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Bhakra Canals and Groundwater in Punjab and Haryana

THE BHAKRA-NANGAL PROJECT

Project Features and Layout

The Bhakra Nangal project is a complex system of several dams, reservoirs, inter-basin transfer linkages, powerhouses and a vast canal network. It is also integrated with the much older Sirhind system in Punjab which too takes off from the Sutluj.

The Bhakra dam, 740 feet from the deepest foundation, is built on the river Sutluj near the Bhakra village in Himachal Pradesh, just before it enters into Punjab. The Govind Sagar reservoir stretches out behind it over 168.35 sq. km. The inflow into the reservoir consists partly of snowmelt, partly of rainfall run-off and partly of the waters of the Beas diverted into the Sutluj. The Bhakra dam has a catchment of 56980 sq. km. The maximum Reservoir Level is 1680 feet, and at this level the reservoir has a gross storage of 9340 million cubic metre (MCM) (or 7.57 Million Acre Feet **-** MAF) and a live Storage of 6911 MCM (5.60 MAF**).**

The Pandoh dam on the Beas river, (called Beas Unit I) diverts 3.82 MAF of Beas waters annually into the Sutluj through an open channel and 2 tunnels with a combined length of 25 kms. This is the Beas Sutluj Link or the BSL. The diversions empty into the Govind Sagar at Dehar, on the right bank of Sutluj near the Slapper bridge, where a powerhouse is built to take advantage of the 150 m fall in the path from Pandoh to Dehar. The Dehar powerhouse has an installed capacity of 990 MW.

The Bhakra dam has two powerhouses, namely the Right Bank and Left Bank. These have an installed capacity of 660 MW and 540 MW respectively. Water released through these powerhouses flows down the Sutluj for about 13 kms to the Nangal barrage at Nangal. Two channels take off from the Nangal dam. One is the Nangal Hydel Channel which goes on for 65 kms up to Ropar, from where it is called the Bhakra Main Line. Two power stations are located on the NHC namely, at Ganguwal (77.65 MW installed) and then at Kotla (77.65 MW). The other channel taking off from the Nangal dam is the Anandpur Sahib hydel channel.

The Bhakra Main Line takes off at Ropar, and then, through several branches serves areas in Punjab, Haryana and Rajasthan. Some parts of the Bhakra command are serviced via the Sirhind system in Punjab. Another canal takes off from Ropar to the North of the Sutluj serving the areas of the Bist *Doab*. (See Figure 1 **-** MAP3 for a schematic diagram of the project)

About 113 kms downstream of the Pandoh dam on the Beas is the Pong dam. From Pong, the river travels down to meet the Sutluj at Harike Patan. A barrage was constructed at Harike in 1952. The Indira Gandhi Nahar (or the Rajasthan Canal as it is called) takes off from here, along with the Sirhind feeder. The Raj Canal, as the name suggests goes to Rajasthan. The construction of this canal cut off several areas at the tail end of the Sirhind system (including some areas that were to be in the Bhakra command). The Sirhind Feeder was constructed to serve these areas from the Harike Barrage. It opened in 1958.

Brief History

The Bhakra project was first suggested in 1908. After that, it underwent many modifications and enlargements. The main justification given for it was the severe drought problem in the then Hissar and Rohtak districts of Punjab (now Haryana). The project was caught up in the inter-province water disputes between Punjab and Sindh. It was only after partition that the work on the project could begin in earnest. Work on the Nangal barrage began in 1946. The Bhakra dam itself underwent several enlargements and its design was finalised in 1953. One of the important decisions taken was that the canal system would be built ahead of the dam itself, so that irrigation could commence at the earliest. In 1954 the Nangal hydel channel and the network of Bhakra canals was declared open and irrigation from the Bhakra-Nangal project started. However, impoundment at Bhakra started only in 1958 and till then irrigation from the project was essentially *kharif* irrigation. Irrigation developed rapidly and by 1963-64, when the dam was completed, irrigation had been more or less fully developed.

Irrigation Design

The 1953 Project Report fixed the following for Bhakra Project:

Gross Commanded Area:	26.8	lakh ha
Cultivable Commanded Area:	23.7	lakh ha
Annual Irrigation:	14.6	lakh ha

Another 9.0 lakh ha were to get benefit of improved irrigation.

Table 1: Statewise Cultivable Command Area and Annual Irrigation of Bhakra Project

State	**CCA** (Million ha)	**% of Bhakra CCA in state**	**Annual Irrigation** (million Ha)
Rajasthan	0.372	16%	0.231
Haryana	1.160	49%	0.676
Punjab	0.840	35%	0.551
Total	**2.373**		**1.460**

Source: Gulhati 1973: 457 for Annual Irrigation, CCA derived by author from BBMB 1988

The Bhakra Command area was divided into 3 zones.

Zone 1: This zone consisted of areas “which lie(s) near the hills and receive(s) good rainfall during the monsoons as well as during the winter months”. The areas are Bist Doab areas (north of Sutluj) and areas South of Patiala. Irrigation here was Restricted Perennial and planned irrigation intensity was 45%.

Zone 2: These were areas adjoining both sides of Sutluj, which were receiving liberal supplies from inundation canals. The irrigation to these areas would be cut-off as the construction of the dam would dry up the river below Ropar. Hence, areas in Zone II were essentially replacement irrigation. Irrigation here was Non-Perennial and intensity of irrigation was to be 35%

Zone 3: These were the dry and arid tracts, essentially of Hissar and Rohtak districts. The rainfall in these areas was meagre, (250 to 380 mm), and spring levels were low. Irrigation was to be Perennial and intensity of irrigation was to be 62%.

As seen, the project had fixed relatively low irrigation intensities for all the three zones. The justification was that there was need to spread the benefits as much as possible; hence, irrigation was to be protective in nature and not intensive. Figure 2 and 3 - (MAPS 4 and 5) show the Bhakra command area in the states of Punjab and Haryana. About 85% of Bhakra irrigation in Punjab is in Zones 1 and 2, while in Haryana, 86% of the area is in Zone 3.

However, the project report itself admitted that the proposed irrigation was overestimated to the extent of 25% when compared to the available water and storage. According to the BBMB, “… the mean storage available from Bhakra reservoir was calculated to be 4.631 MAF against a requirement of

6.207 MAF resulting in a shortage of about 25.4 %" (BBMB 1988: Page 249). It was planned to meet this shortage by diverting Beas water to the Bhakra command areas, which was done many years later, partly through the BSL and partly by shifting some Bhakra command areas to Harike.

One of the most important aspects of the irrigation design that concerns us is that there appears to be no planning of conjunctive use in the command area. This *seems* to be a result of two factors. One, the Indian irrigation establishment at that time thought that the problem of waterlogging and salinisation - already a huge issue in Western (Pakistan) Punjab - could be addressed by better drainage, and that the long term effectiveness of tubewells in controlling / reclaiming waterlogging was not cost effective. Combined with this was also the feeling that Beas-Sutluj-Ravi system would have ample water to meet our needs, and hence there was no need felt for developing groundwater. Of course, groundwater continued to be an element of the community development programs in the country and in Punjab. (Michel 1967: Page 510-511)

It must be emphasised that groundwater - based essentially on dugwells - was a significant source of irrigation even then, and just prior to the start of irrigation from the project, in 1953-54, the total net irrigated area in the then Punjab (today's Haryana and Punjab) was 3.028 million ha (m ha), 1.912 m ha by canals and 1.036 m ha by wells (Statistical Abstract of Punjab 1960).

IRRIGATION DEVELOPMENT

The Green Revolution

As mentioned earlier, irrigation commenced in 1954 and was virtually fully developed by 1963-64. However, around this time came a development that was to completely alter all equations in irrigation and agriculture. This was, of course, the Green Revolution.

At the core of the Green Revolution was a new breed of seeds introduced in 1965. So dramatic was the performance of these seeds – popularly known as High Yielding Varieties (HYV) that they were widely called the "miracle seeds". The spread of these seeds was rapid in Punjab and Haryana as compared to the rest of the country. By 1970-71, 69% of Punjab's wheat area was already under HYV, while the same figure for Haryana was 56%. While the yields were dramatic, they required much higher inputs. Among the most critical of the inputs was water. The performance of the HYV seeds was particularly sensitive to the timing and quantity of water. Ability to control irrigation became critical and this set off an explosive growth in the tubewell based irrigation.

Explosive Growth in Tubewell Irrigation

By the late 60s, tubewell irrigated areas had equalled and soon outstripped canal irrigated areas in Punjab. (See Figure 4) In Haryana too, tubewell irrigation grew rapidly till it now equals the canal irrigation (Figure 5). The number of tubewells in Punjab jumped from 20,066 to over 450,000 from 1965-66 to 1975-76. In 1997-98, this figure was 910,000. In Haryana, the number of tubewells jumped from 25,311 in 1965-66 to 204,736 in 1975-76, and in 2000 stood at 583,705. Tables 2 and 3 show the growth in areas.

Table 2: Net Area Irrigated by Source: Punjab

('000 ha)

	1965-66	1975-76	1997-98	2001-02
Canals	1289	1366	1356	987
Tubewells	887	1742	2356	3068

Table 3: Net Area Irrigated by Source: Haryana

('000 ha)

	1965-66	1975-76	1993-94	1998-99
Canals	960	1036	1353	1433
Tubewells	224	682	1283	1395

Even though the Bhakra project did not envisage any particular growth in groundwater in the command, the new developments completely changed this and even in the canal commanded areas, including Bhakra command, tubewell irrigation grew at a tremendous speed.

Groundwater Irrigation in Bhakra Command Area

Punjab

Over the years, canals have come to play a very limited role in the Bhakra irrigated districts in Punjab. In most of these districts, groundwater is the major contributor to irrigation.

As late as in 1975 (that is, 20 years after irrigation from Bhakra-Nangal had started), the Comptroller and Auditor General (CAG) of India in his report had noted that in Punjab the actual utilisation of irrigation in the Bhakra command was on average 285 thousand ha as against the planned 433 thousand Ha. (5 years average 1971-72 to 1975-76) The CAG report further states the "main reason for non-utilisation …was reported to be the installation of a large number of private tubewells." (CAG 1977: Page 108)

Table 4 gives figures for the total net area irrigated and net area irrigated by canals in the state for the year 2001-02, for those districts that are either in the Bhakra or Sirhind command.

Table 4: Canal Irrigation in Punjab

(in Districts of Bhakra and Sirhind Commands) 2001-02

S.N.	Name of District	Total Net Area Irrigated in Year 2001-02 (000 Ha)	Net Area Irrigated by Canal in Year 2001-02 (000 Ha)	Net Area Irrigated by Canal as % to Total Net Irrigation
1	Kapurthala	136.2	12.0	8.8%
2	Jullundhur	237.5	7.0	2.9%
3	Nawanshahar	84.6	3.0	3.5%
4	Ludhiana	305.3	6.1	2.0%
5	Ferozepore	473.5	144.8	30.6%
6	Faridkot	130.5	25.7	19.7%
7	Moga	199.5	11.3	5.7%
8	Muktsar	217.5	4.3	2.0%
9	Bhatinda	294.9	229.5	77.8%
10	Mansa	199.2	152.1	76.4%
11	Sangrur	455.5	140.2	30.8%
12	Patiala	290.7	9.5	3.3%
13	Sirhind (Fatehgarh Sahib)	103.5	1.6	1.5%

14	Rupnagar	104.9	16.4	15.6%
Total for 14 Districts		**3233.3**	**763.5**	
Total Punjab		**4057**	**987**	**24.33**

Source - Punjab Statistical Abstracts 2003

In the districts having significant part of Bhakra command, like Patiala, Fatehgadh Sahib, Jullundhar, Kapurthala the percent net area irrigated from canals ranges from 1.5% to about 19%.

Haryana

In Haryana, the picture is different. Canal irrigation is a major source of irrigation in many of the Bhakra commanded districts, especially Hissar, Sirsa, Fatehbad. The main reason is that groundwater is not of good quality in these districts.

Table 5 gives the total net area irrigated and net area irrigated by canals in Haryana for the districts in Bhakra command.

Table 5: Canal Irrigation in Haryana in Bhakra Districts 1998-99

Important Note: Last three columns refer to areas irrigated by all sources and all canal systems, not just Bhakra.

S.N.	**Name of District**	**% of District in Bhakra Command**	**Total Net Area Irrigated in Year 1998-99** (000 Ha)	**Net Area Irrigated by Canal in Year 1998-99** (000 Ha)	**Net Area Irrigated by Canal as % to Total Net Irrigation**
1	Hissar	60%	252	243	96.43
2	Bhiwani	2%	212	129	60.85
3	Sirsa	100%	309	262	84.79
4	Fatehabad	100%	196	136	69.39
5	Karnal	5%	206	42	20.39
6	Kurukshetra	50%	148	8	5.41
7	Kaithal	100%	197	100	50.76
8	Ambala	5%	94	14	14.89
9	Jind	50%	217	129	59.45
	Total 9 Districts		**1831.0**	**1063.0**	
	Total Haryana		2842	1433	50.42

Source - Haryana Statistical Abstract 1999-2000
Note: Column 3 – "% of District in Bhakra Command" estimated by the author from maps and other data.

Reasons for Growth of Groundwater Irrigation

HYV Demand Control of Irrigation

The primary driver of tubewell based irrigation was the HYV seeds which required assured supply of water and were sensitive to the timing of waterings. While canal irrigation certainly was helpful with the new seeds, it could hardly provide the kind of assured supply required by them. Increasingly, the farmers in Punjab, and then in Haryana turned to groundwater irrigation.

The Fourth Plan document – which came out in 1969 – after just a few years of experience of the HYV seeds has noted this phenomenon.

> "*... ground water provides the farmer with just the type of 'instant' and controlled irrigation which the new high-yielding varieties of seed demand.* This fact, coupled with the increasing extension of electricity to rural areas, explains the expansion which has taken place in recent years in the development of ground water resources. The expansion has taken place not only in areas which are without any other source of irrigation but also in alluvial tracts already commanded by existing canal systems; … The remarkable development of ground water resources during recent years was stimulated by the droughts of 1965-66 and 1966-67 which also happened to coincide with the development of high-yielding varieties *which perform best under conditions of controlled and timely irrigation.*"(Emphasis added)

Cropping Pattern Needs Excessive Waters

With the advent of the Green Revolution came a series of measures to support the HYV programs, including assured procurement at an assured minimum price, especially for the two crops wheat and rice. This led to dramatic changes in the cropping pattern of the two states, with wheat and rice, along with cotton dominating the cropping pattern. There was no way in which this cropping pattern - and especially paddy - could be sustained only on canal waters. This is not surprising since the canal waters were *designed* for protective irrigation to provide one assured crop to the farmer. We have seen already that the maximum intensity of irrigation in the Bhakra command was only 62%. Thus, the newer cropping pattern, the new varieties of seeds could not be supported on such low intensities. Nor could multiple cropping. This drove the farmers into going in for tubewell based groundwater irrigation. So strong is this force that farmers have gone in for tubewells even in many areas with saline groundwater.

Canal Waters Declining and Unreliable

One of the complaints we heard during our extensive field visits and discussions with farmers in the Bhakra command area was that the waters coming in via canals have gone down over the year, as has the reliability. There could be two reasons for this. General deterioration in the canal system leading to heavier losses could be one reason. There have been, according to the Government of Punjab and Haryana continuous attempts to renovate, line and in general maintain the canals. In particular, loans from the World Bank have come in for this purpose. Clearly these do not seem to have been enough. Another important reason for the decrease in the canal waters could be the siltation in the Bhakra reservoir. By 1975, the Bhakra reservoir had lost 2.5% of its live capacity and 16.42% of its dead storage to siltation. In year 2000, about 10% of the live storage and 31% of the dead storage was silted up. (Duggal *et al*, 2002)

PROBLEMS AND ISSUES WITH GROWTH OF GROUNDWATER IRRIGATION

Over Exploitation of Groundwater

It is not clear when the issue of over-extraction of groundwater started being felt, but by the mid 1980s, the serious impact of massive extractions has already been noted, with several districts being classified as "dark" and "grey". In 1986, 6 out 12 districts in Punjab had a negative groundwater balance, with draft exceeding recharge. These districts were Amritsar, Sangrur, Jalandhar, Kapurthala, Ludhiana and Patiala - several of the Bhakra command districts. (Singh 1991)

As the exploitation continued unabated, the problem has assumed menacing proportions, both, in Punjab and in Haryana. Indeed, it seems that significant part of the farm output now depends on mining of groundwater in both the states.

Tables 6 and 7 give the estimates for sources of meeting the consumptive use of water by crops in the two states.

Table 6: Consumptive Use of Water by Crops in Haryana and its Sources

	In MAF	**In Percentage**
Total consumptive use of the state for agriculture for the prevalent cropping pattern	27.46	
This is met from:		
Rainfall	8.02	29.21%
Groundwater Availability	5.52	20.10%
Canal Water Availability	5.27	19.19%
Mining of Groundwater	**8.65**	**31.50%**

Source: Kumar *et al* 2000: Page 15

Table 7: Consumptive Use of Water by Crops in Punjab and its Sources

	MAF	**Percent**
Total Consumptive Use	38.9	
Met by:		
Rainfall	4.9	13%
Canal Direct	14.0	36%
Canal Indirect (Recharge of Groundwater)	4.8	12%
Groundwater Direct	3.2	8%
Groundwater Mined	**12**	**31%**

Source: For Rainfall: Dhawan 1989
For other figures G.S. Dhillon, Personal Communication
Data pertains to 1989-90

We can see that in both the states, mined groundwater provides about 31% of the water required by crops. This has grave implications for the sustainability of the system as this level of mining cannot be sustained indefinitely.

Overall, one can say that the level and nature of the current agricultural system in the two states have clearly exceeded their carrying capacities. As the mining of groundwater continues unabated, there is a real threat of a collapse of the whole structure.

Serious Impact on Farmers

Apart from the grave threats to the long-term sustainability of the agricultural system in Punjab and Haryana, the overexploitation of ground water in the two states has serious implications for the farmers in the immediate terms. Water is one of the key inputs to agriculture, and its cost – both, the real cost and the cost as borne by the farmer -has gone up dramatically.

Over extraction has meant that groundwater levels are going down fast. The Johl committee report notes that the groundwater level in Punjab is going down by 30 cms per year.(Government of Punjab

2002: Page 13) A critical water table depth below 10 m has been reached in 28% of the area of the state. Districts so affected include Ludhiana, Sangrur, Jalandhar, Patiala –significant parts of the Bhakra command. In Haryana, groundwater levels are falling in 48% of the state area[1]. Districts affected include Mahindragarh, Riwari, Gurgaon, Kurukshetra, Kaithal, Karnal, Panipat and Ambala. Thus, several Bhakra commanded districts are in the grip of this problem.

The falling water levels are of great economic concern to the farmers. As water levels go deeper and deeper, farmers are being forced to re-bore and deepen their wells every few years – at great cost. Small farmers are not able to do this. Farmers have to increase the horsepower of the motors. Many farmers are shifting to submersible pumps now. Even though power supply itself is available at a low price, the farmer has to bear the capital cost of pumping equipment, and the cost of deepening. Yields from the tubewells also can be affected. The sum total is a serious threat to the individual farmers and the larger system both, especially as much of the production is dependent on groundwater. Thus, whether a catastrophic collapse takes place or not, the groundwater crisis leading to escalating difficulties and costs for the farmers, which in the end may have a similar effect.

Drawing waters from increasing depths is likely to have implications for the quality of the water also, but we have not been able to study this aspect.

OPTIONS FOR ADDRESSING THE GROUNDWATER CRISIS

One of the most common suggestions to address the issue is the pricing of electricity. It is suggested that electricity should be priced so that the farmer pays the full and true cost of the electricity. This, it is said will lead to much lesser groundwater extraction. That such a measure will have some impact is not denied. Yet, it is likely that such a high rise in power prices may only have a limited impact on the groundwater extraction, but a far more serious impact on the viability of farming.

It should be noted that a significant number of the pumpsets in Punjab and Haryana are run on diesel. In Punjab, in 2002-03, 2.91 lakh tubewells out of a total of 11.5 lakhs were being run on diesel - 25%. (Statistical Abstract of Punjab 2004). In Haryana, in 1999-2000, 258984 tubewells out of a total of 583705 were running on diesel - 44%. (Statistical Abstract Haryana 1999-2000) These figures indicate that the pressure on farmers to run tubewells is such that a large number are willing to use high cost diesel. Unless this primary driving cause is addressed, it is likely that in spite of increase in tariffs, groundwater extraction would continue with only limited reduction.

On the other hand, increased power tariffs would mean that the cost of one more input for the farmer would rise significantly. Already, the viability of farming in the state is threatened due to sharply rising costs of inputs, need for higher inputs to maintain the same yields, and lack of commensurate increase in the prices for the farm produce. This has led to severe indebtedness and even debt trap among the farmers of Haryana and Punjab, and a large number of suicides have been reported. The increase in power tariffs can only aggravate this.

Thus, the efficacy of this measure will have to be evaluated in the full context of the current structure and viability of agriculture.

A more fundamental suggestion that has been made is that of changing the cropping pattern. (See, for example, Government of Punjab 2002) Paddy especially has been singled out for its high water requirements. It is true that paddy is a high water consuming crop and indeed in a low rainfall area like Punjab it is highly dependent on irrigation. Canal irrigation is grossly inadequate to provide for paddy, and thus paddy in Punjab necessarily depends on tubewell based irrigation. Moreover, with early sowing of paddy becoming common in Punjab, the water requirements have gone up even further. Thus, switching from paddy could be a useful element in controlling groundwater extraction, but only if the substitute is not equally water consuming. Some people have questioned the benefit to

[1] EMCB-ENVIS Node on Water Resource Management at http://www.water-mgmt.com/en/database_haryana6.htm

ground water balance from switching over from paddy. They point out that while the gross water requirement of paddy is high, much of the water extracted infiltrates back into the ground, so the net extraction is much lesser than what is conventionally believed. Of course, it is still very expensive resource-wise as valuable electricity is wasted pumping up water that goes back into the ground.

There is some merit in the argument that mere switching over from paddy will not help much, though it can help to certain extent.

Apart from water intensive crops, the other important reasons for the massive extractions of groundwater are the high cropping intensity and the high irrigation intensity in the two states. There is no way that these levels of cropping and irrigation intensities can be sustained without excessive exploitation of groundwater.

In Punjab, intensity of cropping went up from 129% in 1965-66 to 185% in 2001-02. Equally important, the net irrigated area as percentage of net sown area went up form 60% to 95% in the same period, and the gross irrigated area as percentage of gross sown area went up from 64% to 97% during the same time. Haryana mirrors this growth, and this is one of the major factors in the pressure on groundwater.

The re-look at the cropping pattern has to be done in this larger context. It has to be a part of the holistic assessment of what kind of agriculture and what levels of cropping and irrigation intensities can be maintained by the water resources available on a sustainable basis. But this assessment cannot be limited to only water. The current cropping pattern and agricultural practises have had severe impacts on the soil fertility. A re-assessment has to include this. Most important, the change in cropping pattern has to take into consideration the impact on the livelihoods of the farmers, and the viability of farming. Because of its complexity, range and sensitivity, such a process has to be participative and the solutions have to emerge from a wide-spread and in-depth process of consultations, especially with the farmers.

Unfortunately, the current attempt, in Punjab, to change the cropping patterns is far from this, and hence is nothing more than a little bit of tinkering. It is not surprising that it has met with severely limited success.

In sum, the issue of groundwater depletion is inextricably linked with the agriculture in the state, which is inseparable from the issue of viability of agriculture and livelihoods of farmers. Any attempts to address the issue have to be made in this larger framework.

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These issues have been examined in greater detail in our report *Unravelling Bhakra.* It is available from us or can be downloaded in the pdf format from our website.

References

BBMB (1988): '*History of the Bhakra Nangal Project (Published on Occasion of the Silver Jubilee of The Project)*', Bhakra Beas Management Board, Chandigadh.

CAG (1977): '*Supplementary Report of the Comptroller and Auditor General of India for the year 1975-76* for Union Government (Civil), Comptroller and Auditors General of India. New Delhi.

Dhawan, B.D.(1989): '*Measurement of Linkages Between Surface and Ground Water – The Beneficial Role of Canal Seepage*' in Dhawan B.D. (1989): '*Studies in Irrigation and Water Management*', Commonwealth Publishers, New Delhi.

Duggal, Er. S. K., J. K. Bhalla and N. K. Bhatia (2002): '*Flood and Sedimentation Status of Bhakra Reservoir - A case Study*', Paper Presented at Institute of Engineers, Chandigarh, April 2002. *In* '*Proceedings of All India Seminar on Flood Management April 19-20, 2002, Chandigadh'*, Institutions of Engineers (India), Punjab and Chandigadh State Centre, Chandigadh.

Gulhati, Niranjan D. (1973): '*Indus Waters Treaty : An Exercise in International Mediation'*, Allied Publishers, Bombay.

Kumar, Vinod, A. S. Dhindwal, M. S. Kuhad and B. C. Sethi (Ed) (2000): '*Efficient Management of Irrigation Water in Haryana*', Director of Extension Education, CCS Haryana Agricultural University, Hisar.

Michel, Arthur Alloys (1967): '*The Indus Rivers - A Study of the effects of Partition*', Yale University Press, New Haven and London.

Punjab, Government of (2002): '*Agricultural Production Pattern Adjustment Programme in Punjab for Productivity and Growth (Report of the Johl Committee)'*, A Report by Chief Minister's Advisory Committee on Agriculture Policy and Restructuring, Submitted to the Government of Punjab, October 2002. Available from Punjab Agro Industries Corporation, Chandigadh.

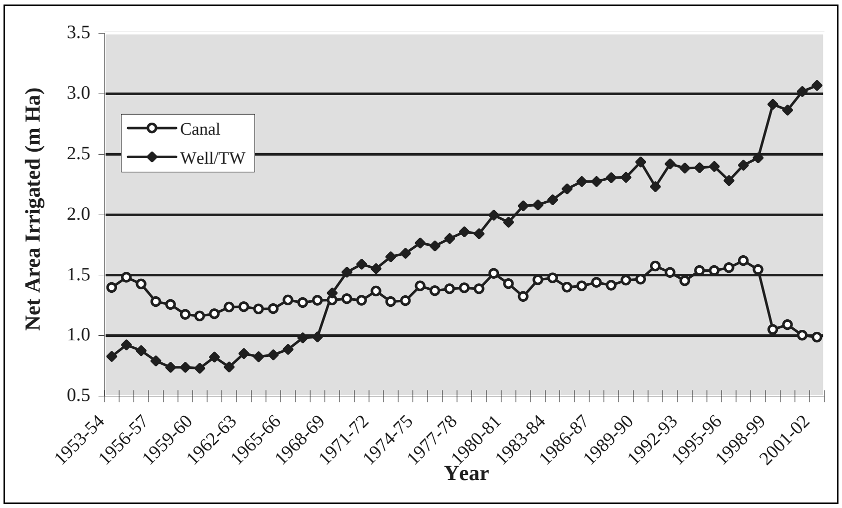
Singh, Surendar (1991): '*Some Aspects of Groundwater Balance in Punjab'*, Economic and Political Weekly; 28 Dec. 1991

Figure 1: "MAP 3" - Attached Separately

Figure 2: "MAP 4" - Attached Separately

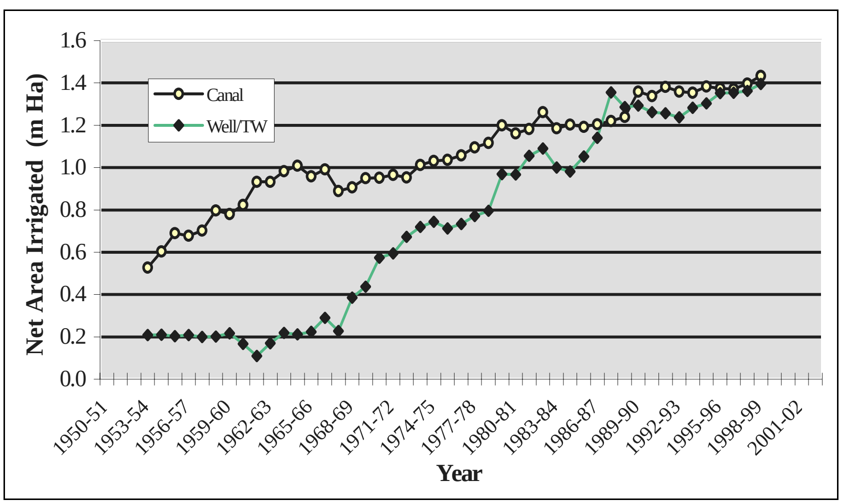
Figure 3: "MAP 5" - Attached Separately

Figure 4: Net Area Irrigated by Source in Punjab



Source: *Various Statistical Abstracts of Punjab*

Figure 5: Net Area Irrigated by Source in Haryana



Source: *Various Statistical Abstracts of Haryana*