoirs. The Ravi, Beas and Sutlej have substantial upper catchments, the Pong catchment extends over 12,560 square kms. The Sutlej catchment of 56980 square kms is much larger. Approximately 27,000 acre-feet of silt flushes down the Sutlej annually, as measured near the Bhakra. The Bhakra dam was originally based on an assumed siltation rate of 4.29 ha-metre per 100 square kms but this had increased to 6.22 by 1979. Similarly in the Beas reservoir, the sedimentation rate during 1981 was 23.58 as against the original rate of 4.29 assumed during 1974 (NLUPB, 1988).

The faster than assumed siltation of reservoirs has resulted in a serious reduction in the carrying capacity of these structures and has accordingly reduced the efficacy of these reservoirs. The Gobindsagar Lake started filling in 1959 and up to the end of 1988 had lost 21.99 per cent of dead and 6.42 per cent of live storage with an overall capacity loss of 10.26 per cent. The total silt deposit in Gobindsagar in 28 years up to 1987 was 0.935 MAF, the average up to 1986 working out to 25,300 acre feet per annum as against the design figure of 27,250 acre feet.

The Sixth sedimentation report of the Pong Dam, 1988-89, indicated an average sedimentation rate of 26,500 acre feet per annum as against the designed figure of 20500 acre feet. The total silt deposit in the reservoir between 1974 and 1989 worked out to 0.3975 MAF or 5.72 per cent of the gross storage capacity. The small Pandoh reservoir, however, had accumulated 16,886 acre feet of silt as against a gross storage capacity of 33,240 acre feet as of October 1989 (BBMB, 1990).

Waterlogging and Soil Salinity

Large dams have diverse and complex ecological impacts and they often generate environmental costs for those very groups who are supposed to be the beneficiaries. Water logging and salinisation are twin problems caused by the wasteful use of water.

Waterlogging is caused by the interaction of a large number of factors such as irrigation intensity, soil characteristics, drainage, seepage from reservoirs, distributaries and field channels and becomes almost inevitable in areas with undulating topography and water retentive soils.

According to an assess-ment of the Ministry of Water Resources, the extent of waterlogged and soil affected areas in the irrigation command area of Punjab is 200 thousand hectares of waterlogged area and 490 thousand hectares of salt affected area. Similarly in Haryana the corresponding figures were 249 and 197 thousand hectares while in Rajasthan the figures are 180 and 70 thousand respectively (Government of India, 1991).

Groundwater Pollution

The availability of Bhakra water supplemented by groundwater led to adoption of intensive cultivation practices based on intensive use of agro

Table 6.19

Nitrate Content of Groundwater in North West India: 1995

State/Nitrate (mg/l)	Content	Number of Samples	Average Nitrate Level
Punjab			
0-45		328 (68.9)	14.50
46-100		71 (15.1)	66.49
>100		71 (15.1)	238.97
Total		470 (100)	56.26
Haryana			
0-45		222 (63.1)	15.41
46-100		62 (17.6)	68.58
>100		68 (19.3)	283.65
Total		352 (100)	85.59
N-W India			
0-45		550 (66.9)	14.84
46-100		133 (16.2)	67.46
>100		139 (16.9)	280.82
Total		8229 (100)	64.97

Note: Figures in parentheses denote percentages.

Source: Singh and Bal (1987).

chemicals in the region. The indiscriminate and unsupervised use of agro chemicals (fertilisers, pesticides and insecticides etc) have been one of the important sources of non point pollution. In addition to loss through run-off, these chemicals leach in to the groundwater aquifer and have the danger of polluting the groundwater.

Table 6.19 shows that the desired level of nitrate in large parts of Punjab and Haryana groundwater has already reached a level above that permissible in drinking water. The results show that 33 per cent of the samples in North-West India had nitrate content well above the permissible limit of 45 mg/l. In fact, in about 17 per cent of the samples, the nitrate content was more than 100 mg/l.

Making Deserts Green

Large dams can also become instruments for improving the environment, as has been the case in Western Rajasthan, which has been transformed in to a green area because of the Indira Gandhi Canal, which draws water from Bhakra Nangal dam. The project has not only allowed the farmers to grow crops in deserts but also has also checked the spread of the Thar desert in adjoining areas of Punjab and Haryana. Besides providing irrigation benefits for over 800 thousand hectares of desert land, which now cultivates crops like wheat, cotton, mustard etc, the most needed water (11 per cent of the project water) is reserved for drinking, domestic, energy and industrial uses in areas around Bikaner, Jodhpur, Jaisalmer towns and 3500 villages. The value of agricultural produce from this vast new areas brought to cultivation is nearly Rs. 12,000 million which is likely to double up as and when the project is complete (Gopalakrishnan, 2000).

Restoration of Loss due to Forest Submergence

The loss in biomass, due to submergence of forest land by reservoirs created for the storage of water, has been more than compensated by the greening of thousands of hectares of land and increased biomass production resulting from increased agricultural production in the project region.

Mitigation of Green House Gas Emission

If the environmentally clean hydro power of 14110 million kWh generated during 1998-99 were to be produced from the next best alternative of coal based thermal power plant, the plants would have emitted, 106 million tonnes of carbon dioxide per year in addition to emitting several other green house gases (taking the carbon dioxide emission from coal based thermal power plants to 330 kg/GJ). The creation of hydropower potential has thus enabled mitigation of GHGs to the tune of 106 million tonnes of carbon dioxide. However, there are other effects of greenhouse gas emissions of reservoirs and rice farming that have to be taken into account to get the net effect of the dam on GHG emissions.

Increased Emission of Methane

The cultivation of wetland paddy is one of the important sources of methane emission. Methane emission from paddy cultivation accounts for about 25 per cent of the total methane emissions from all sources.

The large-scale diversion of cropping pattern in favour of cultivation of rice has thus led to the increased emission of methane from rice fields.

Seismic Impacts

Doubts are often raised about the safety of large dams due to seismic forces. It has been argued that impounding water in reservoirs induces seismicity. The Bhakra dam which has been constructed in the Himalayan region for more than 40 years now has not led to any increase in seismic activity after construction.

Conclusions

The simulation results based on a SAM-based multiplier model show that the Bhakra dam project generated significant indirect or downstream effects in the Punjab state. The multiplier values ranged between 1.78 to 1.90 depending on the assumptions regarding the impact of canals on groundwater availability and availability of power. For every rupee (100 paise) generated directly, another 78 to 90 paise were generated in the region as downstream or indirect effects. These multipliers include the effects of inter-industry linkages as well as consumption-induced effects.

The multiplier effects will be much higher if indirect and induced effects of remittances sent by agricultural workers from Punjab and contributions of the Bhakra dam towards the 'Food for Work' programme are also included in the analysis.

The results on income distribution show that the gains to agricultural labour households from the dam are higher than gains to other rural households and to the urban households. For example, for the agricultural labour households, the income level under 'With Project' situations is estimated to be 65 per cent higher than the income level under the 'Without Project' situation. The corresponding figures for self-employed rural households and urban households are 42 per cent and 16 per cent, respectively.

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